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PROJECT PLUTO

GROUND TEST FACILITIES

DESIGN CRITERIA

REPORT 30003 VOL. I

Contract AF33(616)-6214

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THE Marquardt CORPORATION

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Report 30003
Volume I

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PROJECT PLUTO
GROUND TEST FACILITIES

DESIGN CRITERIA

1959 ADDENDUM TO TR 153-12

CONTRACT AF33(616)-6214

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1.0 INTRODUCTION

A continuing examination of the PLUTO Ground Test Facilities Design Criteria is reported herein.

Operating under Air Force Contract AF 33(616)-6214, The Marquardt Corporation conducted studies of the test facilities required for development of the PLUTO nuclear powered ramjet engine. This facility planning effort was directed toward studying various approaches by which the PLUTO engine could be developed to the point where flight testing might be undertaken. The various approaches were evaluated from the economic, schedule, and technical standpoints, and it was recommended that development of the propulsion system be carried out in a specially designed, blowdown type facility to be located at the Nevada Test Site. These studies and recommendations were submitted to the Propulsion Laboratory, WADC, in Report TR 153-11 in August, 1958 and, subsequently, were approved for continued facility planning purposes.

The Contractor then proceeded with the preparation of design criteria, preliminary design drawings, cost estimate and schedule for the PLUTO Ground Test Facility. These were submitted in March, 1959 to the Propulsion Laboratory, WADC in Report TR 153-12, Volumes I, II, and III. Report TR 153-13 presents the principal nuclear studies which were carried out in support of the facility planning effort and includes detailed analyses of exhaust gas handling requirements, hazards from particles eroded or broken from the reactor, radiation levels in the facility during the following tests, materials heating and activation within the test cell, etc.

Facility planning has continued under Contract AF 33 (616)-6214 subsequent to the submission of the Criteria Report, TR 153-12. This planning effort has included design studies which have been carried out in areas where improvements in operational performance or reductions in cost of the facilities could be made. The planning work is a continuing effort geared to maintain design current with performance requirements of the PLUTO program. The design studies include the air storage facility, the direct burning test air heater, the test cell, the exhaust system and the hot service building. In addition to this work, continuing investigations have been carried on concerning the nuclear safety of the projected test operations. During the current year, the use of an expanded PLUTO facility complex for ground testing the PLUTO engine and the entire missile as well has been studied.

1.0 INTRODUCTION - continued

The results of these continuing facility studies are presented herein and supersede information in similar areas that was given in Report TR 153-12. Since the start of detail facility design has been delayed over the January 1, 1960 date shown in the criteria report, it did not seem warranted to completely revise and reissue the entire Design Criteria at this time. Therefore, the present report is an addendum to TR 153-12.

2.0 REVISIONS TO DESIGN CRITERIA

The basic design criteria for the PLUTO Ground Test Facility has been set forth in Marquardt's Report TR 153-12, Volumes I, II and III. Volume I of the referenced report sets forth a description of the PLUTO engine and testing operations, general design requirements, facility performance requirements, and the facility design criteria and specifications. Volume II contained all of the preliminary drawings of the facility, and Volume III included the facility cost estimate and construction schedule.

It is the purpose of this document to report the changes to the basic criteria which have been generated as a result of Marquardt's work since the issuance of TR 153-12. Since no significant changes have been made to the description of the PLUTO engine and testing operations, the general design requirements, or the facility performance requirements, Chapters 1 through 7 of TR 153-12 are essentially correct as they stand. Chapter 8 of TR 153-12, which is design criteria for the Air Supply System, has not been changed except for the description of the underground air storage system. This section of the criteria, which appeared as Section 8.2.3 of the original report, has been completely revised and is presented as Section 2.1 of this report. Chapters 9 and 10 of TR 153-12, which are design criteria for the Test Cell Installation and Support Service, have been extensively modified as a result of this years effort. Chapter 9 and Section 10.6 have been completely rewritten and appear in this report in Section 2.2. Chapter 15 of Report 153-12, which is the design criteria for the Hot Components Service Building, has been completely revised and the revisions appear in this report as Section 2.3. In addition, Chapter 13 of the original report, which is design criteria for Waste Disposal, has been revised and appears in this report as Section 2.4.

It is recognized that a number of the remaining chapters of Report TR 153-12 have been influenced by the changes described above. However, it is believed that the extent of these changes were not significant enough to justify a detailed revision of the original criteria.

Volume II of TR 153-12, has been reissued in this addendum as Report 30003, Volume II. This volume is a complete set of revised preliminary drawings of the PLUTO facility.

Volume III of TR 153-12 has been partially revised to reflect the cost changes due to the changes in the design criteria. The revised cost estimate summary and construction schedule for the PLUTO facility appear as Section 3.0 of this report.

2.0 REVISIONS TO DESIGN CRITERIA - continued

The following sections describing the revisions to the design criteria also contain a brief justification for making the changes.

2.1 Air Supply System - The study of the air supply system reported herein has been confined principally to a further analysis of the underground air storage system. A number of changes have also been made in the layout of the air supply ducting and valving, as shown in Volume II of this report, but no basic changes have been made to the design criteria. The layout changes are reflected in Drawings 706860, 706861 and Figure 1. The revised arrangement will reduce the number of elbows in the ducting and will improve the design for more efficient thermal expansion. In addition, the regeneration flow system has been revised from a recirculating system to a once-through system which will discharge to atmosphere. This new arrangement will permit a reduction in the high temperature ducting and initial cost at the expense of a slightly higher operating cost due to an increased fuel consumption.

The principal change to the original design criteria for the air supply system has been in the underground air storage. It has been previously established that the PLUTO ground test air supply shall be of the intermittent or "blowdown" type and shall have sufficient capacity to permit a 25 minute run (direct connect) at full capacity. This will require 4,120,000 lbs. of air at 3600 psia. The design criteria for the underground air supply, as presented in TR 153-12, has not been significantly changed, since it is the intent of this section to further amplify the original criteria.

2.1.1 Air Storage Chamber - The test air shall be stored in an underground storage chamber located at sufficient depth to insure that the surrounding rock will be relatively homogeneous and capable of resisting the applied pressures. The actual depth of the storage chamber will be determined after core drills have been made in the area.

An illustration of the proposed air storage system is shown in Figure 2, and the design details are shown in Drawing 706864. As indicated on the drawings, the chamber shall be a vertical cylinder with a diameter of 30 feet and an over-all cylinder length of 370 feet.

The air supply riser shall be a 30" I.D. stainless steel duct similar in design to the main facility air supply ducts. A heavily reinforced concrete anchor will be located at the point where the riser and the transition section join. The riser section above the anchor shall be physically free from the shaft walls, thus providing freedom to expand and contract. The riser shall be designed to withstand 3600 psi air pressure.

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PLUTO TEST CELL AND AIR SUPPLY AREA

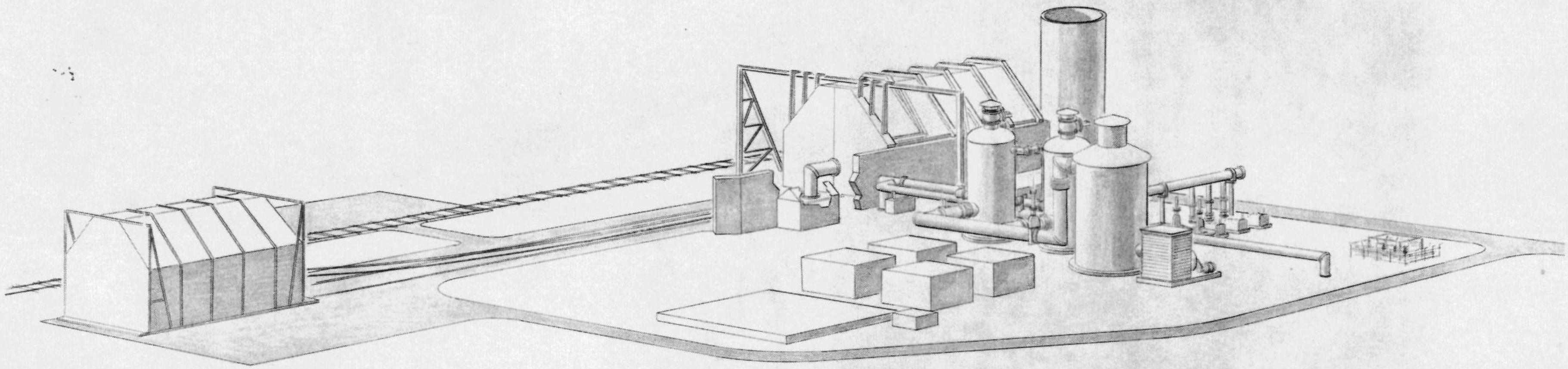

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Figure 1

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PLUTO UNDERGROUND AIR STORAGE CHAMBER

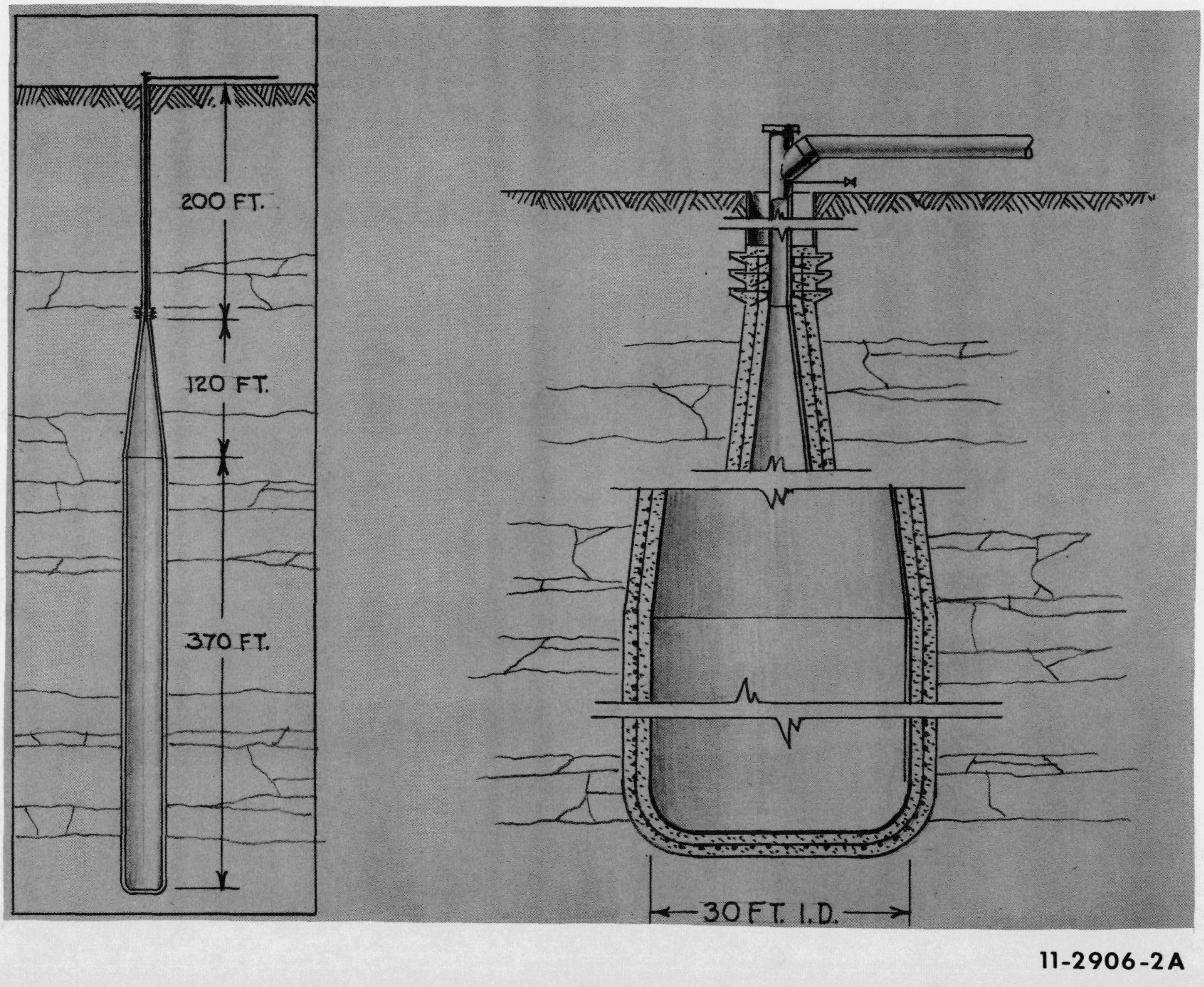

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Figure 2

2.1.1 Air Storage Chamber - continued

The reinforced concrete anchor shall be designed to resist the vertical forces caused by air pressure acting on the ell at the top of the riser. The anchor will also provide a heavily reinforced section wherein the hoop stresses that are resisted by the duct walls in the riser are gradually transferred to the surrounding rock in the transition section. It is anticipated that the anchor will be the most critical part of the storage chamber and will require very careful and detailed analysis and design. The 3600 psi air pressure will be resisted by the rock surrounding the transition area and chamber below the anchor section. Although a liner will be used, its sole function will be to provide an airtight membrane and will not provide any structural strength.

The configuration shown in Figure 2 is based upon a preliminary stress analysis using the theory of elasticity. Preliminary investigations have indicated that the subsurface rocks at the PLUTO site are part of the Oak Springs geologic formation. The rock is assumed to be a homogeneous isentropic mass having a compressive strength of 5000 psi, an internal friction angle of 45° and a Poisson's ratio of .3.

2.1.2 Chamber Liner - The chamber liner shall be capable of acting as an airtight membrane, even when subjected to the working pressure of 3600 psi for long periods of time. Both metal liners and plastic liners are being considered. A 3/16" aluminum plate liner seems to be the most economical material if a metal liner is used. The high oxygen concentration of the compressed air eliminates the possibility of using mild steel. Stainless steel could be used, but would probably result in a higher total cost. Although a metal liner would seem, at first glance, to be the best type of liner, it has a serious drawback. Specifically, if a leak developed in the liner, there is a possibility that the leaked air might be trapped, instead of being vented to ambient as intended. If the pressure of the trapped air built up to equal the pressure of stored air, a blowdown of the storage chamber would cause the metal liner to collapse. However, the probabilities of this type of accident occurring is not very significant since a leaked air vent system will be relatively reliable.

The use of a plastic type liner would have a number of advantages. Its principal advantage would be its economy since it could be applied directly to a gunite concrete surface, either as a "wall paper" or as a spray. Its action differs from a metal liner in that a metal liner will be designed to span any cracks occurring in the con-

2.1.2 Chamber Liner - continued

crete back-up, whereas the plastic material would be forced into the cracks and sealing them. In addition, any trapped air pockets would rupture a small area during blowdown which could be readily repaired, if detected. If the rupture were not detected, and the blowdown operation terminated with a signoff pressure of 600 psi, it is probable that local failure and subsequent geysering action would occur.

It is expected that more data on both metal and plastic liners will be developed in the course of a proposed research program. Based on present information, however, aluminum will be the most predictable, and, therefore, practical material to use for the liner.

2.1.3 Analysis of Behavior of an Underground Air Storage Chamber - A preliminary analysis indicates that the storage chamber can fail in only two ways. One way would be a local failure caused by a large rupture in the membrane, which would permit a large volume of air to escape through the natural rock fissure. Although small leaks would be accommodated by the leaked air venting system, a large rupture could not be vented fast enough. The probable result would be an air geyser venting at the surface at one or more locations. Should this happen, the storage chamber must be "blown-down" as fast as possible since geysering will lead to progressive failure of the surrounding rock. Although an emergency blow-off valve shall be provided in the air supply system, the probabilities of local failure occurring can be reduced to a negligible factor by a careful design of the concrete back-up of the membrane material. The concrete shall be reinforced to produce numerous hairline cracks when the walls expand under pressure, rather than a few large cracks. This can be readily achieved since it is expected that the maximum growth in circumference will not exceed 2" or .018% of the total circumference. The use of weakened planes to control the cracking shall also be carefully considered.

The second type of failure that can occur would be an upheaval of the rock above the chamber. This possibility can be eliminated by placing the top of the chamber at a sufficient distance below the ground surface. Numerous tests made at the Colorado School of Mines, and also by the Los Angeles Water and Power Department have demonstrated that loads applied in a rock mass toward the free surface will be resisted by a plug shaped like an inverted

2.1.3 Analysis of Behavior of an Underground Air Storage Chamber - continued

truncated cone whose small base is the area of the applied load. The angle of the sides of this cone of resistance will be determined by the angle of internal friction of the rock, but will probably be around 45°. It is expected that a minimum safety factor of 10 will be used in determining the depth of the chamber.

2.2 Test Cell Installation

The test cell has been redesigned to provide a facility requiring a minimum amount of maintenance. It is anticipated that the sonic energy inside the cell during a test will be exceptionally high. No data is available at this time to determine the sound energy, but it is reasonable to expect some structural damage to occur occasionally.

The test cell is designed with integral water tanks secured to the outside of the cell to permit relatively easy removal and replacement. The compartmentation which is also achieved will prevent excessive loss of water in the cell should a rupture occur.

The circular arch cell was changed to a straight haunch frame because of the savings to be realized in construction costs.

The other changes that have been made were dictated by economy or operational difficulties, specifically, the crane manipulator design was revised to eliminate a shielded cab for an operator, and using, instead, a 3-D TV system. The 3-D TV system will result in a lower total cost for this piece of equipment, since the use of a shielded manned cab required a very elaborate system to guarantee the safety of the cab occupant. In addition to the safety considerations, the restricted space of the cab prevented the operator from being very effective. It is realized that a TV system will not give as satisfactory viewing quality as a direct look through a window, but a TV system will probably provide a system of viewing that can do the job.

2.2.1 Scope - The test cell shall be designed to provide a complete facility for ground testing the PLUTO propulsion system, and shall incorporate reasonable provisions for future expansion or modifications. The test cell shall be capable of accommodating both axi-symmetric and scoop inlet engine configurations for direct connect and free jet tests.

2.2.2 Materials and Specifications - The cell specifications shall conform to Section 3.0 of the General Design requirements of Report TR 153-12, Volume I. In addition, the test cell design shall consider the following criteria.

2.2.2.1 Structural Materials - The selection of the structural materials will take into consideration the possible effect of neutron or gamma radiation. Materials which can be dangerously activated or which will deteriorate in the radioactive environment described in TR 153-12 shall be avoided. The A & E shall give consideration to the use of 3004 aluminum for the outer surface of the shielded water tanks, and shall consider the use of 5083 aluminum for the structural members of the shielded water tanks. Concrete shall be composed of aggregate which will contain less than 1% by volume of chert or other type of aggregate which will deteriorate due to either chemical reactions or exposure to radiation.

2.2.2.2 Electrical Systems - Electrical equipment and their installations shall be designed or selected to meet the requirements of the National Electric Code and the Marquardt Jet Laboratory Specification MJL 101-A. Installations shall be designed to be compatible with the radiation environment, and all electrical systems shall be so installed that they can be removed and replaced as required with the minimum amount of difficulty. All electrical outlets or fixtures that are exposed in the cell shall be of explosion proof type, meeting all of the requirements as set forth in the above specifications.

2.2.3 General Requirements

2.2.3.1 Location - The test cell installation will be located approximately 8000 feet east of the TORY II installation at Jackass Flats, Nevada Test Station, Nevada. The coordinates of the intersection of the cell centerline and the front face of the cell are 755,450 N, 662,130 E. The centerline of the cell will have an azimuth of approximately 270°. The location as described above however, may be altered at a later date, if future investigations

2.2.3.1 Location - continued

indicate that a more favorable foundation condition can be obtained within a 100 feet radius from the above coordinates.

2.2.3.2 General Arrangement - The primary function of the test cell will be to provide adequate test capabilities needed to develop a nuclear ramjet propulsion system. The facilities shall be arranged to fulfill this function in the most efficient manner. However, the general arrangement of the test cell and its supporting installations shall consider the safety of operating personnel and the population at large, and shall minimize the possible loss of the test cell due to excessive radioactive contamination. These requirements can be satisfied by orienting the test facilities such that the test cell and its exhaust handling facilities will be upwind from the prevailing wind thus insuring that radioactive particles and gases will blow over uninhabited areas. In order to provide further protection to the operating personnel, a concrete shadow shield will be located along the southern side of the cell and its exhaust handling facilities. The shadow shield will protect the test equipment area which will have valves and compressors that will require maintenance. The topography of the test cell area shall be relatively level since it will be necessary to provide level gantry crane track between the test cell and the mock-up area. The general layout of the test cell complex is shown on Drawing 706832.

2.2.4 Cell Detail Design - The test cell configuration is essentially an octagonal prism whose axis is parallel to the ground surface. The top half of the cell will be formed by a steel rigid frame carrying precast concrete wall panels, which, in turn, will support the water tanks needed for neutron shielding. The bottom half of the cell will be formed by excavating the foundation rock to the shape desired. The test cell is shown in Figure 3 and a detail layout of the test cell is shown on Drawing 706838.

The test cell configuration is dictated by a requirement that the water neutron shielding shall be no closer than 15 feet to any part of the reactor during a test run. This will require a depressed floor area near the reactor. The front part of the cell, however, shall be at grade level since the reactor will never be in this location during a test run. Access to the test cell will be through two rolling doors located at one end of the cell as shown. In addition, an instrumentation room and shelter shall be located along the south side of the cell, and a transducer room shall be located under the cell close to the reactor

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PLUTO FACILITY TEST CELL

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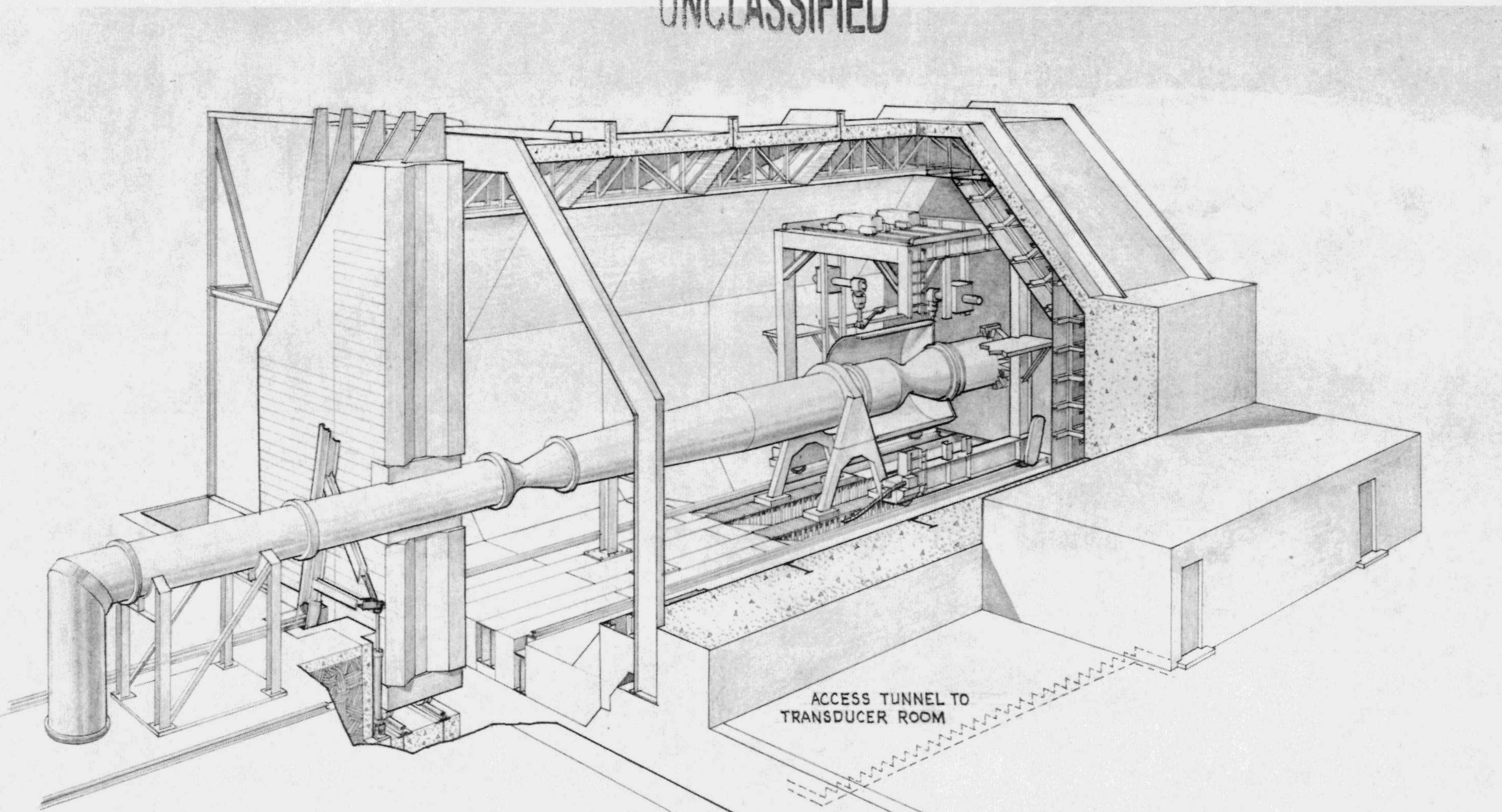

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2.2.4 Cell Detail Design - continued

test location. The corridor shall connect the instrumentation room to the transducer room.

2.2.4.1 Basic Dimensions - The minimum clear distance between the walls of the cell shall be 35 feet and the inside length shall be 74 feet 3 inches. The longitudinal centerline of the cell will coincide with the centerline of the test reactor. The axis of the reactor shall be 10 feet above grade. The cell height, which is dictated by the clearance requirements of the crane-manipulator, shall be 25 feet above the axis of the reactor and, in the rear portion of the cell, the floor level shall be 17 feet 6 inches below the axis of the reactor. The cell doors shall be designed to open to the full width of the cell in order to permit the gantry-type crane-manipulator free access to the cell interior.

2.2.4.2 Design Loads - The test cell design for normal loads will use the allowable stresses set forth in applicable codes. For unusual load conditions, such as blast loads and abnormal impact, allowable stresses will be increased by 33-1/3%.

A. Live Load, Dead Load, and Seismic Loads

The design live load on the floor and platforms shall be as follows:

Working Platforms	100 psf
Cell Floor	50 psf
Protection Grates	20 psf

The weight of filled shield water tanks shall be considered as a dead load. A zone 2 seismic factor, as defined in the Uniform Building Code, shall be used for facilities in this area. The horizontal wind load shall be at least 15 psf.

B. Anchors

All test item and ducting anchors shall be sized to resist the maximum engine thrust caused by a break in the system. The test item anchor shall be designed to resist a load of ± 600,000 lbs. The effects of nuclear heating of the supports and anchors in the cell will be considered in the design and adequate cooling shall be

B. Anchors - continued

provided to insure that the maximum metal temperatures will not exceed 300°F.

C. Cell Pressures and Vibrations

The test cell shall be designed for the following air pressures and air temperatures:

	Air Pressure	Air Temperature
Normal Operations	Amb. to 1 psig	Amb. to 1060°F
Test Item Failure	Amb. to 8 psig	Amb. to 1060°F

Concurrent with these pressures, it is anticipated that the cell will be subject to severe sonic vibrations and pressures, with anticipated sound levels of around 150 decibles.

2.2.4.3 Test Cell Temperatures - The rate of heat generation in the materials inside the test cell will be a function of the reactor power, and the distance the material will be from the reactor. Values for steel and aluminum are presented in TR 153-13.

A. Cell Wall

The cell walls shall be designed for a maximum temperature of 200°F. It is not expected that a temperature of 200°F will be exceeded because of the large mass of water available for cooling. Heating of concentrations of the metal, particularly where the aluminum skin is joined to the aluminum frame within the shield tanks, shall be investigated in accordance with TR 153-13.

B. Test Item Support

Structural supports which are a part of the test cell (including tracks) shall be designed to carry a total distributed load of 30,000 lbs. The test item supports shall be designed with hollow members to insure circulation

B. Test Item Support - continued

of cooling water in all stressed members. The shrapnel shield and the duct supports shall be constructed of aluminum and shall be cooled using deionized water. The reactor thrust anchor structure shall be constructed of stainless steel and shall be designed such that all parts, including the hold-down bolts and thrustcollar, will be cooled with forced circulation of deionized water.

2.2.4.4 Test Facility Shielding Criteria - The shielding requirements for the test facility were established in TR 153-13. In accordance with these requirements, the design of the test cell shielding shall attenuate the radiation to levels not to exceed the following values:

A. Designated working areas protected by shadow shield: 1.0 mr/hr, 24 hrs. after run.

B. Engineering, control building, Hot Component Service, and other support facilities: 2.5 mr/hr at distances more than 4000 feet from test cell during reactor test.

2.2.4.5 Test Cell Structure - The design of a test cell to be installed in a remote area must consider the high costs of field work. The most economical cell will be realized by using shop fabricated components, wherever possible. In line with this approach, the test cell super structure shall be designed to employ shop fabricated support ribs, shop fabricated and precast concrete panels, and shop fabricated neutron shielding water tanks. In addition, the structural strength inherent in the foundation rock at this area will be used wherever possible.

A. Rib Framing

The primary structural framing of the test cell will be six structural steel ribs, each rib approximately 36 inches deep. The ribs shall be fabricated from ASTM A7 steel plate and shall be designed to require minimum amount of field work. All connections and joints shall be welded joints and all knees shall be adequately reinforced with

A. Rib Framing - continued

stiffener plates. High strength steel bolts can be used in place of welding, if more economical.

B. Concrete Shield Panels

The concrete shield panels covering the test cell shall be built up from individual precast concrete panels. Each panel will overlap its adjacent panels by using a ship-lap type joint. All joints shall be thoroughly filled with grout after installation. The concrete panels shall be cast with welding plates at each end so the panels can be installed by welding the ends of each panel to the inside surface of the lower flange of each steel rib. The precast panels shall be cast within a tolerance of 1/8". The panels will be cast with holes, as indicated on the drawings, to carry the neutron shielding tank. The shield water tank support rods will be placed through these holes and anchored to the outside surface of the concrete with a steel plate and nut. After all tank installations have been completed, all cracks, joints, and support rod holes shall be completely grouted to prevent or minimize any possibility of streaming.

C. Cell Floor

The bottom half of the test cell shall be formed by excavating the rock to approximately the proper shape. Concrete shall then be placed over the rough rock surface to achieve the finished shape. This concrete will not act as a structural member, but will be used primarily as a filler material between the irregular rock surface and the lower cell shield water tank. The filler concrete shall be Class "C" concrete with temperature reinforcing only. However, the concrete in areas around the transducer room and corridor will be used to carry loads and

C. Cell Floor - continued

shall, therefore, be Class "A" concrete with the thickness indicated on the drawings. The area at the front end of the cell will support the cell doors, and shall therefore be adequately reinforced.

D. Cell End Wall Support

The end wall of the test cell shall have external supports placed to resist the 8 psi internal pressure. The design of the end wall framing shall consider that a significant portion of shear forces due to the internal pressure can be transferred to the sides and top of the cell. These loads will be transferred to the foundation by diaphragm action of the concrete panels. The center areas of the end wall will be braced with two external steel frames, as shown in Drawings 706838 and 706839.

E. Foundations

Preliminary investigations of the foundation conditions to be found in this area indicate that a conservative strong rock formation is at or near the surface. A conservative bearing value of the rock would be 10,000#/sq. ft. The foundations of the test cell shall be designed using these allowable pressures, since it is estimated that the conservative use of 10,000#/sq. ft. will result in negligible differential settlement. Some of the basic loads to be resisted in this structure will be the uplift load created by; (1) the internal pressure of 8 psi, and (2) the lateral load imposed upon the thrust anchors. These loads will be resisted by utilizing steel anchor bars penetrating the rock to sufficient depth to develop their full strength after being grouted into place. The pull out strength of the rock should be determined by an actual in-place test but will probably be satisfied if the steel rod penetrates at least 20 feet into the rock. Lateral loads shall be resisted by the use of shear

E. Foundations - continued

keys and anchor rods.

2.2.4.6 Cell Doors - The doors to the test cell shall provide adequate shielding to the mock-up facility and shall have adequate strength to contain the 8 psi internal cell pressure, when fully closed it shall provide a gas tight closure. The door will have 4 foot thick neutron shield water tanks on its inside face and a 2-1/2 foot concrete gamma shield on its external face. It is anticipated that it will be necessary to open and close the doors frequently during installation and removal operations, and during pretest checkout. It will therefore be necessary to move the doors even when completely filled with water in order to avoid excessive loss of time.

A. Door Construction

The doors will roll on a series of wheels spaced on approximately 4 foot centers. The principle structural elements of the door will be heavy aluminum vertical ribs extending from the base of the door to the top of the door. The top of each vertical rib will be fitted with a remotely actuated hydraulic clamping device which will securely clamp the door, when in a closed position, to the test cell frame. External structural supports shall be provided in order to carry a top running rail to support and guide the door when it is in the open or partially open position. The bottom of each vertical rib will be fitted with heavy duty thrust rollers to counteract the horizontal reactions at the bottom end of the girder when the door is subjected to the 8 psi internal pressure. The tank walls on the inside face of the door shall be designed to span from vertical rib to vertical rib. The 2-1/2 foot concrete shield will be reinforced to give the door adequate strength in the longitudinal direction. The end surfaces, where the two doors will meet when closed, shall be constructed of "v" sections in order to prevent any streaming through the door when closed.

A. Door Construction - continued

The section of each door surrounding the air supply duct will be a special insert which will be fabricated for each type of duct installation. A pneumatic inflatable seal will be installed around the door opening.

B. Door Actuation

The actuation system for each leaf shall be a hydraulic cylinder having an 18' stroke. The hydraulic cylinders shall be independently actuated, but shall be powered from a single pump unit. The two door leaves shall be designed to be locked together during a test by two remotely controlled hydraulic clamps. In addition to the remote control operating features of the door system, the doors shall also be designed to be opened by using a tractor type vehicle to pull each door should a jam or failure of the hydraulic system occur. The normal door closing, locking, and sealing operations will be interlocked and automatically sequenced as a part of the over-all operating procedure.

2.2.5 Cell and Area Shielding - The primary neutron shielding and cell cooling system shall use a system of aluminum tanks filled with borated water. This system will attenuate the neutron flux outside of the cell to a value of less than 10^8 neuts/cm^2sec. A flux density at or below this level will not cause serious activation of materials outside of the water tanks.

The water filled tanks will prevent excessive heating of the test cell structural members since the combined radiant gamma and neutron heating will raise the water temperature less than 50°F during a 20 minute run at full power. However, the intense radiation during a run will decompose the water at a rate of 1#/1000 cubic feet of cell water per minute. The hydrogen and oxygen liberated shall be vented to atmosphere in such manner as not to cause a fire or explosion hazard.

2.2.5.1 Overhead Water Tanks - The water tanks placed along the sides, back and top of the cell shall be pre-

2.2.5.1 Overhead Water Tanks - continued

fabricated aluminum tanks designed specifically for water tight containment. Each water tank shall be supported by hangers inserted through the concrete shell and fastened to the exterior surface of the shell. The loads thus transferred to the concrete shell shall be carried by the steel structural frame. Each tank shall be constructed with a relatively thin gauge aluminum wall attached to a structural aluminum frame. The walls which will form the inside surface of the test cell shall be fabricated from smooth surface aluminum sheet. The tank surfaces which will adjoin each other shall be tapered as indicated in the drawings, and each adjoining surface shall use corrugated aluminum. The intent in this type of design is to use the slope of the sides and the corrugations of the aluminum to prevent any possibility of streaming. The fabricator shall use care to assure that the corrugations of adjoining tanks will be mated. The sequence of installation of each tank is shown on Drawing 706894. After installation of all of the tanks, the seams between each tank shall be taped with a suitable aluminum strip to prevent any contaminated particles from entering into the space between the tanks. Each water tank shall be equipped with suitable fill and drain lines and shall also be equipped with a vent line.

2.2.5.2 Lower Water Tanks - The shielded water tanks which will be used to protect the bottom of the shell shall also be prefabricated aluminum tanks which shall be brought to the site and installed. The tank surface, which will form the inside surface of the test cell, shall be built of smooth aluminum plate and shall be designed to support a uniform load of 50#/sq. ft. The other walls of each water tank shall be built of light gauge aluminum, and shall have the configurations shown on Drawings 706879 and 706893.

2.2.5.3 Test Cell Shield Water System - The shield water system shall be designed to perform the following functions:

1. Demineralize fill and make-up water.
2. Fill shield water tanks and maintain correct water level.
3. Circulate and cool tank water during and after a test run.
4. Drain and refill tanks.

These functions will be incorporated into four basic operations: fill, circulate, drain and vent.

2.2.5.3 Test Cell Shield Water System - continued

The water tanks will be filled with deionized water obtained from the upper reservoir. The fill water will be borated before it is pumped into the water tanks. Make-up water will be obtained in a similar manner.

During the test run two 35 gpm pumps will circulate the shield water through the water tanks and the fin-fan cooling units. Gases generated by decomposition of the shield water during the test runshall be vented to atmosphere from a vent pipe at the top of each water tank.

If it should become necessary to drain one or more water tanks,the shield water shall be drained to the lower reservoir (which is assumed to be empty for this operation) or, if necessary, the water can be wasted. Stored water will be pumped back into the tank when needed, and the reservoir will be thoroughly flushed to remove traces of boron. The system shall be designed for filling or draining all tanks in a 12 hour period.

2.2.6 Shadow Shield - It is anticipated that the test reactor will occasionally remain in the test cell for several weeks. Assuming that the reactor will be "hot", adequate gamma shielding will be required to permit personnel to work in the air supply equipment area. A one foot concrete shell and a four foot thick shadow shield will be needed to shield the instrumentation shelter and the area adjacent to the test cell. A one and one-half foot concrete shadow shield shall extend from the west end of the test cell and a two and one-half foot shadow shield from the east end. These extensions will protect the air supply area from the inlet and exhaust duct activity. The shield shall have a minimum height of 10 feet above the centerline of the reactor. The shadow shield layout is shown on Drawing 706832.

2.2.6.1 Material - The shadow shield shall have a minimum concrete density of 144 lbs/cubic feet (specific gravity 2.3). Precast materials (block, brick, slabs) may be used if more economical than poured concrete, provided shield thicknesses are corrected for material density changes and all joints are designed to eliminate any"thin" areas or planes permitting "streaming".

2.2.6.2 Openings in Shielding - Where openings in the shadow shielding occur, these openings will be so designed to prevent direct streaming. Incident rays will be attenuated to design levels by staggering the shield penetrations and increasing the shield material density or thickness, as

2.2.6.2 Openings in Shielding - continued

needed, to replace the material removed.

2.2.7 Instrumentation Room and Transducer Room - The test cell shall be equipped with a room designed to house the test data transmitting or recording equipment. Shielding shall be sufficient to provide safe access to the room within 24 hours after a test run.

2.2.7.1 Instrumentation Room - The instrumentation room shall be approximately 16 feet by 32 feet in plan and shall have a clear ceiling height of 8.0". It shall be serviced with normal power but in addition it shall have an emergency power source sized to prevent any serious failure in the instrumentation and control circuits. A recirculating refrigerated air conditioning system shall be provided to cool the instrumentation and recording equipment to 70°F ± 5°. It is estimated that the electrical instrumentation and recording equipment will release heat at the rate of 15 KW per hour.

2.2.7.2 Change Room and Access Tunnel - A personnel monitoring and change room shall be provided to safeguard personnel working in the test facility area. The room will serve as a shelter for operating personnel during the times when the cell doors must be opened. The access tunnel shall provide a shielded, connecting passage between the change room and the transducer room. The tunnel shall be sized to permit passage of one man and shall have cable trays to carry all connecting control and instrumentation lines. The tunnel will also be used as a shelter to supplement the change room.

2.2.7.3 Transducer Room - A 12' X 12' room shall be located beneath the test cell at a location approximately 10 feet in front of the forward part of the reactor. This room shall be heavily shielded to prevent radiation damage to transducer equipment and junction boxes during a test run. The shielding will also protect personnel from radiation while they are servicing the transducer equipment between test runs. Conduits connecting the test cell with the transducer station shall have sufficient curvature to prevent any possibility of streaming.

2.2.8 Cell Ventilation - A cell ventilation system will be needed to prevent hazardous accumulation of contaminated air during a run, and to provide cooling and ventilating air to the cell after a run.

2.2.8.1 Ventilation Air Supply - The nominal ventialtion air for the test cell, transducer room and instrumentation room shall be furnished by a blower mounted on top of the instrumentation room providing five air changes per hour. The ventilation air supply will be capable of being increased by a bleed line from the 50 pps continuous air supply system.

2.2.8.2 Cell Vents - The cell shall be vented to the exhaust stack by a duct designed for the maximum test air flow of 2050 pps in the event of a test item failure. A 12 foot diameter duct has been selected on the basis of an 8 psig maximum cell pressure. This duct will also be used for disposal of nozzle spilled air during free jet tests, when the test nozzle exit is located within the cell. A check valve shall be located at the duct inlet and shall be designed to prevent back flow of contaminated air from the stack into the cell. A louver type check valve is recommended. The valve need not be air right in the closed position as cell ventilation air would be sufficient to provide positive flow from the cell to the stack through the leakage paths.

The duct opening shall be capped with a removable air tight cover and shield when personnel are working in the cell. The cap shall provide enough shielding to protect them from radiation and airborne contamination originating in the cell exhaust system.

2.2.9 Hydraulic System - A 3000 psi hydraulic system shall be provided for operating the test air valves, cell doors, and cell door locks. The design shall satisfy the following requirements:

1. The system shall have a capacity 50 per cent larger than the maximum estimated demand.
2. A nonflammable hydraulic oil shall be used.
3. The hydraulic system shall comply with the Joint Industry Conference (J.I.C.) Hydraulic Standards for Industrial Equipment.

2.2.10 Exhaust Duct System

2.2.10.1 Stationary Duct - The stationary section of the exhaust duct shall be water-jacketed, and shall be mounted as shown on Drawing 706847. The duct shall support the following equipment:

[redacted]

2.2.10.1 Stationary Duct - continued

a. Guide rollers for the retractable duct.
b. Lubrite slide plates for the retractable duct.
c. Seal for retractable section.
The seal shall be a machined housing containing two metallic piston-type rings. The configuration of the housing and rings will insure that 150 psi water pressure inside the housing will force the rings to contract on the outside diameter of the retractable duct and seal against the duct surface and the housing.

2.2.10.2 Retractable Duct - The water-jacketed retractable duct section shall be machined to accommodate the sealing rings, and shall support a rotary flange lock at the forward end. The flange lock shall be rotary locking wedge type, actuated by a portable gantry crane mounted hydraulic system powering hydraulic cylinders. The rotary flange lock shall be designed to permit cooling water circulation during test. An emergency unlocking device shall be provided on each side of the flange lock, at the horizontal centerline. This device will consist of racks and pinions operable with ratchet lever arms, which will unlock the flange when operated by the manipulators and crane hooks on the crane-manipulator.

2.2.11 Test Item Shield, Alignment Fixture, Instrumentation and Control Plug - The description of these items, as described in TR 153-12, Volume I, is essentially unchanged.

2.2.12 Cell-Servicing Crane - The concept of maximum test cell utilization envisions the use of crane-manipulator in the test cell and in the mock-up area. The crane-manipulator shall be designed to meet the following functional requirements:

a. Installation and removal of the test reactor and/or diffuser section.
b. Installation, adjustment, and tear-down of test equipment, including installation anchors and other measuring devices.
c. Emergency operations, especially test cell clean-up.

The primary function of the crane-manipulator will be the installation and removal of the reactor and/or diffuser

2.2.12 Cell-Servicing Crane - continued

section. These particular operations require a piece of equipment capable of operating in a very severe radiation environment. In addition, the ability to service the test item will be an additional important operation. In order to do these operations, the crane-manipulator will resemble a straddle carrier. The complete equipment shall include two lift mechanisms, two heavy duty remotely operated manipulators, two remotely operated slave units, which shall be controlled from master units located in the control building, and a three dimensional television viewing setup.

2.2.12.1 Crane Configuration - The crane configuration, shown on Drawing 706850 shall be a straddle carrier type of gantry. The carrier shall be a minimum distance relatively close apart to clear the sides of the test item, and the hoist height shall be sufficient to permit "up and over" handling. Mounted on the sides and opposing each other shall be two mechanical arms. These arms shall have a twofold purpose: (a) to steady the load during transit and, (b) to perform heavy duty assembly and disassembly operations. A remotely controlled three dimensional TV viewing system shall be mounted at one end of the machine and shall provide clear vision of the handling operation as well as control the basic crane and manipulator movements.

2.2.12.2 Double Hook System - The principle lifting operations of the machine shall be accomplished by two hooks located on a line parallel to the centerline of the reactor. Each hook shall have independent vertical movements to provide flexibility in the handling and maneuvering of test equipment. Each hook hoisting mechanism shall be equipped with an "inching" device, and fail safe brakes. The hoist mechanism shall be designed to give maximum lift height, enabling an up-and-over operation to remove any component. Each hook shall have a working capacity of 7-1/2 tons.

2.2.12.3 Longitudinal and Transverse Movements - Accurate positioning of the hooks shall be obtained by equipping the crane with a two speed drive for the crane wheels, and a low speed drive for the bridge. A total lateral movement of eight feet shall be provided.

2.2.12.4 Controls - The crane-manipulator shall be operated by remote controls from either the main control room or from a duplicate set of controls to be located within the instrumentation shelter. The control signals to the crane and its components shall be transmitted

2.2.12.4 Controls - continued

through an umbilical cord connecting the crane-manipulator with a pick-up reel located at a point midway between the test cell and the mock-up area.

2.2.12.5 Manipulators - Two heavy duty manipulators similar to the General Mills Model #550 shall be provided on each side of the crane in order to (1) assist in the installation and removal of a test item, (2) install and remove the instrumentation packages, (3) operate specialized tools such as tube cutters, cutting torches, impact wrenches, abrasive saws and drills.

2.2.12.6 Slave Units - Two electro-mechanically operated slave units shall be mounted on a movable carriage located at the rear of the crane-manipulator. The movable carriage shall provide vertical flexibility to the slave units. The master-slave system shall be similar in design to the equipment marketed by the Borg-Warner Corporation. The master units, which will control the action of the slaves, shall be located on a mobile mount which can be installed either in the control room or in the instrumentation shelter, as required. The slave units shall have a minimum lifting capacity of 20 lbs. each when extended in the full horizontal position.

2.2.12.7 Three Dimensional TV Viewing - A three dimensional TV viewing system shall be mounted on the crane-manipulator in a position which will permit the maximum utilization of the master-slave manipulators. The viewing cameras shall have coordinate mounts, both in the pan and tilt directions. Serious consideration shall be given to the utilization of a binocular viewing system rather than a super-posed image viewing system. The TV cameras and monitors shall use equipment having a minimum of 1,000 scanning lines in order to achieve the maximum in picture clarity. The viewing equipment, particularly the lenses, shall be suitably mounted to permit easy and frequent removal and replacement since it is anticipated that the average life of a viewing lens will be quite short in the anticipated radiation environment.

2.3 Hot Components Service Building

Chapter 15 of TR 153-12, Hot Components Service Building, is entirely superseded by this revision. The new design provides an improvement of functional capability and flexibility and provides an alternate (emergency) handling of radioactive materials. The modified Hot Components Service Building represents a saving of about $200,000 in comparison to the cost of the previous design.

One of the major changes was made to provide for entry of a flat car (engine conveyance) directly into the hot shop enabling sections from component size to full missile size to be serviced on the flat car or, alternatively, at semi-permanent stations elsewhere in the hot shop. This feature eliminates entry problems and multiple-handling difficulties attendant to bringing the engine directly into the transfer corridor, as previously planned. An airtight shed is provided for contaminant containment immediately preceeding flat car entry into the hot shop.

The hot shop design has also been changed to a single large compartment, rather than the previously planned three compartments. While, in principle, compartmentation is desirable, it presents practical difficulties for material transfer and multiplies the manipulative and lifting requirements. The practicality of a single hot shop depends on provision of a hot storage room capable of adequate and planned storage of all radioactive materials removed from the hot shop.

A hot storage room housing a 5 ton bridge crane has been added. This addition provides capability of safe storage of nuclear engines, radioactive components, radioisotopes, and test specimens and temporary storage of ducts, diffusers, nozzles, etc.

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2.3 Hot Components Service Building

2.3.1 Scope - This section presents design criteria for the Hot Components Service Building where assembly, disassembly, inspection, repair, analysis and calibration of radioactively hot propulsion system components will be carried out.

2.3.2 Applicable Specifications and General Requirements

The specifications and general requirements applicable to the design of this facility are called out in TR 153-12.

2.3.3 Location and General Arrangement - The Hot Components Service Building will be located approximately 3,000 feet to the east of the service area and 4,500 feet southeast of the test cell, as shown on Drawing 706831. A layout of the Hot Components Service area is shown on Drawing 706833.

2.3.4 General Description - The Hot Components Service Building will consist of the following operational areas, each separated by prescribed thicknesses of ordinary concrete shielding: (a) hot shop, (b) five hot cells, (c) decontamination room, (d) Laboratory, (e) operating galleries and, (f) cold shop. In addition, entry and transfer corridors, storage rooms, office, monitoring and clothes change facilities, showers and lavatories will be provided within the building. The Hot Components Service Building is shown on Drawings 706880 and 706881.

2.3.4.1 Hot Shop - The hot shop shall be a single room whose dimensions are 86' X 36'. The size is dictated by the dimensions of a railroad car carrying an engine or, at a later date, can go up to the size of a complete missile. The room shall be equipped with a General Mills manipulator for large component assembling or disassembling and a 10 ton remotely-operated bridge crane for transporting the engine, engine parts, or activated accoutrements to assembly-disassembly stations.

The hot shop will serve for assembly, disassembly, adjustment, modification, inspection, and maintenance of the reactor, diffuser, tailpipe, engine control system, and its various components.

2.3.4.2 Five Hot Cells - Four of the hot cells shall be 8' X 8' in plan, and one cell shall be 10' X 8'. It is planned that substantial apparatus and tools will be installed in the hot cells on a semi-permanent basis.

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2.3.4.2 Five Hot Cells - continued

The 10' X 8' cell will be used for disassembly, inspection, repair, and reassembly of reactor and engine control system components. An adjacent cell shall be designed to accommodate a small remotely-operated machine shop for cutting and machining of radioactive specimens for physical testing, metallurgical examination, and chemical analysis. Both cells shall have ordinary concrete walls which shall be 4' 9" thick.

A third hot cell will contain mounting, lapping, and etching equipment for preparation of specimens for metallographic examination. It will also contain microscopy equipment.

A fourth hot cell will contain spectrographic equipment; and the fifth hot cell will contain equipment for chemical processing, principally for preparing dilute solutions for the laboratory. It is envisioned that the latter three cells will handle only coupons or specimens prepared in the first two cells. Accordingly, the ordinary concrete wall thickness shall be three feet.

A "lazy susan" type of transfer port will permit specimens to be passed from one cell to the next to accomplish the various phases of work described above. The two heavily shielded cells shall contain manipulators having a lifting capability of 200 lbs. The three moderately-shielded cells shall be equipped with Argonne Model 8 Manipulators. Plug-filled holes shall be formed in the cell faces to enable installation of additional manipulators, when required. The spectrographic cell will have two viewing windows; the other cells shall have one each.

2.3.4.3 Laboratory - The laboratory proper, having an area of about 1800 sq. ft., will provide facilities and apparatus for carrying out chemical, physical, and metallurgical type tests of components and specimens which can be handled outside the hot cell area. Operations will include chemical, radiometric, and spectrographic analysis, X ray and metallographic inspection, physical testing, calibration, etc. Counting room and operating galleries shall be adjuncts to the laboratory.

2.3.4.4 Decontamination Room - The decontamination room will be equipped to remove contamination from instruments, manipulating tools, equipment, and other hardware used in handling and transport of radioactive materials. It shall be equipped and shielded to allow operations on materials activated and/or contaminated to dose rates up to 4r/hr at one foot. A one-ton bridge crane and a General Mills manipulator shall be installed capable of handling moderately

2.3.4.4 Decontamination Room - continued

large sections and components (up to several cubic feet). Water-detergent spray and immersion tanks, ultrasonic baths, chemical treatment tanks, and contaminant survey instruments shall be provided. The decontamination room will connect to the transfer corridor, and personnel and cold equipment movement into the transport corridor shall be via the decontamination room (under controlled conditions of entry).

2.3.4.5 Cold Shop Area - The cold shop area shall be equipped to carry out mechanical and electrical work on test items and equipment which are not radioactive. This area will consist of the following three shops:

A. Cold Shop

A shop approximately 40' X 80' in size will provide facilities for assembly, inspection and checkout of the test item and its components prior to initial test. Cold shop operations will include a functional checkout of the test item instrumentation and control system to the maximum extent which can be safely accomplished outside of the test cell. Following this checkout, the test item major components will be transferred on a railroad car to the mock-up area.

B. Mechanical Equipment and Maintenance Shop

This shop shall provide the facilities for mechanical fabrication and modification work in support of the test item assembly and installation, and for fabricating special supports, jigs and fixtures required by various programs.

C. Test Instrumentation and Control Shop

This shop shall provide for the maintenance repair and calibration of both the test item and test facility instrumentation and control equipment.

2.3.5 Building Structure - The hot shop, hot cells, decontamination room, storage room and transfer corridor shall have shielding walls and roof structure constructed of standard density reinforced concrete, designed to provide radiation attenuation in accordance with the requirements of Paragraph 2.3.6. The remainder of the Hot Components Service Building shall be a low cost structure, the design for which shall be based on relative cost studies.

2.3.6 Radiation Shielding Criteria - Design of the shielding walls shall be based on the requirement that operating personnel shall not be exposed to dose rates in excess of 1.0 mr/hr., assuming that the radiation spectra from the source within the large and small hot cells will not exceed the following:

Energy	Hot Shop Gammas/sec	Hot Cells Gammas/sec
.4 Mev.	2.1×10^{16}	6.25×10^{14}
.8 Mev.	4.65×10^{16}	1.38×10^{15}
1.35 Mev.	5.34×10^{15}	1.59×10^{14}
1.65 Mev.	2.73×10^{15}	8.11×10^{13}
2.1 Mev.	2.14×10^{15}	6.37×10^{13}
2.65 Mev.	2.15×10^{14}	6.4×10^{12}

The above activity levels are for a reactor operating at 595 megawatts for one hour, shutdown for 36 hours, and accounts for no reactor self-shielding. For shielding calculation purposes, it will be assumed that one foot clearance will be maintained between the cell walls and the source.

2.3.7 Hot Storage Room - The hot storage room shall be equipped with a five ton bridge crane. The room shall be designed to provide for the storage of two complete reactors. These reactors will be stored vertically on special built dollies equipped with air blowers. The reactors will be placed in specially-ventilated stations and cooling air will be exhausted directly through hoods and ducting out of the storage room.

2.3.7 Hot Storage Room - continued

Special shelving shall be provided for pallet storage. The pallets will hold sources, activated instruments, activated components, and shielded flasks containing radioactive solutions. Irradiated fuel elements will be stored in specially designed caskets having adequate cooling and exhaust ventilation.

Provision shall be made for flat car entry directly into the hot storage room. Emergency or temporary storage of inlet and exhaust ducting and diffuser sections in the storage may be necessary, thus adequate provisions for this type of storage shall be provided.

2.3.8 Manipulators and Transport Equipment - The hot shop shall be equipped with a manipulator similar to the General Mills Model #500 Mechanical Arm, having a 2000# load capacity as a telescoping hoist and a 160# elbow load capacity. Crane-mounted TV cameras, directly wire connected to the control console, will provide crane operators with close-up views of manipulative and transfer operations.

A radio-controlled manipulative vehicle, similar to the Hughes Systems Development Laboratories "Mobot," shall be studied to determine if it can be advantageously used to complement and facilitate the various operations involved in assembly and disassembly of engine and control systems. This vehicle has manipulative arms and viewing cameras mounted on a fork lift chassis, as illustrated in Figure 4 . The vehicle would be valuable for divers radioactivity-handling problems on the facility, as well as in the Hot Components Service Building.

The ability to transport radioactive objects by means alternative to hoists and manipulators is deemed an essential requirement for Hot Components Service Building operations, particularly when breakdown of normally used equipment occurs. In this connection, remotely operated tow and lift vehicles shall also be considered for Hot Components Service Building and general facility use.

Dollies, carts, and pallets shall be used to the fullest extent throughout the Hot Components Service Building in conveyance of radioactive materials. These devices would either carry trays or be constructed with side walls to avoid droppage, spillage, and spread of contaminants. Covered and sealed containers shall be used wherever practical.

MOBILE MANIPULATOR

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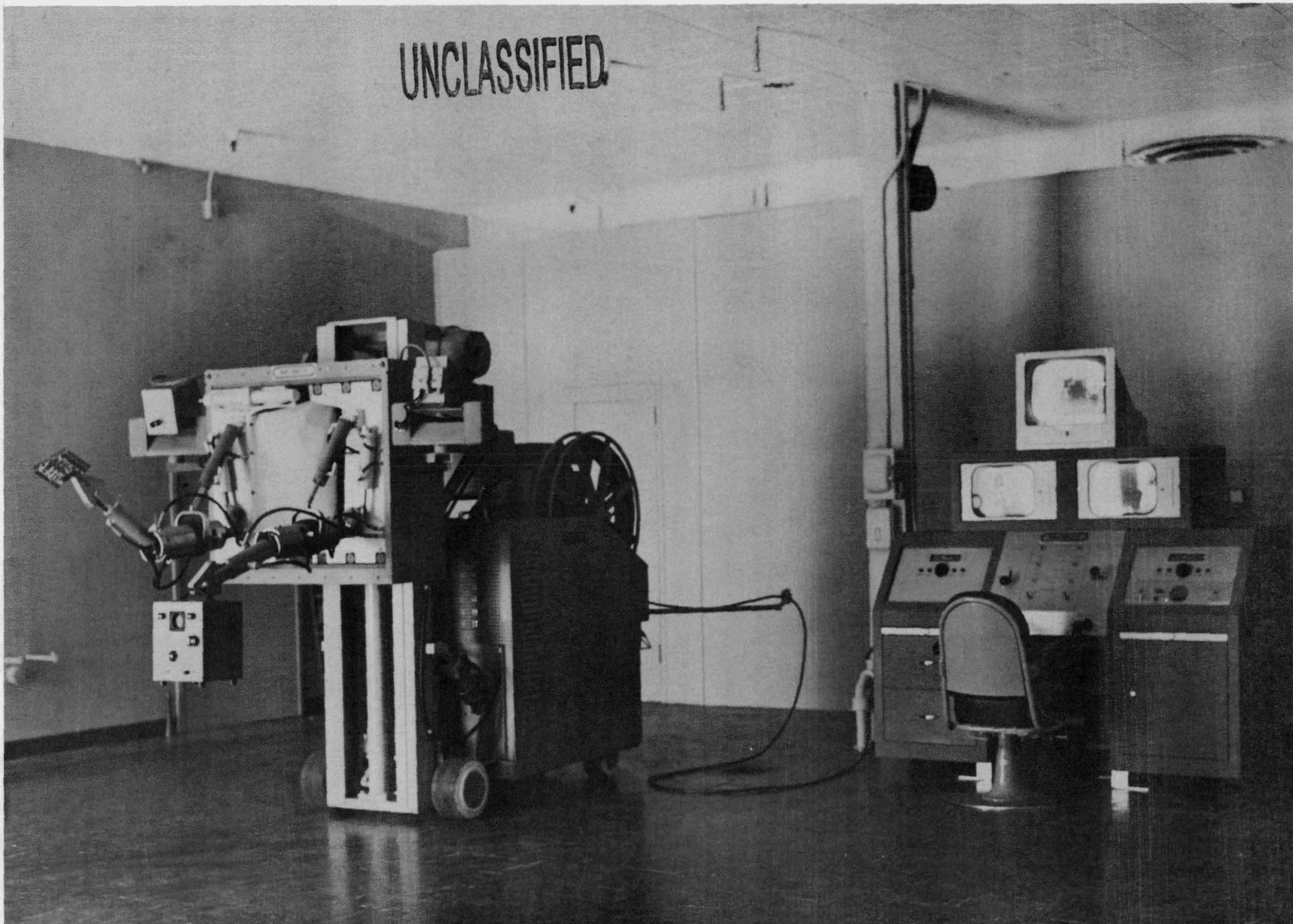

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Figure 4

2.3.8 Manipulators and Transport Equipment - continued

The hot shop and hot cell plug type doors shall also serve as loading door conveyers, and shall be equipped with aprons to transport materials into the compartments that they seal.

2.3.9 Viewing Windows - Hot cell viewing windows shall be filled with zinc bromide solution and shall be approximately three feet square on the viewing side. The windows shall have approximately full wall thickness and will thus exceed slightly the radiation and attenuation requirements of 2.3.6. Similar viewing windows shall be installed in the hot storage room, the decontamination room and the transfer corridor, to facilitate control of the remotely operated bridge cranes and the loading doors.

2.3.10 Illumination - General illumination for the Hot Components Building will be as follows:

Transfer Corridor	200 ft candles
Hot Shop	500 ft candles
Hot Cells	200 ft candles
Hot Storage Room	200 ft candles
Laboratory	65 ft candles
Cold Shop	50 ft candles
Decontamination Room	50 ft candles
Mechanical and Maintenance Shop	50 ft candles
Test Instrumentation and Control Shop	65 ft candles
Waste Storage Room	40 ft candles

The hot cells and the transfer corridor shall be illuminated by sodium or mercury vapor lamps. Incandescent lamps shall be provided for emergency lighting, and in the calibration counting room.

2.3.11 Special Equipment and Tools - The work to be accomplished within the Hot Components Service Building will involve the use of much specialized equipment and a variety of tools, some of which will be specially designed or modified for the required operations. Since the design of the test item is currently only in its initial stages, disassembly and components examination plans have not yet been developed; consequently, the specialized equipment and tools requirements can be described in general terms only. However, it appears that equipment and tools such as the following will be needed.

2.3.11 Special Equipment and Tools - continued

a. Hot Cell - remotely controlled equipment

Impact wrenches, special disassembly tools, rivet deheaders, powered cut-off tools, milling machines, drill presses, cutting torches, cleaners and degreasers, metallographic specimen, cutting equipment, specimen polishers, balances, control components checkout and calibration benches, component disassembly tools.

b. Laboratory Equipment

Chemical analysis equipment, ovens, furnaces, spectrographic analysis equipment, radiometric analysis equipment, radiographic equipment, metallographic equipment, physical testing equipment, electron microscope, X ray diffraction equipment (the latter two upon substantial justification of requirements).

2.3.12 Major Cold Shop Equipment - The cold shop shall be equipped with the following machines and tools:

Horizontal Milling Machines w/Vertical Attachments
16" Engine Lathe
Doall Saw
1" Capacity Drill Press
Horizontal Boring Mill, 4" Bar
Radial Drill, 4' Arm
Welder D. C. W/Heliarc
5 Ton Hydropress
Gas Welding and Cutting Set
Off-hand Tool Grinder
Snag Grinder
1/2" Drill Press
Flex Shaft Grinder
Surface Plate
Miscellaneous Hand Power Tools
Benches and Cabinets
Tool Crib

2.3.13 Services - The following services shall be provided within the building:

Drains hot and cold water to contaminated waste system.

Electric Power	440 volts 3 Ø	60 cycle	100 KVA
	115 volts 1 Ø	60 cycle	5-10 KVA
	115 volts 1 Ø	400 cycles	5-10 KVA
	24-28 volts D.C.		25-50 KVA

Air 125 psig
Vacuum
Air Conditioning

2.3.14 Ventilation and Heating - The ventilation system shall be designed so that any leakage air flow will be from radioactively "colder" areas toward "warmer" areas. Air will enter the facility ventilation system through a pre-filter and absolute filter system. This type of system is necessary to decrease the frequency of changing of contaminated exhaust air filters located elsewhere.

The incoming air shall pass through a thermocouple-controlled heater and conditioning system before passing down into the various compartments of the facility. The air supply shall be at constant volume, scaled to the various compartments to enable initial air replacement every 6 minutes. The air shall exhaust at the floor level through exhaust ducts, connected in the case of the hot shop, hot cells, transport corridor, and storage rooms, to absolute filters housed outside the building. The exhaust air shall then be ducted to a stack slightly higher than the roof height of the building.

Exhaust filters shall be nonflammable and shall be DOP leak tested at the facility prior to installation.

2.3.15 Material Selection for Facilitating Decontamination
The walls and ceilings of the hot shop, the two heaviliy shielded hot cells, the transfer corridor, viewing galleries and the storage rooms shall have a hard, smooth finish, conditioned to receive paint, and shall be spray painted to a 3 mil finish of a hard enamel.

The wall of the hot storage room, at the part nearest to the reactor storage stations, shall be covered by a smooth stainless steel sheet.

2.3.15 <u>Material Selection for Facilitating Decontamination</u>

continued

The walls and ceilings of the three moderately-shielded hot cells shall be covered with pressed fiber board. One mil mylar tape shall be used to cover the butted joints and a strippable coating applied.

The laboratory will be equipped with smooth finished metal furnishings having a baked enamel smooth finish. Bench tops shall be covered with a smooth plastic material such as formica. The walls and ceilings of the laboratory shall be covered with pressed fiber board, furred to permit passage of pipes, covered at the joints with one mil mylar tape, and sprayed with strippable coating.

The floors of the hot shop and hot storage area shall be covered with a vinyl tile. Other floors shall be covered with an asphalt tile (requiring special precautions in the laboratory).

2.3.16 <u>Decontamination of Building</u> - In the decontamination of the building, the principal resort would be to detergent solution and pressurized water hosing of walls, floors and ceilings. Scrubbing is recommended, where practical. Drains and sinks (except in lavatories) will connect to the contaminated liquid waste drainage system.

2.4 Contaminated Waste Disposal

Section 13.4, Contaminated Liquid Waste, and Section 13.5, Contaminated Solid Waste, of TR 153-12 are superseded by this revision. This revision more specifically defines the design requirements of waste disposal. The general intent of the plan is to achieve maximum use of isolation factors and existing AEC waste facilities at NTS.

2.4.1 Liquid Wastes, General - Liquid wastes will consist in the main of "wash down" water used in decontamination of both the Test Cell complex and the Hot Components Service Building. In addition, liquid wastes may contain detergents, complexing agents, and laboratory slop of a heterogeneous nature, including corrosive acids, alkalies, salts, and organic solvents. The acid, alkali, salt, and solvent wastes will result from practices and processes in the Hot Components Service Building.

In general, the acids, alkalies, and salts may be disposed of when diluted, or with adequate dilution, in the contaminant waste system. It is better practice, however, when they are concentrated, to store these materials in crocks or polyethylene containers, shielded or unshielded, for disposal according to whether or not they are radioactive.

Organic solvents may constitute an explosion or fire hazard that will require stringent control. Volatile, inflammable organic solvents shall not be used in the cleaning of glassware. Where degreasing may be required in decontamination, only nonflammable solvents shall be used. All inflammable solvents shall be stored according to fire code before and after usage and must not enter the drainage system.

No liquid waste shall drain into the sanitary drainage system. Conversely, all laboratory and decontamination room sinks and drains shall be part of the contaminated waste system. This requirement necessitates that drain lines and storage tanks shall be inert to a large variety of agents. All pipe lines (feeder or drain) within buildings potentaially exposed to contamination shall be either embedded in the concrete floors or be placed behind removable wall panels.

2.4.3 Contaminated Solid Wastes - Contaminated dry solid waste of very low or negligible activity shall be collected in fiber drums having polyethylene liners. These drums shall be stored in conveniently located, properly designated areas, until they are removed for disposal.

2.4.3 Contaminated Solid Wastes - continued
Contaminated solid wastes of medium activity (total activity less than 20 r/hr at contact shall be collected into open-top steel drums and adequately sealed. Although the drums are intended for disposal, they shall be freshly painted on the outside with corrosion resistant primer and coating, and shall be treated on the inside with vinyl coating. These drums shall be stored in the Hot Components Service Building Waste Storage Room for waste disposal or hauled directly to the disposal area.

Solid waste of total activity greater than 20 r/hr at contact shall be sealed in shielded metal containers designed especially for sealing and handling, and hauled directly to the disposal area.

No special provisions have been made for incineration of contaminated wastes; and, therefore, these wastes should not be incinerated.

Solid waste would be brought to the disposal area on a flat-bed trailer. The disposal area for solid wastes is maintained at NTS by the AEC and would service the TORY, ROVER,PLUTO, and other facilities according to their established practice. The AEC has the continued responsibility for disposal area safegurads.

2.4.4 Contaminated Liquid Waste - With the exception of volatile, inflammable organic solvents and concentrated acids, alkalies, and salts, liquid waste shall be disposed of by entry into the contaminated waste drainage system (with adequate dilution prior to entry and flushing after entry, where required). No further processing of the liquid waste will be required.

Liquid waste from the Hot Components Service Building shall drain to one of two 10,000 gallon gunite-lined steel tanks, interconnected at maximum liquid level. These tanks shall be equipped with liquid level devices, actuating a pump system and an alarm system at different levels.

Two pumps shall be provided,mounted in parallel, one serving as a spare for the other. The pumps shall be canned rotor, centrifugal types designed to facilitate removal. The pumps shall be connected, with adequate valving, to the bottom drains of the steel tanks. A vertical check valve shall be located on the pump discharge line.

[redacted]

2.4.4 Contaminated Liquid Waste - continued
Liquid waste from the Test Cell complex will be primarily washdown water or detergent solution. The waste shall drain to one of two 20,000 gallon gunite-lined steel tanks, equipped as above with liquid level valves, pumps, etc.

The drain lines from the Hot Components Service Building and the Test Cell shall connect to a common pipe which shall run to a drainage well. The well shall be located remotely from the Test Facility at a site determined by the presence of a suitably deep alluvial layer, absence of drainage toward any NTS facility, and absence of entry into any utilizable underground water system. The drainage well shall have a drilled diameter of at least 30 inches and a minimum depth of 50 feet. Waste liquids shall be dumped into the well through a 12" perforated casing. The space between the casing and the well shaft shall be filled with coarse aggregate not less than 1" in size.

Geological knowledge will be required in the establishment of a raw liquid waste well site. The absence of water wells from this area and the ion exchange and absorption qualities of the alluvium shall be ascertained.

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3.0 PLUTO FACILITY COST ESTIMATE

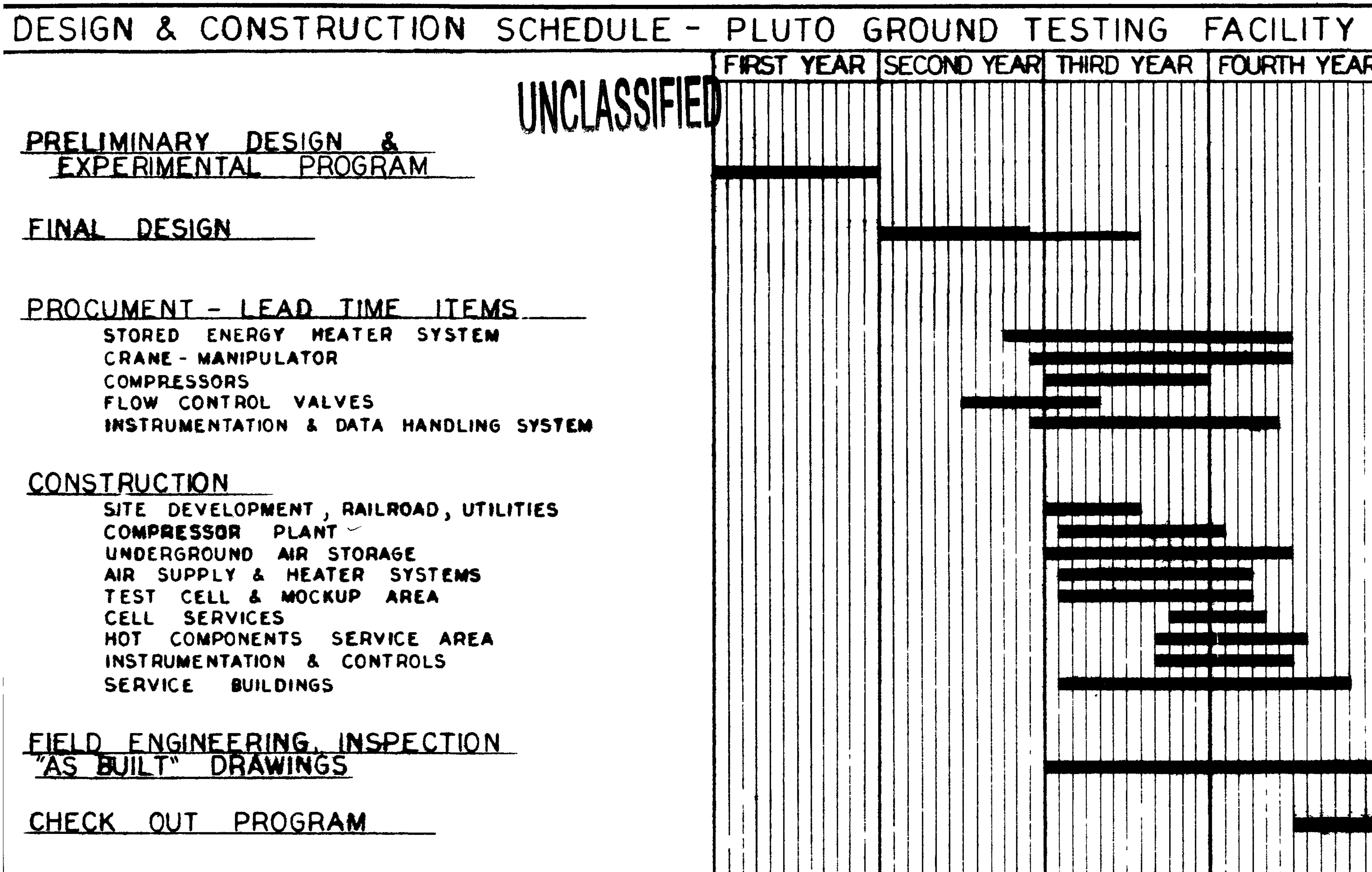
The cost estimate for the PLUTO Facility has been revised to reflect the facility changes discussed in Chapter 2 of this report. In most instances, the cost of the specific items have not changed from those presented in TR 153-12, Volume III, in which cases the reader should refer to that document for detailed breakdowns. The costs of items and installations that have been re-estimated are presented herein in a detailed breakdown. It will be noted that the total estimated cost of $29,378,000 is less than the $29,785,000 estimated in TR 153-12. Further substantial cost reductions can probably be justified after the proposed experimental program for the underground storage chamber has been completed, since the costs shown for the chamber in this estimate are based on very conservative values.

The design and construction schedule is essentially the same as that presented in TR 153-12 except that time scale is now a relative scale, rather than a schedule based on specific years.

PLUTO TEST FACILITY COST SUMMARY

3.1

Estimated Construction Cost, Without Contingency	$19,220,000	
Construction Contingency - 20%	3,844,000	
Total Estimated Construction Cost		$23,064,000
Additional Facility Costs		
Escalation, 2 years @ 4% per year	$ 1,844,000	
Spares, 1%	231,000	
A & E Design, 7½%	1,730,000	
Field Engineering & Inspection, 1½%	347,000	
MAC Project Direction & Liaison, 4%	922,000	
Bid Documents	40,000	
Checkout Program	1,200,000	
Total Additional Facility Costs		$ 6,314,000
Total Estimated Facility Cost		$29,378,000


DESIGN & CONSTRUCTION SCHEDULE - PLUTO GROUND TESTING FACILITY
FIRST YEAR
SECOND YEAR
THIRD YEAR
FOURTH YEAR
PRELIMINARY DESIGN & EXPERIMENTAL PROGRAM
FINAL DESIGN
PROCUMENT - LEAD TIME ITEMS
STORED ENERGY HEATER SYSTEM
CRANE - MANIPULATOR
COMPRESSORS
FLOW CONTROL VALVES
INSTRUMENTATION & DATA HANDLING SYSTEM
CONSTRUCTION
SITE DEVELOPMENT, RAILROAD, UTILITIES
COMPRESSOR PLANT
UNDERGROUND AIR STORAGE
AIR SUPPLY & HEATER SYSTEMS
TEST CELL & MOCKUP AREA
CELL SERVICES
HOT COMPONENTS SERVICE AREA
INSTRUMENTATION & CONTROLS
SERVICE BUILDINGS
FIELD ENGINEERING, INSPECTION "AS BUILT" DRAWINGS
CHECK OUT PROGRAM

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BUDGET PROJECTION BY FISCAL YEAR

ASSUMING FUNDS AVAILABLE FOR EXPENDITURE BY DECEMBER 1 OF PREVIOUS CALENDAR YEAR

DOLLARS IN THOUSANDS

	1st Year	2nd Year	3rd Year	TOTAL
A & E Services - Design	1,730			1,730
A & E Services - Field Engin. & Liaison		173	174	347
MAC - Project Direction & Liaison	315	315	292	922
Bid Documents	20	15	5	40
Lead Time Items				
Stored Energy Heater System	2,517			2,517
Flow Control Valves	438			438
Compressors		* 1,260		1,260
Crane-Manipulator		* 736		736
Instrumentation & Data Handling		1,500		1,500
Construction		16,871	1,817	18,688
Checkout Program			1,200	1,200
TOTAL	5,020	20,870	3,488	29,378

*Assumes that bids can be obtained and selections made prior to fiscal year funding being placed on contract.

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PLUTO FACILITY COST ESTIMATE

FACILITY DESCRIPTION		COST ESTIMATE	
		ITEM COST	TOTAL
3.3	AIR SUPPLY SYSTEM	$ 7,948,000	
3.4	TEST CELL INSTALLATION	1,114,600	
3.5	TEST CELL SUPPORT SERVICES	1,777,000	
3.6	EXHAUST HANDLING SYSTEM	1,915,000	
3.7	CONTAMINATED WASTE DISPOSAL	95,000	
3.8	MOBILE EQUIPMENT	240,000	
3.9	SITE DEVELOPMENT	438,000	
3.10	UTILITIES	1,038,000	
3.11	HOT COMPONENTS SERVICE BUILDING	1,978,000	
3.12	SERVICE BUILDINGS	1,378,600	
3.13	CONTROLS AND INSTRUMENTS	1,250,500	
3.14	HEALTH PHYSICS INSTRUMENTATION & EQUIPMENT	47,100	
	Estimated Construction Cost, without contingency		$ 19,220,000

PLUTO FACILITY COST ESTIMATE

FACILITY DESCRIPTION	COST ESTIMATE	
	ITEM COST	TOTAL
3.3 AIR SUPPLY SYSTEM		
Ref. TR 153-12		$ 7,948,000
3.4 TEST CELL INSTALLATION		
3.4.1 Structure		
1. Excavation	$ 20,600	
2. Concrete Substructure & Walls	86,000	
3. Rib Framing	38,000	
4. Concrete Shell	34,000	
5. Cell Water Tanks	295,000	
	$ 473,600	
3.4.2 Test Cell Doors		
1. Concrete Shield	$ 16,000	
2. Water Tank Shield	45,000	
3. Door Actuation System	55,000	
4. Door Locking & Sealing System	15,000	
5. Door Stabilizer Structure	5,000	
	$ 136,000	
3.4.3 Test Item Supports		
1. Anchor & Anchor Girders	$ 25,000	
2. Test Item Supports, Rails & Structure	18,000	
3. Crane-manipulator Rail & Structure	18,000	
4. Rail Bridges at Door Opening	6,000	
	$ 67,000	
3.4.4 Instrumentation Room		
1. Slab, Walls, & Roof	$ 11,000	
2. Air Conditioning & Ventilation	5,000	
	$ 16,000	

PLUTO FACILITY COST ESTIMATE

FACILITY DESCRIPTION	COST ESTIMATE	
	ITEM COST	TOTAL
3.4.5 Shadow Shield Wall	$ 66,000	
3.4.6 Cell Ventilation		
1. Blowers & Inlet Ducting	$ 6,000	
2. Ventilation Duct & Check Valve	50,000	
	$ 56,000	
3.4.7 Retractable Exhaust Duct		
1. Stationary Duct	$ 15,000	
2. Retractable Duct	30,000	
3. Seal	5,000	
4. Supports	10,000	
	$ 60,000	
3.4.8 Test Item Quick Disconnects (3)	$ 100,000	
3.4.9 Instrumentation & Control Equipment		
1. Disconnects & Actuator	$ 25,000	
2. Water Cooled Conduits	20,000	
3. Cables, Tubing, T/C Wire	15,000	
	$ 60,000	
3.4.10 Miscellaneous		
1. Water Hydraulic Power System	$ 10,000	
2. Adjustable Angle of Attack System	50,000	
3. Cell Illumination System	20,000	
	$ 80,000	
Total Item 3.4		$ 1,114,600

PLUTO FACILITY COST ESTIMATE

FACILITY DESCRIPTION	COST ESTIMATE	
	ITEM COST	TOTAL
3.5 <u>TEST CELL SUPPORT SERVICES</u>		
3.5.1 <u>Demineralized Cooling Water System</u>		
Ref. TR 153-12	$ 1,023,000	
3.5.2 <u>Shield Water System</u>		
Ref. TR 153-12	$ 55,000	
3.5.3 <u>Cell Decontamination System</u>		
Ref. TR 153-12	$ 38,000	
3.5.4 <u>Crane-Manipulator System</u>		
1. Crane Assembly	$ 132,000	
2. Manipulators, heavy duty	77,000	
3. Electro-Mechanical Master Slave	100,000	
4. Rails & Power Supply Reels	38,000	
5. T.V. & Special Instruments & Tools	180,000	
6. Equipment Installation & Supports	80,000	
	$ 607,000	
3.5.5 <u>Mock-up Area</u>		
Ref. TR 153-12	$ 53,000	
Total Item 3.5		$ 1,777,000

PLUTO FACILITY COST ESTIMATE

FACILITY DESCRIPTION	COST ESTIMATE	
	ITEM COST	TOTAL
3.6 EXHAUST HANDLING SYSTEM		
Ref. TR 153-12		$ 1,915,000
3.7 WASTE DISPOSAL		
Ref. TR 153-12		$ 95,000
3.8 MOBILE EQUIPMENT		
Ref. TR 153-12		$ 240,000
3.9 SITE DEVELOPMENT		
Ref. TR 153-12		$ 438,200
3.10 UTILITIES		
Ref. TR 153-12		$ 1,038,000
3.11 HOT COMPONENTS SERVICE BUILDING		
3.11.1 General		
1. Excavation	$ 8,000	
2. Shielding Walls & Roof	740,000	
3. Outside Walls & Floor Slab	177,000	
4. Electrical and Special Lighting	150,000	
	$ 1,075,000	

PLUTO FACILITY COST ESTIMATE

FACILITY DESCRIPTION	COST ESTIMATE	
	ITEM COST	TOTAL
3.11 (cont.)		
3.11.2 <u>Hot Work Areas</u>		
1. Viewing Windows	$ 86,000	
2. Sliding Doors Installed (4)	37,000	
3. Plug Doors Installed (8)	32,000	
4. Decomtamination Provision	20,000	
5. Bridge Crane Installed - Hot Shop - 20 ton	25,000	
6. Bridge Crane Installed - Transfer - 1 ton (2)	8,000	
7. Bridge Crane Installed - Hot Storage - 5 ton	9,000	
8. Model 8 Manipulators (4)	40,000	
9. Bridge Manipulator Arm (1)	45,000	
10. G. M. Type Manipulators (2)	40,000	
11. Small Manipulator Arm (1)	25,000	
12. Remote Control Mobile Unit Mobot	100,000	
13. Air Exhauster System & Absolute Filters	25,000	
	$ 492,000	
3.11.3 <u>Laboratory Area</u>		
1. Lab Benches and Fixtures	$ 20,000	
2. Sanitation Provisions	7,000	
3. Filtered Air Conditioning & Heating System	15,000	
4. Laboratory Unit Gas Burner System	1,000	
	$ 43,000	
3.11.4 <u>Cold Shop & Instrumentation</u>		
1. Bridge Crane Installed	$ 28,000	
2. Air Conditioning & Heaters	9,000	
	$ 37,000	

PLUTO FACILITY COST ESTIMATE

FACILITY DESCRIPTION	COST ESTIMATE	
	ITEM COST	TOTAL
3.11 (cont.)		
3.11.5 <u>General Test Service Facilities</u>		
1. Water De-ionizer	$ 2,000	
2. Shop Air System (125 lb.)	2,000	
3. Vacuum System	5,000	
4. Test Air Heating System	40,000	
	$ 49,000	
3.11.6 <u>Special Equipment</u>		
1. Remote Operated Machine Tools	$ 20,000	
2. Metallurgical Equipment	16,000	
3. Ultrasonic Cleaning Equipment	1,000	
4. Lab Equipment - Ovens, Hoods, etc.	30,000	
5. Emmission Spectograph	20,000	
6. Test Item Checkout Benches	80,000	
	$ 167,000	
3.11.7 <u>Tools</u>		
1. Machine Tools	$ 100,000	
2. Hand Tools	10,000	
3. Welding Equipment	2,000	
4. Work Platforms and Benches	3,000	
	$ 115,000	
Total Item 3.11		$ 1,978,000

PLUTO FACILITY COST ESTIMATE

FACILITY DESCRIPTION	COST ESTIMATE	
	ITEM COST	TOTAL
3.12 SERVICE BUILDINGS		
Ref. TR 153-12		$ 1,378,600
3.13 CONTROLS & INSTRUMENTATION		
Ref. TR 153-12		$ 1,250,500
3.14 HEALTH PHYSICS INSTRUMENTS & EQUIPMENT		
Ref. TR 153-12		$ 47,100

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4.0 FUTURE FACILITIES WORK

It is planned to conduct experimental programs to demonstrate feasibility of unique design concepts and to optimize and maintain current the design criteria for the PLUTO Ground Test Faciliy.

4.1 Complete Weapon System Testing - The design criteria set forth in Report TR 153-12 describes a ground test facility capable of performing the extensive development program of the PLUTO powerplant which will be required to develop the complete propulsion system to the point where flight testing can be undertaken. After completion of the initial criteria, as described in Report TR 153-12, further consideration has been given to the possible future requirement that the functional systems of the complete missile be ground tested in conjunction with the propulsion system to insure that the radiation, thermal and vibration characteristics are simulated on a realistic basis prior to flight testing.

Discussions with the three potential airframe contractors revealed a general concurrence of opinion that ground testing the complete weapon system will be necessary before flight testing can be safely initiated. The ability to safely measure actual radiation effects on missile components and subsystems would be a particularly valuable benefit. A complete missile ground test program would include a program for running the reactor at a low power outside of the cell to obtain the most realistic map of the neutron flux around the missile. A preliminary analysis of this problem indicated that tests inside the cell could not produce a true reproduction of the flux distribution to be expected in flight because of the neutron reflecting characteristics of the cell walls.

An analysis of the general test requirements as indicated by the three potential missile manufacturers demonstrated that the missile can be ground tested in the PLUTO facility, provided the test cell, crane manipulator, cooling systems, instrumentation capabilities and hot components servicing facilities are increased to accommodate the missile tests.

The length of the new test cell design discussed later in this report would have to be increased by 15 feet in order to fit the missile and nozzle in the test cell. It would be necessary to increase the height by 5 feet, and the test item support would be designed to carry a total load of 45,000 lbs. The problem of servicing the flight type missile while in the test cell has no ready solution at this

4.1 Complete Weapon System Testing - continued

time. It is very doubtful that the missile can be separated into sections that are joined by remotely actuated disconnects. In all probability, the missile would have to be assembled and disassembled in the Hot Components Service Building. This will require a crane-manipulator with a lifting capacity of 25 tons.

Unless some measure of disassembly of the missile can be performed in the test cell, the crane-manipulator as presently designed will be of relatively little use except as a gantry crane. Although the final missile configurations have not been established, the preliminary weapon designs proposed to date will require set-up, checkout and maintenance operations which will be relatively intricate, including some that would have to be done from a position underneath the fuselage. Manipulator access to this area will require a complete redesign of the equipment. It is also probable that the large increase in the amount of instrumentation for testing a complete missile will impose a much higher order of sophistication in the capabilities of the crane manipulator than was originally planned.

The instrumentation requirements for testing a complete missile are roughly double the requirements of the propulsion system. In order to provide the necessary facilities, the cell instrumentation room and transducer room would have to be increased in size to about twice the present size. This increase in instrumentation would be reflected throughout the facility, causing increased requirements in the mock-up cell, the control room building, the instrumentation calibration and maintenance equipment, and in the Hot Components Service Building.

The testing of a complete missile in the PLUTO facilities will require a Hot Components Service Building with a shop large enough to accommodate a complete missile. It is anticipated that the Hot Components Service Building would need to be expanded to handle the remote disassembly of a complete missile. This will probably require an increase in the facilities for servicing and testing "hot" controls and instrumentation.

In evaluating the feasibility of providing missile testing capability, the problem of increased capital costs is probably not as important as the problem of interrupting the engine development program, if it is assumed that only one test cell will be provided. The potential missile contractors have indicated that their test programs will require full use of the test cell for periods ranging from six months to over a year, during which time the test cell

4.1 Complete Weapon System Testing - continued
will not be available for product improvement testing of the propulsion system.

Recognizing the potential need for a second test cell, preliminary layouts have been prepared that show a feasible location for an additional test cell that could be installed at some future date for the testing of weapon systems, or increased rate of powerplant testing. Figure 5 shows a two cell facility plan which could lend itself to a phase type of construction. The cell indicated on the drawing as Cell A would be constructed during the initial phase, and Cell B would be built at a later date. In this approach, it is anticipated that all necessary services, instrumentation, buildings, access tunnels and cooling water equipment would be designed and sized to handle the additional cell. The plan permits approach and entry to one cell, when an engine (shut down at least 24 hours) is in the other cell and when activation levels permit. It has the considerable advantage of presenting virtually the same functional orientation to the other facility components.

This preliminary analysis has shown that testing of the complete missile in the PLUTO Facility is feasible and desirable. It is planned to continue this analysis as a part of the 1960 design effort in order to establish detail requirements of the potential missile manufacturers and interpret these into facility design criteria and cost estimates.

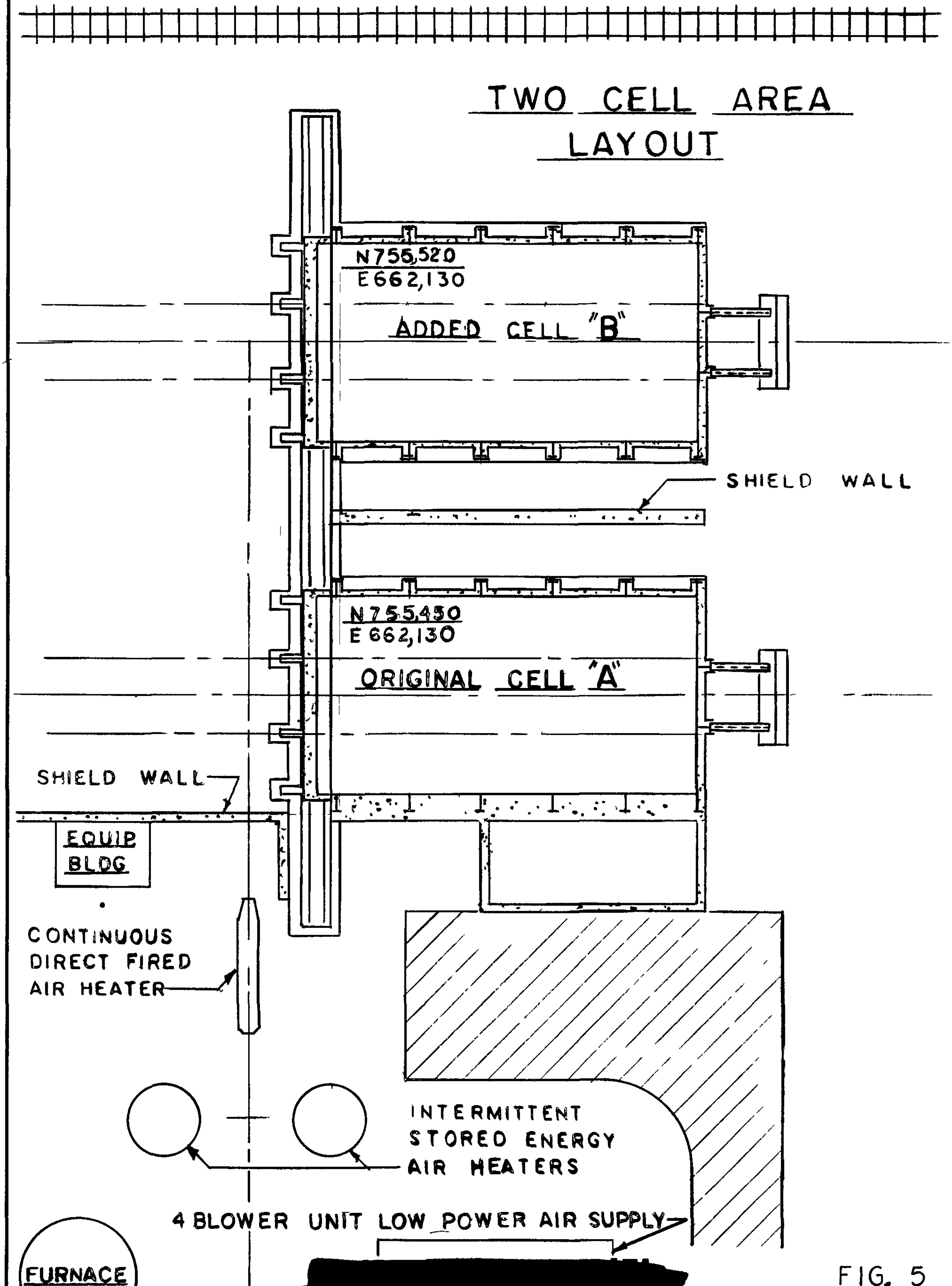
TWO CELL AREA LAYOUT
N755,520
E662,130
ADDED CELL "B"
SHIELD WALL
N755,450
E662,130
ORIGINAL CELL "A"
SHIELD WALL
EQUIP BLDG
CONTINUOUS DIRECT FIRED AIR HEATER
INTERMITTENT STORED ENERGY AIR HEATERS
4 BLOWER UNIT LOW POWER AIR SUPPLY
FURNACE

FIG. 5

4.2 Design Criteria Revisions

It is necessary that the design criteria for the PLUTO Engine Test Facility as presented in Report TR 153-12 and the addendum Report 30003 be revised on a continuing basis, until final detail design of the facility is started. This will involve revisions resulting from refinement of the PLUTO engine and missile design as well as later design data on facility equipment. In addition, several areas in the test facility criteria warrant preliminary design effort to both further define the criteria for the Architect-Engineer and to improve facility design to effect cost savings and improve capabilities. It is planned to issue a completely revised edition of the design criteria and drawings for approval by the Air Force just prior to the time when final design of the facility is scheduled to start.

As more information becomes available regarding the design of the PLUTO propulsion system and missile and the development test requirements, revisions and extension of the facility design must be accomplished in the areas of test item assembly and disassembly, test item installation, instrumentation, safety considerations, exhaust handling and support services.

Further study of missile testing requirements will be conducted with the airframe contractors. The facility additions, which would be required for missile testing in the PLUTO facility complex, would be developed and the design criteria, together with preliminary design drawings would be prepared for the increased scope of testing operations.

A study will be made of the growth potential of the flight engine test facility for powerplant testing at increased Mach numbers. The cost of growth provisions beyond Mach 3 will be analyzed.

Depending upon the scope of the testing operations to be conducted in the PLUTO facility complex, it may be desirable that a less congested site be selected -- preferably on Air Force land. Should this requirement become a reality, site selection studies will be carried out to find a new location that would meet the program requirements.

Additional work is planned in the area of engine installation and servicing to maintain high cell utilization. This will involve design of pipe, instrumentation, and engine mounting remote disconnects. The study of crane manipulator designs for test item installation and servicing will be continued.

4.2 Design Criteria Revisions - continued

The instrumentation and control requirements for the engine and test facility will be further defined and instrumentation equipment specifications outlined. Methods of instrumentation calibration will be carefully studied to provide high accuracy and cell utilization. Further control room layouts will be made.

Shielding studies will be continued in radiation areas where the facility design has not yet been completed. This will include the exhaust system, reactor handling and disassembly facilities where changes in design or scope of operations become necessary.

Continuing studies will be made of the radiological safety associated with the engine test program. Specifically, analyses will be made for engine failure under operating conditions and clean-up procedures developed. The design of the facilities with respect to ease of clean-up will be scrutinized and changes made in the design criteria where recommended.

As more information becomes available on exhaust fission product release from the PLUTO engine, further studies will be conducted on facility exhaust handling systems. This will include selection and layout of equipment in sufficient detail so the design criteria for the exhaust system can be adequately specified.

4.3 Experimental Programs

The design criteria and cost estimate as presented in Marquardt's Report TR 153-12, Project PLUTO Ground Test Facility, Volumes I, II, and III are based on the use of unique design concepts for air storage, air heating and exhaust handling. The application of these new approaches has resulted in approximately a $14,000,000 reduction in over-all facility cost and the safe disposal of contaminated engine exhaust gases.

Although these approaches appear feasible from results of preliminary design work, they are untried and sufficient data are not available to design reliable equipment within estimated facility budgets and schedules. It is Marquardt's opinion, therefore, that experimental programs should be conducted to demonstrate the feasibility of these approaches and to optimize the designs.

The design and construction schedule presented in Section 3 of this report shows three years from the start of detail design. This three year schedule presumes that detail design criteria has been finalized, including design data that must be obtained from experimental programs.

Therefore, experimental test programs to demonstrate the feasibility and provide design data for underground air storage and vitiated air heater have been proposed in Marquardt Proposal 1678B, dated October 28, 1959. Additional experimental programs for evaluation of other unique design concepts for exhaust handling and remote disconnects are being studied and will be proposed next year.

4.3.1 <u>Experimental Program for Underground Air Storage Chamber</u> - The Test Air Supply System proposed by The Marquardt Corporation for the PLUTO Ground Test Facility will have, as a basic component, a large underground high pressure air storage chamber. The configuration of this chamber will probably be a vertical cylindrical chamber with a diameter of 30 feet and an over-all chamber length of 370 feet. The top of the chamber will be at least 200 feet below the ground surface.

Although the theoretical analysis indicated a large deep rock storage chamber could be built to store air at pressures of 3600 psi, no chamber has ever been built to contain fluids at this pressure. In order to evaluate

4.3.1 Experimental Program for Underground Air Storage Chamber - continued

the feasibility of using this concept at the PLUTO test site, a consulting team composed of Dr. J. J. Manning, Consulting Geologist and Dames & Moore -- Foundation Engineers performed a general survey of the proposed site. On the basis of surface evidence, these consultants concluded that the rock at the site would probably be suitable for an underground pressure chamber, but they emphasized that extensive subsurface explorations would be necessary before making final recommendations. The experimental program will be designed not only to demonstrate feasibility of the concept, but also to determine the most economical chamber design and construction techniques.

A research program was, therefore, proposed that would be composed of two phases. During the first phase, a large percentage of the funds would be used for obtaining data on the physical properties of the rock, in-place data as well as laboratory data. It was proposed that two core holes, each with a depth of approximately 700 feet, be drilled in order to obtain continuous core samples. At the completion of the drilling operations, the holes will be used for in-hole tests in order to obtain physical data of the rock mass. These tests will include electrical logging, gamma ray logging, and probably sonic tests. From these data, physical properties such as compressive strength, shear strength, modulus of elasticity, bulk modulus, and Poisson's ratio will be determined. In addition to these properties, other characteristics such as porosity, density, and crystal structure will be determined as needed.

When sufficient data on the physical properties of the rock has been developed, a comprehensive theoretical and experimental stress analysis program would be initiated. The analysis will include the effect of hysteresis, plastic deformations, and localized strains. The two or three most feasible configurations determined by the theoretical analysis would be further studied by suitable experimental stress analysis techniques. The two experimental techniques which will probably be most suitable for this application would be a photoelastic analysis of gelatin models, and stress-coating small laboratory models wherein the original phenomena under investigation would be faithfully reproduced in the model in accordance with the principles of similitude.

4.3.1 continued

The second phase of the proposed research program would be the performance of in-place tests on a large scale model of the proposed chamber. The primary objectives of these tests would be to verify or modify the conclusions arrived at in the stress analysis work described above, and to test several types of chamber liners. The test chamber which would be used for the in-place test would be constructed at the bottom of a 5 foot diameter shaft 80 feet deep. It is planned to run a series of tests at pressures up to 3600 psi to obtain data on chamber strains, liner performance, and work hardening effect due to successive application and release of pressure. The proposed experimental program would also include a test of the leaked air pressure relief system by perforating the liner and observing the results.

4.3.2 Experimental Program for the Vitiated Air Heater

The PLUTO engine development program will include many runs of long duration. These runs will be up to 25 minutes at the design air flow of 2050#/sec. and at a total temperature of 1060°F. A vitiated air heater would be used to provide the required test air temperatures during the long continuous runs. The Marquardt Corporation has accomplished considerable development work in the past two years with vitiated air heaters, which will be applicable to the heater envisioned for the PLUTO program. Since the total pressure level as well as the airflow rate at which the heater will be operating is several items larger than existing experience, the heater is considered a development type of item. The off-design operating conditions for this heater also requires development testing.

The objective of this program is to design, fabricate, and test a high pressure, direct burning type heater that will provide design data for construction of the full scale heater to be used in the PLUTO facility. The primary objective of the program will be to develop a satisfactory heater for steady state duty at high mass flows and pressures. A secondary objective will be to determine the suitability of this heater for simulating transient conditions. The steady state operating conditions will simulate the cruise and full power operating conditions, while the transient conditions will simulate the air flow, pressure and temperature transients occurring during launch operations.

It is planned that a step type of burner with a water-cooled combustion chamber will be developed under this program. This type of heater is simple in construction and durable in operation because of the absence of internal hardware such as combustion cans or flame holders. The burner will be installed in Cell 7, of Marquardt Jet Laboratory, Van Nuys, and a series of runs will be made at several air flow, pressure and temperature levels to simulate both steady state and transient facility operations. The test item will be constructed as a segment of the full scale heater and sized so that, with the flow rates available at Cell 7, the longitudinal velocity profiles will closely simulate the full scale item profiles and provide good heater performance correlation.

The development program requirements will also include investigation and optimization of the temperature profile across the heater exit for proper flight simulation and to avoid local over-heating of the ducting. Particular consideration will also be given to the development of a

4.3.2 Experimental Program for the Vitiated Air Heater - continued

reliable ignition system and provisions for insuring that combustibles will not collect in the downstream ducting. Runs will be made with several different fuels so that the heater design could be optimized for the fuel giving the best over-all performance.

After satisfactory performance for steady state simulation has been demonstrated, tests will be conducted to establish the limits of satisfactory combustion under the low flow, pressure and temperature conditions required for off-design simulation.