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SCREENING EVALUATION. VOLUME 2
APPENDIX A. EQUIPMENT LIST

November 1979

Work Performed Under Contract No. EN-77-C-02-4057

United Engineers & Constructors, Inc.
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GAS REACTOR INTERNATIONAL COOPERATIVE PROGRAM

PEBBLE BED REACTOR PLANT

SCREENING EVALUATION
VOLUME 2
CONCEPTUAL BALANCE OF PLANT DESIGN

Prepared By
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For

GENERAL ELECTRIC

ADVANCED REACTOR SYSTEMS DEPARTMENT
310 DeGUIGNE DRIVE
SUNNYVALE, CALIFORNIA 94086

November 1979
PS-0549

Prepared for
The U.S. Department of Energy
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ABSTRACT

This report consists of three volumes which describe the design concepts and screening evaluation for a 3000 MW_t Pebble Bed Reactor Multiplex Plant (PBR-MX). The Multiplex plant produces both electricity and transportable chemical energy via the thermochemical pipeline (TCP). The evaluation was limited to a direct cycle plant which has the steam generators and steam reformers in the primary circuit. Volume 1 reports the overall plant and reactor system and was prepared by the General Electric Company. Core scoping studies were performed which evaluated the effects of annular and cylindrical core configurations, radial blanket zones, burnup, and ball heavy metal loadings. The reactor system, including the PCRV, was investigated for both the annular and cylindrical core configurations.

Volume 2 describes the conceptual balance-of-plant (BOP) design and was prepared by United Engineers and Constructors, Inc. of Philadelphia, Pennsylvania. The major emphasis of the BOP study was a preliminary design of an overall plant to provide a basis for future studies. There were no optimization or trade-off studies performed.

Volume 3 is an Appendix containing the equipment list for the plant and was also prepared by United Engineers and Constructors, Inc. It tabulates the major components of the plant and describes each in terms of quantity, type, orientation, etc., to provide a basis for cost estimation.

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1.0 INTRODUCTION AND SUMMARY

This document presents the results of a study undertaken by United Engineers and Constructors Inc. (UE&C), under contract to the General Electric Company Advanced Reactor Systems Department (GE-ARSD), to provide a Conceptual Balance of Plant design for a 3000 MWt Pebble Bed Gas Cooled Reactor. The reactor was configured by GE-ARSD to generate process gas and electricity using a closed cycle chemical heat pipe, in which part of heat from the reactor is converted to chemical energy by an endothermic reaction and the product (a mixture of gases) is piped to the user up to a 100 miles distant. The chemical energy is reconverted to heat through an exothermic reaction heat exchanger at the point of usage. The reference reactor is a 3000 MWt Pebble Bed Reactor utilizing spherical fuel elements that permit on-line refueling; the reactor employs a novel fuel cycle scheme named the OTTO cycle (Once-Through, Then Out), which enables the reactor to operate with an outlet coolant temperature of 950^{o}C and is projected to offer a 90% availability factor.

Specific efforts undertaken towards the development of the BOP conceptual design included preparation of conceptual flow and heat balance diagram, sizing of components, equipment specifications, component layouts, and related conceptual design for all systems pertinent to the BOP.

Lists of the major components of the plant were prepared with United Engineer's proprietary computer code PEGASUS, which incorporates a model of the plant that has been stored in tape for quick retrieval. Should a follow-on study be later authorized involving a cost estimate, the model can be retrieved and expanded for that purpose.

2.0 PLANT CONSIDERED AND REFERENCE REACTOR

2.1 PLANT CONSIDERED

The plant considered in this study utilized the PBR as a source of heat for generation of process heat and electricity. The process heat plant is based on a closed cycle chemical heat pipe concept using a pebble bed reactor. Each of the six heat transport loops consist of one steam reformer, one steam generator, one circulator, one process recuperator, plus the necessary isolation valves and associated gas ducting.

The selected flow diagram shown in Figure 2.1 and 2.2 shows the plant as configured by GE-ARSD for the present study. As shown on the diagram, the reactor core is cooled by 7.08×10^6 LBM/Hr of helium gas at 580 psia. The helium leaves the core at $1740^\circ F$ and is directed to the steam reformers through six concentric ducts. The inner duct carries the hot helium while the outer duct contains the returning helium at $572^\circ F$. The helium exits from the steam reformer at $1470^\circ F$ and flows through another concentric duct to the steam generator. The helium leaves the steam generator at $553^\circ F$ and enters the primary circulator. The return helium stream is used to cool the component liners as it passes between the liners and the PCRV.

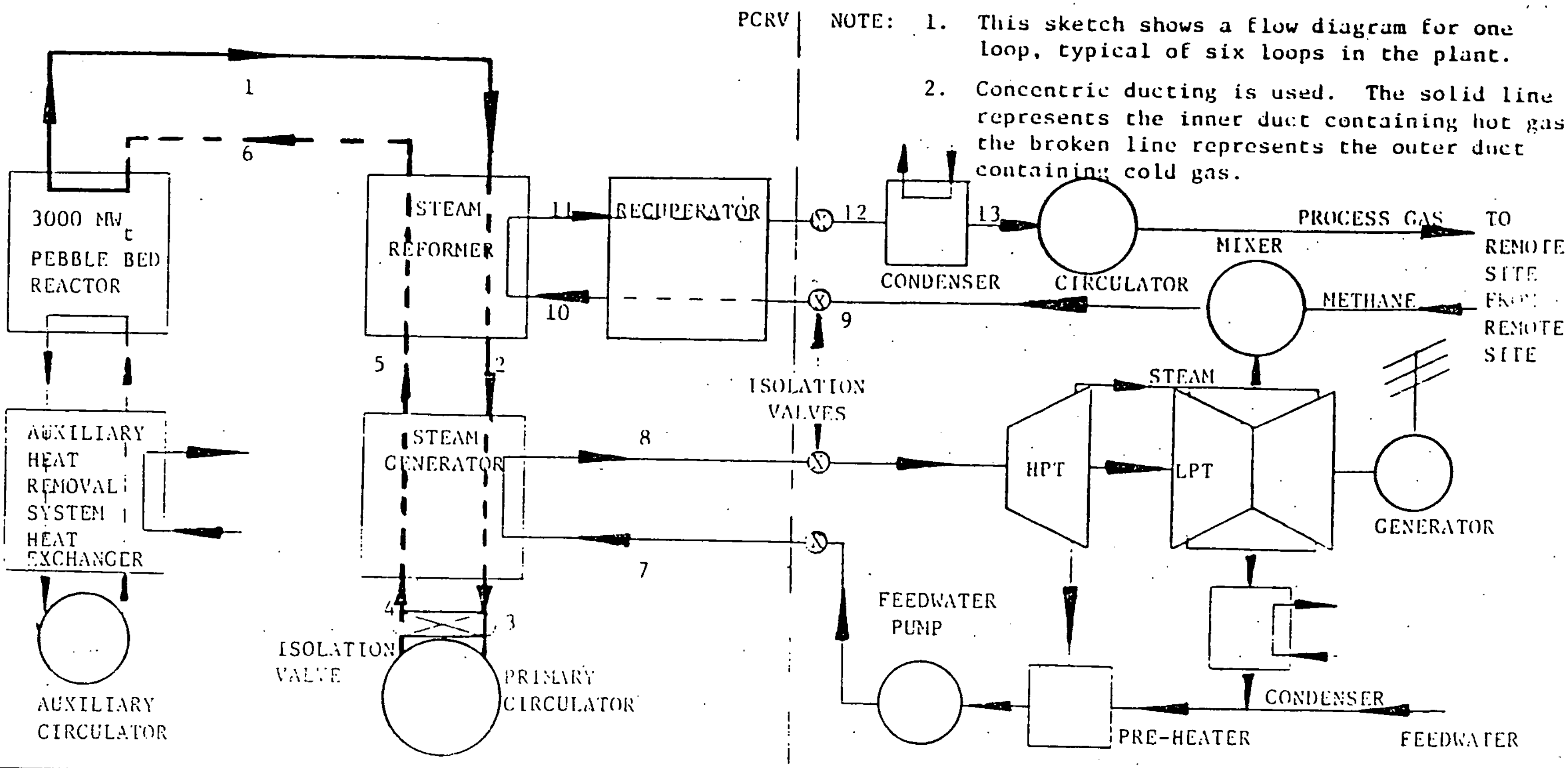
The reformed gas stream leaving the steam reformer consists of CO, H_2, H_2O (vapor) and CO_2 at a temperature of $1255^\circ F$. This gas mixture is then cooled to $967^\circ F$ as it passes through the recuperator. The excess steam is then condensed out of the mixture to avoid any reaction between the CO_2 and H_2O (vapor). The gas is transported to a distant site where it is converted back to CH_4 and H_2O by methanation. The CH_4 can then be returned to the steam reformer to complete the cycle.

Feedwater to the steam generator enters the preheater stage at 355°F and 1740 psia and leaves the superheater stage at 1003°F and 1668 psia. Isolation valves are provided at the PCRV penetrations of the process gas and water/steam lines, and in the main helium loop.

The primary circulator is capable of overcoming a total pressure drop (core plus loop) of 20 psi at a flow rate of 1.18×10^6 LBM/Hr.

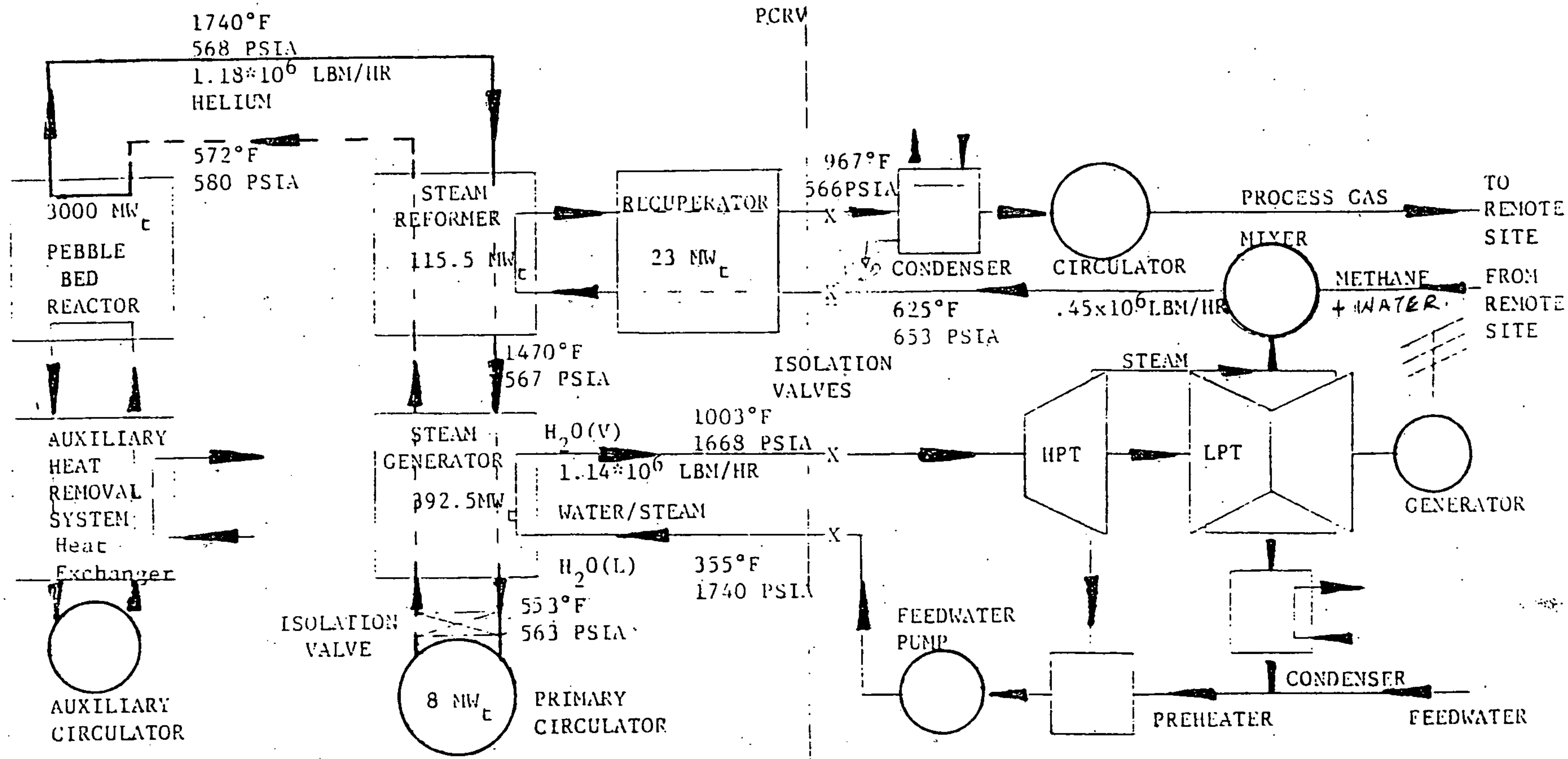
Concentric ducting is sized to limit the maximum gas velocity, for both hot and cold streams, to about 200 ft/sec and 70 ft/sec, respectively. It is advantageous to use a lower gas velocity for the cold gas since the lower velocity will reduce the heat transfer coefficients in the outer duct. This reduces the heat flux across the inner wall and also the heat loss to the PCRV. To standardize fabrication, installation, maintenance, and handling equipment requirements, only one size of concentric duct is used in the main loop, although smaller duct diameters can be used where lower temperature conditions exist.

The heat balance given for the process heat plant is depicted on Figure 2.2. For each heat transport loop, the primary gas circulator will add an estimated 8 MWt to the 500 MWt/loop of nuclear heat. As the figure indicates, 115.5 MWt/loop (23% of the heat) is used in the reforming of the methane/steam mixture. The incoming process gas also recovers 44.5 MWt/loop, (23 MWt/loop in the recuperator and 21.5 MWt/loop in the steam reformer), from the reformed gas stream. The remaining 392.5 MWt/loop, or 77% of the heat, is transferred to the steam generator for the production of steam.



STEAM	TEMPERATURE		PRESSURE		FLOW RATE		INNER/OUTER DUCT DIA.		COMPOSITION
	°F	°C	PSIA	PASCAL	LBM/HR	Kg/s	FT	M	
1	1740	950	568	$3.92*10^6$	$1.18*10^6$	148.21	4.92/8.2	1.5/2.5	Helium
2	1470	800	567	$3.91*10^6$	"	"	"	"	"
3	553	290	563	$3.88*10^6$	"	"	"	"	"
4	568	293	580	$4.00*10^6$	"	"	"	"	"
5	570	299	580	$4.00*10^6$	"	"	"	"	"
6	572	300	580	$4.00*10^6$	"	"	"	"	"
7	355	180	1740	$12.00*10^6$	$1.14*10^6$	143.3	1.97	.6	H_2O(Liquid)
8	1003	540	1668	$11.50*10^6$	$1.14*10^6$	143.3	3.28	1.0	H_2O(Vapor)
9	625	330	653	$4.50*10^6$	$.45*10^6$	57.13	4.43	1.35	H_2O(V)+CH_4
10	931	500	638	$4.40*10^6$	"	57.13	"	1.35	H_2O(V)+CH_4
11	1255	680	580	$4.00*10^6$	"	57.13	"	1.35	H_2 +CO+H_2 (V)+CO
12	967	520	566	$3.90*10^6$	"	57.13	"	1.35	H_2 +CO+H_2O(V)+CO
13	396	203	330	$2.28*10^6$	$.18*10^6$	22.68	"	1.35	H_2+CO+CO_2

FIGURE 2-1 - FLOW DIAGRAM FOR PROCESS HEAT PLANT USING A PEBBLE BED REACTOR



NOTE: 1. THIS SKETCH SHOWS A HEAT BALANCE FOR ONE LOOP, TYPICAL OF 6 LOOPS IN THE PLANT.

FIGURE 2-2 - HEAT BALANCE FOR PROCESS HEAT PLANT USING A PEBBLE BED REACTOR

3. PLANT DESCRIPTION

3.1 REFERENCE PBR

The Reference PBR plant is described in Section 2 of this report. A detailed description of the structures and systems follow in this Section of the report. Minispecifications of the major components in the systems are located in Appendix A.

For the purposes of this study, the annular core concept was utilized in that it provided added support for the top head of the PCRV. This design required twelve discharge stations for spent fuel rather than six if the center support was not used.

The descriptions of the major parts of the plant contained in this Section are:

- 3.2 Plot Plan
- 3.3 Structures
- 3.4 Nuclear Steam Supply System
- 3.5 Engineered Safeguards System Features
- 3.6 Auxiliary Systems
- 3.7 Electrical Systems
- 3.8 Instrumentation and Control Equipment
- 3.9 Turbine Plant Systems
- 3.10 Radioactive Waste Management Systems
- 3.11 Process Gas Chemical System

3.2 PLOT PLAN

A single unit PBR plant layout is shown on Drawing 7122.001-PBR-001. The arrangement of buildings provides for optimum use of space for the various functions performed in the plant. The grouping of structures also provides a controlled access to vital areas of the power plant.

3.3 STRUCTURES

Drawings 7122-PBR-002 through 009 inclusive, show the arrangement of the safety-related buildings, namely:

- o Containment
- o Control and Diesel Building
- o Reactor Service and Fuel Handling Building
- o Penetrations Building

These buildings are designed to seismic Category I requirements.

The major seismic Category I structures required for this plant are:

Reactor Containment Building

The containment houses the NSSS and associated equipment, air purification and cleanup system, provides biological shielding, and is a vapor-tight structure to protect the environment in the unlikely event of a postulated abnormal condition of the reactor coolant system. The interior of the containment is lined with carbon steel plate. Interior concrete substructures in the containment are designed to seismic Category I requirements and are used to support and protect components and equipment.

Reactor Service and Fuel Handling Building

The reactor service and fuel handling building houses auxiliary safety related systems and components. A new fuel storage area is provided. This building also contains a spent fuel storage pool, together with its associated pool cooling and pool water cleaning systems. The fuel pool is sized for approximately 3 years of spent fuel storage.

Radwaste processing, auxiliary, equipment, and equipment decontamination are also accomplished in this building. A loading dock for truck or rail shipments is located alongside the building.

Control and Diesel Building

The CD building houses the emergency diesel generators, the main control room and remote shutdown control room, and cable spreading rooms. This building is designed to operate and control the power plant under both normal and emergency operating conditions. A secondary control room is provided in the CD building should the main control room become uninhabitable during an emergency.

The CD building also houses the helium purification equipment.

Penetrations Building

The penetrations building houses the main steam and feedwater containment isolation valves. Each of the six steamlines are provided with a stubbed header which contains safety relief valves and pressure relief valve.

The containment isolation valves for the chemical process lines entering and returning from the PCRV are located in this building.

Ultimate Heat Sink Structure

These structures, house the air-blast cooling towers and associated pumps to provide cooling water to the after heat removal heat exchangers that operate during emergencies.

Nuclear Service Water Cooling Towers

These structures house the nuclear service water pumps which provide emergency service water to the emergency diesel generators and other essential services during emergencies.

Remote Air Intake Structures

The structures provide fresh air to the main control room during emergencies.

The non-seismic Category I structures contain non-safety related equipment and components that are not required for safety or safe-shutdown. These structures normally are constructed of structural steel framing, metal siding, concrete plank roofing, and founded on concrete spread footings. Drawings 7122.001-PBR-010 through 013, inclusive, show the arrangement of the major non-seismic Category buildings.

Turbine Building

The turbine building houses the turbine-generator, condensers and associated equipment, feedwater heaters and pumps, and auxiliary equipment. Seismic Category I components or equipment are not housed in this building.

Other non-seismic Category I buildings that are a part of this plant complex, includes:

- Service/Administration Building
- Access Building
- Plant Security Building
- Circulating Water and Service Water Pump House
- Makeup Water Intake Structure
- Makeup Water Pretreatment Building
- Fire Water Pump House
- Holding Pond
- Process Gas Chemical System Area

3.3.1 YARDWORK

3.3.1.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The function of yardwork is to prepare the site for the construction of buildings and the receipt of materials.

Design Requirements

Site preparation shall include excavation, backfill and dewatering for structure associated yardwork.

Yardwork shall include all facilities required for drainage, sanitation, access to major roads and railroads, and security as required during construction.

Yardwork shall also include finish grading and final site landscaping.

3.3.1.2 DESIGN DESCRIPTION

The Middletown plant location is a hypothetical site. The reference elevation for site and yard elevations and plant finish grade is at 18 feet above the mean river level.

Site preparation consists of clearing, grubbing and stripping of top soil for all structures, road, railroads, parking areas, materials handling areas and construction facilities. Rough grading quantities included with the general cut and fill do not include cut and fill the main plant structures. Fine grading and landscaping are also included with the general cut and fill work.

Earth excavation, backfill, concrete fill and dewatering for the main plant structures are included with the structure associated yardwork. This includes all excavation work for the main nuclear and turbine plant areas. Excavation work for structures not included with the main excavation are included with the structural work for the building under consideration. The cut and fill work includes hauling, dumping, stockpiling, placing and compacting. The fill is separated into select and compacted Category I fill adjacent to Non-Category I structures and general area fill in the main plant area. In addition, concrete fill is used under major structures to distribute bearing loads at the same elevation to minimize differential settlement between structures. In general, the main plant excavation is a large open cut to accommodate the Reactor Containment Building, Control and Diesel Building, Fuel Handling and Reactor Services Building, Turbine Building, Ultimate Heat Sink Structures.

Excavated material is used on site for general fill as much as possible. Spoil areas and storage areas were established for excavated material not used as fill and for top soil. Erosion and sedimentation control of these areas is assumed to be in accordance with EPA requirements. Temporary settling basins are provided to collect all runoff during construction prior to discharge.

The yard drainage system consists of inceptor ditches (paved and unpaved) and storm drains with catch basins to carry off storm water from developed areas. Water courses that are intercepted near the plant are diverted by ditches into existing stream beds or storm drains. Culverts carry stream flow under the railroad and roads. The yard surface water drainage is discharged via the existing water courses as much as possible. Building roof drainage is directed to the yard drainage system.

Piping and toilet facilities for permanent plant requirements are based on permanent plant personnel requirements.

Highway access is provided to the site by existing secondary roads connecting to a state highway. This road is assumed to be in good condition and needs no additional improvements. An onsite asphalt road is provided around the main plant structures. The road has paving thicknesses equivalent to the standard thicknesses required for public highways. In addition, parking areas, concrete curbs and walks are provided. Service roads are arranged to provide access to all truck sized doors in the plant and to all buildings requiring servicing or maintenance by vehicles.

Railroad access is provided by constructing a railroad spur which intersects the existing railroad. The length of the spur from the main line to the plant site is five miles in length. Additional spurs are provided to the Turbine Building and the Fuel Handling and Reactor Service Building. All roadbed and trackage was designed in accordance with the latest railroad standards.

In addition to the above items, fencing, a gate house and roadway and yard lighting were provided with the yardwork.

3.3.2 REACTOR CONTAINMENT BUILDING

3.3.2.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Reactor Containment Building (RCB) houses the prestressed concrete reactor vessel (PCRV), its support, fuel distribution and collection systems, primary heat transport system, and selected auxiliary systems and components. The RCB protects those systems and components against normal, abnormal and extreme environmental conditions, and externally generated missiles.

Design Requirements

The RCB is designed to limit fission product release during normal and design basis event (DBE), including depressurization of the PCRV, chemical process line break, or a main steam line break, and the postulated maximum hypothetical fission product release (MHFPR). The RCB is designed to sustain the maximum pressure and temperature resulting from:

- Depressurization of the PCRV.
- Rupture of the new fuel distribution or spent fuel collection pressure boundary.
- Malfunction of the new fuel or spent fuel transport systems.
- Main steam pipe rupture.

The conditions and design data are given in Table 3.3.2.

The RCB is provided with a new fuel distribution facility, spent fuel collection system, new fuel transport system with its air-lock, and a spent fuel transport system with its air-lock.

3.3.2.2 DESIGN DESCRIPTION

The containment houses the Nuclear Steam Supply System (NSSS). It is a seismic Category I reinforced concrete cylindrical structure with a hemispherical dome and a flat reinforced concrete base. The reinforced concrete base is 184 feet diameter, 14-feet thick, and founded 34 feet below finished grade. The upright cylindrical portion of the containment has an inside diameter of 171 feet, measures 173 feet - 2 inches from the top of foundation mat to the springline of the dome, and has a 4 foot 6 inch thick wall. The dome portion is a hemispherical-shaped head having an inside height of 85 feet, 6 inches, and a 3 foot 6 inch thickness of reinforced concrete. The inside height from the top of the mat to the inside of the dome is 259 feet, 2 inches. The gross volume of the containment is 5,283,400 cubic feet with a free volume of 3,284,800 cubic feet.

A 3/8 inch thick carbon steel liner is applied to the inner surface of the cylinder, ½" thick liner on the inside of the dome, and a ¼ inch thick liner on the top of the foundation mat. The liner is anchored to the inside face of the containment concrete. All seams of the liner are continuously welded and non-destructively examined to assure that the liner provided an impervious membrane to prevent the release of containment atmosphere to the environs. The bottom liner is supported on top of the foundation mat and is protected by a reinforced concrete slab which forms the floor of the containment. Below the PCRV support, the top mat is depressed 2 feet to provide a shear-key for transmitting horizontal seismic forces from the support into the mat. The liner follows the mat contour. This is protected by a concrete slab 3 feet thick.

An equipment hatch containing an air-lock is provided in the containment at the refueling floor level and is used as an entrance through which equipment is moved into the containment during construction and may be used during maintenance operations.

A personnel air lock is provided in the containment at the bottom of the containment plus the one at the refueling floor level. These air locks may be remote operated during normal plant operation to permit transporting new fuel into and removing spent fuel from the PCRV. Piping, electrical penetrations, and HVAC ducts penetrate the wall at various locations. These penetrations are designed to provide a leak-tight connection during normal and abnormal operating plant conditions. Containment penetrations are housed in either the Penetrations building, the CD building, or the Reactor Service and Fuel Handling Building, which provides protection against environmental conditions and externally generated missiles for the penetrations, containment isolation system valves, and power and instrumentation wiring.

The PCRV is located concentrically inside the containment and is supported on a reinforced concrete foundation. The PCRV is 139 feet, 0 inches diameter and 92 feet, 2 inches high, with its top located 2 feet, 10 inches below the operating floor. This floor is constructed of steel beams and plate and is supported from the top of the PCRV. The bottom of the PCRV is located 25 feet, 0 inches above the containment floor and is supported on a reinforced concrete peripheral ringwall and center pedestal foundation extending to the floor. The ringwall is 136 feet, 0 inches O.D. and 8 feet, 0 inches thick, and contains several large openings to provide for routing of major piping and transfer of spent fuel through the wall and for access. The center pedestal is 30 feet, 0 inches diameter and is solid.

The concentric location of the PCRV creates a 16 feet wide annular space between it and the containment shell. Within this space, and supported from the containment floor, is a steel-framed annular-shaped structure that extends completely around the PCRV and rises to the operating floor level at the top of the PCRV. This structure is independent of the PCRV and the containment shell and supports major equipment, piping, electrical trays, HVAC equipment, and access platforms and stairways.

A 100-ton polar crane is provided for construction and maintenance operations. The crane rail is located near the spring line of the containment and is supported from the wall of the containment. The crane is designed to seismic Category I criteria with the requirements that the suspended load will not drop and that the crane will remain in place and intact during an SSE event. However, a field-installed tower crane placed on top of the PCRV would be required to remove a steam reformer or a steam generator. The steam reformer, with an estimated weight of 275 tons, is the heaviest component in the PCRV. The steam generator, with an estimated weight of 140 tons, is the second heaviest.

The containment design is in accordance with the ASME Boiler & Pressure Vessel Code, Section III, Division 2 - Concrete Reactor Vessels and Containments. Interior concrete support structure is in accordance with the requirements of the ACI Standard 349-76, Code Requirements for Nuclear Safety Related Structures, supplemented with the ACI Standard 318-71, Building Code Requirements for Reinforced Concrete.

The PCRV is provided with a new fuel distribution system which receives fuel from the Reactor Service and Fuel Handling Building and distributes it in the reactor core. The system is supported above the PCRV. A spent fuel collection system is located under the PCRV which is used to collect the spent fuel which is then transported to the Reactor Service and Fuel Handling Building for storage.

TABLE 3.3-2

Containment Design Data

Item	Data
Type	Upright cylinder on a flat base with a hemispherical top head, reinforced-concrete, steel lined.
Inside iameter	171 feet
Inside Height (base to inside of top head)	259 feet, 2 inches
Liner	Carbon Steel
Wall Thickness	4 feet, 6 inches
Dome Thickness	3 feet, 6 inches
Design Leak Rate	0.1 Volume-Percent/24 Hours

3.3.3 CONTROL AND DIESEL-GENERATOR BUILDING

3.3.3.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Control and Diesel (CD) Building houses the control and electrical equipment, including support systems required for plant operation. The CD building also houses essential features including the main control room, remote shutdown area, and the emergency diesel-generators.

Design Requirements

The controls for nuclear steam production and its conversion into electricity are operated from the control room.

The remote shutdown room has the capability to initiate a reactor trip and other functions to safely shut down the reactor. This remote shutdown area is isolated from the main control room and containment with the requirement that it can be continuously occupied in the event an accident renders the main control room inaccessible.

3.3.3.2 DESIGN REQUIREMENTS

The design of the CD building evolved from previous studies conducted over a period of time to combine the functions of the control building, emergency power building, cable tray transition building, and the reactor containment building annulus. The CD building houses the main control room, the safe shutdown control room, computer rooms, standby power supply (diesel-generator units), Class 1E medium and low voltage a-c distribution system, Class 1E d-c power distribution system and batteries, emergency motor controllers, control rod drive cabinets and the major portion of the Class 1E cable and raceway system.

Two separate and independent cable spreading rooms, one above and one below the control room, are provided for the three Class 1E and one non-Class 1E power, control, and instrumentation channels. In addition, a network of four separate and independent vertical cable chases and containment penetration rooms are provided for the four channels.

Redundant heating, ventilating and air conditioning systems are provided for the control room and computer room areas. Redundant heating and ventilating systems are provided for the diesel-generator areas, switchgear area, containment penetration areas, and the cable spreading rooms. A separate and independent heating and ventilating system is provided for non-Class 1E equipment areas. Redundant control room air supply from remote air intakes is also provided.

Equipment access to any location within the CD building is through the equipment hatch area which accommodates the largest piece of equipment to be removed. The diesel-engine crankshaft and generator can also be removed.

The CD building is a reinforced concrete seismic Category I structure. A 4-foot thick reinforced concrete base slab is founded on fill concrete. The overall dimensions of the 7 story reinforced concrete building are 131 feet wide, 147 feet long, and 150 feet high.

The exterior walls, interior walls, and top slab of the building are reinforced concrete. The exterior walls are a minimum of 2 feet thick. Reinforced concrete walls separate the diesel-generators and support the upper floors. All walls and slabs are cast-in-place concrete with slabs supported on concrete beams, reinforced concrete columns and/or bearing walls. The top slab is covered with a roofing membrane.

Design of the structure is in accordance with the ACI Standard 349-76 entitled, "Code Requirements for Nuclear Safety Related Structures". Supplementary design is in accordance with the ACI Standard 318-71 entitled, "Building Code Requirements for Reinforced Concrete".

3.3.4 CONTROL ROOM EMERGENCY AIR INTAKE STRUCTURES

3.3.4.1 FUNCTIONS AND DESIGN REQUIREMENTS

Function

Each air intake structure is capable of providing fresh air to ensure habitability of the control room in the event of an abnormal event during plant operation.

Design Requirements

The emergency air intake structures are designed to:

1. Provide fresh air intake for the control room in event of radioactive contamination in the normal air intake stream.
2. Provide fresh air intake for the control room in the event of chemical contamination in the normal air intake stream.
3. Provide the above functions during SSE or other adverse environmental conditions.

3.3.4.2 DESIGN DESCRIPTION

The control room emergency air intake structures are two Seismic Category I reinforced concrete structures. The air intake piping pit is located below grade and founded on rock ten ft. below grade. Each structure has a base slab and walls of reinforced concrete ten ft. square and nine ft. deep, and has a volume of 500 cu. ft. Each structure has a top slab of reinforced concrete, which covers the piping pit and forms the floor of the security area around the air intake pipe. Each slab is at grade level and is 18 ft. square. The air intake structures are located inside the plant security fence.

3.3.5 REACTOR SERVICE AND FUEL HANDLING BUILDING

3.3.5.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Reactor Service and Fuel Handling Building houses all the mechanical auxiliary systems and emergency systems associated with the reactor plant. The building also houses the fuel handling equipment and related systems.

Design Requirements

The Reactor Service and Fuel Handling Building is a Seismic Category I structure designed to house all radioactive or potentially radioactive systems and materials. The building houses all the emergency process systems required to mitigate the consequences of the following postulated accidents or abnormal occurrences:

1. PCRV depressurization
2. Steam line break
3. Emergency shutdown due to loss of off-site power
4. Emergency shutdown due to safe shutdown earthquake

3.3.5.2 DESIGN REQUIREMENTS

The Reactor Service and Fuel Handling Building is a seismic Category I reinforced concrete building. Provisions are made in the building layout to restrict access into any area that contains engineered safeguards equipment or high level radiation.

The building ventilation system is designed such that air flow is directed from areas of low level contamination into areas of potentially higher level contamination and is filtered before discharge.

The lower level, or basement of the building houses the following systems:

1. Spent fuel storage pool
2. Spent fuel transport and unloading system
3. Spent fuel container loading area
4. Spent fuel pool cooling and purification system

The Reactor Service and Fuel Handling Building also houses the following systems and facilities on various levels:

1. Liquid radwaste system
2. Gaseous radwaste system
3. Solid radwaste and spent resin storage
4. Shipping and receiving area
5. Drum storage and cleaning
6. Laundry and cleaning rooms

The upper floor houses the following:

1. New fuel storage bins, capacity approximately one-million fuel pebbles storage.
2. Fuel loading facility.

The exterior walls, interior walls, floor slabs and roof slab are reinforced concrete. The exterior walls are a minimum of two ft. thick, with the exception of the spent fuel pool wall which is nine and one-half ft. thick for all portions which are above grade. The spent fuel pool is 66' x 125' and will accommodate approximately three years of spent fuel. The pools are lined with ¼ inch thick Type 304 austenitic stainless steel plate. This plate forms a watertight membrane for the pools.

The floor slabs are cast-in-place concrete over metal deck and supported on steel framing. The roof slab is cast-in-place concrete over metal deck, covered with a roofing membrane and supported on steel framing.

Design of the structure is in accordance with the ACI Standard 349-76 entitled "Code Requirements for Nuclear Safety Related Structures". Supplementary design is in accordance with the ACI Standard 318-71 entitled, "Building Code Requirements for Reinforced Concrete".

3.3.6 PENETRATION BUILDING

3.3.6.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Penetration Building provides a structure to house and protect the main steam isolation and relief valves and the safety-related valves of the steam generator feedwater lines. It also houses the isolation valves of the chemical processing feed and return piping. The protection afforded by this building is from normal and abnormal environmental conditions and externally generated missiles.

Design Requirements

The Penetration Building is designed to afford protection and separation of the main steam and steam generator feedwater pipe and valves. It is designed to withstand the pressure transient in the event of a double-ended steam line break.

The Penetration Building provides support, protection, and separation from the main steam and feedwater lines for the chemical processing system piping and valves.

3.3.6.2 DESIGN REQUIREMENTS

The Penetration Building houses the main steam and feedwater piping and valves, and portions of the chemical processing system piping add valves.

The building is a seismic Category I structure constructed from reinforced concrete. It is on a common foundation mat with the containment. The building shares a common wall with the containment on one side and has two-foot thick walls on the other three sides and on the roof.

The penetration building measures 183 ft long, 50 ft wide from outside of containment wall to edge of turbine building, and is 60 ft high. Entry to the main steam and boiler feedwater lines and valves is provided by doors through the separation walls in the building. Stairwells are provided in the building for access to any level. Doors into the Penetration building and doors through separation walls are of the bulk head type designed to withstand the differential pressure loads without plastic deformation.

The main steam and steam generator feedwater lines are separated from the chemical processing system components by reinforced concrete walls. The area containing the main steam piping includes the power operated relief valves and safety relief valves. The relief valves are provided with vent stacks that permit the steam to exit to the environment.

3.3.7 PIPE TUNNELS

3.3.7.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

Pipe tunnels are designed to provide protection for all plant piping between structures.

Design Requirements

The pipe tunnels are reinforced concrete box type structures. Where the pipe in the tunnel is Seismic Category I the tunnel is also designed to be Seismic Category I.

3.3.7.2 DESIGN REQUIREMENTS

Pipe tunnels are reinforced concrete structures eight ft. wide ten ft. high and founded at various elevations. Where pipe tunnels extend beneath a building, the bottom floor of the building serves as the roof of the tunnel. In other areas the roof is cast in place concrete over metal deck and supported on steel framing.

3.3.8 SERVICE AND ADMINISTRATION BUILDING

3.3.8.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Service and Administration Building houses the general offices, conference rooms, auxiliary steam boiler plant, storage and warehousing, laboratories, machine shop, small shops, lockers and change rooms, and toilets.

Design Requirements

The Service and Administration Building has no safety or protection design requirements.

3.3.8.2 DESIGN DESCRIPTION

The design of the Service and Administration Building provides a central location to conduct administrative routines for the successful operation of the power plant. In addition, this building houses the records that must be retained, by law, for the operating life of the plant. The offices and record storage rooms are on the second floor of this two-story structure.

On the ground floor is the auxiliary steam boiler plant, a major-repair machine shop, small specialty shops, and warehousing space. Replacement parts and components, necessary for the continued operation of the plant, are stored in the warehouse section.

This is a two story structural steel framed structure 176 feet wide, 270 feet long, and 38 feet high. The structure is supported on reinforced concrete spread footings on rock. The reinforced concrete ground floor is located at grade. The intermediate floor is reinforced concrete supported on a metal deck on steel framing. The roof is concrete channel plank covered with a roofing membrane. The exterior walls are insulated metal siding, and the interior walls are either concrete block or metal partitions. Most areas are provided with suspended acoustical ceilings. A 20-ton crane is provided to service the machine shop, and suitable hoists are provided in the small shops.

A HVAC system is provided to maintain environmental conditions of normally occupied spaces within the prescribed comfort zone and ensure that temperatures and humidity in other areas are suitable for material storage and equipment operation. Heating and air conditioning is provided by fan cooler heating units located throughout the building. Supply air is heated by steam preheaters and hot water coils in the supply air units. Hot water and chilled water for the fan cooler/heating units are supplied from central hot water heating systems and refrigerated chilled water systems. Steam for preheating supply air to the building is supplied by the auxiliary boiler system. The HVAC machinery room is located on the roof of the structure.

3.3.9 ACCESS BUILDING

3.3.9.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Access Building (AB) shall provide further facilities for controlling personnel access to the restricted areas of the plant.

Design Requirements

The AB shall provide adequate locker room space for the plant population. Space shall be provided for normally clean and contaminated personnel.

The AB shall provide a health physics checkpoint to monitor personnel leaving potentially radioactive areas and assure proper cleanup measures are taken before leaving the area.

3.3.9.2 DESIGN DESCRIPTION

The Access Building is a non-seismic Category I structure. The AB is a two story framed structure approximately 80 feet wide, 100 feet long and 50 feet high. The AB is supported on reinforced concrete spread footings on soil with a reinforced concrete ground floor at grade. The building volume is approximately 400,000 cubic feet. The roof is concrete plank covered with a roofing membrane. The exterior walls are insulated metal siding and the interior walls are concrete block.

All personnel entering restricted plant areas must pass through the health physics checkpoint. Upon leaving, personnel must again pass through the health physics station, and if contaminated, men enter the RCA locker room directly and women enter across the hall.

3.3.10 PLANT SECURITY BUILDING

3.3.10.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The purpose of the plant Security Building is to provide a controlled means of preventing illicit passage into the protected area of the plant and carrying objects such as firearms, explosives, and incendiary devices which could aid in industrial sabotage to the facility or in the theft of special nuclear material.

Design Requirements

The plant Security Building provides a physical barrier to all sections of the plant as well as a central location for monitoring the security of restricted areas and the plant grounds in general.

3.3.10.2 DESCRIPTIONS

The Plant Security Building is a 63 ft by 53 ft 6 inch building located at the perimeter fence of the main plant structures. Personnel to or from the main plant must pass through the Security Building and its associated security systems before entering the plant structures where radioactive materials are stored. The plant security system is monitored and operated from the security building. A separate emergency diesel-generator is provided of sufficient capacity to provide security lighting of the plant site and for the monitoring and alarm systems.

3.3.11 FIRE WATER PUMP HOUSE

3.3.11.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Fire Water Pump House is provided to house the fire protection pumps that furnished water through the entire plant area.

Design Requirements

The structure provides support and weather protection for the fire protection pumps, piping, valves, and controls.

3.3.11.2 DESIGN DESCRIPTION

The Fire Pump House is a non-seismic Category I single story steel frame structure 28 feet wide, 76 feet long, and 17 feet high. The structure is supported on reinforced concrete spread footings. The ground floor is located at grade and is a reinforced concrete slab. The structure has insulated built-up roofing on metal deck supported on structural steel and the exterior walls are insulated metal siding.

Two foundations for 500,000 gallon fire-protection water storage tanks are located near the Fire Pump House. The area within the ring wall has a completed sand fill bed to properly support the bottom plates of the tanks.

3.3.12 HOLDING POND

3.3.12.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Holding Pond collects effluents from non-radioactive plant drains.

Design Requirements

The holding pond is sized to collect the effluent and hold for a sufficient length of time, and treat if necessary, prior to disposal from the plant area.

3.3.12.2 DESIGN DESCRIPTIONS

The holding pond is a non-seismic Category I reinforced concrete basin. It is located near the point where it will be discharged from the plant area.

The foundation of the basin is two feet thick and founded approximately 8 feet below grade. The basin is 80 feet square and eight feet deep. Walls of the basin are one-foot thick. Volume of the basin is approximately 51,000 cubic feet.

3.4 NUCLEAR STEAM SUPPLY SYSTEM

The Nuclear Steam Supply System (NSSS) for the Pebble Bed Reactor Plant is designed for a dual function, namely:

- o Produce steam for generating electricity,
- o Reform a mixture of steam and methane to be supplied by pipeline to remote users that will methanate the process gas for their source of process heat applications.

The Pebble Bed Reactor is a high-temperature helium cooled reactor utilizing enriched uranium fuel encased in spheres of graphite and other coatings. Fuel is fed to and withdrawn from the reactor core on an almost continuous schedule for on-line refueling.

The PBR is contained in a post-tension concrete reactor vessel which, in turn, is supported on a concrete pedestal and ring wall. Walls of the reactor cavities are lined with water-cooled alloy-steel liners plus insulation and another alloy-steel liner cover over the insulation. Major components contained in the PCRV are:

- o Graphite reflector with cast-metal support.
- o Six steam generators.
- o Six electric motor driven coolant circulators complete with flow control valve.
- o Four After-Heat-Removal heat exchangers.
- o Four After-Heat-Removal coolant circulators complete with control valves.
- o Six steam reformers.
- o Six steam thermal recuperators.

- o Control rod assemblies and drives.
- o In-core instrumentation.
- o Fuel inlet and discharge piping.

The reactor and its components are designed for operating conditions of 580 psia helium coolant at 1740°F.

A conceptual description of the on-line refueling of the reactor is described in another portion of this report. There are a total of 42 inlets and 12 outlets in the PCRV designed for an annular core. A cylindrical core would be provided with 43 inlet and 6 outlet connections for the on-line refueling.

The heat-exchanger equipment is designed so all water, steam, and process gas piping connections are at the bottom of the PCRV. The PCRV support ring contains elongated openings through which the piping is routed to containment penetrations. Another elongated opening is provided in the ring wall support to provide a path through which the spent fuel transporter may pass and into an airlock.

The PCRV is provided with instrumentation to provide monitoring of the load conditions in the radial pretensioning material and the vertical pretensioning cables to assure that each element is carrying its load. Other instrumentation is provided to monitor for water in-leakage to the core and for any possible leakage in the double-walled tubing used in the steam-methane reformers.

Design details of the reactor and its associated components and installed equipment will be provided by the General Electric Company, Advanced Reactor Systems Department, Sunnyvale, California.

3.5 ENGINEERED SAFEGUARDS SYSTEM FEATURES

The following systems comprise the Engineered Safety Systems:

- o Containment Air Purification and Cleanup Systems
- o Containment Isolation System
- o Combustible Gas Control System
- o After Heat Removal Cooling Water System
- o Control Room Habitability System

These systems are provided to mitigate the consequences of unlikely postulated accidents. Each of the above systems are described herein after:

Containment Air Purification and Cleanup System

This consists of a cleanup filter system, containment purge system, and a containment recirculating filter system. These are used during normal plant operation for maintaining the containment in a habitable condition.

Containment Isolation System

Isolation valves are provided on all piping that penetrates the containment to establish or maintain isolation of the containment atmosphere from entering the outside environs during an emergency. The valves will be positioned to either isolate non-essential systems or will open for those systems that must perform a function.

Combustible Gas Control System

This system is provided to prevent the accumulation of hydrogen from reaching combustible concentrations in the containment following a leakage of hydrogen from the steam-methane reformer and its associated transport piping system.

After Heat Removal System

This system is provided to remove decay heat energy from the reactor fuel during shutdown, maintenance and accident conditions. During normal operation and emergency conditions, the air-cooled heat exchangers are used to cool water supplied to the heat exchangers located in the PCRV.

Control Room Habitability System

This system is provided to assure accessibility to the main control room and secondary control room during and following the occurrence of postulated accidents.

3.5.1 CONTAINMENT AIR PURIFICATION AND CLEANUP SYSTEMS

3.5.1.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Containment Air Purification and Cleanup System is used to maintain the levels of activity within safe working limits in the containment during normal operation.

Design Requirements

During normal reactor operation the reactor coolant leakage inside the containment can result in a significant buildup of fission products. The level of activity must be maintained within safe working limits for personnel access for inspection and maintenance. This safe level is achieved by periodic filtering and purging of the containment atmosphere to reduce radioactive concentrations and remove the iodine contained therein.

The containment purge system, together with the recirculation filter system, is designed to reduce the containment airborne activity levels below the permissible levels within 16 hours following a reactor shutdown.

These systems are not safety related but are designed to seismic Category I structural requirements.

3.5.1.2 SYSTEM DESCRIPTION

The containment system has different systems for air cleaning, each designed to meet a specific mode of operation.

- o Cleanup filter system
- o Containment purge system
- o Containment recirculating filter system

The three systems are designed for normal plant operation.

Cleanup Filter System

This system is designed to ventilate and to filter air from selected potentially radioactive areas within the containment. When an enclosure area is isolated, the air therein is not filtered. HEPA and treated charcoal are used for the filter media.

The system is designed to reduce airborne concentrations of particulates and iodine to less than one-percent of inlet concentrations. Redundant exhaust fans and dampers are provided to ensure that at least one fan is available during cleanup operations.

Containment Purge System

This system is provided for periodic purging with filtering of the purge stream for iodine removal. This system in conjunction with the containment recirculation filter system is designed to reduce the containment airborne activity level to below the allowable permitted by Appendix B, Table 1, Column 1, of 10 CFR Part 20 within 16 hours following reactor shutdown. This assumes that no purging or recirculation filtering of containment air is initiated prior to reactor shutdown.

The purge system consists of a purge supply and a purge exhaust system. The purge supply system passes outside air through roughing filters, steam heating coils to temper the air in the winter season, supply air fan and a ducted distribution system.

The pre-entry purge exhaust system has pre-filters, HEPA filters, and impregnated charcoal filters for removal of iodine. The air is then exhausted to the primary vent stack.

Containment Recirculating Filter System

The containment recirculating filter system is designed to remove iodine from the containment atmosphere during normal plant operations to limit the iodine concentrations and exposure to plant operating personnel during limited access to the containment. The system is also designed to rapidly reduce the iodine concentrations after reactor shutdown to permit personnel access for inspection and maintenance operations.

The components of the air filtration portion of the containment recirculating air filter system are required only during normal plant operations. The remainder of the system is required for air mixing of the containment atmosphere during post-despressurization conditions. All components of the system are designed to seismic Category I requirements and the air handling components, with the exception of the filters, are qualified to perform under depressurization conditions.

3.5.2 CONTAINMENT ISOLATION SYSTEM

3.5.2.1 FUNCTIONS AND DESIGN REQUIREMENTS

The Containment Isolation Systems establish and/or maintain isolation of the containment from the outside environment to prevent release of radioactive material, and ensure that the public is protected to the extent of not exceeding the requirements of 10 CFR 100 under adverse conditions.

Design Requirements

Each piping system penetrating the containment must be designed, considering that the system must be designed for the process requirements and be designed for the containment isolation requirements, for the most adverse of the design and operating requirements.

The isolation valves of each system are required to be properly positioned, i.e. either opened or closed, automatically upon receiving an initiating signal caused by either a PCRV depressurization, main steam line break, or chemical process pipe break.

In general, double barrier protection is provided for all lines that penetrate containment. A barrier may consist of a valve, a closed system, or a diaphragm depending on its location and application.

3.5.2.2 SYSTEM DESCRIPTION

Containment isolation valves are located in process lines to the requirements of Appendix A of 10 CFR 50, Criteria 55, 56, and 57. Criteria 51, 52, and 53 requirements are incorporated into the containment isolation system materials and testing used in the components.

Containment isolation valves are provided with actuation and control components appropriate to the type of valve. Globe and diaphragm valves are normally furnished with air diaphragm operators designed to fail to the safe position on loss of control air pressure. Gate valves are fitted with motor operated components and are powered from emergency electrical buses. Motor operated valves fail in the "as-is" position. No manual operation is required for immediate containment isolation.

Containment isolation valves, actuators, and controls are protected against missiles, including those caused during a PCRV depressurization. Main steam isolation valves, pressure and safety relief valves, and boiler feedwater isolation valves are located in a seismic Category I Penetration Building.

Only isolation valves located inside containment are subject to high-pressure, high-temperature steam or helium atmosphere resulting from an accident. Operability of these valves are assured by design and qualification tests.

3.5.3 COMBUSTIBLE GAS CONTROL SYSTEM

3.5.3.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Combustible Gas Control System is provided to prevent the accumulation of hydrogen from reaching combustible concentrations in the containment following a release of hydrogen from the heat pipe system. Hydrogen may accumulate in the containment as a result of:

- Leakage from the steam-methane reformer.
- Leakage from heat-pipe pipe break.

Design Requirements

The system is designed to maintain the hydrogen concentration in the containment to below 4.0 volume percent (4.0 v/o), which is the lower flammability limit in air.

3.5.3.2 SYSTEM DESCRIPTION

The primary means of hydrogen control is provided by a hydrogen recombiner. A dilution and purge system is also provided as a backup hydrogen control feature.

The recombiner is designed to start operating when required. Initiating recombiner operation at this time limits the maximum hydrogen concentration to 2.0 v/o. If recombiner operation fails, then periodic sampling of the containment atmosphere is initiated. Dilution and purging of the containment is performed to limit the hydrogen concentration to below 4.0 v/o.

The recombiner is located in a seismic Category I structure adjacent to the containment. The recombiner takes the air from the containment, removes the hydrogen via a catalyst bed, and returns hydrogen-free air to the containment. The recombiner is skid mounted and is provided from the emergency electric buses.

The purge system consists of a flow meter, throttle valve, and associated piping. The piping downstream of the flow meter enters the emergency exhaust filters located within the containment and provides a direct path to the plant vent. Components and piping upstream of the filter are in accordance with seismic Category I requirements. All pressure components upstream of the filter are designed to ASME B&PV Code, Section III, Class 2 requirements.

Mixing of the containment air is provided by the redundant fans in the containment recirculation filter system.

Containment isolation is provided by locked closed valves outside of the containment and either check valves or electric solenoid operated valves inside the containment. The solenoid valves are normally open and are energized to close to provide a fail-safe feature.

Additional analysis of hydrogen evolution during normal operations may dictate the use of containment inerting. An inert atmosphere may also be required after an analysis based on the quantity of hydrogen that could be released on the basis of a spectrum of pipe breaks and the free containment volume.

3.5.4 AFTER HEAT REMOVAL COOLING WATER SYSTEM

3.5.4.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The After Heat Removal Cooling Water System (AHRCWS) shall circulate water through the After Heat Removal Heat Exchanger (AHRHE) to remove stored and decay heat from the primary coolant and reject this heat to the atmosphere.

Design Requirements

The AHRCWS shall consist of four (4) independent cooling water loops. Each loop shall provide 50% heat removal capability for the reactor.

The AHRCWS is a Safety Class 2 system inside the containment and Safety Class 3 outside containment and shall be designed to ASME Section III Class 2 and 3 requirements respectively. The system shall be designed to seismic Category I requirements.

The AHRCWS shall remove the design AHRHE heat loads for all plant operating conditions and provide adequate cooling of the reactor core and its structures.

The AHRCWS shall use an air blast heat exchanger for ultimate heat rejection.

A design pressure rating of 1900 psig is required.

3.5.4.2 SYSTEM DESCRIPTION

The AHRCWS consists of four (4) redundant independent loops. Each loop consists of two (2) 100% pumps for normal operation, two (2) 100% pumps for emergency operation, one (1) 100% air blast heat exchanger, pressurizer tank, and the associated piping, valves and controls necessary to perform the required functions.

The AHRCWS has two (2) discreet modes of operation, defined as "Normal" and "Emergency" modes of operation. The Normal mode of operation of the AHRCWS corresponds to normal plant operation where the pumps for normal operation are used to circulate approximately 290 gpm of cooling water to the AHRHE to maintain AHRHE temperatures within design limits. During Emergency (or extend plant outages) following events causing loss of main loop cooling modes of operation the emergency AHRCW pump circulates 1354 gpm of cooling water to the AHRHE for reactor decay heat removal.

The AHRCWS pressurizer tank is used to provide the required AHRCWS pressure to insure a minimum sub-cooled enthalpy margin at the outlet of the AHRHE.

The air blast cooling tower fans are high velocity fans with propeller blades. During the winter months, the fan blading may be positioned so that little or no air flow is permitted over the tube bundles. Proper fan blade and exhaust damper positioning will limit the air flow in the tube bundle to provide adequate freeze protection of the tube bundle.

The AHRCWS has a chemical control package to provide proper quality of water in the system. The chemical control package is Non-Nuclear Safety and will be isolated from the AHRCWS by automatic isolation valves by high flow in the chemical package.

Demineralized water will provide normal system make-up.

The components and equipment of the AHRCWS are housed in seismic Category I Ultimate Heat Sink structures. The air blast cooling tower structure is designed for both vertical and horizontal missile protection of the fans and heat exchanger.

3.5.5 CONTROL ROOM HABITABILITY SYSTEM

3.5.5.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Control Room Habitability System is provided to assure accessibility and habitability of the main control room and secondary control room subsequent to the occurrence of postulated accidents resulting in release of fission products or hazardous chemical releases such as chlorine.

3.5.5.2 SYSTEM DESCRIPTION

The control room complex has a recirculating air system consisting of two air handling units, two independent refrigeration machines, and two independent air cooled condensers. Each air handling unit and its associated refrigeration equipment is sized to meet the normal and the design emergency conditions.

During normal operations, at least 30 cubic feet per minute of filtered outside air is provided for each occupant, and the air is then exhausted from the system. The control room complex is maintained at a positive pressure with respect to the outside environs by static pressure controls which limit the amount of air discharged from the system and building. Recirculated air and outside air is filtered prior to cooling and flowing into the control room complex.

The control room is supplied with conditioned air through a sheet metal duct system that is supported with seismic Category I supports. Air is distributed through diffusers as necessary to maintain design room temperature. Return air is drawn through return air registers in the plenum above the ceiling. The return air, together with the makeup ventilation air, flows through the air conditioning unit for recirculation.

The control room air cooling system consists of two 100 percent redundant trains. One train is supplied electric power from the train A emergency bus and the other from train B emergency bus.

The design basis of the cooling system for normal operation and for emergency operation is to maintain the control room at 75°F when the outside air is 88°F or less and supplying the control room with 1100 cfm of outside air.

The control room air cooling system is designed and qualified to seismic Category I requirements and to ASME B&PV Code, Section III, Class 3 for pressure boundary components of the systems.

The cable spreading rooms below and above the control room are ventilated with filtered outside air during the summer months. The ventilation system consists of a supply fan, return fan, and sheet metal ducts.

The emergency switchgear areas are ventilated in the summer with filtered outside air. Each ventilating system has redundant supply and return air fans, and sheet metal duct. The battery rooms have redundant exhaust fans, supply and exhaust sheet metal ducts. Battery rooms are maintained at a negative pressure to prevent any hydrogen generated by the batteries from infiltrating the emergency switchgear areas.

The control room complex emergency cleanup filter system consists of a filter train with redundant fans. The filters consists of a roughing filter, HEPA filter, and an impregnated charcoal filter. Redundant, remotely located, seismic Category I air intakes are provided for emergency control room operations.

The control room is provided with toxic chemicals detection equipment. On detecting a toxic substance, the fresh air intakes will automatically close and the emergency cleanup system will be placed in operation.

The control room is provided with radiation detectors that will sound an alarm if the level increases to a set point.

3.6 AUXILIARY SYSTEMS

The auxiliary systems of the PBR plant include fuel storage and handling, water systems, process auxiliaries, HVAC and other auxiliaries.

A description of the various auxiliary systems is provided in the following System Design Descriptions.

- o Fuel Handling, Distribution, and Storage System
- o Spent Fuel Storage Pool Cooling and Cleanup System
- o Helium Purification System
- o Liquid Nitrogen System
- o Helium Storage System
- o Nuclear Service Water System
- o Reactor Plant Cooling Water System
- o PCRV Cooling Water System
- o After Heat Removal Circulator Services System
- o Compressed Air System
- o Heating, Ventilation, and Air Conditioning System
- o Fire Protection System
- o Auxiliary Steam System
- o Standby Power Supply and Auxiliaries

3.6.1 FUEL HANDLING, DISTRIBUTION, AND STORAGE SYSTEM

3.6.1.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Fuel Handling, Distribution and Storage System consists of the following major subsystems:

- o New fuel storage
- o New fuel transport system
- o New fuel distribution system
- o Spent fuel collection system
- o Spent fuel transport system
- o Spent fuel storage

The integrated system provides a means for the continuous on-line refueling of the Pebble Bed Reactor. Means are provided to store new fuel, distribute new fuel to the reactor bed, remove spent fuel, and store the spent fuel in a storage pool.

Design Requirements

The integrated Fuel Handling, Distribution, and Storage System is a semi-automatic remote-operated system designed to permit the reactor to operate continuously with on-line refueling. The system and its subsystems are designed to provide the following fuel handling capacities:

Feeding system capacity	2900 pebbles per hour
Fuel feed and removal per shift	2600 pebbles
Number of shifts per day	1
Duration of shift	1.5 hours

New fuel storage, transport, and distribution subsystems are located above the PCRV and structural supports for the components are anchored to the top face of the PCRV. The structure and components are designed to seismic Category I requirements.

New fuel storage is located on the top floor of the reactor service and fuel handling building. The fuel is transported from the loading platform near ground level to the upper floor by means of an elevator.

Spent fuel is removed from the bottom of the PCRV, intact and damaged fuel pebbles are separated and stored in segregated containers, and allowed to cool-down for a period of eight days prior to removal from the containment.

A spent fuel transporter and container are provided to remove the spent fuel from the containment. The spent fuel container transfers the fuel to final storage containers which are sealed and filled with helium. This operation takes place in a shielded enclosure.

After the spent fuel is loaded into its storage container, it is moved through a transfer canal and loaded into its predetermined position in the spent fuel storage pool. The spent fuel may be loaded into casks after approximately one-year storage for shipment to an independent spent fuel storage facility or to an away from reactor facility.

The spent fuel removal, transport, and storage subsystems are designed to seismic Category I requirements.

The entire fuel management operation is performed remotely and all areas of the reactor plant are provided with close-circuit television and/or observation windows to enable the operators to view each phase of the operation.

During all phases of fuel handling, a helium atmosphere is provided to the fuel to preclude it coming in contact with air or other deleterious material.

The new fuel distribution system and the spent fuel removal system is designed for a maximum pressure of 1400 psig. Design pressure for the new fuel transporter container and the spent fuel transporter container is 30 psig. Appropriate valves are furnished to prevent overpressurizing the transporter containers. Overpressure safety relief valves are provided at appropriate locations in the new fuel distribution and spent fuel removal subsystems piping.

All pressure boundary components are designed in accordance with the requirements of the ASME B&PV Code, Section III, for Class 1 or 3, as appropriate.

3.6.1.1 DESIGN DESCRIPTION

The design description for the Fuel Handling, Distribution, and Storage System describes the six major subsystems which forms an integral part of the continuous, on-line fuel management for the PBR nuclear power plant. This particular design is related to the 3000 MWt General Electric Company annular core Pebble Bed Reactor.

Features of this design includes a new fuel distribution system located above the top head of the PCRV. New fuel is placed in three storage containers which are provided with distribution piping to deposit new fuel pebble to 43 predetermined positions of the reactor fuel bed. The piping system contains pebble feeder valves, pebble counters, isolation valves, safety relief valves, and necessary structural supports.

Spent fuel is collected from 12 positions of the fuel bed and is directed to spent fuel intermediary containers. The spent fuel collection system piping contains pebble feed mechanisms, counters, and a mechanism to separate the damaged spent fuel pellets from the whole pellets.

New Fuel Storage and Loading

Storage containers located on the top floor of the Reactor Service and Fuel Handling Building are provided to store a minimum of one-year supply (approximately one-million pebbles).

Fuel will be shipped to the site in pressure tight containers having a helium gas blanket. These containers will be transported to the upper floor by means of an elevator. Unloading of the containers will be designed to include isolation valves, feeder mechanisms, and new fuel pebble counters. Receipt of the new fuel and counting the pebbles as they are unloaded into the storage container is the initiation of the fuel accountability system. The storage, loading, unloading, and final storage of each pebble is accounted for, including its position in the reactor bed, during its lifetime.

An air lock is provided between the reactor containment and the Reactor Service and Fuel Handling Building in the area of the top floor. The air lock is provided with remote operated doors and with track. During loading operations, a motorized remote-operated cart is positioned inside the air-lock. A vertical new fuel transport container is attached to the cart (or transporter) to convey the fuel to fuel distribution containers located over the PCRV. This transport container is designed for 30 psig pressure and contains a top inlet nozzle and a bottom outlet nozzle. These nozzles are fitted with solenoid operated gate valves and with mechanical motor-driven mechanisms to engage either the new fuel inlet filling pipe from the fuel storage bin, or to the inlet nozzle of any of the new fuel distribution containers.

A connection on both the new fuel inlet filling pipe or the new fuel distribution container, pipe nozzle neck will be used to test the leak tightness of the joint between the transport container by pumping the volume contained between shut-off valves on the transport container nozzles and the valves located on the new fuel filling pipe or the fuel distribution container. If the connection leakage is within the specified leak rate, the valve on the transport container and the valve on either the filling pipe or distribution container to either fill or empty the transport container. After the filling or emptying operation, the valves will be closed and the volume between the valves will be pumped down to a specified vacuum. The exhaust air will be pumped to the gaseous radwaste management system.

The new fuel transport container will be designed in accordance with the ASME B&PV Code, Section III, for Class 3 components. Six-inch nominal inlet and outlet nozzles will be furnished with the container.

The motorized transporter cart will be equipped with flanged wheels and will travel over a steel rail. One rail will be machined with a cog rail. The drive for the cart will have a gear which engages the cog rail to ensure positive traction of the cart. In order to prevent the cart from being overturned during a seismic event, the cart will be fitted with solenoid operated clamps. During normal operation the clamps will ride under a portion of the rail and will have sufficient clearance so as not to interfere with the cart's movement but, at the same time, will prevent the cart from tipping over. The solenoids will be activated to positively clamp the cart to the rails during new fuel loading or unloading operations.

The cart drive will be equipped with a reversing motor that will be energized from the rails carrying the electricity. Rails will be furnished that will allow the transporter cart to travel from the air-lock to any of the three new-fuel distribution containers. A portion of the rail will be hinged and power-operated to provide clearance for the air-lock door when it is in the closed position.

The air lock door will be equipped with a series of mechanisms: one for locking and unlocking the door; one for moving the door away from the flange of the air lock to prevent damaging the flanged surfaces and gaskets; and one for raising and lowering the door to permit the transporter cart to move into and out of the air lock. The air lock gasketed joint will be tested after each use of the door.

The transporter cart will be equipped with closed-circuit television cameras used for guidance and positioning of the cart, and for observing the operation of the remote operation of the mechanism for connecting to the other equipment nozzle connections.

NEW FUEL DISTRIBUTION SYSTEM

The new fuel distribution, supported by structures above the top of the PCRV, consists of three separate similar subsystems. One subsystem distributes new fuel to the outer regions of the core and two subsystems distribute fuel to the center region of the reactor core. Fuel will be fed to 43 locations in the core. Each of the subsystems contain the following components:

- New fuel container
- New fuel primary distribution mechanisms
- Secondary fuel distribution mechanisms

dislodge a fuel pebble in the unlikely event it should become stuck in a portion of the system.

Closed-circuit television cameras are provided at various locations to observe various areas of interest of the new fuel distribution system.

- <u>New Fuel Container</u>

  The new fuel container has a capacity to store 3000 new fuel pebbles. Pebbles are loaded into the container from the new fuel transport container that travels from the new fuel storage area in the Reactor Service and Fuel Handling Building into the Containment on a motorized transporter cart. The container is designed for 1400 psi pressure and is provided with a tight shut-off valve and a device to clamp on to the fuel transport container. A positive helium atmosphere will be maintained at all times in the primary fuel container.

  The container is a vertical vessel having a diameter of 48 inches with a 6'-0" straight side. It will be fitted with hemispherical heads and nominal 6-inch pipe inlet and outlet connections. Material selected will be compatible with the process materials and environment in the system and containment.

- <u>New Fuel Distribution Mechanism</u>

  A new fuel distribution mechanism is furnished with each of the subsystems to further distribute the fuel to the proper secondary distribution system. This mechanism consists of a rotating plug having a recess shaped to contain one new fuel pebble. It will be rotated by a motor drive to locate the fuel at the proper transport pipe.

The mechanism, drive, and controls will be housed in an alloy steel pressure container. Access to the internals is through a bolted-on cover plate. All pressure boundary portions of the housing will be constructed in accordance with the ASME B&PV Code, Section III, Subsection NB for Class 1 components.

- <u>New Fuel Pebble Counter</u>

  The new fuel pebble counter is located at the outlet of the new fuel pressure container and on each of the feeder pipe lines distributing fuel into the PCRV. Counters are provided to account for each fuel pebble fed into the reactor.

  The counter consists of a free-turning four-vaned wheel that will be permitted to turn a quarter of a revolution for a new fuel pebble to pass. This turning motion will activate an electrical contact which in turn will activate a digital counter.

  An alloy steel housing is provided to contain the vaned-wheel, notched disc, electrical contact, and shaft bearings. Access to the internals will be through a bolted-on cover plate. All pressure boundary portions of the housing will be constructed in accordance with the ASME B&PV Code, Section III, Subsection NB for Class 1 components.

- <u>Secondary Container and Distribution Mechanism</u>

  Seven secondary containers with integral distribution mechanisms are provided for the final distribution of the new fuel pebbles to the reactor core. Four of the secondary systems are provided for the primary distribution system feeding fuel to the outer regions of the core. Three of the secondary systems are furnished to share the distribution from the two primary systems feeding fuel to the central portion of the reactor core. Each of the secondary distribution systems are provided with six outlet distribution piping systems to distribute the fuel to a specific location within the reactor core.

The distribution mechanism consists of two concentric discs rotating on a common center. The lower disc is used to rotate a feeder hole to the correct orientation through which the fuel will pass to the desired transport pipe. The upper disc is provided with a hole sized to contain a new fuel pebble. This upper disc is rotated to its unloading position over the pre-oriented hole in the lower disc. After accomplishing its objective of transferring the fuel pebble to the lower disc and thereafter to the proper transport pipe, the upper disc will return to the oriented position where it can pick up another fuel pebble.

The new fuel positioning mechanism, its drives, inlet pipe, and six outlet pipes are contained in an alloy steel pressure container. Access to the internals is through a bolted-on cover plate. All pressure boundary portions of the housing will be constructed in accordance with the ASME B&PV Code, Section III, Subsection NB for Class 1 components. A conceptual design of the distribution mechanism is shown on Figure 3.6.1-2.

SPENT FUEL COLLECTION SYSTEM

The spent fuel collection system, supported by structures under the bottom head of the PCRV, consists of six identical subsystems for the Cylindrical PBR Core design or twelve identical subsystems for the Annular PBR Core design. Each subsystem collects spent fuel from the bottom of the reactor core. The subsystems contain the following components.

- o Spent fuel exit pipe with distributor mechanism.
- o Spent fuel discharge pipe system.
- o Spent fuel element separator.
- o Spent fuel collection container and damaged fuel collection container.

Figure 3.6.1-3 depicts a schematic arrangement of the conceptual design for the spent fuel collection system. Flow of spent fuel from the reactor core passes through a distribution mechanism ("SEVERALIZER") to assure that only one fuel pebble will be fed through the discharge pipe at one time. From the severalizer the fuel flows through a discharge pipe to a spent fuel element separator. The discharge piping contains a safety valve, repair valve, and two isolation valves.

The spent fuel element separator contains a motor driven helical screw which carries a fuel pebble along a pair of parallel bars. These bars are spaced with a clear opening of 5.65 cm. Should the fuel pebble be damaged and measure 5.65 cm or smaller, it will fall through the bar opening through a chute and piping and be lodged in a damaged spent fuel container. If the fuel pebble is larger than 5.65 cm, it will travel the length of the parallel bars and be discharged through a different pipe. This is depicted on Figure 3.6.1-5.

The undamaged fuel pebble will then travel down the discharge pipe and through a counter and then into a spent fuel container. Spent fuel will be stored in the spent fuel container for a period of approximately eight days before removal and storing in the spent fuel storage pool.

Spent Fuel Removal System

A spent fuel motorized transporter cart containing a spent fuel transport container and a spent fuel damaged pebble transport container is provided to remove fuel from the spent fuel containers. The transporter cart runs on rails having a track layout that allows the cart to be positioned under the proper storage container, six for the cylindrical or twelve for the annular core PBR. The track layout contains a turntable to switch the cart to the circular track under the PCRV or onto a section of straight track that allows the cart to travel into an air lock and out of the containment.

The transport containers are sized to hold 3000 pebbles of undamaged fuel and 500 pebbles of damaged fuel. The containers are vertical pressure vessels with ellipsoidal heads and provided a six-inch nozzle opening on both the top and bottom heads. The nozzles will have remote solenoid operated gate valves and a motorized mechanism to engage and make a gas-tight connection with the discharge nozzle of the spent fuel storage containers or the inlet connection of the spent fuel pool storage containers.

Closed circuit television cameras will be mounted on the transporter cart to enable the operator to position the cart and to control the operation of the nozzle engagement mechanism.

The transporter cart will be similar to the new fuel transporter cart in that it has flanged wheels with a cog-wheel drive. It will also be equipped with

Figure 3.6.1-1 depicts a schematic arrangement of the conceptual design for the new fuel loading system. Flow of fuel from the new fuel container passes through a distribution mechanism then through a counter which monitors the flow of each fuel pebble in the subsystem. Fuel then flows through a series of distribution mechanisms until the pebble is aligned over a preselected pipe to transport it to a secondary fuel distribution mechanism. As the pebble leaves the distribution mechanism it flows through a counter.

The secondary distribution mechanism, one of several, provides control of and accounts fo? each fuel pebble by distributing it to one of several transport pipes that permits the fuel to be loaded in its preselected location. When the fuel leaves the distribution mechanism, it passes through another counter and piping containing a shut-off valve and pressure safety relief valve. This new fuel distribution system accounts for each new fuel pebble during its travel from the new fuel container to the reactor core by passing through three counters. This assures that the fuel is accounted for and that it has been deposited in its predetermined location in the core.

The system is designed to provide a tight containment to prevent loss of helium from the PCRV cavity. Pressure boundary components are designed for 1400 psig pressure and in accordance with the ASME B&PV Code, Section III, Subsection NB for Class 1 components. Materials of construction, are selected to be compatible with the product and environs. Temperatures of the system will vary from that in the containment to those approaching the reactor core helium temperature.

Helium connections are provided at various positions in the new fuel distribution system. This helium is used to make up any losses during the fueling operation and also to provide a differential pressure in the system to solenoid operated clamps used to prevent derailment during seismic events and to clamp the cart to the rails during filling and emptying operations.

All pressure boundary components will be designed in accordance with the ASME B&PV Code, Section III, for Class 1 or 3 components, as appropriate. The fuel collection subsystem from the PCRV to the spent fuel container discharge valve will be designed for 1400 psig pressure. The spent fuel transport containers will be designed for 30 psig pressure.

In operation, the transporter cart will be positioned under a preselected spent fuel container and clamped to the rails. The motorized mechanical nozzle connection will be activated and its operation will be observed by means of the closed television circuit. After the connection is made, a vacuum will be drawn from the pipe volume between the valve on the bottom of the spent fuel container and the valve on top of the transport container. When the connection leakage is within specified limits, both valves will be opened and the fuel pebbles will be discharged into the transport container. Valves will be closed after filling and the volume between the valves will be evacuated to a specified volume then purged with helium. A helium atmosphere will be maintained at all times in the collection system and the transport container.

After disconnecting the pipe connection, the transporter cart will be directed to the turntable and then into the airlock. The airlock door will be closed after the transporter is in its proper location in the lock and a portion of the track used to fill the gap in the head area is moved to a clear position.

Spent Fuel Unloading and Storing

When the cart is in the proper location, the motorized mechanical nozzle connection will be activated to engage the nozzle of a pipe used to fill spent fuel storage containers in a location under the air lock. The operation of testing the connection will be observed prior to opening the valves on the transport container and the fuel storage container filling line.

The fuel storage container filling line contains a pebble feeder similar to those in the new fuel distribution system, a pebble counter, and isolation valves. Fuel pebbles will be fed into the spent fuel containers in an area under the containment air lock. The enclosed area will have a controlled atmosphere and will be shielded. After filling the fuel storage container to the proper level, the container will be capped. The cap contains a nozzle and valve which is used to purge and pressurize the container with helium. The capped container will be checked for leak-tightness before being stored.

After examination and pressurization, the spent fuel storage container will be passed through a transfer port into the spent fuel transfer canal. From there, a mechanism will lift, move, and store the container in its preselected location for long term storage.

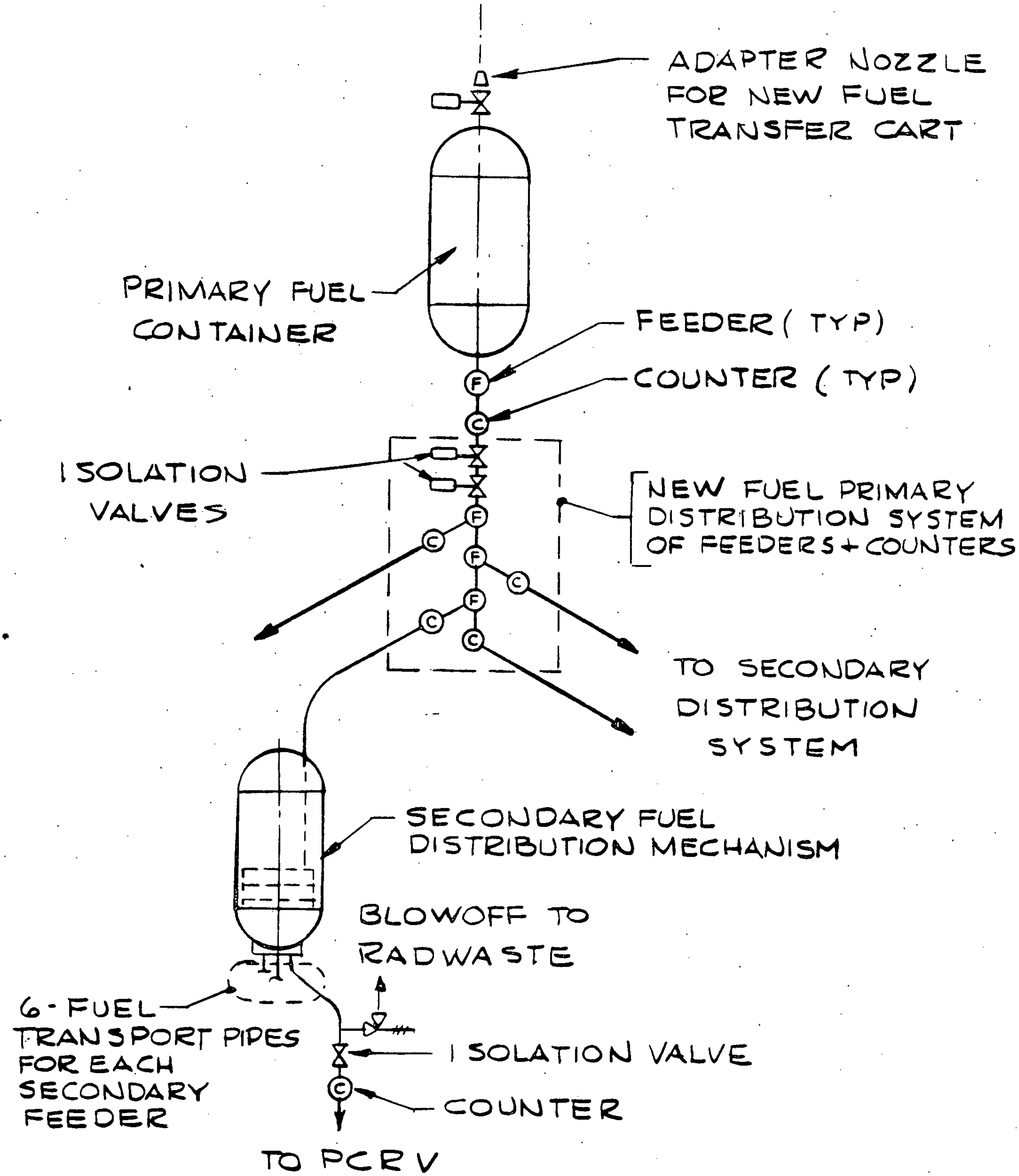


FIGURE - 3.6-1

NEW FUEL DISTRIBUTION SYSTEM CONCEPTUAL DESIGN (3-SYSTEMS REQ)

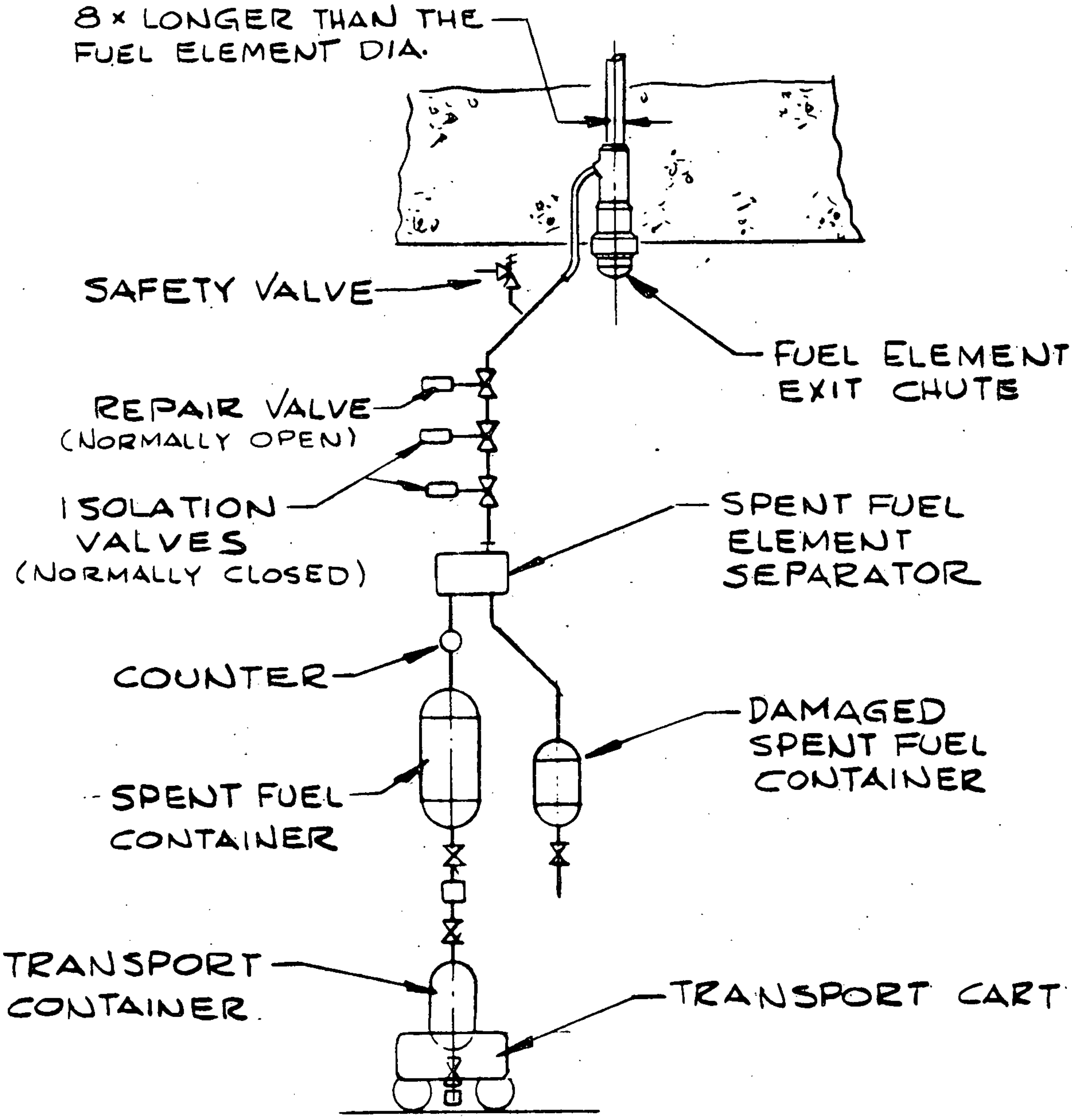


FIGURE 3.6-2

SPENT FUEL COLLECTION AND TRANSPORT SYSTEM CONCEPTUAL DESIGN

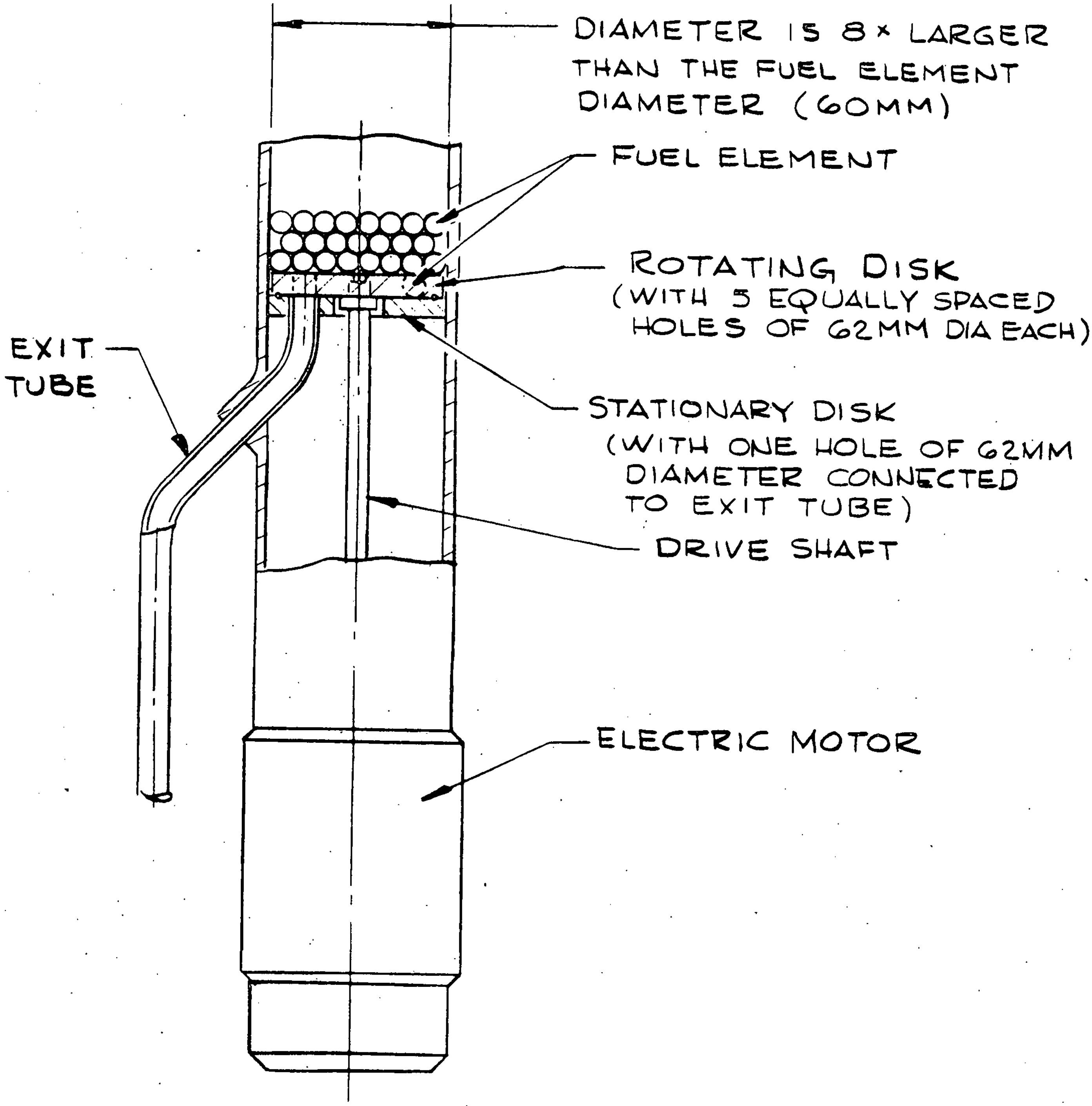


FIGURE - 3.6-3
"SEVERALIZER" CONCEPTUAL DESIGN
(FUEL ELEMENT EXIT CHUTE)

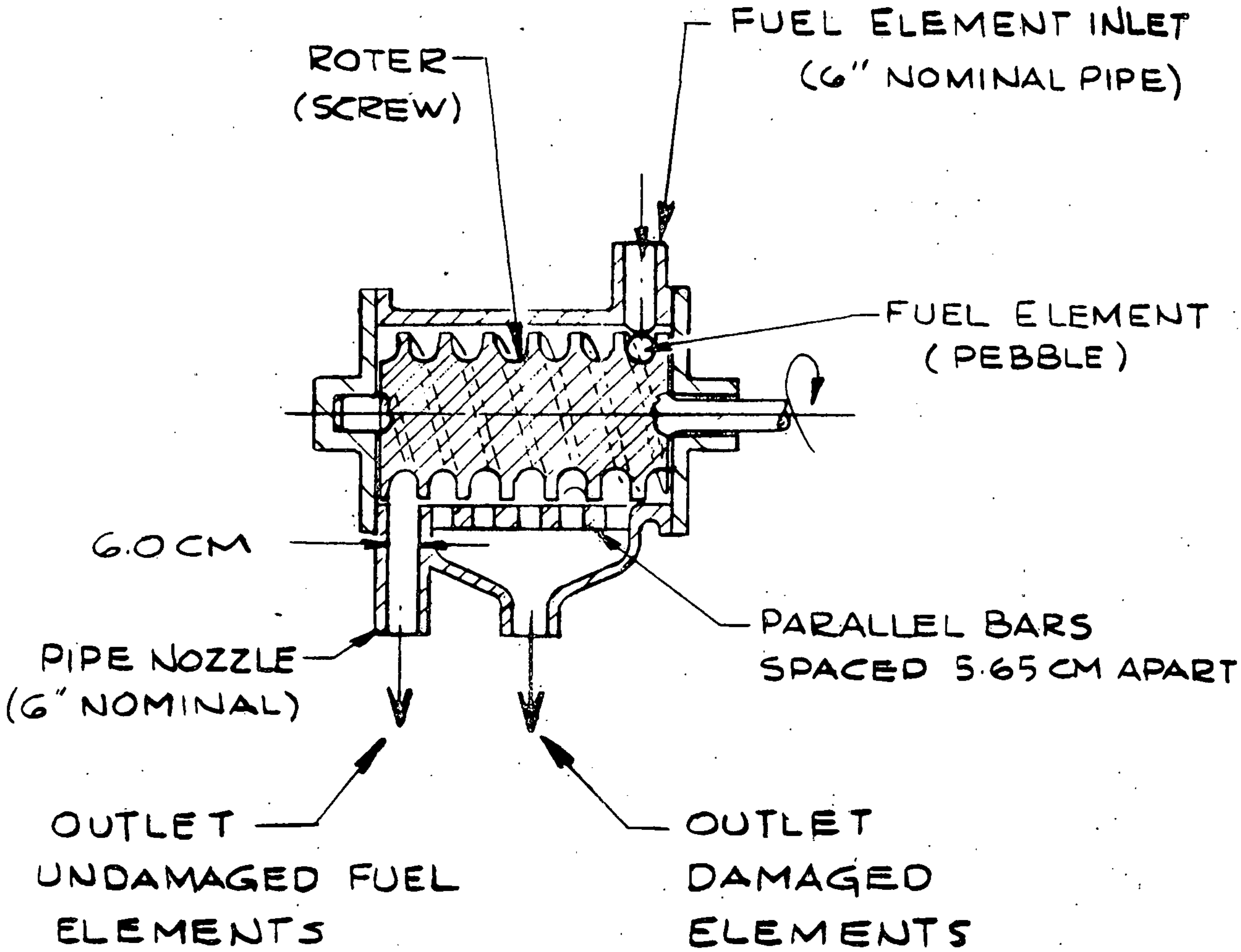


FIGURE 3.6-4

SPENT FUEL ELEMENT SEPARATOR
CONCEPTUAL DESIGN

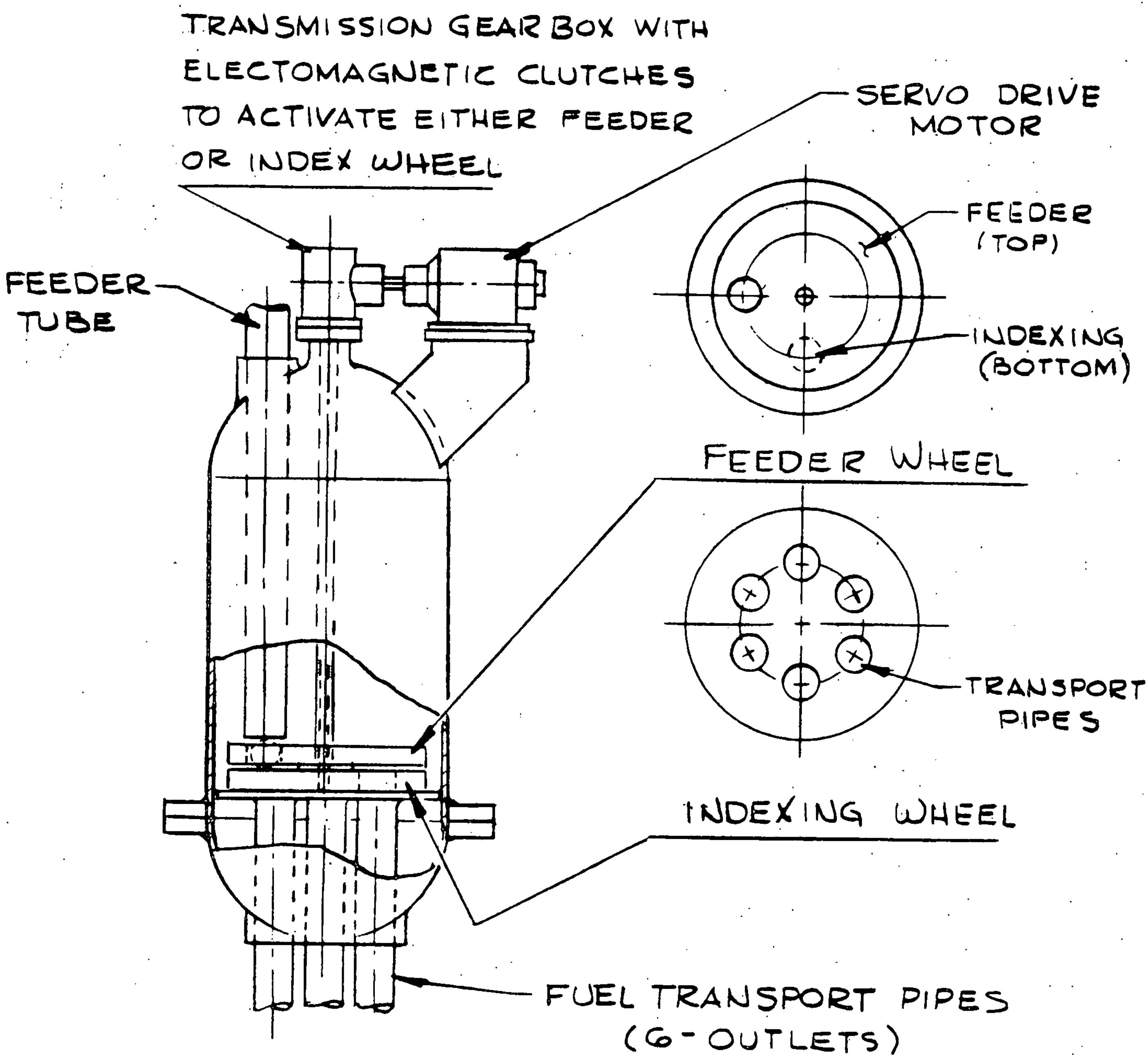


FIGURE - 3.6-5
SECONDARY FUEL DISTRIBUTION MECHANISM CONCEPTUAL DESIGN

3.6.2 SPENT FUEL STORAGE POOL COOLING AND CLEANUP SYSTEM

3.6.2.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The spent fuel storage pool cooling and cleanup system removes heat from the spent fuel in the storage pool as well as the spent fuel reception bay. The system provides clarification of the water for visibility and to reduce the activity of the water to acceptable conservative levels.

Design Requirements

The spent fuel storage pool cooling and cleanup system design provides:

- Maintain the spent fuel pool water at a temperature less than 140°F during normal loading.
- Maintain purity and clarity of the water to permit the underwater observation of fuel handling operations.
- Capability to remove suspended and dissolved radionuclides and maintain pool water activities to acceptable conservative values.
- Capacity to maintain a minimum water level for shielding during all normal phases of operation and for abnormal plant operating conditions.

3.6.2.2 SYSTEM DESCRIPTION

Decay heat is removed from the spent fuel stored in the spent fuel pool by circulating the water through heat exchangers. Cooling water to the heat exchangers is supplied from the Nuclear Service Water System.

The system consists of a main fuel pool loop from the pool to the pumps and heat exchangers and back to the pool. A side stream through the spent fuel pool skimmers is directed to pumps and heat exchangers then through the ion exchanger. Cooling water for the reception bay is taken off the system downstream of the heat exchangers, where it flows through the pools and then flows to the purification pump, ion exchangers, and the heat exchanger. By adjusting the line valves, the flow to any part of the system may be varied to suit the purification requirements. A vacuum cleaning system is provided for cleaning the bay floors.

Piping that penetrates the spent fuel storage pool is located to provide a sufficient depth of water over the stored fuel in the event of a pipe break in the system. Siphon breakers or vents are provided in the system to prevent the loss of fuel pool water.

The cooling and cleanup system components are furnished to meet the requirements of the ASME B&PV Code, Section III, Class 3. The material for the components is either austenitic stainless steel or other material having acceptable corrosion-resistance properties.

Two circulation pumps are provided for the spent fuel pool cooling loops. Each pump is rated at 100% of the normal cooling load requirements. The second pump is normally used as a redundant spare but may be used should it become necessary to temporarily store partially spent fuel from the reactor.

A pump and ion-exchangers are provided for fuel pool water clarification. Normally, one pump will operate; however, one pump from the cooling loop may be used if the demand for water clarification exceeds the capacity of the normal pump flow. The ion exchangers are sized to handle 50 percent of the combined flow from the clarification and cooling loop pumps.

The demineralized water distribution system provides the initial fill for the pools, for transfer cask wash-down, fuel pool water makeup, and for spent resin transfer. Water discharged from the pools and any leakage from the cooling and cleanup system is collected and discharged to the radioactive liquid waste system. Emergency makeup water is provided from the demineralized water storage tank and from the plant fire protection water system.

Instrumentation for the spent fuel storage pool cooling and purification system includes:

- o Control room indication of water level, temperature and alarms for high temperature and high/low radiation levels of the spent fuel pool and the fuel reception and inspection pool.
- o Local indication of water flow in the cooling loop and the purification system.
- o Control and status indication of the pool cooling water pumps from the control room.

Control of the pool water temperature is attained through adjusting valves in the cooling water system.

3.6.3 HELIUM PURIFICATION SYSTEM

3.6.3.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Helium Purification System purifies a small letdown flow from the primary coolant system and provides a purified gas flow to penetrations and seal assemblies. Also during plant shutdown this system transfers purified helium to storage from the primary coolant system.

Design Requirements

Piping and components within the boundaries of the last containment isolation valve and the primary coolant system isolation valve is classified as Safety Class 2, Seismic Category I. Piping and components within the boundaries of the containment isolation valves is classified as Safety Class 3, Seismic Category I. The storage transfer piping is non-safety class. Two 100% trains are provided.

3.6.3.2 SYSTEM DESCRIPTION

High temperature helium (300°C) first enters a high temperature filter/absorber unit where dust and fission products are removed. Afterwards the helium is cooled by a heat exchanger. Driers then remove carbon dioxide and water vapor. Afterwards a low temperature absorber removes noble gases and other gases such as tritium. Later a sponge removes all forms of hydrogen. From this point helium is compressed and transferred to the seal assemblies, penetrations and the storage tanks (if required).

Figure 3.6-6 shows a schematic of the helium purification system.

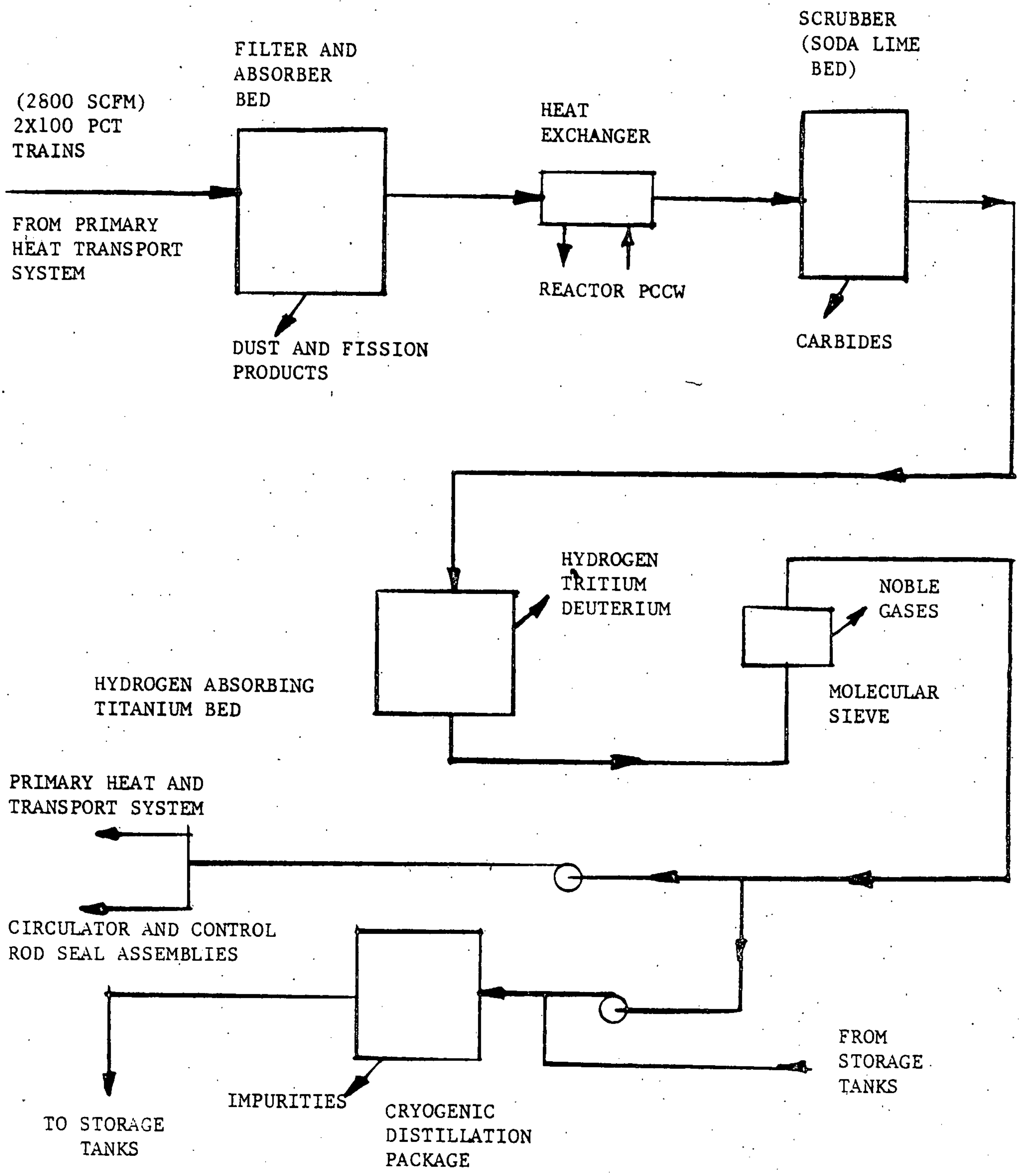


FIGURE 3.6-6 HELIUM PURIFICATION SYSTEM

3.6.4 LIQUID NITROGEN SYSTEM

3.6.4.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The liquid nitrogen system (LNG) supplies refrigeration to the helium purification system low temperature absorbers.

Design Requirements

The LNG system shall be furnished to remove the normal operating heat load and the PCRV depressurization heat load.

The LNG system is not essential to the safe shutdown of the reactor and is a non-seismic Category I classification.

3.6.4.2 SYSTEM DESCRIPTION

The LNG system is comprised of a phase separator/storage tank, one liquid nitrogen recondenser, two pumps, with the necessary piping and valves to provide cooling for the helium purification low-temperature absorbers (LTA's).

The Phase separator/storage tank is of vacuum jacketed construction having a nominal capacity of 10,000 gallons. Sufficient nitrogen is provided to permit normal helium purification operation for 50 hours after loss of the LNG recondenser followed by PCRV depressurization.

Heat from the LTA's vaporize the liquid nitrogen. The gaseous nitrogen returns to the phase separator where the gas and liquid are separated. Liquid drips into the storage tank and the vapor is condensed by the LNG recondenser and returned to the storage tank.

Components and piping are constructed from austenitic stainless steel and are vacuum jacketed to minimize heat losses. Pressure vessels are constructed in accordance with the requirements of ASME B&PV Code, Section VIII.

3.6.5 HELIUM STORAGE SYSTEM

3.6.5.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The helium storage system provides the following functions:

- Transfer helium between the PCRV and the helium storage area.
- Provide helium for purging refueling equipment.
- Control primary coolant pressure during reactor operation and on-line refueling operations.
- Provide initial fill for the PCRV primary coolant and coolant make-up.
- Vent PCRV to the environs.

Design Requirements

The helium storage system is required to store 32,000 lb inventory, that includes approximately 4000 lbs for NSSS yearly makeup requirements.

The helium storage system will have the capability of depressurizing the PCRV through the helium purification system. A 20 hour depressurization schedule without exceeding a maximum flow rate of 4800 lbs per hour shall be provided in the system.

This system is not essential to the safe shutdown of the reactor system. The system is a non-seismic Category I class and pressure vessels are constructed in accordance with ASME B&PV Code, Section VIII.

The helium storage system interfaces with the following systems:

- Helium purification receives purified helium for purging and provides for the transfer of helium from the PCRV to storage.
- Transfer of helium from storage to the PCRV is accomplished at a connection at the PCRV relief valve piping.

- Fuel handling system receives helium from the storage to maintain a helium atmosphere and to maintain the PCRV helium inventory.

3.6.5.2 SYSTEM DESCRIPTION

The helium storage system is comprised of:

- High-pressure storage tanks
- Low-pressure storage tanks
- Two low-pressure, high-flow helium transfer compressors
- Two high-pressure, low-flow helium supply compressors
- Associated piping, valves, electric equipment, and instrumentation.

The low-pressure storage tank is sized to contain the entire helium inventory of the PCRV plus an allowance for make-up and normal operational requirements.

The high-pressure storage tank is sized to provide the refueling needs, helium purification regeneration purge requirements, and normal operational leakage needs.

Two helium transfer compressors are furnished, one of which is capable of depressurizing the PCRV in approximately 18 hours. Both compressors are used during start-up and require approximately 6 hours to pressurize the PCRV to 350 psia.

Two helium supply compressors are furnished to charge the high-pressure storage tank from the low-pressure storage tank. These compressors operate intermittently, as required, to maintain the required helium pressure in the tank.

3.6.6 NUCLEAR SERVICE WATER SYSTEM

3.6.6.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Nuclear Service Water System (NSW) shall provide cooling for Reactor Plant Cooling Water System, the Fuel Pool Cooling System, the PCRV cooling system and other reactor plant auxiliary components.

Design Requirements

Each loop of the NSW system shall be capable of removing 100% of the design heat load.

Those portions of the NSW system which provide cooling to safety related components are Safety Class 3 and shall be designed to ASME Section III Class 3 and seismic Category I requirements. Additionally, the NSW system shall meet the requirements of Nuclear Regulatory Commission Regulatory Guide 1.27.

The NSW system shall supply the required cooling flow at a maximum temperature.

The NSW system shall have the capability to remove seven (7) day DBDA integrated heat load. This shall be accomplished without any makeup to the NSW system.

3.6.6.2 SYSTEM DESCRIPTION

The NSW system consists of two redundant and independent loops each containing a cooling tower, circulating pump, piping, valves and controls necessary for that system to perform its functions.

The NSW system provides cooling to the following:

- Reactor Plant Cooling Water System
- Fuel Pool Cooling Water System
- Helium Storage System Compressors
- Reactor Service Building Chillers
- Containment Building Chillers
- NSS Process Chillers
- PCRV Cooling Water System Emergency Diesel Generator Coolers

During normal operation, cooling is provided by the conventional service water system via crossconnect piping. Should the conventional Service Water System be lost, the conventional service water header is automatically isolated. Nuclear Service Water is then supplied by the NSW pumps and heat is rejected through the NSW cooling towers.

The NSW cooling towers offer both horizontal and vertical missile protection for the fan. The remainder of the SC-3 portion of the NSW system is housed in seismic Category I structures.

The NSW cooling towers are each designed to remove 76.6×10^6 Btu/hr. This heat removal capacity is equal to the faulted heat load of the RPCW system plus the refueling heat load of the FPC system.

The cooling tower basins are designed to seismic Category I requirements. Each basin is sized to hold 50% of the water required for the seven (7) day DBDA heat load.

The NSW system provides a backup source of makeup water for the spent fuel pool.

3.6.7 REACTOR PLANT COOLING WATER SYSTEM

3.6.7.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Reactor Plant Cooling Water System (RPCW) shall provide cooling water to reactor plant auxiliary equipment.

Design Requirements

The RPCW System shall be a closed loop cooling water system maintaining water quality and temperature within required limits.

The RPCW System shall remove the design heat load of the below listed components under all plant conditions in which they are required to operate. The maximum system head load is 72×10^6 Btu/hr.

- Moisture Monitor Hygrometer Modules (Hygrometers and Compressors)
- Auxiliary Circulator Motor and Lube Oil Coolers
- Purified Helium Compressors
- Helium Purification Coolers
- Radioactive Gas Waste Compressors
- Main Circulator Motor and Lube Oil Coolers

The Safety Class 3 portion of the system shall be designed in accordance with ASME Section III Class 3 and seismic Category I requirements.

System Description

The RPCW System consists of two redundant, independent, closed loops each capable of removing 100% of the design heat load. Each loop consists of two 100% capacity pumps, two 50% capacity heat exchangers, a pressurized surge tank and a chemistry control package. During normal operation, each loop operates at 50% capacity.

The RPCW system is a Safety Class (SC) 3 system with a Non-Nuclear Safety Class (NNS) sub-loop. In the event of a failure in the NNS portion of the system, automatic actuated valves shall isolate the NNS sub-loop from the SC-3 portion of the system. During normal plant operation, service water provides cooling for the RPCW system.

During an emergency, the Nuclear Service Water (NSW) System provides cooling for the RPCW System. The NSW flows through the tube side of the heat exchangers and RPCWS through the shell side.

The Nuclear Service Water System will provide seismic Category I makeup for the RPCW system if required; however, the demineralized water system via the chemical control package provides normal RPCW makeup.

The chemical control package processes a side stream flow of the RPCW to maintain water quality within the required limits.

3.6.8 PCRV COOLING WATER SYSTEM

3.6.8.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The PCRV cooling water system shall provide cooling water to PCRV cooling coils.

Design Requirements

The PCRV cooling water system shall be a closed loop cooling water system maintaining water quality and temperature within required limits. Two independent redundant systems are provided. Each is capable of removing the full heat load passing through the liner insulation. Under normal operation and circumstances both systems operate together with 50% load per system. Both systems must be operable after a reactor shutdown.

3.6.8.2 SYSTEM DESCRIPTION

Each system utilizes a 50% capacity pump (50 HP and 427 GPM) for normal operation and has, as a standby, a 100% capacity pump (100 HP and 853 GPM). Two 100% capacity heat exchangers are used to transfer four megawatts of heat to the service water system.

Safety Class 2, seismic Category I containment isolation valves are required on the outside of the eight inch Safety Class 2 penetration assembly. The remainder of the system is Safety Class 3, seismic Category I, except for a 50 GPM water purification loop which is non-safety class. This subsystem has a 50 GPM demineralizer and a 50 GPM filter.

The design specifications for this system are based on General Electric Criteria.

3.6.9 AFTER HEAT REMOVAL CIRCULATOR SERVICES SYSTEM

3.6.9.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Auxiliary Circulator Services System shall provide cooling water to lube oil coolers and motor coolers which are located on each of the four auxiliary circulators.

3.6.9.2 SYSTEM DESCRIPTION

Each auxiliary circulator has one closed loop consisting of two 100% pumps, one expansion tank, one gas trap, one heat exchanger, and associated piping. The heat exchanger is cooled by two redundant Reactor Plant Cooling Water System to satisfy postulated active and passive failure modes of operation since the four 50% system capacity circulators are required for decay heat removal.

Each of the service loops have a design pressure rating of 1900 psig and a design flow capacity of 47 gpm. Since this system is classified as safety class 3, it will be design in accordance with ASME Section III, Class 3 and seismic Category I requirements.

3.6.10 COMPRESSED AIR SYSTEM

3.6.10.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The compressed air system is designed to provide a continuous supply of clean and oil-free air for pneumatic instruments and controls and general plant service. Dry air is supplied for instrumentation and controls, and undried air is supplied for other plant functions.

Design Requirements

The system contains three air compressors each rated at 650 CFM and a 100 psig discharge pressure. Air receivers are designed in accordance with the ASME B&PV Code, Section VIII, for 125 psig design pressure and are equipped with safety valves set at 125 psig.

Instrument and service air piping is designed in accordance with ANSI B31.1 Code for Power Piping.

3.6.10.2 SYSTEM DESCRIPTION

The compressed air system includes three electric motor-driven air compressors rated at 650 CFM and 100 psig discharge pressure. The compressors are connected in parallel, each with an intake filter-silencer, aftercooler, and moisture separator. Each compressor unit is capable of supplying air at 100 psig at a flow rate sufficient to meet normal plant requirements. The compressors discharge to two vertical air receivers.

Both receivers supply air to the service air and instrument air systems. The service air header contains a back-pressure regulating valve which closes when the upstream header pressure is reduced to 75 psig. This prevents the service air system from bleeding down the instrument air supply.

The compressed air for the instrument air system is supplied through two 100-percent capacity parallel headers, each containing:

- o Twin tower air dryer for minus 40°F dew point, with regeneration cycle for reactivating the wet desiccant.
- o Pre- and after-filters for removal of moisture droplets, particles of dirt, rust, and scale.

Each compressor has an automatic dual control. Normal control is with one air compressor operating at constant speed under load-unload control. The second compressor is on standby and starts automatically on heavy demand or low instrument system pressure. The third compressor is used as a spare.

Compressed air for instrumentation and controls within the containment is supplied by two non-lubricated compressors nominally rated at 100 CFM, discharging through filters and air driers to provide clean dry air. Service air to the containment air stations is supplied from the unit service air system for containment air leakage monitoring and other services. Instrument air from outside the containment can be connected to the containment instrument air system by hose connection in an emergency.

The station air compressors are powered from 480 volt emergency buses. Two compressors are powered from one bus and the third from a second bus. Upon loss of off-site power, the compressors may be manually started as emergency diesel generator capacity becomes available.

Air-operated valves and controls throughout the plant are arranged for safe failure with loss of air supply. Conventional instrumentation is provided for the compressed air system, including pressure indication in the main control room.

3.6.11 HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEMS

3.6.11.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The heating, ventilation, and air-conditioning systems are provided for all buildings of the plant for both normal and abnormal plant operations.

Design Requirements

The outside ambient air conditions are:

Summer design temperature:	88°F, DB 75°F, WB
Winter design temperature:	0°F
Coincident wind velocity:	Moderate to 12 MPH

The inside design air conditions are:

Area	Summer, Max°F	Winter, Min°F
Control room complex	75	70
Cable spreading	104	55
4 kV switchgear	104	55
Battery rooms	95	65
Service building (occupied areas)	75	70
Service building (equipment area)	104	50
Turbine building	104	55
Fuel storage room	104	50
Containment	120	50
Circulating water pump house	104	50
Service water pump house	104	50
Penetrations building	104	50
Non-essential switchgear area	104	50
Diesel generator room	104	50

The HVAC systems are not safety related, except for the Control Room Habitability Systems, but the supports of all components in safety-class structures are designed in accordance with seismic Category I requirements. Separate system design descriptions contain the requirements for the control room habitability systems.

3.6.11.2 SYSTEM DESCRIPTION

Heating for the buildings is supplied by steam from the auxiliary boiler located in the administration building.

Containment

During normal reactor operation sufficient heat is lost from the nuclear reactor system to offset building heat-loss during the winter months. Heat is supplied to the containment when the reactor is shut-down through steam-air heat exchange coils and through the air circulation system. In the summer months, cooling is supplied to the air handling system from the chilled water system.

The containment is maintained at a slight negative pressure, with respect to the outside environs, and the general direction of air flow is from the areas of low-to-high levels of probable contamination.

Air intake and exhaust is described in the system design description for the containment air purification and cleanup system.

Reactor Service Building

A one-way air conditioning system is installed in the reactor service building without any air recycling to provide a suitable temperature and humidity in the various rooms by continuous treatment of fresh air.

The fresh treated air follows a forced irreversible flow from zones with a low radioactive contamination to areas having a higher radioactive contamination, without the possibility of any air recycling.

Air is drawn into the building, filtered, and heated or cooled as required. Before being discharged from the building, air is monitored for activity, then discharged through the plant stack filtration system.

The hot water heating system with heating coils in the ventilation inlet ducts is designed to maintain an indoor temperature of 70°F in winter when the ventilation system is running.

An air conditioning system for the Control Room is provided to ensure suitable temperatures and humidity in the various rooms as well as an adequate renewal of ventilated fresh air.

Turbine Building

A cooling system is provided in the Turbine Building which, in conjunction with heaters, will maintain the building temperature between 80°F and 90°F with a maximum temperature of 104°F in the areas where considerable heat rises occur. These include the condenser area, the feedwater heater area and the deaerator area. Cooling is provided from coils and fans with cooling water supplied from the recirculated water system.

In the winter time, ventilation air is drawn from outside the building, mixed with recirculated air inside the building and circulated as required. Ventilators are provided at the hot pieces of equipment to expel the hot air, and special provisions are provided to ventilate the areas where noxious gases may accumulate, including the chemical storage areas.

3.6.12 FIRE PROTECTION SYSTEM

3.6.12.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The fire protection system is provided to minimize the probability and effect of a fire. It is provided so the potential consequence of such an event, should one occur, does not result in undue risk to the health and safety of the public or of plant personnel.

Design Requirements

Where any appreciable quantities of combustible material exist, fire detection devices and/or fire protection systems are provided. The fire protection systems are evaluated and designed to assure that their operation or failure does not produce any unsafe condition nor damage any safety related equipment.

Physical separation or fire barriers are provided between associated redundant systems or redundant equipment where any combustible material exists. Units such as the emergency diesel-generators are placed in separate three-hour NFPA fire rated enclosures.

The occurrence of fire is minimized by the use of non-combustible materials in the construction of the plant. Construction materials are specified in accordance with NEPIA - Basic Fire Protection for Nuclear Power Plants. Electrical cables are specified with either non-flammable insulation or with self-extinguishing and non-propagating fire characteristics in addition to dielectric strength and other electrical-mechanical properties.

Fire barrier walls are provided between outdoor adjacent transformers; hydrogen manifolds are located out-of-doors; and auxiliary boilers are provided with combustion safety features. Automatic smoke and heat power venting is provided for the turbine building and other supporting buildup.

The fire protection system for the control room complex and alternate control room is a carbon-dioxide system with remote carbon dioxide bottles and piping to hose reel stations that provide coverage of the control room.

The cable spreading rooms are provided with a fixed carbon dioxide system with remote carbon dioxide bottles and piping that will flood the area in the unlikely event of a fire. A water deluge system is provided as a backup in the event it becomes necessary to resort to its use.

The battery rooms are provided with portable carbon dioxide fire extinguishers that are located outside of the battery rooms.

The fire protection system is designed in accordance with the applicable portions and requirements of the following:

- Nuclear Energy Property Insurance Association
- National Fire Protection Association Codes
- Criteria 3, Appendix A, Title 10 of Code of Federal Regulations, Part 50.
- USNRC Regulatory Guide 1.120 - Fire Protection Guidelines for Nuclear Power Plants.
- USNRC Branch Technical Position ASB 9.5-1.

The fire protection system is not designed to seismic Category I requirements, but is designed so that failure of the system will not induce failure of a safety related system or safety related equipment.

3.6.12.2 SYSTEM DESCRIPTION

Water Supply

The water supply for the fire protection system is stored in two 500,000 gallon storage tanks of which 300,000 gallons in each tank is reserved for fire protection. Four horizontal centrifugal pumps, two 1500 gpm electric motor-driven and two 1500 gpm diesel engine-driven, are provided and capable of taking suction from either tank. The third pump is redundant and serves as a standby unit. Two 25 gpm jockey pumps, complete with automatic local controls, are provided to maintain system pressure.

The fire pumps supply water to a 12-inch fire main ring header. The fire main ring header is designed as a closed-loop system which surrounds the plant site and permits water flow in either direction. Post indicator isolation valves are installed in the yard piping system to permit partial pipe line isolation without interruption of service to the remainder of the system.

The 500,000 gallon storage tanks at grade are heated and protected from freezing. All piping and valves are buried, electrically traced or installed in a heated area.

Yard Protection System

Fire protection is provided to exterior plant areas by fire hydrants located along the loop at approximately 250 feet intervals. Hose houses, complete with associated accessories, are provided to serve the yard hydrant system to provide coverage for each building.

Fixed Water Spray Systems

Fixed water spray deluge protection is provided for the following types of equipment:

- o Generator step-up transformers.
- o Unit auxiliary transformers.
- o Reserve auxiliary transformers.
- o Standby reserve auxiliary transformers.
- o Station auxiliary transformers.
- o Hydrogen seal oil units.
- o Turbine oil reservoirs.
- o Lube oil conditioner.
- o Cable tunnels, electrical penetration areas, and cable spreading rooms.
- o Diesel generator fuel oil piping in floor trenches and day oil tanks.

Standpipe Systems

The turbine building, office facility, and service building are provided with a standpipe system in accordance with NFPA Standards.

Fixed Carbon Dioxide System

Manually initiated fixed carbon dioxide fire extinguishing systems are provided in the following areas:

- o Cable spreading rooms above and below the control room.

Automatic Sprinklers

The turbine generator areas below the operating floor containing oil lines are protected with an automatically actuated sprinkler system.

Portable Fire Extinguishers

Portable fire extinguishers are located throughout the site for immediate use against small fires.

Fire Detection Devices

The fire detection system consists of the following, and are used as applicable for the service intended:

- o Ionization type detectors capable of sensing the products of combustion before visible smoke, heat or flame are initiated.
- o Combination temperature rise and fixed temperature type thermostats.

3.6.13 AUXILIARY STEAM SYSTEM

3.6.13.1 FUNCTIONS AND DESIGN REQUIREMENTS

The auxiliary steam system provides low pressure saturated steam for the nuclear steam supply system and the power conversion system during normal plant startup and shutdown. The auxiliary steam system also satisfies building heating and miscellaneous plant requirements. During plant startup, steam is supplied to the turbine gland sealing system, waste processing evaporators, and various nuclear heaters. Shutdown steam requirements are similar, except that gland sealing does not consume any auxiliary steam.

3.6.13.2 SYSTEM DESCRIPTION

The auxiliary steam system consists of one package boiler rated at 225,000 lbs/hr of saturated steam at 200 psig and complete with two boiler feed pumps (one spare), a triplex fuel oil pumping set (one spare pump), one deaerator and storage tank, one blowdown tank, two chemical feed units, one main fuel oil storage tank and controls for local automatic operation.

The boiler is fired by No. 2 fuel oil supplied directly from the main oil storage tank to the fuel oil pumping set. Steam atomization and air atomization are used for continuous operation and startup respectively.

Feedwater from the deaerator is pumped to the boiler, evaporated, and piped to building heating units and operating equipment. Heating steam is returned to the deaerator and the equipment steam is added to the main cycle.

The auxiliary steam system and the main steam system interface.

3.6.14 STANDBY POWER SUPPLY AND AUXILIARIES

3.6.14.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The diesel-generators distribute ac power to the plant safety-related auxiliaries during emergency operating conditions.

Design Requirements

The emergency standby power supply is provided with four 50-percent diesel engine generator systems of identical design and characteristics to supply onsite power of sufficient capacity and capability to reliably shutdown the reactor during emergency plant operation or each 50-percent After Heat Removal system electric power requirements and other auxiliaries. The load rating of each diesel generator is 3250 kVA at 8760 hours per year (continuous).

The generator is rated at 2600 kW for continuous duty.

3.6.14.2 SYSTEM DESCRIPTION

Redundant standby diesel-generator units are provided to supply onsite power to the plant safety-related auxiliaries during emergency operating conditions. The capacity of each diesel-generator is adequate to support operation of engineered safeguards systems loads within the continuous load rating. The loads are determined on the basis that the sum of the estimated loads needed to be powered at any one time is equal to or less than the continuous rating of each unit.

Each diesel-generator system comprises the auxiliaries necessary for quick-start operation, connection to the 4,160 volt emergency bus, and connections to the required services. No auxiliaries are shared between the diesel-generator systems. External power sources, other than d-c control power from the plant's batteries, are not required for engine starting or subsequent system operations.

To ensure rapid starting, each diesel generator set has its own independent starting air supply fed from its own set of redundant accumulators. Each accumulator is sized to give a diesel engine 30 seconds of steady engine cranking or five successive starting cranks. Each accumulator is supplied by its own air compressor. Each diesel generator set is supplied with two air starting systems. Elapsed time from receipt of "start diesel" signal to "ready-to-load" condition is 10 seconds.

The diesel engines are water cooled and obtain the water from the nuclear service water system: Each diesel requires approximately 700 gallons per minute of water having a maximum inlet temperature of 97°F. To prevent freezing of the water during standby duty, each diesel is provided with a thermostatically controlled electric immersion heater for the jacket water. The diesel is capable of operating without jacket cooling water for a period of time in excess of that required to start the cooling water pump from the emergency bus.

The redundant diesel-generators are provided with independent fuel oil storage tanks. The tanks are buried and located outside of the control and diesel building and have a capacity to operate each of the diesels for a period of seven days under full-load continuous duty. The fuel oil systems each have a fuel oil pump that supply the engine day storage supply tanks with fuel oil, as required.

The day tank is skid mounted and is sized to provide 3-hours supply of fuel oil for the diesel engine when operating at continuous full load. The day tank is equipped with level switches to provide automatic actuation of the associated fuel oil storage transfer pump, low-low level alarm and high-high level tripping of the pump with alarm. Overflow recirculating piping is provided from the system day tank to the fuel oil storage tank. Fuel oil is transferred from each fuel oil storage tank to its respective day tank by a pump powered from the associated emergency bus. Valving is provided to permit either transfer pump to supply one or both day tanks from either storage tank.

Each diesel-generator unit is located at the lowest level in the control and diesel building. An enclosure wall is designed to withstand limited explosions and provides a barrier against postulated missiles such as crank-case doors or rupture of an air receiver tank. The diesel-generator and its associated auxiliaries are designed to the requirements of seismic Category I.

An independent lubrication system is provided to assure adequate lubrication for the diesel engine moving parts and for lubrication of the generator. The lube oil system is provided with a strainer, pump, oil cooler, and a strainer before the oil enters the engine or generator. When the engine is on standby duty the lube oil is maintained at the recommended temperature with electric heat. Also, a pump is provided to circulate oil through the engine during standby duty to enable the engine to start with a minimum of friction engine wear.

TABLE 3.6.14-1

EMERGENCY ELECTRIC POWER LOAD DATA

Service	Diesel Generator "A"	Diesel Generator "B"	Diesel Generator "C"	Diesel Generator "D"
Nuclear Service Water Pumps				
Reactor Building Closed Cooling Water Pumps				
After Heat Removal Circulators				
After Heat Removal Cooling Water Pumps		TO BE DETERMINED		
Control Room Cooling Tower Fans and Pumps				
Helium Purification Compressors				
Emergency Feedwater Pumps				
Load Centers (Various Bldgs.)				

3.7 ELECTRICAL SYSTEMS

The electric plant equipment conveys the electric power generated in the plant to the low voltage bushings of the generator step-up (GSU) transformers, controls and meters the electric energy, and protects the components through which the power flows. It is the source of power for the plant auxiliaries and the plant control, protection and surveillance systems during normal operation, and for the plant protection system and engineered safety features during normal operation, abnormal conditions, and accident conditions.

The electric plant design features are as follows:

a. The main generator, the three single phase generator step-up (GSU) transformers and the five three phase unit auxiliary transformers (UAT) are interconnected with isolated phase bus.

b. The generator is provided with a load break switch in the mains between the generator and the UAT tap to disconnect the generator from the offsite power system.

c. Five (four 3-winding and one 2-winding) unit auxiliary transformers (UAT), each 24.5 kV to 13.8 or 4.16 kV, are connected to the generator main leads between the generator load break switch and the GSU transformers.

d. Three 3-winding reserve auxiliary transformers (RAT), each 230 kV to 13.8 or 4.16 kV, are connected to an offsite transmission system.

e. The balance-of-plant (BOP) medium voltage a-c distribution system is nominally 13.8 kV and 4.16 kV. Five separate and independent

13.8 kV buses and two separate and independent 4.16 kV buses are provided. The five BOP 13.8 kV buses are fed from two 3-winding and one 2-winding UAT and a 3-winding RAT. The two BOP 4.16 kV buses are supplied from one low voltage winding on each of two 3-winding UAT's and two 3-winding RAT's.

f. The Class 1E medium voltage a-c distribution system is a nominal 4.16 kV. Two separate and independent Class 1E buses are provided. Each Class 1E bus is fed from one low voltage winding on each of the UAT's and RAT's.

g. The low voltage a-c distribution systems are a nominal 480 volts. Nineteen buses are provided for the BOP systems and eight buses are provided for the Class 1E systems.

h. Four separate and independent Class 1E, 120 volt nominal, uninterruptible a-c instrumentation and control power supplies and distribution buses fed from the Class 1E 480 volt buses are provided.

i. Two separate and independent Non-Class 1E, 120 volt nominal, uninterruptible power supplies fed from the BOP 480 volt buses are provided. One supplies power to BOP instrumentation and control and the other to the plant computer.

j. The Class 1E d-c distribution and supply systems are nominally 125 volts. Four separate and independent station barriers and distribution buses are provided.

k. The Non-Class 1E d-c distribution and supply system is nominally 125/250 volts, with center-tapped battery systems. One center-tapped station battery and distribution system is provided.

l. One Class 1E 125 volt battery charger is provided for each Class 1E battery. One Non-Class 1E 125 volt battery charger is provided for each of the two 125 volt sections of the 125/250 volt Non-Class 1E center-tapped battery.

m. Four 50-percent Class 1E, 2600 kw diesel generator units are provided as the standby power supply for the Class 1E buses, and are automatically connected to their respective buses when the normal and preferred power supplies are not available.

Motor starting voltage and frequency and allowable operational variations, at which the required starting and operating torques are developed, are as follows:

a. Continuous operation of a-c motors.
   1) Voltage: ± 10 percent of rated
   2) Frequency: ± 5 percent of rated
b. Starting and short time (approximately 30 seconds) operation of a-c motors:
   1) Class 1E (Voltage): 75 percent of rated
   2) Non-Class 1E (Voltage): 80 percent of rated
c. d-c Motors (Voltage): 210 to 280 volts

All Class 1E loads are furnished with a-c or d-c power from one of the following: the Class 1E a-c emergency buses, the Class 1E uninterruptible instrumentation and control a-c power supplies and the Class 1E d-c buses.

The normal power supply for the plant electric auxiliaries is from the main generator through the unit auxiliary transformers. The preferred emergency power supply is from the 230 kV offsite power supply via the reserve auxiliary transformers. The alternate access power supply is from the 500 kV offsite power supply via the generator step-up transformers and the unit auxiliary transformers, when the generator load break switch is open. The standby emergency power supply is from one of the two redundant diesel generator units to the corresponding Class 1E medium voltage bus.

The power and control circuits, including circuit breakers and cabling, to all Class 1E loads are qualified, channeled and separated to meet Class 1E requirements. Protective devices are coordinated on the basis that protection of the Class 1E systems is the primary goal.

The safety related design bases for the electric power system are tabulated in Table 3.7-1.

Table 3.7-2 presents allowable ranges of temperature and limits for exposure to radiation for electric equipment. Design ambient conditions for spaces housing electric equipment are based on these ranges and limits plus a minimum of 5 percent for margin.

Physical and electrical separation of equipment and systems is provided to assure the availability of the minimum required equipment during any design basis event. Table 3.7-3 presents acceptable types of physical and electrical separation and their application. Physical separation of equipment and circuits is done in such a way that the single failure criterion is met and that the independence achieved cannot be compromised by adjacent or supporting mechanical and structural systems.

Switchgear

A main generator load break switch is provided to disconnect the generator rapidly from the offsite system when no fault is present. This allows rapid connection to the alternate access power supply (GSU transformers and UAT). The switch comprises three single-pole, water-cooled load break switches with a spare single pole and an independent cooling system. The cooling system has redundant active components. The medium voltage metal-clad switchgear comprises five Non-Class 1E 13.8 kV buses, two Non-Class 1E 4.16 kV buses and two Class 1E 4.16 kV buses. Motors rated 3000 hp and above are rated 13.2 kV and motors rated 250 hp to 2500 hp are rated 4.0 kV. Transfer schemes are provided for automatically and manually transferring each train between the preferred emergency power supply and the normal power supply. Load shedding schedules are provided for automatically stripping all Class 1E buses whenever there is an offsite power failure. Sequential loading schemes are provided for the Class 1E buses to automatically connect selected engineered safety features to those buses after load shedding, and re-energizing the buses from the diesel generator units. Overcurrent protection is provided for all circuits. Differential protection, overload protection and zero sequence overcurrent ground protection is provided for all medium voltage motor circuits.

Non-Class 1E and Class 1E 460 volt motor control centers are provided for power distribution to motors 100 hp and below, lighting loads and miscellaneous loads such as motor-operated valves, resistance heaters, heat tracing and motor space heaters.

Station Service Equipment

Five auxiliary transformers (UAT) and three reserve auxiliary transformers (RAT) are provided to furnish power to the plant auxiliary power system. Each transformer is sized with sufficient margin to carry the plant auxiliary load under the heaviest load conditions. Each transformer is protected with differential protection schemes and sudden internal over-pressure devices.

Unit substations are provided to transform the medium distribution voltages to the low distribution voltage for Non-Class 1E and Class 1E low voltage loads. Motors rated 125 hp through 200 hp are connected to the unit substations.

Overcurrent protection is provided for all circuits. Overload protection is provided for motor circuits. The unit substations for the cooling towers are fed from a loop feeder.

The battery systems comprise the plant Non-Class 1E and Class 1E batteries and battery chargers. Each Class 1E d-c bus is supplied from a Class 1E battery and a Class 1E battery charger. The Non-Class 1E 125/250 volt d-c bus is supplied from a 125/250 volt center tapped battery and two 125 volt battery chargers, one for each 125 volt section of the 125/250 volt battery. During normal operation d-c power is supplied from the battery chargers. During emergency operation d-c power is supplied from the batteries. During startup and shutdown d-c power is supplied from whichever source is available.

Four 50-percent diesel generators are provided to furnish the onsite source of emergency a-c power to the Class 1E 4.16 kV buses.

Each diesel generator unit is provided with redundant automatic air starting systems that are initiated when loss of offsite power, loss of power to engineered safety features or when reactor trip occurs. The rating for the diesel generator units was chosen so that each unit has the capability to continuously operate all protection systems and engineered safety features that are necessary for a safe and orderly shutdown following a loss of coolant accident concurrent with loss of offsite power. Minimum voltage that can be experienced at the diesel generator terminals during motor starting is 80 percent. Rating, configuration and switching of the diesel generator units are designed to prevent their use for any purpose other than that of standby power supply in accordance with preferred practice.

Four Class 1E and two Non-Class 1E dual input solid state inverters are provided to serve as uninterruptible power sources for miscellaneous vital and non-vital a-c and plant instrumentation loads. The inverters are supplied with power from the a-c buses through regulating transformers or directly from the station batteries.

Switchboards

Four Class 1E and two Non-Class 1E a-c power distribution panels are provided to distribute a-c power from the inverters to the 120 volt or 120/240 volt uninterruptible loads. They are configured as one panel per inverter for both Class 1E and Non-Class 1E equipment.

Four Class 1E and Non-Class 1E d-c power distribution switchgear lineups are provided to distribute d-c power from the batteries and their associated chargers. There is one lineup per station battery/charger combination.

Sixteen feet of control benchboard is provided in the main control board lineup for control and data acquisition of the main generator and the auxiliary electric power system.

One electric system relay panel lineup is provided for protection and metering of the main generator, the generator step-up transformers and the unit and reserve auxiliary transformers. The main generator is protected by high speed differential, ground current, loss-of-field, negative sequence overcurrent, and voltage restrained overcurrent relays. The main generator, the generator step-up transformers and the unit auxiliary transformers are protected by power directional overall differential relays. The reserve auxiliary transformers are protected by power directional differential relays.

Power and Control Wiring

Isolated phase bus is provided to interconnect generator terminals, GSU transformer low voltage terminals and UAT high voltage terminals. This bus is force-cooled with redundant active components in the cooling unit.

The plant wire and cable consists of three conductor and triplexed single conductor power cable, multi-conductor cable, coaxial, triaxial, shielded twisted pair and multi-shielded twisted pair and shielded quad instrument wire and containment electrical penetrations. Materials for insulation systems are selected to provide optimum system performance in the areas of physical stability, tensile strength, flexibility, aging characteristics, resistance to abrasion, ozone (where required), water absorption, heat distortion, solvent extraction, irradiation, self-extinguishing and non-propagating fire characteristics and resistance to corona effects where required. Wires and cables are assigned to load groups, whether safety related or not, in order to reduce the hazard of non-safety related cables being inadvertently routed between two redundant load groups. The same cable that is qualified for use in Class 1E systems is used in Non-Class 1E systems to reduce the hazard of non-safety related cables being inadvertently routed between two redundant load groups. The same cable that is qualified for use in Class 1E systems is used in Non-Class 1E systems to reduce the hazard of unqualified cables being inadvertently installed in Class 1E systems. In addition to separation by load groups, wire and cable is also separated by energy level to reduce heating and arcing fault problems.

Wire and cable routing is governed by the following:

a. Requirements for the power supply, control network and/or instrumentation signals

b. Requirements for loading

c. Requirements for physical separation of redundant criteria

d. Avoidance of high hazard areas (e.g., areas subject to high ambient temperatures, missiles, firest, and irradiation)

e. Areas having high ambient temperatures (e.g., areas near uninsulated, main-steam pressure and relief valves)

f. Protection from missiles, fire, and/or irradiation, when required

g. Single failure criterion and the effects of common failure modes

h. Simplicity of layout

i. Ease of insulation

j. Ease of access

TABLE 3.7-1

SAFETY RELATED DESIGN BASES FOR THE ELECTRIC POWER SYSTEM
1. Subsystems, equipment and components which are required to achieve a protective function, to perform a protective action or to provide power for engineered safety features are Class 1E design as defined below.
2. Class 1E Design: a. Considers interactive effects of plant conditions and natural phenomena to the extent that power required by the plant protection system and engineered safety features are available during abnormal and accident conditions. b. Is based on the safe shutdown earthquake (SSE) in order to assure safe reactor shutdown and removal and dissipation of reactor stored energy and decay heat for an indefinite period in the event of an SSE. c. Includes provisions to minimize failures due to flame or fire damage and to detect, confine and promptly extinguish any fire which might occur. d. Includes provisions to allow periodic inspection and testing of systems and equipment.
3. Class 1E power sources, power supplies, distribution systems and load groups, have sufficient separation and independence so that loss of any group does not prevent the minimum safety actions from being performed.
4. Class 1E load groups are provided with separate and independent power supplies in order to prevent a common failure mode from being established among the load groups.
5. The degree of physical separation required for redundant Class 1E equipment, including cable and raceways containing cable, is based upon the hazards which exist in the vicinity of the equipment and which would constitute a common failure mode between the redundant equipment if no separation existed.

TABLE 3.7-2

DESIGN AMBIENT CONDITIONS FOR ELECTRIC EQUIPMENT					
		Ambient Temperature Limit (^{o}F)		Ambient Radiation Limit (Rads)	
Type of Equipment	Limit	Equipment	Equipment Space	Equipment	Equipment Space
Battery	Max	90	N/A	N/A	N/A
Battery	Min	77	80	N/A	N/A
Cable	Max	104	100	1×10^8	1×10^7
Cable	Min	N/A	N/A	N/A	N/A
All Other**	Max	104	100	N/A	N/A
All Other**	Min	40*	50*	N/A	N/A

*Or above dewpoint temperature, whichever is higher.

**Sensitive relays and other electrical devices are placed in controlled environment spaces such as the control room, as applicable.

TABLE 3.7-3

ACCEPTABLE PHYSICAL AND ELECTRICAL SEPARATION		
Type	Designation	Used for Protection From:
A	Physical	Low Energy Missiles Mechanical Protection
B	Physical	High Energy Missiles Radiation
C,D,E	Physical	Heat Fire
F,G,H	Electrical	Common Failure Mode
	DETAILED DESCRIPTION	
Type	Barrier	Example
A	Metal	Sheet metal on rigid frame Rigid steel sleeve or plate Rigid steel conduit
B	Concrete	Concrete block wall Concrete foundation Reinforced concrete wall
C	Flame Resistant	Mineral, wool or fiberglass Ablative coating Asbestos cement sheet supported on light steel frame
D	Air Space	1'-0"** or 3'-0" in horizontal direction 3'-0"** or 5'-0" in vertical direction
E	Minimum Air Space	6" in horizontal direction* 6" in vertical direction*
F	Prohibition of sharing among redundant circuits unless electrical isolation is provided by buffers.	
G	Prohibition of automatic transfer of redundant safety circuits between Class 1E power supplies or power sources.	
H	Prohibition of automatic transfer of Class 1E power supplies or power sources between redundant safety circuits.	

*In conjunction with a barrier of Type A, B or C.

**In cable spreading areas only.

3.8 INSTRUMENTATION AND CONTROL EQUIPMENT

General

The reactor plant instrumentation and controls enable the operator to start up, operate and shut down the reactor and monitor the plant to assure the safety of personnel and equipment.

Main Control Room

The main control room contains the C-shaped Main Control console consisting of the following sections:

- Chemical Heat Pipe Control
- Recuperator Control
- Turbine Generator and Electric Distribution
- Feedwater and Condensate Control
- Main Steam Control
- Rod Control
- Plant Data Acquisition and Processing

The main control console contains video information and alarm displays, as well as sufficient additional control and indication equipment to enable the operator to control the plant under normal and plant upset conditions.

The Control Console is surrounded by vertical control boards for the NSS and balance of plant (BOP) auxiliary systems. The vertical control boards contain the analog controls, selectors, instruments and digital logic hardware. The vertical control boards are subdivided into several sections. They contain the control hardware for several systems such as:

- Plant Protection System
- Main and After Heat Removal Coolant Loops
- Plant Control
- NSS Support Systems
- Turbine/Generator System
- Plant Auxiliary Systems

Plant Data Acquisition and Processing (DAP)

The DAP system is a dual computer based instrumentation and processing system designed for data acquisition, scanning, alarming and logging. The system provides operator guidance and executes plant performance and physics calculations. The design objectives of this system are:

- Reduce the amount of information that must be monitored by the operator
- Improve the operator's decision making process and thus the response time by providing the most relevant information
- Reduce the size of the Main Control Console
- Provide dynamic alarm indication
- Provide graphic displays of interrelated system parameters and system trends
- Provide comparative graphic displays of design limits against actual operating data
- Provide core performance and fuel management data
- Provide turbine and reactor performance calculations and displays

The DAP system has redundant dual central processing units, dual mass memory subsystems, dual input data multiplexing subsystems and dual access to displays and other peripherials.

Plant Control System (PCS)

The PCS regulates the power level of the reactor, controls the pressure and temperature of the steam delivered to the turbine and the temperature of the reformed gas stream leaving the gas reformer. These controls operate automatically over the range of 25% to full power. Following a turbine/generator or reactor trip or the loss of flow in the chemical heat pipe, feedwater is automatically reduced, at a specific rate, to a predetermined value.

Reactor Protection System

The reactor protection system receives signals from nuclear instrumentation and process instrumentation bistables, control board pushbuttons and field-mounted devices. These signals are evaluated in digital logic systems and produce the actuation signals for reactor trip and engineered safeguard actuation. The system automatically keeps the reactor operating within a safe operating region by tripping the reactor when the predetermined safe operating limits are exceeded. The safe operating region is defined by several equipment limitations. Therefore, the protection system monitors those process variables which are directly related to equipment mechanical limitations. Typical causes of reactor trips are:

- High Reactor Flux
- High Reactor Power-to-Helium Flow Rate-Ratio
- High Reactor Power
- High Steam Reformer Inlet Helium Temperature
- High Primary Coolant Moisture
- High Primary Coolant Pressure
- Low Primary Coolant Pressure
- Loss of Preferred Electrical Bus Voltage
- Manual Trip

Engineered Safety Features Actuation Systems (ESFAS)

The ESFAS continuously monitors vital plant parameters. The monitored signals are combined in logic matrices. These matrices monitor combinations indicative of potentially hazardous conditions. When a potentially dangerous signal combination is detected, the ESFAS initiates actuation signals to those engineered safety feature systems whose aggregate functions best protect the fission product barriers. The Engineered Safety Feature System consists of:

- After Heat Removal System (AHRS)
- Containment Isolation System (CIS)
- Containment Air Purification System (CAPCS)

The AHRS is an automatically initiated system utilizing four separate auxiliary cooling loops which serve as backup for the main cooling loops. Any two AHRS cooling loops are adequate to provide the safety function. Therefore, instrumentation within a single loop is not redundant.

The containment isolation system monitors the hydrogen content, gamma radiation levels and fission products in the atmosphere. Alarms are provided for high hydrogen or high radiation level conditions. Permenent records of measurements are provided in the control room.

Remote Shutdown Panel

A remote shutdown panel is provided for the orderly shutdown of the reactor to a cold condition from a location remote from the main control room. This panel makes shutdown possible when the main control room becomes inaccessible. Located on this panel are the necessary controls and instrumentation channels required to shut down the reactor, to cool it down through the use of suitable procedures and to maintain it in a safe condition. The following controls and indicators are provided:

- Reactor trip circuit breakers
- Log power level indication
- AHRS automatic initiation and main loop trip switch
- Steam reformer inlet helium temperature indication
- Steam generator inlet helium temperature indication
- Helium temperature indication at the inlet to the heat exchanger of the After Heat Removal System
- Main circulator speed indication
- AHRS circulator outlet temperature indication
- Primary coolant mass flow indication (main loops)
- AHRS circulator speed indication

Radiological Data Management System

The radiological data management system is in compliance with the applicable NRC licensing requirements and provides information concerning the radiological environment of the plant. The system enables the health physicist and plant operating personnel to maintain complete awareness, in real-time, of plant radiation levels. Permanent records are automatically produced to satisfy regulatory requirements. The system consists of:

a. Process Radiation Monitoring System
b. Effluent Radiation Monitoring System
c. Area Radiation Monitoring System
d. Data Acquisition and Processing System

Each monitor channel is complete with detector, preamplifier, digital buffer, microprocessor with alarm outputs, and readout modules. The data acquisition and processing system is a computer-based system that collects the available information from field-mounted detectors, performs the necessary calculations and displays the results on the CRT as required. The system assists in the generation of required NRC reports.

Neutron Monitoring System

The reactor power measurement is derived from the nuclear instrumentation used for monitoring the neutron flux level from start-up to above rated power. Seven complete Nuclear Instrument channels are provided. Three channels are provided for the start-up range. Three dual range channels (with logarithmic mid range and linear power range) are provided and one linear control channel.

The system employs 15 neutron detectors. The three detectors, used in the start-up channels are integral with the control rod drive penetrations of three fuel regions and provide 120 degree separation. The remaining detectors are located (in pairs) in each of six vertical wells in the PCRV at fixed positions near the reactor midplane.

Six out-of-core detectors are used in the dual-range channels and provide wide-range logarithmic and linear power signals to the PPS.

Six out-of-core detectors are used in the flux control channels which are electrically separated from the protection channels.

Post Accident Monitoring

The post accident monitoring system is designed to assist the operator in accident surveillance. The accident monitors help to determine the nature of the accident, to predict the trend and to ascertain if corrective actions of the engineered safeguards system are functioning as required. In addition, the system provides the plant operator with information necessary to assess possible fuel or system damage. Finally, it provides material evidence for post-accident investigation into the causes and consequences of the event. Recording of data for post accident review is not a safety related function and can therefore be satisifed by the DAP system.

Reactor Diagnostic System

Instrumentation is provided to record and analyze internal core motion. The equipment includes data handling system for analysis. Should abnormal conditions develop, the information provided by this system is used to decide if plant operation should continue.

Containment Atmospheric Monitoring System

The containment atmospheric monitoring system monitors the hydrogen content, gamma radiation levels and fission products in the containment atmosphere. Alarms are provided for high hydrogen or high radiation level conditions. Permanent records of the measurements are provided on control room recorders.

Containment Leakage Monitoring

The containment leakage monitoring system measures the containment overall integrated leakage rate at the required periodic intervals. The system measures and records the absolute pressure, the dewpoint temperature, and the dry-bulb temperature. Sensors having high accuracy, resolution and repeatability are utilized, since changes in the measured parameters are small. The data acquisition system computes the containment leakage based on the measured inputs.

Instrument Racks

The instrument racks take the form of an open rack. They are used to mount local instruments such as pressure transmitters, manifolds, pressure switches, and other pneumatic instruments that connect directly with the process pipes. The rack has a rigid structure, suitably braced, to withstand all stress incidental to shipping, installation and operation without warping or twisting. Instruments, conduits and electrical devices are arranged such as not to be placed in the paths of condensation, or water drains from testing or calibrating instruments. Sufficient clearance is provided for maintenance of the instrumentation without interruption of service. Provisions for collecting the drains, when the instrument is removed, are provided. Suitably engraved plastic nameplates are provided for each instrument.

Reactor Plant Instrument Tubing and Fittings

The scope of supply of instrument tubing begins at the first accessible root valve at the piping and extends to the instrument shutoff valve. Materials and certification of instrument lines which are part of the pressure boundary are in accordance with the Instrument Society of America Standards.

3.9 TURBINE PLANT SYSTEMS

The turbine plant equipment includes the steam and power conversion system components of the steam cycle. The thermal energy from the reactor is utilized to produce steam within the steam generators and deliver it to the turbine stop valve at 1600 psia of superheated steam.

A description of the turbine plant equipment is detailed in the following System Design Descriptions:

- Turbine Steam System and Turbine Generator
- Main Steam System
- Condensate and Feedwater System
- Condensing System
- Emergency Feedwater System
- Demineralized Water Makeup System

Other systems furnished are:

Turbine Building Closed Cooling Water System

A closed cooling water system is provided with three 50% capacity motor driven pumps, air tank and heat exchangers which dissipates heat to the main cooling towers.

Chemical Treatment System

The chemical treatment system is used to maintain the water chemistry of the feedwater and consists of two hydrazine feed pumps, two ammonia feed pumps, one hydrazine storage tank and one ammonia storage tank. The hydrazine chemically removes the dissolved oxygen from the feedwater and the ammonia controls the pH.

Neutralization System

The neutralization system consists of two pumps, a blower, and a tank. The tank is used to chemically neutralize the spent reagent from the demineralization system to acceptable levels prior to discharge.

3.9.1 TURBINE STEAM SYSTEM AND TURBINE GENERATOR

3.9.1.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The function of the turbine-generator (TG) and the turbine steam system is to receive steam from the main steam system and to transform the thermal energy in the steam to electrical energy.

Design Requirements

- The turbine generator is designed for load following operation. Load changes are initiated by adjustment of the turbine control system load reference set point which positions the turbine admission valve. The turbine first stage pressure is sensed to control average coolant temperature. Changes in steam flow and feed flow are sensed and SG water level is controlled.

- The turbine is designed for normal operation based on steam conditions at the throttle valve, namely; 1600 psia, 999.5^{o}F. The steam flow rate to the high pressure turbine is 6.84 x 10^6 lbs/hr.

- The TG is designed for safe continuous operation at the maximum capability (valves wide open - VWO).

- The TG and the associated steam systems are capable of 27 percent load reduction without causing a reactor trip by dumping steam into the condenser through the turbine bypass system.

- 2.16 x 10^6 lbs/hr steam is extracted from the HP turbine for the process gas chemical system.

3.9.1.2 SYSTEM DESCRIPTION

This system description includes the following: the turbine and the turbine steam system, the reheaters, extraction steam system, the turbine control system, turbine bypass system, the generator and the subsystems associated with the operation and control of the turbine generator.

The heat balance for the turbine cycle is shown on Drawing 7122.001-PBR-023. The turbine steam system piping/flow diagram is given on Drawing 7122.001-PBR-018. Drawings 7122.001-PBR-010 and 7122.001-PBR-011 show the plan of the turbine building, the heater bay, and the equipment arrangement in these buildings.

The turbine steam system and the TG are non-nuclear safety, with associated piping designed in accordance with the Power Piping Code, ANSI B31.1. Pressure containing vessels are designed in accordance with the ASME Boiler & Pressure Vessel Code, Section VIII, Division 1.

Generator rating, temperature rise, and insulation class are in accordance with the latest ANSI Standards, C50.10 & C50.13.

Turbine and Turbine Steam System

The turbine is 3600 and 1800 rpm, cross-compound, two flow machine with 43-inch last-stage blades. It consists of two cylinders: one double flow high pressure cylinder and one double flow low pressure cylinder.

Steam from the main steam header is admitted to the high pressure turbine through the turbine stop and control valves. The main stop valves are welded directly to the inlet connections of the control valves.

The exhaust steam from the LP turbine flows into individual sections, or shells, of the main condensers, where it is condensed by the circulating water.

Turbine extraction steam, used for feedwater heating, is taken from five extraction points: one from the exhaust of the high pressure turbine, and four from the low pressure turbine casing. Four stages of closed feedwater heaters are provided. In addition, steam is extracted from the high pressure turbine casing for use in the process gas chemical system where it is mixed with methane in pipeline mixers. Motor operated block valves and power-assisted non-return valves in the extraction piping protect against the possibility of turbine water induction or overspeed due to energy stored in the extraction steam system.

Turbine generator bearings are lubricated by a conventional pressurized oil system; the main lubricating oil pump being driven from the turbine during normal operation. During startup or shutdown, a-c motor driven pumps supply bearing oil to the TG.

The design conditions for the turbine are:

a.	Steam pressure at stop valve	1600 psia
b.	Steam temperature at stop valve	999.5^{o}F
c.	Turbine back pressure (design)	3.75 in. Hg. Abs.
d.	System makeup	2.16 x 10^6 lbs/hr for process gas steam
e.	Final feedwater temperature	355^{o}F
f.	Rated steam design flow	6.84 x 10^6 lb/hr
g.	105 percent of rated flow	7.182 x 10^6 lb/hr

Turbine Control System

The turbine control system is capable of remote manual or automatic starting and loading of the unit at a preset rate, and holding speed and load at a preset level. The system contains valve positioning, operating and tripping devices with provisions for testing valve operation.

The turbine control system is an electrohydraulic control (EHC) and consists of three major units to minimize interactions. A speed control unit compares actual turbine speed with the speed reference, or actual acceleration with the acceleration reference, and provides one speed error signal for the load control unit. The load control unit combines the speed error signal with the load reference signal, and provides limits and biases to determine desired steam flow signals for the turbine stop valves, turbine control valves, and intercept valves. Finally, the valve flow control units accurately position the appropriate valves to obtain the desired steam flows to the turbine.

A high pressure fluid system is provided to convert the low power level signals from the EHC circuits to high powered level mechanical outputs for positioning steam valves. This system consists of a fluid reservoir, two independent pumping systems, fluid coolers, accumulators, a fluid transfer and filter unit.

Lubricating and Oil System

The functions of the lubricating oil system are to receive store, purify, cool, and provide lube oil to the thrust and journal bearings of the main turbine-generator and the feedwater pump turbines, to provide oil to the generator hydrogen seal oil system, and to provide high pressure oil to the turbine control system.

The lubricating oil system consists of two integrated sections: (1) the turbine-generator lubricating oil section which includes the bearing oil pumps, turbine lubricating oil reservoir, and the oil coolers; and (2) the lubricating oil conditioning and storage circuit consisting of clean and used oil storage tanks, an oil purifier, and a motor driven transfer pump. The pump is a positive displacement type, capable of two-speed operator to accomplish both the transfer and circulation requirements.

The clean and used oil storage tanks are located inside a fireproof room equipped with a trap drain, water sprays, and vent fans. The pumps and piping are arranged so that oil can be processed from the turbine lubricating oil reservoir or either of the storage tanks. The processed oil can be returned to either of the storage tanks or to the turbine lubricating oil reservoir as required. Vapor extractors purge oil fumes from the reservoir and exhaust them to the atmosphere outside the turbine building.

Lubricating oil to the turbine-generator is normally supplied from a turbine shaft driven pump. An a-c motor driven turning-gear oil pump supplies bearing lubrication for startup, shutdown, and standby operation when a-c power is available. A d-c motor driven bearing oil pump, operated from the normal station battery, ensures bearing lubrication in the event a-c power fails.

Turbine lubricating oil coolers, located in the turbine lubricating oil reservoir, remove heat generated in the turbine-generator bearings and transfer it to the turbine plant component cooling system.

Turbine Gland Sealing System

The turbine gland sealing system provides sealing steam to the main turbine and the two steam generator feed pump turbines. The sealing system prevents the leakage of steam from the turbine packing glands into the turbine building and also prevents the leakage of air into the main condenser.

The annulus space between the turbine shafts and the casings is sealed by steam supplied to labyrinth packings. The labyrinth packing seals against vacuum on one side by allowing the sealing steam to leak outward to a vent annulus that is maintained at a slight vacuum, and seals against atmospheric pressure on the other side by allowing a small amount of leakage inward. The vent annulus also receives air leakage from the outside. This air-steam mixture is then conducted to the gland condenser. When the packing seals against positive pressure, the sealing steam connection acts as a leakoff.

The steam seal header is automatically regulated at 4 psig. At startup and low loads auxiliary steam or main steam is used for the seals. At higher loads when the amount of leakoff from the pressure packings is more than that required by the vacuum packings the excess is discharged to the gland condenser. The gland condenser returns seal leakoff to the condenser as a condensate.

The cooling medium for the gland condenser is the condensate system. During normal plant operation noncondensible gases are removed from the gland condenser by a motor-driven blower, and discharged to the atmosphere.

Turbine Bypass

On a large external electrical load decrease (up to 27 percent), the turbine bypass system relieves main steam directly to the condenser, thus preventing a reactor or turbine trip and lifting of the main steam safety valves.

The turbine bypass system includes a turbine bypass header, branching from the main steam manifold in the main steam system and individual bypass lines connecting the bypass header to the condenser. An isolation valve, a turbine bypass control valve, and a second isolation valve are mounted in series on each individual turbine bypass line.

An uncontrolled plant cooldown caused by a single valve sticking open is prevented by the use of a group of smaller valves installed in parallel instead of a single larger valve.

The full capacity of the turbine bypass system is 27 percent of maximum calculated steam flow at full load steam pressure which, together with the NSSS transient capability, meets the above design requirement. This steam flow is equally distributed among the two condenser shells by the proper opening sequence of the turbine bypass control valves.

After a normal shutdown of the turbine-generator leading to plant cooldown, the turbine bypass control valves are opened to release steam generated from reactor coolant system sensible heat. Reactor cooldown, programmed to minimize thermal transients and based on sensible heat release, is accomplished by gradually decreasing the setpoint of a steam pressure controller. This closes the turbine bypass control valves, thus transferring the cooldown process to the after heat removal system.

Generator

The two generators are sized to accept the output of each turbine at rated steam conditions. The 3600 rpm generator is a direct-coupled, 25,000 Volt, 3 phase, 60 Hz unit rated at 416.9 MVA with 0.90 power factor and the 1800 rpm generator is a direct-coupled, 25,000 Volt, 3 phase, 60 Hz unit rated at 310 MVA with a 0.90 power factor. It is a totally enclosed hydrogen cooled type with deionized water as the liquid coolant. The generator is equipped with an excitation system, hydrogen control system and a seal oil system. The generator terminals are connected to the main stepup transformer and unit station service transformers with generator isolated phase bus leads.

The generator rotor is furnished with an internal cooling system including: hydrogen coolers, terminal bushings, instruments, grounding pads, seal housing insulation, foundation plates, shims, and special tools.

The generator stator is furnished with the following external equipment: deionized water circulating and cooling unit assembled on a skid and including storage tank, pumps, coolers, deionizer, flow meter, conductivity cells, gauges, piping, valves, filters, instruments, and regulating equipment, stator winding control cabinet assembled and combined with the hydrogen control cabinet including annunciator, generator automatic runback logic and all necessary control devices.

The generator hydrogen system includes: two hydrogen coolers, one skid mounted seal oil unit, hydrogen manifold with one bottle pressure regulator with high and low pressure gauges, pressure switch for hydrogen supply pressure "low" alarm, shutoff valves and bottle connectors, generator hydrogen pressure regulator, hydrogen storage bottles, control cabinet, temperature detectors, and special tools.

The alternator bearings, the silicon diode rectifier assemblies, the main generator collector and the brush rigging are all totally enclosed within the alternator exciter housing with suitable heat exchangers and means for circulating air. The closed ventilation circuit is equipped with water to air coolers located in the exciter frame. The excitation switchgear is an integrated unit of standard low voltage, located indoors, and metal enclosed. The function of the excitation switchgear is to connect, rectify and control excitation to the a-c alternator exciter from the alternator stator, and to provide voltage regulation by adjustment of the generator field voltage (d-c regulator) or the generator terminal voltage (a-c regulator). The excitation switchgear houses the exciter field breaker, the thyristor regulator bridge and the a-c and d-c regulator logic.

Exciter

The exciter is a direct driven alternator and stationary silicon diode rectifier type.

Gas Systems

The carbon dioxide system consists of a four ton liquid carbon dioxide storage unit with refrigeration system, vaporizer, relief valves and two pressure reducing valves. Carbon dioxide is used for purging hydrogen from the generator housing during shutdown, and for purging air from the housing before being filled with hydrogen during startup. Sufficient capacity is provided to twice purge the system of air and once of hydrogen.

Hydrogen gas is used to cool the rotor of the generator and is circulated within the generator housing under pressure. Two shell and tube type coolers at the ends of the generator are supplied with cooling water to dissipate the rotor heat and wind losses.

The hydrogen is supplied from a series of bottled containers which are individually connected to a manifold. The manifold is equipped with a relief valve and two pressure regulators, with isolation valves.

Enough hydrogen supply is provided to fill and pressurize the generator once and supply the required makeup for a nominal period.

3.9.1.3 OTHER TURBINE PLANT EQUIPMENT

Turbine Building Closed Cooling Water System

A closed cooling water system is provided with three 50 percent capacity (5000 gpm each) motor driven water pumps, expansion tank and heat exchangers, which dissipates heat to the main cooling towers. The heat exchangers are two 50 percent capacity shell and tube type, designed for a flow rate of 5000 gpm on both the shell and tube sides. The tubes are 90-10 CuNi material, and supply 105 F water to the system based on a supply water temperature of 97 F from the plant service water system.

Chemical Treatment System

The chemical treatment system is used to maintain the water chemistry of the feedwater and consists of two hydrazine feed pumps, two ammonia feed pumps, one hydrazine storage tank and one ammonia storage tank. The hydrazine chemically removes the dissolved oxygen from the feedwater and the ammonia controls the pH.

Neutralization System

The neutralization system consists of two pumps, one blower and one tank. The neutralization tank is used to chemically neutralize the spent regenerant from the demineralization system and condensate polishing system to acceptable levels prior to discharge.

3.9.2 MAIN STEAM SYSTEM

3.9.2.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Main Steam System shall perform the following functions:

The Main Steam System (MS) shall convey steam produced in the superheating section of the steam generators to the HP turbine.

The Main Steam Bypass System shall provide a flow path for the steam generator effluent when the turbine generator is not operating, during low load conditions (less than 25% of rated turbine generator load), or at any other time when the steam generators are producing more steam than needed by the turbine.

Design Requirements

The Main Steam System shall meet the following design requirements:

Main Steam System:

a) The Main Steam piping from the six steam generators to the HP turbine shall be designed to carry 100% of the rated main steam flow within the maximum permitted pressure drop of 15 psi.

b) Under emergency conditions, (i.e., tube leakage in the steam generator(s) or high containment pressure), the Main Steam line(s) from each individual steam generator shall be capable of isolation within 20 seconds, on receipt of the relevant signal. Double isolation valves shall be provided outside of containment.

c) The steam generator superheater(s) shall each be protected from overpressure by spring loaded code safety-relief valves capable of relieving 100% of the steam flow to atmosphere.

Main Steam Bypass System:

a) The Main Steam Bypass System shall be sized to bypass 27% of the rated Main Steam flow from the superheater sections of all six steam generators.

b) Additional controlled overpressure protection shall be provided for the steam generator(s) superheat/economizer section by pneumatically operated pressure control valves capable of discharging the remaining 73% of the rated steam flow to the atmosphere.

General Requirements:

The Main Steam System outside of the reactor containment isolation valves is not required to ensure a safe reactor shutdown or cooldown and will not result in doses at the site boundary in excess of 0.5 Rem. It is, therefore, classified as Safety Class NNS and non-seismic Category I and is designed in accordance with ASME Section VIII and ANSI B31.1 code requirements.

The Main Steam System from the reactor containment isolation valves to the steam generators is Safety Class 2 and seismic Category I and is designed in accordance with ASME Section III Class 2 code requirements.

3.9.2.2 SYSTEM DESCRIPTION

The Main Steam System is comprised of associated piping and valves with instrumentation and automatic/remote controls necessary for all modes of plant operation to perform the functions and design requirements.

The Main System shall provide steam, as required, for the plant auxiliary equipment usage during normal operations.

During startup and shutdown operations when the main steam is not available, the Auxiliary Boiler System shall deliver steam to the auxiliary steam distribution system.

3.9.3 CONDENSATE AND FEEDWATER SYSTEM

3.9.3.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Condensate and Feedwater Systems shall automatically deliver a continuous flow of feedwater to the steam generators during normal plant operation and provide a Non-Nuclear Safety "heat sink" for reactor energy when the main turbine generator (T-G) is not operating.

The Condensate System shall condense the main T-G exhaust, boiler feedwater pump (BFP) turbine exhaust, turbine gland steam and shall provide storage capacity to ensure an adequate supply of condensate for all anticipated modes of plant operation.

The Feedwater System shall provide for regenerative heating of the feedwater and shall isolate and drain affected steam generators upon receipt of a tube leak signal from the Moisture Monitors. The systems shall deliver condensate/feedwater to the steam generators and other systems (if and when required), at the temperature, pressure, and chemistry as specified by NSSS requirements.

Design Requirements

The Condensate System shall contain three 50% condensate pumps, each sized to handle 60% of the guaranteed heat balance condensate flow, at 105% of the calculated system head.

The Feedwater System shall contain two 50% feedwater and booster pumps, each sized to handle 55% of the guaranteed heat balance feedwater flow to the steam generators at 105% of the calculated system head.

The systems combined storage capacity of the condenser hotwell and the deaerating feedwater heater storage tank (DFT) shall be at least seven minutes supply of condensate at maximum flow conditions. The DFT capacity shall be sized to hold at least four minutes maximum flow of feedwater on loss of condensate flow.

The Condensate and Feedwater Systems are required to interface with the following systems:

a) Auxiliary Steam System: condensate is returned to auxiliary boiler deaerator during start-up, shutdown and refueling operations.

b) Demineralized Water System: supplies make up water to the condensate storage tank.

The Condensate and Feedwater Systems upstream, but not including the reactor containment feedwater isolating valves, are not required to ensure safe reactor shutdown or cooldown and will not result in doses at the site boundary in excess of 0.5 Rem. They are, therefore, classified as Safety Class NNS and non-seismic Category I. System components are generally designed in accordance with ASME VIII and ANSI B31.1 code requirements.

The Feedwater System from and including the reactor containment isolation valves to the steam generators are Safety Class 2 and seismic Category I and are designed in accordance with ASME III, Class 2 code requirements.

3.9.3.2 SYSTEM DESCRIPTION

The Condensate and Feedwater System consists of storage facilities, heat transfer equipment, condensate polishing equipment, pumps, and associated piping, valves, instrumentation and controls necessary to perform the functions and design requirements.

A Condensate Storage Tank, 600,000 gal. capacity, acts as a surge and supply tank for the system during plant operation and provides a reservoir for system cleaning during start-up. Level instrumentation automatically controls the demineralized water supply to the tank.

Two 100% capacity Transfer Pumps, deliver makeup water from the Condensate Storage Tank to spray nozzles over the condenser tubes.

Two single shell, single pass, condensers each with 166,575 sq. ft. of surface area are located directly under the LP turbine to receive and condense the exhaust steam from the LP and BFP turbines. The condenser hotwell high and low level controls initiate makeup from, or overflow to, the condensate storage tank. Conductivity monitors are provided to measure leakage of circulating water into the hotwell, indicating condenser tube failure.

Condensate pumps, rated at 7,152 gpm each, are used to transfer the condensate from the hotwell through the gland steam condenser, condensate polishers, and feedwater heaters to the deaerating feedwater heater. Automatic recirculating bypasses from the condensate pump discharge header to the condenser hotwell assures minimum flow to protect the pumps.

A full flow, deep-bed type, Condensate Polisher is provided having six tanks on line and one spare.

The half size, closed feedwater heaters Nos. 1, and 2 are arranged in parallel feedwater trains, with provision for bypassing to permit flexibility in operating the plant on loss of heater(s).

The Deaerating Feedwater Heater (rated capacity 6.84 x 10^6 lbs/hr) is a single heater receiving condensate from the No. 2 heaters and is provided with high and low level controls to automatically maintain the correct water level in the Deaerating Feedwater Heater Storage Tank to insure adequate supply of condensate to the two 50% capacity Feedwater Booster Pumps.

The Feedwater Booster Pumps transfer condensate from the Deaerating FW Heater Storage Tank through half sized FW Heaters No. 4 to the two 55% capacity Main Feedwater Pumps.

The Main Feedwater Pumps, rated at 8,437 gpm each, deliver the feedwater to the six Steam Generators; the principle features of the system downstream of the feedwater pumps are:

a) Each Main Feedwater Pump discharge line is provided with a motorized stop-check valve and a combination check/automatic recirculating control valve (recirculator to Deaerating Heater).

b) Each individual supply line to the steam generators is provided with two hydraulic actuated, quick closing isolation valves in series, arranged for rapid closure on a high moisture signal (tube leak) from Plant Protection System. One of the valves is also used as a control/trim valve for averaging the flow between all the steam generators.

c) The Steam/Water Dump System, operates in conjunction with the steam generator tube failure isolation signal, to open the two hydraulic actuated steam/water dump valves at each steam generator feedwater inlet, to release the contents of the affected steam generator.

Temperature, pressure and flow monitoring through the system provides surveillance during all phases of normal and off-normal operation of the plant.

3.9.4 CONDENSING SYSTEM

3.9.4.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The objective of the condenser system is to provide a heat sink for the low pressure turbine exhaust steam and the boiler feedwater pump turbine exhaust steam. It also receives drains from the two low pressure feedwater heaters and a complement of makeup water equal to that which was diverted to the steam/methane mixer.

Design Requirements

The condenser is capable of accepting a 2.8×10^9 BTU/hr heat load at the rated turbine loads and with the process plant using 2.16×10^6 lb/hr steam accept 1.87×10^6 lbs/hr of bypass steam flow based on 27 percent of full load steam flow without exceeding the turbine low vacuum trip point.

The condenser has been designed to deaerate the condensate and limit the oxygen content to 0.005 cc/liter at any load during normal operation.

3.9.4.2 SYSTEM DESCRIPTION

The main condenser system consists of two deaerating, double-pass, single pressure, radial flow type surface condensers. Each 50% capacity condenser is located beneath the low-pressure cylinder with the tubes oriented transverse to the turbine-generator axis and is rigidly supported on a foundation. The steam passes through piping which exhausts directly down into the condenser shells after leaving the exhaust openings in the bottom of the low pressure turbine casing. The condensers also receive steam from the steam-generator feedpump turbines.

A stainless steel expansion joint is installed between the upper and lower steam inlet sections to permit movement resulting from the temperature changes of the equipment. Cross connections are provided for equalization of pressure between condenser shells. Provisions have been made for the mounting of two one-third capacity low pressure extraction feedwater heaters in the neck of the condensers. The hotwells are sized for a minimum of 3-minute storage.

The main condenser system will produce a backpressure of 3.5 inches of mercury absolute, when operating at rated turbine output with 96.4°F cooling water and 85 percent clean tubes. Valving is provided so that the condenser flow may be reversed for backwashing the circulating water piping to control marine growth and fouling.

Copper/nickel tubes are used throughout the condenser. The condenser tube sheets are copper/nickel. The condenser shells, tube support plates, and waterboxes are constructed of carbon steel.

The condenser maintains a negligible oxygen concentration in the effluent condensate by limiting subcooling and thereby limiting gas solubility. Mechanical vacuum pumps evacuate the noncondensible gases during normal operation and during startup.

The main condenser system is designed as a non-nuclear system. The extraction steam and turbine drain piping located internal to the condensers are designed in accordance with the Power Piping Code, ANSI B31.1.

Condenser Design Parameters

Number of shells per unit	TWU - 1/2 Size
Total condensing surface	333,150 sq ft
Number of passes per shell	2
Tube size	1" x 19 BWG
Tube length	37.1
No. of tubes per shell	17,130
Tube material	90/.10 copper-nickel
Circulating water flow	310,000 gpm
Tube velocity	7.5
Temperature rise	18°F
Condenser pressure - design	3.5 Hg absolute
Inlet water temperature - design	96.4°F

Equipment is provided to regenerate the demineralizer resins. Wastes from this regeneration are discharged to the radioactive liquid waste system.

3.9.5 EMERGENCY FEEDWATER SYSTEM

3.9.5.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The function of the emergency feedwater system is to ensure a sufficient supply of cooling water to the steam generators so they can act as heat sinks for sensible and decay heat removal from the reactor core under the following events:

- o Loss of normal feedwater supply.
- o Loss of normal feedwater supply coincident with a loss of offsite power.
- o A single failure of any component.

Design Requirements

- o The system starts automatically on a loss of station power, a safeguard sequence signal, a trip of both steam generator feed pumps, or a 2/3 low-low level signal in any steam generator.
- o The system is safety related and seismic Category I.
- o The system, from and including the containment isolation valves and up to the connections with the feedwater system, is designed in accordance with ASME B&PV Code, Section III, Class 2.
- o The balance of the system is designed in accordance with ASME B&PV Code, Section III, Class 3.
- o The system delivers sufficient emergency feedwater to the steam generators following loss of normal feedwater to prevent lifting of the pressurizer relief valves caused by temperature and pressure buildup in the reactor coolant system.

- The steam delivers emergency feedwater against a steam generator pressure corresponding to the lowest main steam safety valve set pressure plus accumulation.

3.9.5.2 SYSTEM DESIGN DESCRIPTION

Upon loss of feedwater flow, the reactor is made subcritical by control rod insertion. Decay and sensible heat will be transferred to the steam generators by the reactor coolant system. When power is not available for the primary coolant circulators, natural circulation will suffice. Heat is removed from the steam generator via the safety and relief valves, and the continuation of the process is maintained by water makeup from the emergency feed water system. The emergency feedwater system is designed to operate until the reactor coolant system pressure is reduced to a value below which the residual heat removal system can be operated.

The emergency feedwater system pumps unheated water from the condensate storage tank to the steam generators, and is comprised of one motor-driven pump, one turbine-driven pump and a system of piping, valves and orifices. Either pump has sufficient capacity to satisfy the above design requirements.

An adequate reserve of water is always maintained in the condensate storage tank (approximately 600,000 gallons), and makeup to the tank is available from the demineralized water makeup system.

The motor-driven pump, pump controls and actuating signal are powered from an emergency bus. Steam for the steam turbine-driven pump is supplied from the main steam system via air-operated valves. The solenoid operators controlling the air-operated valves are supplied power from separate battery sources.

Both pumps feed a header which in turn supplies four air-operated flow limiting valves. Each valve is normally in the open position when the system is not operating. The valve fails to the open position on loss of air. During system operation, the valve closes to a position which regulates the minimum flow. The valve controller receives operating air from its own air regulator. The air regulator operates to maintain a differential pressure across the flow orifice which corresponds to the desired flow rate. Should a valve fail to the open position, flow is limited by the flow orifice, assuming a downstream pipe rupture and both auxiliary feed pumps operating. Air is furnished from an air receiver located in the emergency pump room. The receiver is supplied by the station instrument air system through two check valves arranged in series. The receiver is alarmed in the control room should its pressure fall below the minimum requirement. Each flow limiting valve is fitted with a handwheel for manual operation. The flow limiting function is accomplished without electrical input.

Downstream of each air-operated flow limiting valve, the emergency feed line joins one of the steam generator feed lines outside the containment. The combined feed line enters the containment through a single penetration and feeds a single steam generator.

In the automatic mode, emergency feed regulation utilizes a flow control valve using the pressure drop across the orifice to limit the flow to each steam generator. In the manual mode, the valve will be controlled by an operator to provide the flow requested.

The combination of one turbine-driven and one motor-driven emergency feedwater pump provides a diversity of power sources to assure delivery of condensate under an emergency condition.

3.9.6 DEMINERALIZED WATER MAKEUP SYSTEM

3.9.6.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Demineralized Water Makeup System provides and maintains a supply of treated water for makeup to the power conversion system, to the process gas chemical system, and to other plant process requirements.

Design Requirements

Water for the makeup system is obtained from the raw water supply. Two 100-percent demineralizer trains, each having a capacity of 6,800,000 gallons per day for the system.

The demineralizers will produce water of the following quality:

Specific conductivity at 25°C	1 micromho/cm
pH at 25°C	6-8
Silica (as SiO_2)	0.02 ppm
Chloride (as Cl_2)	0.02 ppm

The Demineralized Water Makeup System is not a safety related system.

3.9.6.2 SYSTEM DESCRIPTION

The raw water passes through a train of clarifiers, sand filters, and a vacuum deaerator for turbidity control and removal of oxygen. From there the water passes through two 100-percent parallel lines of demineralizers. Each line of demineralizers consists of a strong acid (cation) exchanger, a strong base (anion) exchanger and a mixed-bed exchanger. The treated water is then pumped to the condensate storage tank and demineralized water storage tank.

Each demineralizer line has a capacity of 6,800,000 gallons per day for the system.

The system includes in-line acid and caustic systems for regeneration requirements. The regeneration system includes pumps, metering equipment, dilution tanks and dilution control. Storage tanks are provided for the concentrated sulfuric acid and 50 percent sodium hydroxide each having a capacity of 5,000 gallons.

The effluent is discharged into a 600,000 gallon condensate storage tank and two 600,000 gallon demineralized water storage tanks.

3.10 RADIOACTIVE WASTE MANAGEMENT SYSTEMS

The radioactive waste management system is provided to remote radioactive contaminants from the plant systems waste prior to discharge into the environment or shipment to a site for permanent disposal.

A description of the systems is provided in the following system Design Description:

- o Radioactive Liquid Waste System
- o Radioactive Gas Waste System

3.10.1 RADIOACTIVE LIQUID WASTE SYSTEM

3.10.1.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The Radioactive Liquid Waste System shall provide the capability to collect, hold, and process the potentially radioactive liquid effluent from various NSS and BOP systems. After processing, the radioactive liquid waste systems shall have the capability of holding, recycling, or discharging the purified waste.

Design Requirements

The radioactive liquid waste system shall have the capability of holding and processing the NSS component effluent. The radioactive liquid waste system shall have the capability of accepting liquid effluent from the helium purification system at 780 psia and 515^{o}F.

This system shall provide drains and sump collection of all potentially radioactive liquid effluent throughout buildings and areas which contain primary plant and auxiliary systems.

The radioactive liquid waste system shall also provide the capability of solidifying high activity and high conductivity liquids for shipment off site.

The radioactive liquid waste system is not essential to the safe shutdown of the reactor nor would its failure result in site boundary doses in excess of 0.5 Rem. The RLW system is therefore classified as non-nuclear safety and non-seismic Category I. RLW components shall be built in accordance with applicable ANSI, ASME Section VIII requirements and manufacturer's standards otherwise applicable.

The radioactive liquid waste system shall provide for the collection and processing of liquid effluent originating in the following systems as described below:

a) Helium purification cooler and regeneration cooler drains.

b) Primary coolant system steam generator drains (and steam/water dump tank drains, if applicable) following tube failure.

c) Decontamination system drains.

d) Radioactive Gas Waste vacuum drain tank effluent.

e) Radioactive laundry and safety shower drains.

f) Equipment and floor drains in potentially radioactive systems and plant areas (through these drains, interfaces exist with all other reactor plant and auxiliary systems).

3.10.1.2 SYSTEM DESCRIPTIONS

The Radioactive Liquid Waste (RLW) system consists of processing equipment tanks, pumps, piping and valves. The RLW system utilizes filtration, demineralization, reverse osmosis, and solidification, as necessary, to collect, hold, and process the radioactive liquid effluent. Normally, after processing, the water is recycled for inplant use; however, the RLW system has the capability to discharge to the cooling tower blowdown if water quality or plant water balance so dictate.

Floor and equipment drains are collected in the sumps of the various buildings. A high sump level automatically initiates transfer of the contents to the on line waste collector tank. A waste collector tank, when full, is recirculated and sampled and then released for processing at a maximum rate of 50 GPM.

The radioactive liquid waste is treated first by a 5 micron absolute filter. The filter unit consists of two parallel filters, each capable of passing a 25 GPM flow rate. The filters are backwashed periodically to the slurry collection tank. The slurry collection tank contents are periodically decanted and the decant is also reprocessed through the filter.

The filter discharge is returned to the collection tank of origin with a 10 GPM side stream being diverted to the reverse osmosis unit for processing to reduce the conductivity below 50 micromhos. The side stream is monitored, and, if conductivity is less than 50 micromhos, diverted quickly to the permeate storage tanks. When bypassing the R.O. unit, the side stream flow may be increased to limit unnecessary recirculation to the waste collector tank. Effluent from the R.O. unit is collected in the permeate tanks, except for the brine stream which is sent to the brine cut tank for reprocessing through the filter and R.O. unit until sufficiently concentrated at which time it is solidified for off site shipment.

When the permeate tank is filled, the alternate permeate tank is connected and the contents are recirculated and sampled. If the conductivity is below 0.5 micromhos and the activity is below 2 mr/hr the contents are transferred to the holdup tanks for reuse. If not, the contents are demineralized in the mixed bed demineralizers and its effluent stored in the holdup tanks. The demineralizers are capable of being charged with a variety of non-regenerable resins to reduce conductivity to less than 0.5 micromhos. Spent demineralizer resins are processed via the slurry collection tank to the shipping cask.

Specific components such as the helium purification oxidizer coolers and regeneration module and the radioactive gas waste system vacuum drain tank drain directly to the high activity waste collection tank.

Effluent from the slurry collection, brine cut, and high activity waste collector tanks are injected into a shipping cask and dewatered. A catalyst and solidification agent are added to effect solidification for shipment off site.

Prior to processing tank contents are piped to a remote sampling subsystem which is provided to allow sampling of all tank contents before treatment or release. Water chemistry is a manually controlled process utilizing stand pipes on pump discharges.

3.10.2 RADIOACTIVE GAS WASTE SYSTEM

3.10.2.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The radioactive gas waste (RGW) system shall collect all NSS and BOP system waste gases that are radioactive or potentially radioactive.

Design Requirements

The RGW system shall provide temporary storage pending acceptable radiation decay and disperse the gas at a controlled rate into the plant ventilation system to maintain normal operational releases within the intent of 10 CFR 50 Appendix I limits.

The RGW system shall have the capability of compressing and transferring those gases requiring further processing to the Helium Purification System.

The RGW system shall be Safety Class 3 and seismic Category I and shall be designed in accordance with ASME Section III Class 3.

3.10.2.2 SYSTEM DESCRIPTION

The RGW system consists of NSSS modules containing a vacuum tank, drain tank, compressors and storage tanks. Potentially radioactive effluent gases are collected in the high level collection header and sent to the RGW vacuum tank which is maintained at sub-atmospheric pressure by the RGW compressors. Any liquid waste present in the vacuum tank is collected in a drain tank and drained to the radioactive liquid waste system for processing.

The compressors discharge to the process module where the flow is either returned to helium purification for further processing or to any of four RGW surge tanks. The surge tank contents are analyzed for activity level and then either transferred to the Reactor Service and Fuel Handling Building vent via the low level subsystem, diverted to the helium purification system for further processing or stored in the surge tanks until the activity level decays to a level compatible with release requirements. Normally only one RGW surge tank is aligned to receive effluent and one other RGW surge tank is aligned to vent stored effluent; the others are isolated, and will be selectively valved on line as required.

The low level collection header feeds into the process module which provides a means for the direct disposal of gases normally expected to be non-radioactive. Upon the detection of unacceptable activity levels the process module has the capability to divert the low level collection header flow to the high level RGW stream for additional monitoring, holdup, and processing, if required.

3.11 PROCESS GAS CHEMICAL SYSTEM

3.11.1 FUNCTIONS AND DESIGN REQUIREMENTS

Functions

The functions of the Process Gas Chemical System is to reform a gas-steam mixture, process the gas, compress and deliver to various users who process the gas and extract its heat, recompress and dry the gas, and return it for continuous recycling. This process constitutes a chemical heat pipe system for delivering energy to distant users from the Pebble Bed Reactor nuclear power plant.

Design Requirements

The process gas chemical system is designed to supply a total of 1,080,000 pounds per hour of gas to a pipeline for use at distances up to 100 miles from the plant site. Nominal composition of the gas is:

Component	% Volume	% Volume*
CO	23.1	7.4
CO_2	3.0	12.4
H_2	69.6	71.7
N_2	3.3	0
O_2	0.5	0
CH_4	0.5	8.5
	100.0	100.0

The gas will be returned after methanization from the point of use via a return pipeline. This gas will be mixed with steam resulting in the following composition:

*Data from duplex steam reformer test in Germany (not used in this study).

Component	Lb/Hr	Mol/Hr	Partial Pressure, psia
CH_4	540,000	33,750	159
H_2O	2,160,000	120,000	566
	2,700,000	153,750	725

Steam-methane mixture will be fed to six steam-methane reformers in the PCRV. The reformed gas will flow to water-cooled condensers, water separators, and to glycol dehydration units to remove trace moisture to a minimum. After the dehydration the gas is recompressed and sent into the pipeline.

The process gas chemical system is a non-seismic Category I system. Those portions of the piping systems that pass into the reactor containment are Safety Class 2 from the reformer to and including the isolation valves in the penetrations building.

3.11.2 DESIGN DESCRIPTION

The Process Gas Chemical System consists of the following major components:

- Steam-methane pipe mixers
- Steam-methane reformers
- Recuperators
- Condensers
- Condensate separators
- Dehydrators
- Centrifugal compressors
- Cooling water system

Outside of the plant-site boundary, the following major components are required:

- Supply pipeline
- Return pipeline
- Dehydrators
- May also require centrifugal compressors to return the gas to the plant

Steam Methane Pipe Mixers

These mixers are an in-line component where steam is introduced to mix with methane being returned from the users plant. The six units are each sized to handle a flow of 90,000 lb/hr of methane and 360,000 lb/hr of steam at a mixture condition of 725 psia @ 618^{o}F.

Steam-Methane Reformer

Six steam-methane reformers are located in the PCRV. These units contain a replaceable catalyst and are heated with helium from the reactor core at a temperature of 1740^{o}F with a 270^{o}F temperature drop in passing through the component. The gas mixture leaving the reformer contains 180,000 lb/hr of gas and 270,000 lb/hr of water at 566 psia and 967^{o}F.

Recuperator

Six recuperators are located in the PCRV steam-reformer cavity. These units heat the incoming process gas stream and cool the leaving process gas after reforming. The gas enters the recuperator at 625^{o}F, enters the reformer at 931^{o}F, leaves the reformer at 1255^{o}F and exits from the recuperator at 967^{o}F.

Condensers

Six water cooled condensers are furnished to condense the water and cool reformed gas stream. The gas and condensate then flows through a moisture separator where the condensate is removed from the gas stream. The gas mixture entering the condenser is the same as that leaving the reformer. Exit conditions from the condenser are 300 psia @ 120^oF.

Heat duty in the condenser is 484.6×10^6 Btu/hr per loop. Each condenser requires 21,550 gallons per minute of cooling water entering at 90^oF and leaving at 135^oF per condenser.

Condensate Separator

The condensate separator removes 268,370 lbs/hr of condensate from the gas stream for each of the six loops.

Dehydrators

Each loop is supplied with a glycol dehydrator unit to essentially remove all water from the process gas stream. It is essential that the gas is dried to prevent moisture from condensing in the pipeline and causing corrosive liquids from forming and accumulating.

The glycol dehydrator consists of an absorber tower, still column and glycol reboiler unit, glycol-glycol heat exchanger, filter, and a glycol recirculating pump.

Approximately 1630 lb/hr of moisture is removed from the gas stream in the dehydrator.

Centrifugal Compressors

Six centrifugal compressors are furnished, one per loop and were initially selected on the basis of performing a lifetime cost of pipeline size, pressure drop, and cost of power.

The discharge lines from the compressors are manifolded into one pipe for the supply line to the user. For the basis of compressor selection a pipeline 100 miles long was selected with 400 psi at point of use and a 90 psi pressure drop in the pipe line which resulted in:

Pipeline:	48" diameter, 15/16" wall thickness, 565 psig design.
Compressor:	Two-stage centrifugal compressor with 5000 HP electric motor drive having a capacity of 111,000 scfm each at 330 psia, 120°F inlet conditions and 490 psia discharge pressure.

Cooling Water System

The cooling water system for the process gas chemical system furnishes water for the condensers and other components of the system. Components furnished with the system includes.

1 - Circular mechanical draft, concrete shell, 300 ft diameter cooling tower having a rating of 130,000 gallons per minute, 74°F design wet bulb, 16°F design approach, 45°F design temperature rise.

5 - 25 percent pumps each having a capacity of 32,500 gallons per minute, 85 ft total head, furnished with 1000 HP motors.

Materials of Construction

Preliminary selection of materials of construction for the piping system required consideration of temperature, pressure, and the materials ability to contain hydrogen. The preliminary selection findings are:

Reformer to Condenser	2¼ Cr, 1 mo.
Condenser to Dehydrator	Carbon Steel
Dehydrator to Compressor	Carbon Steel
Compressor to Pipeline	Carbon Steel
Pipeline	Carbon Steel
Steam-Methane Mixer to Reformer	2¼ Cr, 1 mo.

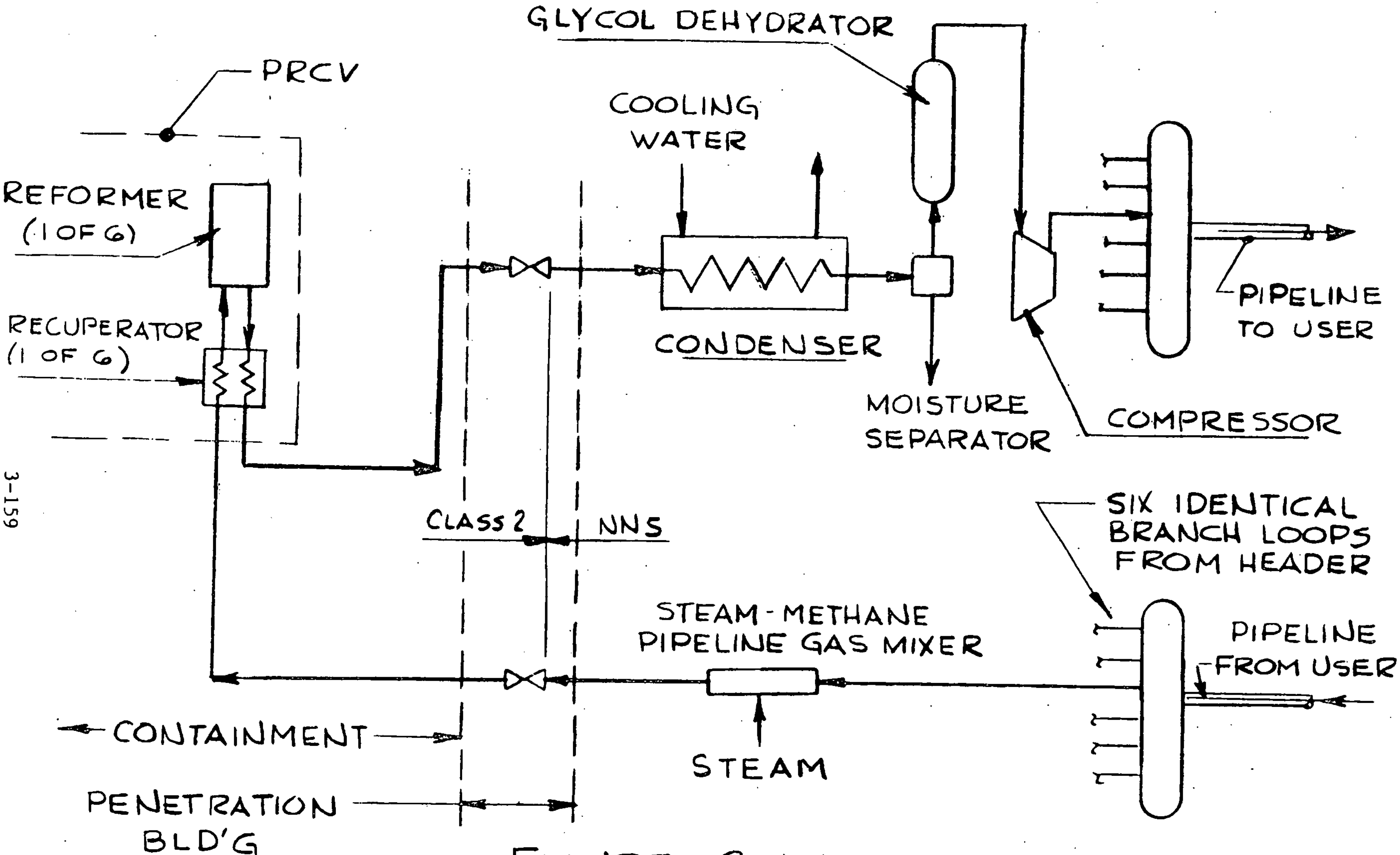


FIGURE - 3.11-1

PROCESS GAS CHEMICAL SYSTEM

4. DRAWINGS

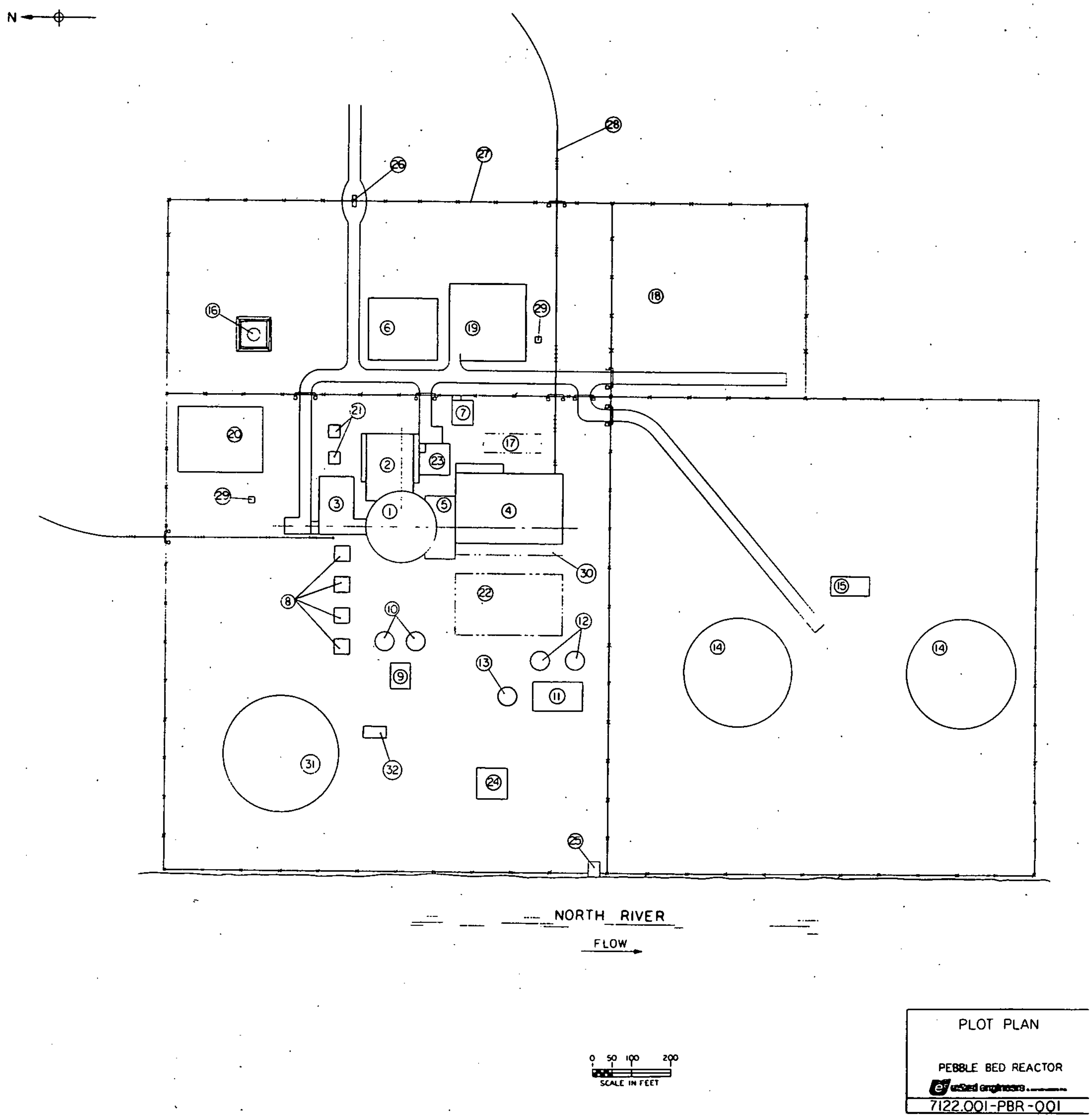
This Section contains the drawings for the 3000 MWt Gas Cooled Pebble Bed Reactor dual purpose plant described in other Sections of this report. The drawings include a CONCEPTUAL plot plan, general arrangement drawings for the major structures, and flow and block diagrams for balance-of-plant (BOP) systems.

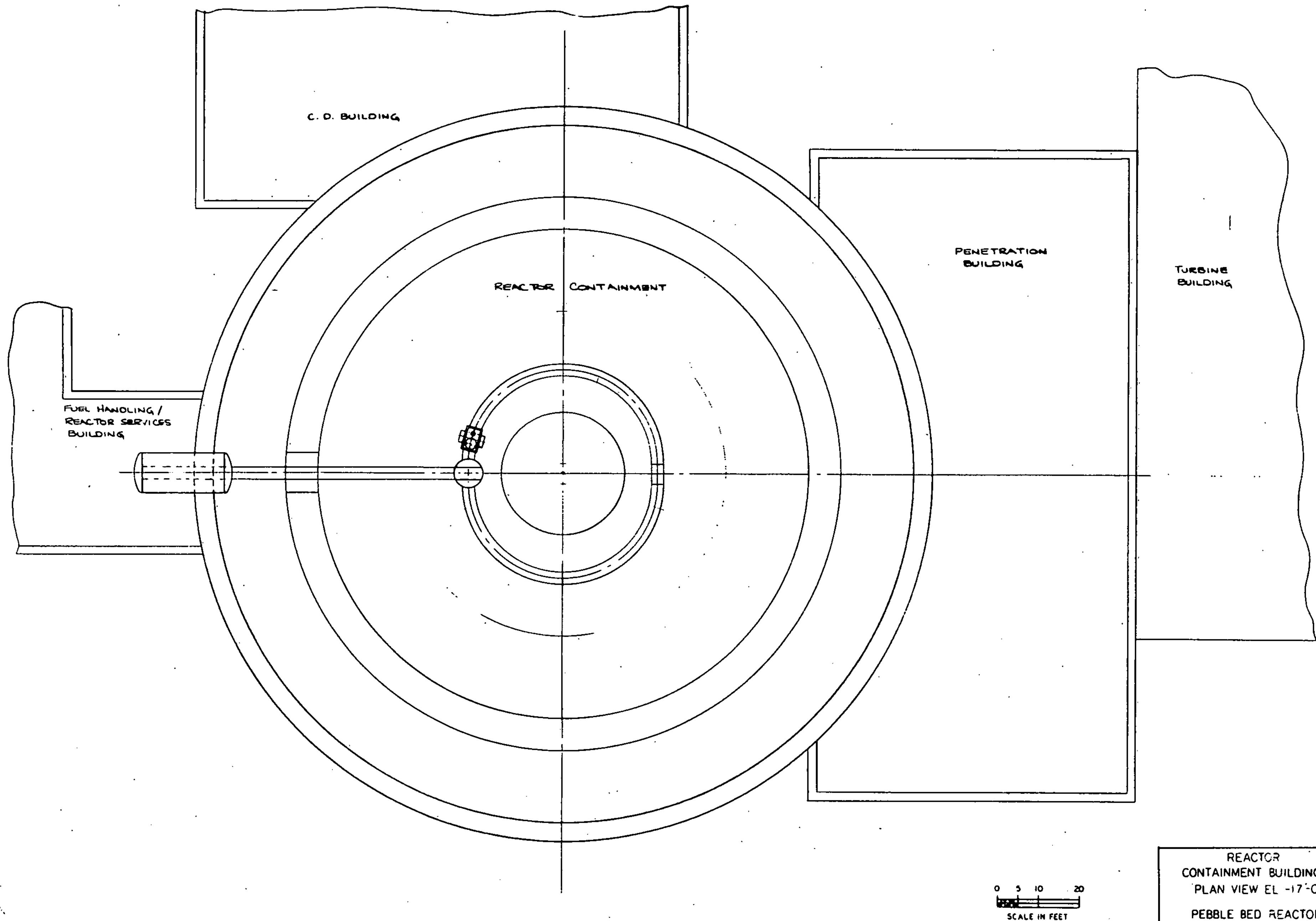
Drawing Number	Title
7122.001 - PBR - 001	Plot Plan
7122.001 - PBR - 002	Reactor Containment Building Plan View El (-) 17'-0"
7122.001 - PBR - 003	Reactor Containment Building Plan View El 134'-0"
7122.001 - PBR - 004	Reactor Containment Building Section A-A
7122.001 - PBR - 005	Fuel Handling/Reactor Services Plan View El (-) 17'-0"
7122.001 - PBR - 006	Fuel Handling/Reactor Services Plan View El 134'-0"
7122.001 - PBR - 007	General Arrangement C/D Building
7122.001 - PBR - 008	General Arrangement C/D Building Control Room Elevation
7122.001 - PBR - 009	General Arrangement C/D Building Section A-A
7122.001 - PBR - 010	General Arrangement Turbine Building Plan Operating Floor
7122.001 - PBR - 011	General Arrangement Turbine Building Plan Ground Floor
7122.001 - PBR - 012	Security Building General Arrangement
7122.001 - PBR - 013	Process Heat Plant Equipment Arrangement
7122.001 - PBR - 014	After Heat Removal System
7122.001 - PBR - 015	Auxiliary Circulator Heat Removal Service System

Drawing Number	Title
7122.001 - PBR - 016	Reactor Plant Cooling Water System
7122.001 - PBR - 017	Nuclear Service Water
7122.001 - PBR - 018	Main Steam System
7122.001 - PBR - 019	Feedwater Condensate System
7122.001 - PBR - 020	Demineralized Water Makeup and Distribution System
7122.001 - PBR - 021	Radioactive Liquid Waste System
7122.001 - PBR - 022	Prestressed Concrete Reactor Vessel Cooling System
7122.001 - PBR - 023	Heat Balance Diagram

LEGEND

1. REACTOR CONTAINMENT BUILDING
2. CONTROL/DIESEL BUILDING
3. FUEL HANDLING/REACTOR SERVICES BUILDING
4. TURBINE BUILDING
5. PENETRATION BUILDING
6. SERVICE/ADMINISTRATION BUILDING
7. SECURITY BUILDING
8. ULTIMATE HEAT SINK
9. FIRE WATER PUMP HOUSE
10. FIRE WATER STORAGE TANKS
11. MAKE-UP WATER PRETREATMENT BUILDING
12. DEMINERALIZED WATER STORAGE TANKS
13. CONDENSATE STORAGE TANK
14. MAIN COOLING TOWERS
15. CIRCULATING WATER PUMP HOUSE
16. FUEL OIL STORAGE TANK
17. TRANSFORMER AREA
18. SWITCHYARD
19. PARKING AREA
20. HELIUM STORAGE AREA
21. NUCLEAR SERVICE WATER COOLING TOWERS
22. CHEMICAL PROCESS AREA
23. ACCESS BUILDING
24. HOLDING POND
25. MAKE-UP WATER INTAKE STRUCTURE
26. GUARD HOUSE
27. SECURITY FENCE
28. RAILROAD
29. AIR INTAKE STRUCTURE
30. METHANE MIXING AREA
31. PROCESS WATER COOLING TOWER
32. PROCESS WATER PUMP HOUSE



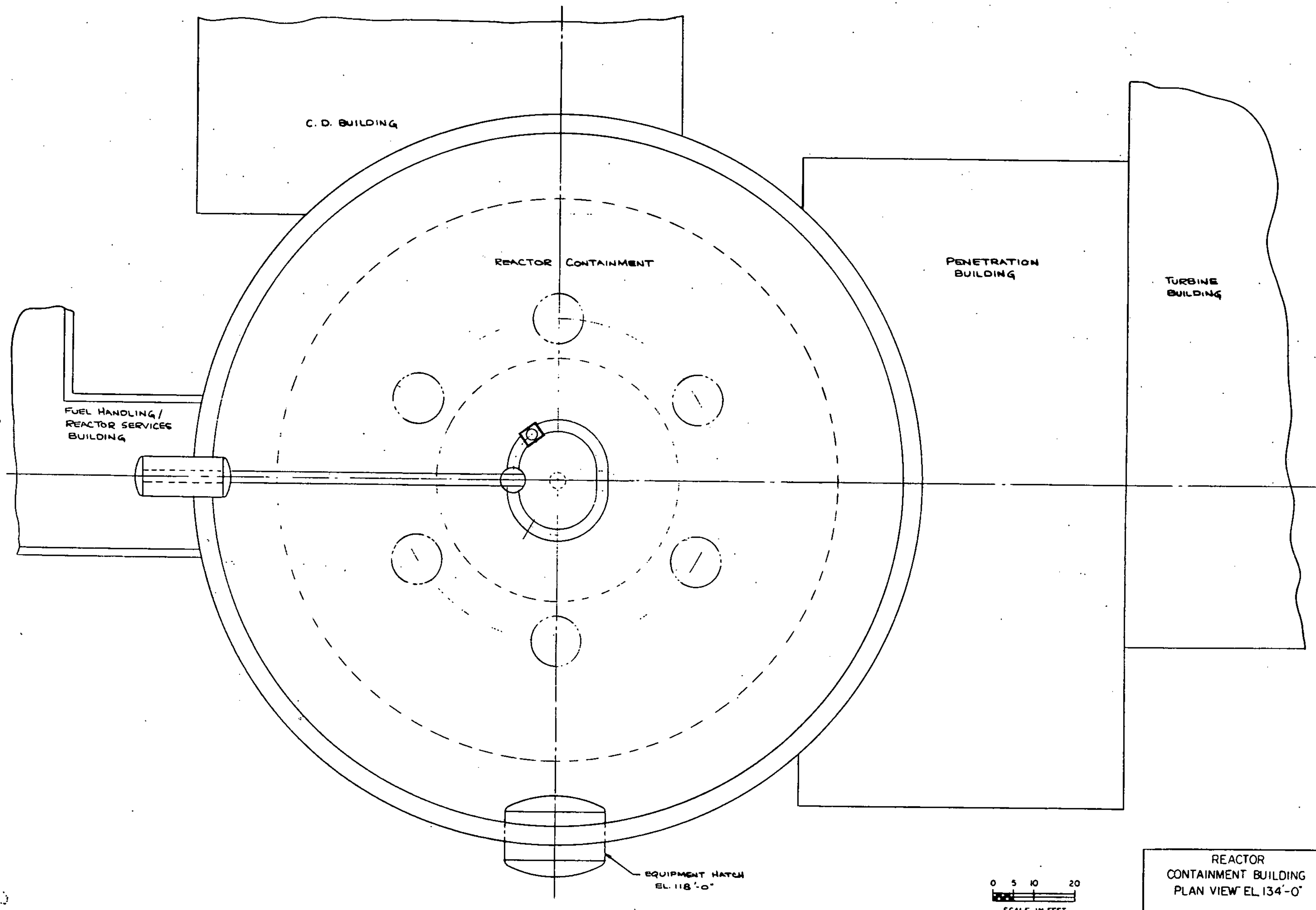


REACTOR
CONTAINMENT BUILDING
PLAN VIEW EL -17'-0"

PEBBLE BED REACTOR

united engineers

7122.001-PBR-002

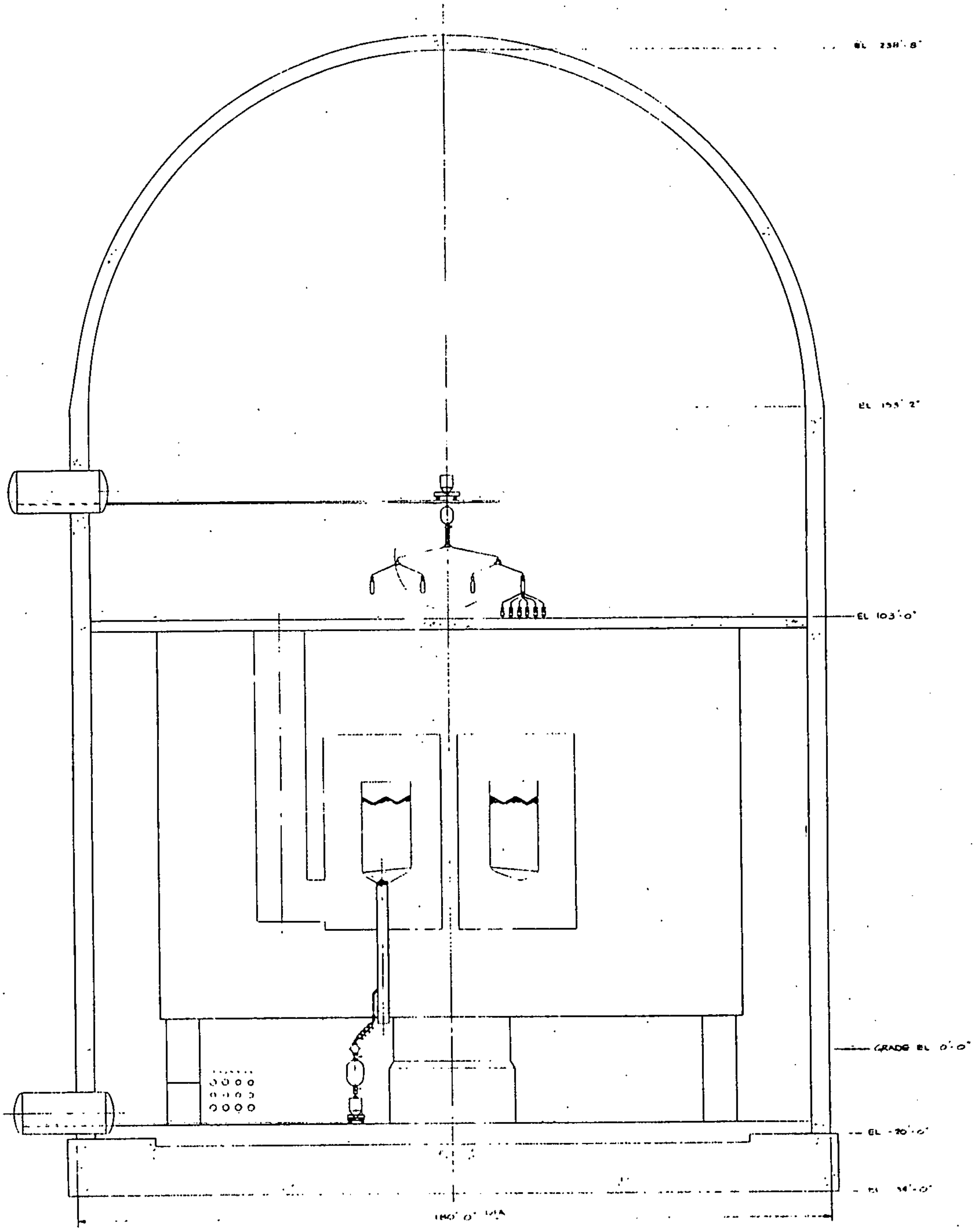


REACTOR CONTAINMENT BUILDING
PLAN VIEW EL. 134'-0"

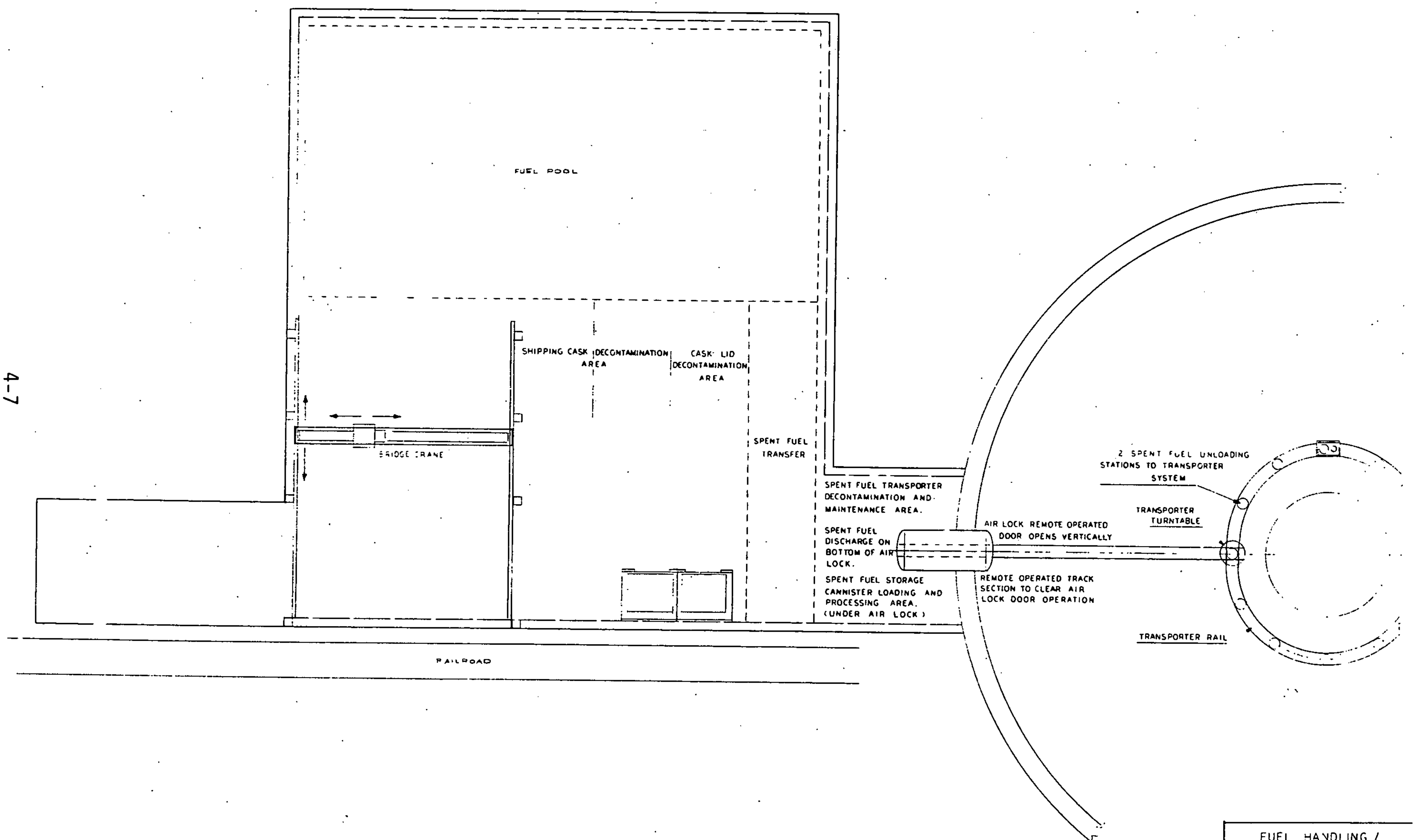
PEBBLE BED REACTOR

united engineers

7122.001-PBR-003



REACTOR
CONTAINMENT BUILDING
SECTION A-A
PEBBLE BED REACTOR
united engineers
7122.001-PBR-004

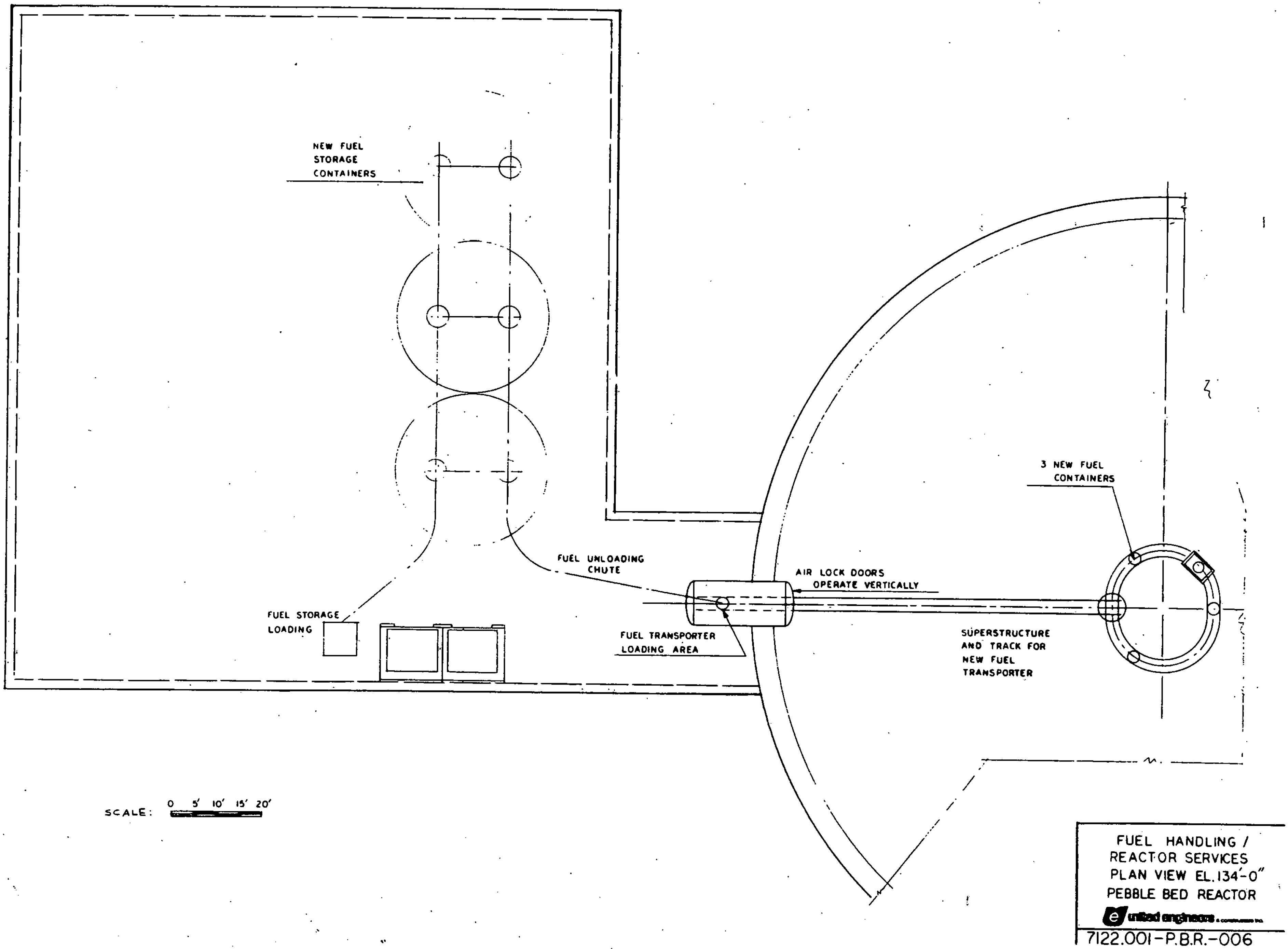


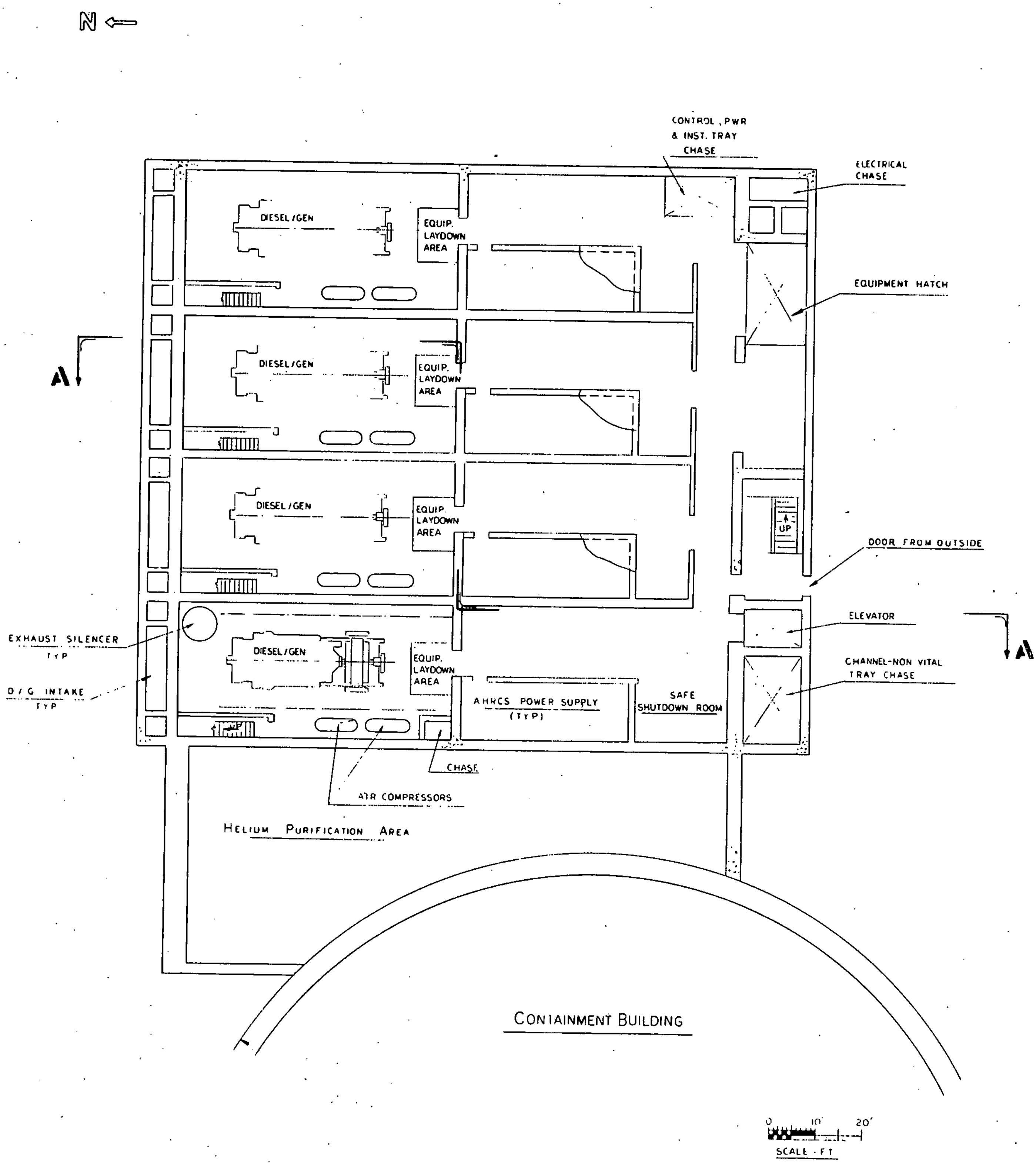
SCALE 0 5' 10' 15' 20'

FUEL HANDLING /
REACTOR SERVICES
PLAN VIEW EL. -17'-0"
PEBBLE BED REACTOR

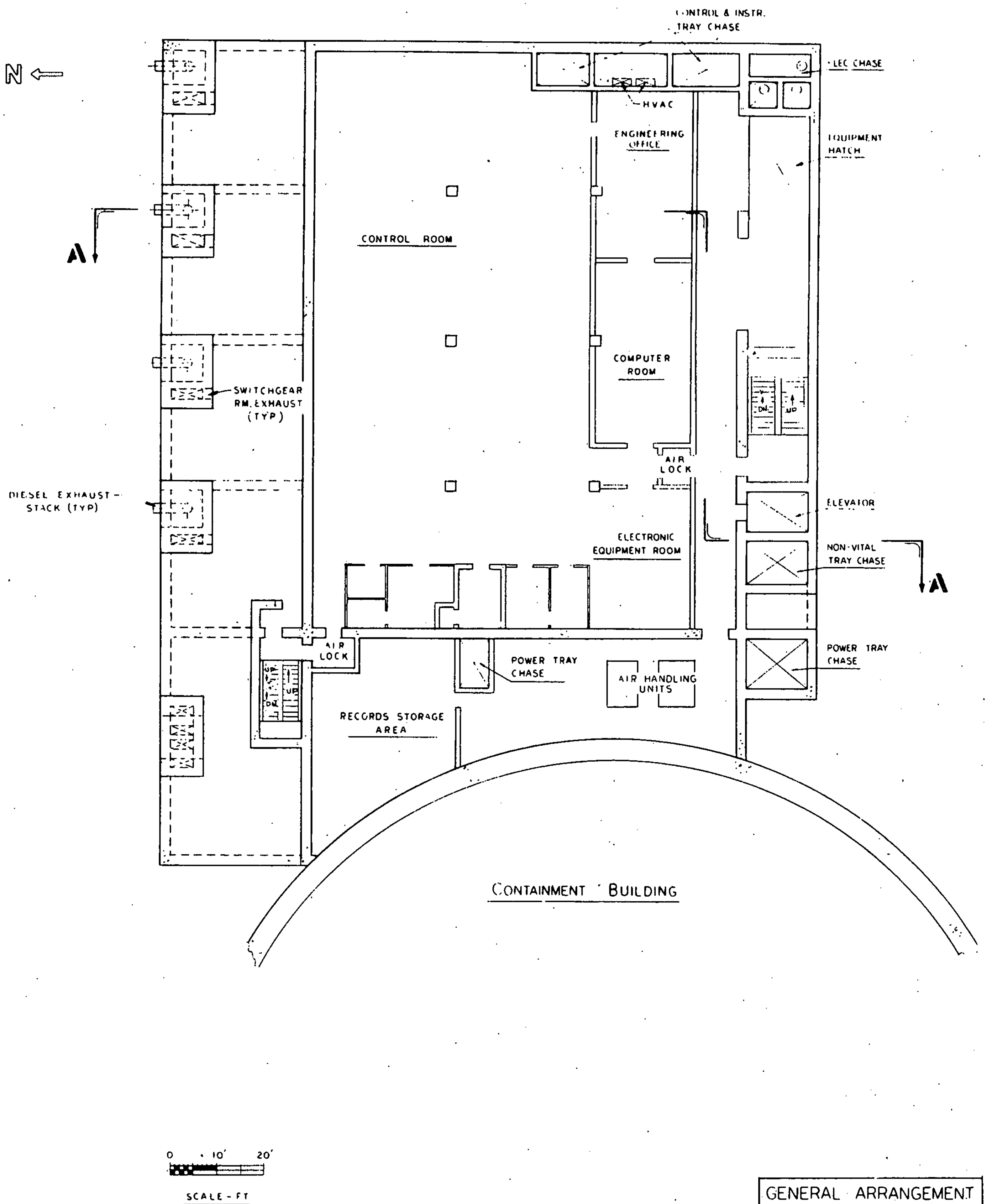
united engineers & constructors inc.

7122.001-P.B.R.-005

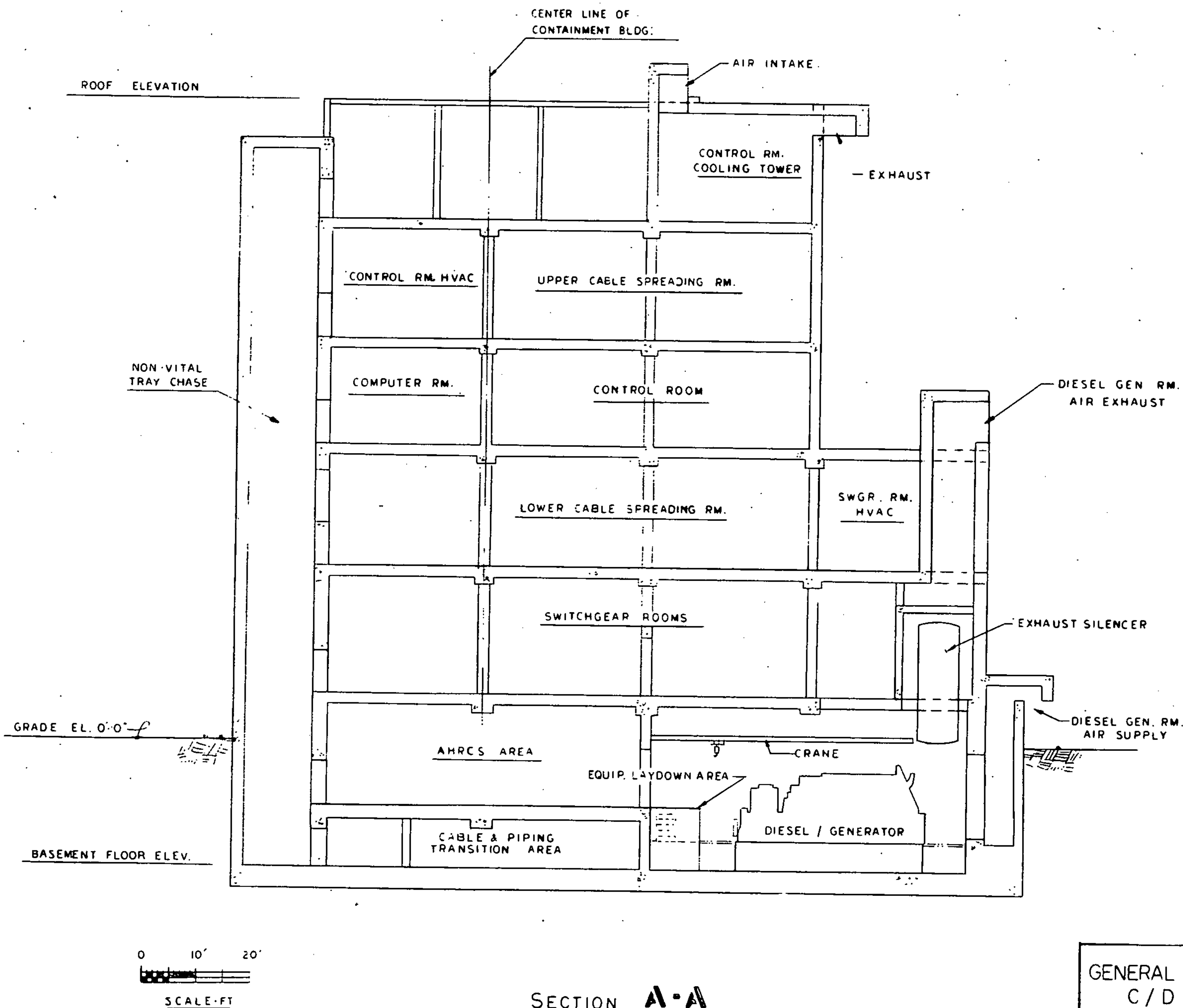

NEW FUEL STORAGE CONTAINERS
FUEL UNLOADING CHUTE
AIR LOCK DOORS OPERATE VERTICALLY
3 NEW FUEL CONTAINERS
FUEL STORAGE LOADING
FUEL TRANSPORTER LOADING AREA
SUPERSTRUCTURE AND TRACK FOR NEW FUEL TRANSPORTER
SCALE: 0 5' 10' 15' 20'
FUEL HANDLING / REACTOR SERVICES
PLAN VIEW EL. 134'-0"
PEBBLE BED REACTOR
united engineers
7122.001-P.B.R.-006



GENERAL ARRANGEMENT
C / D BUILDING
BASEMENT ELEVATION
PEBBLE BED REACTOR
united engineers & constructors inc.
7122.001-PBR-007



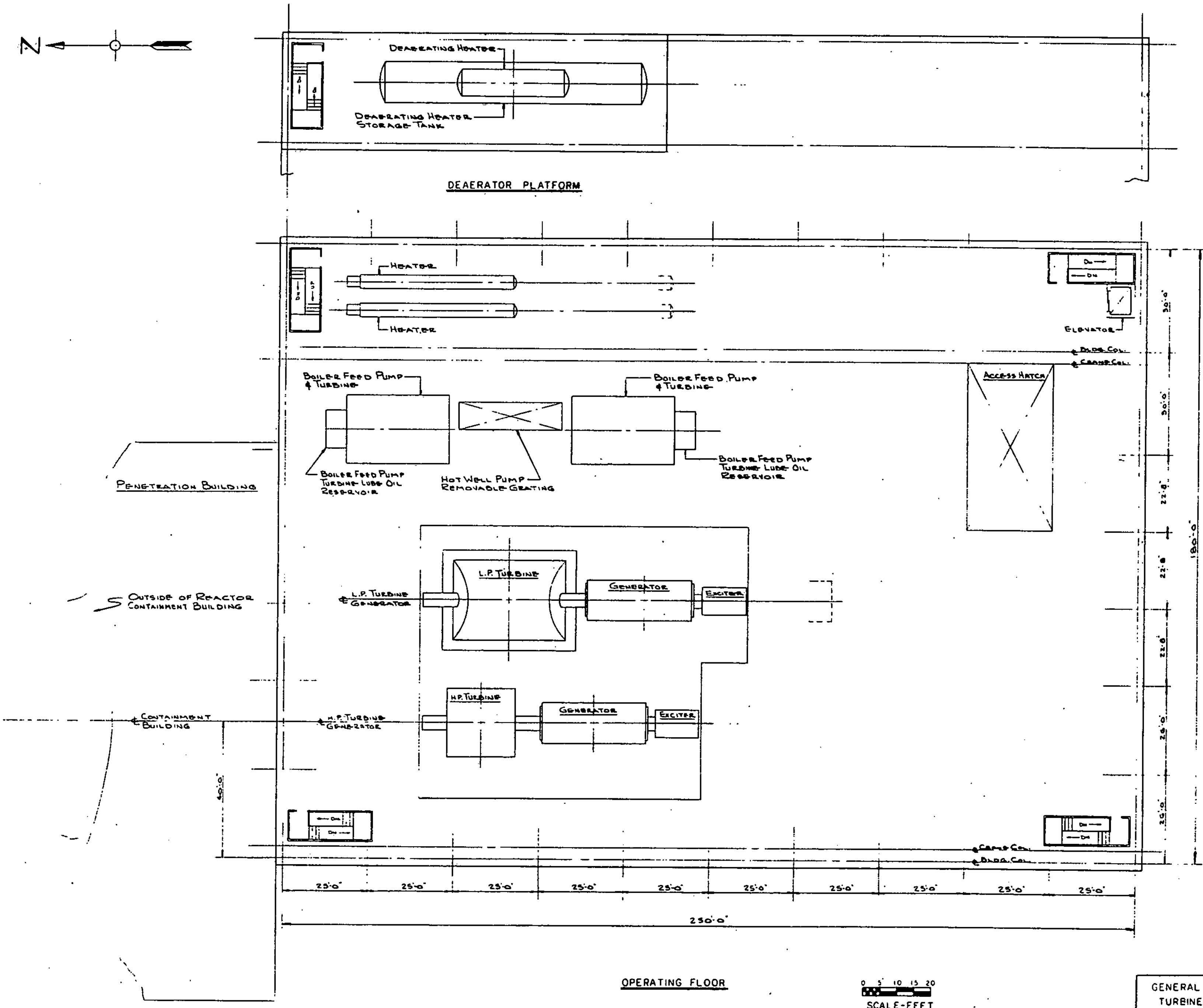
GENERAL ARRANGEMENT
C/D BUILDING
CONTROL ROOM ELEV.
PEBBLE BED REACTOR
united engineers & constructors inc.
7122.001-PBR-008



SECTION A-A

GENERAL ARRANGEMENT
C / D BUILDING
SECTION A A
PEBBLE BED REACTOR
united engineers & constructors inc.
7712.001 - PBR - 009

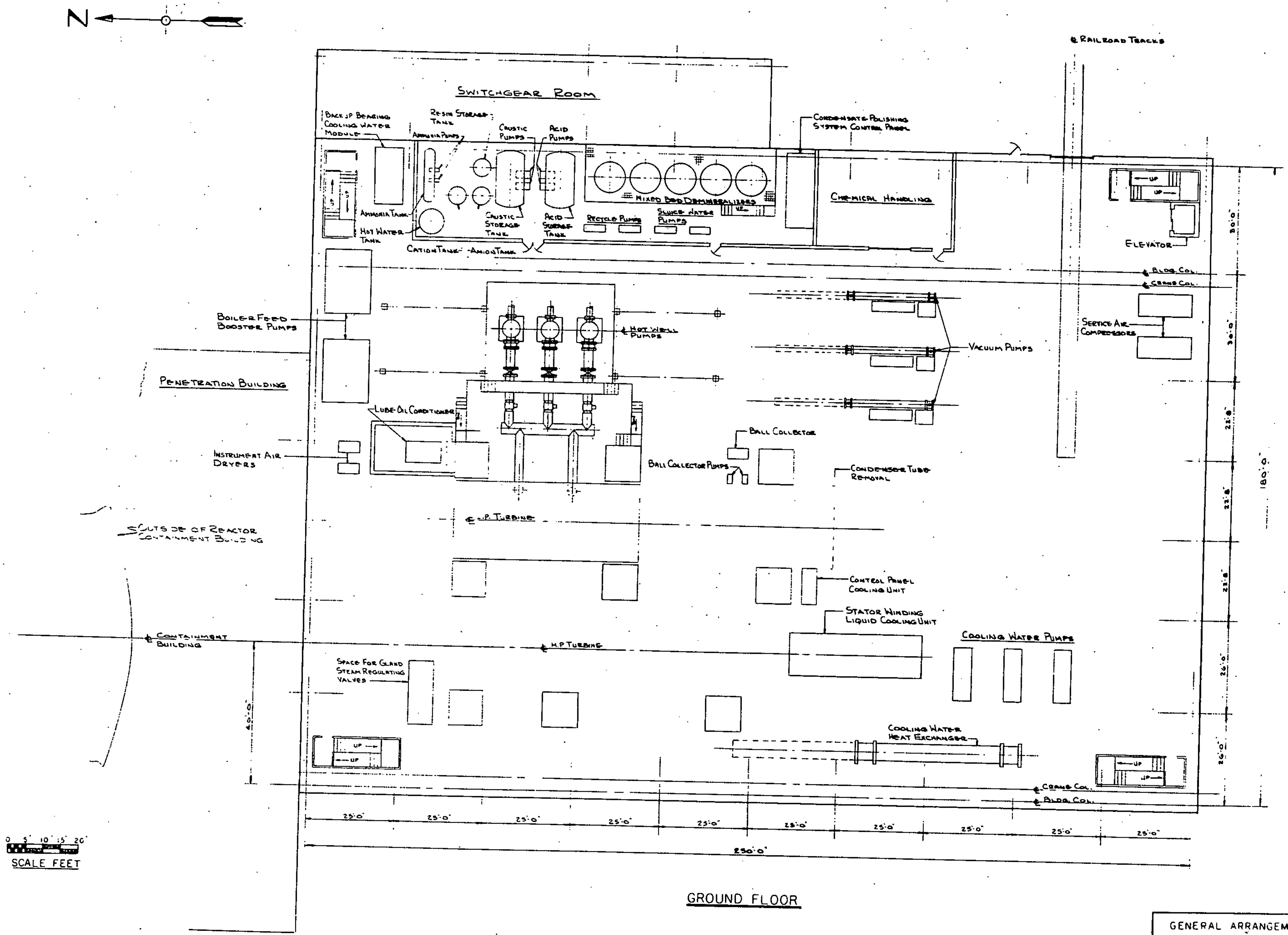
4-12



GENERAL ARRANGEMENT
TURBINE BUILDING
PLAN OPERATING FLOOR
PEBBLE BED REACTOR

united engineers

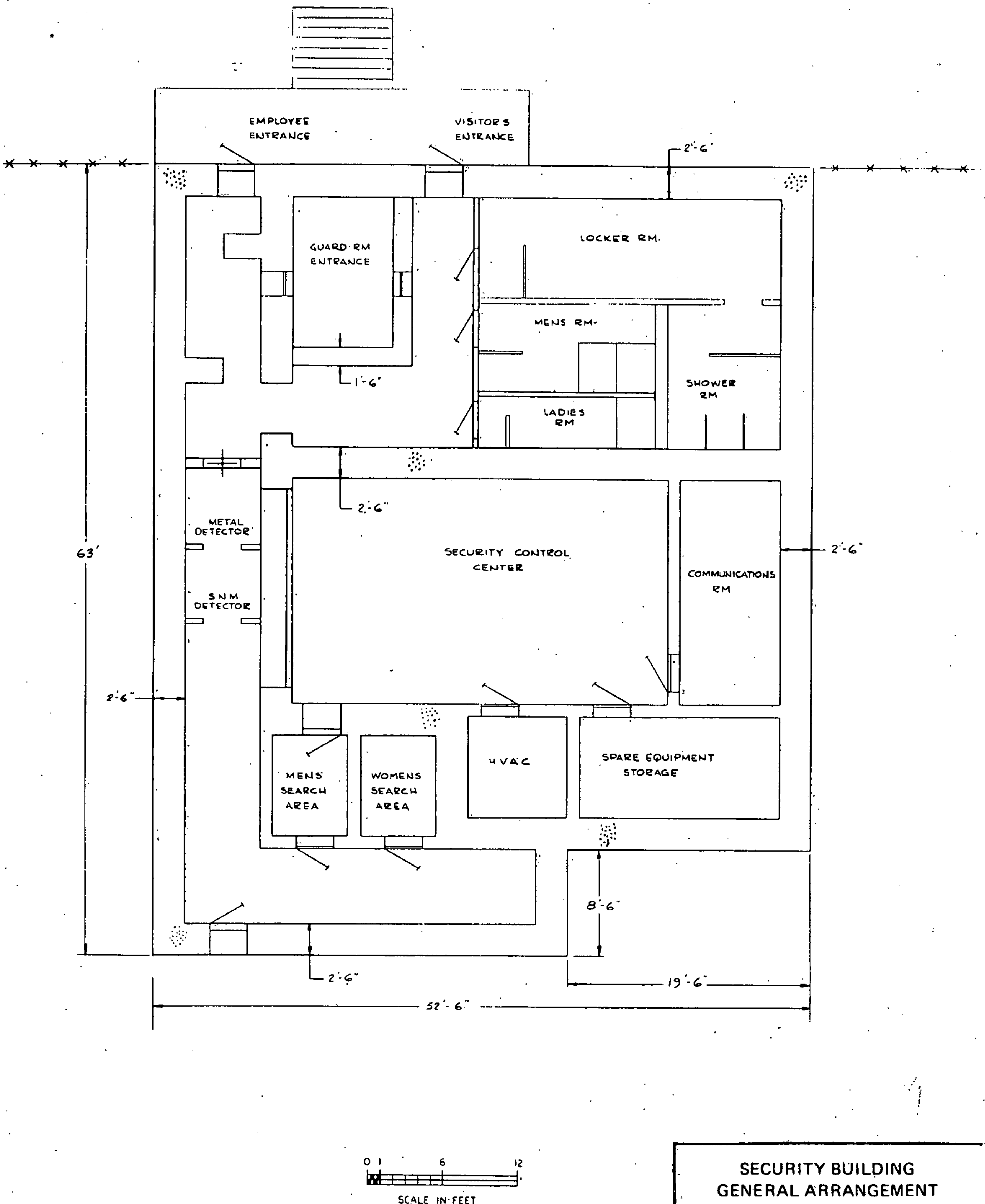
7122001-PBR-010



GROUND FLOOR

GENERAL ARRANGEMENT
TURBINE BUILDING
PLAN GROUND FLOOR
PEBBLE BED REACTOR

7122.001-PBR-011



SECURITY BUILDING
GENERAL ARRANGEMENT

PEBBLE BED REACTOR

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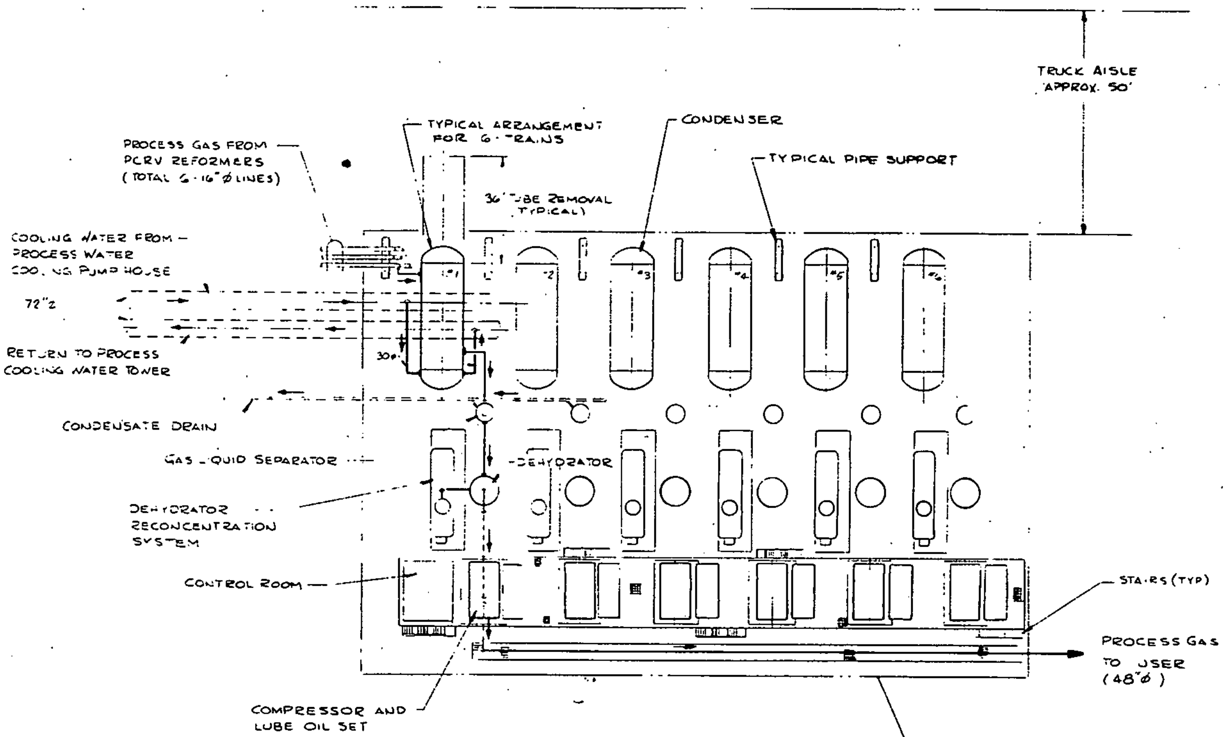
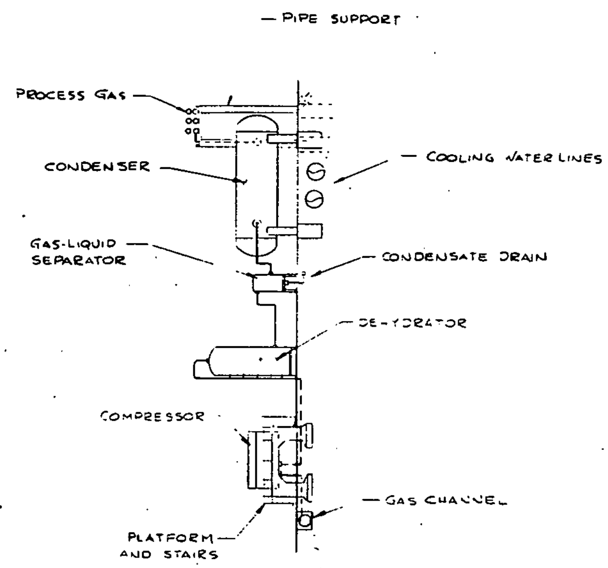
7122.001 - PBR - 012



PLOT PLAN



SIDE ELEVATION

0 20' 40'

SCALE: FT

PROCESS HEAT PLANT
EQUIPMENT ARRANGEMENT

PEBBLE BED REACTOR

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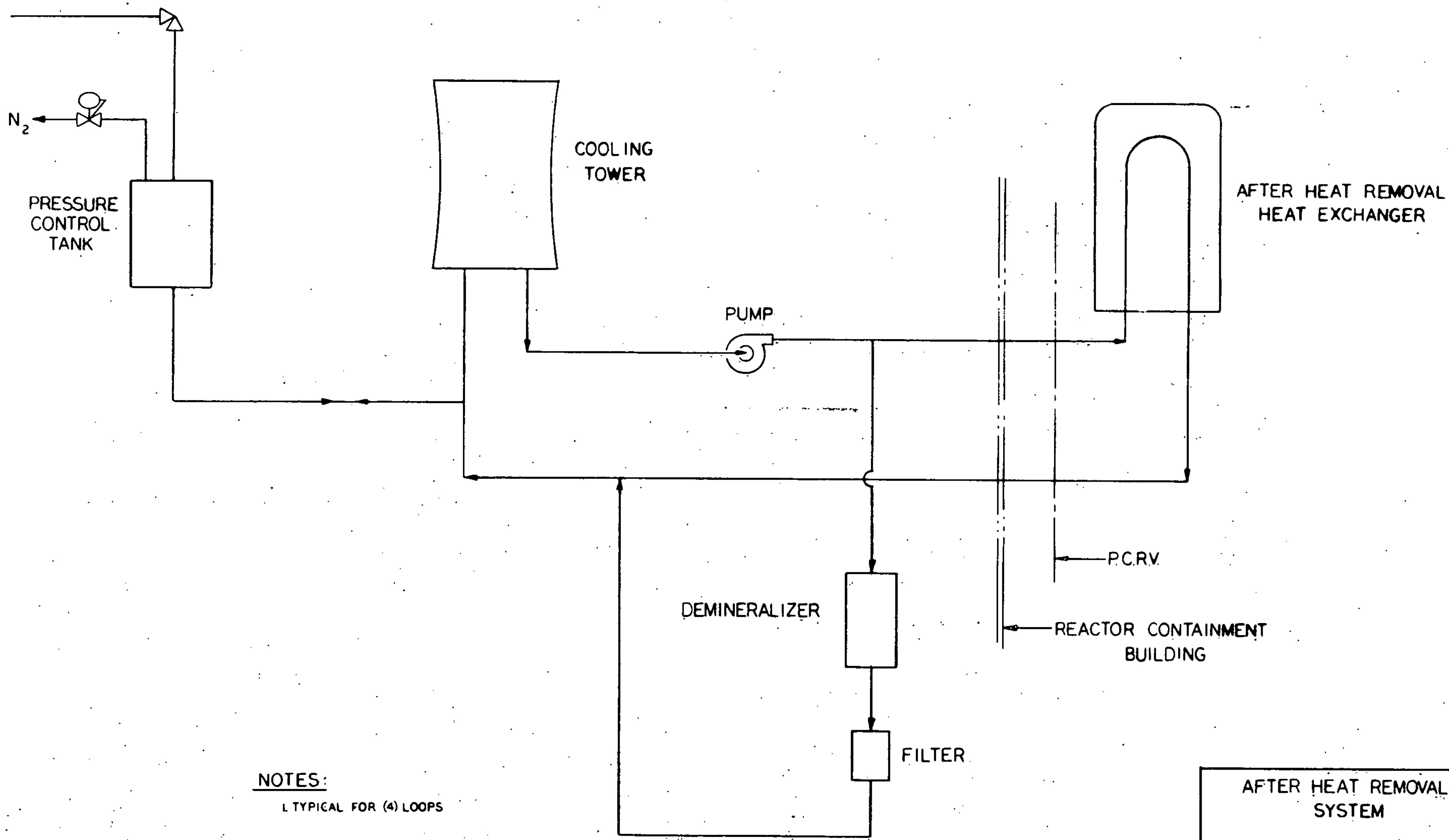
7122.001-PBR-013



NOTES:

1. TYPICAL FOR (4) LOOPS

AFTER HEAT REMOVAL SYSTEM

PEBBLE BED REACTOR

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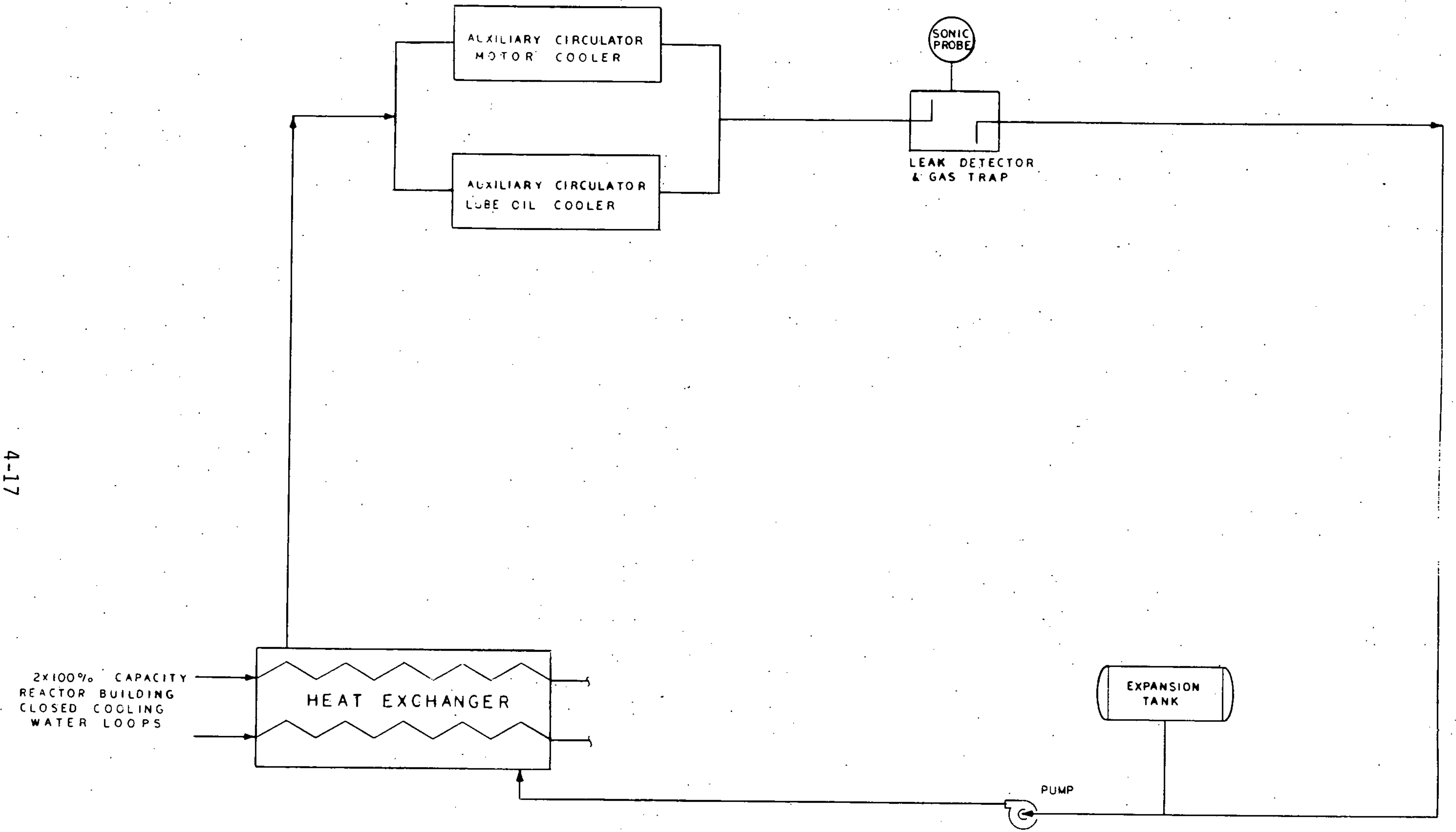
7122.001-PBR- 014

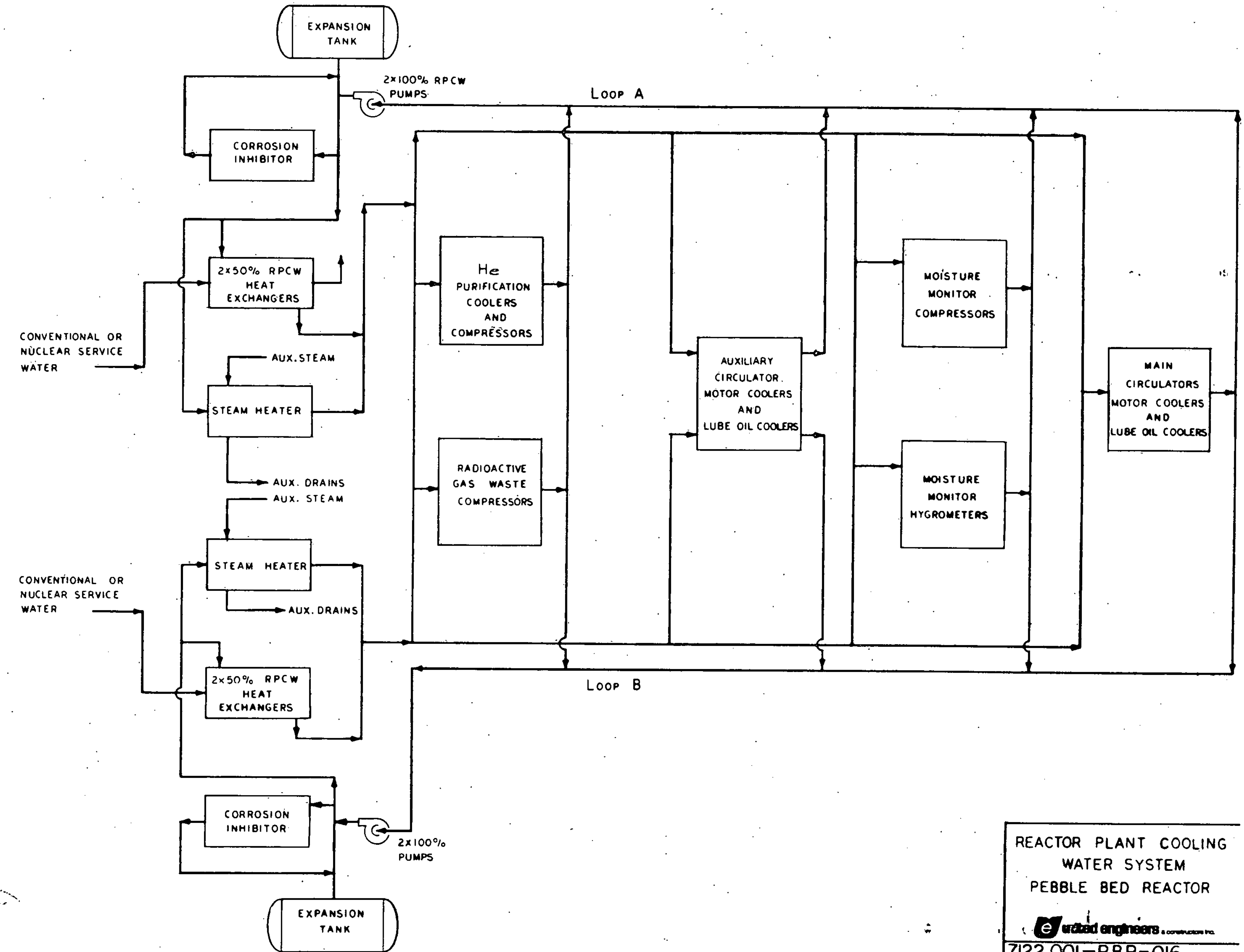


AUXILIARY CIRCULATOR HEAT REMOVAL SERVICE SYSTEM

PEBBLE BED REACTOR

united engineers & constructors inc.

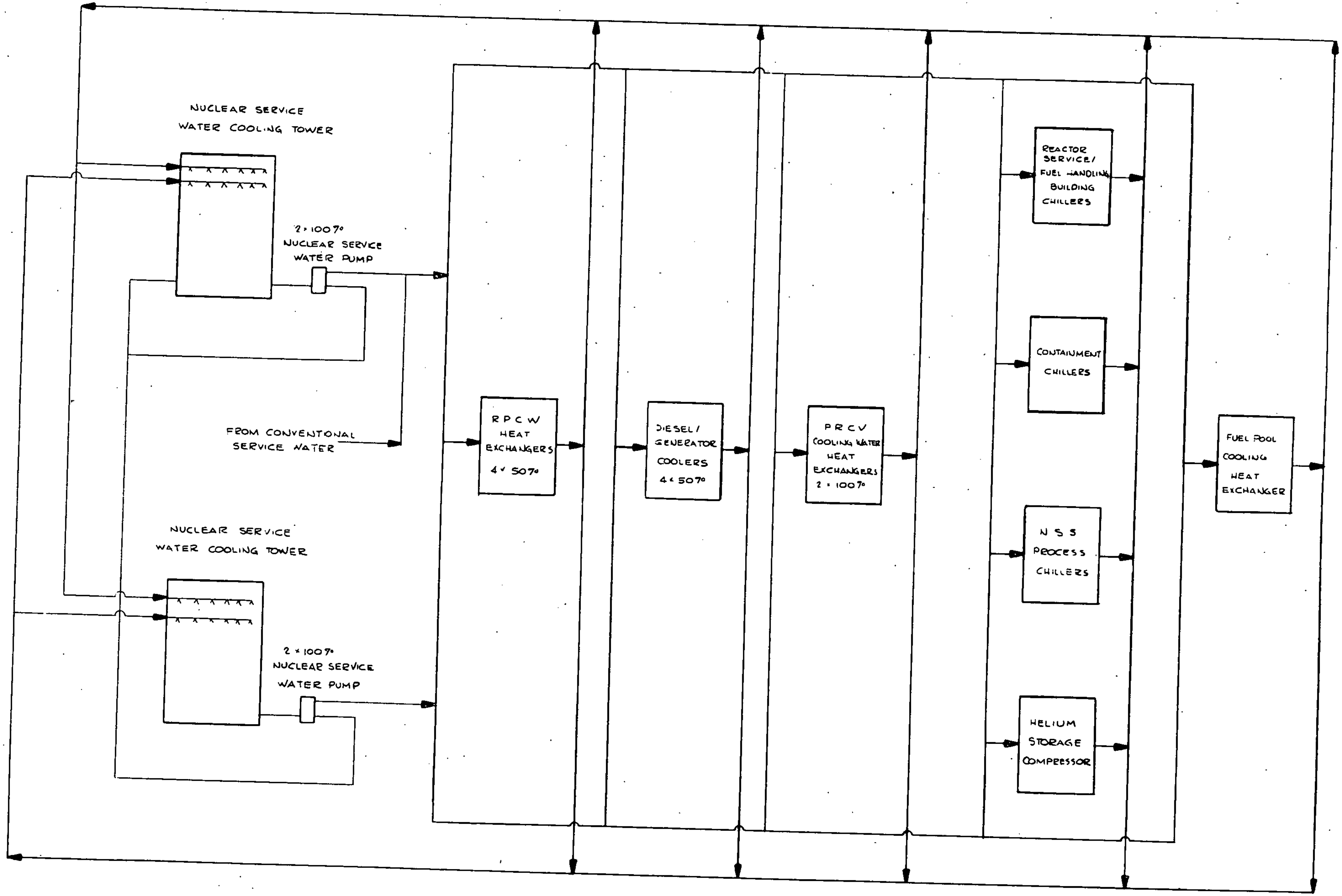
7122.001-PBR-015



REACTOR PLANT COOLING WATER SYSTEM
PEBBLE BED REACTOR

United Engineers & Constructors Inc.

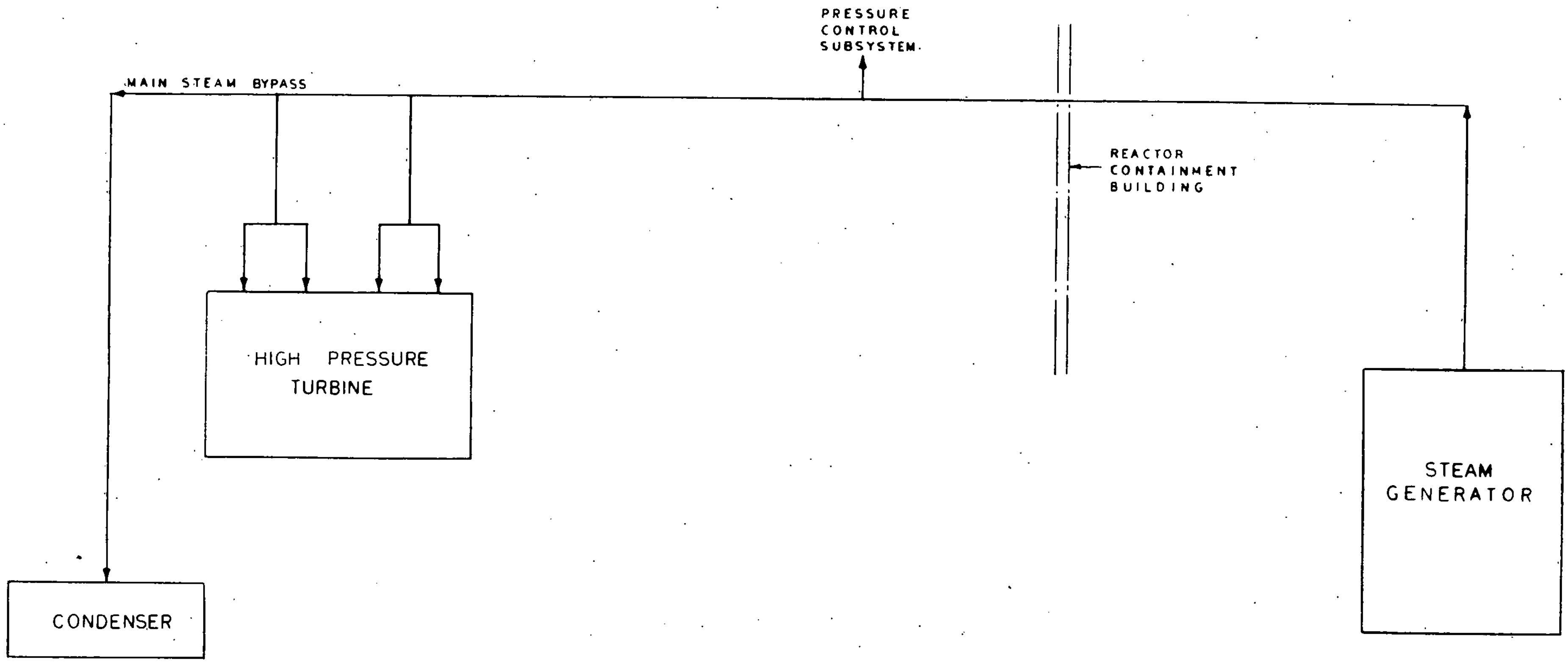
7122.001-PBR-016



NUCLEAR SERVICE
WATER SYSTEM
PEBBLE BED REACTOR

united engineers & constructors inc

7122.001-PBR-017

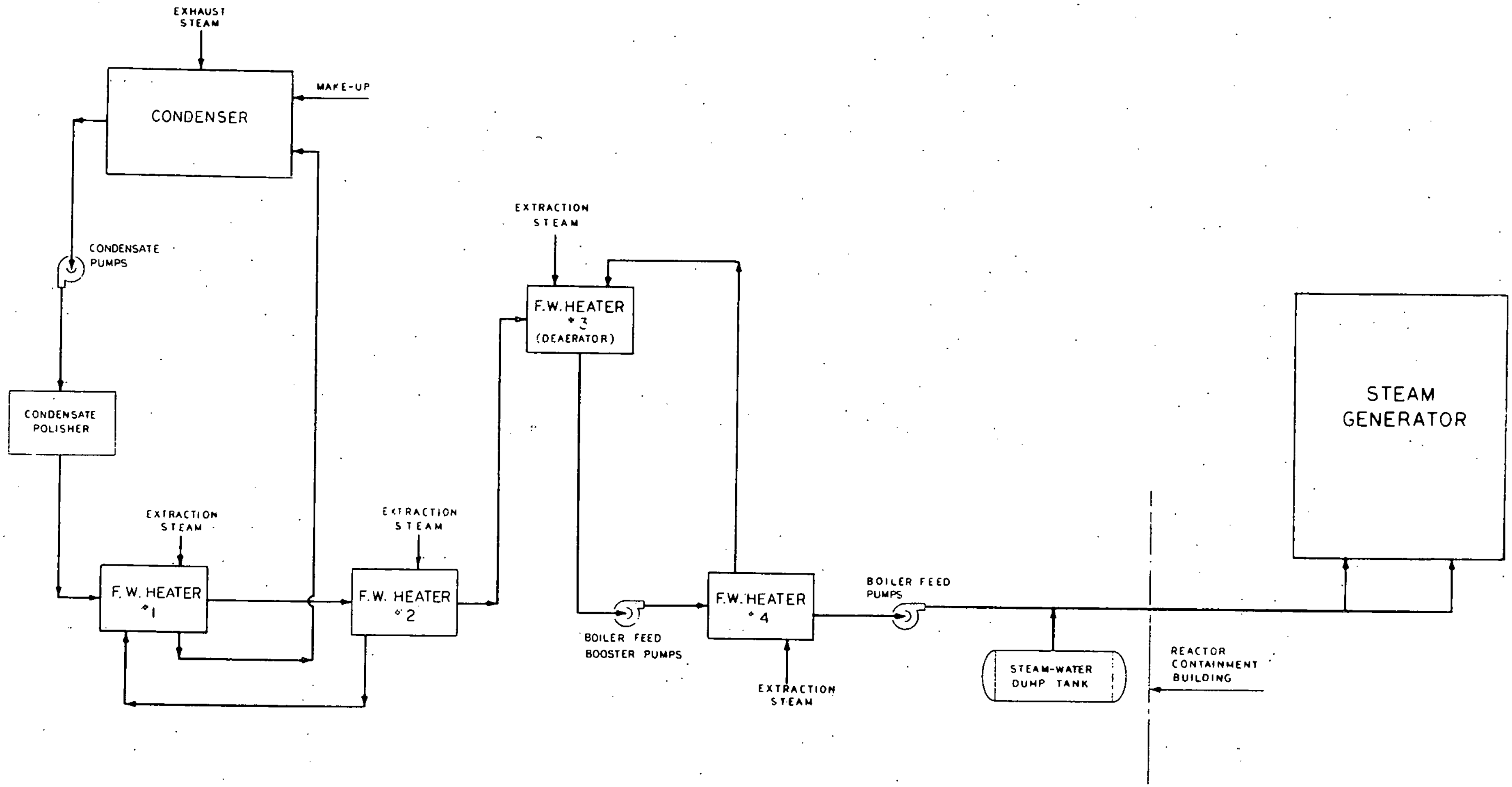


MAIN STEAM SYSTEM

PEBBLE BED REACTOR

united engineers & constructors inc.

7122.001 - PBR - 018

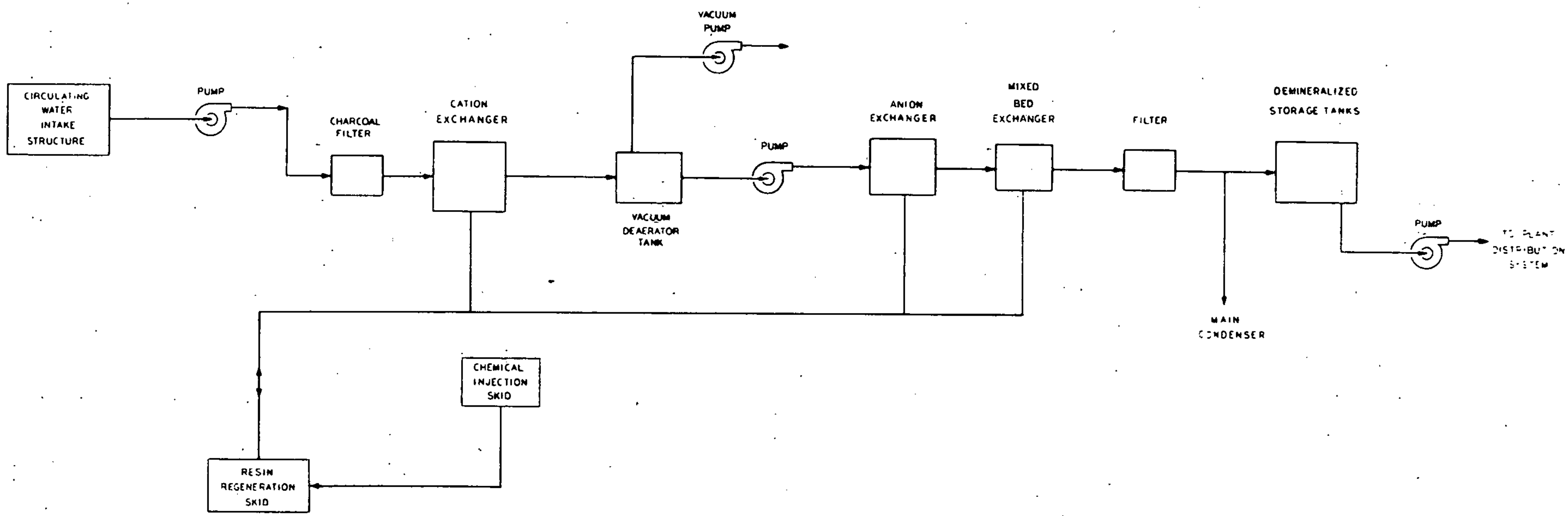


FEEDWATER CONDENSATE SYSTEM

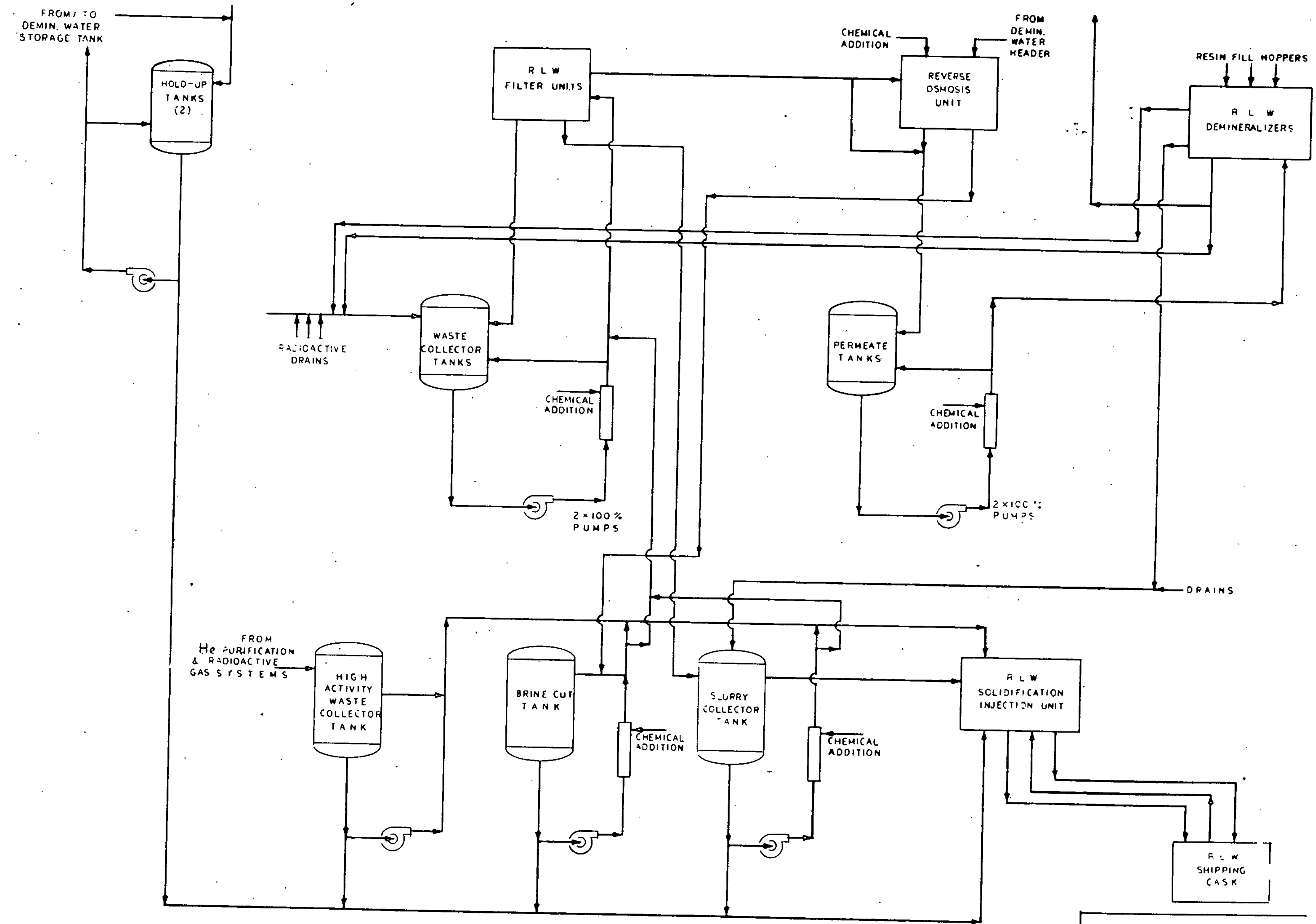
PEBBLE BED REACTOR

united engineers & constructors inc.

7122.001-PBR-019



DEMINERALIZED WATER MAKE-UP & DISTRIBUTION SYSTEM
PEBBLE BED REACTOR
united engineers
7122.001-PBR-C20

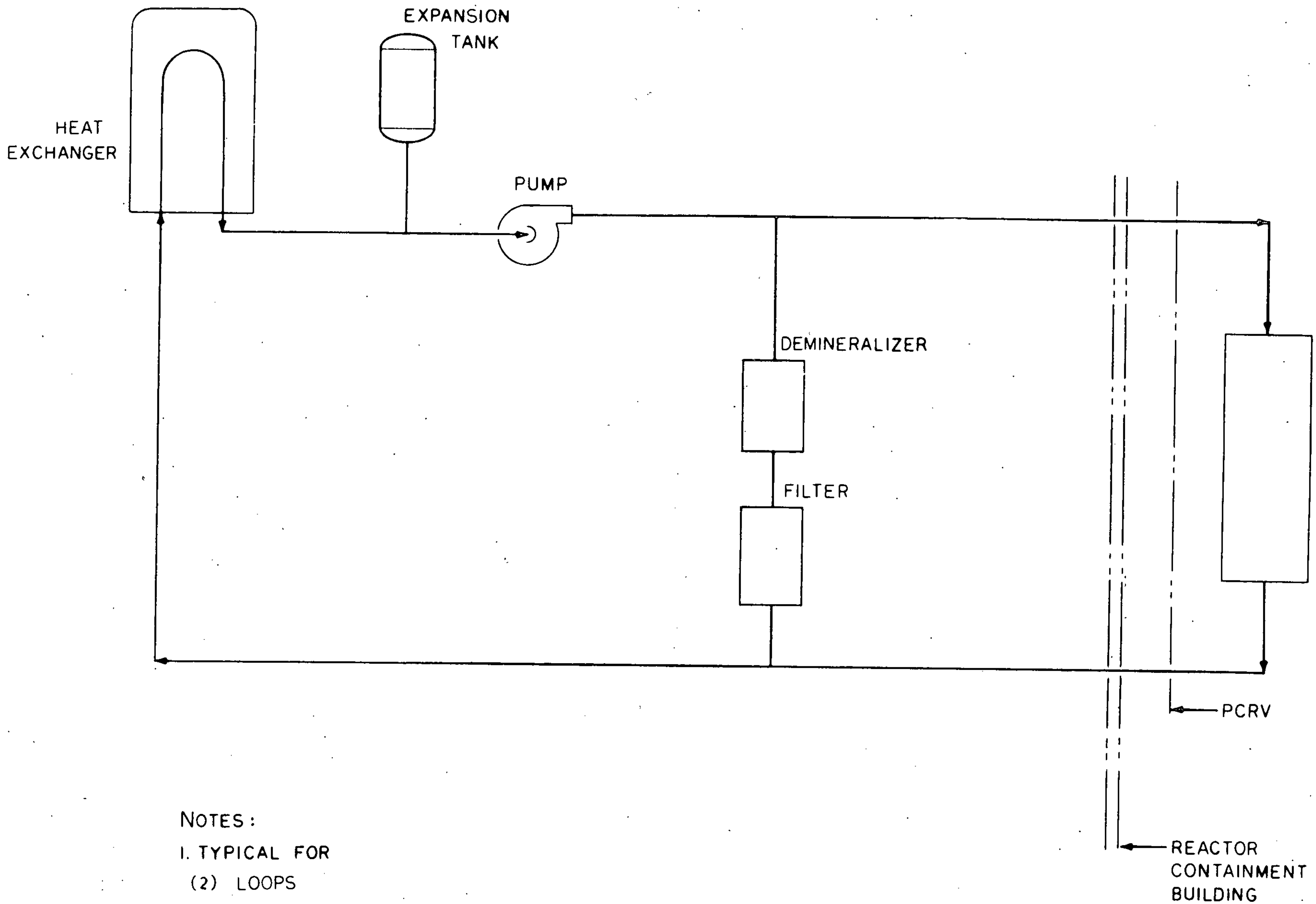


RADIOACTIVE LIQUID WASTE SYSTEM

PEBBLE BED REACTOR

united engineers & constructors inc.

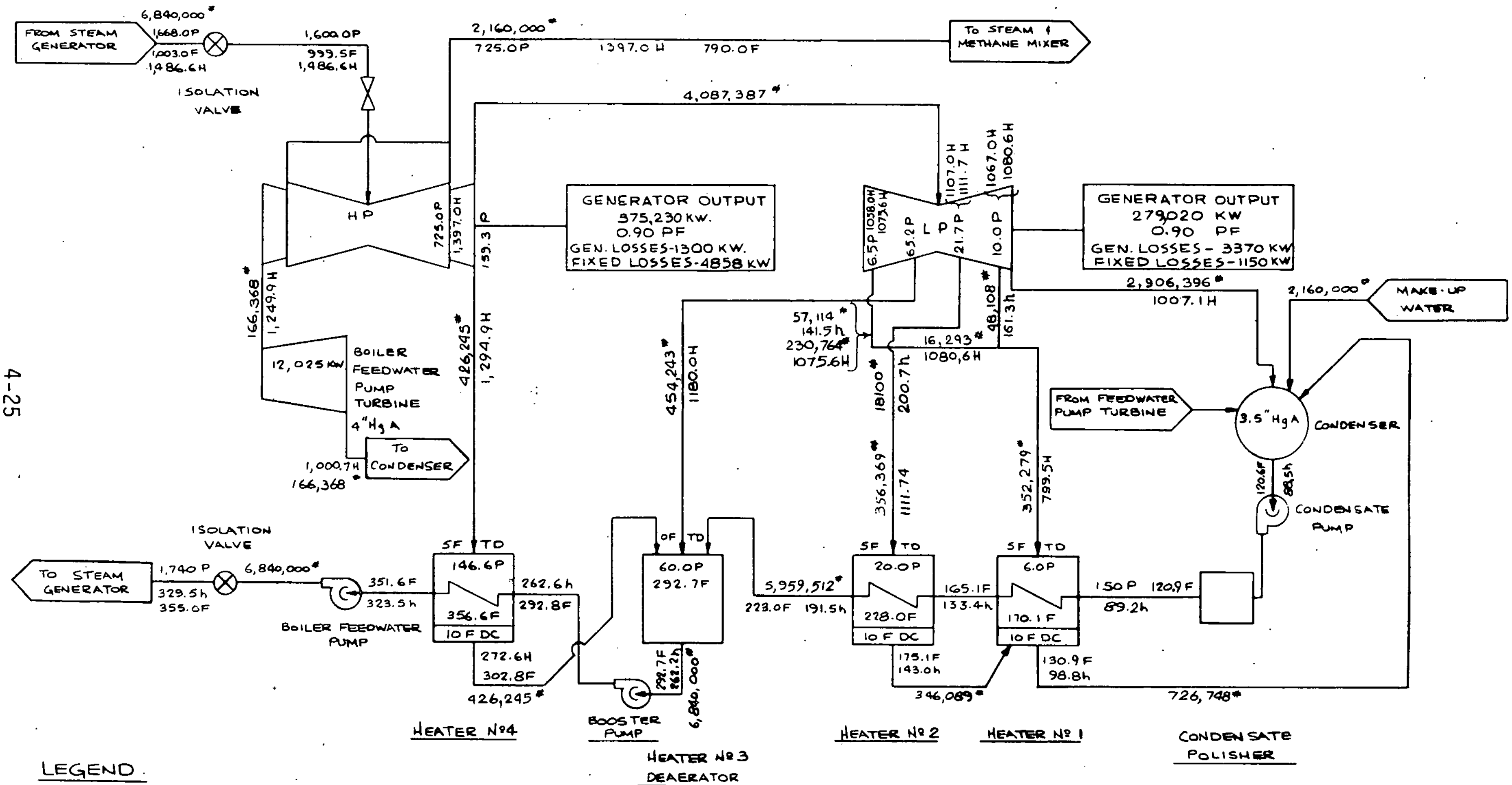
7122.001-PBR-021



PRESTRESSED CONCRETE REACTOR VESSEL COOLING SYSTEM
PEBBLE BED REACTOR

united engineers & constructors inc

7122.001-PBR-022



LEGEND.

H, h - ENTHALPY - BTU/LB
\# - FLOW - LBS/HR
P - PRESSURE - PSIA
F - TEMPERATURE - °F

NOTE:
TURBINE TYPE - TC 6F 26.0"LSB
3600 RPM

HEAT BALANCE DIAGRAM
PEBBLE BED REACTOR
united engineers & constructors inc
7122.001-PBR-023

5. SITE DESCRIPTION

5.1 GENERAL

This section sets forth the site and environmental data, derived from Appendix A of "Guide for Economic Evaluation of Nuclear Reactor Plant Designs", USAEC Report NUS-531, modified to reflect current requirements. These data form the bases of the criteria used for designing the facility and for evaluating the routine and accidental release of radioactive liquids and gases to the environment.

5.2 TOPOGRAPHY AND GENERAL SITE CHARACTERISTICS

The site is located on the east bank of the North River at a distance of 25 miles south of Middletown, the nearest large city. The North River flows from north to south and is one-half mile (2600 feet) wide adjacent to the plant site. A flood plain extends from both river banks an average distance of one-half mile, ending with hilltops generally 150 to 250 feet above the river level. Beyond this area, the topography is gently rolling, with no major critical topographical features. The plant site itself extends from river level to elevations of 50 feet above river level. The containment building, other seismic Category I structures, and the switchyard are located on level ground at an elevation of 18 feet above the mean river level. This elevation is ten feet above the 100 year maximum river level, according to U.S. Army Corps of Engineers' studies of the area.

In order to optimize the land area requirements for the nuclear power plant site, maximum use of the river location is employed. The containment structure is located approximately 400 feet from the east bank of the river. The site land area is taken as approximately 500 acres.

5.3 SITE ACCESS

Highway access is provided to the hypothetical site by five miles of secondary road connecting to a state highway; this road is in good condition and needs no additional improvements. Railroad access is provided by the construction of a spur which intersects the B&M Railroad. The length of the required spur from the main line to the plant site is assumed to be five miles in length. The North River is navigable throughout the year with a 40 ft wide by 12 ft deep channel. The distance from the shoreline to the center of the ship channel is 2000 feet. All plant shipments are assumed to be made overland except that heavy equipment (such as reactor vessel and generator stator) may be transported by barge. The Middletown Municipal Airport is located three miles west of the state highway, 15 miles south of Middletown, and ten miles north of the site.

5.4 POPULATION DENSITY AND LAND USE

The hypothetical site is near a large city (Middletown, 250,000 population) but in an area of low population density. Variation in population with distance from the site boundary is:

Miles	Cumulative Population
0.5	0
1.0	310
2.0	1,370
5.0	5,020
10.0	28,600
20.0	133,000
30.0	1,010,000

There are five industrial manufacturing plants within 15 miles of the hypothetical site. Four are small plants employing less than 100 people each.

The fifth, near the airport, employs 2,500 people. Closely populated areas are found only in the centers of the small towns, so the total land area used for housing is small. The remaining land, including that across the river, is used as forest or cultivated crop land, except for railroads and highways.

5.5 NEARBY FACILITIES

Utilities are available as follows:

- Natural gas service is available two miles from the site boundary on the same side of the river.
- Communication lines are furnished to the project boundaries at no cost.
- Power and water for construction activities are available at the southwest corner of the site boundary.
- Two independent offsite power sources (one at 500 kV and one at 230 kV) are available at the switchyard.

5.6 METEOROLOGY AND CLIMATOLOGY

5.6.1 AMBIENT TEMPERATURES

The winters in the Middletown area are moderately cold, with average temperatures in the low 30's. The summers are fairly humid with average temperatures in the low 70's, and with high temperatures averaging around 82^{o}F. The historic maximum wet bulb and dry bulb temperatures are 78^{o}F and 99^{o}F respectively.

The year round temperature duration curves for the dry bulb temperatures and coincident wet bulb temperatures are shown in Figure 5-1.

5.6.2 PREVAILING WIND

According to Weather Bureau records at Middletown Airport, located ten miles north of the site on a low plateau just east of the North River, surface winds are predominantly southwesterly four to ten knots during the warm months of the year, and westerly six to thirteen knots during the cool months.

There are no large diurnal variations in wind speed or direction. Observations of wind velocities at altitudes indicate a gradual increase in mean velocity and a gradual veering of the prevailing and northwesterly aloft.

In addition to the above, studies of the area indicate that there is a significant channeling of the winds below the surrounding hills into the north-south orientation of the North River. It is estimated that winds within the river valley blow approximately parallel to the valley orientation in excess of 50 percent of the time.

5.6.3 ATMOSPHERIC DIFFUSION PROPERTIES

The transport and dilution of radioactive materials in the form of aerosols, vapors or gases released into the atmosphere from the Middletown Nuclear Power Station are a function of the state of the atmosphere along the plume path, the topography of the region, and the characteristics of the effluents themselves. For a routine airborne release, the concentration of radioactive materials in the surrounding region depends on the amount of effluent released, the height of the release, the wind speed, atmospheric stability and air flow patterns of the site, and various effluent removal mechanisms. Geographic features such as hills and valleys influence diffusion and air flow patterns. Of the diffusion models that have been developed, the straight line trajectory model is utilized to calculate the atmospheric diffusion from the Middletown site.

The straight-line trajectory model assumes that the air flow transports and diffuses effluents along a straight line through the entire region of interest in the air flow direction at the release point. The version of this model which is used is the Gaussian straight-line trajectory model. In this model, the wind speed and atmospheric stability at the release point are assumed to determine the atmospheric diffusion characteristics in the direction of air flow.

During the warm months of the year, according to analysis of Weather Bureau records, the atmospheric conditions near the surface are 25 percent unstable (Pasquill A, B and C), 40 percent neutral (Pasquill D), and 35 percent stable (Pasquill E and F). Average wind speeds are approximately six miles per hour during unstable conditions, ten miles per hour during neutral conditions, and four miles per hour during stable conditions.

During the cool months of the year, the atmospheric conditions are 15 percent unstable, 50 percent neutral, and 35 percent stable. Average wind speeds are six miles per hour during unstable conditions, twelve miles per hour during neutral conditions, and four miles per hour during stable conditions.

Using these atmospheric conditions, the annual average wind diffusion estimates are calculated for ground level release and are found in Table 5-1. Since the data are independent of sector, only a distance dependent diffusion estimate can be calculated. These estimates vary with direction only as the spatial and temporal adjustment factors vary.

5.6.4 SEVERE METEOROLOGICAL PHENOMENA

A maximum instantaneous wind velocity of 100 mph has been recorded at the site. During the past 50 years, three tropical storms, all of them in the final dissipation stages, have passed within 50 miles of the site. Some heavy precipitation and winds in excess of 40 miles per hour were recorded, but no significant damage other than to crops resulted.

The area near the site experiences an average of 35 thunderstorms a year, with maximum frequency in early summer. High winds near 60 mph, heavy precipitation, and hail are recorded about once every four years.

In forty years of record keeping, there have been twenty tornadoes reported within fifty miles of the site. This moderately high frequency of tornado activity indicates a need to design Seismic Category I structures at the site for the possibility of an on-site tornado occurrence. Maximum tornado frequency occurs in May and June.

During the past forty years, there have been ten storms in which freezing rain has caused power transmission line disruptions. Most of these storms have occurred in early December.

5.6.5 POTENTIAL ACCIDENT RELEASE METEOROLOGY

In the event of an accidental release of fission products to the atmosphere, transport and diffusion is determined by the meteorological conditions at the site for the duration of the accident, which is assumed to be 30 days.

The calculation of the potential doses for the various design base accidents is based on meteorological conditions described in NRC's Regulatory Guide 1.4.

Ground-Level Release

The atmospheric diffusion model as a function of the distance from the reactor is based on the following assumptions:

1. The basic equation for atmospheric diffusion from a ground level point source is:

$$\chi/Q = \frac{1}{\pi u \sigma_y \sigma_z}$$

where:

χ = The short average centerline value of the ground level concentration (curies/meter^3).

Q = Material release rate (curies/sec).

u = Wind speed (meters/sec).

σ_y = The horizontal standard deviation of the plume (meters).

σ_z = The vertical standard deviation of the plume (meters).

2. For time periods of greater than eight hours, the plume is assumed to meander and spread uniformly over a 22.5^o sector. The resultant equation is:

$$\chi/Q = \frac{2.032}{\sigma_z ux} \quad (4)$$

where:

x = Distance from the point of release (meters).

3. The atmospheric diffusion model for ground level releases is based on the information in the Table below.

<u>Time Following Accident</u>

0-8 hrs.	Pasquill Type F, wind speed 1 meter/sec. uniform direction.
8-24 hrs.	Pasquill Type F, wind speed 1 meter/sec. variable direction within a 22.5° sector.
1-4 days	(a) 40% Pasquill Type D, wind speed 3 meters/sec. (b) 60% Pasquill Type F, wind speed 2 meters/sec. (c) Wind direction - variable within a 22.5° sector.
4-30 days	(a) 33.3% Pasquill Type C, wind speed 3 meters/sec. (b) 33.3% Pasquill Type D, wind speed 3 meters/sec. (c) 33.3% Pasquill Type F, wind speed 2 meters/sec. (d) Wind direction - variable within a 22.5° sector.

Figure 5-1 gives the ground level release atmospheric diffusion factors based on the above parameters.

In calculating potential exposures, the 0-8 hour concentrations are reduced by a factor ranging from a one to a maximum of three (see Figure 5-3) to compensate for additional diffusion produced by the turbulent wake of the containment building. The volumetric building wake correction, as defined in Section 3.3.5.2 of Meteorology and Atomic Energy 1968, is used only in the 0-8 hr period; it is used with a shape factor of .5 and the minimum cross-sectional area of the containment building (approximately 2000 square meters).

5.7 HYDROLOGY

The North River provides an adequate source of raw makeup water for the station. The average maximum temperature is 75°F, and the average minimum is 39°F. The mean annual temperature is 57°F.

U.S. Army Corps of Engineers' studies indicate that the 100 year maximum flood level rose to eight feet above the mean river level. There are no dams near the site whose failure could cause the river to rise above the eight foot level.

5.8 GEOLOGY/SEISMOLOGY

5.8.1 SOIL PROFILES AND LOAD BEARING CHARACTERISTICS

Soil profiles for the site show alluvial soil and rock fill to a depth of eight feet; Brassfield limestone to a depth of 30 feet; blue weathered shale and fossiliferous Richmond limestone to a depth of 50 feet; and bedrock below a depth of 50 feet. Allowable soil bearing is 6,000 psf, and rock bearing characteristics are 18,000 psf and 15,000 psf for Brassfield and Richmond strata, respectively. No underground cavities exist in the limestone.

5.8.2 SEISMOLOGY

The site is located in a generally seismically inactive region. Historical records show three earthquakes have occurred in the region between 1870 and 1975. A safe shutdown earthquake (SSE) with a horizontal ground accleration of 0.30 g provides conservative design margin. For design purposes, the horizontal and vertical component Design Response Spectra given in NRC Regulatory Guide 1.60, Rev. 1, December 1973, are linearly scaled to a horizontal ground acceleration of 0.30 g.

5.9 SEWAGE AND RADIOACTIVE WASTE DISPOSAL

5.9.1 SEWAGE

All sewage receive primary and secondary treatment prior to discharge into the North River.

5.9.2 GASEOUS AND LIQUID RADIOACTIVE WASTES

The gaseous and liquid effluent releases from this plant comply with 10 CFR Part 20 and the intent of Appendix I of 10 CFR Part 50.

5.9.3 SOLID RADIOACTIVE WASTES

Storage on site for decay is permissible, but no ultimate disposal on site is planned.

TABLE 5-1

ANNUAL AVERAGE ATMOSPHERIC DIFFUSION ESTIMATES

(Sec/m^3)

Ground Level Release

Distance (Miles)	Down-Valley	Up-Valley	Cross Valley
.5	1.2-5*	3.7-6	2.5-6
1.5	2.0-6	5.9-7	4.0-7
2.5	8.8-7	2.6-7	1.8-7
3.5	5.3-7	1.6-7	1.0-7
4.5	3.6-7	1.1-7	7.2-8
7.5	1.7-7	5.1-8	3.4-8
15.0	6.5-8	1.9-8	1.3-8
25.0	6.5-9	9.8-9	6.5-9
35.0	4.2-9	6.3-9	4.2-9
45.0	3.1-9	4.6-9	3.1-9

*1.2-5 = 1.2×10^{-5} (typical example)

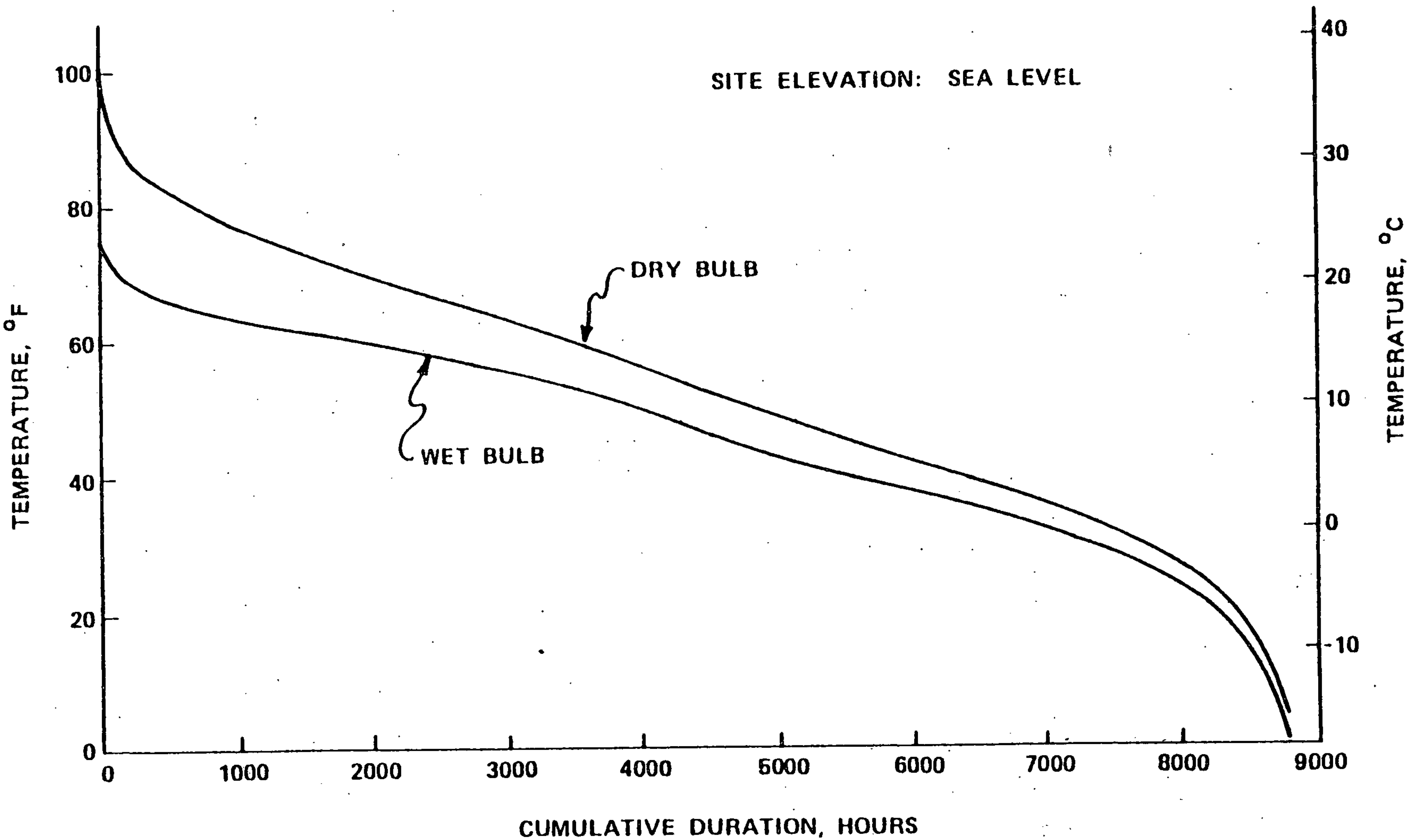


FIGURE 5-1 TEMPERATURE DURATION CURVES: MIDDLETOWN, U.S.A.

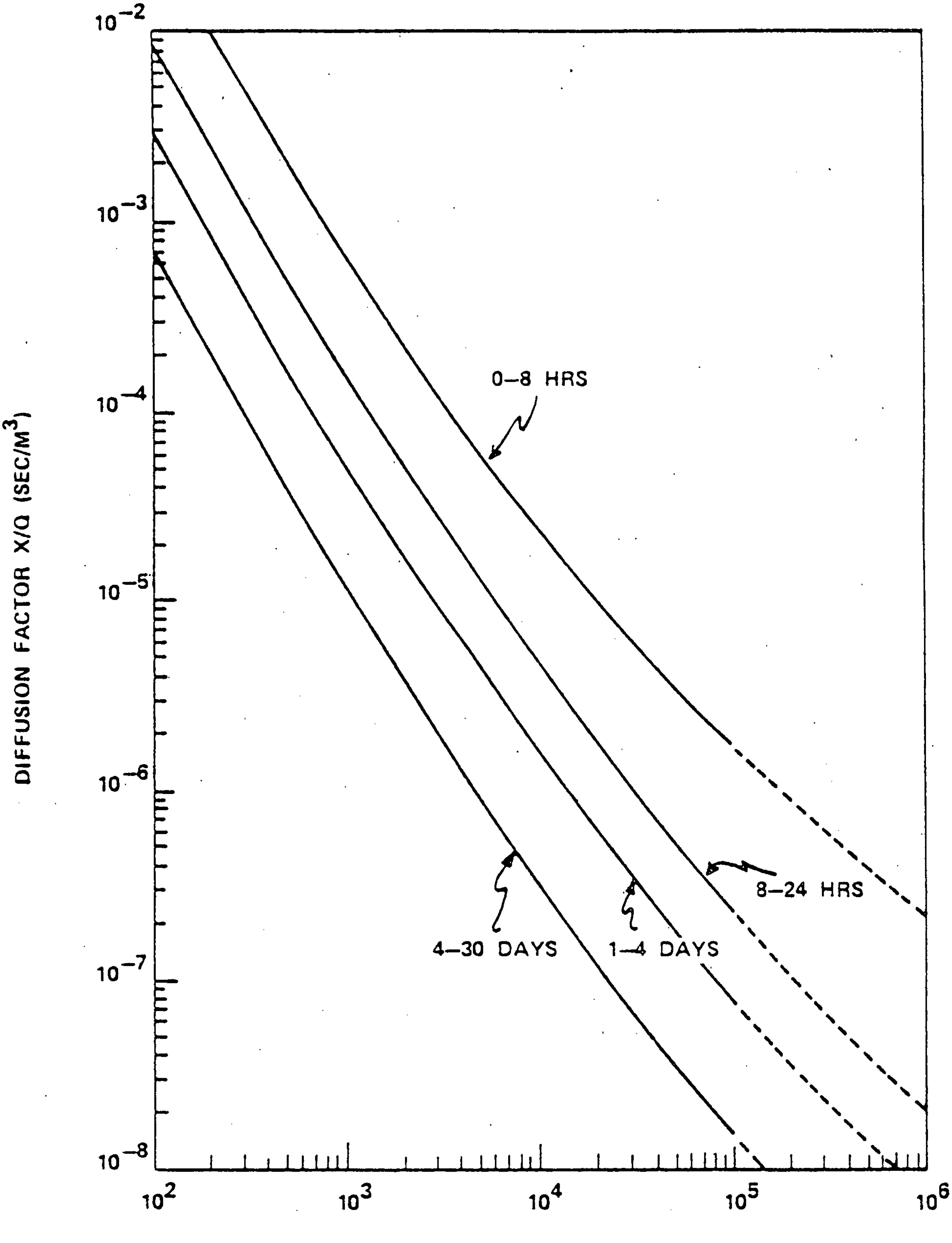


FIGURE 5-2 GROUND RELEASE – ATMOSPHERIC DIFFUSION FACTORS

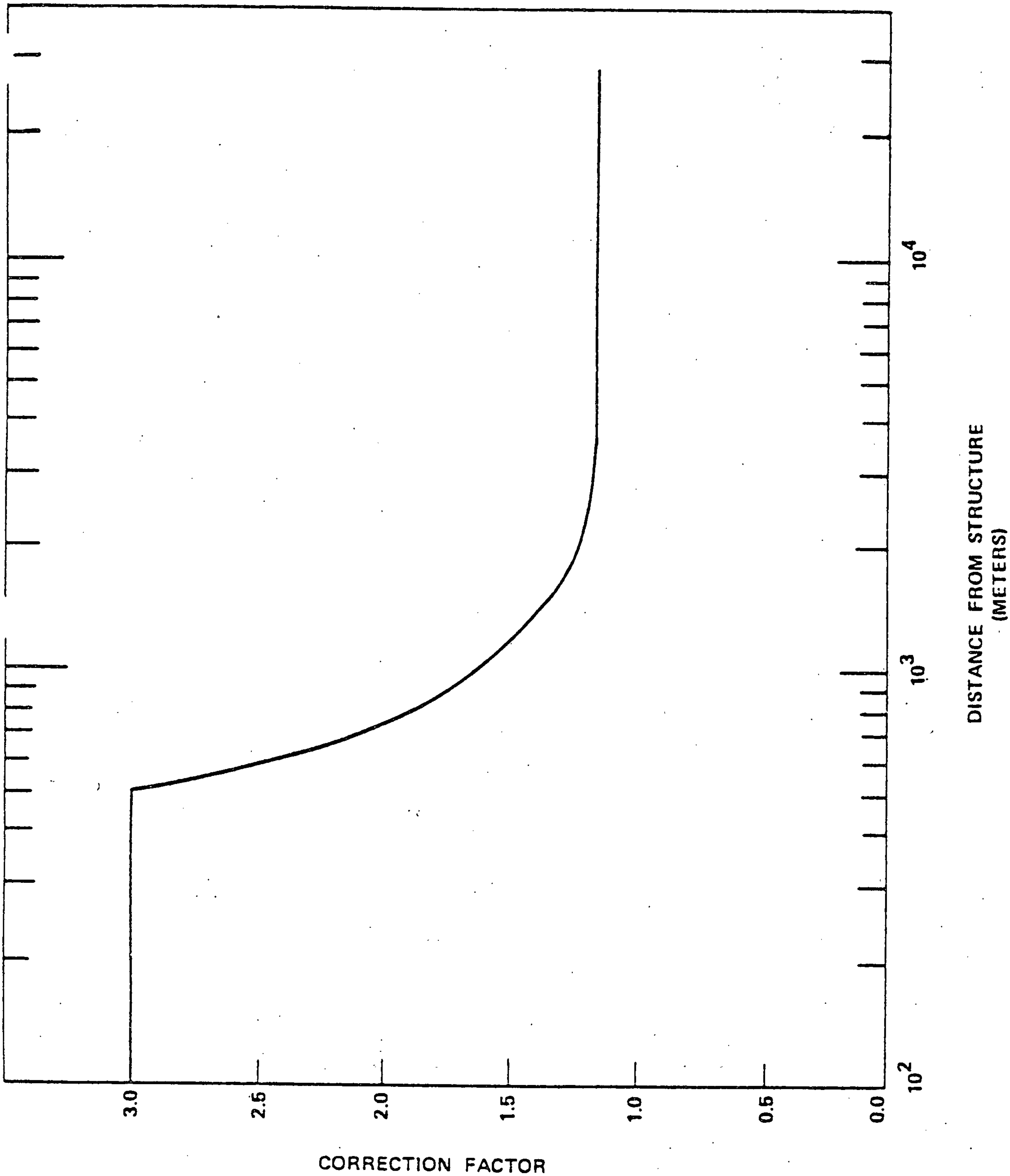


FIGURE 5-3 BUILDING WAKE DIFFUSION CORRECTION FACTOR