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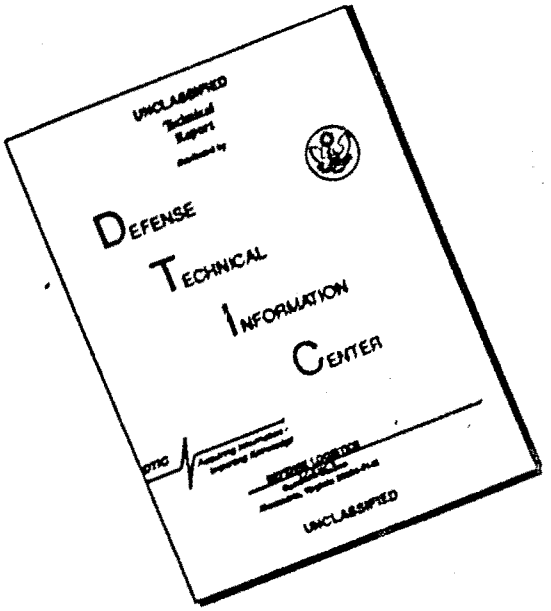

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TANK-AUTOMOTIVE RESEARCH AND DEVELOPMENT TEST RESUMES

VOLUME XI
CLASSIFIED RESUMES

SECRET

Prepared for Research and Development Division, Ordnance Tank-Automotive Command, Center Line, Michigan by LaDriere Studios, Inc., Technical Division, 1700 Cadillac Tower, Detroit, Michigan under Contract No. DA-20-089-ORD-38066.

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TANK-AUTOMOTIVE RESEARCH AND DEVELOPMENT TEST RESUMES

VOLUME XI
CLASSIFIED RESUMES

ORDNANCE TANK-AUTOMOTIVE COMMAND

Center Line, Michigan

APRIL 1957

SECRET

PREFACE

This publication is intended for Ordnance and contractor personnel who desire summarized information on Ordnance research and development test reports written in the last 25 years.

The objectives of the publication are to reveal trends in Ordnance test development, to provide newly assigned technical personnel with an additional source of orientation, and to prevent costly and time-consuming duplication of previous effort. It presents valuable test information in quick-reference form, enabling engineering personnel to grasp quickly the accomplishments and results of the numerous tank-automotive tests.

The publication comprises 12 volumes. Volumes I through X contain resumes of unclassified test reports arranged alphabetically by subject. Resumes of classified reports are contained in Volume XI. Volume XII is a complete index of all test reports summarized in the publication.

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VOLUME XI

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VOLUME XI

Section 2
AMMUNITION

SUMMARY

This summary covers resumes of 36 engineering reports written on ammunition between 1943 and 1955 at Aberdeen Proving Ground, Maryland; Watertown Arsenal, Watertown, Massachusetts; Frankford Arsenal, Philadelphia, Pennsylvania; The Armored Board, Fort Knox, Kentucky; and Army Field Forces Board, Fort Knox, Kentucky.

A third of the reports were studies of foreign ammunition, including Soviet, German, Chinese, and Japanese types.

SOVIET

Soviet 76mm HVAP-T projectiles, 76mm HE shell, 122mm HE shell, and 122mm HEAT projectiles were tested in 1953 and 1954. Procedures consisted principally of metallurgical examinations; methods of manufacture and physical characteristics were also determined. The 76mm HVAP-T projectile was considered to be inefficient in armor piercing ability because of its extremely small core. Gray cast iron used in the 76mm HE shell offered definite advantages in fragmentation characteristics over domestically used wrought steel. A satisfactory quality of steel was used in the 122mm HE shell; machine finish, though poor by U.S. standards, did not detract from ballistic performance and represented a saving in manufacturing costs.

GERMAN

Firing tests during 1943 with German 7.5cm AP, HE, C, and BC ammunition demonstrated these types to be interchangeable with similar U.S. projectiles, providing the rotating bands were modified. German 7.5 and 8.8, APC, BC, and HE projectiles had better penetration characteristics against homogeneous armor plate than comparable American ammunition.

CHINESE

The gray cast iron used in Chinese 60mm HE mortar shell tested in 1953 combined excellent fragmentation characteristics, low cost, and simplicity of manufacture.

JAPANESE

In 1944 a comparison was made of a Japanese AP, HE projectile with a similar American projectile; determination of the fuze action of the Japanese projectile also was sought in the test. The foreign projectile was a 47mm AP, HE shell of the mono-block type with a high explosive loading of cyclonite and a simple set-forward type base detonating fuze. It weighed 3.4 pounds and had a service muzzle velocity of 2700 fps. Standard, American, M51, 37mm APC projectiles were used as test controls. The Japanese projectile was not consistent in its action, and it was generally inferior to the American projectile. Action of the fuze was not positive and the steel was very brittle.

U. S. AMMUNITION

These reports described miscellaneous studies of U. S. ammunition. Results of a 1953 test showed that satisfactory non-metallic thin walled carriers could be developed for application to small arms projectiles. Carriers of this type would eliminate jacketing with copper, resulting in a savings of large quantities of strategic material. General purpose 500-pound bombs were found to be ineffective against heavily armored vehicles.

In 1952 a study was made of the mechanism of cap action in the prevention of projectile deformation. It was concluded that the effectiveness of the cap in aiding penetration was due chiefly to its action in preventing shatter of the core. Functioning of the cap in retarding and turning the core was considered secondary.

The comparative effectiveness of various types of armor-defeating ammunition was determined in a 1951 test. Monobloc steel shot were more effective than capped steel shot for the defeat of undermatching armor at all obliquities of attack, and were more effective than both APC and HVAP shot for the defeat of moderately overmatching armor (up to at least 1-1/4 calibers thick) at all obliquities of attack above approximately 45°. Capped steel shot were superior to monobloc steel shot for the defeat of greatly overmatching armor, (over 1-1/4 calibers in thickness) at obliquities in the range of 20° to 45°, but both capped and monobloc shot were greatly inferior to HVAP shot in the low obliquity range against heavy armor targets. HVAP and HVAPDS shot were most effective against heavy armor targets at low and moderate obliquities of attack (the 90mm tungsten at short ranges), but their effectiveness was markedly degraded at obliquities above approximately 50°. The HEP shell could cause scabbing or spalling of armor up to 1.3 calibers thick, and it was not greatly influenced by angles of obliquity between 30° to 60°. Shock detonation at velocities over 2500 fps made the HEP shell relatively ineffective at high velocity. At low temperature and against brittle or unsound armor containing laminations or inclusions, the effectiveness of HEP increased. Presently available data indicated that the HEAT shell would penetrate armor four times the diameter of the cone up to approximately 70° obliquity. It was recommended that both kinetic and chemical energy ammunition be used, since the exclusion of either type would greatly simplify the enemy's design and construction problem. It was reasonably simple to devise a defense against one type of round, but to devise a defense against both types was considered extremely complicated.

REPORT RESUMES

SUBJECT: Ammuniton AB 609
TITLE: Test of Hyper-Velocity Armor Piercing Ammunition for the 76-MM Gun
IDENTIFICATION: Project No. 609
DATE OF REPORT: 29 August 1944
ORIGIN: The Armored Board, Fort Knox, Ky.
PURPOSE: To determine the suitability of HVAP Shot T4 for the 76mm gun and to compare it with the standard Ammunition M62
METHOD: The test ammunition, normal M62 Ammunition, and long primer, and flash ammunition were fired with and without muzzle brake at targets placed at ranges of 500 to 4500 yards. Three observers in the tank, one at the sights, one with field glasses, and one with naked eye, and one observer 10 yards from the tank timed the interval between firing and the time he could again see the target. Two observers at 4500 yards to the right of the impact area made "enemy" observations for flash and smoke. One round of test shot and one of M62 were loaded in racks to note stowage difficulties.
DESCRIPTION: The test Projectile HVAP T4 was shorter than the M62 by approximately three inches and was a fixed unit. The shot was tested with normal and 19-inch primers.
CONCLUSIONS: The test shot was highly satisfactory and resulted in less obscuration than the M62 with or without muzzle brake. Its armor penetrating ability was greater, and stowage was satisfactory. It was also concluded that use of the long 19-inch primer would result in much less obscuration. It was recommended that quantity production be initiated immediately, that the shot be manufactured with 19-inch primer or suitable substitute, and that practive rounds with core of mild steel or low-priced metal be manufactured for training purposes.
GENERAL: This 22-page report contains eight tables of firing results and 15 photographs of the target and field at intervals during firing.

SUBJECT: Ammunition AFF 2-18-49(IX-I)
TITLE: U. S. Investigation of the Schulman Projectile
IDENTIFICATION: Report No. AFF 2-18-49(IX-I)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To determine the U. S. position regarding the Schulman Projectile
METHOD: Review and analysis were made of four United Kingdom documents relative to the experiment and research of the Schulman Projectile principle as conducted by the British. The documentation included the present status of the projectile, SAE final report, United Kingdom Ordnance report and Brigadier A. W. Brown's reply to the Ordnance Board.
DESCRIPTION: The Schulman round was a cylindrical projectile with a flat, non-ballistic head and a light-weight thin-walled body. It was fired from a smooth bore low pressure gun and depended on air turbulence created by the flat head and the center of gravity and pressure adjustments for its stability in flight. The projectile was 4.5 inches in diameter and 18 inches in length and was developed in both AP and HE rounds.
CONCLUSIONS: The Schulman Projectile was difficult to fuze properly and had an undesirable ballistic coefficient which could preclude its satisfactory use as a flat trajectory antitank weapon. The projectile had a digressive effect of spin and no satisfactory degree of accuracy. A great amount of study and ballistic research would be required to analyze the projectile's ultimate potential. It was believed that the British should develop the projectile sufficiently for U. S. testing. U. S. development of shaped charges offered more promise and a parallel development to the Schulman principle was not recommended.
GENERAL: This four-page report is not illustrated and is contained within Report No. AFF 2-19-49.

SUBJECT: Ammunition APG 5886/13
TITLE: First Report on Interchangeability of Captured Enemy Ammunition and United States Ammunition
IDENTIFICATION: Thirteenth Report on Ordnance Program No. 5886
DATE OF REPORT: 7 April 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To study the interchangeability of foreign ammunition with U.S. ammunition
METHOD: Foreign ammunition from 37mm to 155mm was studied to determine its interchangeability with U.S. ammunition. Possibilities for interchangeability were evaluated on the basis of the dimensions, weight, value, and quantity of the ammunition available.
DESCRIPTION: This report was concerned with foreign ammunition from 37mm to 155mm, inclusive. Ammunition smaller than 37mm was not considered practical for modification to fit U.S. weapons.
CONCLUSIONS: In general, interchangeability was not considered practical. However, certain items which were known to be usable in U.S. weapons were listed in the report. No foreigh cartridge cases were found that could be used in U.S. weapons without extensive modifications. Because no firing tests were conducted with the ammunition listed, it was recommended that the information concerning these projectiles be used with caution.
GENERAL: This 27-page report contains ten photographs of foreign ammunition.

SUBJECT: Ammunition APG 5886/15
TITLE: First Partial Report on German 7.5 cm A.P.-H.E., C&B.C., Ammunition
IDENTIFICATION: Fifteenth Report on Ordnance Program No. 5886
DATE OF REPORT: 5 June 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To study captured German 7.5 cm,

AP, HE, C, and BC ammunition
METHOD: The ammunition and its components were examined for physical and metallurgical characteristics. The various markings on a complete round of the ammunition were interpreted. Functioning of the various components was explained. The rotating bands of 44 of the German projectiles were modified to fit U.S. tank and field guns. British modifications and trials of the projectiles were described. Studies were made of the projectile at Aberdeen with respect to armor piercing qualities, fuse functioning, and spaced armor methods of defeating it.
DESCRIPTION: The captured German 7.5 cm, AP, HE, C and BC ammunition was received from the Middle East Theatre of Operation in good condition. Ninety-two rounds came as complete rounds packed in two-round German ammunition carriers. Forty-four projectiles complete with fuze, tracer, and HE filler, came packed in improvised wooden crates. This ammunition was used by the Germans in their old Model 7.5 cm, short barrel tank gun mounted on the German P_3KW IV tank.
CONCLUSIONS: Based on a limited number of firing tests, the ammunition was found to be interchangeable with U.S. ammunition if the rotating band was modified. However, the tests were not extensive enough to prove safe interchangeability. The German projectile was superior to the U.S. 75mm, M61 APC projectile in penetrating 3-inch rolled homogeneous armor at a 20° obliquity, but was inferior to the same U.S. projectile in penetrating 3-inch face hardened armor at a 20° obliquity. The fuze functioning of the German projectile was very regular. As the obliquity of an arrangement of 1-inch face hardened over 2-inch homogeneous armor was increased, the relative effectiveness of the German projectile over the U.S. M61 APC projectile increased. The projectile was defeated at velocities up to 1944 f/s by spaced armor arrangement of 1-inch face hardened plate 10 inches in front of 1-3/4-inch face hardened plate at 30°.
GENERAL: This 74-page report contains 29 photographs of the German projectiles and the effects of firing the projectiles.

SUBJECT: Ammunition APG 5886/24
TITLE: First Report on Armor Penetration of German and American Armor Piercing Projectiles
IDENTIFICATION: Twenty-fourth Report on Ordnance Program No. 5886
DATE OF REPORT: 18 April 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare German 7.5 cm and 8.8 cm APC projectiles with American 75mm and 90mm armor piercing projectiles
METHOD: The German and American armor piercing projectiles were tested to determine their armor piercing characteristics: using homogeneous armor plates with 3-3/8 to 8-inch thicknesses and obliquities for 0 to 55°.
DESCRIPTION: The German ammunition consisted of projectiles, APC, BC, and HE, 8.8 cm and 7.5 cm. American ammunition tested were projectile, APC, HE, 90mm, M82; shot, AP, 90mm, M77; shot, AP, 90mm, T33; and projectile, APC, HE, 75mm, M61.
CONCLUSIONS: The German projectiles had better penetration characteristics against homogeneous armor plate than the American projectiles and demonstrated less tendency to shatter when fired against homogeneous armor plate at high velocities. It was recommended that the design features, hardness pattern, and composition of the German projectiles be studied for the purpose of improving American armor piercing ammunition.
GENERAL: This 56-page report contains 11 photographs showing the effect of firing on both types of projectiles.

SUBJECT: Ammunition APG AD-518
TITLE: Development of Armor Shields on the 40-mm Gun Carriage M2 and the 90-mm Gun Carriage M1A1
IDENTIFICATION: Report No. AD-518; Project No. 1248
DATE OF REPORT: 19 May 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic characteristics of developmental armor shields
METHOD: Ballistic tests of six armor plates were conducted with 86 rounds of German 20mm API, 36 rounds of German 20mm HE, and 40 rounds of U.S. 20mm AP M75 Projectiles. Ballistic limits of the plates were obtained at 45° and 60° obliquities.
DESCRIPTION: The rolled homogeneous test material included two 1/4-inch plates produced by the Standard Steel Spring Co. and two 3/8-inch plates, one 1/2, and one 3/4-inch plate produced by H. Disston and Sons. The plates had a hardness range of 350 BHN ± 25 BHN. The German ammunition was intended for aircraft and antiaircraft guns.
CONCLUSIONS: The ballistic limits for a given size of the test plates were approximately the same for comparable German and U.S. projectiles. At an impact angle of 45° the U.S. 20mm projectile was slightly superior in penetrating power to the German 20mm API projectile; at 60° obliquity the German projectile was slightly superior to the U.S. projectile. It was recommended that further comparison be made of U.S. and German 20mm AP and API projectiles; that tests of the German API projectile be made to determine the effect of the phosphorous incendiary material; and that the use of face hardened armor for defeating 20mm projectiles be considered.
GENERAL: This eight-page report is not illustrated.

SUBJECT: Ammunition APG AD-1119
TITLE: Investigation of the Effect of Statically Detonated Plastic Explosive Charges on Armor for the Purpose of Developing a Plastic Explosive or Squashead Type Shell
IDENTIFICATION: Report No. AD-1119; Project No. TM1-5002/1
DATE OF REPORT: 10 May 1949
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effects of statically detonated explosive charges of various sizes and

shapes against various types of steel armor
METHOD: Test charges of various sizes and shapes were placed on the upper surfaces of armor plates supported parallel to, and about 4 feet above the ground, by blocks on each corner. The velocities of the spall fragments displaced by some of the explosive charges were measured by means of high speed movies. In some cases, a layer of celotex sheet covered by a piece of sheet steel was placed on the ground below the plate being tested in order to study effects of spall fragments displaced from armor. Spall fragments were counted and weighed, and the extent of bulges measured. Samples were cut from the homogeneous plates and subjected to metallurgical tests.
DESCRIPTION: The test material consisted of C3 and TNT explosives; two 4-inch homogenous, one 4-inch face-hardened, two 6-inch homogeneous, and one 8-inch homogeneous armor plates. A 375 grain 1-inch high and 1-inch diameter Tetryl booster, and a U.S. Engineer's Special Blasting Cap were used with the explosives.
CONCLUSIONS: The C3 explosive charges in the frustum shape were more effective in displacing spalls from armor than an equal weight of explosive in cylindrical form. With the weight of charges constant, weight of spalls displaced by cylindrical C3 charges increased with increases in charge diameter, within certain limits. High homogeneous armor spalled more readily than low hardness armor under C3 explosive charges. Armor with a low Charpy impact value was more readily spalled by detonation of a plastic explosive charge than armor possessing a high Charpy value. The TNT was not as effective as C3 in deforming and displacing spalls from armor. It was thought that a 105mm plastic explosive shell with 6 to 8 pounds of C3 would be effective in displacing fragments from solid steel armor up to and included 6-inch thickness. It was recommended that a group of 105mm plastic explosive shells be prepared for development testing against armor.
GENERAL: This 167-page report contains 24 pages of photographs.

SUBJECT: Ammunition APG AD-1132
TITLE: Development of Plastic Explosive Loaded Shell for the Defeat of Armor
IDENTIFICATION: Report No. AD-1132; Project No. TA1-5002H
DATE OF REPORT: 28 September 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the best design for plastic explosive shells
METHOD: Ballistic tests of the armor plate and plastic shells were conducted as obliquities from 0° to 71° and at various velocities. Drop tests of some 105mm shells were conducted by the use of a 50-foot tower and a steel plate target at the bottom of an 8-foot pit below the tower. Seven 105mm rounds were fired at a disabled Medium T26E4 Tank. Radiographic examinations were made of the test shells before the drop test. In the firing against armor, the maximum depth, width, and length of the impact impression was measured and also of resulting spall. Assessment of the effectiveness of the shells against the various plates and at the various obliquities was made. Similar British shells were fired for purposes of comparison.
DESCRIPTION: The plastic high explosive loaded test projectiles included various designs of HEP and HEAT shells of 105mm, 90mm, and 75mm calibers. The test shells were manufactured by the Chamberlain Corp. and were loaded by the Picatinny Arsenal. The homogeneous armor used in the tests ranged from 2 to 6 inches in thickness.
CONCLUSIONS: The best designs of the test shells were sufficiently effective to offer promise as anti-tank weapons. It was recommended that development of this type of shell be continued and include design of a new shell body. Separation of the war head along filler lines formed during shell loading occurred during the drop test. The 105mm HEP shell tended to spall the armor at 30°, 45°, and 55° obliquity. The test shells were very effective at high obliquities of 45 to 60° and would spall brittle armor much easier than tough armor. The 90mm HEP shell could probably defeat as much as 4-inch armor and the 75mm HEP shell could defeat at least as much as 3-inch armor at 60° obliquities.
GENERAL: This 410-page report includes 67 photographs of the plastic shells, armor and tank components. Firing Records Ar-17189 and Ar-17278 are included in this report.

SUBJECT: Ammunition APG AD-1151
TITLE: Effectiveness of 5-Inch Heat Rocket Heads with Aluminum and Copper Cones Against T26E4 and T26E5 Tanks
IDENTIFICATION: Report No. AD-1151; Fourth Report on Project TB3-1224B
DATE OF REPORT: 25 August 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of 5-inch HEAT rocket heads with aluminum and copper cones against T26E4 and T26E5 Tanks
METHOD: The T26E4 and T26E5 Tanks were stowed with original equipment or wooden mock-ups of ammunition and personnel. Blast meters and live rabbits were placed in the tanks. Test charges were placed in a number of different positions adjacent to the tanks or their components and statically detonated. The damage resulting from each detonation was checked and recorded. Two charges were detonated beneath 5-3/16-inch rolled homogeneous armor and the height and velocity of the incandescent jet were recorded by a camera.
DESCRIPTION: The test ammunition consisted of 16 experimental charges with aluminum cones and 24 Mark 25 Rocket Heads with copper cones. The aluminum-cone experimental charges were manufactured at the Naval Ordnance Test Station at Inyokern, California. The 12-inch long charges had an outside cone diameter of 4.75 inches and contained 10 pounds of composition B explosive. The copper-cone charges were standard Navy Mark 25 Model 1, 5-inch ATAR Rocket Heads containing approximately 16 pounds of composition B explosive.
CONCLUSIONS: Both types of explosives pro-

duced severe damage. It was believed that under actual combat conditions, most of the detonations against the tanks would have caused immobilization and injury to the crew. The damage resulting from the charges with aluminum cones was not appreciably different from that produced by copper cone charges. Considering the disparity in size between the two charges, however, it was believed that in this caliber projectile the aluminum cone charge might have been a more efficient damage producer for the weight of explosive. It was recommended that further testing be carried out using HEAT charges of the same size with copper and aluminum cones so that a direct comparison of the two liner materials could be made.
GENERAL: This 165-page report contains appendices covering correspondence, firing summaries, sketches of charge and blast meter locations, animal injury findings, graphs and tables for blast meters, descriptions of target tanks, and 42 pages of photographs.

SUBJECT: Ammunition APG AD-P157
TITLE: Test of Japanese 57MM AP HE Projectiles for Plate Penetration and Fuze Functioning
IDENTIFICATION: Report No. AD-P157
DATE OF REPORT: 18 January 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare a Japanese AP HE projectile with a similar American projectile and to determine the fuze action of the Japanese projectile
METHOD: Army and Navy ballistic limits were obtained on 1-1/2-inch homogeneous armor plate at 20° obliquity and 2-1/2-inch homogeneous armor plate at 0° obliquity with the Japanese and American projectiles. Also Army ballistic limits were obtained on 1-1/2-inch face-hardened plate at 20° obliquity for both projectiles. Five fuzed explosive rounds of the Japanese projectile were fired at 1-1/2-inch homogeneous armor plate at 20° obliquity. The muzzle velocity of these five projectiles was reduced to 1600 fps.
DESCRIPTION: The Japanese projectile tested was a 47mm AP HE shell of the mono-block type with a high explosive loading of cyclonite and a simple, set-forward type base detonating fuze. It weighed 3.4 pounds and had a service muzzle velocity of 2700 fps. Standard American M51 37mm APC Projectiles were used as test controls.
CONCLUSIONS: The Japanese projectile was not consistent in its action and it was generally inferior to the American projectile. Action of the fuze was not positive and the steel was very brittle.
GENERAL: This 26-page report contains eight photographs.

SUBJECT: Ammunition APG Ar-18614
TITLE: Special 5-Inch Aluminum Cone HEAT Charges Against Stowed Ammunition and Diesel Fuel
IDENTIFICATION: Report No. Ar-18614; Project No. TB3-1224B
DATE OF REPORT: 28 August 1952
PURPOSE: To determine the effectiveness of special HEAT charges against stowed ammunition and diesel fuel
METHOD: Two rounds of Russian 85mm HE ammunition without projectiles were secured behind 3-inch armor plate placed against a concrete wall at 35° obliquity to simulate an ammunition rack inside a tank. The special test charges were fired against two of these target combinations. Two simulated fuel tanks were half filled with diesel fuel and sealed. One of these containers was secured in the driver's compartment of a T26E4 Tank hull. The other container was secured in an inverted T26E4 Tank turret. The special charges were fired to penetrate the 3-inch thick armor of the hull and turret and strike the fuel containers above the fuel line.
DESCRIPTION: The special 5-inch aluminum-cone shaped charges were provided by the Naval Ordnance Test Station, Inyokern, California. The charges were 12 inches long, weighed 1.3 pounds, and contained 10 pounds of explosive.
CONCLUSIONS: The Russian 85mm HE ammunition exploded behind the armor plates, and only small pieces of the targets were recovered. The special charges penetrated the hull and the turret fuel containers and caused flash fires followed by an intense, 30-minute fire in the hull and a slow, 45-minute fire in the turret.
GENERAL: This six-page report includes two photographs showing the fuel containers before and after ballistic test.

SUBJECT: Ammunition APG Ar-18761
TITLE: Effectiveness of 2.36-inch Shaped Charge Rockets Against Diesel Fuel and Gasoline
IDENTIFICATION: Report No. Ar-18761; Project No. TB3-1224B
DATE OF REPORT: 22 October 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of 2.36-inch rockets against diesel fuel and gasoline
METHOD: Five and sixteen gallon fuel cans with varying amounts of diesel fuel and gasoline were secured by cables or wood braces behind 1 or 3-inch plates. One set of targets had the cans placed behind the 3-inch side wall of a T26E4 Tank turret or hull. Another set of targets had the cans fastened by wire against the outer surface of a 1-inch T26E4 hull floorplate. Ballistic tests of the targets at 0° obliquity were conducted by statically detonating 88, 2.36-inch HEAT Rockets M6A6 against the diesel fuel containers and 47 rockets against the gasoline containers.
DESCRIPTION: The tank components had been previously damaged and included six T26E4 Tank hulls with turrets removed and two T26E4 Tank turrets removed from the hulls. Six hundred gallons of tractor grade diesel fuel and 320 gallons of 80-octane gasoline were used in the test.
CONCLUSIONS: Forty-five of the impacts against the diesel fuel containers caused fires, 29 of which were sufficient to render a tank out of action. Forty-three of the impacts against the gasoline containers caused fires and all but one of these would have rendered the tank out of action. The 5-gallon containers were considered unsatisfactory for vulnerability tests of fuel because of the light

gauge of the metal and the size was too small to prevent fragments entering the fuel. The 16-gallon containers were satisfactory and realistically simulated the fuel cells of the Soviet T34 Tank.
GENERAL: This 90-page report includes 25 pages of photographs of the test materials and complete firing data.

SUBJECT: Ammunition APG Ar-19441
TITLE: Effectiveness of 5-Inch HEAT Rocket Heads with Aluminum, Copper, and Steel Liners Against T26E4 and T26E5 Tanks
IDENTIFICATION: Report No. Ar-19441; Project No. TB3-1224B
DATE OF REPORT: 27 July 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the effectivenss of 5-inch HEAT rockets with various liners against T26 Tanks
METHOD: One T26E4 and one T26E5 Tank were equipped with wooden dummies to simulate tank crews. Ballistic tests were conducted using four 5-inch rocket heads and four experimental charges. The ammunition was statically detonated and blast measurements made inside the tanks. The tank engines and intercommunication systems were run as long as operable.
DESCRIPTION: The test ammunition consisted of four 5-inch HEAT Rocket Heads Navy MK25, Model 1. Two were equipped with steel liners and two with copper liners. The four experimental charges had a cone diameter of 4.75 inches and equipped with aluminum liners for use in 5-inch rocket heads.
CONCLUSIONS: All rounds except one aluminum-lined charge put the tank out of action. All of the test ammunition did considerable damage, but it was difficult to determine any difference in the effectiveness of the various rounds because of the similarity in the damage produced. The results of the test were similar to those of an earlier test. There was little difference in the amount of fragmentation produced by the rounds, but fragments apparently caused more interior damage to the tanks than did blast. The escape hatches of the tanks were sprung, indicating interior pressure. To make a comparative test of the liners it was recommended that the charges be of the same size.
GENERAL: This 45-page report includes 18 pages of firing data and photographs of the test tanks.

SUBJECT: Ammunition APG Ar-19723
TITLE: Performance of the 90mm HEP-T T142E3 Projectile at 1200 yds. Range Against 4-inch Armor Plate
IDENTIFICATION: Report No. Ar-19723; Project No. TB3-1224B
DATE OF REPORT: 30 December 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the performance of the 90mm HEP-T T142E3 Projectile against 4-inch armor plate at 1200 yards range
METHOD: Ten rounds of the 90mm HEP-T Projectile T142E3 were fired against 4-inch armor plate. Seven of the rounds were fired at about 0° obliquity and three at 35° obliquity. The spalls on the plate were measured and the effect of spin was determined.
DESCRIPTION: The test ammunition consisted of 10 rounds of 90mm HEP-T Projectiles T142E3 equipped with M91 Fuzes, T70 Primers, T24 Cartridge Cases, and 77.76-ounce propellants. The armor plate was a 12 x 10 x 4-inch rolled armor plate with a BHN of 273.
CONCLUSIONS: Spin had little or no effect on the performance of the ammunition under the conditions tested. One hundred percent spalls resulted from all impacts.
GENERAL: This five-page report includes one photograph of the test plate showing the results of the impacts.

SUBJECT: Ammunition APG TB3-0035/3
TITLE: Tests of 85 MM USSR Tank Material
IDENTIFICATION: Third Report on Project TB3-0035; APG 10-244C
DATE OF REPORT: 13 May 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of Russian 85mm APHE-T and HVAP-T projectiles and Tank T34 mounted 85mm Model 1945 Gun
METHOD: The projectiles were fired against various armor arrangements to determine penetration, velocity and general characteristics. Comparisons were made with U.S. projectiles. The gun was disassembled and photographed.
DESCRIPTION: The test Russian APHE-T projectile was of monobloc construction without a windshield. It had a boat-tail base, double copper rotating band, and was fitted with a base detonating fuse. A 360° notch, just rearward of the bourrelet, was to control body breakage after impact. The fuse incorporated an automatic retarding device that regulated the detonation time to meet the resistance of the target. Propelling charges were in tubular and granular form and granular only. Both types were bagged. The projectile weighed 20.2 to 20.7 pounds. The test Russian HVAP-T projectile weighed 10.9 pounds, had a 1.38-pound tungsten-carbide core and an aluminum windshield. All ammunition was fixed-round type with similar brase cases. The test Russian, Model 1945, 85mm Gun was mounted in a Russian Tank T34.
CONCLUSIONS: Velocity of the APHE-T projectile averaged 2605 fps 83.7 feet from the gun muzzle. It penetrated 2-1/2 inches of homogeneous armor with a striking velocity of 1856 fps at 45° obliquity. This performance was approximately equivalent to that of U.S. 76mm AP Projectile T128 which had a longer effective range. The notch did not fulfill its purpose and the effectiveness of the high explosive detonation was generally lost. The HVAP-T projectile at a striking velocity of 3357 fps penetrated four inches of homogeneous armor at 30° obliquity and was considerably less effective than U.S. 76mm HVAP Projectile M93 in armor penetration and velocity. Russian propellants caused large yellow flashes and grey smoke. Limited observation of the gun showed it to be of simple construction and easy to operate. It was recommended that additional firing tests be con-

ducted with the Russian ammunition if changes in projectile design or velocity were noted.
GENERAL: This 74-page report contains 36 photographs of the gun components and projectiles. Also included are sketches of the APHE-T and HVAP-T projectiles and rifling in the tube and chamber of the 85mm gun.

SUBJECT: Ammunition APG TB3-1224B/3
TITLE: Vulnerability of T26E4 Tanks to Attack by 500 Pound G. P. Bombs
IDENTIFICATION: Third Report on Project No. TB3-1224B
DATE OF REPORT: 6 March 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether 500 pound, general purpose bombs could be considered as effective weapons against heavily armored vehicles
METHOD: Nine 500 pound general purpose bombs, after being partially buried, were statically detonated at distances ranging from five to ten feet from the front, sides, and rear of two T26E4 tanks.
DESCRIPTION: The test 500 pound general purpose bombs were identified as AN-M64A1, TNT lot RVA 613-2. The bombs were equipped with M103 nose bomb fuzes and special engineer blasting caps.
CONCLUSIONS: The T26E4 tank was not highly vulnerable to attack with the test weapon. Only a very close strike was likely to damage the tank seriously, and unless the explosion was close to the side of the vehicle, mobility of the vehicle was likely to be unimpaired. It was recommended the test type bomb be considered an ineffective weapon against heavily armored vehicles; and that weapons such as rockets, which would have a better chance of penetrating the tank armor, be considered more useful. It was further recommended than an investigation be conducted to determine the damage potential of bombs, then current, for use against standard American and typical enemy tanks.
GENERAL: This 44-page report includes five pages of photographs of test results.

SUBJECT: Ammunition APG TB3-1224B/5
TITLE: The Ignition of Diesel Fuel by Statically Detonated 3.5 Inch HEAT Rocket Heads
IDENTIFICATION: Fifth Report on Project No. TB3-1224B
DATE OF REPORT: 6 January 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the suitability of experimental HEAT, 3.5-inch rocket heads with standard rocket heads for use in igniting diesel fuel and gasoline; and to determine the suitability of experimental fuel containers for use in this type of test
METHOD: A total of 267 standard M28A2, 3.5-inch, HEAT and 54 experimental rocket heads were detonated against standard gage and experimental fuel tanks, which were shielded in German Tiger tanks by armor ranging from 3.1 to 5.9 inches thick. Data on frequency, type, and duration of fires occurring in the containers when partially filled with either gasoline or diesel fuel were recorded under each condition of attack. Influence of ambient temperatures, container design, cleanliness of installation, and related ignition factors were noted. Photographs were taken of jet penetrations into containers.
DESCRIPTION: The experimental HEAT, 3.5-inch rocket heads as compared to standard rocket heads embodied modifications in the liner material and design. Modifications included the application of aluminum sleeves over the basic ones, aluminum caps with and without an iron ring, and a lead cap. The experimental fuel containers tested were made of 1/4-inch thick mild steel, reinforced.
CONCLUSIONS: The experimental type heads were no more effective in igniting diesel fuel than were the standard types; moreover, low temperatures, or the experimental type fuel container, would reduce the frequency of fires during attack when using either type of head by 10%. The presence of porous material such as dirt, soot, etc., in the tank hull increased the chances for fires. The frequency of ignition of diesel fuel was higher at relatively high ambient temperatures than at low ambient temperatures. An increase of vehicle hull armor thickness over a wide range of thicknesses had no significant effect on the frequency of fires. It was recommended that further testing of experimental rocket heads be conducted under controlled temperature conditions, and that heavy experimental fuel containers be employed in these tests, since such containers provided severe test conditions.
GENERAL: This 126-page report includes 42 photographs of the tested equipment.

SUBJECT: Ammunition BRL 391
TITLE: Measurements of Shaped Charges with the Ballistic Pendulum
IDENTIFICATION: Report No. 391
DATE OF REPORT: 17 August 1943
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To determine the momentum of the jet of a shaped charge
METHOD: A split block with a 3-inch hole was bolted to the underside of a pendulum suspended from a trestle. Blast from shaped charges were impinged on a target set in the split block on the pendulum. Various masses were used for the target. Swing of the pendulum was measured by a scribe plate. The momentum of the jet was determined by energy formulas from the mass and swing of the pendulum.
DESCRIPTION: The shaped charges consisted of cast 50/50 pentolite with a pressed pentolite booster. They were the standard M9A-1 charges. For comparison two unlined charges and one flat-end charge were fired.
CONCLUSIONS: Two graphs were plotted showing the relationships between the jet penetration, and momentum and volume of the hole with and without correction for the mass of the slug. The flat-ended charge produced a momentum of 7.41 x 10^6 g. cms/sec; the hollow lined charge, 6.59 x 10^6 g. cms/sec; and the hollow, unlined charge, 6.03 x 10^6 g. cms/sec.

GENERAL: This 10-page report contains one drawing and two photographs of the test apparatus, a photograph of a target and two graphs of test results.

SUBJECT: Ammunition BRL 681
TITLE: Comparison of the Blast from Explosive Charges of Different Shapes
IDENTIFICATION: Report No. 681; Project No. TB3-0112J
DATE OF REPORT: January 1949
ORIGIN: Ballistics Research Laboratory; Aberdeen Proving Ground, Maryland
PURPOSE: To compare the blast from explosives of various shapes
METHOD: The shaped test charges were placed in an open area and detonated from a suspended position 30 inches above the ground. Peak pressure and positive impulse of the blasts were measured by tourmaline piezioelectric gages. These gages were suspended two feet off the ground at distances of 35, 45, 60, 70, and 80 feet along lines radiating from the center of the explosive. Several orientations of the explosives were employed.
DESCRIPTION: The main explosive filler for all the charges was 50 pounds of RDX plastic composition C-3 which was detonated by one or more tetryl boosters. The shapes of charges included spheres, cubes, cones, flat plates, long solid cylinders, long hollow cylinders, short hollow cylinders, and short solid cylinders. The explosive charges were all of the same weight.
CONCLUSIONS: The peak pressures and positive impulses resulting from detonation of the spherical, cubical, cylindrical, conical and laminar shaped charges did not differ significantly at large distances when averaged over all directions. The individual peak pressures and impulses of the nonspherical charges varied directionally up to 50%. The double shock waves observed from the nonspherical charges were consistent with shock wave configurations recorded in previous testing.
GENERAL: This 68-page report includes complete testing and recording data.

SUBJECT: Ammunition BRL TN-384
TITLE: Preliminary Report of Terminal Ballistic Tests of Firebombs Against the T26E4 Tank
IDENTIFICATION: Technical Note No. 384; Project No. TB3-1224B
DATE OF REPORT: February 1951
ORIGIN: Ballistics Research Laboratory; Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of firebombs against the T26E4 Tank
METHOD: A T26E4 Tank was equipped with remote control radio equipment and sensing apparatus. The tank was operated in an open area at speeds of approximately five miles per hour. An F-47 aircraft, traveling at 250 knots, dropped 13 test firebombs on the tank from low altitude and various attack angles. Ventilating fans in the tank were operated during some of the tests. Moving and still photographs were made of the tests. Recordings were made of temperatures and oxygen.
DESCRIPTION: The test vehicle was a new T26E4 Medium Tank in battle-condition with some stowage items removed. The test firebombs consisted of 165 gallon, aircraft wing-tip tanks, filled with 150 gallons of gasoline, and ignited by two grenades per bomb.
CONCLUSIONS: Five hits were made on the medium tank, and it was concluded that a direct hit or a very close blast was required to cause serious damage. A temperature rise inside the tank occurred only immediately after the hit and was of low magnitude and short duration. Engine radiators were quickly destroyed by flame. Reduction of oxygen content in the tank was of short duration and not dangerous.
GENERAL: This 21-page report includes four temperature charts.

SUBJECT: Ammunition FA 1109
TITLE: Development of Shot, AP, 76-mm, T128-E6 for T91 Gun
IDENTIFICATION: Report No. 1109; Project No. TA1-1302
DATE OF REPORT: February 1953
ORIGIN: Frankford Arsenal, Philadelphia, Pennsylvania
PURPOSE: To determine the characteristics of 76mm Projectile AP T128E6 in order to develop an effective shot for Gun T91
METHOD: The projectiles were fired against homogeneous armor plates of 289 to 320 BHN as follows: 2-inch plates at 60° obliquity, 3-inch plates at 55° obliquity, and 3-inch plates at 60° obliquity.
DESCRIPTION: The test Projectile AP T128E6 assembly consisted of the following: shot body, rotating band, windshield, and Tracer Loading Assembly M5. The unit was 12.07 inches long, had a shell diameter of 3.1455 inches and weighed 14.51 pounds. The shot body was of NE 98V65 (modified) steel and the windshield of an aluminum-base alloy. The windshield was affixed to the shot by means of cycleweld cement.
CONCLUSIONS: The projectile was considered satisfactory for defeating high obliquity matching and undermatching targets when used with Gun T91. Presence or absence of the windshield attachment did not affect plate penetration of the shell at a range of 100 yards. It was recommended that the projectile be fabricated of SAE 4150 steel and fired against armor plates of 280 to 320 BHN as follows: 2-inch plates at 60° obliquity, 3-inch plates at 55° obliquity, 3-inch plates at 60° obliquity, and 4-inch plates at 20° obliquity. These results were to be compared with those obtained from the projectile fabricated with NE 98V65 (modified) steel. Cycleweld proved satisfactory for windshield attachment.
GENERAL: This 97-page report includes six photographs of the projectile and design sketches for class T128 Shot.

SUBJECT: Ammunition FA R-907
TITLE: Mechanism of Cap Action
IDENTIFICATION: Report No. R-907
DATE OF REPORT: May 1952

ORIGIN: Frankford Arsenal, Philadelphia, Pennsylvania
PURPOSE: To study the mechanism of cap action in the prevention of projectile deformation
METHOD: Available research material was consulted and three hypotheses were proposed to explain the mechanism of cap action. Supporting evidence and related testing were discussed with respect to these hypotheses: "break-face" and decrease initial-inertial-reaction; support of core ogive; and turning the core toward normal. The effects of the cap in retarding and in turning the core were also considered.
DESCRIPTION: Because the nondeforming projectile had not been attained in practice, the addition of an armor piercing cap has been a necessity in many instances. The mechanism of cap action depended upon the conditions under which the deformation took place, and its effect in limiting perforation or otherwise reducing the efficiency of the projectile. Each of these factors could be affected by the use of protective materials and by changes in projectile design and target characteristics.
CONCLUSIONS: It was concluded that the effectiveness of the cap in aiding penetration was due chiefly to its action in preventing shatter of the core. Functioning of the cap in retarding and turning the core was considered secondary. Three separate but not mutually exclusive hypotheses of cap action in preventing core shatter were presented. Insufficient evidence was available to disregard any one of them. The three explanations for cap action were: that the cap dented the armor plate, while itself deforming, so that the core on coming in contact with the plate material was subjected to lower peak forces than would operate on an uncapped core; that the cap material supported the side of the core ogive, thus replacing the nearly uniaxial compressive stress in the core nose by a more nearly hydrostatic pressure which the core material was able to withstand without rupture; and that the cap turned the core toward normal upon oblique impact.
GENERAL: This 36-page report contains one photograph showing the effects of a projectile on armor plate. Also included are drawings of test bullets.

SUBJECT: Ammunition WAL 6-1948
TITLE: An Approach to Design Criteria for Armor-Piercing Projectiles and Armored Vehicles
IDENTIFICATION: Report No. WAL 6-1948
DATE OF REPORT: June 1948
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To present design criteria considerations for armor-piercing projectiles and armored vehicles
METHOD: A discussion was given of the various possible attack conditions to be taken into account in designing projectiles and tanks. Proposals for further research were offered. A statement was made of the factors considered dominant in projectile-armor design criteria.
DESCRIPTION: The presentation of material was in the form of a short essay written by A. Hurlich of the Armor and Ammunition Branch at the Watertown Arsenal Laboratory.
CONCLUSIONS: The writer of this report believed that the basis for design of armor-piercing projectiles should rest not upon one obliquity or other target condition, but rather upon an overall consideration of the geometrical and metallurgical design variables, influencing the projectiles penetrative performance against a variety of targets over a range of obliquities and gun-to-target distances. Further research on the whole range of projectile and armor design variables was recommended. Polar co-ordinate plots of ballistic data showing vulnerability zones of various types of armor for various types of attack were recommended as useful in selecting the optimum type and characteristics of armor and the optimum gun-projectile combination for maximum effectiveness per unit weight. It was thought that all other tank design factors should be subordinated to realizing the best possible gun-projectile-armor combination and disposition to minimize the vulnerability and maximize the offensive potential of the tank under anticipated tactical conditions.
GENERAL: This seven-page report contains one page of vulnerability curves and one page of drawings of projectiles and graphs plotting the critical velocity versus nose dimensions of the projectiles.

SUBJECT: Ammunition WAL 710/930-2
TITLE: Comparative Effectiveness of Armor-Defeating Ammunition
IDENTIFICATION: Report No. WAL 710/930-2
DATE OF REPORT: 8 November 1951
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To compare the effectiveness of various types of armor-defeating ammunition
METHOD: Experimental data from tests at Aberdeen and Watertown were used as a basis for this report which was presented at a symposium on shaped charges at the Ballistics Research Laboratory, Aberdeen Proving Ground.
DESCRIPTION: Ammunition covered in this paper consisted of kinetic energy rounds, which included monobloc (AP) and capped (APC) steel shot, composite-rigid (HVAP) and discarding sabot (HVAPDS) tungsten-carbide cored shot; and chemical energy rounds, which included high-explosive plastic (HEP) and the hollow-charge (HEAT) shell.
CONCLUSIONS: Monobloc steel shot were more effective than capped steel shot for the defeat of undermatching armor at all obliquities of attack and were more effective than both APC and HVAP shot for the defeat of moderately overmatching armor (up to at least 1-1/4 calibers thick) at all obliquities of attack above approximately 45°. Capped steel shot was superior to monobloc steel shot for the defeat of greatly overmatching armor, (over 1-1/4 calibers in thickness) at obliquities in the range of 20° - 45°, but both capped and monobloc shot were greatly inferior to HVAP shot in the low obliquity range against heavy armor targets. HVAP and HVAPDS shot were most effective against heavy armor targets at low and moderate obliquities of attack (the 90mm tungsten at short ranges) but their effectiveness was

markedly degraded at obliquities above approximately 45° - 50°. The HEP shell could cause scabbing or spalling of armor up to 1.3 calibers thick, and it was not greatly influenced by angles of obliquity between 30° to 60°. Shock detonation at velocities over 2500 fps made the HEP shell relatively ineffective at high velocity. At low temperature and against brittle or unsound armor containing laminations or inclusions the effectiveness of HEP increased. Presently available data indicated that the HEAT shell would penetrate armor four times the diameter of the cone up to approximately 70° obliquity. It was recommended that both kinetic and chemical energy ammunition be used, since the exclusion of either type would greatly simplify the enemy's design and construction problem. It was reasonably simple to devise a defense against one type of round, but to devise a defense against both types was considered extremely complicated.
GENERAL: This 24-page report includes four tables of test data, five graphs, and three armor-vulnerability curves.

SUBJECT: Ammunition WAL 761/59
TITLE: Preliminary Investigation of Watertown Arsenal Laboratory Type Discarding Projectile Carriers as Applied to Small Arms Projectiles
IDENTIFICATION: Report No. 761/59
DATE OF REPORT: 26 January 1953
ORIGIN: Watertown Arsenal Laboratory, Watertown, Massachusetts
PURPOSE: To investigate discarding type projectile carriers as applied to small arms projectiles
METHOD: Three experimental types of small arms projectiles were launched into flight from the non-metallic projectile carriers, and the ballistic performance of the projectiles was evaluated. Standard projectiles were fired for comparison from the same gun barrel while using the same quantity and type of propellant. Determinations were made of velocity vs propellant charge and of the degree of accuracy 300 feet from the gun muzzle for both experimental and standard projectiles.
DESCRIPTION: The test items were Watertown Arsenal Laboratory thin-walled non-metallic projectile carriers of the discarding type, to be used as a means of launching small arms projectiles into free flight from rifled gun tubes. This type of carrier or coating would eliminate jacketing with copper, resulting in a savings of large quantities of strategic metal. A thermo-plastic material, Tenite No. 2, was used as the coating material for these tests.
CONCLUSIONS: Tests results showed definite promise that a satisfactory non-metallic carrier or coating could be developed. It was indicated that projectiles covered by a thin-walled carrier would perform as well as standard projectiles with respect to velocity, terminal accuracy, and behavior in the gun bore. Discarding of the carrier was accomplished at normal expectancy beyond the gun muzzle. It was felt that a broader testing program was justified and should incorporate the following: additional sizes or types of projectiles, different coatings or carrier materials, and the expansion to a semi-production scale process for coating projectiles.
GENERAL: This 15-page report contains a photograph showing recovered carrier fragments. Also included are drawings of the projectiles.

SUBJECT: Ammunition WAL 762/231-4
TITLE: Principles of Projectile Design for Penetration
IDENTIFICATION: Report No. WAL 762/231-4
DATE OF REPORT: 10 July 1944
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the suitability of an improved cal. .50 projectile having the same weight and external shape as the standard M2 AP
METHOD: Experimental cal. .50 projectiles were developed having a larger major ogival radius and a smaller minor ogival radius than the standard core and having a high bend strength at the required hardness level. Standard type and two experimental type core-hardened cal. .50 projectiles were fired against 1/2-inch homogeneous plates to determine the Navy ballistic limits for all three types of projectiles at 0°, 20°, 30°, and 40° obliquity.
DESCRIPTION: The two types of experimental cal. .50 projectiles were fabricated with standard FXS-318 manganese-molybdenum core stock. One type was fitted with caps.
CONCLUSIONS: Both the capped and the uncapped experimental cores had penetrating properties superior to those of the standard core at all obliquities. At 30° obliquity the Navy ballistic limit of the uncapped experimental core was 250 fps lower than that of the standard core, and at 40° obliquity the Navy ballistic limit of the capped experimental core was 300 fps lower than that of the standard core. All cores remained intact during penetration.
GENERAL: This 22-page report contains a sketch of the experimental projectile, a photograph showing the steps in the assembly of the projectile, a photograph showing the condition of a few projectiles after tests, and four pages of graphs.

SUBJECT: Ammunition WAL 762/231-8
TITLE: Principles of Projectile Design for Penetration, Eighth Partial Report; Effect of Nose Geometry on the Terminal Ballistic Performance of WC Cores
IDENTIFICATION: Report No. WAL 762/231-8; Project No. TA1-5002
DATE OF REPORT: 15 December 1953
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To compare the armor penetration performance of two truncated conical-nosed and one ogival-nosed tungsten carbide cores
METHOD: The test ammunition cores were weighed and ballistically tested against 0.50, 0.77, and 1.00-inch rolled homogeneous armor at obliquities ranging from 0° to 60°. A protection ballistic limit was obtained for each attack condition. All fragments larger than 1/20 inch in maximum dimension were recovered, and particular emphasis was placed on identification of nose and base

fragments. Ballistic limits were recorded for each test condition and plotted as functions of plate thickness and obliquity. Perforation energies were recorded for each ballistic limit in order that a direct comparison could be made with any cal. .40 tungsten carbide core.
DESCRIPTION: The test material consisted of three types of cal. .40 tungsten carbide cores manufactured by the Carboloy Company. The two truncated conical-nosed cores were designed for high obliquity attack.
CONCLUSIONS: Blunt truncated conical-nosed tungsten carbide cores required less energy for the penetration of rolled homogeneous armor than did the ogival-nosed cores when armor under attack was less than 2.5 calibers in thickness and was inclined at an obliquity greater than approximately 35°. The blunt-nosed cores suffered less shatter than the ogival-nosed cores. A truncated conical core nose remaining intact during penetration generated a conical tip from the armor that effectively acted as a cap in reducing the stresses on the core nose.
GENERAL: This 55-page report contains complete test data, one page of drawings, and eight pages of photographs of the test cores.

SUBJECT: Ammunition WAL 762/231-9
TITLE: Principles of Projectile Design for Penetration, Ninth Partial Report; Effect of Caps on Terminal Ballistic Performance of WC Cores
IDENTIFICATION: Report No. WAL 762/231-9; Project No. TA1-5002
DATE OF REPORT: 5 January 1954
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To compare the performance of steel and tungsten caps on tungsten carbide cores
METHOD: Projectile-cap combinations were weighed and mounted in caliber .60/.40 plastic discarding carriers. Several rounds of each type were fired at .50, .77, and 1.00-inch armor at obliquities of 45° and 60°. Projectile velocities were measured with a Potter Chronograph. Ballistic limits were recorded and projectile-cap fragments were recovered and examined.
DESCRIPTION: The tungsten carbide cores were cal. .40 scale models of the ogival-nosed 90mm HVAP M304 core. The type H-17 and H-18 steel caps were machined from SAE 1020 plain carbon steel, hot rolled and annealed. The steel had an approximate hardness of 200 BHN. The type H-18 tungsten caps were machined from Mallory 1000 metal barstock which was an alloy of 90% tungsten plus 10% carbon and nickel with a density of 16.8 grams per cubic centimeter and a hardness of 250 to 280 BHN.
CONCLUSIONS: Test results indicated that either steel or tungsten caps could be employed effectively for the reduction of core nose shatter and that either cap material improved the penetrating capabilities of the projectile against armor less than two calibers thick at obliquities up to 55°. There appeared to be an optimum weight of cap material for a given cap design which was most effective in reducing the energy required for the perforation of a given armor target.
GENERAL. This 45-page report contains 28 pages of tabulated test data, sketches, graphs, and photographs.

SUBJECT: Ammunition WAL 762/523-1(C)
TITLE: Discarding Projectile Carrier - Part 2 Performance of Scale Model Plastic Sabot Projectiles Fired in a .60 Caliber Test Barrel at Velocities from 700 to 6000 Ft./Second
IDENTIFICATION: Report No. 762/523-1 (C)
DATE OF REPORT: 15 November 1950
ORIGIN: Watertown Arsenal Laboratory, Watertown, Massachusetts
PURPOSE: To evaluate the performance of scale model plastic sabot projectiles fired in a cal. .60 test barrel
METHOD: The projectiles were fired from a cal. .60 barrel, No. S.A.R. 433-D-82866. Observation and bore measurements were made after 511 and 1011 rounds had been fired. Graphs were plotted showing the number of rounds fired at each 100-foot velocity increment from 700 to 6000 ft./sec. Projectile velocity vs. powder charge during a typical firing test was graphically illustrated to show the number of rounds fired, the distribution of projectile velocities, and a typical projectile velocity-powder charge relationship.
DESCRIPTION: The majority of test projectiles were scale model 90mm AP shot, cal. .400-inch. Miscellaneous rounds included scale model rocket assist projectiles and cal. .45 ball ammunition. All of the projectiles were mounted in carriers .608-inch in diameter. The carrier material used was "lucite" except for certain rounds which were made of various plastic materials supplied by the Naval Research Laboratory.
CONCLUSIONS: For the design of projectiles fired, good stability and accuracy were obtained over the velocity range of 700 to 6000 ft./sec.; special provisions in the carrier design were necessary at lower velocities. The bases of the nonmetallic carrier were virtually unaffected during firing, and wear that could be attributed to this type of carrier was negligible. The errosive effect of the powder propellant increased with increased charges, was maximum behind and at the origin of rifling, and gradually diminished over a distance 40 inches forward of the origin of rifling. Limited evidence indicated that unburned powder grains contributed to erosion of the centering cylinder of the barrel.
GENERAL: This 35-page report contains eight photographs showing samples of the engraved plastic carrier, the firing equipment, and typical terminal ballistic results; shadowgraphs of several projectiles in flight are included. Also contained in the report is a brief description, with two accompanying photographs, of a WAL triggering device for actuating the Potter Counter Chronograph.

SUBJECT: Ammunition WAL 762/595
TITLE: Full-Caliber versus Sub-Caliber Steel Shot for the Defeat of Armor
IDENTIFICATION: Report No. WAL 762/595; Project No. TA1-5002

DATE OF REPORT: 19 November 1951
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To compare the effectiveness of full-caliber and sub-caliber steel shot and the effectiveness of capped and monobloc steel sub-caliber shot in defeating armor
METHOD: Equations were developed for determining the muzzle velocity of sub-caliber projectiles, ballistic coefficients, projectile retardation, and terminal velocity. These equations were used to construct range velocity curves for several types of projectiles. Terminal ballistic data were correlated with range by determining the ballistic limit for a given plate thickness and obliquity and substituting the range for the velocity at the ballistic limit. Data obtained from scale model ballistic tests were used as a standard of comparison. The effectiveness of each of the test types of shot was determined by an analysis of the curves and charts constructed during the study.
DESCRIPTION: The types of shot analyzed in this report were capped and monobloc 90mm, 76mm, and 120mm full and sub-caliber shot geometrically similar to the 90mm AP T33 and 90mm APC T50.
CONCLUSIONS: It was found that the most efficient diameter for a sub-caliber steel projectile employed in the penetration of rolled homogeneous armor was equal in size to 7/10 of the bore diameter of the gun from which it was fired. In general, there was little difference in penetrative performance against rolled homogeneous armor between a steel sub-caliber shot of the most efficient diameter and a homologous full-caliber shot. The sub-caliber shot exhibited slightly better penetration at the near ranges, while the full-caliber shot was slightly superior at the longer ranges. Against targets which were overmatched for the full-caliber projectile, a capped sub-caliber shot of 7/10 bore diameter exhibited terminal ballistic performance equal or superior to both capped and monobloc full-caliber shot.
GENERAL: This 40-page report contains 25 pages of tabulated data, graphs, and curves.

SUBJECT: Ammunition WAL 762/604
TITLE: Metallurgical Examination of Soviet 76mm HVAP-T Mod. BR-354P Projectile, FMAM 2153
IDENTIFICATION: Report No. 762/604
DATE OF REPORT: 8 July 1953
ORIGIN: Watertown Arsenal, Watertown, Massachusetts
PURPOSE: To conduct a metallurgical examination of the projectile and to evaluate its design, manufacture, and performance characteristics
METHOD: The components of the projectile were subjected to a metallurgical examination including chemical analyses, macroetch studies, hardness tests, mechanical tests, and microscopic examination.
DESCRIPTION: The Soviet 76mm HVAP was an arrow-head composite-rigid tungsten carbide cored shot having a soft steel body fitted with an aluminum windshield and a copper rotating band.
CONCLUSIONS: The Soviet 76mm HVAP projectile was considered a relatively inefficient armor piercing shot because the core was extremely small for the 76mm caliber and the corresponding low kinetic energy of the penetrator would result in poor armor penetration performance. The penetrator, including the follow-through plug, weighed only 20% of the total projectile weight, whereas previous experience had proved that the maximum armor piercing efficiency was attained, with sub-caliber tungsten carbine cored composite-rigid projectiles, when the ratio of penetration weight to total projectile weight was approximately 50%. Also the tungsten carbide core had low bend strength, high porosity, low binder content and a coarse grained structure. These rather poor metallurgical properties and conditions would degrade the terminal ballistic performance of the subject shot. The projectile design was simple and permitted its efficient manufacture with the use of a minimum amount of highly specialized equipment.
GENERAL: This 23-page report includes three photographs, one blueprint, and six photomicrographs of the subject projectile.

SUBJECT: Ammunition WAL 762/605
TITLE: Metallurgical Examination of Soviet 76mm HE Shell, Mod. 0-354, FMAM 2272
IDENTIFICATION: Report No. 762/605
DATE OF REPORT: 8 July 1953
ORIGIN: Watertown Arsenal, Watertown, Massachusetts
PURPOSE: To conduct a metallurgical examination of the subject shell and to evaluate its method of manufacture, design, and potential performance characteristics
METHOD: The test shell was subjected to a metallurgical examination including chemical analysis, macroetch, hardness and mechanical tests, and microscopic examination.
DESCRIPTION: The subject projectile was of conventional shape, having a long ogival nose, two bourrelets, one copper rotating band, and a boat-tailed base. The most significant feature of the shell was that it was manufactured from pearlitic gray cast iron rather than a forged heat-treated steel which was normally used in domestic HE shell. The explosive cavity was considerably smaller than that of domestic shell and the shell walls were thicker.
CONCLUSIONS: The test shell was made from a gray cast iron material which offered definite advantages in fragmentation characteristics over wrought steel generally specified for domestic HE shell, Model O-353, FMAM 2265. The use of gray cast iron provided a cheap, readily machinable, and easily cast steel that could be produced with relatively simple manufacturing facilities.
GENERAL: This 17-page report includes three photographs, one dimensional drawing, and two photomicrographs of the shell body and rotating band of the test projectiles.

SUBJECT: Ammunition WAL 762/607 (C)
TITLE: Metallurgical Examination of Soviet 76mm or HE Shell, Mod. Unidentified, FMAM 2271
IDENTIFICATION: Report No. 762/607 (c)

DATE OF REPORT: 8 July 1953
ORIGIN: Watertown Arsenal, Watertown, Massachusetts
PURPOSE: To conduct a metallurgical examination of the subject shell and to evaluate its method of manufacture and design characteristics
METHOD: The shell was subjected to a metallurgical examination consisting of chemical analysis, microscopic examination, macroetch, hardness, and mechanical tests. The major fuze train components were examined for hardness, microstructure, and chemical analyses where possible.
DESCRIPTION: The test shell was unidentified, however, it was believed to be a Soviet 76mm HE shell Model 0-345-0, a WWI-type. The ogive was bluntly rounded rather than long and tapering as usually encountered in an HE shell. A single copper rotating band was fitted to the shell which had a cannelure machined into the base for crimping the cartridge case. Knurling in the band seat consisted of six circumferential rows of raised pyramids, 14 pyramids per inch. The fuze adapter was machined from a low carbon free machining steel similar to SAE 1112 Bessemer steel. The booster cup was deep drawn from a very low carbon steel and process annealed. The detonator cup was formed in two sections, the upper section was drawn from steel and soldered to the lower section which was drawn from brass. The entire detonator assembly was tin plated.
CONCLUSIONS: The shell, which was forged from a medium carbon unalloyed steel, was an older type Soviet shell infrequently encountered. The blunt rounded ogive indicated that the shell was employed in low velocity weapons for short range firing. The shell possessed no novel design or metallurgical features. The metal components were of average quality and the workmanship was adequate.
GENERAL: This 20-page report includes two photographs, one blueprint, and 10 photomicrographs of the subject shell.

SUBJECT: Ammunition WAL 762/609
TITLE: Metallurgical Examination of Chinese 60mm HE Mortar Shell, FMAM 2276
IDENTIFICATION: Report No. 762/609
DATE OF REPORT: 22 June 1953
ORIGIN: Watertown Arsenal, Watertown, Massachusetts
PURPOSE: To determine the metallurgical characteristics of a Chinese mortar shell
METHOD: The shell was visually examined to determine significant design features after which dimensions were measured for the preparation of a dimensioned drawing. A longitudinal slice was cut through the center of the shell for a hardness survey and macroetching. Microscopic examination, chemical analyses, hardness, and tensile tests were conducted on specimens obtained from the shell body, fin, and cartridge.
DESCRIPTION: The test item was a 60mm shell, HE, for Chinese mortar, FMAM 2276. The shell body was made from low strength cast iron and was of conventional tear-drop design employed for HE mortar shell. Five gas check bands machined in the bourrelet were almost identical to those of the domestic 60mm HE mortar shell M49A2.
CONCLUSIONS: The shell body was made from a gray cast iron containing 3.95% carbon and having an average Rockwell B hardness of 82.4. The macrostructure indicated that the shell was cast in a metal "chill" mold. The cartridge container, machined from a plain carbon steel barstock corresponding in composition to SAE 1010, and the fins, stamped from a low carbon steel, were identical to the parts of the American fin assembly M2 used for several designs of domestic 60mm mortar shell. The cast iron used in the HE shell provided excellent fragmentation characteristics combined with low cost and simplicity of manufacture.
GENERAL: This 21-page report contains four photographs of the HE shell. Also included is a dimensional drawing of the shell.

SUBJECT: Ammunition WAL 763/851 (C)
TITLE: Metallurgical Examination of Soviet 122-mm HE Shell FMAM 1896 and 2157
IDENTIFICATION: Report No. 763/851 (c)
DATE OF REPORT: 20 January 1954
ORIGIN: Watertown Arsenal, Watertown, Massachusetts
PURPOSE: To determine the metallurgical characteristics of two Soviet shells
METHOD: Because the shells were identical, only FMAM No. 1896 was tested. Following a visual examination and recording of all identification symbols, the shell was photographed and dimensioned. The evaluation included macroetching, hardness tests, microscopic examination, chemical analysis, tensile tests, and V-notch Charpy impact tests. The chemical composition, microstructure, and hardness were also determined for the rotating band.
DESCRIPTION: The test units were two Soviet 122mm HE shells identified as FMAM 1896 and FMAM 2157. The two rounds were of identical design.
CONCLUSIONS: The quality of steel used for the shell body was considered satisfactory. The shell was forged from an unalloyed 0.68% carbon steel and had an average hardness of 249 Brinell. The tensile properties in the bourrelet and band seal regions were similar, averaging 53,000 psi (lower than that specified for similar caliber domestic HE shell) in yield strength and 118,500 psi in tensile strength. The metallurgical structure and mechanical properties of the steel were typical of Soviet forged high explosive steel of the World War II period. Impact values obtained with standard V-notch Charpy specimens ranged from 5.5 ft.-lbs. at room temperatures to 27 ft.-lbs. at 200°C, with fracture becoming ductile at 180°C. The rotating band was made from high purity copper tubing and had a hardness of 120 Brinell after being cold pressed into the seat band. The workmanship of the shell with respect to machine finish was poor according to domestic standards. However, this feature did not detract from ballistic performance and represented a saving in manufacturing costs.
GENERAL: This 20-page report contains three photographs and a dimensioned drawing of the HE shell.

SUBJECT: Ammunition WAL 763/855
TITLE: Metallurgical Examination of Soviet 122-mm Heat Projectile, Mod. BP-460A (FMAM 2158) and Soviet 122mm Wrapped Steel Cartridge Case, Mod. Zh-463 (FMAM 2158)
IDENTIFICATION: Report No. 763/855
DATE OF REPORT: 23 July 1954
ORIGIN: Watertown Arsenal, Watertown, Massachusetts
PURPOSE: To determine the metallurgical characteristics of a Soviet projectile and cartridge case
METHOD: Following a visual examination to determine significant design features and identification markings, the projectile and cartridge case were dimensioned and drawings were prepared. The projectile and cartridge case bodies were then subjected to chemical analyses, hardness surveys, tensile tests, and metallographic and microscopic studies. Similar tests were conducted on all of the other components with the exception that tensile testing was not performed because of section size limitation.
DESCRIPTION: The test units were a Soviet 122mm HEAT projectile, Model BP-460A (FMAM 2158) and a Soviet 122mm wrapped steel cartridge case, Model Zh-463 (FMAM 2158A).
CONCLUSIONS: A gray cast iron, which contained 3.01% total carbon and possessed a yield strength of 35,800 psi and a tensile strength of 41,200 psi, was employed for the projectile body. A mottled cast iron having a composition similar to that of the body was used for the windhield. The cone or liner was made from deep drawn and formed 0.19% carbon sheet steel. The average hardness values for the body and cone were 210 and 152 BHN, respectively. The sidewall of the cartridge case was fabricated from 0.095% carbon sheet steel having a yield strength of 64,250 psi, a tensile strength of 71,000 psi, and hardness of 172 BHN. The remaining components of the cartridge case, the base section and the locking ring, were made of unalloyed 0.37% and 0.12% carbon steel, respectively. The average hardness of the locking ring was 165 BHN, and the base section had a decremental hardness averaging 165 BHN throughout the central area and 241 BHN at its outer surface.
GENERAL: This 31-page report contains nine photographs showing the projectile cartridge case, and microstructures of both items. Also included are dimensioned drawings of the projectiles and cartridge case.

Section 3
AMPHIBIAN VEHICLES

SUMMARY

This summary covers resumes of 11 engineering reports written on amphibian vehicles between 1944 and 1949 at the Army Air Forces Board, Orlando, Florida; Army Field Forces Board No. 2, Fort Knox, Kentucky; Aberdeen Proving Ground, Maryland; Field Artillery Board, Fort Bragg, North Carolina; and the Landing Vehicle Board, Fort Ord, California.

Among the amphibian vehicles tested were the Swamp Buggy; standard LVT 4; lightweight LVT 4; LVT 5; jeep-type lightweight vehicle; 1/2-ton carrier (Weasel type); LVT III; 2-1/2-ton truck, 6x6, DUKW; wrecker; WTCT4 trailer; LVT A4; T86 motor carriage; and M29C cargo carrier.

CARGO TRAILER, WTCT4

The suitability of an amphibian trailer, WTCT4, was determined in a 1944 test. The vehicle was constructed of sheet metal, weighed 4750 pounds, and had a wooden hatch. Towing was accomplished by a prime mover with either a lunette eye or a pintle. The trailer was considered watertight and satisfactory for use. No damage resulted from surf wash. The test unit was recommended for military use provided minor modifications were incorporated in the trailer and towing assembly.

1/2-TON CARRIER, "WEASEL" TYPE

A 1949 study was made to determine the military characteristics that would be most desirable for a low-pressure, general purpose vehicle of the "Weasel" type. Results of the study indicated that the vehicle should be more versatile and durable than normal vehicles, capable of floating and self-propulsion without the addition of special equipment, capable of year-around operation in arctic terrain, capable of cross-country operation without roads and away from normal supply and maintenance facilities; capable of being transportable in 8000-pound assault aircraft; and reliable in starting after long periods of inactivity under all climatic conditions. It was proposed that a test vehicle be designed to carry four men or a minimum load of 1000 pounds, and to tow up to 2400 pounds of cargo or 10 men skijoring. It was also recommended that attention be given to maximum interchangeability of parts with standard vehicles.

REPORT RESUMES

SUBJECT: Amphibian Vehicles AAF (M-4) 434
TITLE: Swamp Buggy, Salvaging and Retrieving, Model 1941
IDENTIFICATION: Project No. (M-4) 434
DATE OF REPORT: 7 April 1944
ORIGIN: Army Air Forces Board, Orlando, Florida
PURPOSE: To determine the suitability of the Swamp Buggy and its power hoist assembly
METHOD: The vehicle was operated over swampy terrain to determine its ability to negotiate swamps, sand and shallow rivers. Characteristics of the hoist assembly were determined.
DESCRIPTION: The test Swamp Buggy was a standard 1-1/2-ton Chevrolet, 4 x 4, truck equipped with 24 x 14 tires. The regular carry-all body was replaced with a 500-gallon gasoline refueling unit. The power hoist assembly consisted of a 10,000-pound Gar Wood winch that was power-driven from a standard SAE take-off on the vehicle transmission, a stiff-legged tripod that was adjustable to three positions, and two jacks mounted on the rear of the vehicle chassis and under the legs of the tripod to support loads.
CONCLUSIONS: The Swamp Buggy was considered unsatisfactory. If further consideration were to be given to this type of vehicle, it was recommended that: the hoist assembly be mounted on a larger vehicle; the winch cable be of sufficient strength to lift 10,000 pounds and still maintain a satisfactory safety margin; closed eyes and clevis pins be used on the rear legs of the tripod; a 1000-gallon tank replace the 500-gallon unit; the modified vehicle be resubmitted for test.
GENERAL: This 22-page report contains 11 photographs of the vehicle and its components.

SUBJECT: Amphibian Vehicles AFF 1234
TITLE: Study of 1946-47 Winter Test of Landing Vehicles, Tracked (4) Lightweight (4), and (A) (5) by Army Ground Forces Task Forces Frost and Williwaw
IDENTIFICATION: Project No. 1234
DATE OF REPORT: 13 July 1948
ORIGIN: Army Field Forces Board No. 2, Fort Knox, Kentucky
PURPOSE: To determine the suitability of standard LVT 4, lightweight LVT 4, and LVT A5 for cold-wet and heavy winter conditions and to evaluate test methods
METHOD: The three vehicles were operated over ice and snow-packed roads, ice slopes, in snow up to 15 inches deep, and over normal and frozen terrain. A surf test was conducted on the LVT A5.
DESCRIPTION: The standard LVT 4, of all-steel

construction, was powered by an air-cooled, 7-cylinder, radial gasoline engine, and had a ground pressure of 7 psi loaded. The lightweight LVT 4 was similar to the standard except that many of its components were of aluminum and its ground pressure was 4.3 psi loaded and 2.6 psi unloaded. The LVT A5, an armored howitzer carriage, was armed with a 75mm Howitzer M2 or M3 on Mount M7, one cal. .30 bow machine gun, and two cal. .30 scarf machine guns. This vehicle's ground pressure was 10.9 psi stowed and 9.95 psi unstowed.
CONCLUSIONS: Test methods were considered generally adequate, though lacking in details. All vehicles operated satisfactorily under maximum relative humidity. The lightweight LVT 4 and the LVT A5 were considered unsatisfactory for use in cold-wet winter conditions. The standard LVT 4, when modified, could be considered satisfactory for cold-wet and heavy winter operations. Torqumatic transmissions for all three types, an increased power-to-weight ratio, and turret revisions were recommended. However, in view of current developments, major modifications for these vehicles should be deferred.
GENERAL: This 97-page report includes 24 photographs illustrating vehicle components and test conditions.

SUBJECT: Amphibian Vehicles AFF 1349
TITLE: Military Characteristics for Jeep-Type Lightweight Vehicle
IDENTIFICATION: Project No. 1349
DATE OF REPORT: 9 April 1949
ORIGIN: Army Field Forces Board No. 2, Fort Knox, Kentucky
PURPOSE: To establish military characteristics for an amphibious jeep-type personnel and cargo vehicle which could be converted to use as a glider
METHOD: A review of all available pertinent reports and studies was made by the Army Field Forces Board No. 2 and conferences were held with officers of varied combat experience to determine the desired characteristics of the vehicle. A characteristic sheet was formulated and drafts of it were circulated to various interested agencies, including the British and Canadian liaison officers, for comment. Several vehicles, incorporating some of the design features, were investigated.
DESCRIPTION: The proposed vehicle was to be designed for operating on land as a wheeled or half-track vehicle with performance at least equal to that of the standard 1/4-ton truck. It was to have satisfactory performance in water as a 1/4-ton cargo amphibian, or as a 3/4-ton cargo trailer with the crew compartment and engine removed. It was also to have satisfactory performance in the air as a glider when combat loaded as a land vehicle and equipped with vehicular flying kit. As many standard component parts as possible were to be considered in the design.
CONCLUSIONS: It was recommended that the military characteristics formulated in this study be used as a basis for preliminary engineering studies with the understanding that these characteristics would be finalized at a conference attended by representatives of the using arms and the development agency prior to submission to the technical committee. It was also recommended that a vehicle based on the finalized military characteristics be designed and pilot models procured for engineering and service tests.
GENERAL: This 20-page report is not illustrated. A list of military characteristics for the proposed vehicle is included.

SUBJECT: Amphibian Vehicles AFF 1376
TITLE: Military Characteristics for a 1/2-Ton Amphibian Carrier (Weasel Type)
IDENTIFICATION: Project No. 1376
DATE OF REPORT: 11 April 1949
ORIGIN: Army Field Forces Board No. 2, Fort Knox, Kentucky
PURPOSE: To determine the military characteristics that would be most desirable for a low-ground pressure, general purpose vehicle of the "Weasel" type
METHOD: Research was conducted on applicable military letters, technical reports, and minutes of meetings. Postwar plans were studied to determine the role of this type of vehicle in future warfare. Opinions and recommendations were obtained from personnel with winter combat experience. Conferences were held with combat-experienced personnel having a variety of backgrounds.
DESCRIPTION: Not applicable.
CONCLUSIONS: Results of the study indicated that the vehicle should be more versatile and durable than normal vehicles, capable of floating and self-propulsion without the addition of special equipment, capable of year-round operation in arctic terrain, capable of cross-country operation without roads and away from normal supply and maintenance facilities, capable of being transportable in 8000-pound assault aircraft, and reliable in starting after long periods of inactivity under all climatic conditions. It was proposed that a test vehicle be designed to carry four men or a minimum load of 1000 pounds and to tow up to 2400 pounds of cargo or 10 men skijoring. It was also recommended that attention be given to maximum interchangeability of parts with standard vehicles.
GENERAL: This 25-page report is not illustrated.

SUBJECT: Amphibian Vehicles APG 5648/8
TITLE: First Report on Tractor, Amphibian LVT III, Engineering Test
IDENTIFICATION: Eighth Report on Ordnance Program No. 5648; APG 100-15
DATE OF REPORT: 28 October 1946
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability and reliability of the test vehicle and to compare it with the LVT IV amphibian tractor
METHOD: Various engineering tests, wall climbing, slope operation, drawbar pull, speed, cooling, tractive resistance, and fuel consumption were run on the vehicle on land and in water. Walls up to 3 feet and slopes up to 60% were negotiated in the tests.
DESCRIPTION: The test LVT III was a full-tracked vehicle powered by two Cadillac 110 hp

engines located in the sponson areas. The driver and assistant driver sat in the front area of the hull. The rear of the hull was formed by a loading ramp on a pivot. Cargo was carried in the center of the hull. The power train consisted of two hydramatic transmissions, two drive shafts, a single transfer and differential unit, and two final drives. The hull was an unarmored, waterproof type with a boat-like front.
CONCLUSIONS: The hydramatic transmissions improved the performance of the vehicle. The LVT III had better drawbar pull on land, and the LVT IV had better drawbar pull and maximum speed in the water. These were the only comparisons made. It was recommended that the LVT III cooling system and ramp control be improved, that the LVT series of vehicles be given extensive tests and that a 2.86 to 1 final drive be used on the LVT III.
GENERAL: This 215-page report contains 27 photographs showing testing and general construction of the vehicle.

SUBJECT: Amphibian Vehicles FAB 1-E-39
TITLE: Truck, 2-1/2-Ton, 6x6, Amphibian DUKW, Lifting "A" and Harness, T-1 (105-MM Howitzer)
IDENTIFICATION: Report No. 1-E-39; Test No. O-52-L
DATE OF REPORT: 22 July 1944
ORIGIN: Field Artillery Board, Fort Bragg, North Carolina
PURPOSE: To determine the suitability of the 2-1/2-ton 6x6 Amphibian Truck DUKW 353, the lifting "A" frame and 105mm Harness T1 for field artillery use
METHOD: The howitzer and gun carriage were mounted on the truck by the use of a winch cable, an "A" frame and special sling operated from a second DUKW truck. The harness then secured the howitzer in position. The vehicle was driven for 229 miles over various terrain and given amphibious operation for 21 hours. Firing tests were conducted during land and sea movements. The total payload was 8900 pounds.
DESCRIPTION: The 2-1/2-ton, 6x6, Amphibian Truck DUKW 353 carried the 105mm Howitzer M2A1 on Gun Carriage M2A2. The lifting "A" frame was standard equipment for this truck. The 105mm Howitzer Harness T1 consisted of curved steel bands holding the howitzer wheels and with cables to the lifting eyes.
CONCLUSIONS: The test equipment was not acceptable for military use. Firing of the howitzer from the truck was impractical and its use was possible in calm water only. The "A" frame was satisfactory except for tearing of the gun carriage tires.
GENERAL: This 20-page report includes 12 photographs of the vehicle and equipment.

SUBJECT: Amphibian Vehicles LVB 4
TITLE: Military Characteristics of Amphibian Wrecker
IDENTIFICATION: Project No. 4
DATE OF REPORT: 5 June 1944
ORIGIN: The Landing Vehicle Board, Fort Ord, California
PURPOSE: To determine the military characteristics of an amphibian wrecker suitable for military units equipped with tracked landing vehicles
METHOD: A Landing Craft LVT (4) was considered as the basic vehicle. Drawings of the vehicle were considered and a list of required equipment and its installation was made up.
DESCRIPTION: The Landing Craft LVT (4) was full-tracked. To this vehicle was added the necessary equipment to salvage and repair other vehicles in the water and on land. This addition included auxiliary power (electric), welding equipment, a 20,000 pound winch, power and hand tools, salvage equipment, auxiliary pump, a 15,000-pound "A' frame boom, and protective covers.
CONCLUSIONS: The military characteristics for an amphibian wrecker as determined in this report were satisfactory for the purpose intended. It was recommended that 13 vehicles be procured for test by the Marine Amphibious Training Center, the 18th Armored Group and the Landing Vehicle Board.
GENERAL: This 11-page report contains four photographs of drawings of the LVT (4) landing craft. A list of the proposed military characteristics is also included.

SUBJECT: Amphibian Vehicles LVB-19
TITLE: Test of Trailer, Cargo, Watertight
IDENTIFICATION: Project No. 19
DATE OF REPORT: 16 October 1944
ORIGIN: Landing Vehicle Board, Fort Ord, California
PURPOSE: To determine the suitability of an Amphibian Trailer WTCT 4
METHOD: The trailer, with a 7000-pound payload, was towed in water and on land by means of DUKW and LVT 4 Amphibian Vehicles. High speed runs were made by the vehicle in water, with and without the towed trailer, to determine trailer weight on vehicle performance. Comparisons were made of these runs to determine whether the trailer could be successfully beached through surf.
DESCRIPTION: The test Cleaner-Brooks watertight Cargo Carrier WTCT 4 was a 4750-pound amphibian vehicle of sheet metal construction and had a wooden hatch. It could use either dual 8.25 x 20 or single 11.00 x 18 tires. Towing was accomplished by a prime mover with either a lunette eye or a pintle. At the rear of the trailer was a towing eye to which another trailer could be fastened. The trailer hitch was so constructed as to be "float free" when in water, or rigid on land.
CONCLUSIONS: The trailer was considered watertight and satisfactory for use with either prime mover. No damage resulted from surf wash. LVT 4 maneuverability was impaired to some degree when entering the water at an angle greater or less than 90°. DUKW maneuverability was hampered by the added load of the trailer. The test unit was recommended for military use providing minor modifications were incorporated in the trailer and towing assembly.
GENERAL: This 52-page report includes 42

photographs illustrating the vehicle and components and test conditions.

SUBJECT: Amphibian Vehicles LVB 20
TITLE: Machine Gun Positions in LVT A4
IDENTIFICATION: Project No. 20
DATE OF REPORT: 22 December 1944
ORIGIN: Landing Vehicle Board, Fort Ord, California
PURPOSE: To determine the seaworthiness of a modified, fully stowed, Amphibious Vehicle LVT A4; and to determine the suitability of two types of armored machine gun mounts designed for use with the vehicle
METHOD: Simulated operating loads were stowed in the positions normally containing vehicle and crew equipment. The following tests were then conducted: the vehicle was weighed empty and fully stowed; vehicle trim in still and open water and stability in surf were determined; and the cal. .30 machine guns were fired from the experimental machine gun mounts.
DESCRIPTION: The hull of the modified LVT A4 was identical with that of the standard. The turret of the modified vehicle, however, was moved forward in order to place two cal. .30 Machine Gun Mounts MK XXI, with armored shields, aft of the turret. One of these mounts was developed by the Bureau of Ships and the other by the Food Machinery Corporation.
CONCLUSIONS: The vehicle when stowed for combat was considered unsatisfactory for surf operations. A definite trim down at the bow and a slight list to port were observed. Neither shielded machine gun mount was satisfactory because of interference encountered with the 75mm howitzer turret. The Bureau of Ships gun mount design was found to be very unstable. The modified vehicle was not recommended for acceptance.
GENERAL: This 70-page report contains 46 photographs showing various views of the vehicle during test operation.

SUBJECT: Amphibian Vehicles LVB 25
TITLE: Carriage, Motor, Amphibian, 76mm Gun, T-86
IDENTIFICATION: Project No. 25
ORIGIN: Landing Vehicle Board, Fort Ord, California
PURPOSE: To determine the suitability of an Amphibian Motor Carriage T86
METHOD: The general performance of the vehicle on land, water, and in heavy surf was determined. The main armament was fired during water operation.
DESCRIPTION: The full-tracked 76mm Gun Amphibian Motor Carriage T86 consisted basically of the lower hull and suspension of a Gun Motor Carriage M18 cut off at the fender line. A boat-shaped hull and an M16 turret formed the upper part of the vehicle. The turret was equipped with a gyro-stabilizer for control of the gun in elevation, and power traverse. Two large rudders, cable-connected to an automotive steering gear operated by the driver, were provided for steering in water. Triple controls in the drivers' compartment were provided for a driver and two assistants.
CONCLUSIONS: The vehicle was considered seaworthy, and the 76mm gun was fired satisfactorily when the vehicle was in water. However, the rudder installation, interior arrangement, and mechanical components of the vehicle were unsatisfactory. It was recommended that the vehicle be considered unsatisfactory for further development because of the deficiencies noted; and that development be continued with the objective of designing a satisfactory vehicle embodying the desirable features of the test vehicle (greater power, larger gun, longer hull, tank type track, semi-automatic transmission, and torsion bar suspension).
GENERAL: This 31-page report contains 22 photographs showing various views of the vehicle, components damaged in operation, and the effect of salt water on unprotected components.

SUBJECT: Amphibian Vehicles LVB 26
TITLE: Test of Cargo Carrier, M29C, and Surf Gear Kit
IDENTIFICATION: Project No. 26
DATE OF REPORT: 16 December 1944
ORIGIN: Landing Vehicle Board, Fort Ord, California
PURPOSE: To determine the suitability of Cargo Carrier M29C for amphibious operation, with and without a surf gear kit installed
METHOD: The vehicles were operated with and without the surf gear kit in calm water, and with the kit in surf ranging in height from a few inches to three feet. One vehicle was operated in Monterey Bay with bow and stern cells removed, and another over swampy land.
DESCRIPTION: The full-tracked Light Cargo Carrier M29C was powered by a liquid-cooled, 6-cylinder engine. Steering on land was accomplished through a controlled differential, and in water by means of two stern rudders. Bow and stern cells of sheet metal were designed to give more freeboard in surf. Aprons of sheet metal on the hull sides were used to increase traction in water.
CONCLUSIONS: The carrier was not considered suitable for amphibious operation because of prohibitive maintenance required after salt water operation. Lack of waterproofing caused water to be sprayed on various electrical parts by the fan, causing engine failure. The surf gear kit was not suitable for field installation. It was recommended that the Cargo Carrier M29C be used for negotiating shallow rivers, streams, ponds, and swamp areas only; that the power train be modified to prevent lubricant contamination; and that the suspension be modified to improve cross-country operation.
GENERAL: This 52-page report contains 36 photographs of the vehicles during test operations.

Section 4
ARMOR

SUMMARY

This summary covers resumes of 689 engineering reports written between 1939 and 1956 on the vulnerability characteristics of various vehicles and the various armor materials. Vulnerability investigations generally were confined to tanks, while the majority of armor material reports were devoted to steel, face-hardened, rolled, and cast homogeneous. A number of the reports covered aluminum, magnesium, and plastics and other nonmetallics.

Tests were conducted at Aberdeen Proving Ground, Maryland; Watertown Arsenal, Massachusetts; Detroit Arsenal, Center Line, Michigan; Armored Board and Army Field Forces at Fort Knox, Kentucky; Frankford Arsenal, Philadelphia, Pennsylvania; Landing Vehicle Board, Fort Ord, California; and such commercial agencies as the Standard Steel Spring Company, Chrysler Corporation, American Locomotive Company, Cadillac Motor Car Division of the General Motors Corporation, American Car and Foundry Company, General Steel Castings Corporation, and Air Reduction Company. Additional reports were provided by the Office, Chief of Ordnance, Washington, D.C.; Bureau of Ships, Washington, D.C.; Inspection Board of the United Kingdom and Canada, Ottawa, Canada; and U.S. Naval Proving Ground, Dahlgren, Virginia. The majority of reports were prepared at Aberdeen Proving Ground, Maryland.

VEHICLE VULNERABILITY

Numerous reports were devoted to the protection against aircraft, artillery, ground fire, and mines offered by the following vehicles: light tanks, M2 series; light and medium tanks, M3; British A-12 infantry tank; light tank, M5; medium tanks, M4 series; medium tank, M46; halftrack car, M2; personnel carrier, M3; medium or heavy tank, M26E4 and M26E5; armored utility vehicle, M44; and the Russian T34/85 tank. The various reports ranged in scope from studies of protection against one weapon to studies of protection against a variety of antitank weapons.

LIGHT TANKS, M2 SERIES

During 1939, 1940, and 1941, reports were prepared on the vulnerability characteristics of this series of vehicles to the following types of fire: cal. .30 and .50 ball and AP machine gun (one test from a Seversky P35 pursuit plane); 81mm trench mortar; 75mm pack howitzer; 20mm Madsen antitank gun (APG and APE); and 37mm antitank gun, M3 (AP and HE). The test vehicles were found vulnerable to attack from all of the preceding weapons except the 81mm trench mortar. One report written in 1941 on the addition of armor to a medium tank, M2A1, indicated that this modification could be accomplished satisfactorily.

LIGHT AND MEDIUM TANKS, M3

A 1941 report revealed that a light tank, M3, would not be seriously affected by attack from cal. .30, cal. .50 ball, AP, and 37mm TP ammunition, and "Molotov Cocktails". However, the turret was immobilized and recommendations were made to correct this deficiency. The vulnerability of a medium tank, M3, to attack ranging from cal. .30 ball to 105mm HE ammunition led to a recommendation for discontinued production of riveted hulls (1942).

MEDIUM TANKS, M4 SERIES

Three 1944 reports on this series of vehicles consisted of two on general ballistic performance and one on the ability to operate within an artillery barrage or concentration. One of the major deficiencies found in the first two tests was the low shock resistance of the traversing mechanism. The third test report demonstrated that the M4 series medium tanks could be operated in a barrage of 105mm or less without serious damage, and in a friendly barrage or concentration of 105mm or less with almost complete immunity if the bursting height was maintained above 12 yards.

MEDIUM TANK, M46 (1951)

Ballistic performance data obtained in Korea were consolidated and analyzed for pertinent recommendations which included the relocation and redesign of numerous components such as hatches, fire extinguishers, and machine guns.

ARMORED UTILITY VEHICLE, M44

This vehicle was found in 1944 to be vulnerable to small-arms attack and subject to immobility from antitank mines, M1 and M6. Gas tanks and storage batteries were vulnerable to high explosive shell fragments and small-arms fire. An increase in main arm obliquity was recommended.

HEAVY (MEDIUM) TANKS, T26E4 AND T26E5

Reports covered vulnerability tests of M26 tanks from 1946 to 1952. The test tanks were subjected to attack from the following weapons and ammunition: 90mm HVAP, HE, AP, and small projectiles; 3.5-inch HEAT rockets; 6.5-inch ATAR; 76mm APC and HVAP-T projectiles; 105mm, HE, M1 shells; 57mm AP napalm or octal dropped from aircraft; and M6A1 type land mines. Firing tests were conducted at ranges of 50 yards from the small-caliber projectiles and up to 500 yards

for the larger sizes. Some of the HEAT rockets were fired as close as 40 feet to the tank. In all tests except three employing napalm bombing, 57mm AP, and 90mm smoke shells, the T26 tanks were either immobilized or damaged to the point of "kill" in the predominant number of rounds fired.

ARMOR CUTTING, SCARFING, AND GOUGING

Of 12 reports, four covered flame, arc, and machine gas cutting of armor, and eight covered removing defects and preparing welds by arc scarfing and the "Arcair" method. Comparison of flame-cut and arc-cut armor samples showed the microstructure of the arc cut to be superior to that of the flame cut. The other three reports on cutting consisted of (1) records of a conference for improving and standardizing methods of flame cutting armor; (2) an outline of successful methods of machine gas cutting of armor plate; and (3) a visual presentation of the common faults usually encountered while flame-cutting armor plate. In the last report, speed, oxygen pressure, nozzle height, and track cleanliness were demonstrated as important factors in flame cutting.

Five reports (1952-1953) covered an investigation of the Arcair method of removing defective sections of welds in homogeneous armor plate. This method of gouging out defective welds was developed by the American Car and Foundry Company. Equipment consisted of a 1/4-inch to 1/2-inch carbon electrode surrounded by a series of air jets. By striking an arc with the electrode, armor weld metal was returned to the molten state. A continuous jet of air around the electrode arc resulted in blowing the molten metal from the point of gouging. In all investigations, this method was found satisfactory and metallurgically sound; weld defects were removed and the resultant cuts were clean and slag free.

Three reports on arc scarfing methods of removing defective weld metal from armor plate revealed satisfactory results. Manual and machine scarfing were compared and found approximately equal in all respects except dimensional accuracy

NON-FERROUS AND NON-METALLIC MATERIALS

Seven reports were written on the ballistic testing of various aluminum alloy plates ranging in thickness from 1/8-inch to 1-1/2 inches. On an equivalent weight basis many of the alloys were equal or superior to steel armor, though some of the harder samples were subject to excessive spalling and cracking.

MAGNESIUM

Two reports (1943-1944) on the comparison of the ballistic properties of Dowmetal (87% magnesium) and steel armor revealed that Dowmetal was comparable to non-magnetic steel on a weight-per-weight basis, but its strong tendencies toward spalling considerably reduced its effectiveness as an armor material. A 1945 report on magnesium, aluminum, and steel plates ballistically tested at normal and subzero temperatures demonstrated that magnesium alloy plates offered considerably less resistance to penetration and shock than aluminum alloy plates. At subzero temperatures, resistance to penetration of magnesium and aluminim alloys increased slightly, but the backspall characteristics were unchanged. Aluminum alloy plates were slightly superior to homogeneous steel armor in resistance to penetration but were inferior to steel in shock and backspall resistance. Magnesium alloy plates were considerably inferior to homogeneous steel armor in resistance to penetration, shock, and backspall.

HAIR FELT ADDITION

Two 1943 reports were devoted to determining the effectiveness of cattle-hair felt bonded to 5/8-inch face-hardened aircraft armor in preventing bullet splash. Both tests showed this method to be ineffective in stopping bullet splash.

PERSONNEL ARMOR

Ten reports were written between 1948 and 1954 on the following laminates designed for use as personnel armor: opaque laminated nylon fabric saturated with varying percentages of certain resins; loose unsaturated glass fabric; "diphasic" materials consisting of laminated fabric and resin faced with layers of aluminum particles bonded with various resins or faced with layers of hard resin; and transparent laminates of cast polymethyl methacrylate, cellulose acetate butyrate, or polystyrene sheets bonded with polyvinyl butyrate and backed with a layer of polyvinyl butyral which in turn was covered with nylon film. Other test materials included orlon; lumite (saran); rayon (fortisan); rayon (celanese); glass floss; fiberglass ECC143, ECC165, and ECC184; aluminum sheet, 61ST; aluminum sheet, 3S 1/2-hard; 80-mesh stainless steel cloth; and nylon duck (2x2 basket weave). Most of he resins employed as binders were of the polyester type.

Conclusions in a 1951 report stated that the most effective lightweight armor as yet developed by an extensive test program on an equal weight basis was a panel made of layers of 2x2 basket weave nylon fabric. The most effective replacement for this material was made of orlon. In the "transparent" phase of the program, a silicate-bonded methyl methacrylate-polyvinyl buryral transparent laminate showed excellent resistance to delamination. High rupture energies and high ultimate elongations were considered indicative of superior ballistic performance of plastic laminates.

Tables and curves were provided in a 1954 report to establish the necessary ballistic requirements for testing conventional personnel armor materials. In addition, it was recommended that the cal. 0.22, fragment simulating projectile (weight: 17 grains) be stipulated as the ballistic test medium in military specifications for the procurement of personnel type fragment resistant armor, and that a protection ballistic limit based on five complete and five partial penetrations within a velocity spread of 125 fps be established.

CORRELATION OF PHYSICAL PROPERTIES AND BALLISTIC PERFORMANCE OF ARMOR STEEL

Approximately 40 of 71 reports were devoted to the effect of hardness on the ballistic performance of various armor steels. The remaining 31 reports covered the effects of other physical properties on ballistic performance.

EFFECT OF HARDNESS

Nine reports were written on tests of 1 to 3-inch cast homogeneous armor with 37mm, 57mm, and 90mm AP, APC, and proof projectiles of various obliquities to determine the most satisfactory hardness ranges of each thickness. The most consistent results were obtained in four reports of 1-inch cast armor in which the Brinell hardness averaged 300. Thirty reports were written on tests of 1/4- to 5-inch rolled homogeneous armor with cal. .30 and .50 ball and AP; 20mm HE I and AP; 37mm PP, AP, HE, and APC; 57mm AP, PP, and APC; 75mm AP and PP; 75mm HVAP; 90mm AP, HVAP, and APC; 3-inch AP and APC; 155mm AP; and German 88mm APC at various obliquities. (Note: projectile size and plate thickness were commensurate.) One report was written on the test of 1-inch face-hardened armor with projectiles up to 37mm. One of the most significant results was that resistance to shock increased rapidly as the hardness increased. Another report covered the determination of the effect on ballistic properties due to variation in hardness.

MISCELLANEOUS PROPERTY EFFECTS

The relationship of ballistic properties to the following factors were studied in 34 reports: position in the ingot from which test plates were obtained; cold forming; embrittling effect of slow cooling; plate size and method of support; visual stringer condition (3 reports); unsoundness of castings (radiographic analysis); dendritic formation; gas cavities; fabricated hole; cross-rolling and straightway rolling; shrinkage in castings; and carburization of face-hardened armor.

LOW TEMPERATURE TESTS

A total of 40 reports were written on ballistic tests of various types of steel armor at temperatures as low as -65°F, though the majority of tests were conducted within a range of -15° to -30°F. The ballistic property, resistance to shick, was of major interest in most of the reports.

COMPONENTS

Of 84 reports on ballistic tests of component armor, 21 were concerned with hulls, 25 with turrets, and 38 with various other components such as hatch covers, final drive housings, and armored engine grilles.

HULLS

Eight of the reports (1941-1943) were devoted to firing tests agains M2, M7, and M3 light and medium tank hulls of welded, cast, and riveted construction. The superiority of welded construction over riveted construction was established during this period. Twelve reports on front hull castings of medium tanks, T25, T26, and M4 (1943-1945), indicated a definite improvement in cast armor quality and ballistic performance over the preceding 1941-1943-span. One Canadian report on a pilot model Armoured Snowmobile hull demonstrated that the test hull offered satisfactory protection against .303 ball ammunition but failed under 37mm HE shell attack due to weld cracking.

TURRETS

Eight reports were written between 1939 and 1942 on the ballistic performance of turrets for the following vehicles: medium tank, T5; light tank, M2; light tank, M3; medium tank, M3; and medium tank, M2. An increasing interest in cast turrets was exhibited during this period together with the elimination of development on riveted and bolted constructions. From 1943 to 1946, 18 reports were written on the ballistic performance of turrets for the following vehicles: tank, T29; heavy tank, T26E2; medium tank, M4; medium tank, T25; armored car, M8; medium tank, T23; armored car, T22; and assault tank, T14. A 1943 report of the assault tank T14 cast turret indicated a trend to improved cast quality and increased wall thicknesses. Satisfactory results were obtained with castings ranging in thickness from 1.19 to 4.00 inches.

OTHER COMPONENTS

Ballistic performance was also obtained on the following components: pistol ports, armored air intake and outlets, gun shields, final drive housings, floor plates, doors, various shock mounts, hatches, vision blocks, cupolas, suspension support castings, hydraulic lines (effect of shock), and splash shields.

BALLISTIC TEST PLATES AND TEST DEVELOPMENT

A total of 207 reports were devoted to tests to determine whether various types and thicknesses of armor steel would meet specification requirements. Closely correlated with these tests was a program to develop more rigid specifications to assure improved ballistic performance. Each of the three important ballistic characteristics -- penetration, cracking, and spalling -- was found to be correlated (see Correlation of Properties above) with certain metallurgical or mechanical properties of armor; the resistance of armor to penetration by a specific projectile is a function of armor hardness; resistance to cracking or shattering under ballistic attack is a function of steel toughness, which, in turn, is related to the microstructure resulting from heat-treatment and working of the armor; and resistance to spalling is a function of the soundness and toughness of steel.

MISCELLANEOUS TESTS

The group of tests not directly related to any of the foregoing categories included the following: composite plates of steel armor and rubber; an

explosive anti-personnel device for combat vehicles; cold heading vs hot heading and rivet design; 1000-pound armor plate kit for amphibian vehicle DUKW; spaced armor for protection against 3.5 HEAT rocket heads; thickness of plate required to remove the cap from APC shot; various studies of spaced and composite armor; and determination of ballistic resistance with one shot.

TDY ACTIVITIES AND OBSERVATIONS IN KOREA

A test was conducted in 1950 to demonstrate the 105mm howitzer HE-P ammunition, T81E17, and to determine the effectiveness of the 2.36-inch rocket and the ENERGA antitank grenade on the Russian tank, T34. All types of ammunition tested resulted in armor penetration of the T34 Russian disabled tanks. Apparently, the T34 had been over-rated with respect to its armor protection. Examination of the captured tanks revealed that the maximum hull thickness was 1.8 inches, maximum turret thickness was 3 inches, and that workmanship and manufacturing methods were very crude.

AIRBORNE POLICY: ARMORED ASPECTS

In 1949 determination was made of the armored vehicles and units required for an airborne division and for the establishment of an airhead. Conclusions: The planned armor support of the assault and buildup phases was confined to reconnaissance and security in lightly armored 1/4-ton vehicles, pending development of a suitable armored car. It was believed that the light tank should be the primary vehicle for training and for missions incident to expansion of an airhead. The T42 medium tank was recommended as a substitute for the heavy tank in the two follow-up tank battalions of the airborne division. It was believed that tank developments must be considered for ground combat needs rather than for air-transportability, that a suitable number of cargo aircraft for airlifting an armored task force should be requisitioned, and that future needs should be based on air loads of 120,000 pounds.

U.S. ARMY POLICIES AND DOCTRINES

The basic U.S. Army policies and doctrines pertaining to armor and armored units were summarized in 1949. Conclusions: The type Field Army was a sound concept for troop basis, organization, and equipment planning and for instructional framework in service schools. The concept of two types of divisions was sound. The proportion and distribution of armored units was adequate. A family of three tanks was required, with the heaviest tank not over 60 tons. The following requirements were established: flexible means of communication; special armored equipment to support tanks; a lightly armored car for reconnaissance; a free machine gun for each armored vehicle; flame projecting equipment for tanks and personnel carriers; AP, HE, and smoke ammunition; and air transportability of the light tank without disassembly. The basic concept of the employment of the combined arms team was sound. Tanks were required to defeat tanks. Army schools must give instructions in armor as a member of the Army Combat Team. It was recommended that the conclusions (of the Army Field Forces Advisory Panel on Armor) be approved and the U.S. Army policies and doctrines conform thereto when applicable.

FRENCH 100MM GUN TANK

Determination of the ballistic vulnerability of the French 100mm gun tank by analysis was made in 1953. The gun tank was an armored, full track-laying vehicle armed with a 100mm gun, two 7.5mm machine guns mounted to the machine gun support ring around the loader's hatch, and one 7.5mm coaxial machine gun. Conclusions: Many features of the 100mm gun tank could be improved which would result in an overall reduction in vulnerability. A thorough discussion of each recommended design to change to improve protection was included in the report. Included in the suggested modifications were improvement of armor protection, splash prevention, and modification of basic and component design. The test vehicle was not considered suitable for combat without considerable alteration.

REPORT RESUMES

SUBJECT: Armor AB 597
TITLE: Test of Coating for Tanks to Defeat Hollow Charge Projectiles
IDENTIFICATION: Project No. 597
DATE OF REPORT: 11 April 1945
ORIGIN: The Armored Board, Fort Knox, Ky.
PURPOSE: To determine the suitability of coating HCR II as an addition to turret and sponsons of tanks to protect them from enemy hollow charge projectiles
METHOD: Hollow charge projectiles, including Panzerfaust, were fired at 82 panels coated with varying thicknesses of HCR II. Firing of Panzerfaust was done at 30-foot range and that of the other projectiles at 200 feet and at varying velocities to simulate varying ranges.

DESCRIPTION: The test hollow charge resistant (HCR II) was composed of 82% Lilesville gravel (1-1/4 to 2-1/4 inches in size), 13.5% asphalt and 4.5% wood flour. Panels of the material were four, five, six, and seven inches in thickness and three feet square.
CONCLUSIONS: It was found that use of such protective armor was not feasible since the minimum weight necessary for a complete suit of plastic armor for 100% protection of turret and sponsons against Panzerfaust hollow charge projectiles would be 7.8 tons. It was recommended that the test material be considered unsatisfactory and that development of other materials be continued.
GENERAL: This 20-page report includes five

tables showing results of firing and eight plates of photographs showing the effects of projectiles on varying thicknesses of panels.

SUBJECT: Armor AFF 2-18-49
TITLE: Report of Army Field Forces Advisory Panel on Armor
IDENTIFICATION: Report No. AFF 2-18-49
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To provide a comprehensive and current statement of policy in matters of doctrine and materiel pertaining to armor
METHOD: The doctrine of armor and the policies affecting equipment requirements and development were established by a review of armor data by studies of the major topics involved including extracts and supporting documents by examination of the reports of previous boards and reports prepared by the several army schools and boards and by interrogation of witnesses including army field officers experienced in the wartime field use of armor and persons with technical and development experience.
DESCRIPTION: Individual studies prepared included the following: U.S. Doctrine-Armor, Utilization of Armor Within the Corps, U.S. Army Tank Policy, Report on Implementation, U.S. Army Reconnaissance Policy, Flame Warfare Policy, Airborne Policy, Armored Personnel Carriers, Tank Support of Infantry, U.S. Investigation of the Schulman Round, Mine Clearing, Flotation Policy, Tank Range Finders, Light Antiaircraft Policy for Combat Vehicles, Engineer Armored Vehicles, Infrared for Tanks, Armored Cars and Armament for Armored Cars, Navigation Aids, and Armament for Tanks.
CONCLUSIONS: The specific conclusions are contained in the individual report for each study and are too numerous to detail in this general report. Each of the individual reports recommended approval of the conclusions and that where applicable they be adopted as the Department of the Army doctrine on armor.
GENERAL: This brief covers the general conclusions and recommendations given in a 39-page section in Volume I of the 428-page, two-volume "Report of Army Field Forces Advisory Board on Armor," Report No. AFF 2-18-49. Included in this two-volume report are the sections separately briefed under Report Nos. AFF 2-18-49 (I through VIII, IX-1 through IX-10, and X).

SUBJECT: Armor AFF 2-18-49 (I)
TITLE: The United States Army Doctrine of Armor
IDENTIFICATION: Report No. AFF 2-18-49(I)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To establish the United States Army doctrine on armor
METHOD: Research and evaluation was made of data on the role of the U.S. Army in the National Defense Establishment, the history of armor, national considerations favoring the use of mechanized warfare, industrial potential and mechanical aptitude of the nation and manpower conservation.
DESCRIPTION: The discussion of this report covered the following topics: Armor, Characteristics Which Armor Bring to the Modern Battlefield, Armor in Modern Foreign Countries, Probable Use of Armor by Russia, Possible Theaters of War, Balancing Requirements of Modern Warfare, Economical Organization for Land Conflict, and General Types of Weapons Required.
CONCLUSIONS: It was concluded that the use of armor permitted the conservation of manpower and offered a means of obtaining rapid and decisive results in wartime as it provided mobility and protected firepower and had the shock effect required for offensive and defensive operations. It was recommended that armor be dimensioned so as to be transportable overseas. The following armor requirements were approved: an armored division, strong for exploitation and heavy assault; additional armor reserve to strengthen the infantry and armored divisions; a highly mobile armor unit for security and reconnaissance purposes; and special organization and equipment for armored engineers, infantry, artillery, and service units to support adequately armored formations. An armored corps or an armored army was not believed to be required in the army organization.
GENERAL: This 16-page report is not illustrated and is bound with Report No. AFF 2-18-49.

SUBJECT: Armor AFF 2-18-49(II)
TITLE: Utilization of Armor Within the Corps (Type Field Army)
IDENTIFICATION: Report No. AFF 2-18-49(II)
DATE OF REPORT: 2 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To determine the number, types, distribution and employment of armored units within a "Type Field Army"
METHOD: Studies were made of the effects of new weapons, the need of highly integrated combat teams, the use of infantry and armored divisions, the distribution of armored divisions, the need of light armored regiments for security and reconnaissance, the need of a three-tank family, and the need of special armored equipment in a "Type Field Army' (a field army plan for modern warfare).
DESCRIPTION: The discussion of this report covered the following topics: Definitions of Tank and Armor, Armored Cavalry, Weapons of Armored Cavalry, Combined Arms Team, Strength and Composition of the Type Field Army, The Type Corps, The Divisions, The Infantry Armored and Airborne Divisions, Armored Troops in the Corps, Armored Cavalry Group, Equipment, Types of Tanks needed, Armored Artillery and Personnel Carriers, Engineer Bridging and Special Equipment, Communications and Service Support, Armored Car, Amphibious tanks, full Machine Guns on Tanks and Other Armored Vehicles, Flame Equipment, Ammunition for Tank Cannon, Air

Transportability of Armored Equipment, Operations Doctrine, Teamwork, Organization, and Amount of Armor.
CONCLUSIONS: The Type Field Army was considered a sound concept for general troop-basis planned organization, equipment planning, and instructional purposes. A complete table of organization and equipment was formed for the Type Field Army. The concept of two types of division and the new division organizations including the proportion and distribution of armored units were believed sound. It was believed that a family of three tanks per unit was required, howitzer tanks were no longer necessary, flexible means of communication and special armored equipment were needed for armored division support, a lightly armored 1/4-ton truck was required for reconnaissance, a flexible mounted machine gun was needed for each armored vehicle, flame projection was required for tanks and personnel carriers, the light tank should be air-transportable without disassembly, and that constant review of organization and equipment should be made for needed modifications.
GENERAL: This 16-page report includes three organizational charts and is bound with Report No. AFF 2-18-49.

SUBJECT: Armor AFF 2-18-49(IV)
TITLE: Report on Implementation
IDENTIFICATION: Report No. AFF 2-18-49(IV)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To detail the implementation of requirements established by the War Department Equipment Board and the Armored Conference
METHOD: Statements of policy were extracted from reports, correspondence, and the action of technical committees. Data on implementation were obtained from minutes of the technical committees, periodic progress reports of the Technical Services, reports of Army Field Forces liaison officers, and correspondence.
DESCRIPTION: The armored equipment requirements, progress in development, and the extent of implementation of each item were detailed in Annex E of Volume II of this report.
CONCLUSIONS: The policies established by the War Department Equipment Board report of 29 May 1946, and the report of the Armored Conference of 7 June 1946 were considered sound, subject to modification indicated in Annex E of Volume II of this report. It was believed that there was a need for towed and self-propelled antitank guns for use in Phase I of airborne operations, for a specially equipped Pioneer tank for an armored bridge launcher, and for a full-track personnel carrier of squad capacity. Listings were made of items for which no general use could be foreseen. Implementation of projects were listed in order of relative priority.
GENERAL: This five-page report is not illustrated and is bound with Report No. AFF 2-18-49.

SUBJECT: Armor AFF 2-18-49(VII)
TITLE: Airborne Policy: Armored Aspects and Considerations
IDENTIFICATION: Report No. AFF 2-18-49(VII)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To determine the armored vehicles and units required for an airborne division and for the establishment of an airhead
METHOD: Analysis was made of the U.S. Airlift capabilities and limitations. The assault, build-up, and follow-up phases for the establishment of an airhead were detailed. Conferences were held with experienced Airborne Division Commanders and extracts made from previous reports and pertinent data.
DESCRIPTION: The topics of discussion included data regarding aircraft availability, armor in the seizure and defense of the airhead, sectionalization of the vehicles for transport, armor support in the follow-up phase, expansion of the airhead, and general considerations.
CONCLUSIONS: The planned armor support of the assault and buildup phases was confined to reconnaissance and security in lightly armored 1/4-ton vehicles pending development of a suitable armored car. It was believed that the light tank should be the primary vehicle for training and for missions incident to expansion of an airhead. The T42 Medium Tank was recommended as a substitute for the heavy tank in the two follow-up tank battalions of the airborne division. It was believed that tank development must be considered for ground combat needs rather than for air-transportability, that a suitable number of cargo aircraft for air-lifting an armored task force should be requisitioned, and that future needs should be based on air loads of 120,000 pounds.
GENERAL: This 13-page report includes one organizational chart and is bound with Report No. AFF 2-18-49.

SUBJECT: Armor AFF 2-18-49B
TITLE: Report of Army Field Forces Advisory Panel on Armor
IDENTIFICATION: Report No. AFF 2-18-49B(II)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To summarize the basic U.S. Army policies and doctrines pertaining to armor and armored units
METHOD: The reports of several postwar boards and conferences were reviewed. These reports covered the World War II history of organization, tactics, and equipment of all armored units. Study was made of recently completed as well as anticipated developments. Review and study was conducted of the testimony of experienced military personnel, extracts and supporting documents, and military characteristics of armored units and equipment. Post war doctrine was developed from the principles which evolved from these studies and was presented and recommended by the Army Field Forces Advisory Panel on Armor.
DESCRIPTION: The subject matter covered in this study included the organization of the Type

Field Army, equipment including tanks, tank equipment, personnel carriers, armored artillery, bridging and special equipment, communication, service support, armored car, amphibious tanks, free machine guns, flame equipment, ammunition, air transportability operations doctrine, teamwork and teams.
CONCLUSIONS: The Type Field Army was a sound concept for troop basis, organization, and equipment planning and for instructional framework in service schools. The concept of two types of divisions was sound. The proportion and distribution of armored units was adequate. A family of three tanks was required with the heaviest tank not over 60 tons. The following requirements were established: flexible means of communication, special armored equipment to support tanks, a lightly armored car for reconnaissance, a free machine gun for each armored vehicle, flame projecting equipment for tanks and personnel carriers, AP, HE and smoke ammunition and air transportability of the light tank without disassembly. The basic concept of the employment of the combined arms team was sound. Tanks were required to defeat tanks. Army schools must give instruction in armor as a member of the Army Combat Team. It was recommended that the conclusions be approved and the U.S. Army policies and doctrines conform thereto when applicable.
GENERAL: This 222-page report includes two tank organizational charts and is otherwise unillustrated. This report represents the second volume of a two-volume report on Armor, and is included with Report No. AFF 2-18-49.

SUBJECT: Armor AFF 2562
TITLE: Fabric Armor (Phase I)
IDENTIFICATION: Phase I of Project No. 2562
DATE OF REPORT: 24 September 1954
ORIGIN: Office, Chief of Army Field Forces, Fort Benning, Georgia
PURPOSE: To determine the suitability of fabric armor for combat vehicles
METHOD: Various methods of applying fabric armor to protect BAT weapon crews on an M38A1 Utility Truck and an M29C Amphibious Cargo Carrier were studied. The most practical method was determined and prototypes were constructed. These prototypes were tested for protection against blast and fragmentation from various types of shells, and against the effects of napalm and white phosphorus. They were also tested for ease of handling, durability, resistance to snagging and tearing, and resistance to water.
DESCRIPTION: A metal frame was used to support the fabric on the vehicles. Three types of armor were used: U.S. fabric armor blankets, Canadian flexible armor, and U.S. Navy flack protective curtains.
CONCLUSIONS: The protective fabric armor was feasible and was recommended for further development.
GENERAL: This 53-page report includes 18 photographs.

SUBJECT: Armor APG 314G
TITLE: Report on TDY Activities and Observations in Korea
IDENTIFICATION: Aberdeen Proving Ground; Library No. 314G
DATE OF REPORT: 28 November 1950
ORIGIN: Aberdeen Proving Ground, Maryland; Suwan and Ascom Cities, Korea
PURPOSE: To demonstrate the 105mm Howitzer HE-P Ammunition T81E17 and to determine the effectiveness of the 2.36-inch rocket and the ENERGA anti-tank grenade on the Russian Tank T34
METHOD: The HE-P ammunition was fired at five disabled Russian Tanks T34 using 105mm Howitzers M2A1. Four guns were used that were placed from 450 to 950 yards from the target. Front, side, and oblique surfaces of the tanks were subjected to the firing. The 2.36-inch rockets and the ENERGA anti-tank grenades were fired at another T34. Firing range was 50 yards.
DESCRIPTION: Ammunition used during the tests was: 105mm Howitzer HE-P Ammunition T81E17; 2.36-inch rockets; and the ENERGA rifle-launched grenades.
CONCLUSIONS: All types of ammunition tested resulted in armor penetration of the T34 Russian Tanks. Apparently, the T34 had been over-rated with respect to its armor protection. Examination of captured tanks revealed that the maximum hull thickness was 1.8 inches, maximum turret thickness was three inches and that workmanship and manufacturing methods were very crude.
GENERAL: This 31-page report contains seven photographs illustrating the result of the firing tests on the captured tanks. An "Observation of Performance of Ordnance Equipment in Korea" report is included which discusses ammunition and weapons in the Korean conflict.

SUBJECT: Armor APG 5525/1 Min.
TITLE: Bullet Splash and Protection Against Small Arms Fire
IDENTIFICATION: First Minor Report on Ordnance Program No. 5525
DATE OF REPORT: 24 July 1942
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the behavior of bullet spatter and to develop devices to protect personnel and equipment
METHOD: Two calibers of ball and armor piercing projectiles were fired at armor plates of an M3 Medium Tank at various incidence angles. Photographs were made of the plates with the projectile striking them. Cardboard or paper splash cards were also used to indicate splash patterns. Various soft materials and designs for splash traps were tested in an effort to eliminate the spatter effects. A study was made of previous tests and of British data on the subject.
DESCRIPTION: Cal. .30 and cal. .50 ball and armor piercing ammunition were used in the tests. The designs for splash elimination were mainly from the M3 Medium Tank and included closing of recesses, deflection modifications and traps.
CONCLUSIONS: Proper design of armor would

eliminate the hazards of bullet spatter, but soft materials were not satisfactory for the purpose. Test data were compiled on the action of bullet splash and methods of reducing or eliminating spatter hazards. It was recommended that all persons responsible for the design of Ordnance materiel become familiar with the principles involved.
GENERAL: This 56-page report contains 28 photographs.

SUBJECT: Armor APG AD-59
TITLE: The Development of an Armor Arrangement for Minimizing the Effect of the Grenades A.T. M9A1
IDENTIFICATION: Report No. AD-59; Project No. A-1-2
DATE OF REPORT: 8 September 1942
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the most suitable armor arrangement for minimizing damage inflicted on a vehicle by the A.T. M9A1 type Grenade
METHOD: A.T. M9A1 type Grenades were fired at various armor plate arrangements. The protection each type of armor plate arrangement afforded against the grenades was determined.
DESCRIPTION: Armor arrangements tested included: single plates of standard armor from the Light Tank M5 and Medium Tanks M3 and M4 set at the obliquity common to the particular vehicle; standard armor plate initially discussed with another piece of armor plate of a minimum practicable thickness spaced from the standard armor plate (spaced plates were tested parallel to and at various angles to the standard plate); and heavier than standard armor plate with a parallel spaced armor plate setting at 0° obliquity.
CONCLUSIONS: The A.T. M9A1 Grenade completely penetrated a single 3-5/8-inch face-hardened plate set at an obliquity of 15°. The most satisfactory protection against A.T. M9A1 Grenades was obtained with two spaced armor plates set parallel to each other. The use of the spaced plate arrangement required that the front plate contain the physical properties which would withstand the detonation of the A.T. M9A1 Grenade; and that the front plate be fastened to the spaced back plate in such a manner as to leave no fasteners exposed at the outside of the front plate. The following armor plate combinations set parallel to each other were considered suitable protection against the A.T. M9A1 Grenade: a 1-inch rolled homogeneous plate set 9-1/2 inches in front of a 2-inch rolled or cast homogeneous plate; a 1/2-inch rolled homogeneous plate set 14-1/2 inches in front of a 1-1/2-inch rolled homogeneous plate; a 1-inch rolled homogeneous plate set 16-3/4 inches in front of a 1-1/2-inch rolled homogeneous plate; a 1/2-inch rolled homogeneous plate set 2-1/2 inches in front of a 2-inch rolled homogeneous plate (both plates were set at an obliquity of 40° to the line of impact). It was recommended that studies be continued on armor arrangements which would minimize damage caused to armor by A.T. M9A1 type Grenades.
GENERAL: This 47-page report contains 12 pages of illustrations showing the armor arrangements tested.

SUBJECT: Armor APG AD-229
TITLE: Ballistic Test to Determine the Value of Deflector Plates
IDENTIFICATION: Report No. AD-229; Project No. A-1-13
DATE OF REPORT: 17 March 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether deflector plates placed in front of reduced thickness armor plates would offer the ballistic protection afforded by single armor plates of equivalent weight
METHOD: A 3-1/2-inch rolled homogeneous armor plate setting at 0° obliquity was ballistically tested and compared with an equivalent weight combination of an armor plate protected by deflector plates. Identical ballistic tests were conducted on a 5-1/2-inch rolled homogeneous plate and compared with an equivalent weight combination of an armor plate protected by deflector plates. Ballistic tests were conducted with 3-inch APC M62 Projectiles.
DESCRIPTION: The deflector plates were set up in a louver arrangement in front of the armor plate. Deflector plates were placed at a 60° obliquity, and the armor plate was placed at a 0° obliquity. Armor plate and deflector plate combinations tested included: 30mm rolled homogeneous armor plate protected by 1/2-inch deflector plates (the weight and area of the combination was equivalent to that of the 3-1/2-inch armor plate); and a 60mm rolled homogeneous armor plate protected by 20mm deflector plates (the weight and area of this combination was equivalent to that of the 5-1/2-inch armor plate).
CONCLUSIONS: The armor plate and deflector plate combination failed to offer the protection afforded by that of an unprotected armor plate of equivalent weight and area.
GENERAL: This 12-page report contains five photographs showing the condition of the armor and projectiles after test.

SUBJECT: Armor APG AD-230
TITLE: Second Report of the Firing of the Grenades A.T. M9A1 at the Medium Tank M3A1
IDENTIFICATION: Report No. AD-230; Project No. V-1-3
DATE OF REPORT: 12 December 1942
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of armored ammunition containers for protecting stored projectiles from fragments of type A.T. M9A1 Grenades
METHOD: A.T. M9A1 Grenades were fired at a Medium Tank M3A1 equipped with standard ammunition containers containing live rounds of 37mm and 75mm projectiles. Identical tests were then performed with the vehicle equipped with test armored ammunition containers containing live 37mm and 75mm projectiles. The relative protection afforded projectiles by the test armored containers as compared to standard ammunition

containers was determined.
DESCRIPTION: The armored ammunition containers installed in place of standard Medium Tank M3A1 ammunition containers included: rectangular shaped armored racks constructed from 1/4-inch mild steel plate; a 37mm armored ammunition box constructed with 1/4-inch mild steel plate and containing 42 separate tubular compartments, with each compartment constructed with 1/16-inch mild steel; and a 75mm armored ammunition container, which was a standard Medium Tank M3 container modified to include a top, left side, and door constructed of 1/4-inch rolled homogeneous armor.
CONCLUSIONS: The armored ammunition containers greatly reduced the possibility of stowed projectiles exploding as the result of fragments from A.T. M9A1 Grenades. Explosion of a projectile stowed adjacent to an exploding projectile was greatly reduced by the use of armored ammunition containers. A major disadvantage of the rectangular armored ammunition racks was that fragments breaking off the racks formed dangerous secondary projectiles. In the case of projectiles stored in armored tubular compartments, the cartridge case of an exploding shell would be violently expelled from the compartment and become a secondary projectile. It was recommended studies on armored ammunition containers be continued.
GENERAL: This 55-page report contains 33 photographs showing the armored ammunition containers as tested.

SUBJECT: Armor APG AD-232
TITLE: Test of Base Detonating APC Projectiles Against Spaced Armor
IDENTIFICATION: Report No. AD-232; Project No. A-1-2
DATE OF REPORT: 29 January 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effect of base-fuzed projectiles on spaced armor arrangements at battle ranges
METHOD: The basic test arrangement consisted of two armor plates spaced 10 inches apart and mounted at a 30° angle to the line of fire. In Phase I of the test, various armor plate combinations of the basic test arrangement were tested with 75mm APC M61, 3-inch APC M62, and 90mm APC M82 inert-type projectiles. In Phase II of the test, similar armor arrangements were tested with 75mm HEAP M61 and 3-inch HEAP M62 Projectiles loaded and base-fuzed with M66A1 fuzes, and with 90mm HEAP M82 loaded and base-fuzed with M68 fuzes. The purpose of Phase II was to observe fuze functioning for those projectiles which gave complete perforations in Phase I against a specific plate combination. Ballistic limits were obtained in all tests. When any projectile failed to perforate both plates, the test was made again at 20° obliquity.
DESCRIPTION: The following spaced armor combinations were tested in either or both phases: 3/4-inch homogeneous and 2-inch homogeneous armor plates; 3/4-inch homogeneous and 2-1/2-inch face-hardened armor plates; and 3/4-inch face-hardened and 2-1/2-inch face-hardened armor plates.
CONCLUSIONS: The projectiles completely penetrated the spaced armor combinations tested with the exception that the 75mm APC M61 failed to penetrate the 2-1/2-inch face-hardened armor in combination with either the 3/4-inch face-hardened or the 3/4-inch homogeneous armor. The 10-inch parallel spacing of armor was not considered the most effective arrangement for protection and additional tests were recommended to determine the best spacing and obliquity for optimum protection. One of the most significant factors revealed in the testing was that the armor piercing cap on the 75mm 3-inch or on the 90mm APC Projectiles would shatter on the thin front plate regardless of whether the plate was homogeneous or face-hardened. The projectile was thus rendered less effective if the rear armor was face-hardened, but more effective if the rear armor was homogeneous.
GENERAL: This 30-page report includes seven photographs showing the projectiles after testing and 14 pages of ballistic data.

SUBJECT: Armor APG AD-369
TITLE: Ballistic Performance of Armor Plates
IDENTIFICATION: Report No. AD-369
DATE OF REPORT: 18 April 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic performance of homogeneous and face-hardened armor plates
METHOD: One 2-1/2-inch homogeneous, one 3-inch homogeneous, and one 3-inch face-hardened armor plates were tested at 46° obliquity with German 88mm APC HE, U.S. 3-inch APC M62, and U S 90mm APC M82 Projectiles at various striking velocities.
DESCRIPTION: The test material consisted of a 2-1/2-inch Carnegie-Illinois Class B homogeneous armor plate having an estimated hardness of 250 BHN, a 3-inch Carnegie-Illinois Class B homogeneous armor plate having a hardness of 253-264 BHN, and a 3-inch Carnegie-Illinois Class B face-hardened armor plate having a hardness of 718-534 BHN on the face.
CONCLUSIONS: The 3-inch face-hardened armor had greater resistance to penetration against the German 88mm projectiles than the other plates. The 3-inch homogeneous armor had greater resistance to penetration against the 3-inch APC projectiles than the other plates. The 2-1/2-inch homogeneous armor had less resistance to penetration against any of the projectiles than the other plates. The performance of the 90mm APC projectile was considered superior to that of the German 88mm APC shell used in these tests. It was recommended that 1/4 to 1/2-inch armor or plain steel carbon plate be placed three or four inches in front of the 3-inch face-hardened armor to fracture the armor piercing cap on AP shot.
GENERAL: This six-page report contains two pages of tabulated test data.

SUBJECT: Armor APG AD-394
TITLE: Report on the Ballistic Test of Additional

Armor Arrangements for the Medium Tank M4
IDENTIFICATION: Report No. AD-394; Project No. 2870 (199 AM10-173)
DATE OF REPORT: 1 April 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the protection increase provided by adding auxiliary plates to the front and sides of the Medium Tank M4
METHOD: Various armor arrangements were made up to simulate basic armor and auxiliary armor plates for an M4 Medium Tank. These armor arrangements were subjected to Army ballistic limit tests at various obliquities with 37mm AP M74, 75mm APC M61, 3-inch APC M62, and 90mm APC M82 Projectiles. The additional protection afforded the basic plates by the auxiliary plates was specified in terms of yards of protection added to the tank.
DESCRIPTION: The test armor consisted of Carnegie-Illinois 1, 1-1/2, and 2-inch rolled homogeneous armor plates having hardness ratings of 302, 269, and 262 BHN, respectively. The following test armor arrangements were used: 1-inch auxiliary and 2-inch basic plates spaced either 0 to 6 inches apart, 1-1/2-inch auxiliary and 1-1/2-inch basic plates spaced either 0 or 20 inches apart, and 1-inch auxiliary and 1-1/2-inch basic plates spaced 20 inches apart.
CONCLUSIONS: In the tests simulating reinforcement of the tank's 2-inch basic front armor plates with 1-inch auxiliary plates, 2700 yards were added to the protection of the tank against 90mm APC projectiles fired at 56° obliquity when no armor spacing was used, whereas there was no improvement in the protection when a 6-inch armor spacing was used. In the tests simulating reinforcement of the tanks 1-1/2-inch basic side plates with 1-1/2-inch auxiliary plates at zero and 20-inch spacing, the auxiliary plates added less additional protection at 20-inch spacing than at zero spacing when tested at 0° obliquity, and more additional protection at 20-inch spacing than at zero spacing when tested at 45° obliquity. At zero obliquity the protection offered by the basic 1-1/2-inch plates against 3-inch APC projectiles was increased 1120 yards by the addition of the auxiliary 1-inch plates at 20-inch spacing, whereas, at 45° obliquity the protection increase was only 170 yards.
GENERAL: This unillustrated 39-page report includes Report Nos. A-11234, A-11259, A-11295, A-11335, and A-12877.

SUBJECT: Armor APG AD-402
TITLE: Test of Uniformity and Acceptability of 3/4-inch Face Hardened Armor for Acceptance of Shot 20-mm AP M75 Production Lot
IDENTIFICATION: Report No. AD-402; Project No. 3290 (283 AM1-144)
DATE OF REPORT: 26 April 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether armor plates manufactured to meet the minimum requirements of Specification AXS-490-1 were suitable for checking the ballistic characteristics of production lot 20mm AP M75 Projectiles
METHOD: Three groups of armor plates heat-treated in various ways to meet the minimum requirements of Specification AXS-490-1 were used in Army and Navy ballistic limit tests of production lot 20mm AP M75 Projectiles. Consistency of ballistic limit data as a result of the firing tests on the various plates were compared. Testing was conducted with the plates setting at 0° and 20° obliquity.
DESCRIPTION: The test ballistic armor plates included: ten 3/4-inch oil quenched, face-hardened plates made and heat-treated by Henry Disston and Sons, Inc.; nine 3/4-inch water-quenched, face-hardened plates made and heat-treated by Henry Disston and Sons, Inc.; and three 3/4-inch, water-quenched, no draw, face-hardened plates made and heat-treated by the Mosler Safe Co.
CONCLUSIONS: Variation of the resistance to penetration results among plates heat-treated by the water-quench method were so great that uniform results on the ballistic limit characteristics of 20mm AP M75 Projectiles could not be determined. Although ballistic limit results obtained in firing tests on the oil-quenched armor was within uniform limits, the resistance to penetration of the oil-quenched plates was lower than that of the water-quenched plates. Because of high brittleness, only preliminary firing tests were conducted on Mosier Safe Co. plates. It was recommended that Specification AXS-490-1 not only include minimum requirements for establishing resistance to penetration limits of projectile proof plates, but also maximum limits; and that a projectile proof plate be metallurgically examined and initially ballistic tested in order to insure good steel quality and uniform hardness before the related group of plates are issued for proof firing 20mm, AP M75 Projectiles.
GENERAL: This 142-page report is not illustrated. Firing Records A-11297, A-12348, and A-12576 are included in the report.

SUBJECT: Armor APG AD-482
TITLE: Study of Additional Protection for the 3-Inch Gun Motor Carriage M10 by the Use of Spaced Armor
IDENTIFICATION: Report No. AD-482; Project No. W-3-11
DATE OF REPORT: 14 June 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine which of several spaced auxiliary armor plate combinations would be most suitable for protecting hull and turret surfaces of the 3-inch Gun Motor Carriage M10 against 37mm AP M74 type Projectiles
METHOD: A 3/4-inch rolled homogeneous armor plate at 38° obliquity and a 1-inch rolled homogeneous armor plate at 25° obliquity representing the standard armor used in the hull and turret surface of the 3-inch Gun Motor Carriage M10 were ballistically tested. Ballistic tests were then conducted on the same two thicknesses of plate resting at the designated obliquities and protected by auxiliary armor plate placed parallel to and spaced from 1 to 10 inches from the standard armor plate. All testing was conducted with 37mm

AP M74 type Projectiles.
DESCRIPTION: Auxiliary protective armor tested in the protection of the hull and turret of the Gun Motor Carriage M10 armor plates included 1/4, 1/2, 3/4, and 1-inch rolled homogeneous armor plate.
CONCLUSIONS: The 1-inch auxiliary armor plate provided better protection for the hull and turret armor of the Gun Motor Carriage M10 than did any of the other auxiliary plates tested. Ballistic data obtained in the limited tests indicated that little advantage was obtained in using greater spacing between standard and auxiliary armor plate surfaces. In addition, ballistic data revealed that when the auxiliary armor plate thickness exceeded that of the standard protected armor the ballistic limit was rapidly increased; this was observed when testing the 3/4-inch armor plate protected by the 1-inch auxiliary armor plate.
GENERAL: This 11-page report is not illustrated.

SUBJECT: Armor APG AD-502
TITLE: Report on the Resistance to Penetration of Duralumin for Use in Connection with Current Design and Development of Gun Shields
IDENTIFICATION: Report No. AD-502
DATE OF REPORT: 29 November 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the protection afforded by Duralumin with that of equivalent weights of steel protective armor
METHOD: Three thicknesses of Duralumin armor plates were ballistically tested at 0°, 30°, 45°, and 60° obliquity with 20mm German API projectiles and United States 20mm AP M75 and cal. .50 AP M2 Projectiles. Ballistic limit characteristics of 1/4, 3/8, and 1/2-inch standard rolled homogeneous armor tested under identical conditions were then compared with the ballistic characteristics of previously recorded test data for equivalent weights of test Duralumin armor plates.
DESCRIPTION: The test Duralumin armor plates were submitted by the Aluminum Corporation of America. Plates tested included four 3/4-inch plates, four 1-inch plates, and four 1-1/2-inch plates.
CONCLUSIONS: Duralumin armor, in all cases, offered more protection against both types of 20mm projectiles than did equivalent weights of rolled homogeneous armor. However, Duralumin offered little or no advantage over an equivalent weight of rolled homogeneous armor when ballistically tested with cal. .50 projectiles.
GENERAL: This 42-page report contains three photographs showing the test Duralumin plates and backspall fragments. Firing Record A-10960 is also included in the report.

SUBJECT: Armor APG AD-517
TITLE: Report on the Ballistic Test of 10-Inch Cast Homogeneous Plate Manufactured by General Steel Castings Co.
IDENTIFICATION: Report No. AD-517
DATE OF REPORT: 3 July 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic suitability of 10-inch armor plate against AP and HEAT projectiles; and to compare the ballistic suitability of the 10-inch armor plate with that of a 6-inch cast armor plate
METHOD: A 10-inch armor plate was ballistically tested at 0° obliquity with 105mm AP M112, 6-inch AP Mk XXXV, 6-inch Com. Mk XXVII, and 105mm M67 HEAT Projectiles. For comparison, ballistic tests were performed on a 6-inch cast armor plate with 155mm AP M112, 2.36-inch HEAT rocket T12, and 155mm HEAT M67 Projectiles. In addition, the 10-inch plate was tested for shock with a 12-inch AP M1896 Projectile at 30° obliquity.
DESCRIPTION: The test 10-inch cast homogeneous armor plate was submitted by the General Steel Castings Co. The plate had a chemical composition of 0.30 C, 0.65 Mn, 0.38 Si, 0.015 S, 0.014 P, 2.74 Cr, and 0.56 Mo. The plate had a tensile strength of 96,000 psi, a yield point of 74,000 psi, and elongation of 13.5% per inch, an Izod rating of 74, and a hardness rating of 197 BHN.
CONCLUSIONS: The 10-inch plate was only partially penetrated by 155mm AP M112, 6-inch AP Mk XXXV, and 6-inch Com. Mk XXVII, Projectiles. The inability of the 155mm and 6-inch projectiles to completely penetrate the 10-inch armor plate was partly caused by the deformation of the projectiles upon impact. The 105mm HEAT Projectiles penetrated the 6-inch plate but not the 10-inch cast plate. The ballistic limit of the 6-inch plate at 0° obliquity against 155mm AP M112 Projectiles was 1840 fps. The 2.36-inch HEAT rockets consistently failed to penetrate the 6-inch armor, and the rockets were therefore not used on the 10-inch armor. Shock test results on the 10-inch armor were unsatisfactory because the 12-inch projectile shattered upon impact. It was recommended that cast armor plates of a thickness below 10 inches be submitted in future tests concerned with the minimum thickness of cast armor necessary to afford protection against 155mm and 6-inch AP Projectiles.
GENERAL: This 31-page report contains four photographs showing the armor plates after test. Firing Records A-14046, A-14088, and A-14125 are also included in the report.

SUBJECT: Armor APG AD-520
TITLE: Spaced Armor Test Report
IDENTIFICATION: Report No. AD-520
DATE OF REPORT: 7 December 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine resistance to penetration of various spaced armor arrangements
METHOD: Ballistic data were compiled to determine the resistance to penetration at 30°, 45°, and 60° obliquity of homogeneous and face-hardened spaced armor combinations. Tests were conducted to determine the best type and spacing of armor and to compare solid armor with spaced armor when the thickness of the solid armor was equal to the sum of both plates of spaced armor.
DESCRIPTION: Plate thicknesses of 1/4, 3/8,

1/2, and 3/4 inches were compared for ballistic protection. The American 20mm AP M75 and the German 20mm API Projectiles were used. All 20mm Projectiles were fired from a U.S. gun to obtain the ballistic limits of spaced armor arrangements. The German projectiles were inert loaded and assembled in U.S. 20mm M21 Cases.
CONCLUSIONS: The superiority of spaced armor over single plate was apparently due to the ability of the front plate to shatter the projectile. If the projectile remained intact after penetration of the front plate, the spaced armor offered less protection. The U.S. 20mm AP M75 Projectile was equal or superior to the German 20mm API in defeating any of the armor arrangements tested.
GENERAL: This 48-page report contains seven appendixes which include Armor Test Report A-11293, one illustration, and 36 pages of test data. Pertinent data from A-11293 has been incorporated herein.

SUBJECT: Armor APG AD-557
TITLE: Spaced Armor Test Report
IDENTIFICATION: Report No. AD-557
DATE OF REPORT: 1 February 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine resistance to penetration of various spaced armor arrangements
METHOD: Ballistic data were compiled to determine the resistance to penetration at 30°, 45°, and 60° obliquity of spaced armor. Protection afforded by filling the space between plates with sand was evaluated. Comparison was made between U.S. and German projectiles on the basis of ability to defeat the test armor. Comparison was made between a single plate of face-hardened armor and spaced armor for protection value. Protection data were obtained using face-hardened armor parallel to mild steel plate.
DESCRIPTION: The shot used in obtaining data was 20mm American AP M75 and German API, inert w/tracer. Shot was fired from an M2, 20mm gun. The spacing of armor was 1/4-inch. Plate of face-hardened, homogeneous, and mild steel, 1/4 to 1/2-inch thick, was used.
CONCLUSIONS: Sand filling was found to increase the ballistic protection of spaced armor. The single 1/2-inch plate offered more protection than any other armor arrangements tested. In general, spaced armor offered better protection than single plate only when the front plate caused the projectile to shatter. The U.S. 20mm Projectile was considered equal or superior to the German 20mm in defeating any of the armor arrangements tested.
GENERAL: This 27-page report includes seven appendixes, 19 pages of test data, and four pages of illustrations. An addendum report titled AD557, Supplement 1, is included with this report.

SUBJECT: Armor APG AD-588
TITLE: Ballistic Test of Spaced Armor Arrangements
IDENTIFICATION: Report No. AD-588; Project No. RCN 1776
DATE OF REPORT: 22 September 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic suitability of spaced 1/4-inch armor plate pairs
METHOD: Pairs of 1/4-inch armor plates spaced 4, 8, 12, and 16 inches apart, and 1/2-inch single armor plates used for purposes of comparison, were ballistically tested with 20mm AP M75, 20mm AP T9, 20mm API German, and cal. .50 AP M2 Projectiles at obliquities of 0°, 30°, 45°, and 60°.
DESCRIPTION: The test material consisted of eight 1/4-inch and two 1/2-inch rolled homogeneous armor plates manufactured by the Republic Steel Corporation. The plates had a hardness rating of 350 to 375 BHN.
CONCLUSIONS: The ballistic performance of the single plate of 1/2-inch armor at 0°, 30°, and 45° obliquity was superior to that of all 1/4-inch spaced armor plate combinations tested. At an obliquity of 60°, the 1/4-inch spaced armor plate combinations offered only slightly better resistance to penetration to the 20mm AP T9 and 20mm API German Projectiles than did the single 1/2-inch armor plate. On the basis of the very limited data, it was believed that 1/4-inch armor plate combinations spaced at 12 and 16-inches offered ballistic protection superior to that provided by armor plate combinations spaced at 4 and 8 inches.
GENERAL: This 38-page report contains one photograph showing a German 20mm API Projectile before and after test.

SUBJECT: Armor APG AD-597
TITLE: Experimental Armor Differentially Tempered From Research Laboratory Division, General Motors Corporation
IDENTIFICATION: Report AD-597; Project No. RCN 3496
DATE OF REPORT: 24 February 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the resistance-to-penetration characteristics of differentially tempered rolled armor and rolled homogeneous armor
METHOD: A 1-inch differentially tempered rolled armor plate and a 1-inch rolled homogeneous armor plate were ballistically tested at 0°, 30°, and 45° obliquity with 37mm AP M74 and M51, 20mm AP M75, and cal. .50 AP M2 Projectiles. A 1-1/2-inch differentially tempered rolled armor plate and a 1-1/2-inch rolled homogeneous armor plate were ballistically tested at 0° and 20° obliquity with 37mm AP M74 and M51 Projectiles.
DESCRIPTION: The 1 and 1-1/2-inch differentially tempered rolled armor plates were processed and submitted by the General Motors Corporation. The front and rear surfaces of these plates had approximate Rockwell C hardness ratings of 50 and 25, respectively. Both plates were initially hardened according to usual practice by the Standard Steel Spring Corp. The 1 and 1-1/2-inch rolled homogeneous plates were submitted by H. Disston and Sons under Specification AXS-495-2.
CONCLUSIONS: The resistance-to-penetration characteristics of the 1-inch differentially tempered armor plate were superior to those of the 1-inch rolled homogeneous armor plate only against cal. .50 AP M2 Projectiles. The resistance-to-

penetration characteristics of the 1-1/2-inch differentially tempered armor plate were inferior to those of the 1-1/2-inch rolled homogeneous armor plate. Backspall from the differentially tempered armor plate was considered excessive.
GENERAL: This 20-page report contains two photographs showing projectiles and armor plates after the ballistics test. Firing Record A-12591 is also included in the report.

SUBJECT: Armor APG AD-598
TITLE: Ballistic Test of 1-Inch and 1-1/2-Inch Flame Softened Rolled Armor, and 1-Inch Flame Hardened Rolled Armor NRC-23
IDENTIFICATION: Report No. AD-598; Project No. RCN 3492
DATE OF REPORT: 23 February 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the resistance-to-penetration characteristics of 1-inch flame softened and flame hardened armor plates and 1-1/2-inch flame softened armor plates as compared to identical thicknesses of rolled homogeneous armor plate
METHOD: The test 1-inch flame softened and flame hardened armor plates setting at various obliquities were ballistically tested in comparison with 1-inch rolled homogeneous armor plate setting at identical obliquities. Each 1-inch plate was ballistically tested with cal. .50 AP M2, 20mm AP M75, 37mm AP M74, and 37mm APC M51 Projectiles. In addition, ballistic tests were conducted on 1-1/2-inch flame softened armor plates setting at various obliquities in comparison with 1-1/2-inch rolled homogeneous armor plates setting at identical obliquities; these tests were conducted with 37mm APC M51, 37mm AP M74, and 57mm APC M86 Projectiles.
DESCRIPTION: The 1 and 1-1/2-inch armor test plates were manufactured by Jones and Laughlin. Flame softening of three 1-inch and two 1-1/2-inch plates submitted and flame hardening of a 1-inch plate submitted was accomplished by the Massachusetts Institute of Technology.
CONCLUSIONS: The resistance-to-penetration characteristics of the 1-inch flame softened rolled armor was superior to those of 1-inch rolled homogeneous armor when used against cal. .50 AP M2 and 20mm AP M75 Projectiles. However, the 1-inch flame softened plate offered no protective advantage over rolled homogeneous armor when used against 37mm AP M74 or 37mm APC M51 Projectiles. Ballistic performance of the 1-inch flame softened armor plate was superior to that of 1-inch flame hardened armor plate. Ballistic limit results obtained in tests on the 1-1/2-inch flame softened armor plates were unreliable because of excessive backspall produced by projectile impacts and were therefore also considered to have ballistic qualities inferior to those of the 1-1/2-inch rolled homogeneous plates.
GENERAL: This 41-page report contains six photographs showing plates and projectiles after test. Firing Record A-12598 is included in the report.

SUBJECT: Armor APG AD-607
TITLE: Uniformity Test of Face-Hardened Armor
IDENTIFICATION: Report No. APG AD-607; Project No. P-1-1
DATE OF REPORT: 17 April 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To obtain information on the uniformity of 3/4-inch face-hardened armor plate
METHOD: One 3/4-inch armor plate was divided into sixteen 8-inch squares and the ballistic limit of 12 of these squares was obtained at 20° obliquity with standard 20mm AP M75 Shot. Two acceptance tests using the same ammunition were then conducted on each of the remaining squares at a velocity of 75 fps above the lowest ballistic limit obtained on the plate. Three more 3/4-inch plates were tested in the same manner except that an additional test at normal obliquity with cal. .50 AP M2 Shot was also made. Alternate areas were used to obtain ballistic limits with the cal. .50 and 20mm AP Shots. Three additional 3/4-inch plates were each tested with 10 rounds of standard 20mm AP M75 Shot at velocities of 1950, 2000, 2050, 2100, 2150, and 2200 fps.
DESCRIPTION: The test material consisted of six 3/4-inch face-hardened armor plates of regular APG stock material used for testing 20mm AP M75 Shot. Two of the plates were manufactured by the Mosler Safe and Lock Co.; the other four were manufactured by Henry Disston and Sons. The two Mosler plates had a face and back hardness of 653 and 311 BHN, respectively. The four Disston plates had hardnesses ranging from 555 to 653 BHN on the face and 331 to 444 BHN on the back.
CONCLUSIONS: The penetration resistance of the 3/4-inch face-hardened plates using 20mm AP M75 Shot at 20° obliquity and cal. .50 AP M2 Shot at normal obliquity varied appreciably over the surface of the plates. The Mosler plates varied less than the Disston. Impacts of 20mm AP M75 Shot cracked the face of some plates. It was believed that these cracks extended to an appreciable depth, possibly making the plates more vulnerable on subsequent shots. The Mosler plates cracked less than the Disston. It was recommended that a research program be initiated to develop armor plate that would uniformly resist penetration over its entire surface throughout a firing test, and that 20mm AP M75 Shot be used for acceptance testing of 3/4-inch face-hardened plate.
GENERAL: This 20-page report includes six photographs of plates, and data on ballistics.

SUBJECT: Armor APG AD-633
TITLE: Test of U.S. Aircraft Armor with German 20-mm HE Projectiles
IDENTIFICATION: Report No. AD-633; Project No. A-1-7-1
DATE OF REPORT: 17 August 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the resistance-to-penetration characteristics of U.S. 3/8-inch and 7mm aircraft armor against German 20mm HE and HEI projectiles
METHOD: One 3/8-inch and one 7mm aircraft armor plate were subjected to Navy ballistic limit

tests with German 20mm HE and HEI ammunition and with U.S. 20mm HEI Mk 1 projectiles used as controls.
DESCRIPTION: The test 3/8-inch and 7mm rolled homogeneous armor plates were manufactured by the Jessop Steel Co. These plates had previously met the requirements of Specification ANOS-1.
CONCLUSIONS: A complete penetration could not be obtained on the 3/8-inch plate setting at 20° obliquity when using the 20mm German projectiles fired at a maximum muzzle velocity of 3030 fps. Firing tests on the 7mm plate revealed that the German projectiles were superior to the U.S. projectiles. It was recommended that further testing be conducted to determine the effect German 20mm shells have on U.S. aircraft armor.
GENERAL: This seven-page report is not illustrated.

SUBJECT. Armor APG AD-640
TITLE: Report on the Ballistic Test of Light Armored Car M8, Serial No. 4704
IDENTIFICATION: Report No. AD-640; Project No. 2862 (244 AM11-233)
DATE OF REPORT: 21 June 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of an Armored Car M8
METHOD: Ballistic tests were conducted on various sections of an Armored Car M8 using cal. .30 AP M2, cal. .50 AP M2, 20mm AP M75, and 37mm APC M51 Projectiles.
DESCRIPTION: The test Armored Car M8, Serial No. 4704, was manufactured by the Ford Motor Co. Vehicle armor ranged from 1/4 to 1-inch in thickness.
CONCLUSIONS: A number of sections of the test vehicle were found to be vulnerable to cal. .30 and cal. .50 projectiles. It was recommended that the driver's door hinges be redesigned to eliminate the vulnerability of the door hinges to small arms fire; that the clearance between the driver's door and the 1/2-inch upper hull front plate be reduced; that the top of the driver's door be machined to permit the opening and closing of the top hatches when the driver's door was closed; that splash shielding be provided to stop splash from entering the clearances around the 37mm gun, machine gun, and the telescopic sight; that flexible wipers be provided on either side of the turret to prevent projectile fragments from wedging between the rollers and turret base ring; and that the radiator grille be redesigned to prevent damage to the radiator by cal. .30 ball and AP projectiles. The gas tank and engine compartment of the vehicle were considered to be adequately protected from small arms fire. Small arms fire had little effect on ammunition stored in the vehicle ammunition boxes.
GENERAL: This 70-page report contains 10 pages of photographs showing the vehicle before and after test. Firing Records A-12864, A-21873, and A-13137 are also included in the report.

SUBJECT: Armor APG AD-668
TITLE: Report on the Ballistic Test of M4A3E2 Assault Turret
IDENTIFICATION: Report No. AD-668; Project No. 4067 (350 AM5-094) APG AD-668
DATE OF REPORT: 31 May 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the resistance-to-penetration characteristics of the armor of an M4A3E2 Assault Tank turret; and to determine the shock resistance of turret welded joints
METHOD: Ballistic tests with 3-inch APC M62 and 90mm APC M82 Projectiles were conducted on an M4A3E2 Assault Tank turret. Impacts were made on various portions of the turret armor and at various angles of obliquity. Shock resistance tests were performed in order to determine the suitability of turret welded joints. The turret was placed on the hull of a Medium Tank M4A2 and additional ballistic tests were conducted in order to determine the effects of ricochets on the roof of a tank hull when a projectile struck areas under the radio bulge and lower sides of the turret.
DESCRIPTION: The turret of the M4A3E2 Assault Tank consisted of a cast turret shell manufactured by the Union Steel Castings Corp. A 1-inch rolled homogeneous armor roof plate and an armored turret ventilator blower outlet were welded to the turret by the Pressed Steel Car Co. The upper sides of the turret were 6 inches thick.
CONCLUSIONS: The resistance-to-penetration characteristics of the test turret were satisfactory. Shock resistance of proof plate welded joints under impacts from 90mm APC M82 Projectiles striking the turret walls at 30° and 45° obliquity were satisfactory. The weld holding the turret ventilator blower outlet to the turret casting completely failed after repeated projectile impacts on the turret walls at points remote from the outlet. It was felt that the reentrant angle formed by the underside of the radio bulge and the lower side of the turret walls would cause projectiles striking these areas to either pass through the thin hull roof plates or to damage the turret traversing mechanism. It was recommended that the underside of the radio bulge be redesigned to improve resistance-to-penetration characteristics and to eliminate the reentrant angle formed with the roof of the tank hull; and that the weld used to hold the turret ventilator blower outlet to the turret be improved.
GENERAL: This 32-page report contains six pages of photographs showing the turret before and after test. Firing Records A-13721 and A-13748 are also included in the report.

SUBJECT: Armor APG AD-669
TITLE: Induction-Tempered Experimental Armor
IDENTIFICATION: Report No. AD-669; Project No. 3175 (322 AM3-224)
DATE OF REPORT: 17 June 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic limits of induction-tempered rolled armor and to compare these limits with those of rolled homogeneous armor of similar thicknesses
METHOD: Army and protection ballistic limits were obtained on 1/2-inch plate with cal. .50 AP

M2 Projectiles at 0° and 30° obliquities, and with 20mm AP M75 Projectiles at 30° and 45° obliquities. Limits on 1-inch plate were obtained with cal. .50 AP M2 Projectiles at 0° obliquity, with 20mm AP M75 Projectiles at 0° and 30° obliquities, and with 37mm AP M74 and 37mm APC M51 Projectiles at 30° and 45° obliquities. Limits on 1-1/2-inch plate were obtained with 57mm APC M86 Projectiles at 45° obliquity, and with 37mm AP M74 and 37mm APC M51 Projectiles at 0° and 30° obliquities.
DESCRIPTION: The test plates were fully quenched and differentially tempered. The 1/2, 1, and 1-1/2-inch plates measured 36 x 40 inches and had Rockwell "C" hardness readings of 47 on the face and 28 to 30 on the back of the 1/2-inch plate, and 42 to 44 on the face and 25 on the back of the 1 and the 1-1/2-inch plates. All plates were submitted by the Research Laboratory Division of General Motors Corp.
CONCLUSIONS: The induction-tempered armor submitted for this test was not considered to offer any advantage over rolled homogeneous armor that could not be obtained by increasing the hardness of normal production armor.
GENERAL: This unillustrated 24-page report includes Firing Reports A-13149, A-13760 and A-13787.

SUBJECT: Armor APG AD-673
TITLE: Ballistic Test of a Plastic Material Used in Combination with Armor Plate
IDENTIFICATION: Report No. AD-673; Project No. 3520 (724 AM-2-254)
DATE OF REPORT: 20 May 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of plastic material used in various combinations with armor plate
METHOD: Various combinations of 1, 1-1/2, and 2-inch face-hardened and homogeneous armor and 4-inch plastic plates were ballistically tested at either 0° or 30° obliquity with 75mm APC M61 and 75mm HE M48 Projectiles with fuze settings ranging from superquick to delay.
DESCRIPTION: The test plastic plates consisted of twenty-eight 4-inch plates submitted by the Flintkote Co. The plastic material was made up of a combination of quartz gravel bound together by a pitch or an asphalt compound. This material was enclosed in a sheet metal container and was made up into 36 x 46-inch plates. Each plate was surrounded by a mild steel frame 1 inch in thickness and 4 inches wide, and welded together at the ends. The homogeneous and face-hardened armor plates used in this test were taken from stock.
CONCLUSIONS: The plastic material was ineffective against the HE shells unless it was covered with armor plate of sufficient thickness (approximately 1/2-inch) to divert the blast of the shell. The combination of 4-inch plastic material in front of 2-inch homogeneous armor plate defeated the armor piercing projectile when the plastic material was covered with a 1/2-inch homogeneous plate (1600 fps velocity 1500-yard range) but not when the cover plate was removed. A combination of 1-1/2-inch face-hardened armor and 4-inch plastic covered with a 1-inch face-hardened plate was not effective in defeating a projectile fired at the same velocity. On a weight-for-weight basis, an equivalent weight of solid armor plate (approximately 4 inches) was superior to 4-inch plastic material in front of a 2-inch homogeneous plate by a ballistic limit margin of at least 278 fps when subjected to attack with a 75mm APC M61 Projectile.
GENERAL: This 35-page report includes Firing Record A-13765 and 12 pages of photographs of the test materials.

SUBJECT: Armor APG AD-674
TITLE: Shell Fragment Resistance of Doron Sheets, Hadfield Steel and Standard Flyers Protective Armor
IDENTIFICATION: Report No. AD-674; Project No. 3863 (336-AM4-114)
DATE OF REPORT: 7 June 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the shell fragment resistance of Doron sheets, Hadfield Steel, and Standard Flyers Protective Armor
METHOD: The test materials were placed on the open ends of separate recovery boxes and the boxes arranged in an equilateral triangle. Armor plate with a 12-inch square window was placed in front of each material so that only an area 12 inches square was exposed to fire. The materials were affixed vertically in front of the open face of the recovery box by one clamp in the middle of the upper edge. This affixing procedure was not used on Flyers standard armor because of its inherent flexibility. The 20mm HEI Shell was suspended, base down, in the center of the test apparatus, statically detonated, and the fragments that passed through the test samples were recovered and weighed.
DESCRIPTION: The test armor materials included eighty-seven Doron sheets composed of pressed glass cloth and a plastic element, ninety-seven Hadfield manganese steel sheets manufactured by the McCord Radiator and Mfg. Co., and 100 Standard Flyers Protective Armor with Back M-1 submitted by the Crawford Mfg. Co. The Back M-1 consisted of 3-inch square Hadfield manganese steel plates. The open-faced recovery boxes were 24 inches square with side plates of mild steel and a back plate of face-hardened steel.
CONCLUSIONS: Statistical analysis indicated that both the Doron sheets and the Flyers Protective Armor with Back M-1 offered more protection than the Hadfield manganese steel sheets against 20mm HEI fragments. It was recommended that the two preferred materials be comparatively tested with fragments of statically detonated 37mm HE M54 Shell or fragmentation hand grenades. It was also recommended that the Flyers Protective Suit, made with 2-inch Doron squares and nylon duck backing, and the standard Flyers Protective Armor Suit be tested with 20mm HEI Shell fragments.
GENERAL: This 138-page report includes three pages of graphs and six pages of photographs of the test setup and materials. Also included are Report Nos. A-13709, A-13716, and A-13745.

SUBJECT: Armor APG AD-676
TITLE: Ballistic Test of Gun Motor Carriage T70
IDENTIFICATION: Report No. AD-676; Project No. 924 (273 AM1-064)
DATE OF REPORT: 15 May 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of the Gun Motor Carriage, T70
METHOD: Ballistic tests were conducted on various sections of the armor of a Gun Motor Carriage T70, using cal. .30 AP M2, cal. .50 AP M2, 20mm AP M75, and 37mm AP M51 Projectiles.
DESCRIPTION: The materiel submitted for test consisted of the hull and turret of Gun Motor Carriage T70, Serial No. 370, manufactured by the Buick Motor Division. Vehicle armor ranged from 1/2 to 1-1/2 inches in thickness. All external joints had been automatically welded with ferritic electrodes.
CONCLUSIONS: A chart was made up showing the vulnerability of the various armor sections of the test vehicle as indicated by the ballistic tests. Fragments of cal. .30 and cal. .50 projectiles were found to have passed through clearances in the front door and front hull plates, read door and rear hull plates, and turret gun mount shield and turret gun mount trunnion casting. It was recommended that bullet deflector strips and splash traps be applied to the front and rear hull plates at positions adjacent to the front and rear doors. It was further recommended that such deflector strips and splash traps be ballistically tested prior to approval.
GENERAL: This 160-page report contains 23 photographs showing the vehicle armor as tested. Firing Records A-13111, A-13377, A-13385, A-13442, A-13457, A-31730, and A-13739 are also included in the report.

SUBJECT: Armor APG AD-683
TITLE: First Report on Ballistic Test of Heavy Tank T26E1 No. 6
IDENTIFICATION: Report No. AD-683; Project No. 4099 (361 AM5-174)
DATE OF REPORT: 8 July 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of the T26E1 Heavy Tank and its components to various types of ballistic attack
METHOD: Ballistic tests were divided into three phases, each of which was described in a separate firing record. In the first phase, the engine compartment grilles were tested with cal. .30 and cal. .50 rifle fire, fragmentation and offensive type hand grenades, and a Molotov cocktail to determine the protection afforded by the grilles to the radiators and other components of the power train. In the second phase, the engine compartment was tested with a statically detonated 105mm M1 HE shell. The driver's, tank commander's, and gun loader's doors, and the clearances between the gun shield and gun tube and between the gun shield and turret, were tested for keying and splash with cal. .30 and cal. .50 rifle fire. In the third phase, the Rotoclone blower was tested with Molotov cocktails. The clearances between the hinges of the assistant driver's door and the clearance between the 90mm gun tube and modified gun shield were tested with cal. .30 and cal. .50 rifle fire.
DESCRIPTION: The T26E1 Heavy Tank, identified as Serial No. 6, was manufactured by the Fisher Tank Division of General Motors Corporation. The tank suspension was removed prior to ballistic tests.
CONCLUSIONS: It was found that the tank could be immobilized by small arms fire, offensive grenades, or shell fragments causing damage to parts located beneath the engine. The tank was only temporarily immobilized by Molotov cocktails broken over the front of the engine air inlet grilles. Fire from cal. .50 rifles could prevent rotation of the turret and could immobilize the tank gun by deforming bearing surfaces so that the gun could not return to battery position after firing. The use of a deflector ring was found effective in preventing damage to the bearing surfaces of the tank gun and sleeve. It was found that rifle fire could impair the operation of the driver's doors, tank commander's cupola, gun loader's hatch, and tank commander's periscope. It was believed that members of the tank crew could be injured by splash or projectile fragments through several clearances. The Rotoclone blower openings were not vulnerable to small arms fire. Molotov cocktails thrown against the Rotoclone blower did not cause fires within the tank.
GENERAL: This 72-page report contains 15 photographs of the tank and its components. Firing Records Ar-14061, 14109, and 14351 are incorporated in this brief.

SUBJECT: Armor APG AD-690
TITLE: Ballistic Test of Welded Joints and Shock Mounts of Medium Tank T23 Welded Turret and 76-mm Gun Mount M1A1
IDENTIFICATION: Report AD-690, Project No. 853
DATE OF REPORT: 12 October 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of a tank turret equipped with a new design gun mount and shock-mounted brackets
METHOD: The gun shield and main welded joints of the turret were radiographically examined to determine soundness. The turret and mount were subjected to small arms fired to determine vulnerability to splash penetration, gun mount locking, and hindrance to recoil or counter recoil. The turret and mount were also subjected to 90mm and 3-inch projectile fire to determine their susceptibility to gun mount elevation restriction and shock impact, and to determine the suitability of shock mounted brackets within the turret.
DESCRIPTION: The test material consisted of a T23 Medium Tank turret welded with austenitic electrodes and submitted by the General Electric Co. of Erie, Pennsylvania; a 76mm gun mount; and shock mounted brackets fastened to the turret by fillet welds between the turret and the legs of the mounts.
CONCLUSIONS: The radiographs were of unacceptable sensitivity. The clearances between the sides of the turret and the gun mount did not cause

binding between turret and mount, nor were they considered a splash hazard for small arms fire fired horizontally from the rear. It was found that cal. .50 projectiles could hinder and gun recoil or counter recoil by lodging against or by deforming the gun tube, and that 75mm projectiles could cause binding between the turret and mount, render the direct and indirect gun sights useless, damage the Timken bearings, and hinder removal of the gun mount from the turret. The resistance-to-penetration of the welded joint areas was less than that provided by the side wall area not affected by welded joints. Some of the shock-mounted brackets were considered satisfactory; others were not. It was found that accelerations up to 3360 times the acceleration of gravity could be imparted to 2.9 pound interior attachments that were non-shock-mounted to the 2-1/2-inch rolled homogeneous armor plate.
GENERAL: This 66-page report contains 24 pages of photographs of the test material and four sketches showing impact locations and stud and lug design.

SUBJECT: Armor APG AD-693
TITLE: First Report on Ballistic Test of Light Tank M24
IDENTIFICATION: Report No. AD-693; Project No. 4294
DATE OF REPORT: 23 November 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of the engine components of the Light Tank M24 to small arms fire; and to determine whether exposed openings and clearances between armor plate would permit entry of splash.
METHOD: Firing tests were conducted on the Light Tank M24 engine compartment grilles and on armor areas which included clearances between armor plate that would probably expose the interior of the vehicle to splash and projectile fragments. Cal. .30 and .50 projectiles were used in the firing tests. In addition, the ballistic vulnerability of engine components to the blast of offensive hand grenades Mk III A1 was also checked.
DESCRIPTION: The test Light Tank T24, Serial No. 8, was manufactured by the Cadillac Motor Division of the General Motors Corp. Vehicle armor ranged from 1/2 to 1 inch in thickness.
CONCLUSIONS: The test vehicle could be immobilized by small arms fire and offensive hand grenades. Generators, oil filters, engine distributors, battery cable, radiators, and the gas tank located below or adjacent to the inlet and outlet grilles were found to be especially vulnerable to ballistic attack. Projectiles and splash were found to easily enter the vehicle at a number of points where clearance between armor plates was excessive. Numerous other points on the vehicle were found ballistically vulnerable, including the 75mm gun tube which could be rendered unusuable by small arms fire. It was recommended that more protection be afforded vehicle engine components; that the excessive clearance found between various portions of the vehicle armor be corrected; and that the numerous other portions of the vehicle vulnerable to ballistic attack be improved.
GENERAL: This 115-page report contains 21 pages of photographs showing the test vehicle and various points at which damage was inflicted on vehicle armor. Firing Records Ar-14139, Ar-14392, Ar-14486, and Ar-14801 are also included in the report.

SUBJECT: Armor APG AD-695
TITLE: Ballistic Test of the M4A3E2 Assault Tank
IDENTIFICATION: Report AD-695; Project No. 4352
DATE OF REPORT: 9 February 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of the Assault Tank M4A3E2
METHOD: Ballistic tests were conducted on the test vehicle using cal. .30, cal. .50, 37mm APC M51B2, 75mm APC M61, 3-inch APC M62, 90mm AP M77, and 90mm APC M82 Projectiles at various obliquities and against various components
DESCRIPTION: The test Medium Tank M4A3E2 was basically a standard Medium Tank M4A3 except for the following changes: 1-1/2-inch rolled homogeneous armor was added to the hull front plate and sponson side plates; the overall thickness of the final drive housing armor was increased to a thickness of 4 to 5-1/2 inches; the turret thickness at the heaviest section was increased to approximately 6 inches; and the gun shield was redesigned and consisted of rolled and cast armor combined by means of a welding fabrication process (cross sectional thickness of the gun shield included 5 inches of rolled and 1 inch of cast armor.)
CONCLUSIONS: The trunnion bearings and collars of the 75mm gun mounted on the test vehicle did not satisfactorily withstand 90mm APC M82 Projectile impacts. Mounting bolts for the hand traversing unit, traversing mechanism, azimuth indicator, and gun level bubble failed when impacts were made on the vehicle with 90mm APC M82 Projectiles; turret hold down bolts and bolts used for securing a bracket to the right outside trunnion cap, which held the linkage to an indirect sight, also failed under 90mm projectile impacts. The reentrant angle formed at the underside of the turret radio bulge was found to cause projectiles to richochet into the vehicle engine compartment. Location of a coaxial machine gun mounted on the vehicle was unsatisfactory in that a 90mm APC M82 Projectile impact on the gun shield near the machine gun opening would deform the opening and make it impossible to remove the machine gun barrel. It was recommended that the deficiencies revealed in test be corrected.
GENERAL: This 83-page report contains 23 pages of photographs showing the test vehicle and the appearance of components after firing. Firing Records Ar-14724, Ar-14725, Ar-14782, Ar-14944 are also included in the report.

SUBJECT: Armor APG AD-696
TITLE: A Comparison of Doron Sheets, Hadfield Mn Steel Sheets, Standard Flyer's Protective Armor, and 0.156-inch 24 ST Aluminum in Resisting

Penetration by 20mm HEI Shell Fragments
IDENTIFICATION: Report No. AD-696; Project No. 4434
DATE OF REPORT: 2 September 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine which of several materials would be most suitabile for use in protection against 20mm HEI Mk I Projectile fragments
METHOD: Rounds of 20mm HEI Mk I Projectiles equipped with Mk II fuzes were statically detonated in the vicinity of three types of protective armor and a material designated Doran. The relative protection offered by each type of material against projectile fragments was determined.
DESCRIPTION: Material submitted for test included 100 Doron panels each 0.155- h thick and composed of glass cloth and a plastic material; 150 Hadfield manganese steel panels ranging from 0.045 to 0.080 inch in thickness; the back portions of 90 Flyer's Protective Armor Vests M1, each composed of 2-inch square plates made of 0.045-inch Hadfield manganese steel (vest backs were constructed with plates overlapping each other); and 256 24ST aluminum panels, each 0.156-inch thick.
CONCLUSIONS: The 0.156-inch 24 ST aluminum plate (37.1 ounces/sq. ft.) offered considerably more protection from fragments of a 20mm HEI Projectile than did 0.055-inch Hadfield manganese steel (36.5 ounces/sq. ft.). By extrapolating the ballistic data obtained with the heavier gages of Hadfield Steel, it was determined that 0.155 inch Doron material (22.0 ounces/sq. ft.) offered protection comparable to that obtained with an equivalent weight of Hadfield steel (0.033-inch thick). Disregarding weight per unit area, both Flyer's armor (50 to 60 ounces/sq. ft.) and 0.80-inch Hadfield manganese steel (53.0 ounces/sq. ft.) offered substantially the same protection and were superior to the other materials tested. Because of the discrepancy which might be encountered in extrapolating data, it was recommended that future ballistic testing of various materials in comparison with other materials be conducted on an equivalent weight basis.
GENERAL: This 467-page report contains 10 pages of photographs showing the various materials after ballistic tests. Firing Records Ar-14138, Ar 14354, Ar-14379, Ar-14405, Ar-14429, Ar-14441, and Ar-14710 are also included in the report.

SUBJECT: Armor APG AD-700
TITLE: Comparison of the Ballistic Properties of Rolled and Cast Homogeneous Armor (1 to 3 inches)
IDENTIFICATION: Report No. AD-700
DATE OF REPORT: 18 October 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the resistance to ballistic attack afforded by rolled and cast homogeneous armor
METHOD: Comparison between the resistance to ballistics afforded by rolled and cast homogeneous armor was based on data obtained from previous tests. The comparisons were based on equivalent thicknesses and included ballistic characteristics; resistance to oblique attack with AP Projectiles; effect of hardness on ballistic properties; and vulnerability of the armor when used in vehicular design.
DESCRIPTION: The test armor included cast and rolled homogeneous armor ranging from 1 to 2-1/2 inches in thickness.
CONCLUSIONS: The resistance to penetration of 1, 1-1/2, and 2-inch rolled homogeneous armor plate averaged 78, 133, and 138 fps higher in ballistic limits than did corresponding sizes of cast plates. Ballistic limits obtained with corresponding sizes of rolled homogeneous armor varied less than the ballistic limits obtained with corresponding sizes of cast homogeneous armor. In tests conducted with 3-inch APC M62 Projectiles fired at plate surfaces resting at obliquities of 45° and 57°, 2 to 2-1/2-inch rolled homogeneous armor plate averaged ballistic limits ranging from 200 to 300 fps higher than corresponding thicknesses of cast armor. From the standpoint of optimum hardness, the resistance to penetration characteristics of 1-inch rolled homogeneous armor were superior to those of 1-inch cast armor. In the case of vehicle design, variable obliquities and variable armor thickness which would improve resistance to penetration characteristics could be more readily obtained in the case of a cast armor structure as compared to the same structure fabricated with rolled armor. Ballistic characteristics of vehicle armor, whether cast or rolled, were considerably poorer in welded joint areas than in primary armor areas.
GENERAL: This 34-page report is not illustrated.

SUBJECT: Armor APG AD-803
TITLE: Protection Afforded by Cast Turret No. D 53526 for Medium Tank T23
IDENTIFICATION: Report No. AD-802; Project No. V-2-16
DATE OF REPORT: 6 August 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the protection provided by the cast turret for the Medium Tank T23
METHOD: The turret was placed so that approximate ballistic limits could be obtained at 0° and 48° obliquities with 3-inch APC M62 Projectiles. The ballistic limit at 48° obliquity was also obtained with 90mm APC M82 Projectiles. Impacts with 3-inch APC M62 Projectiles were placed on the glacis roof plate at 67° obliquity.
DESCRIPTION: The cast turret used for the test was identified as D-53526, Heat No. 7380, plate pattern serial No. 3. The turret had a thickness of 2-5/8 to 2-13/16 inches and was manufactured by the General Steel Castings Corp., Eddystone, Pennsylvania.
CONCLUSIONS: The turret offered less resistance to penetration at 48° obliquity in the area of armor adjacent to the base ring than in the area not adjacent to the base ring. It was recommended that a thorough investigation be made to determine the reason for this difference. The quality of the armor was appraised as being very good as cracking did not result between impacts, although

several were close together.
GENERAL: This 19-page report includes six pages of photographs of the test turret and two pages of development drawings.

SUBJECT: Armor APG AD-818
TITLE: Ballistic Test of New Type Combination Gun Mount and Turret
IDENTIFICATION: Report No. AD-818
DATE OF REPORT: 21 October 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate armor for the 75mm combination gun mount and turret for Medium Tank T23
METHOD: Caliber .50 M2 Ball Projectiles were fired at the trunnion plate to determine splash penetration and at the gun sleeve in an attempt to penetrate the sleeve to the extent of affecting the recoil mechanism. The gun shield resistance to penetration for 37mm AP M74 and 75mm AP M72 Projectiles and the degree of protection afforded the recoil mechanism were investigated. The effects of shock to trunnions, trunnion supports, and other gun components were noted after projectile fire at velocities much lower than required to effect complete penetration. Ninety millimeter projectiles were fired at 0° obliquity to shock-test the elevating mechanism and at 48° obliquity to determine the ballistic limit of the area adjacent to the base ring. Samples were cut from the turret for hardness surveys and fracture tests.
DESCRIPTION: The 75mm combination gun mount for the Medium Tank T23 was manufactured by the Ford Motor Co. The turret for the tank was manufactured by the General Steel Castings Corp. Two shields were submitted for ballistic evaluation, one of which was subjected to radiographic examination. Heat No. 7380 steel was used in the turret casting. The portions of the shield which covered the trunnion lugs, the turret roof, and the lower edge of the opening in the turret for the gun mount were approximately 1-1/2 inches thick whereas the area over the recoil cylinders was 3-1/2-inches thick.
CONCLUSIONS: The 75mm gun mount could be bound to the trunnion lugs of the turret by a 75mm AP M72 Projectile impact at a velocity as low as 1621 f/s on the area along the vertical edge of the shield. Such damage might be difficult to repair. Armor covering the recoil cylinders was vulnerable to 37mm AP M74 Projectiles at 2570 f/s and to 75mm AP M72 Projectiles at velocities as low as 1275 f/s. The mount for the telescopic sight did not have sufficient shock resistance when subjected to shock impacts on the shield by 75mm AP M72 Projectiles at velocities of 1275 f/s. The machine gun cradle was displaced by shield impacts from 75mm projectiles at velocities of 1350 f/s. The turret was vulnerable to 75mm AP Projectiles at velocities below that required to penetrate the frontal areas of the turret walls. The trunnions and trunnion bearings would withstand the shock of repeated impacts on the shield with 75mm AP Projectiles at velocities of 1250 f/s. The recoil mechanism was not affected by cal. .50 AP ammunition. Splash from cal. .50 Projectiles could enter the turret through the clearance between the trunnion lugs and the shield. The penetration resistance of the area adjacent to the base ring against 90mm APC Projectiles at 48° obliquity was equal to that provided by other areas of the turret sidewall.
GENERAL: This 39-page report includes five pages of test data and 12 pages of illustrations.

SUBJECT: Armor APG AD-819
TITLE: Ballistic Test of Gun Motor Carriage M10 Turret and Counterweights
IDENTIFICATION: Report No. AD-819
DATE OF REPORT: 21 October 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic properties of turret welded joints, adjacent areas, and counterweight attaching bolts.
METHOD: Projectiles were fired at the turret side plates, the joints between the trunnion plates and the upper front plate, and the joints between the turret side plates and the front corner plates at the obliquity presented by these plates to horizontal frontal fire. The following projectiles were used: Proof Projectile T21 75mm, Shot APC M61 75mm, and Shot AP M74 37mm. Projectile velocities varied from 775 f/s to 1213 f/s. Resistance to shock and penetration was determined. A radiographic test was conducted to determine the acceptability of weldments on the basis of Specification AXS 476-1.
DESCRIPTION: The test Gun Motor Carriage M10 turret No. E6473 was manufactured by the Fisher Tank Div. of G.M.C. The test turret had counterweights E7993 and E7992 attached.
CONCLUSIONS: The major welded joints of the turret were not damaged by 75mm PP T21 impacts at a veolocity of 775 f/s to an extent where structural strength of the turret was impaired. The turret counterweight attaching bolts did not fail from repeated impacts from 75mm Projectiles at a velocity of 775 f/s on the turret sides. Areas adjacent to the welded joints showed no loss of protection when compared with unwelded armor plate.
GENERAL: This 41-page report includes six pages of photographs of the test turret.

SUBJECT: Armor APG AD-825
TITLE: Development of Spaced Armor
IDENTIFICATION: Report No. AD-825; Project No. A-1-2
DATE OF REPORT: 4 November 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To develop spaced-armor arrangements for defeating the AT M6 2.36-inch Rocket
METHOD: The results obtained in a previous test program for the development of armor arrangements to minimize the effect of the AT M9A1 Grenade were used as a guide in selecting the initial spacing between plates. Spacing was increased and decreased until the minimum spacing that could prevent complete penetration of both plates was obtained. This was done for each combination of plates. The first 6 rounds were fired from a 100-yard range, the next 6 rounds were

fired from a 50-yard range, and all but 11 of the remaining rounds were fired from a 20-yard range. The last 11 rounds were fired from a range of 14 yards. The rocket launcher was mounted on a special wooden ground mount and fired from a distance by means of a battery.
DESCRIPTION: The armor used in the test consisted of rolled homogeneous plates 1/4, 3/8, 1/2, 3/4, 1, 1-1/8, 1-1/2, and 2 inches in width. Two lots of AT rockets from the Delaware Ordnance Depot were used in this test. Various thicknesses of spaced armor arrangements were tested, involving 2 and 3-plate distributions and materials such as sand or gravel used in combination with 2-inch rolled homogeneous plate.
CONCLUSIONS: It was found that the front plate of a 2-plate spaced-armor arrangement would have to be thinner than the basic plate to permit minimum spacing. Mild steel plate when used as auxiliary spaced armor did not give as much protection as armor plate of similar thickness. The AT M6 Rocket could not be defeated by a rolled homogeneous plate one inch thick or less spaced 20 inches or less in front of and parallel to a rolled homogeneous plate 1-1/2 inches or less in thickness.
GENERAL: This unillustrated 33-page report includes 25 pages of test data.

SUBJECT: Armor APG AD-835
TITLE: Additional Armor for Light Tank M24
IDENTIFICATION: Report No. AD-835; Project No. 4290
DATE OF REPORT: 23 January 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine which of several armor combinations would provide complete protection for the Light Tank M24 against Japanese 47mm Anti-Tank Gun Projectiles
METHOD: Standard Light Tank M24 armor plate, setting at obliquities of 12°, 25°, 45°, and 60° and protected by front plates of various thicknesses at zero spacing, were ballistic tested against Japanese 47mm Anti-Tank Gun Projectiles.
DESCRIPTION: The front plates tested in combination with the standard 1-inch Light Tank M24 armor plate were manufactured by the Carnegie Illinois Steel Corp. and the H. Disston and Sons Co. Thicknesses of armor tested as front plate ranged from 3/4 to 3 inches.
CONCLUSIONS: The following armor combinations setting at the respective obliquities were believed to be sufficient to provide complete protection against Japanese projectiles:

Obliquity	Plate Thickness in Inches	
	Base Plate	Front Plate
12°	1	2-3/4
25°	1	2-1/4
45°	1	1-1/4
60°	1	1

Because of the variable performance of Japanese projectiles, it was felt that reasonable protection could be provided by thinner armor arrangements, but some complete penetrations would probably occur.
GENERAL: This 23-page report is not illustrated. Firing Records Ar-14776, Ar-14921, Ar-14937, and Ar-14969 are included in the report.

SUBJECT: Armor APG AD-837
TITLE: Second Report on the Ballistic Test of Heavy Tank T26E1, No. 6
IDENTIFICATION: Report No. AD-837; Project No. 4099
DATE OF REPORT: 19 December 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the shock resistance characteristics of the mechanical components, component mounting attachments, and welded joints of the Medium Tank T26E1
METHOD: The hull and turret of a Medium Tank T26E1 were ballistically tested with 75mm HE M48, 90mm APC M82, 105mm PP T8, and 105mm HE M1 Projectiles. Prior to test, the complete power train and suspension system were removed from the vehicle.
DESCRIPTION: The test Medium Tank T26E1, Serial No. 6, was manufactured by the Fisher Tank Division of General Motors Corp.
CONCLUSIONS: Mechanical components essential to the operation of vehicle armament, turret, and power train were rendered inoperative by the shock produced by adjacent 90mm APC Projectile impacts. Component mounting attachments for a number of items were found inadequate in preventing damage or displacement of the mounted items when 90mm APC Projectile impacts were made adjacent to the items. Shock resistance characteristics of the vehicle welded joints appeared satisfactory.
GENERAL: This 84-page report contains 27 pages of photographs showing various views of the vehicle and components before and after test. Firing Records Ar-14352, Ar-14762, Ar-14777, Ar-14792, and Ar-15386 are also included in the report.

SUBJECT: Armor APG AD-846
TITLE: A Ballistic Test of Heavy Tank, T26E1, Front Hull Casting, Drawing No. E9049, Submitted by General Steel Castings
IDENTIFICATION: Report No. AD-846; Project No. 4951 (34 AR9-274)
DATE OF REPORT: 7 November 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic acceptability of a Heavy Tank T26E1 front hull casting and to compare the ballistic suitability of this casting with an identical type of casting submitted by another manufacturer
METHOD: Ballistic acceptance tests of the hull casting were conducted with 155mm AP M112, 90mm AP M77, 90mm APC M82 and 75mm AP M72 Projectiles at obliquities ranging from 0° to 45°. These tests were in accordance with the requirements of Specifications AXS 1013 and AXS 492-4. Development or Engineering tests were conducted on the various casting surfaces with

90mm APC M82 and 90mm AP M77 Projectiles at obliquities ranging from 30° to 55°.
DESCRIPTION: The test Heavy Tank T26E1 front hull casting, Serial No. 10, was submitted by General Steel Castings.
CONCLUSIONS: The test casting met the requirements of Specifications AXS 1013 and AXS 492-4. The protection afforded by this casting appeared to be equal to that afforded by Continental Foundry Machine Co. casting, Serial No. 74, tested at an earlier date.
GENERAL: This 22-page report contains two pages of photographs showing the test front hull casting after ballistic tests. Firing Records Ar-14907 and Ar-15084 are also included in the report.

SUBJECT: Armor APG AD-847
TITLE: Ballistic Test of Heavy Tank, T26E1, Front Hull Casting, Drawing No. E9049, Serial No. 159, Submitted by the Continental Foundry and Machine Co.
IDENTIFICATION: Report No. AD-847; Project No. 4951
DATE OF REPORT: 24 January 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic acceptability of a Heavy Tank T26E1 front hull casting and to compare the ballistic suitability of this casting with that of another casting submitted by the same manufacturer
METHOD: Ballistic acceptance tests of the front hull casting were conducted with 155mm AP M112, 90mm AP M77, 90mm APC M82 and 75mm AP M72 Projectiles at obliquities ranging from 0° to 45°. Ballistic development or engineering tests of the various casting surfaces were conducted with 90mm APC M82 and 90mm AP M77 Projectiles at obliquities ranging from 30° to 55°. The tests were in accordance with the requirements of Specifications AXS-1013 and AXS-492-4.
DESCRIPTION: The test Heavy Tank T26E1 front hull casting, Serial No. 159, was submitted by the Continental Foundry and Machine Co.
CONCLUSIONS: The test casting met the ballistic requirements of Specification AXS-1013, but failed to meet all the ballistic requirements of Specification AXS-492-4. The protection afforded by the test front hull casting was inferior to that of the same type of casting submitted by the same manufacturer at an earlier date.
GENERAL: This 22-page report contains three photographs showing the casting after the ballistic test. Firing Records Ar-15023 and Ar-15112 are also included in the report.

SUBJECT: Armor APG AD-849
TITLE: Vulnerability of a Captured German Cast Armor Mobile Pillbox to Armor Piercing Projectiles
IDENTIFICATION: Report No. AD-849; Project No. 4339
DATE OF REPORT: 9 February 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the radiographic and metallurgical suitability, ballistic vulnerability, and shock characteristics of the cast armor used in a German mobile pillbox; and to compare the resistance to penetration of the German cast armor with a comparable thickness of American armor
METHOD: The armor of the pillbox was examined radiographically and metallurgically. Firing tests were then conducted on the surfaces of the top portion of the pillbox using 90mm APC M82, 3-inch APC M62, 57mm APC M86, and 37mm APC M51 Projectiles; these firing tests were conducted with the pillbox setting normal to the line of fire. A section from the lower portion of the pillbox was then ballistic tested with 37mm AP M74 and 57mm AP M70 Projectiles; resistance to penetration afforded by the German armor was then compared with a comparable thickness of American armor. Another section of the lower portion of the pillbox was shock-tested using a 105mm T8 Proof Projectile.
DESCRIPTION: The test German mobile pillbox was fabricated with cast armor ranging from 1-1/2 to 5 inches in thickness. With the lower portion of the pillbox buried in the ground, the pillbox appeared as a turret-like structure measuring approximately 5 feet in diameter and approximately 3 feet in height.
CONCLUSIONS: Examination indicated that the cast armor of the pillbox was radiographically sound and that the metallurgical properties of the armor were poor. The ballistic limits of the various armor surfaces against impacts with the different projectiles were listed. Based on simulated air attack conditions in which the angle between the line of attack and the ground was 15°, it was found that a 37mm Projectile fired at a muzzle velocity of 2690 fps would not penetrate the 2-inch pillbox roof armor. Shock resistance of the pillbox armor was poor. Resistance to penetration of the armor was lower than a comparable thickness of American armor.
GENERAL: This 44-page report contains four photographs of the pillbox. Firing Records Ar-14147, Ar-15082, and Ar-15100 are also included in the report.

SUBJECT: Armor APG AD-956
TITLE: Ballistic Test of Front Hull Casting for the Heavy Tank T26E1 Drawing No. E9049, Submitted by the Continental Foundry and Machine Company
IDENTIFICATION: Report No. AD-956; Project No. 4351
DATE OF REPORT: 19 April 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic acceptability of the Heavy Tank T26E1 front hull casting, and the ballistic vulnerability of the casting against German 8.8cm APHE projectiles
METHOD: Resistance to shock test of the hull casting was conducted with 75mm AP M112 Projectiles fired at 30° obliquity. Resistance-to-penetration test of the hull casting was conducted with 90mm AP M77 Projectiles fired at 0° obliquity. These acceptance tests were in accordance

with the requirements of Specification AXS-1013. The ballistic vulnerability of the hull casting was determined by firing German 8.8cm APHE projectiles against various surfaces at obliquities from 30° to 55°.
DESCRIPTION: The test Heavy Tank T26E1 front hull casting, Serial No. B-1, was submitted by the Continental Foundry and Machine Co.
CONCLUSIONS: The front hull casting met the ballistic requirements of Specification AXS-1013. However, the casting failed to afford balanced protection against German 8.8-cm. APHE projectiles as the resistance-to-penetration varied considerably from one area to another.
GENERAL: This 22-page report contains four photographs showing the casting and German projectiles after test. Firing Records Ar-15372 and Ar-15382 are also included in the report.

SUBJECT: Armor APG AD-962
TITLE: Investigation of HCR-2 Plastic Armor as a Method of Defeating Shaped Charge Ammunition
IDENTIFICATION: Report No. AD-962; Project No. 3520
DATE OF REPORT: 3 March 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine suitable minimum thicknesses of layers of HCR-2 Plastic and associated armor cover plates for protection against various types of ballistic attack
METHOD: Various combinations of HCR-2 plastic panels and armor plates, used to simulate the armor of an M4 Medium Tank, were subjected to ballistic attack with 105mm HE M1, 105mm HEAT M67, German Faustpatrone No. 2 (Panzerfaust), 75mm AP M72, and 75mm APC M61 Projectiles.
DESCRIPTION: The armor combinations used to determine the proper cover plate thickness against attack by 105mm HE projectiles, consisted of 5-inch panels of HCR-2 plastic faced with either 3/8, 1/2, or 3/4-inch RH armor and supported in the rear with either 1-1/2 or 2-1/2 inch RH armor. The armor combinations used to determine the protection needed by the sponson and turret sections of the tank against 105mm HEAT M67 Projectiles consisted of 4, 5, 6, or 7-inch HCR-2 panels faced with either 1/2 or 3/4-inch RH armor and supported with 1-1/2 or 2-1/2-inch RH armor. The armor combination used to determine the protection needed by the sponson and turret sections of the tank against German Faustpatrone No. 2 Projectiles consisted of 8, 10, or 12-inch HCR-2 panels faced with either 1-1/2 or 2-1/2-inch RH armor. The armor combinations used against attack by 75mm projectiles consisted of 5, 6, or 12-inch HCR-2 panels faced with 3/4-inch RH armor and supported with 1-1/2 or 2-1/2-inch RH armor.
CONCLUSIONS: The 1/2-inch armor face plate provided adequate protection as a cover plate to retain the HCR-2 plastic against attack by the HE projectiles. Minimum thicknesses of 5 and 6 inches of HCR-2 plastic, faced with a 3/4-inch armor plate, were required to give absolute protection to the turret and sponson side section, respectively, against the HEAT shells fired at striking velocities of 1100 and 1250 fps. At least 12 inches of HCR-2 plastic, faced with a 3/4-inch armor plate, were required to prevent complete penetration of the turret and the sponson side section by the German Panzerfaust shells. Face plate and HCR-2 plastic armor combinations provided an increase in protection of 300 to 500 fps against AP and APC shells. The data covering the increase of protection provided by the HCR-2 plastic alone were inconclusive.
GENERAL: This 73-page report includes 14 pages of photographs and three appendices. Appendix B includes Reports Ar-15081, Ar-15107, Ar-15248, Ar-15260, and Ar-15384, the pertinent data therefrom being incorporated in this brief.

SUBJECT: Armor APG AD-964
TITLE: Second Report on Ballistic Test of Light Tank M24
IDENTIFICATION: Report No. APG AD-964; Project Nos. 4290 and 4944
DATE OF REPORT: 14 April 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic suitability of various inlet and outlet grille arrangements, fragment-absorbing compounds, and air flow sheet metal thicknesses for the rear inlet grilles of a Light Tank M24
METHOD: Ballistic tests were conducted on a set of modified inlet and outlet grilles installed on the Light Tank M24, with cal. .30 and cal. .50 ammunition fired at either 15° or 30° obliquity. The severity of attack was governed by the resistance-to-penetration protection offered by the thickness of hull and turret armor in the locality of the component involved. Hand Grenades Mk III A1 were statically detonated on homogeneous and mild steel armor plates of various thicknesses used to simulate the tank's air flow guide sheet located below the rear inlet grille.
DESCRIPTION: The test material consisted of a forward inlet grille section assembled with the louver bars welded to the frame parallel to the longitudinal axis of the tank; an adhesive compound manufactured by the Minnesota Mining Co. and a felt neoprene compound; six sections of armor panel (3/8-inch thick, 4 inches deep, 16 inches in length, and 6-1/2 inches apart) welded to the underside of the standard outlet grille perpendicular to the louver bars; 10 gage and 3/16-inch mild steel plate; and 1/4, 5/16, 3/8, and 1/2-inch homogeneous armor plate having hardness ratings between 340 and 388 BHN.
CONCLUSIONS: The experimental inlet grille offered more protection than the standard type without cross panels. Fragment-absorbing compounds caught projectile fragments penetrating the grilles. The air flow metal guide, with its thickness increased to 3/16-inch, furnished protection to the engine components against hand grenades. The standard outlet grille with armor panels offered the greatest protection.
GENERAL: This 125-page report includes 15 pages of photographs, four pages of diagrams, 27 pages of sketches, and five appendices. Appendix

B includes Reports Ar-14742, Ar-14926, Ar-15123, Ar-15368, Ar-15376, and Ar-15651, the pertinent data therefrom being incorporated in this brief.

SUBJECT: Armor APG AD-970
TITLE: Ballistic Test of Experimental Armored Air Grilles for Heavy Tank T26E1
IDENTIFICATION: Report No. AD-970; Project No. 5080
DATE OF REPORT: 5 June 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the ballistic protection afforded by experimental engine air grilles with that of standard Heavy Tank T26E1 engine air inlet and outlet grilles
METHOD: Ballistic tests were conducted on four experimental and two standard Heavy Tank T26E1 engine air grilles using cal. .30 and .50 ball and AP M2, 20mm HE Mk III and AP M75, 37mm AP M74, and 75mm AP M72 Projectiles. Fragmentation Mk II and Offensive Mk III Hand Grenades, TNT loaded, were detonated on the top surfaces of the grilles. A few 105mm HE M1 Projectiles were statically detonated 24 inches above the grilles.
DESCRIPTION: Two samples of each of two types of experimental engine air grilles, both of cast armor construction, were submitted for test. One type of experimental grille, No. 1A1, was made up of 3-1/2-inch wide, double-curved, single-trap louvers. The second type of experimental grille, No. 4, was made up of 4-inch wide, single-curved, single-trap louvers. The hardness of one sample of experimental grille was 240 to 250 BHN and the hardness of another sample of grille was 302 to 340 BHN. The two standard grilles for the Heavy Tank T26E1 were made of welded, homogeneous armor; one was an engine air inlet grille made up of straight venturi type louvers, the other was an engine air outlet grille made up of curved venturi type louvers.
CONCLUSIONS: The ballistic protection afforded by both types of experimental grilles was superior to that of both types of standard grilles. In an over-all comparison, the No. 4 experimental grille made with 302 to 340 BHN cast armor afforded better ballistic protection than any of the other experimental grille samples tested. In view of the good results obtained with the experimental grilles, it was recommended that the development of grilles which would provide better ballistic protection for engine compartments be continued.
GENERAL: This 145-page report contains 19 photographs showing the grilles after test. Firing Records Ar-15379, Ar-15400, Ar-15371, and Ar-15650 are included in the report.

SUBJECT: Armor APG AD-971
TITLE: Third Report on the Ballistic Test of Heavy Tank T26E1, No. 6
IDENTIFICATION: Report No. AD-971; Project No. 4099
DATE OF REPORT: 27 April 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of the hull, turret, and gun shield of the T26E1 Heavy Tank against AP projectiles
METHOD: The frontal areas of the hull, turret, and gun shield were tested in the normal running position for resistance-to-penetration with 90mm APC M82 Projectiles and impacts were made on the underside of the gun shield to determine the effects of ricochets from the gun shield on the hull roof. Resistance-to-penetration tests were conducted against the turret and hull sides with 37mm AP M80, 57mm APC M86, 3-inch APC M62, and 90mm APC M82 Projectiles at obliquities ranging from 10° to 65°.
DESCRIPTION: The T26E1 Heavy Tank, identified as Serial No. 6, was manufactured by the Fisher Tank Division of the General Motors Corporation. The turret was manufactured by the General Steel Castings Company and the gun shield and hull front-end casting were manufactured by the Continental Foundry and Machine Company.
CONCLUSIONS: The frontal areas of the tank did not afford a constant level of protection against armor-piercing projectiles, and they were vulnerable to German 88mm projectiles having a muzzle velocity of 3280 fps at all ranges up to 2000 yards. The protection afforded by the major areas of the walls of the turret to oblique attack was less than that afforded by the major areas of the front and sides of the hull. The ballistic properties of all front-end castings were inferior to rolled armor of the same thickness. It was recommended that the thickness of the turret walls and gun shield be increased, the shape of the gun shield be changed, the hull front end casting be modified to provide uniform protection, and a rolled armor front section be developed for the tank.
GENERAL: This 55-page report contains four pages of photographs. Firing Records Ar-14943, Ar-14971, and Ar-15786 are included in this report.

SUBJECT: Armor APG AD-972
TITLE: The Use of HCR-2 as a Means of Defeating the German Panzerfaust
IDENTIFICATION: Report No. AD-972
DATE OF REPORT: 27 April 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ability of 2 and 2-1/2-inch rolled homogeneous armor spaced 4 inches from a 6-inch panel of HCR-2 to defeat the German Faustpatrone 2
METHOD: Four rounds of the German Faustpatrone 2 (Panzerfaust) were statically detonated on the target. Results of the detonation were observed and recorded.
DESCRIPTION: Two targets were used in the test. One target consisted of a 2-inch, the other of a 2-1/2-inch rolled homogeneous armor plate, 36 x 36 inches. Six inch panels of HCR-2 (a ground silicate rock with mastic binder) spaced four inches below the armor plate and backed up by four 1-inch sections of rolled homogeneous armor for determining residual penetration, made up the complete target.
CONCLUSIONS: The combinations of armor and HCR-2 tested did not provide sufficient additional protection for the Medium Tank M4 series to defeat

the Faustpatrone 2. Residual penetrations of 2-3/4 and 2-1/2 inches occurred with the 2-inch armor, and residual penetrations of 3/4 and 2-1/2-inches occurred with the 2-1/2-inch armor.
GENERAL: This eight-page report includes a sketch of the test setup.

SUBJECT: Armor APG AD-982
TITLE: Ballistic Test of the Engine Compartment of Medium Tank T23
IDENTIFICATION: Report No. AD-982; Project No. 4377
DATE OF REPORT: 31 May 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether the engine air inlet and outlet grilles of a medium tank would provide suitable ballistic protection to vehicle engine compartment components
METHOD: Ballistic tests were conducted on the engine air inlet and outlet grilles of a medium tank with cal. .30 ball and AP M2, cal .50 ball and AP M2, and 20mm AP and HE projectiles. Methods of improving the ballistic protection of engine compartment components against small arms fire were developed as testing progressed.
DESCRIPTION: The test Medium Tank T23, Serial No. 8, was manufactured by the Chrysler Motor Corporation.
CONCLUSIONS: It was found that small arms projectiles fired from both aircraft and ground weapons against the engine air inlet and outlet grilles could immobilize the vehicle. The engine compartment components most apt to be damaged by small arms fire were the carburetors, fuel line, ignition and braking resistor cables, and engine coolant radiators. Modifications made to the vehicle during the course of testing greatly increased the protection provided to the engine compartment components against small arms fire. It was recommended that the modifications developed in protecting the vehicle engine compartment components be used as a temporary expedient on all Medium Tanks T23 which were to be used in combat, and that all future production Medium Tanks T23 be equipped with improved engine air inlet and outlet grilles which would provide complete ballistic protection from small arms fire.
GENERAL: This 57-page report contains 12 pages of photographs showing the engine compartment grilles and components. Firing Records Ar-15125, Ar-15251, and Ar-15389 are also included in the report.

SUBJECT: Armor APG AD-986
TITLE: Fifth Report on the Ballistic Test of the Light Tank M24
IDENTIFICATION: Report No. AD-986; Project No. 4628 and 4959
DATE OF REPORT: 6 July 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic performance of a tank commander's cupola assembly
METHOD: The cupola was examined radiographically to determine its soundness and then mounted so that it could be positioned to simulate attack from various elevations and azimuths. Heavy kraft paper was placed behind all areas of expected projectile impact. The assembly was tested for resistance to penetration and bullet splash with cal. .30 AP M2 and cal. .50 AP M2 Projectiles, perforations of the kraft paper being termed complete penetrations. Bundles of Mk III A1 Offensive Grenades, supported 18 and 36 inches from the cupola, were statically detonated to simulate air bursts of artillery ammunition or grenades. The cupola mounting bolts were tested by single Mark III A1 Grenades. The vision blocks were tested with cal. .30 and .50 projectiles at various obliquities and with one Mark III A1 Grenade placed centrally against the outer surface of the rear vision block.
DESCRIPTION: The test material consisted of the tank commander's vision cupola assembly, D90095, for an M24 Light Tank; the cupola vision block, B-285252, with locking wedge and screws; and cupola mounting bolts, Part Nos. 223735 and B-7050801. The cupola assembly was submitted by the Continental Foundry and Castings Company and the vision blocks were submitted by the Libbey-Owens-Ford Glass Company.
CONCLUSIONS: The protection provided by the vision blocks against horizontal small arms attack was approximately equal to that provided by the hull and turret. The protection provided by the vertical side wall of the cupola, periscope trunnion boss of the cupola door race plate, and rounded edges of the door race plate, ball race, door seal joint, periscope recess filler block, and periscope rotor was less under some attack conditions than the protection provided by the hull and turret. The seal joint between the cupola door and body, the seal joint under the cupola door hinges, and the clearance between the periscope holder and door race plate were vulnerable to bullet splash. The cupola afforded complete protection against air bursts of high explosive charges. Grenade explosions caused failure of the cupola mounting bolts, distortion of the turret roof, and displacement of the vision block. Design modifications were suggested for components that had failed and it was recommended that an armor hood be provided over the periscope opening.
GENERAL: This 105-page report contains 25 pages of photographs showing the T24 Light Tank and the test material before and after the tests. Firing Records Ar-14726, Ar-14750, Ar-14929, Ar-14957, and Ar-15509 are included as an appendix to the report.

SUBJECT: Armor APG AD-989
TITLE: Fourth Report on Ballistic Test of Light Tank M24
IDENTIFICATION: Report No. AD-989; Project No. 4290
DATE OF REPORT: 9 June 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability characteristics of a Light Tank M24
METHOD: A Light Tank T24 was subjected to impacts from 37mm APC M51 and 57mm APC M86 Projectiles. Both external and internal damage to

the test tank were observed and evaluated.
DESCRIPTION: The test vehicle was a Light Tank T24, manufactured by Cadillac Motor Car Division of General Motors Corp. In general, the front and side armor was 1-inch rolled homogeneous plate; the rear side and rear armor, 3/4-inch rolled homogeneous plate; and the roof armor, 1/2-inch rolled homogeneous plate. The turret sides were of 1-inch rolled homogeneous plate.
CONCLUSIONS: Mounting blocks welded directly to armor might be displaced together with attached bolts by 57mm APC M86 Projectiles and be a crew hazard. Rigid mounts used to support delicate mechanical components were unsatisfactory in preventing damage resulting from bulges caused by 57mm APC M86 Projectiles. Mechanical components essential to turret traverse and gun elevation were not affected by shock impacts on the turret sides or gun shield from the 57mm projectiles. Space between the hull sides and gas tanks was adequate to prevent bursting of tanks by 57mm projectile impact bulges. The hull roof could not be damaged by 57mm APC M86 Projectiles which ricocheted from the lower portion of the gun shield. It was recommended that ammunition stowage items, and delicate and mechanical assemblies essential to the operation of the test vehicle be attached with flexible shock mounts spaced beyond the bulge limit of the armor.
GENERAL: This 131-page report includes 33 photographs of the tank and components before and after testing. Several sketches of components and complete data on damage are also included in the accompanying Reports, Ar-14741, Ar-15124, Ar-15629, Ar-15639, and Ar-16233.

SUBJECT: Armor APG AD-991
TITLE: Ballistic Test of Turret D-7054408, Serial #B-34, for the Heavy Tank, T26E1
IDENTIFICATION: Report No. AD-991; Project No. 5275
DATE OF REPORT: 31 May 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether a test turret met the requirements of Specifications AXS-1013 and AXS-492-4
METHOD: The turret was tested in accordance with Specifications AXS-1013 and AXS-492-4. The tests included radiographic examination, resistance to oblique attack with 90mm APC M82 Projectiles at 45° obliquity, and resistance to penetration with 75mm AP M72, and 90mm AP M77 Projectiles at 0° obliquity.
DESCRIPTION: The test turret, designed for the Heavy Tank T26, was manufactured by American Steel Foundry. It was made of cast homogeneous armor.
CONCLUSIONS: The test turret failed to meet the ballistic requirements of Specifications AXS-1013 and AXS-492-4. The poor quality of the casting resulted in relatively low ballistic limits on all sections of the turret.
GENERAL: This 33-page report includes four photographs showing the turret after tests and the following incorporated Reports: Ar-15895, Ar-15910, Ar-15960, and Ar-16105.

SUBJECT: Armor APG AD-994
TITLE: Ninth Report on the Ballistic Test of the Light Tank, M24 (Air-to-Ground Vulnerability Test)
IDENTIFICATION: Report No. AD-994; Project No. 5142
DATE OF REPORT: 9 July 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To investigate the vulnerability of the Light Tank M24 to aircraft attack
METHOD: Two light tanks, stripped of outside components except turrets, were placed, stationary, in open, flat terrain. Strafing attacks were conducted against the vehicles by a P-47 aircraft using cal. .50 AP1 Ammunition. The airplane used four different angles of attack: at the front, perpendicular to transverse axis of the tank; at the side, perpendicular to the longitudinal axis of the tank; at the side and rear, approximately 45° to the longitudinal axis of the tank; and at the rear, perpendicular to the transverse axis of the tank. A total of 3750 rounds of cal. .50 ammunition were fired. Additional tests were conducted with 20mm AP M95, 20mm HEI MKI, and 37mm HE M54 Ammunition.
DESCRIPTION: The two test Light Tanks T24 were standard production vehicles.
CONCLUSIONS: The Light Tank M24 could be immobilized and crew become casualties when attacked by aircraft firing small arms ammunition. A total of 467 hits were obtained by the airplane. In every case, the areas or components proved to be deficient by actual aircraft strafing had been shown deficient in simulated aircraft attack tests. Deficiencies were listed and methods for correction to improve protection were made.
GENERAL: This 61-page report includes 12 photographs of various sections of the tanks after strafing tests; a sketch of recommended changes for the tank rear; and a sketch of the method used to determine the dive angle. The following reports are appended: Ar-15240, Ar-15762, Ar-15919, Ar-16074, and Ar-16092.

SUBJECT: Armor APG AD-996
TITLE: Seventh Report on Ballistic Test of Light Tank M24
IDENTIFICATION: Report No. AD-996; Project No. 4290
DATE OF REPORT: 21 June 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of the Light Tank M24 armor
METHOD: Ballistic tests were conducted on the Light Tank M24 hull, turret and gun shield. The firing was with 57mm APC M86, 37mm APC M51, 20mm AP M75 and cal. .50 AP M2 Projectiles at various obliquities. Assessment was made of the ability of the armor to provide a constant level of protection on all frontal areas of the vehicle against frontal and oblique attack with 20mm AP projectiles.
DESCRIPTION: The test vehicle was a Light Tank M24 and the targets included the top, side, rear, and front armor plates; final drive projections, turret gun shield, and front casting of this

vehicle.
CONCLUSIONS: The frontal areas of the vehicle afforded complete protection against frontal attack with the cal. .50 projectile. The frontal areas did not afford a constant level of protection against the 20mm projectiles and the frontal sidewall areas of the turret gave less protection from this projectile against oblique attack than did hull front and sides. It was recommended that the thickness of the weaker sections of the turret extension exposed to frontal attack be increased. It was also recommended that the periscope assembly unit be redesigned and that the grille near the sides be reinforced.
GENERAL: This 52-page report includes one photograph of the tank turret and one page of drawings of the tank. Firing Report Nos. Ar-16083 and Ar-16233 and extracts from Firing Report Nos. Ar-15124 and Ar-15639 are contained in this report.

SUBJECT: Armor APG AD-997
TITLE: Sixth Report on the Ballistic Test of Light Tank M24
IDENTIFICATION: Report No. AD-997; Project No. 4290
DATE OF REPORT: 7 July 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of modified tank components
METHOD: Ballistic tests of two types of reinforcing strips, a modified driver's door hinge, and a hull roof were conducted using various combinations of cal. .30 AP M2, cal. .50 Ball M2, and cal. .50 AP M2 Projectiles. Most of the firing was conducted at a 25-yard range.
DESCRIPTION: Formed and vertical reinforcing strips had been welded around the edges of the doors of a Light Tank M24 to prevent projectile splash. The driver's door hinge of the vehicle had been modified to allow more clearance and prevent keying or binding resulting from projectile impact. The base ring and roof plate of the vehicle had been modified to give greater ballistic resistance of the hull roof at this junction.
CONCLUSIONS: The door equipped with the vertical reinforcing strip gave adequate splash protection against cal. .50 AP M2 Projectiles. The vertical strip provided better protection than the formed strip. Both types of strip, however, allowed cal. .30 Ball M2 splash to enter the driver's compartment. The modified hinge prevented binding by cal. .30 or .50 AP M2 Projectiles. Impact from cal. .50 AP M2 Projectiles on the hull roof at the junction of the roof and the modified base ring of the hinge did not result in complete penetration.
GENERAL: This 32-page report includes eight photographs of the test components and Firing Record Nos. Ar-16235 and Ar-16254.

SUBJECT: Armor APG AD-998
TITLE: Resistance to Penetration Test of Cast Homogeneous Armor with British 6 Pdr. and 17 Pdr. Sabot Type Projectiles
IDENTIFICATION: Report No. AD-998; Project No. 5887
DATE OF REPORT: 11 June 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the obliquity and cast armor thickness required to defeat British ammunition
METHOD: Ballistic tests of the armor were conducted with 50 rounds each of British 6-pounder and 17-pounder sabot type projectiles at a range of 50 yards. The approximate striking velocities were 3900 fps with the 6-pounder and 4000 fps with the 17-pounder. The obliquities required to defeat the projectiles were determined for the various thicknesses of the armor. The test results were judged on the basis of the protection ballistic limit.
DESCRIPTION: The cast homogeneous armor tested included 4, 6, 8, and 10-inch plates manufactured by the General Steel Castings Company and 3-inch plates manufactured by the Scullin Steel Foundry.
CONCLUSIONS: The minimum obliquities required for 3, 4, 6, and 8-inch armor to defeat the 6-pounder projectile were 56°, 39°, 32°, and 0°, respectively. The minimum obliquities required for 3, 4, 6, 8, and 10-inch armor to defeat the 17-pounder projectile were 62°, 54°, 46°, 43°, and 35° obliquities, respectively.
GENERAL: This 34-page report includes two photographs of the test projectiles and complete ballistic data. This report contains Firing Record Nos. Ar-16253 and Ar-16294.

SUBJECT: Armor APG AD-999
TITLE: Report of the Ballistic Test of an 8-inch Cast Homogeneous Armor Plate
IDENTIFICATION: Report No. AD-999; Project No. 3819
DATE OF REPORT: 23 June 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic performance of 8 and 10-inch armor against US AP projectiles and German projectiles
METHOD: Ballistic testing of the 8-inch plate for resistance to penetration was conducted with 155mm AP M112 B2 Projectiles at normal obliquities. The 8 and 10-inch plates were tested to determine the obliquity at which each could defeat the 8.8-cm and 7.5-cm German projectiles. The 10-inch plate was tested at 0° obliquity and the 8-inch plate at 20° obliquity with the 90mm APC M82, AP M77, and AP T33 Projectiles.
DESCRIPTION: The cast homogeneous armor included 10-inch plates with a hardness of 197 BHN and 8-inch plates with a hardness of 206 BHN. The test plates were manufactured by the General Steel Castings Corp.
CONCLUSIONS: The performance of the German 7.5-cm and 8.8-cm AP HE against the 8 and 10-inch plates was superior to that of the US 90mm AP T33, AP M77, and APC M82 Projectiles. The latter projectiles shattered or bulged and broke on impact. The obliquities required for the 8 and 10-inch plates to defeat the 8.8-cm German Projectile were 40° and 0°, respectively. The 8-inch plate required a 20° obliquity to defeat the 7.5-cm

German projectile.
GENERAL: This 56-page report includes 12 photographs of the armor plates after ballistic test and complete firing data. Included with this report are Firing Record Nos. Ar-15254, Ar-15370, and Ar-15904.

SUBJECT: Armor APG AD-1001
TITLE: Eighth Report on Ballistic Test of Light Tank M24
IDENTIFICATION: Report No. AD-1001; Project No. 4290
DATE OF REPORT: 1 August 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the structural integrity of M24 Tank hull and turret welds
METHOD: X-ray examination of the tank welds was conducted. The hull plates and turret sidewalls of the tank were tested for ballistic shock with small arms projectiles, 20mm to 105mm projectiles, MK III A1 hand grenades and Type 3 tellermines. Assessments of damage were made after each of the tests.
DESCRIPTION: The test vehicle was a Light Tank M24. The principal targets for ballistic attack were the front, side, and upper hull plates and the upper and lower turret sidewalls. The test tank hull was submitted by the Cadillac Motor Car Division and the test turret by the Ternstedt Manufacturing Division.
CONCLUSIONS: The principal welded joints of the test vehicle were not seriously affected by the ballistic shock tests of the hull and turret armor. All but approximately 5% of the hull and turret welding was acceptable under the applicable radiographic standards.
GENERAL: This 73-page report includes one drawing of the test vehicle and five pages of photographs of the tank armor. Firing Record No. Ar-14977 is included in this report.

SUBJECT: Armor APG AD-1022
TITLE: The Use of HCR-2 to Protect the Belly of the M4 Tank Against Mine Blast
IDENTIFICATION: Report No. AD-1022; Project No. 5557
DATE OF REPORT: 27 July 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the protection offered by HCR-2 to an M4 Tank belly; to determine the energy developed by the T6E1 Mine
METHOD: Steel plates, used to simulate a tank hull, were reinforced with samples of the HCR-2 and tested with T6E1 Mines. Parts of a M4A2 Tank belly were protected with HCR-2 combined with steel armor and tested with T6E1 Mines. Two T6E1 Mines were detonated beneath a 2000-pound armor plate and the time and height of flight of the plate were estimated.
DESCRIPTION: The HCR-2 material consisted of a mastic binder and silicate rock enclosed in thin sheet steel. One-inch steel armor was used as a face plate to protect the 4-inch panel of HCR-2 in the initial tests. One-half and one-inch armor plates were used with 4-inch thicknesses of HCR-2 for tank protection.
CONCLUSIONS: Accurate evaluation of damage to the HCR-2 panel was not possible in the initial test as two large plates dropped on the panel as a result of the blast. Perforation and distortion of tank belly were prevented in areas protected by four inches of HCR-2 and a 1-inch rolled homogeneous armor plate. The estimated time of flight of the 2000-pound plate was 11 seconds when two of the T6E1 Mines were detonated beneath it. The plate rose 40 feet vertically in the first one-quarter second after detonation of the mines.
GENERAL: This 23-page report includes seven pages of photographs showing the test materials and damage results. This report incorporates Firing Record Nos. Ar-15657, Ar-16094 and Ar-16295.

SUBJECT: Armor APG AD-1024
TITLE: Fourth Report on the Ballistic Test of the Heavy Tank T26E1
IDENTIFICATION: Report No. AD-1024; Project No. 4099
DATE OF REPORT: 8 October 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether certain test components would increase the T26E1 Heavy Tank's resistance to ballistic attack
METHOD: The gun mount trunnions and elevating mechanism bolts were tested with 90mm APC Projectile M82 impacts on the gun shield. To assure only partial penetrations at striking velocities up to 2800 fps, 4-inch homogeneous armor pads were welded to the gun shield. Turret and traversing mechanism bolts were tested with 90mm projectile impacts on the turret at a 45° obliquity. The anti-keying rings and splash traps for the commander's cupola hinges were tested with cal. .30 ball bullets.
DESCRIPTION: The test material for Heavy Tank T26E1 consisted of the following: two sets of gun mount trunnions having a single diameter and separate spacer rings of different lengths; 1/2-inch NF heat-treated standard or stress-resisting elevating mechanism bolts; 5/8-inch standard or heat-treated or stress-resisting turret hold-down bolts; 1/2-inch stress-resisting, rubber-bushed, turret hold-down bolts; a modified traversing mechanism wherein the base ring was cut away to allow mounting the mechanism directly to the turret race; 1/2-inch Micarta, cast iron, and SAE 1065 steel anti-keying rings and splash traps for the commander's cupola.
CONCLUSIONS: The test trunnion pins, bolts used for joining the elevating mechanism to the gun mount, 1/2-inch stress-resisting rubber-bushed turret hold-down bolts, traversing mechanism mounting, Micarta anti-keying rings, and cupola splash trap were satisfactorily recommended for use. Further tests were recommended for the 5/8-inch turret hold-down bolts.
GENERAL: This 56-page report includes nine photographs of test components. Also included are Firing Record Nos. Ar-14712, Ar-14807, Ar-15401, Ar-15386, Ar-15893, Ar-15917, Ar-16085, and Ar-16635, the pertinent data therefrom being incorporated in this brief.

SUBJECT: Armor APG AD-1028
TITLE: Ballistic Test of Heavy Tank M6A2E1 Cast Turret and Gun Shield
IDENTIFICATION: Report No. AD-1028; Project No. 5068
DATE OF REPORT: 10 October 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To investigate the ballistic protection characteristics of a Heavy Tank M6A2E1 cast turret and gun shield
METHOD: The test turret and gun shield were subjected to splash and keying tests with small arms projectiles and to impacts with various types of 90mm, 105mm, and 155mm projectiles. Samples from the gun shield and turret together with samples from the original and tubular trunnions, were sent to Watertown Arsenal for metallurgical examination.
DESCRIPTION: The test gun shield and turret, designed for Heavy Tank M6A2E1, were manufactured by the Continental Foundry and Machine Co. The gun shield was mounted to the turret with solid cylindrical trunnions machined from 4340 steel and having a spacing flange machined on each trunnion. A new type tubular trunnion, having spacer rings instead of the spacing flange, and standard and necked-down front plate bolts were also tested.
CONCLUSIONS: The clearances around the gun shield afforded little or no protection against splash from small arms projectiles on frontal or flank attack. The tubular trunnions were superior to the solid cylindrical trunnions for resistance-to-shock resulting from projectile impacts on the gun shield. The necked-down front plate bolts were superior to the standard bolts for resistance to shock.
GENERAL: This 59-page report includes 13 photographs showing the turret and components after tests. Reports Ar-15090, Ar-16240, and Ar-16603 are included as an appendix to this report.

SUBJECT: Armor APG AD-1033
TITLE: The Comparison of the Ballistic Performance of Light Chilled and Standard Class A, and High Hardness and Standard Class B Armor of 4" and 5" Thicknesses
IDENTIFICATION: Report No. AD-1033; Project No. 5905
DATE OF REPORT: 20 December 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the ballistic performance of 4-inch, high hardness homogeneous armor and Standard Class B armor, 4-inch chill face-hardened armor and Standard Class A armor, 4-inch homogeneous and face-hardened armor, and 5-inch high hardness homogeneous armor and Standard Class B armor
METHOD: The 4-inch homogeneous and face-hardened plates were subjected to ballistic tests with the following projectiles: 155mm AP M112 at 30°, 90mm APC M82 at 30°, and 90mm AP T33 at 0° and 55°. The 5-inch homogeneous armor was tested with the following projectiles: 155mm AP M112 at 30° and 45°, 90mm APC M82 at 30°, and 90mm AP T33 at 0° and 20°.
DESCRIPTION: The 4 and 5-inch homogeneous test plates were heat-treated to give higher than normal hardnesses. Standard Class B armor was procured at approximately 200 BHN; the higher hardness plates were approximately 300 BHN. The special 4-inch face-hardened plates had a lighter chill face than the Standard Class A
CONCLUSIONS: The 4-inch, high hardness armor, submitted by Carnegie and Bethlehem, was superior to the Standard Class B armor. The 4-inch face-hardened armor with chill face, submitted by Carnegie, was superior to the Standard Class A. Based on overall ballistic performance, no difference was apparent between the 4-inch face-hardened and 4-inch homogeneous armor. The 5-inch Class B armor was equivalent to, or better than, any of the high hardness armor submitted.
GENERAL: This 72-page report includes eight photographs of the plates after test. Also incorporated are Reports Ar-16261, Ar-16279, and Ar-16569.

SUBJECT: Armor APG AD-1037
TITLE: The Use of Steel Spikes to Defeat Lined, Shaped Charge Ammunition
IDENTIFICATION: Report No. AD-1037; Project No. 3520
DATE OF REPORT: 30 October 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ability of steel spikes to defeat lined, shaped-charge ammunition
METHOD: Test spike panels were held with clips to a 3/4-inch plate and a series of 1-inch plates were placed behind the mounting plate for measuring residual penetration. German Panzerfaust 60M and 100M, German Rocket 8.8 CM HEAT, U.S. Rocket 2.36-inch HEAT M6A3, and U.S. Shell 105mm HEAT M67 were fired at the test panels from a range of approximately 90 feet. The majority of rounds were fired at normal incidence to the target; some were fired at 15° deflection.
DESCRIPTION: Test panels were prepared by first machining the spikes to a 1-inch diameter, tapering to a point at one end, and then heat treating. The spikes were then set in holes in the armor plate and welded in place. Twenty panels with combinations of spikes 5, 6, and 7 inches long on 1-3/4, 2-1/2, and 3-1/2-inch centers were tested.
CONCLUSIONS: The use of steel spikes reduced or effectively prevented penetration by shaped-charge ammunition. It was recommended that further firing tests should be conducted to investigate the optimum spike diameter, length, and spacing.
GENERAL: This 40-page report includes two sketches of the spike plates and 10 photographs of the plates after tests and one photograph of the test setup.

SUBJECT: Armor APG AD-1040
TITLE: Resistance to Perforation Test of Various Thicknesses of Rolled Homogeneous Steel Armor Against Fragments of Shell, HE, 155-MM HOW., M107
IDENTIFICATION: Report No. AD-1040; Project No. 6371
DATE OF REPORT: 4 January 1946

ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the protection to personnel of 3/8, 1/2, and 3/4-inch rolled homogeneous armor plates against side spray fragments of 155mm HE Howitzer Shells M107
METHOD: One set of each size plates were mounted in an arc with a radius of 25 feet from the projectile detonating point, and an identical group positioned with a 50-foot radius. The center lines of both arcs were located 100° from the nose, with respect to the longitudinal axis, of the statically-fired projectiles.
DESCRIPTION: The 3/8, 1/2, and 3/4-inch rolled homogeneous armor plates were tested with 155mm HE M107 TNT Shells equipped with Boosters M21A4.
CONCLUSIONS: On the plates 25 feet from the detonating point, the total number of impacts ranged from 41 for the 3/8-inch to 68 for the 3/4-inch; the average number of perforations per square yard ranged from 2.2 for the 3/8-inch to 0.2 for the 3/4-inch. On the plates 50 feet from the detonating point, the total number of impacts ranged from 24 for the 3/8-inch to 20 for the 3/4-inch; the average number of perforations per square yard ranged from 0.5 for the 3/8-inch to 0.0 for the 3/4-inch. No qualitative conclusions were presented in the report. It was recommended that development tests be started to establish a method for comparing various light armor plates in regard to their resistance to perforation against shell fragments by means of a "behind the plate" evaluation similar to the test technique prescribed in Specification AXS-1346, Rev. 1, dated 18 April 1945.
GENERAL: This 47-page report contains 15 pages of photographs showing the test setup and plates. Also included are Firing Records Ar-16779, Ar-16787, and Ar-16802, the pertinent data therefrom being incorporated in this brief.

SUBJECT: Armor APG AD-1044
TITLE: Ballistic Test of Hull Front Castings for Heavy Tank T28
IDENTIFICATION: Report No. AD-1044; Project No. 6066
DATE OF REPORT: 4 January 1946
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic suitability of 8-inch and 12-1/2-inch front hull castings for the T28 Heavy Tank
METHOD: The castings were placed in their normal running position and subjected to frontal and 35° flanking attack with German 88mm and U.S. 90mm projectiles. The same type of projectiles were also used to determine the ballistic limit protection of the castings in areas of different thickness and obliquity. The castings were further tested with 16 and 40-pound demolition charges and with 155mm projectiles. The ballistic standard used for the test was protection offered by the vertical area around the gun part of the tank front hull casting.
DESCRIPTION: The two front hull castings for the T28 Heavy Tank were submitted by the General Steel Castings Corporation of Eddystone, Pennsylvania.
CONCLUSIONS: The test castings were considered to offer adequate protection against frontal and 35° flanking attack exc... in the area of the driver's hood bulge. It was recommended that the frontal and side armor of the driver's hood bulges on both size castings be increased in thickness to give protection equivalent to that afforded by the vertical area around the gun port.
GENERAL: This 52-page report contains seven pages of photographs showing the condition of the casting after tests. Firing Records Ar-16576, Ar-16579, Ar-16590, Ar-16593, Ar-16162, and Ar-16304 are included in this report.

SUBJECT: Armor APG AD-1046
TITLE: Ballistic Test of Heavy Tank M26 Turret Assembly
IDENTIFICATION: Report No. AD-1046; Project No. 4099
DATE OF REPORT: 4 January 1946
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the performance of various M26 Heavy Tank components under resistance-to-shock tests
METHOD: The ammunition ready racks on an M26 Heavy Tank were stowed with 10 rounds of 90mm ammunition, loaded to a service weight of 42 pounds, and tested with adjacent 45° oblique impacts from 90mm APC M82 Projectiles on the side of the turret approximately 12 inches above the base ring. The pistol port lock was tested by 45° oblique attack on the left wall of the turret with 90mm projectiles. The bolts joining the gun mount to the gun shield were tested by frontal attack on the gun shield with 90mm projectiles. The mountings of the electrical control box and flashlight were tested by 45° oblique attack on the right wall of the turret with 90mm projectiles.
DESCRIPTION: The test items consisted of the 90mm ammunition ready racks, pistol port, gun loader's periscope mounting, and modified gun shield mounting of an M26 Heavy Tank.
CONCLUSIONS: The 90mm ammunition rack assembly retained the stowed ammunition, but the clamp assembly, hinge pin, and upper mounting plate of the rack assembly were displaced or damaged. The pistol port lock was opened and the lock bar bent by partial penetration impacts adjacent to the pistol port bracket. The pistol port lock bracket was displaced by impacts directly opposite the bracket. Impacts on the gun shield loosened some of the 7/8-inch bolts joining the gun cradle to the gun shield. It was recommended that the diameter of the retaining pins of the ammunition rack clamp assembly be increased, that the upper and side mounting plates of the ammunition rack be formed from one piece of metal, that the ammunition rack hinge pins be more securely welded to the rack, that a resilent material such as rubber be used for the fulcrum of the pistol port lock, that the pistol port latch bracket be more securely welded, and that the gun loader's periscope housing and trunnion be redesigned to give a greater shock resistance.
GENERAL: This 23-page report contains five

pages of photographs and includes Firing Records Ar-16400 and Ar-16789 as an appendix to the report.

SUBJECT: Armor APG AD-1047
TITLE: Report on the Installation, Operation, and Ballistic Test of Plastic Armor (HCR-2) on Medium Tank M4A3E8
IDENTIFICATION: Report No. AD-1047; Project No. 3520
DATE OF REPORT: 5 January 1946
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of HCR-2 Plastic material for mounting on medium tanks
METHOD: An installation kit of the test material was installed on an M34A1 Medium Tank and a check was made on the installation time of the material and on the increase in weight of the tank. The vehicle was operated for 100 miles cross-country to determine the adequacy of the installation fixtures. Ballistic tests of the fixtures used to hold the panels to the tank were conducted using 75mm HE M48 Projectiles. Additional ballistic tests of the HCR-2 material included impacting of the turret and sponson with German Panzerfaust 100 Projectiles, German 8.8-cm rockets, and U.S. 76mm HVAP M93 Projectiles.
DESCRIPTION: The HCR-2 material consisted of silicate rock in a mastic binder. The test kit of this material consisted of panels with two 1-inch aluminum plates installed in the panel face with 10 inches of HCR-2 in back of the plates. The panels were held to the vehicle with 1/2-inch steel cables fastened to brackets welded to the vehicle.
CONCLUSIONS: Installation of the HCR-2 kit required 192 man hours and the material increased the vehicle weight by about 16,000 pounds. The road test did not cause failure or loosening of the attaching cables. The cables were vulnerable to fragments from HE projectiles to the extent that one round could displace an entire panel. The sponson assembly did not protect the sponson area against the German ammunition, but the turret assembly was sufficient to defeat both of the German projectiles.
GENERAL: This 31-page report includes five drawings of the installations and 12 photographs of the test vehicle and installation.

SUBJECT: Armor APG AD-1122
TITLE: Vulnerability Analysis of the Light Tank T37
IDENTIFICATION: Report No. AD-1122; First Report on Project No. TT2-624
DATE OF REPORT: 1 February 1950
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To analyze the ballistic vulnerability of the T37 Light Tank
METHOD: The vulnerability analysis was divided into seven parts under the headings of bullet splash, armor protection against various attacking projectiles, blast and fragmentation, shock, air attack, basic design considerations, and component design analysis. In analyzing the vulnerability of tank components, armor thicknesses and obliquities were determined both by physical measurement with calipers, micrometers, and gunner's quadrant, and by reference to engineering drawings.
DESCRIPTION: The T37 Light Tank mounted a 76mm T94 Gun, two .30 cal. two .50 cal machine guns, and a range finder. It was manufactured by the Detroit Arsenal, Center Line, Michigan.
CONCLUSIONS: The tank was considered vulnerable to bullet splash around the vision periscopes, through the clearance between gun tube and shield, and at the side of the gun shield between the shield and trunnion mounting casting. Some parts of the frontal area of the tank were considered vulnerable to penetration by 37mm APC M51 Projectile impacts from 700 yards range at any angle of fire, and all areas on the front were considered vulnerable to 57mm APC M86 Projectile attack from direct front at a range of 1050 yards. It was thought that the rear hull side plates were vulnerable to .50 cal. AP M2 Bullets at ranges less than 500 yards, and that the floor plate was improperly designed for maximum effectiveness against land mines. It was recommended that modifications be made on splash trap protection, floor plates, escape hatch, vision blocks and periscopes, hand traversing mechanism, cable mounting, turret and bustle design, welding design, trunnion bearings, fuel tank location, storage battery protection, tank commander's cupola, ammunition stowage location, and ammunition containers.
GENERAL: This 55-page report contains 12 pages of photographs and several pages of design sketches and graphs.

SUBJECT: Armor APG AD-1131
TITLE: Ballistic Test to Determine the Protection Afforded by Cast Hulls for the Medium Tank T42 when Subjected to Attack with 90-mm AP and HVAP Projectiles
IDENTIFICATION: Report No. AD-1131; First Report on Project No. TT2-672
DATE OF REPORT: 13 March 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of cast hulls for Medium Tank T42 to 90mm AP and HVAP projectiles
METHOD: Preliminary ballistics tests were conducted on armor plates having thicknesses comparable to that of the test hulls in order to determine the approximate projectile velocities to be used against the hulls. The hulls were examined radiographically and measured for thickness by means of calipers and supersonic reflectoscope. Both hulls were tested for resistance to penetration by attack with 90mm AP T33 and 90mm HVAP projectiles against the frontal areas and against the sides from 20° and 30° with respect to the longitudinal axis of the hull. The protection ballistic limit criterion was used as a basis for all testing.
DESCRIPTION: The test items consisted of two Medium Tank T42 cast hulls submitted by the General Steel Castings Corporation of Eddystone, Pennsylvania.
CONCLUSIONS: The protection afforded by the various armor areas of the T42 Cast Hull against

90mm AP T33 and 90mm HVAP M304 Projectiles was considered typical for armor of the thicknesses and obliquities concerned. It was recommended that either the thickness or obliquity, or both, of the lower front area of the T42 hull be increased, if possible, to provide better protection.
GENERAL: This 59-page report includes 14 photographs showing the test armor before and after firing.

SUBJECT: Armor APG AD-1136
TITLE: Ballistic Test to Determine the Protection Afforded by Turret Body Castings for the Medium Tank T42 when Subjected to Attack with 90-mm AP, 90-mm HVAP, 76-mm AP, and 57-mm AP Projectiles
IDENTIFICATION: Report No. AD-1136; Second Report on Project No. TT2-672
DATE OF REPORT: 23 April 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of Medium Tank T42 turret body casting
METHOD: The turrets were radiographed by the manufacturer and were measured for thickness at the Proving Ground by means of calipers and supersonic reflectoscope. The turrets were tested with 90mm HVAP M304, 90mm AP T33, 76mm AP M79, and 57mm AP M70 Projectiles, frontally and at 30°, 60°, and 90° angles of flank attack as measured from the longitudinal axis of the turret. The protection ballistic limit was used as the criterion for testing.
DESCRIPTION: The two Medium Tank T42 test turret castings were manufactured by the Sculiin Steel Co. The castings had hardnesses values of 273 and 267 B.H.N.
CONCLUSIONS: The protection afforded by the various areas of the test castings against the armor piercing projectiles was considered typical for armor of the thicknesses and obliquities concerned. It was recommended that the turrets be considered of satisfactory ballistic quality. In view of the fact that little cracking developed as a result of 34 rounds on one turret and 43 rounds of the other turret, the turrets were considered to have good toughness characteristics.
GENERAL: This 54-page report includes 13 photographs of the test castings and complete firing data.

SUBJECT: Armor APG AD-1137
TITLE: First Report on the Investigation of the Effect of Statically Detonating Similar Plastic Explosive Charges Against 1-Inch Steel Armor of Three Toughness Groups at Various Temperatures
IDENTIFICATION: Report No. AD-1137; Project No. TAL-5002H
DATE OF REPORT: 14 May 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the correlation between the toughness of armor and its resistance to spalling
METHOD: Specimens of tough, moderately brittle, and very brittle armor plates, tested and classified in previous work on this project, were selected for resistance-to-spalling tests. These specimens were placed 3 feet above the ground with Celotex sheets beneath to catch spall. C4 plastic explosive charges were set on the middle of the armor specimens and detonated electrically by means of blasting caps in the boosters. The tough and moderately brittle specimens were tested at armor temperatures ranging from -85° F to 212° F; the very brittle specimens were tested at temperatures ranging from room temperature to 212° F. Spall fragments were counted and weighed and spall fragment velocities were obtained by taking high speed movies of fragments as they passed between two cross wires.
DESCRIPTION: The previous tests on the armor plates used to supply test specimens were covered in Watertown Arsenal Laboratory Report No. 710/904. The resistance-to-spall test specimens consisted of four samples of tough steel, five of moderately brittle steel, and two of very hard steel, each sample being 1 x 6 x 6 inches in size.
CONCLUSIONS: The test demonstrated a very close interrelationship between the mechanical and metallurgical properties of armor and its resistance to ballistic attack involving a high degree of shock. The weights and velocities of the spall fragments displaced increased as the toughness and temperature of the armor decreased. It was recommended that additional tests of this type be conducted to obtain data for an armor acceptance test.
GENERAL: This 51-page report includes seven pages of photographs of spall in flight, the test setup and materials, and complete ballistic data.

SUBJECT: Armor APG AD-1139
TITLE: Proposed Means of Defeating Shaped Charge and Plastic Explosive Shell Attack
IDENTIFICATION: Report No. AD-1139; Second Report on Project TT1-5
DATE OF REPORT: 8 August 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of an arrangement of steel armor angles for mounting on an armored vehicle in defeating HEAT and HEP rounds
METHOD: The proposed arrangement of steel armor angles was subjected to attack with 3.5-inch HEAT Rocket M28A2 and 105mm HEP Shell T81E17, fired from a Rocket Launcher M20 and a 105mm Howitzer M2A1, respectively.
DESCRIPTION: The armor angle arrangements consisted of four 3-inch rolled homogeneous basic plates, approximately 4x6 feet, with side supports welded on for attachment angles. A sufficient quantity of angles were fabricated of 3/8-inch rolled homogeneous armor to completely fit out each plate twice. The armor angles were 3 inches high and 2-1/2 inches wide at the base and were fabricated so as to have a 45° included angle. The angles were mounted to the plates by means of support bars and "U" bolts. The spacing between the angles was varied during different phases of the test by loosening the "U" bolts and retightening them at a different location.
CONCLUSIONS: The proposed angle arrangement

offered promise as means of defeating shaped charge and plastic explosive shell attack. It was recommended that further tests of the arrangement be planned with attention being given to the possibility of reducing total weight by use of aluminum components.
GENERAL: This 54-page report includes 27 photographs of the test.

SUBJECT: Armor APG AD-1141
TITLE: Ballistic Test to Determine the Protection Afforded by Cast Hulls, Serial Numbers 2 and 3, for the 120-mm Gun Tank T43
IDENTIFICATION: Report No. AD-1141; Third Report on Project TT1-5
DATE OF REPORT: 18 December 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To obtain ballistic data on the protection afforded by two 120mm Gun Tank T43 cast hulls to various projectiles
METHOD: The two best hulls were measured for thickness with calipers and a supersonic reflectoscope and were given a radiographic examination. The hulls were subjected to direct frontal attack and to various angles of flank attack with 120mm AP T116E4, 90mm AP T33, 90mm HVAP M304, 76mm AP M79, 76mm APC M62A1, 57mm AP M70, and Russian 122mm AP Projectiles
DESCRIPTION: The two cast hulls, designed for the 120mm Gun Tank T43, were manufactured by the General Steel Castings Corp.
CONCLUSIONS: The protection afforded by the test hulls against the various projectiles was considered typical for armor of the obliquities and thickness concerned. It was recommended that either the obliquity or the thickness, or both, of the lower front area of the T43 cast hull be increased, if possible, to provide a better level of protection over that part of the casting.
GENERAL: This 104-page report includes 25 photographs of the hulls before and after tests. Armor Reports Ar-17391, Ar-17456, and Ar-17596 are included as an appendix to this report.

SUBJECT: Armor APG AD-1144
TITLE: Ballistic Test to Determine the Protection Afforded by Turret Body Castings for the 90-mm Gun Tank T42 when Subjected to Attack with American 90-mm AP T33, 75-mm APC M62A1, 57-mm AP M70, and Russian 85-mm AP Projectiles
IDENTIFICATION: Report No. AD-1144; Seventh Report on Project TT2-672
DATE OF REPORT: 23 September 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To obtain ballistic data on the protection afforded against various projectiles by the turret body casting for the 90mm Gun Tank T42
METHOD: One turret was subjected to ballistic attack with 90mm AP T33 Projectiles at 0° and 30° obliquity, 76mm APC M62A1 Projectiles at 60° and 90° obliquity, and 57mm AP M70 Projectiles at 60° and 90° obliquity. Another turret was tested with Russian 85mm AP projectiles at 0° and 30° obliquity. The protection ballistic limit criterion was used as a basis for all testing. Prior to the test the turrets were given a radiographic examination and were measured for thickness with calipers and a supersonic reflectoscope.
DESCRIPTION: The two test turrets, designed for use on the 90mm Gun Tank T42, were cast by the Scullin Steel Co.
CONCLUSIONS: Ballistic limit data were presented for the two turret body castings. The protection afforded by the various armor of the T42 turret against the test projectiles was considered typical for armor of the obliquities and thicknesses concerned. It was recommended that the cast armor of the turrets tested be considered of satisfactory ballistic quality.
GENERAL: This 53-page report includes five photographs of the turrets after test and Reports Ar-17705 and Ar-17744.

SUBJECT: Armor APG AD-1159
TITLE: First Partial Report on Tank Vulnerability Program — (Spaced Armor)
IDENTIFICATION: First Report on Sub-Project No. TB3-1224B; Report No. AD-1159
DATE OF REPORT: 5 May 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of various spaced armor arrangements for protection against armor defeating projectiles
METHOD: Skirting plates of various sizes were set up with yaw cards placed at various distances behind the skirting plates. Several types of projectiles were fired at the skirting plates from various obliquities, and the path and orientation of the projectiles after passing through the skirting plates were determined by means of the yaw cards and by taking pictures of the projectiles. Several armor combinations having various size skirting plates, armor plates, spacing between plates, and obliquities were given modified V_{50} ballistic tests with several types of projectiles.
DESCRIPTION: The armor arrangements consisted of various combinations of 1/4, 1/2, 3/4, and 1-inch skirting plates and 2, 3, and 4-inch rolled homogeneous armor having a hardness in the range of 280 to 300 BHN. The following types of ammunition were used: 57mm AP, 57mm APC, 90mm AP, 90mm APC, 90mm HVAP, 90mm HEAT, 3.5-inch Rocket, and 105mm HEP round.
CONCLUSIONS: Although the skirting plates used in the spaced armor combinations did not absorb a significant amount of the kinetic energy of attacking projectiles, they did increase the resistance to penetration. Specific recommendations were given for the most suitable type of armor combinations under various conditions. It was further recommended that consideration be given to the use of spaced armor in the design of combat vehicles such as tanks and personnel carriers.
GENERAL: This 74-page report contains three pages of photographs showing the facility used for testing the spaced armor arrangements.

SUBJECT: Armor APG AD-1170
TITLE: Vulnerability Analysis of the French

100-mm Gun Tank
IDENTIFICATION: Report No. AD-1170; Project No. TT2-673
DATE OF REPORT: 16 July 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of the French 100mm gun tank by analysis
METHOD: The assessment of the 100mm gun tank on the basis of vulnerability to ballistic attack was designed to provide as much data as possible without actually conducting a destructive firing program. Criticisms and suggestions were based, wherever possible, on information obtained from previously conducted ballistic tests against American tanks. The study was somewhat limited because the gun was not removed from the turret or the turret from the hull.
DESCRIPTION: The French 100mm gun tank was an armored full tracklaying vehicle armed with a 100mm gun, two 7.5mm machine guns mounted to the machine gun support ring around the loader's hatch and one 7.5mm coaxial machine gun. The water-cooled, gasoline engine was mounted in the rear of the tank and had a 1000 hp rating. Fighting weight of the tank was approximately 58-1/2 short tons. The most distinguishing characteristic of the tank was an oscillating turret which presented many new vulnerability problems. Other interesting features from the vulnerability standpoint were the sponsons, the shell case ejection opening, the air intake and outlet openings for the engine compartment, and the incomplete penetration welded joints.
CONCLUSIONS: Many features of the 100mm gun tank could be improved which would result in an overall reduction in vulnerability. A thorough discussion of each recommended design change to improve protection was included in the report. Included in suggested modifications were improvement of armor protection, splash prevention, and modification of basic and component design. The test vehicle was not considered suitable for combat without considerable alteration.
GENERAL: This 77-page report includes 16 photographs of the tank and components.

SUBJECT: Armor APG AD-1174
TITLE: Comparison of the Protection Afforded Against Ballistic Attack by Three 90-mm Gun Tank T48 Cast Hulls, Serial Numbers 6, 121, and 4
IDENTIFICATION: Report No. AD-1174; Fourth Report on Project TT2-760
DATE OF REPORT: 8 July 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic suitability of three 90mm Gun Tank T48 cast hulls
METHOD: Thickness measurements of the T48 cast hulls were made by means of calipers and supersonic reflectoscope. The hulls were placed on a turntable and subjected to direct frontal attack and to various angles of flank attack with 57mm, 76mm, and 90mm projectiles. Ballistic limits of the hulls were determined by averaging the velocities of the highest partial and the lowest complete penetration.
DESCRIPTION: The three test 90-mm Gun Tank T48 cast hulls were identified as having Serial Numbers 6, 121, and 4. The No. 6 and the No. 121 hull were produced by the General Steel Castings Company; the No. 4 hull was produced by Birdsboro Armorcast, Inc.
CONCLUSIONS: The No. 6 hull was considered to be inadequate for protection against 30° upper front flank attacks with 90mm AP T33 Projectiles. The No. 121 and No. 4 hulls were considered typical for armor of the obliquities and thicknesses concerned and it was recommended that these hulls be considered acceptable for providing a satisfactory level of protection against ballistic attack. It was thought that the determination of ballistic limits as a method of rating the protection afforded against ballistic attack of cast tank hulls did not always afford a fair method of rating, and it was recommended that additional methods of rating be considered.
GENERAL: This 152-page report contains 36 pages of photographs showing the condition of the hulls before and after ballistic tests. Included as an appendix to this report are Reports Ar-18208, Ar-18512, and APG TT2-760/M.

SUBJECT: Armor APG AD-1178
TITLE: Investigation of Rolled Homogeneous "H" Welded Plates to Study Ballistic Performance Under Various Conditions and to Obtain Laboratory Data Related to Weld Soundness and Shock Resistance
IDENTIFICATION: Report No. AD-1178; Fifth Report on Project No. TB4-10
DATE OF REPORT: 23 September 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effects of welding procedure, cold temperature conditioning, and weld reinforcement removal on the ballistic performance of armor plate; to determine the suitability of dye penetrant for detecting armor cracks resulting from ballistic tests
METHOD: Eighteen 1-1/2-inch H-welded plates were divided into three groups, each group containing two plates welded with old-type ferritic electrodes, two with new-type ferritic electrodes, and two with austenitic electrodes. The weld reinforcements were removed from two of these groups. The group retaining the weld reinforcements and one of the groups with the weld reinforcements removed were examined radiographically and subjected to ballistic attack with 75mm plate proofing M1002 Projectiles. Four plates of the third group, together with two 1-inch H-welded plates welded with austenitic electrodes, were subjected to cold cycling treatment and given radiographic examination during each phase of the cycling. These six plates were tested with 75mm plate proofing M1002 Projectiles and, together with the two 1-1/2-inch plates not ballistically tested, were subjected to a dye penetrant test.
DESCRIPTION: The test material consisted of eighteen 1-1/2 x 36 x 36-inch and two 1 x 36 x 36-inch homogeneous H-welded plates submitted by the Detroit Arsenal.
CONCLUSIONS: The plates from which the weld reinforcements had been removed performed at least as well ballistically as those retaining their

reinforcements. Cold cycling at low temperatures had no apparent effect on the ballistic performance of the plates and did not result in weld cracks. The dye penetrant solution was effective only in making surface defects plainly visible.
GENERAL: This 193-page report contains 24 pages of photographs. Firing Records Ar-18451, Ar-18585, Ar-19030, and Ar-19079 are included as an appendix to this report.

SUBJECT: Armor APG AD-1179
TITLE: Vulnerability of Tanks: 3.5-inch HEAT, 90-mm AP, 105-mm HEP Projectiles vs HCR-2 Coating on T26 Tanks
IDENTIFICATION: Report No. AD-1179; Project No. TB3-1224B
DATE OF REPORT: 23 June 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of HCR-2 coating on T26 Tanks
METHOD: The HCR-2 test material was applied to the lower and upper front slope plates of three previously damaged T26 Tanks. Ballistic tests were conducted with 3.5-inch rockets, 90mm AP projectiles, and 105mm HEP shells.
DESCRIPTION: The HCR-2 material consisted of 86% gravel, 10.5% asphalt and 3.5% wood floor. It was applied to the tanks at 350° to 400°F and hand tamped. The material coatings were secured with bolts welded to the tank plates, washers, and heavy wire netting. One tank had a coating 14 inches thick, and two had coatings 10 inches thick. One of the tanks coated with 10 inches of material had steel tow eyes extending through the coating, and the other had an opening for the bow machine gun.
CONCLUSIONS: The application of the HCR-2 material to the heavily armored front portions of the tank hulls was not considered feasible or tactically justifiable. The material was torn off the tanks with each impact, and on one tank the material blocked the vision of the driver and machine gunner. It was recommended that no further work or funds be expended on the development of this material for use as auxiliary armor.
GENERAL: This 47-page report includes one photograph of the manufacturing unit for HCR-2. This report contains Firing Record Nos. Ar-19008, Ar-18957 and Ar-19128.

SUBJECT: Armor APG AD-1182
TITLE: Ballistic Test to Determine the Effectiveness of Steel Spikes in Defeating the Shaped Charge Attack of the Cartridge, HEAT, T184E3, with Fuze P1BD, T208E7 for 105-mm Rifle M27
IDENTIFICATION: Report No. AD-1182; Project No. TB3-1224B
DATE OF REPORT: 25 August 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of three lengths of steel spikes mounted on 2-inch armor plate in defeating the fin stabilized 105mm Projectile HEAT T184E3 with Fuze P1BD T208E7
METHOD: Two 2 x 72 x 72-inch rolled homogeneous armor plates fitted with spikes were subjected to test with 105mm projectiles. One of the plates was tested with six impacts of 0° obliquity and the other, with four impacts at 60°. Ten rounds were fired at a plate without spikes at 0° obliquity to check the uniformity of fuze functioning.
DESCRIPTION: The two 2 x 72 x 72-inch rolled homogeneous armor plates were fabricated by the Nelson Stud Welding Company. Each plate was fitted with 1-inch diameter hexagon spikes of three lengths, 7-1/2, 8, and 8-1/2 inches. Arrangement of spikes was such that no two of the same length were next to each other and so that the space between spikes was 2-1/2 inches center to center. The spikes were counterbored and threaded at their bases so that they could be screwed onto threaded studs which were welded to the basic plate. All spikes were tightened on the studs to a torque of 60 lb.-ft.
CONCLUSIONS: The test spike arrangement did not provide an effective or practical means of defeating shaped charge weapons. Use of armor fitted with spikes would add prohibitive weight, and displacing and scattering of the spikes upon impact would be hazardous to supporting infantry. It was recommended that steel spikes mounted on armor be given no further consideration.
GENERAL: This 57-page report includes 27 photographs of the spike arrangement before and after testing.

SUBJECT: Armor APG AD-1184
TITLE: Ballistic Test of Two Composite Welded Tank Hulls for the T48 Tank to Evaluate Their Resistance to Penetration and the Resistance of Their Welded Joints to Cracking as a Result of Shock
IDENTIFICATION: Report No. AD-1184; Project No. TT2-760
DATE OF REPORT: 12 March 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To investigate the ballistic equivalency of two composite, welded T48 Tank hulls to one-piece cast hulls of the same design
METHOD: Two composite, welded T48 Tank hulls were tested for resistance to penetration with 76mm APC M62A1 and 90mm AP T33 Projectiles. In addition, weld joints were shock-tested with 105mm and 75mm Proof Projectiles at normal obliquity and 90mm AP T33 and 76mm APC M62A1 kinetic energy projectiles at obliquities up to 60°.
DESCRIPTION: The two test hulls were fabricated from cast armor poured at the Detroit Arsenal Foundry and the General Steel Casting Corporation, and rolled armor shaped by the Standard Steel Spring Company. The cast parts of the hulls were similar in design to the same areas of the one-piece cast T48 hulls. The castings included the front section, top turret support ring, rear corners, and a small section in the rear of the bottom which contained the transmission drain holes. The sides, floor, and rear of the hulls were shaped plates of the minimum thickness necessary to give ballistic protection at least equal to that of cast hulls. The forward half of the sides was 2-inch shaped plate and rear half, 1-1/2-inch shaped plate. The floor was composed of two plates with the thicker one forward.

CONCLUSIONS: The T48 composite welded tank hulls were ballistically comparable to a one-piece cast hull of the same design, except at the welds joining the turret support ring casting to the rolled plates at the sides, which readily develop extensive cracking as a result of shock-producing projectile impacts. It was recommended that the weld joining the turret support ring section to the rolled side plates be relocated somewhat lower on the sides so that the weld would be on a convex surface rather than on a concave surface and thereby afford better resistance to cracking.
GENERAL: This 66-page report includes 25 photographs of the hull before and after testing.

SUBJECT: Armor APG AD-1186
TITLE: Investigation of the Vulnerability to Ballistic Attack of Oscillating Tank Turrets
IDENTIFICATION: Report No. AD-1186; Project No. TT2-586
DATE OF REPORT: 4 April 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of six oscillating turrets manufactured by Rheem
METHOD: The turrets were measured for thickness and each in turn placed on a turntable. Ballistic tests were conducted with various ammunition including: 57, 76, and 90mm shot; cal. .30 and .50 bullets; 37mm HE shells; and 105mm projectiles. Testing was at various ranges, velocities and at obliquities up to 90° and against most armor areas, clearances, and component parts. Assessment was also made of fragment damage.
DESCRIPTION: The six cast oscillating turrets for the 90mm gun were submitted by the Rheem Manufacturing Co. The entire turret or oscillating section elevated within a rotating ring which constituted the trunnion mounting assembly and was so designed that the gun was an integral part of the turret. Twenty layers of nylon cloth were used to protect the clearance between the turret oscillating section and the rotating ring.
CONCLUSIONS: The suitability of the test turrets for Ordnance use was questionable as they had both advantages and disadvantages as compared with standard American production turrets. Various areas of the turret could defeat the projectiles with greater ease than could the standard turret. However, other areas were more vulnerable to attack than the standard design turret including the armor area below the gun and clearance areas of the oscillating section. It was recommended that consideration be given to design changes where the test turret was proven vulnerable including better protection in the oscillating section below the gun, more obliquity to the bustle side. The layers of nylon cloth were effective in preventing the passage of fragments and splash through the clearance between the oscillating section and the rotating ring. It was recommended that this arrangement be given consideration for possible application at clearances on armored vehicles in general.
GENERAL: This 223-page report includes complete firing data, three drawings and 74 pages of photographs of the turrets. This report includes all pertinent information contained in the First, Second, Third, and Fourth Memorandum Reports on Project No. TT2-586. These memorandum reports are under a separate cover.

SUBJECT: Armor APG AD-1192
TITLE: Ballistic Test to Compare the Protection Afforded by Three Turret Body Castings for the 120-mm Gun Tank T43 When Subjected to Attack with the 120-mm AP T116E4, 90-mm AP T33, 90-mm HVAP M304, 76-mm APC M62A1, and 57-mm AP M70 Projectiles
IDENTIFICATION: Report No. AD-1192; Twenty-second Report on Project No. TT1-5
DATE OF REPORT: 27 May 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic suitability of turret castings of original and improved designs
METHOD: Radiographic examinations and thickness measurements were made of the test castings. Ballistic tests were conducted, including resistance-to-penetration by direct frontal attack with 120mm AP T116E4 Projectiles; 30° flank attack from the longitudinal axis with 120mm AP T116E4, 90mm AP T33, and 90mm HVAP M304 Projectiles; and 90° flank attack from the longitudinal axis with 76mm APC M62A1 and 57mm AP M70 Projectiles. The protection ballistic limit criterion was used as a basis for all testing. Two turrets of original design were tested first, and a third turret of modified design was subsequently tested.
DESCRIPTION: The two 120mm Gun Tank T43 turret castings of original design were submitted by Continental Foundry & Machine Co. The turret casting with modified design was submitted by the General Steel Castings Co. This turret provided a more gradual decrease in the armor thickness of the turret sides from the front toward the rear.
CONCLUSIONS: The test turrets of the original design failed to provide a sufficiently high level of protection against 30° frontal attack. The modified turret provided this protection to a considerably greater degree. It was recommended that future tank turrets be designed to incorporate more obliquity for the side wall areas in order to provide more effective protection against flank attack.
GENERAL: This 94-page report includes 17 photographs of the test turrets and complete firing data. Firing Record Nos. Ar-18708 and Ar-17521 are included with this report.

SUBJECT: Armor APG AD-1195
TITLE: Comparative Ballistic Test of Solid and Laminated Mild Steel Plates
IDENTIFICATION: Report No. AD-1195; Twenty-fifth Report on Project No. TT1-5
DATE OF REPORT: 8 September 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the ballistic vulnerability of 1-inch solid and 1-inch laminated mild steel plates
METHOD: Resistance-to-penetration test of the plates was conducted with 10 rounds of cal. .50 AP M2 Projectiles at a range of 300 feet and at 0°

obliquity. Explosion bulge test was conducted by detonating two 5-pound Pentolite charges 27 feet above each plate and taking strain measurements from the center of the plates.
DESCRIPTION: The two 1-inch mild steel test plates were 1 x 36 x 31 inches in size and were submitted by the Rheem Manufacturing Co. One of the plates was of solid steel and the other consisted of 33 thin laminations, each about .037 inch in thickness, bonded by an adhesive.
CONCLUSIONS: The performance of 1-inch solid mild steel plate was vastly superior to that of the 1-inch laminated plate in both of the ballistic tests. The thin layers of the laminated plate tended to separate as a result of bullet impact. Strain measurements of the laminated plate were not practical because of layer separation. It was recommended that no further consideration be given to the laminated type of armor material.
GENERAL: This 23-page report contains six photographs of the test plates and complete firing data.

SUBJECT: Armor APG Ar-15107
TITLE: HCR-2 Used in Various Combinations with Steel Armor
IDENTIFICATION: Report No. Ar-15107; Project No. 3520 (39 Ar9-274)
DATE OF REPORT: 17 November 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of HCR-2 used in various combinations with steel armor
METHOD: Ballistic tests of the various arrangements of steel armor and HCR-2 were conducted at 0° obliquity with 105mm HE M1 and 105mm HEAT M67 Shells having striking velocities of approximately 1450 fps and 110 fps, respectively. Three rounds of the German Faustpatrone #2 (Panzerfaust) were also fired against two combinations of the test materials and ballistic limits of two combinations were obtained with 75mm APC M61 Projectiles and 75mm AP M72 Shot.
DESCRIPTION: The HCR-2 test material consisted of a mastic binder and silicate rock enclosed in thin sheet steel. The combinations consisted of various arrangements of 5 or 6-inch depths of HCR-2, 1/2 or 3/4 inch homogeneous or welded steel, and 1-1/2 or 2-1/2-inch rear plates.
CONCLUSIONS: The 105mm HEAT shell was defeated by combinations of 3/4 inch homogeneous steel, 5-inches HCR-2, and 2-1/2 inches homogeneous steel and by combinations of 3/4 inch homogeneous steel, 6 inches HCR-2, and 1-1/2 inches homogeneous steel. The 1/2 inch frontal steel was considered borderline for protection against the 105mm HE shell with .05 second delay. One round of the German ammunition, fired against a combination of 1/2 inch homogeneous steel, 8 inches HCR-2, and 1-1/2 inches and 1 inch homogeneous steel, resulted in complete penetration of the assembly. The German projectile was defeated by 9-1/2 inches of composite armor formed by 2-1/2 and 1-inch plates.
GENERAL: This six-page report is not illustrated.

SUBJECT: Armor APG Ar-15248
TITLE: HCR-2 Used in Various Combinations with Steel Armor
IDENTIFICATION: Report No. Ar-15248; Project No. 3520 (39 AR9-274)
DATE OF REPORT: 7 December 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of HCR-2 used in various combinations with steel armor
METHOD: Ballistic tests of three HCR-2 combinations were conducted using one round of 105mm HE M1 Shell with a secondary delay fuze against each of the combinations. One round of the German Faustpatrone #2 (Panzerfaust) projectile was also fired at one of the combinations.
DESCRIPTION: The HCR-2 test material consisted of a mastic binder and silicate rock enclosed in thin sheet steel. One of the combinations consisted of 5-inch thick HCR-2 welded to 3/8-inch rolled homogeneous steel. The other two combinations were similar except that they included a 2-1/2-inch steel armor back plate.
CONCLUSIONS: The results indicated that the 3/8-inch front plate was too thin to give protection to the HCR-2 when impacted with the 105mm HE M1 Shell. The one round of the German Panzerfaust failed to function on impact and was destroyed.
GENERAL: This three-page report is not illustrated.

SUBJECT: Armor APG Ar-15260
TITLE: Test of HCR-2 Armor
IDENTIFICATION: Report No. Ar-15260; Project No. 3520 (39 AR9-274)
DATE OF REPORT: 13 December 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of four armor designs against a German shaped charge
METHOD: The four armor design samples were braced vertically in an open area. German shaped charge projectiles were statically detonated against the face of the armor. Depths of penetration of the charges into the armor were measured.
DESCRIPTION: The first armor design consisted of a 3/4-inch rolled homogeneous armor plate welded to a 5-inch HCR-2 plate. These plates in turn were backed by 5 inches of HCR-2 plate, 1-1/2 inches of rolled homogeneous plate, 1-inch rolled armor plate, and three 3/4-inch armor plates. The second design replaced the 5-inch HCR-2 plates with 6-inch HCR-2 plates and used only 1-1/2-inch rolled armor plate as backing. The third design was the same as the second except for a 1-inch and two 3/4-inch rolled homogeneous armor plates added for backing. The fourth design consisted of layers of rolled homogeneous armor plates with a 12-inch air space between the first and second layers. It had a total of 9-3/4 inches of armor plate.
CONCLUSIONS: The shaped charges penetrated 14 inches into the first design, 13-3/4 inches into the second and third designs, and 20-1/4 inches into the fourth design.
GENERAL: This five-page report contains three

pages of data showing the armor designs and records of the firing tests.

SUBJECT: Armor APG Ar-15775
TITLE: Test of Spikes on Armor to Defeat Faustpatrone No. 1 (Panzerfaust)
IDENTIFICATION: Report No. Ar-15775; Project No. 3520 (39 Ar9-274)
DATE OF REPORT: 10 January 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of spikes on armor plate for defeating Faustpatrone No. 1
METHOD: Spikes were welded to the side of an M4 Tank Turret. The turret was impacted with Faustpatrone projectiles without fuzes or boosters to determine the damage to the projectile by the spikes. Three active rounds of the Panzerfaust were then fired at the turret to determine the effect of the spikes.
DESCRIPTION: The turret was from an M4 Tank. Eight-inch spikes cut to 6-inch lengths were welded with their axes perpendicular to the right side of the turret. On the left side of the turret the spikes were welded with axes 30° to the horizontal (60° to the turret). The Faustpatrone No. 1 or Panzerfaust was a German shaped-charge projectile.
CONCLUSIONS: Of the active rounds, one completely penetrated the turret, one failed to impact the target, and one failed due to malfunction. Further study of the spike defense against the German Faustpatrone and Panzerfaust was recommended.
GENERAL: This seven-page report contains six photographs of the spikes mounted on the turret armor.

SUBJECT: Armor APG Ar-17342
TITLE: Vulnerability Test of T26E4 Tanks to 90-mm T108E1 Projectiles
IDENTIFICATION: Firing Record No. Ar-17342
DATE OF REPORT: 30 April 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of a T26E4 Tank to 90mm T108E1 Projectiles
METHOD: A fully-stowed tank was used. Gas tanks were filled with 10 gallons of fuel each, and dummy ammunition and men were used. The engine was run at 1500 rpm and all electrical systems were in operation. Ten rounds of the projectiles were fired at the tank from 100 yards and at various obliquities. Damage to the tank after each round was noted.
DESCRIPTION: Ten 90mm T108E1 HEAT rounds were used. They had a muzzle velocity of 2400 fps. A PI, T209, split-back type fuze was used. The projectiles were fired from a 90mm Gun M3, on an M67 Combination Mount in an M26 Medium Tank.
CONCLUSIONS: Two rounds did not function properly. All of the other rounds penetrated the tank in various areas, causing internal, external, or both internal and external damage. Damage ranged from total destruction by ammunition fire to personnel injury.
GENERAL: This 27-page report includes nine photographs showing damage to the tank.

SUBJECT: Armor APG Ar-17456
TITLE: The Vulnerability of a Cast Hull of a T43 Tank to 122-mm AP Projectiles
IDENTIFICATION: Firing Record No. Ar-17456; Project No. TT1-5
DATE OF REPORT: 27 April 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of a cast tank hull to Russian 122mm AP projectile
METHOD: Three rounds were fired against the upper front area of the tank from less than 50 yards range. Two projectiles were fired from the front and one was fired at an angle of 30 degrees on the flank. Muzzle velocity ranged from 2631 to 2704 fps.
DESCRIPTION: The test armor was a T43 cast hull. The projectiles were Russian 122mm armor piercing, fired from a Russian gun carriage.
CONCLUSIONS: The projectiles made long scoops in the armor. The impacts cracked the armor and were approaching the condition of displacing fragments of armor.
GENERAL: This four-page report is not illustrated.

SUBJECT: Armor APG Ar-17707
TITLE: Vulnerability of Stowed Ammunition in a Tank to 90-MM Projectiles
IDENTIFICATION: Firing Record No. Ar-17707; Project No. TB3-1224B
DATE OF REPORT: 25 August 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of ammunition stowed in a tank
METHOD: The test was run in three phases. In the first phase three rounds of 90mm live shell cases were each placed over the commander's seat, over the gunner's seat, and the floor of one of two tanks. Six rounds were fired and after each firing, three more shell cases were stored for the next round. In phase two the live shell cases were stowed behind a 3-inch armor plate, and one round of 90mm T108E15 was fired at them. In phase three the live shell cases were stowed in a turret lying upside down on the ground, in a tank hull and behind a 3-inch plate. They were fired at with 90mm T108E15 Projectiles.
DESCRIPTION: Damaged T26E4 Tank cast hulls and turrets were used along with 3-inch rolled homogeneous armor plates. Shell cases were 90mm AP, T33 and Soviet 85mm. The projectiles used were 90mm T108E15 HEAT-FS with a T209 Fuze.
CONCLUSIONS: At least one shell case exploded from each hit. Many rounds exploded 2 or 3 shell cases.
GENERAL: The report contains nine pages and five photographs.

SUBJECT: Armor APG Ar-17728
TITLE: Vulnerability of T26E5 Tank to 90-mm T108E40 Projectiles
IDENTIFICATION: Firing Record No. Ar-17728; Project No. TB3-1224B
DATE OF REPORT: 28 April 1952
ORIGIN: Aberdeen Proving Ground, Maryland

PURPOSE: To determine the vulnerability of T26E5 tanks to 90mm HEAT projectiles
METHOD: Two fully stowed tanks were placed in front of a concrete wall. Inert ammunition was stowed in the tanks. A total of 24 complete 90mm HEAT rounds were fired at various parts of the tanks from different attack angles. Dummies were placed in the crew positions. After each round, damage to the tank, components, and personnel was recorded.
DESCRIPTION: The test vehicles were T26E5 Tanks. They were similar to the M26 Tanks except for thicker armor. Type 90mm T108E40 Projectiles with type T208E7 Fuzes were used. They were fired from an M3 gun mounted in a T26E5 Tank.
CONCLUSIONS: The turret was vulnerable to shock at the base. Deformation of the turret ring crushed the master conduit, thus shorting out the ignition. The final drive areas, track, and sprockets were vulnerable to small HE charges.
GENERAL: This 74-page report contains 27 photographs showing damage to the tank. Numerous firing records are also included.

SUBJECT: Armor APG Ar-17801
TITLE: Vulnerability of a Cast Tank Hull and Turret Against 90-mm HEAT Projectiles
IDENTIFICATION: Report No. Ar-17801; Project No. TB4-10
DATE OF REPORT: 19 November 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the protection afforded by cast hull and turret for 120mm Gun Tank T43 against attack by 90mm HEAT Projectile T108E40
METHOD: A stripped tank hull and turret, with 3/4-inch plywood panels placed 5, 12-1/2, and 17-1/2 feet behind the hull. was used as the target. Eight 90mm HEAT projectiles were fired at the front armor at different obliquities. Two rounds were fired at the turret to simulate direct frontal attack. All firing was at a distance of 175 feet.
DESCRIPTION: The cast hull from 120mm Gun Tank T43 was identified as Serial No. 5 and the cast turret as Serial No. 14. The 90mm HEAT Projectile T108E40 was equipped with Electric Fuze T208E7.
CONCLUSIONS: All hull shots penetrated, breaking the first plywood panel and piercing the second and third panels. Both projectiles fired at the turret pierced the most difficult section of armor and damaged the interior of the bustle. One projectile cracked the bustle armor.
GENERAL: This six-page report is not illustrated.

SUBJECT: Armor APG Ar-18090
TITLE: To Determine the Performance of Spaced Armor Against the Attack of AP, APC, HVAP, HEAT, and HEP Rounds
IDENTIFICATION: Report No. Ar-18090; Project No. TB3-1224B
DATE OF REPORT: 25 October 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of parallel and non-parallel arrangements of skirting plates and main armor against various projectiles
METHOD: Skirting and main armor plates of various sizes were grouped into parallel and non-parallel arrangements, the plates being positioned at various obliquities with respect to each other and with respect to the line of fire. These armor arrangements were subjected to fire by 90mm AP T33, 90mm APC T50E1, 90mm HVAP M304, 105mm HEP T81E17, and 90mm T108E20 Projectiles, and 3.5-inch M28A2 HEAT Rockets.
DESCRIPTION: The skirting plates consisted of 1/4-inch unheat-treated armor. The main armor consisted of 3 and 4-inch rolled homogeneous armor.
CONCLUSIONS: The parallel and non-parallel skirting and main armor plate arrangements were considerably less vulnerable than the main armor by itself.
GENERAL: This eight-page report contains details of the test, sketches of the armor arrangement, and ballistic limits.

SUBJECT: Armor APG Ar-18229
TITLE: Vulnerability of T26E5 Tanks to 90-mm HEAT Projectiles
IDENTIFICATION: Report No. Ar-18229; Project No. TB3-1224B
DATE OF REPORT: 21 February 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of tank armor to HEAT projectiles
METHOD: Three fully stowed tanks were used as the targets. Dummy ammunition and crew members were installed in the tanks. The engines were run at 1500 rpm. Electrical equipment was in operation. A total of 18 rounds were fired at the tanks from a distance of 500 yards. Various attack angles were used.
DESCRIPTION: The test armor was that of T26E5 Medium Tanks. Ammunition used was 90mm T108E40, HEAT Projectiles with a muzzle velocity of 2800 fps. Fuze PI, BB, T208E7 was used with the projectiles.
CONCLUSIONS: There was a high percentage of fuze failures. Of the 18 rounds, 17 were hits and nine of these formed jets. One jet caused a kill due to an ammunition fire. The remaining jets put a tank out of action due to loss of mobility, communications, personnel, or firepower.
GENERAL: This 42-page report contains 12 photographs showing the damage to the armor.

SUBJECT: Armor APG Ar-18504
TITLE: Spaced Armor Performance Against the Attack of HEAT Rounds and APC Projectiles
IDENTIFICATION: Report No. Ar-18504; Project No. TB3-1224B
DATE OF REPORT: 3 April 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the resistance to penetration of skirt plates and main armor when subjected to fire from 3.5-inch rockets and 90mm HEAT and APC rounds
METHOD: Main armor, with and without skirting plates, was subjected to fire from 3.5-inch rockets

and 90mm rounds. Where used, two 1/4-inch skirting plates placed together were 8 and 16 inches away from, and parallel to, the main armor. Firing was at an obliquity of 60° to both skirting plates and armor.
DESCRIPTION: The main armor was 3-inch rolled homogeneous material with a hardness of 280 BHN. The skirting plates were of 1/4-inch unheat-treated armor. The rounds fired were 3.5-inch Rocket M28A2, 90mm HEAT Projectile T108E15, and 90mm APC Projectile T50E1.
CONCLUSIONS: Tests with the 3.5-inch rockets showed that two 1/4-inch skirting plates combined and placed 8 inches in front of the main armor would defeat the round. Tests with the 90mm HEAT projectile showed that 16 inches of spacing was needed to defeat the projectiles when two 1/4-inch plates were used in front of the main armor. No advantage was found in using the two 1/4-inch skirting plates in combination against the 90mm APC T50E1 Projectiles.
GENERAL: This 86-page report contains detailed accounts of all firing tests.

SUBJECT: Armor APG Ar-18505
TITLE: Ballistic Vulnerability of the Soviet Tank T34/85
IDENTIFICATION: Report No. Ar-18505; Project No. TB3-1225
DATE OF REPORT: 14 November 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of a Soviet Tank to heavy AT Mines M6
METHOD: One heavy AT Mine M6 was placed 3 inches underground and two were buried 18 inches underground. The test tank was towed over the mines which were detonated inboard of the tank tracks. Metallurgical examinations were conducted, including a Charpy V-notch test of the tank track shoe and chemical analysis and hardness test of the floor plate.
DESCRIPTION: The captured Soviet Tank T34/85 had previously been tested with small mines and napalm. These tests had burned the rubber off the road wheels and bumper brackets and deformed the road wheels.
CONCLUSIONS: All three M6 Mines ruptured the hull floor plate and caused serious damage to the tank interior. The only break in the track was caused by embrittlement from heat and not by mine detonation. The hull armor did not fail as a result of the blast. The 3/4-inch hull floor plate was of the usual Soviet high silicon steel used for this thickness and showed less resistance than the 1/2-inch floor plate of the US T26 Tank. The failed track showed the impact strength to be low, partly because of the damaging effect of the burning napalm and partly because of extreme porosity resulting from poor steel-making practice.
GENERAL: This 20-page report includes one photomicrograph and six photographs of the test materials.

SUBJECT: Armor APG Ar-18517
TITLE: Resistance to Penetration Test of Aluminum Armor in Combination with Steel Armor
IDENTIFICATION: Report No. Ar-18517; Project No. TB3-1224B
DATE OF REPORT: 26 June 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic resistance of aluminum armor combined with steel armor
METHOD: Ballistic tests of three armor combinations were conducted using 90mm AP Projectiles T33 to determine the Army ballistic limits. A fourth armor combination was impacted with one round, and a 3-inch aluminum plate with two rounds, of 105mm HEP Shell T81E17.
DESCRIPTION: The armor test combinations consisted of 2-inch steel plates spaced 1/2-inch behind a 5.6-inch 24ST4 aluminum armor plate, with both plates at an angle of 55° from the vertical. The aluminum plates were about 40 x 45 inches and were equivalent in weight to 4 inches of rolled homogeneous armor.
CONCLUSIONS: The test armor combination had an Army ballistic limit of 2845 fps for 90mm projectiles, approximately 100 fps higher than that previously obtained with 4-inch armor tested under similar conditions. The impacts on the aluminum plate by the 90mm shell resulted in backspall. The toughness of the aluminum plate was below that of rolled homogeneous steel. The impact of the 105mm shell on the test combination resulted in defeat of the shell and in severe cracking and backspall of the aluminum plate. The 105mm shells fired at the single aluminum plate resulted in complete penetration and spalling.
GENERAL: This 19-page report includes 11 pages of photographs of the target setups showing ballistic damage.

SUBJECT: Armor APG Ar-18520
TITLE: Hull of the Soviet T34/85 Tank Against U.S. 57-mm Projectiles
IDENTIFICATION: Report No. Ar 18520; Project No. TB3-0035
DATE OF REPORT: 9 June 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of a Soviet tank hull to ballistic attack
METHOD: Ballistic tests of a Soviet T34/85 Tank hull #2 were conducted with impacts as close as 4 inches apart. The upper front plate was impacted by four 57mm, AP-T, M70 and two 57mm, APC-T, M86 Projectiles. The sponson side plate was impacted by six 57mm, APC-T, M86 and five 57mm, AP-T, M70 Projectiles. Ballistic limits of the test material were determined and compared with limits of American armor. Brinell hardness determinations of the test material were made.
DESCRIPTION: The lower and upper front plates of the Soviet T34/85 test tank hull were joined together with a butt weld. Splash deflectors were welded to the top of the sponson side plates and the upper front plate. The Brinell hardness numbers of the tank hull test plates ranged from 481 to 533.
CONCLUSIONS: Only minor weld cracking resulted from the impacts which in general were not located directly adjacent to welded joints. The

splash deflectors were efficient in protecting the turret base ring from fragments. The 57mm AP projectiles could only defeat the upper front plate from direct attack or the sponson side plates from 47° off the longitudinal axis of the hull at ranges up to 560 yards. The 57mm APC projectiles fired at service velocity could not defeat the upper front plate or sponson side plates from direct frontal or any attack position up to 47° from direct attack.
GENERAL: This 10-page report is not illustrated. This report includes laboratory Report No. 52-T-188.

SUBJECT: Armor APG Ar-18814
TITLE: Vulnerability of T26E4 and T26E5 Tanks to Attack by 105-mm HEP-T Ammunition
IDENTIFICATION: Report No. Ar-18814; Project No. TB3-1224B
DATE OF REPORT: 14 November 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of T26 Tanks to attack by 105mm HEP-T Shells
METHOD: Wooden dummies with radio chest sets were installed in one T26E4 Tank and one T26E5 Tank. The tank engines and electrical and radio systems were placed in operation, and the tanks were tested ballistically with 33 rounds of semi-fixed HEP-T T81E28 Shell.
DESCRIPTION: The T26E4 Tank had a single-pin T81 Track and a 90mm T15E2 Gun with separate loading ammunition. The charges were stored in the turret floor and the projectiles were stowed in the turret racks. The T26E5 had a double-pin T80E1 Track and a 90mm M3 Gun with fixed ammunition. The rounds were stowed in the turret racks in a location similar to that of the cartridge cases in the T26E4 Tank. In general, the T26E5 had heavier armor than the T26E4 Tank.
CONCLUSIONS: Test observers believed that the total firing would have immobilized the test tanks and that several crew members would have been injured or killed. Fourteen of the rounds spalled and three made cracks on the tank interiors. The suspension components offered some protection for the tanks. Impacts below the top track portions broke the single-pin track, but failed to break the double-pin tracks. Impacts on the front of the tracks broke both types. There was no damage to the radio or electrical systems. Five impacts on the sides of the T26E5 Tank failed to produce spall, but five of seven impacts on the sides of the T26E4 Tank did produce spall. Since the side armor thickness of both tanks was the same, it was thought that metallurgical properties accounted for the difference in spalling.
GENERAL: This 85-page report includes 23 pages of photographs of the test tank components and ballistic damage.

SUBJECT: Armor APG Ar-18957
TITLE: Adequacy of the Method of Mounting HCR2 on T26E5 Tanks
IDENTIFICATION: Report No. Ar-18957; Project No. TB3-1224B
DATE OF REPORT: 2 March 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the adequacy of the method of mounting HCR2 on tanks
METHOD: The upper and lower front plates of two previously damaged T26E5 Tanks were covered with 10-inch coats of HCR2. Ballistic tests were conducted on the tanks by firing two 90mm AP-T, T33E2 rounds at the hull front of each tank at service velocity.
DESCRIPTION: The 10-inch thick coat of HCR2 consisted of stone and a light porous matrix of flintkote, The coating was secured to the tanks by 1/2-inch steel plates welded to the front armor with bolts 5/8-inch in diameter welded to the plates. A heavy wire netting was fastened to the ends of the bolts. The arrangement of the mounting plate divided the HCR2 into three sections. The bow machine gun was removed and the coating applied over the gun mount.
CONCLUSIONS: The method of mounting the test material was not considered adequate. After a hit in two HCR2 sections of each tank, the remaining HCR2 was broken and loosened so that it offered little protection. This method of mounting the material was, however, considered superior to the method previously used for testing with 3.5-inch rockets.
GENERAL: This 13-page report includes four photographs of the test material mounted on the tanks and two drawings of the impact areas. This report is in folder with Report No. AD-1179.

SUBJECT: Armor APG Ar-19008
TITLE: Ability of HCR2 to Defeat 3.5-inch Rockets and Adequacy of Method of Mounting HCR2 on T26E5 Tanks
IDENTIFICATION: Report No. Ar-19008; Project No. TB3-1224B
DATE OF REPORT: 30 January 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ability of HCR2 material to defeat 3.5-inch rockets and the adequacy of the method of mounting this material on tanks
METHOD: The test HCR2 was applied to the upper and lower front slope plates of two previously damaged T26E5 Tanks. Ballistic tests were conducted with twenty-one, 3.5-inch rockets fired at the tanks.
DESCRIPTION: The HCR2 test material consisted of stone and light porous matrix of flintkote. The material was applied to the tanks and secured with bolts, washers, and heavy wire netting. The material coat on one tank was 14 inches thick and 10 inches thick on the other. The bow machine gun opening was coated over on both tanks.
CONCLUSIONS: Thirteen impacts were made on the targets and it was believed that this low percentage of hits was caused by the method of mounting and laying the rocket launcher. The method of mounting the HCR2 was not satisfactory because of the covering of the machine gun openings; and on one tank, the coating was extended so as to block the view of the driver and machine gunner. The added weight of the test material reduced the ground clearance of the vehicle and caused side extensions which were dangerous in operation

through wooded areas. The test material in the thicknesses applied gave added protection to the vehicle as evidenced by the 11 valid hits, all of which failed to penetrate the armor completely. The material was brittle and the mounting bolts were easily broken by the impacts.
GENERAL: This 18-page report includes six photographs of the test tanks and materials and is contained in duplicate. This report is in folder with Report No. AD-1179.

SUBJECT: Armor APG Ar-19042
TITLE: The Protection Ballistic Limits of the Frontal Armor of T26E4 Tanks Attacked by Soviet Anti-Tank Weapons
IDENTIFICATION: Report No. Ar-19042; Project No. TB3-0035
DATE OF REPORT: 2 April 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of Tank T26E4 frontal armor to various projectiles
METHOD: Ballistic tests were conducted against the frontal armor of three T26E4 Tanks. Firing ranges varied from 65 to 125 yards, from gun to target. Fifty-nine rounds of ammunition fired included the following: Soviet 57mm AP-T and HVAP-T; U.S. 57mm AP, M70; Soviet 85mm AP-T and HVAP-T, and Soviet 122mm AP-T. The rounds were fired at, or slightly above, service velocities. If the target was not penetrated, the ballistic limit was not obtained. Soviet armament was used in all firing tests.
DESCRIPTION: The three T26E4 Tanks had been damaged by previous ballistic tests but the frontal armor and internal components back of the armor were relatively undamaged. The hull fronts of the test tanks were made of cast armor.
CONCLUSIONS: The U.S. 57mm M70 Projectile defeated armor which was not defeated by the higher velocity Soviet projectiles. The 57mm AP-T projectile would have put the tank out of action and injured the crew. The 57mm HVAP-T defeated the plate, but the tank could have operated. The 85mm AP-T projectiles penetrated the plate, and the tank could have been utilized only if its fire power was necessary. The 85mm HVAP-T projectile failed to defeat the plate. The 122mm AP-T projectile defeated the plate, and the tank would have been out of action from loss of mobility, fire power, and injury to two crew members.
GENERAL: This 46-page report includes complete firing data and three pages of photographs of shell fragments and ballistic damage.

SUBJECT: Armor APG Ar-19128
TITLE: Adequacy of the Method of Mounting HCR2 on T26 Tanks
IDENTIFICATION: Report No. Ar-19128; Project No. TB2-1224B
DATE OF REPORT: 20 March 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the adequacy of the method of mounting HCR2 on T26 Tanks
METHOD: The test material was used to cover the upper and lower front slope plates of one T26E4 and one T26E5 previously damaged tanks. The tank plates were covered with a 10-inch coat of HCR2 secured to the tank by 1/2-inch steel plates welded to the front armor with bolts welded to the plates. A heavy wire netting was fastened to the ends of the bolts. The arrangement of the mounting plate divided the test material into three sections. An opening was left for mounting the machine gun. Ballistic tests were conducted including the firing of one round of 105mm howitzer, semi-fixed Shell HEP-T T81E28 w/fuze, BD, M91 at each tank.
DESCRIPTION: The HCR2 test material consisted of stone and a light porous matrix of flintkote and was about one quarter the density of steel.
CONCLUSIONS: The method of mounting the material was considered more satisfactory than previous test methods due to the opening left for the machine gun. The ballistic impacts were on the front plates near the center lines of the hulls and in each case two-thirds or more of the material was torn off. The material was brittle and that which remained after impact was broken and loosened.
GENERAL: This seven-page report includes two photographs of the test tanks and material. This report is inclosed with Report No. AD-1179.

SUBJECT: Armor APG Ar-19254
TITLE: Ballistic Investigation of Simulated U.S.S.R. T34 Tank
IDENTIFICATION: Report No. Ar-19254
DATE OF REPORT: 5 June 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To investigate a simulated Soviet T34 Tank fitted with spaced armor
METHOD: The tank was subjected to fire at 60° obliquity from HVAP-DS, 76mm, M331A1; HVAP, 76mm, M93; and AP, 76mm T128E6 Projectiles that weighed 8, 9.43, and 14.5 pounds, respectively. Penetration was studied and ballistic limits determined.
DESCRIPTION: The Soviet T34 Tank armor was simulated. American armor of thickness as closely comparable as possible to that of a U.S.S.R. tank equipped with two-centimeter (0.787-inch) thick skirting plates was used. The armor selected was 2 inches thick for the basic plate and 3/4-inch thick for the skirting plate. An armor plate 3 inches thick, without the skirting plate, was also tested. The skirting plates were located 1-1/2 and 26 inches away from the main armor.
CONCLUSIONS: In general, the skirting plates located 26 inches away from the main armor were effective in preventing main armor penetration, while the plates with an air space of 1-1/2 inches were not. It was estimated that the combination of a 2-inch armor plate and a 3/4-inch skirting plate separated by 26 inches of space would afford protection against all projectiles even at greatly increased velocities, unless the projectiles were sufficiently improved to prevent shattering upon impact with 3/4-inch skirting plates.
GENERAL: This 19-page report contains a discussion of the tests, calculated ballistic limits, and firing data.

SUBJECT: Armor APG Ar-19546
TITLE: Ballistic Investigation of Simulated USSR T34 Tank Fitted with Spaced Armor
IDENTIFICATION: Report No. Ar-19546; Project No. TB3-1224
DATE OF REPORT: 18 August 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of simulated Russian tank spaced armor
METHOD: Ballistic tests were conducted using 3.5-inch HEAT rockets against bare plates and combinations of spaced plates. All firings were conducted at 60° obliquity except two rounds fired at a 5-inch plate at 0° obliquity.
DESCRIPTION: The rolled homogeneous steel armor consisted of 2-inch plates of 284 to 314 BHN; 3/4-inch plates of 255 to 269 BHN; and 5-inch plates of 280 BHN. The two plate combinations used included 3/4-inch skirting plates and 2-inch plates with one combination separated by a 26-inch space and the other by a 2-inch space.
CONCLUSIONS: Four fair impacts failed to defeat the 26-inch spaced combination and penetration of the 2-inch plate ranged from 3/4 to 2-3/16 inches. Only one of 12 fair impacts defeated the 2-inch spaced combination; this one round perforated the 2-inch back plate and two 3/4-inch witness plates behind the combination. One round fired against a bare 2-inch plate shattered on the plate face and three more rounds failed to effect complete penetration. Two rounds impaced and perforated the 5-inch plate.
GENERAL: This six-page report includes complete firing data and is not illustrated.

SUBJECT: Armor APG Ar-19718
TITLE: To Determine the Vulnerability of a T26E4 Tank to 90-mm HEP-T, T142E3 at 800 Yards Range
IDENTIFICATION: Report No. Ar-19718; Project No. TB3-1224B
DATE OF REPORT: 4 November 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of a T26E4 Tank to 90mm HEP-T, T142E3 Projectiles
METHOD: The tank was subjected to fire from fifteen 90mm HEP-T, T142E3 Projectiles. The range was 400 yards with the propellant reduced to give the same impact at 400 as the full service charge at 800 yards. Wooden dummies were placed in the tank to simulate human beings.
DESCRIPTION: The target tank was a T26E4 Tank which had been damaged by fire during a previous test. The projectiles were loaded with explosive filler, Composition A3 with Fuze, BD, M91. An M1 propellant weighing 66.20 ounces was used.
CONCLUSIONS: Of the fifteen projectiles fired, four struck the hull front, six struck the hull side (on attached components), and five struck the turret side (on attached components). Four of the projectiles fired at the hull front caused spalling; one was defeated. None of the five projectiles fired at the hull side caused spalling. Four of the projectiles fired at the turret side caused spalling; one was defeated. The wooden dummies were damaged. It was decided that the tank would have been put out of action in combat.
GENERAL: This 52-page report includes 17 photographs of the damaged tank and wooden dummies, and a test discussion and firing report.

SUBJECT: Armor APG Ar-19841
TITLE: Vulnerability of the ONTOS Vehicle to Ballistic Attack
IDENTIFICATION: Report No. Ar-19841; Project No. TT2-740
DATE OF REPORT: 9 February 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of the ONTOS vehicle
METHOD: Ballistic tests of the vehicle were conducted using 155mm HE M107 and 105mm HE M1 Projectiles, and 4.2-inch mortar HE M3, 81mm mortar HE M56A1, and Soviet 82mm mortar HE Shells. The shells were statically detonated at distances varying from 10 to 60 feet from the front, sides, rear, and top of the vehicle and at varying velocities. Brinell hardness surveys were made on selected locations and assessment of damage was recorded.
DESCRIPTION: The test ONTOS vehicle was a modified T166 type with a turret substituted for the ground mount, minus the 106mm recoilless rifle, engine, and transmission, but including all optical units except the driver's periscope.
CONCLUSIONS: Fragment damage from the mortar shells caused more damage to external components of the vehicle than artillery shells. Fragment hits on or adjacent to welded joints did not cause weld cracking. Fragment hits between the turret and roof plate caused no difficulty in traversing the turret. An impact on the retaining collar of the cross shaft made a deep impression but did not affect the elevation or depression of the cross shaft.
GENERAL: This 87-page report includes 15 pages of photographs of the test vehicle and components, and 44 drawings of the vehicle.

SUBJECT: Armor APG Ar-19859
TITLE: Ignition of Diesel Fuel with Statically Detonated 106-mm HEAT Cased Charges
IDENTIFICATION: Report No. Ar-19859; Project No. TB3-1224B
DATE OF REPORT: 23 March 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effect of reduced standoff on the probability of ignition of diesel fuel with statically detonated 106-mm HEAT cased charges
METHOD: The fuel containers were filled to 7/8 of capacity and wedged in place separately in one of the rear fuel compartments of a German Royal Tiger Tank with a 1/4-inch armor back-up plate. The sponson plate in front of the fuel tank was 3.1 inches thick at 20° obliquity. The cased charges were supported at standoff distances of 1, 4, and 9 inches from the plate. Twenty-nine charges were statically detonated to penetrate the containers.
DESCRIPTION: The fuel tested was Federal Specification Class I diesel fuel. Propellant powder

cans of 16-gallon capacity were used for fuel containers.
CONCLUSIONS: No ignition of the fuel occurred from the 13 charges that were fired at the standard standoff distance of 9 inches. The fuel was ignited seven times from the 15 charges that were fired from a standoff distance of 4 inches. Fuel ignition resulted from the single charge fired from a standoff distance of 1 inch. Results showed that incidence of ignition was greater when cases were fired with reduced standoff than when they are fired with built-in standoff.
GENERAL: This 13-page report includes a photograph showing typical damage to fuel containers.

SUBJECT: Armor APG TB4-10A
TITLE: Ballistic Test of Hemispherical Head
IDENTIFICATION: Project No. TB4-10A
DATE OF REPORT: 18 December 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of a hemispherical head as a substitute for a casting or rolled plate in a turret
METHOD: The hemispherical head and plate were ballistically tested with six 75mm T165E2 HEP rounds and 52 rounds of 57mm AP M70 and 90mm AP T33 Projectiles. HEP ammunition firings were from distances of 210 to 235 feet, at obliquities of 0° to 60°, and at striking velocities of 1527 to 1588 fps. AP ammunition firings were from distances of 163 to 186 feet, at obliquities of 0° to 55°, and at striking velocities of 1415 to 2699 fps. Hardness surveys of the target materials were made. Terminal ballistic effects were noted and ballistic limits were obtained with AP ammunition.
DESCRIPTION: The 3-inch rolled armor plate weighed about 15,000 pounds. The hemispherical spun head was designed for possible use in the production of tank turret heads. The hemispherical head was 3 inches thick and 72 inches in interior diameter and weighed approximately 10,650 pounds. The plate and head were from the same heat of Lukens steel.
CONCLUSIONS: There was no significant difference between the terminal ballistic limits or ballistic effects on the hemispherical head and on the rolled plate. The obliquity of the head was considered an advantage with respect to ballistic resistance. Other tests had indicated that rolled armor had a greater resistance than cast armor and it was concluded that a spun turret would be ballistically superior to rolled or cast armor. It was recommended that spinning be considered as a manufacturing method for tank turrets provided that proper dimensions could be obtained. It was also recommended that the production of a turret by pressing be investigated.
GENERAL: This 49-page report includes complete firing data and 17 pages of photographs of the test materials and ballistic damage.

SUBJECT: Armor APG TB4-10/1
TITLE: First Report on Samples of USSR Tank Armor
IDENTIFICATION: Report No. 1; Project No. TB4-10
DATE OF REPORT: 21 December 1950
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of Russian tank armor
METHOD: Ballistic tests of captive T34 and JS II USSR Tank turrets were conducted with 33 rounds of various AP, APC, HEAT, and HEP ammunition. The gun-to-target distance was 180 feet and the turrets were turned in various positions; firing was at obliquities from 0° to 74°. Striking velocities were from 931 to 3320 fps and assessment of cause of damage was made. Metallurgical and physical testing of armor samples was conducted including hardness, thickness, dimension and obliquity determinations.
DESCRIPTION: The test turrets had been cut by acetylene torch and flown out of Germany. The targets consisted of USSR T34 Tank turret with mantlet and 85mm gun, and a USSR JS II Tank turret with mantlet and 122mm gun. The test turrets were of World War II stock.
CONCLUSIONS: The T34 turret could be defeated with 57mm M70 AP rounds; at ranges of 500 yards or less at obliquities up to 17° and with 57mm M86 APC rounds at ranges of 500 yards or less at obliquities up to 42°. The JS II turret could be defeated with 90mm T33 AP or the 90mm T67 HVAP rounds at ranges of 1000 yards or less at obliquities up to 41°. Beyond fuze arming range and up to its maximum range at obliquities up to 54°, the 75mm M310 HEAT round could defeat the T34 turret. Between about 50 and 850 yards at obliquities up to 55° the 3.5-inch M28 HEAT round could defeat the JS II turret. When the obliquity was between 45° and 55° and the striking velocity between 850 and 1200 fps, the 75mm T151 HEP round could cause spawl on the interior of the T34 turret and the 105mm T81 round could cause spawl on the interior of the JS II turret. It was recommended that ballistic testing of a more recent vintage of USSR armor be conducted if possible.
GENERAL: This 67-page report includes 22 photographs of the test turrets and firing damage.

SUBJECT: Armor APG TB4-10/3
TITLE: Third Report on Samples of USSR Tank Armor
IDENTIFICATION: Report No. 3; Project No. TB4-10
DATE OF REPORT: 30 October 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of Russian T34 Tanks
METHOD: Ballistic tests of the T34 Tanks were conducted using 75mm HEP T165E2 Projectiles with C4 filler. Two rounds were fired at a previously tested T34 Tank and 12 rounds were fired at the two T34 test tanks. The impacts were made on the hulls and turrets of the vehicles with the distance from gun to target being approximately 185 feet and at striking velocities from 1499 to 1679 fps. Assessment was made of damage to the armor and welds. The precise horizontal and vertical obliquities at the points of impact were measured.

DESCRIPTION: The two USSR T34/85 Tanks tested were received from Korea and were described in the second report of this series.
CONCLUSIONS: The 75mm HEP T165E2 round was not satisfactory for antitank firing against the Russian T34 Tank. In general, no significant damage was done to the exterior side of the tank by the test projectile. Welding on the tanks was not strong enough to withstand the blast effect of the projectile within an area of 3 feet from the impact point. Spall resulted on the tank interiors only when the obliquity exceeded about 48°.
GENERAL: This 38-page report includes complete firing data and 16 pages of photographs of the test tanks and firing damage.

SUBJECT: Armor APG TT1-5/34
TITLE: Investigation of the Protection Afforded by Special Cast Armor Floor Plates Against Anti-Tank Mine Attack
IDENTIFICATION: Thirty-fourth Report on Project No. TT1-5
DATE OF REPORT: 14 July 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the resistance-to-land mine blast of specially designed and heat-treated cast floor plates
METHOD: Each test floor plate was centrally placed on a cradle of four 12x12 timbers and a heavy plate was placed on top of the floor. The mine was placed under the center of the floor so that the distance between the top of the mine and the bottom of the floor plate was 17 inches. The mine was covered with 2 inches of loose soil. Four mines were used; all were of a special type, consisting of a cylindrical sheet metal container loaded with cast TNT and a pentolite booster. The mines were detonated statically by use of a blasting machine and electrical blasting caps. Two of the mines contained a 20-pound, one a 25-pound, and the fourth a 40-pound explosive charge. Prior to firing, the plates were submitted to radiographic examination and thickness measurements at Aberdeen Proving Ground.
DESCRIPTION: The test plates, manufactured by Continental Foundry and Machine Company, were designed as replacements for 1-inch rolled homogeneous armor floor plates. The thinner plates had a root thickness of 1-5/16-inch and a maximum thickness of 1-3/4-inch; the corresponding dimensions of the thicker plates were 1-1/2 and 1-15/16 inches. One plate of each thickness had a hardness of 240 BHN, and the other a hardness of 280 BHN.
CONCLUSIONS: Test results indicated that the plates could defeat the 20-pound TNT mine with little deformation, but offered no protection against the heavier charges. It was felt that the weights of the tested plates were so much greater than that of the 1-inch homogeneous armor that no fair comparison could be made. It was also felt that there had been several weaknesses in the theoretical analysis which led to the choice of the designs tested. It was recommended that rigorous analyses be conducted, and that the designs resulting from these analyses be manufactured and tested.
GENERAL: This 37-page report includes seven photographs of the test floor plates.

SUBJECT: Armor APG TT1-709
TITLE: Vulnerability of Armored Vehicles to Ballistic Attack
IDENTIFICATION: Report No. APG TT1-709
DATE OF REPORT: 1 December 1948
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To present an over-all view of the vulnerability of armored vehicles to ballistic attack
METHOD: An investigation was made of the results of tests conducted at the Aberdeen Proving Ground and other government installations, of reports of tests by other accredited American and foreign agencies, and of reports of accredited observers at several battle fronts. This material was organized under six main headings, each of which constituted a chapter of this report.
DESCRIPTION: The main headings of this report consisted of Weapons for Ballistic Attack of Armor, Effects of Ballistic Attack of Armor, Armor Materials, Basic Design Considerations, Component Design Considerations, and Performance of Armor and Welds at Sub-Zero Temperatures.
CONCLUSIONS: The comprehensive nature of this report precludes a detailed account of the conclusions given throughout the report. The over-all view of the vulnerability of armored vehicles to ballistic attack included discussions of ball, armor-piercing, high-explosive, high-velocity, and quash-head projectiles; projectile penetration, shock, blast, bullet splash, fragment penetration, jet penetration, and immobilization effects; rolled homogeneous, cast homogeneous, and free-hardened steel and other armor materials; basic design considerations covering equalization of protection, re-entrant angles, spaced armor, and design of hull, final drive, and turret; component design considerations for armored vehicle joints, gun shield and turret mountings, vision or sighting devices, air intake and outlet devices, ammunition racks, doors, covers, hatches, fuel tanks, and additional armor arrangements; and effects of low temperatures on armor, armor structures, and armor welds. It was believed that the material presented on these topics could be used as an aid in minimizing defects in future design and construction of armored vehicles.
GENERAL: This 329-page report contains a considerable number of photographs, sketches, and graphs.

SUBJECT: Armor APG TT1-709/M
TITLE: The Vulnerability of Armored Vehicles to Ballistic Attack
IDENTIFICATION: Project Manual No. TT1-709
DATE OF REPORT: September 1950
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To present an analysis of the vulnerability of armored vehicles to ballistic attack
METHOD: Numerous American and foreign reports were analyzed by personnel experienced in the ballistic testing of armor and armored vehicles. Effects of ballistic attack on armor were discussed

along with armor materials and their metallurgy. Basic design considerations for armored vehicles were presented. Considerations were made of component design in armored vehicles. The performance of armor and welds at sub-zero temperatures was also presented.
DESCRIPTION: The data and materials used to compile this manual were obtained from various American Government agencies, proving ground, and laboratory reports, and from industrial reports and British sources.
CONCLUSIONS: The vulnerability of various armored vehicles to numerous types of attack was presented. The methods developed and suggested for reducing vulnerability were detailed. Welding methods were presented and practical usage outlined. Vulnerability of vehicle components and its prevention were covered in this comprehensive manual.
GENERAL: This 243-page manual contains numerous photographs, drawings, and charts of the vehicles, ammunition, and test data.

SUBJECT: Armor APG TT2-614/7
TITLE: Ballistic Test of Infantry Vehicles, Armored, Tracked, T59 and T18E1 at Ft. Knox, Kentucky
IDENTIFICATION: Seventh Report on Project No. TT2-614; AD-1177; APG 12-24C
DATE OF REPORT: 25 August 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic suitability of various components of tracked armored infantry vehicles
METHOD: Ballistic tests of the grilles of a T59 and a T18E1 Vehicle were conducted with cal. .50 projectiles at a range of 500 yards and with cal. .30 projectiles at a range of 100 yards. The incomplete-penetration welded joints of the T59 were tested with cal. .50 projectiles at a range of 500 yards. The two vehicles were placed on their sides and their roofs were subjected to side spray fragments from statically detonated 105mm HE shells placed 50 to 90 feet away from the roofs. The two vehicles were subjected to fire from 105mm HE VT-fuzed shells at a range of 3450 yards and examined for damage resulting from fragment hits.
DESCRIPTION: The test items were T18E1 and T59 Tracked Armored Infantry Vehicles. The T18E1 Vehicle had 1/2-inch front upper armor at 73°, 5/8-inch lower front armor at 32°, 5/8-inch side and rear armor at 0°, 3/8-inch top armor, 1-1/4-inch floor armor, and 1/2-inch sponson floor armor. The T59 Vehicle was fabricated with incomplete-penetration welded joints and welded with ferritic electrodes. The engine compartment grilles contained "S" shaped louver bars. The vehicle had 3/8-inch roof armor, 5/8-inch side, front, and rear armor, and 1-inch floor armor.
CONCLUSIONS: The tests were not considered suitable for establishing the level of quality of the incomplete-penetration welded joints or of the engine compartment grilles of the T59 Vehicle. However, it was believed that there was only slight possibility of random impacts from small arm projectiles or shell fragments causing significant damage to the incomplete-penetration welded joints. The T59 engine grilles were considered ballistically inferior to standard Ordnance grilles, however; it was believed that because of their location on the vehicle their use might be approved. Further testing of the T59 Vehicle was recommended.
GENERAL: This 38-page report contains six photographs of the test vehicles.

SUBJECT: Armor APG TT2-674/7
TITLE: Vulnerability Analysis of the Tank, 76-MM Gun, T41E1
IDENTIFICATION: Seventh Report on Project No. TT2-674; Armor Test Report AD-1146; APG 10-266
DATE OF REPORT: 17 February 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of the Tank, 76mm Gun, T41E1, to ballistic attack
METHOD: This test consisted of a theoretical analysis of vulnerability, and most of the information about the test vehicle was obtained through physical examination of the tank, with no destructive firing program. Nearly all of the thicknesses and obliquities of the armor sections, with the exception of some of the cast sections, were actually measured with calipers, micrometer, reflectoscope, and gunner's quadrant. Establishment of specific attack conditions and an evaluation of the various tank areas or components when subjected to attack were determined by evidence drawn from ballistic tests previously conducted on similar components of other tanks.
DESCRIPTION: Two production models of the 25-ton, 76mm Gun Tank T41E1 were examined. The T41E1 was an armored, full track-laying vehicle for transport by air, armed with a high velocity 76mm gun and two caliber .50 machine guns. The armor design differed from that of preceding 76mm gun tank series in that the side armor of the turret was changed from one inch at 10° obliquity to one inch at 30° obliquity. The great number of welded points on the frontal areas of the turret and hull were eliminated by using single large plates, the sides of the hull were redesigned, and the pistol port was eliminated.
CONCLUSIONS: In general, the ballistic protection provided by the 76mm Gun T41E1 was considered better than that of the M24 or the T37 tanks, and the changes incorporated in the redesign of the armor were considered advantageous. Protection against splash and land mines was considered inadequate, and modifications were recommended for the turret, gun shield, and hatches to prevent immobilization and give increased protection. Investigation of the use of mortise joints for welded corners was recommended.
GENERAL: This 63-page report contains 16 photographs of the T41E1 and components, 9 sketches including cross-sections of the tank, hull, and turret showing relative armor thicknesses and obliquities, and five vulnerability area diagrams.

SUBJECT: Armor APG TT2-725/17
TITLE: Ballistic Test of Plastic Domes (U) Armor Test Report No. AD-1225

IDENTIFICATION: Seventeenth Report on Ordnance Project No. TT2-725
DATE OF REPORT: 1 February 1956
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic qualities of mock-up plastic domes as compared to mock-up steel equivalent domes against various types of ballistic attack
METHOD: Ten domes, consisting of three white plastic, three green plastic, three plain steel, and one hardened steel, were subjected to tests against various small arms projectiles, fragmentation shells (Type 5HT), fragmentation hand grenades (MK-II), offensive hand grenades (MK-III A1) and Napalm.
DESCRIPTION: The white plastic domes, referred to as Type I, weighed 118 pounds each; the green, Type II, weighed 164 pounds each; the plain steel, Type III, weighed 128 pounds each; the hardened steel dome weighed 142 pounds.
CONCLUSIONS: The green plastic (Type II) domes and the white plastic (Type I) domes offered less protection than the steel domes. The green plastic dome offered a much higher level of protection than the white plastic dome. The hardened steel dome had a higher hardness which resulted in crackings and punchings under ballistic attack. Napalm burning on the surface of the plastic domes did not cause melting or burning of this type of plastic. The plastic domes did not compare favorably with an equivalent steel dome against various types of ballistic attack. It was recommended that the two types of plastic domes tested not be considered for use as a machine gun cupola if protection equivalent to steel was desired.
GENERAL: This 189-page report includes 41 photographs of the test setup and the various test domes before and after being subjected to ballistic attack.

SUBJECT: Armor APG TT2-760/1
TITLE: Test of the Escape Hatch Door in the 90-mm Gun Tank T48 Against the Twenty-Pound Explosive Charge (TNT) Antitank Mine
IDENTIFICATION: First and Second Memorandum Reports on Project No. TT2-760
DATE OF REPORT: 24 February 1953; 1 April 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effect of an antitank mine on a tank
METHOD: A T48 Tank was positioned in an open area with a wooden dummy in the driver's seat and a 125-pound sand bag on top of the dummy to simulate the weight of a man. A 20-pound antitank mine was placed below the driver's escape hatch, with approximately 17 inches between the top of the mine and the hatch. The mine was statically detonated.
DESCRIPTION: The test unit was a 90mm Gun Tank T48.
CONCLUSIONS: Considerable damage was done to the tank components including batteries, escape hatch, driver's seat, road wheel support, torsion bars, and electrical connections. The dummy was severely damaged. It was recommended that the damaged components be redesigned.
GENERAL: The two reports contain a total of 13 pages and 17 photographs.

SUBJECT: Armor APG TT2-760/26
TITLE: Ballistic Test to Compare the Protection Afforded by Seven Production Turret Body Castings for the 90mm Gun Tank M48
IDENTIFICATION: Twenty-sixth Report on Project No. TT2-760
DATE OF REPORT: 8 November 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate the protection provided by the test turrets against ballistic attack
METHOD: The protection ballistic limit criterion was used as a basis for all evaluations. Testing was conducted with 90mm, AP, T33 projectiles utilizing a direct frontal attack, a 30° obliquity off of the longitudinal axis, and a direct frontal attack on the area above the gun shield opening. The 76mm, APC, M62A1 and 57mm, AP, M70 projectiles were fired at 60° and 90° off of the longitudinal axis.
DESCRIPTION: The test turret body castings for the 90mm gun tank, M48, included Nos. 11 and 714, manufactured by the Continental Foundry and Machine Company; No. 207, manufactured by the Pittsburgh Steel Foundry Corporation; Nos. 39 and U534, manufactured by Union Steel Castings; No. 1526, manufactured by the General Steel Castings Corporation; and No. 423, manufactured by the Scullin Steel Company. Metallurgical data for these turrets were outlined in the report.
CONCLUSIONS: Test data indicated that the frontal areas of turrets Nos. 39 and 207 provided less protection against ballistic attack than any of the other test castings. The armor of turrets Nos. 11, 714, 534, 1526, and 423 exhibited adequate toughness and resistance to cracking. The side areas of the turrets were not thick enough to compensate for the low obliquity firing. Correction of this deficiency and thorough metallurgical studies of the turrets were recommended to aid in evaluation of armor to be used in future turrets.
GENERAL: This 153-page report contains 41 photographs showing the effects of testing on the turrets. Laboratory reports and firing records are also included.

SUBJECT: Armor BRL 112
TITLE: Proposed Experimental Program for Tank Vulnerability Study
IDENTIFICATION: Technical Note No. 112; Project No. TB3-1224B
DATE OF REPORT: August 1949
ORIGIN: Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland
PURPOSE: To establish a suitable procedure for obtaining armor vulnerability data which could be used as a reliable basis for determining the armor requirements of future tanks
METHOD: A study was initiated to determine the procedures necessary for accumulating armor vulnerability data. This included establishing a series of ballistic tests which were to be conducted on obsolete M24, M4A3, and M26 tanks while using 75mm M6, 2.36-inch and 3.5-inch HEAT, 105mm

HEAT; and 76mm and 90mm APC and HVAP projectiles. The type and number of vehicles and projectiles which would be required to accumulate sufficient and reliable vulnerability data were determined.
DESCRIPTION: Not applicable.
CONCLUSIONS: It was determined that extensive firing tests were required in order to accumulate enough vulnerability data for determining armor requirements of future tanks. In addition to determining armor vulnerability, injury to personnel and damage to interior mounted equipment, steering, suspension, electrical circuits, and engines were also to be assessed from the standpoint of initiating a tank kill. Though the report outlined a fairly comprehensive test procedure in determining the desired results, other details of the actual test procedure were to be determined as the result of the first firing tests.
GENERAL: This six-page report is not illustrated.

SUBJECT: Armor BRL 648
TITLE: Status of Explosive Armor Studies
IDENTIFICATION: Report No. 648; Project No. TB3-1224B
DATE OF REPORT: February 1953
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of explosive armor for defense against shaped charges
METHOD: Shaped charges were fired into explosive charges of 50/50 pentolite placed on stacks of mild steel plates and covered with a mild steel face plate. Various insulating layers between the explosive and the stack were tested. Tests were made with the explosive confined in cavities machined in a heavy steel plate and in welded boxes, with the explosive unconfined, and with various sizes and weights of explosive.
DESCRIPTION: The shaped charges consisted of DuPont jet tappers and 3.5-inch HEAT Rocket Heads, M28A2. The jet tappers contained two ounces of RDX and had a base diameter of 1.75 inches with an 80° cone of 0.025-inch copper. The rocket head contained 1.8 pounds of Composition B and had a case diameter of 3.08 inches with a 40° cone of 0.09-inch copper. Insulating materials used were 1/4-inch felt, 1/2-inch Celatex, and 1-inch Vermiculite.
CONCLUSIONS: With a confined explosive charge one-inch thick on the armor, the mean penetration of the jet tapper was reduced 63.9% from the penetration without explosive, and the mean penetration of the rocket head was reduced 40.3%. Use of insulation between the armor and the explosive to reduce backspalling also reduced the effectiveness of the explosive charge in defeating shaped charges. Confinement of the explosive increased its effectiveness in reducing jet penetration. Results of the experiments indicated that the effectiveness of unconfined explosives was a function of weight of explosive and was independent of the geometry of the explosive. It was considered that the use of explosives as armor was worthy of further consideration.
GENERAL: This 26-page report contains four drawings of test apparatus and arrangement, three photographs of test fixtures and backing plate, and three curves of test results.

SUBJECT: Armor BRL 755
TITLE: Possibilities for Increasing the Protection of the T165 Vehicle (ONTOS)
IDENTIFICATION: Report No. 755; Project No. TB3-1224B
DATE OF REPORT: December 1953
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To increase the protection offered by the armor on a T165 Vehicle
METHOD: Data were compiled from Watertown Arsenal Report No. 710/956 and curves were constructed to show the probable penetration of steel, aluminum, and titanium armor by cal. .50 AP projectiles fired at 0° elevation. The report and resulting curves concerned cal. .30 machine gun attack, various thicknesses of armor, and various angles of attack.
DESCRIPTION: The T165 Vehicle (ONTOS) was a low cost, highly mobile, front sprocket driven, full track laying, antitank vehicle. The vehicle carried six 105mm recoilless rifles as antitank weapons, two cal. .50 spotting rifles, and a cal. .30 machine gun. Armor on the vehicle was 1/2-inch homogeneous steel.
CONCLUSIONS: The probability-of-penetration curves indicated that the side, rear, turret, and lower front armor plates should be increased to 0.7 inch in thickness to provide satisfactory protection against small arms fire up to cal. .50. It was also indicated that the bottom, top, and upper front plates retain a 1/2-inch thickness. It was also suggested that substitution of titanium or aluminum for steel plate and increase of anti-personnel firepower would be beneficial.
GENERAL: This 21-page report is not illustrated.

SUBJECT: Armor BRL 803
TITLE: Analysis of HE Firings Against Light Armor
IDENTIFICATION: Report No. 803; Project No. TB 3-1224B
DATE OF REPORT: July 1954
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To determine damage to armor plate by PD-fuzed HE projectiles
METHOD: Information was compiled from APG firing record No. Ar-17714 in which 105mm HE Shell M1 was fired at armor plate at 0° obliquity. Information was compiled from an unpublished report on APG Project TB3-1224B in which 120mm HE Shell T15E1 and 155mm HE Shell M107 were fired at armor plate from 2° to 5° from normal. Information on fragment penetration was obtained from Army Field Forces Board No. 1 Report No. FA 748. Probability curves were established to determine the perforating potential of armor plate.
DESCRIPTION: The 105mm shell had been used

against rolled homogeneous armor plate with a Brinell hardness range of 300 to 363 and varying from 1/2 to 2-1/2 inches in thickness. The 120mm and 155mm shell had been fired against rolled homogeneous armor plate with a Brinell hardness range of 300 to 387 and varying from 3/4 to 1-1/2 inches in thickness. The projectiles were PD fuzed HE shells.
CONCLUSIONS: At least 1-1/2 inches of rolled homogeneous armor plate was required to provide protection against direct hits of any of the 155mm and 120mm HE shells. At least 1 inch of rolled homogeneous armor plate was required to protect against perforation from the 105mm shell. Protection against fragments from the 155mm and 120mm shells required one inch of armor and protection against fragments from the 105mm shells required 3/4 inch of armor.
GENERAL: This 11-page report is not illustrated.

SUBJECT: Armor BRL TN-469
TITLE: Present Status of the Tank Armor Program and Proposed Program for Development of Armor to Defeat HEAT and HEP Projectiles
IDENTIFICATION: Technical Note No. 469; Project No. TB3-1224B
DATE OF REPORT: July 1951
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To review the tank-armor development program for defeating shaped charges
METHOD: The armor development program proposed by the Ballistics Research Laboratory in August 1950 was reviewed and proposals for the future program were made.
DESCRIPTION: The development program covered investigations of the application of glass armor to steel, spiked armor, and explosive armor. Future investigations were to be made of Mycalex, Kaylo Plastic, Transite, Vermiculite, and natural materials (sand, gravel, and crushed rock). Other investigations were to include spaced armor, sandwich armor (layers of steel with nonferrous cores), and steel-backed aluminum.
CONCLUSIONS: Two contracts were let for the study of glass armor, and a contract was being negotiated to develop a method of attaching spikes to armor. Tests of sand, gravel, and crushed rock were in progress at BRL. Studies of both active and passive armor were to be continued.
GENERAL: This five-page report is not illustrated.

SUBJECT: Armor BRL TN-494
TITLE: Fitted Armor Penetration Laws for AP, APC and HVAP Ammunition
IDENTIFICATION: Technical Note No. 494; Project No. TB3-1224B
DATE OF REPORT: November 1951
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To determine penetration curves for armor piercing ammunition
METHOD: Ballistic data from two proving grounds were used to prepare penetration curves. A semi-empirical formula was used for fitting the data. Values which best fitted the data were found by minimizing the sum of the squares of the logarithms of the quotients of the experimental values and the values predicted by the empirical formula.
DESCRIPTION: The type of armor reviewed was rolled homogeneous steel. The types of projectiles reviewed were APC, AP, and HVAP. Calibers of the projectiles were .30 and .50; and 57, 75, 76, 90, and 120mm.
CONCLUSIONS: This report was a summary of data and therefore definite conclusions were not presented.
GENERAL: This 37-page report includes 29 ballistic limit charts and is not illustrated.

SUBJECT: Armor DA 9-20-54
TITLE: Silceous Cored Armor
IDENTIFICATION: Report No. 9-20-54
DATE OF REPORT: 20 September 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To evaluate the ballistic performance of siliceous cored armor
METHOD: The investigation of siliceous cored armor was divided into two programs. In the first program, the performance of various arrangements of fused silica plates under shaped-charge projectile attack was compared with the performance of similar arrangements of ordinary plate glass under similar ballistic attack conditions. A set of fused silica castings, comprising various thicknesses and arrangements of front armor, silica core, and back armor, was made up and tested with shaped-charge projectiles at 0° and 60° obliquity. In the second program, various thicknesses and types of siliceous cored armor together with solid castings used as controls, were tested with several types of kinetic energy projectiles at various obliquities. The data from those tests were compared with similar data obtained on armor of similar heats and also with solid armor data obtained under previous armor programs.
DESCRIPTION: The fused silica castings used in the shaped-charge ballistic tests were 6 inches thick; the front and rear armor sections varied from 1 to 3 inches in thickness, and the fused silica cores varied from 2 to 4 inches in thickness. The fused silica castings used in the kinetic energy ballistic tests were 4, 6, and 8 inches thick; the front and rear armor sections varied from 1 to 5 inches in thickness, and the silica cores varied from 1 to 4 inches in thickness. The shaped-charge projectiles employed a 3-inch standoff and were fired from a commercial type jet gun manufactured by the Jet Gun Company of Fort Worth, Texas. The kinetic energy projectiles were of the following types: 57mm APC M86, 76mm APC M62A1, 90mm AP T33, 90mm HVAP M304, 90mm HEP, and 120mm AP T116E4.
CONCLUSIONS: Test results indicated that siliceous cored armor was potentially a practical and effective armor against shaped-charge, high-explosive plastic, and kinetic energy projectiles. Further development, however, was recommended. The siliceous cored armor castings did not perform as

well as geometrically similar unconfined arrangements of armor and fused silica. This difference in performance was believed due to core cracking either in the casting process or in subsequent heat treatment. Tests at high velocity showed that cored armor did not provide protection in the same order of magnitude as that provided at normal incidence. Thick fused silica was not as effective in stopping jets as stacked thin plates of equivalent thickness. It was believed possible that the cored armor might be improved to the point where, at normal and at oblique incidence, one inch of silica would provide as much protection against shaped-charge attacks as 1-1/2 to 2 inches of solid armor.
GENERAL: This 35-page report contains six pages of drawings, five pages of graphs, and four pages of photographs.

SUBJECT: Armor DA 13210/A
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: First Quarterly Progress Report; DA-20-018-ORD-13210
DATE OF REPORT: 2 December 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To investigate methods and materials for defense against shaped-charge attack
METHOD: Hard laminated steel set at an angle to the path of the jet, water cells, hardened steel balls, and various combinations of integrally cast, fused silica plates were subjected to shots with 3.5-inch rockets and jet tappers at various obliquities. Analysis of the jet penetration in the various substances was attempted by high-speed oscillographic measurements. An analytical study of the theoretical mechanics of jet formation and penetration was begun. Testing was conducted at Michigan State College.
DESCRIPTION: The hard laminated steel tested consisted of 11 hardened hacksaw blades separated by cardboard. The fused silica plates were cast in steel casings. No description of the water cells was given. "Herculite" steel balls in containers were used in this test.
CONCLUSIONS: Preliminary investigation indicated that hard laminated steel set at an angle to the path of the jet offered some promise of providing a defense mechanism. Water cells appeared to be effective, but the data were too incomplete to permit drawing any final conclusions. Tests with the steel balls appeared to confirm previous findings that they had a ballistic effectiveness against jet tappers of 2.4 times that of solid mild steel, on a density basis. Work on other phases of the investigation was not yet complete enough for evaluation.
GENERAL: This 33-page report contains three pages of photographs and eight pages of sketches and graphs.

SUBJECT: Armor DA 13210/B
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Report No. 13210/B; Second Quarterly Progress Report
DATE OF REPORT: 2 March 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the suitability of various materials for use in defense against attack by lined shaped charges; to determine the velocity of the front end of a jet tapper
METHOD: Various materials proposed for use in defense against shaped-charge jets were ballistically tested with 3.5-inch lined shaped-charge rockets. The velocity of a shaped-charge jet was measured by an oscillograph having a special timing circuit. All testing was conducted at Michigan State College.
DESCRIPTION: The test materials consisted of Herculite hardened steel balls of various diameters, a prototype tank turret protective pad made up of three layers of 2-inch hardened steel balls and backed by a 4.5-inch homogeneous armor plate, hardened laminated steel plates, and water cells. A spring-loaded defense mechanism was studied from a theoretical viewpoint.
CONCLUSIONS: Hardened steel balls were found to be very effective against shaped-charge jets. On a density basis, 2-inch balls were 2.4 times as effective in stopping a shaped-charge jet as mild steel. The prototype tank turret protective pad was found to be reasonably effective against the shaped-charge jet. It was discovered that the laminated plates were more effective against the front end of a jet than the back portions. Jet resistance results obtained with the water cells were inconsistent. In view of the large number of variables involved, further studies on the water cells were not believed economically feasible in current work. It was believed that the spring-loaded device proposed for use against shaped-charge jets would be almost impossible to devise with the spring materials currently available. The velocity of the front end of a jet tapper was found to be about 18,000 fps. A theoretical method was devised which would permit the determination of the pressures and energies transmitted to and expended in a penetrated jet defense material.
GENERAL: This 109-page report contains two photographs.

SUBJECT: Armor DA 13210/C
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Report No. 13210/C; Seventh Monthly Progress Report
DATE OF REPORT: 2 April 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine whether jet energy could be absorbed or dispersed by Herculite hardened steel balls; to determine the suitability of a prototype protective pad for use in defense against shaped-charge jets
METHOD: A frame was designed to support hardened steel balls in a series of predetermined fixed positions with respect to jet tappers. The jet dispersion or absorption characteristics of the various ball arrangements was determined by observations of the jet penetration patterns formed in a fixture base plate placed behind the balls. In addition, ballistic tests were conducted on a prototype pad using 3.5-inch lined shaped-charge rockets. The suitability of a modification made to the circuits of an oscillograph timing device used in recording ve-

locities of shaped-charge jets in earlier tests was also evaluated. All testing was conducted at Michigan State College.
DESCRIPTION: Ball combinations tested against shaped-charge jets included two balls set in a line with the jet, ball combinations offset from the jet path in various ways and three balls set in a line with the jet. The prototype protective pad contained Herculite hardened steel balls stacked in various layers; the layer combinations including hexagonal packing arrangement and a face-centered packing arrangement.
CONCLUSIONS: Three balls set in line with the jet path effectively prevented penetration of the shaped-charge jet into the fixture base plate. Various offset ball combinations were found to deflect the shaped-charge jet. Studies indicated that the method used in stacking the steel balls in the prototype pad was an important consideration in effectively preventing jet penetration. Extremely low jet penetration resistance was obtained when the balls were packed in a hexagonal arrangement, whereas face-centered packing of the balls increased the jet penetration resistance characteristics of the pad. However, when the pad was warped as the result of additional impacts, it was found that the jet resistance of the face-centered packing arrangement dropped considerably. More work was to be conducted on the prototype pad in order to determine the most satisfactory method of packing the steel balls. The modification made to the oscillograph timing device circuits greatly improved the performance of the device as used in the investigation of jet phenomena.
GENERAL: This 27-page report is not illustrated.

SUBJECT: Armor DA 13210/D
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Eighth Monthly Progress Report; DA-20-018-ORD-13210
DATE OF REPORT: 2 May 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the suitability of various materials for use in defense against shaped-charge jets; to determine the suitability of improvements made to an oscillograph device used to measure the velocity of shaped-charge jets
METHOD: A series of jet deflection studies were conducted on various materials proposed for use in defense against attack by shaped-charge jets. The materials were set in jigs, which kept the surfaces of the materials at various positions relative to the path of the shaped-charge jets. The suitability of the various materials for use in deflecting a jet was determined by noting the pattern and depth of residual penetrations into mild steel plates placed behind the test materials. An oscillograph timing device was used to measure the velocity of shaped-charge jets during the course of testing. All testing was conducted at Michigan State College.
DESCRIPTION: The test material consisted of Ketos tool steel blocks, 2 and 3-inch Herculite hardened steel balls, hardened steel deflecting cones, and hardened steel laminates.
CONCLUSIONS: All the test materials were found satisfactory in deflecting jets. Materials with large surface areas deflected jets more effectively than did the same materials with small surface areas. Materials of high hardness provided greater resistance to jet penetration than did softer materials. It was felt that improvements made to the oscillograph timing device would enable personnel to improve their study of the fundamental aspects of jet behavior.
GENERAL: This 28-page report contains five photographs showing various materials tested.

SUBJECT: Armor DA 13210/E
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Report No. 13210/E; Third Quarterly Progress Report
DATE OF REPORT: 2 June 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To summarize the results of the research studies conducted on materials used for defense against shaped-charge jets; to determine, analytically, whether oblique angle surfaces would aid in improving the jet resistance characteristics of proposed defense materials
METHOD: An account was given of the main research developments during the 3-month period from 2 March to 2 June 1954. In addition, the kinematics of a jet, the force exerted by the jet on a target, and the conditions of deformation and stress in a target were analytically determined for a target material set at an angle to the path of a shaped-charge jet. All testing and studies were conducted at Michigan State College.
DESCRIPTION: The jet-resistance materials considered in this summary included Herculite hardened steel balls, various sizes of hardened tool steel, and a prototype protection pad made up of Herculite steel balls and armor plate.
CONCLUSIONS: Experimentation revealed that Herculite steel balls would satisfactorily deflect a shaped-charge jet. The jet resistance characteristics of the prototype pad were satisfactory; however, additional study was considered necessary before the pad could be considered suitable for use as a jet defense material in actual application on a vehicle. The analytical study revealed that a defense material set at a sufficiently high angle of obliquity could reduce the maximum force of a jet to a point at which the material would be capable of withstanding the ballistic effects of the shaped-charge jet. In addition, the study revealed the possibility of defeating the shaped-charge jets by the following means: by arranging a defense material in layers, which would be capable of absorbing the diminishing force of the jet (with respect to time); and by selecting materials which would afford alternate stress-wave damping and energy-absorbing characteristics.
GENERAL: This 81-page report contains seven pages of photographs showing various materials used in testing.

SUBJECT: Armor DA 13210/F
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Final Report; DA-20-018-ORD-13210

DATE OF REPORT: 2 July 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To develop defense mechanisms to withstand the penetration of the lined shaped charge
METHOD: Various armor arrangements were subjected to ballistic attack by shaped charges. Oscilloscope measurements were made of jet phenomena. A theoretical analysis of jet behavior was presented. This work was done by the Michigan State College.
DESCRIPTION: The armor arrangements were made up from the following materials: Herculite grinding balls, alloy steel solid armor, water cells, fuzed silica cast in steel, and hardened steel laminates.
CONCLUSIONS: Use of Herculite balls enclosed in small containers as armor indicated that this type of defense had weight and space saving possibilities. The strength minimum as measured by the size of the target was about 6 x 6 inches in frontal area, and the hardness minimum about 55 Rockwell C. It was believed that by utilizing the compressibility of water in small-bore open tubes, a defense mechanism as effective as steel, inch-for-inch, could be produced. When using hardened steel laminates for armor defense, it was found that the first lamination was much more effective than succeeding ones. Indications were that jets were deflected by high angle hardened surfaces. It was found that a jet was slowed by 5000 fps from 18,000 fps after penetrating through six inches of steel. It was found that the pressure and energy of a jet during penetration through mild steel could be calculated from graphs, that no significant reduction of penetration by spring action was possible, and that high-angle targets might prove effective against the latter portion of the jet if suitable material was used.
GENERAL: This 52-page report contains 18 photographs of failed armor and many charts and calculations in support of the conclusions.

SUBJECT: Armor DA 13210/G
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Fourth Monthly Progress Report; DA-20-018-ORD-13210
DATE OF REPORT: 2 November 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the effectiveness of silica in affording protection against shaped charges
METHOD: Silica and steel combinations and unconfined silica were fired into by jet guns using shaped charges. Comparative resistance characteristics were determined. This project was conducted by Michigan State College.
DESCRIPTION: Eleven samples were 6 x 6-inch silica cores 1 inch thick and cast into S.A.E. 1030 steel walls 1 inch thick. The other test samples were unconfined 6 x 6-inch silica blocks 1 inch thick with 1-inch thick steel cover plates.
CONCLUSIONS: In the tests on silica cores, it was found that one inch of silica offered as much resistance to jets as 3.79 inches of steel. The one-inch thick unconfined silica blocks offered 2.5 times as much resistance as three 2-inch thick blocks on an inch-for-inch basis; and the resistance of 2-inch thick silica blocks was 1.75 times as great as that of the three 2-inch blocks, also on an inch-for-inch basis.
GENERAL: This 28-page report contains computations and graphs in support of the conclusions.

SUBJECT: Armor DA 13210/H
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Fifth Monthly Progress Report; DA-20-018-ORD-13210
DATE OF REPORT: 2 December 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the effectiveness of oil-filled cylinders and silica-steel combinations as defense against lined shaped charges, and to determine which of three variables had little or no effect on resistance-to-penetration
METHOD: Oil-filled cylinders and silica-steel blocks were subjected to attack by jets and 3.5-inch rockets. A material study, started previously, was continued to determine which of three variables had little or no effect on resistance-to-penetration. This project was conducted by Michigan State College.
DESCRIPTION: The oil test specimen used for jet gun fire was an oil-filled cylindrical hole 1 inch in diameter surrounded by a 3/4-inch steel wall with an inch of steel at top (screw plug) and bottom. A 2-inch diameter hole surrounded by 1-1/2-inch wall with an inch of steel at top and bottom was used for the tests with the 3.5-inch rockets. The silica-steel combination consisted of three 6 x 6-inch silica blocks 2 inches thick separated by 1/2-inch steel plates and surrounded by one inch of cast steel. The three variables in the material study were toughness, hardness, and strength.
CONCLUSIONS: During the oil tests, as the depth of oil was increased from zero to approximately 7 inches, the effectiveness (resistance-to-penetration) of the cylinders decreased, the effectiveness ranging between 3 and 1.5 times that of mild steel. Of the three variables studied, toughness had little or no effect on resistance-to-penetration. One shot fired into the silica-steel specimen showed this specimen to be 1.33 times as effective as steel with respect to shaped-charge defense.
GENERAL: This eight-page report includes two graphs and two tables in support of the conclusions.

SUBJECT: Armor DA 35608/A
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: First Monthly Progress Report; DA-20-089-ORD-35608
DATE OF REPORT: 10 November 1952
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To describe the status of the project on armor defense against lined shaped charges and to present information on the available relevant literature
METHOD: A summary was given of recent work done on the project. A condensed resume was given of available literature, together with abstracts and a few preliminary suggestions or plans. This study was performed by Michigan State College.
DESCRIPTION: The resume and abstracts cov-

ered experimental techniques and data on lined shaped charges, derivation of the theory of jet formation and penetration, and defense against jet penetration.
CONCLUSIONS: Two Chamberlain shock absorption piles and one hundred duPont jet tappers had been ordered for possible use in tests, and a correlation table of all known possible fundamental factors affecting jet penetration was being compiled. Investigation of the literature showed that Kerr cell apparatus had been used to compare the jet velocities of copper and aluminum liners. Experiments had been made to determine the effects of variations in the quantity and distribution of explosive charge, core liner angles, and stand-off distances of lined shaped charges. The theory of jet formation based on simple hydro-dynamic theory had been shown to be inadequate and had been revised to take into account unsteady state conditions. Bethe's theory of penetration by projectiles was believed inadequate. A more direct method of measuring collapse angle velocities had been sought by investigating the wave release theory. Spikes on armor, and glass plates and blocks had been found to provide greater protection against shaped charges than screens, explosive tank linings, oxidizing agents in linings, spaced armor, or skirting plates.
GENERAL: This unillustrated 51-page report contains 41 pages of abstracts of literature relevant to the project.

SUBJECT: Armor DA 35608/B
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Second Monthly Progress Report; DA-20-089-ORD-35608
DATE OF REPORT: 10 December 1952
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the effects of shaped charge penetrations on armor steel areas adjacent to penetration cavities; to determine the suitability of various types of defense against shaped charges
METHOD: A metallographic examination was made of the areas adjacent to a shaped charge penetration into a piece of machinery steel. Shaped charge jets were fired against various types of chemical compounds, glass and plastic plates, and a type of electrical condenser designed to vaporize or spread the jet. The effectiveness of these materials as a means of defense against shaped charges was determined by the amount of shaped-charge residual penetration into backing plates. This study was performed by Michigan State College.
DESCRIPTION: The machinery steel examined metallographically was Type SAE 1030 mild steel. The chemical compounds consisted of samples of pure ammonia nitrate, 40% Atlas dynamite, cuprix oxide and aluminum powder mixture, and red iron and aluminum oxide mixture. The armor plates consisted of combinations of glass plates backed by Chamberlain piles, and plastic and glass cloth and fiber combinations. The electrical condenser charged two 1/4-inch steel plates.
CONCLUSIONS: The metallurgical examination results indicated that penetration had been accompanied by temperatures above the melting point of the copper alloy liner. Marked deformation as far as 0.5-mm from the cavity wall was noted. Normal pearlite had been transformed and replaced by martensite to a depth of 0.2 mm. The tests on chemical defense indicated that chemical reaction rates of the order of exploding dynamite were required. The glass plates backed by Chamberlain shock absorbing piles appeared to have some defensive merit, but the combinations of plastic impregnated glass cloth and mat offered little resistance to penetration. The test on the electrical condenser yielded negative results, but further study of this defense was recommended.
GENERAL: This 17-page report contains two pages of tabulated firing data and seven pages of photographs and microphotographs of the test material.

SUBJECT: Armor DA 35608/C
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: First Quarterly Progress Report; DA-20-089-ORD-35608
DATE OF REPORT: 10 January 1955
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To review work done over a three month period on the project "Defense Against Lined Shaped Charges"
METHOD: A summary was given of research and testing performed over the testing period. The methods of research and testing used for most of the work performed were described in Report Nos. DA 35608/A and DA 35608/B. In addition to the work covered by these two reports, a plan was presented for entering data in a concordance. A summary report was also given on a conference held at the Aberdeen Ballistics Research Laboratory on current and proposed methods of defeating non-kinetic energy projectiles. This study was made by Michigan State College.
DESCRIPTION: The test material and research information investigated over the period reported on were described in Report Nos. DA 35608/A and DA 35608/B. The tentative concordant headings were Effect on Target, Resisting Media, Operational Conditions, Characteristics of Round, and Source. The conference at Aberdeen Ballistics Research Laboratory was held on December 19, 1952 and covered explosive defense, Flintkote reports, and Army stand-off plates.
CONCLUSIONS: The conclusions obtained as a result of research and testing over the period covered by this report were given in Report Nos. DA 35608/A and DA 35608/B. It was suggested that a pilot study be made of the possible usefulness of the concordance prior to developing its final form. Several sample representative headings were given to illustrate the principle of the concordance. In the conference at Aberdeen Laboratory, it was reported that arrangements of angle irons on tank armor provided effective defense against shaped charge attack from oblique shots but not from direct hits. Spike arrangements being investigated at Frankfort Arsenal showed some promise. An investigation on defense by means of a spinning disk was underway at Picatinny Arsenal, but no results had been reported. Flintkote reports indicated that

for glass, maximum effectiveness, in comparison to steel armor defense, was obtained with 5-inch glass. Little value was attached to the use of asphalt and gravel.
GENERAL: This unillustrated 78-page report contains considerable material previously covered in Report Nos. DA 35608/A and DA 35608/B.

SUBJECT: Armor DA 35608/D
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Fourth Monthly Progress Report; DA-20-089-ORD-35608
DATE OF REPORT: 10 February 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the suitability of various devices for protection against shaped charge jets
METHOD: A number of protective devices were tested for use against attack by shaped charge jets. In these tests, the protective devices were placed on the surface of layers of armor plate. Shaped charges, positioned at a standoff distance of 4-1/4 inches from the protective device, were statically detonated. The protection afforded by the various devices was evaluated on the basis of the depth of penetration of the shaped charge jet into the supporting armor. Testing was conducted at Michigan State College.
DESCRIPTION: The test shaped charge protective devices included steel rollers mounted in journals, ball bearing assemblies, steel balls of various sizes contained in pipe nipples, steel water cells made up of alternate layers of steel and water, alternate layers of glass, steel, and Chamberlain piles, spring steel leaves supported at the ends, and cylindrical rod combinations supported at the ends.
CONCLUSIONS: The shaped charge jet was most effectively defeated by steel balls contained in pipe nipples. In general, larger diameter (7/8 and 1-1/4-inch) steel balls were more effective in resistance to the jet than were smaller diameter (3/8 and 1/2-inch) steel balls. Alternate layers of armor, glass, and Chamberlain piles provided good protection against shaped charge jets. Steel water cells provided reasonably good protection against shaped charge jets.
GENERAL: This six-page report is not illustrated.

SUBJECT: Armor DA 35608/E
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Fifth Monthly Progress Report; DA-20-089-ORD-35608
DATE OF REPORT: 10 March 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the effectiveness of various types of defense against lined shaped charges
METHOD: Jet tappers at various positions of standoff were detonated against various charges of explosive cells and against steel balls and bars. The effectiveness of the explosive cells, steel balls, and steel bars was determined by the amount of residual penetration of the jet tappers. This project was conducted by Michigan State College.
DESCRIPTION: The test material used for defense against the jet tappers consisted of explosive cells filled with 60% dynamite, thorough-hardened and case-hardened steel balls, and round bars of tool and of cold-rolled steel.
CONCLUSIONS: Explosive cells, with a dynamite thickness of slightly over 1 inch, effectively dispersed jets detonated at normal standoff. Variations of standoff with a constant thickness of dynamite gave somewhat erratic results, but an appreciable decrease in residual penetration resulted when standoff was increased from 4-1/4 inches to 7-1/4 inches. It appeared that in designing a triggered explosive cell, a minimum or critical thickness of explosive must be used to defeat the jet, and that spacing of the trigger plate with respect to the cell should depend only upon the time delay of the triggered circuit. The firing tests on the steel balls and bars were considered inconclusive. The through-hardened balls shattered upon impact into jagged particles and were reasonably effective in retarding jet progress. The case-hardened balls shattered in a thin surface layer only, exhibiting a fibrous or woody fracture throughout their interior, and they were inferior to the other balls in stopping the slug. The firing tests on the round tool steel and cold-rolled steel bars of comparable hardness reproduced the same shatter versus fibrous fracture action and the same total penetration pattern as was observed in the through-hardened versus case-hardened steel ball tests.
GENERAL: This unillustrated six-page report contains a three-page firing table summary.

SUBJECT: Armor DA 35608/F
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Seventh Monthly Progress Report; DA-20-089-ORD-35608
DATE OF REPORT: 10 May 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the effectiveness of various types of defense against lined shaped charges
METHOD: The effectiveness of layers of round steel balls as a defense against jet tappers was compared with that of mild steel by means of a correlation study of test data for both types of defense. The effect of the number of ball layers and of the tightness of packing of the balls was evaluated by firing jet tappers at various arrangements of the balls. A few jets were fired through highly charged electrical condensers from various amounts of standoff. This study was conducted by Michigan State College.
DESCRIPTION: The calibration study was based on an analysis of total steel penetration, jet tapper calibration penetration, and ball layer thickness. The test ball arrangements consisted of arrangements of single and double balls placed in cylindrical cavities of steel, and arrangements of balls in paper cups placed in pipe nipples (with caps). The test condensers were connected in series with ultra-arc caps embedded in dynamite.
CONCLUSIONS: The results of the correlation study indicated that the weight effectiveness of the steel balls against the jet tappers was 2-3/8 that

of mild steel. In the tests of the various ball arrangements, the performance of the two-ball arrangements seemed to fit very well the correlation curve for balls. Little difference could be noted between firing into the single ball setups on a radius or on a chord. The variable of tightness of packing of the balls was not considered of consequence. The tests on the electrical condensers were considered inconclusive due to the small number of shots and the poor quality of some of the arc caps.
GENERAL: This unillustrated five-page report contains a two-page firing summary.

SUBJECT: Armor DA 35608/G
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Eighth Monthly Progress Report; DA-20-089-ORD-35608
DATE OF REPORT: 10 June 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the effectiveness of various types of defense against lined shaped charges
METHOD: Jet tappers were fired at balls of a proprietary alloy known commercially as Herculite, at an armor plate box consisting of alternate layers of glass and ensolite, and at a triggered dynamite cell. The performance of these targets was indicated by the amount of penetration of the jet tappers. This study was conducted by Michigan State College.
DESCRIPTION: The Herculite balls were of the type used in coal pulverizing and grinding mills and were being investigated as a more economical source of hard balls than ball bearings. The armor plate box materials were 7/8-inch polished plate glass and 1/4-inch ensolite.
CONCLUSIONS: The shots made on the Herculite samples resulted in residual penetrations comparable to those obtained with ball bearing type steel balls. In the first shot on the armored box, the box provided greater protection than that typical for mild steel. On successive shots, the residual penetrations progressively increased. It was believed that this decline in performance may have been due to progressive deterioration of the single sample available. The results of the tests on the triggered dynamite cell were considered inconclusive. It was decided that the arc firing circuit needed overhaul and design changes and that the mechanism of closing the electrical circuit with the jet formed by jet tappers should be investigated.
GENERAL: This unillustrated five-page report contains a two-page firing table summary.

SUBJECT: Armor DA 35608/H
TITLE: Defense Against Lined Shaped Charges
IDENTIFICATION: Third Quarterly Progress Report; DA-20-089-ORD-35608
DATE OF REPORT: 10 July 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To review the work done over a three month period on the project entitled "Defense Against Lined Shaped Charges"
METHOD: The review was organized into four main sections covering mechanical tests, literature review, chemical tests, and application tests. A general summary followed by a more detailed discussion was given on each of these topics. This study was performed by Michigan State College.
DESCRIPTION: The mechanical tests consisted of jet tapper firing tests on blocks of hardened tool steel and on various arrangements of hard steel and hard alloy cast iron balls. The literature review consisted of an investigation of the sources of information available at the Air Service Technical Center at Dayton, The Library of Congress at Washington, and Aberdeen Proving Ground. The chemical tests consisted of jet firing tests on a dynamite cell fired by an ultra-speed arc-fired cap connected in series with a charged condenser-bank and a pair of triggering plates separated by sheet rubber. The application tests consisted of jet firing tests on sandwich-type assemblies of metallic and non-metallic materials.
CONCLUSIONS: The results of the mechanical tests indicated that a combination of hardness and strength or of hardness and size was necessary to reduce jet effectiveness; that certain combinations of steel balls were 2-3/8 times as effective as comparable weight solid mild steel; and that greater armor effectiveness was noted when jets encountered junctions of balls rather than hitting them directly. The literature review showed that the Library of Congress abstracted bibliography on shaped charges was being brought up to date and that a system similar to the Michigan State College concordance system was being developed for use in similar literature situations by an outside agency. In the chemical tests erratic results had prompted additional work on electrical timing circuits. The results of the application tests indicated that a glass and ensolite combination offered promise as a shock absorbing combination for one-round attack, and that combinations of cast steel and quartzite or pyrex gave a ballistic performance superior to that of solid cast steel.
GENERAL: This 50-page report contains 36 pages of tabulated data and graphs.

SUBJECT: Armor DA 35608/J
TITLE: Defense Against Shaped Charges
IDENTIFICATION: Final Report; DA-20-089-ORD-35608
DATE OF REPORT: 10 August 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To summarize the work done on the project entitled "Defense Against Shaped Charges"
METHOD: The work done on the project was organized under five main headings: Mechanical, Electrical, Chemical, Literature, Review, and Pilot Testing. A general summary and detailed discussion were given under each of these headings. This work was done by the Michigan State College.
DESCRIPTION: Descriptions of specific test materials, procedures, and tests were given in Report Nos. DA 35608/A through H.
CONCLUSIONS: One-inch hardened steel balls appeared to offer greater resistance to jet tappers than any other mechanical system tested. Counter explosive investigation showed that jets fired

through charged trigger plates could be used to close electrical circuits. While it appeared somewhat impractical to store sufficient energy in an electrical condenser to vaporize the jet, it was believed possible to store enough energy to disturb the direction of the particles sufficiently to render ineffective the penetrating power of the jet. Chemical tests indicated that any defense mechanism involving chemical reactions must have a reaction rate of explosive dimensions. In the pilot testing, integral cast quartzite in steel gave the most promising results. It was recommended that a detailed concordance be prepared on all literature to enable an intelligent evaluation of the subject.
GENERAL: This 77-page report contains 44 pages of graphs and tabulated data. Much of the information presented in this summary report is a repetition of the material given in Report Nos. DA 35608/A through H.

SUBJECT: Armor DA 36871/1
TITLE: Establishment of the Properties of Glass and Silicious Cored Armor for Defeating Shaped Charges
IDENTIFICATION: Report No. DA 36871/1
DATE OF REPORT: 30 June 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To investigate the properties of silicious cored armor for defeating shaped charges
METHOD: This investigation was divided into the following sections, each of which included tests and evaluation of results: General Properties of Jet Guns, Unconfined Glass and Silica, Armor with Silica Cores, Glass Against Various Shaped Charge Designs, Target Materials Other than Glass, Flash X-ray Pictures, Penetration Velocities in Glass Targets, Lethality, and Miznay-Schardin Mines. This work was done by Carnegie Institute of Technology.
DESCRIPTION: The Jet Gun charge used in most of the experiments was manufactured by Jet Guns Company. The second Section of this report was devoted to the target properties of unconfined fused silica for the purpose of determining whether confinement of the silica in cast armor would produce improvement or deterioration in its performance. In the third section, cored armor, made by casting steel armor around a block of fused silica, was tested with shaped charges fired statically at normal incidence and at 60° obliquity. The fourth section was concerned with correlating the stopping power of glass and the penetration into mild steel of various shaped charge designs. In the fifth section, target materials other than glass were tested: Formica FF-55, Duriron, (a cast mixture of iron and silica), and Vega bricks (a refractory brick having a very high silica content). Section six included X-ray photographs of the nature of the normal lengthening and breakup process for a jet in air, the normal effect of a mild steel target upon the jet, and the abnormal effects of glass upon a jet. In section seven, a simple model, based on present knowledge of the action of glass, was used to estimate the time interval between initial loading of the glass and the resulting disturbance of the jet. Several types of liners were tested in section eight to assess the damage produced behind a glass-containing target. The effectiveness of glass and formica as protection against the Miznay-Schardin mines was studied in the last section.
CONCLUSIONS: The material presented in the report showed clearly that armor cast by standard methods around a core of fused silica was very effective in defeating shaped charges. A report to be issued by APG would show that such protection was also effective against standard kinetic energy rounds. In spite of the weight and/or thickness savings made possible by using cored armor instead of standard cast armor, this type of protection was not yet perfected to the point of optimum efficiency. Armor with silica cores did not perform quite as well as comparable armor using unconfined silica. As core thickness increased, this difference in performance decreased. Tested at high obliquity, cast armor did not perform as well as it did when tested at normal incidence, although the degradation due to obliquity was less than that which was observed with unconfined silic .
GENERAL: This 81-page report includes appropriate tables, graphs, and illustrations at the end of each section.

SUBJECT: Armor DA 36871/2
TITLE: Defeat of Shaped Charge Weapons
IDENTIFICATION: Report No. 36871/2
DATE OF REPORT: 31 December 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To present information on various types of armor for defense against shaped charge projectiles
METHOD: The material on armor defense against shaped charge projectiles was organized under three chapter headings: Introductory Survey, Targets Other than Cored Armor, and Cored Armor.
DESCRIPTION: The introductory survey consisted of a qualitative over-all view of the most important results obtained thus far on Contract DA-36-089-ORD-36871. The chapter on targets other than cored armor consisted of a discussion of unconfined silica and water cells as possible armor materials. The chapter on silicious cored armor consisted of a discussion of cast steel cored armor, woods metal-steel fabricated armor, cast aluminum silica cored armor, and the effects of heat treatment and non-symmetric core location on cored armor performance.
CONCLUSIONS: Cored armor panels of large areal dimensions were found to be less effective than smaller panels of identical cross section. Core performance appeared to be seriously degraded when the core occupied an off-center position in the armor. Cored armor in the as-cast condition performed better against shaped charges than similar armor that had been heat treated. Properly confined silica gave a ballistic performance superior to that of unconfined silica. Although the data were considered too few for definite conclusions, it appeared that Woods metal-steel, cast aluminum, and cast steel cored armor ranked in performance in that order, presumably because core damage became more severe in that order. Although the Woods metal-steel cored targets, presumably without core

compression, gave the best performance, the possibility of increased effectiveness resulting from the core being under "hydrostatic" compression, was not ruled out.
GENERAL: This 40-page report contains 13 pages of tabulated data, two pages of drawings, and one page of graphs.

SUBJECT: Armor OCO 245
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245; Monthly Progress Report
DATE OF REPORT: 26 September 1951
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine which of two types of armor arrangements would be most suitable for use as protection against attack by shaped-charge jets
METHOD: DuPont jet tappers, each consisting of a 2-ounce explosive enclosed in a Durez plastic case with a copper cone liner embedded in the explosive charge, were electrically detonated against stacks of 1-inch mild steel plates from various standoff distance for the armor ballistic tests. A series of jets were then fired into these plates from optimum standoff distance. The average depth of penetration of the jets into the mild steel was taken as a standard for evaluating various armor arrangements. Two types of armor arrangement were placed over stacks of the 1-inch mild steel plates and jet tappers were detonated against each of these arrangements from optimum standoff distance. The average jet penetration depth under each set of test conditions was used to indicate the performance of the armor arrangements. All testing was conducted by the Flintkote Company.
DESCRIPTION: One of the two test armor arrangements consisted of stacks of 1/2-inch plates of untempered polished glass covered with a 1/4-inch mild steel plate; the other was a spaced armor arrangement consisting of a 1/4-inch plate set at a distance of 3 inches from the stacked plates.
CONCLUSIONS: The best shaped charge jet protection was obtained with the stacked plate glass arrangement. The average jet penetration into the stacked 1-inch mild steel plates protected by 3 inches of glass was 2.21 inches as compared to an average penetration of 5.95 inches using the spaced-armor arrangement. The average shaped-charge jet penetration into unprotected stacked 1-inch armor plate was 6.93 inches.
GENERAL: This 28-page report contains 10 pages of photographs showing the appearance of armor plate penetrated by shaped charge jet. DA-30-069-ORD-245 Monthly Progress Reports dated 26 October 1951 through 26 January 1952 are also included in the enclosing cover of this report.

SUBJECT: Armor OCO 245(F)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(F); Final Report
DATE OF REPORT: 1 July 1953
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To summarize the results of an extensive investigation on the suitability of several types of armor arrangements for use as protection against attack by shaped-charge jets
METHOD: A review was made of the most important aspects of the investigation and a listing and discussion were given of the general conclusions and recommendations. These studies were conducted at the Flintkote Company during the period of 26 September 1951 through 26 February 1953.
DESCRIPTION: The investigation covered studies on the ballistic performance of glass, gravel, 24ST aluminum, ceramic and plastic materials, silicon, zirconium, magnetized steel, and various other materials.
CONCLUSIONS: Glass and gravel appeared to provide the best resistance to jet penetration characteristics of all the materials tested. With respect to the ability to resist jet penetration, both glass and gravel were superior to steel on a weight and thickness basis. Equations were developed which could apparently be used to correlate data on any type of protective material used against shaped-charge jets. It was believed that a number of additional studies, as listed in the report, should be conducted.
GENERAL: This 38-page report is not illustrated. A comprehensive index to all materials tested during the testing period is included in the report.

SUBJECT: Armor OCO 245(1)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(1); Monthly Progress Report
DATE OF REPORT: 26 October 1951
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the suitability of several types of armor arrangements for use as protection against attack by shaped-charge jets
METHOD: A series of tests were conducted on several types of armor arrangements set on separate stacks of 1-inch mild steel plates. DuPont shaped charges were electrically detonated against each armor arrangement from a 4-1/4-inch standoff. The average penetration of the shaped-charge jets into the stacked 1-inch plates was taken to indicate the performance of each type of armor arrangement. All testing was conducted by the Flintkote Company.
DESCRIPTION: The materials used in the armor arrangements included polished plate glass, rough rolled plate glass, X-ray lead glass, polished wire glass, alternate layers of polished glass and Tuflex, layers of polished plate glass separated by Flintseal, alternate layers of rough rolled plate glass and mild steel, Pittsburgh 5-inch solid glass block, Pittsburgh 2-1/2-inch solid glass block, alternate layers of polished plate glass and 150° M.P. asphalt, Herculite, Duplate, Duolite, 8-inch layers of compound HCR-1 made from limestone dust, and 5-inch layers of compound HCR-2 made from woodflour.

CONCLUSIONS: None of the protective devices afforded outstanding protection against shaped-charge jets. However, it was definitely established that 5 inches of glass would stop a shaped-charge jet as well as seven inches of mild steel. Both HCR compounds proved superior to steel in protecting against shaped-charge jet; however, both were inferior to glass.
GENERAL: This 39-page report contains three pages of photographs showing the appearance of glass penetrated by shaped-charge jets. The report is included in the cover enclosing DA-30-069-ORD-245, Monthly Progress Report dated 26 September 1951.

SUBJECT: Armor OCO 245(2)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(2); Monthly Progress Report
DATE OF REPORT: 26 November 1951
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the suitability of several types of armor arrangements for use as protection against attack by shaped-charge jets; to compare the test performances of C.I.T. charges and DuPont jet tappers
METHOD: The armor arrangements were tested by the Flintkote Company in a manner similar to that outlined in the brief of Report No. OCO 245(1). In addition, C.I.T. charges and DuPont jet tappers were detonated against unprotected and protected mild steel plate to determine which type of charge was most suitable for use in testing the reliability of various armor arrangements used for defense against attack by shaped-charge jets.
DESCRIPTION: The armor arrangements were made up of the following materials: Borosilicate glass, a number of types of asphalt binders, multiplate bulletproof glass, wire glass, plate glass sheets cushioned with various materials, carborundum brick, HCR type materials, gravel in asphalt binder, plastic materials, asphalt tire, and asbestos shingles. The C.I.T. charges tested were supplied by Picatinny Arsenal. The charge filler was 50/50 Pentolite, the conical liner was copper, and the booster was Tetryl.
CONCLUSIONS: Tests on Borosilicate glass showed that this glass would both reduce the thickness and weight of armor required to stop a shaped-charge jet. The harder types of asphalt binders provided better jet resistance characteristics than did the softer asphalt binders. Multiplate bulletproof glass was found to afford good protection against shaped-charge jets, although the protection was not a great deal better than that afforded by plate glass. Cushioning materials used between plate glass were of little aid in improving plate glass shaped-charge jet resistance characteristics. Carborundum bricks, plastic materials, asphalt tile, and asbestos shingles afforded poor resistance to shaped-charge jets. HCR materials containing large pieces of gravel and a high percentage of gravel provided better jet resistance characteristics than did other HCR materials. The C.I.T. charge, because of a wide variance in jet penetration results, was considered less desirable for use in conducting tests of armor defense arrangements than the DuPont jet tappers.
GENERAL: This 40-page report contains six photographs showing the materials tested. The report is contained in the binder enclosing DA-30-069-ORD-245, Monthly Progress Report dated 26 September 1951.

SUBJECT: Armor OCO 245(3)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(3); Monthly Progress Report
DATE OF REPORT: 26 December 1951
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the suitability of several types of armor arrangements for use as protection against attack by shaped-charge jets
METHOD: The armor arrangements were tested by the Flintkote Company in a manner similar to that outlined in the brief of Report No. OCO 245(1).
DESCRIPTION: The following materials were used in the armor arrangements: plate glass, Borosilicate glass; a tempered plate glass called Herculite, Lilesville gravel, Akrolith glass marbles, corrugated glass, Carborundum, methyl methacrylate resins, and thin armor face plates.
CONCLUSIONS: Little difference was noted between the shaped-charge jet protection afforded by plate, Borosilicate, and Herculite glass. Studies revealed that when a shaped-charge jet was directed parallel to the normal surfaces of plate glass and at 60° obliquities to the normal plate surfaces, jet penetrations were much deeper than when a jet was directed perpendicular to the normal plate surfaces. Results of tests on other materials were not evaluated since additional testing was required before any reliable conclusions could be drawn. The thin armor face plate placed over some of the armor arrangements was found of little value in improving their jet penetration resistance.
GENERAL: This 41-page report contains 10 photographs showing the materials tested. The report is contained in the binder enclosing DA-30-069-ORD-245, Monthly Progress Report dated 26 September 1951.

SUBJECT: Armor OCO 245(4)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(4); Monthly Progress Report
DATE OF REPORT: 26 January 1952
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the suitability of several types of armor arrangements for use as protection against attack by shaped-charge jets
METHOD: The armor arrangements were tested by the Flintkote Company in a manner similar to that outlined in the brief of Report No. OCO 245(1).
DESCRIPTION: The following materials were used in the armor arrangements: Lilesville gravel in combination with a number of types of binders; a block of ice; three forms of formica designated

Pregwood. CN-1 reinforced with duck, and Formica FF-55 made with fiberglass cloth; methyl methacrylate, with and without fiberglass mat reinforcing; plain cellulose acetate Fibersto; polished plate glass; glass marbles; phenol-resorcinol sand-filled resin and a hard asphalt; and a magnetized Red Star tool steel.
CONCLUSIONS: Lilesville gravel had better resistance-to-penetration characteristics than an equivalent thickness of mild steel; on a weight basis, 13 pounds of gravel provided the same protection as 48 pounds of mild steel. Little difference was noted between the gravel when mixed with various binders. Ice, Formica Pregwood and CN-1 samples, and plain cellulose acetate had poor jet resistance characteristics. Formica FF-55, although providing good jet resistance, was found to be so high in cost as to appear impractical for use as a shaped-charge jet defensive material. Glass marbles were found to be somewhat less effective against shaped charge jets than plate glass. The magnetized tool steel appeared to produce relatively satisfactory resistance to jet penetration results; however, since only one shot was attempted, further testing was considered necessary. Results of tests on other materials were not evaluated because additional testing was required before any reliable conclusions could be drawn.
GENERAL: This 45-page report contains six photographs showing the materials tested. The report is contained in the binder enclosing DA-30-069-CRD-245, Monthly Progress Report dated 26 September 1951.

SUBJECT: Armor OCO 245(5)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(5): Monthly Progress Report
DATE OF REPORT: 26 February 1952
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the suitability of several types of armor arrangements for use as protection against attack by shaped-charge jets
METHOD: The armor arrangements were tested by the Flintkote Company in a manner similar to that outlined in the brief of Report OCO 245(1).
DESCRIPTION: The following materials were used in the armor arrangements: 2-inch Lilesville gravel mixed with wood flour and 150° M.P. asphalt, Lilesville gravel mixed with Flintseal, 1-inch Akrolith glass marbles, 2-inch glass balls, magnetic materials, Carborundum, Emerycrite (hard natural Carborundum), glass mat resins, phenol-resorcinol resin, glass mats, and glass cloth.
CONCLUSIONS: It was believed that the results obtained in these tests should not be considered final in view of the fact that the standard deviation of the DuPont jet tappers used in testing were found to be three times as great as that found in a previous lot. Additional testing was considered necessary before final conclusions could be drawn with respect to the ballistic effectiveness of Lilesville gravel and magnetic fields. The 2-inch glass balls provided better resistance-to-penetration characteristics than did 1-inch marbles. Carborundum, Emerycrite, glass mat resins, and phenol-resorcinol resin were all considered unsuitable for use as protective materials against shaped-charge jets.
GENERAL: This 33-page report contains 10 pages of photographs showing various protective devices tested.

SUBJECT: Armor OCO 245(6)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(6); Monthly Progress Report
DATE OF REPORT: 26 March 1952
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To correlate ballistic data on Lilesville gravel; to compare the performance of different lots of DuPont jet tappers
METHOD: The ballistic data on Lilesville gravel was plotted on two graphs. In the first graph, a plot was made of inches of gravel penetrated versus inches of mild steel equivalent in stopping power to one inch of gravel. In the second graph, a plot was made of inches of gravel penetrated (or weight of gravel penetrated) versus total weight of armor penetrated to the mean depth of penetration. A comparison was made of the mean penetration and standard deviation of four lots of DuPont jet tappers and a discussion was given on the possible effects of the variability of these lots on ballistic test results.
DESCRIPTION: The gravel mixture considered by this report consisted of 86% by weight of 2-inch Lilesville gravel, 3-1/2% by weight of wood flour, and 10-1/2% by weight of 150° M.P. Asphalt.
CONCLUSIONS: The plots of the Lilesville gravel ballistic data showed a fairly wide scattering of points. It was believed that this scatter may have been caused by variations in the characteristics of the jet tappers used in the ballistic tests. The comparison of the results of ballistic tests in which different lots of the tappers had been used against similar-type targets did not yield definite conclusions on the reliability of the tests.
GENERAL: This 21-page report contains six graphs of test data and two photographs showing steel plates that had been attacked by Lot 4 samples of jet tappers.

SUBJECT: Armor OCO 245(7)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(7); Monthly Progress Report
DATE OF REPORT: 26 April 1952
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the ballistic effectiveness of various armor arrangements against attack by shaped charges
METHOD: The armor arrangements were tested by the Flintkote Company in a manner similar to that outlined in the brief of Report OCO 245(1).
DESCRIPTION: The material used in the armor arrangements included magnetized steel samples 3 x 3 x 1 inches in size, Alnico 5 and Alnico 6 mag-

nets, heavy glass having density of 4.51 (as compared to 2.52 for plate glass), heavy glass blanks two inches in diameter and about 5/8 inch in thickness, glass balls one and two inches in diameter, and Formica FF-55 having about 100 glass plies per inch of thickness.
CONCLUSIONS: The ballistic performance of the magnetized steel was slightly superior to that of the unmagnetized metal. Small square pieces of polished glass were much lower in stopping power than large plates. White Carrara glass appeared to have slightly greater stopping power than plate and heavy glass, both of which were about equal in stopping power. The glass balls two inches in diameter were better in stopping power than the glass balls one inch in diameter. The Lilesville gravel had about the same stopping power inch-for-inch as mild steel. Formica FF-55 was reasonably effective in stopping shaped charges.
GENERAL: This 32-page report has five photographs of test material.

SUBJECT: Armor OCO 245(8)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(8); Monthly Progress Report
DATE OF REPORT: 26 May 1952
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the ballistic suitability of various armor arrangements against attack by shaped charges
METHOD: The armor arrangements were tested in a manner similar to that outlined in the brief of OCO 245/1. This work was conducted by the Flintkote Company.
DESCRIPTION: The following materials were used in the armor arrangements: polished plate glass of 1/2, 1, and 1-1/4 inches in thickness, mild steel plate 1 inch thick, and magnetized homogeneous armor plate 1 inch thick. The polished plate glass, procured from the Pittsburgh Plate Glass Co., had the direction of rolling indicated by arrows so that the penetration at obliquities with, against, and across the direction of roli could be determined.
CONCLUSIONS: It was found that a jet would penetrate more glass at high obliquities than it would when tested normal to the surface. It also appeared that thin sheets of glass allowed greater penetration than thick sheets. The ballistic performance of glass plates did not seem to be appreciably improved by the use of mild steel face plates up to one inch in thickness and it did not appear to make much difference when the glass and mild steel were sandwiched together. The magnetized armor plate was superior to the non-magnetized plate in resisting shaped charges.
GENERAL: This 30-page report includes eight pages of test charts, two pages of photographs, and numerous charts of test data.

SUBJECT: Armor OCO 245(10)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(10); Monthly Progress Report
DATE OF REPORT: 26 July 1952
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the ballistic suitability of various armor arrangements against attack by shaped charges
METHOD: The armor arrangements were tested in a manner similar to that outlined in the brief of OCO 245/1. This work was conducted by the Flintkote Co.
DESCRIPTION: The armor arrangements were composed of both metallic and non-metallic materials. The non-metallic materials were Lilesville gravel, a substance termed "lazy slurry" which was a fluid tending to solidify when moved rapidly, fiberglass cloth bonded with resin of unknown origin, glass blocks, plate glass, and glass balls. The metals were aluminum plate and mild steel plate. Wood flour, asphalt mastics and a casting resin were employed as binders.
CONCLUSIONS: No improvement was noted when Lilesville gravel was hand packed. Ciba casting resin showed no improvement over asphalt as a binder. White carrara glass was found equal to plate glass in penetration resistance. Glass balls 2-1/4 inches in diameter were found to be more effective than balls of a smaller diameter. Fiberglass cloth was found to be of little value as a protective material. Results obtained with polished plate glass were favorable. The "lazy slurry" test was inconclusive due to the rupture of its container. Tests on sandwiched arrangements of polished plate glass and 24ST aluminum indicated that the 24ST in combination with glass had the same stopping power as mild steel. In tests with smaller charges (DuPont Jet Perforators) against mild steel, 24ST aluminum, and plate glass, the usual scaling laws did not seem to hold for either the mild steel or the 24ST aluminum.
GENERAL: This 35-page report includes five pages of illustrations and numerous pages of test data.

SUBJECT: Armor OCO 245(11)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(11); Monthly Progress Report
DATE OF REPORT: 26 August 1952
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the resistance of various materials to attack by shaped charges
METHOD: Armor arrangements made up of various materials were tested by the Flintkote Company in a manner similar to that outlined in the brief of Report OCO 245(1). The simple residual penetration theory developed by E.M. Pugh was compared with the empirical relationship used in this report for relating the thickness of glass in a target to the total penetration. The penetration depth in mild steel plates by a new lot (No. 5) of jet tappers was determined. Tests were made on cylinders of nitrogen to see if high pressure gas would snuff off a jet. Results of tests with 3-1/2-inch shaped charges at Aberdeen Proving Ground were re-

corded.
DESCRIPTION: The following materials were used in the test armor arrangements: zirconium plates; magnetized steel plates; "lazy slurry", 2-inch Lilesville gravel, wood flour, and asphalt mixture, and panels containing solid glass blocks and Lilesville gravel.
CONCLUSIONS: The resistance to penetration of zirconium plates was in accordance with the simple residual penetration theory. The Pugh equation and the empirical equation used to determine penetration in glass gave slightly differing results, the empirical equation being considered more accurate. The mean penetration of Lot 5 DuPont jet tappers was 7.56 inches into mild steel. There was no apparent difference in penetration into magnetized and non-magnetized steel. Tests to determine whether high pressure gas would snuff off a jet gave negative results. The "lazy slurry" material was not very effective in stopping a shaped charge. Results of tests made at 45° and 60° obliquities were consistent with results of tests run at 0° obliquity.
GENERAL: This 35-page report includes four photographs of test specimens and a comprehensive discussion involving Pugh's equations and the empirical equations.

SUBJECT: Armor OCO 245(12)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(12); Monthly Progress Report
DATE OF REPORT: 26 September 1952
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the ability of various materials to withstand shaped-charge attacks
METHOD: The materials were tested by The Flintkote Company in a manner similar to that described in the brief of OCO Report No. 245(1). In addition, a study was made of all tests using two-inch Lilesville gravel in the original HCR-2 formula.
DESCRIPTION: The test material included large Lilesville gravel, three to six inches in size; 24ST aluminum, brundum, porcelain balls, and flint pebbles (such as used in ball milling) mixed with conventional asphalt binder; a cold setting mastic that showed some promise as a binder for gravel; and magnetized mild steel.
CONCLUSIONS: It was found that to stop a jet tapper completely, one pound of mild steel was equal in stopping power to 0.25 pounds of plate glass, 0.34 pounds of Lilesville gravel, 0.40 pounds of HCR-2, or 0.51 pounds of 24ST aluminum. The three to six-inch Lilesville gravel had slightly better resistance-to-penetration qualities than the two-inch gravel, but the difference was minor. The flint pebbles had the same resistance properties as the Lilesville gravel. The porcelain balls appeared to be slightly superior to the gravel. Burundum did not show any advantages. Further study of the cold setting mastic was recommended. The magnetized steel retarded the penetration of the charge slightly.
GENERAL: This 28-page report includes five graphs of test results.

SUBJECT: Armor OCO 245 (13)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(13); Monthly Progress Report
DATE OF REPORT: 26 October 1952
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the suitability of several types of armor arrangements for use as protection against attack by shaped-charge jets; to confirm an observation made on the behavior of certain materials subjected to shaped-charge explosion
METHOD: The armor arrangements were tested in a manner similar to that outlined in the brief of Report OCO 245(1). Testing was done by the Flintkote Company. In addition, a special test was made to confirm an observation made by Mr. R. V. Heine-Geldern. In this test, a 1/16-inch mild steel plate was placed flat upon a 1-inch thick section of polished plate glass and a shaped charge, lying on its side upon the mild steel plate, was detonated. A similar test was made using a plate of 24ST aluminum instead of the plate glass.
DESCRIPTION: The armor arrangements were made of the following materials: 3 to 6-inch Lilesville gravel mixed in wood flour mastic and 150° M.P. asphalt, 3-inch glass balls mixed in wood flour mastic, and magnetic materials.
CONCLUSIONS: The 3 to 6-inch Lilesville gravel afforded better resistance to shaped-charge jets than did previously tested samples of 2-inch Lilesville gravel. The 3-inch glass balls also provided very satisfactory resistance to jet penetration. Results obtained in tests on magnetic fields varied so radically that no conclusions could be drawn as to the suitability of the field against jet penetration. In the tests made to confirm the observations of Mr. Heine-Geldern, it was found that the shaped-charge detonation caused the mild steel armor plate supported by glass (a good jet penetration resisting material) to bulge upward, and the mild steel armor plate supported by 24ST aluminum (a poor jet penetration resisting material) to bulge downward.
GENERAL: This 24-page report contains two photographs showing some of the armor plates used in the magnetic field tests.

SUBJECT: Armor OCO 245(14)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(14); Monthly Progress Report
DATE OF REPORT: 26 November 1952
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the suitability of several types of armor arrangements for use as protection against attack by shaped-charge jets
METHOD: The armor arrangements were tested by the Flintkote Company in a manner similar to that outlined in brief OCO 245(1). In addition, a series of equations was developed to permit the

determination of the total jet penetration in targets of mild steel and glass arranged in any order. Tests were also conducted on a mock-up section of the front of a tank hull to determine the effect of a jet impact on the fastening device proposed for use in securing a protective material to armor.
DESCRIPTION: The following materials were used in the test armor arrangement: porcelain balls in wood flour mastic, rubber press pads, 2-inch Lilesville gravel in water, and magnetized steel. The series of equations developed for use in predicting armor performance were applicable to glass protected by various thicknesses of mild steel, glass sandwiched between mild steel, and unprotected glass. The mock-up protective armor on the tank hull was composed of Lilesville gravel in wood flour mastic sandwiched between two armor plates which were bolted together.
CONCLUSIONS: Porcelain balls appeared to provide better resistance to jet penetration characteristics than did gravel. Rubber press pads provided better resistance to jet penetration than steel on a weight basis, but not on a thickness basis. The Lilesville gravel-in-water device did not perform as well against jet penetration as did previously tested Lilesville gravel and asphaltic binder devices. Results of jet penetration of magnetic fields were erratic; however, it was revealed that when a shaped-charge jet penetrated magnetized steel a partial loss of magnetization resulted. The series of equations derived for use in determining the suitability of any arrangement of mild steel and glass against jet penetrations enabled more accurate calculations than were previously possible. Jet impacts had little effect on the fastening devices used to secure the protective material to the armor of the mock-up section of the tank hull.
GENERAL: This 57-page report contains nine photographs showing various protective armor arrangements.

SUBJECT: Armor OCO 245(15)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(15); Monthly Progress Report
DATE OF REPORT: 26 December 1952
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the suitability of a set of equations for determining the jet penetration resistance characteristics of various materials; to determine the suitability of two types of materials for use in resisting jet penetration
METHOD: The two types of materials submitted for use in resisting jet penetration were tested by the Flintkote Company in a manner similar to that outlined in the brief designated OCO 245(1). The equations pertaining to jet penetration resistance were developed only to the point where they would apply to the jet resistance afforded by the particular materials at a single standoff distance and when using only Dupont jet tappers and C.I.T. shaped charges. In addition, a method was developed for installing an HCR jet penetration protective device in a tank.
DESCRIPTION: The two types of materials submitted for jet penetration tests included magnetized steel and gravel mixed in a cold setting mastic binder. The equations on jet penetration resistance were applicable to glass, Lilesville gravel, and composite materials consisting of glass, gravel, mild steel, and aluminum.
CONCLUSIONS: The equations on jet penetration resistance were found to fit the experimental data obtained in jet penetration resistance tests conducted on the various materials. The equations were considered basic in that constants were determined from the density of the protective material and the penetration of the shaped charge into mild steel. However, the equations did not seem to have a sound theoretical basis in that there was no reason given for selecting the constants used. The results obtained in jet penetration tests on magnetized steel were erratic, as was found in earlier testing. The cold setting mastic seemed to be a very effective binder for gravel; however, additional tests under various conditions were considered necessary before concluding that the binder and gravel combination would provide ample protection against shaped-charge jets.
GENERAL: This 72-page report contains several illustrations showing the proposed method of installing an HCR jet penetration protective device in a tank.

SUBJECT: Armor OCO 245(16)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(16); Monthly Progress Report
DATE OF REPORT: 26 January 1953
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the suitability of several types of armor arrangements for use as protection against attack by shaped charges
METHOD: The armor arrangements were tested by the Flintkote Company in a manner similar to that outlined in the brief of OCO 245(1). In addition, an analysis was made of the results obtained in firing tests conducted at Aberdeen Proving Ground with 3-1/2-inch rockets on two tank hulls protected by a material found suitable against shaped-charge jets.
DESCRIPTION: The following materials were used in the test armor arrangements: magnetized steel, Obsidian (a mineral resembling glass) and wood-flour mastic binder, Obsidian and cold setting mastic binder, large Lilesville gravel and cold setting mastic binder, cold setting mastic binder, and glass blocks set in cold setting mastic binder. The armor of one vehicle hull tested at Aberdeen was protected with 14 inches of HCR-2 (gravel and an asphalt binder); the armor of the second vehicle hull was protected with 10 inches of HCR-2.
CONCLUSIONS: The results obtained when a shaped-charge jet was fired into a magnetic field were so erratic that no definite conclusions could be drawn. Although appearing to be slightly inferior in performance when compared to glass, Obsidian seemed quite satisfactory for use in protection against shaped-charge jets; however, since the material was imported from Italy, its use was

considered impractical. The resistance to jet penetration characteristics of materials set in cold setting mastic were slightly inferior to the same materials set in hot mastic. The protection afforded tank hull armor by the HCR-2 protective material against 3-1/2-inch rockets was considered excellent.
GENERAL: This 22-page report contains five pages of photographs showing oscilliscope trace patterns which were obtained during jet penetration tests on magnetic field protective devices.

SUBJECT: Armor OCO 245(17)
TITLE: Armor Resistance to Shaped Charges
IDENTIFICATION: DA-30-069-ORD-245(17); Monthly Progress Report
DATE OF REPORT: 26 February 1953
ORIGIN: Office, Chief of Ordnance, Washington, D.C.
PURPOSE: To determine the suitability of several types of armor arrangements for use as protection against attack by shaped charges; and to determine the suitability of an experimental method of determining the resistance to jet penetration characteristics of armor arrangements
METHOD: The armor arrangements were tested by the Flintkote Company in a manner similar to that outlined in brief OCO 245(1). Some of the armor arrangements were tested by the experimental method. A brief analysis was also made of the effectiveness of a protective armor arrangement ballistically tested in tanks at Aberdeen Proving Ground.
DESCRIPTION: The materials used in the armor arrangements included silicon and various plastics. The experimental method of determining the resistance to jet penetration characteristics of armor arrangements consisted of placing a 1/16-inch mild steel plate between the test material and the shaped charge. The shaped charge, positioned on its side against the mild steel plate, was detonated and the direction of bulge produced in the mild steel was used to indicate the characteristics of the test armor material. The tanks tested at Aberdeen were equipped with an HCR type protective material (gravel and binder combination).
CONCLUSIONS: The silicon and plastics were found unsatisfactory for use as protective materials against jet penetrations. Results obtained when using the experimental plate bulge method of determining the jet resistance characteristics of materials were not entirely satisfactory, since the thin armor plates used were so badly distorted after detonating a shaped charge that it was difficult to determine if the plate bulged up or down. Theoretically, a plate tested by the plate bulge method was to bulge up if the material supporting the plate afforded good jet penetration resistance characteristics, and down if the material supporting the plate afforded poor jet penetration resistance characteristics. Tests at Aberdeen indicated that the HCR material tested as a protective material for tanks could satisfactorily withstand impacts made with shaped charges, armor piercing projectiles, and high explosive shells.
GENERAL: This 22-page report contains nine photographs showing various test materials and two photostats of drawings showing the method used in installing the HCR protective materials on a tank.

SUBJECT: Armor WAL 710/506
TITLE: An Empirical Approach to the Efficient Design of Armor for Aircraft
IDENTIFICATION: Report No. WAL 710/506
DATE OF REPORT: 2 June 1944
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To collate, integrate, and analyze ballistic data of steel and lighter alloys for design and fabrication of aircraft armor
METHOD: A survey of literature was made regarding the test armor material, and curve sheets were constructed. The factors of resistance and limits of resistance to perforation, protection from projectiles, and areas of vulnerability were investigated in the first phase. Shock properties, high velocity perforation, low temperature effects, and general data were considered in the second phase of research. Where insufficient data were obtainable, firing was conducted to supply the information.
DESCRIPTION: The sources of information included Aberdeen Proving Ground, Watertown Arsenal, and Navy reports. The aircraft armor materials considered included face-hardened and rolled homogeneous steels, Duralumin, and Dowmetal.
CONCLUSIONS: The use of face-hardened steel under all conditions assured maximum resistance to perforation. It was considered possible that Duralumin, which is about one-third of the density of steel, may overmatch a projectile while an equal weight of steel may be overmatched by the same projectile. The ability of a material to break up a projectile was considered to be a potent factor in promoting the superiority of one material over another. Low temperatures adversely affected the resistance to perforation of Duralumin to a lesser degree than the two types of test steels. Low temperatures lowered the shock resistance of steel but not of duralumin. A graph was drawn of the test materials to enable the designer to make an accurate determination of the most efficient feasible design of armor.
GENERAL: This 107-page report includes 19 pages of test data curves and one page of photographs of the test materials.

SUBJECT: Armor WAL 710/607-2
TITLE: Principles of Armor Protection
IDENTIFICATION: Report No. WAL 710/607-2
DATE OF REPORT: 21 June 1944
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the relative resistance-to-penetration of steel and Dural armor
METHOD: Data were used from previous resistance-to-penetration tests of a 3/4-inch Dural (24ST) plate with artillery type projectiles. Comparison of these data was made with data from a similar test of 321 BHN steel armor with the same type of projectiles. The conditions for these tests were an obliquity of not less than 30° and a striking

velocity not greater than 2700 f/s. It was required to know the theoretical thicknesses of Dural plate necessary to give protection against 57mm or larger artillery type projectiles if and when such plates could be developed. This information was obtained by the development and use of mathematical ballistic formulae for both steel and Dural armor and basing the conclusions on a comparison of the results of the use of the formulae.
DESCRIPTION: Dural (24ST) taken from 3/4-inch plate, and face-hardened and homogeneous armor were used in ballistic tests. Cal. .30 and .50 projectiles had been used in ballistic testing of the materials.
CONCLUSIONS: The 321 BHN steel armor required a 28% greater weight than Dural armor to give the same protection under usual combat conditions. At striking velocities above 2700 f/s, steel armor was superior to Dural in that it shattered the projectiles. Steel armors over 3 inches would be inferior to Dural armor of the same weight, provided Dural could be made in heavier gages and still maintain the quality level obtained in the 3/4-inch gage Dural.
GENERAL: This 27-page unillustrated report contains eight pages of test data.

SUBJECT: Armor WAL 710/607-3
TITLE: Principles of Armor Protection
IDENTIFICATION: Report No. WAL 710/607-3
DATE OF REPORT: 28 June 1944
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To investigate the protection afforded by a spaced decapping armor plate
METHOD: Results and discussions of recent studies of projectile cap removal were recorded for 1/4-inch and 1/8-inch face-hardened and homogeneous plate with 75mm APC M61 and 37mm APC M51 Projectiles. Tests were then conducted to determine the effect of cap removal by firing cal. .30 projectiles against 0.30-inch armor plate. Shatter velocities of capped and uncapped projectiles against homogeneous armor were discussed and analyzed by means of graphs and related ballistic formulae. This shatter velocity discussion included a study of the effects of adding 1/12-caliber plate, either directly or as a decapping plate, to 2.5, 3.0, and 3.5-inch armor for defeating 3-inch projectiles.
DESCRIPTION: Tests conducted specifically for this report incorporated cal. .30 projectiles, modeled after the German 75mm APC Pak 40 Projectiles, and 0.30-inch homogeneous armor with a 321 BHN. Additional test data were obtained from other reports.
CONCLUSIONS: One-twelfth caliber plates would remove the caps of APC projectiles at service velocities, regardless of cap hardness, closeness of cap fitting, or, within wide limits, cap design. Decapping plates would considerably lower the shatter velocity of enemy projectiles, particularly in the obliquity range of 30° to 45°. For example, the lowering of shatter velocity would be sufficient to exclude the possibility of 75mm APC projectiles penetrating, without shattering, 320 BHN plate, 2.5-inch thick at obliquities over 35°.
GENERAL: This 14-page report includes one table of test data for 1/12-caliber additions against 3-inch projectiles and a graph showing shatter velocity areas for cal. .30 projectiles versus 0.30-inch plate.

SUBJECT: Armor WAL 710/930
TITLE: Terminal Ballistics of Armor and Armor-Piercing Shot
IDENTIFICATION: Report No. WAL 710/930
DATE OF REPORT: 17 March 1950
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To summarize ballistic data on various types of armor and ammunition
METHOD: File card test data on armor type, thickness, and hardness; projectile type, caliber, and model number; and ballistic limit, limit criterion, and test observations were used to plot graphs and vulnerability diagrams. These graphs and diagrams were used as a basis for analyzing the ballistic performance of the different types of armor and projectiles considered in the study.
DESCRIPTION: The ballistic data covered by this report had been obtained from tests on rolled and cast homogeneous and wrought, and face-hardened armor ranging in thickness from 1-1/2 inches to 12 inches. This armor had been subjected to fire at various obliquities and velocities by capped and monobloc steel and tungsten carbide core projectiles ranging in caliber from 57 to 122mm.
CONCLUSIONS: Test data indicated that face-hardened armor was considerably inferior to rolled homogeneous armor in affording protection against moderately undermatching and overmatching attack at high obliquities. The monobloc steel shot was more effective than the capped steel and carbide core types of armor-piercing ammunition for the defeat of highly sloped armor, whether the armor was homogeneous or face-hardened. In order to defeat 4-inch armor sloped at 60° at reasonable battle ranges (1000 to 2000 yards), it was necessary to use shot of caliber greater than 90mm. It was recommended that monobloc steel 120mm shot fitted with windshields be developed.
GENERAL: This 29-page report contains 18 pages of graphs and vulnerability diagrams.

SUBJECT: Armor WAL 710/930-1
TITLE: Spaced Armor
IDENTIFICATION: Report No. WAL 710/930-1
DATE OF REPORT: 20 November 1950
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To present information on spaced armor arrangements
METHOD: A brief account was given of the history of modern spaced armor protection. A description was given of a ballistic test program on spaced armor versus tungsten-carbide-core armor piercing ammunition as carried out by Aberdeen Proving Ground. A discussion was given of the effectiveness of spaced armor against squash-head and shaped-charge shells. A tentative proposal was given for armoring vehicles with spaced armor arrangements to provide a well-balanced degree

of protection against various types of ballistic attack.
DESCRIPTION: Many types of spaced armor and projectiles were covered in the report. The ballistic test program at Aberdeen included tests on 2, 3, 4, and 6-inch rolled homogeneous main armor plates used singly and in combination with 1/4, 3/8, 1/2, 3/4, and 1-inch non-heat-treated steel skirting plates against 57mm APC M86, 57mm AP M70, 90mm HVAP M304, and 90mm APC T50 E1 Projectiles.
CONCLUSIONS: Test data indicated that laminated or spaced skirting plates provided less protection than a single skirting plate of comparable thickness. This was thought to be due in part to the lower penetration resistance of the front and rear surfaces of armor. Spaced armor was considered most efficient when the attacking projectile was broken up by the skirting plate. Under this condition, it was believed possible to effect weight savings in the range of 30 to 50% over solid armor. It was tentatively proposed that a spaced armor structure be developed having the main armor sloped at about 30° obliquity with the skirting plate fitted in the opposite direction, either as a single plate, or as a series of plates arranged in a Venetian-window blind arrangement.
GENERAL: This 20-page report contains seven pages of photographs.

SUBJECT: Armor WAL 710/930-3
TITLE: The Design and Selection of Armor Materials
IDENTIFICATION: Report No. WAL 710/930-3
DATE OF REPORT: 20 February 1952
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To describe some of the interrelationships among the physical, mechanical, metallurgical, and ballistic characteristics of metallic armor materials; to suggest logical basis for the selection of armor materials for defense against specific types and strengths of attack
METHOD: The discussion of armor material was divided into four main sections concerned with suitable armor defense against attack by fragments of high explosive shells, small arms armor-piercing projectiles, artillery armor-piercing projectiles, and chemical energy armor-defeating ammunition.
DESCRIPTION: The armor materials discussed in this report consisted of the alloys of iron (steel), titanium, aluminum, and magnesium.
CONCLUSIONS: It was thought that aluminum and titanium alloys came closest to having the low density, moderately high strength, and good toughness requirements considered necessary to provide optimum resistance to shell fragments. In regard to armor defense against small arms armor-piercing projectiles, 24ST aluminum alloy armor was considered superior to rolled homogeneous steel, face-hardened steel, and magnesium alloy armor when the obliquity of armor emplacement with respect to the line of fire was greater than approximately 50°, or when the ratio of plate thickness (converted to equivalent weight of steel) to projectile core diameter was less than 0.6. Under all other conditions of attack, face-hardened steel armor was believed superior to all other materials in resistance to small arms projectiles. It was observed that against greatly undermatching projectiles at very low obliquities of attack, the ballistic resistance of armor increased with increases in hardness, whereas against overmatching projectiles the ballistic resistance generally decreased with increases in armor hardness. Protection against HEP and HEAT types of armor-defeating ammunition was thought to be provided practically only by use of combinations of armor materials such as spaced armor, spikes attached to the surface of armor, or layers of low density material placed over the armor.
GENERAL: This 29-page report includes 11 pages of tabulated test data, one graph, four vulnerability curves, and one photograph.

Section 5
ARMORED CARS

SUMMARY

The subject, Armored Cars, was not summarized because of the limited scope of the armored car reports briefed to date. When a sufficient number of armored car reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Armored Cars AFF 2-18-49(IX-8)
TITLE: Armored Cars and Armament for Armored Cars
IDENTIFICATION: Report No. AFF 2-18-49(IX-8)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To determine the requirement for an armored car and its armament
METHOD: Review was made of previous armored car standards and developments of this vehicle by the U.S. Army and the British. Study was conducted of the armored car requirements and characteristics including mobility armament, armor and airborne, and reconnaissance capabilities. The British armored car doctrine and requirements were reviewed.
DESCRIPTION: The required characteristics for an armored car included a 16,000-pound weight limit, mobility equal or superior to the light tank, incorporation of multiple machine guns, and armor protection for the crew against small arms fire and light artillery shell fragments.
CONCLUSIONS: A requirement existed for an armored car to replace the light tank for reconnaissance use in the light armored cavalry. This vehicle should have a gun equivalent to the 76mm and be capable of being airborne. The mounting of a suitable gun on a 16,000-pound armored car was not practical and the development of such a car using only multiple machine guns was not warranted. The best solution at this time was considered to be the use of the lightly armored 1/4-ton truck for airborne reconnaissance, supported by a transportable self-propelled antitank gun.
GENERAL: This four-page report is not illustrated and is contained with Report No. AFF 2-18-49.

SUBJECT: Armored Cars AFF 1548
TITLE: Military Characteristics for an Armored Car
IDENTIFICATION: Project No. 1548
DATE OF REPORT: 17 April 1951
ORIGIN: Army Field Forces Board No. 2, Fort Knox, Kentucky
PURPOSE: To formulate military characteristics for a wheeled armored car
METHOD: A study of numerous reports and requirements for a wheeled armored car was made by the United States, Canada, and the United Kingdom.
DESCRIPTION: The vehicle required would be a lightly armored fighting vehicle providing high speed road mobility, good cross-country mobility, silent operation, long cruising range, and fire power sufficient to permit its use for battlefield reconnaissance and security missions.
CONCLUSIONS: It was recommended that development and test of the proposed armored car and two alternate turret assemblies be given the highest priority.
GENERAL: This 25-page report is not illustrated. A list of the military characteristics for an armored car is included along with a list of references and a report of the study.

SUBJECT: Armored Cars APG 12-4A
TITLE: Report of Special Armored Vehicle Board
IDENTIFICATION: APG 12-4A
DATE OF REPORT: 5 December 1942
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the comparative suitability of numerous armored vehicles for military use
METHOD: The vehicles were given comparable functional and physical tests. Their respective performance and design characteristics were analyzed by a Special Armored Vehicle Board which arrived at the final conclusions.
DESCRIPTION: The following vehicles were tested: Armored Cars T13, T17, T17E1, T18, T18E2, T19, T19E1, T21; Gun Motor Carriages T67 (T49), T55, and T56; Light Tanks M3A1, M5A1, and Bigley; and Scout Cars T24 and Fargo.
CONCLUSIONS: Armored Car M8 most nearly fulfilled the requirements for an armored reconnaissance vehicle; Armored Cars T13, T17, T17E1, T18, T18E2, T19, T19E1, and T21 were not to be further developed or tested. The 57mm Gun Motor Carriage T67 (T49) was considered capable of being developed as a tank destroyer gun motor carriage; no further development or testing was to be performed on the T55 and T56 Gun Motor Carriages.

Light Tank M5A1 was to be continued as standard; a bulged turret was to be developed for the M5A1 Tank. Light Tanks M3 and Bigley were considered unsuitable. Scout Car T24 was to be standardized for issue to tank destroyer units. The Fargo scout car was not desirable.
GENERAL: This 61-page report contains detailed information on the vehicles, and a summary of individual vehicle characteristics.

SUBJECT: Armored Cars APG TT1-696/8
TITLE: Test of French Armored Car (Panhard)
IDENTIFICATION: Eighth Report on Project No. TT1-696; APG 12-15
DATE OF REPORT: 17 August 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the performance and operating characteristics of the French Armored Car, Panhard
METHOD: A series of engineering tests were conducted on the subject vehicle: field tests, turret tests, firing tests, and stationary dynamometer tests.
DESCRIPTION: The test was of an 8 x 8 vehicle in which the front and rear wheels were rubber-tired and the intermediate wheels were metal-equipped with two-inch cleats. These intermediate wheels could be raised and lowered hydraulically. The vehicle was powered by a 12-cylinder, air-cooled, pancake-type engine coupled to two four-speed transmissions in tandem. Armament consisted of a turret mounted 75mm cannon with a coaxially mounted 7.5mm machine gun and a 7.5mm machine gun located in both the fore and aft driver's compartments. The vehicle was manned by a crew of four.
CONCLUSIONS: The general design and performance of the vehicle was considered good. Cross-country mobility of the test vehicle did not compare to that of a light tank. It was recommended that noteworthy features of the test vehicle such as the pancake engine design and installation, and provisions for forward and reverse drive with equal speed ranges, be considered in any armored car development program initiated in this country.
GENERAL: This 88-page report contains 25 photographs of the test vehicle and its component parts, and curve sheets on fuel economy, tractive resistance, drawbar pull, and engine performance characteristics.

Section 6
ARTILLERY, SELF-PROPELLED

SUMMARY

MORTARS AND HOWITZERS

This summary covers resumes of 10 engineering reports written on self-propelled artillery between 1944 and 1954 at Aberdeen Proving Ground, Maryland; The Armored Board, Fort Knox, Kentucky; and Army Ground Forces Board No. 1, Fort Bragg, North Carolina.

FIRST ATOMIC EXPLOSION AT BIKINI ATOLL

The first report on artillery materiel exposed to the first atomic bomb explosion at Bikini Atoll was prepared in 1947. This artillery had been aboard four target ships, the U.S.S. Arkansas, Pennsylvania, Nevada, and Saratoga. Among the equipment investigated were a 90mm gun, M2; 40mm automatic gun, M1; 75mm aircraft gun, T9E1; 81mm mortar, M1; 105mm howitzer, M2A1; and a 155mm gun, M2.

The damage caused by carelessness in handling and shipping was apparently responsible for a large amount of the damage to the materiel, and the lack of complete information in the matter made the evaluation of the damage caused by exposure to the atomic bomb explosion difficult and possibly, in some instances, inaccurate. Slight shielding prevented the radiant heat of the atomic bomb explosion from damaging artillery components. No residual radioactivity was detected in the artillery materiel under test. External lubricants and preservatives were generally in good condition; however, some burning of preservatives occurred on areas directly exposed to the radiant heat of the atomic bomb explosion. The fire control equipment was more vulnerable and structurally weaker than the other materiel. The 90mm, M2, AA guns removed from the U.S.S. Arkansas and Nevada were unfit for combat use. It was recommended that portable Geiger-Muller counters, electroscopes, ionization chambers, or other radiation detection instruments be available to troops to determine the presence and amount of residual radioactivity existing in Ordnance materiel subjected to an atomic bomb explosion; that Ordnance materiel be painted with an olive drab topcoat (this topcoat was based on lead oxide and a long oil alkyd vehicle, because of the very excellent heat reflectance values of lead pigments and the ability of lead and lead salts to resist the passage of the gamma rays present in the atomic bomb explosion); that glass windows of fire control equipment be replaced by thicker blast resistant glass, or by a strong blast resistant transparent plastic; that armored conduit be used as protection for all exposed electrical wiring; that large flat areas of thin poorly supported metal, such as the shields on the 105mm howitzer carriage, M2A2, be avoided in future Ordnance design; and that additional atom bomb tests be conducted with Ordnance materiel emplaced under normal tactical conditions.

MILITARY CHARACTERISTICS OF FIELD ARTILLERY

A study was conducted in 1946 to determine the desirable characteristics of self-propelled artillery pieces for purposes of development. The weapons under major consideration were the 105mm howitzer, 155mm howitzer, 155mm gun, and 8-inch howitzer. These studies resulted in numerous conclusions and recommendations concerning military characteristics for self-propelled artillery. It was recommended that projects be initiated to design and produce self-propelled field artillery incorporating the proposed military characteristics. It also was recommended that the existing self-propelled weapons, with necessary modifications, be retained in war reserve until the proposed units were in production.

GUN MOTOR CARRIAGES

This summary covers resumes of seven engineering reports written on gun motor carriages between 1943 and 1955 at Aberdeen Proving Ground, Maryland.

Vehicles tested included the 40mm gun motor carriage, T36; 1/4-ton, 4x4, M38A1, with mounted weapons; Ontos vehicle; 155mm gun motor carriage, M40; multiple gun motor carriage, T52; and twin 40mm gun motor carriage, T65.

NUMBER OF GUNS ON THE ONTOS VEHICLE

A test was conducted in 1952 to determine the minimum number of 105mm BAT rifles needed in primary armament to permit the Ontos vehicle to participate in two successful engagements without reloading. The Ontos vehicle was a full-tracked, lightly-armored vehicle of approximately 5 tons, designed to serve primarily as a mobile antitank weapon. It was determined that two pairs (four rifles) of 105mm BAT weapons would be the minimum number of weapons that could be used on the Ontos vehicle to expect the vehicle to participate in two successive engagements without reloading. However, the results of this analysis were derived without consideration of the effect the weight of the guns on vehicle performance.

REPORT RESUMES

MORTARS AND HOWITZERS

SUBJECT: Artillery AB 551
TITLE: Test of 81-MM Carrier, T27 and 4.2-Inch Mortar Carrier
IDENTIFICATION: Projects No. 551 and 552
DATE OF REPORT: 28 August 1944
ORIGIN: The Armored Board, Fort Knox, Ky.
PURPOSE: To determine the suitability of Mortar Carriers T27 and T29 in comparison with Mortar Carrier M21
METHOD: Comparative firing tests were conducted from the test carriers and the ground mounts, at ranges of 1200 and 2600 yards. Both vehicles were combat-stowed to determine the adequacy of stowage provisions. Communication studies were made on various types of radio equipment, and to determine the advisability of using wire communications.
DESCRIPTION: The test 4.2-inch Mortar Carrier T29 and 81mm Mortar Carrier T27 were manufactured by the Cadillac Motor Car Division. They were basically Light Tanks M5A1 less the turret and turret ring. Part of the hull armor supporting the turret race was removed to allow more space in the fighting compartment for a four-man crew. A floor was constructed in the hull, with a track and shoe arrangement for mounting the mortar. Bins were built in the sponsons to carry the bulk of primary ammunition. Each vehicle was powered by two Cadillac 90°, V-8, liquid-cooled gasoline engines. Each engine had a bore and stroke of 3-1/2 x 4-1/2 inches and developed 110 bhp and 200 lb.-ft. torque at 3400 rpm.
CONCLUSIONS: The vehicles were considered unsatisfactory because of limited crew space, inadequate armor, and slow rate of fire. It was recommended that they receive no further consideration. Their mobility was superior to the M21, and their communications system was satisfactory. It was recommended that 4.2-inch and 51mm mortar carriers be developed with provisions for a crew of six men, stowage space for 100 rounds of primary ammunition, adequate armor protection, and AA armament. It was further recommended that these carriers be constructed on a Howitzer Motor Carriage T76 chassis and with a ground pressure not exceeding 7 psi.
GENERAL: This 33-page report includes seven photographs of the test carriers. Also included are comparative dispersion charts on firing from the vehicles and ground mounts.

SUBJECT: Artillery AFF 1746
TITLE: Military Characteristics of Self-Propelled Artillery
IDENTIFICATION: Project No. 1746
DATE OF REPORT: 1 August 1946
ORIGIN: Army Ground Forces, Board No. 1, Fort Bragg, North Carolina
PURPOSE: To conduct a study of the military characteristics of self-propelled field artillery
METHOD: Committee studies were conducted to determine the desirable characteristics of self-propelled field artillery pieces for purposes of development.
DESCRIPTION: The following weapons were of major consideration; 105mm howitzer, 155mm howitzer, 155mm gun, and 8-inch howitzer.
CONCLUSIONS: The studies resulted in numerous conclusions and recommendations of military characteristics for self-propelled artillery development. It was recommended that projects be initiated to design and produce self-propelled field artillery incorporating the proposed military characteristics. It was also recommended that the existing self-propelled weapons, with necessary modifications, be retained in war reserve until the proposed units were in production.
GENERAL: This 47-page report contains individual reports concerning the desirable military characteristics for the proposed weapons.

SUBJECT: Artillery AFF 4647-4
TITLE: Report of Study of 1946-47 Winter Test of 155-MM Howitzer M1 on Carriage M1A2 by Task Forces Frigid, Frost, and Williwaw
IDENTIFICATION: Project No. 4647-4
DATE OF REPORT: 17 September 1947
ORIGIN: Army Ground Forces Board Number 1, Fort Bragg, North Carolina
PURPOSE: To evaluate the results of 11 separate tests of 105mm Howitzer M1 and Carriages M1A1 and M1A2 under arctic, heavy-weather and cold-wet conditions
METHOD: All weapons were subjected to firing and cross-country tests by Task Forces Frigid, Frost, and Williwaw.
DESCRIPTION: The standard 155mm Howitzers M1 were mounted on either the standard M1A1 or M1A2 Carriage. The principal difference between the two carriages existed in the firing jack which had an exposed ratchet on the M1A1 and an enclosed screw on the M1A2.
CONCLUSIONS: The 105mm Howitzer M1 on Carriage M1A2 was considered unsuitable for arctic, heavy-weather and cold-wet conditions. Numerous modifications covering various components would be necessary before this equipment could be considered satisfactory. No recommendations were given for the howitzer on Carriage M1A1.
GENERAL: This 15-page report contains a discussion concerning the use of various prime movers for transporting the howitzer. Also included is a list of the individual test reports.

SUBJECT: Artillery AFF 4647-4(3A)
TITLE: Report on Heavy Winter Test of 155-MM Howitzer M1 on Carriage M1A2
IDENTIFICATION: Project No. 4647-4; Annex 3A
DATE OF REPORT: 5 September 1947

ORIGIN: Army Ground Forces Board No. 1, Fort Bragg, North Carolina
PURPOSE: To determine the suitability of 155mm Howitzer M1 on Carriage M1A2 under heavy winter conditions
METHOD: For a test of the stability and accuracy of the weapon a total of 389 rounds were fired at various elevations and from extreme left to extreme right traverse. The weapon was fired from its firing jack and wheels, mounted on Artillery Sled M6, and using trail spades and improvised frost spades. The howitzer was towed on roads and cross-country. The weapon was emplaced on frozen and unfrozen ground in temperatures ranging from 0°F to +26°F.
DESCRIPTION: The test Howitzer M1 on Carriage M1A2 was towed by High-Speed Tractors M5 and M5A3.
CONCLUSIONS: It was concluded: that the weapon's stability, accuracy, and mobility were satisfactory; that all parts functioned satisfactorily except the replenishers of the recoil system; that insufficient traction of artillery prime movers was the greatest deficiency noted during the entire operation; that Firing Lock M17 had no advantages over Firing Lock M1; that present packaging of ammunition was unsatisfactory. It was recommended that: further tests be made with Artillery Sled M6, and of frost spades; cold weather tests be made of replenishers with "O" type packing in place of the present "T" types; ammunition packaging be improved to facilitate handling while wearing heavy gloves.
GENERAL: This 30-page report includes 10 photographs of the weapon, components, and failures.

SUBJECT: Artillery AFF 4647-4A
TITLE: Report of Test 155-MM Howitzer M1 on Carriage M1A1
IDENTIFICATION: Project No. 4647-4; Annex 4A
DATE OF REPORT: 3 April 1947
ORIGIN: Army Ground Forces Board No. 1, Fort Bragg, North Carolina
PURPOSE: To determine the serviceability of the 155mm Howitzer M1 on Carriage M1A1 under conditions of cold-wet weather, with special emphasis on mobility, stability, and spade reaction in tundra
METHOD: The weapon was tested at Adak, Alaska, on soft and firm tundra in severe cold-wet winter weather. Stability was observed with several different spades in combination with several types of platforms. Mobility was observed with five different prime movers.
DESCRIPTION: The test 155mm Howitzer M1 was mounted on a limited standard split-trail Carriage M1A1. Artillery Sled M6 was used. Prime movers included: Tractors TD14, D7, and D8 with low ground pressure tracks: 18-ton High-Speed Tractor M4A1; LVT 4 standard and lightweight; and 13-ton High-Speed Tractor M4A1. Standard, German and auxiliary spades were used.
CONCLUSIONS: Mobility of the weapon on its wheels alone was unsatisfactory for cross-country operation. With the weapon mounted on sleds and towed by Tractor D7, mobility, within limits, was acceptable. However, development of a self-propelled medium howitzer was recommended. Artillery Sled M6 was considered satisfactory and essential. The German spades were superior to the standard and auxiliary, but a larger spade and a larger jack float were considered necessary for stabilizing the piece on soft tundra.
GENERAL: This 29-page report includes 45 photographs showing the weapon and mountings, the prime movers, and conditions encountered.

SUBJECT: Artillery APG 5696/10
TITLE: First Report on Test of 105-MM Howitzer Motor Carriages T88
IDENTIFICATION: Tenth Report on Ordnance Program No. 5696; APG 225-105
DATE OF REPORT: 10 October 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine suitability of 105mm Howitzer M4, Mount T20, and Flotation Device T7 for Howitzer Motor Carriage T88
METHOD: The howitzer was proof fired and characteristics of the mount determined. The flotation device was installed and the vehicle was operated in water at which time additional firing tests were conducted.
DESCRIPTION: The Howitzer Motor Carriage T88 was basically the Gun Motor Carriage M18 in which the 76mm gun had been replaced by a 105mm howitzer and Mount T20. The T7 Flotation Device was to be installed to permit amphibious operation.
CONCLUSIONS: The vehicle was not generally satisfactory and modifications were recommended. The recoil mechanism of Mount T20 was unsatisfactory. The standard Flotation Device T7 was considered unsuitable for the 105mm Howitzer Motor Carriage T88.
GENERAL: This 95-page report includes 12 photographs of the T88 and flotation device. Also included is a drawing of howitzer counterweight and three pages of pressure-time curves of the recoil cylinder.

SUBJECT: Artillery APG 6192/3
TITLE: First Report on Artillery Materiel Exposed to the First Atomic Bomb Explosion at Bikini Atoll
IDENTIFICATION: Third Report on Ordnance Program No. 6192
DATE OF REPORT: 22 May 1947
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To examine and evaluate the damage to the artillery materiel subjected to the effects of the first atomic bomb explosion at Bikini Atoll
METHOD: The artillery materiel was first inspected visually. It was then subjected to residual radioactivity tests and was examined to determine whether the damage was caused by the peculiarities of an atomic blast such as extreme pressures, temperatures or radioactivity, or by secondary causes such as flying debris.
DESCRIPTION: The artillery materiel had been aboard four target ships, the U.S.S. Arkansas, Pennsylvania, Nevada, and Saratoga. Among the

materiel investigated were a 90mm gun, M2; 40mm automatic gun, M1; 75mm aircraft gun, T9E1; 81mm mortar, M1; 105mm howitzer, M2A1; and a 155mm gun, M2.
CONCLUSIONS: The damage caused by carelessness in handling and shipping was apparently responsible for a large amount of the damage to the materiel, and the lack of complete information in the matter made the evaluation of the damage caused by exposure to the atomic bomb explosion difficult and possibly, in some instances, inaccurate. Slight shielding prevented the radiant heat of the atomic bomb explosion from damaging materiel. No residual radioactivity was detected in the artillery materiel under test. External lubricants and preservatives were generally in good condition; however, some burning of preservatives occurred on areas directly exposed to the radiant heat of the atomic bomb explosion. The fire control equipment was more vulnerable and structurally weaker than the other materiel. The 90mm, M2, AA guns, removed from the U.S.S. Arkansas and Nevada, were unfit for combat use. It was recommended that portable Geiger-Muller Counters, electroscopes, ionization chambers, or other radiation detective instruments be made available to troops to determine the presence and amount of residual radioactivity existing in Ordnance material subjected to an atomic bomb explosion; that Ordnance materiel be painted with an olive drab topcoat which was based on lead oxide and a long oil alkyd vehicle, because of the very excellent heat reflectance values of lead pigments and the ability of lead and lead salts to resist the passage of the gamma rays present in the atomic bomb explosion; that glass windows of fire control equipment be replaced by thicker, blast resistant glass, or by a strong, blast resistant, transparent plastic; that armored conduit be used as protection for all exposed electrical wiring; that large, flat areas of thin, poorly supported metal, such as the shields on the 105mm howitzer carriage, M2A2, be avoided in future Ordnance design; and that additional atom bomb tests be conducted with Ordnance materiel emplaced under normal tactical conditions.
GENERAL: This 185-page report includes 63 photographs of the damaged materiel and components.

SUBJECT: Artillery APG TT2-695/3
TITLE: First Report on the Development Tests of Gun, 90mm, Self-Propelled, T101, and Related Materiel (Artillery Phase)
IDENTIFICATION: Third Report on Project No. TT2-695
DATE OF REPORT: 6 October 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of the armament of a self-propelled, 90mm gun, T101
METHOD: Firing tests were conducted with the armament of the test vehicle. During tests, observations were made of the following: recoil oil pressures; vehicle hop; general performance of artillery materiel; and accuracy of fire at a target at a range of 1000 yards. A total of 151 rounds were fired, at various gun elevations.
DESCRIPTION: The test self-propelled, 90mm gun, T101 was a lightweight, aluminum constructed vehicle powered by a Continental, 6-cylinder, horizontally-opposed, air-cooled, gasoline engine, rated at 175 hp. Vehicle armament consisted of a high velocity, 90mm gun, T125, which was mounted on the centerline of the vehicle; the ballistics of this gun were the same as those of the 90mm guns T119 (M36) and T139 (M41). The vehicle weapon was elevated, traversed, and loaded manually. The weapon could be traversed through an angle of 60° and elevated through angle of 15° to -10°. Weapon mounting was accomplished by means of a hydraulic recoil mechanism, T70. The mechanism consisted of one recuperator and one recoil cylinder located on each side of the centerline of the gun. Oil reserve in the recoil system was established by a hand pump situated between the two upper recuperator cylinders. The average recoil length of the weapon was 41 inches. On the right side of the vehicle was a direct-sighting telescope, T152, by which the gunner aimed the gun. Weight of the vehicle when combat loaded was 15,475 pounds. Maximum vehicle speed was 30 mph and cruising range was 100 miles.
CONCLUSIONS: Vehicle weapon accuracy was good, even though the hop characteristics of the vehicle were excessive. The general over-all functioning of the recoil mechanism was satisfactory at the test temperature levels. The elevating and traversing systems were critically weak for combat conditions, and the blast deflector WTV-D-1132 used with the gun was unsatisfactory. It was recommended that the general functioning of the artillery materiel be considered satisfactory; and the development work be continued toward increasing the strength of vehicle component design, especially with regard to the elevating and traversing systems.
GENERAL: This 124-page report includes 24 photographs of the test weapon and components.

SUBJECT: Artillery APG TT2-695/4
TITLE: Second Report on the Development Tests of Gun, 90mm, Self-Propelled, T101, and Related Materiel (Artillery Phase)
IDENTIFICATION: Fourth Report on Project No. TT2-695
DATE OF REPORT: 17 February 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether the armament of the self-propelled, 90mm gun, T101, Pilot No. 2, would be suitable enough for use in extensive field tests
METHOD: A total of 117 rounds were fired from the vehicle weapon during a preliminary firing test. The following data were recorded while the weapon was equipped with two types of experimental blast deflectors: recoil pressures; cycle time and travel; muzzle flash; blast pressures; vehicle hop; weapon accuracy; and over-all performance of the weapon when firing at various angles of elevation, traverse, and cant. Crew safety factors were also observed.
DESCRIPTION: The test self-propelled, 90mm gun, T101, Pilot Model No. 2, was a modified full-tracked, front sprocket driven vehicle of light-

weight, aluminum construction. The vehicle was powered by a Continental, 6-cylinder, horizontally-opposed, air-cooled, gasoline engine which drove through a GMC cross-drive, CD-150-4 transmission. The vehicle armament consisted of a high velocity, 90mm gun, T125, which was mounted in mount T170E1 along the centerline of the vehicle. Traversing, elevating, and loading of the weapon were accomplished manually. The weapon could be traversed through an angle of 60° and elevated from -15° through 10°. Experimental blast deflectors tested with the gun were of the two and four part WTV-D-1132 types. Gun sighting was accomplished by means of a direct-sighting telescope T152. Weight of the fully loaded vehicle was 15,475 pounds; maximum vehicle speed was 30 mph and its cruising range was 100 miles.
CONCLUSIONS: The performance of the test vehicle armament was considered generally satisfactory and safe for use in extensive field tests, although several deficiencies were noted. The four port blast deflector was considered superior to the two port deflector with respect to antiobscuration features, however, its design strength was considered unsatisfactory; blast pressures with both designs were excessive. It was recommended that the test vehicle be considered suitable for extensive field testing; that caution be exercised when using experimental blast deflectors on the gun; and that deficiencies noted be corrected.
GENERAL: This 166-page report includes 28 photographs of the vehicle.

SUBJECT: Artillery BRL 393
TITLE: Results of Light AA Study
IDENTIFICATION: Technical Note No. 393; Project No. TB3-0224
DATE OF REPORT: March 1951
ORIGIN: Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland
PURPOSE: To determine which of several types of short range weapons would be most suitable for use in aircraft defense by the Army Field Forces
METHOD: Analytical studies were conducted to determine the effectiveness of a series of conventional short range guns against F47 aircraft; type, size, and muzzle velocity of various projectiles fired from the weapons were considered in the study. Effectiveness of a rocket gun against the same type of target was also included in the studies. Each type of weapon was analyzed from the standpoint of the following considerations stipulated by the Army Field Forces: ability of weapon with and without radar fire control to destroy maneuvering and non-maneuvering targets; and the effect various economic considerations would have on the choice of a suitable weapon. Economic considerations included cost of weapon; whether the weapon with accessories, fire control equipment, personnel, etc., would exceed a 5000-pound weight limitation; etc.
DESCRIPTION: The following projectiles fired from appropriate weapons were considered: 30, 35, 37, 40, and 50mm HE projectiles equipped with PD fuzes; and 20mm and 0.6 and 1-inch API projectiles equipped with friction fuzes. The rocket gun considered was identified as the T131; weight of a projectile for the weapon was 10.2 pounds. The rocket gun was originally designed for air-to-air application.
CONCLUSIONS: Studies revealed that the most effective short range anti-aircraft weapon which would fall within Army Field Force requirements was a weapon which would fire 36 or 37mm HE shells at a velocity of 3000 fps. This weapon would be similar to a T37E1 gun except that it would be used to fire a lighter shell. The T131 rocket gun, though not designed for ground AA application, appeared effective enough to warrant a general study of rocket-assist AA weapons. It was recommended that a 37mm gun which could fire a light weight, high capacity HE shell at 3000 fps be developed (rate of fire should be 400 rounds per minute); and that a sensitive PD fuze with a delay sufficient to allow penetration of aircraft armor be developed for the weapon chosen. It was further recommended that additional studies be made of the desirable features of rocket-assist weapons with various types of fuzing in order to determine whether such weapons would be suitable for AA defense.
GENERAL: This 41-page report contains several graphs demonstrating study results.

REPORT RESUMES

GUN MOTOR CARRIAGES

SUBJECT: Gun Motor Carriages APG 5701/1
TITLE: First Report of Development Test of Pilot 40mm Gun Motor Carriage, T36 No. 1, and Remote Control System, T9
IDENTIFICATION: First Report on Ordnance Program No. 5701
DATE OF REPORT: 6 February 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate the operation of the pilot gun motor carriage T36, and its components
METHOD: The gun and mount were proof fired; additional rounds were fired at 0, 90, 180, and 270 degrees to proof the turret. Service rounds were also fired during the test of the remote control system, T9. The vehicle was operated for 50 miles over hard surface roads at 20-30 mph to determine the effect of shock on the gun carriage.
DESCRIPTION: The experimental gun motor carriage, T36, No. 1, consisted of a standard medium tank M3 chassis modified to accommodate a special turret containing a 40mm automatic gun, M41, a 40mm gun mount, T4; a T10 computer; and a T9 remote control system.
CONCLUSIONS: There was insufficient clearance for loading the gun with four rounds of ammunition at elevations below 10°. Turret traversing and gun elevating interior travel locks were required for road operation. Artificial ventilation

was required in the turret to exhaust powder gases. The remote control system was dynamically accurate at all transmitted angular rates of speed in elevation and azimuth. The signal system for fire control and general intercommunication was inadequate. The controls were substantially mounted and withstood shocks encountered during secondary road operation of the gun motor carriage. It was recommended that deficiencies be corrected, and that the T36 gun motor carriage be shipped to the AA Board, Camp Davis, for opinions concerning the general design, structural features, and the advisability of further development.
GENERAL: This 185-page report contains 19 photographs of the T36 gun motor carriage and components. Also included are oscillograph records of dynamic accuracy tests and operating instructions for the remote control system, T9, and the computer, T10.

SUBJECT: Gun Motor Carriages APG 5701/4
TITLE: First Report on Development Test of First Pilot Twin 40-MM Gun Motor Carriage T65
IDENTIFICATION: Fourth Report on Ordnance Program No. 5701; APG 335-2
DATE OF REPORT: 30 July 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of Gun Motor Carriage T65 and its twin cal. .40 antiaircraft armament
METHOD: After a proof firing trial of the weapons, extensive firing tests were conducted. These included synchronization of guns, accuracy, stability, and tracking ability. During stability tests, vehicle hop was electrically recorded and high-speed motion pictures were taken. Tracking ability tests included: tracking while firing: effect of hop on tracking ability; handwheel efforts; and maximum rate of tracking both electrically and manually. The vehicle was given a 100-mile endurance run over paved roads.
DESCRIPTION: The test self-propelled Twin 40mm Gun Motor Carriage T65 was a modified Light Tank M5 employing a Twin 40mm Gun Mount T12. Although volute spring suspension was used with the test vehicle, production models were to incorporate torsion bar suspension. Two 40mm guns, modified for left and right-hand operation, were used in the mount. Gun traversing and elevating were actuated through an electrical system developed by the Servomechanism Laboratory of Massachusetts Institute of Technology; manual controls could be used in the event of power failure. The guns were fired electrically by solenoids, or mechanically by a foot pedal.
CONCLUSIONS: Although the vehicle was unsatisfactory as an antiaircraft weapon, it had sufficient merit to warrant further development. The accuracy and stability of the vehicle when on its suspension were considered unsatisfactory, as evidenced by the hop and dispersion records; when the vehicle was on blocks, free of the suspension, satisfactory results were obtained. Relative movement between the operator's eye and the sight reticle, when the vehicle was on its suspension, resulted in unsatisfactory tracking ability during continuous burst firing. Other numerous conclusions were drawn with respect to armor, armament, and the top carriage. Because of the short duration of the road test and since a different suspension was to be used on production models, no recommendations based on suspension shortcomings were made.
GENERAL: This 92-page report contains 15 photographs illustrating the vehicle and weapon installation. Firing and vehicle hop records are included.

SUBJECT: Gun Motor Carriages APG 5706/6
TITLE: First Report on 155-MM Gun Motor Carriage M40, Additional Armament, Study of
IDENTIFICATION: Sixth Report on Ordnance Program No. 5706; APG 225-106
DATE OF REPORT: 10 October 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine which of several types of small arms would be most suitable for use in increasing the close-range ground fire power of the 155mm Gun Motor Carriage M40
METHOD: Several types of small arms were mounted in various positions on the 155mm Gun Motor Carriage M40. Tests were conducted to determine which of the small arms and mounting positions were most suitable for use on the vehicle.
DESCRIPTION: Small arms tested on the 155mm Gun Motor Carriage M40 included: a ball mount cal. .30 machine gun mounted in the front plate of the vehicle; a cal. .30 machine gun mounted in each rear corner of the vehicle; and a 57mm recoilless rifle mounted in each rear corner of the vehicle. Tests were made of two alternate cal. .30 machine gun mounts, identical to the mounts installed in the rear corners of the vehicle, welded to the loading platform. In traveling position, the loading platform formed the rear of the vehicle.
CONCLUSIONS: The ball mount cal. .30 machine gun mounted in the front plate of the vehicle, the cal. .30 machine gun mounted in each rear corner of the vehicle, and the alternate cal. .30 machine gun mounts welded to the loading platform were found to be satisfactory. It was recommended these installations be included in the standard armament on the 155mm Gun Motor Carriage M40. Recoilless rifles were considered unsatisfactory for use on the carriage for the following reasons: traverse was extremely limited; no ammunition stowage space was available; and if fired from the vehicle, the blast from the rifles would be extremely hazardous to the gun crew.
GENERAL: This 23-page report contains nine photographs showing the various small arms installations tested on the vehicle.

SUBJECT: Gun Motor Carriages APG 5706/8
TITLE: First Report on 155-MM Gun Motor Carriage M40, Additional Armor Protection
IDENTIFICATION: Eighth Report on Ordnance Program No. 5706, APG 225-108
DATE OF REPORT: 2 January 1946
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of a

proposed armored cab for 155mm Gun Motor Carriage M40 in protecting a gun crew from small arms fire and shell fragments
METHOD: An armored cab for protecting the gun crew of a 155mm Gun Motor Carriage M40 was designed, and a wooden mock-up of the cab was made and installed over the rear of an M40 Vehicle.
DESCRIPTION: The armored cab designed for the rear of the 155mm Gun Motor Carriage M40 consisted of two vertical sides and a flat roof sloping to the rear. Attached to the permanent structure were to be two side extensions, a top extension, and two front shields.
CONCLUSIONS: The armored cab was considered suitable for the protection of a gun crew from small arms fire and shell fragments, however, other parts of the vehicle were still extremely vulnerable. It was recommended that the test armored cab as designed be considered unsuitable for use on the M40 Vehicle; and that, if the tactical need existed, consideration be given to redesigning the upper hull and gun mount of the M40 Gun Carriage so that all parts of the vehicle, as well as the gun crew, were protected.
GENERAL: This 37-page report contains 16 photographs showing a wooden mock-up of the proposed armored cab installed on the vehicle.

SUBJECT: Gun Motor Carriages APG 5946/4
TITLE: Second Report on Development Test of Pilot Model Multiple Gun Motor Carriage, T52 (First and Second Pilots)
IDENTIFICATION: Fourth Report on Ordnance Program No. 5946; APG 243-6A
DATE OF REPORT: 10 January 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether the experimental Multiple Gun Motor Carriage T52 was worthy of further development
METHOD: Vehicle components were operated to determine ease of handling and suitability; tracking tests were conducted; the gun was removed from the mount to determine ease of removal and installation; and the vehicle was endurance tested for a total of 349 miles over various terrain.
DESCRIPTION: Multiple Gun Motor Carriage T52 consisted of a 40mm Anti aircraft Gun M1 and two cal. .50 Machine Guns M2HB mounted coaxially in a manually controlled, power-operated, armored turret (Combination Gun Mount T62) which, in turn, was mounted in the turret ring of a Medium Tank M4A2.
CONCLUSIONS: The vehicle was not considered worthy of further development. If, however, further development was deemed necessary, the numerous deficiencies and suggested remedies listed in the report were to be considered.
GENERAL: This 128-page report includes five photographs of vehicle components and engineering data.

APG TT3-732/2
SUBJECT: Gun Motor Carriages
TITLE: Test of Truck, Utility, 1/4-Ton, 4x4, M38A1, with Mounted Weapons
IDENTIFICATION: Second Report on Project No. TT3-732
DATE OF REPORT: 17 January 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To modify the M38A1 truck for mounting the (BAT) recoilless weapon
METHOD: A method of constructing a split windshield and dash-mounted traveling lock was developed. Volute helper springs were clamped to the rear axle outboard of the frame. Development of the split windshield and traveling lock was accomplished on an M38 truck. For test purposes, an M38A1 truck was loaded to simulate a "BAT" weapon equipped vehicle, volute helper springs were installed, and the vehicle was operated on the cross-country and Belgian Block courses.
DESCRIPTION: The "BAT" weapons system consisted of the 106mm rifle, M40, mount M79; and fire control equipment. The D.V.M. included six rounds of ammunition, with the crew of three men, the total load imposed on the vehicles was 1350 pounds, which was 550 pounds over the rated cross-country payload of the truck. Weight distribution imposed most of the load on the rear axle.
CONCLUSIONS: The development of the split windshield and traveling lock, achieved as a part of this test, pointed the way to the solution of the problem. Although the volute helper springs were unsatisfactory for carrying the desired load, it was felt that their use would increase the life of the rear axle housing. It was recommended that development work on split windshields and dash-mounted traveling locks be continued to obtain practical accessories for the 105mm rifle mount, M75, and 106mm rifle mount, M79, on 1/4-ton trucks, 4x4, M38 and M38A1; and that volute helper springs, which were continuously under load, be developed for the M38 and M38A1 trucks.
GENERAL: This 44-page report includes nine photographs of the vehicle and the test equipment.

SUBJECT: Gun Motor Carriages BRL 608
TITLE: The Number of Guns on the Ontos Vehicle
IDENTIFICATION: Memorandum Report No. 608; Project No. TB3-1224B
DATE OF REPORT: June 1952
ORIGIN: Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland
PURPOSE: To determine the minimum number of 105mm BAT rifles needed in primary armament to permit the Ontos vehicle to participate in two successful engagements without reloading
METHOD: An Ontos vehicle equipped with one through four sets, or pairs, of 105mm battalion antitank rifles, was considered in the study. Analytical procedures were developed for computing the probability of a hit from at least one of the shots of a salvo fired from each type of vehicle rifle installation; salvos were considered from the standpoint of firing vehicle rifle pairs and from the standpoint of firing all rifles simultaneously. Consideration was also given to the probability of hitting a target when firing one rifle alone.
DESCRIPTION: The Ontos vehicle was a full-tracked, lightly-armored vehicle of approximately five tons, designed to serve primarily as a mobile antitank weapon. Main vehicle armament consisted of recoilless 105mm battalion antitank BAT rifles, which fired fin-stabilized projectiles with a muzzle

velocity of approximately 1800 fps. The main armament was aimed by means of a cal. .50 spotting machine gun, the trajectory of which closely matched that of the main armament.

CONCLUSIONS: It was determined that two pairs (four rifles) of 105mm BAT weapons would be the minimum number of weapons that could be used on the Ontos vehicle to expect the vehicle to participate in two successful engagements without reloading. However, the results of this analysis were derived without consideration of the effect the weight of the guns on vehicle performance.

GENERAL: This 24-page report contains several curves which were derived in the analysis.

Section 10
CARRIERS

SUMMARY

This summary covers resumes of seven engineering reports written on cargo and personnel carriers between 1945 and 1955 at Aberdeen Proving Ground, Maryland; Army Field Forces Board, Fort Knox, Kentucky; and Army Field Forces Board No. 3, Fort Benning, Georgia.

SNOW MOBILITY TESTS

A test was conducted in 1955 to determine the relative mobility and drawbar pull abilities in deep snow of the T107, M29C, and M76 amphibious cargo carriers, and the space-link test vehicle, T60. The snow at Houghton (Michigan) had had very little wind-packing and presented a poor bearing surface for the test vehicles. In general, the open-type of track proved disappointing when compared to a vehicle having a closed-type track. The tracks provided for the T107 were unsatisfactory for use in snow because of their low flotation ability. The M76 (Otter) was marginal in mobility, having inadequate power in some situations and insufficient traction in others. The T60, with its "space-link" track, negotiated all obstacles presented; however, even straight line travel over deep snow required great expenditures of power. The M29C (Weasel), with its standard "closed-type" track, proved to be the most mobile of the four vehicles, operating over deep snow with relative ease. It was recommended that extensive study and redesign be initiated to provide experimental tracks for the T107 to give the vehicle greater mobility for over-snow use. It was recommended that subsequent development models of the T60 be made with narrow keels, to reduce the exposed hull bottom surface which plowed into deep snow and "bellied" the vehicle.

FRENCH SIX-MAN PERSONNEL CARRIER

A study and evaluation of the design features of the French carrier, with special emphasis on those features which could be utilized in the design of U.S. vehicles, was made in 1952. The French six-man personnel carrier was a full tracklaying vehicle with space for six men and full equipment in the personnel compartment, and a driver in the compartment at the left front. The vehicle was designed, insofar as possible, to incorporate standard available commercial components. Its gross weight was 11,900 pounds. A maximum speed of 28 mph, inadequate shop performance and the necessity of shifting down from fourth gear for turning were indications of insufficient power. The 110 horsepower engine was inadequate. Size and low silhouette lent the vehicle to security from observation. Simplicity of construction and the use of standard available commercial components permitted maintenance by personnel with limited mechanical experience. The braking capacity of the foot brake was inadequate for stopping the vehicle within a reasonable distance. The carrier did not provide sufficient space for six fully-equipped infantrymen. The carrier could not maintain convoy speeds over all types of terrain required of U.S. vehicles. It was recommended that the French six-man personnel carrier be considered unsuitable as a substitute for proposed U.S. vehicles of this type until provision was made to improve maximum speed, slope climbing ability, and troop seating space.

REPORT RESUMES

SUBJECT: Carriers AFF 2-18-49 (VIII)
TITLE: The Requirement for and the Organization and Use of Armored Personnel Carriers
IDENTIFICATION: Report No. AFF 2-18-49(VIII)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To determine the requirements, use, and organization of personnel carriers
METHOD: The need for a full-track, armored personnel carrier was established by review of recommendations by several postwar boards and conferences. Various types of vehicles were discussed as to requirement, suitability, and industrial production capacity. Development programs in progress for the T18 and M44E1 Vehicles were reviewed. British proposed specifications for similar vehicles were considered. No discussion was required as to the tactical use of this type of vehicle.
DESCRIPTION: The required vehicle as recommended by the Infantry and Armored Conferences, the War Department Equipment Board, and the Army Ground Forces Equipment Review Board was to be an armored, full-track, self-propelled personnel carrier, with overhead cover, having similar characteristics as the tanks with which it would operate. The carriers in the process of development were the T18, a 12-place, 33,000-pound vehicle and the M44E1, a 26-place 50,000-pound vehicle.
CONCLUSIONS: An armored personnel carrier of squad size only (T18) for universal use was required in the armored division for armored infantry and engineer squads. This type of vehicle was also required for rifle squads in reconnaissance platoons.

It was recommended that the development of the M44E1 Vehicle should be completed. A pool of armored personnel carriers was not required. It was also recommended that the Chief, Army Field Forces should conduct a study of equipment tables to determine any other essential requirements of the T18 Carrier.
GENERAL: This five-page report is not illustrated and is contained with Report No. AFF 2-18-49.

SUBJECT: Carriers AFF 2272
TITLE: Military Characteristics for Motor Carrier
IDENTIFICATION: Project No. 2272
DATE OF REPORT: 27 July 1950
ORIGIN: Army Field Forces Board No. 3, Fort Benning, Georgia
PURPOSE: To prepare military characteristics for Armored Utility Vehicle T18 and Amphibian Cargo Carrier T46 for use with 81mm, 105mm and 4.2-inch mortars
METHOD: The Infantry and Armored Schools in conjunction with Army Field Forces Board No. 3 had stated the necessity of developing a heavy motor carrier in both Infantry and Armored Units. Proposed military specifications were determined relating to physical characteristics, armament, fire control equipment, armor, stowage, and communication system. The Armored Utility Vehicle T18 was in the design stage, and "mock-ups" of the vehicle had been built. A pilot model of the Cargo Carrier T46 was undergoing engineering tests.
DESCRIPTION: The Armored Utility Vehicle T18 was full-tracked, self-propelled, full-armored and weighed 17 tons gross. Its cargo compartment measured 122 x 108 x 56 inches. The 1-1/2-ton Amphibian Cargo Carrier T46 was full-tracked, self-propelled, and had a completely enclosed aluminum body. The vehicle weighed 11,345 pounds gross. Its cargo compartment measured 98 x 72 x 60 inches.
CONCLUSIONS: The test carriers for the 81mm, 105mm or 4.2-inch mortars with the proposed or similar military characteristics were recommended for development under priority 2A.
GENERAL: This 58-page report contains 13 photographs of the 81mm, 105mm and 4.2-inch mortars, mock-ups of the Armored Utility Vehicle T18, and a pilot Model Cargo Carrier T46. Appended are loading plans and proposed military characteristics for both vehicles.

SUBJECT: Carriers APG 5715/3
TITLE: First Report on Mortar Carrier 4.2 Inch, Consisting of Trailer, 1/4-Ton 2-Wheel Cargo, and Truck, 1/4-Ton 4x4
IDENTIFICATION: Third Report on Ordnance Program No. 5715
DATE OF REPORT: 23 February 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of the 1/4-ton, 2-wheel cargo trailer and 1/4-ton 4x4 truck for use in transporting 4.2-inch chemical mortar, mortar ammunition, and mortar squad
METHOD: The two sets of trucks and trailers, loaded with 4.2-inch chemical mortar, mortar ammunition, and weights equivalent to that of the mortar squad, were operated on a Belgian Block course for 250 miles. A similar truck and trailer, loaded with 800 and 500 pounds of payload, respectively, were operated during this and the remainder of the tests for comparison. The trailers were floated in deep water to check the suitability of the load balance for amphibious operation. Tests were conducted on ice-covered cross-country terrain. The trailers were purposely overturned while operating at 20 to 35 mph, and the resulting damage noted. Each of the loaded trailers was suspended by cables to determine its center of gravity.
DESCRIPTION: The test items were two 1/4-ton 2-wheel cargo trailers coupled to 1/4-ton 4x4 trucks. These vehicles were modified to conform to the Chemical Warfare Board method of transporting the 4.2-inch mortar squad and mortar squad equipment. The eight man mortar squad was carried in the two trucks, four men in each truck. The mortar squad equipment consisted of one 4.2-inch chemical mortar mounted on a mortar and ammunition cart, M1A1, loaded in one trailer, and twelve rounds of 4.2-inch mortar ammunition mounted on a similar cart and loaded in the other trailer. Eight rounds of 4.2-inch mortar ammunition were also carried in each truck.
CONCLUSIONS: The trucks and trailers were considered satisfactory for transporting the 4.2-inch chemical mortar, mortar ammunition, and mortar squad. The load characteristics of the trailer, as loaded during the tests, made it more susceptible to overturning and detracted slightly from its amphibious properties. The standard canvas top covers used on the trailers were unsatisfactory, and it was recommended that they be replaced with well fitted top covers.
GENERAL: This 68-page report contains 27 photographs of the trucks and trailers.

SUBJECT: Carriers APG TB5-1401/66
TITLE: Arctic Test of Utility Vehicle, Tracked, Infantry, T55, Fort Churchill, Canada
IDENTIFICATION: Sixty-sixth Report on Project No. TB5-1401
DATE OF REPORT: 26 August 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of a T55 tracked, infantry, utility vehicle for use under arctic conditions
METHOD: The test vehicle was operated for a 24-day period under arctic conditions at Fort Churchill, Canada. A careful check was made of its over-all performance.
DESCRIPTION: The test T55 tracked, infantry, utility vehicle was a lightly armored, front sprocket driven, full tracklaying vehicle equipped with a GMC Type 302, 6-cylinder, liquid-cooled engine and a semiautomatic, XT-90, cross-drive transmission. There were provisions for transporting five men with field equipment in the personnel compartment. Top speed of the vehicle was 30 mph, and cruising range was approximately 150 miles. Vehicle statistics included: combat weight, 12,100

pounds; ground clearance, 15 inches, and ground pressure, 3 psi.
CONCLUSIONS: Difficulties encountered with the vehicle during test were of a comparatively minor nature; in all, eight specific faults were listed. It was recommended that corrective action be taken to eliminate the faults outlined; and that in the future all test items be tested in coldrooms prior to field testing.
GENERAL: This 96-page report includes 14 photographs of the test equipment, and seven photographs of temperature charts.

SUBJECT: Carriers APG TB5-1401/263
TITLE: Snow Mobility Tests at Houghton, Michigan, 1954-1955
IDENTIFICATION: Two Hundred Sixty-third Report on Project No. TB5-1401
DATE OF REPORT: 29 April 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the relative mobility and drawbar pull abilities in deep snow of the T107, M29C and M76, amphibious cargo carriers, and the space-link test vehicle, T60
METHOD: Drawbar tests were conducted on a large, level field over snow that was dry, light, and fluffy, and which varied in depth from 22 to 27 inches. Mobility tests were conducted on similar snow, on rolling terrain.
DESCRIPTION: The T60 was a vehicle designed to test experimental concepts in the development of space-link tracks. The T107 was a new, amphibious cargo carrier in pilot model form, which was provided with three different types of track and suspension. The M76, was an amphibious cargo carrier previously tested in snow at Kapuskasing, Ontario, Canada, during the winter of 1953-54. The M29C was an amphibious cargo carrier of World War II vintage. It, too, had been tested at Kapuskasing.
CONCLUSIONS: The snow at Houghton had had very little wind-packing and presented a poor bearing surface for the test vehicles. In general, the open type of track proved disappointing when compared to a vehicle having a closed type track. The tracks provided for the T107 were unsatisfactory for use in snow because of their low flotation. The M76 (Otter) was marginal in mobility, having inadequate power in some situations and insufficient traction in others. The T60, with its "space-link" track, negotiated all obstacles presented; however, even straight line travel over deep snow required great expenditures of power. The M29C (Weasel), with its standard "closed-type" track, proved to be the most mobile of the four vehicles, operating over deep snow with relative ease. It was recommended that extensive study and redesign be initiated to provide experimental tracks for the T107 to give the vehicle greater mobility for over-snow use. It was also recommended that subsequent development models of the T60 be made with narrow keels, to reduce the exposed hull bottom surface which plowed into deep snow and "bellied" the vehicle.
GENERAL: This 77-page report includes six photographs of the test vehicles and laboratory measuring instruments.

SUBJECT: Carriers APG TT2-614/6
TITLE: Fourth and Final Report on Test of Armored Infantry Vehicle T18E1
IDENTIFICATION: Sixth Report on Project No. TT2-614; APG 12-21
DATE OF REPORT: 3 February 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the engineering and endurance characteristics of the Armored Infantry Vehicle T18E1
METHOD: Three vehicles accumulated a total of 1793 miles of endurance testing over gravel, cross-country and hilly courses. Center of gravity was determined by the suspension method and fording tests were conducted in water up to five feet deep.
DESCRIPTION: The test Armored Infantry Vehicle T18E1 was lightly armored, weighed 42,000 pounds and provided space for 14 men. It was equipped with an AO-895-4 engine, CD 500-4 transmission, individual torsion bar suspension and a cal. .50 machine gun.
CONCLUSIONS: Center of gravity was three feet 8-1/2 inches above ground level, six feet 10-1/4 inches to the rear of the forward drive sprocket center. Fording characteristics were satisfactory. Operation of two vehicles was discontinued since they were equipped with obsolete suspension components, and the third vehicle was to have further tests after modification. It was recommended that operation be discontinued on all Armored Infantry vehicles T18E1 which did not incorporate current production parts, and that a new production model T18E1 be prepared for endurance operation to observe the effectiveness of the latest type of suspension components.
GENERAL: This 70-page report contains two photographs of the T18E1 and 11 photographs illustrating failed and worn components.

SUBJECT: Carriers APG TT2-673/4
TITLE: French Six-Man Personnel Carrier
IDENTIFICATION: Fourth Report on Project No. TT2-673
DATE OF REPORT: 15 May 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To study and evaluate the design features of the carrier, with special emphasis on those features which could be utilized in the design of U.S. vehicles
METHOD: The vehicle was tested to determine its general operational and performance characteristics and to evaluate its suitability on the basis of U.S. standards. The test carrier also was evaluated for its tactical possibilities from the user's point of view. Endurance tests were limited due to the fact that the vehicle had to be returned to the French government in reasonably good operating condition.
DESCRIPTION: The French six-man personnel carrier was a full tracklaying vehicle with space for six men and full equipment in the personnel compartment, and a driver in the compartment at

the left front. The vehicle was designed, insofar as possible, to incorporate standard available commercial components. The carrier was powered by a V-8 French Ford type engine, rated at 110 hp at 3500 rpm. Its gross weight was 11,900 pounds. The vehicle was supported by four rubber-tired road wheels on each side. The wheels traveled on an all-steel, single-pin type, track. A 24-volt electrical system (not waterproof) was used. The vehicle represented the latest French development in this field. Its armor was 0.28-inches thick all around.
CONCLUSIONS: Maximum speed of 28 mph, inadequate slope performance and the necessity to down shift from fourth gear for turning, were indications of insufficient power. A 110-horsepower engine was inadequate. Size and low silhouette lent the vehicle to security from observation. Simplicity of construction and the use of standard available commercial components, permitted maintenance by personnel with limited mechanical experience. The braking capacity of the foot brake was inadequate for stopping the vehicle withing a reasonable distance. The carrier did not provide sufficient space for six fully-equipped infantrymen. The carrier could not maintain convoy speeds over all types of terrain required of U.S. vehicles. It was recommended that the French six-man personnel carrier be considered unsuitable as a substitute for proposed U.S. vehicles of this type until provision was made to improve maximum speed, slope climbing ability, and troop seating space.
GENERAL: This 66-page report includes 21 photographs of the test carrier and components, and four drawings.

Section 12
COOLING TESTS

SUMMARY

The subject, Cooling Tests, was not summarized because of the limited scope of the cooling test reports briefed to date. When a sufficient number of cooling test reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Cooling Tests APG 4361/3-43-1
TITLE: Laboratory Air Flow Tests on Tank Grilles
IDENTIFICATION: Project No. 4361/3-43-3; APG 45-1(1)
DATE OF REPORT: 5 January 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate by laboratory tests the resistance to air flow of five grilles
METHOD: Each grille was fitted into the upper half of a duct through which a flow of air was furnished by a laboratory fan testing setup. To test each grille, a 50 hp dynamometer was operated at nine speeds ranging from 1000 to 4000 rpm, and at each speed, velocity and pressure heads were measured in the duct by pilot tubes at the center of cross-sections. All five grilles were tested in the position they occupied in the vehicle, and the Barber-Coleman and single trap grilles were also tested in reverse position.
DESCRIPTION: The five test grilles were an M24 standard, a single trap, a Barber-Coleman, a T26E1 standard, and a T23 curved teardrop. The fan testing setup consisted of a 50 hp dynamometer, a chronotachometer, a set of fans from a Medium Tank T23 modified for installation in a Heavy Tank T26E1, a set of radiators from one side of a Heavy Tank T26E1, and a 14 x 2 x 2-1/2-foot duct. Pilot tubes used to measure air flow and pressure were located three feet from the duct discharge end.
CONCLUSIONS: Curves of grille restriction plotted against CFM per square foot of grille area and CFM per square foot of open grille area, revealed that the closer the louver bars conformed to the outline of the walls of a venturi tube, the less was the grille restriction per square foot of open area to the passage of air. On the basis of restriction per square foot of grille area the M24 grille rated best, and on the basis of restriction of open grille area the T26E1 grille was best. Reversing the single trap grille with respect to air stream did not reduce restriction appreciably, although with the Barber-Coleman grille it reduced restriction by approximately one third at air speeds above 1500 feet per minute. It was considered questionable whether the laboratory test results would be the same as those of an actual installation on a tank.
GENERAL: This 30-page report contains two photographs of the laboratory test setup, five pages illustrating cross-sections of louver bars of the test grilles, and four curve sheets of air flow comparison tests.

SUBJECT: Cooling Tests APG 4361/3-43-2
TITLE: Laboratory Air Flow Tests on Tank Grilles
IDENTIFICATION: Project No. 4361/3-43-3; APC 45-1(2)
DATE OF REPORT: 20 March 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To develop a ballistically improved grille with reduced restriction to air passage
METHOD: Six grilles were tested in a duct supplied with an air stream by a laboratory fan testing setup. Each grille was tested with its entrance side inclined at 45°, 90°, and 135° to the air stream, and then with its exhaust side at 90°. For each grille position the fans were operated to produce approximate air flows per square foot of grille area of 500, 1000, 1500, 1750, and 2000 CFM. The effect of unfilled grille traps and air stream direction upon grille restriction was also investigated. A standard single trap grille and a standard T26 exhaust grille were tested for comparison.
DESCRIPTION: The six test grilles had been modified by decreased space between louvers, thickened louver trailing edges, and circular and streamlined passages, giving the passages more venturi-like characteristics. The standard, experimental and modified grilles were designated: 1, 2A, 2B, 3A, 3B, 4, 5, 6, 7, and 8. The fan testing apparatus consisted of a 50 hp dynamometer, two chronotachometers, and the Heavy Tank T26 fan radiator section. The end of the duct was made with a swivel mounting frame and adjustable sides so that the grille could be inclined to the air stream at angles between 45° and 135°.
CONCLUSIONS: Grille No. 6 restricted the air flow the least of any ballistically acceptable. The single trap grille could not be redesigned in louver spaces and restriction without weakening its ballistic properties. Louver traps without a filler increased air flow restriction. Air stream

direction changes were found to change the grille restriction. Diverging discharged air did not reduce grille restriction.

GENERAL: This 62-page report includes six pages illustrating cross sections of the louver bars used in the test grilles, ten sketches of grille positions, and restriction-air flow curves. Photographs mentioned in this report are not included.

Section 14
ENGINES

SUMMARY

The subject, Engines, was not summarized because of the limited scope of the engine reports briefed to date. When a sufficient number of engine reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Engines APG TB5-0010J/1
TITLE: Cold Starting Studies of Ordnance Tactical Vehicle Engines
IDENTIFICATION: First Report on Project No. TB5-0010J
DATE OF REPORT: 21 March 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the cold staring characteristics of Ordnance tactical vehicle engines; and to determine whether current specification fuels and lubricants would be adequate for use under cold starting conditions
METHOD: Cold starting characteristics of 12 different Ordnance engines were evaluated in the coldrooms at Aberdeen. Minimum passing requirements in test consisted of 15-second starts down to 0°F using summer grade fuel and OE 10 oil, and 15-second starts down to -25°F using arctic grade fuel and OES oil. All starting attempts followed Coordinating Research Council Method F6-943.
DESCRIPTION: The 12 engines tested included: GMC auxiliary, A41-1; Wisconsin auxiliary, TFT; Willys RMD; Dodge T-245; GMC 302; REO OA-331; Continental R6602; and Ordnance, air-cooled, AOI-268-3A, AO-895-4, AOS-895-3, AV-1790-5B, and AV-1790-7. Fuels tested in the engines conformed to Specification MIL-G-3056. OE 10 oil conformed to Specification MIL-O-2104, and OES oil conformed to Specification MIL-O-10295.
CONCLUSIONS: Cold starting characteristics of the A-41-1, Model 302, and Model AOI-268-3A engines were satisfactory. The Model OA-331 engine could be satisfactorily cold started only when the wet manifold procedure was used. Cold starting characteristics of the remaining engines were unsatisfactory. Specification fuels and lubricants, which were then considered current, were adequate for use under cold starting conditions. The Coordinating Research Council Method F6-943 was considered a valid procedure for conducting cold starting tests, since it was not dependent upon operator techniques. It was recommended that primer nozzles and pumps be authorized for use on OA 331 engines at temperatures below 20°F; and that attempts be made to improve the cold starting characteristics of those engines which did not satisfactorily pass the test. It was further recommended that the specification fuels and lubricants used in test be considered satisfactory for use under cold starting conditions; and that the Coordinating Research Council Method F6-943 be used in future cold starting tests of vehicle engines.
GENERAL: This 213-page report includes 13 photographs of the test engines and components.

5-4-55 CM
SUBJECT: Engines DA Special
TITLE: Tank Engine Development (1940-1960)
IDENTIFICATION: Tank Engine Development, Status Report
DATE OF REPORT: 8 May 1952
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To present information on tank engine development
METHOD: The material on tank engine development was organized under five main sections entitled "Yesterday's Engines", "In Retrospect", "Today's Engines", "Tomorrow's Engines", and "Appendix".
DESCRIPTION: The material on tank engine development, given in this report, is comprehensive in scope, covering many of the tank engines designed and produced from 1940 to the date of the report, and also proposed engine developments up to the year 1960.
CONCLUSIONS: In the section entitled "Yesterday's Engines", two different programs were distinguished for the period from 1940 to 1949: an immediate short term development of engines for use in World War II tanks, and a long term development of an air-cooled gasoline family in which consideration was given to interchangeability of critical parts. In regard to the short term development, it was believed that, with the possible exception of the Ford GAA engine, most of the engines produced during the first part of World War II were improvised units leaving much to be desired. In regard to the long term development, considerable progress was made in developing a basic unit that afforded satisfactory performance and durability.

In the section entitled "In Retrospect", a comparison was made of air-cooled and liquid-cooled engines. On the basis of this comparison, the air-cooled engines were considered more desirable, from an Ordnance point of view, than the liquid-cooled engines.

The section entitled "Today's Engines" covered testing programs for current production engines and also for new models. General agreement was expressed that it would be economically unsound and strategically unwise to introduce other types of power plants (for example, those used in commercial applications) into the military engine development or production program. The research and development programs had as their goals increased stability of low speed operation and acceleration at reduced fuel consumption and power loss, decreased power package bulk, simplified design and reduced cost, and decreased cooling horsepower. An account was given of new model development projects on several specific types of engines such as the AVSI-1790-6, AV-1195-3, AOI-895-4, AO-536, and other engines.

In the section entitled "Tomorrow's Engines", the following predictions were made: (a) the gas turbine of velocity energy design would show excellence in power plant compactness and reduction in weight as well as the ability to operate on a multiplicity of different fuels. This, however, would be at the expense of increased fuel consumption, exhaust temperature and, perhaps, a requirement for increased noise suppression. It was believed that the inherent torque multiplication characteristic of gas turbines should be considered an advantage to the complete power package. (b) The gas turbine of positive displacement design (Q engine) would achieve a two-thirds reduction in engine volume and a one-third reduction in weight, while consuming approximately the same amount of fuel as a gasoline piston engine of comparable horsepower. In addition, this engine would have the inherent turbine torque multiplication, as well as the ability, to operate on a variety of fuels. A disadvantage, however, was its probable inability to reduce the present rate of fuel consumption. (c) The diesel cycle, multi-fuel engine, (the "X" engine) would make itself more promising than the two previous engines, in its application to tanks because of its ability to satisfy, to some extent, all of the future engine design objectives. Preliminary study showed that it would reduce size, weight, and fuel consumption while having the ability to operate on a variety of fuels with the improved torque characteristics inherent in diesel cycle engines. For these reasons, the "X" engine should be termed a true forerunner of the ultimate engine, particularly if compounded after initial development. (d) The combination, or compounding of both the diesel and turbine cycles in one power plant, promised to result in what now appears to be the ultimate engine (Project Orion). Large reductions in engine size, weight, and fuel consumption, as well as increased specific power, multi-fuel operation, and turbine-type torque multiplication, could result from this development.

A comparison of specific air-cooled engine models, and other relevant information is given in the section entitled "Appendix".

GENERAL: This 140-page report contains approximately 50 pages of drawings, graphs, and photographs.

Section 15
EQUIPMENT, MISCELLANEOUS

SUMMARY

The subject, Equipment, Miscellaneous, was not summarized because of the limited scope of the miscellaneous equipment reports briefed to date. When a sufficient number of miscellaneous equipment reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

APG 5679/2

SUBJECT: Equipment, Miscellaneous
TITLE: First Report on Smoke Projectors
IDENTIFICATION: Second Report on Ordnance Program No. 5679
DATE OF REPORT: 27 November 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of smoke projectors for installation on combat vehicles
METHOD: One set of smoke projectors consisting of four clusters with three projectors in each cluster was installed on a medium tank M4A3 and subjected to a firing test. A second set of projectors was installed on a heavy tank, M26, which was operated 75 miles over rough cross-country terrain. At the conclusion of this operation the projectors were fired. The range and distribution of the projected smoke grenades were determined during each of these tests.
DESCRIPTION: The test units were smoke projectors which used the M15, WP, smoke grenade and No. 8 blasting cap as a projectile and propellant, respectively. The projectors, developed in the European Theatre of Operation, were external installations designed for the purpose of providing an emergency smoke screen for an armored vehicle. Each projector unit consisted of three barrels welded to a baseplate so that the barrels were set parallel, at 20°, and at 40°, respectively to the plane of the baseplate.
CONCLUSIONS: The smoke projectors were considered satisfactory and were recommended for installation on combat vehicles. The range for each projector was 85 feet; when the four units were fired simultaneously, their total coverage was 108°. The projectors were easily installed, and weather proofing of the electrical connectors could be accomplished in the normal weather proofing installation.
GENERAL: This 65-page report contains 18 photographs of the smoke projectors. Also included are drawings of the installation.

APG TS4-4019/2

SUBJECT: Equipment, Miscellaneous
TITLE: First Report on Development Tests of Launcher, Rocket, Repeating, 3.5 Inch, T115E1
IDENTIFICATION: Second Report on Ordnance Project No. TS4-4019
DATE OF REPORT: 19 December 1950
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether the design and performance characteristics of the repeating rocket launcher T115E1 were satisfactory
METHOD: The launcher was received and given physical, dimensional, preliminary operational checks, and then cycle tested with inert rockets. A total of 208 rounds were then fired from the launcher for functioning, accuracy, pendulum, flame, dust, mud, and rain tests at different temperatures. The rocket launcher was then disassembled and the components inspected for deformation.
DESCRIPTION: The 3.5-inch repeating rocket launcher T115E1 had provisions for supporting a magazine above the firing chamber in the main body. The main body was designed to mount on a special cradle on the T113E2 tripod. A section of the front barrel, approximately 30 inches long, was secured to the body by an interrupted-thread device. With the magazine positioned on the main body, manipulation of the operating lever fed a rocket into the firing chamber, closed the chamber, and positioned the rocket for firing. Firing was accomplished by a combination trigger and hand magneto to generate firing current.
CONCLUSIONS: The general design and the performance characteristics of the repeating rocket launcher T115E1, with minor exceptions were satisfactory. It was recommended that the minor deficiencies of the launcher noted in this report be corrected in any future production model.
GENERAL: This 73-page report includes 14 photographs of the test rocket launcher and components.

APG TT2-586A/1

SUBJECT: Equipment, Miscellaneous
TITLE: Test of Automatic Loading Equipment for 76mm Gun Tank, T14E1
IDENTIFICATION: First Report on Project No. TT2-586A
DATE OF REPORT: 4 August 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the reliability and durability of the Rheem automatic loader for the T41E1,

76mm gun tank
METHOD: The test automatic loading equipment was subjected to 407 firing cycles and 750 dummy round cycles with the gun at approximately zero elevation.
DESCRIPTION: The test automatic loader was designed primarily to dispense with one crew member, the loader, as well as to increase the rate of controlled fire. The inital prototype Rheem automatic loader for light tanks had been tested at APG in 1949 and 1950 and had proved practical. The loader used in this test had been returned to the Rheem Philadelphia plant in March, 1954, to undergo a series of modifications recommended by APG. The test device consisted essentially of a hoist, and two magazines. The magamagazines were symmetrically located on either side of the hoist, conforming to the turret ring.
CONCLUSIONS: The Rheem automatic loading device in its current stage of development, was considered too unreliable and hazardous for acceptance. However, most deficiencies were of a minor nature and could be corrected without major modifications. It was recommended that all deficient parts of the test loader be modified to increase dependability and safety to a level at which further testing would be profitable; and that consideration be given to redesigning the turret to accommodate only the commander and the gunner.
GENERAL: This 71-page report includes 17 photographs of the test equipment.

Section 17
FIRE CONTROL EQUIPMENT

SUMMARY

This summary covers 27 report resumes on field and laboratory testing of standard, modified, and experimental components of fire control equipment for Ordnance vehicles. The reports were written between 1947 and 1955. Tests were conducted at Aberdeen Proving Ground, Maryland; Detroit Arsenal, Center Line, Michigan; Frankford Arsenal, Philadelphia, Pennsylvania; Army Field Forces Board and Army Ground Forces Board No. 2, both at Fort Knox, Kentucky; and Army Ground Forces Board No. 1, Fort Bragg, North Carolina. The primary concern of these investigations was the need to increase the probability of first-round hits, and to lessen vulnerability of the fire control equipment to shock and vibration.

In general, the fire control components of contemporary tanks consist of the following: an electric-hydraulic power traversing system and 360° traverse turret; high velocity large caliber guns with gun and fire control equipment, both automatic and manual; telescopic and periscopic sighting devices; vision blocks; a stabilizer which gives horizontal and vertical stabilization to the tank gun during movement; and a rangefinder integrated with a computing sight mechanism and incorporating a sight reticle capable of rapid change to correspond to the type of ammunition used.

ARCTIC TESTS

In August, 1954, arctic tests were conducted on a standard, 90mm, M48 tank equipped with a Phase IV gun sighting system. A Model 30 aircraft armaments gun mount with a cal. .50 machine gun was installed in the commander's cupola. This mount incorporated manual traverse and elevation independent of the tank turret. Several antiobscuration devices were utilized to eliminate frost and fog on the glass surfaces of the sight and vision devices. Functioning of the manual and power gun control system, sighting system, the cal. .50 machine gun turret, and the antiobscuration devices were tested while the tank was in motion, stationary, and after the vehicle had been exposed to arctic conditions for various lengths of time.

The principal deficiencies were caused by vehicle condition and design rather than the arctic climate. Fire control and turret performance were not seriously reduced by weather conditions, but an excessive amount of force was necessary for manual operation of the 90mm gun breech operation crank. Vision obscuration and loss of boresight retention were caused by the personnel heater vapors and by thermal expansion and contraction aggravated by these heaters.

T41 FIRE CONTROL SYSTEM

During June, 1953, a pilot Model T141 self-propelled twin 90mm gun vehicle fire control system was tested. The T141 was a self-propelled full tracklaying front sprocket driven antiaircraft vehicle. The fire control system consisted of twin 40mm guns, a T154 computing sight, M24C reflex sight, manual controls, and an OilGear M6A1E1 unit which served as a power traverse and elevating mechanism for the primary vehicle armament.

The fire control system proved satisfactory for field use, but several deficiencies, including excessive lateral play in the M24 reflex sight, were observed. Numerous modifications were suggested for incorporation in the final vehicle design.

IMPACT VULNERABILITY

Tests were conducted at Aberdeen in September, 1953, to determine the vulnerability of fire control instruments to shock from nonpenetrating projectiles. Using the two separate fire control systems in a 90mm gun, T48 tank as the subject, AP and HE projectiles were directed against the turret of the vehicle. An M82 direct sighting telescope was installed coaxially with the 90mm gun, and its effectiveness as a possible emergency sight was determined.

These fire control instruments proved to be extremely vulnerable to shock produced by impact from the projectiles. Lack of adequate shock mounting and poor shock resistance of the component material were primarily responsible. Recommendations were made for improvement of shock mounting and strengthening of structurally weak components. The direct sighting telescope which had been removed undamaged was recommended as standard equipment.

RUSSIAN STABILIZED TELESCOPE

A Russian stabilized telescope designed to deliver accurate fire from a moving tank was tested in October, 1953. The design was essentially a direct telescope of approximately 2-power magnification, and contained a stabilized optical prism. The angular position of the prism was slaved to the elevation axis of a free gyro through a pulley and metallic belt arrangement, thereby stabilizing the line of sight.

Performance of the telescope was inferior to WWII, single-degree (elevation stabilization only) stabilization systems. Stabilization of the optical element, except for a slight drift tendency, was considered good. It was recommended that the single degree line-of-sight stabilization be considered unsuitable as a means of satisfying stabilization requirements; however, investigation

should be conducted for application of stable optical elements to existing gun and turret stabilization systems, slaving the gun and turret to the optical elements.

OTHER STABILIZATION SYSTEMS

During April, 1955, evaluation of some alternate systems for tank stabilization was conducted. The following systems of tank stabilization were considered: the gun and sight stabilized as a unit; the gun and sight stabilized separately with various degrees of stabilization; and each of these systems in conjunction with a mechanism which would utilize three switches in series to prevent firing until a sufficient hit probability existed.

The results of this study indicated that future tank development should consider the following: stabilization of the sight as tightly as possible in azimuth and elevation; stabilization of the gun in azimuth and elevation only as required for following the sight gyro; and the use of the three-switch firing arrangement with limited gun stabilization. It was suggested that the angular velocity be measured for an unstabilized gun in azimuth and elevation to determine the necessity of limited gun stabilization. It was recommended that an investigation be made of the optimum firing region dimensions under the three-switch proposal, and that magnitudes of sight and gun errors be studied.

TANK RANGEFINDERS

A determination of the requirements for a tank rangefinder was made in a 1949 test. It was concluded that the radar type of rangefinder for tank use was superior to the optical type in accuracy and general suitability. However, the radar type was not sufficiently developed and the optical type was, as a result, more practical. The stereoscopic optical rangefinder was apparently superior to the coincidence type for tank use, because of superior vision and ease of use. It was recommended that a final choice between the two types of optical rangefinders should not be made without additional investigation and service testing.

TELESCOPE, PANORAMIC, M12

In 1947, a test was conducted to determine the general characteristics of panoramic telescope, M12, under extreme cold-wet weather conditions. Mechanical functioning of the telescope proved satisfactory until the temperature dropped to around -60° F. At this temperature the mechanism became stiff, indicating a need for either a better lubricant or a smoother operating telescope mechanism. Vision was obscured in cold-wet weather by condensation forming on the inside of the lenses. It was recommended that the telescope be made moisture proof, and that it be provided with larger knobs to permit operation without personnel having to remove their mittens.

REPORT RESUMES

AFF 2-18-49(IX-4)

SUBJECT: Fire Control Equipment
TITLE: Tank Range Finders
IDENTIFICATION: Report No. AFF 2-18-49(IX-4)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To determine the requirements for a tank range finder
METHOD: Review of established factors and discussion of various types of range finders and their use was conducted. The various aspects of error in range finders and the effect on firing were discussed. Comparison and overall rating was made of the different types of range finders based on accuracy, ruggedness, suitability, utility, ease of operation and maintenance and on the availability, selection and training of operators.
DESCRIPTION: The radar range finder operated with small constant error. The optical range finder included the stereoscopic and coincidence types. The stereoscopic instrument was used for range determination and as a wide base binocular observation instrument. The coincidence instrument had a field of vision which was unchanged by the movement of the firing tank or of the target.
CONCLUSIONS: The radar type of range finder for tank use was superior to the optical type in accuracy, and general suitability. However, the radar type was not sufficiently developed and the optical type was, as a result, more practical. The stereoscopic optical range finder was apparently superior to the coincidence type for tank use because of superior vision and ease of use. It was recommended that a final choice between the two types of optical range finders should not be made without additional investigation and service testing.
GENERAL: This nine-page report includes a table of errors and a chart of maximum ranges and is contained with Report No. AFF 2-18-49.

SUBJECT: Fire Control Equipment AFF 1246
TITLE: Study of 1946-1947 Winter Test of Obscuration, Sensing, and Adjusting of Tank Fire by Army Ground Forces Task Forces Frigid, Frost and Williwaw
IDENTIFICATION: Project No. 1246
DATE OF REPORT: 27 February 1948
ORIGIN: Army Ground Forces Board No. 2, Fort Knox, Kentucky
PURPOSE: To study and evaluate reports pertaining to obscuration, sensing, and adjusting of tank gun fire under various winter conditions
METHOD: Various types of tank gun ammunition and fire control methods were tested under arctic, heavy, and cold-wet winter conditions at Fairbanks, Alaska, Camp McCoy, Wisconsin, and Adak Island, Alaska, respectively. Numerous reports were made and summarized into one general report.
DESCRIPTION: Numerous 75, 76, and 90mm tank gun and 75mm howitzer rounds were fired for the tests. The weapons used were those mounted in tanks, landing vehicles, and gun motor carriages.
CONCLUSIONS: The tests showed the limitations

and capabilities of accepted methods of sensing, adjusting and controlling tank gun fire within the range of temperature, humidity, and barometric pressure encountered. It was recommended: that additional testing and further improvement of material be considered; that prescribed methods of sensing, adjusting and controlling fire of tank guns be considered adequate for interim use in cold weather operations; and that special tests be conducted to determine the optimum muzzle velocity-fuze combination for delivery of accurate timed fire from flat trajectory weapons in a direct fire role.
GENERAL: This 118-page report contains 63 photographs showing results of tests. The report is a summary of tests conducted by task forces Frigid, Frost, and Williwaw, whose individual test reports are included.

AFF 4647-4
SUBJECT: Fire Control Equipment (4B, 6)
TITLE: Observation Report on Test of Telescope Panoramic M12
IDENTIFICATION: Project No. 4647-4; Annex 4B, 6
DATE OF REPORT: 5 September 1947
ORIGIN: Army Ground Forces Board No. 1, Fort Bragg, North Carolina
PURPOSE: To determine the general characteristics of Panoramic Telescope M12 under extreme cold-wet weather conditions
METHOD: Four different weapons were used to test the telescope: a 155mm gun, 155mm howitzer, 105mm howitzer, and 8-inch howitzer. Each of three tested telescopes saw at least eight days service, in conjunction with artillery firing during the test period, in weather conditions of rain and snow accompanied by high winds.
DESCRIPTION: The test unit was described only as Panoramic Telescope M12.
CONCLUSIONS: Mechanical functioning of the telescope proved satisfactory until the temperature dropped to around -60° F. At this temperature, the mechanism became stiff, indicating a need for either a better lubricant or a smoother operating telescope mechanism. Vision was obscured in cold-wet weather by condensation forming on the inside of the lenses. It was recommended that the telescope be made moistureproof, and be provided with larger knobs to permit operation without personnel removing their mittens.
GENERAL: This four-page report is not illustrated.

APG Ar-18583
SUBJECT: Fire Control Equipment
TITLE: Vulnerability of Fire Control Equipment in the 90-mm Gun Tank M47 to Shock
IDENTIFICATION: Report No. Ar-18583; Project No. TT2-777
DATE OF REPORT: 1 August 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of fire control equipment in the 90mm Gun Tank M47
METHOD: Ballistic tests were conducted against the gun shield and left turret wall of a 90mm Gun Tank M47 with low-velocity, 75mm, M1002 and 105mm, M1004 Projectiles. Three pound TNT charges were detonated at vertical distances of 5, 4, 3, and 2 feet, and 1-inch above the turret top plate on which the range finder was mounted. Assessment of damage was made after each round was fired or charge detonated.
DESCRIPTION: The test tank was equipped with a turret fire control system complete with T41 Range Finder, T35 Periscope, T23E1 Ballistic Drive, and all linkages. The test tank was completely stowed except for ammunition and some interior items on the turret wall.
CONCLUSIONS: Structural weaknesses resulting from the ballistic tests were indicated in the periscope-head mounting flange, commander's periscope linkage, and the end housing casting at the flange. Severe damage caused by the TNT blast at 1-inch indicated the need for shock mounting the components on the turret top plate. Direct shock was not transmitted to the range finder by the turret armor plate. The periscope heads were fully exposed to blast due to the absence of blast deflectors. The bolts holding the armor blister protecting the end housing were exposed and vulnerable. The charges detonated at 4 and 5 feet separated the bonded joints and cracked portions of the reflectors in the penta reflectors in the range finder collimating system and end boxes.
GENERAL: This 48-page report includes 28 photographs of the test tank and fire control equipment.

APG TB5-1401/160
SUBJECT: Fire Control Equipment
TITLE: First and Final Report on Arctic Test (1953-54) of Tank, 90mm Gun, M48, Fire Control
IDENTIFICATION: One Hundred Sixtieth Report on Project No. TB5-1401
DATE OF REPORT: 4 August 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of the fire control equipment for the M48 tank under arctic conditions
METHOD: The fire control equipment was installed on the M48 tank which was then operated for 152 miles in the Fort Churchill area. Tests were conducted with ambient temperatures ranging from -38° F to 34° F. Gunlaying, tracking, boresight retentions, and firing runs were performed and the effectiveness of the antiobscuration devices was noted. The tank remained exposed to the elements during the major part of the test.
DESCRIPTION: The standard, 90mm M48 gun tank was equipped with a Phase IV gun sighting system. A Model 30 aircraft armaments gun mount with a cal. .50 machine gun, was installed in the commander's cupola. The mount incorporated manual traverse and elevation independent of the tank turret. Several antiobscuration devices were utilized to eliminate frost and fog on the glass surfaces of sight and vision devices.
CONCLUSIONS: The principal deficiencies were caused by vehicle condition and design rather than the arctic climate. Fire control and turret performance were not seriously reduced by weather conditions. Difficulties were encountered with respect to the incomplete ejection of the 90mm

cartridge cases, frosting of the sight eyelenses, and the entry of blown snow. An excessive amount of force was required for manual operation of the 90mm, gun breech, operating crank. Vision obscuration and loss of boresight were caused by the personnel heater vapors; and by thermal expansion and contraction, aggravated by the heaters. It was recommended that these design deficiencies be corrected.
GENERAL: This 161-page report contains 21 photographs of the vehicle and components. Graphs of test results, data sheets, deficiency records are also included.

APG TT2-644/1

SUBJECT: Fire Control Equipment
TITLE: Test of Fire Control Equipment for Armored Vehicles T39
IDENTIFICATION: First Report on Project TT2-644, APG 12-16A
DATE OF REPORT: 27 December 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of the fighting compartment of the pilot model Armored Engineer Vehicle T39
METHOD: A 6.5-inch demolition gun was installed in the vehicle, boresighted, and firing conducted at ranges of 500, 1000, and 2000 yards. Dispersion firing was also conducted on the coaxial cal. .30 machine gun. Studies were also conducted on turret vision devices to determine normal and maximum limits of vision and the minimum ranges of fire. Suitability of the telescope, telescope mount, ammunition stowage, traversing and elevating systems were determined.
DESCRIPTION: The primary armament of the vehicle was a British 6.5-inch demolition gun. Secondary armament consisted of a coaxially mounted cal. .30 machine gun and a cal. .50 antiaircraft machine gun. Turret and gun controls included a manual and power traversing system of Medium Tank M46 design and a manually operated hydraulic elevating system of 90mm Gun Tank M47 design. A commander's override control was provided for power operation of the turret in azimuth. The fire control consisted of direct Telescope M76E5 mounted in a coincident correcting Telescope Mount T182.
CONCLUSIONS: The fighting compartment of the Armored Engineer Vehicle T39 was satisfactory except for deficiencies in ammunition stowage, vision limitations and certain features of fire control. It was recommended that the fighting compartment be redesigned; that firing circuit safety features be provided to prevent gun discharge into the boom assembly; and that gun mount interferences be eliminated. Suggestions included replacement of Telescope M76E5 with a periscope of the T35 design.
GENERAL: This 46-page report contains five photographs showing the vehicle, loaders position, and fire control components. Also included are charts on vision limitations.

APG TT2-674/10

SUBJECT: Fire Control Equipment
TITLE: Second Partial Report on Tank, 76mm Gun, T41E1 (Fire Control)
IDENTIFICATION: Tenth Report on Ordnance Project No. TT2-674
DATE OF REPORT: 12 May 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate all standard and modified fire control components in the T41E1 tank, with particular reference to a comparison of the selected production and the Cadillac modified equipment; and to evaluate the firing characteristics of the 76mm gun, T91E3, when used in conjunction with the standard and modified T156 telescope and T35 periscope systems
METHOD: The standard production, selected production and Cadillac modified fire control systems in the 75mm tank, T41E1 were studied and evaluated. Extensive boresight retention and firing tests were conducted on each system, during which individual vehicles were operated from 200 to 1500 miles and their major armament fired from 35 to 280 rounds of 76mm ammunition.
DESCRIPTION: A description of the standard fire control components in the T41E1 tank appeared in the first partial report on tank, 76mm gun, T41E1 (fire control). The changes which were incorporated in the selected production and Cadillac modified systems included the T35 periscope and T178 telescope mount for the selected production system, and the ballistic drive T23 and associated linkage, gunner's periscope mount T176M1, commander's periscope mount T177E2, periscope T35, and telescope mount, T178 for the Cadillac modified control system.
CONCLUSIONS: Boresight retention test results indicated that the T156 telescope as installed in both the selected production and Cadillac modified vehicles would retain adjusted alignment within .3 mils during extended operation. Variations in the sighting alignment of the T35 periscope systems in both types of vehicle, however, could be expected to exceed the .3 mil specification during extended operation because of certain inherent and uncontrollable variables such as thermal effects and vehicular vibration. The gun, ammunition, fire control combination in the selected production and Cadillac modified vehicles was not capable of placing all rounds of the three types of service ammunition on a 7-1/2 x 7-1/2-foot target at ranges from 200 to 2000 yards after having zeroed at an intermediate range with the AP round. It was recommended that care be taken in the design of future tank fire control systems to minimize the length of linkage arms and to avoid mounting linkages and sighting components on thin turret sections which were subjected to considerable deflections under varying thermal effects and vehicular vibration; that the selected production fire control system be adopted for use in standard production T41E1 vehicles; and that the various design modifications of the Cadillac system be further evaluated to determine whether they could be profitably incorporated in the future design of light tank sighting systems.
GENERAL: This 193-page report includes three drawings of ballistic drive shaft couplings.

APG TT2-685H/1

SUBJECT: Fire Control Equipment
TITLE: First Report on Test for Dust and Fogging

of T35 Periscope on Tank, 90mm Gun, M47
IDENTIFICATION: First Report on Project No. TT2-685H
DATE OF REPORT: 24 August 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of anti-obscuration equipment for the M20 periscope (T35)
METHOD: During driving and firing tests of the M47 tanks, obscuration of the periscope line of sight by foreign matter on the glass surfaces inside the turret was observed. Special anti-obscuration devices were tested for use in eliminating the observed conditions.
DESCRIPTION: The T35 periscope M20 was a part of the secondary fire control system of the M47, 90mm gun tank. A six-power section of the periscope was used as a sight, and a unit-power section was used for observation. The periscope design featured a removable head, separated by an air gap from the periscope body. An object window was installed on the periscope head to prevent dust accumulation in the well. An antidust and fogging kit consisting of a 24-volt blower, tubing, Y-connection, and two boots was tested. Also tested was an improved boot without a blower; this boot was a compressible, spring-loaded, tubular device used to close the gap between the periscope head and object lenses.
CONCLUSIONS: Accumulations of foreign matter on the periscope glass were capable of seriously reducing sighting efficiency. The object lens window was considered desirable as a mounting surface for the test anti-obscuration boots, both of which satisfactorily combated dust. However, the boot arrangement containing a blower was unsatisfactory in combating frost, whereas the improved anti-obscuration boot was effective for preventing fogging and was recommended for further development. It was also recommended that a heating element be provided in the periscope for anti-frosting protection.
GENERAL: This 30-page report contains three photographs of the anti-obscuration devices and drawings of a proposed application of electrically conductive glass which would prevent moisture condensation on optical surfaces.

APG TT2-689/8
SUBJECT: Fire Control Equipment
TITLE: First Report on Automatic Target Lead Indicator
IDENTIFICATION: Eighth Report on Project No. TT2-689
DATE OF REPORT: 10 March 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine suitability of the performance characteristics of an automatic target lead indicator kit
METHOD: The test kit was installed in a 76mm gun, M41 tank. Evaluation of the kit included installation, tracking tests, firing tests, cross-country operation, hit probability calculation, and utility of operation studies.
DESCRIPTION: The test kit consisted of the following: a tachometer-generator which was geared to the bottom of an azimuth indicator; a range and ammunition data box, which contained a variable resistor; an M20 periscope, which was modified by adding an experimental meter movement, with the indicating needle in front of the reticle in the eyepiece; and a wiring harness. To operate the lead indicator, the gunner merely selected the desired ammunition type and range on the dial of the ammunition data box. This action varied the resistor inside the box. The tachometer-generator impressed a voltage proportional to the tracking rate, i.e., the speed of the target being tracked, across the resistor. The output voltage of the resistor, in turn, deflected the lead meter, in the periscope by the desired amount of lead.
CONCLUSIONS: The basic principle of the lead indicator was good, and its performance substantially increased the probability of hitting a moving target, compared with the other methods of lead estimation and applications considered. However, several major deficiencies existed in the test kit which required modification to bring the over-all performance characteristics to an acceptable level. It was recommended that operational research studies be initiated to determine the frequency of engagement of moving targets under typical combat conditions, since the inclusion of lead computation into tank turrets ultimately became dependent on a requirement for its use. It was further recommended that development be continued on the test lead indicator in order to eliminate the several deficiencies listed in the report.
GENERAL: This 36-page report includes five photographs of the test equipment.

APG TT2-689L/1
SUBJECT: Fire Control Equipment
TITLE: First Report on Line of Sight Stabilization (Russian)
IDENTIFICATION: First Report on Project No. TT2-689L
DATE OF REPORT: 12 October 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of a Russian stabilized telescope to deliver accurate fire from a moving tank; and to obtain an indication of the practicability of line-of-sight stabilization for possible future application in U.S. combat vehicles
METHOD: The test telescope was fitted to an M46 medium tank turret in place of the direct telescope T152. The scope of the test was limited to visual observation of the telescope prism stability during brief static tests and a minimum number of actual firing trials while operating the vehicle over various test courses.
DESCRIPTION: The Russian stabilized telescope was essentially a direct telescope of approximately two-power magnification, and contained a stabilized optical prism. Angular position of the prism was slaved to the elevation axis of a free gyro through a pulley and metallic belt arrangement, thereby stabilizing the line of sight.
CONCLUSIONS: Performance of the test telescope was inferior to the World War II, single degree (elevation stabilization only), stabilization systems. The telescope, as tested in a nonstabilized turret, offered little improvement over unassisted,

non-stabilized moving fire. Stabilization of the optical element, except for a slight drift tendency, was considered good. It was recommended that single-degree, line-of-sight stabilization be considered unsuitable as a means of satisfying stabilization requirements; and that consideration be given to the initiation of studies for application of stable optical elements to existing gun and turret stabilization systems, slaving the gun and turret to the optical elements.
GENERAL: This 33-page report includes one photograph of the test telescope.

APG TT2-693/2

SUBJECT: Fire Control Equipment
TITLE: Tank, 76-MM Gun, T41 Integrated Fire Control System and Comparative Test of Tank Gun Stabilizers
IDENTIFICATION: Second Report on Project No. TT2-693; APG 229-i1
DATE OF REPORT: 29 January 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness, reliability, and desirability of a T41 Tank integrated fire control system; and to compare the performance of the stabilizer systems of 76mm Gun Tank T41 (Vickers), Light Tank M24 (Westinghouse), and British Centurion Tank III (Metrovick)
METHOD: Firing tests and range checks were conducted with the T41 range finder with the tank in motion and at rest. Results were compared with those of previous tests of Tanks T31 and T37 range finders. Firing tests were conducted with the three tanks to compare stabilizing systems.
DESCRIPTION: The 76mm Gun Tank T41 was a 25-ton vehicle of the light tank class. Its integrated fire control system consisted of the following: a 69-inch, 6-power, superimposed image, coincidence type range finder; automatic lead computer; and gyro-controlled, hydraulically operated (Vickers) stabilization for the gun and turret in elevation and azimuth. The British Centurion Tank III was a 54-ton vehicle. Its fire control system included a 6-power Periscope AFV MK II, and completely electrical stabilization for the gun in azimuth and elevation. No provision was made for range determination. The 20-ton Light Tank M24 was used for stabilizer test control purpose. Its fire control system consisted of a 6-power periscopic telescope and Westinghouse stabilization for the gun in elevation only.
CONCLUSIONS: The integrated fire control system in the tank T41, although reliable, did not completely fulfill design objectives regarding range finder accuracy and stabilizer efficiency, and was considered unsatisfactory. The Centurion Tank III (Metrovick) stabilizer system was superior to the Vickers and Westinghouse. It was recommended that the Metrovick system be further evaluated in Tanks M47 and M48 before initiation of additional stabilizer development programs. Further development of the Tank T41 fire control system was recommended.
GENERAL: This 152-page report contains 27 photographs of the three tanks, an interior view of the T41, and schematics of the three fire control systems.

APG TT2-736A/1

SUBJECT: Fire Control Equipment
TITLE: Gun, Twin 40mm, Self-Propelled T141, Pilot No. 1, Fire Control System
IDENTIFICATION: First Report on Project No. TT2-736A
DATE OF REPORT: 23 June 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of the fire control system of a pilot Model T141, self-propelled, twin 40mm gun
METHOD: Static tests were conducted on the computing and reflex sights of the fire control system of the T141 vehicle. Functional tests of the on-carriage fire control components were then tested under normal operating conditions. Following these, firing tests were conducted to determine the capabilities of the fire control equipment to withstand shocks due to firing.
DESCRIPTION: The pilot Model T141, was a self-propelled, full tracklaying, front sprocket driven, antiaircraft combat vehicle. The vehicle chassis was a modified version of a light tank T41 chassis equipped with two Continental air-cooled engines, a Hydramatic transmission, and a torsion bar suspension system. Armament of the test vehicle consisted of M2A1, 40mm, dual automatic guns mounted on an M4E1, 40mm gun mount with an auxiliary cal. .30 machine gun. A T154 computing sight, which was a modified version of the M19 computing sight, served as a means of furnishing fire control data to the 40mm guns. Reflex sight M24C was also included in the fire control system of the test vehicle. An Oil Gear M6A1E1 unit served as a power traverse and elevating mechanism for the primary vehicle armament; manual controls for traversing and elevating the weapon were also provided.
CONCLUSIONS: The fire control system of the vehicle was satisfactory for field use except for several minor deficiencies including excessive lateral play which was noted in the case of the M24 reflex sight. It was recommended that the several modifications listed in the report be incorporated in the final vehicle design in order to make the vehicle more efficient.
GENERAL: This 124-page report contains 21 photographs of the test vehicle and components.

APG TT2-760/2

SUBJECT: Fire Control Equipment
TITLE: To Determine the Vulnerability of Fire Control Instruments in the 90mm Gun Tank, T48, to Shock from Non-Penetrating Projectiles
IDENTIFICATION: Second Report on Ordnance Project No. TT2-760
DATE OF REPORT: 15 September 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of fire control instruments to shock from nonpenetrating projectiles
METHOD: The turret of the T48, 90mm gun tank was subjected to a total of 10 hits by 90mm APT 33 projectiles and 90mm HE M71 shells. Two armor piercing projectiles and two high explosive shells were used to determine the vulnerability of turret-mounted components under shock loads. Six armor

piercing projectiles were used to find the magnitude of the shock causing the damages and to evaluate experimental shock mounting for the turret. An M82 direct sighting telescope was installed coaxially with the 90mm gun, and its effectiveness as a possible emergency sight was determined.
DESCRIPTION: Two separate fire control systems for the T48, 90mm gun tank were tested. The interim system included a commander's T157 elbow sight, T35 periscope, and a gunner's T24 ballistic drive with a T24 quadrant and T25 range drive. Also tested was the final design for this equipment, which incorporated a T46 range finder. Because the completed system was not yet available, a properly weighted and installed casting was used in place of the T46 range finder. Shock mounting for the T46 range finder shell included 1/4-inch rubber bushings and 3/16-inch rubber pads; synthetic plastic gaskets separated the two range finder armor blisters from the turret walls.
CONCLUSIONS: The fire control instruments proved to be extremely vulnerable to shock produced by impact from non-penetrating projectiles. Lack of adequate shock mounting and poor shock resistance of the component materials were primarily responsible for these test results. Data regarding specific parts of the fire control system were outlined in the report. The direct coaxial telescope remained undamaged and its accuracy was unimpaired. It was recommended that shock mounting be improved, structurally weak components be strengthened, and the direct sighting telescope be included as standard equipment.
GENERAL: This 173-page report contains 82 photographs showing test effects.

APG TT2-777/1
SUBJECT: Fire Control Equipment
TITLE: Vulnerability of Turret Control and Fire Control Components to Non-Penetrating Hits of the Tank, 90-mm Gun, M47
IDENTIFICATION: First Memorandum Report on Project No. TT2-777
DATE OF REPORT: 29 January 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine suitable shock absorbing and dampening material for tank range finders
METHOD: A range finder mock-up was installed in the turret of an M47 Tank with pads of various shock mount materials between the top mounting plate and the range finder. Thirty-eight tests were made by detonating a static charge of three pounds of TNT above the mounting plate. Deflection of the top plate was measured by impression gages and accelerometers mounted on the range finder mock-up and on the mounting brackets.
DESCRIPTION: The test shock mounting materials consisted of 1/8 and 3/8-inch wood, 1/16 and 1/4-inch rubber, 5/8 and 11/32-inch Fabreeka, 1/8-inch Enrup, and 1/4-inch Vibraglass.
CONCLUSIONS: Recorded acceleration values varied considerably during consecutive blasts with the same shock mounts, and at times the negative attenuation was realized; i.e., the range finder registered greater shock than the top plate. Owing to lack of uniformity and questionable reliability of the test results, no definite conclusions were reached, and the test was to be repeated using a dropped weight instead of explosive.
GENERAL: This 12-page report contains a 2-page tabulation and two curve sheets of the test results.

SUBJECT: Fire Control Equipment BRL 453
TITLE: Monocular Stereoscopic Sight
IDENTIFICATION: Technical Note No. 453; Project No. TB3-0538C
DATE OF REPORT: April 1951
ORIGIN: Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of a monocular stereoscopic sight for use as a sight-range finder combination; and to determine the suitability of two methods of superimposing sight fields
METHOD: Tests were conducted to determine the accuracy when sighting on targets at ranges of 600 to 2400 feet; range error was recorded in feet. Next, tests were conducted to determine the superelevation error of the sight when sighting on targets at 1300, 2400 and 3200-foot ranges; gun error was recorded in mils deviation. Two methods of presenting the superimposed field were tested in the sight, and the advantage of each method was evaluated.
DESCRIPTION: The test monocular stereoscopic sight permitted the determining of target range by means of the superimposing of two target images. By placing the resulting image on a retical curve it was possible to aim the vehicle gun by means of the sight. Basically, sight construction consisted of two optical assemblies located at the extremities of a base line, a light distributing system, and a single eyepiece with calibrated reticle. The optical assembly at one extremity of the base line consisted of a prism. The following optical assemblies were tested as methods of superimposing sight fields on a silvered mirror with pie shaped sections removed from the disk (this mirror was designed to rotate in a plane 45° to the optical axis); and a semi-silvered mirror which replaced the silvered mirror.
CONCLUSIONS: Results indicated that the test sight could be used as a range finder with a moderate degree of accuracy and as a means of determining the superelevation of a gun for a target at any reasonable range. Good intensity of target images was obtained when using the silvered mirror in superimposing sight fields; however, the semi-silvered mirror, though presenting weaker images, reduced eye strain.
GENERAL: This five-page report contains one drawing showing the method by which target range was determined when using the sight.

SUBJECT: Fire Control Equipment BRL 554
TITLE: A Study of the Range Finder for the Light Tank T41E1
IDENTIFICATION: Memorandum Report No. 554; Project No. TB3-1224B
DATE OF REPORT: 25 June 1951
ORIGIN: Ballistic Research Laboratories, Aber-

deen Proving Ground, Maryland
PURPOSE: To determine whether it would be advantageous to add a rangefinder to the fire control system of a T41E1 light tank equipped with a 76mm gun, T91
METHOD: Relative advantages and disadvantages of including a range finder in the fire control system of a T41E1 light tank were determined analytically. Factors considered were accuracy, ability to fire first round, probability of scoring first hit, and cost.
DESCRIPTION: Calculations were based on World War II records of accuracy characteristics of vehicles with and without range finders. Projectiles considered included HE, AP, and HVAP types.
CONCLUSIONS: It was concluded that there would be no advantage in including a range finder in the fire control system of a T41E1 light tank. At a distant target, the first shot from a vehicle with a range finder would be the more accurate. However, due to time required to adjust range finder, vehicle without range finder could fire spotting shot and second shot before first vehicle fired first shot. Second round from non-equipped vehicle would be as accurate as first round from equipped vehicle. At closer range, there would be no difference in accuracy, but the equipped vehicle would be at a disadvantage in firing the first round. Increased cost of additional spotting rounds was considerably less than cost of range finder. These conclusions were reached without considering additional problems of crew training and range finder maintenance.
GENERAL: This 26-page report contains several curve sheets depicting the results of the study.

SUBJECT: Fire Control Equipment DA 1773
TITLE: Tracking Performance, T42 Fire Control System
IDENTIFICATION: Report No. 1773
DATE OF REPORT: 10 June 1952
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To evaluate the tracking performance of the T42 fire control system
METHOD: The test fire control system, containing a double pump unit and other associated parts, was installed in accordance with Ordnance Drawing K7401455, and was instrumented for oscillogram recordings. The system was tested for traverse lines pressure, traverse line return pressure, control and charging pressure, slide block position, control shaft position, feedback position indicator, turret acceleration and turret position.
DESCRIPTION: The fire control system was identified as T42.
CONCLUSIONS: The best azimuth tracking performance was obtained by modifying the fire control components, as described in the report. This performance gave a variation in the turret position with respect to the desired position at a given time (surge) of $\pm 1/2$ mil for the entire tracking range. This exceeded the $\pm 1/8$ mil surge considered to be acceptable. Less desirable azimuth tracking performance was obtained in all the other test runs. Surge was in excess of $\pm 1/2$ mil, as well as periods of erratic oscillation. Elevation tracking performance showed undesirable drift and surge, present under all conditions tested. The T42 fire control system produced surge in traverse and elevation which exceeded field force allowances. It was recommended that the fire control components of the elevation and traverse system be redesigned and arranged to simplify the elevation and traverse feedback linkage. It was recommended that the traverse feedback control run directly from the hydraulic motor output shaft to the slide block control; that the pump unit be package-mounted on the hydraulic motor and gear box unit to obtain rigidity between the motor shaft and the slide block control; and that the components be arranged to obtain the shortest elevation feedback cable or rigid linkage.
GENERAL: This 39-page report includes 32 oscillogram readings obtained in the tests.

SUBJECT: Fire Control Equipment DA 1881
TITLE: A Constant Pressure Hydraulic Fire Control System for Tanks
IDENTIFICATION: Report No. 1881
DATE OF REPORT: 7 August 1952
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To provide a hydraulic fire control system and conversion kit for M47 tanks which would be acceptable for use by field forces
METHOD: The system, which was outlined in schematic form in Figures 1 and 2 of the report, was installed in an M47 tank. The hydraulic motors were tested for slip and external leakage, the combined total of slip and leakage at 1000 rpm, 100°F, 1000 psi, not to exceed 20 cipm red oil, Specification MIL-O-5606. The differentials were tested for torque load. The valves were tested for leakage, flow capacity, and axial operating force at 150°F. The assembled valve, differentials, servo valve, and tracking motor were tested for motor speed control at 2400 rpm maximum, and 0.03 rpm minimum.
DESCRIPTION: The test fire control system was an improved version of the standard M47 fire control system. It was a constant pressure hydraulic system which, particularly at low speeds, was designed to give improved control.
CONCLUSIONS: The system provided improved performance as compared to that of the standard M47 fire control system, and exceeded the minimum acceptance limits for use by field forces. Two men could install the complete system conversion kit in a clean tank in eight hours or less. The constant pressure system provided satisfactory control of the gun and turret for application to M47 tanks. It was recommended that the system be utilized in future vehicles, either in its present form or in some improved form; that additional investigation be made to devise a closed loop servo control having a constant pressure source, which could result in a gyro reference system of automatic control; and, that investigations be made into the use of this control system on power-controlled devices such as bulldozers, winches, and booms on tank recovery vehicles, and on any other device where accurate fire control of position and rate was required.
GENERAL: This 29-page report includes 14

drawings of the control system's design characteristics.

SUBJECT: Fire Control Equipment DA 2105
TITLE: Test of Angular Vibration Between the Range Finder and Gun, Tank, M47E1
IDENTIFICATION: Report No. 2105
DATE OF REPORT: 16 December 1952
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the amplitudes and frequencies of angular vibration between the range finder and gun of the M47E1 stabilized tank, during cross-country operation
METHOD: The maximum amplitude of angular vibration between the range finder and gun was recorded during 15 test runs. Secondary vibrations were recorded during the testing at various frequencies. A linear variable differential transformer coil was mounted on one pivot tube and its core on the other tube. The phase and magnitude of the transformer output was continually recorded by a brush recorder during the test runs. The output of the transformer was calibrated in thousandths of inches of core displacement.
DESCRIPTION: The angular vibration pickup consisted of a linkage attached to the range finder and gun with two pivots which, with the pivoted axes of the range finder and gun trunnion, formed a parallelogram under static conditions. The vehicle used in the test was a M47E1 Tank.
CONCLUSIONS: Peak amplitudes exceeded 1.2 mils only six times. All major angular vibration frequencies were about 17.5 and 18.3 cps. Maximum amplitudes of secondary vibrations were .7 mils at .77 cps; .7 mils at 100 cps; and .3 mils or less at other frequencies. Angular vibration between the gun and range finder was of small amplitude and short duration. In over 2000 seconds of testing, an error of 1.2 mils was exceeded only six times, for a total time of less than 2 seconds. Motion between the ballistic box and the gun linkage was not responsible for the larger amplitudes of vibration. Sight vibrations frequently occurred without range finder vibration. The location of the elevation gyro on the rangefinder vs the location of the gun had little apparent effect on range finder vibrations.
GENERAL: This eight-page report is not illustrated.

SUBJECT: Fire Control Equipment DA 2175
TITLE: Automatic Target Lead Indicator for Rate System Tanks
IDENTIFICATION: Report No. 2175
DATE OF REPORT: 26 January 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To evaluate an automatic target lead indicator for tanks using rate control of gun movement
METHOD: The indicator functioned on the principle that angular lead is equal to the number of mils the target moves during the flight of the projectile. Range combined with ballistic data for the ammunition used provided flight time. The gunner had only to set the range on the lead range potentiometer to obtain lead data directly in his periscope sight. The equipment was tested by tracking a truck on a prepared course.
DESCRIPTION: The lead indicator was made up of a modified electric meter movement, mounted on a T35 periscope, a tachometer mounted on the azimuth indicator, plus two standard potentiometers and connecting wires. Neither power source nor batteries were required.
CONCLUSIONS: Limited laboratory tests indicated that this device should be of great value because of making possible first-round hits on a moving target. The lead indicator was applicable to any tank with a range finder, regardless of the caliber of gun or the type of ammunition used. It was recommended that development of this lead indicator be continued, to provide periscopes with built-in movements and a tachometer for early production models for both gunner and commander. It was also recommended that a built-in lead indicator movement be included in the development of a simple range finder, and, that an azimuth indicator with a built-in tachometer be developed for future production models.
GENERAL: This 14-page report includes four photographs of the test equipment and one photograph of the lead indicator.

SUBJECT: Fire Control Equipment DA 2646 B
TITLE: Hydraulic Gun Control System, Tank, T43, 120mm Gun
IDENTIFICATION: Report No. 2646 B
DATE OF REPORT: 24 February 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the backlash and flexibility of the sight linkage, and the performance characteristics of the hydraulic gun control system of the T43 tank
METHOD: The sight linkage was tested by applying effort on the sight and shafts of the sighting system drive, and measuring the resulting deflections. The performance characteristics were obtained by tracking and targeting tests run by experienced gunners. The power losses in the hydraulic system were obtained by assuming the electric motor efficiency to be 60%. Accelerating and running characteristics were recorded, using a tachometer and brush recorder. The turret traverse speed and response were obtained by slewing various increments of rotation and recording the total elapsed time to start, run, and stop.
DESCRIPTION: The hydraulic gun control system was manufactured by the Cadillac Gage Co., of Detroit, Michigan. The T43 tank, 120mm gun, was register No. 30163674.
CONCLUSIONS: The time required for "laying on" a 1/4-mil target averaged five seconds, the tracking accuracy on a moving target was 79% or better at all speeds with experienced gunners, using the test hydraulic gun control system. The test hydraulic gun control system, when driving the turret at 3 rpm, consumed 5.6 hp, of which 3.0 hp was consumed by the electric motor driving the pump, while the remaining 2.6 hp was consumed in the control and pressure reducing valves. It was recommended that the gunner's and the com-

mander's linkage of the T43 tank be corrected to improve stiffness and eliminate backlash; that the part of the linkage contained within the range finder also be corrected; that the design of the test hydraulic gun control system be changed to provide for increased flow capacity; and, that the electronic system being developed for the T58 tank be considered before selecting equipment for this application.
GENERAL: This 15-page report is not illustrated.

SUBJECT: Fire Control Equipment DA 2685
TITLE: Investigation of Sighting Ability in Relation to Angular and Linear Accelerations, Tank, 90mm Gun, M47
IDENTIFICATION: Report No. 2685
DATE OF REPORT: 30 October 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the relation between the linear and angular accelerations of a vehicle and the gunner's ability to see through the sight in an M47 tank, 90mm gun
METHOD: Acceleration and angular rate was recorded for the M47 tank, traveling at 10 mph average speed in a straight path over the test course, and a 8.5 mph average speed, in a zig-zag course. Calibrations were recorded of angular accelerometers and rate gyros on the torsional pendulum.
DESCRIPTION: The vehicle used in the test was an M47 tank, 90mm gun.
CONCLUSIONS: The gunner could see through the sight at all times when the vehicle was driven at 7 mph in a straight path over the test course. The gunner could see through the sight, regardless of the path of the vehicle over the test course, at 5 mph. The average maximum angular acceleration about the pitch axis which permitted the gunner to see through the sight was 7.45 rod/sec^2+20%; the average maximum vertical linear acceleration was 1.43 G's±10%. (G=32.2 ft./sec.^{2}). It was recommended that further investigation of sighting ability with relation to angular and linear accelerations be performed with improved instrumentation; such as commercially available rate gyros and angular accelerometers having a high natural frequency, that tests be run to impart acceleration about or along one axis at a time; that the effect of protective and support equipment for the gunner be investigated; and, that further investigation be conducted, using a stabilized gun for more realistic sighting on a target, and to record the position of the vehicle with respect to the ground.
GENERAL: This 40-page report includes three photographs of the test setup and equipment.

SUBJECT: Fire Control Equipment DA 2747
TITLE: Automatic Target Lead Indicator for Rate System Tanks
IDENTIFICATION: Report No. 2747
DATE OF REPORT: 21 December 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To fabricate and test an automatic target lead indicator kit suitable for field installation
METHOD: Limited calibration tests were run of two automatic lead indicator kits, which were fabricated, waterproofed, and installed in a M47 tank. Studies were made of installations in the T42, T41E1, T41E2, M48, T43 and T54 tanks.
DESCRIPTION: The test items included a tachometer generator, an azimuth indicator, a T35 periscope, a range and ammunition data box, wiring harness, and a Weston experimental meter Model 1011.
CONCLUSIONS: The kit for this lead indicator can be easily installed in the field. Kits can be used on the M47, T42. and T41 as supplied and can be used on the M48, T43, and T54 with only slight modifications of the kit but without modifying the vehicle. The meter movement used in the demonstration kit was too sensitive and not rugged enough for production kits to be supplied in the fields.
GENERAL: This 14-page report includes seven photographs of kit components and one circuit diagram.

SUBJECT: Fire Control Equipment DA 2789
TITLE: British M4 Gun Stabilization Equipment, M47E1 Tank
IDENTIFICATION: Report No. 2789
DATE OF REPORT: 22 January 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To review the activities of the DA Fire Control Laboratory in connection with the development, assembly, testing and maintenance of 20 sets of British M4 gun stabilization equipment, installed in the M47E1 tank
METHOD: Twenty vehicles were assembled. Each vehicle required an extensive "setting up" procedure, after assembly. A field operation test was conducted. Twelve of the vehicles were shipped to other installations for various tests.
DESCRIPTION: The British M4 gun control equipment was of the type used in the British Centurion III, medium tank. The vehicles used in this test were M47 tanks. One vehicle was sent to Willow Run Research Center; two were shipped to Aberdeen Proving Ground; two to Army Field Forces, Board No. 2, Fort Knox, Kentucky, and seven to Camp Irwin, California.
CONCLUSIONS: In general, the installation of the stabilizer in the M47E1 tank was successful. The initial objective of giving the using forces an idea of how a stabilized tank gun performed was realized in Project Stalk, performed at Camp Irwin, California. The ballistic drive design involved more problems in the stabilized tank because the drive must not respond to vibration induced by the motion of the vehicle. The placement of components in the turret required further thought because the crew must be able to carry on their operations in the presence of road shocks. The gun control system itself required additional investigation. The British did a very good job in the design of the system, but it was felt that several improvements could be made. The elevating mechanism could be considerably improved. It was recommended that a Laboratory Work Order be issued to cover further maintenance and engineering work on one of the vehicles; that if a production prototype of a stabi-

lized tank was attempted, correction of deficiencies discovered in this program be considered; that laboratory personnel who had been associated with the stabilized vehicles be allowed to participate in the new program; and, that the unserviceable parts which accumulated in the laboratory be sent to the United Kingdom for repair or replacement.
GENERAL: This four-page report is not illustrated.

SUBJECT: Fire Control Equipment FA R-841
TITLE: Examine Materiel Tested by Manhattan Engineering District; Disassembly and Examination of Ordnance Materiel Returned from Bikini
IDENTIFICATION: Report No. R-841
DATE OF REPORT: 1 April 1948
ORIGIN: Frankford Arsenal, Philadelphia, Pennsylvania
PURPOSE: To examine the various items of Ordnance equipment which had been exposed at Bikini during atom bomb test A, in order to determine the effect of the blast on the functioning of the fire control instruments
METHOD: Visual examination was first made of the items. Next, the equipment was operated in the normal manner unless the damage was sufficient to render it inoperative. If only minor repairs or adjustments were needed to make the instruments function, they were made. In cases where the items were inoperative or where damage was suspected, they were disassembled and the components examined. Accuracy tests were not conducted since it was felt that it would be impossible to distinguish between the inaccuracies caused by handling and normal exposure, and those caused by the bomb blast. All materiel was checked for radioactivity, with radiation measurement set at GLR-200, before any tests were made.
DESCRIPTION: The report covered all the materiel received by the Arsenal except range finders and height finders. The items received were grouped into three classes - optical, mechanical, or electrical and had been aboard the four expendables, the U.S.S. Arkansas, Nevada, Pennsylvania, and Saratoga. Among the specific items tested were binoculars, M15A1; telescopes, T108-E1, BC, M65, M71K, M82; periscopes, M4A1, M6, M10F, M10P; quadrants M1, M4; generating units, M7A1; cables, clocks, and watches.
CONCLUSIONS: The effects of the blast varied in proportion to the distance of the item from the center of the blast. Flash burning of the items was the most noticeable effect and was present to some extent on nearly every instrument. The severity was dependent not only on the distance from the center of the blast but also on the marking of the item. The major damage to items having housings made of sheet material was the distortion, bending, and breaking of such housings. There was little primary damage to the interior parts which were protected by these covers. Most of the damage was caused by secondary effects, such as falling or flying debris, distortion of the housing, or corrosion on inferior components left exposed by damage to the protective covering. It was recommended that the effect of test B on fire control materiel be considered before any changes were made, since the effect of test A on the functioning of the equipment examined did not warrant any immediate changes; and that the results from reports of groups analyzing the effect of the atom bomb blast on basic material such as metal, glass, insulation, lubricants, protective finishes, etc. be investigated before any modifications were attempted.
GENERAL: This 55-page report is not illustrated.

SUBJECT: Fire Control Equipment FA R-944
TITLE: Fire Control Systems for Field Artillery and Combat Vehicles Range Finders for 40mm Weapons AA Range — Only Radar
IDENTIFICATION: Report No. R-944
DATE OF REPORT: 30 October 1949
ORIGIN: Frankford Arsenal, Philadelphia, Pa.
PURPOSE: To develop an antiaircraft range-only radar for interim use with automatic weapons
METHOD: Development was initiated on the various major circuits of the radar with the emphasis placed on simplification of circuits and reduction in bulk. The various circuits, such as the transmitter, receiver, RF system, modulator, timer, ranging system, and control circuits were developed, constructed and tested in breadboard form, and brought to the point of system operation.
DESCRIPTION: A complete detailed description of the system was included in the body of this report.
CONCLUSIONS: The results indicated that design of a packaged range-only radar for the 40mm or twin 40mm guns was feasible. Tentative estimates of size and weight of such a unit, based on the breadboard circuit, lead to a total of less than one cubic foot in bulk (exclusive of antenna) and approximately 50 pounds in weight. This circuitry could be divided into two major components, an RF unit, back of the antenna, and a control unit, near the operator. Recommendations were made that this project be continued to completion of the breadboard system, breadboard system tests, and design and test of a packaged on-carriage range-only radar.
GENERAL: This 42-page report includes one sketch of artist conception of improved 40mm gun with radar, two photographs of the breadboard system, four block diagrams, four wiring diagrams and one schematic diagram of the RF system.

SUBJECT: Fire Control Equipment FA R-1108
TITLE: Tank Fire Control Systems Study — Evaluation of Some Alternative Systems of Tank Stabilization
IDENTIFICATION: Report No. 1108
DATE OF REPORT: April 1955
ORIGIN: Frankford Arsenal, Philadelphia, Pa.
PURPOSE: To study tank stabilization systems
METHOD: An investigation of various aspects of tank stabilization was conducted. Several types of stabilization systems were evaluated as they affected the single shot hit probability and the time to fire the first shot. Total error was considered from these aspects: the inherent accuracy of the system, the ranging error, error caused by the

moving sight, and error resulting from the moving gun. A method was studied for the relation of time and accuracy to tank survival chances (or kill probabilities); in this method a mathematical model of a tank duel was used.

DESCRIPTION: The following systems of tank stabilization were considered: the gun and sight stabilized as a unit; the gun and sight stabilized separately with various degrees of stabilization; and each of these systems in conjunction with a mechanism which would utilize three switches in series to prevent the gun from firing until a sufficient hit probability existed.

CONCLUSIONS: Results of this study indicated that future tank development should consider: stabilization of the sight as tightly as possible in azimuth and elevation; stabilization of the gun in azimuth and elevation only as required for following the sight gyro; and the use of the three-switch firing arrangement with limited gun stabilization. It was recommended that the angular velocity be measured for an unstabilized gun in azimuth and elevation to determine the necessity of limited gun stabilization; investigations should be made of the optimum firing region dimensions under the three-switch proposal, and the magnitudes of sight and gun errors should be studied. It was further recommended that programs be initiated involving detailed investigations of the tactical uses of tanks, battle situations relating to tanks, and the use of more detailed and elaborate tank duels.

GENERAL: This 59-page report includes probability curves, graphs of truncated normal distribution variance, and graphs of firing rates.

Section 18
FORDING

SUMMARY

This summary covers resumes of seven engineering reports written on fording between 1942 and 1949 at Aberdeen Proving Ground, Aberdeen; and Armored Force Board and Army Field Forces Board, both at Fort Knox, Kentucky.

FLOTATION OF ARMORED FIGHTING VEHICLES

Determination of the policy for floating fighting vehicles was decided on in 1949. Conclusions: Land tanks, once ashore, were superior to amphibious tanks. The rigid pontoon was a good firing platform but was awkward on land. The duplex drive device was not seaworthy and prevented firing afloat. The optimum was the elimination of special amphibious tanks by the flotation of conventional tanks. Ship-to-shore devices were acceptable only if they had satisfactory land characteristics and permitted firing afloat. Reflotation of any device was desirable but not mandatory. Shore-to-shore swimming devices must permit approach to shore from rivers, not interfere with fightability and mobility, and must be easily transported, installed, and maintained.

STRAUSSLER FLOTATION SYSTEM

A test was conducted in 1943 to determine the suitability of the Straussler flotation system for the British Valentine tank and the possible use of this system for the M5A1 light tank. The Straussler flotation system consisted of a canvas hull mounted on a sheet steel deck. The hull was raised to the upright position by air pillars filled with air at 35 psi. Four mechanical struts with a hydraulically controlled breakaway feature provided a safety measure to prevent failure of the pillars. The vehicle was operated in water by means of a screw propellor driven by the vehicle transmission. The Straussler flotation system was considered satisfactory for floating the British tank. It was recommended that an investigation be made to determine the need for operating American tanks in water deeper than fording depth. If such a need existed, the Straussler system was recommended for use.

WATERPROOFING OF TANKS AND HALFTRACK VEHICLES

In 1942, a test was conducted to develop the waterproofing of combat vehicles to minimize the dangers of debarking from landing boats. A light tank, M3, a light tank, M5, a medium tank, M4A1, and a halftrack, M2, were modified for landing operations. The waterproofing material included metal shrouds to protect air inlet and outlet openings, fuel tank covers, and various sealing and caulking compounds, including heavy grease. It was concluded that light and medium tanks could be so waterproofed that they could be operated in water deep enough to all but submerge them. The vehicles could be run in water for about three minutes, depending on depth, waves, and care taken in waterproofing. It was recommended that vehicles be waterproofed if landing operations warranted it; that future vehicle designs consider possible waterproofing; and that shrouds be redesigned to simplify their construction and application.

REPORT RESUMES

SUBJECT: Fording AB 328
TITLE: Report on Test of Light Tank, M3E4, with Straussler Device
IDENTIFICATION: Project No. 328
DATE OF REPORT: 25 November 1942
ORIGIN: Armored Force Board, Fort Knox, Ky.
PURPOSE: To determine the suitability of Straussler flotation devices for Light Tanks M3
METHOD: A Light Tank M3E4, equipped with the device, was operated in a pond for an hour. Efficiency and durability of the device were determined.
DESCRIPTION: The tank was prepared for this test by sealing the hull below the fender line. The Straussler flotation device, attached at the fender line, consisted of a rubberized canvas shell held aloft by a frame, the upright members of which were flexible, inflatable air bottles. When inflated, the frame and shell rose to five or six feet above the fender line, forming a waterproof hull, the bottom consisting of the tank itself. Two 9 hp outboard engines were used for propulsion in water. A bilge pump was also included in the kit.
CONCLUSIONS: Flotation with the device was successful, and the bilge pump was required for only a few minutes. However, the device was considered impractical for the following reasons: vulnerability, loss of driver's vision when it was raised and immobilization of tank armament.
GENERAL: This six-page report includes three photographs showing installation, construction, and operation of the flotation device.

SUBJECT: Fording AFF 2-18-49(IX-3)
TITLE: Flotation of Armored Fighting Vehicles
IDENTIFICATION: Report No. 2-18-49(IX-3)
DATE OF REPORT: 18 February 1949

ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To determine the policy for floating fighting vehicles
METHOD: Extracts were made from policy as stated by the War Department Equipment Board. The requirements for flotation as related to bridging, fording, wading, and amphibian capabilities were reviewed. The Army and Navy requirements and the various experimental methods of effecting flotation were summarized. Review and analysis was made of various flotation methods and devices as developed and used by the British, Germans and the U.S. Army, Navy, and Marine Corps.
DESCRIPTION: The topics reviewed were Army and Navy combat amphibians and their limitations, Marine Corps pontoon device, the British canvas hull (DD duplex drive device) bridging, fording and wading, German submerged fording, amphibious carriers, U.S. rigid foam-filled pontoon device and non-rigid pontoons.
CONCLUSIONS: Land tanks, once ashore, were superior to amphibians. The rigid pontoon was a good firing platform but was awkward on land. The duplex drive device was not seaworthy and prevented firing afloat. The optimum was the elimination of special amphibious tanks by the flotation of conventional tanks. Ship-to-shore devices were acceptable only if they had satisfactory land characteristics and permitted firing afloat. Reflotation of any device was desirable but not mandatory. Shore-to-shore swimming devices must permit approach to shore from rivers, not interfere with fightability and mobility and must be easily transported, installed, and maintained.
GENERAL: This seven-page report is not illustrated and is contained with Report No. AFF 2-18-49.

SUBJECT: Fording APG 5684/1
TITLE: First Report on Water Proofing of Tanks and Half Track Vehicles to Increase Fording Ability
IDENTIFICATION: First Report on Ordnance Program No. 5684; APG 10-89
DATE OF REPORT: 21 October 1942
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To develop the waterproofing of combat vehicles to minimize the dangers of debarking from landing boats
METHOD: A Light Tank M3, a Light Tank M5, a Medium Tank M4A1, and a Half Track M2 were modified for landing operations. In the case of tanks, waterproofing consisted of two phases. In the first, the tank was sealed only to the height of the cooling air outlet. The second involved the use of metal shrouds to protect air inlet and outlet openings.
DESCRIPTION: The waterproofing material included metal shrouds to protect air inlet and outlet openings, fuel tank covers, and various sealing and caulking compounds including heavy grease.
CONCLUSIONS: It was concluded that light and medium tanks could be so waterproofed that they could be operated in water deep enough to all but submerge them. The vehicles could be run in water for about three minutes, depending on depth, waves, and care taken in waterproofing. It was recommended that: vehicles be waterproofed if landing operations warranted it, future vehicle designs consider possible waterproofing, and shrouds be redesigned to simplify their construction and application.
GENERAL: This 88-page report includes 31 photographs illustrating fording tests and waterproofing methods. Five drawings are also included illustrating fabrication of waterproofing equipment.

SUBJECT: Fording APG 5684/2
TITLE: First Report on British Valentine Tank with Straussler Flotation System, Fording Test
IDENTIFICATION: Second Report on Ordnance Program No. 5684; APG 10-129
DATE OF REPORT: 13 October 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of the Straussler flotation system for the British Valentine Tank and the possible use of this system for Light Tank M5A1
METHOD: The British tank, with the flotation equipment installed, was operated in more than six feet of water on five occasions. The canvas hull was raised and lowered before and after each test to determine functional characteristics.
DESCRIPTION: The test materiel was a British Valentine Tank equipped with a Straussler flotation system. This system consisted of a canvas hull mounted on a sheet steel deck. The hull was raised to the upright position by air pillars filled with air at 35 psi. Four mechanical struts, with a hydraulically controlled breakaway feature, provided a safety measure to prevent failure of the pillars. The vehicle was operated in water by means of a screw propeller driven by the vehicle transmission.
CONCLUSIONS: The Straussler flotation system was considered satisfactory for floating the British tank. It was recommended that an investigation be made to determine the need for operating American tanks in water deeper than fording depth. If such a need existed, the Straussler system was recommended for use.
GENERAL: This 48-page report contains five photographs illustrating the Straussler flotation and American fording equipment.

SUBJECT: Fording APG 5688/17
TITLE: First Report on Test of Collapsible Ponton Device
IDENTIFICATION: Seventeenth Report on Ordnance Program No. 5688; APG 100-13
DATE OF REPORT: 3 January 1946
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of collapsible pontons for fording operations of medium and heavy tanks
METHOD: Pontons were attached to a Medium Tank T25E1. The mounting brackets were stress tested by using them to lift one side of the vehicle. The tank was launched into and maneuvered in the water. The pontons were then collapsed for land operation. An installation of the pontons on Heavy Tank M26 was attempted but not completed.

DESCRIPTION: The ponton device consisted of two large, rectangular-shaped rubber floats supported on a tubular steel frame. It was mounted by brackets, one on each side of the tank. The frame was hinged at the ends to permit the shell to be collapsed inward with a hand crank. Canvas covered catwalks were provided for protection of the rubber shell.
CONCLUSIONS: The pontons were satisfactory only when the tank was operated in protected waters. The tank and pontons required additional waterproofing during the test. It was recommended that further work on collapsible pontons be discontinued.
GENERAL: This 33-page report contains seven photographs showing installation and testing of the pontons on the medium tank.

SUBJECT: Fording APG 5688/109
TITLE: First Report on Floating Device T8, Medium Tank, M26
IDENTIFICATION: One Hundred Ninth Report on Ordnance Program No. 5688; APG 100-17
DATE OF REPORT: 4 June 1947
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of Floating Device T8 for water operation of Medium Tank M26
METHOD: The device was attached to a medium tank equipped with Tracks T80E1. Speed tests were conducted over land and in the water using various types of grousers. An outboard engine was also used for several of the water tests. Cooling tests were conducted on land and in the water. Firing and simulated firing tests were made with the tank floating in the water.
DESCRIPTION: The Floating Device T8 was a series of watertight compartments filled with a unicellular foam type of plastic. The device consisted of four units; two side pontons, and a front and back ponton. The side pontons were fastened to a supporting frame on the tank by release hooks and "T" slots. The front and rear pontons were in turn fastened to the side pontons by release hooks. The front and rear pontons were identical except the rear unit had two rudders attached. The floating device formed a barge which was carried by the tank on land and which in turn suspended the tank in the water. Propulsion was by the tank tracks. The tank was waterproofed and had exhaust and air inlet stacks attached.
CONCLUSIONS: The device was mechanically reliable, but provided a satisfactory gun platform only in still water. Cooling of the vehicle, with the device installed, was unsatisfactory. Other shortcomings included poor maneuverability in water due to slow speed. It was recommended that no further consideration be given this type of device and that other methods be evolved to meet the flotation problem.
GENERAL: This 105-page report includes 35 photographs showing the device, installation and testing.

SUBJECT: Fording APG 6000/5
TITLE: Second Report on Test of Light Tank M24, Flotation Equipment
IDENTIFICATION: Fifth Report on Ordnance Program No. 6000; APG 10-183
DATE OF REPORT: 10 October 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of a modified rudder system used in connection with flotation equipment for the Light Tank M24
METHOD: The vehicle, equipped with flotation equipment, was operated in water to test the modified steering system. After determining optimum speed in water, the vehicle was operated in low transfer and "direct" transmission range at an average speed of 13 mph. Rudder steering characteristics and turning requirement were observed.
DESCRIPTION: The test vehicle was a Light Tank M24 equipped with flotation equipment. The rudder system had been modified by increasing the rudder area, strengthening the rudder supports for land operating position, modifying the tie bar linkages, using guide pulleys and steel tiller cables in place of the original guide eyes and tiller ropes, and installing a driver-operated steering control.
CONCLUSIONS: The rudders were considered to have sufficient area and provide adequate control and maneuverability. The turning circle of 80 feet was considered satisfactory. Poor mechanical advantage of the tiller bar resulted in excessive steering effort, and the folding feature of the rudders contributed to flutter during water operation. It was recommended that the folding feature of the rudders be redesigned to eliminate excessive plate and flutter; that steering effort be decreased to permit one-hand control during operation; and that a better means be provided for securing the tiller cables to the steering drum.
GENERAL: This 22-page report contains seven photographs of the Light Tank M24 equipped with flotation equipment.

Section 19
GUN ELEVATING AND TRAVERSING MECHANISMS

SUMMARY

The subject, Gun Elevating and Traversing Mechanisms, was not summarized because of the limited scope of the gun elevating and traversing mechanism reports briefed to date. When a sufficient number of gun elevating and traversing mechanism reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

APG 5887/19

SUBJECT: Gun Elevating and Traversing Mechanisms

TITLE: First Report on Installation and Test of Oilgear Traversing Mechanism for Russian Tank, T34

IDENTIFICATION: Nineteenth Report on Ordnance Program No. 5887

DATE OF REPORT: 6 June 1944

ORIGIN: Aberdeen Proving Ground, Maryland

PURPOSE: To determine the feasibility of installing an M4 medium tank Oilgear traversing mechanism in the Russian Tank, T34

METHOD: The Oilgear traversing mechanism was installed in the Russian T34 tank. Because of limited space in the turret of the T34 tank, and because of the contour of the turret, it was necessary to replace the Oilgear motor with a special motor. Tests were conducted to check the power requirements and speed of operation on level ground, and on a 30% slope.

DESCRIPTION: The two vehicles used in the test were a U. S. M4 medium tank, and a Russian T34 tank.

CONCLUSIONS: The standard Oilgear traversing mechanism as used in the M4 medium tank could not be satisfactorily installed in the Russian T34 tank. Satisfactory installation of the Oilgear traversing mechanism could be made using a special Oilgear motor. It was recommended that the installation of an Oilgear traversing system as detailed in the report be considered satisfactory.

GENERAL: This 16-page report includes three photographs of the Oilgear traversing mechanism installation.

APG TT2-693/3

SUBJECT: Gun Elevating and Traversing Mechanisms

TITLE: First Report on Unstabilized Gun Control Systems for Tanks; First and Final Report on Modified (Mechanical) Turret Control System for Tank, 90mm, Gun, M47

IDENTIFICATION: Third Report on Project No. TT2-693

DATE OF REPORT: 15 March 1954

ORIGIN: Aberdeen Proving Ground, Maryland

PURPOSE: To evaluate and compare four types of pilot gun control systems for tank, 90mm gun, M47

METHOD: The four gun control systems were installed in M47 tanks and duplicate tests of each system were conducted with respect to effectiveness, ruggedness, reliability and simplicity of operation. Comparison tests of the systems included engagement of targets, tracking, firing of 590 rounds, driving 1880 miles, and operating the power control systems a total of 340 hours.

DESCRIPTION: The simplified gun control systems included a standard Oilgear unit modified to function as a mechanical control; an electric Amplidyne unit; a Cadillac Gage Company hydraulic constant pressure unit; and a Vickers, Inc., hydraulic control system.

CONCLUSIONS: The Amplidyne and constant pressure unstabilized gun control systems exceeded AFF Specification performance requirements in most respects. With certain modifications, it was felt that these systems would be suitable for incorporation in future tank designs. The Vickers hydraulic system was considered unsatisfactory since it did not meet several of the minimum requirements for gun control systems. The modified Mechanical gun control system performance was only marginal in many respects. It was recommended that the constant pressure and/or Amplidyne gun control systems be used in future tank design, provided recommended changes were incorporated, and the influence of ballistic attack and extreme temperature were determined. It was also recommended that development of Vickers and Mechanical control systems be discontinued.

GENERAL: This 599-page report includes 34 photographs of the various components of the test systems. Modification records, deficiency records, and descriptions of the gun control systems are also included.

DA 2007

SUBJECT: Gun Elevating and Traversing Mechanisms

TITLE: Installation of Electric Power Manual Gun Control System in Tank, 90-MM Gun, T42

IDENTIFICATION: Report No. 2007

DATE OF REPORT: 21 October 1952
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To install an electric power and manual fire control system in the 90mm Gun Tank T42
METHOD: The Oilgear power traversing and elevating units, except the elevating cylinder were removed, and electrical components were installed. Equipment removed from the turrets included the oil gear double pump and reservoir, traverse gear box, gunner's and commander's control handles, all rigid hydraulic tubing, override control box, relay box, and all electrical harnesses for the above components. Various brackets were fabricated for the new installation. A standard M47 traverse gear box was modified by changing the hand crank to the T41E1 type.
DESCRIPTION: The electric power and manual fire control system using amplidyne motor generators, were for use in the 90mm Gun Tank T42. A special combination relief valve and locking valve unit was connected by a flexible hose to two hydraulic elevating pumps. One pump was driven by an electric motor, and the other was operated manually. Either pump could be used at any time without the use of a selector valve. A second installation was made, similar to the first except that a standard relief valve and two standard locking valves were mounted with rigid lines to the moveable end of the elevating cylinder.
CONCLUSIONS: The system was practical to install in the T42 turrets, utilizing space previously occupied by the hydraulic equipment. Only slight modification was required.
GENERAL: This 42-page report contains seven photographs illustrating the installed equipment. Sketches of brackets, equipment, and a schematic diagram of the system are included.

DA 2391
SUBJECT: Gun Elevating and Traversing Mechanisms
TITLE: Gun Control System, Tank, 76mm Gun, T41E2
IDENTIFICATION: Report No. 2391
DATE OF REPORT: 22 April 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To evaluate the elevation and traverse gun control systems of the T41E2 tank
METHOD: Tests were conducted for accurate laying, tracking, response rate, and manual elevating and traversing effort. Interim specification, dated 14 January 1953, titled, "Tank, 76mm Gun, T41E2, Turret Controls", was used as a basis for evaluation. The requirements included the ability to accurately track a small target moving at a wide range of speeds, or to accurately lay on a stationary target in a short time.
DESCRIPTION: The vehicle used in the test was a T41E2 tank, 76mm gun. The turret and gun controls of the tank consisted of a gunner's manual traverse and elevation system, a gunner's power traverse system, and a commander's power traverse and elevation system.
CONCLUSIONS: The test system failed to meet the interim specification in the manual traverse effort and manual elevating backlash tests. Continuous operation of the power controls could not be maintained during cross-country operation. Field maintenance was extremely difficult due to the time and special equipment required for removing the 350-pound unit. Tracking performance, control response, and accurate laying ability met or exceeded the interim specification. Operation under field conditions was unreliable.
GENERAL: This 16-page report is not illustrated.

DA 2646a
SUBJECT: Gun Elevating and Traversing Mechanisms
TITLE: Functional Test of Cadillac Gage, Gun Control System in the T43 Tank, 120mm Gun
IDENTIFICATION: Report No. 2646a
DATE OF REPORT: 24 September 1953
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To test the performance of a gun control system
METHOD: The gun control system was installed in the tank and tested for its functional control operation only. Tracking and laying-on tests were conducted, and the maximum speed for the system was determined. No consideration was given to the disposition of stowage or rearrangement of parts for ease of operation by the gunner.
DESCRIPTION: The test unit was a gun control system with a 12 gpm pump. The system was manufactured by the Cadillac Gage Company and was used in the T43 tank, 120mm gun.
CONCLUSIONS: The gun control system with the 12 gpm pump operated at a turret speed of 4 rpm and layed on a 1/4-mil target in less than six seconds. The tracking accuracy dropped from 98% at low target speeds to 90% at high target speeds. For a satisfactory installation with regard to convenience, the reservoir unit should have been separated from the valve unit. The elevation control was very sensitive and difficult to operate. Additional tests were to be conducted with the valves and other components to determine the characteristics of a valve suitable for control of the T43.
GENERAL: This four-page report is not illustrated.

Section 20
GUN MOUNTS

SUMMARY

The subject, Gun Mounts, was not summarized because of the limited scope of the gun mount reports briefed to date. When a sufficient number of gun mount reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

AFF 4647-4 (2B,3C)

SUBJECT: Gun Mounts
TITLE: Report of Test of 155-MM Howitzer on Howitzer Motor Carriage M41 Report of Study of Heavy Winter Test of 155-MM Howitzer on Motor Carriage M41
IDENTIFICATION: Project No. 4647-4; Annex 2B, 3C
DATE OF REPORT: 6 September 1946 and 8 May 1947
ORIGIN: Army Ground Forces Board No. 1, Fort Bragg, North Carolina
PURPOSE: To determine operational characteristics of 155mm Howitzer M1 recoil mechanism under extreme cold conditions
METHOD: The test weapon was fired from center traverse, 283 mils to 500 mils elevation, with charges 5 and 6, in temperatures ranging from +30°F to -3°F. This test was conducted near Ladd Field, Alaska, during the winter of 1946-1947. Test, Frost 1-106, was evidently given at Camp McCoy, Wisconsin.
DESCRIPTION: The test weapon was a 155mm Howitzer M1 on Howitzer Motor Carriage M41.
CONCLUSIONS: The recoil and counter-recoil action was satisfactory. Considerable difficulty was encountered with recoil oil leaking past the rear end of the replenisher piston after the weapon was cold-soaked at -50°F. It was thought this leak was caused by the contraction of neoprene packing No. A-175831, due to the extreme cold. The Camp McCoy report mentioned five replenisher failures.
GENERAL: The report on Project FGD-113.0 contains two pages. The report on Project 1-106 (Frost) contains one page. Neither report is illustrated.

APG 5676/47

SUBJECT: Gun Mounts
TITLE: First Report on Test of Gun Mount Installation on Cargo Carrier, M29C
IDENTIFICATION: Forty-seventh Report on Ordnance Program No. 5676; APG 19-11
DATE OF REPORT: 5 April 1946
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine safe limits of elevation and traverse, accessibility of weapons, and adequacy of mount installations for field operation
METHOD: Two gun mount installations were made on a Cargo Carrier M29C. Dispersion firing tests were conducted with Cal. .50, M2 H.B. Machine Gun and 37mm Gun T32 on forward mount. Firing test of 75mm Recoilless Rifle T21 was made with rear gun mount. A 660-mile endurance test was conducted on the vehicle with 37mm Gun T32 and a 75mm Recoilless Rifle T21 mounted.
DESCRIPTION: The forward gun mount consisted of a standard machine gun pintle socket supported over the engine compartment by four tubular legs. Legs were welded to the frame of the vehicle. The rear mount was a standard machine gun pintle socket incorporating a cross levelling device giving a plus or minus adjustment of 15°. The installation was designed to allow use of 57mm Recoilless Rifle T15E9 or the 75mm Recoilless T21 on a M1917A1 Machine Gun Cradle.
CONCLUSIONS: The forward mount with rear support legs welded was deemed adequate for the Cal. .50, M2HB Machine Gun or the 37mm Gun T32. The modified forward mount with toggle secured legs was considered superior, however. The rear mount was satisfactory for 75mm Recoilless Rifle T21; however, installing mount at center of vehicle permitted approximately 10% greater area of fire. Servicing and sighting were also more satisfactory. It was recommended no further consideration be given to rear installation of mount and further development be made on the center mount.
GENERAL: This 35-page report includes four photographs illustrating the vehicle, damage to windshield resulting from test, front mounting with 37mm Gun T32 and rear mount with 75mm Rifle T21.

APG 5696/14

SUBJECT: Gun Mounts
TITLE: First Report on Firing Tests of Recoilless Weapons on 105-MM Howitzer Motor Carriage, M37
IDENTIFICATION: Fourteenth Report on Ordnance Program No. 5696; APG 42-20
DATE OF REPORT: 25 January 1946
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the feasibility of mounting the 75mm Recoilless Rifle T21 and the 4.2-inch Recoilless Mortar E34R1 with Ring Mount M68

on the 105mm Howitzer Motor Carriage M37
METHOD: Firing tests were conducted on the rifle and mortar after installation on the vehicle to check dispersion and operational ease.
DESCRIPTION: The 75mm Recoilless Rifle T21 was installed with Cradle M1917A1 and Ring Mount M68. The 4.2 Recoilless Mortar E34R1 was installed with Cradle M27 and Ring Mount M68.
CONCLUSIONS: The rifle and the mortar could be operated, serviced, and sighted within Ring Mount M68. Dispersion results were satisfactory. Neither weapon could be synchronized to supplement principal weapon. The field of fire was limited to 60° over the left front of vehicle and it was recommended no further consideration be given to the installation of these guns on Ring Mount M68 as installed on 105mm Howitzer Motor Carriage M37.
GENERAL: This 32-page report includes five photographs of vehicle and gun installations.

SUBJECT: Gun Mounts APG 5697/3
TITLE: First Report on Mounting of Four 75mm Rifles on 40mm Gun Motor Carriage M19
IDENTIFICATION: Third Report on Ordnance Program No. 5697
DATE OF REPORT: 26 February 1946
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine mount stability and dispersion characteristics of four 75mm rifles installed on the 40mm gun motor carriage M19
METHOD: The rifles were checked for bore alignment and average recoil length. Dispersion firing was conducted at 1100 yards on 16x16 vertical target. Seven groups of salvos were fired after a check of the weight of the propelling charges and projectiles.
DESCRIPTION: The test units were four 75mm recoilless rifles T121 installed in a cluster on the mount M4 (T12) of the twin 40mm gun motor carriage M19. The original M4 mount was modified by the addition of a gear train to bring the traverse handwheel to the left side of the gun, thus permitting one gunner to control the direction of fire. The mount was equipped with four firing solenoids to permit ripple or salvo firing. Sighting of the unit was accomplished by telescope sight T126E2.
CONCLUSIONS: The mount was considered feasible for multiple installation of 75mm recoilless rifles T21. Dispersion characteristics of the experimental multiple mount were satisfactory. However, each rifle had to be zeroed-in by firing instead of bore-sighting them on the same point. It was recommended that the electrical firing system be redesigned to provide volley or ripple firing; that elevation safety stops be used; and that deflection and elevation adjustments be redesigned to facilitate proper adjustment and locking when zeroing-in the rifles.
GENERAL: This 35-page report contains two photographs of the test installation. Also included are scaled drawings of the installation.

SUBJECT: Gun Mounts APG TT2-503/1
TITLE: 75mm AA Gun Mount T18, Self-Propelled, Firing Test to Determine Stability
IDENTIFICATION: First Report on Program No. TT2-503
DATE OF REPORT: 2 July 1948
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether the T18, 75mm antiaircraft gun mount, could be mounted on the M19, 40mm gun motor carriage; and, whether the vehicle was stable when a T22, 75mm gun, was automatically fired
METHOD: The 40mm gun mount was removed from the M19. The adapter ring and the 75mm gun mount, T18, were then installed. The test vehicle was operated for 50 miles and single round firing was accomplished.
DESCRIPTION: The adapter ring was designed and fabricated at the Detroit Arsenal.
CONCLUSIONS: The 75mm gun mount, T18, could be satisfactorily mounted on the chassis of the 40mm gun motor carriage, M19, after certain interferences were corrected. In general, the use of the Detroit Arsenal adapter was satisfactory. Automatic firing could not be conducted because of the unsatisfactory performance of the load rammer, T18. It was recommended that, pending a decision to use gun motor carriages of this type, additional tests of the gun and self-propelled carriage be conducted to establish that the vehicle could be a satisfactory mount for an automatic gun.
GENERAL: This 52-page report includes 13 photographs of the 75mm AA gun mount, T18, and some of its component parts.

Section 21
GUNS

SUMMARY

This summary covers resumes of 10 engineering reports written on guns between 1949 and 1955 at Aberdeen Proving Ground, Maryland; Watertown Arsenal, Massachusetts; and Army Field Forces Board No. 2, Fort Knox, Kentucky.

EXPERIMENTAL BORE EVACUATORS

A 1955 test was conducted to determine the suitability of an experimental-type bore evacuator for use on 90mm guns, M36 (T119) and M41 (T139). The test bore evacuator, identified as WTV-D1720, was a high strength steel cylinder weighing approximately 58 pounds. The test evacuator was about twice as resistant to cal. .50 projectiles as the standard evacuator. Evacuation efficiency of the test evacuator was also superior to that of the standard evacuator. It was recommended that the test evacuator be considered acceptable for use with 90mm guns, M36 and M41, in place of the standard type.

LIGHT ANTIAIRCRAFT POLICY FOR COMBAT VEHICLES

In 1949 a review and discussion was engaged in to determine the light antiaircraft policy for combat vehicles (AFV'S) in the U.S. Army. Conclusions: There was an urgent need for a dual purpose, small-caliber weapon mounted on combat vehicles and capable of firing against ground targets and aircraft flying at speeds up to 800 miles per hour at ranges from 200 to 2500 yards. The weapon should be rapid in operation and available for use by the vehicle commander. The antiaircraft use of the weapon was considered of secondary importance to the ground use. The basic doctrine on security against hostile aircraft, as stated in the field manuals, was generally sound. However, the field manuals should include the use of small-caliber antiaircraft firing against aircraft when identified as hostile and when within range.

BRITISH 6.5-INCH DEMOLITION GUN AND AMMUNITION

Determination of the effectiveness of the British 6.5-inch demolition gun using squash-head ammunition was made in a 1950 test. The test British 6.5-inch demolition gun was designed to fire demolition projectiles at short ranges with extreme accuracy. The large chamber area, along with a small propellent charge, produced a low chamber pressure and projectile velocity. The breech mechanism could be opened manually or automatically, but had to be closed manually. In addition, the breechblock opened obliquely. The gun was mounted on a 155mm gun carriage and used the 155mm recoil mechanism. It was concluded that the squash-head round, while very effective against reinforced concrete, was somewhat retarded by the protrusion of the reinforcing steel. During this test an unusually high percentage of duds was encountered.

REPORT RESUMES

SUBJECT: Guns AFF 2-18-49(IX-5)
TITLE: Light Antiaircraft Policy for Combat Vehicles
IDENTIFICATION: Report No. AFF 2-18-49(IX-5)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To determine the light antiaircraft policy for combat vehicles (AFV'S) in the U.S. Army
METHOD: A review and discussion was conducted of pertinent extracts from War Department Equipment Board report, Antiaircraft Material Standardization Conference report, and field manuals. Antiaircraft weapon requirements and types for combat vehicles were also discussed.
DESCRIPTION: Light antiaircraft weapons for combat vehicles were short range machine guns capable of engaging low-flying aircraft, operating at speeds up to 1000 miles per hour and at ranges of from 200 to 2500 yards.
CONCLUSIONS: There was an urgent need for a dual purpose, small-caliber weapon mounted on combat vehicles and capable of firing against ground targets and aircraft flying at speeds up to 800 miles per hour at ranges from 200 to 2500 yards. The weapon should be rapid in operation and available for use by the vehicle commander. The antiaircraft use of the weapon was considered of secondary importance to the ground use. The basic doctrine on security against hostile aircraft, as stated in the field manuals, was generally sound. However, the field manuals should include the use of small-caliber antiaircraft firing against aircraft when identified as hostile and when within range.
GENERAL: This five-page report is not illustrated and is contained with Report No. AFF 2-18-49.

SUBJECT: Guns AFF 1307
TITLE: Military Characteristics for a Dual-Purpose (Antiaircraft-Ground) Machine Gun To-

gether with Associated Fire Control Equipment and Mount for Installation on Tanks
IDENTIFICATION: Project No. 1307
DATE OF REPORT: 22 July 1949
ORIGIN: Army Field Forces Board No. 2, Fort Knox, Kentucky
PURPOSE: To determine desirable military characteristics for the development of a short range antiaircraft machine gun mount and fire control equipment for tanks
METHOD: Since the equipment was in the predevelopment stage, no testing had taken place.
DESCRIPTION: The machine gun, including the mount and fire control equipment, was to be developed as a tank mounted anti-aircraft-ground weapon. Weapon control, sighting, and operation was to be performed by one man, preferably the tank commander.
CONCLUSIONS: Two tank mounts were required, one for a short term use suitable for adaption to existing equipment and the other to be developed as a long range program. The heavy barrel cal. .50 Machine Gun M2 was considered suitable for short term use but not for the long range project. It was recommended that both projects be developed and that pilot models be procured for appropriate service tests.
GENERAL: This 19-page report contains five appendixes which present detailed military characteristics required for both projects.

SUBJECT: Guns APG TR1-1031/3
TITLE: British 6.5-Inch Demolition Gun and Ammunition
IDENTIFICATION: Third Report on Project TR1-1031; APG 314-13
DATE OF REPORT: 17 October 1950
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of the British 6.5-inch demolition gun using squash-head ammunition
METHOD: The gun was weighed and measured. Chamber pressures, velocities, and weapon accuracy were established by firing inert ammunition. Sufficient squash-head rounds were fired at a reinforced concrete block, measuring 26 x 10 x 7 feet, to produce an opening large enough to allow a heavy tank to pass through.
DESCRIPTION: The test British 6.5-inch demolition gun was designed to fire demolition projectiles at short ranges with extreme accuracy. The large chamber area, along with a small propellent charge produced a low chamber pressure and projectile velocity. The breech mechanism could be opened manually or automatically, but had to be closed manually. In addition, the breechblock opened obliquely. The gun was mounted on a 155mm gun carriage and used the 155mm recoil mechanism. Additional information on this gun is contained in Report No. APG 314-10.
CONCLUSIONS: The squash-head round, while very effective against reinforced concrete, was somewhat retarded by the protrusion of the reinforcing steel. During this test, an unusually high percentage of duds were encountered.
GENERAL: This 60-page report contains 20 photographs illustrating the gun and its destructive effect on the concrete block. Gun measurements and a schematic of the breech mechanism are also included.

SUBJECT: Guns APG TR3-3045/1
TITLE: First Report on the Development Tests of the 90-MM Gun, T119, Materiel
IDENTIFICATION: First Report on Ordnance Project No. TR3-3045; APG 314-4
DATE OF REPORT: 7 May 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the durability and suitability of 90mm Gun T119, and to compare the erosion and accuracy characteristics of plated and unplated tubes
METHOD: A total of eight guns, 12 tubes, and five recoil mechanisms were tested. The pilot model of the gun was mounted on a 90mm (AA) Gun Mount M1 for test purposes. Later guns of the same model were mounted on a 155mm Gun Carriage M1, modified to receive Concentric Recoil Mechanism T76. Erosion comparison was made with one chrome plated tube and one unplated tube. The gun was tested for accuracy by firing groups of shots at 24 x 24-foot targets at a range of 1000 yards. The gun was fired after "soaking" for a protracted period in the cold room at a temperature of -65°F.
DESCRIPTION: The test 90mm Gun T119 consisted of an alloy steel monobloc tube fitted by means of screw threads into a ring at the breech end. A bore evacuator and a muzzle brake were mounted at the muzzle end. The interior of the breech ring was machined to receive a vertical sliding block. Rounds were loaded manually, the loading operation automatically closing the breech when the cartridge case rim tripped the ejector lips. During the counter-recoil action, the breech was opened, the cartridge case was ejected, the percussion mechanism was cocked, and the breech-block was locked in its "open" position. A handle was provided to open the breech manually. The Concentric Recoil Mechanism T76 was of the hydro-spring type.
CONCLUSIONS: Due to the limited number of rounds fired (204 rounds per tube), no definite conclusions were reached on the relative superiority of the plated over the unplated tube. The muzzle brake lacked sufficient strength for the high muzzle pressures, and the recoil mechanism lacked sufficient strength and buffering action. It was recommended that the gun, tube, and bore evacuator be considered satisfactory. It was also recommended that a more suitable muzzle brake and recoil mechanism be developed for the weapon.
GENERAL: This two-volume 387-page report includes 61 photographs of the test installation and gun components.

SUBJECT: Guns APG TR3-3045/2
TITLE: The Development Tests of the 90-mm Gun, T119, and T119E1 Material
IDENTIFICATION: Second Report on Ordnance Project No. TR3-3045
DATE OF REPORT: 6 September 1951

ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the acceptability of 90-mm guns and associated components under various temperature firing conditions
METHOD: A modified breech ring for a 90mm gun was subjected to firing tests at temperatures ranging from -40°F to 70°F. A case ejection test was also conducted at these temperatures with 18-pound projectiles fired at a muzzle velocity of 2100 fps and powder chamber pressure of 30,000 psi. A 90mm gun tube, received from an outside source, was assembled in a 90mm mount and subjected to a special erosion and accuracy test. Time-pressure-travel data were also recorded and plotted for the mount concentric recoil mechanism. An evaluation was made of the performance of two new blast deflectors used in these development and proof acceptance tests.
DESCRIPTION: The test breech ring was designed for a T119 90mm Gun and had been modified by increasing the shell loading slot from 4.75 to 6.00 inches. The test gun tube assembled in the mount had been received from the Erie Ordnance Depot. The recoil mechanism of the mount was similar to the T76 Mechanism described in an earlier project report except that the push-pull cable for firing assembly had been replaced by a mechanical system of steel shafts and linkages. One of the test blast deflectors, designated as "X", was a one piece, forged steel, single baffle type weighing about 65 pounds. The gas ports and shell exit had been enlarged and the baffle concavity reduced to minimize firing stresses. The other deflector, designated as "Y", was similar except that it was made of a one piece casting and weighed about 85 pounds.
CONCLUSIONS: The test performances of the modified breech ring, Erie Ordnance Depot gun tube, and test 90mm mount combination were considered acceptable. The Type "X" deflector was considered tentatively satisfactory pending the results of further testing. It was recommended that this deflector be tested with a minimum of 300 rounds to determine the effect of gas erosion on adaptor life.
GENERAL: This 180-page report contains many illustrations and numerous charts of test data.

SUBJECT: Guns APG TR3-3045/4
TITLE: Third Report on the Development Tests of the 90mm Gun, T119, Materiel
IDENTIFICATION: Fourth Report on Project No. TR3-3045
DATE OF REPORT: 3 December 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the suitability of two types of 90mm gun tubes T119 when used to fire hypervelocity rounds exclusively; and to determine the suitability of three types of blast deflectors and one prong-type flash suppressor for use on the tubes
METHOD: Serviceability limits of both test-type gun tubes were determined during firing tests from a proof facility mount; HVTP-T83 shot was used during the entire test program. Three different types of blast deflectors and one prong type flash suppressor were tested for suitability while installed on the subject tubes.
DESCRIPTION: The two test-type 90mm gun tubes, T119, manufactured by Watervliet Arsenal, were identical except that the bore of one tube was chrome plated, while the other was unplated. The three types of blast deflectors tested were manufactured by the Republic Steel Company and included: T-types, Drawings Nos. WTV-F1095, F730-5834, and F7305844. The test flash suppressor, APC Drawing No. DS-5056D, was manufactured at Aberdeen.
CONCLUSIONS: Service life of the chrome-plated tube was about 50% greater than that of the unplated tube; extreme inaccuracy marked the end of serviceability of both tubes. Although gas erosion was excessive at the shell exit hole, none of the test blast deflectors or flash suppressor failed; strength of the test blast deflectors was superior to that of the conventional type muzzle brake. It was recommended that the plated tube be considered superior to the unplated tube when firing hyper-velocity rounds; and that of the blast deflectors tested the strength of blast deflector No. 7305844 be considered the most superior, although deflector metal resistance to gas erosion still required improvement. It was further recommended that the flash suppression characteristics of the prong-type suppressor be considered superior to that of the conventional style muzzle adapter. However, its weight factor precluded its use at the time.
GENERAL: This 139-page report contains 37 photographs of the test equipment, two photomicrographs, and five photographs of curve sheet results.

SUBJECT: Guns APG TR3-3045A/1
TITLE: First Report on the Development Tests of Experimental Bore Evacuators for Guns, 90mm, M36 (T119) and M41 (T139) (U)
IDENTIFICATION: First Report on Project No. TR3-3045A
DATE OF REPORT: 3 June 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of an experimental-type bore evacuator for use on 90mm guns M36 and M41
METHOD: Vulnerability of the test evacuator to small arms fire was determined; cal. .50 projectiles were used in this test. Efficiency of the test evacuator when mounted on several 90mm guns was visually observed while using various types of 90mm projectiles. For the purpose of comparison, a standard bore evacuator was tested under similar conditions.
DESCRIPTION: The test bore evacuator, identified as WTV-D1720, was a high strength steel cylinder weighing approximately 58 pounds. Test evacuator statistics included: length, 29-5/8 inches; diameter 8 inches; and wall thickness, 1/4-inch. The wall of the evacuator was constructed of alloy steel (FS8630, 8730, or 4130) with a determined Rockwell hardness of C43-C46. The standard bore evacuator, Ordnance Drawing No. 7237763, was a mild steel cylinder weighing 33 pounds; the only similarity between this evacuator and the test evacuator was the length.
CONCLUSIONS: The test evacuator was approxi-

mately twice as resistant to cal. .50 projectiles as the standard evacuator. Evacuation efficiency of the test evacuator was also superior to that of the standard evacuator. It was recommended that the test evacuator be considered acceptable for use with 90mm guns M36 and M41 in place of the standard-type.
GENERAL: This 48-page report contains 10 photographs of the test and standard bore evacuators. A second type of test bore evacuator WTV-F1676, which was tested only with relation to vulnerability to small arms fire, is also included in the photographs.

SUBJECT: Guns APG TT2-644/2
TITLE: Test of Gun, 6.5-inch, T13 and its Concentric Recoil Mechanism
IDENTIFICATION: Second Report on Project No. TT2-644; APG 314-10
DATE OF REPORT: 18 August 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the characteristics of the concentric recoil mechanism on British 6.5-inch Gun T13, and to proof test the gun
METHOD: Critical diameters in the recoil mechanism of two guns were measured; the springs were calibrated to meet specifications; buffering action was adjusted in gymnastication tests; propellant charges were preheated to 140° F to obtain chamber pressures 115% of normal; and the guns were proof fired to obtain data on the recoil cycle.
DESCRIPTION: The British 6.5-inch Demolition Gun T13 with concentric recoil mechanism was being developed and adapted for use in the Engineer Armored Vehicle T39. The propellant case was perforated and permanently attached to the projectile, thus eliminating the need for cartridge case ejectors. The sliding breech block opened downward at a 30° angle from vertical. A 24-volt, non-percussion type, firing mechanism was used. Additional description of this gun is contained in Report APG 314-13.
CONCLUSIONS: A maximum recoil oil-pressure peak of about 2500 psi was considered extremely high when compared to a maximum design pressure of 1000 psi. The general performance of the recoil mechanism was otherwise satisfactory. It was recommended that the oil flow restriction near the beginning of the recoil cycle be reduced to improve the characteristics of the pressure curve. The breech block was difficult to open manually and reduction of the tolerances in guide assembly was suggested.
GENERAL: This 64-page report includes a photograph and six drawings of the recoil mechanism components. Also included are tabulations of recoil mechanism characteristics, critical diameters, stargauge measurements, and 18 curves of recoil pressures, velocities, and travel.

SUBJECT: Guns APG TT2-777/16
TITLE: Fourth Report on the Development Tests of 90mm Gun, T119/T119E1, Materiel
IDENTIFICATION: Sixteenth Report on Project No. TT2-777
DATE OF REPORT: 4 October 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the low-temperature performances of two types of front followers; and to evaluate the effectiveness of an anticorrosion seal, and an experimental bore evacuator for 90mm guns
METHOD: Firing tests at temperatures ranging from 45° to -40° F were conducted with two 90mm T119E1 guns, each equipped with a different type of front follower. To determine the protective qualities of the anticorrosion seal under firing and non-firing conditions, one seal was installed on the tube of a 90mm gun in an M47 tank; the other was installed on a gun and mount, assembled to a 155mm gun carriage, M1, which was then exposed to all types of range weather. The experimental bore evacuator was also tested on the M47 tank gun while firing various types of ammunition with muzzle velocities varying from 2400 to 4100 fps; for comparison purposes, standard bore evacuators were tested under similar conditions.
DESCRIPTION: The two types of test front followers differed only in that one was made of aluminum-bronze and the other of steel-bronze. The test-type anticorrosion seal, identified as No. LK-4026, was a thin steel tubing with grease grooves, a lubrication fitting, and seven felt wipers; the device was designed to fit over the exposed recoil slide surfaces. The experimental bore evacuator was identified as WTV-D1663.
CONCLUSIONS: Low temperature performance characteristics of aluminum-bronze front followers were superior to those of steel-bronze-lined front followers. The anticorrosion seal afforded protection to gun recoil slide surfaces, but required certain modifications to be practical. The test bore evacuator had a higher bore evacuation efficiency than the standard type. It was recommended that aluminum-bronze front followers be considered superior to steel-bronze-lined front followers; that the test seal be considered suitable as a temporary expedient for use with the recoil slide surfaces of tubes, 90mm, T119/T119E1; and that the test bore evacuator be considered superior to the standard bore evacuator, No. 7237763.
GENERAL: This 142-page report includes 43 photographs of the test equipment.

SUBJECT: Guns WAL 730/622
TITLE: Stress Analysis of 76-mm T124 Gun
IDENTIFICATION: Report No. WAL 730/622; Project No. TR1-1029F
DATE OF REPORT: 20 August 1951
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the stress at various stragetic locations on plastic models of a 76mm gun breech ring and block under simulated loads; to determine the effect of an artificially produced crack on ring stresses
METHOD: A plastic breech ring and block model was loaded in a standard testing machine at 10% increments until approximately 70% of the design load was applied. The load was held constant at each increment of load for five minutes before strains were measured by means of standard SR-4

Type A-7 gages with an SR-4 strain indicator and SR-4-20 channel switch in a unit. For the fracture test, the load on a second plastic model was continually increased until fracture occurred.

DESCRIPTION: The test material consisted of two plastic half-scale models of the 76mm T124 breech block and ring. These models had been constructed for stress analysis following failure of a 76mm T124 Gun at Aberdeen Proving Ground. Metallurgical examination of this gun pointed to failure from cracks originating in the extractor link pivot holes at the assembly weld.

CONCLUSIONS: The maximum stress in the plastic model (259,000 psi) occurred at the base of the sear spring hole; rupture of the model appeared to have initiated in this area. At the edge of the extractor link pivot hole in the ring, critical stresses of 300,000 psi and 233,000 psi occurred at the inside surface of the ring side web and the outside surface of the ring side web, respectively. A crushing stress of -113,000 psi occurred at the block-ring surface. The ring was loaded nonsymmetrically due to the non-symmetry of the block. The effect of a cracked block was to increase the critical tensile stress and decrease the crushing stress.

GENERAL: This 38-page report contains five pages of tabulated data, 12 pages of photographs, and eight pages of drawings of the test models and test setup.

Section 22
HALF-TRACK VEHICLES

SUMMARY

The subject, Half-Track Vehicles, was not summarized because of the limited scope of the half-track vehicle reports briefed to date. When a sufficient number of half-track vehicle reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Half-Track Vehicles AB 366
TITLE: Service Test of Half-Track Personnel Carriers M3 and M5
IDENTIFICATION: Project No. 366
DATE OF REPORT: 20 August 1943
ORIGIN: Armored Board, Fort Knox, Kentucky
PURPOSE: To compare the general automotive and military characteristics (including vulnerability) of Half-Track Personnel Carriers M3 and M5
METHOD: An M3 and M5 were operated 1102 and 1319 miles over highways, secondary roads and cross country terrain. Vulnerability testing was with cal. .30 AP ammunition at ranges of 250 to 500 yards.
DESCRIPTION: The Half-Track M3 incorporated the latest modifications developed in an effort to correct deficiencies. These modifications included: spring-loaded idlers, closed wing track guides, and improved bogie hubs, all developed to alleviate track throwing, and a radiator surge tank. The M3 body carried 1/4-inch face-hardened armor. The M5 was newly developed by International Harvester to the same general specifications as the M3. Although similar to the M3, the only interchangeable components were the suspension and transmission. The M5 carried 5/16-inch homogeneous armor plate and weighed 1410 pounds more than the M3.
CONCLUSIONS: The M3 modifications were successful; track-jumping was practically eliminated. The M5 was found equal to or better than the M3 in durability, reliability, and ease of steering. The M5 proved inferior in protection as it was found vulnerable to cal. .30 AP ammunition up to 450 yards while the M3 was invulnerable at 300. In view of the increased thickness and weight of armor, and decreased protection, it was recommended that the M5 be equipped with face-hardened armor. However, the M5 was recommended only as a substitute standard vehicle because its superiority over the M3 was slight and the non-interchangeability of parts was undesirable.
GENERAL: This 37-page report contains 14 photographs of the vehicles and parts failures.

Section 24
LUBRICANTS AND LUBRICATION EQUIPMENT

SUMMARY

The subject, Lubricants and Lubrication Equipment, was not summarized because of the limited scope of the lubricants and lubrication equipment reports briefed to date. When a sufficient number of lubricants and lubrication equipment reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

APG 5632/12

SUBJECT: Lubricants and Lubrication Equipment
TITLE: First Report on Test of 130-B-O-100 Engine Oil
IDENTIFICATION: Twelfth Report on Ordnance Program No. 5632; APG 216-13A
DATE OF REPORT: 19 April 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of experimental engine oil 130-B-O-100 for use in vehicles operating in cold weather
METHOD: One vehicle with 75% standard oil and 25% experimental oil in its crankcase and six vehicles with 100% experimental oil in their crankcases were received from tests on the Alcan Highway for further testing. The units were operated from 2603 to 17,480 miles as facility vehicles at the proving ground. At test termination the engines were disassembled for inspection.
DESCRIPTION: The experimental engine oil 130-B-O-100 was manufactured by the Carbide and Carbon Chemicals Corporation. It was a synthetic oil with a low pour point and a high viscosity index. Test vehicles were: one 3/4-ton, two 1/4-ton, one 1-1/2-ton, and three 2-1/2-ton trucks.
CONCLUSIONS: The experimental oil proved satisfactory and was recommended for use in transport and combat vehicles operating in extremely low temperatures.
GENERAL: This 167-page report contains 37 photographs showing condition of engine components after the test.

Section 26
METALS

SUMMARY

This summary covers resumes of 54 engineering reports written on metals between 1941 and 1954 at Watertown Arsenal, Massachusetts; National Research Council, National Academy of Sciences, Washington, D.C.; and Aberdeen Proving Ground, Maryland.

CONSERVATION OF NICKEL FOR FULL MOBILIZATION

In 1953, a report was issued presenting information on the conservation of nickel. It was recommended that the government promptly prepare plans for wartime distribution of primary nickel within the scope of existing supplies; that the government requirements be developed by nickel-alloy classes and by product forms; that current procurement and test procedures be reexamined with a view to improving their flexibility; that the government establish conservation objectives at the stages where military equipment was being designed and developed; that a permanent government-industry group be established with authority to complete needed development and testing projects; and that the government provide incentives to contractors to prepare for wartime conservation of nickel. In addition to these general recommendations many specific recommendations were also given.

Another report issued in 1952 dealt specifically with nickel conservation in military aircraft. The studies covered by this report indicated that a total savings of as much as 130,000,000 pounds of the estimated 366,000,000 pounds of primary nickel required for a 5-year full mobilization period was possible. It was believed that such conservation might be increased significantly by better manufacturing yields and by improvements in technology which would reduce the number of spare parts needed. Large opportunities for nickel conservation appeared to exist in the application of austenitic stainless steels and nickel-base alloys in sheet metal parts. Further research was recommended on ferritic steel alternates for the nickel alloys used in jet engine turbine wheels.

Still another report in 1952 presented information on the use and conservation of nickel-containing alloys in the chemical and process industries. Important reductions were believed to have been made in the consumption of nickel by the chemical industry, principally through the substitution of the ferritic stainless steels for the austenitic grades, of Monel for nickel, and of nonmetallic materials for construction. Although active research was being conducted on further possible conservation of nickel, further major reductions in nickel consumption by the chemical industry were believed to be unlikely if operating efficiency, volume of output, and project quality were to remain unimpaired. The corrosion existance of titanium offered a promising alternate for nickel containing stainless steels in the chemical industry.

A fourth report, also dated 1952, presented information on the use and conservation of nickel by the Department of the Army. Analysis of the nickel requirement data indicated that the Ordnance Corps used 93% of the nickel requisitioned for the Army, that most of this nickel was used in steel, and that the tank-automotive program was the major nickel consumer (72% of the total supply). The use of nickel for tank armor had been substantially reduced since World War II by modern controls and facilities. It was recommended that stainless welding electrodes and the WC binder be considered for use. The mobilization requirement data used for this report was considered difficult to analyze, and it was thought that such data might not be truly indicative of the actual nickel required.

Still another 1952 report presented information on the use of nickel by the Department of the Navy. Analysis of the data showed that the Bureau of Ships used 74% of the nickel required by the Navy, and that about 40% of this supply was destined for use in condenser tubes and sonar transducers. The Bureau of Aeronautics was alloted 17% and the Bureau of Ordnance 9% of the total nickel used by the Navy. It was anticipated that under full mobilization conditions, the nickel requirements for the guided missiles program would increase considerably.

RUSSIAN MEDIUM TANK T34 AND HEAVY TANK KV-1

In 1943 a test was conducted to determine the metallurgical characteristics of armor and weld joint samples from Russian medium tank, T34, and heavy tank, KV1. Chemical anslyses indicated that the following four types of alloy steels were used for the armor: Mn-Si-Mo alloy steel for rolled plates 5/8-inch to 3/4-inch in thickness; Cr-Mo alloy steel for 1-1/4-inch rolled armor; Ni-Cr-Mo alloy steel for 3-5/8-inch cast armor; and Mn-Si-Ni-Cr-Mo alloy steel for both cast and rolled components, 5 inches and 1-7/8 inches in thickness, respectively. The silicon content of the Mn-Si-Ni-Cr-Mo and Mn-Si-Mo steels was high. All compositions provided hardenability adequate for satisfactory quench hardening of the sections. With the exception of one component, the armor components were heat treated by quenching, probably in oil, followed by tempering. The armor components of the T34 medium tank were heat treated to very high hardness levels, whereas the compo-

nents of the KV-1 heavy tank were treated to hardnesses more nearly approaching American practice. Welding appeared to have been done in the flat or horizontal fillet position primarily with two types of ferritic electrodes, one of a carbon-manganese, and the other of a similar analysis with a substantial molybdenum additive. Shallow penetration, poor fusion, and severe undercutting were observed in most of the welds. Weld joint design was characterized by dovetailing which protected the weld from direct ballistic attack.

In 1952, a metallurgical evaluation of armor from Russian T34 and JSII tanks of World War II manufacture was made. Contrary to American practice, widespread use had been made of silicon as an alloying element in the Russian armor. In general, the test armor had a very high hardness. Correlation of ballistic data with the test results showed that this high hardness reduced ballistic resistance and resulted in excessive tendencies toward cracking and backspalling. Ferritic and austenitic electrodes had been intermixed in welding the armor. Extensive porosity and cracking was noted in most of the welds and the workmanship was poor. The fit of armor sections joined by welds was inferior, but careful attention had been given to dovetailing so that welds were not exposed to ballistic attack.

SOVIET PROJECTILES

A metallurgical determination of a Soviet 122-mm AP-T projectile, FMAM none, Model BR471B, and a Soviet 122mm APHE-T projectile, Model BR471B, FMAM 2233, was made in 1954. The AP-T projectile was similar in general design to previously examined Soviet shot except for the indication of a forging flow line around the explosive cavity and in the nose of the body. The steel selection differed radically from American practice. The 0.38% carbon content limited the maximum as-quenched surface hardness to a Rockwell C hardness of 51 to 53; on the other hand, the high alloy content assured thorough hardening. The projectile had a simple design and lacked fine machined finishes on nonfunctional surfaces. Surface finishes on the bourrelet lands, however, were closer than those required by U.S. Specifications. The limited investigation of the APHE-T projectile indicated that its design, construction, material, and manufacture were identical with that of the AP-T projectile.

FOREIGN ARMOR

A summary of the metallurgical examinations of foreign armor made prior to 1 June 1945 was prepared in 1945. Conclusions: In general, foreign armor was no better metallurgically than American armor. American methods were superior in the conservation of strategic alloying elements. Recent German tank armor was very brittle due to scarcity of proper alloying elements. German helmets gave better protection than the American helmets by virtue of increased thickness of the helmet shell. The Japanese aircraft armor was susceptible to cracking due to extreme hardness. The British, like the Germans, depended on chromium, molybdenum, and vanadium for alloying purposes. The British armor material did not have satisfactory toughness according to American standards, as measured by notched bar impact tests.

SOVIET ORDNANCE METALLURGY

Data on Soviet armor and ammunition was summarized in a 1953 report. It was emphasized that in view of the fact that the Soviet material represented design concepts established as early as 1940-1942, the report should not be considered as presenting an adequate view of current Soviet metallurgy. On the basis of the material investigated, it seemed that the Soviets had attained equality with the U.S. in the matter of technical information, but not in technical development or in skill and training of metal workers. The use of high silicon steels for many Ordnance applications was considered unique with the Soviets. There appeared to be a definite tendency to conserve molybdenum. It was recommended that the U.S. consider the possibility of following the Soviet practice of employing finely machines finishes and high quality, carefully prepared welded joints, castings, and other metal products only where needed.

JAPANESE 70MM HE SHELL

Determination of the metallurgical properties of a Japanese 70mm HE shell was made in a 1953 test. Conclusions: The design, metallurgical quality, and quality of workmanship of the 70mm shell were considered adequate for good performance. The shell body was manufactured to a higher strength level than similar domestic shells, but this higher strength was not believed necessary for proper ballistic performance at the normal velocity of 850 fps. The shell had high tensile strength and was designed for high capacity with blast effect rather than fragmentation being of primary importance.

SOVIET 120MM MORTAR SHELL

In 1954, a test was conducted to determine the metallurgical properties of a Soviet 120mm mortar shell. The simplicity of design and the low machining requirements of the test shell were typical of Russian shells previously examined. The use of gray cast iron for the shell body was considered very suitable because this metal has good fragmentation characteristics and is an economical and nonstrategic material easily machined in shell production.

REPORT RESUMES

SUBJECT: Metals APG AD-1120
TITLE: First Report on Investigation of the Ballistic and Metallurgical Properties of the Armor of a Foreign Tank Hull Section
IDENTIFICATION: Report No. AD-1120; First Report on Project No. TB4-150L
DATE OF REPORT: 22 August 1949
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of the hull section of a tank

METHOD: The thickness of the hull section was measured at several points with large calipers. The hull section was mounted on blocks at gun muzzle level with a steel plate butt for support behind and was tested with two rounds of 90mm APC T39 Projectile. Specimens of the armor were given a metallurgical examination.
DESCRIPTION: The hull section was believed to have been taken from a Russian JS I Tank found in the Berlin area held by British and U.S. authorities. The section was about 4-1/2 feet long, 18 inches wide, and varied in thickness from about 4 to 5 inches. It had been torch cut from the right and forward side of the sponson.
CONCLUSIONS: The first impact, against an area about 5 inches thick, broke the armor in two at the point of impact, with the smaller section breaking up into about six pieces. The second impact, against an area about 4 inches thick, broke the remaining section into two sections. Due to the limited size and poor shock resistance of the section, further ballistic tests were not made. Metallurgical examination showed that specimens of the hull section had an extremely high silicon content and high hardness. It was thought that the results of this test should not be given undue weight because of the inadequate size of the test specimen and because it was known that the Russians themselves had not been satisfied with this type of tank.
GENERAL: This 36-page report contains four photographs, four microphotographs, and two macroetchings.

SUBJECT: Metals APG Ar-18065
TITLE: To Determine the Ballistic Performance of Experimental Cast Armor Manufactured by the Lebanon Steel Foundry
IDENTIFICATION: Report No. Ar- 35; Project No. TB4-10A
DATE OF REPORT: 14 February 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic performance of experimental cast armor of one, two, and three-inch thicknesses containing rare earth additives
METHOD: The armor plates were subjected to firing tests with the following projectiles: one-inch armor with 20mm AP and 37mm AP projectiles; two-inch armor with 37mm APC, M51B1 and 57mm AP, M70 projectiles; and three-inch armor with 57mm APC and 90mm projectiles. Ballistic limits were determined, and the plates were sent to Watertown Arsenal for metallurgical analysis.
DESCRIPTION: The test armor plates, submitted by the Lebanon Steel Foundry, were of three basic compositions. The one and two-inch plates were of types C and D. The three-inch plate was of type E. These three types had the following compositions: type C contained 0.28 C, 1.20 Mn, 0.25 Cr, 0.50 Ni, and 0.50 Mo; type D contained 0.28 C, 0.80 Mn, 0.60 Cr, 0.60 Ni, and 0.50 Mo; type E contained 0.28 C, 0.60 Mn, 2.30 Cr, 0.50 Ni, and 0.50 Mo. All plates contained Lan-Cer-Amp rare earth additives.
CONCLUSIONS: Improved hardness was obtained by use of the rare earth additives. No significant ballistic differences were noticed between plates of the different compositions.
GENERAL: This 28-page report contains a firing record and metallurgical analysis of the test armor.

SUBJECT: Metals APG Ar-18084
TITLE: To Determine the Ballistic Performance of Experimental Cast Steel Armor as Manufactured by General Steel Castings Corp.
IDENTIFICATION: Report No. Ar-18084; Project No. TB4-10A
DATE OF REPORT: 8 December 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic performance of experimental cast armor of 2, 2-1/2, 3, 4, and 5-inch thicknesses in which rare earth additives were used
METHOD: The test plates were subjected to the following ballistic tests: 2-inch armor, 37mm APC and 57mm AP projectiles; 2-1/2-inch armor, 57mm APC projectiles; 3-inch armor, 57mm APC and 90mm projectiles; 4-inch armor, 3-inch APC, M62A1 and 90mm AP, T33 projectiles; and 5-inch armor, 90mm APC, T39 and 120mm AP, T116E4 projectiles. After ballistic limits were determined, the plates were sent to the Watertown Arsenal for cross-sectional hardness and V-notch Charpy impact tests.
DESCRIPTION: The test armor plates, of thicknesses indicated above, were submitted by the General Steel Castings Corp. The armor was of two basic types: Type A contained 2.5 Cr and 0.5 Mo; type B contained 1.25 Mn, 1.0 Cr, 1.0 Ni, and 0.6 Mo. Both types contained Lan-Cer-Amp rare earth additives.
CONCLUSIONS: For plates of two and three-inch thickness, the ballistic limits for type B composition were slightly higher than for type A. For plates four and five inches thick, the ballistic limits for type A composition were slightly higher than for type B.
GENERAL: This 34-page report contains a complete firing record and the results of the metallurgical analysis made at the Watertown Arsenal.

GRG MMAB-39-M
SUBJECT: Metals R and D Bd
TITLE: Report on the Conservation of Nickel for Full Mobilization
IDENTIFICATION: Report No. GRG MMAB-39-M
DATE OF REPORT: 20 March 1953
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on conservation of nickel
METHOD: Studies were made of government-stated requirements for nickel; of the government procedures for nickel development, procurement, testing, and acceptance; of industrial procedures and activities in regard to nickel; and of current and potential sources of nickel. On the basis of these studies, a series of general and specific recommendations were made covering conservation of nickel under various conditions of mobiliza-

tion. These studies were coordinated by the Nickel Conservation Panel established by the Minerals and Metals Advisory Board of the National Academy of Sciences.
DESCRIPTION: The material on nickel conservation included studies on conservation of nickel in constructional alloy steels, high-strength steels, wrought stainless steels, corrosion-resistant nickel-chromium alloy castings, cast and wrought aluminum alloys, copper-nickel, and other nickel alloys.
CONCLUSIONS: It was recommended that the government promptly prepare plans for wartime distribution of primary nickel within the scope of existing supplies, that the government requirements be developed by nickel-alloy classes and by-product forms, that current procurement and test procedures be re-examined with a view to improving their flexibility, that the government establish conservation objectives at the stages where military equipment was being designed and developed, that a permanent Government-Industry group be established with authority to complete needed development and testing projects, and that the government provide incentives to contractors to prepare for wartime conservation of nickel. In addition to these general recommendations many specific recommendations were also given.
GENERAL: This 19-page report contains the general conclusions and recommendations of the 413-page report on the Conservation of Nickel for Full Mobilization. The 413-page report includes as appendices Report Nos. GRG MMAB-39-M (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12), (13), (14A), (14B), and (15), each of which is briefed as a separate report.

GRG MMAB-39-M(2)
SUBJECT: Metals R and D Bd
TITLE: Nickel Conservation in Constructional Alloy Steels
IDENTIFICATION: Report No. GRG MMAB-39-M(2)
DATE OF REPORT: 22 April 1952
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on, and recommendations for, nickel conservation in constructional alloy steels
METHOD: Studies were made of statistical data on the nickel industry supplied from several sources including AISI and NPA; of methods currently followed by NPA Conservative Section; of consumer attitudes toward government policies; and of other pertinent information. This information was analyzed to determine various possibilities for reducing the nickel requirements for constructional alloy steels. A series of proposals for nickel conservation, based on estimates of industrial needs, was advanced. These studies were guided by the Nickel Conservation Panel established by the Minerals and Metals Advisory Board of the National Academy of Sciences.
DESCRIPTION: The material on nickel conservation in constructional alloy steels included 1951 production statistics, historical data on the total alloy steel production versus nickel steel production, automotive tonnage versus nickel conservation, nickel grade mixes, and various other data.
CONCLUSIONS: A procedure should be established immediately to assure the orderly conservation and use of nickel in an emergency. It was recommended that the number of old standard steels be reduced; that a new carburizing series about in line with the 9800 series be established; that proper detail committees be set up to investigate the possibility of lower nickel levels in large contour forgings, sucker rods, die blocks, rotary rock-bit cutters, and bearings; that the uses of TS-4118-50B20-14B20 steels in simple carburized parts be expanded; that consideration be given to flexible end-use controls; and that various studies underway be continued.
GENERAL: This 60-page report is a section of the 413-page Report on the Conservation of Nickel for full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(3)
SUBJECT: Metals R and D Bd
TITLE: Conservation of Nickel in High Strength Steels Under Full Mobilization
IDENTIFICATION: GRG MMAB-39-M(3)
DATE OF REPORT: 11 December 1952
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on, and proposals for, the conservation of nickel in high strength steels
METHOD: Studies were made of the properties of various grades of special high tensile steels, their sources, the military specifications covering their manufacture, their military uses, and the facilities for their production. These studies were under the guidance of the Nickel Conservation Panel established by the Metals Advisory Board of the National Academy of Sciences.
DESCRIPTION: The high strength steels considered in these studies consisted primarily of three grades having minimum yield strengths of 50,000 psi, 70,000 psi, and 90,000 psi.
CONCLUSIONS: It was recommended that the use of alternate high strength specifications permitting an elimination or reduction of critical alloys be continued; that the use of alloy scrap such as Monel and of alloy-rich steel scrap in making high strength steels be eliminated; that a test program be conducted to evaluate lean alloy heat-treated steels; that a survey be made of plant facilities suitable for manufacturing steel with 90,000 psi minimum yield strength; that steel producers be encouraged to determine the role of boron in the high strength steels of 50,000 psi minimum yield strength; that steel having a minimum yield strength of 70,000 psi be considered for use wherever possible in applications currently employing steel with a 90,000 psi rating; that high strength specifications be submitted to individual manufacturers for their approval; and that the effects of plate thickness and cross-rolling be considered in the selection of the proper steel for a specific application.
GENERAL: This 29-page report is a section of

the 413-page Report on The Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(4)
SUBJECT: Metals R and D Bd
TITLE: Nickel Conservation in Wrought Stainless Steels Under Full Mobilization
IDENTIFICATION: Report No. GRG MMAB-39-M(4)
DATE OF REPORT: 4 February 1953
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on, and proposals for, nickel conservation in wrought stainless steels
METHOD: Material on nickel conservation of wrought stainless steels was organized into three sections dealing with stainless steel nickel requirements, the problems involved in stainless steel manufacture, and the problems involved in stainless steel welding. These studies were under the guidance of the Nickel Conservation Panel established by the Minerals and Metals Advisory Board of the National Academy of Sciences.
DESCRIPTION: The material covered in this report included discussions on the use of nickel in aircraft "A" products, "B" products, and civilian and supporting programs; the function and sources of nickel used in stainless steel; product and grade mix; development of low-nickel austenitic alloys; low-hydrogen ferritic and shielded bare electrodes for welding stainless steel; and recommended research and development topics.
CONCLUSIONS: It was believed that Government-estimated requirements for stainless steels under full mobilization were large and it was recommended that a re-examination be made of the Government's use of a conversion factor based on peacetime levels of use. It was estimated that the essential requirements for full mobilization might be met with about 27,000 tons of primary nickel annually by maximum nickel conservation in the recovery of nickel from scrap, by maximum reduction of nickel content to the lowest levels providing satisfactory performance, and by reducing the amount of nickel-containing stainless ingots to be made. Realization of these conservation objectives was believed to require research and testing programs designed to provide acceptable alternates lower in nickel content. Extensive investigations of welding procedures for stainless steel were recommended.
GENERAL: This 42-page report is a section of the 413-page report on The Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(5)
SUBJECT: Metals R and D Bd
TITLE: Consumption, End Use, and Conservation of Heat Resistant and Corrosion Resistant Nickel Chromium Alloy Castings
IDENTIFICATION: Report No. GRG MMAB-39-M(5)
DATE OF REPORT: 20 March 1953
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on, and proposals for, the use and conservation of heat-resistant and corrosion-resistant nickel chromium alloy castings
METHOD: The material on the use and conservation of the heat-resistant and corrosion-resistant nickel chromium alloy castings was organized under the following headings: Introduction, Production, Nickel Conservation, End-Use Distribution, An Estimate of the Proportion of Current High-Alloy Casting Shipments Used for New Construction, Research Programs Directed Toward Conservation, and Possible Further Conservation Under Full Mobilization. This study was under the guidance of the Nickel Conservation Panel established by the Mineral and Metals Advisory Board of the National Academy of Sciences.
DESCRIPTION: The castings investigated in this study were classified as high-alloy castings, that is, iron-base and nickel-base alloy castings (other than investment castings) containing not less than 8% chromium, for corrosion-resistant and heat-resistant applications.
CONCLUSIONS: The output production of HH-type heat-resistant and CF-type corrosion resistant alloy castings was marked by considerable growth in recent years. It was estimated that slightly more than half of the high-alloy casting output was used for new construction with the remainder used for replacement in 1951. In attempting to conserve nickel, the tendency of designers had been to shift from high-nickel alloys to well known low-nickel alloys of well established properties. It was recommended that an exhaustive survey be made of the possibilities of more extensive use of cast iron-base austenitic alloys in aircraft turbines. It was believed that in the event of full mobilization, little, if any, further conservation of nickel would be achieved by attempting further downgrades of high alloy castings. It was believed preferable to eliminate high-alloy castings entirely from some uses rather than waste nickel by employing it in ineffective quantities.
GENERAL: This 22-page report is a section of the 413-page Report on The Conservation for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(6)
SUBJECT: Metals R and D Bd
TITLE: Conservation of Nickel in the Gray Iron Industry Under Full Mobilization
IDENTIFICATION: Report No. GRG MMAB-39-M(6)
DATE OF REPORT: 9 July 1952
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on the use and conservation of nickel in the gray iron industry
METHOD: The material on the use and conservation of nickel in the gray iron industry was organized under the following headings: Definition of Gray Iron, Place of Gray Iron Industry in War and Domestic Economy, Place of Alloys and Nickel in Particular in Manufacture of Gray Iron Castings, Fields in Which Nickel is Employed in Gray Iron, Ni-Hard (Martensitic Irons), Ni-Resist (Austenitic Irons),

General Engineering Applications (Acicular and Pearlitic Irons), Special Applications (Spheroidal Graphite or Nodular Irons), Conclusions, and Suggestions for Research in Preparation for Full Mobilization. This study was under the guidance of the Nickel Conservation Panel established by the Minerals and Metals Advisory Board of the National Academy of Sciences.
DESCRIPTION: The types of gray iron covered in this study included all iron castings containing slightly over 2.0% carbon and 0.5% silicon with or without appreciable percentages of other alloying elements. These irons were sometimes designated as "gray", "mottled", or "white" irons.
CONCLUSIONS: Under full mobilization conditions, the normal annual consumption of 18,000,000 pounds of nickel by the gray iron industry might be cut in half. It was pointed out that gray iron had certain minumum nickel requirements due to the character of its product, its method of production, and the limited ability of foundrymen to utilize substitute processes such as heat treating to compensate for the absence of alloys. Four main fields of research were recommended: studies of steel and other mill tests on essentially nickel-free "grain" rolls currently containing 1% to 3% nickel; studies on austenitic irons; studies on nickel-containing irons with under approximately 5% nickel such as martensitic white irons and general engineering irons; and studies on heat treatment methods for promoting tensile strength or hardness as a possible substitute for alloys. It was also recommended that determination be made of the harmful effects of contaminants in alloy irons.
GENERAL: This 16-page report is a section of the 413-page Report on The Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(7)
SUBJECT: Metals R and D Bd
TITLE: Cast and Wrought Aluminum Alloys Containing Nickel Under Full Mobilization
IDENTIFICATION: Report No. GRG MMAB-39-M(7)
DATE OF REPORT: 28 May 1952
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on the use and conservation of nickel in cast and wrought alloys containing nickel
METHOD: The general fields of application of the major nickel-containing aluminum alloys were reviewed, the purpose of nickel as an alloying element in these metals was discussed, and the possibility of lowering the nickel content of these metals was commented upon. This study was under the guidance of the Nickel Conservation Panel established by the Minerals and Metals Board of the National Academy of Sciences.
DESCRIPTION: The alloys considered in this report consisted of A132, D132, 142, and 750 casting alloys and 18S, B18S, and 32S wrought alloys. These nickel-containing aluminum base alloys were primarily used for jet engine and other aircraft and tank purposes.
CONCLUSIONS: The current demand for nickel in the aluminum base alloys was approximately 215,000 pounds per month. A decrease in the automotive demand and an increase in aircraft requirements were expected. It was thought that under full mobilization, current government controls would be satisfactory for limiting production to military or essential civilian requirements. Considerable effort had been made on evaluating a new aluminum product comprising a suspension of extremely finely divided aluminum oxide particles in an aluminum matrix. Because of its favorable high temperature properties, it was thought that this product would have application in jet engines. It was recommended that nickel-free aluminum alloys be developed for heavy duty truck and diesel engine pistons; that chromium, manganese, or iron be substituted for nickel in air-cooled cylinder heads, aircraft pistons, and heavy duty diesel engine applications; that the nickel content of bearing alloys be reduced by the addition of silicon for bearings of heavy duty combustion engines; and that further evaluation be made of the new sintered aluminum oxide-aluminum products for use at high temperatures.
GENERAL: This 11-page report is a section of the 413-page Report on the Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(8)
SUBJECT: Metals R and D Bd
TITLE: Copper Alloys Containing Nickel Under Full Mobilization
IDENTIFICATION: Report No. GRG MMAB-39-M(8)
DATE OF REPORT: 11 December 1952
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on the use and conservation of copper-base nickel alloys
METHOD: A discussion was given of the composition, production, and applications of several copper-base nickel alloys. Recommendations were given for the most practicable lines of nickel conservation in preparation for a full mobilization condition. This study was under the guidance of the Nickel Conservation Panel established by the Minerals and Metals Board of the National Academy of Sciences.
DESCRIPTION: The copper-base nickel alloys covered in this report consisted of cupro-nickel, nickel-silver, constantan, bearing alloy, and permanent magnet alloy.
CONCLUSIONS: Replacement of 70-39 cupro-nickel by 90 Cu-1 FE-10 Ni, 76 Cu-22 ZN-2 Al, 80 Cu-20 Ni, 91 Cu-7 Al-2 Fe formulations for various applications was recommended. It was believed that usage of nickel-silver for tableware should be eliminated in full mobilization periods, that 57 Cu-12 Ni-31 Zn rather than 18 Ni nickel silver be used for spring strip in telephone and similar circuits, that investigations be made of resistors to determine whether adequate performance could be obtained by lower Ni content than the 55 Cu-45 Ni material currently used, and that various bearing materials such as "bi-metal" be

tested to determine their suitability as bearing alloys.
GENERAL: This 13-page report is a section of the 413-page Report on the Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(9)
SUBJECT: Metals R and D Bd
TITLE: Miscellaneous Nickel-Containing Alloys and Applications
IDENTIFICATION: Report No. GRG MMAB-39-M(9)
DATE OF REPORT: 6 March 1953
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on the use and conservation of miscellaneous nickel-containing alloys
METHOD: A discussion was given of various miscellaneous applications of nickel-containing alloys covering past production procedures and output and possible nickel substitutes for full mobilization conditions. This study was under the guidance of the Nickel Conservation Panel established by the Minerals and Metals Board of the National Academy of Sciences.
DESCRIPTION: The miscellaneous nickel-containing alloys included cast alloy steels, coinage, expansion and thermo-elastic alloys, high temperature materials, naval armor, naval guns, nickel-base alloys, nickel catalysts, nickel salts, nickel plating, nickel cadmium, and nickel-iron-alkaline cells.
CONCLUSIONS: It was believed that the Air Force, Navy, and Atomic Energy Commission would have the largest quantity requirements for malleable nickel, nickel-copper alloys, and nickel-chromium alloys in the event of war. The problem of nickel conservation in their fields of use was considered primarily an individual problem requiring cooperation between government and industry for solution. It was recommended that the performance requirements of each specific use be closely examined to determine the necessity for nickel or nickel-base alloys.
GENERAL: This 25-page report is a section of the 413-page Report on The Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(10)
SUBJECT: Metals R and D Bd
TITLE: Utilization of Nickel-Containing Scrap Materials
IDENTIFICATION: Report No. GRG MMAB-39-M(10)
DATE OF REPORT: 20 March 1953
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on the utilization of nickel-containing scrap materials
METHOD: The information on nickel-containing scrap materials was organized according to various product classifications. Under each of these classifications a discussion covered the places or conditions deserving special study together with conservation proposals based on organized methods of scrap utilization. This study was under the guidance of the Nickel Conservation Panel established by the Minerals and Metals Board of the National Academy of Sciences.
DESCRIPTION: The nickel-containing scrap materials considered in this report included scrap from constructional alloy steels, wrought stainless steels, gray iron, heat-resistant and corrosion-resistant nickel-chromium castings, complex high temperature alloys, aluminum-base nickel-containing alloys, and copper-base nickel-containing alloys.
CONCLUSIONS: The best percentage of nickel recovery from nickel-containing scrap materials was estimated to be 45 to 50% of the nickel from all nickel-containing constructional alloy steel scrap from mill home scraps and consumer generated scrap. Current controls were not considered adequate to cope with the problems involved in recovery of nickel from scrap material. It was recommended that the government establish a board or committee of specialists to study the scrap utilization problem. It was believed that such a board or committee should include representatives of both producing and consuming industries in each of the major alloy categories as well as government personnel. It was believed that the study should include such matters as industrial incentives, methods of segregation and identification of nickel-containing alloy scrap in both industrial and government establishments, and recommendations for wartime controls of the distribution and consumption of these materials.
GENERAL: This 21-page report is a section of the 413 Report on The Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(11)
SUBJECT: Metals R and D Bd
TITLE: Nickel Conservation in Military Aircraft Under Full Mobilization
IDENTIFICATION: Report No. GRG MMAB-39-M(11)
DATE OF REPORT: 11 December 1952
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on nickel conservation in military aircraft
METHOD: Estimates of mobilization aircraft requirements furnished by the Munitions Board were used to estimate material requirements for a five-year mobilization period for various types of engines, airframes, and other aircraft components considered representative of aircraft construction generally. Proposals were given for the conservation of nickel in these aircraft components. This study was under the guidance of the Nickel Conservation Board established by the Minerals and Metals Panel of the National Academy of Sciences.
DESCRIPTION: The information on nickel conservation in military aircraft included an account of the methods of manufacture and scrap recovery of constructional alloy steels, stainless steels, and super alloys used in jet engines, reciprocating

engines, airframes, propellers, and landing gear assemblies.
CONCLUSIONS: The studies covered by this report indicated that a total savings of as much as 130,000,000 pounds of the estimated 366,000,000 pounds of primary nickel required for a five-year full mobilization period was possible. It was believed that such conservation might be increased significantly by better manufacturing yields and by improvements in technology which would reduce the number of spare parts needed. Large opportunities for nickel conservation appeared to exist in the application of austenitic stainless steels and nickel-base alloys in sheet metal parts. Further research was recommended on ferritic steel alternates for the nickel alloys used in jet engine turbine wheels.
GENERAL: This 53-page report is a section of the 413-page Report on The Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(12)
SUBJECT: Metals R and D Bd
TITLE: The Use of Nickel-Containing Alloys in the Chemical and Process Industries
IDENTIFICATION: Report No. GRG MMAB-39-M(12)
DATE OF REPORT: 14 August 1952
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on the use and conservation of nickel-containing alloys in the chemical and process industries
METHOD: A discussion was given of the function and properties of the nickel-containing alloys used in the chemical and process industries. Alternate materials and constructions were presented and a brief account was given of current research and development. This study was under the guidance of the Nickel Conservation Panel established by the Minerals and Metals Board of the National Academy of Sciences.
DESCRIPTION: The material considered in this report included Types 304, 316, and 347 austenitic stainless steels; Monel, Inconel, and Hastelloy alloys; high and low-alloy cast irons; and cupro-nickel.
CONCLUSIONS: Important reductions were believed to have been made in the consumption of nickel by the chemical industry, principally through the substitution of the ferritic stainless steels for the austenitic grades, of Monel for nickel, and of non-metallic materials for construction. Although active research was being conducted on further possible conservation of nickel, further major reductions in nickel consumption by the chemical industry were believed to be unlikely if operating efficiency, volume of output, and project quality were to remain unimpaired. The corrosion resistance of titanium offered a promising alternate for nickel containing stainless steels in the chemical industry.
GENERAL: This 23-page report is a section of the 413-page Report on The Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(13)
SUBJECT: Metals R and D Bd
TITLE: The Use of Nickel and Nickel-Containing Alloys in the Electrical and Electronics Industries
IDENTIFICATION: Report No. GRG MMAB-39-M(13)
DATE OF REPORT: 24 September 1952
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on the use and conservation of nickel in the electrical and electronics industries
METHOD: A study was made of the various applications of nickel in the electrical and electronics industries covering the approximate nickel production requirements, the suitability of substitute materials, and suggestions for research in preparation for full mobilization. This study was under the guidance of the Nickel Conservation Panel established by the Minerals and Metals Board of the National Academy of Sciences.
DESCRIPTION: The applications of nickel in the electrical and electronics industries considered by this report included electrical heating, electrical control devices-resistors, glass sealing alloys, non-magnetic alloys, shielding, transformers, capacitors, telephone apparatus, permanent magnets, and vacuum tubes.
CONCLUSIONS: It was recommended that further research be done on non-magnetic chromium-manganese-iron alloys, alloy and powder-field permanent magnets, ferrites and non-metallic magnetic materials; that zinc-plated, chromium stainless, and silicon steel be used as substitutes for nickel alloys in communications equipment wherever possible; and that continued effort be made to substitute iron base products such as plain steel, aluminized steel, and nickel plated and clad steel for nickel throughout tube structures.
GENERAL: This 22-page report is a section of the 413-page Report on The Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(14A)
SUBJECT: Metals R and D Bd
TITLE: Nickel Requirements for Mobilization, Department of the Army
IDENTIFICATION: Report No. GRG MMAB-39-M (14A)
DATE OF REPORT: 22 March 1952
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on the use and conservation of nickel by the Department of the Army
METHOD: The over-all quantitative nickel requirements were broken down into basic categories in terms of tonnage and percentage of nickel consumption for each category. An examination was made of various army programs to determine the tonnage and percentage of nickel required for various end-products and to indicate the technical services of the army responsible for these end products. This study was under the guidance of the Nickel Conservation Panel established by the Minerals and Metals Board of the National Academy of

Sciences.
DESCRIPTION: This report covered the mobilization nickel requirements of the Department of the Army for the following end-use categories: tank-automotive program, weapons program, ammunition program, building supplies and equipment, guided missiles program, and A-7 Electronics Program.
CONCLUSIONS: Analysis of the nickel requirement data indicated that the Ordnance Corps used 93% of the nickel requisitioned for the Army, that most of this nickel was used in steel, and that the tank-automotive program was the major nickel consumer (72% of the total supply). The use of nickel for tank armor had been substantially reduced since World War II by modern controls and facilities. It was recommended that stainless welding electrodes and WC binder be considered for use. The mobilization requirement data used for this report were considered difficult to analyze and it was thought that such data might not be truly indicative of the actual nickel required.
GENERAL: This 23-page report is a section of the 413-page report on The Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(14B)
SUBJECT: Metals R and D Bd
TITLE: Ordnance Corps Use of Nickel in Armor, Guns, and Armor-Piercing Projectiles
IDENTIFICATION: Report No. GRG MMAB-39-M(14B)
DATE OF REPORT: 11 December 1952
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on Ordnance Corps use of nickel in armor, guns, and armor-piercing projectiles
METHOD: A historical resume was given of past developments in Ordnance Corps armor, guns, and armor-piercing projectiles. A brief account was given of current practices used in the production of these items. Predictions for future nickel requirements and applications were made. This study was under the guidance of the Nickel Conservation Panel established by the Minerals and Metals Board of the National Academy of Sciences.
DESCRIPTION: The material on nickel applications considered by this report concerned nickel uses in Ordnance items over the period of about 1940 to 1952.
CONCLUSIONS: Analysis of data on Ordnance practices indicated that since World War II the alloy content of much tank armor had been reduced even though the average thickness of armor had increased and its quality improved. Over the same period, the alloy requirements for gun steels had remained fairly constant even though the minimum yield strength of these steels had greatly increased. Some reduction in alloy requirements by the use of hot-extrusion methods for gun steels was considered possible. In the ammunition programs, large reductions in nickel requirements were not considered probable in view of the constantly increasing section of AP shot. Because of the extensive work already accomplished on nickel conservation in armor, gun steels, and armor-piercing projectiles, it was believed that the forcible end point in alloy conservation was close at hand. Further savings were considered possible, however, and additional research was recommended.
GENERAL: This 14-page report is a section of the 413-page report on The Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

GRG MMAB-39-M(15)
SUBJECT: Metals R and D Bd
TITLE: Nickel Requirements for Mobilization, Department of the Navy
IDENTIFICATION: Report No. GRG MMAB-39-M(15)
DATE OF REPORT: 20 May 1952
ORIGIN: National Research Council, National Academy of Sciences, Washington, D.C.
PURPOSE: To present information on the use of nickel by the Department of the Navy
METHOD: A tabulation was made of the expected nickel consumption by programs. This tabulated data was organized into time phases and presented graphically to illustrate the initial and continuing impact of Navy requirements on the total nickel supply. This study was under the direction of the Nickel Conservation Panel established by the Minerals and Metals Advisory Board of the National Academy of Sciences.
DESCRIPTION: The material on the uses of nickel by the Department of the Navy included nickel requirements by weight and percentage for Navy programs on ships, aircraft, weapons, ammunition, electronics, and guided missiles.
CONCLUSIONS: Analysis of the data showed that the Bureau of Ships used 74% of the nickel required by the Navy, and that about 40% of this supply was destined for use in condenser tubes and sonar transducers. The Bureau of Aeronautics was allotted 17% and the Bureau of Ordnance 9% of the total nickel used by the Navy. It was anticipated that under full mobilization conditions, the nickel requirements for the guided missiles program would increase considerably.
GENERAL: This 11-page report is a section of the 413-page Report on The Conservation of Nickel for Full Mobilization, indexed under Report No. GRG MMAB-39-M.

SUBJECT: Metals WAL 10-18-50
TITLE: Examination of Right Sponson Plate from Medium Tank, M4A3, Perforated by Enemy Projectile
IDENTIFICATION: Report No. WAL 10-18-50
DATE OF REPORT: 18 October 1950
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the type of ammunition that produced the penetration of a test armor plate
METHOD: A visual inspection was made of the penetration, followed by a qualitative spectrographic chemical analysis of the inside surface of the hole through the armor as well as of the base metal. The sample was sectioned to observe details of the deformation and to survey the hardness of the base armor.

DESCRIPTION: The sample examined was identified as a damaged section from a Medium Tank M4A3 (right sponson plate) measuring 1-1/2 x 3-1/2 x 4-1/2 inches.
CONCLUSIONS: The armor penetration was thought to have been caused by a composite-rigid tungsten carbide cored armor-piercing projectile, presumably of the arrow-head type. It was recommended that spaced armor arrangements be seriously considered as a protection against this type of high-velocity kinetic energy projectile as well as other types of ammunition.
GENERAL: This 10-page report includes three photographs showing the armor sample and the projectile believed to be the type having caused the penetration.

SUBJECT: Metals WAL 401/17
TITLE: Some Mechanical and Ballistic Properties of Titanium and Titanium Alloys
IDENTIFICATION: No. WAL 401/17: OO Project No. TB4-103B
DATE OF REPORT: 7 March 1950
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the suitability of titanium and some of its alloys for Ordnance armor and structural members
METHOD: Samples of titanium and titanium alloys were tested for hardness, tensile strength, impact strength, and stress and strain over a wide range of temperatures. Various size sheets of these metals, together with conventional steel sheets used as controls, were subjected to attack by scale model artillery-type armor-piercing projectiles.
DESCRIPTION: The test material consisted of seven plates of commercially pure titanium supplied by the U.S. Bureau of Mines, one plate of commercially pure titanium supplied by Remington Arms Co., one plate of commercially pure titanium and one plate of titanium alloy containing iron and chromium supplied by Allegheny-Ludlum Steel Corporation, and one plate of titanium alloy containing chromium and aluminum supplied by P. R. Mallory Company.
CONCLUSIONS: Test results indicated that tensile properties of titanium could be varied widely by alloying and heat treatment of the alloys, and that higher strength-weight ratios were possible with titanium alloys than with aluminum and iron alloys. Notched-bar impact tests indicated that titanium and its alloys exhibited transitions similar to the type found in steel. The strain hardening exponent of titanium was about the same as that of steel. In thin sheet form, the titanium and its alloys tested with fragment-simulating projectiles gave an inferior ballistic performance than comparable weight Hadfield manganese steel. The thicker plates of unalloyed titanium tested at 0° and 45° obliquity with scale model artillery-type projectiles gave a ballistic performance superior to that of heat-treated alloy steel armor of comparable weight. A good correlation was observed between the notched-bar impact properties and the ballistic characteristics of the unalloyed titanium. Material having low toughness in the notched-bar impact test exhibited a tendency to crack and back-spall.
GENERAL: This 73-page report contains 18 pages of tabulated test data, six pages of graphs and 24 pages of photographs.

SUBJECT: Metals WAL 640/91
TITLE: Metallurgical Examination of Armor and Weld Joint Samples from Russian Medium Tank T34 and Heavy Tank KV-1
IDENTIFICATION: Report No. WAL 640/91
DATE OF REPORT: 24 November 1943
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical characteristics of armor and weld joint samples from Russian Medium Tank T34 and Heavy Tank KV-1
METHOD: Armor specimens from the two Russian tanks were subjected to chemical analyses, hardenability tests, hardness surveys, tensile tests, elongation tests, and macrostructure and microstructure examination. Welded joint specimens were given a visual examination, chemical analyses, hardness surveys, macroexamination, and microexamination.
DESCRIPTION: The test material consisted of three welded joint sections from a Russian Medium Tank T34 and one welded joint section from a Russian Heavy Tank KV-1.
CONCLUSIONS: Chemical analyses indicated that the following four types of alloy steels were used for the armor: Mn-Si-Mo alloy steel for rolled plates 5/8-inch to 3/4-inch in thickness, Cr-Mo alloy steel for 1-1/4-inch rolled armor, Ni-Cr-Mo alloy steel for 3-5/8-inch cast armor, and Mn-Si-Ni-Cr-Mo alloy steel for both cast and rolled components 5 inches and 1-7/8 inches in thickness, respectively. The silicon content of the Mn-Si-Ni-Cr-Mo and Mn-Si-Mo steels was high. All compositions provided hardenability adequate for satisfactory quench hardening of the sections. With the exception of one component, the armor components were heat treated by quenching, probably in oil, followed by tempering. The armor components of the Medium Tank T34 were heat treated to very high hardness levels, whereas the components of the Heavy Tank KV-1 were treated to hardnesses more nearly approaching American practice. Welding appeared to have been done in the flat or horizontal fillet position primarily with two types of ferritic electrodes, one of a carbon-manganese, and the other of a similar analysis with a substantial molybdenum additive. Shallow penetration, poor fusion, and severe undercutting were observed in most of the welds. Weld joint design was characterized by dovetailing which protected the weld from direct ballistic attack.
GENERAL: This 37-page report includes 16 pages of photographs.

SUBJECT: Metals WAL 642/8
TITLE: Weldability of Armor Plate (1" Rolled Homogeneous) 0.50% Carbon, Chrome-Moly-Vanadium
IDENTIFICATION: Report No. WAL 642/8
DATE OF REPORT: 16 July 1941
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the effects of various

welding procedures on the hardness and microstructure of the test armor
METHOD: Single weld beads were deposited in the middle of 6 x 3 x 1-inch annealed plates and tempered plates by an automatic welding machine using 3/16-inch diameter low-carbon and austenitic stainless steel (25/20) electrodes with 200 amperes current at 5 inches per minute. Two of the plates were given a 400°F preheat. Vickers hardness tests were made on these weld specimens in the "as welded" condition and after oil quench and stress relief treatments. Some of the weld specimens were given a macroexamination.
DESCRIPTION: The 1-inch test armor had the following approximate composition: 0.490 carbon, 0.560 manganese, 0.230 silicon, 0.019 phosphorus, 0.019 sulphur, 1.22 chromium, 0.60 molybdenum, and 0.20 vanadium.
CONCLUSIONS: The maximum hardness produced in the heat-affected zone of the single weld bead was the same for both the low-carbon electrode and the austenitic 25/20 stainless steel electrode on either the annealed or the tempered armor plate. Cracks were produced in the heat-affected zone by the low-carbon electrode without preheating, whereas no cracks were produced by the austenitic stainless steel 25/20 electrode. The average depth of penetration of heat effect of the low-carbon electrode into the armor plate was greater than that of the austenitic stainless steel 25/20 electrode. When a 400°F preheat was used, the depth of penetration of heat effect of both electrodes was increased. The quench and draw treatment removed all trace of the heat-affected zone due to weld bead deposit. The weld metal deposited by the covered low-carbon electrode was approximately 40% higher in hardness than the weld metal deposited by the austenitic metal in the "as welded" state; this ratio was slightly reduced when a 400°F preheat was used. The quench and draw treatment reduced the hardness of the two weld metals to approximately equal values.
GENERAL: This 13-page report contains eight pages of photographs of the weld bead sections.

SUBJECT: Metals WAL 642/146
TITLE: Hard-Surfacing by Metal-Arc Welding
IDENTIFICATION: Report No. WAL 642/146; OO Project No. TB4-40F
DATE OF REPORT: 25 May 1948
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine whether the hardness and soundness of weld metal could be used as an adequate criterion of the abrasion resistance of the metal
METHOD: Pads of weld metal deposited by 19 commercially available electrodes were examined for porosity, cracks, and separation from base metal. Satisfactory pads were tested for corrosion and abrasion resistance and hardness. Chemical analyses and micro-examinations of the specimens were made.
DESCRIPTION: The test electrodes consisted of the following hard-facing electrodes: American Manganese Steel Economy Hardface; Hollup Corporation No. 450 and No. 450H; Page Steel and Wire Surface Saver No. 3; Harnischfeger Corporation Hartung; Chicago Hardware Foundry Fusewell No. 19; Mir-O-Col No. 2 and No. 4; Lincoln Electric Abrasoweld; Coast Metals Co. No. 112 and No. 101; Dymonhard Corp. No. 65; Brown-Wales Hardcote; Bergstrom Corp. Ranalloy A, Ranalloy B, and Ranalloy C; and McKay Chain Co. Hardalloy G-584, Frogaloy G-87, and Frogaloy E-973.
CONCLUSIONS: The data included in the report were regarded only as indicating trends since the program of testing as originally planned was not completed. The abrasion test data indicated that two of the electrodes approved under Specification 57-203-5 deposited weld metal having the highest resistance to abrasion of any of the twelve metals tested, whereas the weld metal and from a third approved electrode brand exhibited the lowest resistance to abrasion. Thus the combination of soundness and hardness level of weld metal did not appear to be an adequate criterion of abrasion resistance. Those weld metals which gave good abrasion resistance appeared to have the lowest resistance to corrosion. There did not appear to be a typical metallographic structure of weld metal indicative of good abrasion resistance which could be used as a criterion for approval testing.
GENERAL: This 60-page report contains 30 pages of photographs.

SUBJECT: Metals WAL 700/22
TITLE: Metallurgical Investigation of a Soviet 122-MM AP-T Projectile, FMAM None, Model BR 471B and a Limited Investigation of a Soviet 122-MM APHE-T Projectile, Model BR 471B, FMAM 2233
IDENTIFICATION: Report No. WAL 700/22; Project No. TB3-0035
DATE OF REPORT: 1954
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties of two Soviet projectiles
METHOD: The AP-T projectile was examined visually and under the binocular microscope for machining marks and surface imperfections. Surface coatings were identified by microchemical and microscopic tests. Hardness surveys were made in external surfaces and cross-sectional planes. The composition of all components of the shot assembly was examined by wet chemical methods and quantitative spectrographic analysis. The hardenability of the core body was measured by a Jominy end-quench test and the mechanical properties of this part were measured by tensile and Charpy impact tests. The APHE-T projectile was subjected to chemical analysis, hardness traverse, and microexamination. This study was performed by the Armor Research Foundation of the Illinois Institute of Technology.
DESCRIPTION: The description of the test material is given below under "Conclusions".
CONCLUSIONS: The AP-T projectile was similar in general design to previously examined Soviet shot except for the indication of a forging flow line around the explosive cavity and in the nose of the body. The steel selection differed radically from

American practice. The 0.38% carbon content limited the maximum as-quenched surface hardness to a Rockwell C hardness of 51 to 53; on the other hand, the high alloy content assured thorough hardening. The projectile had a simple design and lacked fine machined finishes on non-functional surfaces. Surface finishes on the bourrelet lands, however, were closer than those required by U.S. specifications. The limited investigation of the APHE-T projectile indicated that its design, construction, material, and manufacture were identical with that of the AP-T projectile.
GENERAL: This 30-page report contains complete test data, four pages of photographs, three pages of drawings, and three pages of photomicrographs of the test projectiles.

SUBJECT: Metals WAL 700/22-1
TITLE: Metallurgical Investigation of a Chinese 105-mm HE Shell (Copy of U.S. Design FMAM 2368B)
IDENTIFICATION: Report No. WAL 700/22-1; Project TB3-0035
DATE OF REPORT: 1954
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties of a Chinese shell
METHOD: The projectile was examined visually and under a binocular microscope for markings. A hardness survey was made on a longitudinal section of the shell body. Two flat tensile specimens machined from the shell wall were subjected to mechanical tests. Samples taken from the wall and the base of the projectile were used for microexamination and chemical analysis. This study was performed by the Armor Research Foundation of the Illinois Institute of Technology.
DESCRIPTION: The description of the test shell is given under "Conclusions".
CONCLUSIONS: The dimensions of the test shell followed rather closely the U.S. prototype with the following exceptions: the bursting charge had a flat bottom and the shell body had a pressed-in copper bourrelet but no safety plate on the bottom. The shell body contained a lower manganese content and a higher carbon content than its U.S. counterpart. The shell had been slack quenched and, although it met mechanical strength requirements, it showed an erratic hardness distribution, and, in one tensile specimen, substandard elongation. The outer surface of the shot body was machined over-all with a finish that was adequate for the intended application. No protective paint or lacquer coating was observed on the exterior. The walls of the bursting charge cavity were covered with an acid resistant coating.
GENERAL: This 19-page report contains complete heat data and a photograph and drawings of the test projectile.

SUBJECT: Metals WAL 710/393
TITLE: Metallurgical Examination of Punchings from Cast Turret of British A-12 Infantry Tank
IDENTIFICATION: Report No. WAL 710/393
DATE OF REPORT: 29 October 1941
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical characteristics of punchings from a British tank
METHOD: Three punchings from the cast turret of a British tank were subjected to chemical analyses, hardness surveys, macroexamination, and microexamination. One of the punchings was homogenized and given a ballistic heat treatment to determine the effect on segregations of massive carbides.
DESCRIPTION: The test material consisted of three punchings from the cast turret of a British A-12 Infantry Tank which had failed a ballistic test at Aberdeen Proving Ground.
CONCLUSIONS: The carbon content was considered too high for the armor thickness. There was no evidence of homogenization as indicated by the presence of segregations of massive carbides in the interdendritic fillings. The hardness tests indicated that the turret had been heat treated to a relatively high hardness. The cast armor was considered of inferior quality, showing evidence of poor deoxidation practice and occasional hair-line cracks in the metal. The microstructure of the samples revealed a fairly uniform acicular structure with an occasional segregation of massive carbides and nonmetallics in the dendritic fillings. It was thought that the ballistic failure of the casting from which the test punchings were taken was due to unsoundness, lack of homogenizing treatment, and relatively high hardness.
GENERAL: This 28-page report contains 10 pages of photographs, photomicrographs, and photomacrographs.

SUBJECT: Metals WAL 710/472
TITLE: Metallurgical Examination of Armored Vehicle Components (Armor Attachment Bolts and Welded Armor Sections) from a German PZKW III Tank
IDENTIFICATION: Report No. WAL 710/472
DATE OF REPORT: 2 January 1943
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties of the armor components of a German tank
METHOD: The metallurgical examination of the test vehicle components and weld metal deposits included visual inspection, chemical analyses, hardness surveys, determination of physical properties, and microscopic examination.
DESCRIPTION: The German PZKW III Tank test components included .625-inch x 4-inch and .546-inch x 2-3/4-inch attachment bolts and welded, 11mm, homogeneous, cross-rolled armor sections.
CONCLUSIONS: The forged test bolts were made of relatively poor medium carbon Cr-Mo-V type steel with a hardness of 372 to 393 BHN. The test armor was of good quality steel with a hardness of 320 to 340 BHN. This material was similar to SAE 4150 steel and was not easily adaptable to welded fabrication. The weld metal deposits were of three chemical compositions with Vickers hardness ranging from 370 to 464. It was believed that the high chromium-manganese type weld metal, with varying amounts of manganese and nickel, could be considered as substitutes for the modified

18-8 austenitic weld metal used in the United States.
GENERAL: This 18-page report includes three pages of photomicrographs and five pages of photographs of the test materials.

SUBJECT: Metals WAL 710/695
TITLE: Metallurgical Examination of 10'' Cast Homogeneous Armor Manufactured by General Steel Castings Corp. and 6" Cast Homogeneous Armor Manufactured by Union Steel Castings Co., Heat 8630 and 1242B Respectively
IDENTIFICATION: Report No. WAL 710/695
DATE OF REPORT: 31 August 1944
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical and impact properties of 6 and 10-inch cast homogeneous armor plates of two heats
METHOD: Metallurgical examination included Brinell hardness surveys, and macroetch, Jominy hardenability and Charpy impact tests. Ballistic tests were conducted with 155mm AP projectiles to determine the protection afforded by the plates.
DESCRIPTION: The samples were from a 10-inch cast homogeneous armor section produced by the General Steel Castings Corporation, heat No. 8630 and a 6-inch cast homogeneous armor plate by the Union Steel Castings Company, heat No. 1242-B.
CONCLUSIONS: The 10-inch plate offered complete protection against the 155mm AP projectiles up to 2700 fps. Ballistic limit of the 6-inch plate at 0° obliquity was 1509 fps. Cross-sectional hardnesses of the 6 and 10-inch plates averaged 200 BHN and 209 BHN. Impact energies of the 6 and 10-inch plates were 60 ft.-lbs. and 100 ft.-lbs.
GENERAL: This 16-page report contains two pages of illustrations and three pages of test data.

SUBJECT: Metals WAL 710/751
TITLE: Summary of the Metallurgical Examinations of Foreign Armor Made Prior to 1 June 1945
IDENTIFICATION: Report No. WAL 710/751
DATE OF REPORT: 7 June 1945
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine trends, developments, and weaknesses of foreign armor and compare it with domestic armor
METHOD: Previous arsenal tests of foreign armor were summarized and evaluated. In general, these tests included chemical analysis, macroetching, microscopic examination, and tensile and notched bar impact tests. Later, fracture and hardenability tests were added to the procedure.
DESCRIPTION: The test materials included German Panther PzKw homogeneous and flame hardened armor from 1/8 to 3-1/4 inches thick and other armor components; various German aircraft armor; Japanese aircraft armor from 1/2 to 3-1/4 inches thick. Italian 5/16-inch aircraft armor; British homogeneous and face hardened tank armor from 2 to 4-1/2 inches thick, and helmets from Germany, the Netherlands, France, the Irish Free State, and the U.S.A.
CONCLUSIONS: In general, foreign armor was no better metallurgically than American armor. American methods were superior in the conservation of strategic alloying elements. Recent German tank armor was very brittle due to scarcity of proper alloying elements. German helmets gave better protection than the American helmets by virtue of increased thickness of the helmet shell. The Japanese aircraft armor was susceptible to cracking due to extreme hardness. The British, like the Germans, depended upon chromium, molybdenum, and vanadium for alloying purposes. The British armor material did not have satisfactory toughness according to American standards as measured by notched bar impact tests.
GENERAL: This 14-page report is not illustrated.

SUBJECT: Metals WAL 710/764
TITLE: Metallurgical Examination of 150mm Armor and Welded Joints of Front Glacis Plate of a German Tiger II (Royal Tiger) Tank
IDENTIFICATION: Report No. WAL 710/764
DATE OF REPORT: 9 July 1945
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical characteristics of the armor and welded joints of a German tank
METHOD: The metallurgical examination of the armor test section included chemical analysis, hardness survey, fracture, tensile, and impact tests, macroscopic and microscopic examination, and reheat treatment to determine temper brittleness. Examination of the welds included chemical analysis, hardness surveys, and microscopic examination.
DESCRIPTION: The 150mm armor test section with welds was taken from the front glacis plate of a German Royal Tiger II Tank and was 15 x 12 inches in size. The weld deposit metal was approximately 1/4 inch in depth.
CONCLUSIONS: The armor was probably processed by hot forging a poor quality steel with considerable nonmetallic segregations and was below the usual German standard for armor. The material had a 1.5% nickel content and had very poor shock properties due to severe temper embrittlement. The armor had a Brinell hardness range of 223 to 235. Extensive cracking was found near the weld fusion zone. The electrodes used for weld deposits were apparently of plain carbon steel and the welding exhibited poor workmanship.
GENERAL: This 17-page report includes one drawing, one photograph, and two pages of photomicrographs of the test material.

SUBJECT: Metals WAL 710/789
TITLE: Metallurgical Examination of Sections from the Cast Armor Turret Made by Continental Foundry and Machine Company and Two Trunnion Pins from a Heavy Tank M6A2E1
IDENTIFICATION: Report No. WAL 710/789
DATE OF REPORT: 30 October 1945
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical characteristics of cast turret armor and tank trunnion pins
METHOD: Metallurgical examination of two-sec-

tions of armor included hardness surveys, fracture and V-notched Charpy impact tests, and microscopic examination. The same examination was given the trunnion pin except the fracture test was eliminated and a chemical analysis and tensile test were added.
DESCRIPTION: One armor sample was from the gun shield of a Heavy Tank M6A2E1 turret and varied in thickness from 2 to 3-1/2 inches. The other was from the turret and varied in thickness from 4-1/2 to 9 inches. The armor samples were manufactured by the Continental Foundry and Machine Co. The tubular trunnion pins were from the gun mount of the Heavy Tank M6A2E1 and were 5 inches in diameter and 11-1/2 inches long.
CONCLUSIONS: The armor sample from the gun shield had a high hardness of 300 BHN and temper embrittlement which resulted in poor shock resistance. The sample from the turret had a hardness range of 248 to 269 BHN and possessed acceptable toughness. The trunnion pins had a hardness of 300 BHN which was considered too low for their application. It was thought that a hardness of 340 BHN would be more satisfactory in preventing distortion resulting from ballistic impact.
GENERAL: This seven-page report is not illustrated.

SUBJECT: Metals WAL 710/863
TITLE: Metallurgical Evaluation of Commercially Produced Heavy Wrought Armor to Improve the Specification Requirements
IDENTIFICATION: Report No. WAL 710/863; O. O. Project No. TB4-150F
DATE OF REPORT: 2 February 1948
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical characteristics of heavy wrought armor
METHOD: Metallurgical examination of 12 armor samples included fracture, macroetch, Brinell hardness, and tensile tests. V-notch Charpy bars were broken at -40°F. Microscopic examination of structure was made at 1 inch below the center surface of the plates. Analysis of test data was made to determine if commercial production of this type of material would comply with tentative Armor Plate Specification AXS-1803.
DESCRIPTION: Four samples each of the test armor were manufactured by Bethlehem Steel, Carnegie-Illinois Steel, and the Midvale Co. The armor was Navy Class B wrought homogeneous ranging in thickness from 6 to 13-1/2 inches.
CONCLUSIONS: The armor was capable of meeting the specification requirements. Modification of the notched bar impact requirements of the specification was considered necessary. The high carbon content of 0.40% and the excessive laminations in some of the plates were thought to decrease their suitability for welding purposes. The macroetch test was considered inadequate for evaluating steel soundness. It was believed that proper processing of this type of material would result in substantially improved impact values.
GENERAL: This 54-page report includes seven pages of photographs, 18 pages of photomacrographs and six pages of photomicrographs of the armor samples. Also included is a drawing of the test set up.

SUBJECT: Metals WAL 710/914
TITLE: Metallurgical Examination of a 3/16-inch Thick Russian Aircraft Armor Plate
IDENTIFICATION: Report No. WAL 710/914; Project No. TB4-150L
DATE OF REPORT: 9 February 1950
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical characteristics of Russian aircraft armor and compare them with those of domestic armor
METHOD: Metallurgical examination of the test armor included chemical analysis, hardness surveys, visual inspection, tensile and fracture tests, and microscopic examination. The characteristics of the armor were compared with those of American armor and shock resistance tests were conducted with cal. .50 ball ammunition. Aluminum alloy hinges attached to the armor were also given metallurgical examination.
DESCRIPTION: The test section of aircraft armor was taken from a Russian 1L-2 aircraft and was 3/16 inch in thickness. The hinges attached to the armor were of aluminum alloy.
CONCLUSIONS: The 3/16-inch Russian aircraft armor varied greatly from the equivalent type of American armor in both chemical composition and hardness. The high-quality rolled homogeneous test armor had a content of .33 carbon, 1.26 M manganese, 1.48 silicon, and 1.83 nickel and had a Brinell hardness of 514. Equivalant American armor did not use even a moderate amount of silicon and was about 100 points Brinell softer. The test armor had good toughness characteristics considering its high hardness. This high hardness accentuated the effect of the directionality of rolling of the material and caused excessive breaking up during the ballistic test. The test hinges were of an alloy similar to Alcoa A17S and were apparently solution quenched and age heat treated to their maximum hardness.
GENERAL: This 22-page report includes one drawing, two pages of photographs and one page of photomicrographs of the test material.

SUBJECT: Metals WAL 710/930-4
TITLE: Review of Soviet Ordnance Metallurgy
IDENTIFICATION: Report No. WAL 710/930-4
DATE OF REPORT: 10 April 1953
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To summarize data on Soviet armor and ammunition
METHOD: The discussion on Soviet armor was organized into four main topics: artillery, tank armor, armor-piercing projectiles, and high explosive ammunition.
DESCRIPTION: The Soviet material described in this report included several tank and field guns ranging in caliber from 76 to 122mm, armor from JS II and T-34 Tanks, kinetic energy armor-piercing ammunition of both steel and tungsten carbide core types, and high explosive ammunition, most of which had been captured in Korea, with a

certain amount recovered from German battlefields of World War II.
CONCLUSIONS: It was emphasized that, in view of the fact that the Soviet material represented design concepts established as early as 1940-1942, this report should not be considered as presenting an adequate view of current Soviet metallurgy. On the basis of the material investigated, it seemed that the Soviets had attained equality with the U.S. in the matter of technical information, but not in technical development or in skill and training of metal workers. The use of high silicon steels for many ordnance applications was considered unique with the Soviets. There appeared to be a definite tendency to conserve molybdenum. It was recommended that the U.S. consider the possibility of following the Soviet practice of employing finely machined finishes and high quality carefully prepared welded joints, castings, and other metal products only where needed.
GENERAL: This 31-page report contains six pages of tabulated data, ten pages of photographs of the Soviet material, and one page of photomicrographs of a projectile core.

SUBJECT: Metals WAL 710/940
TITLE: Metallurgical Examination of Cast Armor Hull Section and Welded Joints of a Russian JS-1 Tank
IDENTIFICATION: Report No. WAL 710/940; Project No. TB4-10
DATE OF REPORT: 7 August 1950
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine and compare the metallurgical characteristics of Russian hull armor and welded joints with domestic materials
METHOD: Metallurgical examination covering chemical analysis, hardness, tensile, V-notch Charpy impact and macroetch tests and microscopic examination was made on specimens of the test material. The welded joints received the same examination except that the tensile and impact tests were eliminated.
DESCRIPTION: The test material was from the Russian JS-1 Tank and included portions of the upper sidewall of the cast hull, turret ring, sponson floor plate and weld joints by which the turret ring and floor plate were attached to the hull casting. The cast hull was Si-Ni-Cr-Mo steel of essentially martensitic structure, quenched and tempered without softening the steel.
CONCLUSIONS: High silicon content of the Russian armor resulted in a high hardness of 475 Brinell. For balanced protection against undermatching and overmatching projectiles the American optimum of 240 to 280 Brinell was preferable. Russian armor did possess a relatively high toughness of 11-13 ft.-lbs., V-notch Charpy. The weld joints demonstrated good armor joint design and were not exposed to direct ballistic attack, however, poor welding practice was apparent. The sponson floor plate was made from Mn-Si-Mo steel welded with an austenitic electrode. The sponson floor plate and turret ring were not heat treated. The turret ring was welded to the hull roof with a ferritic electrode.
GENERAL: This 33-page report includes five pages of photomacrographs, four pages of photomicrographs, and one drawing of the test materials.

SUBJECT: Metals WAL 710/956
TITLE: Metallurgical Examination of a 4-inch Thick Armor Plate Subjected to Detonations of Plastic Explosive Charges
IDENTIFICATION: Report No. WAL 710/956; Project No. TM1-5002
DATE OF REPORT: 5 October 1950
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties of 4-inch armor after ballistic testing
METHOD: Metallurgical examination of the armor included visual examination, macroetch, hardness, tensile, fracture and notched bar impact tests and microscopic examination. The tests were made of both the spalled and the unaffected areas to determine whether the characteristics of the material had been changed by the detonations of the charges.
DESCRIPTION: The three test samples of 4-inch rolled homogeneous armor were from a plate of Bethlehem steel which had been subjected to detonations of various sizes and weights of plastic explosive charges of the "squash-head" type. These charges had caused shallow craters in the armor surface and severely deformed and work-hardened the craters to depths of about 0.3 inches.
CONCLUSIONS: Where spalling occurred, a roughly circular button of metal, somewhat greater than the diameter of the surface crater, was thrown off the back of the armor. The force of the detonations of plastic explosive charges on the armor caused extensive rupturing and opening up of the laminations in areas away from the main fracture. The substantial internal cracking produced even when spalling does not occur would reduce the resistance of the armor to subsequent attack. The spalling of the armor was influenced by the soundness of the metal. It was recommended that for additional tests conducted with "squash-head" type ammunition the soundness of the armor be considered, since laminations provide planes of weakness in the direction of failure, laminated, unsound armor is less resistant to "squash-head" attack than is sound armor.
GENERAL: This 33-page report includes five pages of photomacrographs, two pages of photographs, and three pages of photomicrographs of the test armor.

SUBJECT: Metals WAL 710/1001-1
TITLE: Metallurgical Evaluation of Armor from Russian T-34 and JS-II Tanks of World War II Manufacture
IDENTIFICATION: Report No. WAL 710/1001-1; O.O. Project No. TB4-10
DATE OF REPORT: 15 February 1952
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical characteristics of Russian tank armor
METHOD: Metallurgical examination of the Russian armor sections included chemical analyses,

hardness, tensile and notched-bar impact tests, and micro and macrostructure examination. The metallurgical and ballistic properties were correlated. Chemical analyses, hardness tests and micro and macroexaminations of the weld joints were also conducted.
DESCRIPTION: The test armor sections were flame cut from destroyed Russian Tanks T-34 and JS-II. The sections were taken from upper and lower glacis plates, sponson floor and sidewall plates, a hull side and roof plates of a T-34 Tank and from the turret sidewall and roof armor and gun mantlet of a JS-II Tank. Most of the armor had been ballistically tested.
CONCLUSIONS: Contrary to American practice, widespread use had been made of silicon as an alloying element in the Russian armor. In general, the test armor had a very high hardness. Correlation of ballistic data with the test results showed that this high hardness reduced ballistic resistance and resulted in excessive tendencies toward cracking and backspalling. Ferritic and austenitic electrodes had been inter-mixed in welding the armor. Extensive porosity and cracking was noted in most of the welds and the workmanship was poor. The fit of armor sections joined by welds was inferior but careful attention had been given to dovetailing so that welds were not exposed to ballistic attack.
GENERAL: This 15-page report is not illustrated.

SUBJECT: Metals WAL 710/1019
TITLE: Ballistic and Metallurgical Evaluation of Samples of Special Armor and Weldments Developed by L.V. Sullivan and Company
IDENTIFICATION: Report No. 710/1019; Project No. TB4-10
DATE OF REPORT: 30 December 1952
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the suitability of specially treated SAE 1060 steel for armor applications
METHOD: Ballistic test of two welded plates was conducted using cal. .50 and cal. .30 AP M2 Projectiles at 0° obliquity and cal. .50 AP M2 Projectiles at 0° and 45° obliquity. Metallurgical examination of the test armor and weldments included chemical analysis, hardness and macroetch tests and microscopic examination. V-notch Charpy impact tests of the base metal were made at room temperature and -40°F.
DESCRIPTION: Two samples of 7/16-inch SAE 1060 steel had been specially heat treated and welded by L.V. Sullivan and Co. of Hamilton, Ontario. The steel had been heat treated by a patented process to a 460 Brinell hardness. The plates were submitted by the British after preliminary ballistic tests in Canada.
CONCLUSIONS: The test steel did not indicate any difference from normal SAE 1060 steel of the same hardness. The test material was not suitable for use as armor because of inferior ballistic penetration qualities. The material was also undesirable for welding due to the high carbon content which resulted in excessive cracking and brittleness in the weldments after ballistic testing.
GENERAL: This 26-page report includes three pages of photographs and three pages of photomicrographs of the test material.

SUBJECT: Metals WAL 730/626-2
TITLE: Metallurgical Examination of Soviet 85-mm Tank Gun Model 1944 (FMAR1403)
IDENTIFICATION: Report No. WAL 730/626-2
DATE OF REPORT: 7 November 1952
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To analyze the metallurgical properties and evaluate the design features of the Soviet 85mm Tank Gun Model 1944 FMAR1403
METHOD: The gun was disassembled, the markings were identified, the rifling characteristics were noted, and elastic strength computations were made. Component parts were subjected to chemical analyses; mechanical tests including hardness tensile and Charpy impact; macroexamination, and metallographic study.
DESCRIPTION: The test gun was a Soviet 85mm Tank Gun, Model 1944. The gun tube was of monobloc construction and was held in the breech ring by a locking collar fitted around the tube and screwed into the ring. The rifling had a uniform right-hand twist of one complete turn per 25 calibers. The breech block was a semi-automatic, vertical sliding wedge.
CONCLUSIONS: The gun tube was a Ni-Cr-Mo steel with approximately equivalent amounts of nickel and chromium. The breech block and breech ring compositions were similar to that of the tube except for a lower nickel content in the ring. Optimum metallurgical properties were not attained during manufacture. In general, metallurgical properties of the weapon would be unacceptable according to current standards for domestic weapons. The design features emphasized simplicity of components which facilitated assembly and disassembly and minimized machining operations during manufacture. Critical surfaces had good finishes, but noncritical surfaces were inferior to that of domestic weapons. Chemical compositions of the steels indicated that the Soviets possessed a sufficient supply of major alloying elements.
GENERAL: This 33-page report contains six pages of photographs showing component parts and microstructures.

SUBJECT: Metals WAL 730/636-1
TITLE: Metallurgical Examination of Soviet 76-mm Gun Model 1942 (FMAR 1261A)
IDENTIFICATION: Report No. WAL 730/636-1; Project TB3-0035
DATE OF REPORT: 8 June 1953
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties and design features of the Soviet Model 1942 76mm Gun
METHOD: A Soviet 76mm gun was given a visual examination and subjected to chemical analysis, hardness survey, tensile tests, Charpy impact tests, macroexamination, and microexamination.
DESCRIPTION: The test Soviet 76mm Gun, Model 1942, FMAR 1261A, was reportedly the standard

light field piece of the Soviet rifle division and was also found in antitank and mechanized units. The components examined included tube, breech ring, breech block and operating mechanism, breech locking collar, and muzzle brake.
CONCLUSIONS: The metallurgical properties of the gun were considered comparable to those of domestic weapons manufactured during the 1942 era. Chemical compositions of the tube and components were comparable to those of Soviet gun components previously examined at Watertown employing nickel and chromium as the major alloying elements with the characteristic 1:1 ratio of these elements being used in the tube and breech block steels. The most noteworthy design features were the lightness of the weapon, the simplicity of component design, facility of component assembly, and the typical coarse machine finishes of noncritical surfaces. The heat treatment used for the tube was considered inadequate since large amounts of tempered bainite were observed in the microstructure causing the impact resistance to be inferior to the yield strength level of the steel. The Soviet muzzle brake was made from a plain carbon steel whereas domestic brakes were made from alloyed steel of considerably higher strength levels.
GENERAL: This 40-page report includes seven pages of tabulated data, five pages of photographs, and two pages of photomicrographs.

SUBJECT: Metals WAL 760/314
TITLE: Metallurgical Examination of Cold Extruded 65-mm Shell, H.E., T1
IDENTIFICATION: Report No. WAL 760/314; Project No. TM1-1304A
DATE OF REPORT: 15 June 1949
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine and evaluate the metallurgical properties of a 65mm HE shell manufactured by the cold extrusion process
METHOD: Sample shells from three separate lots of the test ammunition were given a visual examination and subjected to chemical analysis, hardness tests, tensile tests, compression tests, hydrostatic tests, macroetch tests, and microscopic examination.
DESCRIPTION: The test material consisted of five samples each from three lots of 65mm HE T1 Shells. The shells were made of SAE 1020 steel and were fabricated by the cold extrusion method by the Mullins Manufacturing Corporation of Warren, Ohio. The shells from only one of the lots contained splines.
CONCLUSIONS: The cold extrusion technique employed appeared to be metallurgically suitable, although it was suggested that the method used to cut the rotating band splines be modified to eliminate high stress concentrations at the spline-shell body fillet. The average ductility values were considered satisfactory. Yield strength in compression was markedly higher for transverse tests as compared to longitudinal tests, and the strength values obtained in compression were generally higher than the corresponding values for tests in tension. The hydrostatic test was believed to be more desirable than tests on individual specimens removed from sample shells because the shell may be tested in its entirety and service conditions approximated.
GENERAL: This 37-page report contains tabulated data; three pages of drawings; eight pages of photographs; and four pages of photomicrographs of the test shells.

SUBJECT: Metals WAL 762/231-10
TITLE: Principles of Projectile Design for Penetration, Titanium Carbide as a Substitute for WC in HVAP Cores
IDENTIFICATION: Tenth partial report on Project No. TA1-5002; WAL 762/231-10
DATE OF REPORT: 11 January 1954
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To investigate the use of titanium carbide as a substitute for tungsten carbide in armor-piercing cores, and to study the projectile-plate reaction of titanium carbide cores when fired against homogeneous armor
METHOD: Armor used for the terminal ballistic tests of the titanium carbide cores was identical to that used for previous tests with the tungsten carbide cores. Armor thickness measured .50, .77, and 1.00 inch. After each core was accurately weighed and an average determined it was mounted in a plastic discarding carrier forcing the core base into the cylindrical cavity of the carrier with an interference fit of .003 inch. The armor target was 30 feet from the gun muzzle. Each round was separately loaded so that velocity variations could be accomplished by charge-weight variations. The missile velocity was measured with a Potter Chronograph actuated by two printed circuit grids spaced 10 feet apart. A protection ballistic limit was obtained for each test consisting of the arithmetic mean of the highest partial and lowest complete penetrations. Projectile fragments were recovered for each complete penetration and the armor at the penetration was sectioned to facilitate visual inspection. Data from previous tungsten carbide core tests were used to compare with the results of the titanium carbide core tests.
DESCRIPTION: Three types of titanium carbide cores, identified as K-12, K-16, and K-152, each geometrically identical with the H-13 tungsten carbide core, were manufactured by Kennametal Inc.
CONCLUSIONS: The titanium carbide cores shattered very severely under all test conditions while the tungsten carbide cores either shattered to a lesser degree or penetrated with noses intact. Shattering and rapid disintegration precluded any further consideration of titanium carbide as a substitute material. The titanium carbide cores tested showed excessive porosity. Titanium carbide for use in the body or base section was rejected as its value in penetration performance proved inferior to steel.
GENERAL: This 33-page report includes three pages of photographs showing the nature of penetrations and one page of photomicrographs.

SUBJECT: Metals WAL 762/313
TITLE: Metallurgical Examination of One Fired and One Unfired Standard 90-mm M77 A.P. Pro-

jectiles Reheat Treated by Frankford Arsenal
IDENTIFICATION: Report No. WAL 762/313
DATE OF REPORT: 7 March 1945
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical characteristics of one fired and one unfired standard 90mm M77 AP reheat treated projectile
METHOD: The unfired shot was subjected to a magnetic powder test. After visual examination, a central longitudinal slice was cut from each projectile for hardness survey and macroetch. Microspecimens from the fired shot were examined and a chemical analysis of samples taken from both shots was made. A Jominy bar was machined from each shot to determine hardenability.
DESCRIPTION: The two 90mm M77 AP test Projectiles were reheat treated by Frankford Arsenal to a resultant hardness pattern of Rc 63 in the nose, Tc 61 at the bourrelet, and Rc 40 in the base. One shot had been fired and the other was unfired. The particular projectiles were described as exhibiting superior ballistic performance and were of WD-4150 steel.
CONCLUSIONS: The shot bodies were of acceptable quality steel and of adequate hardenability but contained slight centerline segregation. The shots possessed hardness as described but a slight decrease was evident below the bourrelet at the center of the section as compared with corresponding hardness near the surface. Heavy carbide banding did not affect ballistic performance. Large quenching cracks emanating from the sharp forward corners of the tracer cavity of the unfired shot were revealed. A fracture at the base of the fired shot was possibly caused by similar cracks. The superior ballistic performance of the projectiles was found to be the result of the over-all quenching technique used on the steel which produced high hardness at the bourrelet and nose, decreasing gradually to the base which was tempered to a level of hardness capable of developing a high degree of toughness.
GENERAL: This 11-page report includes two pages of photomicrographs.

SUBJECT: Metals WAL 762/560
TITLE: Metallurgical Examination of Unfired Soviet 76.2mm HVAP Projectiles
IDENTIFICATION: Report No. WAL 762/560; Project TA1-5002
DATE OF REPORT: 31 January 1951
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical characteristics of an unfired Soviet 76.2mm HVAP projectile
METHOD: A visual examination was made to determine significant design features. One projectile was disassembled and another sectioned longitudinally except for the core. Component parts of the projectiles were subjected to a metallurgical examination including chemical analyses, macroetch tests, hardness surveys, tensile tests, and microscopic examination.
DESCRIPTION: The three unfired Soviet 76.2mm HVAP test projectiles were fitted with arrow-head composite-rigid tungsten carbide cores, soft steel carriers, and copper rotating bands.
CONCLUSIONS: Test results indicated that the projectiles were made of relatively non-strategic materials except for the tungsten carbide core. The core was excessively small for the caliber and the penetrator, including the follow-through plug, weighed only 21% of the total weight of the projectile. The metallurgical quality of the carbide core was poor. The design and the material used were such that this type of projectile could be manufactured with minimum specialized equipment.
GENERAL: This 40-page report includes one detailed dimensional drawing of the projectile and nine pages of photographs showing the projectile components and microstructure.

SUBJECT: Metals WAL 762/582(C)
TITLE: Metallurgical Examination of Soviet 45-mm, 57-mm, and 85-mm APHE Projectiles, FMAM 1121, 1935 and 2175
IDENTIFICATION: Report No. WAL 762/582(C); Project No. TB3-0035
DATE OF REPORT: 6 August 1952
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties and evaluate the design, manufacture, and performance characteristics of three Soviet projectiles
METHOD: The test projectiles were visually examined, markings and measurements recorded, and engineering drawings prepared. A longitudinal slice was cut through the center of each test projectile and the projectile was surface ground and macroetch tested. Chemical analysis and microscopic examination were conducted on samples cut from the shot bodies, windshields, and rotating bands.
DESCRIPTION: The three Soviet APHE projectiles were captured in Korea. These were identified as follows: 45mm APHE-T, FMAM 1121; 57mm APHE-T, FMAM 1935; and 85mm APHE, FMAM 2175.
CONCLUSIONS: The Soviet projectiles differed radically from American projectiles. The method of manufacture stressed simplicity and economy in production. The Soviet shot had coarse machining and heavy cuts. Fine finishes were used only for bearing surfaces. Close dimensional control was used only for bearing and mating surfaces. The 45mm and 57mm shot were very blunt nosed and were fitted with windshields. The carbon content of the shot ranged from 0.32 to 0.38% as compared to 0.50 to 0.60% carbon content for domestic shot steels. The 85mm shot was poorly heat treated. It was estimated that the 45mm and 57mm shot were effective against overmatching armor targets at angles through 60° obliquity; the 85mm shot was effective against slightly undermatching armor at all angles through 60° obliquity; and against overmatching armor at 0° to 30° obliquity.
GENERAL: This 38-page report includes five pages of photographs, six pages of drawings, and three photomicrographs of the test projectiles and compartments.

SUBJECT: Metals WAL 762/589(C)
TITLE: Metallurgical Examination of Soviet 76-MM APHE Projectiles MOD, BR-354B, FMAM 2267
IDENTIFICATION: Report No. WAL 762/589(C); Project No. TB3-0035
DATE OF REPORT: 10 April 1953
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties and evaluate design, methods of manufacture, and performance of a Soviet 76mm projectile
METHOD: The test projectile was examined to determine design features, measurements were recorded, and a drawing made. A longitudinal slice was cut through the slot and the surface ground. Metallurgical examination was conducted including analysis, hardness tests, macroetch tests and microscopic examination of all projectile components.
DESCRIPTION: The test Soviet ammunition was a 76mm APHE Projectile MOD. DR-354B, FMAM 2267. The shot body was machined from medium carbon-silicon-chromium steel. The shot was blunt nosed with a low-carbon-steel windshield and a single copper rotating band.
CONCLUSIONS: The test shot was similar in design to shot of other calibers which had been previously examined. The shot body had a low carbon content of 0.34% and a resulting hardness below American standards. The projectile had a high silicon content of 1.54%. The shot probably was designed to defeat armor up to 2 inches thick with moderate to high obliquities of impact. The method of manufacture stressed simplicity and economy in production practice.
GENERAL: This 22-page report includes three pages of photographs, two pages of drawings, and one page of photomicrographs of the test materials.

SUBJECT: Metals WAL 762/594(C)
TITLE: Metallurgical Examination of Chinese 57-mm Heat Shell, FMAM 2039
IDENTIFICATION: Report No. WAL 762/594(C); Project No. TB-3-0035
DATE OF REPORT: 3 April 1953
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties and evaluate the design, manufacture, and performance of a Chinese shell
METHOD: Metallurgical examination of the test shell was made including chemical analyses, hardness surveys, and macroscopic and microscopic examination. The test shell was photographed, weighed, measured, and sectioned. Test specimens were taken from all of the components of the shell.
DESCRIPTION: The test projectile was a Chinese 57mm HEAT Shell FMAM 2039. The body was forged from a medium carbon steel and had a pre-engraved rotating band machined in the body, a cast aluminum windshield, a medium-carbon base plug with a gas-tite copper seal and a brass liner fitted into the body with a flash tube attached to the rear of the liner.
CONCLUSIONS: The Chinese test shell was an obvious copy of the American 57mm HEAT M307A1 Shell. The principal difference was a shorter body and higher twist to the pre-engraved rotating band of the Chinese shell. The smaller explosive charge and almost double rate of spin for the test shell probably made it less effective against armor. The appearance of the shell indicated economy in materials, production and machining practices. All of the shell components were made of unalloyed carbon steels, and the non-ferrous components were made by economical methods from available materials.
GENERAL: This 21-page report includes two pages of photographs, one drawing, and three pages of photomicrographs of the test shell and components.

SUBJECT: Metals WAL 762/604-1
TITLE: Metallurgical Examination of Cemented Carbide Core From Soviet 76-mm HVAP-T Projectile (Model UBR-354-P) FMAM 2153
IDENTIFICATION: Report No. 762/604-1; Project No. TB3-0035
DATE OF REPORT: 9 December 1952
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties of a Soviet 76mm projectile core
METHOD: Visual examination was made of the test projectile core. Metallurgical examination of the core included chemical analysis, determination of specific gravity, hardness surveys, and metallographic and bend test studies.
DESCRIPTION: The cemented carbide test core was from a Soviet 76mm HVAP-T Projectile (Model UBR-354-P) FMAM 2153. The core was composed of tungsten carbide bonded with 5.6% nickel. It weighed 0.88 pounds.
CONCLUSIONS: The test core apparently had been cold-pressed from a WC-Ni powder mixture and sintered by a conventional powder metallurgy technique. The light weight core was considered suitable for mass production in standard process equipment and useful for anti-tank projectiles at short range. The core had been processed by the same methods as previously tested Soviet cores and had a low nickel binder content, excessive porosity, and the coarse-grained structure common to all these cores. It was thought that a reduction of the porosity in the core would improve its mechanical properties but that its optimum strength would still be inferior to domestic cores cemented with 15% cobalt.
GENERAL: This 12-page report includes one page of photomicrographs of the test material.

SUBJECT: Metals WAL 762/606
TITLE: Soviet 122-MM APHE-T Projectile Mod. BR-471B, FMAM 2233
IDENTIFICATION: Report No. WAL 762/606; Project No. TB3-0035
DATE OF REPORT: 3 November 1953
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical characteristics of a Soviet 122mm projectile
METHOD: The test projectile was weighed and visually examined for significant markings and design features. A metallurgical examination of

the projectile and its components included a chemical analysis, hardness surveys, macroetch tests, and microscopic studies. A physical and chemical comparison was made with comparable American AP shot.
DESCRIPTION: The Soviet 122mm APHE-T test projectile was identified as follows: BC-T Model BR-471B, FMAM 2233. The projectile was fitted with a windshield, or ballistic cap and tracer. The total weight of the shot including the windshield and rotating band was 53 pounds.
CONCLUSIONS: The major design features which differed from American rounds of comparable type were: the blunt nose shape, the circumferential V-notches, and the use of a roll crimp to attach the windshield. The shot body was forged from a medium .35% carbon steel and heat treated to an average hardness of Rockwell C50. Apparently the hardness patterns were developed directly by poorly controlled differential quenching procedures and base treatments were avoided.
GENERAL: This 28-page report includes two pages of drawings, four pages of photographs, and one page of photomicrographs of the test projectile.

SUBJECT: Metals WAL 762/610
TITLE: Metallurgical Examination of Chinese 81-mm HE Mortar Shell FMAM 2278
IDENTIFICATION: Report No. WAL 762/610; Project No. TB3-0035
DATE OF REPORT: 25 January 1954
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties of a Chinese 81mm shell
METHOD: The test shell was examined visually and its dimensions were measured and incorporated in a drawing. Metallurgical examination of the shell body was conducted including chemical analysis, tensile and hardness tests, and metallographic and macroetch studies. The cartridge container and fins were tested in the same manner except that the tensile test was not given.
DESCRIPTION: The test Chinese 81mm HE Mortar Shell FMAM 2278 was of the tear-drop design and was coated with black paint. The shell body had been forged from plain carbon steel but not subsequently heat treated. The cartridge container and fin assembly had been made from 0.23% carbon steel.
CONCLUSIONS: The Chinese test mortar shell was considered adequate for field use. Standard forging and hot nosing manufacturing techniques had been used in its production. The metallurgical quality and workmanship of the shell body were satisfactory. The cartridge container was of secondary metallurgical quality. The shell components were almost identical in design and metallurgical properties with the domestic 81mm HE motar Shell M43A1.
GENERAL: This 20-page report includes three pages of photographs, two pages of photomicrographs, and one drawing of the test materials.

SUBJECT: Metals WAL 762/611
TITLE: Soviet 82-MM HE Mortar Shell Mod. O-832D, FMAM 2171
IDENTIFICATION: Report No. WAL 762/611; Project No. TB3-0035
DATE OF REPORT: 7 May 1954
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical characteristics of a Soviet 82mm mortar shell
METHOD: The test projectile was visually examined, dimensioned, photographed, and identification symbols recorded. Metallurgical examination included chemical analysis, hardness surveys, tensile tests, and macroscopic and microscopic studies.
DESCRIPTION: The inert round of Soviet 82mm HE mortar ammunition was identified as Model O-832D, FMAM 2171. The projectile was of the tear-drop design with five pairs of fins attached to the cartridge container. The exterior and interior surfaces were in the "as-cast" condition with the exception of the external gas-check bands and internal threads.
CONCLUSIONS: The test Soviet projectile was manufactured of low cost gray cast iron which was not heat treated. The shell was very sound and had a wall thickness double that of domestic mortar shells. The cast iron body was very brittle and would result in fine fragmentation upon impact. The fin assembly and cartridge container were similar in metallurgy and design to comparable domestic components.
GENERAL: This 20-page report includes one page of drawings, two pages of photographs, and two pages of photomicrographs of the test projectile.

SUBJECT: Metals WAL 762/612
TITLE: Metallurgical Examination of Soviet 120-mm Mortar Shell, HE, MOD. OF-843A, FMAM 1829
IDENTIFICATION: Report No. WAL 762/612; Project No. TB3-0035
DATE OF REPORT: 4 May 1954
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties of a Soviet 120mm Mortar shell
METHOD: The test shell was given a visual examination and its dimensions were measured and incorporated in a drawing. Metallurgical examination of the shell body and components included hardness surveys. chemical analysis, microscopic examination, and macroetching. Charpy impact and tension tests were also conducted on specimens from the shell body.
DESCRIPTION: The inert test round was a "tear-drop" shape Soviet 120mm Mortar Shell, HE, MOD. OF-843A, FMAM 1829. The shell body was made of gray cast iron. Six gas-check bands constituted the bourrelet and the shell wall was fairly thick. A cast component was attached to the mouth of the shell which served as fuze adapter and booster cup. The shell body and adapter weighed 26 pounds and the tail assembly 2.13 pounds.
CONCLUSIONS: The simplicity of design and the low machining requirements of the test shell were typical of Russian shells previously examined. The use of gray cast iron for the shell body was con-

sidered very suitable because this metal has good fragmentation characteristics and is an economical and non-strategic material easily machined in shell production.
GENERAL: This 20-page report includes two pages of photographs, one drawing, and two pages of photomicrographs of the test shell and components.

SUBJECT: Metals WAL 763/850(C)
TITLE: Metallurgical Examination of Japanese 70-mm HE Shell, FMAM 412
IDENTIFICATION: Report No. WAL 763/850(C); Project No. TB3-0035
DATE OF REPORT: 9 September 1953
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine the metallurgical properties of a Japanese 70mm HE shell
METHOD: The test shell was examined visually, weighed, photographed, and its dimensions and markings recorded. Metallurgical examination of the shell included hardness surveys, chemical analyses, and microscopic and macroscopic studies. Tensile tests were also conducted on the shell body.
DESCRIPTION: The test 70mm HE Shell FMAM 412 was of Japanese design and Chinese manufacture. The shell had a small radius ogive, a single copper rotating band and a "square" base. It was classified as a semi-fixed round.
CONCLUSIONS: The design, metallurgical quality, and workmanship of the 70mm shell were considered adequate for good performance. The shell body was manufactured to a higher strength level than similar domestic shells but this higher strength was not believed necessary for proper ballistic performance at the normal muzzle velocity of 850 fps. The shell had high tensile strength and was designed for high capacity with blast effect rather than fragmentation being of primary importance.
GENERAL: This 23-page report includes two pages of photographs, one drawing, one photomacrograph, and one page of photomicrographs of the test shell.

Section 27
MISCELLANEOUS SUBJECTS

SUMMARY

The subject, Miscellaneous Subjects, was not summarized because of the limited scope of the individual categories that comprise the subject.

REPORT RESUMES

AB 364(S)

SUBJECT: Ammunition Boxes and Racks
TITLE: Incendiary Effect of Firing on Medium Tanks
IDENTIFICATION: Supplemental Report; Project No. 364
DATE OF REPORT: 20 April 1943
ORIGIN: Armored Force Board, Fort Knox, Kentucky
PURPOSE: To determine the effectiveness of wet stowage ammunition boxes in preventing ammunition fires
METHOD: An M4A1 Tank was equipped with the proposed ammunition stowage facilities and fired on with 37 and 75mm APC rounds at a range of 300 yards. The wet stowage boxes were intentionally penetrated to determine the tendency of the propellant charges to ignite.
DESCRIPTION: The wet stowage ammunition boxes were made of light sheet metal with individual, dry cells for each round. The ammunition was placed base down in the cells with only the projectile protruding. The space surrounding these cells in each container was filled with water. The capacity of this water jacket was about two quarts per round.
CONCLUSIONS: Fourteen hits on the boxes resulted in only two fires. This proved wet stowage of ammunition to be 86% effective in preventing ignition. Previous tests on dry stowed ammunition indicated that penetration of propellant charges by projectiles or spall fragments invariably resulted in fires. Since combat experience indicated that 60% of the hits sustained by M4 Tanks were above the track line, it was recommended that stowage of all but ready rounds be stowed below this level. The wet stowage boxes were recommended for future vehicles and for modification of existing vehicles. A wet stowage rack was proposed for the ready rounds in the turret. Since the ammunition cells were large enough to clear the rim of the ammunition case, it was recommended that some device be developed to prevent rattling of the upper ends of stowed rounds.
GENERAL: This 57-page report contains 33 photographs and eleven drawings of the wet stowage boxes, the relocated stowage, and effects of hits on the boxes. This report is a supplement to Report No. 364 which is classified as Restricted.

APG AD-959

SUBJECT: Ammunition Boxes and Racks
TITLE: Third Report on Ballistic Test of Light Tank M24 (Water Protected Ammunition Racks and Mine Test)
IDENTIFICATION: Report No. AD-959; Project No. 4290
DATE OF REPORT: 23 June 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of water-protected ammunition racks in minimizing fire hazards from the ignition of powder charges in the Light Tank M24; to evaluate the damage on the tank suspension system and other components by a statically detonated German Tellermine; and to establish the time required for field repairs to the tank suspension system.
METHOD: Two M24 Tanks were positioned to allow 57-mm shots to penetrate at 45° obliquity. Two motion picture cameras were used to record the time interval between projectile impact and the ignition of the stowed ammunition and the over-all impact and progress of the fire. One 57mm AP round was fired at a striking velocity of 1650 fps and subsequent rounds were fired at striking velocities of 2200 fps. One firing test was made with the water cans empty; all other tests were made with the cans filled with a 40% solution of Prestone. German Tellermines were statically detonated beneath the tanks with a ground clearance of 16-1/4 to 17-3/4 inches. A record was made of the damage and of the time needed for field repairs.
DESCRIPTION: The two test Light Tanks M24 were built by the Massey-Harris Tank Plant, Racine, Wisconsin, and the Cadillac Motor Division. The tank front and rear section floors were 1/2-inch armor plate and 3/8-inch mild steel plate, respectively. The right and left rack sections had flat water cans surrounding the 75mm ammunition. The German Tellermine was the TM1-42, Type 2. The Ammunition stowed in the racks was 75mm APC M61 and 75mm AP M72.
CONCLUSIONS: The value of water-protected ammunition racks was found to depend on the location of the penetration. Although the racks delayed ignition and reduced fire intensity, the resultant fires caused serious damage to the tank and the delay interval was considered too brief to provide a safe departure time for tank personnel. Tem-

porary immobilization resulted from mine detonation under the tank front track wheel. It was estimated that the time required for the repairs necessary to place the tank in operating condition would be approximately three hours. Many propelling charges ignited from the mine detonation under the racks. A permanent immobilization was caused by mine detonation between the tank tracks.

GENERAL: This 81-page report includes 34 pages of photographs, three pages of photostats, two pages of sketches, and three appendices. Appendix B includes Reports Ar-15510, Ar-15776, Ar-15782, and Ar-15892, the pertinent data therefrom being incorporated in this brief.

SUBJECT: Armaments AFF 2-18-49(IX-10)
TITLE: Armament for Tanks
IDENTIFICATION: Report No. AFF 2-18-49(IX-10)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To analyze and clarify the U.S. position and development policy on tank armament
METHOD: A summary was made of the general characteristics required of tank guns and ammunition, and a study was made of the conflict between tank weight limits and size and weight of guns. A survey of the requirements of the War Equipment Board Report included armament items such as cal. .30 machine guns, antiaircraft machine guns, conventional high velocity guns, and gun mountings. The requirements for tank gun ammunition was studied including shaped and plastic charges, HE shells and conventional standard, and one-half weight shot type projectiles. Progress was summarized in the development of new type and experimental guns.
DESCRIPTION: The machine guns in current use were cal. 30 M1919A4, cal. .30 M2AC and the cal. .50 M2, HB Guns. The basic antipersonnel weapons of a tank were the machine guns. New development tanks were to be equipped with one or more coaxial machine guns, one of which would be of .50 caliber. The optimum cycle rate for machine guns was between 450 and 700 rounds per minute.
CONCLUSIONS: The requirements for tank armament established by the War Department Board were sound. Research and development of tank guns and ammunition should be continued and gun size and weight reduced. The use of the conventional high velocity gun was required until more lethal lightweight guns were developed. The best immediate potential was offered by the 76mm Gun T91, 90mm Gun T119, and the 120mm Gun TX. A tank mounted howitzer was not required. There was a need for a tank machine gun for ground firing and antiaircraft protection. The cal. .30 M1919A4 and cal. .50 M2 HB Machine Guns required modification.
GENERAL: This 10-page report is not illustrated and includes two tables of tank and gun requirements and is included with Report No. AFF 2-18-49.

SUBJECT: Armaments APG 5680/3
TITLE: First Report on Test of German Tank, PzKpFw, Tiger II, Model B
IDENTIFICATION: Third Report on Ordnance Program No. 5680; APG 10-216
DATE OF REPORT: 7 March 1947
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the desirable features of the armament and installation of the 8.8-cm KwK43 Gun on the German Tank PzKpFw, Tiger II, Model B, which might be incorporated in our combat vehicles
METHOD: Only a limited operation of the power plant was possible, but sufficient operation was obtained to verify the power turret characteristics. The 8.8-cm gun was removed from the turret in order to examine installation, special attention given the turret plate, weights of components, equilibration system, recoil mechanism, and breech mechanism. In addition, minimum areas of fire, steps in loading and case ejection and analysis of the telescopic sight were studied.
DESCRIPTION: The German Tank PzKpFw was powered by an HL 230 P30 engine rated at 600 hp at 2600 rpm, and used an eight-forward, four-reverse speed transmission and overlapping suspension. The main armament was an 8.8-cm KwK43 Gun. The traverse was controlled by two foot pedals located on the turret floor. There was a hand lever connected to the foot pedal linkage for manual control, as well as a hand wheel for traversing the turret through 360°.
CONCLUSIONS: It was concluded that the following armament features were desirable: installation of the gun on support brackets on the turret plate; the use of foot control for turret traverse; features of Telescope TZF9D for stabilized gun operation; two-piece gun tube construction; a reduction of 71.75 pounds in the weight of the muzzle brake; and the simplicity in construction of the equilibrator. It was recommended that all these features be studied further for possible consideration in future tank design, with the exception that the German equilibrator design not be tested further for application.
GENERAL: This 89-page report contains 48 photographs of the tank and components, and photostats of diagrams showing the assembly of the 88mm Tank Gun KwK43, muzzle brake, trunnion assembly, trunnion, trunnion support, and assembled views of the telescopic sight.

SUBJECT: Armaments FA R-1237
TITLE: Recoilless Rifle Systems, Ammunition and Related Systems
IDENTIFICATION: Report No. R-1237
DATE OF REPORT: 31 March 1954
ORIGIN: Frankford Arsenal, Philadelphia, Pennsylvania
PURPOSE: To report progress on recoilless rifle systems being developed at Frankford Arsenal
METHOD: Progress on recoilless rifle systems was reviewed with respect to the weapons and accessories, ammunition, fire control, ballistic studies, and related items. Investigations were described concerning propellant and ignition, flash, blast, front orifice, and torque studies. Also discussed was research relating to methods of ballistic measurement, the light-weight cartridge case, heat transfer, nozzle erosion, dry film lubricants, and principles of rifle construction. A description of the facilities at the Frankford Arsenal Brindle Lake Range, Fort Dix, New Jersey, was included.
DESCRIPTION: Test items included the U-Bat System as well as the 105mm repeating rifle, 90mm, 75mm, 2.75-inch, and 57mm recoilless rifle systems.
CONCLUSIONS: Progress in the development of recoilless rifle systems was reviewed to coordinate results of tests and studies on these items. Composite information contained in this and similar reports was to be used in maintaining a backlog of data on Ordnance projects; the accumulation of

research material would then contribute to the preparation of final test reports.
GENERAL: This 84-page report contains eight photographs of the Brindle Lake Range and one photograph of a test gun barrel.

SUBJECT: Armaments FA R-1238
TITLE: Recoilless Rifle Systems, Ammunition, and Related Items
IDENTIFICATION: Report No. 1238
DATE OF REPORT: 30 June 1954
ORIGIN: Frankford Arsenal, Philadelphia, Pennsylvania
PURPOSE: To report progress on recoilless rifle systems being developed by Frankford Arsenal
METHOD: Progress in the development of recoilless rifle systems was reviewed with respect to the weapons and accessories, ammunition, ballistic studies, fire control, and related items. Investigations were described concerning blast studies, methods of ballistic measurements of the lightweight cartridge case, heat transfer, drill rounds, and the titanium rifle. Human engineering studies with respect to recoilless rifles were listed.
DESCRIPTION: Test items included the U-Bat System as well as the 105mm, 106mm, 90mm, 75mm, 2.75-inch, and 57mm recoilless rifle systems.
CONCLUSIONS: Progress in the development of recoilless rifle systems was outlined in an effort to coordinate pertinent tests and studies. This and similar reports were to be used as a backlog of data on Ordnance projects. Information on the many items discussed was presented in composite form; the accumulation of these progress reports would then facilitate the preparation of final reports.
GENERAL: This 71-page report contains 12 photographs of rifle components and detailed drawings of test guns.

SUBJECT: Armaments FA R-1271
TITLE: Recoilless Rifle Systems, Ammunitions and Related Items
IDENTIFICATION: Report No. R-1271
DATE OF REPORT: 30 June 1955
ORIGIN: Frankford Arsenal, Philadelphia, Pa.
PURPOSE: To report progress on recoilless rifle systems being developed at Frankford Arsenal
METHOD: Progress on recoilless rifle systems at Frankford Arsenal was outlined with respect to the weapons and accessories, ammunition, fire control, ballistics tests, and related items. Investigations were described concerning propellant and ignition studies, methods of ballistic measurement, light-weight cartridge cases, nozzle erosion, and dry film lubricants. Also discussed were studies relating to principles of rifle construction, drum loading, range operation, polymers, and an interior ballistics theory. Progressive stress damage in recoilless rifles, stress analyses, and design studies were reviewed.
DESCRIPTION: Test items included the U-Bat System as well as 105 and 106mm, 90mm, 2.75-inch, and 57mm recoilless rifle systems.
CONCLUSIONS: Progress in the development of recoilless rifle systems was reviewed and the results of tests and studies were coordinated. Information collected in composite form in this and similar reports was to be used to maintain a backlog of data on Ordnance projects; the accumulation of such material would then facilitate the preparation of final test reports.
GENERAL: This 78-page report contains eight photographs of the recoilless rifle systems. Also included are drawings of the rifles, ammunition, and related components.

SUBJECT: Ballistics APG 314-B
TITLE: Gun versus Armor - Report on Demonstration and Test for AFF Representatives
IDENTIFICATION: APG 314-B
DATE OF REPORT: 19 December 1949
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of various weapons and projectiles against a Russian Tank JS III
METHOD: Each weapon was fired at a simulated front glacis plate of a JS III Tank. Two such plates were used: the 5-inch upper at 55° obliquity, and the 4-inch lower at 50° obliquity. Another plate, three inches thick at 40° obliquity, was also used.
DESCRIPTION: Guns tested included: 120mm T53E1, 90mm T119, 90mm T54, British 20-pounder, and 76mm T91. Other weapons included: 105mm Howitzer M2A1 with the HEAT round and the British Squash-head; standard 2.36-inch and 3.5-inch rockets.
CONCLUSIONS: Only the 105mm Squash-head projectile defeated the 5-inch plate at 55° obliquity. The 120mm, with APC projectiles, failed against the 4 and 5-inch plates at 55° obliquity. The 90mm T54 failed against the 5-inch plate. The 90mm T119 and British 20-pounder failed against the 5-inch plate, but both penetrated the 4-inch plate at 40° obliquity. The 76mm T91 defeated the 3-inch plate at 40° obliquity.
GENERAL: This 41-page report contains 25 photographs illustrating the plates before and after firing.

SUBJECT: Ballistics APG AD-625
TITLE: Report on the Ballistic Test of German Tanks PzKw III, IV, and VI
IDENTIFICATION: Report No. AD-625; Project No. 3206
DATE OF REPORT: 5 May 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic suitability of standard U.S. armor piercing projectiles against German Tanks PzKw III, IV, and VI; and to compare the ballistic vulnerability of German and U.S. armor and weld joints
METHOD: The ballistic characteristics of various U.S. projectiles against the armor of German Tanks PzKw III, IV, and VI were determined. Vulnerability charts of the armor of the three German tanks were prepared; these charts depicted the maximum range at which the various projectiles used could inflict damage on various tank armor sections. The resistance to penetration of American and German armor plate ranging from 7/8 to 4 inches in thickness was compared. In addition the ballistic suitability of U.S. and German welded joints was compared.
DESCRIPTION: Standard U.S. projectiles tested against German tank armor included: 20mm AP M75, 37mm APC M51; 57mm APC M86; 75mm APC M61 at various muzzle velocities; 3-inch APC M62; and 90mm APC M82. The German tanks were constructed with rolled homogeneous and face-hardened armor. Armor thickness of the Tank PzKw III ranged from 1.22 to 2.04 inches; Tank PzKw IV armor ranged from 0.87 to 2.04 inches; and Tank PzKw VI armor ranged from 2.50 to 7.50 inches.
CONCLUSIONS: U.S. projectiles were reasonably effective against the armor of both the German Tanks PzKw III and IV. However, U.S. projectiles were reasonably effective against only the lower hull sides of the PzKw VI tank. The 90mm APC M82 Projectiles were the most effective against the armor of all three tanks. In addition, 57mm projectiles with a muzzle velocity of 2700 fps more readily penetrated German tank armor than did 75mm projectiles fired at a muzzle velocity of 2030 fps or lower. Although German 3-1/4 and 4-inch homogeneous armor afforded more resistance to penetration against undermatching projectiles, its performance against matching and overmatching projectiles was only comparable to that of U.S. armor. U.S. weld joints were found ballistically superior to German weld joints. It was recommended that the base cavity diameter of the 90mm APC M82 Projectile be decreased to insure adequate functioning of the bursting charge.
GENERAL: This 193-page report contains 37 pages of photographs showing the tank armor after projectile impacts. German tank vulnerability charts and Firing Records A-11334, A-11832, A-11844, A-12071, A-12073, A-12309, A-12331, A-12577, and A-12593 are also contained in the report. A 37-page British Army publication covering "Attack on Panther PzKw V and Tiger PzKw VI is attached to the report.

SUBJECT: Ballistics APG AD-647
TITLE: Test of Armor Used in U.S. Aircraft With German 20mm HE Ammunition
IDENTIFICATION: Report AD-647; Project No. 1855
DATE OF REPORT: 10 March 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether the ballistic characteristics of five types of German 20mm projectiles were superior to U.S. 20mm projectiles; and to study the resistance to penetration offered by armor plate
METHOD: Five types of German 20mm projectiles were used in ballistic tests against three types of U.S. 1/4, 5/16, and 3/8-inch armor plates. Identical ballistic tests were performed with U.S. 20mm HEI, Mk I Projectiles equipped with Fuze PD No. 253. Ballistic performance of the German projectiles was compared with that of the U.S. projectiles, and comparisons were made between the resistance-to-penetration characteristics offered by each of the three types of plates of the respective plate sizes.
DESCRIPTION: German 20mm projectiles tested were designated: Solothurn HE equipped with Fuze PD No. 245 (FMAM-11); Mauser HEI, T, equipped with Fuze PD AZ-1504 (FMAM-354); Mauser HE equipped with Fuze PD SD-ZZ-1505(FMAM-391); Oerlikon HEI equipped with Fuze PDAZ-1504 (FMAM-397); and Mauser HE,T equipped with Fuze PD AZ-1504 (FMAM-420). Armor plate tested in the three sizes included: rolled homogeneous (AXS-495); aircraft homogeneous (ANOS-1); and face hardened (AXS-490).

CONCLUSIONS: The ballistic characteristics of the German 20mm Projectile FMAM-420 were superior to those of the other German projectiles. In general, the FMAM-420 Projectile was more effective in completely penetrating U.S. armor than the U.S. 20mm projectile. It was recommended that a study of the design of the FMAM-420 Projectile be made in order to determine why it was better, and that a study be conducted on the self destroying feature of the tracer element used in the German projectile. Resistance-to-penetration performance of the three types of 1/4 and 5/16-inch armor plates varied only slightly. However, the resistance-to-penetration performance of 3/8-inch aircraft homogeneous armor (ANOS-1) was superior to that of either 3/8-inch rolled homogeneous or face-hardened armor.
GENERAL: This 46-page report contains one photograph showing the FMAM-420 Projectiles after firing tests. Firing Records A-11582, A-12629, and A-12863 are also included in the report.

SUBJECT: Ballistics APG AD-968
TITLE: Determination of the Shatter Characteristics of the German AP HE Projectile (FMAM-289) for the 7.5-cm PAK 40 Gun
IDENTIFICATION: Report No. AD-968; Project No. 5094
DATE OF REPORT: 4 June 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic characteristics of German 7.5-cm AP HE projectiles when equipped with and without armor-piercing caps; and to determine whether a decapping device would satisfactorily limit the ballistic effect of the German projectiles equipped with armor piercing caps
METHOD: Ballistic testing was conducted on a 2-1/2-inch rolled homogeneous armor plate setting at 47° obliquity using capped and uncapped German 7.5-cm projectiles fired from a PAK 40 Gun. In an effort to reduce the effectiveness of the capped projectiles, 1/4-inch armor plate was set 12 inches in front of and parallel to the 2-1/2-inch armor plate and ballistic tests were conducted with capped German 7.5-cm projectiles; identical tests were conducted with two thicknesses of 1/4-inch plate in front of the 2-1/2-inch armor plate.
DESCRIPTION: The test German 7.5-cm AP HE projectiles were designated as No. FMAM-289. Armor piercing capped projectiles weighed 14.9 pounds, and projectiles without armor piercing caps weighed 13.1 pounds.
CONCLUSIONS: The nose of the German projectiles equipped with armor piercing caps were still intact after passing through the 2-1/2-inch armor plate at striking velocities of approximately 2130 fps. In the case of the projectiles without armor piercing caps, the projectile nose upon striking the 2-1/2-inch armor was found to shatter and the portion of the projectile containing the explosive cavity broke apart. In no case did projectiles without armor caps pass through the armor plate intact. The decapping devices consisting of 1/4-inch armor plate failed to reduce the ballistic effect of the projectiles.
GENERAL: This 44-page report contains five pages of photographs showing the plate and projectiles after test. Firing Records Ar-15380, Ar-15516, and Ar-15637 are included in the report.

SUBJECT: Ballistics APG AD-1127
TITLE: First Report on Investigation of the Effectiveness of the British 105-mm Squash-Head Shell in Defeating Armor
IDENTIFICATION: Report No. AD-1127; First Report on Project No. TM1-5002H
DATE OF REPORT: 7 December 1950
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of the British 105mm Squash-head shell in defeating armor under various conditions
METHOD: British 105mm Squash-head shells were fired at 4, 5, 6, and 7-inch homogeneous armor plates at 0, 30, 55, and 60-degree obliquities, and against a T26E3 Tank. Movies were taken of the impact of the shells upon armor to determine fuze functioning time, spall fragment velocities, and other data. The armor was examined for impressions, bulges, cracks, and spall openings after each impact, and spall fragments were measured and weighed. Information concerning shell detonation time as well as data regarding size of spall fragments displaced from the armor and their velocity was obtained.
DESCRIPTION: The British 105mm Squash-head shell contained a plastic explosive and was fitted with a base detonating fuze. Two variations of this basic shell were tested: (1) the shell fitted with both inert and live fuzes and (2) the shell loaded with inert composition and fitted with a live fuze. A 105mm Projectile T8, machined to a weight of 17.84 pounds to simulate the British shell, was used for proof purposes.
CONCLUSIONS: The British 105mm Squash-head shell was capable of displacing fragments from the rear face of armor up to 5 inches thick at a 55 degree obliquity, or armor 6 inches thick at a 60 degree obliquity. The effectiveness of the shell decreased greatly, however, at high striking velocities (above 1756 fps), and decreased progressively with decreased obliquity. It was recommended that tests of this type of attack continue with the purpose of developing a shell giving improved performance at high striking velocities and low obliquities.
GENERAL: This 94-page report includes 27 photographs of the projectiles striking the armor and of the armor after the firing tests.

SUBJECT: Ballistics APG AD-1166
TITLE: Vulnerability of T26E4 Tanks to Attack by 2.75-Inch and 8-cm HEAT Aircraft Rockets
IDENTIFICATION: Report No. AD-1166; First Report on Project No. TB3-0226
DATE OF REPORT: 29 April 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the terminal ballistic performance of the 2.75-inch FFAR and 8-cm Oerlikon rockets when fired from an airplane at a

stationary Tank T26E4
METHOD: Two tanks were stationed in front of a concrete wall. An Airplane F84 fired a total of 225 of the 2.75-inch and 192 of the 8-cm rockets at the targets. The tanks were inspected after each hit to determine damage.
DESCRIPTION: The test 2.75-inch FFAR rocket had a burnt velocity of 2350 fps and a burning time of 1.7 seconds. It measured 2.79 inches in diameter, had a length of 48 inches, and weighed 18.51 pounds. The rocket used solid fuel and had fins that folded within its diameter, which permitted the use of tubular launchers. The test 8-cm Oerlikon rocket had a burnt velocity of 2130 fps and a burning time of 0.92 seconds. It measured 3.19 inches in diameter, had a length of 26.5 inches, and weighed 20.05 pounds. The rocket also used solid fuel, but had a fixed fin which necessitated the use of launcher adapters. Both rockets used the impact-point-initiating-base type of fuze.
CONCLUSIONS: No significant difference in terminal damage, accuracy, or malfunctions was noted when comparing the results of the two rockets. The tank turret top components and engine compartment were extremely vulnerable to attack and it was recommended that corrective measures be taken to provide adequate protection for those areas. Fenders, stowage boxes, and suspension components provided good protection for the tank. It was recommended that: additional tests be conducted, and a fuze which would guarantee faster jet formation be used in conjunction with the rocket selected for military use.
GENERAL: This 147-page report contains 80 photographs illustrating the effect of rocket hits on the two tanks.

SUBJECT: Ballistics APG AD-P154
TITLE: Projectile Test Report
IDENTIFICATION: Report AD-P154; Project No. 2832
DATE OF REPORT: 13 February 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic suitability of various types of 37mm APC M51 Projectiles
METHOD: Several types of experimental and standard 37mm projectiles were fired at 1-1/2-inch face hardened armor at 20° from normal to obtain the Army and Navy ballistic limits of the projectiles. A comparison was made of the penetrating ability of experimental, standard, and "work lot" 37mm projectiles fired at 1-1/2-inch face hardened armor at 20°, 30°, 40°, 45°, and 50° obliquity. Firing tests were also conducted on 2-1/2-inch homogeneous armor at 0° and 20° obliquity in an attempt to determine the critical velocity at which the experimental, standard, and "work lot" 37mm projectiles would shatter.
DESCRIPTION: The test projectiles consisted of 12 lots of Tokheim Oil Tank and Pump Co. projectiles; six lots of National Pneumatic Co. projectiles; W. F. and John Barnes standard projectiles consisting of bodies made from WD 4150 forgings equipped with WD 74100 steel caps; and Picatinny Arsenal standard "work lot" projectiles consisting of bodies made from WD 4150 bar stock equipped with WD 74100 steel caps. Various steels were used in the bodies and caps of the Tokheim and National Pneumatic projectiles. Various nose and armor-piercing cap designs were incorporated in the projectiles.
CONCLUSIONS: The Tokheim projectiles were, in general, more ballistically suitable than the National Pneumatic, standard, or "work lot" projectiles. There was some indication that caps made with WD 74100 steel were superior to caps made with WD 52100 and WD 4170 steels used in some of the Tokheim and National Pneumatic projectiles. Because of the insufficient number of test projectiles available, it was recommended that this testing program be continued.
GENERAL: This 119-page report contains 12 pages of photographs and microphotographs of the projectiles.

SUBJECT: Ballistics APG AD-P160
TITLE: Projectile Test Report
IDENTIFICATION: Report No. AD-P160; Project No. 3182
DATE OF REPORT: 13 February 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To detemine the yaw effect of the windshield on the penetrative ability of APC projectiles against armor plate
METHOD: Firing tests were conducted with the three types of APC projectiles. Average yaw angle and Army and Navy ballistic limits were determined for each type of projectile equipped with and without windshields. The M62 Projectile was fired from weapons equipped with tubes containing rifling twists of 1 in 32 and 1 in 40. The M61 and M62 Projectiles were fired from weapons equipped with tubes containing rifling twists of 1 in 25 and 1 in 32, respectively.
DESCRIPTION: The ammunition tested included 75mm APC M61; 3-inch APC M62; and 90mm APC M82 projectiles equipped with and without windshields. The projectiles were inert loaded with barium sulphate, red lead oxide, and paraffine. Cavities of the M61 and M62 Projectiles were closed with the (empty) BD Fuze M66A1, and the cavities of the M82 Projectiles were closed with the BD Fuze M68 body.
CONCLUSIONS: The average yaw of the M62 Projectile equipped with windshield and fired at low velocities from a gun tube with rifling of one twist in 40 inches was excessive as compared with the same type of projectile without a windshield fired under similar conditions. The yaw characteristics of the M62 Projectiles equipped with windshields were improved when the projectiles were fired from a gun tube with rifling of one twist in 32 inches. Average yaw characteristics of M61 and M82 Projectiles equipped with and without windshields were satisfactory. It was recommended that future tests of M62 Projectiles be made without windshields from a gun tube with rifling twists of 1 in 32 (76mm M1E6); and that the gun be set at the shortest practical range to permit minimum missile yaw.
GENERAL: This 44-page report is not illustrated.

SUBJECT: Ballistics APG Ar-19268
TITLE: Effectiveness of 90-mm HEP-T Shell T142E3 Against 2 and 4-inch Rolled Homogeneous Armor Plate
IDENTIFICATION: Report No. Ar-19268; Project No. TB3-1224B
DATE OF REPORT: 9 December 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of 90mm HEP-T Projectiles T142E3 against 2 and 4-inch rolled homogeneous armor plate
METHOD: Targets were set up consisting of 2-inch and 4-inch armor plates, backed either by two 1/8-inch mild steel witness plates or by single pieces of chipboard. Approximately 75 rounds of the test ammunition were fired against these targets at various striking velocities and obliquities to determine the obliquity within which spalling occurred and the behind-the-plate damage resulting from these spalls. The spalled fragments were weighed, and the sizes of the impressions on the face of the plates and on the back of the plates were recorded.
DESCRIPTION: The test ammunition consisted of 90mm HEP-T Shells T142E3 loaded with Composition A3 Explosive Filler, and used with BD Fuzes, M1 Propellant, T70 and T88E1 Percussion Primers, and T24 Cartridge Cases. The target materials included four 2-inch and seven 4-inch rolled homogeneous steel armor plates.
CONCLUSIONS: The T142E3 Projectiles caused the 4-inch armor to spall at obliquities from 45 to 70 degrees at ranges of 500 to 1200 yards. The 2-inch armor plate spalled at obliquities from 0 to 70 degrees at ranges over 1200 yards. The spalls in most cases were of uniform size and produced about the same amount of damage on the witness plates.
GENERAL: This 60-page report includes firing records and 19 photographs of the test setup and damaged plates.

SUBJECT: Ballistics BRL 1/1
TITLE: The Shaped Charge Journal
IDENTIFICATION: BRL Volume 1
DATE OF REPORT: July 1954
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To present a comprehensive summary of all recent research activities devoted to the development of and defense against shaped charges
METHOD: Information pertaining to the latest shaped charge development and shaped charge defense development was gathered from various research centers throughout the U.S. This information consisted of the following types of studies: methods of improving the ballistic penetration characteristics of the shaped charge; effect of shaped charges on fuel ignition; and methods of defeating the shaped charge. Studies dealing with the medical aspects of fragmentation and a proposed method of determining the effect of shaped charge impacts on personnel under various conditions were also included in the accumulated information.
DESCRIPTION: The publication was the first of a series of journals proposed for use in orienting all research personnel on the latest information pertaining to the development of shaped charges, as well as methods of defeating the shaped charge. Shaped charge information was obtained in the form of papers presented at a committee meeting, as summaries of development work and tests and as letters to the editor of the journal.
CONCLUSIONS: The information obtained with reference to the development of and defense against shaped charges revealed the necessity of continuing work in both phases of study. Quarterly summaries of progress or status of the primary research programs revealed some of the avenues of study that were exhausted and other avenues that were to be investigated.
GENERAL: This 201-page report contains numerous radiographs showing the appearance of shaped charge jets developed as a result of shaped charge detonations. Other illustrations and information outlining an IBM card index system used to assist in rapidly obtaining information dealing with various types of shaped charge studies are also included.

SUBJECT: Ballistics BRL 592
TITLE: Body Nose Shapes for Obtaining High Static Stability
IDENTIFICATION: Memorandum Report No. 592
DATE OF REPORT: February 1952
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To develop high static stability nose shapes for shaped-charge projectiles
METHOD: Various types of nose shapes were designed. Considered in the designs were the center of gravity, center of pressure, amount of lift, standoff distances, drag, and amount of spin. Full scale models were constructed and tested in a wind tunnel at Mach number 1.7. Various attack angles were used in the wind tunnel tests. Schlieren pictures were made of the test projectiles while in the wind tunnel.
DESCRIPTION: The projectile caliber was 105mm. The projectile requirements called for a dispersion angle of less than .5 mils at 1000 yards, easy mass production, penetration of 12 inches of armor, a low rate of spin, and a stability factor of 1-1/4 to 1-3/4.
CONCLUSIONS: Designs were developed that placed the center of pressure farther to the rear of the projectile, improving the stability. Drag on the projectiles increased with the movement of the center of pressure to the rear.
GENERAL: This report contains 54 pages including photographs and curve sheets.

SUBJECT: Ballistics BRL 716
TITLE: An Evaluation of the Terminal Effectiveness of the 2.75-in. FFAR and 8-cm Oerlikon HEAT Rockets Against a U.S. Medium Tank
IDENTIFICATION: Report No. 716; Projects No. TB3-1224B and TB3-0226A
DATE OF REPORT: August 1953
ORIGIN: Ballistics Research Laboratory, Aber-

deen Proving Ground, Maryland
PURPOSE: To determine effectiveness of two test rockets and the ballistic vulnerability of the M47 Tank
METHOD: Two T26E4 Tanks were placed near the target center and attacked by a F84E fighter plane in a 30° dive. Seventy-one hits were achieved out of 408 rounds fired. The projectiles included 2.75-inch FFAR and 8-cm Oerlikon HEAT rockets. Damage resulting from each hit was assessed in detail. Study of vulnerable areas was made based on accumulated data to determine the terminal ballistic behavior of the two types of rockets against the M47 Tank. Determinations were made of required repair time, armor penetrating properties of the rockets, and personnel injury potential resulting from crew compartment perforations.
DESCRIPTION: The M47 Tank was used for the vulnerability calculations rather than the test T26E4 Tank because the M47 was more representative of modern U.S. tanks. The test tanks were combat equipped and included inert ammunition and wooden crew members. The 2.75-inch FFAR and 8-cm Oerlikon HEAT rockets weighed 18.5 and 20.6 pounds and were 48.3 and 38.6 inches long, respectively.
CONCLUSIONS: There was no significant difference in the armor penetrating ability of the two types of rockets. The probability of perforation of a random hit on the tank averaged 0.38 percent for both rockets and was considered reasonably adequate. Damage after penetration was similar for both rockets and had average probability of a kill of 0.18 percent. The probability of a hit being a kill at the rear of the tank was the greatest of all types of kills. The probability of a shot however, being a kill was greater for attack against the sides because of the greater presented area.
GENERAL: This 51-page report includes complete test and vulnerability data and 16 photographs showing damage resulting from firing.

SUBJECT: Ballistics BRL 800
TITLE: Methods of Computing the Effectiveness of Fragmentation Weapons Against Targets on the Ground
IDENTIFICATION: Report No. 800; Project No. TB3-0112
DATE OF REPORT: January 1952
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of fragmentation type weapons against ground targets
METHOD: Analytical methods were derived for use in determining the lethal areas, single shot probabilities of kill, and area coverage capability of various types of fragmentation type weapons.
DESCRIPTION: Artillery shells, rockets, and guided missiles with fragmentation type warheads were considered in the study.
CONCLUSIONS: Over-all effectiveness of fragmentation type weapons depended upon the following: weight of the weapon; number, size, and initial velocity of fragments that resulted after weapon detonation; degree of protection offered a target by natural terrain conditions or foxholes; presented area of each target; accuracy of aim of the weapon, etc. Equations were developed to show how the influence of these quantities on over-all effectiveness of fragmentation type weapons could be determined.
GENERAL: This 123-page report contains several graphs showing the results of the study.

SUBJECT: Ballistics BRL 905
TITLE: Critical Review of Shaped Charge Information
IDENTIFICATION: Report No. 905; Project No. TB3-0134
DATE OF REPORT: May 1954
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To present a comprehensive summary of all previous research activities devoted to the development of the shaped charge; and to summarize all research activities devoted to defeating shaped charges
METHOD: Information necessary to summarize all research activities devoted to developing and defeating shaped charges was obtained from the authorities of several different research laboratories and universities. Information gathered included: an historical resume of all research conducted on shaped charges; a theoretical analysis of shaped charge ballistic impact performance; studies on shaped charge liner performance, projectile body ballistic flight performance, performance of fuzes used in shaped charges, effect of projectile spin on shaped charge jets, and methods of compensating projectile spin; methods of defeating the shaped charge projectiles; and a study of the terminal ballistic effectiveness of shaped charges against tanks. In addition, statistics were compiled for all American shaped charge projectiles.
DESCRIPTION: Organizations submitting information relative to spaced charges included: Naval Ordnance Laboratory; Harvard University; Carnegie Institute of Technology; Ballistic Research Laboratories; National Bureau of Standards; Watson Scientific Computing Laboratory; and Firestone Tire and Rubber Company.
CONCLUSIONS: Numerous new fields of study in improving the ballistic performance of shaped charges were revealed as a result of compiling the information presented in the review. It was also revealed that major advances were being made on methods of defeating shaped charges.
GENERAL: This 348-page report contains numerous radiographs showing the appearance of shaped charge jets developed as a result of shaped charge detonations. A number of illustrations of various U.S. shaped charges are also included.

SUBJECT: Ballistics BRL TN-396
TITLE: Penetration of Shaped Charges into Sand, Gravel, and Other Aggregates: A Survey of Data Available at Aberdeen Proving Ground
IDENTIFICATION: Report No. 396; Project No. TB3-1224B
DATE OF REPORT: March 1951

ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To present information on the ability of shaped charges to penetrate various aggregates
METHOD: A survey was made of data available at the Proving Ground regarding the ability of shaped charges to penetrate various aggregates. Searches were made of D & PS firing records, APG library documents, file cards, and many records and reports. To supplement the data contained in this literature, test was conducted by detonating five rounds of the 3.5-inch HEAT rocket against a steel plate and sand target at a 60° obliquity.
DESCRIPTION: The relevant material obtained in the literature survey was drawn primarily from nine reports which were abstracted in the present report. The target used in the supplementary test consisted of a laminate of steel plates over 3 inches thick, covered with a 6-inch layer of damp sand, the combination being held together by a 1/2-inch cover plate.
CONCLUSIONS: Very little pertinent data were found in the literature survey. The data obtained indicated that the materials tested were useable but were not outstanding for the purposes intended and were inferior to the related material, HCR-2, on both a weight and a thickness basis. The data indicated that HCR (hollow charge resistant) armor, which consisted of a variety of concretious materials in which pieces of aggregates were cemented together, gave a performance superior to non-concretious materials. It was suggested that additional tests of natural aggregates with shaped charges be conducted.
GENERAL: This seven-page report is not illustrated.

SUBJECT: Ballistics OCO TB3-1224(2)
TITLE: Effectiveness of the Fire from Tank-Mounted Weapons Part II — Estimates of Weapon Effectiveness
IDENTIFICATION: Report No. OCO TB3-1224(2); Project No. 5B0304004
DATE OF REPORT: 7 October 1954
ORIGIN: Ordnance Department, Research and Development Division, Department of the Army
PURPOSE: To determine the fragmentation properties of tank high-explosive shell fire from shell design parameters, and to evaluate the effects of direct hits on targets by such shells
METHOD: A fragment damage study was made by using calculations simulating fire accuracy and shell burst pattern. All fire conditions were specified in terms of basic shell or weapon parameters converted to burst properties by use of fragmentation theories provided in Part I of the report. The effects of variations in such parameters as caliber, charge-to-weight ratio, explosive brisance, muzzle velocity, trajectory angular dispersion, and method of estimating the range on simulated standard personnel targets of variable range and inclination were calculated. The calculations made use of extensive sampling of simulated salvos using adjusted fire. This report was compiled by the Battelle Memorial Institute.
DESCRIPTION: The subjects covered in this report included accuracy of tank gunnery, shell-fragment effects deduced from simulated salvos, analytical methods of computing lethal areas, direct hits by HE tank fire, and some remarks on models for evaluation of HE fire from tanks.
CONCLUSIONS: It was found that the lethality of shell bursts could be factored in terms of the separate influences of caliber, charge-to-weight ratio, brisance, muzzle velocity, and shape of burst pattern. Variations in salvo effectiveness seemed related to an exponential function of lethality, having a coefficient that was a measure of the efficiency of use of the lethality under the prescribed conditions of fire. The factors controlling accuracy, or the use coefficient, seemed to be more important than the factors controlling lethality itself. Under certain simplifying assumptions, it was possible to derive an algebraic expression for a lethal area in terms of the fragmentary properties of a shell. In the study on the effect of direct shell hits, it was suggested that certain experiments be performed which included some determinations of the kinds of lethal spray that were produced. Further studies were recommended in all the phases covered by this report.
GENERAL: This 190-page report includes one page of photographs, nine pages of graphs, 20 pages of tables, six pages of reference sources, and various calculations throughout the report.

SUBJECT: Ballistics WAL 762/523-3(C)
TITLE: Non-Metallic Projectile Carriers — Part 4: Discarding Projectile Carriers as Sabots for Launching Flechettes
IDENTIFICATION: Report No. WAL 762/523-3(C); Project No. TA1-5003
DATE OF REPORT: 15 October 1953
ORIGIN: Watertown Arsenal, Massachusetts
PURPOSE: To determine the suitability of discarding-type flechette carriers
METHOD: Four types of flechette carriers were loaded with standard flechettes and launched from a modified Springfield Armory caliber 0.27 smooth-bored and hand-lapped barrel by means of Hercules Unique and IMR No. 4759 propellants. The primary and secondary free flight velocities of the flechettes were measured with Potter-type 400-KC Counter Chronographs. The down range and terminal ballistic performance of the flechettes were evaluated by means of pine board targets and shellacked Kraft paper witness targets. The aerodynamic behavior of the flechettes was analyzed by means of spark photography. The performance of the flechettes as determined by these tests was used to indicate the suitability of the various types of carriers.
DESCRIPTION: The test carriers consisted of WAL-Type Discarding Projectile Carriers prepared from extruded rods of methyl methacrylate (lucite). The design of these carriers varied in regard to cavity shape. The bases of the carriers were covered with cellulose tape to improve the reproducibility of test results.
CONCLUSIONS: Three of the four types of test

carriers were considered suitable for launching flechettes and for experimental and developmental evaluation of flechettes or similar missile types used as potential fillers for multi-missile (canister) type ammunition. It was recommended that a broader testing program be undertaken, covering injection-molded carriers, measurements of linear velocity losses in flight, effect of atmospheric conditions, flechette design and packing modifications, and more comprehensive shadowgraph picture studies.

GENERAL: This 28-page report contains six pages of test data and nine pages of photographs showing the flecheites and carriers in flight.

TANK AUTOMOTIVE TEST RESUMES

SUBJECT: Bulldozer Blades AB 523
TITLE: Final Report on Test of Bulldozers for Medium Tanks
IDENTIFICATION: Final Report on Project No. 523
DATE OF REPORT: 17 March 1944
ORIGIN: Armored Board, Fort Knox, Kentucky
PURPOSE: To determine the suitability of La-Plant-Choate bulldozer blades mounted as special equipment on Medium Tanks M4
METHOD: Two medium tanks, an M4A1 and an M4A3, were equipped with the units and tested by performing a series of bulldozer operations. These operations included clearing antitank obstacles, trees and mine fields, and filling soft spots and bridge approaches.
DESCRIPTION: The test bulldozer units, manufactured by the LaPlant-Choate Mfg. Company, were 124 inches wide and weighed 8800 pounds. The blade trunnion supports were secured to the first and second suspension units on each side, and a hydraulic jack, controlling the blade position, was mounted on the front of the tank. The bow machine guns were removed to provide passage for the hydraulic lines in the installation. These hydraulic lines would pass through the right headlight socket in production vehicles.
CONCLUSIONS: Operation of the "tankdozer" was generally satisfactory, with the exception of the mine-clearance test. The additional weight of the unit imposed an excessive load on the front suspension unit and necessitated road speeds too low for satisfactory strategic moves. Consideration was given to transportation of this vehicle with the Tank Transporter M19 and, as an alternative, a trailer was under development with which the bulldozer blade could be towed by the tank itself. The Tank M4A1 due to the poor lugging ability of the Wright-Continental radial engine, was considered inadequate for bulldozer operation. Due to the design of the attaching parts the bulldozer assembly would fit only the current M4 Tanks with vertical volute spring suspension and narrow tracks.
GENERAL: This 33-page report contains 15 photographs of the bulldozer equipment and its installation.

SUBJECT: Castings FA R-945
TITLE: Precision Investment Casting of Experimental Aluminum Tail Fin for 90mm Heat Projectile
IDENTIFICATION: Report No. 945
DATE OF REPORT: November 1949
ORIGIN: Frankford Arsenal, Philadelphia, Pa.
PURPOSE: To cast, by the precision investment process, aluminum tail fins for the experimental 90mm HEAT projectile
METHOD: The problem of making the complex patterns of this component was solved by assembling the final pattern from a number of separate sub-patterns.

DESCRIPTION: The subject items were a small experimental lot of tail fins for the experimental 90mm HEAT projectile.
CONCLUSIONS: The assembly of a complex wax pattern from a number of sub-patterns has been shown to be economical for the tail fin components and to be satisfactory in so far as meeting dimensional tolerance requirements. The mechanical properties of heat treated ALCO 356 alloy tail fin castings were comparable with the properties associated with sand cast test bars.
GENERAL: This 16-page report includes five photographs of the subject items.

TANK AUTOMOTIVE TEST RESUMES

APG TT2-604/1

SUBJECT: Fire Fighting Equipment and Fire Prevention

TITLE: Fire Fighting Equipment for Combat Vehicle

IDENTIFICATION: First Report on Project No. TT2-604; APG 248-8

DATE OF REPORT: 22 June 1944

ORIGIN: Aberdeen Proving Ground, Maryland

PURPOSE: To determine methods for reducing the fire hazard offered by ammunition exposed to small caliber projectile impacts

METHOD: One hundred and sixty-five 90mm powder cases, containing various propellants, were fired upon by a cal. .30 machine gun to study impact reaction.

DESCRIPTION: The test 90mm standard shell cases used nitrocellulose, nitroguanidine, or dummy propellants, and inert, live, or aluminum foil-lined primers. The 90mm shells were selected for the test because they represented the greatest concentrated hazard in standard tank ammunition.

CONCLUSIONS: Current large caliber tank ammunition could not be made hazard or explosion proof when struck by high velocity ammunition. The tests indicated that nitroguanidine propellant was not as readily ignited as nitrocellulose. Nitroguanidine, when not ignited or exploded, tended to smolder and produced smoke. When actually penetrated by a cal. .30 AP round, the nitroguanidine propellant exploded less violently than the nitrocellulose type. It was recommended that nitroguanidine be used as a replacement for nitrocellulose to reduce the fire and explosion hazards. It was also recommended that the ammunition be stowed with the projectile ends pointing in the most vulnerable direction, that shell case crimping be reduced to the minimum requirement, and that the primer be prevented from functioning except by a direct hit.

GENERAL: This 71-page report contains 40 photographs showing the results of shell cases subjected to cal. .30 impacts.

TANK AUTOMOTIVE TEST RESUMES

APG TR3-3046/1

SUBJECT: Firing Mechanisms
TITLE: Devlopment Test of Electric Firing Mechanisms for Guns, 120mm, T123E1 Type
IDENTIFICATION: First Report on Project No. TR3-3046
DATE OF REPORT: July 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine which of three types of electric firing mechanisms would be most suitable for use with 120mm, T123E1, type guns
METHOD: The test firing mechanisms were used in limited proof firing tests on a proof facility 120mm T123E1 gun. Firing tests using each mechanism were conducted at both ambient and -40° F temperatures.
DESCRIPTION: Test electric firing mechanisms included: a solenoid-type, No. 7306641; a wiping contact-type, Drawing No. WEV-D-1430 and D-1429; and a mechanical retract-type, Drawing No. WTV-D-1484, F-1485, and F-1496. The solenoid-type incorporated a solenoid operated firing plunger; in the wiping contact-type, a spring held the firing pin in contact with the primer when the breech was closed; and in the mechanical retract-type the firing pin was mechanically retracted before the breech block was dropped. The firing circuits of the three types were similar, except that additional power was required to actuate the solenoid of that type.
CONCLUSIONS: Results indicated that the design and functioning of all three test mechanisms were satisfactory. However, the wiping contact mechanism was considered superior in that it did not have a moving firing pin, required less power than the solenoid-type, and was of simpler construction. It was recommended that the wiping contact mechanism be considered satisfactory for standardization for use on the 120mm gun T123E1 when combination electric percussion primers were used with the weapon; and that the retainer spring used in the mechanical retract mechanism be redesigned if this mechanism was to be considered for use.
GENERAL: This 59-page report contains four photographs showing the components of the test firing mechanisms. Drawings of mechanism components are also included.

TANK AUTOMOTIVE TEST RESUMES

SUBJECT: Flame Throwers APG TT2-570/1
TITLE: Installation of Stowage in Three Pilots of Tanks, Flame Thrower, T33
IDENTIFICATION: First Report on Project No. TT2-570
DATE OF REPORT: 13 December 1948
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To report on the stowage provisions and other modifications necessary to accommodate a flame thrower in the T33 tank; to determine the suitability of the flame thrower fuel and air bottles for low temperature operation
METHOD: The stowage preparations and required revisions were completed on a pilot model tank, flame thrower, T33. The maximum pressures allowable on the flame thrower fuel and air bottles at -70°F were determined by hydrostatic pressure tests, using trichloroethylene as the pressurizing medium. Firing tests were also conducted to evaluate the functional performance of the flame thrower and associated equipment.
DESCRIPTION: The T33 flame thrower tank was essentially a medium tank, M4A3E2 with the hull, turret, and turret basket modified to accommodate an E20 mechanized flame thrower and gun, E20 fuel and pressure units, and E12R4 periscope flame gun, and associated equipment. The E20 flame gun and a 75mm gun projected through separate turret front shields, and the E12R4 flame gun was mounted in a vision cupola in the rear turret roof.
CONCLUSIONS: The functional performance of the flame thrower system was considered satisfactory. However, installation arrangement and the excessive bulk of the flame thrower equipment resulted in a difficult stowage arrangement, decreased fighting efficiency of the crew compartment. At -70°F, the fuel and air bottles were capable of withstanding pressures much higher than their normal operating pressures. It was recommended that the vehicles be regarded as unsatisfactory relative to the stowage installation and the crew compartment fighting efficiency; that the fuel and air bottles be considered adequate for use at their normal operating pressures under extreme low temperature conditions; and that further testing be conducted on the flame thrower equipment alone, to determine its adequacy for proper functioning under varied climatic conditions, and its adaptability for installation in other vehicles.
GENERAL: This 107-page report includes 12 photographs of the test flame thrower tank. A complete list of items for stowage and O.V.M. equipment, and sketches and drawings of various modifications necessary for stowage preparation are also included.

TANK AUTOMOTIVE TEST RESUMES

SUBJECT: Fuel Tanks APG Ar-18617
TITLE: Vulnerability of Tank-Stowed Diesel Fuel to Attack by 90-mm T108E15 Ammunition
IDENTIFICATION: Report No. Ar-18617; Project No. TB3-1224B
DATE OF REPORT: 21 August 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability to ballistic attack of diesel fuel stored in powder cans
METHOD: Six powder cans were half filled and one completely filled with diesel fuel. Six of the containers were placed in inverted tank turrets and one in the driver's compartment of a tank hull. One round of 90mm Cartridge T108E15 HEAT-FS was fired at each target to penetrate the turret or hull wall at zero obliquity at a range of 50 yards and strike the fuel container.
DESCRIPTION: The seven powder cans, simulating fuel tanks mounted in a tank, were 24-1/2 x 16-1/4 x 9-5/8 inches in size and had a capacity of approximately 16 gallons. The tanks consisted of one previously damaged T26E4 Tank and two previously damaged T26E4 Tank turrets.
CONCLUSIONS: All seven rounds fired caused flash fires. The powder cans were unable to withstand the pressure of the penetrating jet even after it had pierced the 3-inch hull or turret armor. The most severe damage occurred when the hits were below the fuel level.
GENERAL: This seven-page report includes four photographs of the powder cans showing ballistic damage.

SUBJECT: Fuel Tanks APG Ar-18707
TITLE: Obtaining Information on Vulnerability of Diesel Fuel Tanks in Soviet T34/85 Tank when Attacked by U.S. 57mm Projectiles
IDENTIFICATION: Report No. Ar-18707; Project No. TB3-1224B
DATE OF REPORT: 9 June 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of U. S.S.R. diesel fuel tanks to 57mm projectiles
METHOD: A lubricating oil tank and two fuel tanks were filled one-half full and wedged in place behind the sponson plate of a Soviet T34/85 Tank. The tanks were located from two to three inches behind the sponson plate. Six rounds of 57mm AP-T, M70 Projectiles and three rounds of 57mm APC-T, M86 Projectiles were fired at the sponson plate.
DESCRIPTION: The tanks tested consisted of one 17-1/2-gallon lubricating oil tank and two 16-gallon fighting compartment lower fuel tanks.
CONCLUSIONS: Seven rounds penetrated the plate and tanks. Two small fires resulted from AP-T projectiles which entered the tanks at fuel level heights. The first fire was put out readily. The second fire spread onto fuel that had been splashed about by a previous round and became intense in about 60 to 90 seconds. It was indicated that the low percentage of fires started was due to the fact that the mass and velocity of 57mm projectiles was too low.
GENERAL: This two-page report contains a description of the test observations.

TANK AUTOMOTIVE TEST RESUMES

SUBJECT: Instruments AFF 2-18-49(IX-9)
TITLE: Navigational Aids for Armored Vehicles
IDENTIFICATION: Report No. AFF2-18-49(IX-()
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To determine the adequacy of the development of navigational aids for armored vehicles
METHOD: A review was made of the requirement for new and improved types of navigational aids for use with armor as established by the War Department Equipment Board Report. A study was made of the types of compasses, odographs, chronometers and electronic devices including their performance under various conditions, their deficiencies, limitations and new developments. A study was also made of tactical and stowage considerations and radio security of the navigational systems.
DESCRIPTION: The basic requirement for vehicular navigation included a completely compensating vehicular compass, a precise odometer, and a map of the area to be traversed. The three basic types of compasses were magnetic, sun, and gyroscopic. The land odograph was an instrument which continually indicated the position of the moving vehicle. The chronometer was a precision portable timekeeper. The test electronic systems included those designated as LORAN, SHORAN and DECCA.
CONCLUSIONS: The development program for conventional and electronic engineer navigational aids was adequate. However, the development of electronic aids was limited by existing techniques and the need of minaturized components. It was recommended that a conference be held between using arms and development agencies to evaluate the tactical considerations of the navigational aids. Deficiencies were found in all types of compasses, and a universal sun compass was being developed which could be used in all latitudes and a gyrocompass which would be unaffected by magnetic and electrical fields.
GENERAL: This five-page report is not illustrated and is contained with Report No. AFF 2-18-49.

TANK AUTOMOTIVE TEST RESUMES

SUBJECT: Lamps and Lights AB 288
TITLE: Test of Medium Tank M4A1E2
IDENTIFICATION: Project No. 288
DATE OF REPORT: 6 May 1943
ORIGIN: The Armored Force Board, Fort Knox, Kentucky
PURPOSE: To determine the suitability of infra-red equipment as a night driving aid
METHOD: Infra-red headlighting equipment was installed on the following vehicles: Medium Tank M4A1E2, 1/4-ton truck with NDRC equipment, 1/4-ton truck with British equipment. Two infra-red searchlights were installed on a 2-1/2-ton Amphibian Truck DUKW. Infra-red marker lights, marker buttons, and flashing identification lights were also tested.
DESCRIPTION: Infra-red sources developed by NDRC for driving consisted of headlights and spotlights which were 450 and 600 watt sealed-beam units, mounted in standard headlamp shells with modified rims for special glass filters. Searchlights employed a 3000-watt incandescent white light bulb positioned at the focus of a 36-inch reflector which was contained in a Crouse-Hinds housing for a special glass filter. Driving and searchlight equipment required 1500 to 6000 watts of electric power which was supplied by auxiliary engine-generator units. Self-contained infra-red emitting marker lights consisted of a white light source of moderate power (5 to 6 watts), a filter glass, and dry cell batteries, all contained in a 6 x 6 x 8-inch metal case. Infra-red marker buttons were metal discs approximately three inches in diameter, painted with a material having a high reflectivity of incident infra-red light and practically no reflectivity of ordinary light. Monocular and binocular electronic image tubes were used to make the infra-red flashing identification lights visible to the human eye.
CONCLUSIONS: The headlighting equipment was not considered suitable for combat vehicles. The searchlight equipment was not considered satisfactory because of its limited range and field of illumination. Although the marker buttons were found satisfactory for route marking, they were not considered sufficiently superior to other less complicated means already available to justify their use. Flashing infra-red emitting sources arranged to flash code letters could be used for identification, but were not considered suitable for use due to the complexity and quantity of necessary equipment. Monocular and binocular image tubes were found suitable for observing the various types of infra-red emitting sources. It was recommended that a small quantity of portable viewing units be procured and held in a pool available for use in any theater of operation in which the enemy was suspected of using infra-red lighting equipment.
GENERAL: This 17-page report contains 10 photographs of the vehicles and a three page discussion of infra-red equipment including the British.

SUBJECT: Lamps and Lights AFF 2-18-49(IX-7)
TITLE: Infrared Devices
IDENTIFICATION: Report No. AFF 2-18-49(IX-7)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To determine the adequacy of infra-red research
METHOD: Review and analysis was made of the requirements, limitations, developments, and expectations of infrared systems. Infrared development had been conducted along such functional lines as area observations, night driving, and surveying. A study was made of infrared developments with binoculars using a new image tube, and an invisible light viewing device for night tank operation, a light-weight detector-viewer for detecting infrared souces and infrared surveying equipment and of other projects for developing infrared range finders, beacons, camouflage screen, elimination of infrared heat radiation, and flashbulbs, and camera.
DESCRIPTION: The two types of infrared radiation were "near" infrared and "far" infrared. Near infrared devices required a special source of near infrared radiation which was reflected from the object and converted to a visible image. Far infrared systems used only the heat radiation from the object and did not require an auxiliary source.
CONCLUSIONS: The development program was adequate for fulfilling the requirements of the War Department Equipment Board Report. It was expected that infrared devices would eventually revolutionize the concepts of armored night combat operation. Development of these devices would allow tanks to be driven at greater speeds and tank guns to be fired with fair accuracy at night. Further accomplishments with infrared would be dependent on research.
GENERAL: This five-page report is not illustrated and is contained with Report No. AFF 2-18-49.

SUBJECT: Lamps and Lights APG 5568/7
TITLE: Preparation of Medium Tank M4 for Desert Maneuvers
IDENTIFICATION: Seventh Report on Project No. 5568; APG 10-88
DATE OF REPORT: 16 September 1942
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate special infra-red equipment installed on a Medium Tank M4A1
METHOD: The tank was equipped with infra-red lighting equipment, a recording odograph, infra-red reflecting exterior paint, sand shields, and ultra-violet instrument panel lighting equipment. The vehicle was then operated over desert terrain.
DESCRIPTION: The infra-red lighting equipment was for vehicle operation in total darkness and consisted of five airplane landing lights with infra-red filters and four electronic periscopes. The recording odograph provided a means for mapping the vehicle course automatically and continuously, and consisted of a magnetic compass and electrically operated turntable connected to a speedometer drive cable. The infra-red paint was applied to the exterior of the tank to reduce inside temperatures by reflecting a maximum amount of the sun's radiation. The ultra-violet instrument panel lighting

was used in an attempt to reduce illumination and still permit reading of instruments.

CONCLUSIONS: The vehicle could be driven over average smooth terrain at speeds from 15 to 20 mph by means of infra-red lighting in total darkness. The recording odograph operated properly and represented a well developed stage of design. The ultra-violet instrument panel lighting was an aid in night driving with visible or infra-red lighting. It was recommended that further development on infra-red viewing devices and light sources be done to improve sensitivity and ruggedness; that further recording odograph development work be concerned with permitting more accurate compass needle compensation; that further development be directed toward providing a more satisfactory ultra-violet instrument panel; that no consideration be given to the use of infra-red reflecting paint; and that sand shields be used on all vehicles for desert operation.

GENERAL: This 84-page report includes 11 photographs of test equipment.

AFF 2-18-49(IX-2)
SUBJECT: Mines and Mine Detection
TITLE: Mine Clearing
IDENTIFICATION: Report No. AFF 2-18-49(IX-2)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To review existing policies and military characteristics of armored equipment for mine clearing
METHOD: The basic policy of equipment requirements and development as stated in War Department Equipment Board and Armored Conference reports was reviewed and summarized. The military characteristics of the equipment was summarized and included the required operating characteristics of mine detecting devices and mechanical and explosive mine eradication equipment. The progress in development of mine detection, detonation or neutralization of metallic and non-metallic mines was reviewed.
DESCRIPTION: The intended purposes of the mine detecting devices was to be able to locate all antivehicular, antipersonnel, and antitank metallic and non-metallic mines in the path of the tank. It was also intended that the device could be readily attached to the tank and automatically stop the tank upon approach to a mine. It was intended that mine eradication equipment be capable of destroying or neutralizing all land mines encountered.
CONCLUSIONS: Established military characteristics of mine equipment were sound. There was a requirement for a mechanism to be used with tanks within armored units which would detect and remove or detonate land mines. Present mechanical methods of mine removal were not satisfactory. Progress in development of a metallic mine detection device was satisfactory but development of a non-metallic mine detection and a mechanical means for mine removal or detonation were not satisfactory. It was recommended that development in all these fields be continued.
GENERAL: This four-page report is not illustrated and is contained with Report No. AFF 2-18-49.

APG 5688/57
SUBJECT: Mines and Mine Detection
TITLE: First Report on Mines, Anti-Personnel Protection for Combat Vehicles
IDENTIFICATION: Fifty-seventh Report on Ordnance Program No. 5688; APG 236-18
DATE OF REPORT: 10 October 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To develop suitable antipersonnel mine protection for medium tanks
METHOD: Various types of mounting brackets were designed to fasten the antipersonnel mines to the sides, front, and top of the tank. Several types of electrical firing circuits were designed for detonating the mines. Splash cards were placed on the tank and the mines were detonated. Effect of the mines on external components of the tank was checked and the effect of .30 caliber ammunition on the mounted mines was also determined.
DESCRIPTION: The mines used were of the M2 series antipersonnel mines. They consisted of a modified 60mm mortar projectile inside a tube. An explosive charge at the base of the tube propelled the projectile 6 feet, at which time it exploded.
CONCLUSIONS: The mines were not completely satisfactory for the intended use, but were considered the most satisfactory means available at the time. The antiaircraft machine gun, periscopes, and radio antenna were vulnerable to fragments from the mines. The design of the time delay fuze and the charge of the mine required improvement.
GENERAL: This report contains 55 pages and 22 photographs.

APG 5691/3
SUBJECT: Mines and Mine Detection
TITLE: First Report on Test of Medium Tank Mine Exploder Unit T3
IDENTIFICATION: Third Report on Ordnance Program No. 5691
DATE OF REPORT: 17 April 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of the mine exploder T3 in cleaning a path through a mine field
METHOD: The mine exploder T3 was installed on the front of a medium tank M4 and operated through a field sowed with antitank mines. The American practice mines M1B1 were buried with the body flush and the spider projecting from the ground, whereas all foreign antitank mines were buried 2 to 4 inches below the ground. Various experimental combinations of the number and position of chain assemblies, speed and direction of rotor, the hydraulic equipment, the projecting boom, etc., were conducted. Observations were made as to the ability of the T3 to withstand damage and the mobility and maneuverability of the medium tank M4 with the mine exploder T3 installed.
DESCRIPTION: The mine exploder T3 consisted of a rotor on the end of a 16-foot boom, projecting from the front of a medium tank M4. The original rotor had two sets of 13 flails; as modified the rotor was equipped with 24 flails or chain assemblies. An auxiliary engine mounted on the outside of the tank hull drove the rotor through a long drive shaft. The boom was elevated and depressed by a pair of hydraulic cylinders. All the hydraulic and auxiliary engine controls were within reach of the assistant driver. The total weight of the mine exploder was approximately 10,000 pounds.
CONCLUSIONS: The effectiveness of the T3 was considered mediocre in functioning American practice mines M1B1. The ability of the exploder to withstand damage from the mines was satisfactory. The mobility and maneuverability of the medium tank M4 were greatly reduced with the T3 installed. The following recommendations were made: that the weight be kept to a minimum; that means be provided for mounting the worm gear upright or inverted so that rotor direction could be changed in the field; stagger the chains; eliminate the hydraulic boom elevating system; provide armored cover for the auxiliary engine and cooling air openings in the armor; chain assembly should be of light weight and simple design.

GENERAL: This 76-page report includes 20 photographs of the various test components.

APG 5691/17

SUBJECT: Mines and Mine Detection
TITLE: First Report on Japanese Type 99 Magnetic Armor Piercing Mine
IDENTIFICATION: Seventeenth Report on Ordnance Program No. 5691
DATE OF REPORT: 30 August 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of a spiked steel plate as a countermeasure against the Japanese-type 99 magnetic armor piercing mine on horizontal surfaces
METHOD: Several spiked plates were constructed using different designs and fabricating methods. Five tests were conducted on a light tank M3A3 with spiked plates or discarded tracks placed over the engine compartment. The Japanese mine type 99 was placed on the spike plate or track in various positions and detonated. The extent of protection offered by the various designs was noted.
DESCRIPTION: The test vehicle was a light tank M3A3 with spike plates fabricated of mild steel, armored steel, straight and tapered spikes, and various combinations of drilled holes and welds. The mine used in the test was the Japanese-type 99 magnetic armor piercing mine.
CONCLUSIONS: The spiked plate and tapered pins of 1/2-inch mild steel was considered satisfactory protection on horizontal surfaces to the extent of preventing the Japanese-type 99 mine from immobilizing tanks. It was recommended that the spiked plates be fabricated of 1/2-inch armor or 1/2-inch mild steel and that the plates be drilled and spikes be inserted through the holes 1/2-inch to allow a space between the surface to be protected and the base of the spiked plate. Also that the spikes, tapered with a shoulder turned at the base, be heavily welded on top and bottom of the base plates. It was further recommended that a light tank be prepared with this protection on all horizontal surfaces and subjected to further tests.
GENERAL: This 17-page report includes 12 photographs of the test components.

APG 5691/19

SUBJECT: Mines and Mine Detection
TITLE: First Report on Test of Canadian Laminated Mine Exploder Rollers
IDENTIFICATION: Nineteenth Report on Ordnance Program No. 5691
DATE OF REPORT: 1 December 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the relative indestructibility and effectiveness of Canadian laminated mine exploder rollers
METHOD: The rollers, without being mounted in a complete exploder unit, were towed over various mines in different combinations and planted at varying depths. In each case, results were noted and recorded. Mines used in the test were Teller, M1A1 AT, and T6E1 AT. Two rollers were tested.
DESCRIPTION: The rollers, 28-1/4-inch diameter and 18 inches wide, weighing 3200 pounds each, consisted of nine 1-inch mild steel concentric cylinders, fitted over each other with 1/16-inch copper sheathing between the steel cylinders to absorb shock. The cylinders were built on a mild steel core, 9-inch diameter, that was mounted on a 4-inch shaft. The rollers were received from the Dominion Engineering Works, Montreal, Canada.
CONCLUSIONS: As a result of the tests, it was concluded that these rollers were relatively indestructible; but that towing the rollers without their being mounted in a complete exploder unit was not a conclusive means of testing their effectiveness. It was recommended that no further tests be performed on these rollers.
GENERAL: This 24-page report includes 17 photographs of the rollers and tests.

APG 5691/26

SUBJECT: Mines and Mine Detection
TITLE: First Report on Protector Plates, Defense Against Japanese Magnetic Anti-Tank Mines
IDENTIFICATION: Twenty-sixth Report on Ordnance Program No. 5691
DATE OF REPORT: 28 March 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of a spiked steel plate as a defense against the Japanese-type 99 magnetic armor piercing mine
METHOD: A light tank M3A3 was prepared with sufficient protector plates to cover the deck of the tank and the top of the turret. A metal skirt was constructed for the turret and the surface treated with an antimagnetic coating of Truscon No. 260. Trial casts were made at the tank with the Japanese mine and results in each case noted. Mines were then detonated at representative locations.
DESCRIPTION: The test vehicle was a light tank M3A3 with 1/2-inch thick mild steel protection plates. Tapered spikes were attached to the plate in rows 4-1/2 inches apart and 4-1/2 inches between spikes. The Japanese Type No. 99 magnetic armor-piercing mine was directional in character. Much of its effect could be obviated by a method that prevented the face of the mine from attaching itself parallel to the tank armor.
CONCLUSIONS: The results of the test indicate that it was impossible to protect all of the horizontal surfaces on the light tank M3A3 and that the initially protected area was decreased with each mine exploded. The weight of the complete protector plate installation was prohibitive and interfered with vision through the periscope. It was recommended that the spiked protection plates installation be considered impractical and that no further development be made on this specific type of antimagnetic mine protection.
GENERAL: This 38-page report includes ten pages of photographs of the test components.

APG 5691/27

SUBJECT: Mines and Mine Detection
TITLE: First Report on Effect of German Reigle Mines on Light, Medium, and Heavy Tanks
IDENTIFICATION: Twenty-seventh Report on Ordnance Program No. 5691
DATE OF REPORT: 29 May 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effect of German

Reigle mines on light, medium, and heavy tanks
METHOD: The vehicles used in the test were two light tanks, M5A1 and M24, weighing 34,000 and 38,000 pounds respectively; two M4 medium tanks weighing 68,000 pounds; and two T25E1 medium tanks weighted to 92,000 pounds to simulate the T26E1 heavy tank. The mines were positioned with 3 inches of soil between the top of the mine and the bottom of the track. One Reigle mine was placed on top of the other to determine the effect of double mines. The mines were placed under the right front bogie wheel of the vehicles and statically detonated. Double mines were used with the M4 and T25E1 tanks.
DESCRIPTION: The German Reigle mines consisted of a rectangular box, 31-1/2 x 3-3/4 x 3-1/2 inches, containing an 8.8-pound charge. The total weight of the mine was 20.5 pounds.
CONCLUSIONS: The tracks, suspensions, and escape hatches of the light, medium, and heavy tanks were not capable of withstanding the mine explosions. However, the floor plates of all of the vehicles except the light tank, M5, withstood the detonations.
GENERAL: This 43-page report contains 14 photographs showing the effects of the mines on the vehicles. Also included is a drawing illustrating the construction of the Reigle mines.

APG AD-1180
SUBJECT: Mines and Mine Detection
TITLE: Effectiveness of Mines, Antitank, T29, Against Tanks and Special Tank Components
IDENTIFICATION: Report No. AD-1180; First Report on OCO Project TA3-5917
DATE OF REPORT: 1 October 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of T29 Mines against American and foreign tanks and their components; to compare the performances of the T29 and T23E2 Mines
METHOD: Twenty-four T29 Mines were detonated against U.S. T32 and T26 Tanks, Soviet T34/85 Tanks with various thicknesses of floor plate, and against diesel fuel and live ammunition stowed in tank hulls. Four T23E2 Mines were detonated against U.S. T32 and T26 Tanks and diesel fuel containers stowed in the tank hulls. The effectiveness of the T29 Mine against tanks was obtained and compared with that from T23E2 Mines.
DESCRIPTION: The T29 Mines contained a black powder charge for removing the earth over the mine. Before initiation, the fuzes were armed by pulling a lanyard attached to the safety fork, after which the tilt rod was pulled, initiating the fuze train. All the mines were buried 2 inches below the ground surface and covered with fairly loose soil. The four HEAT T23E2 Mines were buried approximately 7 inches underground and statically detonated by a Corps of Engineers special blasting cap.
CONCLUSIONS: The T29 Mine was a very effective weapon against tanks of the type used in this test. The performance of the T29 Mine was considered superior to that of the T23E2 Mine. The T29 Mine was effective against both tracks and the belly of tanks, whereas the T23E2 Mine was effective only against the belly, and even against the belly, its success depended on its being located directly under a vital component. It was recommended that the T29 Mine be further investigated to determine the optimum mine weight, dimensions, and fuzing desirable for the defeat of armored vehicles.
GENERAL: This 94-page report includes 32 photographs showing the damage to the tanks and components resulting from the mine blasts.

APG Ar-18198
SUBJECT: Mines and Mine Detection
TITLE: Vulnerability of Tank Suspensions to Mines
IDENTIFICATION: Firing Record No. Ar-18198
DATE OF REPORT: 10 July 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of tank suspensions to land mines
METHOD: Mines were modified by filling the fuzes with composition C3 and Corps of Engineers special blasting caps. The mines were buried singularly or in pairs at depths of 3 or 18 inches. A tank was positioned over a mine charge such that the mine was inboard, under, or outboard of the track. Charges were between the road wheels or centered under a wheel. After detonation of each charge the damage to the track was noted.
DESCRIPTION: The tanks used were a T26E4 and a T26E5. The suspensions were of the individually sprung torsion bar type. The tracks were T80E1 rubber-backed, steel chevron, center-guide type with open end connectors. The mines were T6E1 Heavy Antitank Mines. Two mines were placed back to back with the pressure plate of the top mine up. Depth of the mines was measured from the pressure plate to the surface.
CONCLUSIONS: Lower depths were required on the double mines than the single mines. The top of the track was damaged when a double mine was set shallow and outboard. Of the 18 single and seven double mine charges, eight of these severed the track.
GENERAL: This 25-page report contains four photographs.

APG TA3-5920/2
SUBJECT: Mines and Mine Detection
TITLE: Comparison of the Armor Penetrating Characteristics of the French Mine, AT, Plate Charge, Model 48T, with the U.S. Mine, AT, T29
IDENTIFICATION: Second Report on Project No. TA3-5920
DATE OF REPORT: 13 October 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the armor penetrating characteristics of the French mine, AT, plate charge, Model 48T, with that of the U.S. mine, AT, T29
METHOD: Nine APG manufactured Model 48T mines, one French manufactured Model 48T mine, and two U.S. mines, AT, T29, were emplaced and fired at 1-1/2-inch and 3-inch armor plate targets. All the mines were fired by means of an electric blasting cap inserted into the fuze or activator well. In addition, one APG manufactured

Model 48T mine was fired for measurement of plate velocity and recovery of plate fragments.
DESCRIPTION: The French Model 48T plate charge mine had a total weight of some 29 pounds, of which some 16 pounds was explosive (TNT or Picric acid) and 10 pounds was the "plate". The mine was 11 inches in diameter and 5-11/32 inches high. The "plate" was 9-3/8 inches in diameter and 7/16 inches thick, with a radius of curvature of 13-5/16 inches (measured to the top of the plate). The Model 48T mines fabricated at APG were essentially the same as the French manufactured mines except that the carrying handle was eliminated on all rounds and the side initiator well was eliminated on all but one round. Since WD 1010 steel, used by the French for the plates was not available, SAE 1018 was used. All APG fabricated mines were TNT-loaded.
CONCLUSIONS: The Model 48T mine did not match the T29 mine in its ability to penetrate comparatively heavy armor plate, or to penetrate thinner armor plate when covered with 2-1/2 inches or more of earth. When fired without earth cover at armor plate targets up to 1-1/2 inches thick, the Model 48T mine was an extremely effective armor defeating device.
GENERAL: This 35-page report includes eight photographs of the test mines and test results, and two drawings.

APG TB3-1225/2

SUBJECT: Mines and Mine Detection
TITLE: Vulnerability of the Soviet Tank T34/85 to Heavy Anti-Tank Mines, M6
IDENTIFICATION: Second Report on Project No. TB3-1225
DATE OF REPORT: 15 May 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of the Soviet tank, T34/85, to standard U.S. heavy anti-tank mines; and to compare the effectiveness of double and single mines against this vehicle
METHOD: Eighteen single and 10 double standard U.S. heavy anti-tank mines were statically detonated at locations partly under, or outboard, of the outer edge of the tracks of two of the Soviet vehicles. The relative efficiencies of the mine arrangements against the suspension systems and hulls of the vehicles were determined.
DESCRIPTION: The standard U.S. heavy anti-tank mines tested against the vehicles were of the M6A1, T6E1; and M6A1E1 types; the only difference between the mines was the method used in arming. Two Soviet T34/85 tanks equipped with complete suspension systems and inoperative engines were submitted for test with the mines.
CONCLUSIONS: A single mine with standard fuze was a fairly efficient weapon against the T34/85 tank, since 85% of the mines detonated by track pressure would probably immobilize the vehicle; however, modification of the fuze by the addition of delay or proximity features could possibly make the mine even more effective against the tank track and belly. Double mines, stacked base to base, and initiated by the pressure plate of the uppermost mine, would break the vehicle track and damage the suspension almost 100% of the time. However, a given number of M6 mines used as single mines could fairly effectively protect a larger combat front than the same number of mines used as doubles, provided the standard pressure fuze was used. It was recommended that a delay or proximity feature, preferably both, be devised and incorporated in the fuzing of the M6 mine. It was further recommended that an investigation be conducted to determine if an untoughened floor plate was typical of current Soviet produced armored fighting vehicles; this information should be taken into account in the future development of mines.
GENERAL: This 125-page report includes 38 photographs of the vehicles at various stages of test.

APG TT2-725C/7

SUBJECT: Mines and Mine Detection
TITLE: Effects of Land Mine Attacks on Turret-Mounted Components and Commander's Caliber .50 Machine Gun Cupola Model 30 of Tank, 90mm Gun, M48A1(U)
IDENTIFICATION: Seventh Report on Project No. TT2-725C
DATE OF REPORT: 28 February 1956
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate the effects of land mine attacks on turret-mounted components and commander's cal. .50 machine gun cupola Model 30, of tank, 90mm gun, M48A1
METHOD: Tank M48A1 was subjected to two land mine attacks, the first, an M6A2 mine containing 12 pounds of Comp B, was detonated beneath the left No. 2 road wheel; the second, a T18E2 mine containing 22 pounds of 80/20 Tritonal, was detonated beneath the left No. 1 road wheel. Damages or effects on the turret-mounted components and commander's cal. .50 machine gun cupola Model 30 were evaluated by operation, disassembly, and visual inspection.
DESCRIPTION: The facility vehicle was a standard tank, 90mm gun, M48A1 and completely equipped except for OVM, machine guns and ammunition. The sighting and fire control equipment included T31 ballistic computer, T46E1 rangefinder, T24E2 ballistic drive, T28 azimuth indicator, T191 telescope mount, T156E1 telescope, T184 periscope mount, and T35 periscope. The turret was fitted with a Model 30 commander's machine gun cupola which had Marblett plastic balls in its traverse bearing.
CONCLUSIONS: The fire control and armament equipment of the tank, 90mm gun, M48 was physically able to withstand, with no serious permanent damages imparted to the systems, the effects of a land mine attack of the magnitude associated with the T18E2 mine. The Model 30 commander's cupola fitted with Marblett plastic ball bearings was unable to withstand the effects of a T18E2 mine. It was recommended that instrumented tests on vulnerability of production cal. .50 machine gun commander's cupola Model 30 to shock applications be conducted with the cupola utilizing a type of bearing (balls and spacers) other than Marblett plastic in order to better resist damage.
GENERAL: This 27-page report includes eight photographs of the test vehicle components.

SUBJECT: Mines and Mine Detection BRL 616
TITLE: An Effectiveness Evaluation of Several Types of Antitank Mines
IDENTIFICATION: Report No. 616; Project No. TB3-1225
DATE OF REPORT: June 1952
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effect of M6 Antitank Mines on tank tracks
METHOD: Seventy-five mines were detonated beneath the tracks of Russian T34/85 and U.S. T26E4 Tanks. Single and double mines were buried 3 inches below the surface. The U.S. tank was equipped with a single pin T81 Track on one side and a double pin T80E1 Track on the other side for part of the test. The mines were detonated statically at the center line of a road wheel and midway between the road wheels. Comparative evaluation of the tracks and an estimate of tank kill probability were made.

DESCRIPTION: The single and double M6 Mines were hollow charge type mines with both single and double cones. The T81 Track consisted of all-metal links held together by link pins through mating hinges. The T80E1 Track consisted of links with integral pins held together by guides and end connectors. The Russian Tank was equipped with single-pin tracks similar to the T81 Track.
CONCLUSIONS: The single M6 Mine was more effective on a cost basis than the double M6 Mine for attack on double pin tracks. The single-cone mine was ineffective against the test tracks. The single-pin track offered greater resistance to HE mines than the double-pin tracks. Complete evaluation of the test items was not possible, and further testing was recommended to obtain definite conclusions.
GENERAL: This 43-page progress report includes seven test data charts and six pages of drawings of the test tanks, mines, and tracks.

TANK AUTOMOTIVE TEST RESUMES

APG TT2-529/1
SUBJECT: Robot and Remote Controls
TITLE: Test of Equipment, Remote Controls for Combat Vehicles
IDENTIFICATION: First Report on Project No. TT2-529; APG 10-229
DATE OF REPORT: 16 July 1948
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of using television and radio as a means of remotely controlling the maneuverability and armament of a tank
METHOD: A crew of two men, working in a weapons carrier (the controlling vehicle), by means of television and radio subjected a medium tank (the controlled vehicle, to the following tests: operation over all types of terrain when the controlling vehicle was stationary and moving; and to accuracy and ease of tracking and firing the controlled vehicle weapons at moving and stationary targets.
DESCRIPTION: Two television transmitters, one located in the driver's position for viewing terrain and the other coaxially mounted in a gun shield for viewing targets, and FM radio receiver, and other related remote controlled equipment were installed in a Medium Tank T23. This vehicle, powered by a gasoline engine which drove through an electrical power train, was equipped with a 76 mm gun and a coaxially mounted cal. .30 machine gun. Controlling equipment installed in a 3/4 ton, 4 x 4, weapons carrier, consisted of one FM radio transmitter, and, for both driver and gunner, a control box and a television receiver. The FM radio transmitter, operating at a carrier frequency of 62.27 megacycles, controlled 19 functions of the tank through servo mechanisms and solenoids actuated by the controlled vehicle FM receiver.
CONCLUSIONS: The test remote control equipment demonstrated workable principles, although considerable refinement was required. Among a number of deficiencies, the following features were predominately weak: controls functioned too slowly for accurate maneuvering, although this could be corrected; radio and television equipment had very short range (0.25 miles); and armament could not be traversed and elevated simultaneously. The results of firing at stationary targets were satisfactory, since a good percentage of hits were scored. It was recommended the equipment be developed further, with consideration being given to suggested improvements.
GENERAL: This 71-page report contains 15 photographs showing views of the vehicles, remote control equipment, and terrain, as viewed at the TV receiver. Block diagrams of the equipment are also included.

APG TT2-747/2
SUBJECT: Robot and Remote Controls
TITLE: Development of Radio Control Equipment for LVT MKIII
IDENTIFICATION: Second Report on Ordnance Project No. TT2-747
DATE OF REPORT: 7 July 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To develop radio control equipment for the LVT MKIII
METHOD: Radio control equipment was developed and fabricated in kit form for installation in the LVT MKIII. This remote control system was designed for the direction of a crewless vehicle from the controlling vehicle, and its functions included traversing the turret, firing the main and secondary armaments, and operating the camera. Provision for automatic destruction of the remote controlled vehicle was also included. The appearance and fighting ability of the LVT MKIII were not to be affected by installation of the equipment. Tests were conducted to determine its effectiveness.
DESCRIPTION: The radio kit for the LVT MKIII consisted of the following: operator's control box, audio modulator, audio demodulator, master relay unit, steer servo, shift servo, prop shaft locking brake, and a dual ignition and starting circuit.
CONCLUSIONS: Radio control equipment for LVT MKIII was successfully designed and tested. Outstanding features of the system included the use of the controlled vehicle's radio to receive radio control intelligence, good operational range with anti-jamming features, light weight, and ease of installation. Direct servo applications to the driver's controls enabled the driver to switch from manual to remote within two minutes. It was recommended that this development be considered acceptable. Investigations should be made at this time if application on amphibious vehicles is being considered.
GENERAL: This 55-page report contains numerous sketches and diagrams of the equipment.

APG TT2-747/3
SUBJECT: Robot and Remote Controls
TITLE: Development of Radio Control Servo Equipment for Cargo Carrier, M29
IDENTIFICATION: Third Report on Ordnance Project No. TT2-747
DATE OF REPORT: 7 July 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To develop radio control servo equipment for M29 cargo carriers
METHOD: Radio control equipment was developed and installed in seven M29 cargo carriers. The carriers were stripped of unnecessary components and extensive vehicle modifications were made. Operation of the control system was tested and deficiencies were recorded.
DESCRIPTION: The radio equipment was designed for the M29 cargo carrier. Components of the electro servo mechanism which applied to the vehicular controls consisted of the following: operator's control box, master relay unit, steer servo, clutch and accelerator servo, shift servo, and starting circuit. Provisions for automatic decoupling were made by connecting a heavy duty, pull-type solenoid to the pintle release.
CONCLUSIONS: The radio control servo system for the M29 cargo carriers was successfully designed and operated. With the conversion of the vehicles to radio control it was apparent that the generating system in use was inadequate. For this reason a 24-volt, 150-ampere system was designed. Body and suspension modifications were made which lowered the silhouette and compensated for

abnormal loading of the carriers. When the generator was coupled to the vehicle engine, a high engine speed was required if equipment drawing heavy amperage was switched into the circuit. A low maximum forward speed restricted the proper utilization of the shift servo. It was recommended that the following changes be considered if the vehicle is to be used in the future: proportional control of steering and acceleration; a separate auxiliary generator not dependent on the vehicle engine; and installation of an automatic transmission.

GENERAL: This 21-page report contains drawings of the control system.

SUBJECT: Stabilizing Systems APG 5887/20
TITLE: First Report on Gyrostabilizer Installation for Russian Medium Tank, T34
IDENTIFICATION: Twentieth Report on Ordnance Program No. 5887
DATE OF REPORT: 9 June 1944
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the feasibility of installing a M4 medium tank gyrostabilizer on the 76mm gun in the Russian T34 tanks
METHOD: A test was conducted to determine the magnitude of the turning moment around the trunnions caused by the gun recoil. This was done by attaching a cylinder 24-1/2 inches in front of the trunnions and measuring the pressure developed by means of a resistance-type electric pressure gage. A test was made to determine if the addition of relief valves to the stabilizer system would decrease these pressures and allow the stabilizer to function satisfactorily.
DESCRIPTION: The two vehicles used in the test were a U.S. M4 medium tank and a Russian T34 tank.
CONCLUSIONS: A standard gyrostabilizer as used in the M4 medium tank could not be successfully installed in the Russian tank T34, without major redesign of the gun mount. The pressure developed in a stabilizer cylinder set approximately 6 inches from the centerline of the gun trunnions was approximately 21,600 lbs./sq.in. The trunnion friction of this gun was 1843 in.-lbs. It was recommended that if further consideration was given to installing a gyrostabilizer in this vehicle, investigation be made as to the possibility of relocating the gun tube on the centerline of the trunnions and reducing the trunnion bearing friction.
GENERAL: This 48-page report includes two photographs of the test equipment.

SUBJECT: Stabilizing Systems APG TT2-645/2
TITLE: British Centurion II Tank, Stabilizer Test
IDENTIFICATION: Second Report on Project No. TT2-645
DATE OF REPORT: 23 December 1948
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the Centurion II stabilizer system with that developed for the M4 tank
METHOD: The Centurion II tank and the M4 comparison vehicle were subjected to the following tests to evaluate operation of the stabilizing systems: simulated firing using a camera to record the gunner's point of aim, actual firing, and continuous performance runs using a motion picture camera to record the gunner's point of aim. Over 500 rounds of ammunition and 4000 feet of motion picture film were expended during these tests.
DESCRIPTION: The British Centurion II, 54-ton tank was powered by a 600 hp V-12 gasoline engine and utilized a Merritt-Brown mechanical shift transmission. A completely electrical stabilizer system provided azimuth and elevation stabilization for the gun. Gyroscope assemblies were of conventional design, and the gyroscopic principle of precession was used to measure the rate of turn of the turret or gun. A 17-pound rifle and a 7.92 Besa machine gun were mounted on the turret. The stabilizer system developed in 1945 for the M4 medium tank was manufactured by the IBM Corporation. Because this equipment was not available, an M4 with elevation but no azimuth stabilization was used in these tests.
CONCLUSIONS: No significant difference in performance was found between the stabilized systems for the test conditions to which they were individually subjected. However, determination of superiority would require simultaneous testing under the same conditions of course, gunners, sighting device, etc. Test conditions to which the original M4 stabilizer system had been subjected could not be exactly duplicated. It was recommended that the Centurion II stabilizer be considered satisfactory; the correction of certain defects found in this equipment was also recommended.
GENERAL: This 97-page report contains six photographs of components of the British tank.

APG TT2-693F/1

SUBJECT: Stabilizing Systems
TITLE: Medium Tank M46 (Westinghouse Stabilizer System)
IDENTIFICATION: First Report on Project No. TT2-693F; APG 10-269
DATE OF REPORT: 18 June 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of a Westinghouse stabilizer system for a Medium Tank M46 turret
METHOD: The stabilizer system was installed in a Medium Tank M46. Two shutterless, strip cameras were used to record gun and vehicle movement on a series of "free drop" tests and on continuous performance tests conducted over various courses. A firing test was also conducted with the tank operating on straight, zig-zag, and circular courses. Performance was compared with that of other systems previously tested.
DESCRIPTION: The Westinghouse stabilizer was applied to the Medium Tank M46, a 48-ton vehicle mounting a 90mm Gun M3A1. The stabilizer components, designed to function in conjunction with the existing M46 turret power control units, followed closely the World War II design, but incorporated changes in the manner of precessing the gyro for tracking purposes. The elevation system embodied a restrained rate-type gyro located on the gun mount oriented to precess against a group of silverstat leaves when subjected to elevation error rates. These leaves when closed by contact set up an electrical imbalance on a magnetically controlled teeter-bar in the elevation pump assembly. This imbalance resulted in an increase in oil flow or a resistance, causing a pressure differential on the elevation cylinder piston located between the turret and gun. The pressure differential drove the gun to oppose hull motion. The azimuth stabilization circuit used the Medium Tank M46 power supply unit and traverse gear box components. A magnetically influenced teeter-bar controlled by silverstat resistances at the azimuth gyro controlled the direction of oil flow to the traverse motor.
CONCLUSIONS: The Westinghouse stabilization system in the Medium Tank M46, although having

advantages of compactness and simplicity, did not meet performance criteria. It was considered inferior in both azimuth and elevation to the Light Tank T41 (Vickers) and Centurion III Tank (Metrovick) systems. The power traverse minimum response was considered too high to permit good tracking and laying performance; traverse gear box backlash was excessive; and reliability of the stabilizer system was unsatisfactory. It was recommended that the system as tested be considered unsatisfactory and that further development be postponed pending final evaluation of experimental systems currently developed for the M46 and M47 Tanks.
GENERAL: This 64-page report contains seven photographs of the tank and the installation of the Westinghouse stabilizer system; and sketches of the closed center valve, hydraulic circuits, and the stabilizer electrical system.

SUBJECT: Stabilizing Systems APG TT2-693/6
TITLE: First Partial Report on Comparative Test of Stabilization Systems
IDENTIFICATION: Sixth Report on Project No. TT2-693
DATE OF REPORT: 15 November 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate and compare seven types of gun stabilization systems for use in medium tanks
METHOD: Each system was installed in a tank and subjected to various tests to determine comparative stabilizer performance. The tests included sighting, tracking and laying, free drop, pilot steer, strip camera runs, planned firing, electrical power requirements, maintenance complexity study, and gun camera motion picture runs.
DESCRIPTION: The gun stabilization systems tested were: Metropolitan Vickers Electrical Company Ltd., (Metrovick) Mark IV systems in the British Centurion III Tank and M47E1 Tank; Westinghouse Electric Corporation (I) system in the M46 tank and (II) system in the M47 tank; Minneapolis-Honeywell Regulator Company system in the M46 tank; General Electric Company system in the M47 tank; and Vickers Corporation system in the M47 tank.
CONCLUSIONS: The Minneapolis-Honeywell system in the M46 tank achieved the best over-all performance in the stabilization test but had the highest electrical power consumption. The Metrovick MKIV system in the M47E1 tank followed closely in performance and required the least power. The Westinghouse II system in the M47 tank and the General Electric system in the M47 tank were erratic in performance and unable to achieve reproducible results. The Vickers system in the M47 tank and the Westinghouse I system in the M46 tank were dependable but the performance of both systems deteriorated under severe test conditions. It was recommended that the Minneapolis-Honeywell and Metrovick MKIV stabilization systems be considered the most satisfactory approaches to medium tank gun stabilization and that development be continued by further integration of these systems into tank fighting compartments.
GENERAL: This 426-page report includes 32 photographs of the test vehicles and stabilization systems.

SUBJECT: Stabilizing Systems DA 668
TITLE: Centurion III Stabilization Equipment (MK IV)
IDENTIFICATION: Report No. 668
DATE OF REPORT: 23 January 1951
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To explain the electrical portion of the Centurion III stabilization equipment with special reference to the control and feedback circuits
METHOD: None.
DESCRIPTION: The entire report was based on information furnished by Messrs. A.E. Hampton and R.W. Wrathall of the Fighting Vehicle Design Establishment of the British Ministry of Supply, on FVDE Report No. EL-122, and FVDE Drawing No. EV128385. The Centurion stabilizing system was a rate-gyro operated servomechanism, electronic in nature, and effective on both traverse and elevation. The traverse and elevation channels were essentially independent and each consisted of four basic units: 1) the gyro; 2) the electronic amplifier; 3) the metadyne; 4) the driving motor.
CONCLUSIONS: Since this entire report was in the nature of an explanation, no conclusions were reached.
GENERAL: This 19-page report includes a stabilization system schematic drawing and a copy of FVDE Drawing No. FV128385.

SUBJECT: Stabilizing Systems DA 1137
TITLE: Second Report on Centurion Stabilization Equipment
IDENTIFICATION: Report No. 1137
DATE OF REPORT: 31 July 1951
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To clarify the problems treated in the British Report No. EL-122 on stabilization of tank armament, together with the procedure for setting up the MK IV equipment prior to its operation
METHOD: None.
DESCRIPTION: This report was divided into three separate sections. The first was a design section in which an attempt was made to clarify some of the materiel presented in British Report No. EL-122. The second section was a step-by-step setting up procedure which would permit the equipment to be put into operation after the installation was completed. The third section was merely a description of the system components which would be useful whenever repairs were necessary.
CONCLUSIONS: None.
GENERAL: This 51-page report includes ten photographs of the system components.

APG TB5-1401/256

SUBJECT: Tractive Resistance and Traction Studies

TITLE: Winter Test 1954-1955, Traction Device for Transport Vehicles

IDENTIFICATION: Two Hundred Fifty-sixth Report on Project No. TB5-1401

DATE OF REPORT: 14 March 1955

ORIGIN: Aberdeen Proving Ground, Maryland

PURPOSE: To determine the general characteristics and effectiveness of the "Jungletrac" traction devices, as compared with the standard tire chains

METHOD: Two trucks, wrecker, 5-ton, M62, were used to compare the mobility characteristics of the test traction devices with standard tire chains, when operated over adverse arctic terrain. Durability characteristics were obtained by operating the devices on a truck, dump, 5-ton, M51. The vehicles were run a total of 127 miles. Also, installation requirements of the test devices were compared with those of the standard chains.

DESCRIPTION: The "Jungletrac" traction device consisted of a number of individual grousers and connectors that enclosed the intermediate and rear axle tires in the form of a track when connected together. A unique feature of the device was the single connector between two grousers. For ease of mounting, the grouser was designed so that the connector served the dual purpose of securing the grousers together, and once connected, for making tension adjustments. For stability, each grouser had a single guide which followed between the dual tires.

CONCLUSIONS: The test traction devices increased the mobility characteristics of the wrecker, M62, as compared to a similar vehicle equipped with tire chains. The devices required considerable stowage space. Use of the "Jungletrac" on hard surfaced roads was unsatisfactory, due to frequent connector failures, grouser formation and extremely hard vehicle riding characteristics. The devices were not difficult to install, even by personnel wearing arctic clothing. It was recommended that the test traction devices be considered satisfactory for improving the mobility characteristics of the vehicles on which they were tested; that vehicles equipped with such traction devices not be operated continually over hard surfaced roads; and that additional testing of the devices be conducted on other types of vehicles, operating with various payloads, over typical arctic terrain.

GENERAL: This 58-page report includes eight photographs of the test traction devices.

Section 30
NON-METALLIC MATERIALS

SUMMARY

The subject, Non-Metallic Materials, was not summarized because of the limited scope of the non-metallic material reports briefed to date. When a sufficient number of non-metallic material reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

GRG MT-TOM 201/2

SUBJECT: Non-Metallic Materials
TITLE: Design Criteria for Reinforced Plastics
IDENTIFICATION: Report No. GRG MT-TOM 201/2
DATE OF REPORT: 23 April 1953
ORIGIN. The Department of Defense Research and Development Board
PURPOSE: To present information on design criteria for reinforced plastics
METHOD: Symposium papers were presented to an audience composed of Government and private industry personnel directly interested in present use and possible future use of reinforced plastics. The presentation of each paper was followed by a question-and-answer period during which various points brought up in the paper were discussed.
DESCRIPTION: The symposium papers covered a variety of topics including the use of reinforced plastics in guided missiles, naval aircraft structures, tactical stream crossing equipment, boats and boat hulls, guided missile shipping containers, ammunition containers, pipes, storage tanks, shipboard piping, naval weapons, small arms, closing plugs for semifixed ammunition, Ordnance weapons, Signal Corps equipment, and hollow core sandwich constructions.
CONCLUSIONS: The amount of information on design criteria and design handbooks for reinforced plastics was found to be quite limited. Establishment of precise design criteria were believed to have been hampered generally by non-uniformity of reinforced plastics and by a lack of non-destructive inspection test methods. It appeared that individual fabricators had developed certain specific techniques with little reference to over-all problems in the industry. Because of this, it was difficult to obtain direct comparisons of physical properties of the various types of reinforced plastics. Little data existed on the mechanism by which reinforcement occurred. Much of the work seemed to have been carried out on a cut-and-try basis. The need for a comprehensive fundamental study of reinforced plastics was believed evident. It was proposed that existing information be gathered into a handbook for use by the military departments. It was suggested that further small group meetings be held to discuss certain limited phases of reinforced plastics in greater detail than was possible in the symposium.
GENERAL: This 353-page report includes 52 pages of illustration, 12 pages of tables, and 24 pages of graphs.

Section 31
PROTECTIVE COATINGS AND CLEANERS

SUMMARY

The subject, Protective Coatings and Cleaners, was not summarized because of the limited scope of the protective coatings and cleaner reports briefed to date. When a sufficient number of protective coatings and cleaner reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

DA 1433

SUBJECT: Protective Coatings and Cleaners
TITLE: Testing Moisture Properties of Seal Peel Protective Coating
IDENTIFICATION: Report No. 1433
DATE OF REPORT: 3 February 1949
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To test moisture resistance of Seal Peel protective coating on canvas and steel parts
METHOD: Loosely woven cloth specimens were sprayed with light, medium, and heavy applications of Seal Peel Packaid and tested for average weight per sq.ft., and for moisture penetration under conditions of extreme cold, room temperature of 70°F and a humidity of 65%, at a humidity cabinet temperature of 100°F and at a humidity of 100%. A 73-hour accelerated weathering test was also conducted in a weatherometer, using a cam which emitted steady light at a temperature of about 115°F and a cycle consisting of 3 minutes of rain followed by 17 minutes without rain. Metal spindles were coated with Seal Peel plastic and tested for resistance to weathering, cold, and salt spray conditions.
DESCRIPTION: Seal Peel protective coating could be applied by hot spray or by hot dip in a tank. The coating dried to a film after exposure to room temperature.
CONCLUSIONS: The cloth covered with a heavy application of Seal Peel and the metal spindle coated with Seal Peel withstood all conditions to which they were subjected. It was determined that a heavy spray on fabric (six coats approximating 15 gms per sq.ft.) would be required as a standard to provide adequate protection against high relative humidity conditions.
GENERAL: This unillustrated 11-page report includes three data sheets showing weights and test results.

Section 35
SHIELDS

SUMMARY

The subject, Shields, was not summarized because of the limited scope of the shield reports briefed to date. When a sufficient number of shield reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Shields APG TT2-689/6
TITLE: Investigation of the Protection Afforded by a Nylon Shield Against Passage of Fragments at the Clearance Around the Gun Mantlet of the 90mm Gun Tank, M47
IDENTIFICATION: Sixth Report on Project No. TT2-689
DATE OF REPORT: 10 June 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine whether openings between the gun mantlet and turret of an M47 tank would be vulnerable to small arms fire and fragmentations; and in the event these areas were vulnerable to determine whether a nylon splash shield would be suitable for use in remedying the situation
METHOD: The openings between the gun mantlet and turret of an M47 tank were subjected to cal. .45 and cal. .50 rifle fire at various angles of attack; fragmentation grenades were also detonated adjacent to the openings. Testing was conducted with the 90mm gun of the vehicle at various angles of elevations and traverse. These tests were repeated after a nylon splash shield was installed over the openings. Several revisions were made to the shield during the course of test.
DESCRIPTION: The design of the gun shield of the M47 tank was such that relatively large openings existed along the sides, top, and bottom of the shield at various positions of the gun elevation and turret traverse. An internally mounted nylon splash shield submitted by the American Locomotive Company was designed to reduce the vulnerability of these openings to small arms fire. A revision of this shield consisted of wide side flaps, 18 layers of nylon in the top flap, and metal braces of spring steel.
CONCLUSIONS: The openings between the gun mantlet and turret of the M47 tank were susceptible to small arms attack and fragmentation. The nylon shield easily remedied the situation and was considered acceptable for use.
GENERAL: This 42-page report contains 15 photographs of the test installation and test results.

Section 39
SUSPENSIONS

SUMMARY

The subject, Suspensions, was not summarized because of the limited scope of the suspension reports briefed to date. When a sufficient number of suspension reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Suspensions APG Ar-19340
TITLE: Ability of Tank 90-mm, Gun, T48, to Withstand Mine Attack
IDENTIFICATION: Report No. Ar-19340; Project No. TT2-760/F
DATE OF REPORT: 15 May 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ability of the 90mm Gun Tank T48 to withstand mine attack
METHOD: Special 20-pound TNT mines were detonated under each of two previously damaged 90mm Gun Tanks T48. The detonations were at the inboard edge of the right tracks - in one tank below the No. 1 road wheel and in the other below the No. 3 road wheel. Assessments of damage were made.
DESCRIPTION: The 90mm Gun Tanks T48 each had a suspension consisting of 12 road wheels with associated torsion bars. Each bar was fixed ... one end of a road wheel arm upper spindle and at the other end to an anchor plug in the support for the opposite road wheel arm.
CONCLUSIONS: The tanks were immobilized by the mine blasts. It was estimated that the tracks broken by each charge could be replaced in two hours by the tank crew. The road arm supports were torn off and could not be replaced in the field due to the way in which these supports were bolted to the tank hull. One of the four fuel cells in each tank developed a leak due to the weak consiruction of the cells. Also in each tank the batteries were displaced from their mountings and the cases cracked.
GENERAL: This 12-page report includes four photographs of the damaged tank components.

Section 41
TANKS (COMBAT)

SUMMARY

This summary covers 32 report resumes written on combat tanks from 1939 to 1955 at the following locations: Aberdeen Proving Ground, Maryland; Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland; Armored Board, Fort Knox, Kentucky; Army Field Forces Board, Fort Knox, Kentucky; and the Army Field Forces Board No. 2, Fort Knox, Kentucky. Testing was conducted for three main purposes: to determine the suitability of various tank vehicles and related equipment; to determine the vulnerability of several tanks against certain projectiles and weapons; and to evaluate the development of general tank policy and requirements.

PERFORMANCE EVALUATION OF TANKS

Performance operations were conducted to determine the combat suitability of the following: (test dates included) gas proofing of the T5 medium tank (1939); British infantry tank, Mark II A (1940); modifications for the M4A1 medium tank (1944); military characteristics for the T39 pioneer tank (1949); French light tank AMX (1951); French heavy tank (1952); T26E5 medium tank (1953); proposed T26E4 medium tank (1953); T41-E1, 75mm gun tank (1953); Russian T34 medium tank (1953); Russian V2-34 diesel engines (1953); desert characteristics of the T43E1, 120mm tank (1953); and the T67 flame thrower tank (1954). Results of these tests were generally satisfactory, although numerous deficiencies were noted. It was recommended that all available foreign automotive material with design different from standard Ordnance vehicles be tested for performance and engineering design. Strong and weak points of foreign tank designs were recorded after each testing. The oscillating turret for the French heavy tank offered several advantages, such as simplicity of gun mount, ammunition handling, and sight installation; good utilization of turret space, low silhouette, and possible weight savings in armor. Desert cooling of the T43E1, 120mm gun tank was found to be inadequate.

TANK VULNERABILITY

Tank vehicles were subjected to numerous firing tests to determine their vulnerability to various military weapons and projectiles. The results, which are summarized below, varied greatly with the different tanks and types of attack employed. The T26E1 heavy tank and the M26 heavy tank, both tested in 1945, were readily immobilized by small arms fire, explosives of offensive type hand grenades, bursting of high explosive shell in or near the vehicle, and partial penetrations of armor piercing shell on the vehicle.

The remaining tank vulnerability data were accumulated during the 1951 to 1953 period. A revised design of a T43 tank hull provided satisfactory ballistic protection. A Russian T34 tank was too well designed to be affected by the action of napalm bombs. T26E5 medium tanks proved vulnerable to air attack by AP, API, HEI, INC, and HVAR projectiles; damage was noted on the tank sides, turret tops, rear deck armor, air intake grilles, and final drives. The fuel tank of the M26 combat tank was susceptible to 90mm T108-E15 projectiles, and the M26E4 medium tank demonstrated vulnerability to firing of 90mm HEAT FS projectiles. M46 and USSR, T34/85 tanks subjected to napalm bomb air attacks could not be put out of operation except by a direct hit.

GENERAL REQUIREMENTS FOR TANKS

Several tests and investigations were described with respect to general requirements for combat tanks and methods for evaluating tank effectiveness. In 1948, studies were conducted to secure sufficient information on the employment of heavy tanks to form a basis on which future requirements and development of heavy tanks for the U.S. Army could be determined. A model of tank warfare was analyzed in 1949 to determine the factors which would be essential in increasing the effectiveness of tank weapons against primary targets. In the same year, pertinent data were reviewed in order to establish the tank and associated equipment policy of the U.S. Army and the national military establishment. Also in 1949, investigations and analyses were made to define the doctrine of organic and attached tanks and to determine the tank requirements of the Infantry Division. A 1950 report described investigations of the relationship existing between gun and armor, the former of which was considered the most important in tanks of all classes. Studies in 1951 were made in the determination of the probable ranges of engagement and angles of attack in tank and antitank engagements. A 1952 report stated that the BRL methods for analyzing tank vulnerability and effectiveness were considered to be approaching a point where specific information could be made available. Further data (1953) were presented concerning a probability of penetration to fire analysis for the equivalent armor of a T43 tank.

SUBJECT: Tanks (Combat) AB 426(F)
TITLE: Modifications, M4 Series Medium Tanks
IDENTIFICATION: Final Report, Project No. 426
DATE OF REPORT: 26 January 1944
ORIGIN: Armored Board, Fort Knox, Kentucky
PURPOSE: To determine the suitability of numerous modifications to the M4A1 Medium Tank, including possible use of the T23 turret
METHOD: Three tanks incorporating various modifications were operated cross-country and on highways. The modifications were checked for durability and suitability during and after test operation.
DESCRIPTION: The modifications consisted of changes in the tanks' hatches, splash plates, drivers' controls, clutches, lighting systems, suspensions, power plants, gun mounts, sights, turret baskets, fire control systems, and numerous small components. The three M4A1 Medium Tanks on which the modifications were made were identified as Nos. W-3036871, W-3036973, and W-3037734, supplied by the Pressed Steel Car Company of Chicago, Illinois.
CONCLUSIONS: Most of the modifications were considered satisfactory, although several additional changes were believed necessary. A detailed account of the test findings for the W-3037734 tank was included in this report; detailed accounts of the test findings for the other two tanks were given in Report AB 426(1). The T23 turret was not considered satisfactory for use on the M4 Medium Tank.
GENERAL: This 40-page report contains nine pages of photographs showing the tank and some of the modifications.

SUBJECT: Tanks (Combat) AFF 2-18-49(III)
TITLE: The United States Tank Policy
IDENTIFICATION: Report No. AFF 2-18-49(III)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To establish the tank and associated equipment policy of the U.S. Army and the National Military Establishment
METHOD: The tank and associated equipment policy was established by review of the following data: definition and mission of the tank, foreign tank positions and policies, tank development in the United Kingdom and the USSR, U.S. tank position, tanks available, tank requirements, mobilization, postwar tank development, derivative and related equipment, factors affecting tank production, retention of technical and productive skill, material and manpower demands, agency for coordinating tank automotive program, highway and rail and water movement, ships for transporting tanks, craft for landing tanks, available navy shipping, air transportability, augmentation of present units bridging, trends in tank development, and time-space factors in tank production.
DESCRIPTION: Discussion was concerned with the following factors: tactical requirements of minimum types, advantages of lighter tanks, "universal" type tank, assault guns, special engineer armored equipment, kits for attachment to tanks, need for development and limited production, purpose of standard classification for equipment, American Tactical Doctrine and Industrial Procedures, tank ammunition, and Armored Personnel Carriers.
CONCLUSIONS: Only light and medium tanks were sufficient in number to meet the peacetime requirements. Medium and heavy tanks were inadequate in number to combat the present supply of the potential enemy. The potential enemy had developed tanks superior in quantity, armor, and armament. A single "universal" tank was not tactically sound. Expediting of the Light Tank T37 was required. Unless the tank situation was improved, it would take 2-1/2 years after a declared emergency to supply an adequate number of tanks. Twenty million dollars a year starting with 1950 would be required for an adequate tank program. Special financing and development of various tanks, equipment, and vehicles was urgently recommended.
GENERAL: This 26-page report includes two tables of current tank status and requirements and is contained with Report No. AFF 2-18-49.

SUBJECT: Tanks (Combat) AFF2-18-49(IX-6)
TITLE: Engineer Armored Vehicles
IDENTIFICATION: Report No. AFF2-18-49(IX-6)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To review the military characteristics for the Tank, Pioneer, T39 and to determine modifications needed to expedite production
METHOD: Review was made of the military characteristics and original requirements of the engineer tank. Progress in the development of the basic vehicle had been halted because of difficulties which had arisen. These problems were discussed and included the problem of overloading the vehicle due to displacement of the center of gravity when the bridge was in launching position on the tank; failure to develop a suitable rocket launcher, and the feasibility of using a mine exploding flail and mine detector on the vehicle. Study was made of the British development of the AVRE engine vehicle with 6.5-inch gun.
DESCRIPTION: The projected Tank, Pioneer T39 was to be an armored vehicle permitting engineer troops to perform missions under fire. The vehicle was to mount an attachment for launching a short span bridge, a closed-breech rocket launcher, mine detector clearing devices, and a dozer blade. The basic vehicle was to be the chassis of the M46 Medium Tank.
CONCLUSIONS: Two types of armored vehicles were required for engineer use and should include a vehicle of the Pioneer tank type equipped with a dozer blade, mine detecting and removing attachments, and a rocket launcher. The second vehicle should have attachments for carrying and launching a bridge for assault purposes with the longest possible span and should carry personnel and cargo. Development of the Pioneer tank should be continued awaiting development of a rocket launcher. It was recommended that the British 6.5-inch demolition gun be investigated for possible

U.S. use.
GENERAL: This five-page report is not illustrated and is contained with Report No. AFF 2-18-49.

SUBJECT: Tanks (Combat) AFF 2-18-49(X)
TITLE: Infantry-Tank Teams of Infantry Division
IDENTIFICATION: Report No. AFF 2-18-49(X)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To define the doctrine of organic and attached tanks and to determine the tank requirements of the Infantry Division
METHOD: A summary was made of the history and background of tank employment with the Infantry Division. A study was conducted of the use of tanks to defend and aid the infantry in offensive operations. An analysis was made of the purpose and employment of tank platoons in defense and assault battalions and of organic and attached tank battalions with Infantry and Airborne divisions. The principal military tank characteristics were detailed, including fire power, mobility, and armor.
DESCRIPTION: The reference material for this report was obtained from the War Department Equipment Board, Type Field Army, the Infantry Conference report and TM2 AFF, 10 January 1948.
CONCLUSIONS: The doctrine for employment of tanks with the Infantry Division was sound and practicable. The principal characteristics required in infantry support tanks were: armament comparable to that of the enemy, ability to accompany infantry over most terrain, and as much armor as possible within a total weight limit of 36 tons. The three tank corps battalions should be equipped with the heavy tank. There was a need for a lightly armored vehicle with a powerful antitank gun which could be airborne. There was no need for a mobile antitank weapon in the standard infantry battalion.
GENERAL: This six-page report is not illustrated and is contained with Report No. AFF 2-18-49.

SUBJECT: Tanks (Combat) AFF 1328
TITLE: Tactical Equipment, Heavy Tanks, T29 and T30
IDENTIFICATION: Project No. 1328
DATE OF REPORT: 30 June 1948
ORIGIN: Army Field Forces Board No. 2 at Fort Knox, Kentucky
PURPOSE: To secure sufficient information on the employment of heavy tanks to form an intelligent basis on which future requirements and development of heavy tanks in the U.S. Army could be determined
METHOD: Documents were studied to determine the tactical employment and heavy tank policy of Germany, the Soviet Union, Great Britain, and the United States. Transportation Corps officers were consulted with respect to the feasibility of transporting the T29 and T30 Heavy Tanks, both on United States and European railways. Data on landing craft were obtained from official naval sources. An actual engineer reconnaissance was made from Lexington to Fort Knox, Kentucky to determine the feasibility of moving heavy tanks over secondary roads in the United States. Additional information was obtained by actual test of the vehicles.
DESCRIPTION: The two test tanks were similar except the Heavy Tank T29 had a 750 hp Ford water-cooled engine and mounted a 105mm gun, while the T30 had an 810 hp Continental air-cooled engine and mounted a 155mm gun. Each weighed about 70 tons and had a cross drive transmission.
CONCLUSIONS: Heavy tanks were considered to be tactically employable, in spite of certain special provisions that would be required and certain difficulties that would be encountered. The Soviet Union was considered to be ahead of the U.S. in this field since a battle-proven heavy tank was already in the hands of troops. To meet Soviet armor on at least equal terms, a U.S. heavy tank was deemed necessary. It was recommended that Heavy Tanks T29 and T30 be considered unsatisfactory. Heavy tank development was recommended for continuation with a priority below that accorded the medium until an acceptable vehicle could be obtained. Development of a tank that sacrificed 360° traverse for portability, mobility, and protection, was recommended. The weight of this proposed tank would not exceed 50 tons, would mount the best possible armor-piercing weapon, and have at least the armor protection of the medium tank.
GENERAL: This 29-page report is not illustrated.

SUBJECT: Tanks (Combat) APG 5388/1
TITLE: Joint Preliminary Report of the Chemical Warfare Service and the Ordnance Department on the Gas-Proofing of Tanks
IDENTIFICATION: First Report on Ordnance Program No. 5388
DATE OF REPORT: 14 March 1939
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the feasibility of gas-proofing tanks for use in gassed areas
METHOD: All avenues of air escape from the medium tank T5 were sealed as well as possible, and positive air pressure was maintained within the crew compartment by means of a blower taking air through a pistol port in the left door. Four runs were made using tear gas candles installed on the tank in the center of the front plate, or the tanks armament, or both, as the variables. All operations were conducted with the vehicle running in an average wind speed of 15 mph and the crew remaining in the vehicle with all doors shut throughout the test.
DESCRIPTION: The vehicle used in the test was the standard medium tank T5 with a 250 cu. ft. per minute blower driven at 3600 rpm by an electric motor. Leather, wood plugs, putty, bellows of gas mask fabric, rubber patches, rags and masking tape were used as sealants.
CONCLUSIONS: The results of the test proved that gas-proofing was both necessary and feasible and that any required changes in the tank were minor with the possible exception of the seal about the turret. Additional tests to eliminate the contamination of air by gas fumes from the arma-

ments installed in the tank were recommended. It was also recommended that consideration be given to the proposed outlines for general design of air-purifying equipment and gas-proofing of tanks.
GENERAL: This 31-page report includes two photographs of the vehicle during test.

SUBJECT: Tanks (Combat) APG 5459/1
TITLE: First Report of British Infantry Tank Mark II A
IDENTIFICATION: First Report on Ordnance Program No. 5459; APG 10-32
DATE OF REPORT: 18 November 1940
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the operating characteristics of the British Infantry Tank Mark II A
METHOD: The vehicle was tested according to T.S.T.P. 1935-709, except for the continuous operation tests and studies of cooling. A performance comparison between the 40mm tank gun and our 37mm antitank gun was made, and the ballistic limit of the tank turret with our 37mm M51 Projectile was determined.
DESCRIPTION: The test British Tank Mark II A weighed 53,260 pounds and was powered by two parallel, water-cooled, A.E.C. diesel engines, each rated 95 bhp at 2000 rpm. These engines were coupled together by a transverse train of gears. The transmission was a Wilson epicyclic preselective gearbox having six speeds forward and one reverse. Steering was by Rackham steering clutches. Bogies of the bell-crank, coil-spring type were used, and the suspension was protected by skirting plates. The hull was fabricated of armor castings and plates, with a maximum thickness of 3-1/2 inches. Armament consisted of a 40mm quick firing Vickers gun and a 7.9mm Besa machine gun mounted coaxially within the turret. Turret rotation was accomplished either by manual or power traverse.
CONCLUSIONS: Although the vehicle was considered a well-armored and compact fighting unit, overheating of the engines, breaking of track shoes and pins on concrete roads, and abnormally high unit ground pressure made it less dependable than the Medium Tank M2A1. The M2A1 was much faster, and its superior horsepower-to-weight ratio permitted greater maneuverability. Although the British tank turret proved less vulnerable than that of the M2A1 and the use of power traversing increased fighting effectiveness, the armament was considered inadequate. From the comparative study it was recommended that periscopic vision and power turret-traversing mechanism be adopted as standard for American tanks, and that some form of transfer case be evolved to lower propeller shaft turrets in order to increase space in the fighting compartment. It was also recommended that the principle of increasing armor protection of light and medium tanks to the maximum limit consistent with performance requirements and current fundamental design be adopted.
GENERAL: This 208-page report includes 35 photographs and a copy of the 1940 Tank Infantry Mark II and II A Instruction Book containing 14 pages of sketches illustrating all vehicle components.

SUBJECT: Tanks (Combat) APG 6004/2
TITLE: First Report on Correction of Ballistic Deficiencies of Heavy Tank, T26E1
IDENTIFICATION: Second Report on Ordnance Program No. 6004
DATE OF REPORT: 27 November 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To correct the ballistic deficiencies of the heavy tank, T26E1
METHOD: The heavy tank, T26E1, and the heavy tank, M26, were subjected to a series of assorted firing tests, the details and results of which were presented in the report.
DESCRIPTION: Early tests had determined that the heavy tank T26E1, used in this test, could easily be put out of action even by a single rifleman firing a weapon as light as a cal. .30 rifle.
CONCLUSIONS: The heavy tank, T26E1, and also the heavy tank, M26, could be readily immobilized by small arms fire, explosives of offensive-type hand grenades, bursting of high explosive shell on or near the vehicle, and partial penetrations of armor piercing shell on the vehicle. The hull front section of the heavy tank, T26E1, did not successfully withstand the impact of 88mm APC-BC-HE shells at ranges of 2000 yards or less. The protective area included by the turret armor of the vehicle could be penetrated by the 88mm armor piercing projectiles at ranges up to 5000 yards. Many components and/or accessories of the tank could be displaced or rendered inoperable by impacts that otherwise would not impair the combat efficiency of the vehicle. Enemy fire could cause injury to the tank crew that would not damage the tank or otherwise tend to cause its immobilization. It was recommended that the air grilles be considered unsatisfactory from the standpoint of vulnerability from air-to-ground attack and from ground attack, because they did not meet Ordnance requirements; and, that a study be made prior to the laying out of the initial design of combat vehicles with the primary objective of not permitting the design or a future design to materialize repeating weaknesses of prior vehicles.
GENERAL: This 407-page report includes 54 photographs of the test tank, its components, and the effects of various ball and shell impacts.

SUBJECT: Tanks (Combat) APG 6009/12
TITLE: First Report on Test of Medium Tank T26E5
IDENTIFICATION: Twelfth Report on Ordnance Program No. 6009; APG 10-206
DATE OF REPORT: 22 July 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the performance characteristics of a Medium Tank T26E5 and a proposed Medium Tank T26E4
METHOD: The vehicle was loaded to 102,300 pounds and tested to determine turret traverse characteristics, bow gun limits of traverse and elevation, maximum speed, slope operation, and turning and steering effort requirements. The vehicle was then loaded to 110,000 pounds to simulate a proposed T26E4 and slope operation, fuel economy, and cross-country tests were made.

DESCRIPTION: The test Medium Tank T26E5 was identical to the standard M26 except that heavier armor plate was employed in the front hull, turret casting, front turret ring shield, and gun shield. A reduced final drive ratio was employed to accommodate the heavier vehicle weight. The proposed Medium Tank T26E4 was to employ a Heavy Tank T32 turret and gun mount, and the vehicle weight was to be 110,000 lbs.
CONCLUSIONS: Except for the suspension and fuel economy, the general performance characteristics of the test vehicle compared favorably with those of the Medium Tank M26. There was little difference between the performance of the vehicle at 102,300 pounds and at 110,000 pounds. The cruising range of the heavier vehicle was 37 miles and was considered unsatisfactory. The standard inner front road wheel bearings were inadequate for a 110,000-pound vehicle. Larger torsion bars, road wheel hubs, and bearings and increased capacity shock absorbers were recommended for the front road wheels. Jettison fuel tanks were recommended to increase cruising range.
GENERAL: This 74-page report contains seven photographs of the Medium Tank T26E5. Laboratory Reports No. 45-111 and 45-125 are also included.

SUBJECT: Tanks (Combat) APG Ar-17579
TITLE: Vulnerability of Tanks Against Air Support Weapons (Phase III)
IDENTIFICATION: Firing Record No. Ar-17579; Project No. TB3-1224B
DATE OF REPORT: 19 July 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of tanks against air attack
METHOD: Five tanks without ammunition, machine guns, sighting equipment, tools or equipment were used as targets. They were remotely controlled by radio from an L19 Aircraft. The tanks were brought into an area, camouflaged, and then deployed for battle. Reconnaissance missions and simulated day and night attacks were flown by Navy, Marine, and Air Corps aircraft against the tanks. Various flares, 5-inch inert and live rockets, napalm and 500-pound GP bombs, .50 caliber machine guns, and 20mm cannons were used by the aircraft.
DESCRIPTION: The tanks were T26E5 Medium Tanks. The aircraft used were Navy F2H-2, F9F-2/4, and P2V; Marine F7F-3N and F4U-5N; and Air Force F-84E and AD-4N. Projectiles used were AP, API, HEI, INC, and HVAR types.
CONCLUSIONS: The sides of the tanks were vulnerable to attack. Damage was done to turret tops, rear deck armor, air intake grilles, and final drives. The napalm bombs would not have put the tanks out of action.
GENERAL: The report contains 40 pages.

SUBJECT: Tanks (Combat) APG Ar-17706
TITLE: Vulnerability of a Tank to 90-mm T108E15 Projectiles
IDENTIFICATION: Firing Record No. Ar-17706
DATE OF REPORT: 6 May 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effect of a projectile on a Medium Tank M26 fuel tank
METHOD: A five gallon varnish can was filled with diesel fuel and placed inside the target tank. A 90mm projectile was fired at the tank and the resulting damage recorded. The test was repeated six times using filled or partially filled varnish cans placed at various points in the tank for each test.
DESCRIPTION: Six rounds of 90mm, T108E15, HEAT-FS Projectiles with 2370 fps muzzle velocity were fired from an M3 Gun on a T99E2 Combination Mount mounted on an M26E5 Tank at the target tank from a range of 50 yards. The target tank was a burned-out, stripped, and previously fired on M26E4 Tank.
CONCLUSIONS: Four of the rounds started fires in the tank that were considered greater than the capacity of the vehicle fire fighting equipment to control. The other two rounds started fires of lesser intensities.
GENERAL: The report contains three pages and one photograph.

SUBJECT: Tanks (Combat) APG Ar-18098
TITLE: Vulnerability of a Tank Against 90-mm HEAT-FS Projectile
IDENTIFICATION: Firing Record No. Ar-18098; Project No. TB3-1224B
DATE OF REPORT: 23 January 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of a tank to 90mm HEAT-FS projectiles
METHOD: A 26E4 Medium Tank was stowed with gear including dummy shells and three-dimensional wooden dummies used to simulate the five-man tank crew. The tank engine and its electrical and radio systems were placed in operation, and the tank was attacked by 34 rounds of 90mm HEAT-FS T108E15 Projectile from various angles. The tank and its components were checked for damage after each round.
DESCRIPTION: The test tank was an M26E4 Medium Tank.
CONCLUSIONS: All but three of the projectiles hit the test tank. Test observers estimated that 15 direct hits and one round which detonated beneath the tank would have placed the tank out of action under actual battle conditions. Of 24 hits considered to provide possible penetration, 15 penetrations occurred, 12 of which were thought serious enough to put the tank out of action.
GENERAL: This 76-page report contains 22 photographs showing the condition of the tank and its components after the tests.

SUBJECT: Tanks (Combat) APG Ar-19274
TITLE: To Obtain Information on Effectiveness of Napalm Bombs Used Against U.S. M46 and U.S.S.R. T34/85 Tanks
IDENTIFICATION: Report No. Ar-19274; Project No. TB3-1224B

DATE OF REPORT: 8 July 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of U.S. M46 and U.S.S.R. T34/85 Tanks and their crews to napalm bombs
METHOD: A U.S. M46 and a U.S.S.R. T34/85 Tank were subjected to napalm bomb air attacks by F47, F80, and B17 Airplanes. Both of the tanks were stationary and their engines were operating, one under load. Three live goats were placed in the crew compartments of the tanks to determine the physiological effects of fire and carbon monoxide resulting from the bombs.
DESCRIPTION: The test ammunition consisted of E74 Firebombs, weighing 750 pounds and containing 100 gallons of jellied gasoline. Their containers were 137.31 inches long and had maximum diameters of 18.55 inches.
CONCLUSIONS: The tanks could not be put out of operation except by a direct hit of which there was only one. The goats were not seriously injured; slight burns on one goat were thought due to incomplete closure of the hatch. The test was suspended before completion due to insufficient hits and excessive costs.
GENERAL: This 33-page report includes seven photographs of the test tanks.

SUBJECT: Tanks (Combat) APG TB3-0035/4
TITLE: First Report on Napalm versus Russian T34 Tank
IDENTIFICATION: Fourth Report on Project No. TB3-0035; APG 10-244B
DATE OF REPORT: 21 April 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the effectiveness of Napalm against the Russian Tank T34
METHOD: The tank was placed on the range as the target. Three rounds of Napalm were individually detonated. Round one was placed above the center of the right top louver. Round two was faced 10 inches above the left center of the air outlet wire mesh grille over the transmission. Round three was placed the same as round one. Ten thermocouples were installed in the engine compartment and a gas analyzer extension tube was installed adjacent to the starboard air intake.
DESCRIPTION: The target was a Russian Tank T34. The Napalm for rounds one and two were contained in the M69 type bomb and for round three in the M74 type. Rounds one and two contained 2.6 pounds of Napalm and round three contained 2.5 pounds.
CONCLUSIONS: The tank was too well designed for the bombs to present a hazard. It was recommended that Napalm bombs not be considered as an antitank agent.
GENERAL: This 21-page report contains two photographs of the vehicle showing the results of the explosions.

SUBJECT: Tanks (Combat) APG TB3-0035/16
TITLE: Performance Characteristics of the Russian T-34 Medium Tank and the Russian V2-34 Diesel Engine
IDENTIFICATION: Sixteenth Report on Project No. TB3-0035
DATE OF REPORT: 30 October 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To supply engineering data for the evaluation of the Russian T34 medium tank and the Russian V2-34 Diesel Engine
METHOD: Field engineering tests conducted on the test vehicle included determining the drawbar pull, acceleration, maximum speed, full-load fuel consumption, road-load fuel consumption, resistance-to-towing, and cooling characteristics. A mock-up of the T34 tank engine compartment was constructed in the laboratory in order to determine net installed engine output and fuel consumption. Accessory losses were determined by removing the accessories and conducting a full-load full-throttle power test. Field tests were conducted on engine A(B2-805K8283) and C(B2-812K8526), partial tests on engine B(B2-906K132).
DESCRIPTION: The Russian Diesel engines, Model V2-34, "A", "B", and "C" were 12-cylinder, 60°V, 4-stroke diesel cycle, liquid-cooled, naturally aspirated engines. The vehicle tested was a Russian F34 medium tank weighing 66,400 pounds, and mounting an 85mm tank gun. It had a 4-speed spur gear transmission, which distributed equal power to each final drive. The suspension was of the helical spring type with five dual road wheels on each side and utilized a full-floating dry pin, loose all steel track, which had a center guide drive. Clutch-brake steering was employed with multi-disc type clutches and external-contracting type brakes with cast iron linings.
CONCLUSIONS: The vehicle and the engine could not be tested under conditions favorable to representative operation and performance, however, the performance was in general good when considering the high road load fuel economy and the acceleration characteristics. The combination of large-displacement high-torque Diesel engine, gear-type transmission with only four forward speeds, and low towing resistance was efficient and economical. It was recommended that all foreign automotive material, with designs different from standard Ordnance vehicles, and available to Aberdeen Proving Ground, be tested for performance and engineering design; also that an investigation be made of a diesel cycle engine design for use in Ordnance combat vehicles.
GENERAL: This 100-page report includes 27 photographs of the test equipment.

SUBJECT: Tanks (Combat) APG TB5-1401/118
TITLE: Desert Tests (1953) Tank, 120mm Gun, T43E1
IDENTIFICATION: One Hundred Eighteenth Report on Project No. TB5-1401
DATE OF REPORT: 3 December 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the over-all characteristics of the test vehicle during operation in desert terrain
METHOD: The test vehicle was operated over 1461 miles of varied terrain at Yuma Test Station, Arizona. Data were obtained on full-throttle cool-

ing, vapor lock characteristics, road-load and cross-country cooling, cross-country mobility, personnel compartment temperatures, auxiliary engine cooling, and fire control system performance.
DESCRIPTION: The tank 120mm gun, T43E1, was a heavily armored, full-tracklaying vehicle that mounted a 120mm gun, T123E1, in an equilibrated gun mount with a multiple cylinder recoil mechanism. Steel plate was added to the bottom of the hull to bring the vehicle gross weight to an estimated combat weight of 120,000 pounds. Power was supplied by a Continental Model AV-1790, 12-cylinder, V-type, air-cooled, gasoline engine driving through a Buick Model CD-850-4A cross-drive transmission. Other features included torsion bar suspension, dual road wheels, and T97 rubber tracks. The T41E2 range finder and T35 periscope were the only fire control components identified in the report.
CONCLUSIONS: Extrapolation of operational temperatures encountered indicated that the test vehicle would not cool satisfactorily when operating under a full load at an ambient temperature of 125°F. Vehicle cooling was considered borderline at an ambient temperature of 115°F and satisfactory at 100°F. The vapor locking characteristics were satisfactory. The personnel compartment temperatures did not severely impair crew efficiency. High ambient temperatures had no significant effect on fire control system performance. It was recommended that an investigation be conducted to obtain satisfactory engine oil and transmission oil temperatures for operation at an ambient temperature of 125°F.
GENERAL: This 109-page report includes five photographs showing several components of the test vehicle.

SUBJECT: Tanks (Combat) APG TT2-673/1
TITLE: Ballistic Test of the Cast Hull, Serial Number 45, for the 120-mm Gun Tank, T43
IDENTIFICATION: First Memorandum Report on Project No. TT2-673
DATE OF REPORT: 3 November 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of a cast tank hull
METHOD: The cast tank hull was subjected to direct frontal attack and 30° frontal flank with 90mm, T33 and 120mm, T116E4 Armor Piercing Projectiles. Damage to the hull was recorded and protection ballistic limits determined.
DESCRIPTION: The cast hull was for a 120mm Gun Tank, T43. It was a revised hull from one that had been previously tested. Design changes had been made to overcome weaknesses in protection exhibited by previous tests.
CONCLUSIONS: The revised T43 Tank hull provided improved protection against 30° frontal attack with 120mm AP T116E4 Projectiles on the upper front section. The test hull was considered a satisfactory improvement over previous T43 hulls.
GENERAL: This four-page report is not illustrated.

SUBJECT: Tanks (Combat) APG TT2-673/5
TITLE: First Report on Test of French 100-MM Gun Tank
IDENTIFICATION: Fifth Report on OCO Project No. TT2-673; APG 10-259
DATE OF REPORT: 14 November 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of the test French heavy tank as a combat vehicle; to obtain performance and design data for possible adoption to U.S. tanks
METHOD: The test tank was operated 286 miles on the Munson, Perryman, and Churchville test courses to determine its tactical and engineering characteristics. A total of 78 rounds of ammunition were fired in evaluating the effectiveness of the 100mm gun, the turret, and associated components.
DESCRIPTION: The design of the test French tank was based on the German Panther. It was a heavily armored, 117,400-pound vehicle powered by a Mayback V-12, liquid-cooled engine rated at 1000 hp at 2800 rpm. In addition to the 100mm gun, this tank carried three 7.5mm machine guns. A selective gear transmission, wet clutch steering, and a torsion bar suspension were utilized on this vehicle. The trunnion mounted turret was of the oscillating type. The gun slide, sight, mechanical loader, and rammer were fixed to the turret and oscillated as a unit in elevation and depression about a trunnion mounting on the turret skirt. The elevating system had both mechanical and hydraulic drive systems integrated in one cylinder assembly, with turret balance provided by a hydraulic equilibrator. The turret skirt, carrying the oscillating turret, was driven by a conventional traversing system that included both hydraulic and manual control.
CONCLUSIONS: In general, many deficiencies were noted, a few are given in the brief on Report No. APG 10-262. The oscillating turret, however, was thought to offer several advantages such as simplicity of gun mount, ammunition handling, and sight installation; good utilization of turret space; low silhouette; and possible weight savings in armor. It was recommended that this type of turret be considered for U.S. combat vehicle design.
GENERAL: This 180-page report includes 28 photographs of the test vehicle, its components and laboratory test setups. Operating data, curve sheets, and a description of the French tank are also included.

SUBJECT: Tanks (Combat) APG TT2-673/6
TITLE: Second and Final Report on Test of French 100-MM Gun Tank
IDENTIFICATION: Sixth Report on Project TT2-673; APG 10-262
DATE OF REPORT: 22 January 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the characteristics of the French 100mm gun tank to those of the equivalent American vehicles
METHOD: Data on the following features of the French tank were collected for comparison purposes: ballistic characteristics; firing accuracy, turret design, gun installation, ammunition

handling, vulnerability, turret and gun control systems, road performance, steering and turning characteristics, and ease of maintenance.
DESCRIPTION: The test French 100mm gun tank was described in Report No. APG 10-259.
CONCLUSIONS: The oscillating turret of the tank eliminated relative motion between the gun and turret; this simplified gun mount design and permitted an integral mantlet at the front of the turret. The method of equilibration used to balance the muzzle-heavy turret and gun combination, however, resulted in high elevation cranking torque and gun instability during rapid fire. In addition, the turret control systems had a high degree of backlash that reduced potential accuracy and speed of gun lag. Although the armor penetration characteristics of the French 100mm gun compared favorably with those of U.S. 90 and 120mm tank guns, the effectiveness of the French tank in bringing fire to bear quickly and accurately on tank-size targets was inferior to that of U.S. tanks due to limitations of the fire control, turret drive, and equilibration mechanisms. It was recommended that a redesigned application of the oscillating turret principle be considered for U.S. tanks.
GENERAL: This 29-page report contains 12 photographs of the test vehicle and comparable American vehicles.

SUBJECT: Tanks (Combat) APG TT2-673/11
TITLE: Ballistics Test of the Design Cast Hull for the 120mm Gun Tank T-43
IDENTIFICATION: Eleventh Report on Project No. TT2-673
DATE OF REPORT: 28 October 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the protection afforded by the revised design cast hull, serial No. 45, with cast hull, serial No. 13, for the 120mm gun tank, T43
METHOD: The two hulls were measured for thickness by means of calipers and a supersonic reflectoscope and also were subjected to radiographic examination. The hulls were then mounted on turntables to give the desired angle of attack. Each hull was subjected to direct frontal attack and to a 30° flank attack from the longitudinal axis of the hulls on the upper front area and the lower frontal area, by using the following projectiles: 120mm, AP, T116E4, Shot, w/windshield, Lot MDV -1-1 and 90mm, AP, T33, Shot, w/windshield, Lot FA-2.
DESCRIPTION: The two test hulls were furnished by General Steel Castings Corporation.
CONCLUSIONS: The frontal areas of the revised design of cast hull for the 120mm gun tank T43 as represented by hull serial 45 afforded greatly improved protection against ballistic attack as compared to earlier hull designs for the same tank. It was recommended that the revised design of T43 tank hull be considered satisfactory.
GENERAL: This 85-page report contains 14 photographs of the test hulls.

SUBJECT: Tanks (Combat) APG TT2-674/2
TITLE: First Report on Test of Light Tank, French
IDENTIFICATION: Second Report on Project No. TT2-674
DATE OF REPORT: 17 February 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate the French light tank with respect to overall design, methods of construction and vehicular and component construction; and to study characteristics which would be applicable in future Ordnance Corps design in combat vehicles
METHOD: The test tank was subjected to engineering, operational and firing tests. In 211 miles of operation over the Munson, Churchville, and Perryman automotive test courses, the tactical and technical characteristics were determined. To evaluate the turret, its components, and the effectiveness of the primary weapon, 107 rounds of 75mm ammunition were fired.
DESCRIPTION: The French light tank was a post-World War II development of the French Military Establishment designed to meet the requirement for a modern air-borne light tank capable of accomplishing reconnaissance or other missions normally assigned to light tanks. The tank chassis could be universally employed for tank, antiaircraft, or self-propelled artillery use by means of interchangeable turrets which mounted a 75mm cannon, two 40mm or four 20mm guns, or a 105mm howitzer. The light vehicle weight of 31,140 pounds, combat loaded, and a 75mm gun capable of delivering an armor piercing round at 3280 feet per second were combined with a low silhouette made possible by the unique oscillating turret design. The power plant, mounted in the forward portion of the hull, combined a 270 hp, liquid-cooled, horizontally-opposed, 8-cylinder engine with a conventional type selective gear transmission through a double-disc clutch.
CONCLUSIONS: The French vehicle generally conformed to accepted standards of light tank performance, but many specific design defects enumerated in the report required correction before it could be considered acceptable for field use. It was recommended that the oscillating turret be investigated for applicability to U.S. combat vehicle design, particularly as a basis for a stabilized turret system; that the mechanical ammunition handling system also be studied for application to U.S. vehicles; and that the test vehicle, or a pilot model to be constructed, be modified to incorporate the improvements in design recommended in this report before quantity production by the French government.
GENERAL: This 98-page report includes 11 photographs of the test tank and components.

SUBJECT: Tanks (Combat) APG TT2-674/3
TITLE: Second and Final Report on Test of French Light Tank
IDENTIFICATION: Third Report on Project No. TT2-674; APG 10-244A
DATE OF REPORT: 25 July 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the design, methods of construction, and performance of the 12-ton French Light Tank AMX

METHOD: The vehicle was subjected to field engineering tests to determine engine performance, mobility, gun control and general characteristics.
DESCRIPTION: The test French 12-ton Light Tank AMX mounted a 75mm gun in an oscillating turret controlled in elevation by a shock-mounted, hydraulically-driven screw. The power plant was an 8-cylinder, liquid-cooled, horizontally-opposed engine rated at 270 hp at 3250 rpm. A conventional selective gear transmission and a double-disc clutch were used. The suspension was of the torsion bar type with individually sprung wheels.
CONCLUSIONS: The test vehicle had satisfactory speed, acceleration, and braking characteristics, and the turret elevation system acted as an effective traveling lock. Faults were as follows: elevation and traversing handwheel efforts were too great; unsatisfactory tracking characteristics; clutch capacity was too small; excessive track power losses; and the poor mechanical condition of the engine produced erratic performance.
GENERAL: This 51-page report contains eight photographs of the vehicle.

SUBJECT: Tanks (Combat) APG TT2-674/9
TITLE: Second Report on Engineering and Operational Test of Tanks, 75 MM Gun, T41E1
IDENTIFICATION: Ninth Report on Project No. TT2-674; APG 10-264
DATE OF REPORT: 10 January 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine performance and durability of late production T41E1 Tanks with emphasis on fuel consumption
METHOD: Several modified T41E1 Tanks with face-type oil seals on all suspension components, heavier section road wheel support arms and redesigned support arm bumper stop assemblies, improved final drive components and torsion bars, and redesigned tracks were given performance tests by repeated cycles of operation on hard-surface, gravel, and cross-country courses. Fuel consumption analysis and performance characteristics were determined with the following variation in high-range transmission operation: converter lockup at 32 mph (normal), converter lockup at 20 mph (minimum speed), and converter lockup feature blocked out.
DESCRIPTION: The 75mm Gun Tank T41E1 was a revised version of Light Tanks T37 and T41. Designed primarily for reconnaissance and suitable for airborne operations, it was lightly armored and weighed 51,000 pounds combat-loaded. This vehicle was powered by a 500 hp, air-cooled, supercharged, six-cylinder, horizontally-opposed, AOS-895-3 gasoline engine and equipped with a cross-drive CD-500-3 transmission. A top speed of 46 mph was possible. A single pin, rubber-bushed Track T91E3 with detachable rubber pads was used.
CONCLUSIONS: Except for high fuel consumption, performance characteristics and other design features were good. Over-all fuel economy could have been improved by extending the transmission lockup operation, and lowering top speed by increasing final drive ratio in combination with the use of an non-supercharged AO-895 engine. While improved over previous models of Tanks T41E1 durability of some components was still poor. It was recommended that provision be made for optional use of lockup at low speeds and that the vehicle be tested with increased final drive ratio and a naturally aspirated engine.
GENERAL: This 139-page report includes 16 photographs of the vehicle and components.

SUBJECT: Tanks (Combat) APG TT2-685H/2
TITLE: First Report on Evaluation of Jump in Tank Guns
IDENTIFICATION: Second Report on Project No. TT2-685H
DATE OF REPORT: 27 April 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To study the effects of jump in tank gunnery
METHOD: Testing was conducted using M41, M47, and M48 tanks mounting the 76mm T91E3, 90mm T119E1, and 90mm T139 guns, respectively. Standard ammunition components were utilized, and a total of 730 rounds were fired.
DESCRIPTION: Methods for obtaining jump data were based on a general procedure outlined in the report. The "apparent jump" considered in this study was defined as the angle formed by a reference line passing through the gun bore before firing, and the projectile's line of departure. Jump data were recorded using various muzzle attachments on the guns. Studies were made concerning the influence of solar radiation, droop, and tube warmup on jump characteristics.
CONCLUSIONS: Jump in tank gunnery was considered a source of error equivalent in order of magnitude to that of cross wind and trunnion cant, which unless corrected would ultimately limit first round hit probabilities. The ultimate stipulation was made in that the elimination of jump without equal consideration devoted to reducing cross wind, cant, parallax, drift, and linkage errors would not greatly improve hitting accuracy of tanks which were then considered current design. It was recommended that studies be initiated to fully define and isolate sources of jump error in tank mounted weapon systems with the ultimate aim of eliminating the major components of jump by redesign of the gun and gun mount, application of corrections to fire control systems, or modifying gunner techniques. Several other specific conclusions and recommendations were included in the report.
GENERAL: This 63-page report contains one photograph of a test vehicle.

SUBJECT: Tanks (Combat) APG TT2-741/1
TITLE: Final Report on Tank, 90mm Gun, T49 (U)
IDENTIFICATION: First Report on Project No. TT2-741
DATE OF REPORT: 6 October 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the feasibility of up-gunning the tank; and to evaluate the performance of the fire control and gun control systems
METHOD: Two pilot models of the tank were

tested at Aberdeen Proving Ground. The first was used for all tests in accordance with 14 features of the Ordnance proof manual; the second was used to check and verify data, when necessary, and for spare parts. A total of 369 rounds of mixed HE, HEP, and HEAT ammunition were fired. The vehicle was operated for 500 miles cross-country for an endurance test of experimentally mounted components.
DESCRIPTION: The pilot vehicles, developed by the United Shoe Machinery Company, were basically the 76mm gun tank, M41A1, armed with a low pressure 90mm gun, T132 type, with a "Quick-change" tube feature. The gun mount incorporated an improved, concentric recoil mechanism. Primary fire control was accomplished by the previously-tested system of the M47 tank, including a stereoscopic rangefinder, type T41. The hydraulic gun control system of the M41A1 tank was replaced by an experimental Amplidyne electric gun control system for gunner and commander.
CONCLUSIONS: Use of the low pressure 90mm gun was an effective method of up-gunning the light tank, M41A1, within the limitations of provided ammunition types. The superior armor defeating capabilities of HEAT ammunition were seriously limited in this application by large dispersion results. Dispersion and accuracy of fire were satisfactory as the primary armor defeating round for the T49 tank. The gun mount was basically satisfactory, pending minor design changes. The rangefinder required mechanical design corrections to provide correct superelevation values and to improve its boresight retention characteristics. The experimental Amplidyne gun control system was suitable for its application in the 90mm gun tank, T49. It was recommended that use of low pressure guns be considered a satisfactory approach to increasing tank fire power at minimum expense in weight, but that effectiveness be considered limited by performance of current low and medium velocity armor defeating projectiles.
GENERAL: This 129-page report includes 12 photographs of the test vehicle and components.

SUBJECT: Tanks (Combat) APG TT2-757/3
TITLE: Test of Tank, Flame Thrower, T67
IDENTIFICATION: Third Report on Project No. TT2-757
DATE OF REPORT: 25 October 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of a T67, flame thrower tank for use as a carrier of flame thrower equipment
METHOD: The test vehicle was inspected. Following firing tests with the flame gun, the vehicle was subjected to engineering tests, which included determinations of the center of gravity, stability of vehicle components on a 30% side slope, forward performance on various slopes, and total weight distribution. During 73 miles of vehicle cross-country operation, special emphasis was placed on determining the effects of shock on flame thrower components. An evaluation was made of the secondary armament. Performance characteristics of automotive and flame thrower components were checked in a coldroom.
DESCRIPTION: The test T67, flame thrower tank was basically a T48 tank fitted with an E-30-R-1, heavy duty, flame gun in place of the standard 90mm gun installation. Standard gun controls with a foot button for firing of the flame and a flame fuel unit, E28, were included. The exterior design features of the flame gun were similar in appearance to the standard 90mm gun. The manufacturer of the vehicle was the Chrysler Corporation.
CONCLUSIONS: The vehicle was satisfactory as a carrier for the flame thrower equipment. Automotive characteristics were essentially the same as those for the M48 tank. The auxiliary engine of the vehicle failed to start during low temperature testing. Certain components of both the flame equipment mounting and the machine gun installation were unsatisfactory. The vehicle was recommended for acceptance after deficiencies noted in the report were corrected.
GENERAL: This 66-page report contains 19 photographs of the test vehicle and components.

SUBJECT: Tanks (Combat) BRL 107
TITLE: A Model of Tank Warfare Including the "Concept" of Mobility
IDENTIFICATION: Technical Note No. 107; Project No. TB3-1224B
DATE OF REPORT: August 1949
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To determine the factors which would be essential in increasing the effectiveness of tank weapons against primary targets
METHOD: An analysis was made of the effectiveness of a tank force to invade enemy held positions and destroy desired targets. Various assumptions were used as the basis for developing equations which would permit evaluation of such an attack assuming that an equivalent number of enemy tanks were incorporated in defense of the targets.
DESCRIPTION: The analysis was primarily based on the assumption that the primary purpose of a tank was to attack infantry and lightly defended positions. Performance of the tanks when engaging another tank was considered as a secondary purpose.
CONCLUSIONS: Results of the study were considered to be useful, to a limited degree, in indicating the effectiveness of the weapons of a tank force during an attack on primary enemy targets. The study also indicated how mission effectiveness varied with the armor, armament, and mobility of both attacking and defending tanks. The study, therefore, was considered a rational basis, subject to all the assumptions and simplifications of the examples and results acquired, for determining the design requirements of a tank. Because of the very preliminary nature of the methods developed in the analysis, no actual solutions to the example were made; however, it was felt that further studies along the lines described in the report would yield useful results. Comments and discussion of the assumptions and arguments presented in the study were desired.

GENERAL: This seven-page report contains two drawings depicting the hypothetical case upon which the analysis was made.

SUBJECT: Tanks (Combat) BRL 505
TITLE: An Introductory Study of the Characteristics of Tanks, Guns and Armor
IDENTIFICATION: Report No. 505; Project No. TB3-1224B
DATE OF REPORT: February 1950
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To investigate some of the relationships which exist between guns and armor
METHOD: Preliminary observations were made on the basic characteristics of tanks and their targets, and on the symbiosis of guns and armor. Discussions were presented on the tank versus infantry armor; armor and the weapons that defeat it; empirical approximations; projectile weights: guns firing APC projectiles versus homogeneous armor; the tank, its gun and armor; the mobile antitank weapon; the super tank problem; probability of hitting; tank vulnerability; armor distribution; other aspects of the tank problem; and some empirical relations correlating tank characteristics.
DESCRIPTION: The discussions on the topics outlined above were confined to weapons similar to existing "tanks", i.e., gun-bearing vehicles, moving on the ground, and protected by armor.
CONCLUSIONS: In all classes of tanks the gun was fundamentally more important than the armor. The only ultimate defense of a tank against a mobile weapon of equal weight was considered to be its own gun. Tank armor was important to defend it against the most common infantry weapons, but it was concluded that it could always be defeated by an adequate gun carried in a lighter, cheaper, and more mobile vehicle. An improvement of tank offensive weapons was recommended.
GENERAL: This 87-page report contains charts, graphs, and 56 pages of appendix material.

SUBJECT: Tanks (Combat) BRL 590
TITLE: The Range and Angular Distribution of AP Hits on Tanks
IDENTIFICATION: Report No. 590; Project No. TB3-1224B
DATE OF REPORT: December 1951
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To determine the probable ranges of engagement and angles of attack in tank and antitank engagements
METHOD: Data from studies of tank casualties in Northwest Europe in World War II were analyzed, and mathematical formulas were developed for calculating the probable frequency of any angle of attack and of any range of engagement. Frequencies determined by the formula for probable angle of attack were checked against the data, and for probable range were checked against a combat map.
DESCRIPTION: Data on the ranges and angle of attack were taken from intelligence reports of the U.S. First and Third Armies and from a British report, "Survey of Casualties Amongst Armored Units". Range probability was checked against a 1:50,000 scale map of the region of Mortain, France.
CONCLUSIONS: The probable frequency of angle of attack could be expressed as $F(\theta) = \frac{1}{2\pi}[1 + a \cos(\theta)]$ where a = 1 for the hull and 3/4 for the turret. The probable frequency of any range of engagement could be expressed as $F(R) = \frac{4}{R^{-2}} Re^{-2R/\overline{R}}$, where R is the average range as determined by the terrain. It was concluded that the distribution of tank combat ranges was determined by terrain and that the range of future tank engagements could be obtained by map studies of the region in which the battles were expected.
GENERAL: This 42-page report contains 15 curve sheets.

SUBJECT: Tanks (Combat) BRL 727
TITLE: Armor Distribution on the T43 Tank
IDENTIFICATION: Report No. 727; Project No. TB3-1224B
DATE OF REPORT: September 1953
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To present probability of penetration to fire analysis for the equivalent armor of a T43 Tank
METHOD: Design drawings of the T43 Tank were used for computing equivalent armor thickness. Various types of projectiles were considered. Probability curves of the projectiles hitting various thicknesses of armor were determined. Distribution curves of obliquity of presented armor to random hits were made. Comparisons were made between the T43 Tank and the Soviet JS III Tank.
DESCRIPTION: The design drawings, of T43 Tank referred to, were as of October 1952. Types of projectiles considered were AP, HVAP, HEAT, and HEP.
CONCLUSIONS: Data were presented on random hits considering only ground attacks. Exterior components reduced the armor perforation of the various projectiles up to 29%. The front armor of the T43 Tank gave better protection than the Soviet tank. There was a 40 to 58% probability that armor encountered would not be thicker or more oblique than the upper glacis plate of the T43 Tank. Probability of perforating the T43 Tank by a random hit by an infinitely powerful armor piercing projectile from any azimuth was .73.
GENERAL: This 44-page report includes an appendix.

SUBJECT: Tanks (Combat) BRL TN-472
TITLE: Estimates Concerning the Vulnerability of the Russian T34/85 Tank to the 3.5-inch and 2.36-inch Hollow Charge Weapons
IDENTIFICATION: Technical Note No. 472; Project No. TB3-1224B
DATE OF REPORT: August 1951

ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of a Russian tank to hollow charge weapons
METHOD: Drawings of top, front, and side were made of the Russian T34/85 Tank showing the thickness of armor and vulnerable areas. Data from tests of hollow charge projectiles on T26E4 Tanks were used as basis for the effect of the projectiles on various thicknesses and designs of Russian armor. Probabilities of damage to fire power or mobility and probabilities of a kill on the tank were computed for several shells from various air and ground attack angles. Also, the probabilities of damage to tank components and crew were computed.
DESCRIPTION: The projectiles considered were the 2.36 and 3.5-inch HEAT rockets. This study was conducted at the request of the Air Force.
CONCLUSIONS: Probabilities for damage to mobility and fire power, and probabilities for a kill were listed for the two types of rockets at 0 and 30° elevation angles. The results obtained were at the best only fairly good estimates. Accurate data could be obtained only by improved methods of evaluating damage and improved procedures for calculating vulnerable areas.
GENERAL: This 38-page report contains charts and graphs showing the derivation of the probabilities.

SUBJECT: Tanks (Combat) BRL TN-727
TITLE: BRL Tank Effectiveness and Vulnerability Work
IDENTIFICATION: Technical Note No. 727; Project No. TB3-0230A
DATE OF REPORT: September 1952
ORIGIN: Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland
PURPOSE: To review the tank effectiveness and vulnerability analysis program at the Ballistics Research Laboratory
METHOD: The work of the Ballistics Research Laboratory in developing methods of tank effectiveness and vulnerability analysis was described.
DESCRIPTION: Basic vulnerability data obtained from firing tests at Aberdeen Proving Ground were assessed as to probability of kill or damage, and these basic data were used to evaluate other tanks after correction for such differences as armor thickness and obliquity, and location of vital components. Vulnerability studies of tanks to HVAP, AP, HEAT, and HEP rounds and to land mines and fire bombs were made. Studies were made to determine the distribution of directions of attack and range at which tank combat took place. Advantages of a range finder and a gyrostabilizer were studied, and studies were proposed for evaluating such variations as gun caliber, muzzle velocity, armor, horsepower. Methods for determining optimum armament based on enemy armor and for determining optimum armor based on enemy armament were also considered.
CONCLUSIONS: The BRL methods for tank vulnerability and effectiveness of analysis were considered to be approaching a point where concrete information could be made available. It was believed that useful information for tank and weapon design would result at a continually increasing rate.
GENERAL: This seven-page report contains a bibliography listing 27 related publications.

Section 42
TEST EQUIPMENT

SUMMARY

The subject, Test Equipment, was not summarized because of the limited scope of the test equipment reports briefed to date. When a sufficient number of test equipment reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Test Equipment APG 2689
TITLE: Positional Control Components Assembly
IDENTIFICATION: Report No. 2689
DATE OF REPORT: 9 November 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To devise a positional control reference for servo analysis
METHOD: A pair of single synchro differential generators were assembled with a turret mock-up using a circuit whose output was fed into the traverse circuit of the electric system described in Report No. 2014. The load synchro was installed with 180° movement of the synchro equal to approximately 100° movement of the turret mock-up. Test of the controls was made by reference to the azimuth indicator.
DESCRIPTION: None.
CONCLUSIONS: This positional control will provide accuracy of control within 0.1 mil and indexing control within 0.25 mil. It was recommended that this control be refined and considered for application to mobile artillery vehicles, particularly those requiring indexing to 10° elevation for loading.
GENERAL: This five-page report includes one wiring diagram of positional control and two photographs of the test components.

SUBJECT: Test Equipment FA R-949
TITLE: Firing Mechanism, Bomb Tester T4, the Electronic Control and Recorder
IDENTIFICATION: Report No. R-949
DATE OF REPORT: 15 December 1949
ORIGIN: Frankford Arsenal, Philadelphia, Pa.
PURPOSE: To review the research leading up to the design of the electronic control and recorder for the bomb tester T4
METHOD: The electronic control and recorder were installed for proof firing and general testing of the 75mm gun T85 which was a smaller bore gun of the same length as bomb tester T4. In some 30 firings of the 75mm gun T85, the equipment never caused a misfire or failed to record the interior ballistics. The stage was reached in which two charges were fired successively. Besides reviewing the development and design of this equipment the methods of calibration and the reading of the records were discussed.
DESCRIPTION: The electric control and recorder for the bomb tester T4 was a device developed for automatically firing and recording the internal ballistics of the weapon which was used for proof testing bombs against concrete fortifications. A more detailed description of the bomb tester T4 and the instrumentation is included in the body of this report.
CONCLUSIONS: Detailed recommendations were made for changes in the recorder unit and for the wiring at the gun when the bomb tester T4 was finally assembled.
GENERAL: This 37-page report includes two photographs of the test equipment and 11 schematic and block diagrams.

Section 43
TESTS, SPECIAL, MISCELLANEOUS

SUMMARY

The subject, Tests, Special, Miscellaneous, was not summarized because of the limited scope of the tests, special, miscellaneous reports briefed to date. When a sufficient number of tests, special, miscellaneous reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

APG TB5-1401/126

SUBJECT: Tests, Special, Miscellaneous
TITLE: The Ordnance Corps Envanal Chart. First Report on Project Envanal
IDENTIFICATION: One Hundred Twenty-sixth Report on Project No. TB5-1401
DATE OF REPORT: 24 August 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To develop an effective method for recording data reflecting the performance of Ordnance equipment, and for the comparative presentation of such data to indicate performance limitations under various world-wide environmental conditions
METHOD: Studies were conducted to define in over-all terms those environmental factors which could prove hazardous to the satisfactory operation of military equipment, and to establish from these studies a rating scale by which equipment performance could be graded.
DESCRIPTION: The typical Envanal chart (Appendix A of the report) was an accumulation of test data submitted by project engineers based on the test results from the Summer Climatic Tests, 1952, at Yuma, Arizona, and the Arctic and Winter Climatic Tests, 1952-1953, at Fort Churchill, Canada, and Devils Lake, North Dakota.
CONCLUSIONS: The Envanal chart (an environmental analysis) was considered a useful and practical means of producing data and information essential to the selection of army equipment for strategic use, and research and development programming and testing. The over-all approach to the selection of appropriate environmental factors for the Envanal chart was also considered suitable. The Envanal rating form assisted Ordnance engineers in the preparation of formal test reports by indicating comparative aspects of the environment that were important to the proper analysis of equipment performance. It was recommended that the Ordnance Corps continue the development of the Envanal chart in general over-all terms. On the basis of the tests and field observations, modifications were made to improve the definition of the rating scale factors, and to expand and clarify the scope of the scale.
GENERAL: This 54-page report is not illustrated.

APG TT1-698/4

SUBJECT: Tests, Special, Miscellaneous
TITLE: Some Predictions of Vehicle Performance by Means of Laboratory Methods
IDENTIFICATION: Fourth Report on Project No. TT1-698
DATE OF REPORT: 9 February 1949
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the practicability of laboratory methods for determining the tractive and flotation characteristics of vehicles in known soil conditions
METHOD: Two identical cargo carriers M29C were fitted with different tracks. By varying the gross vehicle weight from 5500 to 4500 pounds, the tractive effort of the two vehicles in Munson Loam was measured with standard Aberdeen equipment. Tests on model plates were also conducted in the Soil Laboratory in the same type of soil and on the basis of laboratory and field tests. Expected and actual trafficability curves were plotted and compared.
DESCRIPTION: The two cargo carriers M29C were identical except for the tracks. One was fitted with a standard closed M29C track, 20 inches wide, with links altered by adding 3-inch high grouser plates on each leading edge. The second vehicle was equipped with a track of the same design except that 4-1/4-inch at each end of every second track link had been removed. The laboratory used a mock test setup with scaled model tracks and spacing.
CONCLUSIONS: The estimated tractive effort based on scale model tests was proved to be reasonably accurate by means of full size vehicle field tests, and the basic concepts of grip and ground failure of soil under vehicle action appeared to be correct. The method proposed for estimating vehicle performance by means of laboratory tests appeared to have great potential value for application to trafficability problems of design and soil intelligence. It was recommended that a test of a full size vehicle, with properly designed spaced-link tracks, be pursued and that the methods of laboratory investigation be expanded to embrace non-homogeneous soil media.
GENERAL: This 36-page report includes nine

photographs of the field test vehicles and laboratory test setup.

DA 3195 F

SUBJECT: Tests, Special, Miscellaneous
TITLE: Intensity of Infrared Radiation Emitted by Various Material
IDENTIFICATION: Report No. 3195 (Final)
DATE OF REPORT: 7 February 1955
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the ability of ceramics and paints to reduce emitted infrared radiation
METHOD: The ceramics and paints were coated on panels of low carbon steel. A type 16 SAE stainless steel panel was used as a standard in determining the effectiveness of the coatings in reducing surface temperatures. The stainless steel reference and coated panels were mounted on a fixture and inserted in the opening of a refractory type, electrically heated, muffle furnace. While the temperatures of the stainless steel standard were held constant, the surface temperatures of the coated ceramics panels were measured. Temperatures of 150, 300, 500, 750, and 1000°F were used.
DESCRIPTION: The test items included 16 specimens of ceramic materials; high temperature aluminum paint and olive drab enamel were also tested. Manufacturers of the ceramics were the California Metal Enameling Company, Toledo Metal Enameling Company, Wolverine Porcelain Enameling Company, Erie Enameling Company, and the Seapercel Company. The Aluminum paint was made by Libby-Owens-Ford.
CONCLUSIONS: The ceramic coatings did not effectively suppress infrared radiation emitted at wave lengths longer than 3.7 microns. Tests indicated that the best material for suppressing radiant flux density was the aluminum paint, which lowered the infrared energy by 50% at temperatures between 150 and 500°F. It was recommended that future investigation on infrared suppressive ceramics be limited to the development and evaluation of coatings expressly formulated for their suppressive properties.
GENERAL: This 50-page report contains three photographs of test equipment. Also included are tables showing the radiant flux of the test material.

DA 3196F

SUBJECT: Tests, Special, Miscellaneous
TITLE: The Spectral Reflectance of Ordnance Materials at Wavelengths of 1 to 12 Microns
IDENTIFICATION: Report No. 3196 (Final)
DATE OF REPORT: 8 February 1955
ORIGIN: Detroit Arsenal, Center Line, Michigan
PURPOSE: To determine the spectral reflectivity of various Ordnance materials in the spectral region of 1 to 12 microns
METHOD: Preparation of the sample materials was outlined in the report. Through the use of a hemispherical integrating sphere in conjunction with a Perkin-Elmer recording spectrometer it was possible to irradiate test specimens with nearly monochromatic radiation in the determination of infrared reflectance. Freshly deposited magnesium oxide was used as a reflectance standard for diffuse reflectance measurements; a freshly aluminized front surface mirror was used as a standard for specular measurements. Spectral reflectivity data were presented as a function of wavelength in the spectral region of 1 to 12 microns in 1 micron increments.
DESCRIPTION: The test Ordnance materials were categorized into the following groups: wood, paper products, ceraminc coatings, paints, mirrors, metals, fabrics, standard ducks, uniform fabrics, and miscellaneous. Manufacturers were listed in the report.
CONCLUSIONS: Values of infrared reflectivity for the various materials were listed in the report. Materials which appeared to reflect highly in the visible spectrum also tended to reflect highly in the infrared. Chemical composition of a material, as well as physical characteristics of the surface, affected reflectivity. To camouflage an Ordnance vehicle from active infrared detectors, low reflecting materials should be utilized on all exposed surfaces. By special formulation and compounding, it would be possible to produce a variety of material with a desired infrared reflection range. It was recommended that the reflectivity values in this report be used only as a guide in qualifying Ordnance materials and that further investigations concerning the infrared properties of materials be conducted. It was also recommended that specifications for exposed vehicle surfaces include limitations on infrared resistance.
GENERAL: This 68-page report contains four photographs of test equipment. Also included are graphs showing spectral reflectivity of the materials.

PA TB4-521/1

SUBJECT: Tests, Special, Miscellaneous
TITLE: Effect of Rubber Compositions Upon the Stability of Explosives
IDENTIFICATION: First Report on Project No. TB4-521; PA Report No. 1797
DATE OF REPORT: 20 February 1951
ORIGIN: Picatinny Arsenal, Raritan, New Jersey
PURPOSE: To determine whether representative rubber compositions had seriously adverse effects on the stability of explosives and propellants
METHOD: Twenty-four rubber-type compositions were given a 100°C, 40-hour vacuum stability test.
DESCRIPTION: The code designation or chemical name, the commercial designation, and the source of supply of the 24 rubber-type polymers were shown in the report.
CONCLUSIONS: Ten representative rubber compositions had no seriously adverse effects on the stability of 16 explosives and one composite propellant listed in the report. The polysulfide rubber composition seriously affected 60/40 amatol and 50/50 pentolite, although it did not seriously affect the other explosives or the composite propellant. The isobutylene-isoprene rubber composition seriously affected 50/50 pentolite but none of the other explosives or the composite propellant. The 10 representative rubber compositions had no seriously adverse effects on the stability of one double base propellant (M9) and one single base propellant (Powder, Smokeless, for cartridges Cal. .45, M1911, USA Specification FXS-

426). It was recommended that vacuum stability tests be performed with each new rubber composition that is contemplated for use in contact with an explosive or a propellant; that 60/40 amatol not be used in contact with compositions containing polysulfide rubber unless specific tests have been conducted which demonstrate that the particular rubber composition in question is free of adverse effects on the explosive; that 50/50 pentolite not be used in contact with compositions containing either polysulfide rubber or isobutylene-isoprene rubber unless specific tests have been conducted which demonstrated that the particular rubber composition is free of adverse effects on the explosive; and that the results of the accelerated tests be correlated with the results of long-term-storage tests.
GENERAL: This 44-page report is not illustrated.

PA TB4-521/2

SUBJECT: Tests, Special, Miscellaneous
TITLE: Effect of Rubber Compositions Upon the Stability of Explosives
IDENTIFICATION: Second Report on Project No. TB4-521; PA Report No. 1885
DATE OF REPORT: 5 January 1952
ORIGIN: Picatinny Arsenal, Raritan, New Jersey
PURPOSE: To establish an accelerated test suitable for determining whether rubber compositions had a serlously adverse effect on the stability of exolosives and propellants
METHOD: Vacuum stability tests were performed according to standard procedure. For explosives and T9 composite propellant, the vacuum stability test temperature was 100°C, while 90°C was used for the single-base propellant and M9 propellant powder. In each case, the test was conducted for 40 hours.
DESCRIPTION: The code designation or chemical name, the commercial designation, and the source of supply of 26 rubber-type polymers were shown in the report.
CONCLUSIONS: The 100°C, 40-hour vacuum stability test was a suitable accelerated test to determine whether compositions based on four certain rubber polymers had an adverse effect on the stability of 16 certain explosives and the T9 composite propellant. The 100°C 40-hour vacuum stability test was recommended for use to determine whether compositions based on polychloroprene-isoprene had an adverse effect on the stability of 15 certain explosives. In general, the majority of the rubber compositions did not affect the stability of the explosives and propellants investigated. A sufficient number of exceptions were noted, however, so that the stability of these materials should be checked whenever it was contemplated that they be used in contact with rubber compositions. It was recommended that additional work be conducted to determine suitable test conditions for an accelerated means of determining whether rubber compositions had a seriously adverse effect on the stability of 75/25 tetrytol, black powder and M9 propellant powder.
GENERAL: This 46-page report is not illustrated.

Section 44
TIRES and TUBES

SUMMARY

The subject, Tires and Tubes, was not summarized because of the limited scope of the tires and tubes reports briefed to date. When a sufficient number of tires and tubes reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Tires and Tubes N-251
TITLE: Russian Synthetic — 6.00 x 16 Highway
IDENTIFICATION: Test N-251
DATE OF REPORT: 30 July 1943
ORIGIN: Ordnance Tire Test Fleet, Normoyle Field, San Antonio, Texas
PURPOSE: To determine the comparative durability of Russian and General Tire Co. 6.00 x 16 synthetic rubber tires
METHOD: The Russian and control tires were mounted in a staggered arrangement on 1/4-ton, 4x4 Ford reconnaissance cars. Front and rear tire loads were 650 and 915 pounds and all tire pressures were 30 pounds. Vehicle operation was over varied terrain. All the original tires accumulated approximately 5000 miles.
DESCRIPTION: The test 4-ply, synthetic rubber, cotton constructed tires were of Russian manufacture. The control tires were manufactured by General Tire Company and were of 100% synthetic rubber and 6-ply cotton construction. All tires were 6.00 x 16.
CONCLUSIONS: The Russian tires were superior from the standpoint of tread cutting, cracking, and chipping. However, their tread life was determined to be less than one-half of that calculated for the control tires.
GENERAL: This 14-page report contains seven pages of photographs showing the tires after test.

Section 47

TRACKS

SUMMARY

This summary covers resumes of six reports written on tracks between 1947 and 1952 at Aberdeen Proving Ground, Maryland; and Army Ground Forces Board No. 2 and Army Field Forces Board, both at Fort Knox, Kentucky.

EFFECTIVENESS OF MINES AGAINST TANK TRACKS

A test was conducted in 1952 to determine the performance of various types of tank tracks subjected to mine attack. Four types of tracks mounted on tanks were tested with a total of 60 light antitank mines, M7. The test material consisted of U.S. T80E6 tank track equipped with closed-type end connectors; U.S. T80E1 tank track equipped with open-type end connectors; U.S. T81 single-pin track; and a Soviet single-pin track. The single-pin T81 track was the strongest of the test tracks for all conditions. In the tests in which mines were detonated directly under road wheels the Soviet track was as strong as either U.S. double-pin tracks. In the other tests, the Soviet track was the weakest of the test tracks. This difference in performance was believed to be due to the peculiar suspension of the T34/85 tank (Soviet). The T860E1 track was stronger than the T80E6 track. It was recommended that the closed-type end connector be strengthened by increasing the thickness of the sides and by adding a flange such as is found on the older open-end type of track.

SOVIET T35-85 TANK

A 1951 test was conducted to determine the vulnerability of the track and suspension of a Soviet T35-85 tank to heavy antitank mines, M6. The test Soviet tank was less its power train but included complete suspension assemblies. The mines were placed singly and in pairs in the Palmer House Mine Field area. The tank was towed over the mines which were statically detonated. After each explosion the tank was inspected and the damage recorded. A total of 14 single and 10 pairs of mines were detonated. Every mine attack damaged the road wheels. The tracks were severed by eight of the mines and their vulnerability was established.

MOBILITY OF TRACKED VEHICLES ON ICE AND FROZEN TERRAIN

Determination of the traction characteristics of several vehicles equipped with various tracks for arctic winter conditions was made in a 1951 test. The test material included: light tank, M24, using T72 track (with continuous deeper grouser) and track, T85E1; medium tank, M26, using T80E1 track (modified, and with ice cleats) and track, T84E1; high speed tractor, M4, using T74 track (with ice cleats). The T72 track with continuous deeper grouser showed better traction under various conditions than the T85E1 for the M24 light tank. Track, T74, with ice cleats greatly increased the mobility of the high-speed tractor, M4. Track, T72, with continous deeper grouser on the light tank, M24, was dangerous under icy conditions due to extreme side slippage. It was recommended that tracks, T72E1, with ice cleats and continuous deep grousers be furnished the Arctic Test Branch for test.

REPORT RESUMES

SUBJECT: Tracks AFF 1237
TITLE: Study of 1946-47 Winter Test of Special Synthetic Track, T84E1, for Medium Tank M26, under Arctic Conditions by Task Force Frigid
IDENTIFICATION: Project No. 1237
DATE OF REPORT: 1 December 1947
ORIGIN: Army Ground Forces Board No. 2, Fort Knox, Kentucky
PURPOSE: To determine the suitability of special synthetic Track T84E1 for winter use in comparison with standard steel Track T80E1
METHOD: A Medium Tank M26, equipped with the special tracks, was operated over packed snow while towing a disabled tank, and alone over frozen and snow-covered terrain. These operations included climbing 30 to 40% slopes and were in temperatures ranging from 40°F to -20°F. Another Medium Tank M26, employing standard tracks, was operated for comparison purpose.
DESCRIPTION: The special synthetic rubber Track T84E1, made by Goodyear, was a 23-inch wide, double-pin, rubber-bushed, center-guide, end connector type with a 6-inch pitch and 1-1/2-inch molded chevrons. Total track weight was 8050 pounds and the ground pressure was 13.2 psi.
CONCLUSIONS: Task Force Frigid's test of the special track was considered inadequate because the units were received too late for extreme-cold testing. The special track provided better traction on level hard-packed snow than the standard T80E1. However, neither track provided sufficient traction to enable the vehicles to negotiate 34% slopes. It was recommended that special Track T84E1 receive extreme-cold testing, and that efforts be continued to develop a track for satisfactory traversing of ice, snow and frozen tundra.

GENERAL: This 25-page report contains five photographs of the test tracks installed and of individual track shoes.

SUBJECT: Tracks AFF 1428
TITLE: Test of Mobility of Tracked Vehicles on Ice and Frozen Terrain
IDENTIFICATION: Project No. 1428
DATE OF REPORT: 30 March 1951
ORIGIN: Army Field Forces Board No. 2, Fort Knox, Kentucky
PURPOSE: To determine the traction characteristics of several vehicles equipped with various tracks for arctic winter conditions
METHOD: The towing, braking, turning and hill climbing characteristics of the test vehicles on unprepared snow-covered slopes and level surfaces, using various types of tracks, were studied by the Arctic Test Branch at Big Delta, Alaska. The temperature ranged from 45°F to -51°F and the depth of snow was from zero to 29 inches.
DESCRIPTION: The test materiel included: Light Tank M24 using Track T72 (with continuous deeper grouser) and Track T85E1; Medium Tank M26 using Track T80E1 (modified, and with ice cleats) and Track T84E1; High-Speed Tractor M4 using Track T74 (with ice cleats).
CONCLUSIONS: Track T72 with continuous deeper grouser showed better traction under various conditions than the T85E1 for Light Tank M24. Track T74 with ice cleats greatly increased the mobility of the High-Speed Tractor M4. Track T72 with continuous deeper grouser on the Light Tank M24 was dangerous under icy conditions due to extreme side slippage. It was recommended that Tracks T72E1 with ice cleats and continuous deep grousers be furnished the Arctic Test Branch for test.
GENERAL: This 51-page report contains 22 photographs showing construction of the tracks, test results, and track failures.

SUBJECT: Tracks APG AD-1153
TITLE: Vulnerability of Tank Tracks to Light Antitank Mines, M47
IDENTIFICATION: Report No. AD-1153; First Report on Project TB3-1225
DATE OF REPORT: 6 October 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of various types of tank tracks to M7 Light Antitank Mines
METHOD: Single-pin track on a Russian tank, and single-pin and double-pin tracks on American tanks were tested by exploding M7 Light Antitank Mines at various track positions and directly under the road wheels at various mine burial depths. After each detonation the tanks were moved to enable an examination of the top and bottom track surfaces. Damages were repaired after each detonation so that the track was intact for each test.
DESCRIPTION: The test material consisted of a single-pin type T81 Track mounted on a T26E3 Tank, a new T80E6 Track with closed-type end connectors, and a T80E1 Track with open-type end connectors mounted on the left and right sides, respectively, of an M26 Tank, and a single-pin track mounted on a T34/85 Russian Tank. The test ammunition consisted of 60 M7 Light Antitank Mines, having a rectangular shape 7 inches long by 4-1/2 inches wide by 2-1/2 inches high, and containing about 3-1/2 pounds of tetrytol as an explosive charge.
CONCLUSIONS: The American single-pin T81 Track was considered to be strongest of the test tracks. It was believed however, that peculiarities of the different suspensions may have caused some of the differences in the results of track tests on the Soviet T34/85 and American T26E4 Tanks. The T34/85 type appeared to be the weakest track tested when the mines were detonated between the road wheels, whereas it appeared stronger than the double-pin tracks with either boxed or open-end connectors when mines were detonated directly under a road wheel. There was no significant difference in the strength of the tracks with open and closed end connectors when the mines were detonated between the wheels, but for the less severe conditions (under a road wheel) the open-end type was considered superior.
GENERAL: This 55-page report has appendices covering correspondence, summaries of track damage, charge-by-charge assessments, sketches, and five photographs.

SUBJECT: Tracks APG Ar-17488
TITLE: Vulnerability of Tracks and Suspension of a Soviet Tank
IDENTIFICATION: Firing Record No. Ar-17488; Project No. TB3-1225
DATE OF REPORT: 25 July 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the vulnerability of the tracks and suspension of a Soviet T35-85 Tank to Heavy Antitank Mines M6
METHOD: The mines were placed singly and in pairs in the Palmer House Mine Field Area. The tank was towed over the mines which were statically detonated. After each explosion the tank was inspected and the damage recorded. A total of 14 single and 10 pairs of mines were detonated.
DESCRIPTION: The test Soviet Tank T35-85 was less its power train but included complete suspension assemblies. The explosive unit was Heavy Antitank Mine M6.
CONCLUSIONS: Every mine attack damaged the tank's roadwheels. The tracks were severed by eight of the mines. Numerous remarks, difficult to classify, were made concerning the tracks and suspension, but their vulnerability was established.
GENERAL: This 36-page report contains 33 photographs showing tank damage.

SUBJECT: Tracks APG TB3-1225/1
TITLE: Effectiveness of Mines Against Tank Tracks with Closed Type End Connectors
IDENTIFICATION: Project No. TB3-1225
DATE OF REPORT: 27 June 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the performance of

various types of tank tracks subjected to mine attack
METHOD: Four types of tracks mounted on tanks were tested with a total of 60 light anti-tank mines, M7. Thirty-seven of the mines were detonated between the road wheels at various depths beneath the tracks; the remaining mines were detonated directly under the road wheels at various depths beneath the tracks.
DESCRIPTION: The test material consisted of U.S. T80E5 Tank Track equipped with closed-type end connectors, U.S. T80E1 Tank Track equipped with open-type end connectors, U.S. T81 Single-Pin Track, and a Soviet single-pin track. The T80E6 and T80E1 Tracks were mounted on the left and right sides, respectively, of an M26 Tank. The T81 Track was mounted on a T26E3 Tank and the Soviet track was mounted on a Soviet T34/85 Tank.
CONCLUSIONS: The single-pin T81 Track was the strongest of the test tracks for all conditions. In the tests in which mines were detonated directly under road wheels the Soviet track was as strong as either U.S. double-pin tracks; in the other tests, the Soviet track was the weakest of the test tracks. This difference in performance was believed to be due to the peculiar suspension of the T34/85 Tank. The T80E1 Track was stronger than the T80E6 Track. It was recommended that the closed-type end connector be strengthened by increasing the thickness of the sides and by adding a flange such as is found on the older open-end types of track.
GENERAL: This 152-page report contains extensive correspondence, and photograph of the test setup, and three pages of drawings of track components.

SUBJECT: Tracks APG TT1-698/5
TITLE: Application of Spaced-Link Track to Light-Weight Vehicles
IDENTIFICATION: Fifth Report on Ordnance Project No. TT1-698
DATE OF REPORT: 11 August 1949
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the tractive ability of spaced-link and conventional closed-link tracks; and to determine the accuracy of performance predictions based on laboratory tests
METHOD: Tractive ability tests were conducted on two M29 cargo carriers equipped with conventional tracks. Similar tests were also performed on an experimental, light-weight "Ground Hog" cargo carrier, equipped with test spaced-link track. Tests were conducted in the Munson Sand Bin. Tractive effort versus track slip was measured by standard field dynamometer test equipment. Field test results were then compared; these results were also compared with results obtained for similar types of model tracks which had been tested in the laboratory.
DESCRIPTION. The design of the test spaced-link track was based on laboratory investigations which were conducted in order to determine the dimensions of a track which would be necessary to provide optimum performance characteristics to a vehicle of 4000 to 6000 pounds gross weight. Testing was accomplished by use of a special laboratory device. Track shoes 4 inches long, equipped with 4-inch grousers, and spaced 14 inches apart were selected for use in the spaced-link track. This was decided after an analysis of laboratory data indicated that the tractive effort of such a spaced-link track in sand would be about 900 pounds greater than that of closed-link track of the same dimensions.
CONCLUSIONS: Performance characteristics of spaced-link track exceeded those of conventional closed-link track by 55%. Performance prediction, based on laboratory tests, was in close agreement with the results of the vehicle tests conducted in the field. It was recommended that tests of the spaced-link track be continued in soils of all available types and in snow; that the principles embodied in the test track be considered for use in the design of prototype, light-weight vehicles; and that the principles of vehicle performance prediction be applied to the design of vehicles so that optimum performance in anticipated soil conditions could be designed into the vehicle. Since the laboratory method of prediction applied to only homogeneous soils, it was further recommended that studies be continued to develop similar methods of vehicle performance prediction for non-homogeneous soils.
GENERAL: This 39-page report includes 14 photographs of the test and standard tracks and laboratory test equipment.

Section 48
TRACTORS and BULLDOZERS

SUMMARY

This summary covers resumes of six engineering reports on tractors and bulldozers written between 1937 and 1955 at Aberdeen Proving Ground, Maryland; Army Ground Forces Board No. 1, Fort Bragg, North Carolina; and Chrysler Engineering Division, Detroit, Michigan

CARGO TRACTORS, T85 AND T86

A 1954 test was conducted to determine the suitability of a T85 cargo carrier under desert environmental conditions. The test carrier, manufactured by the International Harvester Company, was a full tracklaying cargo and personnel carrier designed to tow artillery loads up to 33,000 pounds. Conclusions: Cooling and vapor lock characteristics of the vehicle were satisfactory for operations in ambient temperatures of 125°F. Vehicle mobility was satisfactory except when the vehicle was used to tow its maximum trailed load on sandy terrain. It was recommended that further consideration be given to the tracking relationship between the trailed load and prime mover in future designs. It was also recommended that various deficiencies listed in the report be corrected.

The same year a test was conducted with a T86 cargo tractor to determine the performance characteristics of the vehicle under desert environmental conditions. The T86 was a full tracklaying high speed cargo and personnel carrier designed to carry a payload of 12,000 pounds while towing artillery loads up to 62,000 pounds. Conclusions: The cooling and vapor lock characteristics of the vehicle were satisfactory. The mobility of the cargo carrier was generally satisfactory except when operating in sandy terrain towing the 155mm gun carriage, M1. Several modifications to the cab were necessary for the safety and comfort of the personnel. To improve mobility, it was recommended that further consideration be given to the tracking relationship between the trailed load and prime mover in future designs intended for off-the-highway use. It was further recommended that the inlet to the air cleaners be redesigned to draw air from a location nearer the front of the vehicle; that the holes in the muffler well for the flexible exhaust lines be relocated to prevent interference; and that the right bushing for the winch be secured from rotation in the bearing cap.

WINTER TESTS, T72 AND T121 TRACTORS

Determination of the operating and mobility characteristics of T72 and T121 snow tractors under arctic conditions was made in a 1954 test. The test tractors were both tracklaying vehicles designed to carry a 250-pound payload while towing a 750-pound trailed load. The T72 was manufactured by the Gladden Products Corporation; the T121 by the Crosley Motors Corporation. Conclusions: The snow tractors were considered unsatisfactory for arctic operation. Poor steering characteristics were exhibited by the T72 and the T121 in dry powdery snow at both test sites. The snow terrain seriously hindered functioning of the clutch, starter, throttle, and choke on the T121, but did not affect control operation of the T72. The cross-country snow operation of both vehicles was poor, especially with a towed load. It was recommended that the snow operating and mobility characteristics of the test vehicles be improved before further testing was conducted.

REPORT RESUMES

AFF 4647-4

SUBJECT: Tractors and Bulldozers (2C)

TITLE: Report of Army Ground Forces Task Force Frigid

IDENTIFICATION: Annex 2C, Report of Study-Project No. FAWT 4647-4, Final Report (Extract)

DATE OF REPORT: 5 September 1947

ORIGIN: Army Ground Forces Board No. 1, Fort Bragg, North Carolina

PURPOSE: To determine the starting and operating characteristics of two Caterpillar tractors in extreme low temperatures

METHOD: The tractors were employed for clearing areas, breaking trails, and for towing loaded trailers and disabled vehicles, in temperatures down to -62°F. Cabs were fabricated to protect the operators from cold.

DESCRIPTION: Test Caterpillar Tractor D7 was powered by a 4-cylinder Caterpillar diesel engine and equipped with Bulldozer Blade XD7B. Test Caterpillar Tractor D8 was powered by a 6-cylinder Caterpillar diesel engine and equipped with Bulldozer Blade XD9.

CONCLUSIONS: Both vehicles had poor traction on ice, and numerous mechanical failures limited testing. The engines were difficult to start in cold weather. It was recommended that the tractors be equipped with a cab for the operator, be provided with better traction, be equipped with an angle dozer blade in place of a bulldozer blade, and be provided with some suitable means for easier starting of the engines in cold weather.

GENERAL: This three-page report is not illustrated.

SUBJECT: Tractors and Bulldozers APG 5344/1
TITLE: Report on Silver King Model R-38 Tractor
IDENTIFICATION: First Report on Ordnance Program 5344; APG 15-19
DATE OF REPORT: 29 July 1937
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of the Silver King Tractor Model R-38 for military use
METHOD: The vehicle accumulated 105.5 miles during one month of testing. Tests were in accordance with TSTP 1935-709.
DESCRIPTION: The test Silver King Tractor Model R-38, manufactured by the Fate-Root-Heath Company, was powered by a Hercules engine rated at 40 hp. It was a commercial 4-wheeled type vehicle with large (9.00 x 24) tires on the rear (driving) wheels.
CONCLUSIONS: The vehicle was unsuitable for military use because of poor weight distribution for high-speed or full-power operation. It was recommended that the Silver King Tractor Model R-38 be given no further consideration.
GENERAL: This 77-page report contains two photographs showing construction of the tractor.

SUBJECT: Tractors and Bulldozers APG 5740/3
TITLE: Third Report on Preliminary Investigation of Automotive Vehicles for Use in Jungle Warfare
IDENTIFICATION: Third Report on Ordnance Program No. 5740
DATE OF REPORT: 1 October 1943
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate the performance of commercial crawler tractors, and personnel and cargo carriers, under simulated jungle conditions
METHOD: The test vehicles were operated under simulated jungle conditions in the Phillips Field Area. This test area was a swamp section of ground covered with reed and bullrush growth. The results of the operation of each vehicle were summarized.
DESCRIPTION: The test crawler tractors were being considered as prime movers for the 105mm howitzer carriage, airborne, M3A1. The cargo tractors tested were the Engineer Corps Crawler Tractor (Clark Equipment Company) and the Cletrac Model AGH (Cleveland Tractor Company). A modified shoe was installed on the Engineer Corps tractor. The shoe, formed of 4x4x3/8-inch stock angle iron, consisted of a 19x4-inch plate with 3-inch grouser. The Cletrac Model AGH was equipped with 20-inch width, closed-type track shoes with grousers 1-1/2-inches high. The carriers tested were the light cargo carrier T-30 (Crosley), a cut-down light tank M5, and a cut-down universal carrier T16.
CONCLUSIONS: As a result of these tests, and those reported in the first and second reports on Ordnance Project No. 5740, it was concluded that the most satisfactory prime mover for the 105mm howitzer carriage, airborne, M3A1, would be the Cletrac Model AGH crawler tractor equipped with an open track of modified plates with 5-inch grousers, resulting in a ground pressure of 3.1 psi and that the cut-down universal carrier T16 was the most satisfactory vehicle for use as a light cargo or personnel carrier. It was recommended that pilot model tractors with characteristics comparable to those of the Cletrac Model AGH be obtained from each of the commercial crawler tractor manufacturers and tested under simulated jungle conditions; that the modified universal carrier T16 be considered the most satisfactory personnel or cargo carrier; and that skid plates for the 105mm howitzer, airborne, M3A1 and the standard 1/4-ton cargo trailer, in accordance with sketches in the report, be adopted for operation of these units in jungle warfare conditions. It was further recommended that if requirements for a small jungle vehicle are sufficient to warrant it, further consideration be given to the light cargo carrier T30 (Crosley).
GENERAL: This 98-page report includes 44 photographs of vehicles under test.

APG TB5-1401/181
SUBJECT: Tractors and Bulldozers
TITLE: Winter Tests (1953-54) on Tractors, Snow, T70, T72, T121 at Kapuskasing, Ontario, and Fort Churchill, Manitoba, Canada
IDENTIFICATION: One Hundred Eighty-first Report on Project No. TB5-1401
DATE OF REPORT: 1 June 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine operating and mobility characteristics of T72 and T121 snow tractors under arctic conditions
METHOD: The test T72 and T121 vehicles were operated with and without towed loads for 24 and 20 hours, respectively, in the Kapuskasing and Fort Churchill, Canada, areas. Cold starting characteristics of both vehicles were evaluated according to a procedure outlined in the report. A T70 snow tractor which was also to have been tested was held at Aberdeen because of an engine crankshaft failure.
DESCRIPTION: The T72 and T121 snow tractors were both full-tracklaying vehicles designed to carry a 250-pound payload while towing a 750-pound trailed load. The T72, manufactured by the Gladden Products Corporation, was equipped with the following: a Gladden Model 85, single-cylinder, air-cooled engine, which developed 24.9 hp; a synchromesh transmission; coil spring loaded idler; solid suspension; spaced link track; and differential clutch steering. The T121 manufactured by Crosley Motors Corporation, was equipped with the following: a Crosley, 4-cylinder, liquid-cooled engine, which developed 25.5 hp at 5200 rpm; a synchromesh transmission; a suspension consisting of track guides mounted on leaf springs; differential braking steering; and spaced link track.
CONCLUSIONS: The snow tractors were considered unsatisfactory for arctic operation. Poor steering characteristics were exhibited by the T72 and the T121 in dry, powdery snow at both test sites. The snow terrain seriously hindered functioning of the clutch, starter, throttle, and choke on the T121, but did not affect control operation of the T72. The cross-country snow operation of both vehicles was poor, especially with a towed load. It was recommended that the snow operating

and mobility characteristics of the test vehicles be improved before further testing was conducted.
GENERAL: This 70-page report contains nine photographs of the vehicles

APG TB5-1401/Y10/196
SUBJECT: Tractors and Bulldozers
TITLE: Desert Test 1954 Tractor, Cargo, T86
IDENTIFICATION: One Hundred Ninety-sixth Report on Project No. TB5-1401/Y10
DATE OF REPORT: 25 October 1954
ORIGIN: Aberdeen Proving Ground Maryland; Yuma, Arizona
PURPOSE: To determine the performance characteristics of a cargo tractor T86 under desert environmental conditions
METHOD: The vehicle was inspected and necessary instrumentation for the tests was installed. The cargo tractor was loaded to simulate combat weight with 12,800 pounds payload, making a gross weight of 59,040 pounds. Full-throttle cooling, road-load cooling, cross-country cooling, vapor lock, mobility and dust tests were conducted over 1022 miles of various types of desert terrain.
DESCRIPTION: The cargo tractor T86 was a full-tracklaying, high speed cargo and personnel carrier designed to carry a payload of 12,000 pounds while towing artillery loads up to 62,000 pounds. The hull of the vehicle was a box-line welded steel structure which served as a mounting for the cab and cargo body. The vehicle was powered by an Ordnance Model AOS-895-3, 6-cylinder, air-cooled, supercharged engine. Power was transmitted through a 1:1 ratio transfer case to an Ordnance Model XT 500-3 transmission which drove the front mounted final drives and track sprockets. The transmission was a combined torque converter, transmission, steering and braking unit. The vehicle was also equipped with torsion bar suspension, T91E3 tracks, and a 24-volt, waterproof electrical system.
CONCLUSIONS: The cooling and vapor lock characteristics of the vehicle were satisfactory. The mobility of the cargo carrier was generally satisfactory except when operating in sandy terrain towing the 155mm gun carriage, M1. Several modifications to the cab were necessary for the safety and comfort of the personnel. To improve mobility, it was recommended that the inlet to the air cleaners be redesigned to draw air from a location nearer the front of the vehicle, the holes in the muffler well for the flexible exhaust lines be relocated to prevent interference, and the right bushing for the winch be secured from rotation in the bearing cap.
GENERAL: This 110-page report includes 11 photographs of the test vehicle and components.

APG TB5-1401/Y11/197
SUBJECT: Tractors and Bulldozers
TITLE: Desert Test 1954 Tractor, Cargo, T85
IDENTIFICATION: One Hundred Ninety-seventh Report on Project No. TB5-1401/Y11; and Second Report on Project No. TT2-785
DATE OF REPORT: 11 October 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of a T85 cargo carrier under desert environmental conditions
METHOD: The test vehicle was inspected, loaded with rated payload, and then subjected to full throttle cooling, vapor lock, and cross-country cooling tests. Mobility tests were also conducted on available terrain while the vehicle towed various types of trailed loads. All testing was conducted at Yuma, Arizona under high ambient temperature conditions. A total of 379 miles of operation over varied terrain was conducted during the test period.
DESCRIPTION: The T85 cargo tractor, manufactured by the International Harvester Company, was a full-tracklaying cargo and personnel carrier designed to tow artillery loads up to 33,000 pounds. The vehicle was equipped with a Continental, Model AO-895-4, 6-cylinder, horizontally-opposed, air-cooled, gasoline engine and a General Motors, Model XT-500-3, cross drive transmission. A torsion bar suspension system, individually sprung road wheels, and T91E3 combination rubber and steel track were also included in the vehicle design.
CONCLUSIONS: Cooling and vapor locks characteristics of the vehicle were satisfactory for operations in ambient temperatures of 125°F. Vehicle mobility was satisfactory except when the vehicle was used to tow its maximum trailed load on sandy terrain. It was recommended that further consideration be given to the tracking relationship between the trailed load and prime mover in future designs. It was also recommended that various deficiencies listed in the report be corrected.
GENERAL: This 178-page report includes 19 photographs of the test vehicle and components.

APG TT2-785/1
SUBJECT: Tractors and Bulldozers
TITLE: Engineering Evaluation Test of Tractor, Cargo, T85
IDENTIFICATION: First Report on Project No. TT2-785
DATE OF REPORT: 8 September 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate selected engineering characteristics of a T85 cargo tractor
METHOD: The test vehicle was initially inspected and a 12,000 pound payload was distributed evenly in the cargo bed. Load distribution, ground pressure, and slope operating characteristics of the vehicle were then determined. The load distribution and ground pressure phases of test were repeated after the vehicle payload was removed; vehicle center of gravity was also determined at this time.
DESCRIPTION: The T85 cargo tractor, built by the International Harvester Company, was a full-tracklaying, high speed vehicle equipped with an AO-895-4 engine and an XT-500-3 cross-drive transmission. Rated vehicle payload was 12,000 pounds, and rated towed load was 33,000 pounds. The vehicle was primarily intended for use as a prime mover for trailed artillery loads, ranging from the standard 155mm howitzer, weighing 13,000 pounds, to the standard 90mm antiaircraft gun, M2,

weighing 33,000 pounds. Secondary uses included ammunition, troop, and general purpose cargo transportation.
CONCLUSIONS: Mechanical inspection revealed no major faults or deficiencies and preliminary engineering test results were satisfactory. It was recommended that a complete engineering and field performance evaluation be conducted on the test vehicle at the earliest practicable date.
GENERAL: This 26-page report includes eight photographs of the test vehicle.

T-60115.5

SUBJECT: Tractors and Bulldozers
TITLE: Bulldozer Assembly on M48 Tank
IDENTIFICATION: Report No. 60115.5
DATE OF REPORT: 16 September 1955
ORIGIN: Chrysler Engineering Division, Detroit, Michigan
PURPOSE: To determine the suitability of a redesigned T18E1 bulldozer prototype assembly for use on an M48 tank
METHOD: The test bulldozer assembly was installed on an M48 tank and limited tests were conducted with the vehicle installation.
DESCRIPTION: The test redesigned T18E1 bulldozer prototype assembly consisted of a modification kit which would permit the M48 tank, or M48A1 tank, to be changed from a combat vehicle to a combat service vehicle in the field. The kit could be easily removed in the event the vehicle had to be returned to its original state. Vehicle combat effectiveness or ballistic protection was not reduced as a result of kit installation. The test unit was controlled and operated hydraulically. Primary differences between the redesigned T18E1 bulldozer prototype assembly and the original T18E1 assembly included: quantity of moldboard mounting brackets welded to the front lower glacis of the hull were reduced from six to two; the hydraulic reservoir was relocated from the hull interior to the exterior, thus permitting an increase in ammunition capacity of 11 rounds; the hydraulic valve and pump were mounted inside the reservoir to simplify the installation; and it was not necessary to cut additional holes in the M48 tank hull in order to install the kit. Total weight of the kit installation including the hydraulic oil was 9026.68 pounds.
CONCLUSIONS: Two test assembly components failed during the limited operation. However, it was considered that neither of these failures occurred as the result of design deficiencies.
GENERAL: This 36-page report contains 30 photographs showing the test assembly components.

Section 49
TRAILERS AND SLEDS

SUMMARY

This summary covers resumes of six engineering reports written on trailers and sleds between 1944 and 1954 at Aberdeen Proving Ground, Maryland; Army Field Forces Board No. 2, Fort Knox, Kentucky; The Field Artillery Board, Fort Bragg, North Carolina; Office, Chief of Ordnance, Detroit, Michigan; and Landing Vehicle Board, Fort Ord, California.

BOGIE FOR MISSILE LAUNCHER, MARK III

A 1954 test was conducted to determine the adequacy of the bogie carrying the missile launcher, Mark III. The bogie was engineered and manufactured by the W.L. Maxson Company. The Navy missile launcher, Mark III, engineered and built by the same company, was designed to launch the Terrier Missiles, one from the underside of each arm. The launcher was mounted on bogies, fore and aft, for transporting. The bogies had solid axle suspensions. The test bogie was satisfactory from an automotive standpoint at the speeds for which it was designed. It was recommended that the test vehicle be considered satisfactory after certain deficiencies had been corrected by the manufacturer.

SLEDS, TRACKED TRAILERS, and WANAGANS

Formulation of military characteristics of sleds, tracked trailers, and wanagans for arctic conditions and temperatures were prepared in 1948. The proposed equipment consisted of three cargo sleds of 4000, 8000, and 16,000 pounds capacity; four tracklaying cargo trailers of 1000, 4000, 8000, and 16,000 pounds capacity; and a small and a large prefabricated knockdown wanagan. It was recommended that the military characteristics for the sleds, trailers, and wanagans, as set forth in the report, be used as a basis for preliminary engineering studies with the understanding that these characteristics would be finalized at a conference attended by representatives of the using arm and development agency prior to the technical committee meeting; that after the above, a sufficient number of pilot models be procured for appropriate service tests; and that the interior arrangement of the wanagan be planned after receipt of the pilot model.

4-WHEEL BOMB TRAILER, T75

Plans to develop and procure 25 trailers to deliver the 12,000-pound bomb, BP, T10, to the hoisting position under the bomb bay of B29 bombardment aircraft were formulated in 1945. The test trailer, designed to deliver a single 12,000-pound T10 bomb, BP, to B29 aircraft, had four wheels and an underslung frame body. It used single 7.50 x 20 tires and had a ground clearance of 2-1/2 inches. The trailers were built of Government Free Issue Parts by the Cleaver Brooks Company. The trailer was considered satisfactory for its design function and recommended for use.

2-1/2-TON 2-WHEEL AMPHIBIAN TRAILERS

In 1945 three amphibian trailers were developed and tested. Two trailers were provided with wheels, hubs, bearings and grease seals that were interchangeable with those on the rear axle of a 2-1/2-ton 6x6 amphibian truck. The other unit had parts interchangeable with those of the rear axle of the 4-ton 2-wheel M21 ammunition trailer. All test vehicles had an open-top steel-box type cargo body. The front of the body was slanted like the prow on a barge. A drawbar was provided having means for quick coupling and uncoupling under water and with a foot landing gear. The amphibious tests were satisfactory, but sand and cross-country tests were inconclusive. It was recommended that further development be initiated to provide a trailer that would combine satisfactory land and water performance.

REPORT RESUMES

SUBJECT: Trailers and Sleds AFF 1217
TITLE: Military Characteristics for Sleds, Tracked Trailers, and Wanagans for Arctic use
IDENTIFICATION: Project No. 1217
DATE OF REPORT: 8 August 1948
ORIGIN: Army Field Forces Board No. 2, Fort Knox, Kentucky
PURPOSE: To formulate military characteristics of sleds, tracked trailers, and wanagans suitable for Arctic conditions and temperatures
METHOD: The Army Ground Forces Board No. 2 studied pertinent reports and previous tests of equipment of this nature. Conferences were held with personnel who had been members of winter task forces and observers of winter operations. Other boards and schools were also consulted. Efforts were made to incorporate the ultimate feasible requirements in this equipment and to seek versatility. A draft of this report was seen by various interested agencies and their comments considered.
DESCRIPTION: The proposed equipment consisted of: three cargo sleds of 4000, 8000, and 16,000 capacity; four tracklaying cargo trailers of

1000, 4000, 8000, and 16,000 pounds capacity; a small and a large prefabricated knockdown wanagan.
CONCLUSIONS: It was recommended that: The military characteristics for the sleds, trailers and wanagan, as set forth in the report, be used as a basis for preliminary engineering studies with the understanding that these characteristics would be finalized at a conference attended by representatives of the using arm and development agency prior to the technical committee meeting; after the above, a sufficient number of pilot models be procured for appropriate service tests; interior arrangement of the wanagan be planned after receipt of the pilot model.
GENERAL: This 66-page report includes tentative military characteristics of all items and comments of interested agencies. No illustrations or sketches are included.

APG TR1-1058/1

SUBJECT: Trailers and Sleds
TITLE: Test of Bogie for Missile Launcher, Mark III
IDENTIFICATION: First Report on Project No. TR1-1058
DATE OF REPORT: 10 November 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the adequacy of the bogie carrying the missile launcher
METHOD: An endurance test was conducted, utilizing the gun carriage and Belgian Block test courses. The bogie with launcher was towed over this test course for 100 laps (185 miles) at speeds of under 6 mph. Slope tests on the 20% and 30% slopes also were conducted. A modified T41 tank was used as the prime mover.
DESCRIPTION: The bogie was engineered and manufactured by the W.L. Maxson Company. The Navy missile launcher, Mark III engineered and built by the same company, was designed to launch the Terrier Missile, one from the underside of each arm. The launcher was mounted on bogies, fore and aft, for transporting. The bogies had solid axle suspensions.
CONCLUSIONS: The test bogie was satisfactory from an automotive standpoint at the speeds for which it was designed. It was recommended that the test vehicle be considered satisfactory after certain deficiencies had been corrected by the manufacturer.
GENERAL: This 35-page report includes 11 photographs of the bogie for the Mark III missile launcher, and laboratory testing equipment.

FAB O-54-K (711)

SUBJECT: Trailers and Sleds
TITLE: Test of Trailer, Ammunition, T34E2
IDENTIFICATION: FAB Test No. O-54-K; Item No. 711
DATE OF REPORT: 24 April 1944
ORIGIN: The Field Artillery Board, Fort Bragg, North Carolina
PURPOSE: To determine the suitability of the Ammunition Trailer T34E2 for field artillery use
METHOD: Two trailers without loads and with 19,000 to 27,500-pound payloads were towed to a total of 1356 and 1409 miles over pavement and desert terrain. A 7-1/2-ton, 6x6, cargo truck and an 18-ton High Speed Tractor M4 were used as prime movers. A Heavy Carriage Limber M5 was used when towing was done by the M4. The rear towing pintle of the test trailer was modified and a short run was made with a 27,500-pound low bed trailer attached, using the M4 as the prime mover.
DESCRIPTION: The test Ammunition Trailer T34E2, manufactured by the Utility Trailer Manufacturing Company, was designed to carry 60 rounds of 8-inch howitzer, 96 rounds of 155mm gun, 36 rounds of 240mm howitzer, or 36 rounds of 8-inch gun ammunition. The rear of the trailer was suspended on bogies of the walking beam type. An "A" frame on the front was designed for direct coupling to a prime mover or heavy carriage limber. Air brakes were on all four wheels of bogie and manually operated brakes on the two rear wheels. A mono-rail crane with a 1/2-ton chain block was provided for moving ammunition.
CONCLUSIONS: The trailer was unsuitable for field artillery use. It was recommended that numerous modifications be made on the shell racks, fuse box, "A" frame, rear pintle, brakes, false bottom and the trailer in general before it could be considered satisfactory.
GENERAL: This 32-page report contains 11 pages of photographs showing general characteristics and testing of the trailer.

SUBJECT: Trailers and Sleds LVB 41
TITLE: Test of Modified Trailers, 2-1/2-Ton, 2-Wheel, Cargo, Amphibian
IDENTIFICATION: Project No. 41
DATE OF REPORT: 9 April 1945
ORIGIN: Landing Vehicle Board, Fort Ord, Calif.
PURPOSE. To determine the suitability of three types of 2-1/2-ton, 2-wheel, amphibian cargo trailers
METHOD: The units were towed over a sandy beach by Amphibian Vehicles LVT 4 and DUKW and their characteristics noted.
DESCRIPTION: The three 2-1/2-ton, 2-wheel, Amphibian Cargo Carriers LVB 110, 111, and 112 were tested carrying payloads of 7077, 5119, and 7149 pounds. Trailers 110 and 111 weighed 4361 pounds net and were each equipped with 10-ply 11.00 x 18 tires and a 15-3/4-inch towing coupling cone. Trailer 112 weighed 4831 pounds net and was equipped with 12-ply 14.00 x 20 tires and a 14-1/2-inch towing coupling cone.
CONCLUSIONS: Failures were numerous. It was recommended that the trailers receive no further consideration.
GENERAL: This five-page report is not illustrated.

SUBJECT: Trailers and Sleds OCO KG-521
TITLE: Trailers, 2-1/2-Ton, Two-Wheel, Cargo, Amphibian
IDENTIFICATION: Project No. KG-521
DATE OF REPORT: 12 September 1945

ORIGIN: Office, Chief of Ordnance, Detroit, Mich.
PURPOSE: To develop and test three amphibian trailers
METHOD: Based on studies of previous amphibian trailer designs, three pilot models were built. They were then shipped to the Landing Vehicle Board, Fort Ord, California, where they were tested for seaworthiness, stability, ability to be coupled and jettisoned from the prime mover at sea, and performance in sand. The trailers were tested with and without loads.
DESCRIPTION: Two trailers were provided with wheels, hubs, bearings and grease seals that were interchangeable with those on the rear axle of a 2-1/2-ton, 6x6, amphibian truck. The other unit had parts interchangeable with those of the rear axle of 4-ton, 2-wheel, ammunition Trailer M21. All test vehicles had an open-top, steel-box type cargo body. The front of the body was slanted like the prow on a barge. A drawbar was provided having means for quick coupling and uncoupling under water and with a foot landing gear.
CONCLUSIONS: Amphibious tests were satisfactory, but sand and cross-country tests were inconclusive. It was recommended that further development be initiated to provide a trailer that would combine satisfactory land and water performance.
GENERAL: This 24-page report contains eight photographs and two drawings showing general characteristics of the trailers.

SUBJECT: Trailers and Sleds OCO KG-572
TITLE: Trailer, Bomb, Four-Wheel, T75
IDENTIFICATION: Project No. KG-572
DATE OF REPORT: 18 October 1945
ORIGIN: Office, Chief of Ordnance, Detroit, Mich.
PURPOSE: To develop and procure 25 trailers to deliver the 12,000-pound Bomb, BP, T10 to the hoisting position under the bomb bay of Bombardment Aircraft B-29
METHOD: A tentative design was made and a pilot model built and shipped to Eglin Field, Florida, for further modification and testing. A contract was then let for 25 additional units based on the modified pilot model. The first trailer was completed in one week and shipped to Eglin Field for test. The remaining 25 units were not expedited due to cessation of hostilities. They were finally completed and shipped to Fairfield Air Depot, Ohio.
DESCRIPTION: The test trailer, designed to deliver a single 12,000-pound Bomb, BP, T10 to Aircraft B-29, had four wheels and an underslung frame-body. It used single 7.50 x 20 tires and had a ground clearance of 2-1/2 inches. The trailers were built of Government Free Issue Parts by the Cleaver Brooks Company.
CONCLUSIONS: The trailer was considered satisfactory for its designed function and recommended for use.
GENERAL: This 17-page report contains three photographs showing general construction of the trailer.

Section 51
TRANSPORTERS

SUMMARY

The subject, Transporters, was not summarized because of the limited scope of the transporter reports briefed to date. When a sufficient number of transporter reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Transporters APG TB5-1401/150
TITLE: Winter Arctic Tests 1953-54 Transporter, Heavy Artillery, T10
IDENTIFICATION: One Hundred Fiftieth Report on Project No. TB5-1401
DATE OF REPORT: 26 March 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine suitability of the T10 transporter and related winterization equipment under arctic conditions
METHOD: Testing was conducted at Fort Churchill, Manitoba, Canada. The cold-starting ability of both vehicles was evaluated with and without power plant heating at ambient temperatures down to -25°F. The effectiveness of the personnel heaters, defrosters, and cab insulation was determined. Mobility characteristics of the T10 were observed during operations over snow covered frozen muskeg and drifts of snow. The M249 was operated for 383 miles and the M250 for 259 miles. Each truck accumulated 59 miles while transporting the 28mm gun and carriage.
DESCRIPTION: The T10, heavy artillery transporter consisted of two 4x4, heavy gun lifting trucks, an M249 in the front and an M250 in the rear. This vehicle combination was used for transporting the T131 and the T72, 280mm gun carriages. Two series E500, Perfection heaters supplying 30,000 BTU/hr. provided power plant, defrosting, and personnel heat. A 100-ampere, a.c.-d.c. system and four, 6TN, 12-volt batteries were installed in the vehicle. A direct acting throttle was utilized as a cold starting aid.
CONCLUSIONS: Successful cold starts using no winterization equipment were obtained at temperatures down to -20°F with the M249 and -15°F with the M250. The personnel and defrosting system was considered inadequate. Vehicle deficiencies included low cylinder head and engine oil temperatures, as well as carburetor ring, and hydraulic system failures. Mobility of the T10 when transporting the gun and carriage over frozen muskeg and drifted snow was satisfactory. It was recommended that the power plant heating system be further evaluated at colder temperatures, and that the personnel heating system and cab sealing be improved.
GENERAL: This 101-page report contains 17 photographs of the test vehicles and components.

SUBJECT: Transporters APG TB5-1401/237
TITLE: Winter Tests 1954-1955, Transporter, Heavy Artillery, T10
IDENTIFICATION: Two Hundred Thirty-seventh Report on Project No. TB5-1401
DATE OF REPORT: 15 March 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate the performance of the test vehicle and components at low temperatures over arctic terrain
METHOD: Mobility tests were conducted while transporting the 280mm gun over frozen muskeg through snow of varlous depth. Cold starts were conducted with and without cold starting aids. Operational, crew comfort, and power plant warm-up data were recorded. Observations were made relative to the test components.
DESCRIPTION: The test units were transporters, heavy artillery, T-10, "A" unit, M249 and "B" unit, M250 coupled to the 280mm gun, T131, and carriage, T72. The "A" unit weighed 89,150 pounds (with its share of the gun load) and the "B" unit, 80,150 pounds. Both vehicles were equipped with a dual purpose arctic heater kit. A Reichhelm Gasifier cold starting aid was installed on the M250 transporter. In addition, the test vehicles were equipped with a pancake muffler, and a two-stage lifting shackle.
CONCLUSIONS: It was recommended that modifications be made to the engine to enable it to maintain higher operating temperatures; that the carburetor air intake system be modified to eliminate the oil bath air filter and to provide for heated intake air; that the dual purpose arctic heater kit be modified to provide proper fuel supply at all times; that the test vehicle be considered unsatisfactory for starting without aids in temperatures below -15°F; that the Reichhelm gasifier be considered unsatisfactory as a cold starting aid; that the pancake muffler be considered satisfactory for the prevention of torching; that the two-stage lifting shackle be considered satisfactory for its intended use; and that consideration be given to utilizing a more reliable hydraulic pump

in the hoist system.
GENERAL: This 129-page report includes 14 photographs of the test transporter and its component parts.

APG TB5-1401/Y14/230

SUBJECT: Transporters
TITLE: Desert Mobility Tests (1954) Transporter, Heavy Artillery, T-10
IDENTIFICATION: Two Hundred Thirtieth Report on Project No. TB5-1401/Y14
DATE OF REPORT: 5 November 1954
ORIGIN: Aberdeen Proving Ground, Yuma, Ariz.
PURPOSE: To determine the mobility characteristics of the T10 transporter while operating over desert terrain
METHOD: The T10 transporter was subjected to mobility tests over various desert test courses including prepared sand slopes, and severe, untraveled terrain. Tire pressures were varied to determine the requirements for operation through sand and over severe desert terrain.
DESCRIPTION: The T10 heavy artillery transporter consisted of two propelling vehicles (M249 and M250), a T72 gun carriage coupled between the vehicles, and a T131, 280mm gun. The front propelling vehicle was identified as the M249; both vehicles were equipped with an early production AO-895-4 engine, a TX-500 transmission, and single front and rear axles.
CONCLUSIONS: Mobility of the complete unit (transporters and guns) over off-the-road desert terrain was limited by stability of the vehicle on side slopes, interference between low-hanging components of the gun carriage and the terrain, interference of the fifth wheels, and buckling of the tires under full torque at low inflation. Extreme dust hindered operations but did not make such operations impractical. The long time required for tire inflation and deflation of the unit made frequent changes in tire pressure impractical. It was recommended that the unit be considered satisfactory for use at slow speeds over typical desert terrain, including soft sand, at 40 psi tire pressure (30 psi for emergencies) where no grade exceeded 15% and where the irregularity of the terrain did not subject the vehicle to ground interference or side slopes in excess of 15%.
GENERAL: This 30-page report includes six photographs of the test vehicle.

Section 52
TRUCKS

SUMMARY

The subject, Trucks, was not summarized because of the limited scope of the truck reports briefed to date. When a sufficient number of truck reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Trucks APG TT1-696/9
TITLE: Test of Truck, Utility, 1/4-Ton, 4x4, XM38E1
IDENTIFICATION: Ninth Report on Project No. TT1-696
DATE OF REPORT: 11 October 1951
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of a 6-volt electrical system for general use in the Zone of Interior and Communications Zone
METHOD: A truck, XM38E1 was operated under heavy rain and splash conditions to determine whether the electrical system would give satisfactory performance. The truck was stopped, soaked with a hose and started again. With the engine running at low speed, the vehicle was sprayed heavily from tops and sides. The truck was then run at speeds of 20 to 30 mph through 4 to 6 inches of water.
DESCRIPTION: The XM38E1 truck weighed 2550 pounds, unloaded, and was basically the truck utility, 1/4-ton, 4x4, M38, with the following modifications: a 6-volt electrical system; capacitance suppression on the generator and generator regulator; and omission of all waterproofing equipment for fording.
CONCLUSIONS: The electrical system operated satisfactorily under all conditions. The standard truck, utility, 1/4-ton, 4x4, M38, modified to exclude fording equipment and equipped with a 6-volt electrical system was considered satisfactory for use in the Zone of Interior and Communications Zone.
GENERAL: This 18-page report includes three photographs of the test vehicle.

Section 53
TURRETS

SUMMARY

The subject, Turrets, was not summarized because of the limited scope of the turret reports briefed to date. When a sufficient number of turret reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Turrets AB 434
TITLE: Turret Deficiency, Medium Tank, M4, Series
IDENTIFICATION: Project No. 434
DATE OF REPORT: 22 June 1943
ORIGIN: Armored Force Board at Fort Knox, Ky.
PURPOSE: To determine the effect of welding two pieces of reinforcing armor on the right front of the turret, and to determine practicability as a field modification
METHOD: Before the armor was welded on, the turret was freed by removing the power traverse unit and measuring the torque required to move the turret with the tank on level ground. The maximum torque was then measured with the tank on a five-degree slope. After the armor was welded on, the torque was again measured as before. The gun was freed by disconnecting the stabilizer piston and the friction on the trunnions was measured to determine binding. Three days later the trunnions were again tested for excessive friction. Firing tests were conducted by Aberdeen Proving Ground.
DESCRIPTION: The additional armor consisted of two pieces of armor plate electrically welded to the right front of the turret.
CONCLUSIONS: The additional armor gave the necessary protection and did not affect turret balance. The method of welding did not affect the freedom of the gun trunnions or turret bearings, but was thought to present a problem as a field modification since an expert welder would be needed for the vertical welding which constituted the major part of the work. It was recommended that the turret reinforcing armor, as installed by the Armored Force Board, be considered a satisfactory modification to protect the thin sections of the Medium Tank M4 Series; however, the time required for installation and the lack of expert welders would present a tremendous problem for field service installation.
GENERAL: This 12-page report contains six photographs of the modification and the effect of projectiles on the modification.

SUBJECT: Turrets APG AD-1021
TITLE: Report on the Ballistic Test of Turret for the Heavy Tank M26E2
IDENTIFICATION: Report No. AD-1021; Project No. 5987
DATE OF REPORT: 31 October 1945
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic acceptability and vulnerability of a Heavy Tank M26E2 turret
METHOD: Ballistic acceptance tests were conducted on the test turret using 90mm APC M82 Projectiles at 45° obliquity, 75mm AP M72 Projectiles at 0° obliquity, and 90mm AP T33 Projectiles at 0° obliquity. These tests were conducted in accordance with the requirements of Specifications AXS 492-4 and AXS 1013. Protection ballistic limits were obtained with 90mm AP T33 Projectiles at 45° obliquity. Further testing of the turret was conducted with 90mm AP projectiles to obtain data for comparison with 5-inch armor plates of other manufacturers.
DESCRIPTION: The Heavy Tank M26E4 test turret was manufactured by the American Steel Foundry and was designated as C1. Items used for comparison were 5-inch cast armor plates from the Pittsburgh Steel Foundry, turrets submitted by General Steel Castings, and a B-34 Turret also from the American Steel Foundry.
CONCLUSIONS: The test turret failed to meet the ballistic requirements of Specifications AXS 492-4 and AXS 1013. The General Steel Castings turrets gave greater protection against 90mm AP projectiles than the American Steel Foundry turrets. The test Turret C1 gave greater protection against 75mm and 90mm AP projectiles at all obliquities than the B34 Turret and also gave about the same protection as the 5-inch cast armor plates.
GENERAL: This 25-page report includes five photographs of the test turret. Firing Report Nos. Ar-16434, Ar-16438, and Ar-16586 are included with this report.

SUBJECT: Turrets APG TT2-725C/6
TITLE: Caliber .50 Machine Gun, Commander's Cupola Model 30. Vulnerability to Ballistic Attack (U)
IDENTIFICATION: Sixth Report on Ordnance

Project No. TT2-725C
DATE OF REPORT: 15 August 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To evaluate the pilot Model 30 cupola vulnerability to a single ballistic attack on the main turret of a M48 tank, 90mm gun, in order to determine whether further vulnerability tests were desirable for the production cupola
METHOD: The pilot Model 30 cupola was subjected to ballistic attack on the main turret of the M48 tank, 90mm gun, by a 105mm proof projectile at a striking velocity of 1086 feet per second. Damage to the cupola was evaluated by operation, disassembly, and visual inspection.
DESCRIPTION: In this vulnerability test, the pilot Model 30 cupola, Serial No. 7, containing Marblett plastic balls and spacers in its mounted bearing, was mounted on a facility vehicle, M48, Registration No. 30176786.
CONCLUSIONS: The pilot Model 30 cuploa, equipped with Marblett plastic ball bearing, was unable to withstand nonpenetrating kinetic energy ballistic attack on the M48 tank main turret at moderate energy levels. The major failure was associated with the use of Marblett plastic balls and spacers, which were unsatisfactory for use as a mounting bearing on cal. .50 commander's machine gun cupolas. It was recommended that instrumented tests of production Model 30 cupola vulnerability to ballistic attack on the M48 tank turret be conducted, utilizing 404 plastic balls and any other means of increasing resistance to damage; that balls of a ferrous or other alternate material compatible with the cupola design be utilized experimentally in the bearing; and that other means of resisting bearing damage be investigated, such as a shock mounting method to be determined from current tests on tank fire control equipment.
GENERAL: This 20-page report includes six photographs of the cal. .50 machine gun turret and cupola, as well as failures of the Marblett plastic ball bearings.

Section 55

VEHICLES, MISCELLANEOUS

SUMMARY

The subject, Vehicles, Miscellaneous, was not summarized because of the limited scope of the vehicles, miscellaneous reports briefed to date. When a sufficient number of vehicles, miscellaneous reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

AFF 2-18-49(V)

SUBJECT: Vehicles, Miscellaneous
TITLE: U. S. Army Reconnaissance Policy
IDENTIFICATION: Report No. AFF 2-18-49(V)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces Board, Fort Knox, Kentucky
PURPOSE: To define certain U. S. Army reconnaissance policies
METHOD: Study was made of the purposes, operating methods, requirements, and accomplishments of reconnaissance units. Pertinent extracts of material relative to the use of ground reconnaissance units were analyzed and summarized. The unit requirements, organization, and equipment of these units were investigated. Experienced commanders and staff officers of reconnaissance units including those with cavalry and airborne experience were interrogated and valuable testimony was thus obtained.
DESCRIPTION: The reconnaissance doctrine was in FM 100-5 (Draft) "Field Service Regulations, Operations" January 1949. Reference material used was listed in Tab 2, Annex B, and Tab 8, Annex C, Volume II, of this report.
CONCLUSIONS: The reconnaissance doctrine and principles of employment of ground reconnaissance units as contained in FM 100-5 (Draft) were considered sound. Reconnaissance units required the following: a combat vehicle mounting a high powered gun; a light tank for reconnaissance companies of armored and infantry divisions, a lightly armored 1/4-ton truck, and a light amphibious vehicle. A lightly armored 1/4-ton truck and self-propelled antitank gun were practical for airborne use. It was recommended that a continuing study be made to determine the feasibility of an adequately maneuverable wheeled armored car mounting not less than a 76mm gun and weighing about 20,000 pounds as a substitute for the light tank.
GENERAL: This nine-page report is not illustrated and is contained with Report No. AFF 2-18-49.

AFF 2-18-49(VI)

SUBJECT: Vehicles, Miscellaneous
TITLE: Flame Warfare Policy (Mechanized)
IDENTIFICATION: Report No. AFF 2-18-49(VI)
DATE OF REPORT: 18 February 1949
ORIGIN: Army Field Forces, Fort Knox, Ky.
PURPOSE: To re-examine the United States policy on mechanized flame throwers
METHOD: A conference was held for the purpose of reviewing the current policy and the tactical use of mechanized flame throwers and of determining basic military characteristics of the weapon. Representatives of the U.S. Army General Staff, interested Technical Services and Army Field Forces Agencies, and the British and Canadian Armies attended the conference. Re-examination and implementation was made of recommendations contained in the War Department Equipment Board Report. A minority report was presented by the U.S. Marine Corps.
DESCRIPTION: The type of flame throwing equipment, types of vehicles used in conjunction with the equipment, the tactical use and requirements of equipment and the airborne aspects were the topics of review and discussion.
CONCLUSIONS: The U.S. tactical concept for the employment of mechanized flame throwing vehicles was sound. There was a requirement for a large capacity, attachable type of flame thrower adaptable in kit form for combat vehicle or trailer. There was no requirement for an antipersonnel type of small capacity auxiliary flame thrower or for a vehicle which could junction only as flame thrower. Standard and auxiliary flame throwers for the M4 series tanks should be retained until stocks of these tanks are exhausted. The Marine Corps had a need of large capacity flame throwers for tanks.
GENERAL: This eight-page report is not illustrated and is contained with Report No. AFF 2-18-49.

APG TB5-1401/133

SUBJECT: Vehicles, Miscellaneous
TITLE: Summer Arctic Test (1953) of Utility Vehicle, Tracked, Infantry, T55, Fort Churchill, Manitoba, Canada
IDENTIFICATION: One Hundred Thirty-third Report on Project No. TB5-1401
DATE OF REPORT: 4 December 1953
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the mobility and over-all characteristics of the test vehicle in the summer

muskeg
METHOD: The test utility vehicle was operated over all types of terrain in the area of Fort Churchill, Manitoba, Canada. Observations were made with respect to the mobility and general operating characteristics of the vehicle in the muskeg.
DESCRIPTION: The utility vehicle, tracked, infantry, T55 was a lightly armored, front sprocket driven, full-tracklaying vehicle powered by a GMC, 6-cylinder, liquid-cooled, gasoline engine. Power was transmitted through a semi-automatic, hydraulic torque converter, Allison XT-90 transmission. The vehicle carried a crew of six men, weighed 11,900 pounds completely equipped, had a top speed of 30 mph, and a cruising range of 150 miles. Other features included a 15-inch ground clearance and a projected ground pressure of 3.2 psi.
CONCLUSIONS: The test vehicle was capable of operating in the muskeg found in the Fort Churchill area. It was recommended that from a military standpoint, the utility vehicle, tracked, infantry, T55, be considered satisfactory for use in the summer muskeg of the test area.
GENERAL: This 18-page report includes five photographs of the test vehicle.

APG TB5-1401/224
SUBJECT: Vehicles, Miscellaneous
TITLE: Summer Arctic Comparative Tests of Tracked Vehicles
IDENTIFICATION: Two Hundred Twenty-fourth Report on Project No. TB5-1401
DATE OF REPORT: 11 January 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the general performance characteristics of several types of tracked vehicles operating over varied terrain
METHOD: The test vehicles were operated over varied terrain in the Fort Churchill area. Vehicle drawbar pull tests were also conducted during operation in a heavy swamp. Performance characteristics of the various vehicles were observed and compared.
DESCRIPTION: Tracked vehicles tested included: a 1/2-ton, T107 amphibious cargo carrier provided with five sections, band-type tracks and three different track and suspension configurations; a T60 vehicle, which was primarily developed for the purpose of testing experimental concepts featuring spaced-link track principles; T72 and T121 light snow tractors designed for transporting small loads over snow and ice; M76 and M29 cargo carriers; and a 5-ton, T43E2 cargo tractor.
CONCLUSIONS: The T60, T107, and M76 vehicles could satisfactorily negotiate any type of terrain which was encountered, with the exception of the boulder-strewn area along the shore of Hudson Bay. The M29 could negotiate most of the terrain encountered provided the route was carefully planned; however, this vehicle was unable to traverse deep, soft mud, or lakes. The T72 and T121, due to their small size, could negotiate only solid and level terrain. With an experienced driver, performance of the T43E2 was generally satisfactory. It was recommended that further testing be conducted to evaluate more thoroughly the different track and suspension systems of the T107 vehicle; and that further development and testing be devoted to the power train of this vehicle.
GENERAL: This 124-page report includes 27 photographs of the test vehicles and terrain conditions encountered.

APG TT2-644/3
SUBJECT: Vehicles, Miscellaneous
TITLE: Engineering and Endurance Tests of Two Engineer Armored Vehicles, T39, Pilot Models
IDENTIFICATION: Third Report on Project No. TT2-644; APG 12-17
DATE OF REPORT: 20 May 1952
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of Engineer Armored Vehicle T39 for field engineering use
METHOD: Two pilot models were tested to determine bulldozing, winching and general fieldwork abilities. The rear winch was subjected to endurance pulls of 40,000 pounds and bulldozing operation included earth-moving and tree and stump removals. Automotive tests included cooling, center of gravity, slope operation, drawbar pull, maximum speeds, braking acceleration, and towing resistance.
DESCRIPTION: The test Engineer Armored Vehicle T39 was basically a Medium Tank M46 modified to incorporate a Bulldozer Blade M3, a single release 20,000-pound capacity 31-foot boom, a 40,000-pound capacity A-frame, a 36-ton capacity single drum winch, and a British 6.5-inch demolition Gun Mk 1.
CONCLUSIONS: The winch failed to pull its rated load. The boom and A-frame were satisfactory, however, the latter required redesigning to provide a higher vertical lift. It was recommended that: a governing device be provided to limit winch operation to 850 engine rpm, winch controls be redesigned to properly control lowering loads when using the A-frame for front boom, and the bulldozer emergency lift and carrying hooks be redesigned for positive and easier operation.
GENERAL: This 173-page report contains 23 photographs of the vehicle and components.

Section 56
VISION DEVICES

SUMMARY

The subject, Vision Devices, was not summarized because of the limited scope of the vision device reports briefed to date. When a sufficient number of vision device reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Vision Devices APG TT2-725/10
TITLE: Report on Experimental Vision Block Inserts
IDENTIFICATION: Tenth Report on Project No. TT2-725
DATE OF REPORT: July 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the ballistic vulnerability characteristics of three experimental methods of mounting vision blocks with those of the standard method of mounting vision blocks
METHOD: Several vision blocks mounted by three experimental methods were subjected to ballistic attack using cal. .50 AP projectiles; firing tests were conducted at various muzzle velocities and angles of attack. Blast sensitivity characteristics of additional test type vision block mountings were then determined using 3-pound spheres of 50-50 pentolite and TNT. For comparison purposes, the ballistic vulnerability and blast sensitivity of standard mounted vision blocks were determined under identical conditions.
DESCRIPTION: The three experimental methods of mounting vision blocks were developed by Aircraft Armaments, Incorporated. The experimental methods of mounting the vision devices were developed in an attempt to eliminate the high cost necessary in machining the standard vision block openings of armored cupolas. One experimental mounting method, identified as the welded insert, consisted of welding a cast liner insert into an oversized vision block cupola opening. The second method, identified as an "as cast" opening, consisted of a zircon sand cored hole cast integral with the cupola opening. The third method, identified as the plastic liner, consisted of casting the cupola with oversized openings containing integral peripheral ridges: a suitable plastic material was then cast as a liner between the casting opening and a male form. The internal surfaces of the welded insert, as cast, and plastic liners were smooth and each conformed closely to the vision block case. Vision blocks were inserted into the openings from inside the cupola; three bolts held each vision block in place.
CONCLUSIONS: The welded insert and plastic liner methods of mounting vision blocks showed some promise of equaling the standard method of mounting vision blocks and were recommended for further development. Bullet splash between the vision block and opening demonstrated the inadequacy of the "as cast" type mounting. The plastic materials used in the plastic liner mountings were badly damaged due to cracking after firing tests conducted with cal. .50 AP ammunition. The standard mounted vision blocks were more vulnerable to high explosive blasts than any of the experimental blocks. Several recommendations were made for improvement of the plastic materials used as fillers in the plastic liner mountings.
GENERAL: This 43-page report contains 27 photographs of the experimental vision block mountings.

Section 57
WELDING

SUMMARY

The subject, Welding, was not summarized because of the limited scope of the welding reports briefed to date. When a sufficient number of welding reports are briefed that establish trends, a summary will be prepared and made available.

REPORT RESUMES

SUBJECT: Welding APG TT1-5/31
TITLE: Ballistic Shock Test of the Ferritic Welds on a Composite M48 Tank Hull Fabricated by the Fisher Grand Blanc Tank Plant (U)
IDENTIFICATION: Thirty-first Report on Project No. TT1-5
DATE OF REPORT: 30 August 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the ballistic vulnerability of the ferritic weld joints of a composite M48 tank cast hull
METHOD: The ferritic weld joints of an M48 tank hull were shock tested with 105mm and 75mm proof projectiles at normal obliquity. A 20-pound explosive charge (TNT) mine was detonated under the forward floor plate of the hull.
DESCRIPTION: The composite M48 tank hull submitted was fabricated at the Fisher Grand Blanc Tank Plant by welding castings and rolled armor sections together with Grade 230 MIL-E-986 Specification low hydrogen ferritic welding electrodes. All pieces comprising the hull were cast with the exception of one formed rolled armor piece, which comprised a rear plate, and two sections of floor armor.
CONCLUSIONS: The ferritic weld joints of the test hull were ballistically satisfactory and superior to austenitic welded joints of M48 hulls tested at earlier dates. It was recommended that Grade 230 ferritic low hydrogen electrodes be considered for use as a replacement for austenitic electrodes in the fabrication of composite M48 tank hulls. Because of severe plate cracking noted in the turret ring casting, it was further recommended that the hull turret ring casting design be revised so that the casting in itself would provide better ballistic protection.
GENERAL: This 72-page report contains 26 photographs showing the test hull and drawings showing points of hull impacts.

SUBJECT: Welding APG TT1-5/33
TITLE: Investigation of the Shock Resistance of 2 Inch Welded Strips When Subjected to Ballistic Test at -40°F (U)
IDENTIFICATION: Thirty-third Report on Project No. TT1-5
DATE OF REPORT: 14 November 1955
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the approximate striking velocity at which weld cracking occurred
METHOD: Forty-two welded strips were cut from six 2-inch rolled homogeneous plates and were placed in a coldroom where the temperature of the strips was lowered to -40°F. All strips were tested with 57mm Plate Proofing projectile, M1001, at a gun distance of 78 feet. Striking velocities were varied in an attempt to obtain the lowest velocity at which cracking was initiated and the highest velocity at which no cracking occurred.
DESCRIPTION: Each test item was a 2x3-1/2x18-inch double-V austenitic welded strip. All strips were welded in a similar manner using the same type of electrode, and all welds were ground flush with the plate. The weld in each strip was located equidistant from each end of the strip.
CONCLUSIONS: The velocity at which cracking was initiated could not be determined; however, the velocity at which fracture occurred was obtained. It was felt that the fracture-velocity method was suitable for testing 2-inch thick welded armor plate to show differences in ballistic shock resistance between welded metals as well as welding procedures. It was recommended that further testing of this type of welded strip, fabricated with other types of electrode, be conducted and that this type of test be considered for use as a supplement to the double-I and H-welded plate tests for investigating the performance of various weld metals and welding procedures in resisting ballistic shock.
GENERAL: This 58-page report includes 13 photographs of the test strips.

SUBJECT: Welding APG TT2-614/16
TITLE: Ballistic Tests of the Welded Joints of the Hulls of the T59 and T18E1 Armored Infantry Vehicles and the Engine Compartment Grilles of the T59 Armored Infantry Vehicles
IDENTIFICATION: Sixteenth Report on Project No. TT2-614
DATE OF REPORT: 25 November 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare several types of welded joints on armored infantry vehicles; to evaluate

the ballistic protection afforded by the grilles of the AIV-T59
METHOD: The welded joints of two AIV-T59 hulls and one AIV-T18E1 hull were shock-tested with 57mm proof projectiles, 40mm HE shell, and anti-tank mines loaded with 12 and 20 pounds of explosives. The T59 grilles were tested with small arms projectiles, 37mm AP projectiles, and hand grenades.
DESCRIPTION: Two T59 armored vehicle hulls constructed with incomplete penetration joints, one with ferritic and the other with austenitic welded joints, were tested. Testing was also conducted with a T18E1 armored infantry vehicle hull fabricated with complete penetration, austenitic welded joints. The incomplete penetration weld joints were joints in which each plate at the corner of the joint was butted against the other plate so that the weld metal did not penetrate the root of the joint, the corners of the plates were positioned to provide a root gap so that the weld metal extended completely through the joint. Eight T59 engine compartment grilles with L-shaped louver bars 3/16-inch thick were evaluated.
CONCLUSIONS: The incomplete penetration weld joints of both the T59 ferritic and austenitic welded hulls were inferior to the complete penetration, austenitic welded joints of the T18E1. However, this inferiority was not considered sufficient to justify the exclusive use of these joints. It was recommended that, except for certain joints, the incomplete penetration welding (both austenitic and ferritic) be considered satisfactory for T59 use. The thickness of the louver bars of the engine compartment grilles on the T59 hulls was considered insufficient. It was recommended that this thickness be increased to a minimum of 1/4-inch and to 5/16-inch if possible.
GENERAL: This 215-page report contains 95 photographs of the test vehicles. Also included are laboratory reports and summaries of ballistic results.

SUBJECT: Welding WAL 900/92
TITLE: Summary of Research and Development Activities of the Watertown Arsenal Welding Branch
IDENTIFICATION: Memorandum Report No. WAL 900/92
DATE OF REPORT: 31 May 1945
ORIGIN: Watertown Arsenal, Mass.
PURPOSE: To determine whether the extensive research and development of welding techniques during World War II should be continued after the cessation of hostilities
METHOD: All the results of the research and development of welding techniques during the years 1941 to 1945 were summarized. In addition, a brief discussion was given of the results of studies conducted on German vehicle weldments.
DESCRIPTION: Most of the information devoted to the research and development of welding techniques during World War II was obtained from laboratory reports written at the Watertown Arsenal Laboratories.
CONCLUSIONS: The research devoted to developing welding techniques during World War II was believed to have answered a number of military requirements. Numerous other requirements remained, however, and it was felt that the program devoted to developing welding techniques during World War II should be continued. It was recommended that various research and development projects as outlined in the report be used as the basis for a plan in conducting future welding technique studies.
GENERAL: This 63-page report contains 14 pages of photographs showing various welding specimens and two pages of photomicrographs.

Section 59
WINTERIZATION TESTS

SUMMARY

This summary covers 11 resumes of winterization tests written in 1947, 1949, and 1954. The following origins were represented: AGF Task Force Frigid, Ladd Field, Alaska; AGF Task Force Frost, Camp McCoy, Wisconsin; AGF Task Force Williwan, Adak, Alaska; Army Field Forces Board No. 2, Fort Knox, Kentucky; Aberdeen Proving Ground, Maryland; and the Detroit Arsenal, Center Line, Michigan. Experimental winterized vehicles and equipment were subjected to cold weather operation, data were recorded, and the items were evaluated for their appropriate uses under the various test conditions.

Determinations were made concerning the suitability of Ordnance equipment for permitting the effective functioning of ground troops under winter arctic dry-cold, arctic cold-wet, and cold-temperate conditions. Many of the conclusions were so detailed that they were not covered in the resume but only in the actual report. It was recommended that desired types of equipment and personnel training techniques be developed for additional testing, and that Alaskan territory deficiencies be improved. It was further recommended that in all future tests, the following two agencies be established: a permanent cold weather testing board; and a permanent cold weather training installation.

The mobility of various wheeled and tracked vehicles was observed during operations over frozen and unfrozen tundra. The wheeled vehicles were found to be unsatisfactory for unfrozen tundra, while tracked vehicles weighing less than 15 tons and with a ground pressure of 5 psi or less were considered satisfactory. Beetle and Groundhog vehicles, both equipped with spaced link tracks, were outstanding with regard to snow mobility; however small tractors and Rolligon vehicles were inadequate. It was concluded that good snow mobility depended upon a combination of design features which included low ground pressure, low vehicle movement resistance, a low center of gravity, and a large vehicle size.

Cold temperature operating characteristics were determined for a 76mm gun tank, M41A1, and a self-propelled twin 40mm gun, M42, Detailed conclusions and recommendations made concerning these vehicles were included in the report resume.

REPORT RESUMES

SUBJECT: Winterization Tests AFF 1247
TITLE: Study of 1946-1947 Winter Test of Tundra Passage by Army Ground Forces Task Force Williwaw
IDENTIFICATION: Project No. 1247
DATE OF REPORT: 25 February 1949
ORIGIN: Army Field Forces Board No. 2, Fort Knox, Kentucky
PURPOSE: To determine the mobility of various wheeled and tracked vehicles over frozen and unfrozen tundra
METHOD: The vehicles were operated at Adak Island, Alaska in conjunction with the 1946-47 winter test operations of Task Force Williwaw.
DESCRIPTION: The wheeled vehicles included: 1/4, 3/4, 1-1/2, 2-1/2, and 7-1/2-ton trucks; Heavy Wrecking Truck M1A1; Truck-Tractor M26A1 with 45-ton Semitrailer M15A1, and 8-ton Trailer M23. The tracked vehicles included: Cargo Carrier M29C; LVT's; Light Tank M24; Medium Tank M26; Tank Recovery Vehicle M32; Motor Carriages M43 and M36; and Tractors M4 and M6.
CONCLUSIONS: The wheeled vehicles were unsatisfactory for unfrozen tundra, while the tracked vehicles weighing less than 15 tons and with a ground pressure of 5 psi or less were considered satisfactory. Frozen tundra offered no additional problems to those encountered with other types of frozen terrain. It was recommended that the vehicles be tested on arctic terrain during summer months in order to obtain a more complete measure of performance.
GENERAL: This 127-page report contains 45 pages of photographs showing wheeled and tracked vehicles operating over frozen and unfrozen tundra.

AFF Vol. I
Winter Test 1946-47
SUBJECT: Winterization Tests
TITLE: Final Report on Army Ground Forces Winter Test Program 1946-1947
IDENTIFICATION: Vol. I of III, Arctic-Dry Cold Conditions
DATE OF REPORT: 8 July 1947
ORIGIN: AGF Task Force Frigid, Ladd Field, Alaska
PURPOSE: To determine the suitability of Ordnance equipment for permitting the effective functioning of ground troops under arctic winter conditions
METHOD: The task force was based at, and operated in the vicinity of, Ladd Field, Alaska, for the purpose of determining the military requirements for cold weather warfare. The testing period extended from October 1946 to April 1947. During this time, numerous tests were conducted on old

and new Ordnance equipment; field exercises were executed by troops using the test equipment. The lowest temperature obtained during the test was -62° F.
DESCRIPTION: The following personnel and equipment studies were conducted: task force organizational requirements; effects on Table of Organization and Equipment; infantry and airborne equipment and problems; personnel clothing, sleeping equipment, shelters, rations, and mess equipment; mobility of motor vehicles and armor; field and antiaircraft artillery requirements; firing tests with various types of military weapons; personnel physiological studies; requirements of personnel and equipment used in the task force engineer, signal corps, ordnance, and medical detachments; cold weather effect on tactics and techniques; and personnel cold weather training requirements.
CONCLUSIONS: General and specific results on the suitability of personnel and Ordnance equipment during the testing period were included in this report. "Supplement No. 1 of The Final Report on Winter Test Program, Vol. I, AGF Task Force Frigid," classified "Secret", summarizes the pertinent results of the test.
GENERAL: This 1951-page report contains numerous photographs showing views of personnel, equipment, terrain, etc.

AFF Vol. II
Winter Test 1946-47

SUBJECT: Winterization Tests
TITLE: Final Report of Army Ground Forces Winter Test Program 1946-1947
IDENTIFICATION: Volume II of III, "Cold-Temperate Conditions"
DATE OF REPORT: 25 June 1947
ORIGIN: AGF Task Force Frost, Camp McCoy, Wisconsin
PURPOSE: To determine the suitability of Ordnance equipment for permitting the effective functioning of ground troops under temperate zone heavy winter conditions
METHOD: Personnel and Ordnance equipment were transported to Camp McCoy, Wisconsin, for extended operations under temperate zone heavy winter conditions. The testing period lasted from November, 1946, to March, 1947. During this period, old and new Ordnance equipment was tested for suitability under the prevailing weather conditions; and combat exercises were executed by troops using the test equipment. Maximum and minimum temperatures experienced during the test period were 61 and -27.8° F, respectively.
DESCRIPTION: The personnel and cold weather equipment studies included the following: task force organizational requirements; effects on Table of Organization and Equipment; effect on combat tactics and techniques; infantry and airborne equipment and problems; personnel clothing, sleeping equipment, shelter, rations, mess, and physiological requirements; mobility of various types of motor vehicles; suitability of field artillery, armor, cavalry, and antiaircraft artillery; firing of weapons; requirements of personnel and equipment used in engineer, signal corps, quartermaster, ordnance, medical, and chemical warfare service detachments.
CONCLUSIONS: Numerous conclusions and recommendations on the various phases of study were included in the report. In summarizing, it was specifically recommended that a board be established to carry out the following functions: correlate all information gained in winter warfare test operations and other sources; recommended changes in winter warfare training and tactical literature; coodinate military development of clothing, equipment, arms, ammunition, vehicles, etc., for use under cold weather conditions; and coordinate joint Ground and Air Force supporting and supply activities.
GENERAL: This 649-page report contains numerous photographs of personnel, test equipment, testing terrain, failures which occurred during test, etc.

AFF Vol. III
Winter Test 1946-47

SUBJECT: Winterization Tests
TITLE: Final Report of Army Ground Forces Winter Test Program 1946-1947
IDENTIFICATION: Volume III of III, "Cold-Wet Conditions"
DATE OF REPORT: 12 June 1947
ORIGIN: AGF Task Force Williwaw, Adak, Alaska
PURPOSE: To determine the suitability of Ordnance equipment for permitting the effective functioning of ground troops under cold-wet climatic conditions
METHOD: Task force "Frost" was based at Adak Island, Alaska, for the purpose of determining the military requirements of cold-wet winter operations. The testing period extended from July 1946 to June 1947. During this period, old and new Ordnance equipment was tested in order to determine the suitability of performance under adverse conditions. Combat exercises were carried on by troops using the test equipment. Cold-wet climatic conditions were described as having temperatures ranging from 20° F to 40° F, high humidity (rain, fog, and snow), and generally unfrozen (wet and muddy) terrain.
DESCRIPTION: The personnel and equipment studies conducted in cold-wet weather covered the following: task force organizational requirements; effects on Table of Organization and Equipment; effects of weather on tactics and techniques; infantry and airborne equipment and problems; personnel clothing, sleeping equipment, shelter, rations, mess, and physiological and psychological effects; mobility of motor vehicles; suitability of amphibious operations, armor, field artillery, and liaison aircraft; animal transportation; and personnel and equipment requirements for engineer, signal corps, quartermaster corps, ordnance, medical, and chemical corps detachments.
CONCLUSIONS: Numerous conclusions and recommendations were drawn on each of the test studies. In summarizing, it was recommended that, in the future, intensive testing be conducted by permanent testing groups located in each of the major climatic zones (tropical, temperate, and arctic).
GENERAL: This 598-page report contains numer-

ous photographs showing views of personnel, test equipment, the condition of terrain during various phases of test, failures which occurred, etc.

AFF Vol. S
Winter Test 1946-1947

SUBJECT: Winterization Tests
TITLE: Winter Test Program 1946-1947
IDENTIFICATION: Supplement No. I to Final Report
DATE OF REPORT: 15 August 1947
ORIGIN: AFG Task Force Frigid, Ladd Field, Alaska
PURPOSE: To determine the suitability of Ordnance equipment for permitting the effective functioning of ground troops under arctic winter conditions
METHOD: The results of arctic operations conducted in the vicinity of Ladd Field, Alaska, were evaluated. These operations took place during the winter of 1946-1947 by AGF Task Force Frigid.
DESCRIPTION: None.
CONCLUSIONS: General conclusions and recommendations on equipment used during testing were included in "Final Report on Army Ground Forces Winter Test Program, 1946-1947, Vol. I of III". In studying the results of the above test, the following was concluded: Army Ground Forces could not operate efficiently with Ordnance equipment used during the testing period; all unsatisfactory equipment would have to be replaced with new equipment designed for arctic use, and partially satisfactory equipment required modification; development of equipment to fulfill the needs for which no equipment existed was recommended; special personnel training would be required for each individual connected with arctic operations; with proper equipment, warfare could be conducted by personnel in temperatures of -62°F; the transportation system, road network, and the economy of Alaska, at the time of testing, would not support any large scale operation. It was recommended that desired types of equipment and personnel training techniques be developed for additional testing; and that the Alaskan territory deficiencies be improved. It was further recommended that in all future tests. the following two agencies, both entirely divorced from one another, be established: a permanent cold weather testing board, and a permanent cold weather training installation.
GENERAL: This six-page report is not illustrated.

APG TB5-1401/159

SUBJECT: Winterization Tests
TITLE: Winter Tests (1953-54) Tank, 90-mm Gun, M47
IDENTIFICATION: One Hundred and Fifty-ninth Report on Project TB5-1401; Seventeenth Report on Project TT2-777
DATE OF REPORT: 30 March 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the suitability of special components and winterization equipment installed on the Tank, 90mm Gun, M47
METHOD: The experimental test components were installed and the vehicle prepared for test by the Detroit Arsenal. The vehicle was shipped to Fort Churchill, Canada where it was road tested for 2004 miles, 1831 miles of which were over a cross-country course consisting of muskeg. deep snow, and ice. Limited cold starting tests were conducted after cold soaking and under ambient temperatures ranging from -3° to -29°F. The experimental engine was replaced at 933 miles.
DESCRIPTION: The experimental test items included a Model AV1790-7X (austerity) engine, boron and titanium alloy suspension components, arctic terpolymer rubber chevron track shoes, polymer rubber road wheel tires, track drive sprocket hub, de-icer, shock-mounted tail lamps, arctic air cleaners and power plant, and personnel heaters.
CONCLUSIONS: The austerity engine was found capable of starting at temperatures as low as -25°F with the use of only a hand primer, but the engine failed at 933 miles of operation due to a bent connecting rod. The air induction system was considered unsuitable. The alloy suspension components were satisfactory. The terpolymer track shoes showed less wear than standard shoes. The performance and suitability of polymer rubber road wheel tires were about the same as that of standard rubber wheels. The power plant heaters were unreliable and the canvas grille covers did not maintain constant engine temperatures but the personnel heaters gave satisfactory operation. High carburetor intake air temperatures tended to reduce the maximum engine ouput. The control linkage reduced operating efficiency due to ice formation in the bottom of the hull. It was recommended that controlled shutters be provided in the air cleaners to control temperatures of the carburetor intake air, that the power plant heaters be completely enclosed, that the canvas grille fastening devices be redesigned, and that a method of preventing freezing of the control linkage be devised.
GENERAL: This 141-page report includes complete testing data and 25 pages of photographs of the test vehicle and test components.

APG TB5-1401/162

SUBJECT: Winterization Tests
TITLE: First and Final Report on Arctic Test (1953-54) of Periscope Anti-Frost Devices
IDENTIFICATION: One Hundred Sixty-second Report on Project No. TB5-1401
DATE OF REPORT: 30 June 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To determine the most suitable frost prevention device for Periscope M20 glass surfaces
METHOD: Seven anti-obscuration devices were installed in 90mm Gun Tanks M47 and M48 and daily observation was made of frost, snow, and ice on vision device glass caused by overnight standing and operators' breath. The time required to dissipate frost on M20 Periscope glass was measured for each device. Power requirements for heater elements and the effect of heat on vision and alignment of the periscope were determined. Flexibility of rubber components and ease of operation on the test devices were observed.
DESCRIPTION: The anti-frost devices consisted

of standard blower type defrosters with inlet heater or in-line heaters, anti-obscuration boot No. 8295477, electrically heated glass, and an installation with a heater at the periscope splash shield.
CONCLUSIONS: None of the test devices were completely satisfactory for the Periscope M20. The electrically heated glass showed promise as it rapidly and efficiently defrosted the glass surfaces with low electrical power requirements. Further development of this glass and of blower type defrosters with heaters was recommended. The other test devices were not satisfactory but further study was recommended. Additional recommendations were that external vapors on glass be mimimized by grouping exhaust, personnel heaters, and tank engines at the rear of the vehicle; that methods be found to remove snow from external turret glassware without exposure of crew; that the scope of these studies be extended to include gun sight eye lenses and cupola vision blocks; and that defroster heaters be fitted with electrical control switches and, if possible, with temperature control devices to provide maximum heat for defrosting.
GENERAL: This 68-page report includes 17 photographs of the test periscopes and devices.

APG TB5-1401/182
SUBJECT: Winterization Tests
TITLE: Over-all Summary Report on Winter Environmental Tests 1953-54
IDENTIFICATION: One Hundred Eighty-second Report on Project TB5-1401
DATE OF REPORT: 24 May 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To summarize data on winter environmental tests
METHOD: A survey was made of the results of 40 winter environmental tests conducted at Fort Churchill and Flin Flon, Manitoba, Canada; Kapuskasing, Ontario, Canada; Big Delta, Alaska; and Yuma Test Station, Yuma, Arizona. Data were obtained and coordinated from test reports, environmental analyses, progress reports, weather data charts, and motion pictures.
DESCRIPTION: The winter environmental tests included various tests on combat and transport vehicles and their components.
CONCLUSIONS: The winterization and preparation of the test materials were not adequate to prevent operational difficulties in arctic conditions. These difficulties included carburetor icing, engine and transmission control rod freezing, unsatisfactory heating, hardening of rubber seals, entry of snow into turrets, frosting of sighting glass, and snow and ice accumulation on mechanical parts of weapons. It was recommended that changes be effected in the design and installation of winterization equipment or that a change in the winterizing methods and procedures be made to correct the difficulties encountered. It was also recommended that the environmental conditions available at Fort Churchill be considered when selecting test items and when determining the types of tests be be conducted.
GENERAL: This 96-page report includes 15 pages of photographs of the test items and areas, two maps, three weather charts, and two progress charts.

APG TB5-1401/187
SUBJECT: Winterization Tests
TITLE: Snow Mobility Test at Kapuskasing, Canada (1953-1954)
IDENTIFICATION: One Hundred Eighty-seventh Report on Project No. TB5-1401
DATE OF REPORT: 31 March 1954
ORIGIN: Aberdeen Proving Ground, Maryland
PURPOSE: To compare the snow mobility of numerous production and pilot model over-snow vehicles when operating under arctic conditions; and to determine whether accumulated data would aid in the future design of over-snow vehicles
METHOD: The test vehicles were operated while towing a dynamometer at Kapuskasing, Ontario, Canada, where the terrain was covered with a low density, loosely bonded snow. Pull slip curves, derived by holding the track speed of the test vehicle constant and changing the resistance of the dynamometer, were determined. Drawbar readings were taken at several slip ranges.
DESCRIPTION: Various vehicles were furnished for test by the Canadian Army, U.S. Transportation Corps, and U.S. Ordnance Corps. Vehicles submitted by the Canadian Army included: the Beetle, the 1/2-ton Penguin, the 3/4-ton Beaver, a German Cargo Carrier identified as the Raupenschlepper Ost., and an M29C Weasel. U.S. Transportation Corps vehicles submitted included: two types of Dodge power wagons, each identified as Rolligons; a Muskeg tractor; and the Marshbuggy. Ordnance vehicles tested included: an M76, 1-1/2-ton amphibious cargo carrier; the Frandee Snosh, a steel wheeled Swamp Skipper; the Goundhog; and the Gladden, T72, and Crosley, T121, snow tractors.
CONCLUSIONS: Beetle and Groundhog vehicles, both equipped with spaced link tracks, were outstanding with regard to snow mobility. Small tractors and the Rolligons were unsatisfactory. Most vehicle steering systems were unsuitable for the type of snow encountered. It was concluded that good snow mobility depended upon a combination of design features which included low ground pressure, low vehicle movement resistance, a low center of gravity, and a large vehicle size. It was felt that the test data obtained would aid in the development of vehicles for snow operation. It was recommended that comparative testing with various vehicles be continued; and that close attention be paid to determine the effect various additional design factors would have on vehicle snow performance.
GENERAL: This 46-page report contains seven photographs of the vehicles.

SUBJECT: Winterization Tests DA 2931/351
TITLE: Low Temperature Performance Evaluation of Tank, 76-MM Gun, M41A1 and a Twin 40-MM Gun, Self Propelled, M42 in the Climatic Hangar Eglin Air Force Base, Florida
IDENTIFICATION: Report No. DA 2931/351
DATE OF REPORT: 17 December 1954
ORIGIN: Detroit Arsenal, Center Line, Michigan

WINTERIZATION TESTS

PURPOSE: To determine the cold temperature operating characteristics of a 76mm Gun Tank M41A1 and a Self Propelled, Twin 40mm Gun M42
METHOD: Testing was conducted in the cold room at Eglin Air Force Base, Florida, by personnel from the Cadillac Motor Car Division, Cleveland Tank Plant. Tests included actual vehicle operation and firing of weapons at temperatures of +70°, +20°, -20°, -40°, and -65°F. Careful study was made of the following vehicle components: engine and power train, hull and suspension; turret, gun mount, and on vehicle materiel; electrical and communication systems; and personnel heaters.
DESCRIPTION: The test 76mm Gun Tank M41A1 and Self Propelled, Twin 40mm Gun M42 were standard production vehicles. The following cold weather equipment was included on the vehicles: an electrical pre-heating kit for the main engine of the M41A1 (batteries were warmed by heat supplied through ducts from the auxiliary engine); a heating duct network extending from the auxiliary engine to the main engine and batteries of the M42; special automatically adjusting grille covers mounted on both the M41A1 and M42; and an experimental gun mount heater in the M42.
CONCLUSIONS: The starting characteristics of both vehicle main engines at temperatures as low as -65°F were satisfactory. However, the pre-heat time required to raise the temperatures of the engines to a point at which starting could be accomplished was considered unnecessarily long. With the exception of the elevating mechanism of the M41A1 and the computing sight of the M42 at -65°F, the performance of the turret control and sighting systems of both vehicles was satisfactory. Firing of the weapons at low temperatures led to adverse effects. Auxiliary engine starting at temperatures below +20°F and personnel heater performance below -40°F were unsatisfactory. Radio communication was unsatisfactory below -40°F. Rubber parts were very unsatisfactory at low temperatures. The manual operation of vehicle components by personnel wearing arctic clothing was difficult; the main engine primer pump in the M42 was practically inaccessible to personnel with normal arctic clothing. Performance of the winterization grille cover kits and of the experimental, gun-mounted heater was satisfactory. It was recommended that the cold weather performance of the auxiliary engines, rubber components, communication systems, and personnel heaters be improved; that a system be developed for shortening the pre-heat time required to start the main engines of both vehicles; that the M42 main engine primer pump be relocated; that the rubber torsilastic hatch hinges of the M42 be eliminated; that studies be conducted on the effectiveness of the vehicle fire extinguishing system (CO_2) at low temperatures; and that the winterization grille kit be simplified and adopted for use on military vehicles.
GENERAL: This 586-page report contains 47 photographs showing vehicles and components and 440 pages of progress reports.