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N. S. SAVANNAH - PORTENT OF THINGS TO COME

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Two weeks from today the world's first nuclear-powered passenger-cargo vessel will have resumed the program of port visitation which was interrupted last year. Two months from today she will be about to enter the harbor of the first European port of call on her scheduled foreign cruises to demonstrate the peaceful use of the atom. This demonstration of the interest of the United States in developing peaceful uses of Atomic Energy was the principal reason for construction of Savannah, and is still one of the main functions she fulfills, but Savannah has proven to be far more than a mere demonstration "show boat," as I hope to be able to indicate to you shortly. One of the many hurdles she has successfully cleared to date has been the resolution of labor difficulties which beset her during her early operations, and which made necessary the training of a completely new crew under a newly authorized operating agent, American Export and Isbrandtsen Lines. This crew has been trained and licensed to operate the reactor plant and the ship; successful sea trials have been completed, and the port visitation program is re-commencing. I should add here that the labor difficulties mentioned were entirely divorced from the nuclear power aspect of Savannah's operation.

Fig. 1. shows the Savannah at sea shortly after her launching in July, 1959. The ship is a sheltered-deck vessel of modern design with a raked stem and modified cruiser stern. She is 595.5 ft. in length overall, with a molded beam of 78 feet and a design draft of 29 ft. 6 in.[1] The ship fully loaded displaces approximately 22,000 tons, of which about 10,000 tons is cargo. Her sustained speed at design draft is 20½ knots while developing 20,000 shp under normal conditions. The ship has 10 transverse, water tight bulkheads which divide it into eleven compartments; 7 holds, 2 peak spaces, a reactor compartment, and an engineering machinery space.

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The ship's complement is: 60 passengers,
102 officers and crew,
22 supernumerary.

The main propulsion unit for the ship is a pressurized water nuclear reactor generating 80,000 KW of heat at full power, located in the area of the ship slightly forward of the superstructure and aft of the 4 forward hold spaces.

Fig. 2, is a view of the nuclear reactor plant as seen through a cutaway through the shield and containment vessel. The uranium oxide-containing fuel elements, slightly enriched in uranium-235, are located in a roughly cylindrical core inside a 6½" thick reactor pressure vessel, and coolant water is flowed through the core and pumped through two closed loop at 1735 psig pressure and 508° F. Steam is formed on the secondary side in the heat exchangers and steam drums, and sent on to the propulsion turbines. The illustration shows the concrete biological shield located around the lower portion of the containment vessel and the lighter weight lead and polyethylene shielding over the top portion. The containment vessel itself is designed to remain intact with an internal pressure of 175 psig, thus restricting any radioactive products of an accident to the confines of the containment vessel. I would like to emphasize, however, that the Savannah reactor, like the navy's shipboard reactors, was designed as a low-enriched, pressurized water reactor because of the proven safety and reliability of this kind of machine. Two things in particular are important to remember in this respect:

(1) A reactor of the type installed on Savannah has a negative temperature coefficient and a doppler coefficient which make it tend to be self-regulating. Any sudden rise in power is automatically "damped" by the resulting rise in temperature of the coolant water, and of the fuel itself, tending to again reduce the power. For example, some Savannah fuel was safety-tested at the National Reactor Testing Station in Arco, Idaho in an attempt to determine the damage from sudden very large power increases. It was found that when control rods were removed so fast that reactor power was increasing by more than a factor of 100 every tenth of a second, the reactor shut itself down before the fuel heating could melt the steel cladding of the fuel pins and permit fuel or fission products to escape.

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(f) It is impossible for the low enriched Savannah core to have a reaction like an atomic bomb. The worst that could happen would be loss of primary coolant water with failure of auxiliary core cooling arrangements so that the core would overheat and melt, releasing activity to the shielded containment vessel. For this circumstance, even under the worst assumed conditions, the plant has been designed to prevent physical injury to the crew of the ship or to the general public.

Fig. 3.[2] shows the general arrangement of the lead used over the top of the containment vessel. Lead thickness varied from about 5¼" to 6" due to location of the two water coolant loops inside the vessel. The lead was applied in pre-molded slabs of maximum thickness 2" and built up to the required thickness.

Fig. 4.[2] is a construction detail showing the manner in which the lead was held in place. The large stud bolts were welded to the containment vessel. Lead slabs were laid around the studs through holes in the lead, and lead calking was then used to fill in the holes around the studs. The lead was thus supported by the containment vessel and held in place by the studs and washer and nut arrangement. Polyethylene was held by stud extension pieces and was nailed in place as well. The function of the lead was primarily to reduce the gamma ray dose rate to below design levels. The polyethylene serves as a fast neutron shield, and its presence makes the lead more effective as a fast neutron shield also. The shield survey[3] made by Oak Ridge National Laboratory personnel with the reactor at a constant 69 MW power showed the shield to be adequate in all respects in maintaining dose rate levels below the design maximums. The shield was, however, designed very close to minimum thickness, since dose rates observed were within a factor of one-half to one-fourth of those calculated on decks "C", "B", and "A" in many locations. This represents little or no change in the thickness of lead specified.

The lead for the secondary shield was furnished by Federated Metals Division of American Smelting Co., Perty Amboy, N.J. and was molded to fit the containment vessel at New York Shipbuilding Corp., Camden, N.J. Lead applied to the primary shield was furnace bonded to steel primary shield tank walls and supplied by Knapp Mills of Wilmington, Delaware.

Before leaving this description of the Savannah, I would like to mention briefly some of the unique features and programs developed by our first mobile nuclear reactor - some of the significant achievements of Savannah. Besides demonstrating the feasibility and safety of nuclear power in merchant ship applications, she has done the following things:

(1) Produced, through the AEC-Maritime Administration Joint Group program administration, a nuclear ship engineering support organization, the Savannah Technical Staff, with nuclear hardware support facilities at Todd Shipyard in Galveston, Texas. This staff is under the direction of the nuclear plant designer, The Babcock & Wilcox Co.-Atomic Energy Division, and includes experienced senior engineering personnel of both Todd and B&W.

(2) Produced cadres of trained and experienced design engineers, nuclear plant maintenance personnel, training staffs, and shipboard deck and engineering personnel.

(3) Gained acceptance for, and established much of the basis for acceptance of, nuclear powered vessels in many foreign nations and in both foreign and domestic ports.

a) Standards and criteria for port operation.

b) Insurance availability and third party liability coverage.

(4) Developed a "double-containment with filtered leakage" concept which provides an extremely high degree of plant integrity and protection for the general public, and combined this with sophisticated leakage testing techniques.

(5) Lastly, Savannah has shown the way to new and improved "second generation" nuclear power plants designed specifically for shipboard use.

I have mentioned some of the things Savannah can do and has done, but there is one very important thing she has not done. That is to demonstrate the economic feasibility of nuclear power. Obviously, in this first-of-a-kind maritime reactor with the emphasis on conservative design and proven technology, economy could not be (and was not) a design objective. The things Savannah has accomplished are quite enough justification for her existence, and without her the economically competitive nuclear maritime plants could not be as near at hand as they are today.

Savannah's re-emergence into the limelight of public attention comes at a time when there is reawakened interest in the nuclear powered ships for which she is a trail-blazer. This interest is by no means confined to the United States. The Government of Germany, through and with the Euratom organization, has selected an advanced maritime pressurized water reactor, the CNSG concept developed by The Babcock & Wilcox Company, as the reactor for an ore-carrier vessel now under construction. The government of Japan and that of Great Britain have serious studies under way to choose the most suitable reactor type for their purposes, and in this country a very high degree of interest has been aroused by the recently developed consolidated nuclear plants with much abbreviated volume, weight, and auxiliary system design.

Before making any further mention of the "new generation" of reactors, however, let us examine a fundamental question. "Of what real benefit are nuclear powered ships when oil fueled ones are hauling our cargo satisfactorily?" There is only one meaningful answer to that question: dollar economy. It is true that with nuclear powered ships we can steam for many years and many thousands of miles without refueling, and that we eliminate the storage required for fuel oil. (The Savannah has logged over 30,000 nautical miles while using up only about 10% of her first core to date.) These facts, combined with high power operating requirements, make nuclear power very attractive to the navy. But we know that to compete in the Maritime industry we must offer an economically attractive propulsion plant while writing off the higher initial cost of a nuclear system. A