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ORO-649

BOILING NUCLEAR SUPERHEATER (BONUS) POWER STATION

PUNTA HIGUERA SITE NEAR RINCON, PUERTO RICO

Project Completion Report

June 1966

Oak Ridge Operations Office
Oak Ridge, Tennessee

UNITED STATES ATOMIC ENERGY COMMISSION • DIVISION OF TECHNICAL INFORMATION

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E R R A T A

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On Page I-38 of the report, in the second line, Instrumentation, Purchase Order C-99-330, CompuDyne Corporation, the Original Purchase Order Amount should be corrected to read, "405,465" and the Final Purchase Order Amount should be corrected to read "535,910*".

August 24, 1966

ORO - 649
REACTOR TECHNOLOGY
(TID - 4500)

BOILING NUCLEAR SUPERHEATER (BONUS)

POWER STATION

PUNTA HIGUERA SITE NEAR
RINCON, PUERTO RICO

PROJECT COMPLETION REPORT

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Power Station

PROJECT COMPLETION REPORT

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SUMMARY OF REPORT FORMAT

This report covers the Boiling Nuclear Superheater (BONUS) Power Station located at Punta Higuera near Rincon, Puerto Rico. The authorization for this project, as set forth in Public Law 86-50, reads as follows: "60e15, power reactor of advanced design capable of utilizing nuclear superheat, to be undertaken either as a cooperative project or conducted solely by the Atomic Energy Commission." Under the provisions of the authorization for this project, the AEC and the Puerto Rico Water Resources Authority entered into a cooperative arrangement similar to the Second Round provisions of the Cooperative Power Reactor Demonstration Program, whereby the AEC built the reactor and carried on the necessary research and development, and the Utility furnished the land, turbo-generator, and other conventional type facilities. This report is set forth in three sections: Sections I and II covering the AEC portion of the nuclear power plant, and Section III the PRWRA portion,as indicated below:

Section I - This section covers work funded by AEC under P&CE projects consisting of Title I engineering services under Project 04-1-59-D-014-24 and Titles II, III, and IV engineering services (including start-up), procurement, and construction work under Project 04-1-60-E-015-24. The work described in this section is that normally contained in Construction Completion Reports as prescribed by AEC Manual Appendix 6101, Part V. Facilities provided under the construction project include the containment structure and required services and utilities; reactor plant equipment including reactor pressure vessel, reactor core structure, control rods and control rod drives, instrumentation, reactor core shims, reactor cooling systems, emergency cooling system, fuel storage pool cooling system, reactor preheating system, emergency condenser, fuel handling and storage equipment, radioactive waste disposal system, feedwater supply and treatment system, and other associated equipment; and certain accessory electric and miscellaneous power plant equipment.

Section II - This section covers AEC work costed under Operating Expenses including research and development for the nuclear superheat program under Chicago Operations Office; research and development in support of BONUS design and construction; first core design, fabrication, and inspection; operator and start-up training; and superheater fuel element leakage investigations.

Section III - This section covers the BONUS conventional-type facilities, known as the generator plant, furnished and financed by the Puerto Rico Water Resources Authority including land, entrance building, roads and parking areas, outside utilities, seawater intake and discharge structures, and the turbo-generator and condenser unit with associated equipment.

A summary of the estimated final costs under the sections shown above is as follows:

Section I	Project 04-1-59-D-014-24	$ 82,500	
	Project 04-1-60-E-015-24	13,110,000	
	Subtotal Section I		$13,192,500
Section II	Operating Expenses Activity 04-1-01-05		
	BONUS First Core (incl. engr.)	$ 1,393,591	
	Operator & Start-Up Training	1,361,061	
	BONUS Research & Development	502,994	
	Research & Development under COO	995,703	
	Other	191,213	
	Subtotal Section II		$ 4,444,562
Section III	PRWRA Financed Facilities		
	Land and Land Rights	$ 148,000	
	Construction & Engineering	4,832,000	
	Pre-Construction R&D	220,000	
	Training	900,000	
	Subtotal Section III		$ 6,100,000
GRAND TOTAL			$23,737,062

SECTION I - CONSTRUCTION PROJECT

AEC PROJECT 04-1-60-E-015-24

A. INTRODUCTION AND GENERAL INFORMATION

1. Identification of Project

Name: Power Reactor of Advance Design - Nuclear Superheat - BONUS

Location: Punta Higuera, near Rincon, Puerto Rico, the westernmost tip of the island

Operations Office: Oak Ridge

Budget Project Numbers: 04-1-59-D-014-24 (Preliminary Design)
04-1-60-E-015-24 (Remaining Engineering and Construction)

2. Brief Description of BONUS Plant

The Boiling Nuclear Superheater (BONUS) Power Plant's reactor is designed to deliver 152,000 lb/hr. of steam to the turbine throttle at 850 psig and 900°F. The reactor operates at a nominal pressure of 975 psig, and produces a total of 50 megawatts of heat with feedwater returned at 354°F. Of the 50 Mw total heat output, 37 Mw are generated in a central boiler region, and 13 Mw are generated in a superheater region which is located at the radial periphery of the core. The gross electric output is 17.3 Mw, corresponding to a gross plant efficiency of 35.0%. The net electric output is approximately 16.5 Mw.

The plant uses a conventional regenerative steam cycle with four closed feedwater heaters and a standard two-pass shell-and-tube condenser cooled with sea water.

The reactor, turbine-generator, and all auxiliaries are housed within a single, gas-pressure-tight, low pressure containment building.

The BONUS Power Station will be operated such that it will deliver to the electric transmission system whatever power is generated from the reactor superheated steam.

3. General Organization and Responsibilities

The Boiling Nuclear Superheater (BONUS) Power Plant is a joint undertaking of the United States Atomic Energy Commission (AEC) and the Puerto Rico Water Resources Authority (PRWRA). The decision to build the BONUS Plant was made when studies and a preliminary design of the plant under AEC Contract AT-(40-1)-2484 with PRWRA were completed. The primary objective of the project was to demonstrate the feasibility of producing superheated steam in a nuclear reactor. Secondarily, the plant was built to show the economics of operating a nuclear plant at a remote location in an area of high fuel cost. The AEC was responsible for design and construction of the reactor and the related auxiliary facilities.

3. General Organization and Responsibilities (contd)

PRWRA was responsible for the plant site and for the design and construction of the power generating portion of the plant, site, and transmission facilities. The respective responsibilities of the AEC and PRWRA are delineated in AEC Contract AT-(40-1)-2672 with PRWRA.

Responsibility for execution of the project rested with the Manager, Oak Ridge Operations (ORO). The Deputy Director, Engineering Division, under the Assistant Manager for Construction and Engineering, was responsible for administering the General Nuclear Engineering Corporation (later Combustion Engineering Nuclear Division) contract on design; preparation of checkout, pre-critical, criticality and operating procedures; hazards summary reports; and required research and development. The Reactor Division provided technical assistance during design, construction, hazards reviews, and start-up, and had program responsibility for research and development. The Area Manager, Puerto Rico Area Office, was responsible for administration of the GNEC-CEND contract on Title III inspection services, precritical testing and start-up, and training of PRWRA personnel. The Area Manager was also responsible for administering the construction contract with Maxon Construction Company and the operating contract with the Puerto Rico Water Resources Authority. Other ORO divisions, such as Research and Development, Contract, Finance, Budget and Reports, Supply, etc., provided staff assistance to the contract administrators, as required.

The design and inspection of the nuclear portion of the BONUS Plant was carried out by the General Nuclear Engineering Corporation (GNEC) of Dunedin, Florida, a wholly-owned subsidiary of Combustion Engineering, Inc. (CE) of Windsor, Connecticut, under AEC prime CPFF Contract AT-(40-1)-2674. Effective as of September 1, 1964, GNEC was merged into CE with the latter assuming all the rights and privileges, obligations, and liabilities under the contract. Thereafter, all work under the contract was carried out by Combustion Engineering's Nuclear Division (CEND). This contract also covers checkout and start-up of the BONUS Plant, as well as a Research and Development Program (funded under Operating Expenses).

Jackson & Moreland, Inc. (J&M) of Boston, Massachusetts, was engaged by GNEC under a CPFF subcontract for conventional type architect-engineering services. On January 1, 1964, J&M was acquired by United Engineers & Constructors, Inc., of Philadelphia, Pennsylvania, with the latter assuming all the rights and privileges, obligations, and liabilities under the subcontract. Thereafter, all work under the subcontract was carried out by J&M as a division of United Engineers & Constructors, Inc.

Construction of the AEC portion of the BONUS Plant was accomplished under AEC prime CPFF Contract AT-(40-1)-2696 with the Maxon Construction Company, Inc., of Dayton, Ohio.

Participative work under the construction project was accomplished by PRWRA under AEC prime Contract AT-(40-1)-2672.

4. Factors Affecting Choice of Design

Major factors which affected the choice of design were described in the BONUS Preliminary Design Study. 1/ Several of the factors leading to the selection of certain design parameters are discussed briefly in the following paragraphs:

1/Boiling Nuclear Superheater (BONUS) Power Station, Preliminary Design Study, Alternate Design Studies, PRWRA-GNEC 3A, Vol. 3, PRWRA and GNEC, January 8, 1960, pp. I-1 and I-2.

4. Factors Affecting Choice of Design (Contd.)

In the initial stages of the study, it was felt the superheater fuel assemblies should be designed on the basis that steam cooling could be maintained at all times in much the same manner as is required for fuel elements in gas-cooled reactors. After considering the various methods of maintaining continuity of flow under emergency conditions and after evaluating the potentials of fuel assemblies that could dissipate shutdown heat without dependence on power following a reactor shutdown, the safety advantage of "self-cooling" type fuel assemblies was judged to outweigh the disadvantages of this type. The major design effort on superheater fuel assemblies was, in general, restricted to cylindrical UO_2 rod types. Other applicable types, such as the annular UO_2 fuel element required extensive manufacturing development and irradiation testing and were, therefore, not examined extensively.

Two main considerations governed the selection of the operating steam temperature and pressure for the BONUS reactor. In order to obtain the lowest possible cost for the conventional portion of the plant, the steam conditions should correspond to those for a "handbook" or "preferred standard" turbine-generator unit of the electrical rating required. The second interrelated consideration is that the exit steam temperature from the reactor should be sufficiently below the maximum permissible cladding temperature in the superheater to allow operation of the superheater fuel at reasonably high specific power without resorting to very highly subdivided fuel or finned elements.

Early investigations on the strength and corrosion resistance of various cladding materials resulted in a limit of 1200°F. being selected as representing a reasonable upper limit for stainless-steel cladding in contact with superheated steam. Since gas film temperature drops of the order of 200°F. to 400°F. were anticipated, the choice of 1200°F. maximum surface temperature dictated an exit steam temperature of 800°F. to 1000°F. These facts, coupled with the popularity of the 850-psig 900°F. throttle conditions for small turbines, led to the choice of 850 psig and 900°F. as the throttle conditions for the BONUS Plant.

The comparison of forced versus natural circulation was of interest. The requirement of maintaining a reasonable steam void fraction in a high power density boiling water reactor core implies either a low-temperature condensate return or a high-velocity water flow in the core. Low-temperature condensate return is not consistent with the high cycle efficiency desired for the BONUS Plant, so that relatively high core velocities are needed. Achieving high core velocities in a natural-circulation system is difficult without going to a comparatively open-fuel lattice, resulting in a penalty in both power density (hence core size) and conversion ratio. Whereas this compromise might prove economically feasible for a small reactor such as the BONUS reactor, it will not be so for larger reactors for which BONUS is a prototype.

The results of the study reported in Section VI of the above-referenced report indicate the performance characteristics of a natural-circulation boiling water core. This core requires 104 fuel assemblies with a comparatively open lattice. The core has an effective diameter of 4.33' and a power density of 22.7 kw/liter of core. This compares with the BONUS forced circulation reference boiling core effective diameter of 3.34' and power density of 32.9 kw/liter of core, which is more representative of the power density required of large boiling water reactors for economical power generation.

4. Factors Affecting Choice of Design (Contd.)

Forced circulation pumps for the BONUS reactor provide a system which probably suffers an economic penalty when compared with natural circulation but which is more reliable in its performance characteristics; and, also, since it operates at comparatively high coolant channel power density, the BONUS reactor is a possible prototype of larger reactors of this type to follow.

In summary, the BONUS Power Station design was developed from an evaluation of the many forms which a small boiling nuclear superheater plant could take. The design chosen is believed to be near optimum from the standpoint of the objectives of the Atomic Energy Commission and the Puerto Rico Water Resources Authority. Since the BONUS Power Station is one of the first to utilize a reactor which incorporates integral nuclear superheat, safety was considered of paramount importance in developing the design. The result is a boiling water reactor which incorporates an integral superheater section without sacrificing the high degree of safety which has characterized boiling water reactors in the past.

5. Scheduled, Actual Completion, and Beneficial-Use Dates

a. Design, Construction, and Start-Up

	Title II Engineering	Construction	Start-Up
Original Schedule			
Start	2-4-60	8-13-60	9-1-62
Complete	12-31-61	11-30-62	1-31-63
Actual			
Start	2-4-60	8-13-60	2-1-64
Complete	12-27-63 1/	9-30-64 2/	12-19-65

1/Plans and specifications completed 4-24-63.
2/Essential completion of construction.

Figures 1 through 5 show proposed and actual design, construction, and start-up schedules.

b. Beneficial Use of Major Components

Item	Date
Cooling Water System	9-12-62
Air Conditioning System	9-12-62
Control Air Compressor System	10-10-62
Building	6-29-63
Piping and Electrical Systems	8-31-63
Reactor Pressure Vessel	11-30-63
Control Rods	11-30-63
Reactor Plant Systems (Shield Cooling, Shutdown Cooling and Purification, Heat Transfer, Fuel Handling, and Storage, Radioactive Waste, Feedwater Supply, etc.	11-30-63
Reactor Core Structure	11-30-63
Accessory Electrical Equipment	11-30-63
Miscellaneous Power Plant Equipment	11-30-63
Ventilating Systems, Modified	2-1-64
Control Rod Drive Mechanism	4-1-64
Instrumentation, Controls, and Boards	4-1-64
Reactor Safety System	4-1-64
Pressure Control System	4-13-64

B. CONTRACT AND COST DATA

1. Architect-Engineer Work

a. GNEC

(1) Contractor Identification

Prime Contract AT-(40-1)-2674 for design, architect-engineer, and research and development services in connection with the BONUS Power Plant was awarded to the General Nuclear Engineering Corporation (GNEC), P. O. Box 10, Dunedin, Florida, on February 4, 1960. On September 1, 1964, GNEC was merged into their parent organization, Combustion Engineering, Inc.(CE), 1000 Prospect Hill Road, Windsor, Connecticut, with the latter assuming all the rights and privileges, obligations, and liabilities under the contract. Thereafter, all work under the contract was carried out by Combustion Engineering's Nuclear Division (CEND), P.O. Box 500, Windsor, Connecticut. The AEC entered into Contract AT-(40-1)-2672 with the Puerto Rico Water Resources Authority (PRWRA) on January 12, 1960, whereby PRWRA would furnish all the conventional parts of the generator plant, such as the turbine-generating equipment, switchyard, and transmission facilities.

GNEC subcontracted, under Subcontract GNEC-66-100 effective March 4, 1960, the conventional aspects of the reactor plant to Jackson & Moreland, Inc.(J&M), 600 Park Square Building, Boston, Massachusetts. On January 1, 1964, J&M was acquired by United Engineers & Constructors, Inc., of Philadelphia, Pennsylvania, with the latter assuming all the rights and privileges, obligations, and liabilities under the contract. Thereafter, all work under the contract was carried out by J&M as a division of United Engineers & Constructors, Inc.

The scope of the work required of GNEC and J&M, including the modifications, is included in this report as Exhibit A and Exhibit B, respectively. Part I of the Statement of Work describes GNEC's architect-engineer services performed for the BONUS Power Station.

(2) Schedules Estimated and Accomplished

GNEC performed a preliminary design of the BONUS Plant jointly with PRWRA from December 1958 through January 1960 under Contract AT-(40-1)-2484 and PRWRA Subcontract NP-1.

The schedule for engineering design and construction including start-up was shown in GNEC's BONUS proposal[2/] to extend from February 1960 through January 1963. As actually accomplished the work continued until December 19, 1965. Figure 3 is a composite of the proposed and accomplished schedules.

2/Boiling Nuclear Superheater (BONUS) Power Station, A Proposal to U.S. Atomic Energy Commission for Detailed Design and Development, P.72.

(3) Manpower Estimated and Required

In the BONUS proposal, GNEC calculated the manpower that would be required to accomplish the work. Figure 4 compares the initial estimate with actual manpower expended.

GNEC's subcontractor, J&M, also prepared an estimate of the manpower it would require to perform their portion of the work. J&M's estimate is compared to their actual experience in Figure 5.

A breakdown by month of the BONUS startup manpower showing GNEC and PRWRA effort separately is contained in Figure 6.

(4) Costs Incurred

The applicable Title I engineering costs incurred under PRWRA Subcontract NP-1 were $82,500 under Project 04-1-59-D-014-24. Titles II, III, and IV engineering costs incurred under Project 04-1-60-E-015-24 totaled $3,802,717 including costs of $971,192 under the J&M subcontract. A breakdown of these costs is shown in Table III.

(5) Material Developed

The results of the preliminary design studies are contained in PRWRA-GNEC 3A, dated January 8, 1960, Volume 1, Reference Design; Volume 2, Technical and Economic Evaluation of Reference Design; and Volume 3, Alternate Design Studies. A total of 183 drawings and 33 specifications were prepared by GNEC and 165 drawings and 75 specifications were prepared by J&M during Title II design.* In addition, GNEC prepared 137 checkout procedures, 27 pre-critical procedures, 37 criticality procedures, 89 technical operating procedures, and one administrative procedure.

b. Other Engineering Participants

The Puerto Rico Water Resources Authority, under Contract AT-(40-1)-2672, provided personnel for assistance to GNEC during start-up, prepared certain piping and equipment specifications, and assisted in testing and checkout. The final costs of PRWRA engineering charged to the project were $777,851.

Union Carbide Corporation-Nuclear Division (UCC-ND) under Contract W-7405-eng-26, provided certain participative engineering services in connection with pressure control system corrections, problems with the preheater-dryer piping, and investigation of the seal package of the control rod drives. The final costs of UCC-ND engineering services were $13,583.

Computer services required by GNEC for project-connected work were provided by New York University under New York Operations Office Contract AT-(30-1)-1480, at a cost of $29,525.

The Factory Mutual Engineering Division of the Associated Factory Mutual Fire Insurance Companies, under Contract AT-(40-1)-2455, provided consulting services and advice on the design of the fire protection facilities of the BONUS Plant. Costs for this work totaled $6,703.

*Includes 14 GNEC drawings and 2 GNEC specifications for design of first core, all charged to Operating Expenses.

AEC provided certain training for GNEC personnel at the Oak Ridge School of Reactor Technology and furnished miscellaneous reproduction services, at a cost of $3,741.

Argonne National Laboratory, under Chicago Operations Office, furnished consulting services in connection with investigation of the seal package of the control rod drives at a cost of around $2,000.

Under prime construction Contract AT-(40-1)-2696, the Maxon Construction Company arranged for services of the Corps of Engineers for certain inspection services at equipment vendor plants, and under a purchase order with PRWRA provided for concrete testing and inspection services of certain electrical work. The final costs of these engineering services were $131,597.

2. Construction Work

a. Maxon

(1) Contractor Identification

The major construction of the AEC portion of the BONUS Plant was accomplished by the Maxon Construction Company, 2600 Far Hills, Dayton, Ohio, under AEC prime Contract AT-(40-1)-2696, entered into on April 8, 1960. The contract with Maxon was a cost-plus-fixed-fee type, but maximum use was made of fixed-price purchase orders and subcontracts in carrying out the required procurement and construction work. A tabulation of major items of procurement under the Maxon Contract is reflected in Table VI.

(2) Schedules Estimated and Accomplished

The original construction schedule provided for completion of construction by November 30, 1962. Maxon construction started on August 13, 1960, and the last Maxon employee left the Site on July 15, 1964. Project construction work by PRWRA was essentially completed on September 30, 1964. Figure 7 is a composite of the estimated and accomplished schedule to essential completion of construction.

(3) Manpower Estimated and Required

The manpower requirements for the construction of the BONUS Plant, exclusive of start-up, are contained in Figure 8.

(4) Costs Incurred

Direct and indirect construction costs incurred by Maxon totaled $8,078,362 details of which are tabulated in the final cost summary included in this report as Table VI. Table VII lists the major equipment suppliers.

b. Other Direct Construction Cost Participants

GNEC fabricated certain special tools for BONUS at a cost of $90,768.

Union Carbide Corporation-Nuclear Division furnished a filter for use in the pressure control system and certain materials and welding services in connection with steam dryer-preheater piping repairs. The costs applicable to this work totaled $11,948

PRWRA provided valve identification services, calibrated non-nuclear instrumentation, completed plant changes required by the Division of Reactor Licensing, HQ, accomplished main steam by-pass modifications, and performed certain other miscellaneous items of construction and modification work. The final cost of this work was $149,149.

C. DESCRIPTIVE DATA

1. AEC-Owned Buildings and Related Facilities

a. Reactor Containment Building and Facilities

The BONUS station features a containment building which is different from the usual structures associated with nuclear power plants. The design is based on the total containment principle; i.e., the pressure-tight building houses not only the reactor and its associated auxiliaries, but also the turbine generator, electrical equipment, control, service, and sanitary facilities.

The containment building, shown in cutaway view in Figure 9, consists of a 166 ft-8-in. diameter steel shell (13/32 in. thick) with hemispherical roof (5/16 in. thick) and the concrete mat to which the steel shell is anchored and sealed. A concrete retainer wall anchored to the foundation mat encloses the cylindrical shell portion.

The containment building is designed for the following: internal pressure, 5 psig; external pressure, 1/4 psig; wind speed, 150 mph; horizontal seismic load coefficient, 0.20; leakage rate, not to exceed 0.2% of the building volume per day with internal 5-psig pressure for the steel shell and not to exceed .4% of the building net volume (1.59×10^6 ft^3) per day with internal 5 psig pressure for the complete building including floor slab and all penetrations. The verification of the structural design and leaktightness of the building has been demonstrated by a pressure proof test at 6.25 psig, a vacuum test at 1/4 psig, and two leak rate tests after the plant was completed and all equipment installed. The measured leak rate in September 1964 one year after the initial precritical test was the same; i.e., 0.10% of the building volume per day which is a factor of four less than allowed by the Technical Specifications.

The concrete foundation mat, which is poured directly on the soil base, consists of 15 individual monoliths. Each monolith is tied to an adjacent monolith by reinforcing steel dowels. The construction joints between the individual monoliths are made pressure-tight with polyvinyl waterstops midway through the slab thickness and elastic joint sealing compound poured in the construction joint slots on the top surface of the foundation mat. The mat thickness is 3.5 ft throughout, except locally below the reactor where the base thickness of the steel-lined recessed pit portion is 6 ft and directly below the reactor and fuel storage pool structures where the raised foundation is steel lined and 5 ft 4 in. thick. The large extent of the foundation mat surface is made gas tight with a membrane covering of multiple layers of roofing felt saturated with alternate layers of waterproofing pitch.

The intake and discharge sea water tunnels for the condenser are an integral part of the underside of the foundation mat. Flanged pipe sleeves, for connection to the condenser intake and discharge nozzles, are embedded in the foundation mat.

At the periphery of the foundation mat an 8-inch diameter perforated clay drain pipe ring embedded in a 4-foot deep layer of crushed stone collects rain runoff from the building and surrounding backfill, and prevents hydraulic pressure buildup in the space between the steel shell and the retainer wall. A flexible flashing ring, anchored to the building and to the top of the retainer wall, prevents water from entering this space. Any water that seeps into this space drains to the drain ring through weep holes in the retainer wall.

The steel cylindrical shell is welded to a ring of vertical 4" x ½", flat steel bars spaced on 1-foot centers and embedded in the 182 ft. diameter reinforced concrete foundation mat. The anchor bars extend to within 6 inches of the bottom of the foundation mat and are alternately placed on the inside and outside of the shell to which they are welded. These anchor bars are designed to resist an upward lifting force of 19.5 million pounds which results on pressurizing the building at 6.25 psig (structural proof test pressure). This lift force on the foundation mat is counteracted by the static mass weight of the retaining wall around the shell, the weight of a portion of the foundation mat and internally supported structures, and by the weight of the granular fill between these two elevations. The factor of safety against uplift of the building when exposed to an internal pressure of 6.25 psig resulting from the aforementioned weights is approximately 2.0.

The main function of the circular retainer wall that surrounds the shell is to prevent the lateral pressure due to the surrounding backfill from acting on the cylindrical shell portion of the building. The wall reinforcing steel and wall shape have been designed to resist a static horizontal earth pressure loading of 1490 psf in combination with a horizontal seismic loading of 620 psg (seismic factor of 0.2 applied to mass of wall and earth backfill). The retainer wall is anchored to the foundation mat by interconnecting dowels and is formed from five vertical pours concrete. The retainer wall construction did not commence until after the radiographic and vacuum tests of the building shell portion were completed and the test results indicated sound and pressure tight shell weld joints. To permit thermal expansion of the shell relative to the retainer wall, a 10-foot high layer of fiberboard is placed between the shell and the wall.

The rain runoff water from the dome is collected in the 18-inch wide gutter formed in the retainer wall top. Drains from the low points in the gutter are connected into the site drainage system.

Cast integral with the retainer wall are six concrete manholes. Three manholes are located at the entry points for the power, control, and instrumentation cables, two at the points of entry and exhaust of plant ventilation and cooling air, and one at the entry point for the internal fire protection piping.

Two vacuum relief valves admit air to the building in case the pressure inside drops below atmospheric pressure as a result of changes in barometric pressure or cooling of the building atmosphere by one of the spray systems while the building is closed. Both valves are set to open at 5 inches of water negative pressure.

Personnel entry and exit from the containment building is normally through the entrance air lock leading into the administration building at the turbine floor level. An air lock of the same size, located on the opposite side of the building at the same level and leading to the outside, is used during plant operation for the delivery of plant supplies which are small enough for fork-lift truck handling within the air lock and also for emergency escape of the operating staff from the building in case the other air lock is damaged or inoperative. Each air lock is 11 feet in diameter with an inside length of 12 feet and can accommodate 25 people in an emergency. The air lock access doors provide a clear opening 5 feet wide by 8 feet high.

Deliveries of heavy supplies into the plant that cannot pass through the emergency air lock, or heavy shipments out of the plant are made when the plant is shut down and the building freight door opened. The bolted and gasketed freight door is supported by an overhead trolley, and can be rolled away from the 12' wide x 14' high opening.

To protect the building and equipment from fire damage, a separate wet pipe, automatic sprinkler fire protection system, designed in accordance with Factory Mutual Standards for "improved risk", is installed in the BONUS building. In addition to the sprinkler protection system, two hose racks are provided in the basement, one on the wall outside of the building exhaust fan room and the other outside of the intake fan room. Two similar hose racks are provided on the main floor.

An internal building spray is provided and the function of the internal spray system is the reduction of the building pressure following an accident involving the uncontrolled release of steam into the building space from a break in the reactor and/or plant piping systems. Although the containment building is designed to safely resist the pressures that can result, the rapid reduction of the pressure by the quenching action of the spray system will reduce the total amount of the radioactive contaminants that can leak to the outside due to the resulting lower pressure level and also by the scrubbing action of the water spray which will retain a large fraction of the water-soluble iodine. The internal building spray system is designed to discharge the spray water at a rate of 1000 gpm, which flow rate will reduce the building pressure following the maximum credible accident from 4.3 psig to 2.4 psig within 50 minutes.

An external building spray system is also provided and can be used for limited cooling of the containment building in situations where it is undesirable to spray the interior of the building. In case of a major accident, it can be used for periodic cooling of the shell over an extended period of time to keep the building pressure low after the initial pressure reduction has been accomplished by using the interior spray. This manually-operated back-up system, by keeping the building shell cool, will absorb the decay heat from the fuel elements inside the building and will minimize daily pressure fluctuations due to variations in atmospheric air temperatures and solar heat loads.

This external spray system consists of two circular ring headers which are perforated at regular intervals and are mounted on the building at two elevations. These ring headers are connected to a 4 inch supply line which is, in turn, connected to the 12-inch emergency water supply header. The total design flow of water to the two headers is 450 gpm, which is the minimum rate needed to assure thorough wetting of the building exterior surface.

There are four water storage tanks, each having a capacity of 25,000 gallons, for fire protection inside the containment building, the reactor core spray, the internal and external building spray systems, and future warehouse sprinkler system.

All personnel access areas of the plant, including the limited and restricted access shielded compartments, are ventilated by the forced circulation of fresh intake air which is inducted into the building by a 62,000 cfm intake fan and discharged from the building to the stack by an exhaust fan of the same capacity.

Fresh air enters the building after being cooled by the chilled water heat exchangers mounted on the air inlet manhole on the east side of the building. The pipe penetration leading into the fan suction chamber compartment contains two air-operated quick-closing butterfly valves, one on the building side and the other in the air intake manhole; both of the intake valves and the dual-exhaust valves are the same type and automatically close on the detection of high radiation levels in the stack discharge.

The intake and exhaust fans are similar centrifugal type and V-belt driven by a 50 hp, squirrel-cage induction motor.

The exhaust ventilation air enters the filter compartment of the exhaust fan room where particulates picked up are removed prior to entry into the exhaust fan inlet and discharged to the stack. The filter bank consists of 40 fiber glass units each rated at 2000 cfm with .25 in. water pressure drop when clean. A prefilter upstream of the main filters picks up larger particulates and minimizes the fouling of the main filters.

The discharge from the building exhaust fan, with dual air operated valves in the discharge line similarly located with respect to the building shell as for the intake valves, enters the base of the 5 ft diameter steel-guyed stack mounted on the exhaust air manhole.

The working spaces normally occupied by the staff and operating personnel throughout a full shift are air-conditioned for comfort. The air pressure in these air conditioned rooms is maintained at a slightly higher pressure than the surroundings. The two air conditioners for the separately air conditioned bays are of the same type. The unit for air conditioning the occupancy areas to the left of the entrance air lock is mounted above the laboratory. The other unit for controlling the air temperature in the control room and adjacent offices is mounted above the control room. Each air conditioner is a twenty ton self-contained "packaged" unit.

The sanitary wastes are discharged from the building by the sewage pump to the septic tank and outside sanitary waste sewage piping system. The sewage pump with integral steel wet well, is located at basement floor level and outside the liquid waste process shielded compartment. The effluent from the sewage pump is discharged through a normally open, pneumatically operated valve with integral-mounted, pilot solenoid valve. The valve automatically closes on building stack high activity. The sanitary wastes are discharged into an underground concrete septic tank located south of the entrance building. The wastes from the sanitary facilities in the entrance building also discharge into this same tank.

Ceiling-suspended, semi-direct, fluorescent lighting fixtures are used in the offices, control room, laboratory, parts storage room, fuel storage room, electrical maintenance shop, and machine shop within the containment building. Pendant-type incandescent lamp fixtures are used for lighting of electrical equipment, dry storage, service rooms, and general areas within the containment building.

Emergency lighting, powered by the emergency diesel, provides sufficient illumination throughout the reactor building to permit personnel to perform emergency duties. As an additional safety feature, battery powered portable lamps are located near each stairway, entrance and emergency air locks, control room, basement area, operating floor, and entrance building. Thirteen lighting fixtures in the control room are equipped with a single incandescent lamp operated from the station battery during ac power failure.

The routine handling of heavy equipment, such as the steel rotating shield plug, vessel cover, and concrete shield plugs, as well as the turbine upper casing is carried out with the 60 ton polar gantry crane. Its size is based on the future use of a 60 ton cask for the shipment of irradiated fuel elements back to a stateside processing center. The separate positioning of the dc motor-driven bridge, trolley and hoist hook is controlled by a retractable push-button pendant station operable from either the reactor or turbine floor levels. Stepless variable-speed regulation of the respective drive motors allows fine control positioning of the load. The maximum speeds of the hoist, trolley, and bridge are 15 ft/min, 33 ft/min, and 90°/min, respectively.

The drive motors for the 75 hp main hoist, 2 hp trolley, and 7-½ hp gantry are all 240 vdc, separately excited and provided with shaft coupled electric disc brakes.

Off-site and on-site communication is available in the site administrator's office, shift supervisor's office, control room, and switchboard in the entrance building. Off-site communication is available through the commercial telephone system and the PRWRA microwave communication system. On-site communication is available through the plant paging or intercommunication systems.

The intercommunication systems are divided into the operating and maintenance systems. The operating system consists of five telephone stations; pillbox, entrance building, control room, supervisor's office, and building office. The system is arranged to provide two independent conversations between any two stations at any given time. The maintenance system is used to provide communication between any location throughout the plant and the control room during maintenance. It consists of a fixed telephone in the control room and a series of jacks located throughout the plant and outside, all on common-talk, common-ring circuits.

b. Chiller House

The chiller house that contains the refrigeration equipment for the building ventilation chilled water system is 19 ft 8 in. long, 12 ft 4 in. wide and 11 ft 5-½ in. high with 6 in. thick concrete block walls, an 8 in. thick reinforced concrete floor, and 4 in. to 5½ in. thick reinforced concrete flat roof covered with concrete tile. The building is located 125 ft north and 222 ft east of the center of the containment building. The gross floor area of the building is 193 ft^2 and the gross internal volume is 1980 ft^3. A 5 ft 0 in. x 6 ft 8 in. x 1-3/4 in. Kalamein door is located in the north wall and two sets of windows in the east and west walls. Mounted on the roof of the chiller house are two air cooled condensers.

c. Caustic Mixing Shed

The caustic mixing shed contains the chemical mixing tank and transfer pump for mixing 50% sodium hydroxide for regenerating the plant ion exchange demineralizers. The equipment is housed in a 10'-0" long, 9'-0" wide, and 10'-4-3/4" high concrete block structure. The floor slab is 8 inches thick reinforced concrete, the walls are 6-inch hollow concrete block, and the roof slab is 4 inches to 5½ inches thick reinforced concrete covered with multi-ply roofing felt.

2. AEC-Owned Equipment and Systems

a. Reactor Core

The reactor core structure consists of two regions, a central boiler region and a peripheral superheater region. The boiler region provides space for 64 boiler fuel assemblies arranged in a 4.43-inch square lattice. The superheater region provides space for 32 superheater fuel assemblies with 8 assemblies located on each side of the square boiler region. Nine cruciform-type control rods are located entirely within the boiler region, and 8 slab-type rods are located between the two regions, making a total of 17 control rods for the core. The boiler fuel assemblies provide space for removable boron-stainless shims located in the central Zircaloy-2 box of each assembly. Between the boiler and superheater region, space is provided for removable slab-type boron-stainless shims in parallel with the slab control rods. The shims provide additional flux flattening and reactivity control. The boiler region has provision for a shim in each fuel assembly with the exception of the four natural-uranium assemblies and the assembly containing the start-up source. Provisions are thus made for a total of 59 shims of types differing in boron content and arrangement. Also, there are provisions for 52 boiler-superheater shims of different types. The boiler region is approximately 35 inches across flats with an equivalent diameter of 39.5 inches; the entire core is approximately 55 inches across flats and has an equivalent diameter of approximately 58 inches. The active core height is 54.6 inches. A lattice spacing of 4.43 x 4.43 inches is used for the boiler and 4.46 x 9.27 inches for the superheater. The spacing between the boiler assembly boxes is ½-inch for channels containing control rods and 3/8-inch for channels without any rods.

Both boiler and superheater regions are fueled with sintered, cylindrical compacts of uranium dioxide (UO_2). The central four boiler fuel assemblies contain UO_2 with natural enrichment (0.71 wt. %U^{235}), and the remaining 60 boiler assemblies contain 2.40 wt. % U^{235} enriched UO_2. This arrangement flattens the power distribution in the central region of the core. The superheater fuel has a uniform enrichment of 3.25 wt.% U^{235}. All of the structural material in the active portion of the boiler region is Zircaloy-2 in order to obtain high neutron economy. Since Zircaloy-2 is not corrosion-resistant to steam at 900°F., the superheater region is constructed of type 348 stainless-steel which has good strength and corrosion resistance at the operating conditions, and the fuel clad is Inconel and the shroud is Zircaloy. Control rods are of 1.09 wt.% boron-stainless steel alloy with the boron enriched to 92% by weight of boron-10.

The primary core support structure is a 5-inch thick stainless-steel grid plate. The grid plate is supported from the bottom of the vessel by a cylindrical structure which transmits the full core load through a welded connection to the bottom of the pressure vessel. This cylinder also serves as a flow barrier between the inlet and outlet nozzles.

The core baffle support translates the full load of the upper superheater grid structure and the control guide structure to the bottom grid. The superheater fuel assemblies are suspended from the superheater outlet nozzles through their outlet standpipes. A locating grid, bolted to the bottom support grid, accommodates the lower assembly guide fitting to position the assembly within the structure. The major portion of the assembly dead weight load is carried by the locating grid through a spring located on the superheater assembly lower guide fitting.

Each boiler fuel assembly is supported directly by the bottom grid and is held in place by the action of a stainless-steel holddown assembly. The holddown assembly, when in position, exerts a lateral force on each of four boiler assemblies through a wedging and spacing action. This force holds the assemblies under the control rod guide structure so that they cannot be removed as long as the holddown assembly is in place. Leaf springs are provided on the holddown assembly so as to exert a continuous lateral load on the upper fitting and thereby assure their proper positioning. Failure of the leaf springs will still not permit removal of any boiler assembly.

The control rod guide structure is constructed of double-walled, 1/8-inch thick stainless-steel sheets, the space between walls forming the channel for control rod motion. Spacers are provided between sheets to retain true dimensions and to insure adequate control rod clearance and free motion. Support for this structure at its lower end is provided at four corner points through gusset plates and a horizontal plate which is fastened to the main core baffle-support. Sway braces at the upper end are tied to the pressure vessel and provide lateral support. Double walled Zircaloy-2 panels extend downward from the upper guide structure to the bottom grid at each of the eight slab-type control rod positions. These panels define the outer wall of the slab control rod channels and provide channels for the location of the boiler-superheater shims.

b. Heat Transfer and Fluid Flow

To achieve the steam velocities needed for efficient heat transfer, the fuel elements in each superheater assembly are arranged into a four-pass flow circuit with eight fuel tubes in each pass. These flow paths are defined by partitions in the stainless-steel plenums at the top and bottom ends of each assembly.

Water is circulated through the boiler region of the reactor core at a rate of 9,000 gpm by means of two forced-circulation pumps. Before being withdrawn from the reactor vessel, this recirculating coolant is mixed with 354°F. feedwater injected into the lower part of the pressure vessel. The slightly subcooled (8°F.) water passes from the pressure vessel through two 12-inch diameter pipes to two pumps located in a room beneath the reactor. Discharge pipes from the two pumps merge into a single 16-inch diameter pipe which leads back to the reactor.

The amount of coolant flowing from the plenum at the bottom of the pressure vessel to each fuel assembly is determined by orifices which distribute the flow in proportion with the expected power output. A small amount of water is also circulated through the moderator spaces between fuel elements in the boiler and superheater regions to sweep small quantities of steam from these areas and to provide cooling for the control rods. The slightly subcooled water is heated as it rises through the boiler assemblies and reaches its boiling point after traversing about 20% of the height of the core. Thereafter, steam bubbles begin to accumulate progressively until these bubbles occupy 42% of the coolant channel area as the steam-water mixture emerges from the top of the fuel assemblies. This corresponds to a steam weight fraction (quality) of about 4.4% at the top of the core.

The steam water mixture emerging from the top of the core continues upward through the cells of the egg-crate superstructure. In the steam dome above the water level, gravitational separation of water from the steam takes place. The steam, still containing traces of water, passes through dryer/preheater units bolted to the walls of the reactor vessel. From the dryer/preheater units the slightly superheated steam then passes through the individual superheater inlet pipes to the superheater fuel assemblies. The water passes downward through the annular downcomer between the reactor core and the reactor pressure vessel to the forced-circulation outlet pipes.

The total flow of steam from the boiler region at rated power is 152,000 lb/hr. This corresponds to an average inlet velocity of 76 feet/sec. at the beginning of the first pass of the superheater assemblies. Each superheater fuel assembly is orificed at the exit to make the amount of steam flowing into that assembly proportional to its expected heat output.

Exhaust steam from the 32 superheater fuel assemblies is collected in 11 separate pipes leading from the reactor vessel to the outside of the reactor biological shield where temperature, flow, and radioactivity monitoring are performed. Seven of the pipes collect steam from seven identical groups of four superheater assemblies. The other four pipes collect steam from <u>individual</u> superheater assemblies in the remaining group of four assemblies. In this way, the performance of the four individual assemblies in a typical group can be monitored while the groups consisting of four assemblies each can be compared with each other.

Maintaining the steam outlet temperature constant irrespective of changes in over-all reactor heat output required to accommodate variations in electric load is one of the major problems in designing an integral boiler-superheater reactor. Reductions in over-all heat output can be readily accomplished by inserting control rods, but it is difficult to do this without distorting the ratio of the heat output of the boiler to the heat output of the superheater. Insertion of control rods in the boiler region must be paralleled by insertion of rods in the superheater region by amounts such that the power ratio, as indicated by steam outlet temperature, remains constant. Since perfection should not be expected in this manipulation of control rods, the steam outlet temperature of the BONUS reactor will be allowed to vary slightly, as necessary, within the range 900°F. The temperature will be reduced to 900°F. before the steam reaches the turbine by controlled injection of the required amount of feedwater into the steam in an external attemperator.

c. Pressure Vessel

The reactor core is contained in a SA-212 Gr B carbon steel pressure vessel which has a 7-foot ID, a 3-1/8-inch nominal base metal thickness, an over-all inside height of 26.6 feet and which is clad internally with 1/4-inch thick stainless-steel (a combination of Type 308 and Type 309). It is designed for a pressure of 1150 psig and a temperature of 600°F. but will operate at a nominal pressure of 950 psig and a temperature of 540°F. The total weight of the vessel, including the head and nozzles, is 61 tons.

d. Reactor Auxiliaries

Although the strength of the 17 control rods is enough to make the shimmed reactor subcritical under all circumstances, an additional shutdown mechanism is provided in the form of a solution of sodium pentaborate which can be made to flow into the reactor by gravity upon opening of pressure equalizing valve and the poison injection valve. This liquid poison solution will make the reactor subcritical in the cold, clean, shimmed condition by at least 3%, even if all control rods were stuck in fully withdrawn positions.

A continuous flow of 15 gpm of reactor water through a system of filters and ion exchange columns keeps the total solids content of reactor water below 1 ppm and the chloride ion concentration below 0.1 ppm. Oversize heat exchangers are used to reduce the temperature of the water to 120°F. before it reaches the ion exchange resins. During refueling operations, these exchangers are also used to remove fission product decay heat and maintain the reactor water at a low temperature.

An emergency condenser system is provided to serve as a second sink for reactor heat if the main condenser is withdrawn from service or all electric power is lost. Automatic valves leading to this condenser open to pass about 5.0% of reactor full-power steam flow to the emergency condenser whenever there is a loss of power or whenever turbine bypass valves fail to open to the main condenser upon closure of the turbine admission valves or the turbine trip valve. The amount of water stored in the emergency condenser is adequate to remove reactor shutdown heat for a period of eight hours without the addition of make-up water.

To prevent melting of fuel elements in the core if all water is lost from the reactor pressure vessel, spray nozzles are mounted inside the vessel so that both the boiler fuel elements and superheater fuel elements can be sprayed generously with water. The water will flow by gravity from elevated water storage tanks outside the containment building. The elevated tanks also supply water for the containment building spray system.

A large electric preheater is provided which can raise the reactor water temperature to about 560°F.

A shield-cooling loop, consisting of water pumps, heat exchanger, filters, and a surge tank, removes heat generated within the reactor shield as a result of absorption of radiation therein or heat transferred thereto from the reactor pressure vessel, piping, etc., by normal thermal processes.

A combined cooling and water purification system removes decay heat and impurities from water in the fuel storage pool.

e. Summary of Reactor Safeguards

The reactor has been designed with primary emphasis on inherent safety. Automatic designed-in safety systems are used to augment the inherent safety and to prevent or terminate any potential hazard. Most of the safeguards incorporated in the BONUS reactor are similar to those which exist in conventional boiling water reactors. However, several additional safeguards have been added because the integral superheater region within the pressure vessel has introduced three new features not associated with conventional boiling water reactors. These features are: (1) the change in reactivity due to expulsion of water from or addition of water to the steam coolant flow passages of the superheater fuel elements; (2) the increase in superheater clad temperature which may result because of loss of steam coolant flow; and (3) the possibility of superheater pressure tube collapse because of too high a steam flow.

The first feature, concerning the reactivity change on expulsion or addition of water in the superheater elements, has been resolved by designing the superheater fuel assembly to have a very small change in reactivity at the reactor moderator operating temperature of 540°F. The reactivity change at 500°F. due to the expulsion of water from all of the superheater fuel assemblies has been calculated to be approximately zero with the reactor at low power. Sudden simultaneous failure of all the superheater pressure tubes which results in flooding of all the superheater elements in the hot full power operating condition causes a plus 0.16% k_{eff} change in reactivity. This sudden failure and subsequent flooding is not considered to be possible. BONUS R&D experiments have shown that after a complete rupture of a superheater assembly inlet pipe, entering moderator water will flash to steam initially and only after 15 to 30 seconds will any significant quantity of water flow be present in the assembly (as two-phase steam-water flow).

However, rapid expulsion of the water from all the fuel elements is considered possible during startup conditions if a series of operational errors is predicated. This can occur with the reactor moderator cold or hot. In the cold moderator condition (68°F.), the reactivity increase resulting from complete unflooding of the superheaters is positive and has been measured in a critical mockup to have a value of 0.64% k_{eff} in the worst critical rod configuration; the increase amounts to 0.303% k_{eff} for the normal critical rod configuration at startup.

Although this positive reactivity effect would be automatically compensated by the negative reactivity effects due to the temperature and void coefficients associated with the boiler region of the reactor, operating procedures only allow operation of the reactor when the water temperature has been raised above 337°F. (100 psig). An electrical preheater will be used to heat the moderator water to above 300°F., where gradual unflooding of the superheater fuel will be accomplished by opening a series of valves one by one. This unflooding will cause practically zero change in reactivity of the shutdown reactor. The reactor temperature will then be raised to about 500°F. by operating the reactor at a power of less than 7 Mw(t); above 500°F. the reactor power may be increased to full power. By incorporation of the preheater, this reactor retains a high degree of inherent safety during nuclear startup.

The second feature which is not normally associated with boiling water reactors is concerned with the loss of superheater coolant flow and the consequent clad temperature rise accompanying this loss of coolant. This hazard has been resolved by the inherent heat dissipation properties of the particular fuel element design and the designed-in safety features of the steam flow coolant paths. The superheater coolant system has been designed to always provide sufficient coolant flow through the superheater assemblies to prevent excessive clad temperature rise. In addition, the superheater fuel elements have been designed so that steam cooling could be completely stopped for approximately two minutes after a scram has occurred without damaging the fuel. Thus, it will not be necessary to maintain a continuous flow of steam through the superheater assemblies to prevent excessive clad temperatures. Further, calculations have shown that even with a simultaneous scram and complete stoppage of coolant flow, no fuel melting or clad melting will occur, although some damage to the fuel clad may occur due to the thermal transient. The radiation-heat dissipation properties of the BONUS-type element have been verified by a preconstruction experimental program.

Additional protection against complete loss of flow to the superheater is provided by the steam bypass valve and scram system. The scram system is designed to drop control rods, by gravity, into the reactor whenever the steam temperature in two superheater outlet lines serving any quadrant of the superheater core exceeds 950°F., or whenever an operating condition which could result in a loss of steam flow is detected. The steam turbine bypass valve system is designed to initially bypass a minimum of 40% of full flow whenever a complete loss of flow would otherwise result; the bypass flow can be reduced to about 5% of full flow after about 30 seconds. This provides sufficient cooling for the superheater fuel to remove the stored heat energy and the decay heat energy after the reactor has shut down.

The third new feature of an integral superheater reactor concerns the superheater fuel and its coolant path which must be isolated from the pressurized moderator water. Should the coolant flow become excessive, the resultant pressure drop in the superheater fuel assembly may cause the external moderator pressure to collapse the thin walled stainless-steel superheater pressure tube. For the BONUS superheater design, it has been determined that the superheater region can safely accommodate a total flow of 212,000 lb/hr. of 900°F. steam. Therefore, the flow control valve system has been designed such that valve failures cannot open steam paths which will allow a steam flow of greater than 212,000 lb/hr. This is accomplished by using a 3-way turbine bypass valve, which cuts off the steam flow to the turbine whenever it opens to bypass steam to the condenser.

Besides the specific safeguards incorporated for the superheater fuel assemblies, many other safeguards, similar to those used in conventional boiling water reactor plants, have been designed into the reactor plant. A summary list of these safeguards appears below:

(1) The boiler region of the reactor will automatically limit the power level of the reactor due to the negative reactivity effect of additional steam voids formed as the power level increases;

(2) An electrically-heated boiler preheater is provided for heating the reactor water to greater than 337°F. prior to removal of control rods; this eliminates any possibility of an excursion due to an increase in reactivity resulting from removal of water from the superheater elements when the reactor is cold;

(3) The superheater fuel assemblies are so designed that only an unimportant change in reactivity occurs when water is expelled from the steam coolant gaps at operating temperature; reactor operation at power levels above 7 Mw(t) is not allowed until the water temperature is above about 500°F.;

(4) Two independent safety shutdown systems are incorporated into the reactor. The primary system consists of 17 control-safety rods which can be inserted into the reactor within two seconds;

a backup system, under normal control of the operator, will shut the reactor down by the slow injection of a soluble neutron absorber;

(5) When the reactor loses its normal cooling system, which causes a reactor scram, an emergency cooling system is provided which is capable of cooling the reactor in the shutdown condition independent of all power sources;

(6) The reactor primary steam system has been designed to insure adequate coolant steam flow in the superheater fuel elements under all conditions when shutdown;

(7) Two minutes after a shutdown occurs, the superheater fuel elements can radiate all shutdown decay heat directly to the moderator; flow of steam could be stopped at this time without exceeding temperature limits on the fuel cladding;

(8) Melting of the Inconel clad or the UO_2 fuel will not occur even with simultaneous loss of coolant and a reactor shutdown, although some mechanical damage to the cladding may occur; protective instrumentation and automatic controls have been incorporated to insure a reactor scram and continuation of adequate steam flow to prevent mechanical damage to the superheater elements upon closure of turbine admission or trip valves;

(9) All safety devices are designed to either prevent malfunction or to cause the reactor to shut down in case of malfunction;

(10) With all plant components within the containment building shell, there is no danger that radioactive gaseous or particulate matter can enter the surrounding atmosphere without passing through the plant monitoring system and up the exhaust stack;

(11) Because of its large volume, and the consequent low pressure and temperature which result from the release of all the hot water in the reactor, the containment building will retain radioactive fission products more effectively than small, higher pressure containment buildings; the low temperature and pressure resulting from the maximum credible accident also enable personnel who are in the building to leave without injury; prompt evacuation of the building will minimize the exposure of plant personnel to large amounts of fission products because of the time required for the fuel clad and UO_2 fuel to reach melting;

(12) An emergency water spray in the pressure vessel of the reactor will provide sufficient cooling to prevent melting of the UO_2 fuel and release of fission products from the fuel even in case of drainage of all water from the pressure vessel;

(13) A building emergency spray system has been provided to gradually reduce the pressure and temperature resulting from the release of all the reactor water; this spray system is also effective in washing radioactivity from the building air;

(14) The reactor containment building has been designed to withstand hurricane winds. In addition, the reactor will be shut down and the vessel depressurized whenever a hurricane warning is given by the U. S. Weather Bureau at San Juan, Puerto Rico;

(15) An emergency water supply and an emergency power supply are provided to maintain the necessary shutdown cooling of the reactor even after a complete power failure;

(16) A 3-way turbine bypass valve is used to prevent excessive steam flow through the superheater fuel and eliminate the possibility of collapsing the superheater pressure tubes under normal operating conditions.

The components of the various reactor auxiliary and turbine-generator systems are shown in Figures 9 through 14. All of the equipment shown, with the exception of the turbine-generator and its foundation, associated turbine and condenser auxiliaries, the auxiliary cooling water system, the station compressed air system, the electrical load centers, and the turbine-generator and switchgear control panels are owned by the USAEC. All Title II drawings produced indicate ownership of equipment and facilities by either AEC or PRWRA.

Photographs of the plant are included as Figure 15, A through P.

D. COST SUMMARY

1. Total Project Cost

The total project cost is summarized in Table I.

2. Original Budget Estimates and Revisions

In the FY 1960 Authorizing Legislation, Project 60e15 for a power reactor of advanced design capable of utilizing nuclear superheat at an estimated total cost of $11,000,000 was added to the FY 1960 AEC Authorizing Legislation (Public Law 86-50) by the Joint Committee on Atomic Energy, which was approved by the President on June 23, 1959. The Joint Committee stipulated that the AEC was not expected to proceed with construction until and unless full evaluation of the design studies being accomplished under Project 59d14 (included under the FY 1959 Authorizing Legislation) shows the project to be technically feasible. AEC was to keep the Committee fully and currently informed as to the progress on this project. The FY 1960 Appropriation Act provided $3,000,000 for Project 60e15 to begin working drawings and advance procurement in FY 1960. Based on completion of the design and feasibility studies under Project 59d14 and receipt of a revised proposal from the Puerto Rico Water Resources Authority, the Joint Committee on Atomic Energy was advised on December 23, 1959, that the Commission had approved the PRWRA proposal as the basis for proceeding with the BONUS project. The FY 1961 Appropriation Act provided the balance of $8,000,000 of the $11,000,000 authorization for BONUS, and this amount was divided subsequently into $8,500,000 under the construction project for engineering and construction, and $2,500,000 under operating expenses for research and development, fuel fabrication, training, etc.

Subsequently, however, the estimated cost of Project 60e15 and related Operating Expenses activities increased as follows:

Date	Project 60e15	Operating Expense	Total
January 1962	$ 9,200,000	$ 3,200,000	$ 12,400,000
April 1962	9,800,000	3,500,000	13,300,000
January 1963	10,400,000	3,500,000	13,900,000
October 1963	12,060,000	3,500,000	15,560,000
May 1964	12,700,000	4,100,000	16,800,000
December 1964	13,154,378	4,250,000	17,404,378
May 1965	13,400,000	4,450,000	17,850,000
Estimated Final Cost	13,110,000	4,444,562	17,554,562

In general, the increases in Project 60e15 resulted from (a) the delay in construction completion from the originally scheduled date of November 30, 1962, to September 30, 1964 (essential completion), and delay in scheduled completion of full power testing and start-up from January 31, 1963, to December 19, 1965; (b) additional engineering costs resulting from the firming-up of the scope of engineering work as the project progressed; additional on-site manpower required in inspection and check-out supervision; design revisions; increases in costs for check-out, precritical, and criticality procedures and hazards work; and additional requirements for inspection services at major equipment vendor plants; (c) inclusion of start-up costs in the construction project estimate subsequent to authorization due to a revised accounting determination, the firming-up of start-up scope based on the need for a much longer period for start-up than anticipated originally, and the assignment of the responsibility to the prime architect-engineer for management and direction of the BONUS plant beginning with check-out and continuing through the completion of full power testing; (d) increases in direct construction costs due primarily to increases in costs of certain major items of reactor plant equipment and addition of certain items to project scope, and increases in indirect construction costs due to delay in project completion; and (e) added engineering, procurement, and construction costs due to late changes in the BONUS plant resulting from revisions to the Technical Specifications by the Division of Reactor Licensing, AEC Headquarters. The reasons for cost increases are discussed more fully in Subsection E of Section I.

While the work accomplished under Operating Expenses is discussed under Section II of this report, the reasons for the increases in cost are included herein, since it was determined that the original authorization and appropriation covered both Construction and Operating Expense costs. The increase in Operating Expenses costs was due primarily to (a) the arbitrary addition of research and development under the Chicago Operations Office Nuclear Superheat Program to BONUS costs subsequent to the original estimate, (b) increases in costs for fuel fabrication and fuel inspection, (c) additional research and development work required for chloride stress corrosion studies on the superheater fuel elements, (d) increased costs for operator and start-up training, and (e) delay in completion of full power testing and start-up of the completed BONUS plant from January 31, 1963, to December 19, 1965.

PERFORMANCE DATA

E. PERFORMANCE DATA

1. Scheduled and Actual Completion Data

The original schedule and actual accomplishment for design, construction, start-up, and manpower are reflected in Figures 1 through 8. Title II engineering design started on February 4, 1960, and was originally scheduled for completion by December 31, 1961. However, plans and specifications were not completed until April 24, 1963, and all work under Title II, including technical operating procedures, was not completed until December 27, 1963.

The original construction schedule was based upon the completion of construction by November 30, 1962, with start-up to be completed by January 30, 1963. Construction started on August 13, 1960, and was essentially completed September 30, 1964. Fuel loading was started on April 9, 1964, initial criticality was attained on April 13, 1964, and start-up and full power testing was completed December 19, 1965.

2. Factors Affecting Schedules

During the course of the project, it was necessary to revise the construction schedule a number of times. The original construction forecast, dated December 1, 1960, reflected a construction completion date of November 30, 1962.

A revised construction forecast, dated March 1, 1962, reflected a revised construction completion date of May 15, 1963, due to delay in delivery of the reactor pressure vessel. The original delivery date of the reactor pressure vessel was September 6, 1961, and the original construction schedule provided for installation of the vessel by December 31, 1961. However, due to considerable difficulty encountered by the manufacturer in the fabrication of this unique component, it was estimated that the vessel would not be delivered until August 20, 1962, and the start of on-site installation would be delayed until around September 1, 1962. The effect of the delay in the delivery of the pressure vessel resulted in the revised completion date of May 15, 1963.

Further delays in the various production steps for fabrication of the pressure vessel occurred, which resulted in a revised estimated date of January 5, 1963, for delivery of the vessel. In order to minimize the effect of the revised delivery date for the vessel on overall construction completion, it was planned to use, where necessary and practicable, two eight-hour shifts, six days per week, for construction work after arrival of the vessel. On this basis, a new scheduled construction completion date of July 31, 1963, was established as reflected in a revised construction forecast, dated September 1, 1962.

Delivery of the reactor pressure vessel at the BONUS site was accomplished on February 4, 1963, with the additional delay due primarily to difficulty encountered during the checking of the gasket O-rings in order to meet specified leak rate requirements. On the basis of actual delivery of the vessel and a re-evaluation of construction progress, a revised construction completion date of September 15, 1963, was adopted and incorporated in a revised construction forecast dated January 30, 1963.

Problems were subsequently encountered in the completion of check-out procedures, the pressure control system, and containment building ventilation. A revised construction forecast, dated October 21, 1963, was prepared reflecting a revised construction completion date of January 15, 1964, including time required for modifications to the pressure control system and containment building ventilation.

Subsequently, difficulties and delays were encountered during the check-out of other components, particularly that encountered with the control rod drives. Also, further check-out of the modified pressure control system revealed that an extensive replacement of hydraulic system components would be required. In addition, revisions to the Technical Specifications were required by the Division of Reactor Licensing, which caused changes in the completed plant consisting of modifications to nuclear instrumentation, environmental monitoring, and the off-gas system. These further delays and additional work required a revised date for the completion of construction. This was estimated to be August 3, 1964. Construction work was essentially completed on September 30, 1964.

The completion of start-up and full power testing was scheduled originally for completion by January 31, 1963, but actual completion was not accomplished until December 19, 1965, or a delay of 34½ months. This delay was due to the following circumstances:

a. A 22-month delay in the completion of construction.

b. As requirements for start-up were firmed-up, it became evident that considerably more time for this phase of the work would be necessary than that allowed in the original schedule.

c. Time required for the investigation of superheater fuel element leaks, which were discovered in November 1964, and for determination of criteria for continued use of the existing fuel.

d. Problems with instrumentation, pressure control valves, and the need for replacement of certain pressure vessel internal preheater-dryer piping during the start-up period.

Fg. 3a reflects the chronological history of start-up as actually accomplished.

3. <u>Factors Affecting Costs</u>

The increase in project costs was discussed in general terms under Subsection D.2, Original Budget Estimates and Revisions. The factors covered below concern specific items that contributed to the major portion of the increase in project costs.

In the original estimate, a total of $153,810 was included under Operating Expenses for start-up. Inclusion of such costs under Operating Expenses was in accordance with AEC accounting practices in effect at the time the original estimate was prepared. However, during the course of the project, a revised accounting determination was made that required start-up costs to be included as a part of the construction project. The final cost for start-up charged to the project was $1,979,434, none of which was included in the original estimate under project costs. The considerable increase in start-up cost was due primarily to the need for a much longer period of time than anticipated originally, and to the delays noted under Factors Affecting Schedules.

Increases in other engineering costs resulted from the delay of 22 months in construction completion with a corresponding increase in Title III inspection costs; the addition of certain inspection services at vendor plants; delays in receipt of vendor drawings; additional design work required for modifications to the pressure control system and containment building ventilation, and changes required as the result of DRL review; increased costs in preparation of the Hazards Summary Report and for an extensive number of meetings plus preparation of answers to DRL questions; and increased manpower for check-out supervision.

Construction work on the conventional features of the AEC-financed portion of the project, i.e., buildings, services, etc., was completed below the original estimate. The major increase in direct construction costs resulted in the Reactor Plant Equipment account due to difficulty in the fabrication and delay in delivery of certain major equipment items and to low initial estimates for such items versus actual bid prices received. Two of the equipment items contributing substantially to this increase are discussed as follows:

a. Reactor Pressure Vessel - The effect of the late delivery of the reactor pressure vessel on overall construction progress has been discussed under Factors Affecting Progress. The purchase order for the pressure vessel was placed on September 6, 1960, in the amount of $285,000 with a delivery period of 365 days. However, the vendor encountered considerable difficulty in design, material, welding fabrication, and inspection.[3] Also, during the course of the work, 16 change orders were entered into between Maxon and the vendor relating to various aspects of design or fabrication changes in the pressure vessel, which increased the amount of the purchase order by $142,116 to a revised total of $427,116. Subsequently, the vendor submitted a claim for additional compensation in the amount of $188,650 based on the vendor's contention that they were required to go beyond the scope of the specifications and perform a great deal more engineering and inspection than required by their previous experience. However, during a routine examination at the BONUS reactor in June 1965, it was noticed that cracks had developed in the preheater-dryer piping of the pressure vessel, and investigations revealed that certain elbows in the piping were non-specification material. Actual AEC costs allocable to the investigations and replacement of the non-specification materials totalled $52,368,

3/Problems associated with fabrication of the pressure vessel are covered in GNEC-210, Interim Report and Supplements 1, 2, and 3, dated February 10, 1962, November 1, 1962, December 21, 1962, and July 31, 1963, respectively.

which was claimed from the pressure vessel vendor. At a pre-hearing conference held by the AEC Board of Contract Appeals, agreement was reached between AEC and the vendor that AEC would pay $25,000 for settlement of the vendor's claim and AEC would drop its claim for the defective elbows. Thus, the final amount for the reactor pressure vessel purchase order was $452,116 but the material cost to AEC for this component was $512,435, including all preheater/dryer repairs.

b. Instrumentation and Controls - The purchase order for this equipment was placed in the original amount of $405,465, and the final cost of the work under the purchase order was $599,465. Subsequently, however, certain deficiencies were discovered in the instrumentation items, particularly in the pressure control system, and Maxon terminated the subcontract because of non-performance by the vendor. AEC, through various contractors, expended an additional sum of $137,713 for the correction of these deficiencies. Agreement was reached with the vendor whereby $15,555 of the balance due the vendor under the purchase order would be permanently retained by AEC and, in addition, the vendor would pay AEC $48,000. This resulted in a final total cost of $673,623 for the instrumentation and controls items procured under this purchase order after correction and settlement of all claims.

The above two items are major examples of procured equipment items that had an impact on both costs and schedules of the BONUS project. Other items on which costs increased considerably from the original estimate, based on bid prices received, included the control rods, control rod drives, boiler fuel holddown and reactor core assemblies, and reactor shielding.

Indirect construction costs increased over $500,000 from the original estimate due almost entirely to the considerable delay in the completion of construction work.

Many parties participated in BONUS design, construction, and start-up. It appears reasonable to assume that costs were influenced by the fact that many organizations were involved in the planning, design, construction, and start-up. These parties were enumerated previously in this section of the report. The costs were also influenced by the large geographical spread among the organizations participating, and the liaison required to administer the work of the many parties involved.

A further factor which had an effect on the cost of the BONUS Plant is its location at a rather remote site, far from the United States mainland. Although some thought was given to this point in preparing the initial estimates, actual experience later proved that insufficient weight was given to it. Although this difficulty most certainly influenced the increased costs, the exact value cannot be determined.

Another factor contributing to the cost increases was the fact that construction progressed more slowly at nearly every stage than had been optimistically anticipated in the original scheduling. The combination of slow vendor deliveries and slow construction progress caused the date for construction completion to slip 22 months. In some cases, slow correction of recognized deficiencies by the vendor, such as repair of the control rod drives, caused schedule slippages whose effect on total plant cost was very large.

It is easily recognized that these extensions were costly because certain organizations required for particular tasks could not be readily dismissed and then called back to work when the delay was over. Hence, PRWRA startup personnel who were trained for operations had to be kept on PRWRA's payroll. Likewise, GNEC and J&M continued to participate actively throughout construction, with the resultant effort being far in excess of estimates made early in the project. The engineering organizations participated in performing checkouts and in helping to oversee that deficiencies were corrected. Though these tasks were necessary and useful, it was never anticipated in the original estimates that the design organizations would participate to the extent actually required.

When the BONUS Plant construction was nearing completion in October 1963 and at the time of GNEC and PRWRA request for operating authorization, the Division of Reactor Licensing made the request that certain systems be altered to meet stricter standards. This late timing proved to be extremely costly, because completed systems had to be revised. Four new channels for the nuclear instrumentation system had to be bought and installed. The off-gas system was modified in major ways: a much larger delay tank was bought, new charcoal traps were added, and off-gas piping for the fuel pool and fuel transfer coffin had to be built.

Start-up operations, as initially visualized, required considerably less GNEC participation than was eventually needed. At the time the contract was written, it was thought that GNEC would merely supervise initial criticality and operation of the reactor plant. Actually, GNEC took full charge of all BONUS start-up activities and was given operating authorization jointly with PRWRA to conduct all phases of start-up. In line with the increased role, GNEC personnel were required to train for and obtain senior reactor operator licenses. Not only was it necessary to assign a staff of people to the site on a full-time basis for start-up, but it was also necessary to send approximately a dozen specialists to Puerto Rico for assignments of varying length during the same period. It was this expanded role that GNEC had which caused their start-up costs to far exceed the initial estimate.

BOILING NUCLEAR SUPERHEATER (BONUS)
POWER STATION

PROJECT COMPLETION REPORT

SECTION I - LIST OF TABLES

TABLE I

BOILING NUCLEAR SUPERHEATER (BONUS) POWER STATION

PROJECT COST SUMMARY

	Description	GNEC	Jackson & Moreland	Maxon Const. Company	Others	PRWRA	Total
I.	Engineering, Design & Inspection (Titles I, II, III, IV)	$ 1,682,161	$ 971,192	$ 131,597	$ 39,969	$ 45,864	$ 2,870,783
II.	Start-Up (Engineering Design & Inspection Title IV)	1,231,864	0	0	15,583	731,987	1,979,434
III.	Direct Construction Cost	90,678	0	6,807,043	11,948	149,149	7,058,818
	Structures and Improvements	0	0	2,391,826	0	10,638	2,402,464
	Reactor Plant Equipment	90,678	0	4,015,100	11,948	136,868	4,254,594
	Accessory Elec. Equipment	0	0	199,949	0	0	199,949
	Misc. Power Plant Equipment	0	0	200,168	0	1,643	201,811
IV.	Indirect Construction Cost	0	0	1,271,319	0	0	1,271,319
	Gross Project Cost	$ 3,004,703	$ 971,192	$8,209,959	$ 67,500	$927,000	$13,180,354
V.	Non-Fund Cost	0	0	-4,378	-10,000	0	-14,378
	Total Project Fund Cost	$ 3,004,703	$ 971,192	$8,205,581	$ 57,500	$927,000	$13,165,976
VI.	ORO Reserve						12,146
	Estimated Total Project Fund Cost						$13,178,122 1/

1/ Includes $82,500 for GNEC Title I engineering services funded under Project 04-1-59-D-014-24, and $13,095,622 for remaining engineering services, and construction and start-up funded under Project 04-1-60-E-015-24.

TABLE II

BOILING NUCLEAR SUPERHEATER (BONUS) REACTOR
SIGNIFICANT UNIT COSTS

	Description	Quantity	Direct Cost Installed	Unit Cost
A.	Containment Building - Total Cost	1,920,000 cu.ft. (Gross)	$2,334,195	$ 1.22/c.f.
1.	Excavation	19,000 cu.yds.	40,358	2.12/c.y.
2.	Backfill	14,800 " "	33,388	2.26/c.y.
3.	Substructure Concrete (Foundation Slab)	4,882 " "	378,757	77.58/c.y.
4.	Superstructure Concrete			
	a. Exterior Ringwall	1,505 " "	195,990	130.23/c.y.
	b. Reactor Pedestal, Biological Shield, Fuel Storage Pool	1,648 " "	111,758	67.81/c.y.
	c. Interior Walls, Slabs, Equipment Bases, etc.	1,965 " "	199,403	101.48/c.y.
5.	Containment Structure	1,158,000 lbs.	567,722	$0.49/lb.
6.	Structural-Steel & Misc. Steel	167,437 lbs.	266,154	1.59/lb.
7.	Biological Steel Liner (¼" steel)	52,000 lbs.	25,836	0.50/lb.
8.	Storage Pool Liner (Stainless Steel Plate)	6,147 lbs.	27,907	4.54/lb.
B.	Reactor Pressure Vessel Proper, Excluding Internals	61 tons	493,401	$8,088/ton or $4.04/lb.

TABLE III(A)

BOILING NUCLEAR SUPERHEATER (BONUS) POWER STATION
GNEC'S & J&M'S PROJECT ENGINEERING COSTS

	GNEC	J&M	Total
Title I[1/]	$ 82,500.	$ -	$ 82,500.
Title II	667,516.	559,998.	1,227,514.
Title III	630,102.	406,460.	1,036,562.
Title IV			
Hazards and DL&R Changes	148,051.	4,734.	152,785.
Startup Management	1,231,864.		1,231,864.
Other	153,992.		153,992.
	1,533,907.	4,734.	1.538,641
Total Excluding Tools[2/]	$2,914,025.	$971,192.	$3,885,217.

1/ Costs incurred under subcontract NP-1 with PRWRA - Contract AT-(40-1)-2484

2/ Cost of tools $90,678, included under direct construction costs, Reactor Plant Equipment.

NOTE: For further breakdown of GNEC-J&M Titles II, III and IV, see Table III(B).

TABLE III(B)

COST BREAKDOWN OF COMBUSTION ENGINEERING NUCLEAR DIVISION'S TITLES II, III, AND IV ENGINEERING SERVICES (INCLUDING JACKSON AND MORELAND SUBCONTRACT)

	Title II	Title III	Title IV					Total
			Hazards	DRL Changes	Start-up	Other	Total	
Direct Labor	$621,141	$476,973	$47,310	$25,189	$460,436	$78,369	$611,304	$1,709,418
Materials and Services 1/	8,717	58,937	504	-	190,538	5,125	196,167	263,821
Other Costs	76,920	128,925	14,261	2,864	102,568	10,046	129,739	335,584
Overheads & Gen'l Admin.	460,046	344,942	36,869	18,438	398,340	54,315	507,962	1,312,950
Fees								
CEND	30,590	16,750	2,750	4,100	79,982	6,137	92,969	140,309
J&M	30,100	10,035	500	-	-	-	500	40,635
TOTAL	$1,227,514	$1,036,562	$102,194	$50,591	$1,231,864	$153,992	$1,538,641	$3,802,717

1/ Consists primarily of site related expenses associated with relocation and living expenses during construction and start-up.

TABLE IV

PRWRA'S PROJECT ENGINEERING COSTS

Startup Assistance	$731,987[1/]
Miscellaneous	45,864
Total PRWRA Engineering	$777,851

1/ Includes credit of $52,059 for purchase of steam by PRWRA during the full power testing and start-up phases to December 19, 1965.

TABLE V

OTHER ENGINEERING COSTS FUNDED UNDER PROJECT

New York University, Prime Contract AT-(30-1)-1480 Computer Services in Connection with Title II Design	$ 29,525.
Factory Mutual Engineering Division, Prime Contract AT-(40-1)-2455 - Consulting Services in Connection with Fire Protection Aspects of Title II Design	6,703.
AEC Direct - GNEC Experience at ORSORT, Reproduction and Miscellaneous	3,741.
Union Carbide Corp., Nuclear Division, Miscellaneous Engineering Assistance	13,583.
Maxon Construction Company Purchase Orders	
a. Corps of Engineers, Inspection Service Agreements and Various Purchase Orders, Vendor Plant Inspection	113,713.
b. Puerto Rico Water Resources Authority, Concrete Testing and Inspection and Inspection of Certain Electrical Work	17,884.
Argonne National Laboratory - Consulting Services	2,000.
	$187,149.

TABLE VI

MAXON CONSTRUCTION COMPANY
DIRECT AND INDIRECT COSTS

Structures and Improvements	$2,341,025
Reactor Plant Equipment	4,065,901
Accessory Electrical Equipment	199,949
Miscellaneous Power Plant Equipment	200,168
Total Direct Construction Cost	$6,807,043
Indirect Construction Cost	1,271,319
Total Construction Cost - Maxon	$8,078,362
Non-Fund Cost	-4,378
Total Fund Cost - Maxon	$8,073,984

TABLE VII (A)

MAXON CONSTRUCTION COMPANY, INC.
PURCHASE ORDERS OF $5,000 OR MORE

Item	P. O. No.	Vendor	Original P.O. Amt.	No. of Change Orders	Final P.O. Amount
Reactor Pressure Vessel	C-99-20	Pacific Coast Engineering Co.	$285,000	17	$452,116
Polar Gantry Crane	C-99-35	Pacific Coast Engineering Co.	87,000	2	97,852
Circulating Water Pumps	C-99-36	Peerless Pump Co.	47,960	4	49,274
Reactor Feedwater Pumps	C-99-37	Pacific Pumps, Inc.	34,108	2	34,432
Vertical Feedwater Htrs.	C-99-38	Maryland Shipbuilding and Drydock Co.	30,679	2	32,844
Reinforcing Steel	C-99-39	Garcia Commercial	67,800	1	65,158
Reactor Water Preheater	C-99-81	Southwest Engineering Co.	30,485	1	32,710
Reactor Purification Pmps.	C-99-83	Bingham Pump Co.	11,588	2	11,742
Structural Steel	C-99-85	Belmont Iron Works	147,205	0	147,205
Water Treatment Equip.	C-99-128	Hungerford & Terry, Inc.	199,313	1	202,320
Emergency Condenser Sys.	C-99-129	Southwest Engineering Co.	10,033	1	10,068
Poison Injection Tank	C-99-140	Avery & Sand Co.	9,600	2	11,183
Relief Valves	C-99-141	Crosby & Ashton	11,043	1	11,118
Embedded Metal	C-99-177	Chicago Bridge & Iron Co.	12,315	2	14,780
Regenerative Cooler	C-99-182	Southwest Engineering Co.	10,250	0	10,250
Secondary Cooler	C-99-183	American Standard	14,400	0	14,400
Reinforcing Steel	C-99-188	Garcia Commercial	60,000	1	84,802
Guard Services	C-99-191	Wackenhut Corporation	25,000	4	80,000
Steam Dryer Preheater	C-99-202	Dresser Products, Inc.	33,816	1	40,160
Ventilation Fans	C-99-203	Trane Co.	6,835	1	6,835
Neutron Shield Tank	C-99-211	Allis-Chalmers	34,700	1	44,083
Bottom Shield Plug	C-99-212	Chicago Bridge & Iron Company	10,385	1	11,481
Liquid Waste Evaporator	C-99-215	Aqua-Chem., Inc.	8,985	4	9,573
Fuel Transfer Equip.	C-99-233	Process Equipment Co.	43,605	3	57,174
Building Vent Air Intake & Exhaust Butterfly Valves	C-99-271	Henry Pratt Co.	38,720	0	38,720
Fuel Discharge Rotating Shield Assembly	C-99-272	Pacific Coast Engineering Co.	27,500	2	27,603
Valves	C-99-278	William Powell Co.	24,754	2	27,334
Air Cond. Equip.	C-99-284	Dunham-Bush, Inc.	5,414	0	5,414

Item	P. O. No.	Vendor	Original P.O. Amt.	No. of Change Orders	Final P. O. Amount
Fuel Storage Racks	C-99-310	Yuba Consolidated Industries	$ 28,269	0	$ 28,269
Instrumentation	C-99-330	CompuDyne Corporation	194,000	1	548,835*
Miscellaneous Tanks	C-99-339	Eastern Steel Plate Fabrication, Inc.	21,257	1	21,309
Control Rod Drive Sys.	C-99-341	AMF Atomics	225,059	7	323,869
Removable Shield Struct.	C-99-356	Chicago Bridge & Iron	13,335	1	14,785
Control Valves	C-99-357	Black, Sivals, & Bryson	15,253	4	19,562
Iodine Traps	C-99-431	Process Equipment Co.	13,420	1	13,879
Miscellaneous Iron	C-99-437	Porto Rico Iron Works	22,294	2	32,479
Seal Water Pump	C-99-451	Manton Gaulin	5,678	0	5,678
Fuel Pool Liner	C-99-475	Process Equipment Co.	15,828	0	16,007
Miscellaneous Instruments	C-99-531	CompuDyne Corporation	17,931	1	19,485
Laboratory Furniture	C-99-532	Kewaunee Mfg. Co.	7,704	0	7,704
Control Rods	C-99-537	Dresser Products, Inc.	92,944	1	94,109
Neutron Startup Source Assembly	C-99-568	International General Electric Puerto Rico, Inc.	20,514	5	35,637
Boiler Fuel Holddown and Reactor Core Structure Assemblies	C-99-575	Ex-Cell-O	102,385	3	225,761
Valves	C-99-580	Edwards Valves	36,801	0	36,801
Valves	C-99-582	Crane Co.	40,921	5	52,156
Power and Control Cable	C-99-613	Collyer Insulated Wire Co.	15,363	3	14,649
Paging System	C-99-620	Gai-Tronics Corporation	6,046	0	6,046
Waste Transfer Cask	C-99-654	National Lead Co.	5,380	0	5,380
Turbine Shield	C-99-703	Sobrinos DePortilla, Inc.	10,379	0	10,379
Superheater Nozzles, Arifices, & Fittings	C-99-738	Jerbak-Bayless	8,325	2	10,133
Internal Cleaning of Piping & Equipment	C-99-754	Dow Industrial Service	7,700	2	21,460
Boiler & Boiler Superheater Shims	C-99-770	Dresser Products, Inc.	75,900	1	76,919
Reactor Water Preheater 440 Bus Duct	C-99-844	Westinghouse Electric	5,500	1	6,348
Wire and Cable	C-99-856	Collyer Insulated Wire Co.	5,098	0	5,098
Water Preheater Switching Panel	C-99-980	Kelek Co.	7,839	0	7,839

*Including credit for settlement of claims

Item	P. O. No.	Vendor	Original P.O. Amt.	No. of Change Orders	Final P. O. Amount
Reactor Borescope	C-99-1097	Lenox Instrument Co.	$ 8,578	0	$ 8,578
Superheater Shims	C-99-1249	AMF Atomics	9,785	0	9,785
Chloride Analyzer	C-99-1250	Milton Roy	13,752	1	13,812
Feedwater Temp. Control	C-99-1288	Copes Vulcan	9,731	1	10,021
Impact & Fatigue Specimen Holders	C-99-1381	Southwest Research Institute	7,730	0	7,730
Nuclear Incident Monitoring System	C-99-1532	Ampex Pan American	23,502	0	23,502
Ventilating Air Cooling Apparatus	C-99-1864	Acme Industries	13,706	0	13,706
Main Steam Pressure Control System	C-99-1956	Foxboro Co.	6,537	1	5,948
"O" Ring Gaskets	C-99-2130	Advanced Products Co.	9,072	0	9,072
Micromicroammeters and Power Channels	C-99-2203	Bendix Corporation	24,350	0	24,350
Special Valve Actuators	C-99-2379	Oilgear Co.	17,983	0	17,983
Iodine Traps	C-99-2389	Process Equipment Co.	20,616	0	20,616
Continuous Air Monitors, Pulse Generator, Probes	C-99-2390	William B. Johnson Associates	13,472	2	15,346
Health Physics Equipment	C-99-2416	Technical Measurement	6,961	0	6,961

TABLE VII (B)

MAXON CONSTRUCTION COMPANY, INC., CONSTRUCTION SUBCONTRACTS

Item	Subcontract Number	Subcontractor	Original Subcontr. Amount	No. of Mods.	Final Subcontract Amount
Containment Structure	2696-1	Chicago Bridge & Iron Co.	$518,700	11	$ 603,391
Ready Mix Concrete	2696-2	Ready Mix Concrete Co.	296,010	2	279,361
General Excavation	2696-3	Raymond	34,306	1	35,253
Foundation Slab	2696-4	Formel, Inc.	116,646	1	116,279
Certain Site Work, Electrical, Outside Water Supply, Concrete Testing, & Other Miscellaneous Services	2696-5	Puerto Rico Water Resources Authority	Funds Provided as Subcontract Modified	24	377,844
Concrete Retaining Wall	2696-6	Formel, Inc.	116,000	2	128,940
Guyed Steel Stack and Vapor Sphere	2696-7	Chicago Bridge & Iron Co.	15,575	1	25,495
Sump Pumps, Plumbing, and Drain Piping	2696-8	Hicks and Ingle	47,000	8	58,220
Sand Blasting & Paint Seal.	2696-9	Francisco Levy	3,750	1	5,450
Steel Linings - Upper Biological Shield	2696-10	Kelvin Engineering Co.	31,929	4	39,910
Piping & Equip. Install.	2696-11	Grinnel Co.	383,856	19	605,688
Vent. & Air Conditioning	2696-12	Hicks and Ingle	55,616	4	59,775
Concrete Unit Masonry and Ceramic Tile	2696-13	Francisco Levy	20,557	1	20,757
Suspended Plaster & Acoustic Board Ceiling	2696-14	Armstrong Cont. & Supply Corp.	4,945	0	4,945
Insulation of Piping and Equ.	2696-16	Armstrong Cont. & Supply Corp.	31,897	2	38,922
Vinyl-Asbestos Floor Tile	2696-17	Armstrong Cont. & Supply Corp.	2,420	0	2,420
General Painting	2696-18	Commonwealth Coatings Corp.	24,900	4	28,139
Total Final Subcontract Amounts					$2,430,789

TABLE VIII

PRWRA DIRECT COSTS FUNDED UNDER PROJECT

Structures and Improvements	$ 10,638
Reactor Plant Equipment	136,868
Miscellaneous Power Plant Equipment	1,643
	$149,149

TABLE IX

OTHER DIRECT COSTS FUNDED UNDER PROJECT

UCC - Reactor Plant Equipment	$ 11,948
Less AEC Non-Fund Cost	-10,000
Total Fund Cost - Other	$ 1,948

BOILING NUCLEAR SUPERHEATER (BONUS) POWER STATION

PROJECT COMPLETION REPORT

SECTION I - LIST OF FIGURES

ACTUAL AND PROPOSED SCHEDULES - BONUS REACTOR PROJECT

USAEC - OROO

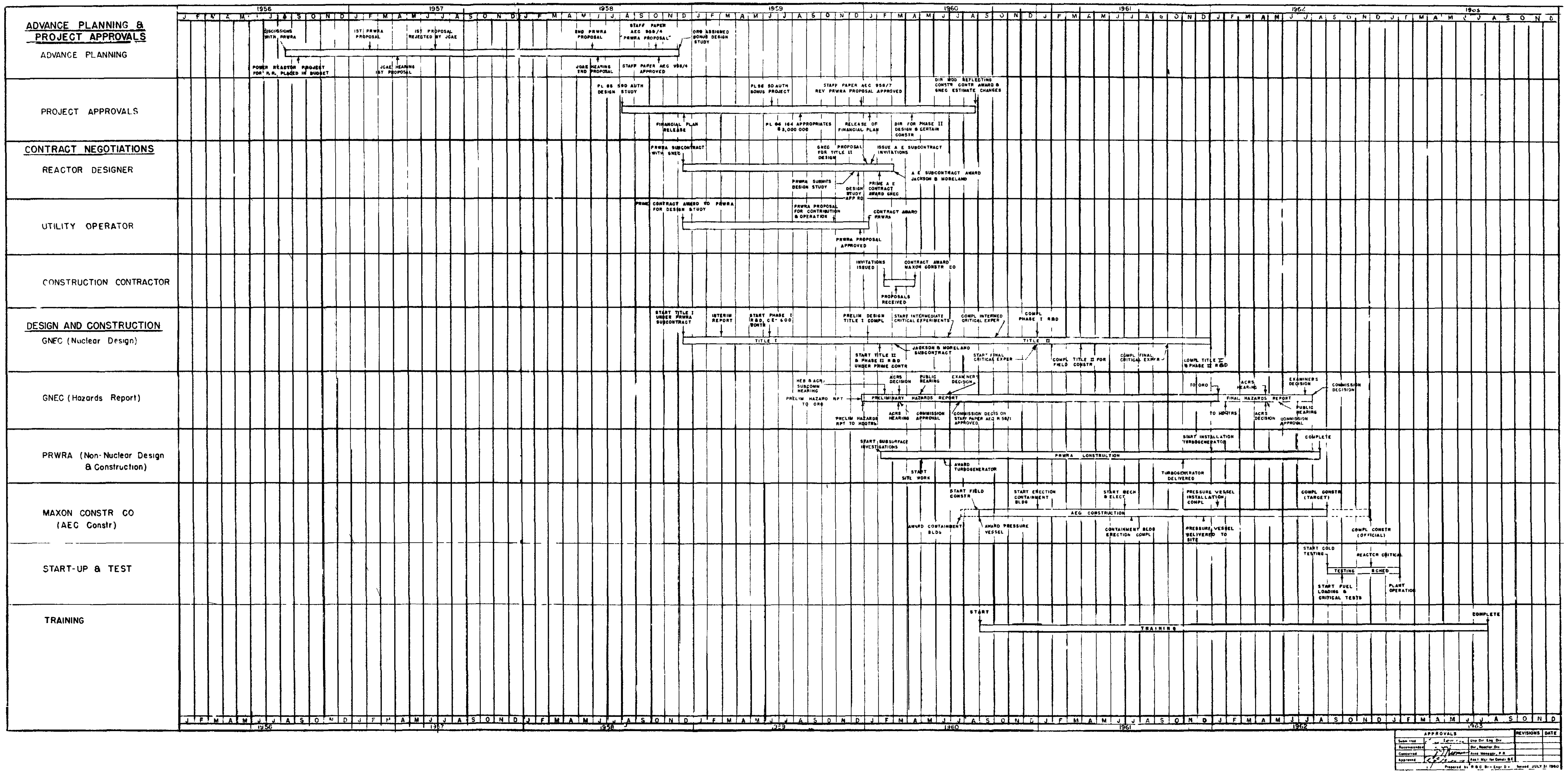
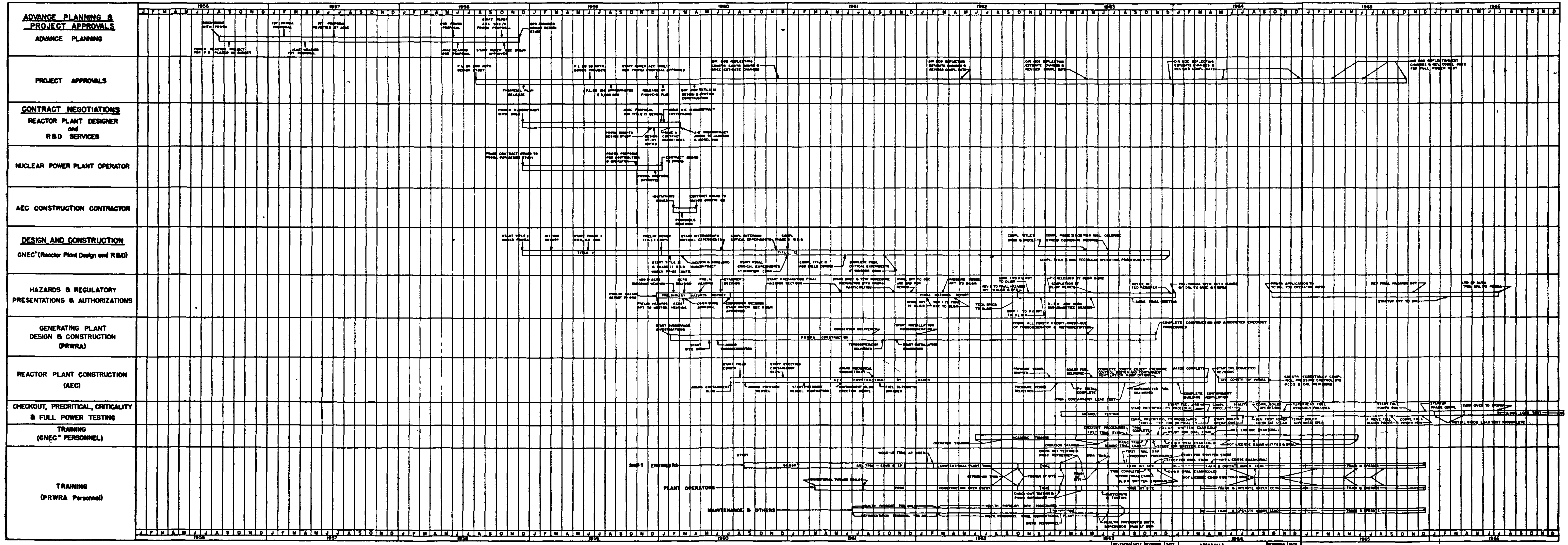


Figure 1

ACTUAL AND PROPOSED SCHEDULES - BONUS REACTOR PROJECT

USAEC - OROO



* GNEC MERGED WITH PARENT COMPANY 9-9-64 & BECAME COMBUSTION ENGINEERING-NUCLEAR DIVISION

BONUS NUCLEAR SUPERHEATER (BONUS) POWER STATION
SUMMARY OF SCHEDULED AND ACTUAL ENGINEERING
DESIGN AND CONSTRUCTION INCLUDING STARTUP

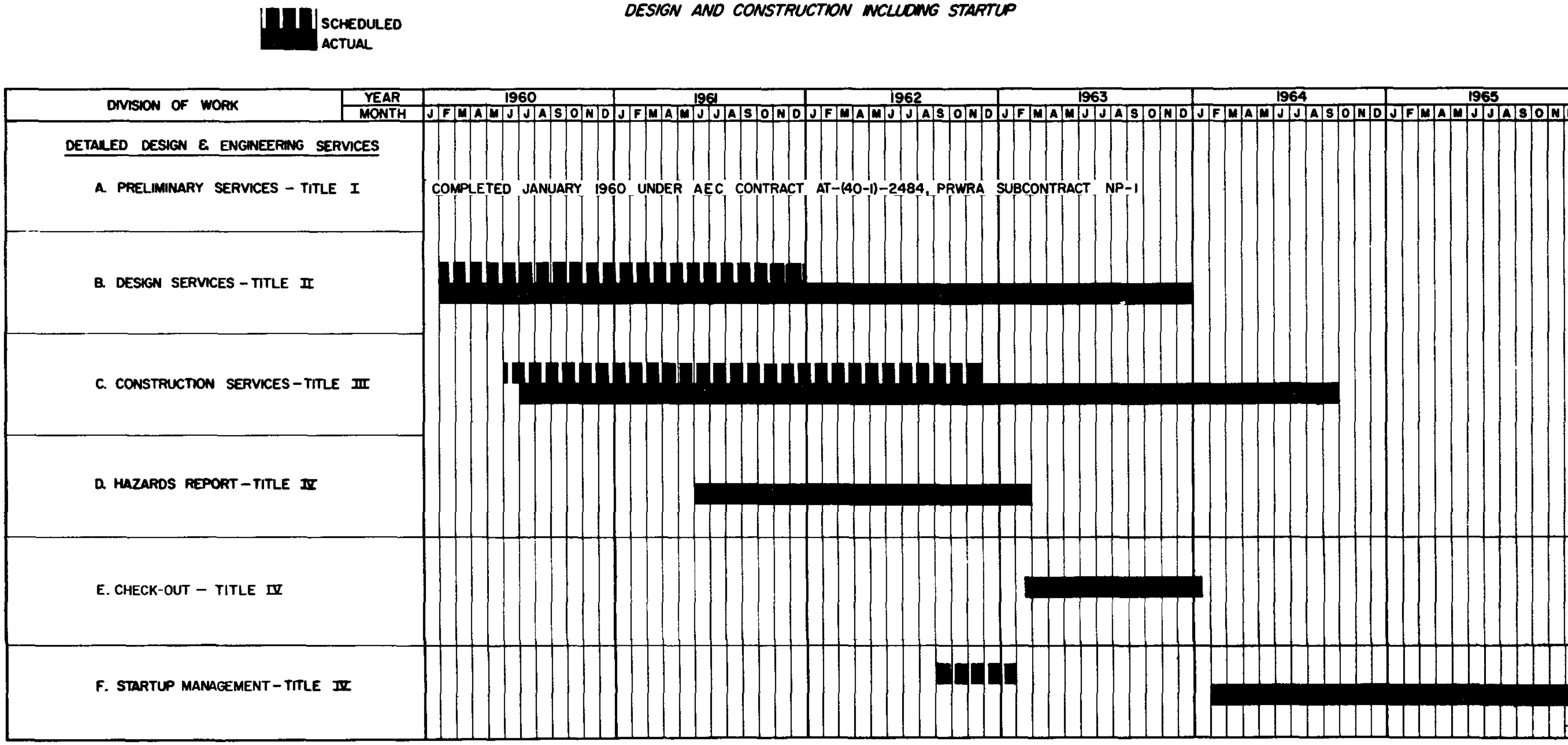


Figure 3

CHRONOLOGICAL HISTORY OF START-UP

Date	Operation
February - April 1964	Precritical testing.
April 9, 1964	Initial loading of 6x6 boiler fuel.
April 13, 1964	Initial criticality with 6x6 unshimmed boiler core.
April 23-27, 1964	Experiments with 8x8 shimmed boiler core.
May 1-8, 1964	Cold critical experiments with full core.
May 19-31, 1964	Hot critical experiments with full core.
June 22-24, 1964	Criticality runs to determine magnitude of full core asymmetry.
July 1-5, 1964	Cold critical experiments in preparation for power operation with boiler core.
July 17 - August 14, 1964	Power operation with boiler core.
August 15, 1964	First electrical generation during test operation of turbine-generator with saturated steam.
August 16 - October 25, 1964	Power operation with boiler core up to a maximum of 30 Mw(t).
September, 1964	Containment building leak rate test.
November 3-11, 1964	Hot critical experiments with full core.
November 11, 1964	Superheater fuel assembly No. 9 clad failure.
December 8-15, 1964	Low power operation of full core for locating defective superheater fuel assemblies.
February 15, 1965	Start of cold critical experiments of the reduced, 24-superheater assembly core.
March 1, 1965	Start of power operation with reduced core.
April 13, 1965	First electrical generation utilizing superheated steam with reduced core.

Figure 3a

Date	Operation
May 26, 1965	Reached maximum steady-state power of 40 Mw(t), 7.4 Mw(e) with reduced core.
June 15 - July 30, 1965	Steam dryer-preheater piping repairs.
August, 1965	Full core criticals and reactor power to 10 Mw(t).
September 15, 1965	Design 50 Mw(t) reactor power level achieved with all of the reactor steam by-passed to condenser.
September 20, 1965	Turbine loaded to 16 Mw(e).
October, 1965	Annual inspection of turbine, control rod bushing replacement, and maintenance activities.
November 9-10, 1965	Reactor overload test at 55 Mw(t), generator design output of 17.3 Mw(e) achieved, and generator maximum capability of 19.1 Mw(e) demonstrated.
November 10 - Dec. 9, 1965	9,965 Mw(e) hr. Full Power Demonstration Run.
December 19, 1965	Completion of start-up period.

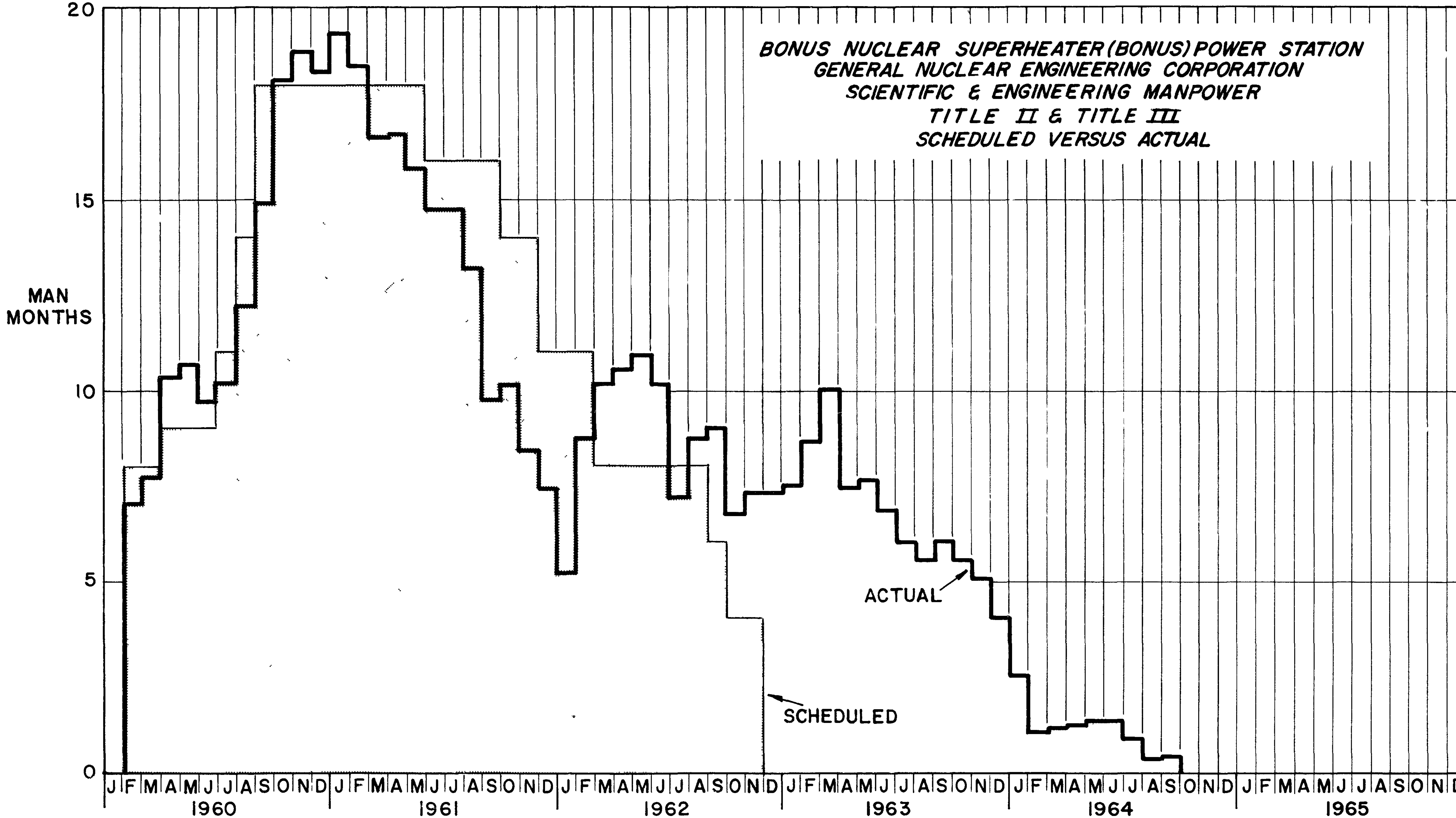
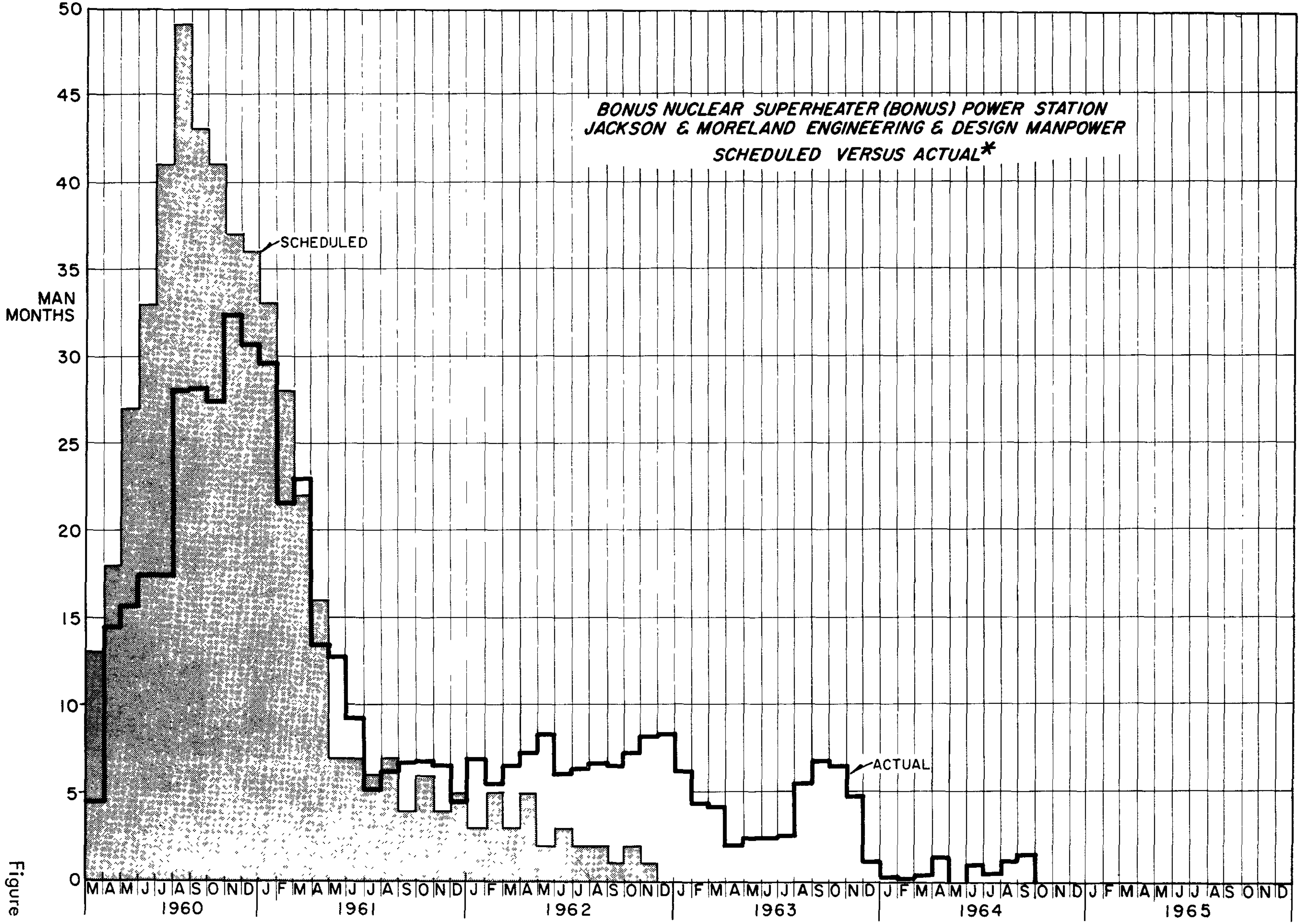

BONUS NUCLEAR SUPERHEATER (BONUS) POWER STATION
GENERAL NUCLEAR ENGINEERING CORPORATION
SCIENTIFIC & ENGINEERING MANPOWER
TITLE II & TITLE III
SCHEDULED VERSUS ACTUAL
MAN MONTHS
20
15
10
5
0
ACTUAL
SCHEDULED
J F M A M J J A S O N D
1960
1961
1962
1963
1964
1965

Figure 4



*TITLE II & TITLE III EXCLUDING FIELD INSPECTION & TITLE IV HAZARDS SUMMARY REPORT WORK

Figure 5

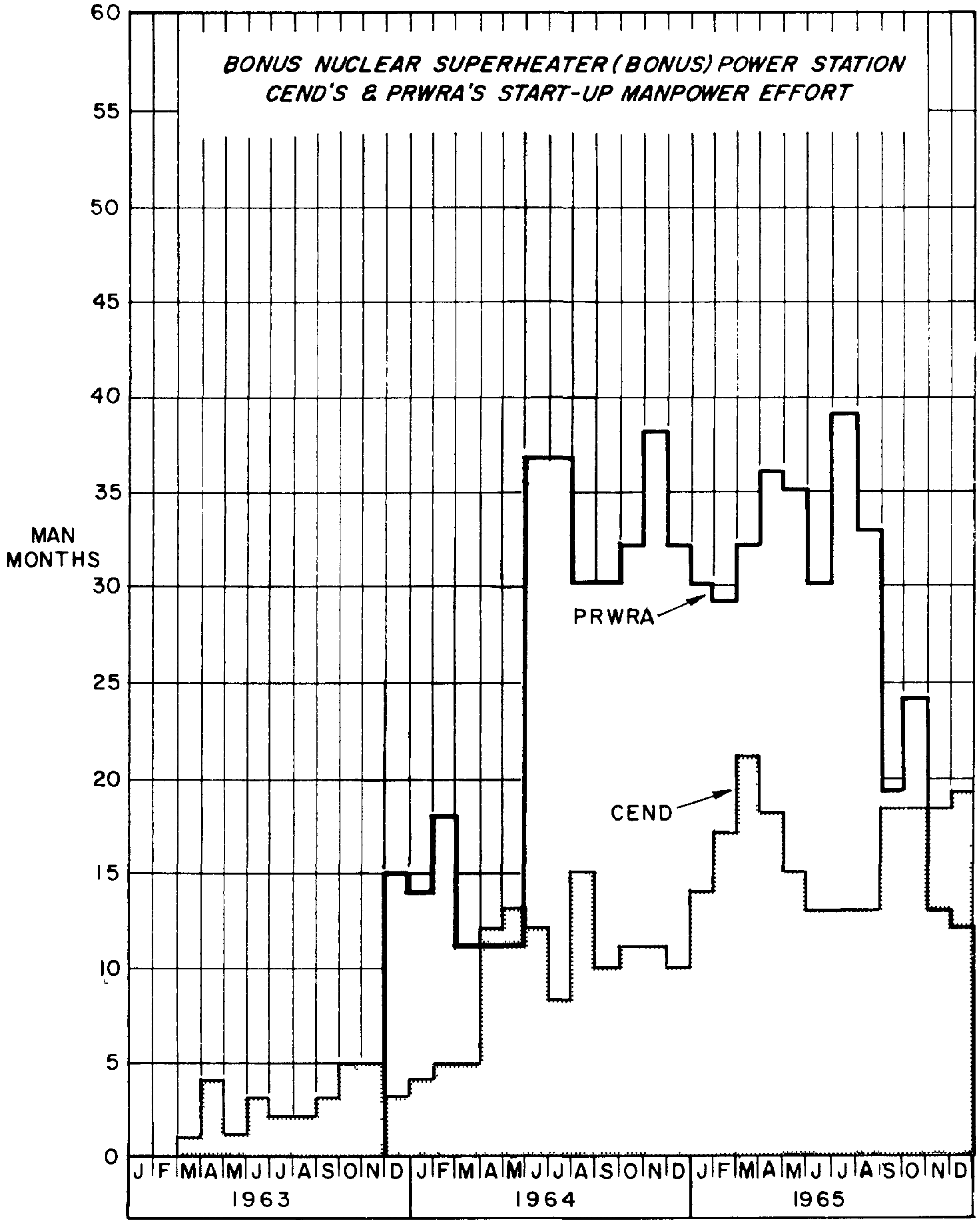

BONUS NUCLEAR SUPERHEATER (BONUS) POWER STATION
CEND'S & PRWRA'S START-UP MANPOWER EFFORT
MAN MONTHS
60
55
50
45
40
35
30
25
20
15
10
5
0
PRWRA
CEND
J F M A M J J A S O N D
1963
1964
1965

Figure 6

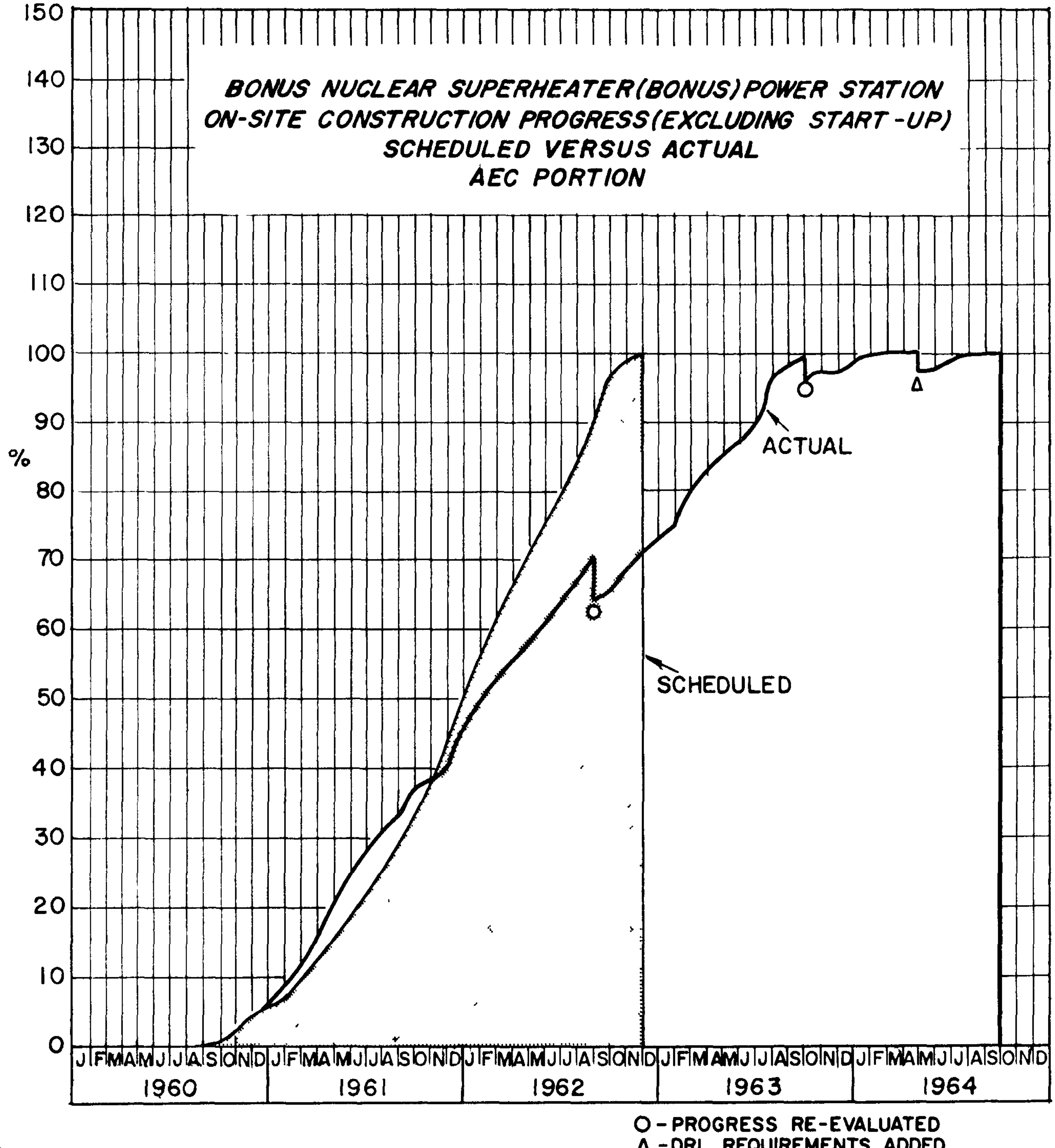
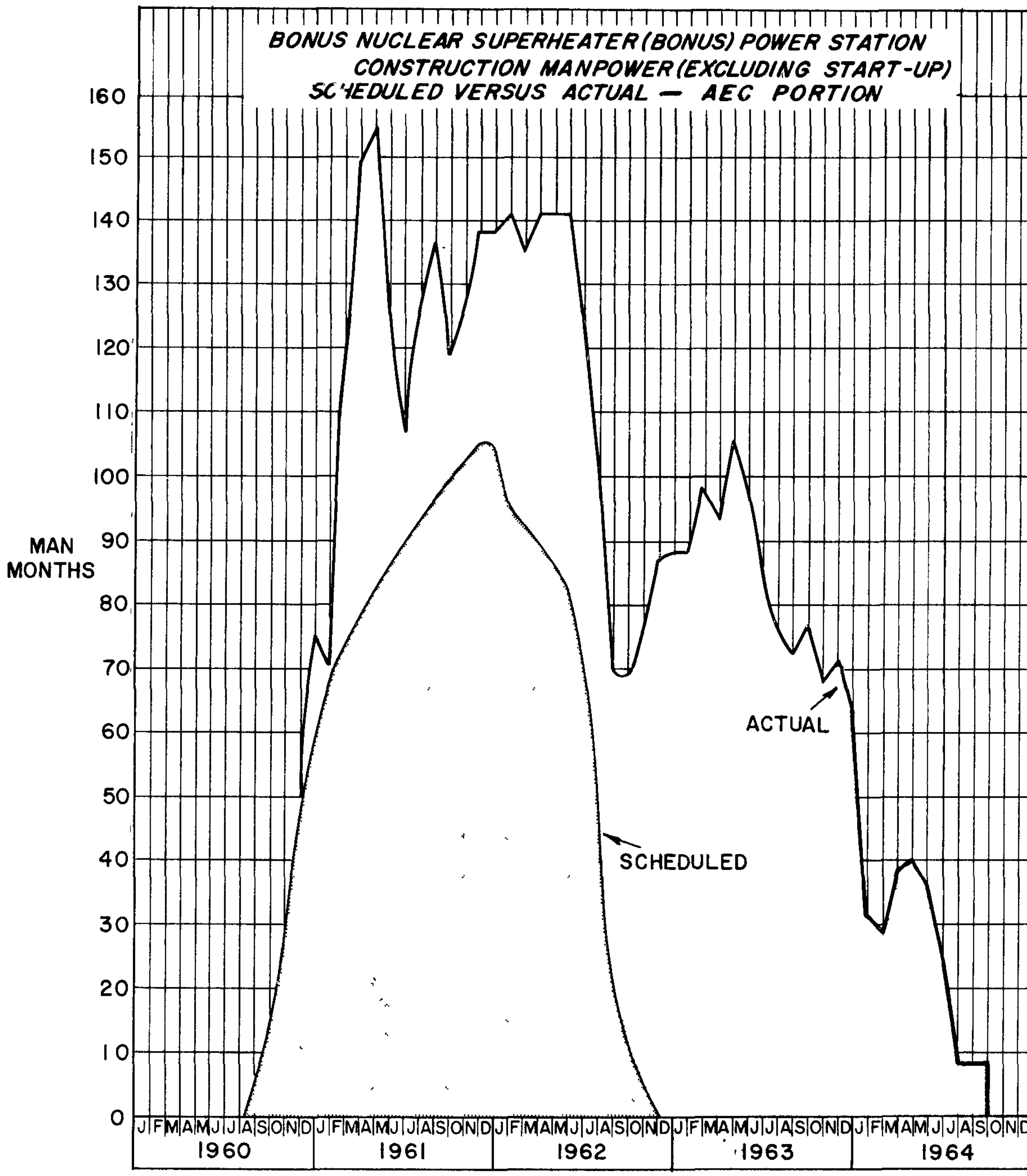

BONUS NUCLEAR SUPERHEATER (BONUS) POWER STATION
ON-SITE CONSTRUCTION PROGRESS (EXCLUDING START-UP)
SCHEDULED VERSUS ACTUAL
AEC PORTION
%
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ACTUAL
SCHEDULED
J F M A M J J A S O N D
1960
1961
1962
1963
1964
O - PROGRESS RE-EVALUATED
Δ - DRL REQUIREMENTS ADDED

Figure 7



BONUS NUCLEAR SUPERHEATER (BONUS) POWER STATION
CONSTRUCTION MANPOWER (EXCLUDING START-UP)
SCHEDULED VERSUS ACTUAL — AEC PORTION
MAN MONTHS
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ACTUAL
SCHEDULED
J F M A M J J A S O N D
1960
1961
1962
1963
1964

Figure 8

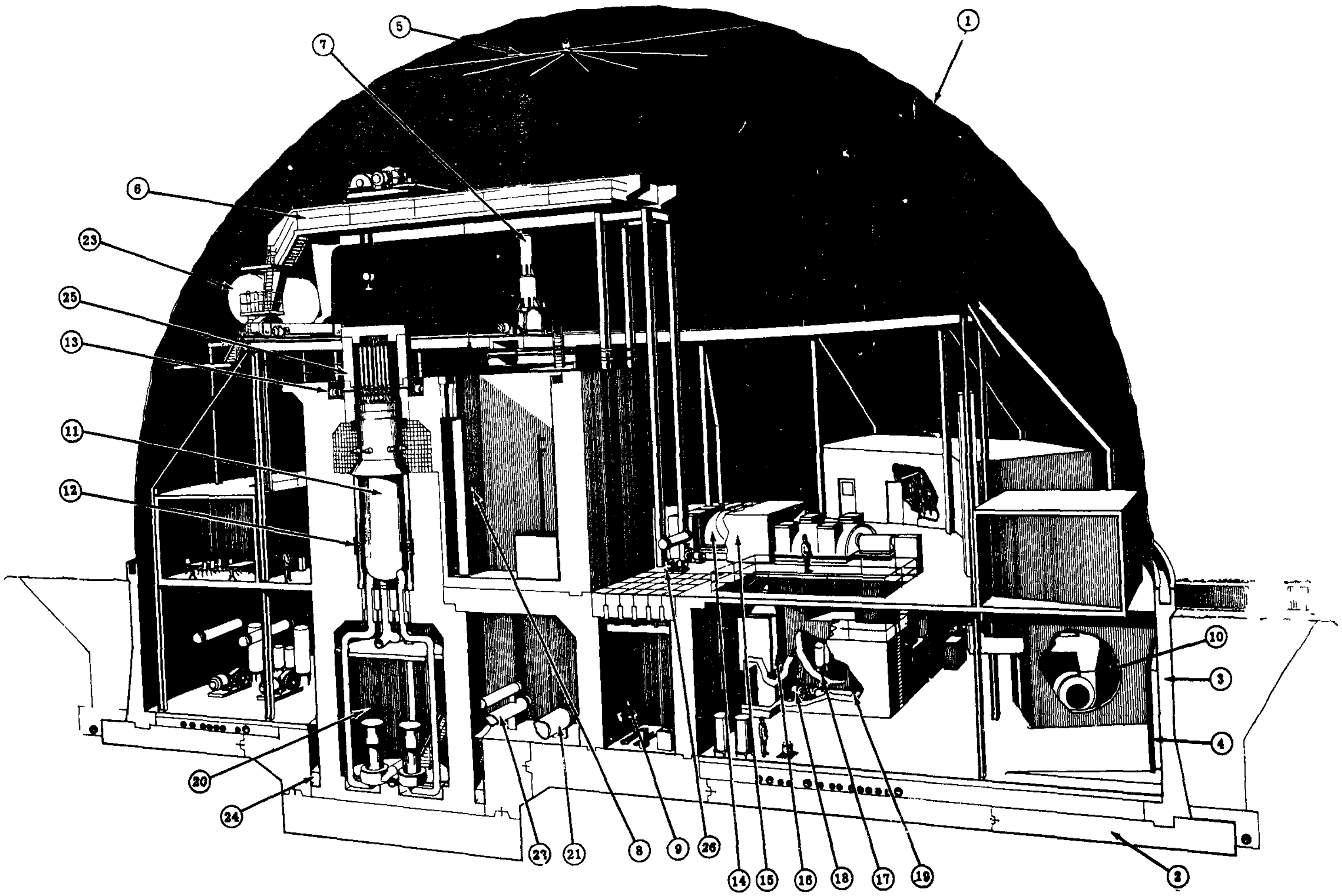
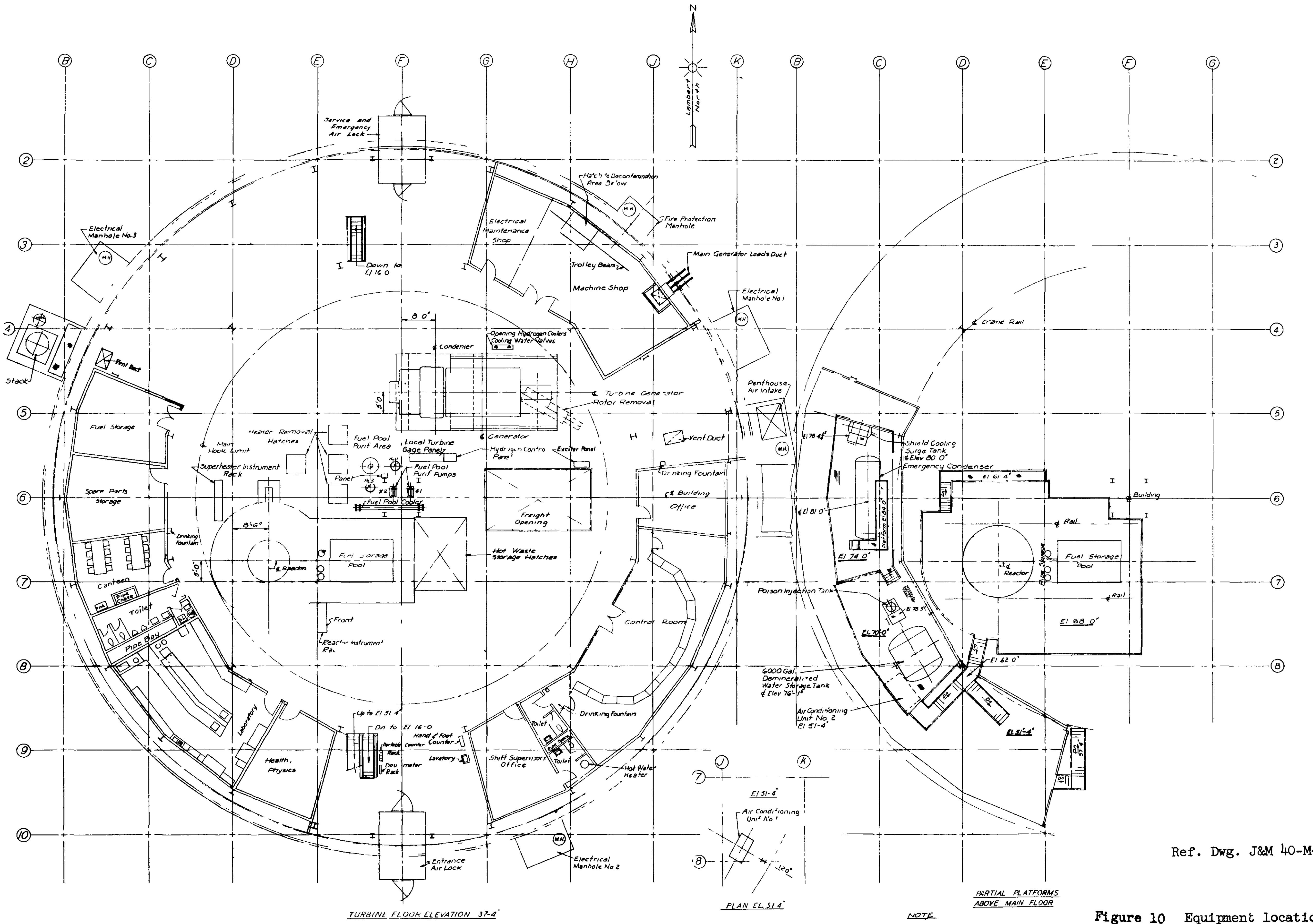


FIGURE 9 PERSPECTIVE OF CONTAINMENT BUILDING

KEY

1. Steel Dome
2. Foundation Mat
3. Retainer Wall
4. Freight Door
5. Building Spray
6. Polar Gantry Crane
7. Fuel Unloading Coffin
8. Spent Fuel Storage Pool
9. Solid Radioactive Waste Storage
10. Building Ventilation Intake Fan
11. Reactor Pressure Vessel
12. Neutron Shield Tank
13. Control Rod Drive Motor Trench
14. Turbine-Generator
15. Turbine Shield
16. Condenser
17. Condensate Pumps
18. Evactor Pump
19. Gland Seal Condenser
20. Reactor Circulating Water Pump Room
21. Start-up Heater
22. Reactor Water Purification Coolers
23. Emergency Condenser
24. Reactor Pit Water Moat
25. Removable Concrete Shield
26. Fuel Pool Cooling System



Ref. Dwg. J&M 40-M-2

Figure 10 Equipment location plan for main operating floor (El. 37 ft, 4 in.).

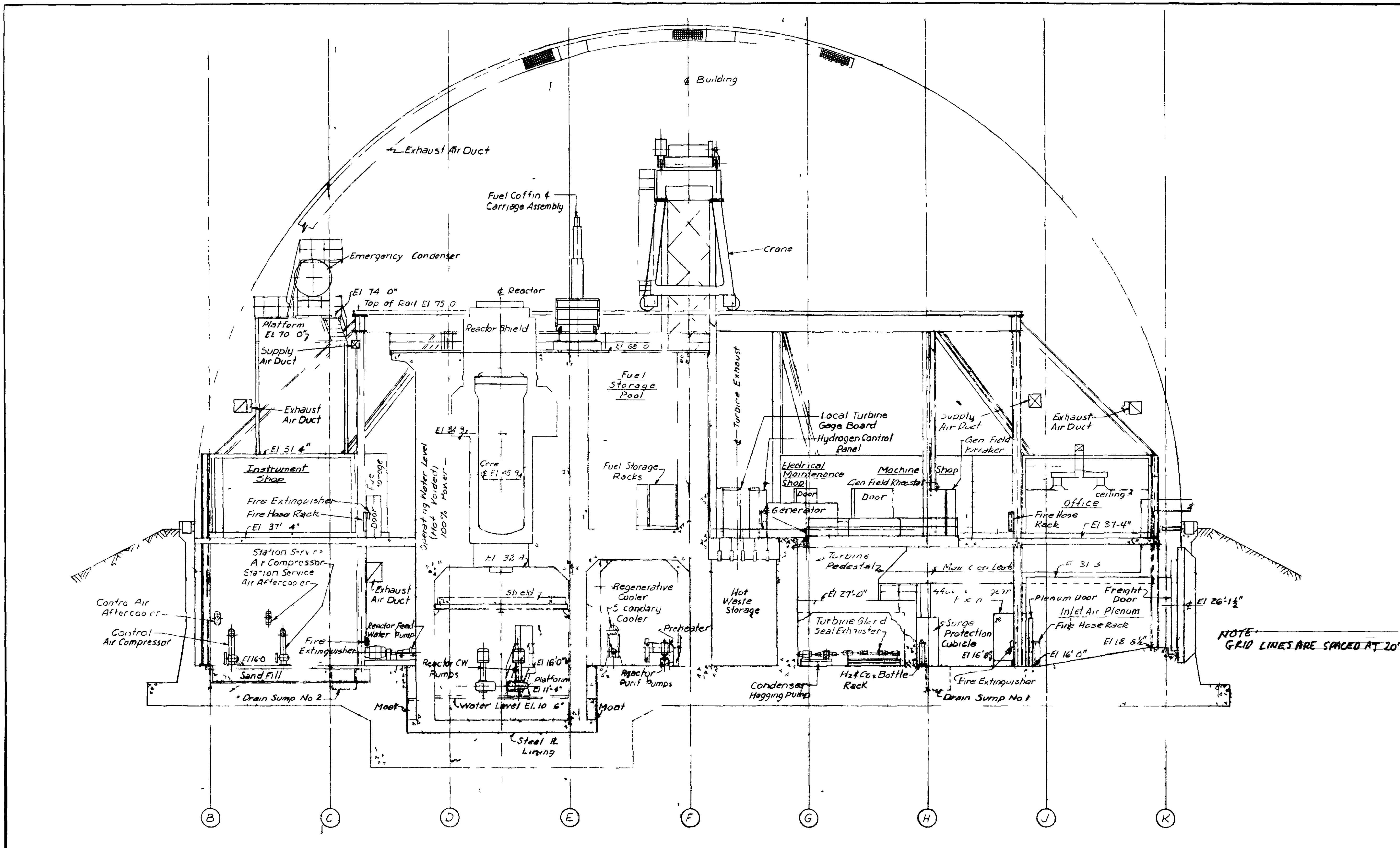


FIGURE 11
VERTICAL ELEVATION OF CONTAINMENT BUILDING LOOKING NORTH

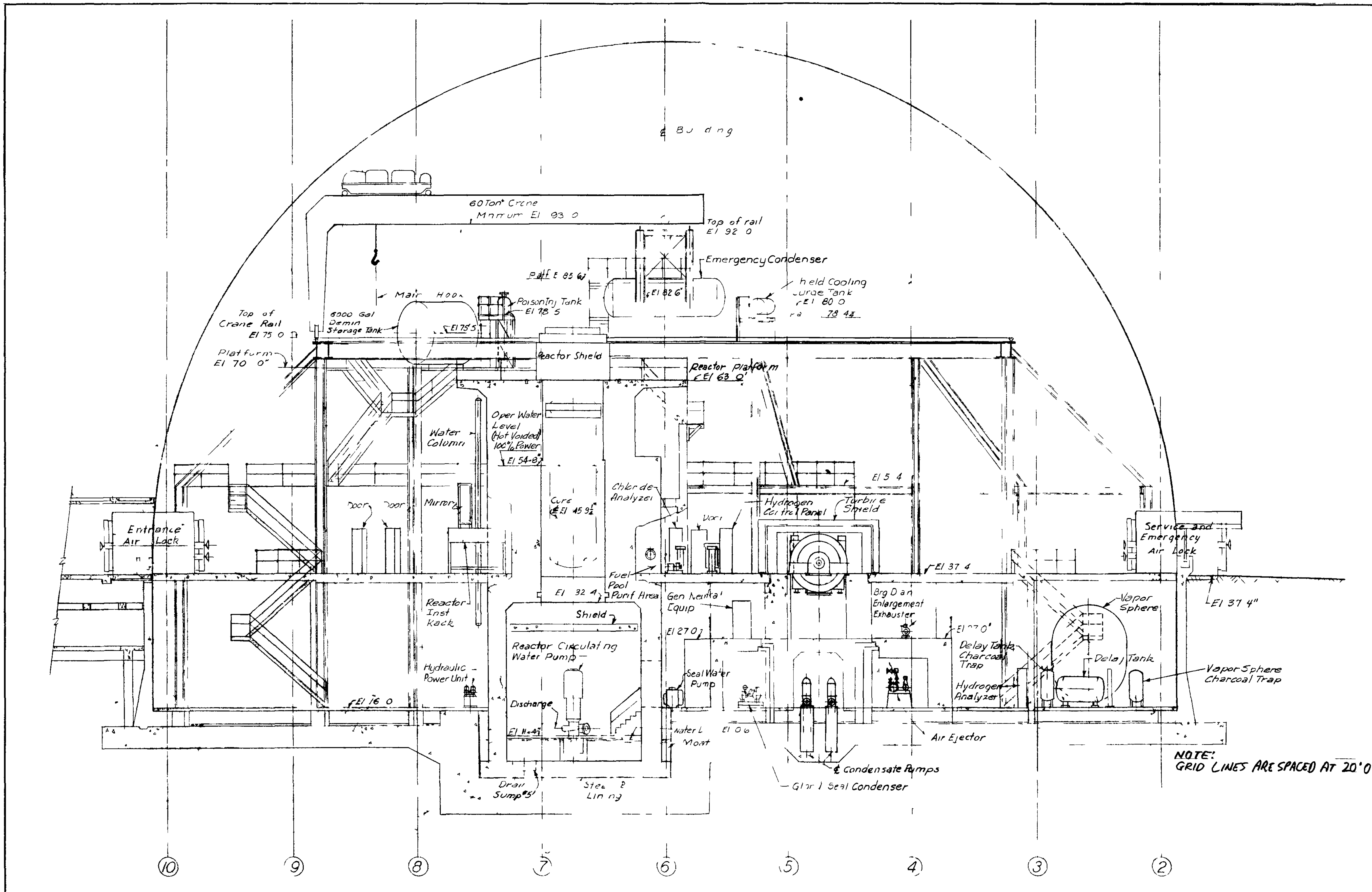
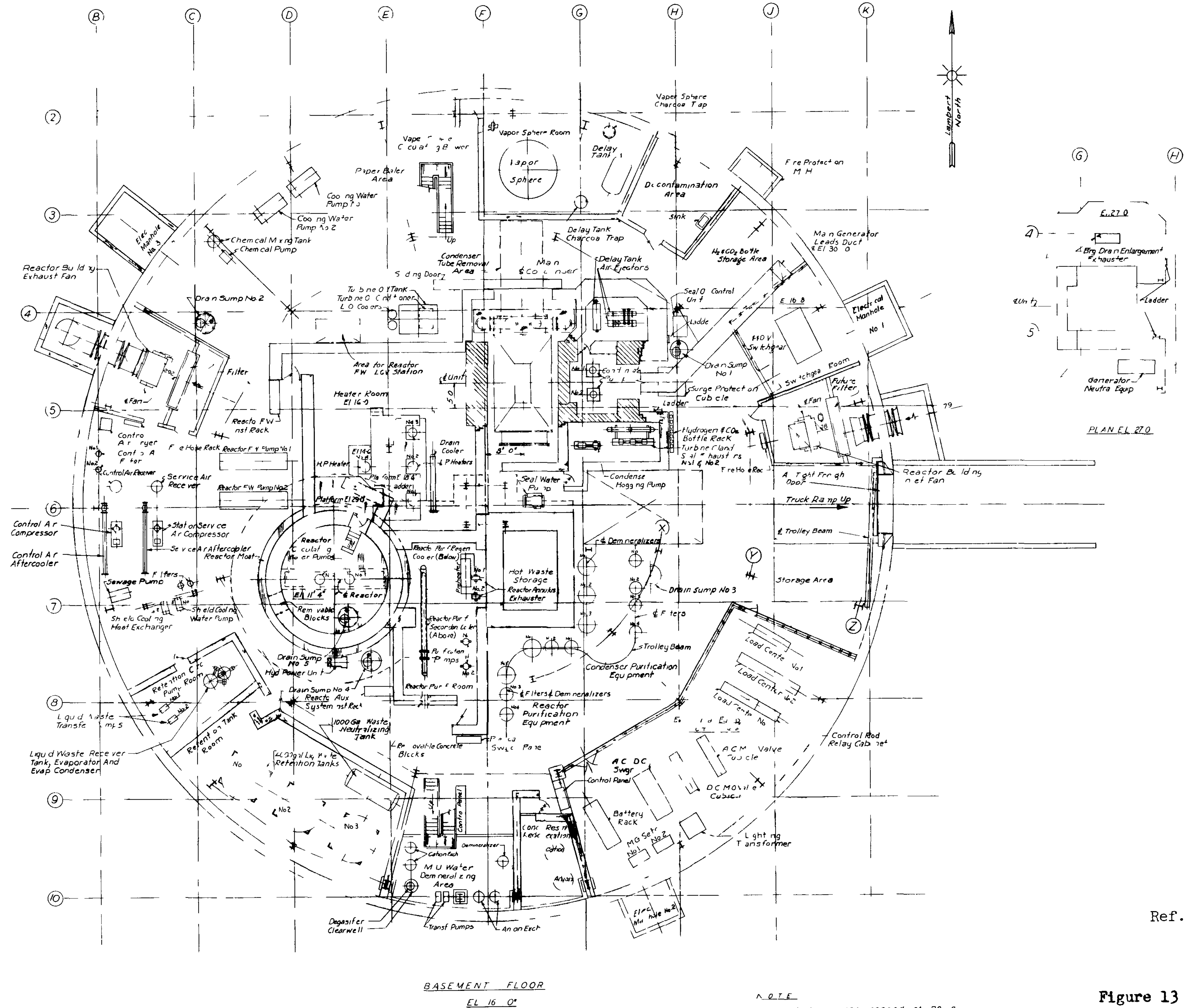


FIGURE 12
VERTICAL ELEVATION OF CONTAINMENT BUILDING LOOKING WEST



Ref. Dwg. J&M 40-M-1

Figure 13 - Equipment location plan for basement floor (El. 16 ft, 0 in.).

FIGURE 14

BONUS DRAWINGS, DIAGRAMS, AND PLANS FROM FINAL HAZARDS SUMMARY REPORT

Number	Title
301-1	Perspective Drawing of Reactor Vessel and Internals
301-2	Vertical Cross Section of Reactor Pressure Vessel
301-18	Layout of Control Rod Drive System
301-26	Reactor Biological Shield
302-1	Schematic Diagram of Reactor Pressure Control System
303-12	Over-all Layout of the Main Control Panel (Panels A through I are AEC-owned and Panels J through N are PRWRA-owned)
307-2	Schematic Diagram of Reactor Auxiliary System
307-7	Fuel Coffin In Place Over Reactor During Refueling Operations
403-1	Schematic Diagram of Radiolytic and Radioactive Waste Disposal System
502-1	Station Heat Balance at Rated Load
1001-3	Site Plan
1003-2	Plot Plan

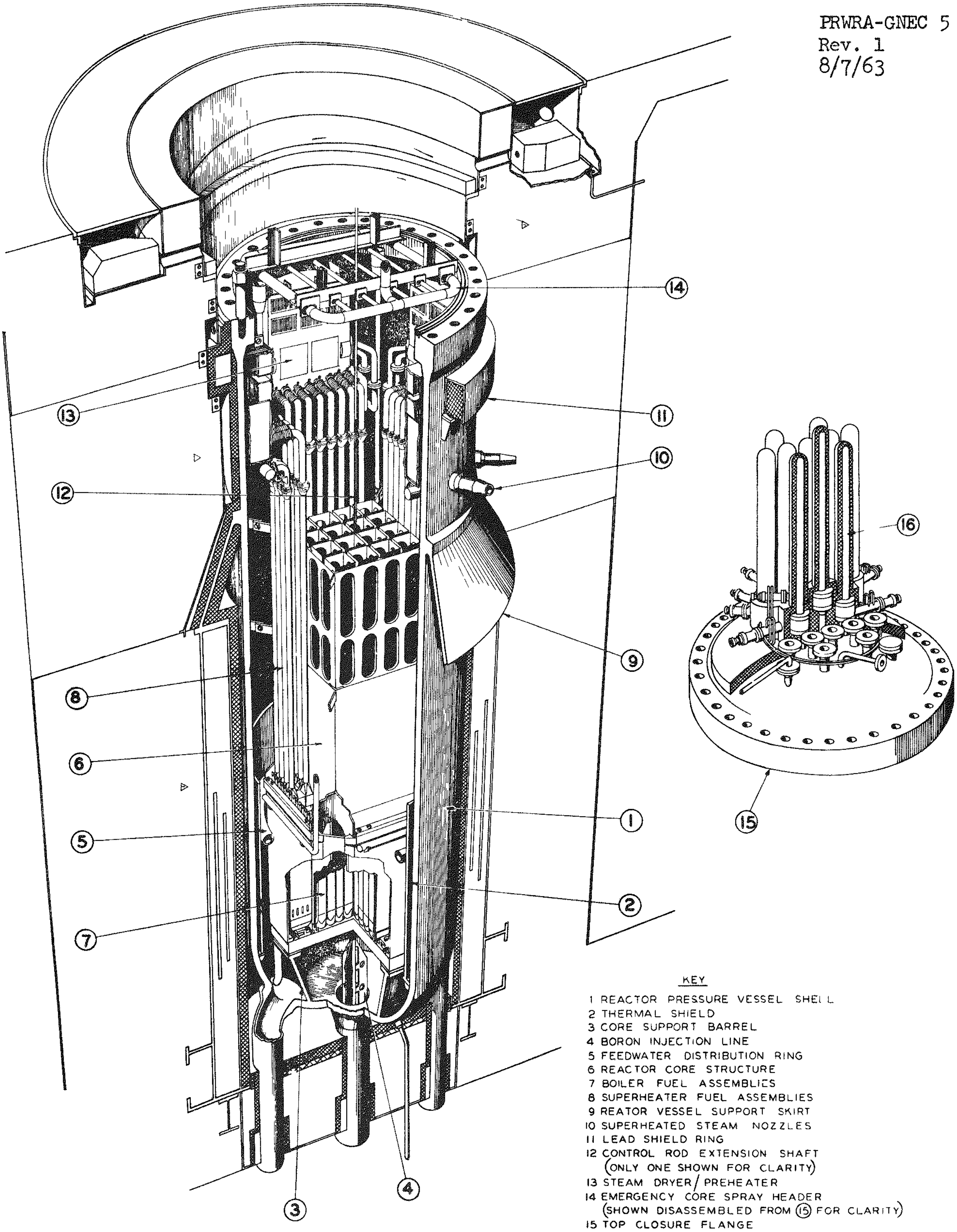
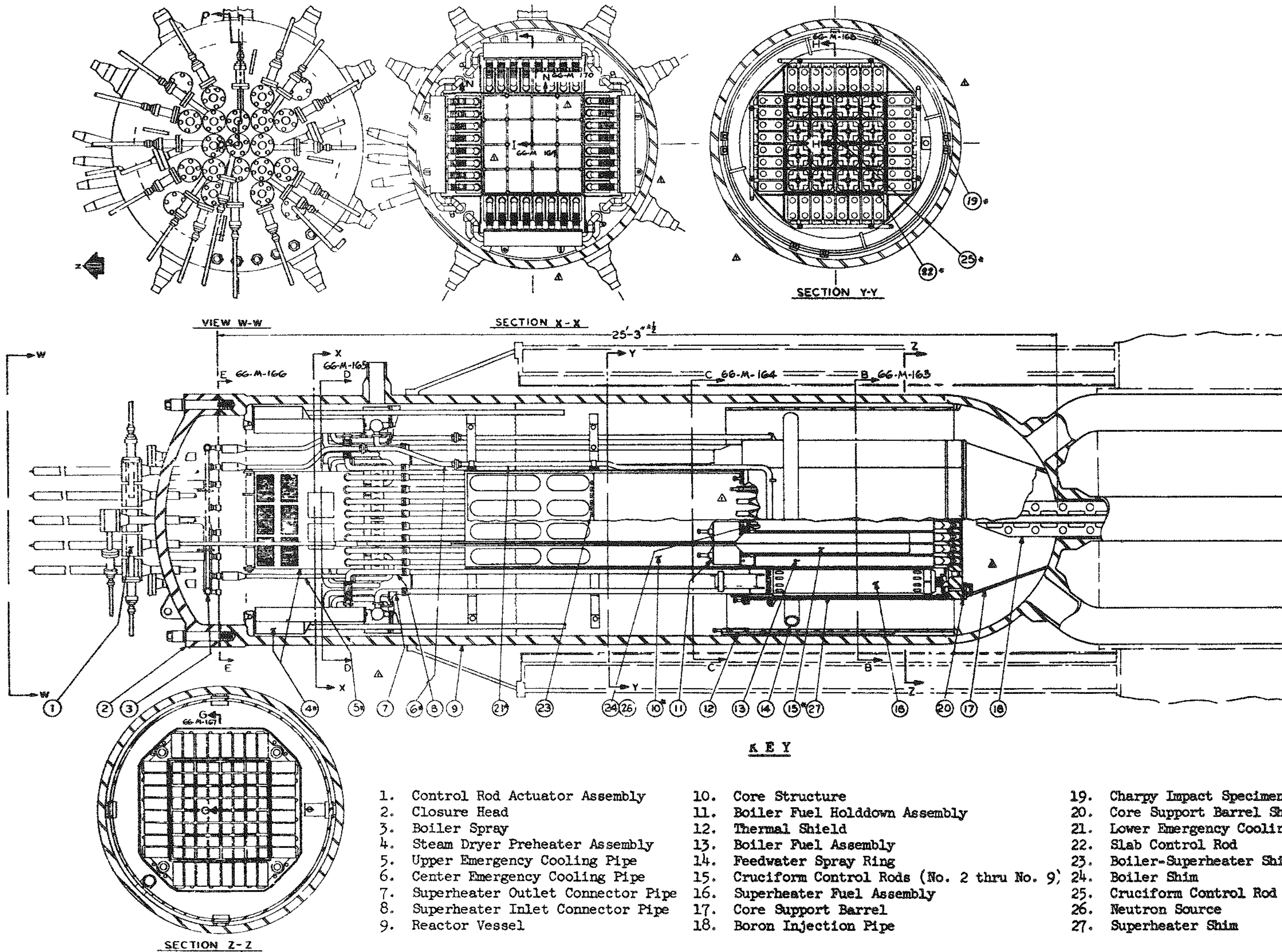


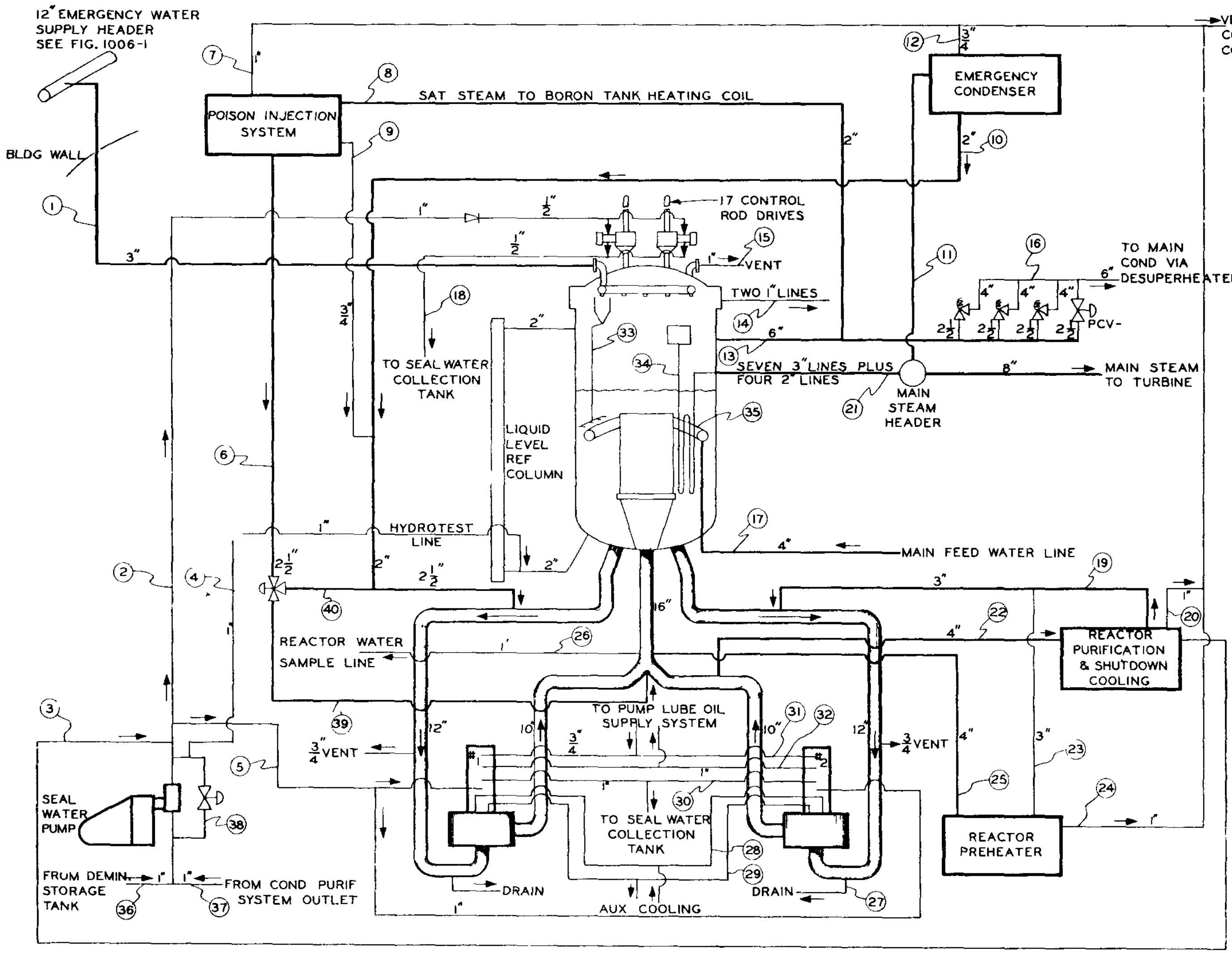
Fig. 301-1 Perspective drawing of reactor vessel and internals



KEY

1. Control Rod Actuator Assembly
2. Closure Head
3. Boiler Spray
4. Steam Dryer Preheater Assembly
5. Upper Emergency Cooling Pipe
6. Center Emergency Cooling Pipe
7. Superheater Outlet Connector Pipe
8. Superheater Inlet Connector Pipe
9. Reactor Vessel
10. Core Structure
11. Boiler Fuel Holddown Assembly
12. Thermal Shield
13. Boiler Fuel Assembly
14. Feedwater Spray Ring
15. Cruciform Control Rods (No. 2 thru No. 9)
16. Superheater Fuel Assembly
17. Core Support Barrel
18. Boron Injection Pipe
19. Charpy Impact Specimen Hold
20. Core Support Barrel Shim
21. Lower Emergency Cooling Pi
22. Slab Control Rod
23. Boiler-Superheater Shim
24. Boiler Shim
25. Cruciform Control Rod No. 1
26. Neutron Source
27. Superheater Shim

Fig. 301-2 Vertical cross section of reactor pressure vessel

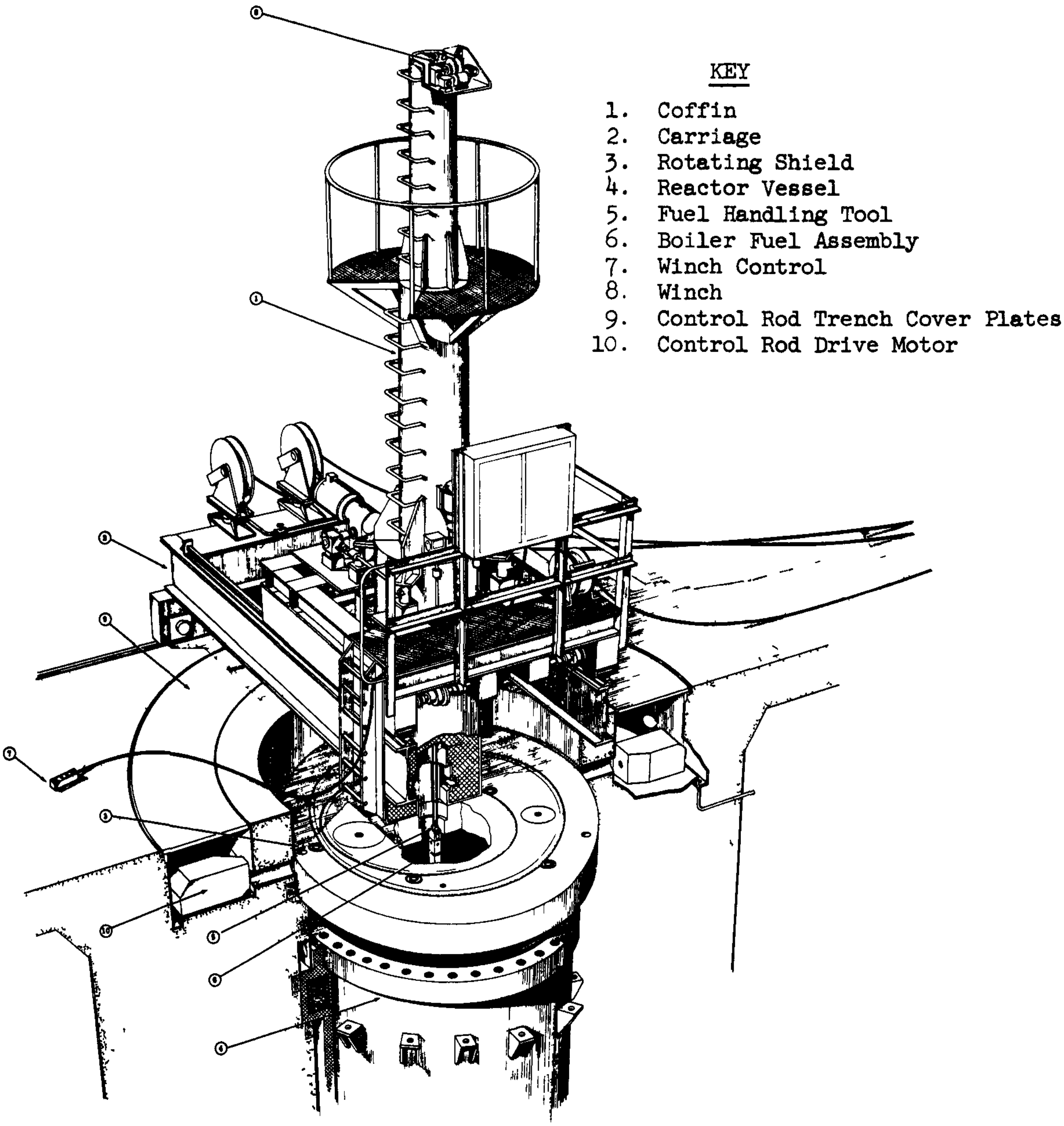


Note This diagram is designed to indicate the major connections between the primary reactor system and the auxiliary systems. Instrumentation, valves, auxiliary equipment air vent lines and equipment drains have been omitted from this simplified diagram. See individual system drawings for these details

KEY

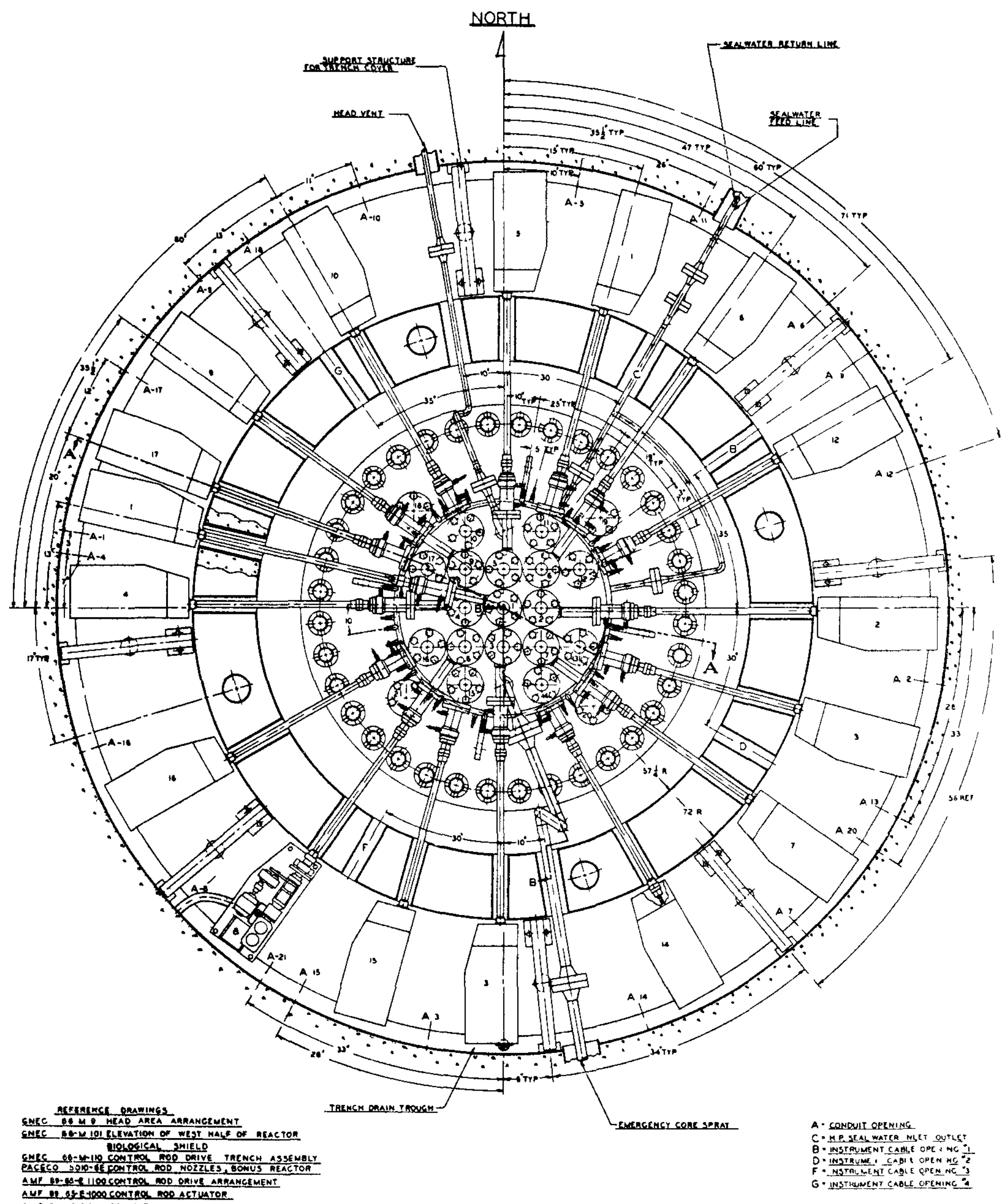
1 Core spray line to vessel nozzle
2 Seal water to rod drives
3 Auxiliary seal water supply from reactor purification
4 Hydrotest line
5 Seal water to reactor circulating pumps
6 Liquid poison into reactor
7 Poison system vent line
8 Saturated steam to poison tank coil
9 Condensate from poison tank coil
10 Condensate from emergency condenser
11. Superheated steam to emergency condenser
12 Emergency condenser vent line
13 Saturated steam line from reactor vessel
14 Gasket leakoff lines
15 Reactor vessel vent line
16 Safety valve discharge header
17 Main feedwater line
18 Rod drive seal leakage line
19 Return line from reactor purification system
20 Reactor purification system vents
21 Superheated steam lines from reactor vessel
22 Water supply to reactor purification
23 Water supply to reactor preheater
24 Preheater safety valve discharge
25 Steam-water mixture from preheater
26 Reactor water sampling line
27 Reactor circulating loop drain
28 Reactor circulating pump backplate cooling inlet
29 Reactor circulating pump backplate cooling outlet
30 Circulating pump seal injection water return line
31 Circulation pump lube oil supply
32 Circulation pump lube oil return
33 Emergency superheater spray standpipes (typical)
34 Saturated steam to superheater fuel (typical)
35 Feedwater distributor
36 Alternate seal injection water supply line
37 Normal seal injection water supply line

Fig. 307-2 Schematic diagram of reactor auxiliary systems.



Ref. Drawing GNEC 66-m-80

Fig. 307-7 Fuel coffin in place over reactor during refueling operations.



Ref. Dwg. GNEC 66-M-9

Fig. 301-18 Layout of control rod drive system.

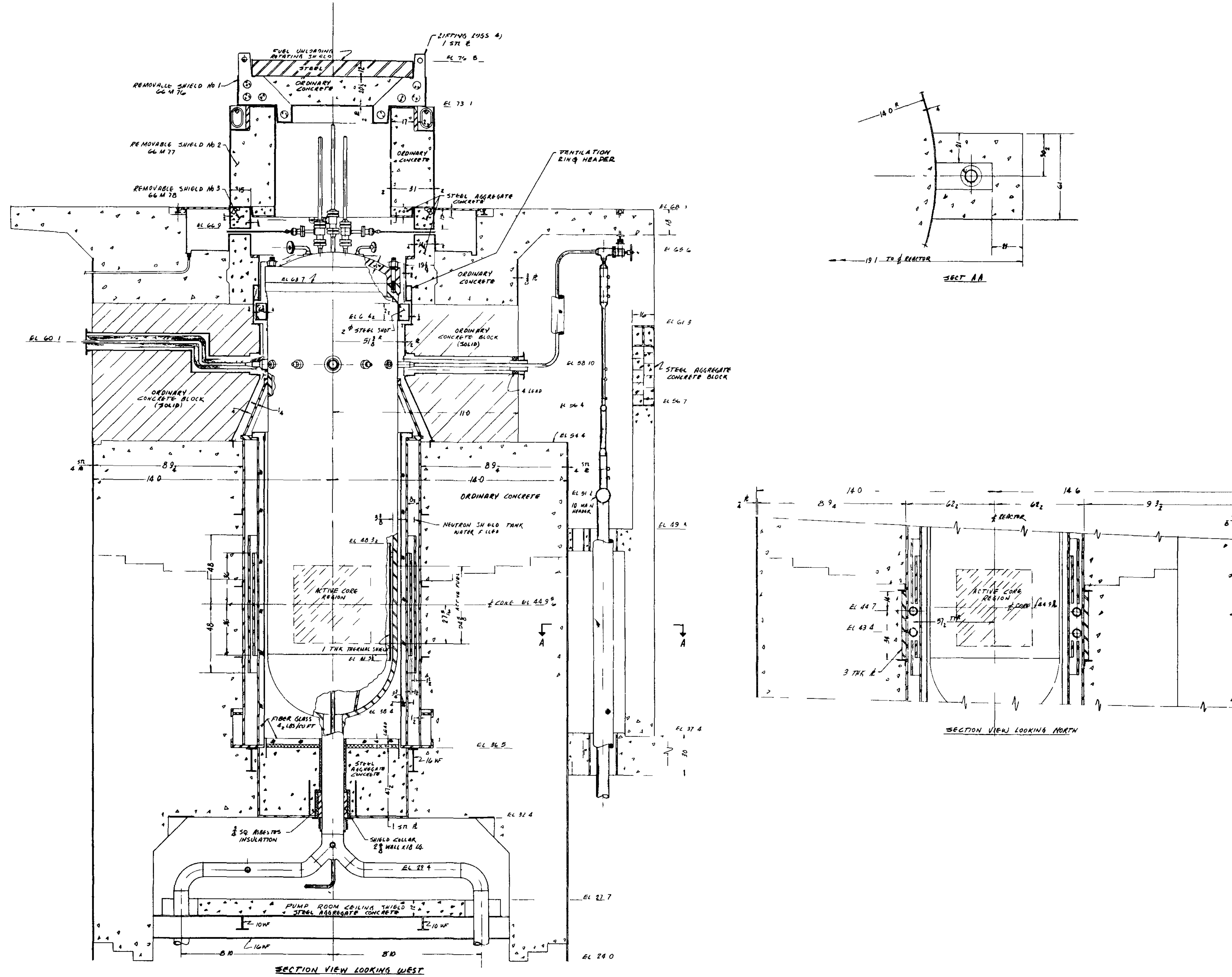
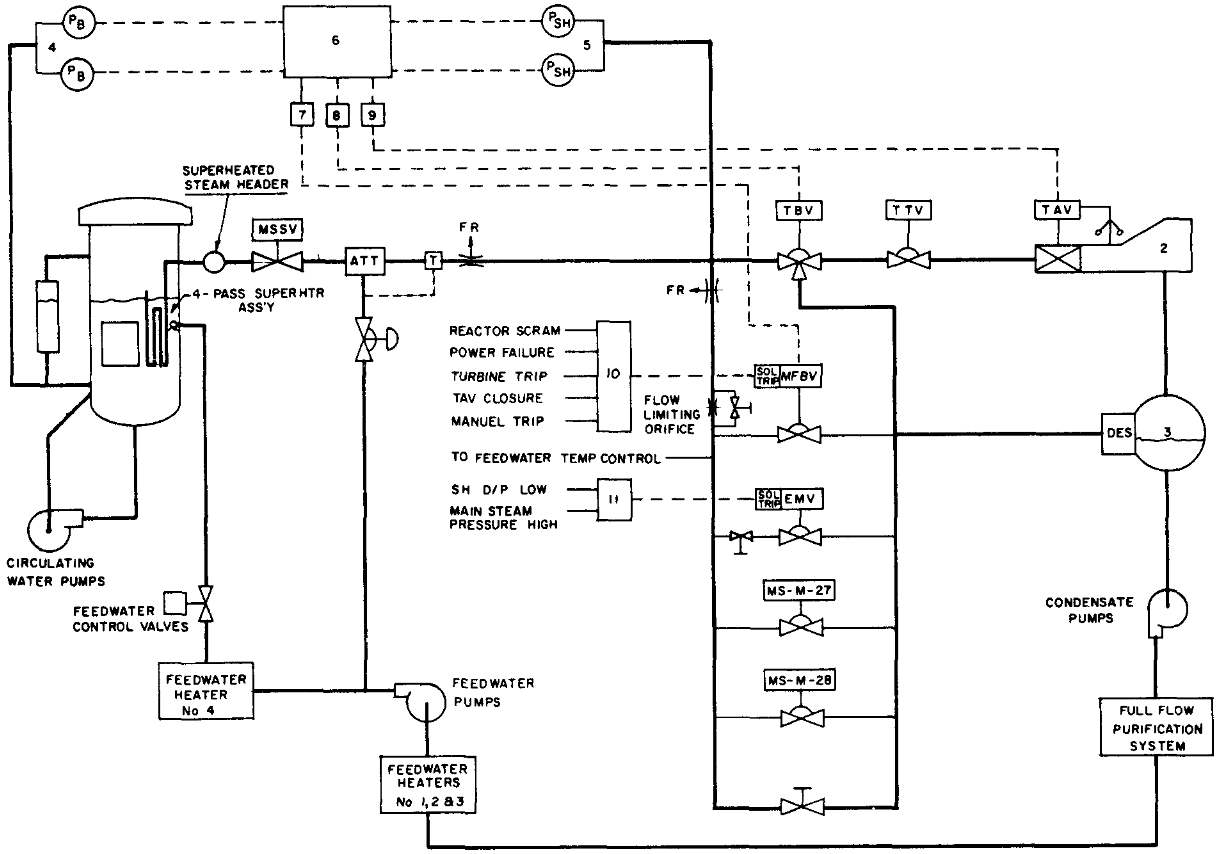


Fig. 301-26 Reactor biological shield.



KEY

1.	Reactor Pressure Vessel
2.	Turbine
3.	Main Condenser
4.	Reactor Pressure Transducers
5.	Main Steam Line Pressure Transducers
6.	Mixer - Selector Panel Interlocks, etc.
7.	Minimum Flow Bypass Valve (MFBV) Control Station
8.	Turbine Bypass Valve Control Station
9.	Turbine Admission Valve (TAV) Control Station
10.	MFBV Trip Station
11.	EMV Trip Station
MSSV	Main Steam Stop Valve
TBV	3-Way Turbine Bypass Valve
MFBV	Minimum Flow Bypass Valve
TTV	Turbine Trip Valve
TAV	Turbine Admission Valve
EMV	Electromatic Valve
DES	Desuperheater
ATT	Attemperator
FR	Flow Recorder
T	Thermocouple

Fig. 302-1 Schematic diagram of reactor pressure control system

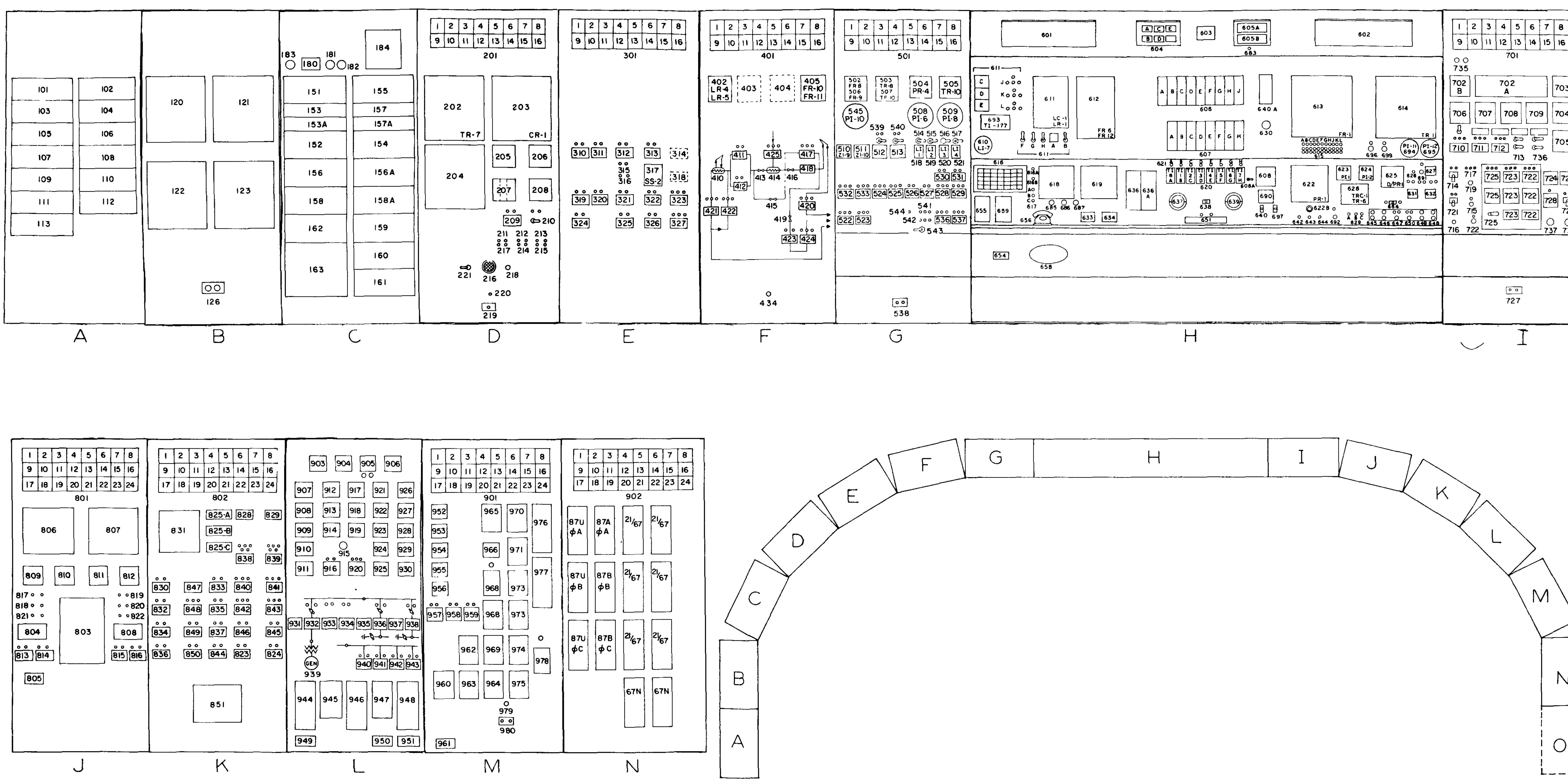


Fig. 303-12 Over-all layout of the main control panel.

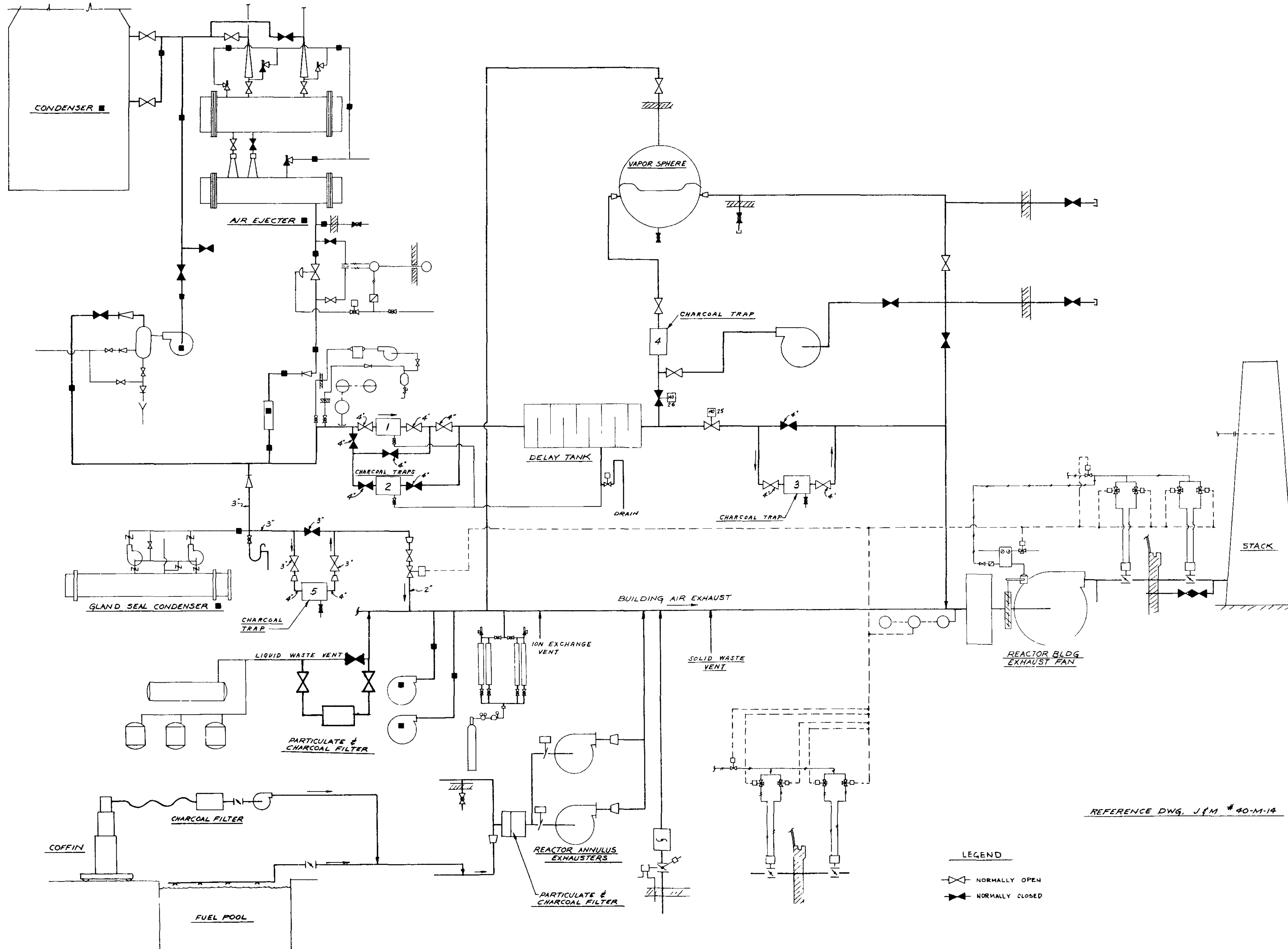


Fig. 403-1 Schematic diagram of radiolytic and radioactive waste disposal system.

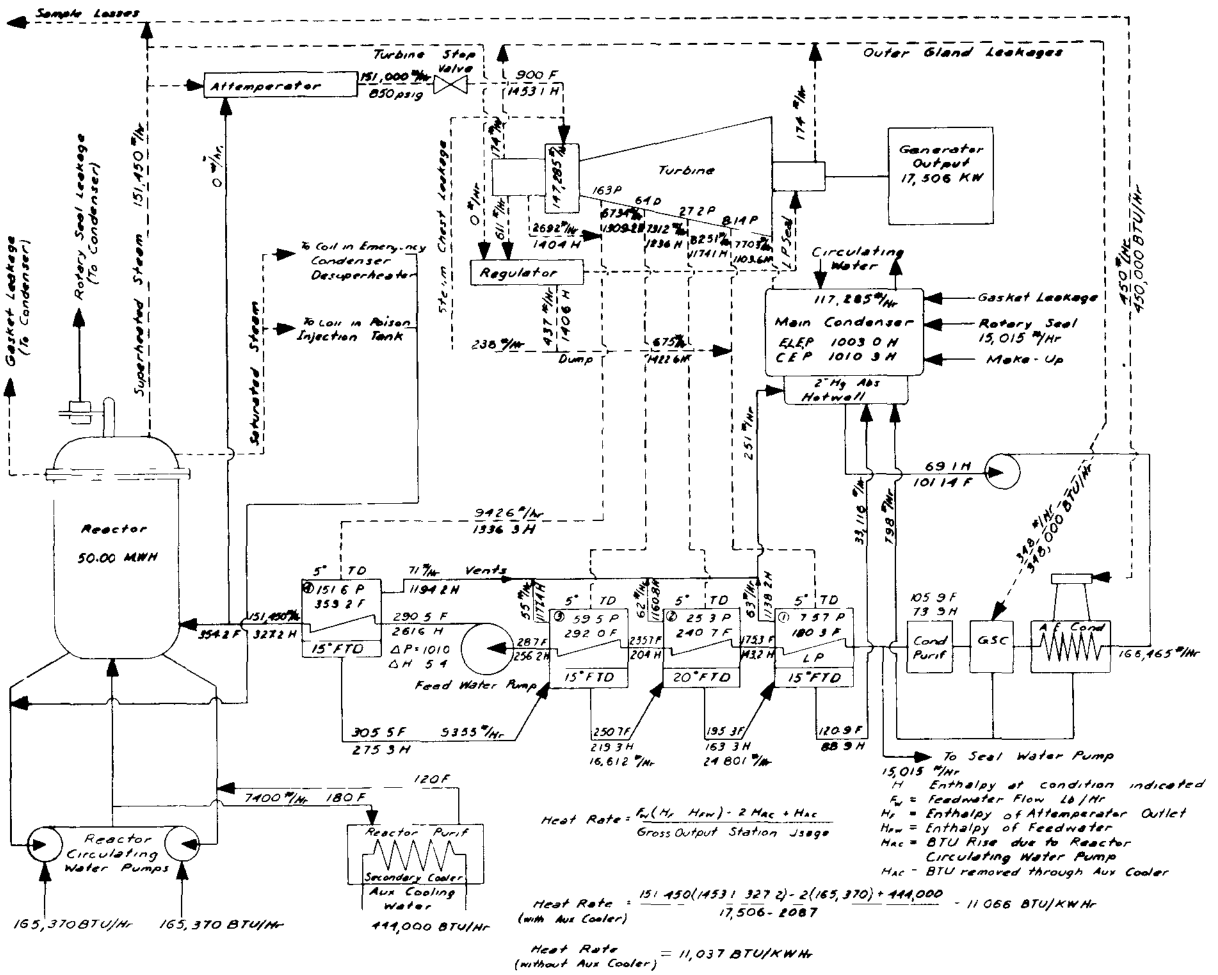


Fig. 502-1 Station heat balance at rated load.

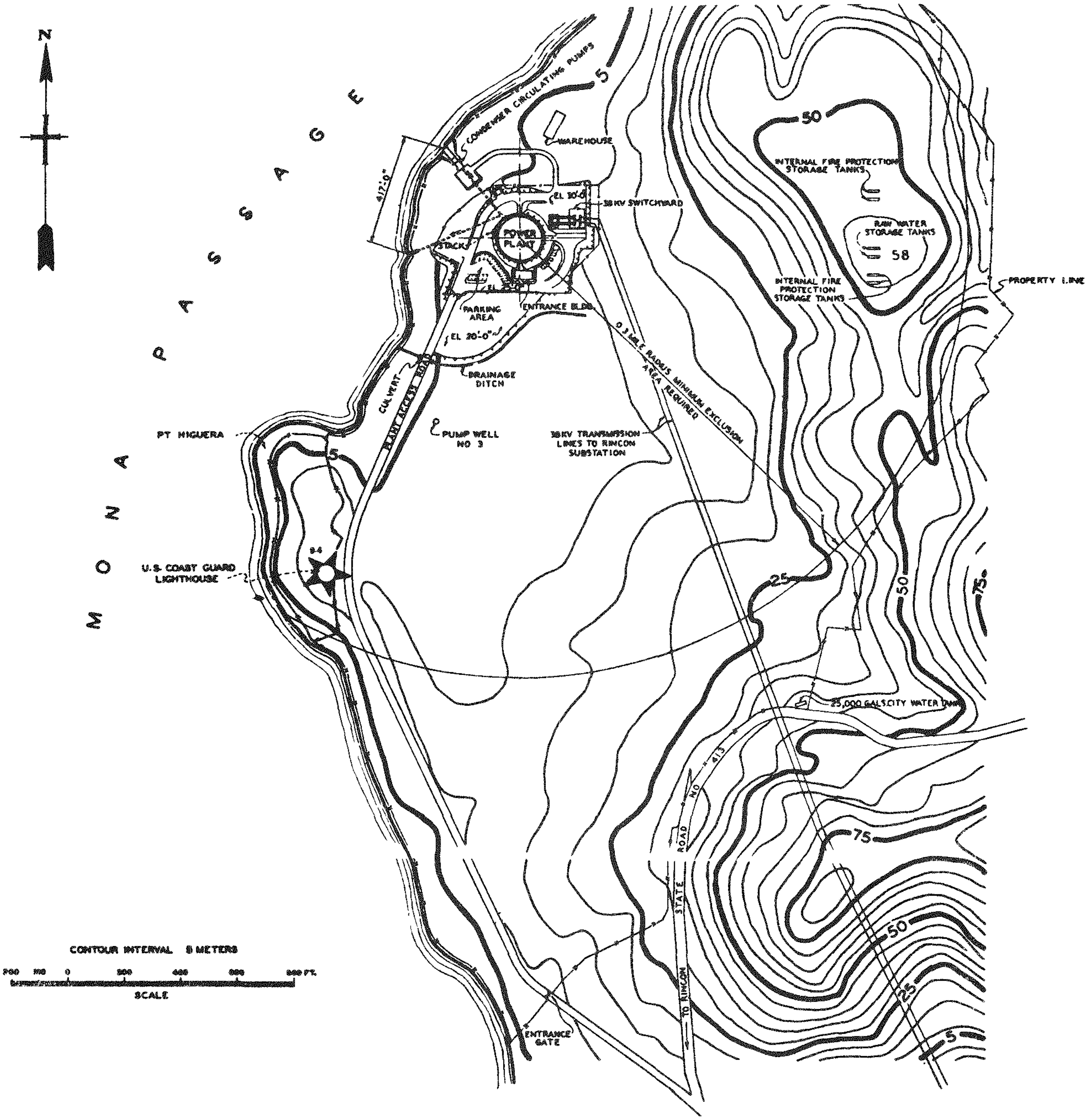


Fig. 1001-3 Site plan.

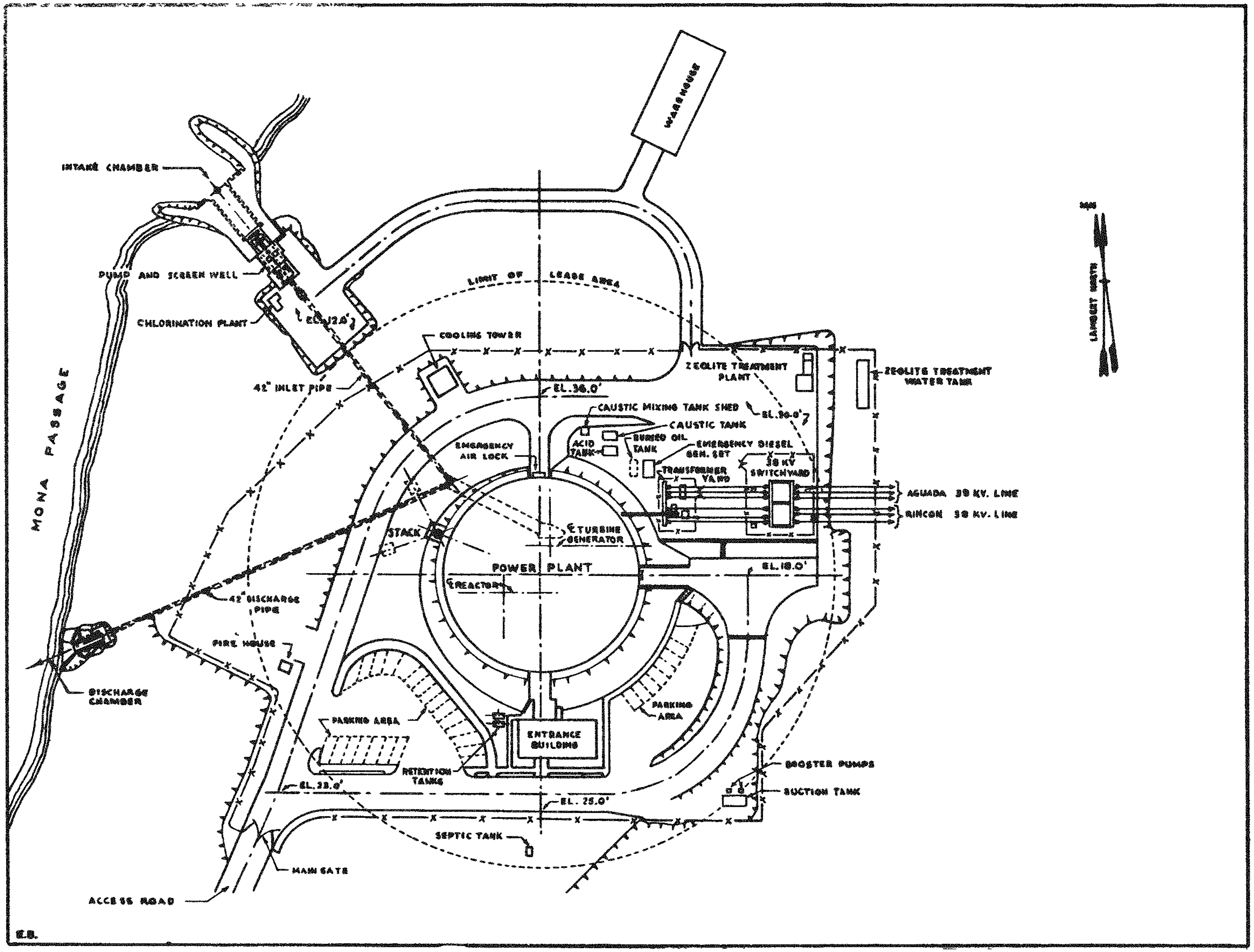


Fig. 1003-2 Plot plan.

FIGURE 15

<u>PHOTOGRAPHS</u>

A. Site Prior to Beginning of Construction

B. Overall Site View

C. Overall Site View

D. General View

E. View Inside Containment Structure

F. Fuel Storage Pool and Reactor

G. Reactor Pressure Vessel

H. Reactor Head Area

I. Reactor Head Area

J. Reactor Head Area

K. Steam Dryer/Preheater with Control Rod Drives Installed

L. Installing Core Structure

M. Reactor Head Area

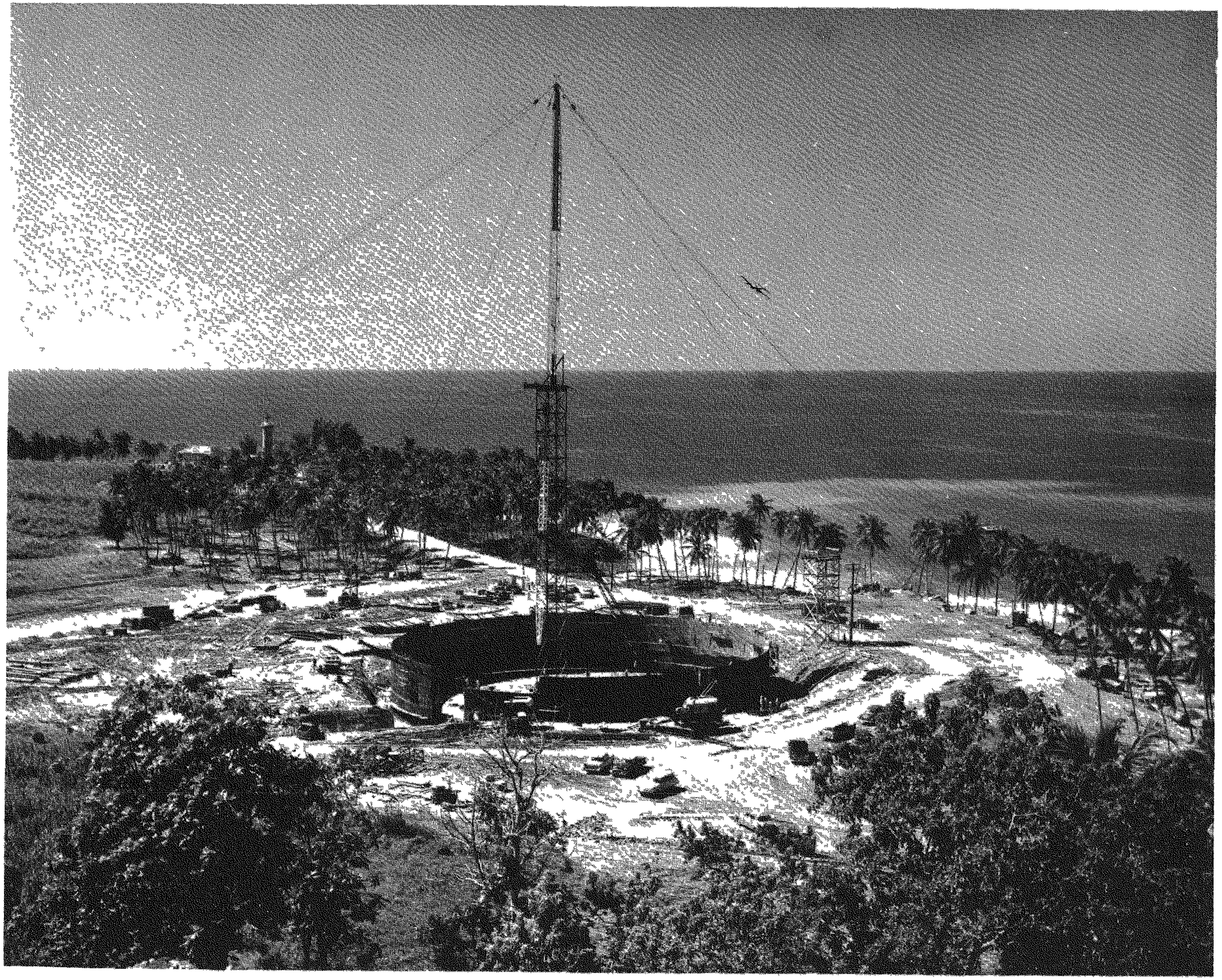
N. Angle Valve Enclosure and Ventilation Duct at Reactor Face

O. Preparation for Initial Boiler Fuel Loading

P. Overall Site View

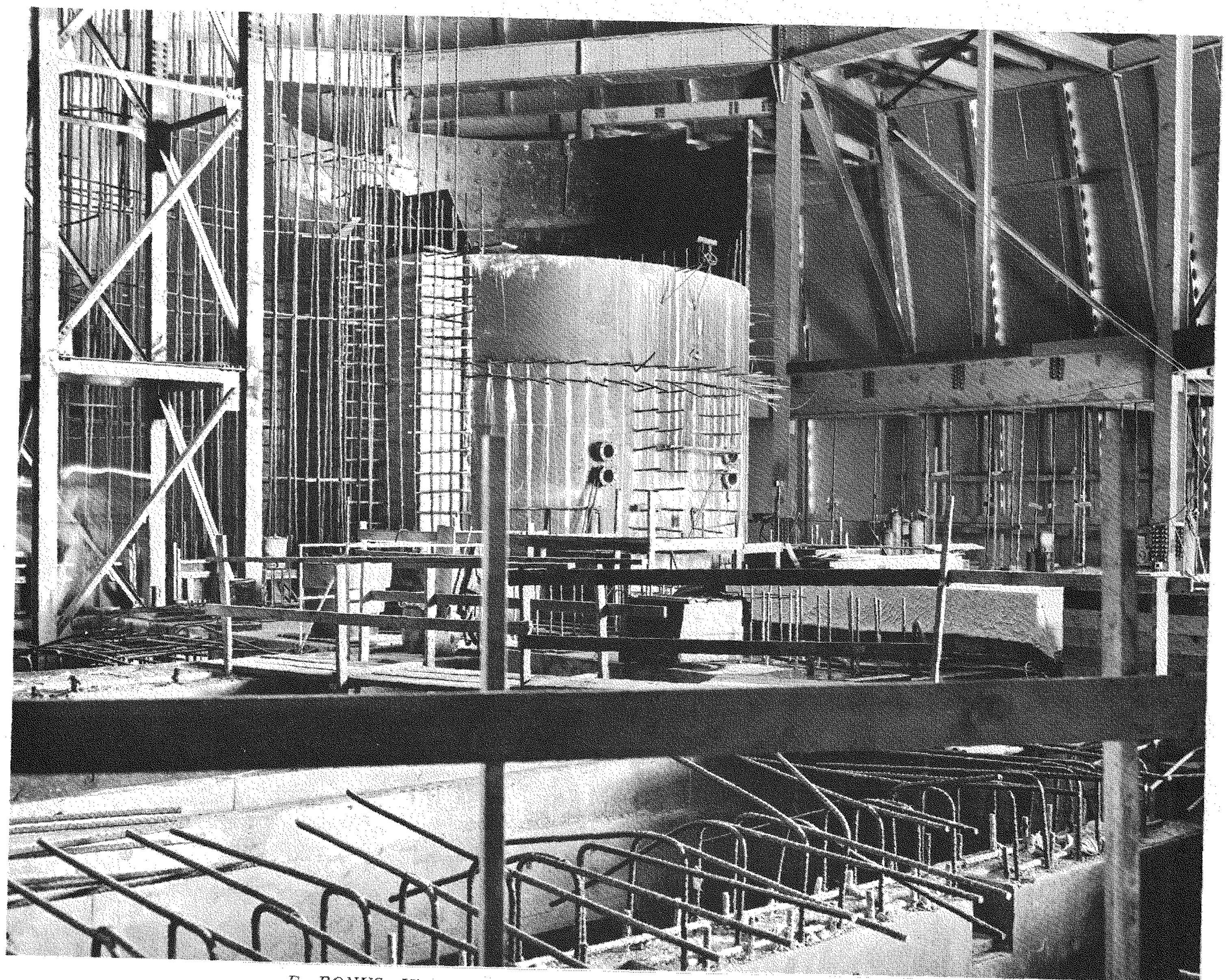
A BONUS—Aerial Photograph of Site Prior to Beginning of Construction

B. BONUS—Overall Site View Looking Southwest November 20, 1960

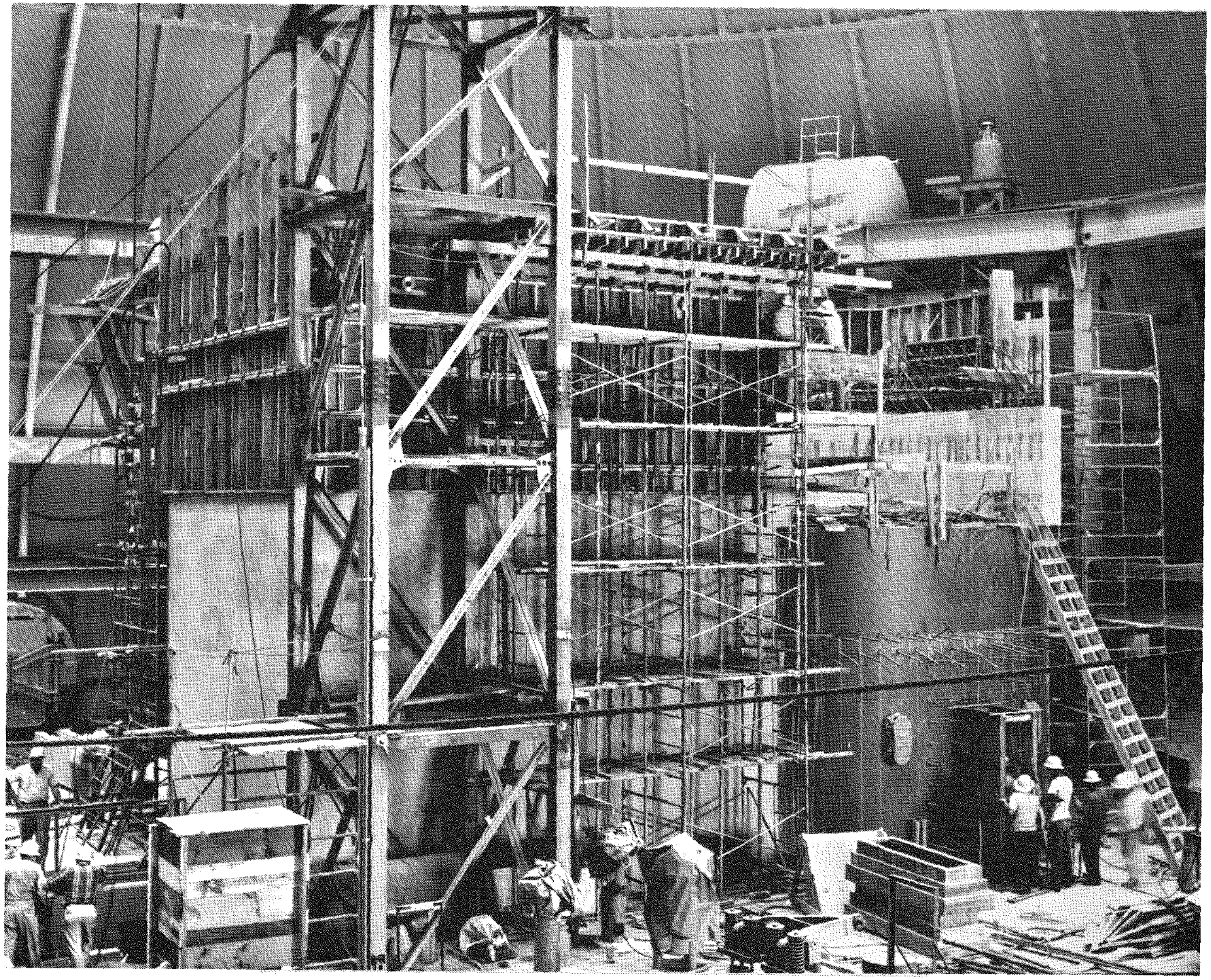


C. BONUS—Overall Site View Looking Southwest January 20, 1961

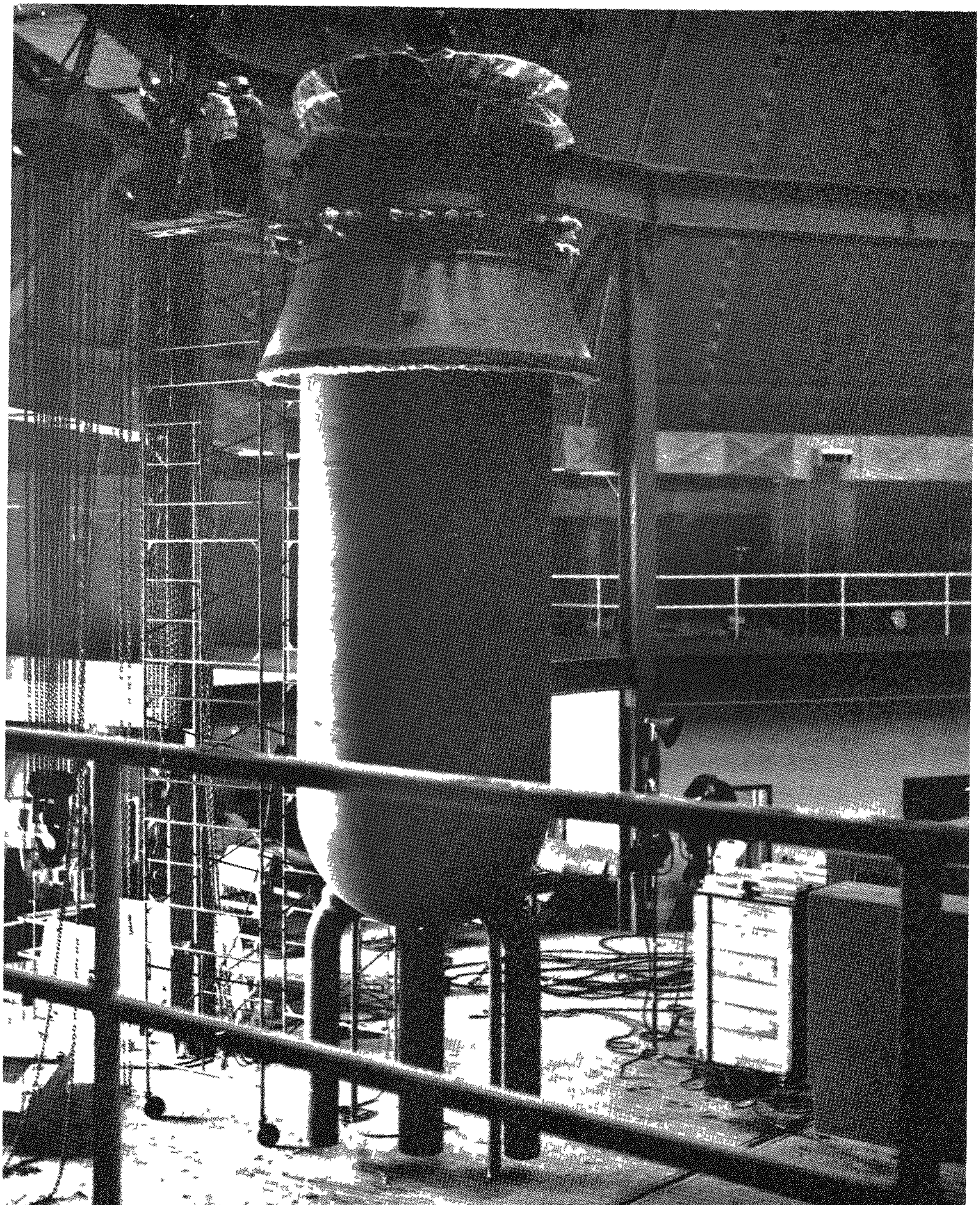
D. BONUS—General View Looking Southwest June 20, 1961



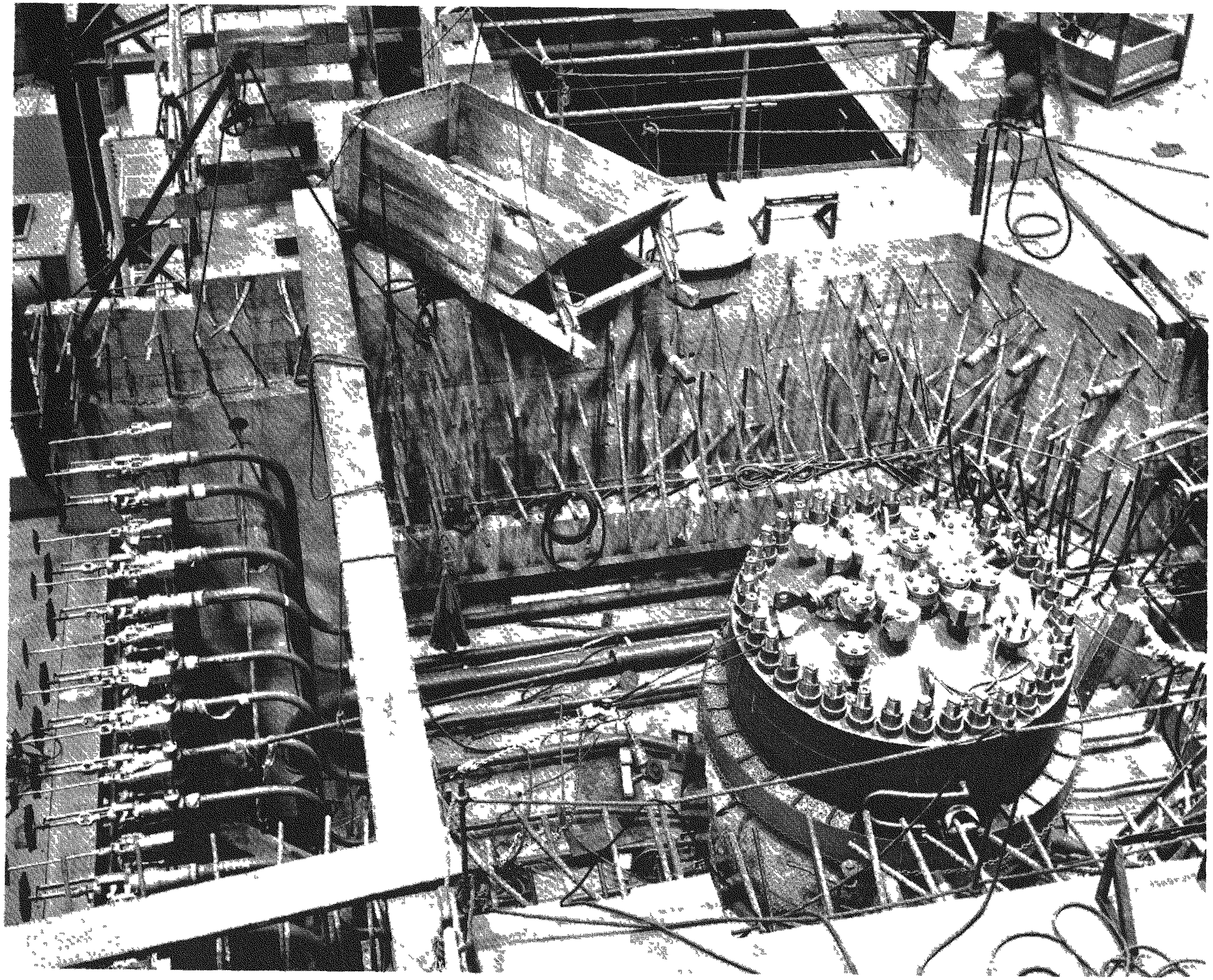
E. BONUS—View Inside Containment Structure   October 20, 1961



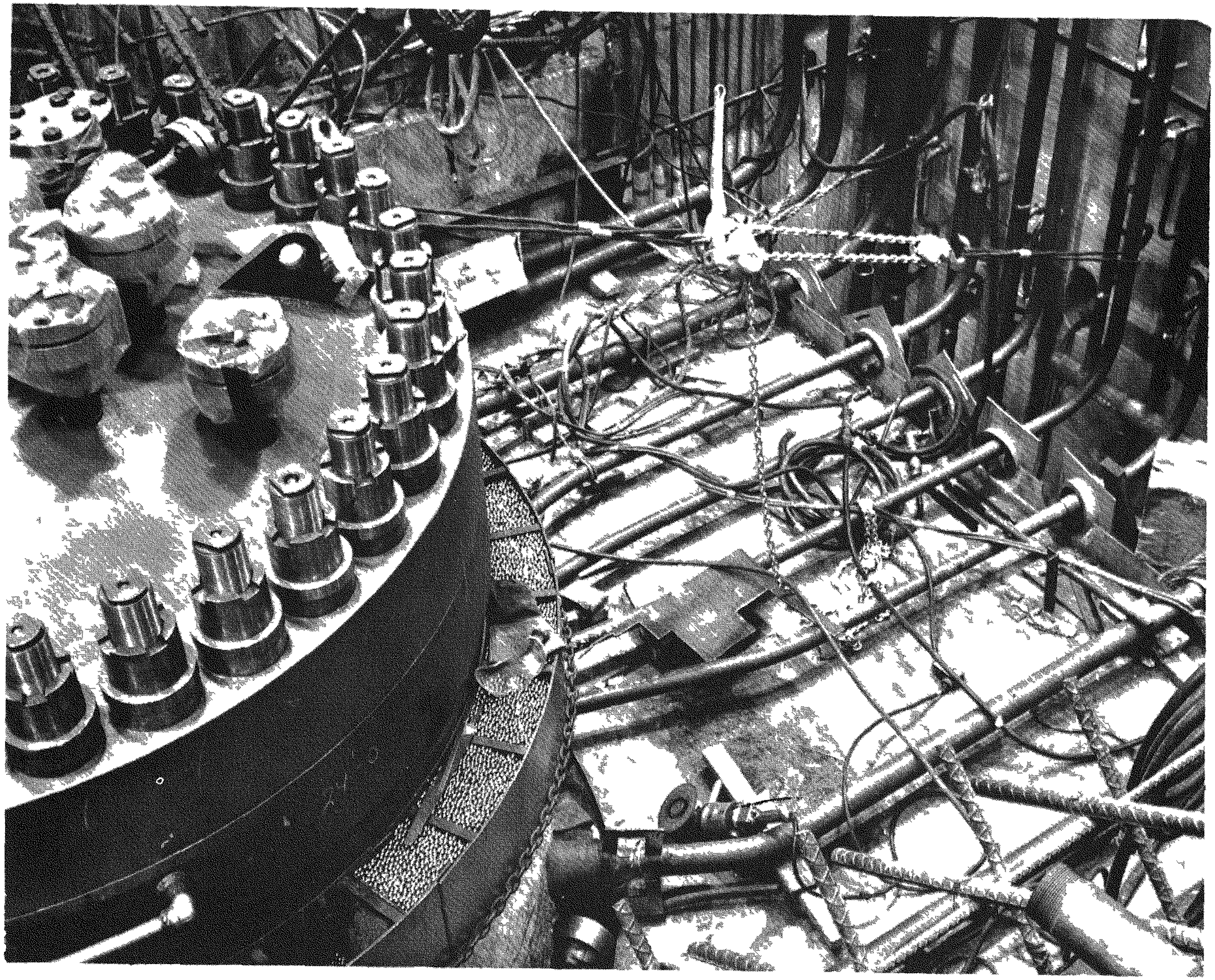
F. BONUS—Fuel Storage Pool and Reactor   January 20, 1962



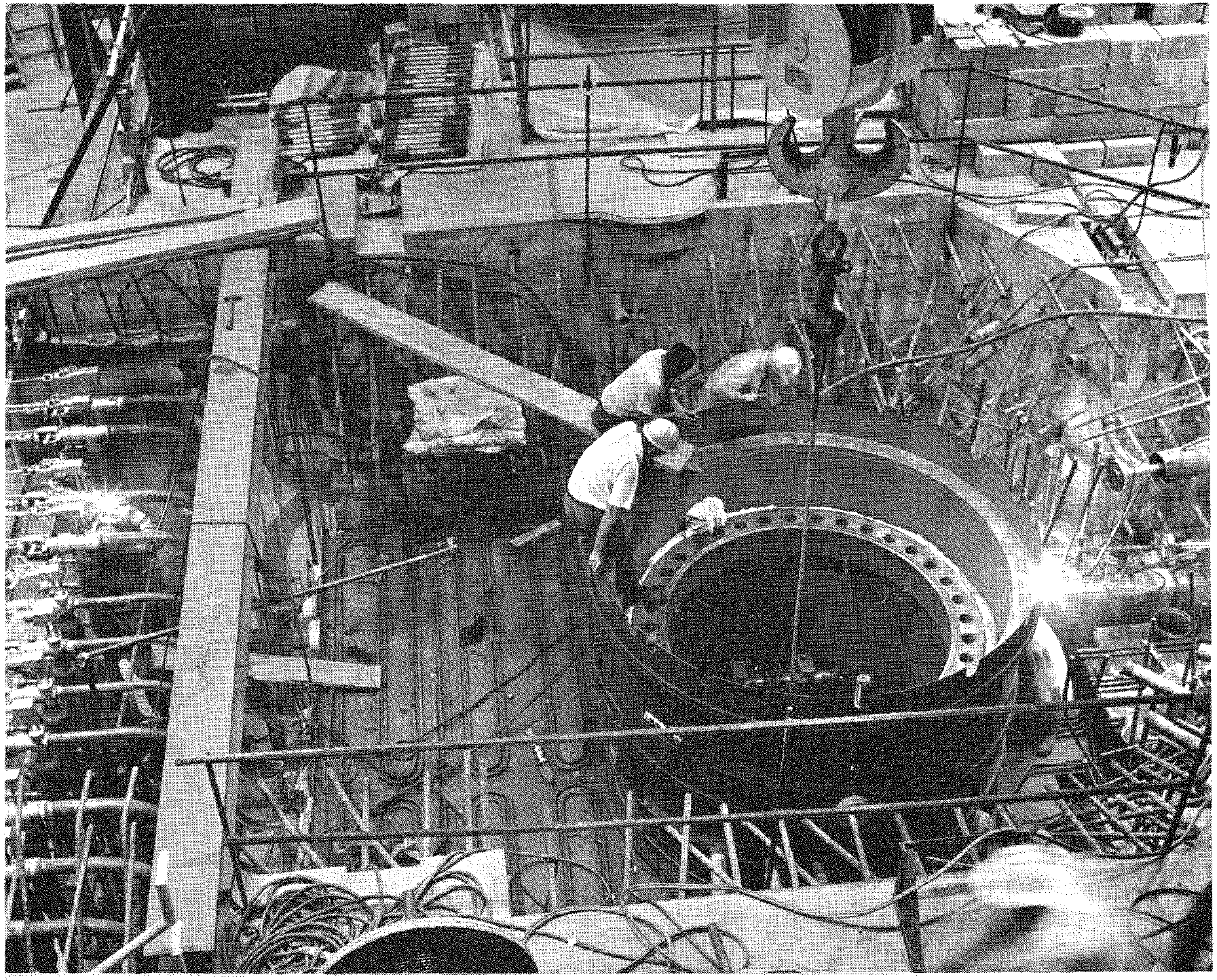
G. BONUS—Reactor Pressure Vessel   February 9, 1963



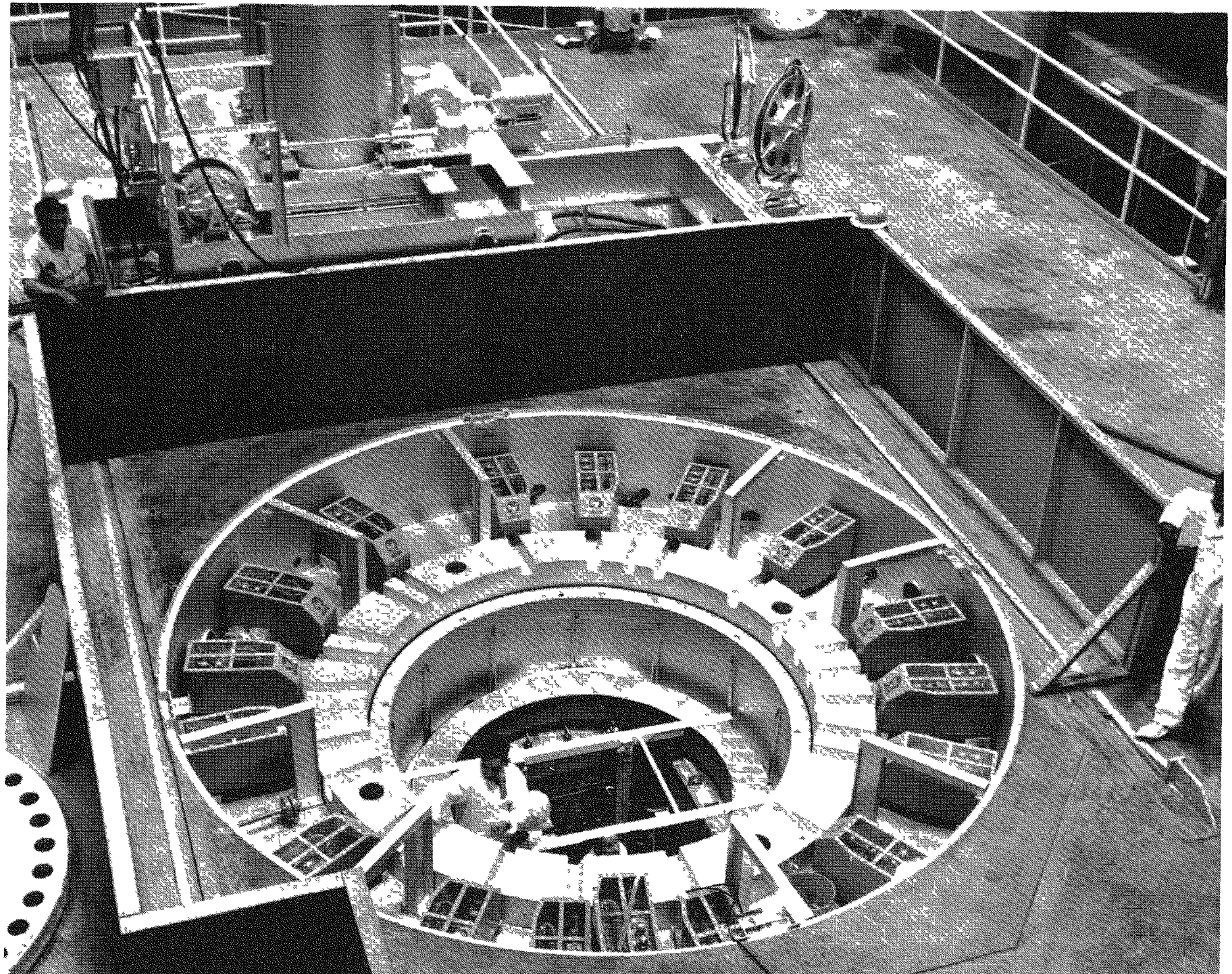
H. Reactor Head Area *March 20, 1963*



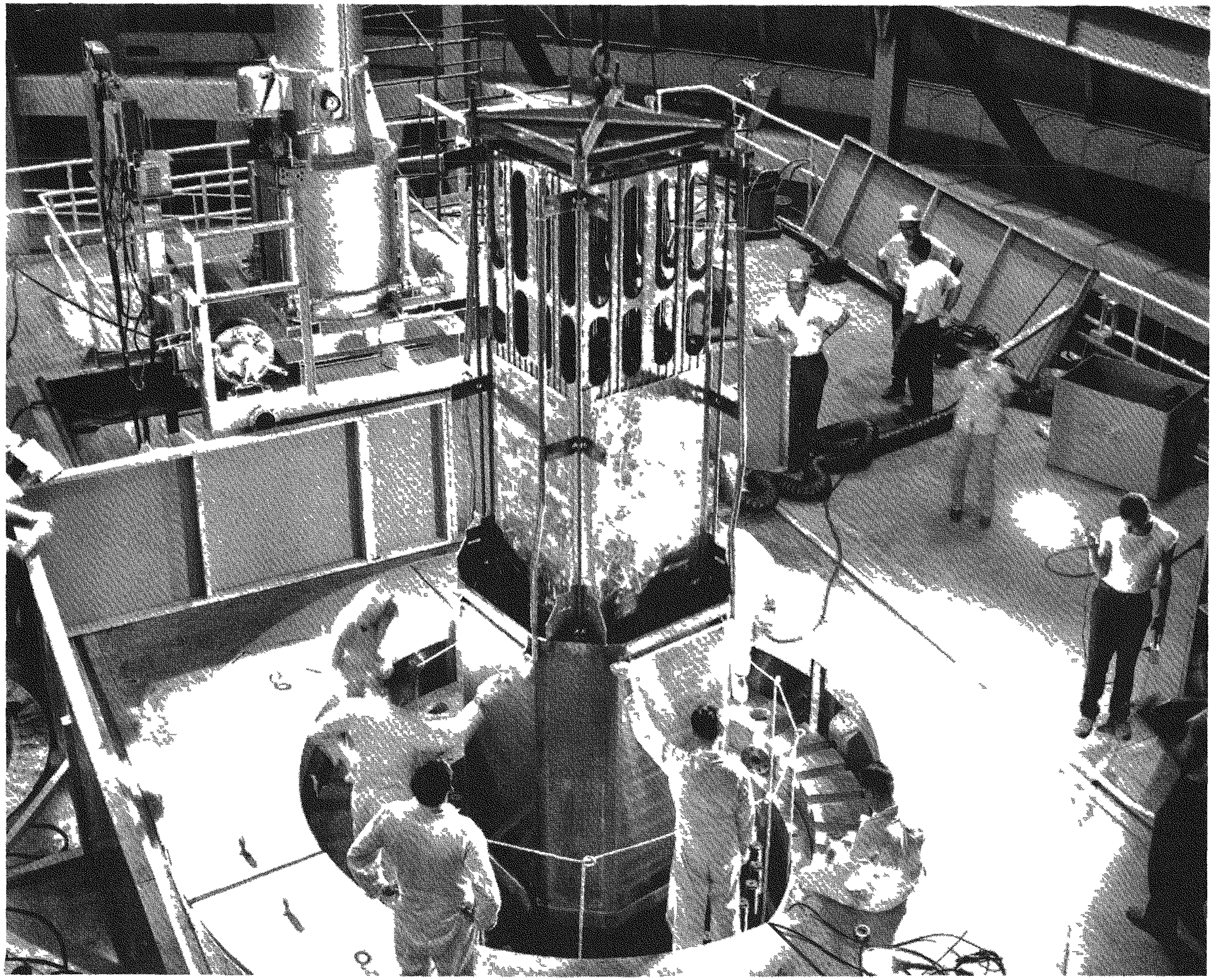
I BONUS—Reactor Head Area March 20, 1963



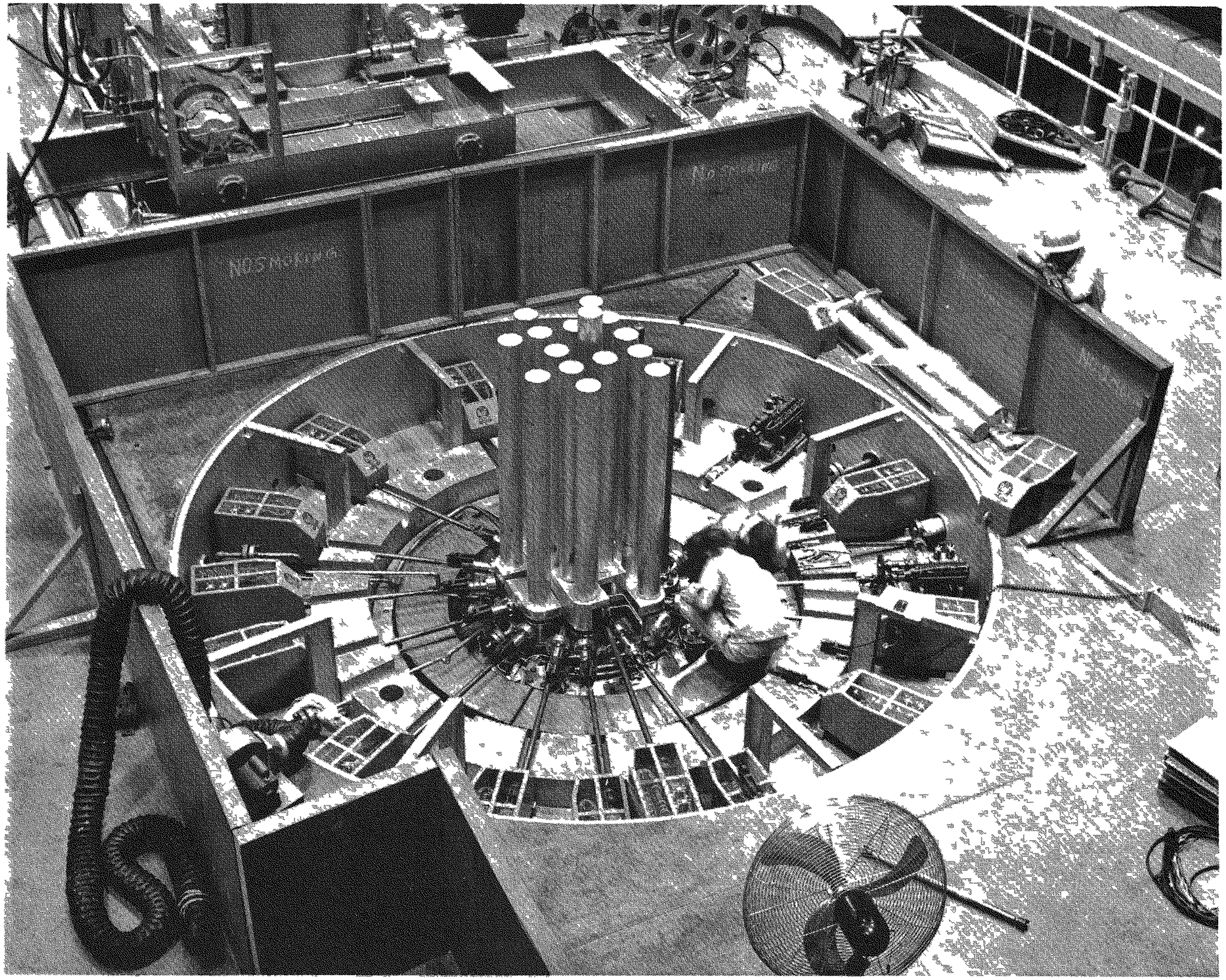
J. BONUS—Reactor Head Area   April 20, 1963



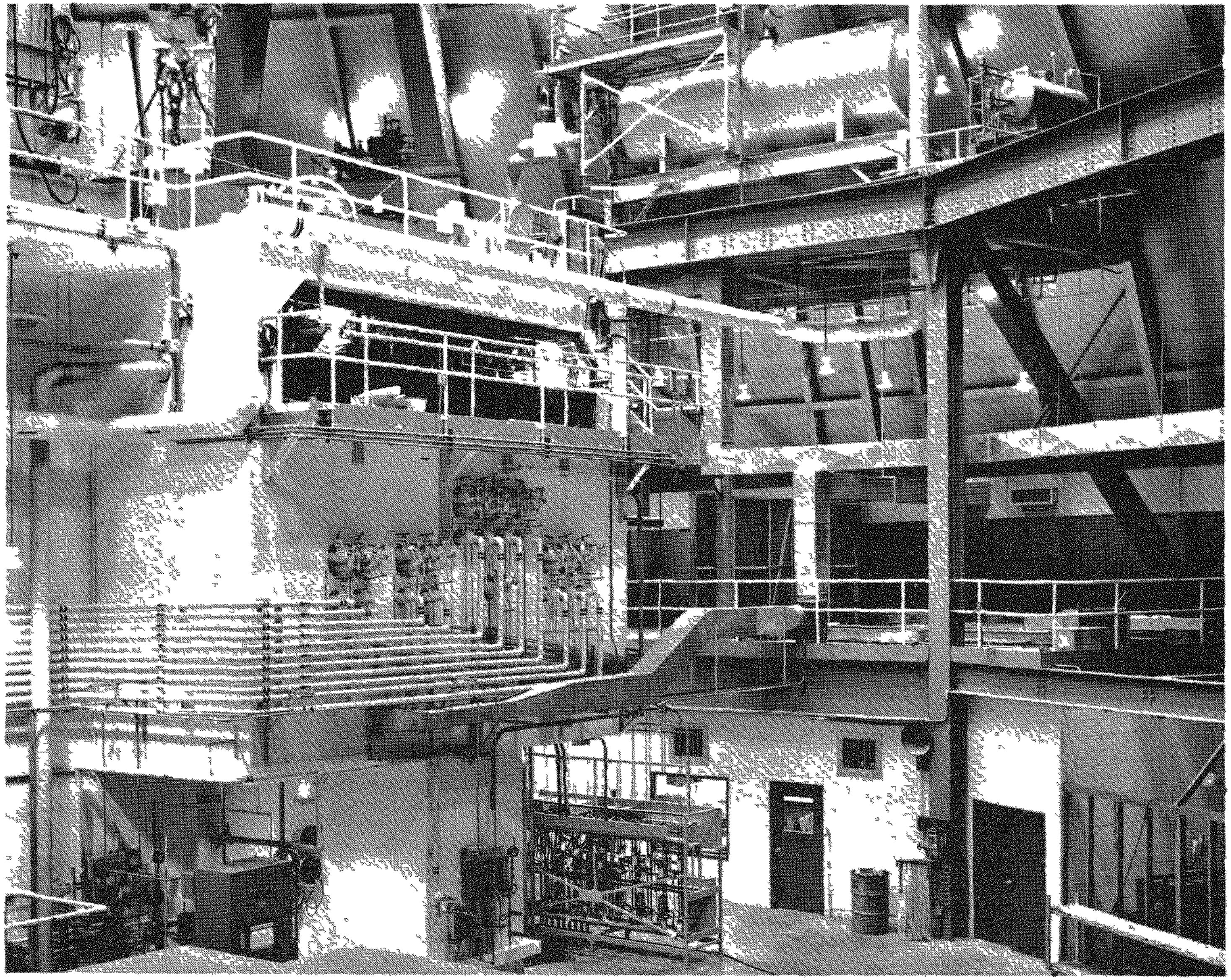
K. BONUS—Steam Dryer/Preheater with Control Rod Drives Installed June 20, 1963



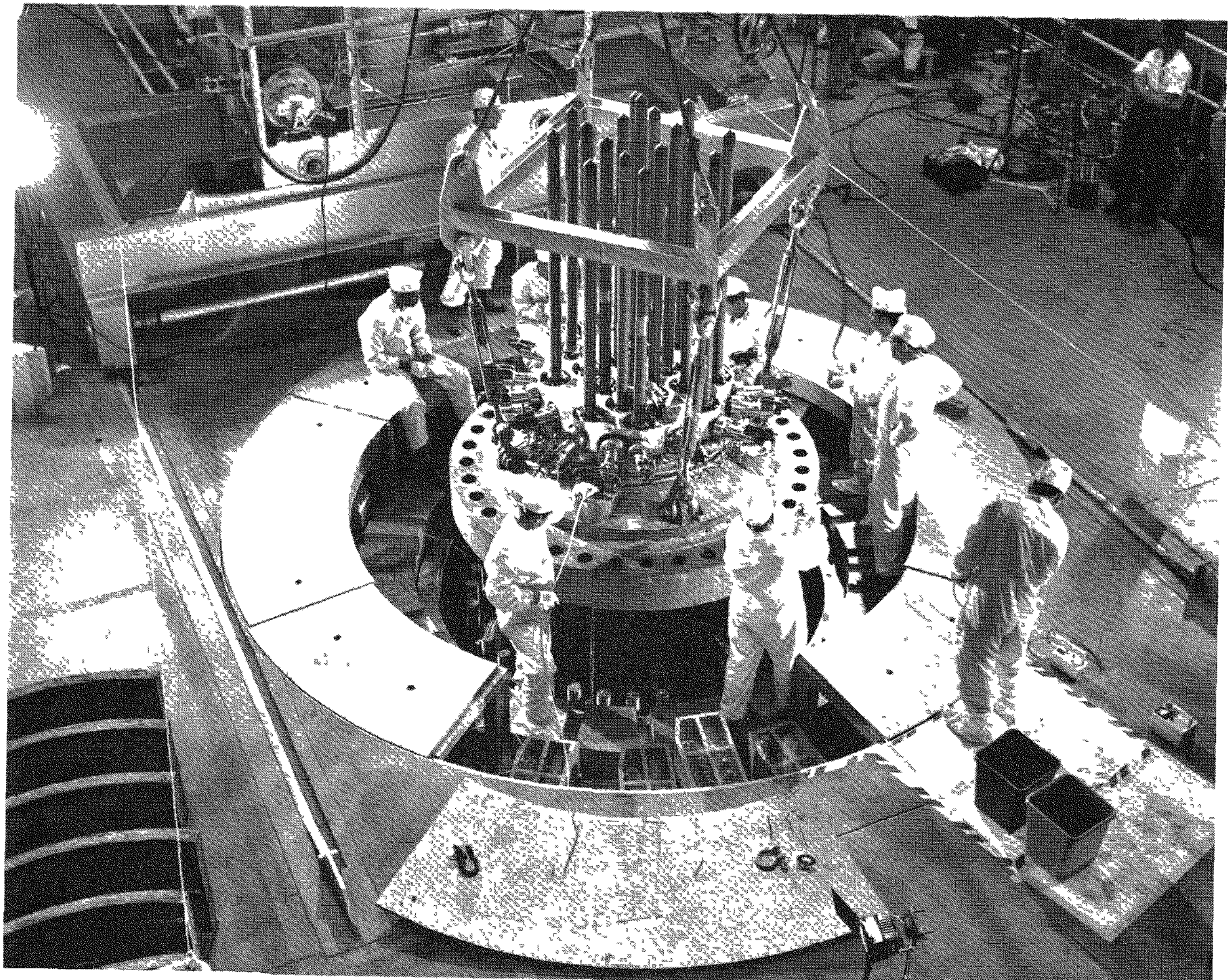
L BONUS—Installing Core Structure August 7, 1963



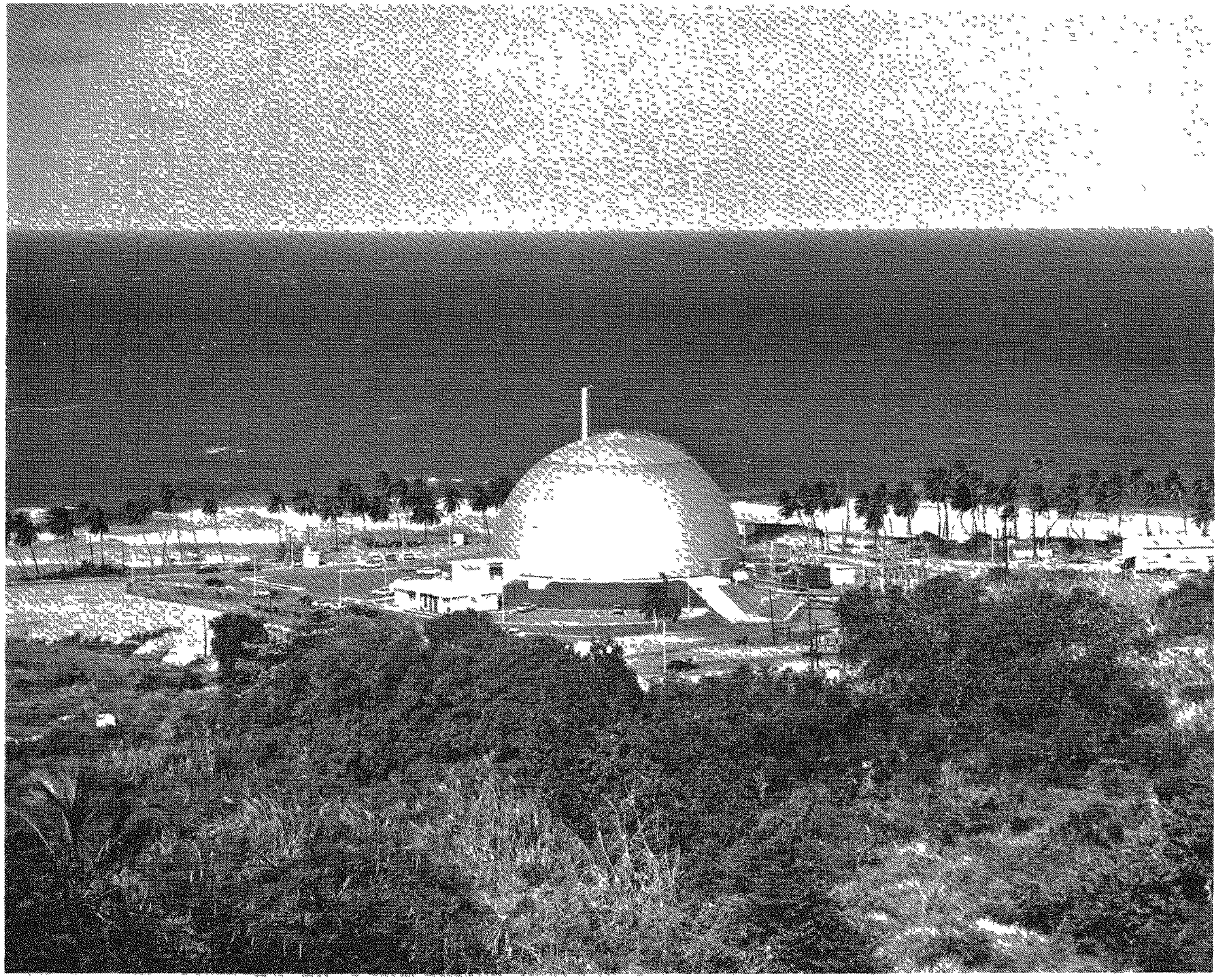
M BONUS—Reactor Head Area October 20 1963



N. Angle Valve Enclosure and Ventilation Duct at Reactor Face January 20, 1964



O. BONUS—*Preparation for Initial Boiler Fuel Loading* April 1964



P. BONUS—Overall Site View Looking West December 19, 1964

Boiling Nuclear Superheater (BONUS)
Power Station

Project Completion Report

Section I - Exhibits

Exhibit A - Scope of Work Through Modification 20
Contract No. AT-(40-1)-2674 - General Nuclear Engineering Corporation

Exhibit B - Scope of Work Through Modification 3
Subcontract No. GNEC-66-100
Contract No. AT-(40-1)-2674 - Jackson and Moreland, Incorporated

EXHIBIT A

SCOPE OF WORK THROUGH MODIFICATION 20

CONTRACT NO. AT-(40-1)-2674

GENERAL NUCLEAR ENGINEERING CORPORATION

SUBSEQUENTLY MERGED INTO

COMBUSTION ENGINEERING, INC.

ARTICLE I - STATEMENT OF WORK

The Contractor shall furnish,for the performance of the work specified below to be done by the Contractor, the services, labor, materials, facilities, plant, equipment, and all other things (except such items as are furnished by the Government) necessary to accomplish the work specified below to be performed by the Contractor.

Part I - Construction Project

A. Description of Construction Project

The construction project for which architect-engineer services are to be furnished consists of a nuclear power plant utilizing a boiling water reactor with integral nuclear superheat to be installed near Rincon, Puerto Rico, at the Punta Higuera site. The reactor portion of the plant shall be capable of producing approximately 152,000 pounds of steam per hour at 850 psig and 900°F. to the throttle of a preferred standard turbine generator with nominal rating of 16,500 kw at 3.5" Hg condenser back pressure but to be operated at a gross output of 17,300 kw at 2.0" Hg condenser back pressure. The turbine generator, condenser, and related conventional generating facilities are not a part of this project but will be designed, furnished, and installed within the nuclear power plant by the operating contractor to be designated by the Commission. The Commission's project will include the following major items:

(1) A boiling water reactor with integral nuclear superheat complete with pressure vessel, core structure, control rod system, reactor instrumentation, fuel handling, fuel storage, shielding, coolant system with pumps, emergency condenser system, purification system for reactor water, and all required auxiliary facilities to produce the steam for operating the turbine generator having capabilities indicated above.

(2) An initial fuel loading with fuel assemblies for the boiling section utilizing fuel rods made up of sintered UO_2 compacts contained in Zircalloy tubes and fuel assemblies for the superheater section utilizing fuel rods of sintered UO_2 compacts contained in stainless-steel tubes.

(3) A nuclear power plant building for the reactor facilities and conventional power facilities providing such containment as required to fulfill reactor safety requirements for the facility in the above-mentioned site.

(4) Auxiliary buildings, supporting structures, equipment, and systems required to serve the reactor facilities including waste disposal, water supply, power, and other utilities and services. In general, the work under this contract will be related to those objectives and items stated in Appendix A of Contract No. AT-(40-1)-2672 and excluding items stated in Appendix B of such contract between the

Commission and the Puerto Rico Water Resources Authority. The referenced appendices are attached hereto and designated Attachments 1 and 2 of this contract.

B. Statement of Architect-Engineer Services

The Contractor shall furnish for the construction project the architect-engineer services described in Titles II, III, and IV below, subject to such further detailed requirements as may be appended to this contract by agreement of the parties.

(a) Title II - Design Services - Under this Title, the Contractor shall:

(1) Upon approval by the Commission of preliminary plans and estimates, or as directed by the Commission, undertake the design of the construction project.

(2) Undertake restudy and redesign work due to such changes and deviations within the scope of the construction project from the approved preliminary design work as may be required by the Commission. This work is to include, but not be limited to, performing work for firming-up BONUS equipment location plans, integrating shielding requirements into the plant layouts, and altering concepts contained in the BONUS Reference Design (PRWRA-GNEC 3A) as may be necessary or advisable to achieve a completely integrated and optimized design.

(3) Prepare and revise for the approval of the Commission and furnish working drawings, details, and specifications for the construction project including the reactor and reactor core, bills of material for critical items of procurement, and equipment specifications in such form and quantity and including such provisions as may be required by law or by the Commission's regulation and instructions. Close cooperation shall be provided with the operating contractor (Puerto Rico Water Resources Authority, hereinafter referred to as PRWRA) or its designees to assure that the design will provide a completely integrated facility.

(4) Prepare a detailed study of the water supply and storage and firefighting systems necessary for the BONUS Power Station. The study is to include, but not be limited to, a consideration of all water requirements both inside and outside the containment building, and a consideration of water supply sources and storage facilities both on-site and off-site.

(5) Prepare detailed electrical wiring diagrams, including wire and cable list sheets, pertaining to all Commission-owned equipment.

(6) Prepare detailed conduit and cable tray layouts for all equipment inside the containment building and the remote control cubicle, except as otherwise directed by the Commission.

(7) Make detailed designs, drawings, or specifications, or make reviews and recommendations of such other equipment or facilities which are part of the BONUS Power Station, as may be required by the Commission.

(8) Prepare working drawings, design details, or specifications for Commission-owned equipment or facilities to be located outside the containment building, as may be required by the Commission.

(9) Prepare or, when directed by the Commission, assist the Commission or participate with others in the preparation of a detailed estimate of the cost and time schedules of construction based on approved design, working drawings, and specifications.

(10) Prepare such recurring reports as drawings and specifications schedules, monthly progress and schedule reports, weekly manpower and progress reports, and such other reports as may be requested by the Commission.

(11) Prepare procedures and operating manuals for the reactor, auxiliary systems, and equipment designed by the Contractor.

(12) Prepare the necessary drawings, specifications, and/or bills of material for new and/or modified components and systems required in the Nuclear Instrumentation and the Off-Gas System; and supervise the installation of the new and/or modified components and systems. This work will be confined to effecting the Nuclear Instrumentation and Off-Gas System physical changes required by the DRL prepared Technical Specifications (Appendix A to BONUS Provisional Operating Authorization DPRA-4), and as more definitively described in GNEC letter of February 5, 1964, J. M. West to F. P. Trent.

(b) Title III - Supervision of Construction - Under this Title the Contractor shall:

(1) Assist the Commission and its designees in analyzing and evaluating proposals and bids for materials, equipment, and services required for construction.

(2) Check and approve, or require revision of, all vendors' drawings and construction contractor's field drawings to assure conformance with the approved design and working drawings and specifications.

(3) Supervise the execution of construction so as to assure adherence to approved drawings and specifications.

(4) Make or procure and/or analyze such field or laboratory tests of construction workmanship, and materials, and equipment as the Commission may require or approve.

(5) Inspect construction workmanship and materials and equipment of facilities designed by the Contractor and report to the Commission as to their conformity or non-conformity to the approved drawings and specifications.

(6) Prepare reports and make recommendations on status of delivery of materials and equipment as the Commission may require or approve.

(7) Prepare monthly reports of the progress of construction and such other reports as the Commission may request, including

weekly activity reports, partial, interim, and final estimates and reports of quantities and values of construction work performed for payment or other purposes.

(8) Furnish approved tracings in such form as the Commission requires showing construction as actually accomplished.

(9) Prepare a Project Completion Report including final cost reports in the form and quantity prescribed by the Commission.

(c) Title IV - General - Under this Title the Contractor shall:

(1) When requested, consult with and advise the Commission and such other individuals as the Commission may designate, with respect to any matters connected with the Contractor's undertakings under Part I of this contract.

(2) Supplement, as required, the Preliminary Hazards Summary Report prepared by the Contractor as a subcontractor under Commission Contract AT-(40-1)-2484 with the Puerto Rico Water Resources Authority. Such supplementary work may be necessary either prior or subsequent to submittal of the Preliminary Hazards Summary Report to the Advisory Committee on Reactor Safeguards.

(3) Prepare and submit an acceptable Hazards Summary Report as soon as sufficient data are available for review by AEC and in form for submittal to the Advisory Committee on Reactor Safeguards. The report shall be in sufficient detail and of quality which would be required if it were being submitted with respect to a utilization facility subject to licensing by the Commission. The report should provide a complete description of the facility, an analysis of the site selected, the potential reactor hazards with a discussion of the maximum credible accident and its effect on the surrounding area, the safety features of the reactor, the control system, the reactor supporting services, and the methods of containment. Emphasis should be placed on the effects of the potential hazards on public safety. The report shall also contain the preliminary start-up and operating procedures which are to be developed in cooperation with the Operating Contractor. Final operating procedures will be prepared upon completion of start-up tests.

(4) Prepare and submit acceptable supplemental information to the Hazards Summary Report in the event that additional data are required to obtain approval to operate the reactor. This supplemental report should reflect any changes in the design of the reactor, the containment, the supporting facilities, and the adjustment of the complex to the site. Potential hazards, including the maximum credible accident shall be re-evaluated, as necessary, based on any design changes or new criteria which may develop after submission of the Hazards Summary Report.

(5) a. The Contractor shall direct precritical testing, fuel loading, start-up, and operational testing of the Nuclear Power Plant (which term as herein used includes both the Government-owned portion of the plant, the 'Reactor Plant'; and the portion owned by the Puerto Rico Water Resources Authority, the 'Generator Plant'; and notwithstanding the

provisions of Article I, Part I, A (4)), in accordance with operating procedures agreed to by the Commission, the Puerto Rico Water Resources Authority, and the Contractor, up to that point where the Commission determines that the Nuclear Power Plant is ready for the extended load test described in Contract No. AT-(40-1)-2672 or at such earlier time as the parties may agree upon; provided that the Contractor shall not be required to perform these services beyond October 31, 1965, unless further extended by the parties, which extension for up to two months beyond October 31, 1965, may be accomplished by notice from the Contracting Officer and the provision of sufficient funds for such additional period, including additional fixed fee as provided in Article II, Section 1, Paragraph e.

b. It is recognized that work under this subparagraph will include necessary training of Contractor personnel and the securing of AEC licenses for operators and supervisory operators. Such training may be accomplished in part at other reactor sites including those of the Commission and in the latter cases, the Commission will make the necessary arrangements.

c. The accomplishment of the work under this subparagraph is dependent upon a force of adequately trained employees of the Puerto Rico Water Resources Authority being available in the Nuclear Power Plant to work under the Contractor's direction. The availability of such personnel, whether engaged in activities with respect to the Reactor Plant, the Generator Plant, or both, will be under terms and conditions satisfactory to the Contractor to assure the degree of unified organization and responsiveness to direction which is essential to the safe, efficient, and orderly start-up and operation of the facility. The Contractor shall determine and make known to the Commission its requirements for such personnel and the Commission will use its best efforts to obtain the personnel at the time required by the Contractor.

d. In the performance of the work under this subparagraph B.(c) (5), the Contractor will not be required to furnish at the plant site any facilities, equipment, materials, supplies, or housekeeping, maintenance, or other supporting services.

e. The Contractor shall, to the extent requested by the Commission, initiate or participate in any proceedings necessary to obtain authorization to operate the Nuclear Power Plant. The Contractor's obligations under this subparagraph shall not extend beyond the date upon which the Puerto Rico Water Resources Authority is granted authorization to begin the extended load test mentioned in subparagraph a. above, or shall not extend beyond the date upon which the responsibility for operation of the Nuclear Power Plant is assigned to the Puerto Rico Water Resources Authority, whichever comes first.

(6) Conduct a program of training for the Puerto Rico Water Resources Authority personnel beginning on or about December 1, 1961, and ending four months after the start of reactor fuel loading. The number of persons to be trained

is expected to be approximately eight supervisors and twelve reactor operators. The training program, the details of which shall be established with the concurrence of the Contracting Officer, shall be essentially as described in the five parts as outlined on pages 3 to 5 of the Contractor's proposal, dated July 27, 1961, and shall have the objective of fully preparing the trainees for the safe operation of the Reactor Plant and the securing of necessary AEC operator's licenses.

(7) Prepare procedures for functional checkout of reactor equipment and reactor systems; supervise functional checkout work on reactor equipment and reactor systems to be performed by others at the reactor site; and advise the Commission as to the adequacy of the equipment and systems for their intended use. These services cover checkout of the reactor equipment and systems prior to precritical testing.

(8) The Contractor shall analyze the deficiencies in the Pressure Control System (procured in an uncompleted or unsatisfactory condition from another company) as it relates to the Contractor's Specification 66-11A; propose methods of correcting those deficiencies which may prevent safe operation of the Nuclear Power Plant; prepare necessary drawings for the correction of the deficiencies; prepare necessary specifications and/or bills of material for components or services required for the correction of the deficiencies; and supervise the actual correction of the deficiencies at the place of fabrication or installation.

C. Except for such work and services as may be performed under subcontracts and purchase orders entered into in accordance with the article entitled "Subcontracts and Purchase Orders", the Contractor shall perform the services required under Part I at its facilities in Dunedin, Florida, and at such other locations as may be approved by the Contracting Officer.

Part II - Research and Development Project

A. The Contractor shall utilize, under Part I-B, the results of specific research and development activities applicable to the BONUS reactor completed or being performed under Commission Contract AT-(11-1)-795 with Combustion Engineering, Inc. Following is a list of certain problem areas being resolved under the aforementioned contract which are applicable to the BONUS reactor:

(1) Fuel element mock-ups.

(2) Loss of coolant experiments.

(3) Development of stagnant steam gap as an insulating medium.

(4) Development of seal connectors.

(5) Control development.

(6) Intermediate critical experiment.

B. The Contractor shall perform, for use under Part I-B, research and development work consisting of the following items:

(1) Critical Experiment - Assist in planning, coordinating, and evaluating, and check BONUS core calculations utilizing data resulting from a critical experiment to be performed under Commission Contract No. AT-(11-1)-795 with Combustion Engineering, Inc. The critical experiment is expected to simulate, from a nuclear point of view, the actual proposed BONUS core and will include the following typical and representative types of measurements and analyses:

(a) Resonance escape probability.

(b) Thermal utilization of fuel assemblies as a function of geometry.

(c) Gross power distribution for the boiling region relative to the superheating region for different configurations.

(d) Reactivity effect of variable water channel between boiling and superheating regions.

(e) Detailed power distribution within fuel elements.

(f) Void coefficients as a function of temperatures and metal to water ratio.

(g) Temperature coefficients as a function of metal to water ratio.

(h) Effects of control rods on over-all reactivity and on the relative power outputs of the boiling and superheating regions.

(i) Soluble poison concentration as a function of shutdown margin for different configurations.

(2) Fuel Assembly Performance Tests - The following typical and representative types of investigations, evaluations, and/or tests shall be made on superheating fuel element mock-ups fabricated under Commission Contract AT-(11-1)-795:

(a) Evaluate performance of the proposed and alternate fuel rod centering springs and flow spacers in superheated steam under anticipated velocity.

(b) Evaluate the effect of the steam flow and vibration of the fuel rod on the thin wall coolant tube guide member.

(c) Reproduce the flow of superheated steam through the fuel element - with saturated water surrounding the element - to simulate the thermal gradients and actual vibration conditions. Similarly, reproduce the flow on sections of the concentric tube standpipes.

(d) Measure the pressure drop through the multi-bend standpipes and cross-over plenums of a complete superheater fuel assembly using air flow.

(e) Make air flow measurements to properly size the orifice within the steam seal connectors utilizing full-scale assembly mock-ups.

(3) Removal of Moisture from Steam - To determine the effectiveness of moisture removal from the steam which enters the superheater assembly, tests are to be conducted on the proposed moisture separator or steam drier.

(4) Fuel Unloading Technique - To determine the functional reliability of special tools for disconnecting and reassembly of the superheater steam seal connectors, mock-ups simulating the pressure vessel top geometry are to be constructed and the actual operations which are required for fuel unloading shall be carried out.

(5) Water Spray for Cooling Superheater Fuel Elements - To determine the effectiveness of the water spray in cooling the superheater fuel assemblies after complete loss of moderator from the pressure vessel, the fuel lattice geometry is to be simulated and the design of the spray system checked out.

(6) Miscellaneous Small Items - Miscellaneous research and development tasks which cannot be specifically identified at present. This category is intended to cover all miscellaneous small tasks, of which the following are typical examples: Testing of bellows for boiler fuel assemblies; testing of hold-down devices for boiler fuel assemblies; determination of flow characteristics of orifices for boiler and superheater fuel assemblies; mock-up of temporary poison shims; investigation of efficiencies with which steam can be removed from the moderator region of the superheater zone; proof test of production model of the control rod drive mechanism ordered for the reactor.

(7) Determination of, by testing and study of stainless-steel overlay samples, the structural integrity of the reactor pressure vessel. This work will be as described in Southwest Research Institute proposal 7-2192, dated April 25, 1962, entitled "Demonstration of the Structural Integrity of the Cladding on the BONUS Reactor Pressure Vessel". The actual testing will be performed under the Contractor's subcontract with Southwest Research Institute and the Contractor will supervise performance and analyze the results of the work.

C. Except for such work and services as may be performed under subcontracts and purchase orders entered into in accordance with the article entitled "Subcontracts and Purchase Orders", the Contractor shall perform the services required under Part II at its facilities in Dunedin, Florida, and at such other locations as may be approved by the Contracting Officer.

D. Work to be performed by Combustion Engineering, Inc., under Contract No. AT-(11-1)-795 includes the fabrication of certain mock-ups, jigs, fixtures, etc. (presently estimated cost of $20,000), which may be required by the Contractor in the performance of work described in Paragraphs B.(2) through B.(6) above and also includes the provision of computer labor and related assistance (presently estimated cost of $9,500), which may be required by the Contractor in connection with the Contractor's analysis of the critical experiment as described in Paragraph B.(1) above. The estimated costs stated in this Paragraph D. are not included in the estimates of cost for the contract work stated in Article II.

E. The Contractor shall perform development work required to obtain special tools and devices best suited to the Reactor Plant operating requirements. The special tools and devices covered by this paragraph are of a class which includes, but is not necessarily limited to, lock nut crimping tool, underwater lamp, underwater cutting tool, filter and demineralizer lifting tool, drum fill indicator, and special handling tools for use in the reactor vessel. Development work shall include design and fabrication of the tools or devices, testing under simulated reactor conditions, and reworking when necessary. After satisfactory operation of each tool or device, it is to be suitably packaged and shipped to the Reactor Plant site. The approval of the Contracting Officer shall be secured prior to beginning work under this paragraph on any special tools or devices. (This approval requirement is agreed to have been met with respect to those items itemized in the Contractor's letter of July 26, 1961, to R. B. Somers.)

F. The Contractor shall perform a program of tests to determine some of the effects of chloride corrosion on the superheater fuel system. The tests shall be conducted using various chloride-to-oxygen ratios in the steam coolant and at various flow rates and will conform generally to Phase I of the test program described in the Contractor's letter of August 16, 1961, and authorized by letter dated September 8, 1961, from R. B. Somers.

G. Commencing on May 3, 1962, the Contractor shall perform studies on the irradiation of SS 348 clad BONUS fuel elements in E-SADE loop, as authorized by the Commission's teletype to the Contractor dated May 3, 1962, from S. R. Sapirie to J. M. West. The Contractor will be responsible for the design of the BONUS type fuel element utilized, the coordination of the irradiation and post-irradiation examination at the E-SADE steam loop, and for providing the final mechanical and metallurgical evaluation of the success of this test element in the referenced environment.

H. Commencing on May 18, 1962, the Contractor shall perform studies on the chloride deposition on superheater surfaces, as authorized by the Commission's teletype to the Contractor dated May 18, 1962, from S. R. Sapirie to J. M. West. These studies will be conducted in the steam loop at the Bayboro Plant of the Florida Power Corporation and will be an attempt to evaluate the amount and location of chloride deposit that will possibly plate out of the superheat steam that has passed through the BONUS design preheater-dryer section. To accomplish these studies, the Contractor will be required to: (1) make certain hardware modifications to the steam loop; (2) inject the radiochloride addition to the loop coolant steam while maintaining the required control and accountability; (3) determine the plate out rate of the chloride under the referenced environment; and (4) evaluate the effects of steam velocity, fuel clad temperature, inlet steam moisture content, and geometry on chloride-type scale deposition.

I. Commencing on June 4, 1962, the Contractor shall perform steam corrosion tests on brazed joints in BONUS superheater fuel, as authorized by the Commission's teletype to the Contractor dated June 4, 1962, from S. R. Sapirie to J. M. West. Combustion Engineering, Inc., under another contract with the Commission, will braze nine spacer rings on to each of three type 347 SS clad electrical heaters furnished by the Contractors. The Contractor will insert these heaters into the existing BONUS superheat steam loop at the Bayboro Plant of the Florida Power Corporation and will evaluate the performance of these brazed joints under simulated BONUS nuclear superheat conditions. The Contractor will be required to provide the final mechanical and metallurgical evaluation of the results of these tests.

J. The Contractor shall perform development work required to obtain small miscellaneous hardware best suited to the reactor plant operating requirements. Miscellaneous hardware covered by this paragraph is of a class which includes, but is not necessarily limited to, such items as start-up instrument thimble, reactor superstructure box cover, superheater lifting plate, standpipe extension, shim baskets, fuel pool service rack, and failed fuel fission gas accumulators. Development work shall include design and fabrication of the miscellaneous hardware, testing under simulated reactor geometries, and reworking when necessary. After satisfactory operation of each item of miscellaneous hardware, it is to be suitably packaged and shipped to the reactor plant site. Development and/or fabrication work shall be performed only on those small miscellaneous hardware items which are recommended by the Contractor. The approval of the Contracting Officer shall be secured prior to beginning work under this paragraph on any item of miscellaneous hardware. (This approval requirement is agreed to have been met with respect to Items 2, 3, 8, 11, 12, 13, 14, 15, 17, 18, and 22, listed in Contractor's letter of September 19, 1962, to R. B. Somers.)

K. The Contractor shall perform, beginning as of July 23, 1964, a preoperational analysis program, including systematic recording, analysis, and reporting in a form which can be utilized to guide future plant operations, the content to include the areas outlined in the document entitled BONUS PREOPERATIONAL PROGRAM, dated July 1, 1964, attached hereto and made a part hereof. Taking on data shall not be required after completion of start-up; analysis and extrapolation shall have the objective of providing guidelines for a minimum period of two months of operation after completion of start-up. Start-up is completed when it is mutually agreed that the plant is technically and physically ready for extended (6-month) load test. Thirty-five copies of all reports shall be furnished.

L. The Contractor shall perform enrichment studies for BONUS replacement fuel and related fuel management analysis. The studies shall be made with respect to the following assumptions and conditions:

(1) The Commission will attempt to provide within about eight months an additional eight spare superheater assemblies having the same general design, geometry, materials, and the same enrichment as the present superheater fuel, but with a fuel clad of Incoloy-800 rather than Inconel-600.

(2) The Contractor shall initiate and conduct related studies having the purpose of:

(a) Satisfactorily describing the physics characteristics of the seactor core at the time replacement boiler or superheater fuel of new enrichment is needed for insertion.

(b) Developing calculational methods suitable for use in BONUS fuel management.

(3) Replacement boiler fuel shall have the same general design, geometry, and materials as the present boiler fuel, except that:

(a) A full length fuel rod shall be used rather than two half length rods.

(b) Uncored pellets shall be used in the corner of the boiler

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assemblies if the Contractor studies indicate such to be desirable.

(c) Several new assemblies of natural uranium shall be specified for use around the central control rod if the Contractor studies show such to be required.

(4) The Contractor shall calculate the enrichment for two types of replacement superheater fuel having the same general design, geometry, and materials as the present superheater fuel, except that:

(a) Type I replacement fuel shall have an Incoloy-800 fuel cladding of 18 to 20 mil wall thickness and shall have Incoloy-800 coolant tubes and pressure tubes of the approximate dimensions as the present superheater fuel.

(b) Type II replacement fuel shall have Incoloy-800 fuel cladding of 18 to 20 mil wall thickness and shall have stainless-steel 348 coolant and pressure tubes of present dimensions.

(5) Enrichment calculations shall be made with reference to the following two assumptions as to the residence time of the present superheater fuel in the reactor:

(a) The residence time is limited only by reactivity requirements.

(b) The residence time is limited by structural failures, the numbers of which and occurrences in time are to be estimated by the Contractor.

The term for this additional work shall run from September 28, 1965, concurrently with Startup Operations for a best effort to provide tentative recommendations for enrichment within three months. If the study is not complete at the completion of Startup Operations, the effort will continue in the operational phase contemplated to begin after Startup Operations.

Attachment No. 1 to
Contract No. AT-(40-1)-2674

APPENDIX "A"

CONTRACT NO. AT-(40-1)-2672

REACTOR PLANT DESIGN OBJECTIVES

The division of responsibility for providing the nuclear power plant represented by the lists in this Appendix and Appendix "B" is made upon the premise of use of a geodesic dome to house and provide general containment for the nuclear power plant. In the event the Commission determines for reasons of safety or the parties mutually agree for any reason that such a structure would not be suitable for the proposed plant, the parties will negotiate in good faith a revision of Appendices "A" and "B" to reflect a sharing of plant construction responsibility and related costs comparable with that included in the Appendices as originally written, but related to a different concept for plant housing and containment.

It is the Commission's objective to design and furnish a boiling water reactor plant with integral nuclear superheat and install same as part of a nuclear power plant to be located near Rincon, Puerto Rico, at the Punta Higuera site. The reactor plant shall be capable of producing approximately 152,000 pounds of steam/hour at 850 psig and 900°F. to the throttle of a preferred standard turbine generator.

Facilities and equipment furnished by the Commission, as distinct from that furnished by the Contractor, are set forth in the following paragraphs:

1. Reactor Plant Building

The Reactor Plant Building shall provide containment for the reactor plant and also includes space for the generator plant equipment. The reactor plant building will include the following:

a. Excavation, substructures, and floor except for foundation work for generator plant equipment.

b. Superstructure except for generator plant equipment supporting structure.

c. Geodesic containment dome (complete with air lock doors, etc.).

d. Control and operating rooms.

e. Internal plumbing.

f. Painting except generator plant equipment.

g. Crane and crane structures.

h. Structural steel except for generator plant.

i. Ventilation and air conditioning system.

j. Fire protection system.

k. Telephone, Intercommunication, and Paging Systems.

l. Lighting and convenience outlet system complete with branch circuits and distribution panels but excluding main feeders to the panels.

2. Storage facility for radioactive solid waste.

3. <u>Reactor System Equipment</u>

a. Reactor and associated equipment which include pressure vessel and all internals, and control rod systems.

b. Reactor fuel handling and storage equipment.

c. Reactor water recirculation system (including preheater).

d. Reactor steam and feed water return system including attemporator, feedwater purification system, feedwater heaters, and feedwater pumps.

e. Emergency condenser system.

f. Soluble poison system.

g. Reactor water purification and shutdown cooling system.

h. Fuel storage pool cooling and clean-up system.

i. Shield cooling system.

j. Reactor water supply system including storage tanks and demineralizers.

k. Radioactive waste disposal and treatment system.

l. Biological shield.

m. Gas Disposal System.

4. Elevated water storage tank system and reactor plant building gas exhaust stack system.

5. Instrumentation and control for all systems furnished by the Commission. These instruments and controls will be connected by the Commission to provide signals to and from Contractor furnished equipment, instruments and/or junctions, as required; included are source sensing devices, interconnecting intelligence channels, indicating and/or recording instruments, local, and central panels and consoles.

6. Piping and valving will be furnished by the Commission in the direction of process flow from services and process equipment provided by the Commission to the nearest connection to, or at, the Contractor's services and process equipment. Connections to services and process

piping provided by the Contractor will be made by the Commission using flanges or other connectors provided by the Contractor in accordance with the Commission requirements.

7. Health Physics Equipment.

8. Any items of structure, equipment, or auxiliaries not specifically provided for either in the above or in Appendix "B" shall be assigned for construction and related costs, by mutual agreement between the Commission and Contractor, in accordance with the over-all division of responsibility reflected by specific assignments in these appendices.

Attachment No. 2 to
Contract No. AT-(40-1)-2674

APPENDIX "B"

CONTRACT NO. AT-(40-1)-2672

GENERATOR PLANT DESIGN OBJECTIVES

The division of responsibility for providing the nuclear power plant represented by the lists in this Appendix and Appendix "A" is made upon the premise of use of a geodesic dome to house and provide general containment for the nuclear power plant. In the event the Commission determines for reasons of safety or the parties mutually agree for any reason that such a structure would not be suitable for the proposed plant, the parties will negotiate in good faith a revision of Appendices "A" and "B" to reflect a sharing of plant construction responsibility and related costs comparable with that included in the appendices as originally written, but related to a different concept for plant housing and containment.

The general criteria or characteristics of the Generator Plant Equipment and services to be furnished by the Contractor, including complete installation, are set forth in the following paragraphs:

1. Ground improvements and services for the entire site including the following:

    a. Clearing and Grading Site.

    b. Yard Storm Drainage System.

    c. Sanitary Sewer System.

    d. Area and Substation Fencing.

    e. Access and Site Roads, Parking Lot, Sidewalks.

    f. Landscaping.

    g. Deep Well, Pumping Equipment, and Other Appurtenances.

    h. Sea Walls.

    i. Outdoor Fire Protection System.

2. Entrance Building adjacent to wall of Reactor Plant Building, complete with plumbing, lighting, ventilation, and heating. The Entrance Building will provide access to the reactor plant and will furnish about 2,700 square feet to house at least the following: site administrator's office, change area for operational personnel and guards (including lockers and clean-up facilities), lobby with a

reception and information desk, men's and women's toilets, and janitorial services.

3. Auxiliary cooling system including cooling tower.

4. General area lighting.

5. Instrumentation systems for turbogenerator unit and for other conventional (non-nuclear) equipment provided by Contractor; instrumentation systems shall include source sensing devices, intelligence channels, local and central panels, and consoles.

6. Foundation work in Reactor Plant Building for generator plant equipment including all bars, sleeves, expansion joints, and recesses in concrete for receiving adjacent flooring provided by the Commission.

7. Turbo-Generator Unit complete including piping and wiring systems, hydrogen cooling equipment, starting and turning equipment, governor control system, turbine stop valve, etc. All Generator Plant Equipment shall be rated to be capable of using at least the 152,000 lbs/hr. steam to be delivered from the Reactor Plant. In this regard, the turbine generator should have a nominal rating of at least 16,500 kw at 3.5" mercury condenser back pressure but be capable of at least 17,300 kw at 2.0" mercury condenser back pressure.

8. Condenser equipment complete including the following:

    a. Condenser and Desuperheater.

    b. Air Ejector.

    c. Hogging Pump.

    d. Condensate Pumps (2).

    e. Circulating Pumps (2).

    f. Connector Between Condenser and Intake and Discharge Chambers.

    g. Seal Blower.

    h. Gland Seal Condenser.

    i. Condensate Piping, Valves, etc.

    j. Insulation.

    k. Intake Screen, Mechanism, and Pump.

    l. Intake Rack and Crane.

    m. Intake and Discharge Chambers.

9. Outdoor substation equipment (to be connected to additional switchyard equipment provided by Contractor for power distribution) including the following or equivalent:

    a. Transformer (1), 13.8/115 KV, 16.7/22.2 MVA.

    b. Transformers (2), 115, 4.16 KV, 1000 KVA.

c. Circuit Breakers (3), 115 KV, 3000 MVA, 600A.

d. Potential Transformers (5), 115 KV/115 V.

e. Current Transformers (3 sets), 115 KV, 1000/5 A.

f. Disconnects (5), 115 KV, 600A.

g. Structures and foundations; main structure and equipment including transfer bay, transformer bays, and line dead-end structures at transformers.

h. Lightning Arresters.

i. Distribution Boards.

j. Air Compressor and Equipment for Air Blast Circuit Breakers.

10. Indoor Accessory Electrical Equipment including the items listed below:

a. 4.16 KV Load Control Center.

b. 480-V Load Control Center.

c. Distribution Transformers (2), 100 KVA, 4.16 KV/120-208 V.

d. Generator Neutral Grounding System with Transformer.

e. Generator Surge Protection Equipment.

f. Station Battery, 125 V.D.C.

g. Battery Charger - MG Set.

h. Emergency Diesel Power Supply.

i. Motor Control Centers.

j. Carrier Current Equipment.

k. 4.16 KV Electrical Installation.

l. 480-V Electrical Installation.

NOTE: Contract not modified to reflect final features of above equipment as installed. See descriptive data in Section III.

m. 15 KV Generator Lead Installations.

n. 125 V.D.C. and 120/208 V Central Installation.

o. 120/208 V Lighting Installation.

p. Distribution Boards except as modified under Appendix "A", Item 1.1.

q. Main Switchboards (Protective Breakers for Turbogenerator and Reactor Plants).

NOTE: Contract not modified to reflect final features of equipment under Items 9 & 10 as finally installed. See descriptive data in Sect.III of this report.

11. Temporary Power and Light except as required for reactor installation.

12. Conventional machine shop equipment not solely related to servicing of nuclear equipment.

13. Equipment for Entrance Building office and locker rooms.

14. Miscellaneous fire fighting equipment.

15. Piping and valving shall be provided by the Contractor, in the direction of process flow, from services or process equipment provided by the Contractor, to the nearest connection to, or at, the Commission's services and process equipment.

    Connections to services and process piping provided by the Commission shall be made by the Contractor, using flanges or other connectors provided by the Commission in accordance with the Contractor's requirements.

16. Electrical service for equipment and devices shall be provided to Contractor furnished junction boxes and other terminals located and designed in accordance with the Commission's requirements.

17. Any items of structure, equipment, or auxiliaries not specifically provided for either in the above or in Appendix "A" shall be assigned for construction and related costs, by mutual agreement between the Commission and Contractor, in accordance with the over-all division of responsibility reflected by specific assignments in these appendices.

Attachment No. 3 to
Contract No. AT-(40-1)-2674

BONUS PRE-OPERATIONAL PROGRAM

The Pre-Operational Program shall include in a single or a series of continuous reports with a summary report all the most important recorded data and calculations during critical experiments and initial operation of the BONUS Reactor under GNEC direction. Analysis and extrapolation of the data shall be made and reported as requested herein. Sustaining data shall normally be presented whether stated or not. The following is intended to describe generally the contents of the pre-operational program:

I. Criticality Experiments

1. Initial cold start-up 6x6 boiler assembly without boiler shims and with boiler shims.

    a. Report count rate vs. water level.

    b. Report on count rate vs. rod withdrawal and prediction of criticality if achievable.

    c. Report measured rod worth values and any interpretation thereof.

    d. Report on flux distribution and discuss effect of shims on flux distribution, location of natural assemblies.

    e. Report hold down reactivity of shims and sustaining data.

    f. Report estimated reactivity worth of a single shim and basis for estimated values.

2. Cold start-up of 8x8 boiler assembly core with boiler shims installed.

    a. Report count rate vs. water level and prediction criticality on level if achievable.

    b. Report on count rate vs. rod withdrawal and prediction of criticality if achievable.

    c. Report measured rod worth values.

    d. Report on flux distribution.

3. Cold start-up of the full BONUS core with superheaters voided.

    a. Report count rate vs. water level and prediction of criticality on level if achievable.

    b. Report on count rate vs. rod withdrawal and prediction of criticality if achievable.

c. Report measured rod worth values.

d. Report on flux distribution.

e. Report reactivity worth value of the complete superheater.

4. Cold start-up of the full BONUS core with superheaters flooded.

   a. Report count rate vs. water level and prediction of criticality if achievable.

   b. Report count rate vs. rod withdrawal and prediction of criticality if achievable.

   c. Report measured rod worth values.

   d. Report on flux distributions and discuss effect of shims on flux distribution, location of natural assemblies.

   e. Reactivity inventory.

   f. Report flux distribution.

   g. Report flooding coefficient (cold) of reactivity for the superheater and basis of calculations. Compare value with estimated design value and explain difference.

5. Hot start-up of 8x8 boiler assembly core with boiler shims.

   a. Report count rate vs. water level and prediction of criticality on level if achievable.

   b. Report count rate vs. rod withdrawal and prediction of criticality if achievable.

   c. Report measured rod worth values.

   d. Report flux distribution.

   e. Report curve of temperature coefficient of reactivity vs. temperature.

   f. Report curve of void coefficient of reactivity vs. pressure (voids estimated by calculations).

   g. Reactivity inventory.

6. Hot start-up of the full BONUS core with superheater voided.

   a. Report count rate vs. water level and prediction of criticality, on level if achievable.

   b. Report count rate vs. rod withdrawal and prediction of criticality if achievable.

   c. Report rod worth values by rod drop tests.

   d. Report flux distributions.

   e. Reactivity Inventory.

f. Report curve of temperature coefficient of reactivity vs. temperature.

g. Reactivity inventory at all temperature values when criticality was attained. Compare with 8x8 hot boiler assembly.

II. Operation at Power as a Straight Boiling Water Reactor

Operation of the reactor up to approximately 30 MW (th) with 64 boiler fuel assemblies will be carried out as a part of start-up tests. During this period, the following information shall be obtained, analyzed, and reported. No extra operation to be carried out solely for this purpose.

1. Total MW (th) power delivered.

2. Estimated burn-up in each assembly.

3. Reactivity Inventory.

4. Control rod position as a function of power level, Zenon, and Samarium.

III. Operation at Power with Full Core

During this period of operation during start-up tests, the reactor will be operated up to approximately 50 MW (th) with full core. The following information shall be obtained, analyzed, and reported. No extra operation to be carried on solely for this purpose.

1. (a) Total MW (th) power delivered.

   (b) Estimated burn-up in each assembly.

   (c) Reactivity inventory.

   (d) Control rod positions as a function of power level, Xenon, and Samarium.

2. Void coefficient of reactivity vs. power level. This shall be an estimated value obtained by calculation of void changes produced by trading voids with a calculated control rod.

3. Power coefficient of reactivity vs. power level. This value shall be obtained by the simple ratio of power change (ΔP) to reactivity addition (Δk) by pulling out a calibrated control rod while holding constant other variables.

4. Pressure coefficient of reactivity.

   (a) Static: This value shall be obtained by increasing pressure slightly, by closing steam outlet, and estimating the change in reactivity by moving a calibrated control rod to bring the reactivity back to the original value. This value shall be compared to the theoretically calculated value.

   (b) Dynamic: To evaluate the dynamic pressure coefficient of reactivity use the simple relation $(\frac{dk}{dp})dP$ / dp/dt.

Take an oscillographic record of reactor power output, the input to the pressure rate meter, and the input to the pressure recorder while closing or opening the steam outlet valve. The ratio of the first two numbers multiplied by the power coefficient of reactivity evaluated under part (4) is an approximate value of the dynamic pressure coefficient of reactivity. Compare this value with theoretical calculations.

5. Power Pressure Coefficients.

   The ratio of the power and pressure recorded in (6) above gives the power-pressure coefficients. Report this value at the operating pressure. This coefficient shall be divided into a transient and a steady state term by the appropriate selection of the corresponding portions of the oscillograph record. A recheck on the power coefficient reactivity determined under (4) shall be done from the relation:

$$dk/dp = \frac{dk}{dp} \times \frac{dp}{dP}$$

6. Report on control of power split between boiler and superheater at various power levels. Values of power operation in each zone. Report on thermal analysis of core, including data such as feedwater inlet temperature and flow, superheater outlet steam flows temperature.

7. Effect of feedwater temperature on reactor power and power split. This can be accomplished by shutting down a feedwater heater, recording feedwater temperature variation, and recording total thermal power, and thermal power in the four individual superheater assemblies and in the eight octants of superheater assemblies.

8. Effect of feedwater flow (same as 7 above).

9. Effect of pressure changes or reactor power split.

10. Effect of burn-up during the start-up period on power split, rod configuration.

11. Radiation levels around the plant at full power operation, after shutdown from full power, and after several hours of shutdown.

12. Trends in contamination levels in plant equipment and trends in radioactive content of plant effluents.

13. Effect of Xenon and Samarium. Report reactivity holddown by Xe and Sm vs. time and extrapolate results at least two months ahead.

14. Effect of Xenon and Samarium on power distribution and desired control rod patterns.

15. Compare daily control rod patterns during the first month of operation and extrapolate results to at least two months ahead.

16. Shims programs. Discuss the effect of shims and their burn-up.

17. Report curve of void coefficient of reactivity vs. pressure. (Voids estimated by calculations.)

18. Performance of reactor pressure control system.

    This shall include a report of the best practical adjustment of the pressure control system including basis for setting pressure controller and valve positioners, reset rates, proportional band, and derivative control. This shall be a separate, self-sufficient report.

IV. <u>Conventional Equipment and Reactor Auxiliaries</u>

Initial performance data, having a significant effect on operations of the reactor, shall be reported on items such as Reactor Recirculating Pumps, Reactor Feedwater Pumps, Demineralizers, Air Ejector, Gland Seal Condensers, etc. (The portion of the report dealing with PRWRA equipment shall be provided by PRWRA.)

EXHIBIT B

SCOPE OF WORK THROUGH MODIFICATION 3

SUBCONTRACT NO. GNEC-66-100

CONTRACT NO. AT-(40-1)-2674

JACKSON & MORELAND, INC.

SUBSEQUENTLY ACQUIRED BY

UNITED ENGINEERS & CONSTRUCTORS, INC.

ARTICLE I - STATEMENT OF WORK

The Subcontractor shall furnish certain architect-engineer services as may be required by the Contractor in connection with the design and construction of certain facilities near Rincon, Puerto Rico, at the Punta Higuera site. Said facilities may be described generally as follows:

1. Boiling Water Reactor with Integral Nuclear Superheat (hereinafter called the "Project")

   a. The project for which the architect-engineer services are to be furnished consists of a nuclear power plant utilizing boiling water reactor with integral nuclear superheat. The reactor portion of the plant shall be capable of producing approximately 152,000 pounds of steam per hour at 850 psig and 900°F. to the throttle of a preferred standard turbine generator with nominal rating of 16,500 Kw at 3.5" Hg condenser back pressure, but to be operated at a gross output of 17,300 Kw at 2" Hg back pressure. The turbine generator, condenser, and related conventional generating facilities are not a part of the project for which architect-engineer services will be required.

   b. The Contractor will furnish the design and engineering services required in connection with the following items:

      (1) A boiling water reactor with integral nuclear superheat complete with pressure vessel, core structure, control rod system, reactor instrumentation, fuel handling, fuel storage, shielding, coolant system with pumps, emergency condenser system, purification system for reactor water, and all required auxiliary facilities to produce the steam for operating the turbine generator having capabilities indicated above.

      (2) An initial fuel loading with fuel assemblies for the boiling section utilizing fuel rods made up of sintered UO_2 compacts contained in Zircalloy tubes and fuel assemblies for the superheater section utilizing fuel rods of sintered UO_2 compacts contained in stainless-steel tubes.

      (3) A nuclear power plant building for the reactor facilities and conventional power facilities providing such containment as required to fulfill reactor safety requirements for the facility in the above-mentioned site.

      (4) Auxiliary buildings, supporting structures, equipment, and systems required to serve the reactor facilities including waste disposal, heating, and ventilating, water supply, power, and other utilities and services.

c. The Subcontractor shall render architect-engineer services as required by the Contractor in connection with the following items which are a part of the services specified in "b". above, to be performed by the Contractor:

(1) Nuclear Power Plant Building
(2) Biological Shield
(3) Radioactive Waste Disposal System
(4) Reactor Water Recirculation System
(5) Main Steam and Feedwater Return Systems
(6) Main Condenser Circulating Water Tunnels within Foundation Mat and extending no more than 30' beyond the edge of the Mat
(7) Emergency Condenser System
(8) Soluble Poison System
(9) Water Storage and Supply System
(10) Firefighting Water Supply System
(11) Firefighting System within the Containment Building
(12) Reactor Water Purification and Shutdown System
(13) Fuel Storage and Pool Cooling System
(14) Shield Cooling System
(15) Radioactive Gas Disposal System, including Stack with Foundation
(16) Caustic and Acid Tanks and Foundations
(17) Instrumentation and Control Systems related to Contractor's Work, and to PRWRA's Work as directed by the Contractor
(18) Lighting, Electrical, and Electrical Equipment related to Contractor's Work, and to PRWRA's Work as directed by the Contractor
(19) Miscellaneous Other Equipment and Structures

2. <u>Statement of Architect-Engineer Services</u>

To the extent required by the Contractor, the Subcontractor shall furnish, under this subcontract with respect to the project, the architect-engineer services described in "a", "b", and "c" below. All of the architect-engineer services to be furnished by the Sub-contractor hereunder shall be performed under the direction of a representative of the Subcontractor, who shall be satisfactory to the Contractor and the Commission, and shall be in responsible charge of the work at all times, except as the Contractor and the Commission may otherwise authorize.

a. <u>Title II - Design Services</u> - Under this Title the Subcontractor shall:

(1) Undertake design studies and prepare designs on portions of the items set forth in Article I.1.c., as directed by the Contractor. In general, the role of the Subcontractor will be to prepare detailed designs in accordance with concepts and preliminary overall design patterns developed by the Contractor.

(2) Undertake restudy and redesign work due to such changes and deviations within the scope of Article I.1.c, herein from the approved preliminary design work as may be required by the Contractor. This work is to include, but not be limited to, performing design work for firming-up of BONUS equipment location plans, integrating shielding requirements into the plant layouts, and altering concepts contained in the BONUS Reference Design (PRWRA-GNEC 3A) as may be necessary or

advisable to achieve a completely integrated and optimized design.

(3) Prepare and revise for the approval of the Contractor and furnish working drawings, details, and specifications for the items set forth in Article I.1.c. herein, bills of material for critical items of procurement and equipment specifications in such form and quantity and including such provisions as may be required by law or by the Commission's regulations and instructions to the Contractor or its designees to assure that the design will provide a completely integrated facility.

(4) Prepare a detailed study of the water supply and storage and fire fighting systems necessary for the BONUS Power Station. The study is to include, but not be limited to, a consideration of all water requirements both inside and outside the containment building, and a consideration of water supply sources and storage facilities both on-site and off-site.

(5) Prepare detailed electrical wiring diagrams, including wire and cable list sheets, pertaining to all Commission-owned equipment.

(6) Prepare detailed conduit and cable tray layouts for all equipment inside the containment building and remote control cubicle, except as otherwise directed by the Contractor.

(7) Make detailed designs, drawings, or specifications, or make reviews and recommendations of such other equipment or facilities which are part of the BONUS Power Station as may be required by the Contractor.

(8) Prepare working drawings, design details, or specifications for Commission-owned equipment or facilities to be located outside the containment building, as may be required by the Contractor.

(9) Prepare or, when directed by the Contractor, assist the Contractor or participate with others in the preparation of detailed estimates of costs and time schedules of construction based on approved designs, working drawings, and specifications.

(10) Prepare such recurring reports as drawings and specifications schedules, monthly progress and schedule reports, weekly manpower and progress reports, and such other reports as may be requested by the Contractor.

(11) Prepare procedures and operating manuals for the systems and equipment designed by the Subcontractor as required by the Contractor.

(12) When requested by the Contractor, consult with and advise the Contractor on any question which may arise in connection with the services pertaining to the Subcontract.

b. Title III - Supervision of Construction - Under this Title the Subcontractor shall:

(1) As requested by the Contractor, analyze and evaluate proposals and bids for materials, equipment, and services required for construction.

(2) As requested by the Contractor, check and approve all vendors' drawings and construction contractor's field drawings to assure conformance with the approved design and working drawings and specifications.

(3) As requested by the Contractor, make or procure and/or analyze field or laboratory tests of construction workmanship and materials.

(4) Inspect construction workmanship and materials and equipment or facilities designed by the Subcontractor and Contractor and report to the Contractor as to their conformity or non-conformity to the approved drawings and specifications.

(5) Furnish approved tracings in such form as the Contractor requires showing construction as actually accomplished.

(6) Prepare material for a Project Completion Report, including final cost reports in the form and quantity prescribed by the Contractor.

(7) As requested by the Contractor, provide up to three engineers at the BONUS site until November 15, 1963, to assist in the check-out of equipment and systems at an intermediate supervisory level.

(8) As requested by the Contractor, assist in the modifications and corrections required in the circuitry and instrumentation of the pressure control system.

c. Title IV - General - Under this Title the Subcontractor shall:

(1) As directed by the Contractor, assist with the preparation of data, evaluations, drawings, or other material which is required to prepare a Hazards Summary Report acceptable to the Advisory Committee on Reactor Safeguards and which pertains to equipment, systems, or other work performed by the Subcontractor in "a" or "b" above.

(2) As directed by the Contractor, prepare and submit supplemental information for the Hazards Summary Report in the event that additional data are required to obtain approval to operate the reactor, which pertains to equipment, systems, or other work performed by the Subcontractor in "a" or "b" above. This supplemental information should reflect any changes in design.

(3) Assist the Contractor in supervising precritical testing and startup of the auxiliary systems of the reactor and coordination of entire plant until reactor criticality is obtained and necessary post-critical tests are completed.

3. Except for such work and services as may be performed under sub-subcontracts and purchase orders entered into in accordance with the article entitled "Sub-Subcontracts and Purchase Orders", the Subcontractor shall perform the services required under this Article I at

its facilities in Boston, Massachusetts, and at such other locations as may be approved by the Contractor.

SECTION II - OPERATING EXPENSE FUNDING

AEC ACTIVITY 04 01 01 05

A. INTRODUCTION

1. Identification of Work Covered

a. R&D in Support of Design and Construction

The BONUS R&D program carried out under the direction of General Nuclear Engineering Corporation was summarized in a series of monthly reports. The work was done to guide certain design alternates and to provide information on expected behavior of certain pieces of plant equipment. On completion of each of the major R&D projects, a terminal report covering the work was prepared.

(1) Critical Experiments - A series of zero power critical experiments[4/] was run at Combustion Engineering's Laboratories at Windsor, Connecticut, under Contract AT-(11-1)-795 between CE and the Chicago Operations Office. The program consisted of making full-scale critical experiments to investigate the physics characteristics of nuclear mockups of the BONUS reactor. Both a cold-clean mockup and a simulated hot-operating mockup were studied.

(2) Fuel Assembly Performance Tests - An out-of-pile test program[5/] was selected as being economical and suitable for checking the ability of the BONUS fuel subassembly to withstand the BONUS dynamic steam environmental conditions. Since the major questionable mechanical design areas were mainly associated with the methods of spacing the concentric tube arrangement of the fuel subassembly, single fuel subassemblies were selected as the test elements. These test elements were fabricated similar to the reference design of the BONUS fuel subassembly under AEC Contract No. AT-(11-1)-795. Simulation of the dynamic steam environment was obtained by using a source of superheated steam from a local power company, Florida Power Corporation, St. Petersburg, Florida. The test program was established to obtain test results as quickly as possible in order to complete the detailed design of the BONUS superheater fuel assemblies prior to the release of the BONUS superheater fuel assembly specification.

(3) Fuel Unloading Techniques - To accomplish the simulation of handling the fuel under reactor design conditions, a water

4/BONUS Zero Power Critical Experiments and Application to the Reactor Design, Terminal Report GNEC 198 Under BONUS Activity 66-3, February 10, 1962.

5/Steam Environment Testing of BONUS Superheater Fuel Subassemblies, Terminal Report GNEC 211 Under BONUS Activity 66-4, June 30, 1962.

tank mockup of the BONUS pressure vessel was constructed. In this tank, portions of the reactor core and other components were mocked-up.

Handling tools were developed and constructed for use in the simulated fuel handling tests.

Functional reliability of the special tools were checked by actually disconnecting and reassembling the superheater steam inlet and outlet connectors and by performing simulated fuel loading procedures. The results of these experiments are described in monthly R&D reports submitted by GNEC, which are listed in Table I.

(4) Water Spray for Cooling Superheater Fuel Elements - Should a complete loss occur of both moderator and steam in the BONUS reactor, there is danger that melting of the fuel may occur. To preclude this possibility, GNEC designed an emergency core spray system[6/] based on information determined in a series of fuel cooling experiments.

(5) Miscellaneous Small Items - A number of miscellaneous studies, such as porosity of the concrete building slab[7/], purification resin transfer, corrosion of low alloy steels, various tests with the reactor mockup, etc., were performed. These small but important contributions to the over-all BONUS work are described in the monthly R&D reports submitted by GNEC.

(6) Removal of Moisture from Steam - Two reports were prepared by GNEC relating to this item. The first report[8/] recognized that the integral superheater fuel for the BONUS reactor was designed to use type 348 stainless-steel for the UO_2 fuel pellet cladding. Type 348 stainless was selected on the basis of having the best strength, corrosion resisting, and neutron absorbing characteristics of cladding materials available. However, analysis of data obtained as part of the nuclear superheating program indicated that chloride stress corrosion problems associated with stainless-steel were far more severe than initially anticipated. Therefore, GNEC undertook to determine the adequacy of the drying-preheating device which is used in BONUS to minimize moisture and chlorides carried over from the steam and deposited on the superheater fuel.

The short-term tests of chloride deposition described above were inadequate to measure the low chloride buildup which may have occurred on mockup superheater fuel in a test rig. Therefore, a series of longer experiments were run using chlorine-36, to allow radioactivity counting techniques to be used in measuring chloride buildup.[9/] In the tests, Type 304 and Type 347 stainless-steels were used, as well as Inconel.

6/BONUS Reactor Superheater Fuel Emergency Cooling, Terminal Report GNEC 154 under BONUS Activity 66-7, Superheater Fuel Cooling Tests, December 21, 1960.

7/Containment Membrane Development for the BONUS Reactor Building, Terminal Report GNEC 168 under BONUS Activity 66-8, May 15, 1961.

8/Chloride Corrosion Effects on BONUS Superheater Materials, Terminal Report GNEC 257 under Job. No. 66-14, Chloride Corrosion Program, April 10, 1963.

9/Chloride Deposition from Steam on Superheater Fuel Clad Materials, Terminal Rpt. GNEC 295 under JOB 66-16, Chlorine-36 Deposition Tests, 10-18-63.

(7) In-Pile Test - An in-pile test was made of a BONUS mockup superheater fuel element. The element was built at Combustion Engineering, Inc.'s, Windsor, Connecticut, plant and tested at General Electric Company's Vallecitos Laboratory, under GNEC's direction. The favorable results of the tests were reported in G.E.'s reports 10/of their nuclear superheat activities as well as in GNEC's monthly R&D reports.

(8) Brazed Joint Program - The chloride deposition tests showed that significant quantities of deposits would accumulate at discontinuities in the flow path of the steam as it passed through the superheated fuel elements. The fuel rod is positioned with a number of brazed-on spacers inside the superheater fuel element, and a program was run to determine how the joint could be expected to behave in service. The final report 11/describes the test results.

b. SwRI Pressure Vessel Cladding Investigations

Difficulties encountered in the weld overlay of a vessel manufactured in a manner similar to the BONUS pressure vessel led to investigations of the manufacturer's fabricating techniques. These studies and the results were published in a series of four reports 12/issued by GNEC. Southwest Research Institute, San Antonio, Texas, received a subcontract from GNEC to make detailed tests and analyses of actual weld samples under this program.

c. First Core

Engineering and fabrication of the fuel assemblies were accomplished under Operating Expenses. A total of 74 boiler fuel assemblies, including an initial complement of 10 spares, and a total of 36 superheat fuel assemblies including an initial complement of 4 spares, were fabricated under the original order. Descriptive information relative to the fuel is shown in Table II of this section of the report.

d. Operator Training

While planning for plant operations, the AEC, PRWRA, and GNEC recognized the desirability of using GNEC's design experience in an operating training program. Consequently, it was agreed that GNEC would send members of its staff to the BONUS site to teach operator license applicants details of BONUS plant design and engineering. Such information would be useful to their understanding of how BONUS works. As a follow-up to the training program conducted before fuel was loaded into the reactor, GNEC continued teaching the PRWRA operators what was happening as start-up progressed. The training program during start-up was meant to

10/Corrosion of Type 304 Stainless Steel in Simulated Superheat Reactor Environments, G. C. Gual and W. L. Pearl, CPAP-3779, General Electric Company, October 16, 1961.
11/Steam Environment Testing of BONUS Superheater Fuel Subassemblies, Terminal Report GNEC 211 under BONUS Activity 66-4, June 30, 1962.
12/Design and Fabrication of the BONUS Reactor Pressure Vessel, Interim Report, GNEC 210, February 10, 1962.

help operators interpret observations and phenomena which were witnessed while the plant was being readied for full power operation.

e. R&D Under COO NUSU Program

A number of programs useful to BONUS design and engineering were carried out by Combustion Engineering, Inc. (CE). The programs were under GNEC's direction, but the contract for the work, AT-(11-1)-795, actually was between AEC-COO and CE. Various phases of this program are described in the following paragraphs:

(1) Critical Experiments - The BONUS critical experiments performed by CE are described under subsection A.1.a.(1) Critical Experiments, above.

(2) Structural Restraint of Fuel Elements - The experimental program[13] was aimed at developing a superheater fuel rod having the thinnest possible cladding. This objective was achieved by building a fuel rod on which the clad was stretched over pellets, thus getting support from the pellets, rather than having a free-standing fuel rod.

(3) Zero Flow Shutdown Cooling of Superheater Elements - This series of experiments[14] verified that the BONUS superheater fuel will safely dissipate the decay heat generation existing two minutes after a shutdown.

(4) Moderator Flooding of Superheater Fuel Assembly - An important feature of the BONUS reactor design is the small change in reactivity which will occur if all the superheater fuel assemblies were instantaneously flooded at operating conditions. In addition, flooding is so delayed that reactivity additions cannot be fast. An experiment[15] was run on a simulated BONUS superheater subassembly to verify the flooding delay.

(5) Superheater Fuel Unflooding Test - The BONUS reactor start-up procedure calls for the removal of water from the normally dry superheating fuel assemblies and from the steam discharge piping by exhausting high temperature high pressure steam through these components. A test[16] was performed to ascertain the practicability of such an operation and to establish a basis for quantitative requirements of such a system.

13/Development of the BONUS Type Superheater Fuel Assembly, Terminal Report GNEC 197 under Activity No. 40 00 00, Structural Restraint of Fuel Elements, October 31, 1961.

14/Zero Flow Shutdown Cooling Test for BONUS-Type Superheater Elements, Terminal Report GNEC 144 under Activity No. 50 00 00, Heat Transfer Tests Simulating Loss of Coolant, November 21, 1960.

15/Water Injections Test Simulating Moderator Flooding of BONUS Superheater Assembly, Terminal Report GNEC 156 under Activity No. 50 00 00, Heat Transfer Tests Simulating Loss of Coolant, February 15, 1961.

16/BONUS Superheater Fuel Assembly Unflooding Test, Terminal Report GNEC 177 under Activity No. 60 00 00, Insulation and Seal Connector, June 15, 1961.

(6) Superheater Seal Connector Development - During reactor operation, water surrounds the BONUS superheater fuel assembly, which is accepting steam from a dryer/preheater and delivering superheated steam to a header. The superheated steam leaves the fuel assembly at about 75 psi less than the surrounding water and steam. Hence, a seal had to be developed[17/] to prevent leakage into the outlet of the superheater fuel assembly. The seal had to be capable of numerous reconnect operations, and had to be interchangeable in all core locations where it was to be used.

(7) Tape and Radial Drives - Alternate simplified control rod drive systems were studied[18/] having possible application to the BONUS reactor. Since there were numerous other areas in which BONUS was to pioneer, it was decided to use the proven EBWR control rod drive system as a basis for design.

f. Superheater Fuel Failure

On November 11, 1964, during an inadvertent reduction in steam flow, a BONUS superheater fuel assembly failed. This assembly was returned to Oak Ridge National Laboratory (ORNL) for hot cell examination. It was found that one rod had ruptured and that another was swollen. The hot cell examination revealed that this was due to water logging, caused by water entering the fuel elements through manufacturing defects. Later, a new assembly was returned to ORNL in order that it might be examinad to obtain base line data. This assembly was repaired and returned to the site. The examination is reported in an ORNL report.[19/]

17/BONUS Superheater Assembly Seal Connector Development, Terminal Report GNEC 192 under Activity No. 60 00 00, Insulation and Seal Connector, September 11, 1961.

18/Tape Drive and Radial Drive Control Systems, Terminal Report GNEC 155 under Activity No. 70 00 00, Control Development, February 27, 1961.

19/BONUS Reactor Superheater Fuel Assemblies - An Investigation of Failure and Method of Correction, ORNL-3910, December 1965.

B. Contract and Cost Data

1. GNEC Scope of Work

   a. R&D in Support of Design and Construction

   The scope of the R&D work performed by GNEC is given in Section I, Exhibit A. The actual costs incurred were $475,824.

   b. SwRI Pressure Vessel Cladding Investigations

   Southwest Research Institute, under GNEC Purchase Order, conducted tests and studies of stainless-steel overlay samples to determine the structural integrity of the reactor pressure vessel. The cost to perform this work was $16,542 including GNEC support.

   c. First Core Design

   The scope of the first core design for BONUS performed by GNEC is contained in Section I, Exhibit A. The actual cost of the design, which was performed under AEC Contract AT-(40-1)-2674, amounted to $139,978.

   d. Operator Training

   The scope of the operator training program conducted by GNEC is outlined in Section I, Exhibit A. The actual costs incurred amounted to $78,422.

   e. Other

   Recent contract modifications have increased the scope of the work under the contract to include Fuel Enrichment and Management, Reactor Operations, and Operations Analysis; however, no cost data covering these items will be included in this report.

2. Other Participant's Scope of Work

   a. Fuel Fabrication

   The fuel for both the boiler and superheater regions of the BONUS core were fabricated by Combustion Engineering, Incorporated. The initial contract for boiler fuel was for $411,950. During the course of the contract, changes were made which increased the contract cost by $13,014, making a total of $424,964. This contract for 74 fuel assemblies, including 10 spares, was awarded on September 18, 1961, and the fuel was delivered in May 1963. The initial contract for the superheater fuel was $488,200. During the course of this contract, changes were made amounting to $164,050 which resulted in a contract cost of $652,250. The principal change was a substitution of Inconel for SS-348 as the clad of the fuel elements, which resulted in an increase of $99,838. This contract for 36 fuel assemblies, including 4 spares, was awarded on September 14, 1961, and fuel was delivered in October 1963.

b. First Core Inspection Costs

Since Combustion Engineering was the parent company of the fuel designer, GNEC, it necessitated the AEC engaging independent inspection services for the fuel fabrication. The services were performed by the Union Carbide Corporation-Nuclear Division through the use of their ORGDP Engineering group. The cost for this inspection service was $168,276.

c. R&D Under Chicago Operations Office NUSU Program

In the summer of 1959, COO entered into a contract with Combustion Engineering, Incorporated, for work on a nuclear superheat program. Included as a part of this program were four items of R&D which were to be applied to the BONUS reactor program. This Phase I R&D included fabrication of fuel elements, assemblies, and mockups; heat transfer tests simulating loss of steam coolant; development of insulation seals for connectors and development of radial control elements. The final cost for Phase I R&D was $213,766. In early 1960, additional work (Phase II R&D) was added to the Combustion Engineering contract to be performed for the BONUS reactor. This was to carry out intermediate criticals and final critical experiments on the BONUS reactor. The intermediate criticals cost $235,000. Due to a conflict in schedule, ORO was required to equip a second cell at the Combustion Engineering facilities for the final critical experiments and the incremental cost was $200,000. The total for this Phase II R&D work, including the intermediate criticals, was $781,937.

d. PRWRA Operator and Start-up Training

The PRWRA paid the salaries of their operators during the course of their formal training. The AEC provided training at PRNC, ANL, ORSORT, ORAU, and later at the Dresden reactor for the PRWRA personnel. Starting November 11, 1963, at the beginning of the precritical checkout, certain PRWRA costs in connection with start-up and operating systems that had been beneficially occupied were borne by AEC since they were considered to be of direct benefit to future plant operations. This period extended to December 19, 1965. PRWRA operators received on-the-job training by working directly under the supervision of the GNEC people who designed and started up this reactor. The total AEC cost for this phase was $1,282,639.

e. Superheater Fuel Failure - The cost for the superheater fuel failure examination and the repair of unused assembly was $179,846. This includes transportation charges by Military Air Transport Service and assistance by Westinghouse Corporation.

f. Other

As a part of the GNEC R&D work, it was necessary to have Combustion Engineering fabricate fuel elements which could be irradiated in a special loop which was installed in the VBWR. Other minor items for the R&D program were also fabricated by Combustion Engineering. These were performed under the superheater fuel contract and the additional cost was $11,367.

Maxon Construction Company, at the request of the AEC, procured from the Pacific Coast Engineering Corporation pressure vessel samples which were taken during the fabrication of the BONUS pressure vessel. These samples will be placed in the BONUS reactor and removed at various time intervals and examined in order to ascertain the effect of nuclear radiation on the pressure vessel. The cost of these samples was $10,628.

The AEC received the BONUS fuel elements from Combustion Engineering at Windsor, Connecticut, and made its own arrangements for commercial transportation of the elements to the BONUS site. The transportation costs were $8,123.

3. Summary Costs

The actual costs incurred for work performed under this section totalled $4,444,562, and are reflected in detail in Table III of this section. Changes in estimated costs under Operating Expenses and the reasons therefor are set forth under Section I, Subsection D.2., "Original Budget Estimates and Revisions".

BOILING NUCLEAR SUPERHEATER (BONUS) POWER STATION

PROJECT COMPLETION REPORT

SECTION II - LIST OF TABLES

TABLE I

BONUS RESEARCH AND DEVELOPMENT PROGRAM

Monthly Technical Reports

Month	GNEC No.	Report	Month	GNEC No.	Report
July 1960	139	1	January 1962	216	19
August	143	2	February	222	20
September	146	3	March	226	21
October	152	4	April	229	22
November	157	5	May	236	23
December	161	6	June	239	24
January 1961	163	7	July	243	25
February	166	8	August	246	26
March	171	9	September	252	27
April	173	10	October	256	28
May	178	11	November	260	29
June	183	12	December	265	30
July	188	13	January 1963	269	31
August	193	14	February	273	32
September	200	15	March	277	33
October	203	16	April	281	34
November	206	17	May	285	35
December	213	18	June	289	36
			July	293	37
			August	300	38
			September	303	39

TABLE II

BOILING NUCLEAR SUPERHEATER (BONUS) POWER STATION

FUEL ASSEMBLY DATA

	Core Regions	
	Boiler	Superheater
Fuel Assembly		
Total number of assemblies (normal)	64	32
Fuel elements per assembly	32	32
Fuel element pitch, in.	0.625	0.958
Assembly structural material	Zircaloy-2	S.S. Type 348
Assembly can outside dimensions, in.	3.990 square	8.87 x 4.05
Can wall thickness, in.	0.086	0.032
Central moderator tube	Square	---
Moderator tube outside dimensions, in.	1.200x 1.200	---
Moderator tube wall thickness, in.	0.030	---
Thermal insulation within assembly	---	Stagnant steam
Composition of pressure & coolant tubes	---	S.S. Type 348
Pressure tube O.D., in.	---	0.833
Pressure tube I.D., in.	---	0.797
Thickness of steam insulation annulus, in.	---	0.0315
Coolant tube O.D., in.	---	0.734
Coolant tube I.D., in.	---	0.710
Fuel clad O.D., in.	0.500	0.540
Thickness of steam coolant annulus, in.	---	0.085
Fuel Element		
Element type	Rod, segmented	Full length
Fuel type	UO_2 sintered pellets	UO_2 sintered pellets
Fuel elements per assembly	32	32
Fuel element pitch, in.	0.625	0.958
Total length of fuel, in.	54.0	54.6
Fuel length per rod segment, in.	27.0	54.6
Fuel clad material	Zircaloy-2	Inconel 600
Fuel clad O.D., in.	0.500	0.540
Fuel clad thickness, in.	0.025	0.018
Fuel-to-clad thermal bond	Helium	Helium
Thermal bond thickness, in.	0.005	0.0018
UO_2 fuel pellet diameter, in.	0.445	0.500

TABLE III

BOILING NUCLEAR SUPERHEATER (BONUS) POWER STATION
OPERATING COST SUMMARY

GNEC Scope of Work		
GNEC R&D in Support of Design and Construction	$ 475,824	
SwRI Pressure Vessel Cladding Investigations	16,542	
First Core Design	139,978	
Operator Training	78,422	$ 710,766
Other Participant's Scope of Work		
Fuel Fabrication (74 boiler and 36 superheater assemblies) ; CEND	1,077,214	
First Core Inspection; UCC-ND	168,276	
R&D Under Chicago Operations Office NUSU Program; CEND Contract AT-(11-1)-795	995,703	
PRWRA; Contract AT-(40-1)-2672	1,282,639	
Superheat Fuel Leakage Examination; UCC-ND	179,846	
Other; CEND, Maxon, and AEC	30,118	3,733,796
Total Operating Costs		$4,444,562

SECTION III

PRWRA FINANCED FACILITIES

A. GENERAL INFORMATION

1. Site Location - The BONUS Power Station is located in the most westerly tip of Puerto Rico at Punta Higuera near Rincon.

   Puerto Rico is the eastern-most island of the Greater Antilles, lying between latitudes 17°55'N and 18°31'N and longitudes 65°30'W and 67°15'W in the northeast trade winds zone of the tropics. The island is nearly rectangular in shape and extends approximately 113 miles from east to west and 41 miles from north to south with an area of about 3,435 square miles. The island is bordered on the south by the Caribbean Sea; on the north by the Atlantic Ocean; on the east by the Virgin Passage, which separates it from the Virgin Island Group; and on the west by the Mona Passage, which separates it from the Dominican Republic. It is located about 1,600 air miles southeast of New York and 525 miles due north of Caracas, Venezuela. Its nearest neighbor, at a distance of 60 miles to the west, is the Dominican Republic.

2. Surrounding Area - The airline distance from the site to Ramey Field of the Air Force Strategic Air Command in Aguadilla is about 13 miles, and to the Puerto Rico Nuclear Training Center in Mayaguez about 13 miles.

   The site location map, Fig. 1001-1, shows the position of the site in relation to Puerto Rico, to adjacent islands, and to the principal cities and towns within a 15-mile radius. Also shown in the map are the principal highways, rivers, and electrical transmission lines.

   The average ground elevation of the power station site is around 37 feet. From this elevation, the land slopes down to the sea west of the plant. The surrounding land east of the plant area slopes up to elevations as high as 246 feet. The drainage area for the site is about 160 acres.

   The community nearest to the site, at a distance of two miles, is the town of Rincon, which has a total population of 1,094 inhabitants. The rural population in the surrounding two-mile radius totals 2,044 inhabitants. The closest large city, Mayaguez, with 58,887 inhabitants, is located 13 miles away.

3. Starting and Completion Dates - On February 4, 1960, the United States Atomic Energy Commission contracted separately with General Nuclear Engineering Corporation and the Puerto Rico Water Resources Authority for the detailed design of the Boiling Nuclear Superheated Power Station. Contracts AT-(40-1)-2674 and AT-(40-1)-2672 were awarded, respectively, to GNEC and PRWRA for the nuclear power plant and the generating plant of the nuclear power plant, respectively. These awards followed completion by GNEC and PRWRA of studies and a preliminary design of the BONUS Power Station under Contract AT-(40-1)-2484. The results of this study stabilized the technical feasibility and safety of a small

17.3 MW nuclear power plant using a boiling water reactor with integral nuclear superheating.

The PRWRA engineering design work on the generator plant started in March 1960 and was completed in November 1961. PRWRA prepared a total of 156 drawings and 26 specifications.

The PRWRA construction work on this project started in May 1960 and was completed on November 15, 1963.

B. CONTRACT AND COST DATA

1. Contract Data

As covered previously, construction of BONUS was a joint undertaking of the AEC and the Puerto Rico Water Resources Authority (PRWRA). AEC prime Contract AT-(40-1)-2672 with PRWRA provided that AEC was responsible for design and construction of the reactor and related auxiliary nuclear facilities, while PRWRA was responsible for the plant site and for the design and construction of the electric generating portion of the nuclear power plant, site work, and transmission facilities. The responsibilities of AEC and PRWRA are delineated in Appendix A and B, Exhibit A, of Section I of this report.

In addition to financing the costs for the land, and engineering and construction work in connection with generator plant facilities, site work, and transmission facilities, PRWRA paid the costs of certain pre-construction research and development work and salaries of certain PRWRA personnel undergoing training. The majority of PRWRA construction work was accomplished by PRWRA personnel. However, the Maxon Construction Company, under AEC prime Contract AT-(40-1)-2696, entered into Subcontract 2696-5 with PRWRA wherein each party was to accomplish certain work for the other as provided in the subcontract. Costs of the work were paid by the party for whom the work was performed. Work accomplished by Maxon for PRWRA under this arrangement included construction of the turbine pedestal and other equipment foundations; certain procurement including procurement of the main control and relay boards; installation, painting, and insulation of certain PRWRA-owned piping and equipment; and other miscellaneous items of work.

A listing of PRWRA contracts is contained in Table II and a listing of PRWRA purchase orders is contained in Table III.

2. Cost Data

The total costs incurred by PRWRA financed work were $6,100,000. Details of these costs may be found in Table I.

C. DESCRIPTION OF PRWRA OWNED FACILITIES

1. Land and Land Rights

   The BONUS Nuclear Power Plant is located in a 134.105-acre tract which extends around a 1/4-mile radius from the plant.

2. Structures and Improvements

   a. Roads - An asphalt access road, 0.66 miles long, 26 feet wide, maximum grade 3%, which leads from the existing State Road No. 413 through the site entry gate and ends on the site parking lot area.

   b. Landscaping - Approximately 27,770 square feet of San Agustin Grass planted in the areas between the sidewalks, the parking areas, and the Containment Building.

   c. Streets - The streets are 30 feet wide with a crushed stone base topped with tibuminous asphalt, and concrete curbs.

   d. Parking Areas - Two parking lots suitable to accommodate a total of 30 cars (22 west of the Entrance Building and 8 to the east) constructed with crushed stone base topped with bituminous asphalt, and concrete curbs.

   e. Fence - The site is enclosed by a 6-foot high chain link fence, with one foot barbed wire top. The entrance gate is 24 feet wide, swing-type, and motor-operated.

   f. Storm Sewers and Channels - An earth diversion channel was provided immediately to the east of the switchyard area and a larger one to the south of the site. Water flows under the access road through a 48-inch reinforced concrete pipe culvert towards the sea. Streets are provided with catch basins and concrete pipes to collect storm water.

   g. Transformer Yard and Switchyard Fence - Located east of the plant at elevation 30 feet. A 6-foot high galvanized steel chain link fence with a 12-foot gate encloses the transformer yard and switchyard areas.

   h. Water Supply and Storage System - The main source of raw water for the make-up, supply, and storage systems is Well No. 3 located 657 feet south and 293 feet west of the Containment Building. This non-potable water is pumped from a 60-foot deep well. The deep well pump is driven by a 7½ hp, 440-volt, 3-phase, 60-cycle motor and discharges into a 5-foot-6-inch diameter, 5,000-gallon steel suction tank located in the southwest corner of the site at grade elevation 18 feet. The pump has a rated capacity of 5,000 gph at 80 psig discharge pressure; at 25 gpm the corresponding pump outlet pressure is 400 feet of water.

The well water source is supplemented by the 93,000-gallon capacity Rincon City Aqueduct located 13,000 feet from the site. The water supply from this source, which is discharged into the 5,000-gallon tank, is limited to a maximum of 50 gpm. Two horizontal centrifugal pumps draw from this tank and supply raw water to the outside fire hydrant system, the interconnected 25,000-gallon storage tanks, and the zeolite treatment plant.

i. Drainage System - The drainage system is of a gravity flow type collecting surface water through a series of intercepting catch basins and directing the flow through appropriate underground piping for disposal at neighboring low points of natural drainage.

The system consists of nine regular 2' x 3' standard catch basin gratings and one 2' x 34' grating trench. All the aforementioned catch basins are appropriately connected to disposal fields through a system of reinforced concrete piping of various diameters and lengths, 18 inches being the dominating diameter.

j. Sea Water Structures and Tunnels - The sea water intake and discharge structures and the 42-inch reinforced concrete pipe lines leading from the rectangular channels under the Containment Building foundation mat to the structures are located to the west of the Containment Building. This system is designed to convey 17,000 gpm of sea water to the condenser and back. The sea water outlet structure is located 417 feet along the shore line southwest of the sea water intake structure. The intake structure is made of 5,000 psig strength concrete and is 60 feet long by 16 feet wide. The structure is erected 47 feet inland from the seashore to provide protection from sea waves.

The reinforced concrete outlet structure is 25 feet long and 5 feet wide, protected by sheet piling on one end and sides.

A transition section of reinforced concrete is provided at the place where the circular pipes join the rectangular channels below the Containment Building floor slab. Two cast iron pressure manholes with inverts at elevation +6.4 feet are located in the transition section. Access to these manholes is reached through a reinforced concrete vertical shaft 7 feet 9 inches long by 4 feet wide, extending up to elevation +35 feet.

k. Outdoor Fire Protection System - The outdoor fire protection system consists of a 6-inch mechanical joint, pipe ring header containing five fire hydrants and four post indicator valves. The header is connected by a 6-inch cast iron, mechanical joint, pipe line to two 25,000-gallon raw water storage tanks at grade elevation 194 feet. From this same ring header, water for fire-fighting is piped to the cooling tower, the sea water intake structure, and the storage warehouse. A 6-inch branch line is provided from the internal fire protection system supply lines for future connection to a storage warehouse sprinkler system.

The sources of raw water for the storage tanks supplying the outdoor fire protection system are Well No. 2 and the Rincon City Aqueduct.

l. Site Lighting - The underground site lighting system has 26 fluorescent liminaires, 12,000 lumens lamp (Power Groove) each. Luminaires are installed on concrete poles (33 feet long) projecting 27 feet from ground level. The system is connected in multiple circuits controlled by a photocell working at 120 volts. The site lighting system is fed from the Entrance Building transformer bank.

m. Entrance Building - The Entrance Building is a conventional type concrete structure located adjacent to the south side of the Containment Building. Access to the Entrance Building is from the south, directly from the main parking lot. The gross area of this building is 2,615 square feet and the gross volume is 29,940 cubic feet.

This building, in addition to serving as the principal access to the power plant, contains the administrative offices, the reactor remote shutdown station, receptionist lobby, change room, and conference room.

The building load-bearing members consist of reinforced concrete beams and columns. The reinforced concrete floor is 4 inches thick with 12" x 12" terrazo tiles. The exterior and interior walls are concrete blocks with cement plaster on both sides. The roof slab construction consists of a steel bar joist frame topped with a 2½ to 4½ inch thick concrete over expanded metal matting which is, in turn, covered with four-ply tar impregnated roofing felt and gravel. The building is completely air-conditioned. The general layout of the Administration Building is shown in Figure 402-4.

The Reactor Shutdown Room is heavily shielded by 30-inch thick concrete on the side facing the Reactor Building. The roof concrete slab is 24 inches thick. All other walls have a concrete thickness of 12 inches. The shielding calculations were based on source terms obtained by assuming infinite reactor operation; 30% of the fission products were assumed to be released after 50 seconds, being spread uniformly in the Containment Building volume. The only attenuation assumed was through the walls of the room.

n. Zeolite Treatment Plant - A zeolite treatment plant for chemically treating city and well water is enclosed in a reinforced concrete and block building 29 feet long and 16 feet wide. The building has a gross area of 354 square feet and a gross volume of 4,602 cubic feet.

o. Chlorination Plant - The chlorination plant is housed in a prefabricated steel frame structure, which has a gross area of 344 square feet and a gross volume of 4,475 cubic feet.

p. Communications Equipment Building - This is a reinforced concrete frame structure, which houses radio equipment, and has a gross area of 165 square feet and a gross volume of 1,815 cubic feet.

q. Warehouse Building - The warehouse is a prefabricated steel frame building, 40' x 100' x 16' high, with ¼-inch thick corrugated asbestos-cement siding and roofing. The building has a gross area of 4,000 square feet and a gross volume of 64,000 cubic feet.

r. Emergency-Diesel Generator Set House - This is a reinforced concrete frame structure having a gross area of 247 square feet and a gross volume of 2,097 cubic feet.

s. Cooling Tower - The cooling tower is a steel and redwood structure, 19' x 19' x 11' high, with redwood fillings and eliminators and corrugated cement asbestos cassing and removable louvers. Equipment includes a fan, cooling water chemical feed pump, and two cooling water pumps.

3. Turbo-Generator Unit

a. Turbine Pedestal and Turbine Oil Tank - The turbine pedestal is a reinforced concrete structure located inside the dome north and east of the reactor. The principal dimensions are 41 feet long and 17 feed wide and 21 feet 4 inches high.

The turbine oil tank, which is located northwest of the pedestal, is supported by four steel columns braced by a rigid frame.

b. Turbo-Generator - The turbine-generator unit, manufactured by International General Electric Company, is an ASME-AIEE Preferred Standard Unit, nominally rated at 16,500 kw with a back pressure of 3½ inch Hg abs., 3% make-up and with throttle steam condition of 850 psig, 900°F. With a back pressure of 2 inch Hg abs., and 0% make-up, the maximum expected output is 17,300 kw. The turbine-generator unit is of standard construction, except that ductile Ni-Resist rings are substituted for the normal leaded-bronze rings in the steam seals because of the corrosive action of oxygenated steam on leaded-bronze.

The turbine is a single-casing, single-flow, 3,600 rpm machine, having four extraction openings for feedwater heating. The area of the turbine exhaust annulus is 16.4 square feet. The guaranteed non-extraction steam rate is 7.79 lb/kw-hr. with a generator output of 16,500 kw at 0.5 psig hydrogen pressure, 0.935 power factor, and a condenser back pressure of 1½ inch Hg abs.

The generator is a standard 13.8 kv, 3-phase, 60 cycle, hydrogen cooled unit with a capability of 22,059 kva output at 0.85 power factor at 30 psig hydrogen pressure. It has a direct-coupled shaft-driven main exciter which has a power output of 90 kw at 250 vdc and a direct connected pilot exciter with a power output of 4 kw at 125 vdc.

c. Condenser and Auxiliaries - The main condenser is a two-pass, 20,000 square-foot unit, with 7/8-inch, 16 BWG aluminum brass tubes 20 feet long welded to the tube sheets. The tube sheets are of silicon bronze. The condenser has a divided hotwell and divided water boxes and is equipped with a controlled flash dearating hotwell which is guaranteed to decrease the dissolved oxygen concentration to 0.01 cc/liter or less. The holdup capacity of the hotwell is approximately 4-9 minutes at full flow conditions.

The condenser is also capable of condensing the full output of the reactor when the turbine bypass valves are opened with a condenser pressure of 3.5 in Hg abs. A desuperheater was installed as part of the condenser to prevent tube damage due to high temperatures during dumping operations. The desuperheater consists of a series of concentric perforated pipes which have internally mounted water spray heads. The sprays automatically receive water from the condensate pumps under the control of a temperature sensing element.

The condenser is approximately 30% larger than normal for a conventional plant of this size to allow for operation at high experimental flow rates as may be approved at a future date and/or to accommodate steam dumping conditions.

d. Air Ejectors - The air ejectors are standard twin-element, two-stage units with inter and after condenser cooled by condensate direct from the condenser hotwell. These ejectors have a capacity of 138 lb/hr of air plus vapor, which is somewhat larger than normal for a 20,000 square-foot condenser in order to accommodate the radiolitic gases expected during operation. The steam consumption of the jets will be approximately 450 lb/hr of steam at 400 psig. Steam which is condensed in the ejector coolers is drained back to the main condenser hotwell. Air and other gases are sent through a one-minute hold-up pipe then dilution air from the gland seal exhaust blowers is added to give a non-explosive mixture. This mixture is finally discharged to the building exhaust system after it has passed through a charcoal trap and a 20-minute hold-up tank.

e. Mechanical Vacuum Pump - The vacuum pump is a water-filled centrifugal displacement pump (Nash-Hytor Vacuum Pump, Model L-5). It is all iron construction and is driven by a 20 hp, 900 rpm a-c motor. It has a capacity of 295 cfm measured at 19-inch vacuum referred to a 30-inch barometer with 60°F. water seal.

f. Condensate Pumps - The condensate pumps are vertical, multi-stage, pit-type units constructed of standard materials equipped with mechanical shaft seals. The pumps take condensate from the main condenser hotwell and force it through the air ejector, gland seal condenser, condensate purification system, drain cooler, and three feed heaters to the feed pumps. Two units are provided, each having a capacity of 235 gpm, or approximately 60% of the maximum expected condensate flow of 400 gpm. These units develop a head of approximately 490 feet, part of which is used to provide the necessary net positive suction head to prevent cavitation in the reactor feed pumps section.

g. Condenser Sea-Water Circulating System - The condenser circulating water pumps are located outside the Containment Building at the sea water intake structure. They are standard, vertical mixed-flow, single-stage units but have stainless-steel shafts and impeller for added corrosion resistance. Two pumps are used to deliver 18,000 gpm of sea water to the condenser. Each pump is capable of delivering half the required flow with a discharge head of approximately 38 feet. Each pump is driven by a 125 hp, 440-volt, a-c motor, which operates at 1,170 rpm.

4. Accessory Electric Equipment

a. 440-V Switchgear - The indoor 440-v switchgear is similar in construction to the outdoor switchgear. It contains the air circuit breaker supplying power to motor load centers 1 and 2, a circuit breaker for load center 3, the individual circuit breakers for the plant auxiliaries (reactor feedwater pumps, and reactor preheater), and the plant lighting circuit breaker.

b. Main Control and Relay Board - The main control and relay board (conventional part) consists of five vertically mounted panels for the control and indication of the condensate water system, circulating water system, raw water system pumps and motors, station service air compressor, and turbine generator, miscellaneous auxiliary equipment relay boards for Mayaguez and Aguadilla 38 kv lines, and the control for all station service equipment. Main control panels designated J through N serve this purpose and are PRWRA-owned.

c. Direct Current Supply - Equipment and control which demand uninterrupted direct current power are connected to the 125-volt d-c bus provided within metal enclosed switchgear. The station battery is a calcium alloy C&D type PCL-15, 60 cells, 125 volts d-c, with a 20-year life expectancy and with the following ampere-hour discharge ratings to a final voltage of not less than 1.75 volt per cell, at an initial temperature of approximately 77°F.

The battery is capable of delivering a one-minute discharge rate of 945 amperes at 1.50 volt per cell. The battery is maintained fully charged by means of two automatically regulated, 3 kw silicon rectifiers (one spare). The charger maintains the battery at full charge by continuously floating the battery, and handles the plant normal d-c load such as indicating lights, relays, and d-c instruments. The static battery charger was preferred to the conventional motor generator set for its higher dependability and low maintenance.

Connected to the 125-volt, d-c battery bus are the following services:

(1) D-C instruments and relays
(2) D-C motor-operated valve load center
(3) Controls for the 38 kv line and generator breaker
(4) Controls for the 480-volt outdoor switchgear breaker
(5) Controls for the generator field breaker
(6) D-C control circuits
(7) Emergency bearing and seal oil pump
(8) Hydrogen control cabinet
(9) Controls for the 480-volt indoor switchgear breaker
(10) 2 kw of emergency lighting

d. Main Generator Leads - The generator terminal leads are connected directly to the outdoor main power transformer 13.8 kv low voltage terminals through a three-phase, non-segregated, bus duct. The 4-foot wide by 2-foot high aluminum bus duct contains the three 1½-inch, extra heavy (IPS) copper phase leads which are anchored and supported 15 inches apart by integral 15,000 volt insulator bushings. The phase leads are each continuously rated at 1,200 amperes. The support bushings are spaced along the bus length to adequately withstand the forces imposed by a 10,000 ampere short circuit at 13.8 kv. The bus duct rating is 15 kva, 60 cycle, 95 bil. The generator-leads bus duct (at centerline elevation 30 feet 10 inches) extends from the underside of the generator to the Containment Building shell where the generator-leads penetrate the shell in going to the outdoor main power transformer. The generator-leads duct penetrates the main floor in the machine shop in the vertical run to elevation 43 feet 4 inches, where the leads are connected to the three 15 kv gas-tight bushings. In the machine shop, the bus duct is enclosed within a wire mesh partition with double doors to prevent unauthorized access to the bus section.

e. Station Service Equipment - The station power from the 440-volt outdoor switchgear to the 440-volt indoor switchgear cubicle is delivered by a 4,000 ampere, metal enclosed, bus duct. The individual three phase leads penetrate the building shell through gas-tight, fixed-stud, 1.2 kv insulator bushings. The indoor 440-volt switchgear is similar in construction to the outdoor switchgear. It contains the air circuit breaker supplying power to motor load centers 1 and 2, a circuit breaker for load center 3, the individual circuit breakers for the plant auxiliaries (reactor feed-water pumps, and reactor preheater), and the plant lighting circuit breaker. All of the motor load centers are located in the switchgear room below the control room. In this same location are the 440-volt valve motor load center and the 225 kva, 440-volt primary, 120/208 volt secondary transformer for lighting and general plant services.

f. Emergency Diesel Supply - Upon failure of the normal station service supply, power to load center 2 is automatically transferred to a diesel-electric generating plant, 150 kw continuous rating; 175 kw stand-by rating at 80% power factor, 480 volts, 3-phase, 60 cycles, 3-wire with static exciter and voltage regulator. The transfer from normal power to emergency supply takes place in less than fifteen seconds after the start signal to the diesel generator is given. The diesel generating plant control is provided with a 24 volt d-c, 200 ampere hour rated, starting battery which will be kept fully charged with a 120-volt a-c operated trickle charger. When the plant is started, battery charging is transferred to the battery charger generator provided with the set. Load center 2 feeds all essential loads considered necessary to reactor safety such as:

(1) Fuel Pool Purification Pumps
(2) Instruments Transformers
(3) Reactor Annulus Exhausters
(4) Reactor Purification Pumps
(5) Shield Cooling Pumps
(6) Bearing Drain Enlargement Exhauster
(7) Turbine Gland Seal Exhauscer
(8) Turbine Oil Tank Vapor Extractor
(9) Turbine Bearing and Seal Oil Pump
(10) Turbine Turning Gear Motor
(11) Auxiliary Cooling Water Pumps
(12) Cooling Tower Fan
(13) Control Air Compressor
(14) Station Battery Chargers
(15) AC Motor-Operated Valve Load Center
(16) Building Emergency Lighting Transformer
(17) Pressure Control System

All motor starters are provided with undervoltage release and are returned to operation on the emergency bus in sequence by timing relays to prevent overloading the diesel generator with excessive inrush currents.

5. Miscellaneous Power Plant Equipment

a. Compressed Air System - A compressed air system for general use, such as condenser tube cleaning, operation of power tools, etc., is installed with service connections distributed over the plant at different floors. This same system is used as a stand-by for control air supply in case of an emergency. Upon failure of the control air compressor, a pressure control valve will open to permit the use of the service air and warrant continuity of service.

The station service air system is fed by two Ingersoll-Rand compressors each driven by a 40 hp, 1,800 rpm, 440-volt, a-c motor and will deliver approximately 160 cfm of free dry air at 100 psig. The compressors are equipped with teflon non-lubricated wearing and piston rings to avoid oil carry-over to the system. They are also equipped with an automatic dual control regulation with timer relay, forced feed lubrication, low oil pressure shut-down switch, automatic water valve, air filter and silencer, oil trap, after-cooler, moisture, separator, and a receiver tank.

6. Transmission Plant

a. 38 KV Switchyard - The 38 kv switchyard contains the galvanized steel bus support structures and the three 1,200 ampere continuous rated, 46 kv, 1,500 mva interrupting capacity, oil circuit breakers. These breakers (Westinghouse 460 G 1,500) for the generator feeder and one each for the incoming Aguada and Rincon 38 kv lines, are each provided with electro-pneumatic, mechanical and electrical trip-free mechanism. The circuit breaker operating mechanism is spring opened and pneumatically closed with air supplied by an integral compressor. Each circuit breaker is operated from the control room and is furnished with six 1,200/5 multi-ratio relaying current transformers and three single ratio metering current transformers. The oil circuit breakers are provided with manually operated 46 kv, 600 ampere disconnect switches for isolating the circuit breaker from the 38 kv bus for routine maintenance or repair. The disconnect switches are key-interlocked with the circuit breaker so that the disconnects cannot be opened unless the circuit breakers are opened first.

b. Protection Equipment - The generator 1-inch (IPS) copper neutral lead is grounded through a 25 kva, single-phase, 12,000/240-volt, 60 cycle, Askarel insulated distribution transformer with a secondary side loading resistor. The neutral grounding cubicle housing the transformer, resistor, and neutral disconnect switch is located below the generator at floor elevation 27 feet. A ground detector relay (64) and a sensitive overvoltage relay (59) in parallel with the loading resistor annunciate the presence of a ground fault.

The generator is protected by a differential relay (87G), over-current relays (51G), a field failure relay (21F), a negative phase sequence relay (46), and the generator surge protection equipment. Current transformers, 1,200/5 amp for the protective relays are mounted on the three generator leads and the three neutral leads. Three current transformers are on each generator lead and on one of the neutral leads; the other two neutral leads have two each. A unit differential relay (87U) is provided to protect the generator, main power transformer, and the generator breaker. Supplementary current transformers (600/5 amp) in the three 38 kv phases, on either side of the generator breaker operate with the generator current transformers to give the differential protection.

c. Main Power Transformer - The main power transformer (Westinghouse Type SL, Class OA/FA, Insuloar Insulation) is a three-phase, two-winding, outdoor, oil-immersed type, rated 20,000 kva continuous self-cooled, and 26,667 kva forced-air cooled at 55°C rise above a 40°C ambient. The WYE connected primary side is provided with four 2½% taps above the 38 kv high tension voltage; the no-load tap changer permits changing the connections in the high voltage side from outside the transformer tank when the transformer is deenergized. The 13.8 kv low voltage secondary winding is delta connected. The respective insulation rating of the primary and secondary windings is 46 kv and 15 kv,respectively.

d. Transmission Station Service Equipment - Normal station power is obtained through the station service transformer which steps down the voltage from 38 kv to 480 v. This transformer (Maloney Electric Company Design No. 60985) is a three-phase, two-winding, outdoor, oil immersed type rated 2,500 kva continuous self-cooled and 3,125 kva continuous forced air cooled at 55°C rise above a 40°C ambient. The WYE connected 38 kv primary winding is provided with four no-load 2½% full load taps above the 38 kv rating. The 480-volt secondary winding is delta connected. The respective insulation rating of the primary and secondary windings is 46 kv and 600-volt, respectively.

The station service transformer secondary side circuit breaker is an integral part of the 440-volt outdoor switchgear cubicle mounted in the transformer yard. The station service secondary breaker in the switchgear cubicle is a Westinghouse Type DB-100, drawout type, 4,000-ampere rated, 100,000 ampere interrupting capacity, air circuit breaker type, remotely operated from the control room. The outdoor switchgear also contains a 1,600 ampere ACB for motor control center 4 at the sea intake structure and space for the future addition of a 1,600 amp breaker. The 1,600 ampere breakers are Westinghouse Type DB-50 with an interrupting capacity of 50,000 amperes.

The station power from the 440-volt outdoor switchgear to the 440-volt indoor switchgear cubicle is delivered by a 4,000 ampere, metal enclosed, bus duct. The individual three-phase leads penetrate the building shell through gas-tight, fixed-stud, 1.2 kv insulator bushings.

BOILING NUCLEAR SUPERHEATER (BONUS) POWER STATION

PROJECT COMPLETION REPORT

SECTION III - LIST OF TABLES

TABLE I

BOILING NUCLEAR SUPERHEATER (BONUS) POWER STATION

PRWRA FINANCED COSTS

Preconstruction R&D	$ 220,000
Land and Land Rights	148,000
Construction	4,832,000
Training	900,000
Total PRWRA Financed Costs	$6,100,000

TABLE II

CONTRACTS

CONTRACTOR	ADDRESS	CONTRACT NO.	SCOPE OF WORK	DATE STARTED	DATE COMPLETED	AMOUNT
Maxon Construction Co.	Dayton, Ohio	AEC AT-(40-1)-2696, Sub. 2696-5	Construction and Procurement Services	2-6-61	8-31-63	$158,710
Development and Resources Corp.	New York, N. Y.	Agreement 1-2-63	Advisory Services on matters relating to the organization and program of the Authority	Jan. 1963	Dec. 1963 Subject to Re-newal	15,000 Per Annum
Volpe and Boskey	New York, N. Y.	Agreement	Legal Council for the Authority			12,000 Per Year
Victor M. Diaz Canales	Bayamon, P. R.	Agreement 12-6-62	Calibration services of BONUS Instruments	Dec. 1962		$75/Day

TABLE III

MAJOR EQUIPMENT SUPPLIERS

ITEM NO.	REQ. NO.	P. O. NO.	MANUFACTURER OR VENDOR	AMOUNT
Steam Turbine Generator	120-1	C-54093	Int'l. General Electric P. R., Inc.	$723,874.65
Surface Condenser	120-2	C-55123	Maryland Shipbuilding & Drydock Co.	104,082.97
Condensate Pumps	120-2	C-55123	Maryland Shipbuilding & Drydock Co.	8,030.00
Circulating Pumps	120-2	C-55123	Maryland Shipbuilding & Drydock Co.	29,140.00
Ejectors	120-2	C-55123	Maryland Shipbuilding & Drydock Co.	6,100.00
Desuperheaters	120-2	C-55123	Maryland Shipbuilding & Drydock Co.	2,450.00
Hogging Air Pump	120-2	C-55123	Maryland Shipbuilding & Drydock Co.	2,848.00
Steel Structures for Switchyard and Transformer Area	120-35	L-56136	The Joslym Company	5,900.00
38 KV Outdoor Substation Equipment	120-35	L-56136	The Joslym Company	19,536.75
Potential Transformers	120-35	L-56136-A	American Elin Corporation	5,160.00
Main Power Transformers	120-35	L-56136-B	Westinghouse Electric Int'l. Co.	48,410.00
Sta. Service Transformers	120-35	L-56136-C	Moloney Electric Co.	14,715.00
Cooling Tower for Outdoor Serv.	120-50	L-56527	Lilie-Hoffman Cooling Tower, Inc.	7,550.00
Travelling Water Screens	120-66	L-56823	The Jeffrey Manufacturing Co.	18,781.00
42" x 42" Sluice Gates	120-74	L-56850	Rodney Hunt Machine Co.	7,058.00
Circulating Water Piping	120-133	L-58762	American Cast Iron Pipe Co.	5,498.97

ITEM NO.	REQ. NO.	P. O. NO.	MANUFACTURER OR VENDOR	AMOUNT
Storage Battery	120-149	L-58979	Mera Equipment Company, Inc.	$ 4,662.98
Indoor Sta. Serv. Switchgear	120-176	L-59476	Westinghouse Electric Int'l. Co.	13,750.00
Outdoor Sta.Serv. Switchgear	120-176	L-59476	Westinghouse Electric Int'l. Co.	11,900.00
Set of Motor Control Centers & Miscellaneous Motor Control	120-176	L-59476	Westinghouse Electric Int'l. Co.	22,600.00
Set of Valve Control Centers	120-176	L-59476	Westinghouse Electric Int'l. Co.	9,700.00
AC-DC Switchgear Assembly	120-176	L-59476	Westinghouse Electric Int'l. Co.	5,300.00
600 Volts Metal-Clad Non-Segregated Phase Sta. Serv. Bus Duct Complete w/Accessories	120-176	L-59476-A	Int'l. General Electric Co.	10,120.00
Motor-Operated Butterfly Valves 24" Size Vertical Mounting	120-177	L-59478	Henry Pratt Company	4,496.00
Motor-Operated Butterfly Valves 24" Size Horizontal Mounting	120-177	L-59478-A	B-I-F Industries, Inc.	8,900.00
Butterfly Valves - 6" & 10"	120-177	L-59478-B	Keystone Valve Corporation	587.00
46 KV Oil Circuit Breakers	120-182	L-59596	Westinghouse Electric Int'l. Co.	29,255.00
Metal Clad Generator Surge Protection & Potential Transformer Cubicle	120-189	L-59609	The Kelek Company	5,762.00
One Metal Clad Generator Neutral Grounding Cubicle	120-189	L-59609	The Kelek Company	2,796.00
One Excitation Switchgear Assembly Complete w/Circuit Breaker	120-189	L-59609-A	G&N Engineering Co.	1,465.00

ITEM NO.	REQ. NO.	P. O. NO.	MANUFACTURER OR VENDOR	AMOUNT
Battery Charging Motor Generator Set	120-193	L-59710-A	Westinghouse Electric Int'l. Co.	$ 3,483.99
Emergency Diesel Generator Set	120-196	L-59538	West India Machinery & Supply Co.	12,824.28
Cathodic Protection System for Condenser & Travelling Screens	120-231	L-60267	Badrena & Perez	3,500.00
Station Serv. Air Compressor	120-237	L-60371	Ingersoll Rand Company	4,821.55
Light & Power Transformer	120-240	L-60611	P. R. Iron Works, Inc.	3,246.00
Main Generator Leads	120-245	L-60733	Int'l. General Electric Co.	11,500.00
Power & Control Cable	120-254	L-61052	Collyer Insulated Wire Co., Inc.	10,011.01
Power & Control Cable	120-254	L-61052-A	Simplex Wire & Cable Company	6,104.00
Chlorine Injection Equipment	120-266	L-61315	Badrena & Perez, Inc.	5,066.50
Miscellaneous Piping	120-347	L-63563	Grinnell Corporation	14,640.53

BOILING NUCLEAR SUPERHEATER (BONUS) POWER STATION

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SECTION III - LIST OF FIGURES

NOTE: For PRWRA Equipment, see Equipment Location Plans in Section I of this report.

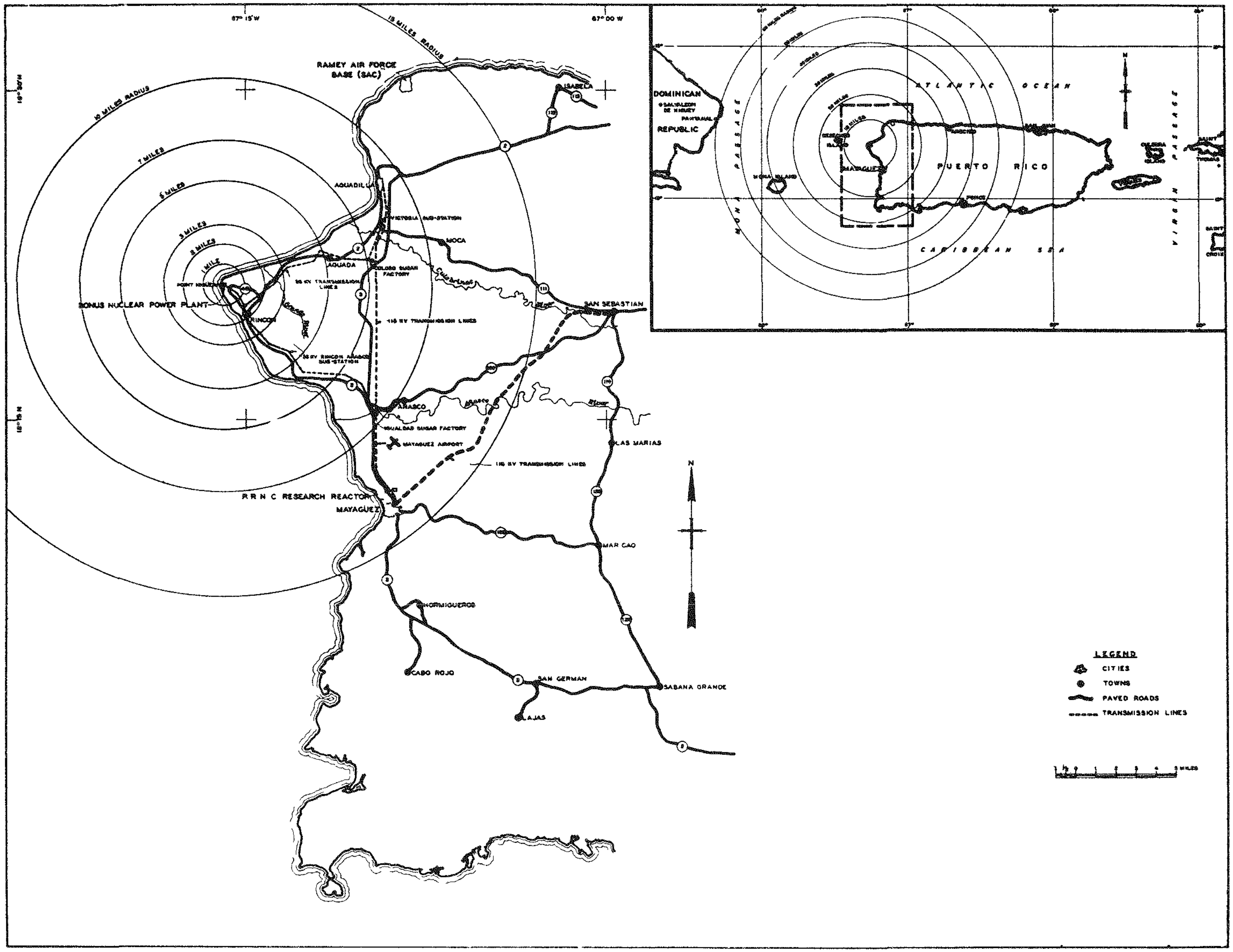

Fig. 1001-1 Site location map.

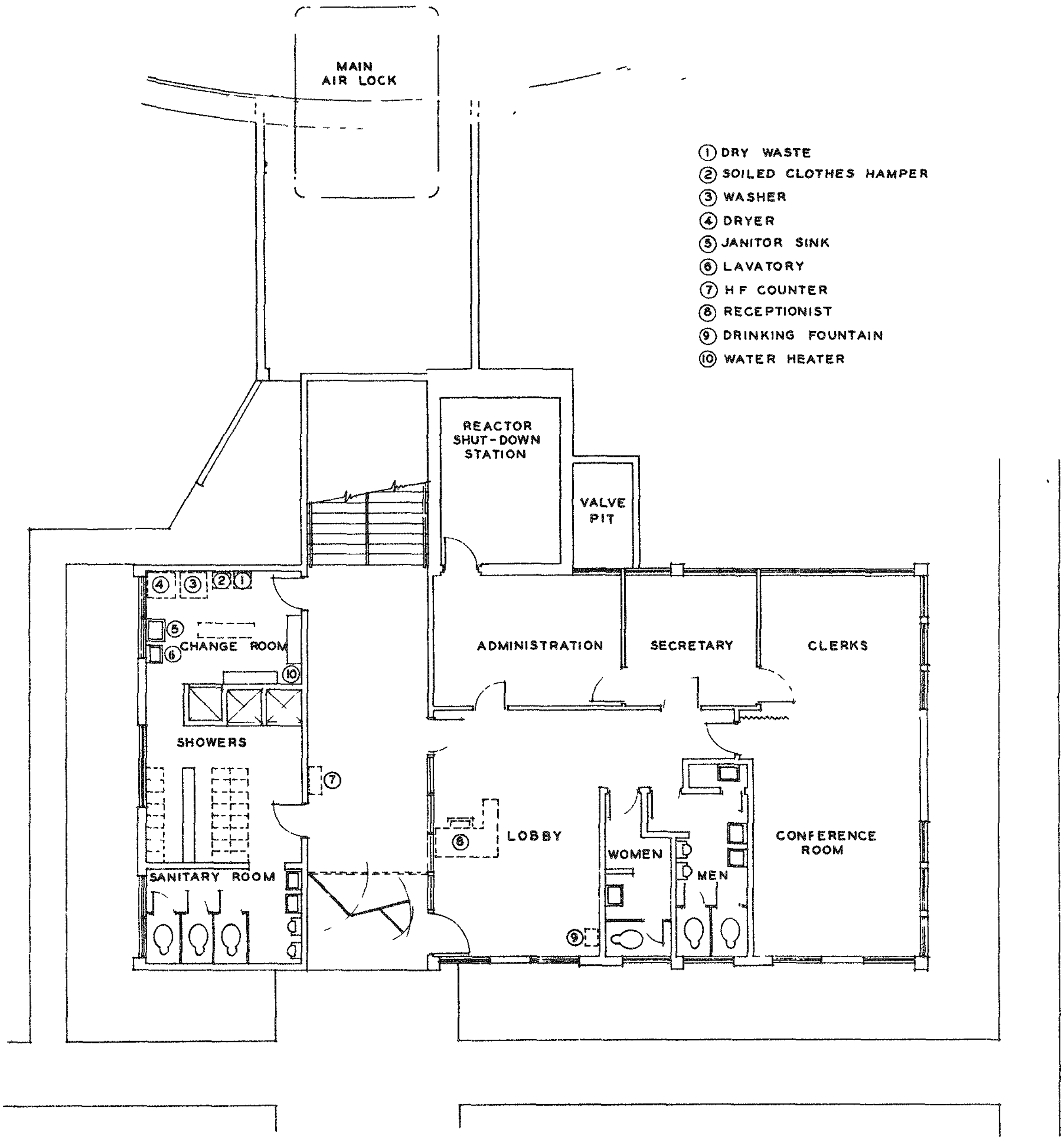

Fig. 402-4 Layout of entrance building.