TECHNICAL REPORT ARBRL-TR-02359

TERMINAL BALLISTICS DIVISION'S RANGE 14 (R14), LARGE CALIBER, KINETIC ENERGY PROJECTILE, TERMINAL BALLISTIC TESTING FACILITY

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September 1981

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BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER TECHNICAL REPORT ARBRL-TR-02359	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* TERMINAL BALLISTICS DIVISION'S RANGE 14 (R14), LARGE CALIBER, KINETIC ENERGY PROJECTILE, TERMINAL BALLISTIC TESTING FACILITY		5. TYPE OF REPORT & PERIOD COVERED FINAL 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) L. Giglio-Tos W. Gillich L. Herr J. Wilson		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Ballistic Research Laboratory ATTN: DRDAR-BLT Aberdeen Proving Ground, MD 21005		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS RDT&E 1L162618AH80
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Armament Research and Development Command U.S. Army Ballistic Research Laboratory ATTN: DRDAR-BL Aberdeen Proving Ground, MD 21005		12. REPORT DATE SEPTEMBER 1981 13. NUMBER OF PAGES 39
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Terminal ballistics
test range facilities
large caliber
kinetic energy projectiles
test range instrumentation
environmental pollution controls

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

(hib) Events leading up to the construction of the Terminal Ballistics Division's provisional, large caliber, kinetic energy projectile, terminal ballistic testing facility at Range 14, Spesutie Island, APG are discussed. The facility is described in considerable detail with attention given to: site preparation and range development plan, construction, instrumentation, structural integrity and operational readiness testing; and operational capabilities.

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I. INTRODUCTION

In January 1980, the Terminal Ballistics Division (TBD) of the Ballistic Research Laboratory (BRL) completed a major portion of construction of a new, fully instrumented, large caliber kinetic energy (KE) terminal ballistic testing facility. The concept and plans for the facility, designated as Range 14 (R14), were developed by personnel of the Penetration Mechanics Branch (PMB) of TBD who also supervised construction and instrumentation of the facility and are charged with responsibility for its operation.

R14 is located on Spesutie Island at the Aberdeen Proving Ground, MD. Structural integrity and operational readiness testing of the facility was accomplished shortly after construction was completed, and the facility was placed on limited operational status, in March 1980, while the Nuclear Regulatory Commission (NRC) was considering an application for license granting permission for testing involving certain classes of hazardous materials*, eg, depleted uranium (DU). The NRC license was granted in September 1980, at which time the facility was placed on full operational status.

R14 is a provisional facility intended as an interim solution to the overburden placed on other BRL and APG testing facilities over the past ten years by the ever increasing, urgent requirements of the BRL for the full-scale terminal ballistic testing of large caliber KE munitions of all kinds and of new, experimental ballistic armors. The other BRL and APG test ranges proved to be both insufficient and inadequate to meet the demands put upon them particularly for the testing of hazardous materials munitions testing.

This report presents a discussion of events leading up to the construction of the R14 facility, of the main features of facility construction and instrumentation, and of facility operational capabilities.

II. BACKGROUND

A. General.

The BRL was established in 1935 as a government owned and operated laboratory charged with conducting research in ballistics, a branch of applied mechanics, and related fundamental sciences. The ballistic research at the BRL is compartmented, for convenience, into five main areas, vulnerability, ballistic modeling, interior ballistics, exterior ballistics, and terminal ballistics. It is this last area

*Within the contents of this report, "hazardous materials" are those which pose an environmental hazard.

which has a direct bearing on the need for and construction of the provisional R14 facility and of a similar but more advanced and permanent terminal ballistic testing facility, also conceived and planned by PMB personnel, which is expected to be ready for use in FY83. The permanent facility, currently awaiting approval for construction, is referred to as the Advanced High Kinetic Energy Launch System (AHKELS).

Terminal ballistics is concerned with phenomena associated with the interaction between a projectile and a target when the projectile impacts on the target. A subarea of terminal ballistics, penetration ballistics or penetration mechanics is concerned with the interaction between a projectile, eg, a KE projectile or penetrator, and a target during the penetration process and with the behavior of the residual projectile or penetrator behind the target in cases of complete penetration. At the BRL, the development and, particularly, the verification of ballistic theory supporting advancement in terminal ballistic research require the acquisition and analysis of considerable quantities of accurate, empirical terminal ballistic data. The acquisition and analysis of such data are also integral parts of the BRL conducted designing and design testing in exploratory and advanced development of armor defeating penetrators for large caliber KE projectiles and of highly penetration resistant ballistic armors. In order to fulfill its basic mission in the area of terminal ballistic research and to discharge its additional responsibility in this area for providing adequate and timely response to special requests from the Department of the Army (DA), from the Department of Defense (DOD), and from numerous customer agencies, it follows that the BRL needs large caliber terminal ballistic testing facilities dedicated to its own use and meeting the following criteria:

1. Availability for BRL use when and as required.

2. Adequacy:

a. Capability of handling current and anticipated future workloads without undue delay, ie, providing:

(1) All weather operability.

(2) Freedom from interference or undesirable interaction with or from other testing facilities.

b. Environmental acceptability.

(1) Providing protection to the environment against the dispersion of unacceptable amounts of hazardous material, such as depleted uranium, DU, and possible serious contamination of areas outside of the range proper.

(2) Providing protection to the neighboring public against excessive noise and against blast focusing damage to private property, damage which has been experienced as a result of testing, under certain atmospheric conditions, on open ranges relatively close to populated areas.

c. Suitability of design and instrumentation:

(1) Designed specifically for the terminal ballistic testing of a large variety of KE projectiles (including high velocity launch, high density and hazardous material cored, spin and fin stabilized projectiles) against a large variety of targets.

(2) Fitted with the latest instrumentation for complete, accurate acquisition and reduction of all types of terminal ballistic data.

(3) Provided with environmental controls to minimize the effect of environmental variables on test results.

d. Operational safety and security:

(1) Fitted with up-to-date safety equipment and operated under procedures designed to assure safety of operating personnel and qualified visitors.

(2) Providing adequate security against clandestine surveillance for special projects or programs.

Previous to 1970, the BRL managed to satisfy its requirements for large caliber terminal ballistic testing reasonably well by:

1. Requisitioning use of the Test and Evaluation Command (TECOM) facilities at APG. These facilities, open (not structurally enclosed) ranges, are operated by the Military Testing Directorate (MTD), and they are subject to preemptive use by TECOM to satisfy its own priorities and requirements, which usually do not coincide with those of the BRL, for the proof testing of materiel items which are in engineering or operational development.

2. Having TBD share the use of the exterior ballistic Transonic Range at APG with its operator, the Launch and Flight Division (LFD) of the BRL. The LFD uses this open range for its research in exterior ballistics associated with the designing and design testing of projectile flight bodies and hardware.

3. Making use of contractor facilities such as the open range facilities operated by the New Mexico Institute of Mining and Technology (NMIMT) at Socorro, New Mexico.

B. Need for a BRL, In-House Facility

Several factors combined during the early 1970's to make the need for a large caliber terminal ballistic testing facility meeting the criteria outlined above and dedicated to BRL use one of compelling urgency:

1. There was a general, sustained, and fairly rapid increase in the demand for all types of ballistic testing on the APG ranges, proof testing such as is usually performed by MTD for TECOM on the TECOM facilities and both exterior and terminal ballistic testing by the BRL. The result was a severe overburdening, which is still continuing, of all of the APG testing facilities. Consequently, the TECOM facilities were generally not available to the BRL on short notice or for other than very limited use, and the sharing of the Transonic Range by LFD and TBD resulted in conflicts in scheduling. Also increased activity on all of the open ranges created interaction problems between ranges in the same vicinity, e.g., for reasons of safety, exterior ballistic testing of some types of projectiles at the MTD Main Front, B1 or B2 Ranges or at the BRL Transonic Range could not be conducted simultaneously with terminal ballistic testing at the Transonic Range.

2. Use of existing range facilities was extended beyond regular working hours in an attempt to reduce the workload overburden. Almost immediately, there was an increase in complaints from the neighboring public about blast focusing damage to property and, especially, about excessive noise from the firing of large caliber guns during the evening hours.

3. A sharp increase in interest in and demand for terminal ballistic testing of high density, DU penetrators (testing which had started on a relatively modest scale at APG as early as the mid - 1960's) created an environmental pollution problem which rapidly became acute. The resulting new and very stringent environmental control regulations, e.g., those issued and enforced by the NRC, which culminated in July 1979 in a ban on open range destructive testing involving DU, seriously delayed the progress of several high priority, exploratory and advanced development weapons programs.

4. Existing ranges at APG were totally inadequate to provide necessary, full-scale terminal ballistic testing support for recently imposed BRL mission requirements for experimental research and design testing of high velocity launched KE projectiles. This is a research area which shows reasonable probability of significant payoff.

5. The use of contractor facilities to relieve the workload overburden on the APG ranges was considered. Generally such facilities were found to be inadequate in one or more respects, e.g., they could not handle the broad range of projectile and target configurations of interest, or they were not environmentally acceptable, or they did not provide sufficient security for classified programs. Even had these facilities been adequate in most respects, their use was usually economically unjustifiable; they were seldom available when and as required, and they were often too remote from the BRL to permit reasonable supervision or required coordination of related in-house activities at the BRL with those at the contractor site.

C. Plan to Meet the Need for an In-house Facility

As early as 1976 plans for AHKELS, the large caliber, high velocity terminal ballistic facility which would meet BRL's long range needs and would satisfy all of the criteria previously outlined, were being drawn up. A suitable site for construction, Range 9 (R9) on Spesuite Island at APG, was tentatively selected, and studies of construction feasibility, cost, and time for completion were initiated. The results of the feasibility study, completed in 1977, were favorable, and estimated costs did not seem prohibitive. However, operational availability in approximately five years, according to the best estimates of time for completion, offered no relief for the BRL's immediate or short term needs. In order to relieve the situation to some extent pending completion of the AHKELS facility, TBD personnel proposed construction of an interim or provisional facility through improvements to and expansion of an existing firing site, R14, on the south end of the west side of Spesutie Island at APG. Although the design of the proposed facility would not meet all of the criteria set forth above for a large caliber test range, e.g., it would not provide all-weather operability, it would provide many desirable characteristics not present in existing APG test ranges. Furthermore, it was estimated that the proposed facility could be operational within 15 to 18 months after the start of construction. The TBD proposal was accepted, and the provisional R14 terminal ballistic testing facility described below is the result.

III. The R14 FACILITY

A. Site Preparation and Range Development Plan

Approval of the proposed site for construction of the R14 facility was obtained in December 1978, and site preparation commenced immediately with grading and leveling of the entire area. The grade level of areas where the principal structures were to be placed and of surrounding work areas was raised considerably through introduction of a compacted gravel fill with a depth of about 0.46 m (1.5 ft). This fill significantly increased the load bearing capability of the ground and reduced the probability of storm flooding of structures and work areas. The range development plan called for:

1. Functional capability for the terminal ballistic testing of large caliber (up to 155 mm) KE projectiles fired from suitably mounted tank guns, with muzzle velocities of up to approximately 2300 m/s (7500 fps), over distances of from 50 to 200 m (197 to 656 ft) into targets of a variety of materials and configurations. The projectiles generally would be of the armor-piercing, fin-stabilized, discarding-sabot (APFSDS) type with penetrators of steel, tungsten alloy (Wa), or DU.

2. Functional capability for acquiring and recording raw terminal ballistic data, i.e., evidence of the behavior of and of the interaction between a projectile or penetrator and a target at the time of impact, during the penetration process (for tests involving multiple-plate targets), and behind the target if penetration is complete.

3. An enclosed target bay capable of containing and withstanding the overpressures generated in the vicinity of the target during terminal ballistic testing and of containing any fragments, including air-suspended residues, resulting from penetrator-target interaction. The target bay would be fitted with airtight seals on doors providing access from the exterior and with an exhaust ventilation system with absolute filters. The exhaust system would clear the target bay of any hazardous, air-suspended residues after a test and provide safe access for operating personnel to examine or exchange targets or to clean up the area. The door seals and ventilation system filters would prevent contamination of the outside atmosphere with hazardous residues. The target bay would also be fitted with a wash down and drainage system, including a washdown residue and waste water holding tank, to facilitate cleanup and disposal of hazardous material fragments, other than air suspended fragments, after a test.

4. A cylindrical range tunnel enclosing all but the initial portion, about 12 m (40 ft), of the projectile trajectory between the gun muzzle and the projectile entry port in the uprange wall of the target bay enclosure. A stripper plate, to prevent both lateral and downrange travel of discarded sabot segments, would be placed at the uprange end of the range tunnel. The range tunnel and stripper plate would, for all practical purposes, restrict the downrange danger zone between gun muzzle and target bay to the interior of the range tunnel.

5. An enclosed, support equipment area adjoining the target bay and containing subareas: for the housing and use of data acquisition, processing, and reduction equipment; for the housing and use of contamination checking and control equipment; for the performance of administrative functions; and for an operating personnel ready room, a wash room, and toilets.

6. Protection against clandestine surveillance. This would be provided by enclosure of target bay, trajectory, and support equipment areas and by range security controls.

7. Numerous safety features, in addition to the environmental pollution controls in the target bay enclosure, intended to assure the safety of operating personnel and others in the testing area. These features would include equipment malfunction and area evacuation warning systems; electric, ground fault protected gun firing circuitry with remote firing controls; approved "bombproof" shelter for gun crew, etc.

B. Construction

Above ground construction of the R14 facility commenced in June 1979 and was completed by January 1980. The overall layout is shown in Figure 1. Figure 2 shows several of the range structures with the gun located in extreme downrange position. A bound set of 64 engineering drawings showing construction details is available for inspection at PMB. The facility includes:

1. Gun Location. The gun may be located, as desired, at any of 11 positions, approximately 12 m (40 ft) apart, along the centerline of the outer 140 m (450 ft) of a strip of compacted gravel fill which extends for some 200 m (656 ft) in a north-northeasterly direction from the target bay enclosure. The outer portion of the strip designated for gun positioning is approximately 23 m (75 ft) wide, and the remaining 60 m (197 ft) is approximately 14 m (46 ft) wide. A horizontal line about 1.5 to 2.0 m (5 to 6.5 ft) above ground level and parallel to and directly above the gravel strip centerline defines

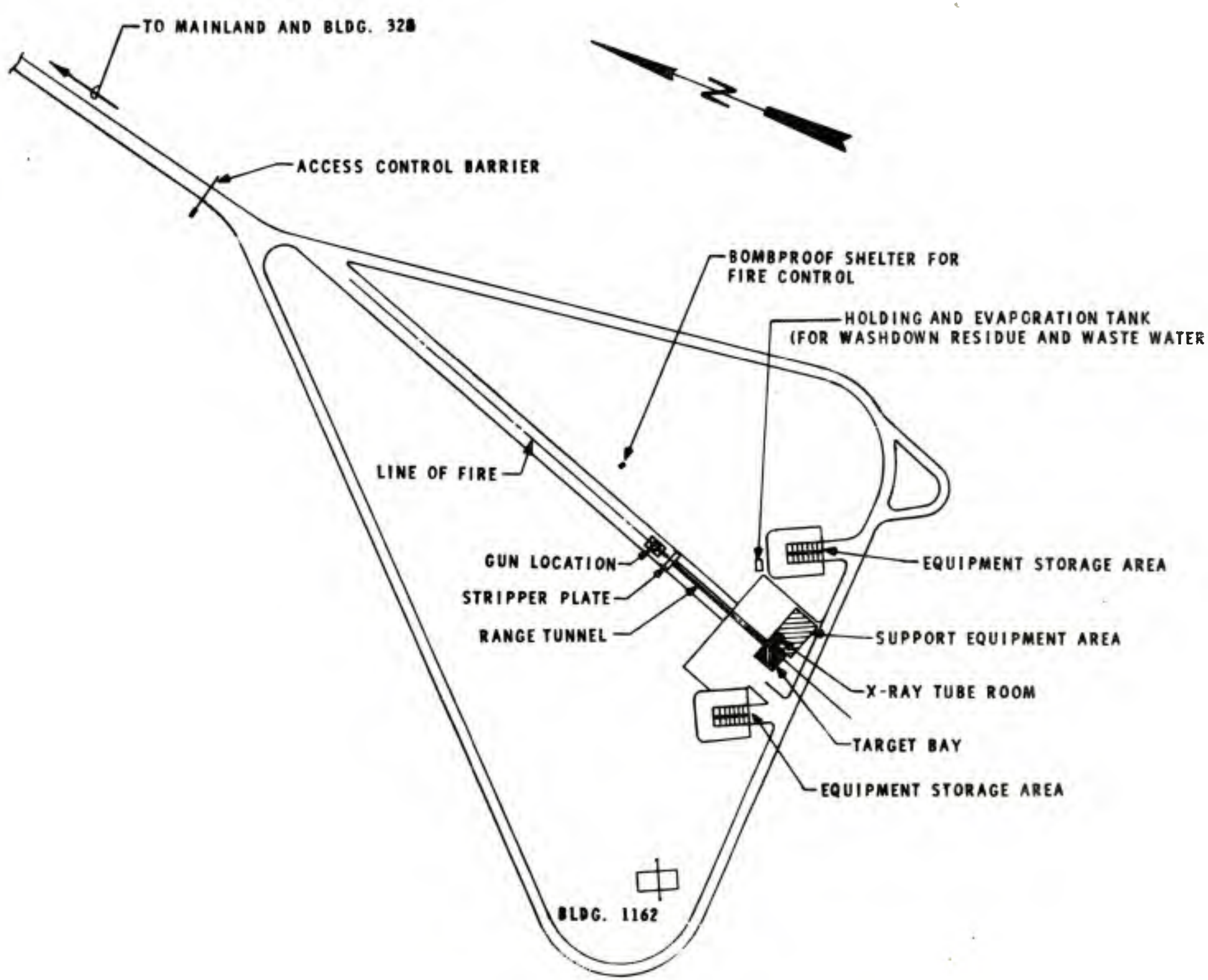

Figure 1. Range 14 (R14) Site Plan

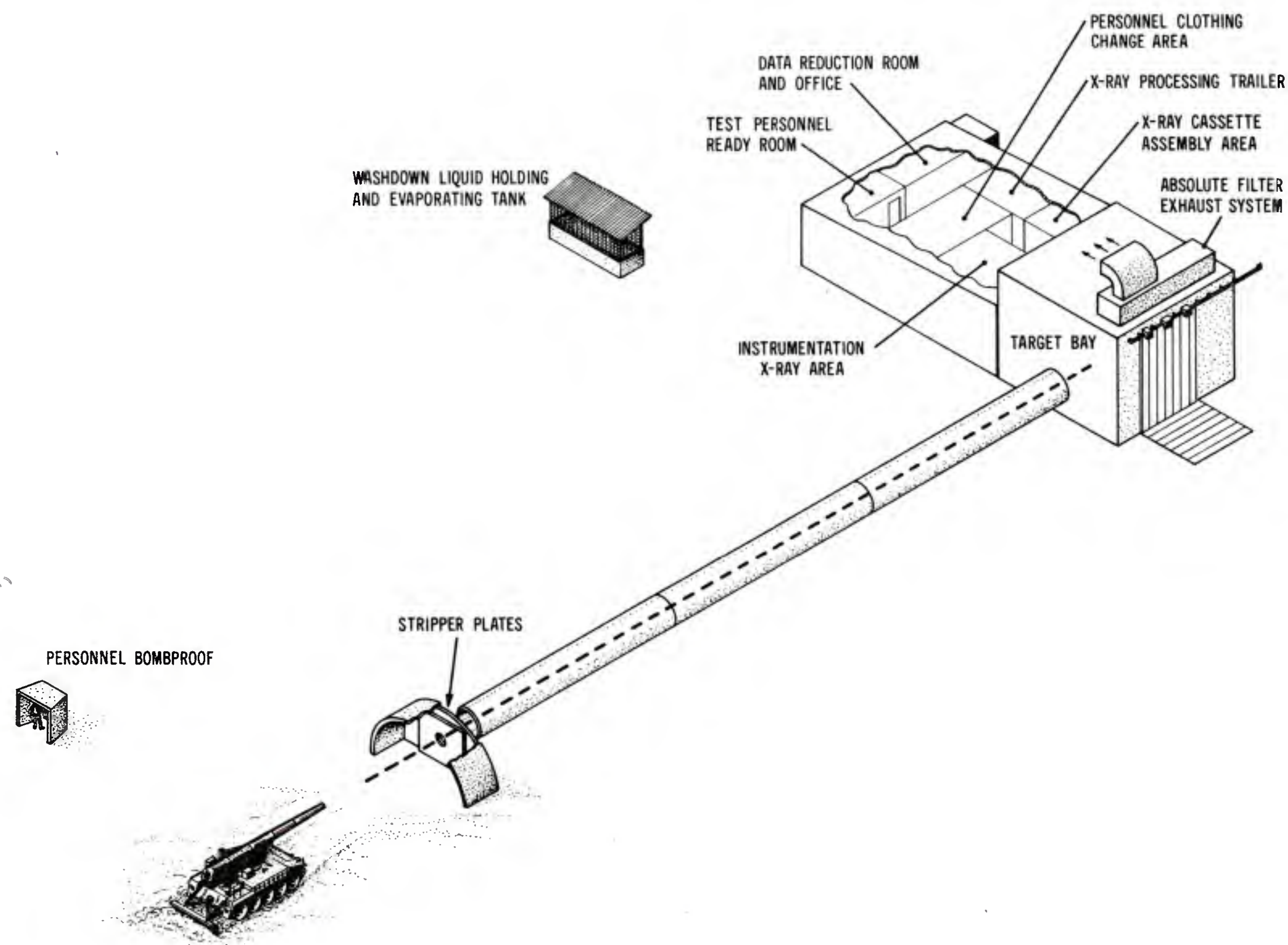

Figure 2. Range 14 (R14) Showing Target Bay and Other Structures with Gun in Extreme Down Range Position

the projectile line of fire or trajectory from the gun muzzle to the aim point on the target. The gun location and the initial portion of the trajectory, approximately 12 m (40 ft), between the gun muzzle and the stripper plate (see below) are not enclosed.

2. Stripper Plate Assembly. A portable assembly consisting of a steel armor plate, the stripper plate, with a thickness of 100 to 125 mm (4 to 5 in.) and side baffles or a semicircular barbette of the same material is located about 12 to 18 m (40 to 60 ft) downrange from the gun muzzle with the stripper plate athwart the line of fire at the upper end of the range tunnel (see below). The stripper plate has an orifice, centered on the trajectory which permits passage of the subprojectile but is small enough to prevent portions of the discarded sabot from proceeding downrange toward the target. The side baffling or the barbette which extends uprange one to two metres (3.3 to 6.6 ft) from the stripper plate prevents sabot parts which strike the stripper plate from traveling laterally outside of the immediate vicinity of the stripper plate.

3. Range Tunnel. The range tunnel, which centers around and encloses the projectile trajectory downrange from immediately behind the stripper plate to the projectile entry port in the uprange wall of the target bay enclosure, consists of:

a. Permanent Installation. Three sections of 2.44 m (8 ft) diameter steel tubing with a wall thickness of 25.4 mm (one in.). Each section of tubing is 15.24 m (50 ft) long, and the sections are joined with metal seam bands and clamps to form a continuous tunnel extending uprange 45.72 m (150 ft) from the target bay enclosure projectile entry port. The tube sections are supported at approximately 3 m (10 ft) intervals, longitudinally, by paired struts resting on transverse steel footer plates. The section end abutting the target bay wall fits into a wide, metal receiving collar welded to the wall.

b. Sub-permanent, Portable Installation. Eleven sections of 0.91 m (3 ft) diameter steel tubing with a wall thickness of 19.1 mm (0.75 in.) and a section length of 12.2 m (40 ft) are available for extending the range tunnel uprange, in section increments as desired, for up to 134 m (440 ft) beyond the uprange end of the permanent range tunnel installation. The tube sections are fitted with lifting brackets to provide portability. Seam bands and clamps, similar to those used on the larger diameter tubing, are used to join tube sections. Tube sections are supported, in the same manner as the larger diameter tube sections, by permanently emplaced strut-type supports.

4. <u>Target Bay Enclosure</u>. This enclosure is 9.14 m (30 ft) square by 7.32 m (24 ft) high. It is an all-welded, armor-lined steel structure which accommodates a target butt or support, the target of interest, a massive target backstop, various items of data acquisition and recording equipment, e.g., electronic projectile-sensing actuators for triggering chronographs and radiographic equipment, x-ray film holders and films, etc. A 0.46 m (1.5 ft) diameter projectile entry port centered at the point of intersection of the projectile trajectory and the uprange wall provides passage for the projectile from the range tunnel into the target bay. A floor plan of the target bay enclosure and of the contiguous support equipment enclosure (see subsection 5 below) is shown in Figure 3. The target bay enclosure is fitted with a high efficiency, forced air, absolute filter, exhaust ventilation system and with its own drainage system to conduct wash down residue to an externally located holding and evaporation tank. A personnel access doorway provides intercommunication between the target bay and the contiguous support equipment enclosure, and an equipment access doorway provides for movement of targets and other heavy equipment between the target bay and the adjoining, unenclosed work area. When secured in closed position during ballistic testing, the doors on both access doorways are hermetically sealed. Enclosure construction details are as follows:

a. Foundation and Flooring. The area under the target bay enclosure is filled, as previously noted, with compacted gravel. The enclosure is floored with 25.4 mm (one inch) thick mild steel plate which is reinforced in several areas, subject to heavy loading, by inserts of heavier steel base plates, e.g., under the target butt with a 203 mm (8 in.) thick plate; under the 3.66 m (12 ft) square by 619.6 mm (24 in.) thick, heavy armor target backstop with a 102 mm (4 in.) thick plate; etc. The floor is supported completely around its perimeter by 10WF112 steel footer beams which are in turn supported by 25.4 mm (one in.) thick steel footer plates. The area inside the footer beam structure was filled with compacted gravel to a level even with the top of the footer beams after drain piping and load-bearing reinforcement base plates had been located.

b. Walls.

(1) With the exception noted in (2), immediately below, the wall structure consists of an outer shell of 25.4 mm (one in.) thick mild steel plate which is welded to and supported by an external framework of vertically mounted 10WF60 steel beams capped by horizontally mounted beams of the same type. A liner of 70 mm (2.75 in.) thick steel

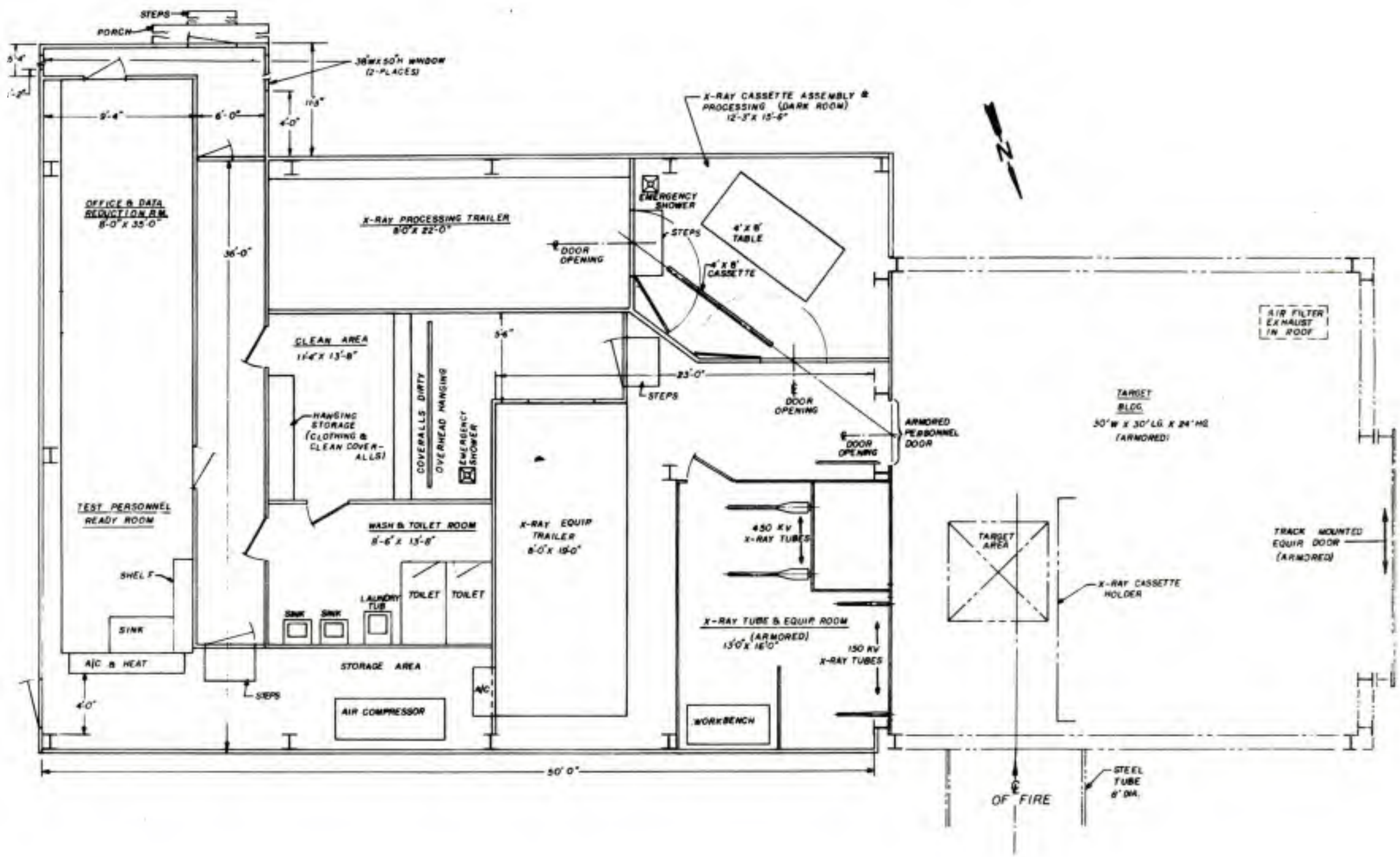

Figure 3. Range 14 (R14) Floor Plan of Target Bay and Support Equipment Enclosures

armor plate, supported by T-bars and angle irons welded to the inner surface of the mild steel shell, completes the wall structure.

(2) One portion of the outer shell of the target bay enclosure, a section extending upward 3.66m (12 ft) from the floor and downrange 4.87 m (16 ft) from the uprange wall of the enclosure, abuts the x-ray tube and equipment room in the support equipment enclosure. This portion of the outer shell is 38 mm (1.5 in.) thick steel armor plate. It is supported in the same manner as the remainder of the outer shell, but it does not have an armor liner. At a height of 1.52 m (60 in.) and extending almost the full length of the shell plating is a horizontal, 25.4 mm (one in.) slit which permits uninterrupted passage of x-rays from the tubes in the x-ray tube and equipment room into the target bay enclosure.

c. Roof. The roof consists of three sections, a central section of 38.1 mm (1.5 in.) thick steel armor plate and two side sections of 63.5 mm (2.5 in.) thick steel armor plate. The roof is supported around its perimeter by the horizontal capping beams of the wall-support framework and through its center, between the uprange and downrange walls, by a simple, double truss assembly whose two ends are supported by the horizontal capping beams. The truss consists of two main members, 10WF112 steel beams, and various cross pieces and strengthening members. The central section of the roof plating spans the space between the two truss beams and is entirely supported by the truss, being bolted to truss cross pieces and welded to the underside of the bottom flanges of the beams. The remaining roof plates, which are seam welded along adjoining edges, have one end supported by the top side of the bottom flange of a truss beam and the other by a horizontal capping beam of the wall-support framework. A series of 10WF60 steel beams; each beam welded to the upper side of the roof plating, covering the full length of a seam weld, and keyed into a truss beam; completes the roof structure. The 10WF60 roof beams strengthen the roof against blast pressure from within the target bay, and the beams on the side of the roof toward the equipment access doorway are cantilevered to provide support for the monorail track from which the equipment access door is suspended and along which it moves.

d. Access Doors.

(1) Personnel Access Door. The closure for the doorway between the target bay and the support equipment enclosure is a door of 38 mm (1.5 in.) thick steel armor plate. Door latching devices are manually operated. The door is provided with a perimeter seal of soft rubber tubing which provides an hermetic seal when the door is secured in closed position.

(2) Equipment Access Door. The closure for the 4.27 m (14 ft) wide by 6.3 m (20.66 ft) high doorway between the target bay and the unenclosed work area is a massive, track mounted, armored door consisting of a framework grid of 10WF60 steel beams with an outer plating of 38 mm (1.5 in.) thick steel armor and an inner plating of 6.35 mm (0.25 in.) thick mild steel. The door is suspended on trolleys which ride on a 381 mm (15 in.) I beam, monorail track. The lower end of the door moves in a guiding recess, fitted with guide rollers, between inner and outer ramps. Door opening and closing is effected by an electrically controlled monorail tractor-drive unit. Door latches are manually operated. The door is provided with a perimeter seal of inflatable, 63.5 mm (2.5 in.) diameter fire hose which provides an hermetic seal when the door is secured in closed position and the hose is inflated. Hose inflation is provided by means of an air compressor located in the support equipment area.

e. Wash down Drainage System. Wash down residues from target bay decontamination flow into one of three interconnected floor drains and are conducted by a 101.6 mm (4 in.) diameter drain pipe to a holding and evaporating tank, with a minimum capacity of 18.93 m^3 (5000 gal), located external to and approximately 30.5 m (100 ft) east of the target bay structure. The holding tank is rectangular, 2.7 m (9 ft) deep by 1.8 m (6 ft) wide by 6.1 m (20 ft) long, with half of its depth below grade. The tank is covered by a fiberglass roof bolted to spaced supports in such manner that adequate ventilation is provided and removal of the roof is not required to gain entry to the tank.

f. Exhaust Ventilation System. The pollution controlling exhaust ventilation and filtration system is a draw through type with three fan units, connected into a common plenum, which create an air flow into the target bay enclosure through the projectile entry port, through the target bay enclosure into the ventilation system exhaust duct in the roof of the enclosure, and through three banks of filters (prefilters, secondary filters, and final high particulate air (HEPA) filters) and a discharge stack into the outside atmosphere. The fan units are powered by 2HP motors and provide a total air flow through the system of 170 m^3 (6000 ft^3) per minute. Each of the filter banks consists of six fire resistant/retardant filters with a rated efficiency for filtering 0.3 micron particles as follows:

- Prefilters - 25 to 35 percent
- Secondary filters - 85 to 95 percent
- Final, HEPA filters - 99.7 to 99.9 percent

A combination fragment shield and blast wave deflector consisting of a set of one-inch steel baffles is mounted at the intake end of the exhaust duct. The baffles serve to protect filters and other parts of the exhaust ventilation system against damage from projectile fragments, armor spall, and/or the blast wave resulting from high speed impact of a penetrator on an armor target.

5. Support Equipment Enclosure. This enclosure, which is contiguous with the target bay enclosure, covers an area of, roughly, 10.97 m (36 ft) by 15.24 m (50 ft), is approximately 3.65 m (12 ft) high, and comprises:

- An x-ray tube and equipment room
- A dark room for x-ray film cassette assembly and processing
- A laundry, a lavatory, and a toilet room
- A general storage area (an air compressor is located in this space)
- A clothes changing area with storage space for protective clothing
- Three equipment trailers, with wheels removed, which are supported on blocks and are secured in place with angle bars welded to the steel floor of the enclosure:
  - An x-ray equipment trailer
  - An x-ray film processing trailer
  - An office trailer, used for administrative purposes and data reduction and as a ready room for operating personnel.

a. Foundation and Flooring. The area under the support equipment enclosure is filled with compacted gravel, and the enclosure flooring of 25.4 mm (one in.) thick steel plate is supported directly by the gravel without additional reinforcement.

b. Walls. The structure of the portion of the exterior wall of the support equipment enclosure which forms a partition between the support equipment enclosure and the target bay enclosure is described in subsection B.4.b.(1) and (2), above. The uprange wall consists of 69.9 mm (2.75 in.) thick steel armor plate supported by vertically mounted 10WF steel beams. The remaining exterior walls consist of heavy plywood, with an outer sheathing of aluminum, supported by a combination of vertically mounted 10WF steel beams and a wooden framework. Interior walls which subdivide the support equipment enclosure, with the exception of the aluminum walls of the equipment trailers and the armor plate walls of the x-ray tube and equipment room (see e, below), are plywood on a wooden framework.

c. Roof. The roof consists of heavy plywood with an outer sheathing of aluminum. The roof is supported by wooden rafters which rest on a series of horizontally placed steel I beams spanning the space between the tops of the vertically mounted 10WF beams which support the uprange and downrange walls of the support equipment enclosure.

d. Access Doors. There are three doorways which provide personnel access to the support equipment Enclosure. Two of the doorways which communicate with the outdoors have solid-core, wooden doors. The third doorway which communicates with the target bay enclosure has the closure described in subsection B.4.d.(1) above.

e. X-ray Tube and Equipment Room. This 3.96 m (13 ft) by 4.88 m (16 ft) area in the northwest corner of the support equipment enclosure has steel armor plate walls and ceiling. The portion of the outer shell of the target bay area described in subsection B.4.b.(2), above, serves as one wall of this room; a section of the uprange wall of the support equipment enclosure (see b, above) serves as a second wall; the remaining two walls are 25.4 mm (one in.) thick steel armor plate supported by vertically mounted 6x6WF and 10WF steel beams. The ceiling is 25.4 mm (one in.) thick steel armor plate supported by a framework of angle bars and one 6x6WF steel beam mounted horizontally and spanning the tops of the vertical beams supporting the wall opposite to the target bay enclosure. There is a personnel access doorway in the room which communicates with the interior of the support equipment enclosure. The closure for this doorway is a door of 25.4 mm (one in.) thick steel armor plate. Latching devices and perimeter seal are the same as those of the personnel access door of the target bay (see B.4.d.(1), above).

6. Personnel Bombproof Shelter. An approved, portable Class A armored shelter or "bombproof" provides housing for electronic fire control devices, permitting remote firing of the gun, and ballistic protection for range personnel engaged in gun firing. The position of the bombproof can be varied to accommodate changes in gun location (see B.1, above). The actual position of the hombproof relative to the gun location is, of course, governed by Army explosive regulations applicable to the test being conducted.

7. Equipment Storage Areas. There are two 9.1 m (30 ft) by 15.24 m (50 ft) areas, one on either side of and about 15.24 m (50 ft) from the contiguous target bay and support equipment enclosures, which are designated for general equipment storage. These areas, whose construction predates the recent R14 development, are protected on three sides, including those facing uprange, by earthen revetments approximately 3.66 m (12 ft) high and are covered with wooden roofs.

8. Explosives Loading/Storage Structure. A concrete and plastic structure, designated as Building 1183 and located on Spesutie Island approximately 1.6 km (one mi) from the R14 site and considerably closer to the R9 (AHKELS) site, will serve as an explosives loading and/or storage area for test firings conducted at R14 and for those conducted at R9 after it becomes operational. The structure, whose construction predates the recent development of R14, was specifically designed for its intended use. It is rectangular, 7.62 m (25 ft) by 6.10 m (20 ft), and has a height of 3.66 m (12 ft). The floor, roof, and three of the four walls are of heavy, prestressed, reinforced concrete. The fourth wall, which faces in a northwesterly direction toward the waters of Spesutie Narrows, is of corrugated translucent plastic. The interior is divided into two bays, each with a separate entrance. In case of an accidental detonation of explosives within the structure, the plastic wall is designed to collapse and relieve the pressure on the rest of the structure before it becomes too critical. Thus, damage to the structure will be limited, and the effects of an accidental blast will be channeled toward an area which is normally unused and unoccupied and to which access is rigidly controlled and strictly limited.

C. Instrumentation

Although the R14 test facility is operational, instrumentation installation is not quite complete as of the date of this report since certain items of equipment, e.g., electronic data processing equipment, which are on order have not been received. Some of the instrumentation for the facility is sophisticated and somewhat innovative. The experience gained from its installation and use on the R14 facility should prove extremely beneficial in making decisions regarding instrumentation selection for and installation on TBD's permanent, large caliber terminal ballistic testing facility, AHKELS or R9, which is currently in the site preparation stage. When the installation is completed, the R14 instrumentation will include:

1. Projectile/Target Performance Data Acquisition and Processing Equipment.

a. Pressure Gages/Transducers. These are electronically monitored, gun mounted devices used to provide a record of peak chamber pressure and pressure-time histories for projectile launchings. The pressure gages/transducers also serve to trigger muzzle x-ray equipment.

b. Muzzle X-ray Equipment. This electronically controlled radiographic equipment, suitably positioned near the gun muzzle, is used to record flight characteristics of the projectile immediately after it exits the gun muzzle.

c. Smear Cameras, 35 mm, high-speed. These cameras, mounted at designated stations along the line of fire (up to approximately 5.5 m (18 ft) from the gun muzzle), are used to record flight characteristics of the projectile/subprojectile as it passes each station.

d. High-speed Framing Cameras, 16 mm. An "underlying" camera, located under the line of fire and approximately 12 m (40 ft) downrange from the gun muzzle, is used to record projectile launch and muzzle exit behavior and subprojectile flight characteristics over the initial portion of the trajectory. An additional camera, appropriately mounted in the target bay Enclosure, is used to record behind-target penetrator fragmentation and armor spall distribution characteristics.

e. Sky Screens, Break Screens, and Counter Chronographs. Electronically monitored sky screens or break screens, located at designated stations along the line of fire in the 2.44 m (8 ft) diameter range tunnel, and associated counter chronographs are used to detect the passage and record the time of passage of the subprojectile at each station in the range tunnel. Electronically monitored break screens, located along the line of fire in the target bay enclosure (just inside the projectile entry port and at other selected stations, dependent on the target under test), and associated counter chronographs are used to detect the passage and record the time of passage of the subprojectile/penetrator at each station. The target bay enclosure break screens and counter chronographs also serve to control the target bay enclosure x-ray equipment (see g, below).

f. Yaw Cards. Heavy paper or cardboard cards, mounted on specially constructed stands (often in conjunction with a break screen) and located at designated stations along the line of fire in the 2.44 mm (8 ft) diameter range tunnel and at one station just inside the projectile entry port in the target bay enclosure, are used to record the subprojectile signature, from which yaw may be determined, as it passes each station.

g. Target Bay X-ray Data Acquisition Equipment. A multiple-flash radiographic system consisting of a 150 kv, 12 channel unit and a 450 kv, 4 channel unit is used to obtain chronologically sequenced radiographic records of changes in subprojectile/penetrator physical condition (dimension, shape, number of pieces), attitude, direction of travel, and position at selected times from just prior to subprojectile impact on the target until the penetration process is complete. Some of the radiographic, data acquisition equipment, e.g., overhead mounted x-ray flash heads and cassette encased x-ray films mounted in frames adjacent to the target butt, is located in the target bay enclosure; the rest of the equipment is located in the x-ray tube and equipment room in the support equipment enclosure. The 150 kV unit is used to obtain preimpact, orthogonal (horizontal and vertical plane) views of the subprojectile and, for multiple-plate, spaced armor targets, vertical plane views of the residual penetrator in the between-plate intervals. The 450 kV unit is used to obtain vertical plane views of the residual penetrator, penetrator fragments, and armor spall behind the target.

h. X-ray Film Processing and Reading Equipment. An x-ray film developer, located in the x-ray film processing trailer in the support equipment area, provides practically instantaneous, automatic developing of radiographic film once it is recovered from the cassettes in the target bay enclosure after a test firing. An x-ray accessory light table, also located in the trailer, is used for reading (initial, by-hand reduction) and interpretation of the raw radiographic data, i.e., processed film.

i. Electronic Data Recording and Processing and Monitoring Equipment. Several items of electronic equipment, e.g., a remote access terminal linked directly by cable to the main, CDC CYBER 76, BRL computer, peripheral computer equipment, and microprocessors, are to be housed in the office trailer in the support equipment enclosure. The computer equipment will be used to store, process, and retrieve or record information or data associated with projectile/target performance and generated during a test firing, i.e., interior, exterior, and terminal ballistic data, and operational information such as the chronicling of events and ambient conditions during a test firing or a series of such firings. The microprocessors will be used to monitor and automatically control or adjust the sequencing of certain performance data acquisition equipment.

2. Environmental Pollution Control and Monitoring Equipment.

Environmental pollution control is accomplished by the absolute filter, exhaust ventilation system (see subsection B.4.f, above) of the target bay enclosure. The exhaust system is monitored to assure that it is operating properly, and the environment at several stations in the vicinity of the target bay enclosure is monitored to assure that emission of air-suspended hazardous material does not exceed maximum permissible concentration as defined by NRC regulations.

a. Exhaust Ventilation System Monitoring Equipment. Magnehelic gages in the ventilation system are used to measure the differential pressures across filters when the system is placed in operation for a test firing. The differential pressure is an indication of system efficiency. Currently, readings are recorded manually. In the future, it is planned to have the differential pressures monitored and recorded electronically. An isokinetic, moving air filter monitoring system, which is on order, will be mounted in the exhaust ventilation discharge stack. This system will be used to monitor hazardous material emission levels automatically over selectable periods of 8 hours, 24 hours, or 30 days and will provide a record of the emission level associated with each test firing within the selected period as well as the average of cumulative emissions from successive test firings during the period.

b. Environmental Air Monitoring Equipment. Five, continuously operating air samplers with filters and electric motors and timers to create and control airflow are mounted near ground level in the vicinity of the target bay enclosure. These samplers are used as an aid in determining hazardous material emission levels over periods of approximately one week between inspections. Four of the air samplers are about equally spaced around the circumference of a circle with radius of 91.44 m (300 ft) centered on the target bay enclosure. One of these four samplers is located approximately 39.62 m (132 ft) northeast of the uprange end of the permanent installation portion of the range tunnel (see subsection B.3.a). The fifth air sampler is located just inside the uprange end of the same portion of the range tunnel.

3. <u>Operational Safety and Security Equipment.</u>

a. Gun Firing Circuitry. The electrical gun firing circuitry provides for remote control of gun firing from the bombproof shelter (see subsection B.6). The circuitry is ground fault protected and is fitted with three interlocking limit switches, one on the equipment access door and one on the personnel access door of the target bay enclosure (see subsection B.4.d) and the third on the personnel access door of the x-ray tube and equipment room (see subsection B.5.e), all of which must be closed before firing can be accomplished. Proper securing of the three doors, including pressurization of the inflatable seal of the equipment access door in the target bay enclosure, will close the limit switches and provide the circuit continuity necessary for firing.

b. Danger Warning Lights. A set of two, high intensity, rotating beacons with red lights are located on top of the roof of the target bay enclosure, one beacon at each uprange corner. When the beacons are activated, the red flashes are visible for several miles, even in broad daylight, over an arc of the horizon of 360 degrees; except where obscured near ground level by intervening trees, shrubbery, foliage, or structures; and at considerable elevation. Beacon visibility along the single access road to the R14 area extends outward from the range and back along the road from the access control barrier (see d below) for at least 304.8 m (1000 ft). The beacons, which are remotely controlled from the bombproof shelter (see subsection B.6), are activated when a test firing is imminent and remain activated while danger from the test firing is deemed to exist. The beacons serve to warn persons in the R14 area to evacuate the area or take cover and to warn persons approaching the area to stay clear while test firing is in process.

c. Audible Warning Signal. An electric siren, mounted on a post approximately 45.7 m (150 ft) northeast of the uprange end of the permanent installation portion of the range tunnel (see subsection B.3.a) and remotely controlled from the bombproof shelter (see subsection B.6), is used to provide a distinctive, audible signal to persons in or approaching the R14 area indicating the imminence of a test firing or a different signal indicating the all clear after a test firing has been completed.

d. Access Control Barrier. An electrically/electronically operated barrier located approximately 289.6 m (950 ft) north-northeast of the target bay enclosure controls access to the R14 area by vehicles using the single access road. The barrier is normally in lowered position, closing the road to vehicular traffic into or out of the R14 area. Raising of the barrier to permit vehicular passage is accomplished by insertion of a properly encoded plastic card in a receptacle at the barrier or by operation of a switch in the office trailer in the support equipment enclosure (see subsection B.5). The barrier closes automatically after vehicle passage. A telephone with direct line to the office trailer in the support equipment enclosure is located at the barrier site.

D. <u>Structural Integrity and Operational Readiness Testing</u>

In the fall of 1979, some time before the R14 construction was completed, the Target Loading and Response Branch (TLR) of TBD was requested by PMB to perform a conservative structural stress analysis of the target bay enclosure design with respect to both static and dynamic loading. The analysis, results of which are presented in a memorandum report[1] to be published shortly, pinpointed several critical areas in the enclosure design. Design modifications recommended by the analyst to improve structural integrity and to provide the structure with an adequate margin of safety for withstanding any anticipated combination of environmental and experimental stress and for containing the effects of experimentation, e.g., overpressure generated as a result of high velocity impact of large caliber projectiles/penetrators on penetration resistant armor, were implemented during the final stages of construction.

Construction of the R14 facility was completed, except for minor items and installation of some instrumentation which was on order but had not been received, by late January 1980. Before being placed on operational status, the facility was subjected to rigorous structural integrity and operational readiness testing. This testing was performed:

- To demonstrate that the target bay enclosure is structurally adequate to contain/withstand the effects of the maximum peak and related residual overpressures, e.g., overpressures resulting from the energy release associated with the impact and complete oxidation of a 5.0 kg (11.0 lb) DU penetrator with an impact velocity of approximately 2200 m/s (7218 ft/s), which may be generated during the normal course of terminal ballistic testing for which the facility was designed.

- To demonstrate that the entire facility is environmentally and otherwise operationally adequate and safe for performance of the functions for which it was designed.

- To acquire facility performance data to support the application for NRC licensing for the destructive testing of hazardous material items on the R14 facility.

The structural integrity and operational readiness testing of the R14 facility was carried out, over the period between 8 February and 8 April 1980, in three stages:

- Stage 1 Testing. The structural integrity of the target bay enclosure was tested by statically detonating a series of three high explosive charges; one each of 0.113 kg (0.25 lb), 0.226 kg

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1 Aaron D. Gupta, "Stress Analysis of the Target Enclosure of the R14 Firing Range," Ballistic Research Laboratory Memorandum Report in publication.

(0.50 lb), and 0.340 kg (0.75 lb) of spherical pentolite. These charges were chosen since their static detonations, according to TLR research[2], were expected to produce overpressures within the enclosure roughly equivalent to those which would be generated by 2.0 to 3.5 kg (2.2 to 7.5 lb) KE projectile penetrators, made of DU material, impacting on an armor plate target with velocities of approximately 1500 to 1700 m/s (4921 to 5577 ft/s). The overpressure predictions for the static charge detonation were confirmed in subsequent testing employing DU penetrators.

•Stage 2 Testing. The structural integrity of the target bay enclosure and the operational readiness of data acquisition and operational safety and security instrumentation and equipment were tested by the firing of three 105 mm, APFSDS projectiles with Wa penetrators against standard armor targets. Each of the three projectile penetrators had a mass of approximately 2.1 kg (4.6 lb) and an impact velocity of approximately 1510 m/s (4954 m/s).

•Stage 3 Testing. The structural integrity of the target bay enclosure and the operational readiness of data acquisition, environmental control and monitoring, and operational safety and security instrumentation and equipment were tested by the firing of ten 105 mm APFSDS projectiles with DU penetrators against standard armor targets. Each of the penetrators of the first six projectiles had a mass of approximately 2.0 kg (4.4 lb) and an impact velocity of approximately 1696 m/s (5564 ft/s). Each of the last four projectile penetrators had a mass of approximately 3.4 kg (7.5 lb) and an impact velocity of approximately 1300 m/s (4265 ft/s).

TLR personnel assisted in all of the structural integrity testing. They recommended the explosive charge masses for the stage 1 testing, as noted, and they calibrated and located the pressure gages and recorded, reduced, and interpreted the pressure data acquired in all three test stages. Details and results of the pressure data acquisition are presented in Reference 2.

Personnel of the BRL Operations Safety and Health Physics Division assisted in the operational readiness performance evaluation of safety, and environmental control and monitoring instrumentation and equipment in the stage 2 and 3 testing. They calibrated and located special environmental pollution monitoring equipment for the stage 3 testing, and they recorded, reduced, and interpreted all environmental

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2 Brian Bertrand, Rodney Abrahams, Robert Peterson, and Sterling Dunbar, "Blast Pressures Produced by Impact of Kinetic Energy Penetrators on Steel Targets in an Enclosed Range," Ballistic Research Laboratory Memorandum Report ARBRL-MR-03074, February 1981. (AD #A098039)

pollution data acquired during this testing and prepared it for submission to the NRC in support of a BRL request for an amendment to the US Army Ballistic Research Laboratory Source Material License SMB-141 authorizing destructive testing of hazardous material, specifically DU, on the R14 facility. Details and results of the environmental data acquisition are presented in an enclosure to the license amendment request.* A copy of the enclosure is available for examination at PMB.

The results of the structural integrity and operational readiness testing of the R14 facility indicated that the facility, in particular the target bay enclosure, was structurally adequate to perform its intended functions and that all of the facility instrumentation and equipment was in satisfactory working order. Consequently, the facility was placed on limited operational status in March 1980 pending receipt of NRC authorization for destructive testing of hazardous material. In September 1980 when the NRC authorization for such testing was received, the R14 facility was placed on full operational status.

E. Range 14 Operational Capabilities

The provisional R14 terminal ballistic testing facility provides an environmentally acceptable and operationally surveillance secure and safe arena for the full-scale testing of:

Projectiles. Large caliber (75 to 155 mm), KE, armor piercing projectiles with:

Spin or fin stabilization.

Monolithic or sheathed, high density penetrators, e.g., penetrators of steel, Wa, or DU alloys, with mass up to 5 kg (∿11 lb).

Launch velocities of up to 2200 m/s (7218 f/s).

Armor. Standard and special armor configurations including single plate, multiple plate, and spaced, multiple plate targets.

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*The BRL Operations Safety and Health Physics Division plans to publish the details and results of the R14 environmental pollution data acquisition from stage 3 testing in an unclassified report in the late spring of 1981.

The range tunnel construction (subsection III.B.3) permits adjustment of muzzle to target distance from approximately 58 m (190 ft) to 166 m (545 ft) in increments of approximately 12 m (40 ft). For each gun location, all but the first 12 m (40 ft), approximately, of the trajectory between gun muzzle and target is enclosed.

Range 14 capabilities for acquisition of interior, exterior, and terminal ballistic data and for acquisition of environmental data indicating the effectiveness of environmental control equipment and the effect on the environment of testing various combinations of projectiles and targets under controlled conditions are both extensive and comprehensive. Automation of data acquisition and recording processes has already been effected in some areas, and studies of the feasibility of further automation are underway. It is planned to extend automation as far as is practicable and economically justifiable. Innovative experimentation with data acquisition automation on the Range 14 facility will not only serve to enhance the usefulness of R14; it will also provide direct carryover and benefit in the planning of instrumentation for the permanent, large caliber, high velocity terminal ballistic facility, AHKELS (see subsection II.C), which is in initial stage of construction at R9, Spesutie Island, APG.

The Range 14 data acquisition and recording capabilities currently include the following:

1. Interior ballistic data acquisition:

a. peak pressure

b. pressure-time history

c. obturation effectiveness

d. projectile launch and muzzle exit behavior

2. Exterior ballistic data acquisition:

a. projectile (or subprojectile) muzzle velocity

b. sabot discard effectiveness (for rounds fitted with discarding sabots)

c. projectile flight characteristics, yaw and velocity, at several selected downrange stations between gun muzzle and target.

3. Terminal ballistic (penetration process) data acquisition:

a. Impact data:

(1) projectile velocity

(2) projectile yaw

b. Between-target-plate or behind-target data

(1) residual penetrator velocity

(2) residual penetrator deformation - mass, breakup, etc.

(3) residual penetrator trajectory and attitude

c. Target damage data - depth of penetration and/or hole size.

4. Environmental data:

a. Exhaust system operational efficiency - differential pressures across ventilation system filters.

b. Record of continuous air sampling at several stations external to and in the vicinity of the target bay enclosure.

ACKNOWLEDGMENT

The Terminal Ballistic Division gratefully acknowledges the stinting services and invaluable contributions of Ms Judy A. Fortier, BRL Safety Specialist, Mr. Richard Markland, BRL Radiation Protection Officer, and Dennis Chambers, Health Physicist, of the BRL Operation Safety Division and of Mr. Robert Lehner, design engineer, and Mr. Frank Kohl, layout designer of AAI Corporation, to the construction of the R14 terminal ballistic testing facility.

Ms Fortier, Mr. Markland, and Mr. Chambers interpreted safety and environmental rules and regulations (particularly those issued by the Nuclear Regulatory Commission involving testing with hazardous materials), advised TBD on the purchase and installation of personnel safety and environmental protection equipment, tested the equipment after installation, and assured that the R14 facility met all safety and environmental requirements.

Mr. Lehner and Mr. Kohl worked in concert with and under the general guidance of TBD personnel from the inception of R14 construction until completion of the facility and provided expert advice, innovative ideas, and assistance on facility design and construction.

The contributions by Mr. Robert Smith, primary welder with the Experimental Fabrication Branch, Mr. Grat Blackburn, Technician with the Shaped Charge Branch, and Mr. Dale Smith, Technician with the Penetration Mechanics Branch were invaluable to the completion of Range 14.

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