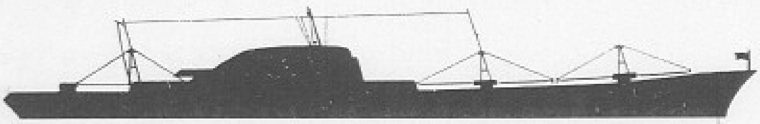

TECHNICAL
PRESS INFORMATION
N.S. SAVANNAH

COMPILED FOR THE
U.S. ATOMIC ENERGY COMMISSION
U.S. DEPARTMENT OF COMMERCE
MARITIME ADMINISTRATION

BY NEW YORK SHIPBUILDING CORPORATION, CAMDEN, NEW JERSEY

PART II-B

PROPULSION PLANT

The world's first atomic-powered merchant ship, the SAVANNAH will have one of the most advanced, yet conservatively designed atomic power plants (Pressurized Water Reactor) in existence. This is the same type of nuclear reactor that has propelled the USS NAUTILUS on its record-making voyages since 1955; and has been used in the Shippingport (Pennsylvania) Atomic Power Station since 1957.

The Atomic Energy Commission awarded the prime contract for design and manufacture of the SAVANNAH's nuclear power plant to The Babcock and Wilcox Company. B&W is also supervising the installation and will participate in the testing of the entire power plant. The steam turbines and reduction gear were subcontracted by B&W to the De Laval Steam Turbine Company.

The SAVANNAH has been referred to as a floating laboratory because of the valuable operational data and experience she will furnish. Although the basic design and operating criteria for the reactor propulsion system were fixed at the very beginning, a number of significant improvements were incorporated in the plant as it was built. Nuclear experts have also given thought to a future version incorporating further improvements, some of which may be tested on the SAVANNAH after she is in operation.

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TABLE No. 1

GENERAL SHIP DESIGN DATA

Type	Single Screw
Length	595' - 6"
Beam	78 ft.
Draft	29½ ft.
Displacement	21,800 tons (24,416 short tons)
Cargo Capacity	10,000 tons (11,200 short tons)
Passengers	60
Operating personnel (approx.):	
Officers	25
Crew	85
Speed	
Normal	21 knots (25 mph)

PRINCIPAL POWER PLANT FEATURES

The SAVANNAH has nine water-tight subdivisions consisting of seven cargo holds, a reactor compartment, and a machinery compartment, as shown in Figure No. 1.

The nuclear propulsion system is subdivided into a reactor system and a steam propulsion system. The steam propulsion system is located in the 60-foot machinery compartment just below the superstructure. It comprises the main turbines and reduction gear, the main condensers, the feed water system, the turbine generators to supply propulsion auxiliaries and ship's "hotel" load, and the emergency diesel generators and package boiler to supply the ship's emergency needs. To enable visitors to inspect the machinery compartment, a gallery is provided at an upper level, and the control room (visible from the gallery) will be glass enclosed.

The reactor system is located amidships, between the bulkheads forming the reactor compartment. The major portion of this system, including the reactor with its primary loops, pressurizer, steam generators, primary circulating pumps, air conditioning system and other auxiliary systems, will be enclosed within a cylindrical containment vessel, centrally located in this compartment. Certain low pressure reactor system auxiliaries, such as the primary water demineralizers, charge pumps, drain tanks, and a few other components are located just outside the containment vessel for reasons of better access or maintenance.

Table No. 2 gives the general characteristics of the power plant.

TABLE NO. 2

POWER PLANT PERFORMANCE DATA

		Normal	Maximum Continuous
Shaft Power	SHP	20,000	22,000
Shaft Speed	rpm	107	110
Steam pressure at drum (Dry, saturated steam)	psia	490	474
Main Condenser	" Hg	28.5	28.5
Feed water temperature	°F	347	343
Steam consumption:			
For main turbines	lb/hr	186,610	205,100
For other uses	lb/hr	55,590	56,360
Total steam generation required	lb/hr	242,200	261,460
Total electrical load	kw	2200	2200
Reactor:			
Design power	mw	74	74
Operating power	mw	63.5	69
Design pressure	psia	2000	2000
Operating pressure	psia	1750	1750
Primary coolant flow	lb/hr	8,000,000	8,000,000
Primary water temperature rise through reactor	°F	22.8	24.8
Primary water mean temp.	°F	508	508

(more)

The estimated gross weight of the power plant is as follows:

Propulsion system	1,265	short tons
Reactor system	665	short tons
Containment and shielding	2,418	short tons
Total	4,348	short tons

The operating period between each refueling of the core is expected to be about 3.5 years. All other structural and mechanical features of the plant are being designed for the normal life of a merchant ship, in excess of 20 years.

DESCRIPTION OF PROPULSION PLANT

The SAVANNAH's power plant consists of a reactor system and a propulsion system which are an integrated unit, different from conventional ships only in that the reactor replaces the ordinary oil-fired boiler. The propulsion system is comprised of the main turbines and reduction gears, the main condensers, the feed water system, and the turbine generators. Auxiliary diesel generators and a package boiler will supply power when the reactor is shut down. The propulsion system is located in the machinery compartment just aft of the reactor compartment and below the superstructure.

The power plant control room is located at the rear of the machinery compartment on the "D" deck level.

The reactor system is composed of a pressurized water reactor, a pressurizer vessel, and two primary coolant loops.

Each loop contains two canned motor pumps, one heat exchanger, two check valves, and two stop valves. The heat added to the primary coolant as it flows through the reactor is given up in the heat exchanger. Here the primary water generates low quality steam which is led through risers to a steam drum directly above the heat exchanger. The moisture is removed in the steam drum and dry saturated steam led to the steam main.

CONTAINMENT VESSEL

All of the equipment in the reactor system is housed within a steel containment vessel in the reactor space. (See Figure No. 2). Because of the weight of the reactor vessel and the various components associated with the reactor system, including approximately 2,000 tons of lead and concrete shielding, the reactor space has been located amidship, just forward of the machinery compartment.

The containment vessel serves to prevent the escape of radioactive particles to the atmosphere in the event of an accident. The vessel is made up of a 35-foot diameter cylindrical section, with two hemispherical ends, and has an overall length of 50 feet. A 14-foot diameter cupola is located on top of the cylindrical section. The control rod drives, which are mounted on the reactor vessel head, are housed within the cupola.

The vessel has been designed to withstand a pressure of 186 psig. The wall thickness of the containment vessel varies from 2-3/8 to almost four inches of carbon steel.

The 186 psig is the pressure that would result from the rupture of a primary coolant pipe and the instantaneous release and expansion of the entire contents of the primary system which is the maximum credible accident to the reactor plant.

A total of 82 penetrations for piping, electrical cables, pneumatic lines, and access, are provided in the containment vessel shell. The largest penetration is the 14-foot diameter opening at the top of the cupola. This opening was used for initial installation of equipment within the containment vessel. In addition, it will be utilized for refueling the reactor core.

Two 24 x 18-inch manholes in the lower portion of the vessel and two 42-inch diameter manholes in the upper portion provide means of access to the containment vessel. Should the ship sink the two lower manholes have been designed to open inwardly under an external head pressure of 100 feet of water. This feature allows flooding and prevents the collapse of the containment vessel in the event of sinking.

The bottom half of the vessel rests in a cradle of steel surrounded by a wall of reinforced concrete four-foot thick which forms the lower portion of the secondary shield. The top half of the containment vessel is encased in a six-inch layer of lead plus a six-inch layer of polyethylene which forms the upper portion of the secondary shield. In addition, both sides of the vessel are protected by a thick collision mat, constructed of alternate layers of steel and redwood. The amount of radiation at the surface of the shield will not exceed five rems* per yeat at normal operation.

Except when entry is required, the vessel will be sealed. If entry is required, it can be done thirty minutes after reactor shutdown when the radiation level within the vessel is below 200 millirem per hour, or less. Entry into the containment vessel will be kept to a minimum since the internal equipment that could be expected to require normal maintenance is installed in duplicate. In addition, certain segments of the reactor system can be isolated and bypassed without affedting plant operation.

The containment air conditioning system continuously circulates and cools off all of the air in the containment vessel, maintaining an average ambient temperature of 130 degrees F and humidity of 72 per cent.

The design of the containment vessel follows the highest engineering standards, and was approved by the Coast Guard and the American Bureau of Ships. (See Appendix "A" for further details on the containment vessel.)

(*) Rem (roentgen equivalent, man) is the dose of any ionizing radiation that will produce the same biological effect as that produced by one roentgen of high-voltage X-radiation.

SHIELDING DESIGN AND CONSTRUCTION

The main sources of radiation during operation of the SAVANNAH power plant are the reactor itself and the primary loop coolant water. This water, which passes through the reactor core, is irradiated in the process and becomes a source of radiation. There are also radiation sources of lesser magnitude including process piping, hold-up tanks, pumps, and demineralizers. By and large, these need not be considered in the design of the main shield, but must be considered during access and maintenance studies.

The shield on the SAVANNAH serves the dual purpose of:

(1) limiting the radiation dose outside the containment to prescribed safe levels and

(2) permitting access to the interior of the containment vessel within 30 minutes after shutdown.

In order to accomplish these functions the shield has been divided into a primary shield, which surrounds the reactor itself, and the secondary shield which surrounds the containment vessel.

The primary shield consists of a water-filled tank surrounding the reactor, augmented by an outer lead annulus varying in thickness from two to four inches. The tank is 17-feet high, with an annular water space of 33 inches. The lead annulus is bonded to the outer wall of the tank. The primary shield is more than sufficient to limit the dose rate within the containment vessel from core gamma sources and activated nuclei to 200 mrem/hr., a half hour after the reactor has been shut down. This level will permit limited access of personnel to the containment vessel for maintenance and repair purposes.

The secondary shield consists of lead, polyethylene, concrete, and water of sufficient thickness to reduce reactor and coolant doses to allowable levels. The total weight of this secondary shield is approximately 2,000 tons.

A concrete wall, which encloses the lower part of the containment vessel comprises the lower portion of the secondary shield. Where available space limited the thickness of the wall, a heavy density concrete was used in lieu of ordinary concrete. This wall extends outward from the forward end of the containment vessel to form a compartment between the shield and the containment vessel. This compartment houses the purification demineralizers and components of the waste collection, buffer seal, and gaseous waste systems.

A series of fresh water shield tanks in the double bottom follow the line of the concrete. These tanks minimize the dose rate outside the shield due to radiation scatter under the concrete.

The upper part of the shield is composed of lead slabs bolted to the containment vessel. The thickness of the lead varies from 2.5 to six inches. Boundaries between slabs are caulked with lead wool rope. The lead support studs are extended to provide attachment for the polyethylene, whose thickness is adjusted to provide a constant shield thickness of 14 inches. Gaps are provided between adjacent sheets of polyethylene to allow for its high coefficient of expansion.

The unique features of this shielding are due primarily to the introduction of the containment. As a consequence of the size and shape of the containment vessel, the shield must be very large, very heavy and of extremely awkward shape.

Full account of this complex geometry was taken in the development of shielding programs written for the IBM-650 digital computer. This computer was utilized for all shielding calculations. This required the development of several special programs which calculated the effect of such things as radiation streaming through shield penetrations and scattering beneath the concrete shield.

Table No. 3, below, lists the weights of the shielding components:

TABLE NO. 3

TABULATION OF SHIELDING WEIGHTS

	Long Tons
Heavy Concrete	552
Ordinary Concrete	508
Lead	481
Polyethylene	68
Redwood Lumber (collision mat)	22
Steel (collision mat)	136
Total Secondary	1,767
Primary Shield Tank (dry)	150,179 pounds
" " " (wet)	260,326 pounds
Containment Shell	250 short tons

DESCRIPTION OF REACTOR SYSTEM

The SAVANNAH's reactor is moderated and cooled by light water at 1,750 psia. It is fueled with uranium oxide (UO_2) of about 4.4 percent enrichment in uranium 235, clad in stainless steel rods. The reactor design was aimed, primarily, at a long core lifetime; the design target was approximately 52,000 megawatt days, or 1,230 days at the average operating power.

The active core is approximately a right circular cylinder with an equivalent diameter of 62 inches and a height of 66 inches. The core is made up of 32 fuel elements, each one consisting of 164 fuel rods. Reactivity control is provided by 21 cruciform control rods. Each rod is a composite of a boron-stainless steel plate jacketed with stainless steel plates.

Three basic thermal considerations were followed in the reactor:

(1) No bulk boiling is permissible in the core during steady-state operation;

(2) The local heat flux at the outside surface of the cladding will not exceed the design value of burnout heat flux during steady-state operation; and

(3) Melting of the oxide fuel will not happen under the worst possible combination of manufacturing tolerances, neutron flux distribution, and fluid flow effects during steady-state or transient operations.

(more)

A multipass arrangement was selected because it possessed several advantages in thermal performance over a single pass core. There are three passes. The first flow path is upward in the annuli between the vessel and the inner thermal shield; the second and third passes are through the core.

In order to attain the long core lifetime, a large, low power density core is used. The inclusion of uranium 238 as a fertile material extends the core life through its conversion to plutonium.

The core is basically stable because of the large negative prompt fuel temperature coefficient*. This, backed up by the delayed negative moderator temperature coefficient*, adds to the safety of the system. However, this stability requires that the control system drive the reactor whenever there is a change in the steam load.

A pressurized water reactor system operates on the principle that water under high pressure can be heated to high temperature without boiling (primary loop). This heat is then transferred to water under much lower pressure, causing it to turn to steam (secondary loop) to operate the turbines and produce power.

In steady operation, the SAVANNAH reactor system will respond automatically to slight variations in steam demand at the turbine throttle by virtue of its negative temperature coefficient. For changes of power demanded from the bridge, automatic control rod operation will cause the reactor to respond without serious lag or deviation in its average coolant temperature. A graphic,

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color coded display of the operation of the reactor system will be provided on the main control panel.

Figure No. 3 shows the arrangement of the major components of the reactor system within the containment vessel. Appendix "B" describes the mock-up of the nuclear power plant that was constructed to check design clearances, and for training purposes. Table No. 4 gives the major reactor design and performance characteristics.

(*) Increased heat tends to reduce the neutron efficiency of the reactor, hence it reduces or quenches the chain reaction.

TABLE NO. 4

REACTOR DESIGN AND PERFORMANCE CHARACTERISTICS
THERMAL, HYDRAULIC, AND NUCLEAR

CORE DIMENSIONS

Core over-all length	90.24 inches
Active fuel length	66 inches
Equivalent core diameter	62.06 inches

FUEL ELEMENT DATA

Fuel	Uranium Oxide (UO_2)
Cladding	Stainless Steel
Ferrules	Stainless Steel
Springs	Inconel-X
Can	Stainless Steel
Straps	Stainless Steel

Fuel pellet diameter		0.4255 inch (nominal)
Cladding outside diameter		0.500 inch (nominal)
Cladding thickness		0.035 inch (nominal)
Fuel rod spacing (square lattice)		0.663 inch (nominal)
Fuel rods per element		164
Ferrule outside diameter		0.4375 inch (nominal)
Ferrule inside diameter		0.3975 inch (nominal)
Length of ferrule		1.0 inch
Fuel elements in core		32
Fuel element can thickness	(outer pass -	0.109 inch
	(inner pass -	0.094 inch
Heat transfer area	Inner	3,778 square feet

THERMAL AND HYDRAULIC DATA

Reactor maximum operating power	69 mw
Reactor normal operating power	63.5 mw.
Design pressure	2,000 psia
Operating pressure	1,750 psia
Total reactor flow rate	8.0×10^6 lb/hr
Velocity (average, outer pass)	9.29 ft/sec
Velocity (average, inner pass)	8.40 ft/sec
Percent leakage flow (outer pass)	5%
Percent leakage flow (inner pass)	10%
Percent total leakage flow	15%
Number of passes within reactor vessel	3
Bulk coolant inlet temperature at max. power	495.6°F
Bulk coolant outlet temperature at max. power	520.4°F
Core average coolant temperature	508°F
Average heat flux at maximum power	62,330
Maximum heat flux at maximum power	275,000

(more)

TABLE NO. 4
(Cont'd.)

THERMAL AND HYDRAULIC DATA (Cont'd.)

	Nominal Channel* (Third Pass)	Hot Channel ** With Flux Peaking (Third Pass)
Maximum coolant temperature (°F)	534	541
Maximum surface temperature (°F)	603	623
Maximum fuel temperature (°F)	3,310	3,794
Power to start local boiling (percent of maximum power)	121%	98%
Power to start net boiling	---	314%

NUCLEAR DATA

Metal H_2O ratio	0.76
Volume fractions:	
Water	0.5655
Control rods	0.0405
Helium gap	0.0052
Fuel	0.2467
Stainless steel	0.1421
Typical inventory and fuel burnup data for 52,200 megawatt days (mwd) core life:	
Initial enrichment (average, wt %)	4.4%
Initial U-235 loading	312.4 kg
Initial U-238 loading	6787.5 kg
Average burnup	7352 mwd/ton
Final enrichment (wt %)	3.63%
Final U-235 loading	254.8 kg
U-235 consumed	57.6 kg
Final Pu-239 loading	17.2 kg
Final total plutonium loading	19.9 kg
Percent metal atom burnup	1.06%
Average thermal neutron flux (at 63.5 mw)	7.2×10^{12}

* The nominal channel is assumed to be located in the region of maximum flux but does not include the effect of manufacturing tolerances.

** The hot channel combines the maximum flux with the accumulated effects of all manufacturing tolerances.

REACTOR CORE AND FUEL

Each of the core's 32 fuel elements is 8.5-inches square. The elements are confined within a stainless steel "egg crate" type lattice. This lattice --- the equivalent of a pressure can around each element --- serves to withstand the pressure differentials that arise as a result of the multipass flow pattern.

Each fuel element contains 164 rods. Each rod is 0.5-inch in diameter. The wall is 0.035-inch-thick stainless steel. The fuel in the rod is uranium oxide pellets, enriched to an average of 4.4 percent of uranium 235.

Details of a fuel element are shown in Figure No. 4.

The fuel rods in the inner 16 fuel elements contain uranium oxide (UO_2) at an enrichment of 4.2 percent U-235, and in the outer 16 fuel elements the enrichment is 4.6 percent in U-235. Within each fuel element, the fuel rods are arranged in four bundles of 41 rods each. Center to center spacing of the rods is .663 inch, giving an over-all metal to water ratio of 0.76. The rod spacing is maintained by small tubular stainless steel ferrules brazed in place approximately every 8 inches along the length of the element.

The uranium oxide pellets, .4255-inch in diameter, are made from pressed and sintered UO_2 powder. The space between the pellets and the inner tube wall will contain helium gas under pressure to assure good heat transfer across the fuel rod. The gas is sealed in at the time the tube is loaded and the ends plugged.

The initial core loading will include 6,788 kg. of U-238; the U-235 content, at the enrichments of 4.2 and 4.6 percent, will be 312.4 kg. The conversion ratio will be about .4; that is, for each gram of U-235 that is burned up, .4 grams of Pu-239 will be produced from the fertile material (U-238).

The reactivity requirements as listed below indicate that the cold clean core should have an excess reactivity of approximately 11.2 percent.

Temperature coefficient - 68 F - 508 F (including power coefficient)	- 3.2%
Xenon and Samarium poisoning	- 2.0
Power doppler effect (zero to full power)	- 1.3
Fuel burnout and isotope build-up	- 4.7
Total	11.2%

The control rods will control reactivity in the range of 14 to 18 percent from cold starting to full power. This value includes an allowance for resonance capture of neutrons by the rods. This data would therefore indicate a margin of 2.8 percent for the cold clean core.

Many factors are involved in estimating the core life, but all calculations to date conservatively indicate that at normal power, corresponding to 63.5 mw of heat, the core should have a life of over 700 normal power operating days. Based on operating 60 percent of the time at normal power, and 40 percent at port power, it should not be necessary to reload the core for 3.5 years.

(more)

CONTROL RODS AND DRIVE MECHANISMS

There are 21 control rods, arranged as shown in Figure No. 5. The amount of heat generated by atomic fission in the reactor depends upon how far from the full down position the control rods are raised. The principle of operation is simple. When the rods are in the full down position, they absorb the neutrons emitted by the nuclear fuel. Raising the rods, in effect, is like raising a curtain from between the neutrons, thus permitting them to bombard surrounding fissionable uranium atoms and sustain the chain reaction necessary to produce heat continuously. The higher the rods are raised, the greater the heat that is generated. Inversely, lowering the rods restricts the fissioning action and reduces the heat, and in the full down position shuts the chain reaction off entirely. Dropping all rods quickly and simultaneously to the full down position is called "scramming".

Each rod is in the shape of a cruciform, and each is equipped with an electro-mechanical control, plus a hydraulic cylinder for reactor scram. All drive rods are buffer-sealed where they pass through the reactor head, and each seal is charged with purified water at 1,800 psi pressure. In the event of failure, a seal can be isolated from the system. Each control rod drive assembly can be disconnected from its control rod and removed.

Each rod measures eight-inches across, tip to tip, and is .375-inch thick. The effective length of each rod is 66-inches. Construction consists of a 3/16-inch-thick plate of boron stainless steel sandwiched between two 3/32-inch-thick stainless steel plates.

It is the boron that restricts the atomic fission process, and provides control.

Positioning, and motion of the rod is accomplished by the combined use of an electromechanical drive unit and hydraulic pressure. The portion of the drive line that moves during a scram consists of the control rod, seal shafting, safety latch, hydraulic piston rod, and hydraulic piston. These scram components are held against the underside of the drive carriage during normal positioning by the force of reactor pressure acting on the area of the seal shaft, and will, therefore, follow the carriage. The carriage is positioned by twin lead screws driven by an electric drive motor.

The hydraulic pressure necessary for a scram is maintained continuously in a scram accumulator. Each rod has its own accumulator, each of these acts independently of the others. The scram pressure is held in check by a pilot-operated scram valve. By release of the pilot pressure, the full scram accumulator pressure is applied to the piston. This results in a net downward force on the rod drive line sufficient to accelerate the rod into the core at the required rate.

There is a safety latch on the rod drive which will not allow it to be withdrawn unless it is in contact with the drive mechanism. Consequently, under no circumstances can the reactor pressure or the hydraulic piston withdraw a rod at a faster rate than the driving carriage will allow, and once a control rod has been driven in by a scram, it cannot be withdrawn until the drive carriage has been moved down to release its latches. The safety latch will also hold the rods in position within the core in the event of a capsized ship.

REACTOR CONTROL AND SAFETY SYSTEM

The automatic control system is designed to adjust the reactor power level to meet the steam load requirement. The system also maintains the average reactor temperature at 508 degrees F. The average temperature is maintained independent of reactor power level.

Variations in coolant temperature and steam flow are detected by sensors which supply corrective action to the control rods. This corrective signal, or power error, initiates movement of a rod group with a velocity proportional to this error up to a pre-set velocity limit. This maximum velocity will limit the reactivity insertion rates to a safe value and still permit rapid maneuvering of the plant. The control system prevents excessive transients in the primary coolant temperature during demand load changes.

The reactor safety system monitors signals from the nuclear and non-nuclear instrumentation to detect unsafe conditions and initiates corrective action as necessary. Two modes of corrective action, scram and fast insertion, are initiated by the safety system depending upon the nature of the abnormal condition. For scram action, all withdrawn control rods are rapidly inserted into the core by the force of hydraulic pressure in about 1.6 seconds. During a fast insertion, all withdrawn rods are inserted at the maximum rate available through the electromechanical drive, about 15 inches per minute. A scram signal overrides all signals while a fast insertion signal will override all automatic control or manual rod signals.

The reactor safety system is designed to protect the reactor from damage during all abnormal conditions with the exception of a major rupture in the primary system. The number of scram signals has been kept to the minimum consistent with the philosophy of reactor protection. To minimize spurious scrams due to minor malfunctions, coincidence of unsafe indications from two independent instruments is utilized wherever possible.

The safety system also contains a group of annunciator signals. These signals warn operators when any system parameter is outside its normal operating range allowing corrective action to be taken before a serious condition arises.

PRIMARY SYSTEM

The function of the primary system is to transfer the heat generated in the reactor core to the steam generators. Demineralized water is circulated through the reactor and boilers by means of two closed loops. Each loop contains two circulating pumps, one steam generator, two check valves and two stop valves together with the necessary piping, as shown in Fig. No. 3.

The system is designed to transfer 74 megawatts or 252.6 million Btu/hr. from the reactor core at full load with a flow rate of 8,000,000 lb./hr. The inlet temperature to the reactor at this power level is 494.7 degrees F. and the outlet temperature is 521.3 degrees F. The heat added to the water as it flows through the reactor is given up in the steam generators.

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All material in contact with the reactor coolant water in the primary system is type 304 stainless steel or its equivalent. Primary loop water is pressurized to 1,750 psi by an electrically-heated pressurizer vessel in which normal operating conditions are automatically maintained by alternate use of electrical heaters or spray coolers. The water level in the pressurizer is maintained by regulating the rate of primary loop water flow to the purification system, and the recharging flow to the purification system, and the recharging flow introduced by the charge pumps.

Water in the primary loop is circulated by four pumps of the canned rotor type, each with half and full speed windings. The system is designed to use all four pumps at full speed during normal operation of the power plant. Their main design characteristics are as follows:

Power - 230
Flow - 5000 gpm at 495°F
Head 70 psi

The main primary piping, shown in No. 3, is 12/9/16 inches inside diameter, and the branch piping between the boiler outlets and the Y-fittings, containing the pumps, is 8-9/16 inches inside diameter. All primary piping is from Type 304 stainless steel hollow forgings with a design pressure of 2,000 psi. Each primary loop also contains two main valves by which its boiler and pumps may be isolated from the reactor. A check valve is downstream of each pump.

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All four primary pumps are centrifugal, canned-rotor, zero-leakage pumps installed vertically, motor is equipped to operate the pump at half speed, as may be desirable for decay heat removal after reactor shutdown. The gate valves for the primary system are actuated by electric motor operators. Thesee valves are located in the inlet and outlet lines of each loop adjacent to the reactor so that either loop can be isolated from the reactor, if necessary. A check valve is located at the discharge of each pump to prohibit reverse flow in the event of a pump failure in either loop. Each valve is of conventional swing type. A small hole in the disk permits a low flow through the branch piping, to maintain equal temperature throughout the loop.

SECONDARY SYSTEM

In this system feed water is heated to steam in two steam generators. Each steam generator consists of a U-tube, U-shell lower drum with the primary piping connecting to the inlet and outlet nozzles on the heads of the drum. The shell side is connected to an upper drum, located on the center line and above the lower drum, by means of thirteen risers and eight downcomers. The risers and downcomers are designed to insure natural ciraulation of all loads and attitudes of the ship.

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Cyclone separators and scrubbers are provided in the upper drum to supply dry saturated steam at the outlet nozzles. Steam quality will be maintained at approximately 0.25 percent moisture. The steam generators are designed for 2,000 psig on the tube side and 800 psig on the shell side. The design temperature for the tube and shell sides is 650 degrees F.

BUFFER SEAL SYSTEM

This system supplies high-pressure purified water to the control rod drive buffer seals, thereby preventing outward leakage of the primary coolant. It will also inject purified makeup water into the primary system when needed.

Water for the control rod buffer seals will be obtained from the purification system. There are three charge pumps which will supply water to the seals. Only one pump will operate under normal conditions when the leaks are new. Two pumps will operate toward the end of seal life when flow through the seals increases. The standby pump starts automatically in the event of a pump failure or increased flow requirements.

This system also provides additional make-up water to the primary system when necessary. The make-up flow is controlled by the level indication from the pressurizer.

The buffer charge pumps, the booster pumps, the coolers, and the control valves will be located outside the secondary shield and will be accessible for maintenance.

(more)

PRIMARY PURIFICATION SYSTEM

This system removes impurities from the primary cooling water, consisting of dissolved and undissolved corrosion products, fuel and fission products from defective fuel rods and residual impurities in the make-up water.

The system is low pressure, and consists of two letdown coolers, two pressure reducing valves, three demineralizers and two filters. During the reactor operation, o.1 (approximately 20 gallons per minute) of the primary coolant is drawn from the system, cooled in the letdown coolers and depressurized by the reducing valves to 110°F and 50 psig; following pressure and temperature reduction the water is purified by the demineralizers and filters outside of the containment vessel. The three demineralizers have an estimated life of 50 days each. They will be used in sequence so as to allow the plant to operate 150 days before demineralizer replacement is required. Normally the purified water will be returned to the primary loop by the buffer seal system. However, a direct-charging line, with a regulating valve capable of passing a maximum of 60 gpm is also provided. This will permit a high rate of purification to continue even after reactor is shutdown, if necessary.

HYDROGEN ADDITION SYSTEM

This system maintains a minimum concentration of 20 cc/liter of dissolved hydrogen in the primary loop to scavenge oxygen liberated by irradiation of water in the core.

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COMPONENT WASTE AND DRAIN COLLECTION SYSTEM

This system collects all drainage that might be radioactive. This drainage may occur during initial fill and testing, normal shutdown, decontamination and emergency shutdown. Provisions have also been made to collect the floor drainage from the area inside the secondary shield in drain wells.

The system includes two pumps, a containment drain tank, four waste storage tanks, a laboratory waste tank and the associated valves and piping. The total tank capacity is 1,320.5 cubic feet.

There are provisions so that the waste in any tank can be sampled. After sampling, the contents of the tank may be pumped to either the aboard-ship stowage tanks or to dock facilities. Although the SAVANNAH will be equipped with overboard seachests for dumping the contents from the waste tanks at sea, this procedure will not be used until such time as an international agreement has been reached regarding the permissable level of radioactivity that may be discharged at sea. Normally, the waste collected in the drain system will be of very low radioactivity.

GASEOUS ADSORPTION AND WASTE COLLECTION SYSTEM

This system has two basic functions. First, it will collect the majority of the radioactive gases that could be released should a fuel cladding defect develop. Second, it will provide for the dilution of some gaseous activity in conjunction with filteration and release to the atmosphere at tolerable levels.

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The adsorption equipment operates on the vent gas from a stripping column located on the buffer seal surge tank. The gas is purified by combining any oxygen present with part of the hydrogen flow and by adsorbing the fission product gases on charcoal maintained at a reduced temperature (- 280 degrees F.)

Any uncondensable gases that are vented from the various systems are collected in a common manifold. The manifold gases will be discharged into the containment vessel or under proper environmental conditions to the stack at a point upstream of the filters. A radiation monitor on the discharge side of the manifold will provide an alarm if the activity released exceeds pre-set levels. Following the alarm the vents may be selectively closed to isolate the offending source and allow for some delay before release.

The secondary shield area will be continuously ventilated to prevent accumulation of activity. The containment will be purged prior to entry to dilute and remove possible accumulations of radioactivity.

SAMPLING SYSTEM

This system has three functions. First, it supplies representative liquid samples to indicate the effectiveness of the primary purification system. Second, it supplies liquid samples of the drains collected in the lab waste tank, the high - and low - activity waste storage tanks and the inner bottom tanks. Finally, it supplies a continuous flow of primary water to a fission product monitor and purified water to a radiation monitor.

PRIMARY RELIEF SYSTEM

This system prevents the pressure at any point in the nuclear portion of the plant from exceeding that for which it was designed and collects and condenses effluent that may be radioactive.

The effluent from all relief valves that vent potentially radioactive fluids is passed into the effluent condensing tank. This tank contains water which condenses the vapor. The uncondensable gas is handled by the gaseous waste disposal system. The condensed liquid is handled by the component waste and drain collection system. Since the heat and storage capacity of the effluent condensing tank may be exceeded in an extreme emergency, the tank is equipped with its own relief valve. The discharge from this valve will pass directly into the containment vessel.

INTERMEDIATE COOLING SYSTEM

The prime function of this system is to provide fresh water 95 degrees F to cool such components as the primary circulating pumps, the primary shield tank, the containment air conditioning unit, the letdown coolers and the gaseous waste collection system. It also provides an intermediate barrier between the primary system coolant and the sea water used in turn to cool the fresh water of the intermediate system. The system consists of two coolers (heat exchangers), two fresh water pumps, a surge tank, and the appropriate piping and valves.

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The fresh water removes the heat from the primary component and gives it up to the salt water through one of the two coolers. The salt water is then returned to the sea. It picks up no radioactivity during the heat exchange.

EMERGENCY COOLING SYSTEM

The purpose of this system is to remove decay heat from the core when all electrical power supplies----except the 300 kw, diesel generator----are inoperative due to an accident, such as collision,fire or flooding of the machinery space.

This heat extraction is accomplished by passing a portion of the primary coolant through a heat exchanger and then pumping it aack into the primary system. The heat is removed from the heat exchanger by salt water that is returned in a non-radio active condition to the sea. Salt water in this system is also used as an emergency supply to the cooling coils in the containment cooling system and also serves to cool the emergency canned pump.

RADIATION MONITORING SYSTEM

The function of this system is to determine the amount of radiation at selected points throughtout the ship and gives an alarm if the level becomes dangerous at any point. The system is designed to provide adequate protection for personnel and equipment associated with a nuclear-powered commercial merchant ship, yet afford the flexibility that may be required for future technical investigations.

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There are thirty-two monitoring points. Twelve of these points are monitored constantly, the remainder being scanned either automatically or manually as the operating conditions dictate.

The entire system is divided into the following general catagories:

(a) Fixed Health Physics Monitoring - There are three channels that make up this portion of the system. Channels #1 and #2 each handle six area detectors. These detectors monitor the environmental radiation level in the selected locations. In addition to indicating the radiation level, the monitoring panel provides a recording facility to maintain a permanent record.

Channel #3 covers three access detectors which determine the background level at points of entry into the containment or demineralizer compartment. These detectors indicate whether or not the compartment may be entered after reactor shutdown.

(b) Plart Functional Monitoring- This portion is comprised of five channels. Channel #4 consists of five detectors that detect any leakage of radioactive water from the primary system to the intermediate cooling water system. Channels #5 and #6 with one detector each, detect radioactive leakage into the secondary system. Channel #7, with one detector detects the presence of fission products in the primary coolant due to fuel element failures. Channel #8 detects radioactive material passing through the ion-exchangers which indicates that the exchange resin is depleted and must be renewed.

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(c) Waste Disposal Monitoring - This portion consists of eight channels, each channel has one detectr. Channels #9, #11, #13, and #15 will detect radioactive particles and Channel #10, #12, #14, and #16 will detect radiogas in the stack gas.

(d) Portable Equipment - The ship carries a complete set of portable equipment for measuring various forms of radioactivity throughout the ship.

(e) Film Tags - There are over 400 locations throughout the ship where film tags are installed to keep an accumulative record of radiation.

REACTOR SAFETY SYSTEM

The reactor safety system monitors signals from the nuclear and non-nuclear instrumentation to detect unsafe conditions and ititiates corrective action as necessary. Two modes of corrective action, scram and fast insertion, are initiated by the safety system depending upon the nature of the abnormal condition. During scram, all withdrawin control rods are rapidly inserted into the reactor core by hydraulic pressure. During a fast insertion, all withdrawn control rods are rapidly inserted at the maximum rate available through the electromechanical drive.

The reactor safety system is designed to protect the reactor from damage all during abnormal conditions except a major rupture in the primary system. The number of scram signals has been kept to a minimum consistent with the philosophy of reactor protection.

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To minimize spurious scrams, coincidence of unsafe indications from two indepandent instruments is utilized wherever possible.

The signals which initiate a scram during power operation of the reactor are:

(1) neutron flux greater than 130 maximum power;

(2) primary coolant temperature greater than 540°F;

(3) Primary system pressure less than 1,2000 psi;

(4) loss of power to all four primary coolant pumps;

(5) low hydraulic supply manifold pressure;

(6) reactor period less than three seconds;

(7) Operator action.

REACTOR PLANT BACKUP

During normal operation of the reactor plant, two 1,500 turbo-generators supply power to the electrical system. During this period, two 750 auxiliary diesel generators are on standby. In the event of reactor scram or emergency these generators will be automatically started and synchronized onthe main bus.

In addition the diesel generators can serve the following functions:

(1) Provide power for reactor startup;

(2) Provide spare generator capacity for normal operation;

(3) Provide power for decay heat removal after a scram or normal shutdown of the reactor;

(4) Provide power to the 750 hp "take-home" motor should the nuclear power plant fail.

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A 300 emergency diesel generator is provided to furnish power to the 450-volt emergency switchboard. This generator will operate only in an emergency in which both the turbo-generators and the auxiliary diesel generators are inoperable. Loads such as emergency lighting, the low speed windings of the primary coolant pumps and the emergency cooling system will be connected to the emergency switchboard.

A battery protected source is provided for supplying power to those loads requiring an especially dependable power source with no interruption due to loss or switching of auxiliary power.

Electrical loads associated with the nuclear plant may be grouped as follows:

(1) Battery protected loads

Those loads which cannot be interrupted by loss or switching of auxiliary power. Included are instrumentation, reactor control, and radiation monitoring system loads.

(2) Emergency Diesel Generator Protected Loads

These loads are so vital to reactor and ship safety that they must be maintained despite the loss of all auxiliary power. Included in this category are emergency lighting, emergency cooling system, and the low speed windings of the primary coolant pumps.

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(3) Auxiliary Diesel Generator Protected Loads:
These loads must be operable whenever power from the main turbo-generators is not available; e. g. during periods of reactor shutdown or turbo-generator failures. These loads include the primary coolant pumps, air conditioning fans, pressurizer heaters, buffer charge pumps, and the circulating pumps in the intermediate cooling system.

(4) Non-Critical Loads
These loads are not required for reactor cooling after shutdown. Also, their loss would not greatly affect the operation of the nuclear steam generator. These loads are tripped from the line in the event of a reactor scram.

ELECTRICAL PLANT

As most of the reactor auxiliaries and other vital auxiliaries are electrically driven, the electrical generating plant of the SAVANNAH is extensive.

Electric generating equipment consists of two 1,500 turbo-generators, two 750 auxiliary diesel generators and a 300 emergency diesel generator. The 300 emergency diesel generator is located on the Naviagation Bridge Deck and will supply power to the emergency switchboards when the main turbine generators and auxiliary diesel generators are inoperable.

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The turbine and auxiliary diesel generators, which are located in the machinery space, will supply power to the main switchboard.

The main generators consisting of two 1,500 turbo-generators located in the machinery space are rated at 450-volts, 3-phase, 60-cycles, and are capable of delivering a 25% overload for two hours.

Operation of the main generators is possible during periods of nuclear reactor operation and for a few minutes after reactor shutdown. During normal ship operation, power for the electrical system will be supplied by the main generators.

750 KW DIESEL GENERATORS

Two 750 diesel generators located in the machinery space are provided for the following functions;

(1) Provide power for reactor startup;

(2) Provide spare generator capacity for normal operation;

(3) Provide power to operate loads required for decay heat removal after a "scram" or normal (shutdown of the reactor; and

(4) Provide "take home" power when nuclear propulsion plant in inoperative.

300 KW EMERGENCY DIESEL GENERATOR

The 300 KW emergency diesel generator is located on the Navigation Bridge Deck. This generator will supply power to the emergency switchboard during times when both the main turbo-generators and the "standby" diesel generators are inoperable.

MAIN AND EMERGENCY SWITCHBOARDS

The main switchboard is divided into two sections and located in the Control Console Room. One turbo-generator and one diesel generator are connected to each section of the main switchboard and the two sections are connected by a normally closed circuit breaker. The primary function of the main switchboard is to control the generating equipment and distribute electrical power to all electrical equipment on the ship.

The emergency switchboard is located on the Navigating Bridge Deck where it can be used to control the emergency generating equipment and to supply power for vital loads during periods of emergency, either from the main switchboard or the 300 kw emergency diesel generator.

AUTOMATIC SWITCHING SEQUENCES

During normal operation, power for the electrical system will be supplied by the two 1,500 kw turbo-generators with the two 750 kw diesel generators on standby. The emergency switchboard in turn is normally supplied from the main switchboard by means of bus ties. During this period, occurrence of any one of the following conditions will result in automatic starting of the two diesel generators and automatic tripping of the ship's non-vital loads:

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(1) Overcurrent on either turbo-generators;

(2) Tripping of either turbo-generator breaker;

(3) Reactor scram; or

(4) Reverse power relay indication on either turbo-generator.

The "standby" diesel generators have a ten second startup capability and the first unit reaching rated voltage is automatically synchronized with the turbo-generators already in operation. Automatic paralleling of the second diesel then follows. The loss of all power from the main switchboard will result in automatic startup of the emergency diesel generator and the emergency cooling system.

GROUP CONTROL

The majority of the motor controllers for the electrical loads associated with the nuclear propulsion plant are grouped in marine group control centers. The group control centers are also divided into two sections like the split bus arrangement of the main switchboard. In order to maintain continuity of power to each section of the group control centers, even in the event of a main switchboard bus fault, automatic bus transfer equipment is provided at each group control center section.

INSTRUMENTATION MOTOR GENERATORS

Two AC/DC motor generator sets fed from the main switchboard have their output connected to a 125-volt DC bus. This bus is also supplied by a storage battery. During normal operation, the battery floats on the line and is maintained fully charged. This battery-protected source is provided for supplying power to the two 25kw DC/AC closely-regulated instrumentation motor generator sets. These latter motor generator sets supply power to those loads requiring an especially dependable power source, subject to a minimum of interruption and surges. The AC output of the sets provides the 120-volt, single-phade, 60-cycle power for the critical loads. Each motor generator set is capable of carrying the full demand load of the system it serves. Non-critical 120-volt power is supplied from the lighting bus on the main switch-board.

STEAM PROPULSION SYSTEM

The major components of the propulsion system have been supplied by the De Laval Steam Turbine Company. In this system, saturated steam supplied from the reactor system is expanded through high and low pressure turbines between which s moisture separator serves to reduce the final exit moisture and losses. The turbine drives the main shaft through a double reduction gear. The main condenser is of welded tube-sheet construction and designed for 28.5 inch vacuum at 75 degrees F sea water. The feed water system consists of three feed water heaters with turbine driven main feed pump and motor driven port feed pump. Two 1,500 kw steam turbine generators, each with its own condenser, provide power for all propulsive and ship's service auxiliaries. A low pressure (150 psi) heat exchanger type steam generator of 7,500 lb/hr capacity provides steam for ship's hotel services and cargo heating and air conditioning.

Each of the three condensers has a baffled vestibule at each end in which the condensation can be isolated and separately drained if the salinity detectors indicate a leak through the adjacent tube sheet. This provides extra protection against chloride stress corrosion in the boilers.

For emergency take-home power, a 750 hp electric motor has been provided which can be coupled to the main turbine through the main gearing. Two 750 kw diesel generators, designed to start automatically upon failure of either turbine generator, will insure reliable power for reactor heat removal after shutdown, and will also provide sufficient power for the take-home motor and other essential ship's electrical load. One 7,500 lb/hr oil-fired package boiler will provide 150 psi pressure steam for the emergency heating requirements.

DESCRIPTION OF MACHINERY SPACE

The steam propulsion machinery space is located aft of the nuclear space between Frames 126 and 148. This space is 55 feet long and 78 feet wide and extends from the tank top to "C" deck, a distance of 32 feet. This space contains all of the major machinery required to propel and service the ship. An observation gallery is located at "C" deck level that permits viewing of the machinery space.

The following is a highlight description of the major

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equipment located in the machinery space. No attempt has been made to include in this listing the many smaller auxiliary units which are required to complement major components.

MAIN TURBINES AND REDUCTION GEARS

The turbine is located on the center line of the ship in the machinery space and drives a single propeller through the main reduction gear at 107 rpm when delivering 20,000 shp under normal power conditions. The unit is also capable of continuous operation when developing 22,000 shp at about 110 rpm under maximum power conditions.

The turbine system consists of a high and a low pressure turbine, with a crossover line and moisture separator located between them. The power, and connection to the reduction gear, is divided approximately equally between the high pressure and low pressure turbines at full power.

The turbine nozzles are divided into groups for the purpose of obtaining best efficiency at varying speeds of the ship. The main nozzle group will be controlled by the main throttle valve. Each other group of nozzles will be controlled by the throttle valve but will have, in addition, separate hand-operated nozzle control valves built into the turbine casing. The propulsion equipment for this vessel was designed and built by the De Laval Steam Turbine Company of Trenton, New Jersey.

The astern turbine is an integral part of the low pressure turbine; when turning astern at 50 percent of the normal ahead rpm, it will deliver at least 80 percent of the normal ahead torque.

The main reduction gear is fitted with a suitable connecting arrangement so as to permit the operation of the ship by means of a 750 hp electric motor as an emergency measure. The motor will not be engaged until the shaft is not rotating.

LUBRICATING OIL SYSTEM

The lubricating oil system consists of two service pumps, one purifier heater, one purifier, and two coolers.

This system furnishes the lubricating oil for the main turbines, reduction gears, and main turbo generators.

The lubricating oil service pumps are of the rotary type driven by a 40 hp motor with a capacity of 500 gpm.

MAIN CONDENSER

There is one main condenser of the single pass reheating type, installed in athwartship position and bolted directly to the turbine exhaust.

Scoops deliver circulating sea water at normal and maximum ahead operating conditions. For astern operation, maneuvering, and slow ahead speeds, the necessary water is furnished by the main circulating pump.

MAIN CIRCULATING PUMP

There is one main circulating pump, mounted vertically.

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It is of the mixed flow, single stage type driven by a 150 hp motor with a capacity of 20,000 gpm.

FEED AND CONDENSATE SYSTEM

The steam generator feed system is a closed feed system and will folly de-aerate all of the feed water. It consists of condensate pumps, air ejectors with inter, after and gland exhaust condensers, low pressure feed heater and drain cooler, direct contact de-aerating heater with vent condenser, main feed pumps, high pressure feed water heater, steam generators, regulators, traps, thermometers, and other necessary equipment for complete and efficient operation.

MAIN FEED PUMPS

There are two main boiler feed pumps each driven by a horizontal single stage turbine mounted on a bedplate common with its pump. The normal operating conditions should be about 650 gpm for the main feed pumps with steam conditions of 430-480 psia pressure.

MAIN CONDENSATE PUMP

There are two main condensate pumps which will be mounted vertically. Each is of the two stage centrifugal type, driven by a 40 hp motor with a capacity of 285 gpm.

DE-AERATING FEEDWATER HEATER

The de-aerating feed tank is of the direct contact spray type with a fixed orifice designed to keep the oxygen content

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to a minimum over the complete range of operation. Water leaving the heater will contain dissolved oxygen not exceeding 0.005 ml/liter. The heater will have a normal outlet capacity of 242,200 pounds per hour at 269 degrees F.

LOW PRESSURE FEED HEATER

There is one low pressure feed heater of the horizontal straight tube closed type. It has a normal feed flow of 170,000 pounds per hour at an outlet temperature of 200 degrees F.

HIGH PRESSURE FEED HEATER

There is one high pressure feed heater of the horizontal straight tube closed type. It has a normal feed flow of 242,200 pounds per hour at an outlet temperature of 347 degrees F.

MAIN AIR EJECTORS

There is one main air ejector of the twin element, two-stage type mounted on a combined inter and after and gland seal leak-off condenser of sufficient surface to serve both ejector elements operating together. This combined unit has a capacity of dry air removal of 33.8 lb/hr and a capacity of air vapor removal of 108.8 lb/hr at a steam consumption of 500 pounds per hour.

LOW PRESSURE STEAM GENERATOR

A low pressure steam generator furnishes auxiliary and ship's service steam. Steam from the main steam drum is bled to the low pressure steam generator to produce this steam at a pressure of 150 psig.

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The low pressure steam generator will supply steam to the following:

(a) Lubricating oil heating services;

(b) Ship's steam heating system (through a reducing valve set at 35 psi);

(c) Domestic fresh water heater;

(d) Galley services;

(e) Cargo conditioning and heating requirements; and

(f) Cargo refrigeration defrosting heater.

These systems will also be provided with an emergency supply from the emergency package boiler for use when the low pressure steam generator is shut down for cleaning or repairs.

EMERGENCY PACKAGE BOILER

A small emergency oil-fired package boiler is supplied to furnish heating steam for living quarters and auxiliary steam to operate the fire pumps. Additional steam is to be used from this package boiler to operate the air ejectors for the main condenser in order to maintain a vacuum on the main turbine.

This boiler will not be kept on the line during normal conditions, but will be used in event of reactor shutdown or failure of the low pressure steam generator.

DISTILLING PLANTS

There are two complete distilling plants, each consisting of a low pressure, multiple-effect evaporator, distilling condenser, feed pumps, drain pump, brine pump, distillate pump and other necessary equipment for the distillation of sea water

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to be used for potable drinking water, washing, and culinary water.

The distillers also furnish all primary and secondary make-up water for the power plant via the ion exchangers.

Each distiller has a capacity of 16,000 gallons of water a day with a maximum of 0.25 grains of sea salt distillate per gallon.

REFRIGERATION AND AIR CONDITIONING

The refrigeration system consists of two compressors, two condensers, and two receivers, and other necessary equipment necessary for efficient operation.

This system furnishes all of the refrigeration requirements for the ship's stores, ice water, and two brine chillers which in turn cool all galley boxes, mess rooms and bar.

The capacity of the compressor units are 10.6 tons each. They are driven by a 50 hp motor.

The air conditioning plant consists of a self-contained package unit. This unit is capable of maintaining a constant chilled water temperature of 42 degrees F within plus or minus one degree F.

The capacity of this plant is 210 tons refrigeration which services all passenger and crew areas, electronic areas, and nuclear control areas.

TURBO-GENERATORS

There are two turbo-generators, each driven by a geared turbine. Each turbine will develop sufficient power for a continuous generator output of 1,500 kw, 450-volt, three-phase, 60-cycle alternating current and 25 percent overload for two hours when supplied with 415 psi pressure at the turbine throttle and exhausting to a condenser at 29 hg (mercury) vacuum.

MAIN CONTROL ROOM

The Main Control Room is located in the upper level of the machinery compartment just aft of the propulsion units. This space is responsible for the safe operation of the ship's entire power plant much in the same manner as the Pilot House is responsible for the safe navigation of the vessel. Access to this area is by stairways down from "C" deck and doors at both ends leading directly into the engine room. In addition, the bulkhead common with the engine room is fitted with large, double-thickness glass windows to permit observation of the main control console from the visitors gallery and the machinery space. Likewise, the console operators can visually monitor the engine room situation at all times. This arrangement minimizes some of the uneasiness associated with the remote operation of large machinery units without being able to see what is going on.

The operating areas of the control room are air conditioned. The overhead ceiling is of translucent plactic material with illuminated sections. All visible surfaces are finished in distinctive color combinations.

The major components contained in this compartment are:

(a) Central Control Console and associated auxiliary cubicles;

(b) Main Electric Power Generator and distribution switchboard;

(c) Radiation Monitoring Cabinets;

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(d) Reactor Control and Safety Cabinets; and

(e) Television Equipment for monitoring the reactor plant inside of the containment vessel.

The main control console is a nerve center whose primary function is to monitor, display and control all the essential functions pertaining to the ship's nuclear reactor, propulsion system, and electrical power plant including related auxiliary systems. While the main control console is physically a single unit, functionally it is divided as follows when facing the operating, indicating and recording surfaces.

(a) Left Wing Panel and Desk:
These areas include switches, lights and position indicating gages for establishing the initial non-critical positions of all 21 nuclear Reactor control rods.

(b) Left 450 Angle Corner Panel and Desk:
These areas contain operating and indicating elements for temperature, pressure, flow, level, conductivity and pH to produce maximum control of desired efficiencies from the

(1) Primary Purification,
(2) Buffer Seal,
(3) Intermediate Cooling Water,
(4) Pressurizer (Operation only),
(5) Pressure Relief, and
(6) Containment Vessel Cooling and Pressure.

Control and indicating elements for systems, Items

(c) Left Center Panel and Desk:

The upper 75 percent of this panel includes a graphic presentation of indicating and controlling elements for conditions listed under Item (b) above with the exception of conductivity and hydrogen-ion consentration (pH). Measurement is not necessary for maximum efficiency production by the following systems:

(1) Primary (reactor water system),

(2) Secondary (steam system, indicating only), and

(3) Pressurizing (indicating only).

The lower 25 percent of the Left Center Panel and Desk includes all elements for final control of the Nuclear Reactor control rods. Gages are also included in this Console section to show the position of individual rods, or of groups of rods. The other gages show power level and period.

Switches are included to operate rods individually or in groups and to choose which group sequence is desired.

Other switches located here, can deactivate individual rods or groups.

A switch is provided for travel speed of individual rods or groups.

Three major switches are the:

(1) "Start-Run" switch, employed after desired sub-critical rod positions are realized and the reactor is about to become critical;

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(2) The "Fast Insertion" switch used to temporarily decrease reactor power output while overcoming small maladjustments; and

(3) The "Scram" switch to fully insert all rods and totally deactivate the Reactor power output. This switch is used only when major system piting is ruptured, main pumps fail, ship is in collision, etc.

(d) Right Center Panel and Desk:

The upper 75 percent of this panel includes a graphic presentation of indicating and controlling elements for conditions listed under (c) above for the following systems;

(1) Secondary System and Condensate Systems, and

(2) Secondary System and Propulsion Units.

The lower 25 percent of this panel contains the Central Control Room, Engine Order Telegraph with two selector switches for receipt of signals from the Navigating Bridge or Stern Docking Bridge. In addition, the Shaft Revolution Counter is located in this area.

The Right Center Desk includes the Master Main Throttle Unit which automatically operates the "Forward", "Astern" and Guardian valves from this one point by the operation of a single lever---forward from dead center for "Forward" and aft from dead center for "Astern", dependent on orders from the Engine Order

Telegraph just above on the Right Center Panel. This desk portion also includes additional push buttons and lights for the operation of miscellaneous Secondary Steam-Propulsion pumps and valves.

(e) Right 45o Angle Corner Panel and Desk:

The upper 75 percent of this panel contains a graphic presentation of the ships main electrical distribution system buses, transfer switches, breakers, transformers, voltmeters and ammeters.

The lower 25 percent of this panel contains push buttons for operation of the Main Propulsion Injection Valve, Circulation Pump Suction Valve, Pump and Overboard Discharge Valves.

In addition, this panel section includes level, pressure and temperature indication for the following systems:

(1) Equipment Drain and Waste (tanks),
(2) Lubricanting Oil,
(3) Salt Water Pumping,
(4) Low Pressure Steam Generation,
(5) Diesel Generator (air starting),
(6) Auxiliary Condensate,
(7) Instrument Air Supply, and
(8) Air Ejection.

The Right Angle Desk includes push buttons and indicating lights for the desired operation of valves, pumps, etc., integral with the eight above systems as listed above.

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(f) Right Wing Panel and Desk:
With one exception, the Emergency Cooling System, main switchover push button, this console area includes all necessary pressure and temperature indication and operating control for the Gaseous Waste and Disposal System. The purpose of this system is to decontaminate any gases created throughout the ship's piping and pumps and certain areas directly or indirectly in contact with the reactor fission products.

General:

(A) Each of the six above panel-desk sections includes a push button, the purpose of which is to energize all indicating light circuits on that particular section for "Failure" check.

(B) Total number of control and indicating items for all systems included on the Main Console are as follows:

20 - Flow Indicators
15 - Level Indicators
100 - Indicating Lights (lights only)
55 - Meters, all types such as rod position, reactor power level and period, volt and ampere meters.
45 - Pressure Indicators
2 - Conductivity Indicators
1 - Hydrogen-ion concentration pH Indicators

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120 - Push Buttons (20% Illuminated)

60 - Selector Switches

35 - Temperature Indicators

31 - Valve Selector Switches

An annunciator section extends over the top of the entire console. These annunciator sections are identified with the systems located on the panels and desk sections directly below.