Safeguards for Crew Members of the Nuclear Ship "Savannah"

by

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On 13 May 1958 the 41st (Maritime) Session of the International Labour Conference unanimously adopted a resolution calling upon the Governing Body of the International Labour Office " to study... the problems created by the application of atomic power to shipping in so far as the protection of the crew is concerned ". The following article describes in detail the safety features incorporated in the design of the N.S. Savannah, *scheduled to be commissioned in the United States early in 1960, as well as the special operating and training procedures evolved to protect crew members and others concerned (e.g. passengers, dock and port workers, etc.) from the risks inherent in atomic-powered vessels.*

The N.S. Savannah, *it will be observed, is not designed primarily for economic operation but rather in order to provide practical experience,* inter alia, *in safety procedures and to promote the international acceptance of this new mode of propulsion.*

The United States Nuclear Ship Programme

In April 1955 President Eisenhower first suggested the construction of a nuclear-powered merchant ship as a demonstration of the peaceful uses of atomic energy. In the following year the United States Congress passed legislation which made this construction possible and on 15 October 1956 the nuclear ship programme was initiated.

In undertaking this programme the United States Government also has a broader aim—to build an economic fleet of merchant

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ships. While it is known that the first vessel with nuclear power cannot attain competitive operation, it is intended to use this first ship to learn the practical economics of construction and operation. A major facet of this experimental operating period will be the manning requirements of nuclear vessels and this article will attempt to demonstrate that a trained crew can safely and efficiently operate a nuclear ship without substantial changes in regulations or working conditions.

In order to take advantage of the talents of two governmental units a Joint Group, drawing its members from both the Maritime Administration and the Atomic Energy Commission, was created to administer the programme. Actual construction, testing and operation, however, are being performed by private contractors to whom frequent reference will be made in the remainder of this article.

The principal contractors associated with the *N.S. Savannah* are George G. Sharp, Inc., naval architects ; the Babcock and Wilcox Company, builders of the reactor ; the New York Shipbuilding Corporation, builders of the vessel ; and the States Marine Lines, general agents for operation of the vessel.

Three government agencies (other than those in the Joint Group) and one private association are directly involved in the programme.

Of the government agencies the U.S. Coast Guard has a major regulatory function in the construction, manning and operation of the ship ; the Public Health Service has regulatory functions related to safe health and medical care procedures on the ship ; and the Advisory Committee on Reactor Safeguards of the Atomic Energy Commission performs a thorough examination of the reactor construction and operating procedures on behalf of the Commission in order to ensure the safety of the crew, the passengers and the public.

The private association which performs ship classification for insurance and other purposes is the American Bureau of Shipping ; this association employs resident inspectors in the shipyard and at the propulsion plant manufacturing site to ensure that construction adheres to design standards.

Safeguards for the crew are built into the ship and are further enhanced by specialised training courses for engineering and deck officers and the medical staff, as well as orientation courses for the remainder of the crew.

In most of the following, emphasis will be placed on safety features incorporated into the vessel and the operating procedures to be used on the ship. Finally a word will be said about international acceptance of nuclear ships.

Ship Description

The *N.S. Savannah* is a single-screw passenger-cargo ship with a raked stem and modified cruiser stern.[1] It has three complete decks, and platform decks at various levels. Passenger staterooms are on the " A " deck ; public rooms and the swimming pool are on the promenade deck which extends over " A " deck for about one-third of the ship's length.

The hull is subdivided by a total of ten watertight transverse bulkheads into peak spaces, seven holds, a machinery space and a reactor space. At load draft of 29 ft. 6 in. (9 m.) in salt water, the *N.S. Savannah* is designed for a total deadweight of 9,990 tons.

Power Plant and Propulsion System

The power plant is made up of a primary system (a reactor located amidships within a cylindrical containment vessel)[2] and a secondary system (comprised of the main turbines and reduction gears, the main condensers, the feed water system, the turbine generators to supply propulsive auxiliaries and ship's hotel load, and the auxiliary diesel generators and auxiliary boiler to supply the ship's needs when the reactor is shut down). The propulsion system is located in the 60 ft. (18.3 m.) long machinery compartment just aft of the reactor system compartment and below the superstructure.

All equipment and systems in this power plant are designed to function properly with the ship at a permanent list of 15° or a permanent trim of 5°. The equipment will also function normally and satisfactorily during a condition of continuous oscillating roll of 30° from vertical to each side with a roll period of approximately

[1] Principal characteristics are as follows :

Length (over all)	595 ft. (181 m.)
Beam	78 ft. (23.8 m.)
Depth to promenade deck	59 ft. 9 in. (18.2 m.)
Capacities :	
General cargo (bale cubic at 77 cu.ft. per ton)	727,000 cu.ft. (20,586 cu.m.)
Passengers (one class)	60
Speed and power :	
Normal power speed	21 knots
Normal power to shaft	20,000 h.p.
Maximum continuous power	22,000 s.h.p.

[2] A portion of the reactor system auxiliaries, such as the primary water demineralisers, filters, charge pumps, drain tanks and gaseous waste collection system, will be located in the reactor compartment outside the containment vessel but within the secondary shield provided by the bulkheads.

14 seconds and a continuous oscillating pitch condition of 7° from the horizontal up and down by the bow, with a pitch period of approximately 7 seconds.

Equipment in this plant is designed to comply in all respects with applicable statutes, rules and regulations of the U.S. Coast Guard, the American Bureau of Shipping, the Public Health Service and the Atomic Energy Commission.

Reactor Characteristics and Containment Vessel

The reactor is moderated and cooled by light water at 1,750 lb./sq. in. (123 kg./sq. cm.) above atmospheric pressure at a temperature of 508°F (265°C) and fuelled with uranium oxide of about 4.4 per cent. enrichment, which is clad in stainless steel rods. The active core is a cylinder 62 in. (157.5 cm.) in diameter and 66 in. (167.6 cm.) high containing 32 fuel elements arranged in an " egg crate " type lattice. Reactivity control is provided by 21 cruciform control rods of boron and stainless steel. The core is designed for an operating life of approximately 52,200 MW/days or three years of normal operation.

An extensive experimental programme has been developed to verify the assumptions upon which the reactor core is designed. The confirmatory physics measurements are being conducted at the Babcock and Wilcox laboratories, the hydraulic and mechanical tests at their Alliance Research Centre, and the irradiation testing portion at the National Reactor Testing Station and at General Electric Company's Vallecitos Laboratory.

As noted above, the containment vessel serves principally to surround the whole primary reactor system so as to provide complete containment of any radioactive matter that might escape from the system. It is a welded cylinder with hemispherical heads and an inside diameter of 35 ft. (10.67 m.) and length of 50 ft. 6 in. (15.40 m.). A cupola, 13 ft. 6 in. (4.12 m.) in diameter and 16 ft. 6 in. (5.03 m.) high, on the vessel houses the control rod drive mechanism. A hatch at the top of this cupola provides access for refuelling and servicing the reactor. Two other hatches on each side of the cupola provide access to the components outside the reactor vessel but inside the containment shell, such as pumps, valves, condensers, etc.

The containment vessel will be sealed at all times during plant operation and is designed to withstand the instantaneous release and expansion of the entire contents of the primary system. No high-pressure, high-temperature piping containing the water of the primary system will be permitted to penetrate the containment vessel. Other penetrations for wiring or piping are designed to withstand the containment design pressure and the number of such penetrations is kept to an absolute minimum.

Normally no entrance to the containment will be permitted until the plant has been shut down, the air in the containment vessel has been purged, and the radiation level has been reduced to a maximum of 200 millirem [1] per hour. (See the table below.) It has been designed according to the best engineering practice and subject to the approval of the U.S. Coast Guard and American Bureau of Shipping. In general the design is in conformance with the unfired pressure vessel code of the American Society of Mechanical Engineers.

Electrical System

The electrical system is designed to provide a high degree of reliability so as to ensure safety both when the reactor is in operation and when it is shut down. Power will be supplied by two 1,500 kW turbine generators either of which will automatically take over all vital loads if the other fails.

Two auxiliary 750 kW diesel generator sets in the engine room supply power for decay heat [2] cooling for the reactor after scram [3] or shutdown and power for reactor start-up and emergency " take-home ".[4] Although normally on standby, these generators are started automatically and each can supply all necessary emergency power and " hotel " services.

A third source of power to remove decay heat and provide emergency power is a 300 kW diesel generator located above the bulkhead deck, which is connected to the 450-volt emergency switchboard. Thus, should the main turbine generators and auxiliary diesel generators become inoperable, emergency lighting, 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 (such as instrumentation) where no interruption due to loss or switching of auxiliary power is tolerable.

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[1] The rem is a unit of radiation dose taking account of the biological effects.

[2] When a reactor is used to produce power by the controlled fission of uranium-235, radioactive fission products are formed in the reactor core. On shut down, these fission products continue to decay radioactively. The released radiation heats the reactor core, which must then be cooled until decay has reduced heat generation to a lower rate.

[3] Rapid reactor shut down.

[4] A special safety feature of the *N.S. Savannah* is provision of a 750 h.p. electric motor, which may be coupled to the reduction gears and used to propel the ship, if it is necessary to shut down the reactor for any reason.

The electrical system has been described here in some detail to indicate the engineering standards incorporated into the *N.S. Savannah.* These alternative systems provide ample flexibility to permit the crew to make repairs without putting the ship out of service.

Control Instruments

For the crew the most important new element on the ship will be the nuclear instrumentation system. This system consists of ten neutron flux measuring channels that (in four measuring ranges) cover the entire flux range of the reactor from the initial starting power to 150 per cent. maximum power. Neutron flux information is supplied to the reactor operator and to the automatic control and safety devices. The system is designed to provide maximum reliability and safety with a minimum of false reactor shutdown. A carefully planned procedure for testing before the reactor is started up and a schedule of weekly maintenance testing by the reactor operator will assure proper adjustment and calibration of the system. Here again minimum responsibility is placed on the crew ; to accomplish most of these tests built-in test equipment is provided in a meter and test panel, which not only tests and calibrates but detects and locates faults.

The reactor of the *N.S. Savannah* is sufficiently flexible to permit either automatic or manual control : either control mode may be used in normal cruising, whereas only the automatic control mode can be used during docking, emergency or other manoeuvring. Whatever the mode, reactor operators will be at the control console continuously to obtain the safest and most efficient reactor operation. Thus, the 21 power-control rods may be moved up and down, individually or in groups, to meet the thermal demand placed on the steam system under all operating conditions.

Radiation Monitoring System

Closely associated is the radiation monitoring system which provides protection for all aboard ship and for the nuclear power plant itself.

The ship will have 25 fixed monitoring points. Six will be monitored constantly, the remainder being scanned either automatically or manually as operating conditions dictate. The main radiation indicator panel will be located within the ship's main control room. Each channel will transmit the radiation level seen by its detector ; an alarm is sounded by an audible and visible signal at the control console and the monitoring panel when the detected radiation exceeds the pre-set permissible level. An auxiliary monitoring panel containing radiation indicator lights for each channel will be located in the " health physics " office for the convenience of the ship's physician. In the selection of monitoring points the locations chosen were those of greatest proximity to the reactor containment accessible to crew members and others during normal operating times.

The special systems monitoring the operation of the nuclear power plant (5 channels, 7 detectors) and the disposal of wastes (3 channels, 3 detectors) are designed to detect faults in the operating system and to indicate the necessity for modification of operating procedures or for maintenance and repairs. For example the gaseous wastes discharged through the radio mast are monitored through 2 channels and 2 detectors, so that proper control of these wastes can be assured at all times under all weather conditions.

Disposal of Radioactive Wastes

The general principle for the collection and disposal of radioactive wastes in the *N.S. Savannah* is to contain all solid, liquid and high activity gaseous wastes for dockside transfer.

Low-activity gaseous wastes, such as the voids in the liquid waste storage tanks, can be discharged at sea with dilution from a 1,500 cu.ft./min. (42 cu.m./min.) fan. The air in the containment vessel is purged periodically according to a fixed schedule. All discharges of gaseous wastes will be at concentrations well below those specified in the National Bureau of Standards Handbook 52 for continuous lifetime exposure.

Shielding and Design Dose Rates

A primary shield surrounding the reactor pressure vessel attenuates the core neutron flux to such an extent that materials outside this shield will not undergo sufficient neutron interaction to become important sources of gamma radiation. It also shields fission product decay radiation emanating from the core. The primary shield reduces induced gamma radiation originating in the reactor pressure vessel and insulation cover, permitting safe access to the interior of the containment after shutdown.

The secondary shield which is attached to the outside of the 35 ft. (10.67 m.) diameter containment vessel consists of lead, polyethelene and concrete of sufficient thickness to reduce reactor and coolant radiation doses to the levels specified in the accompanying chart, which applies equally to crew and dockside personnel. It may be noted that the recommendations of the International

Commission on Radiological Protection and the National Committee on Radiation Protection relating to occupational exposures set a maximum permissible limit of 3 rem cumulative exposure per 13-week period or 5 rem exposure per year.[1] Should this level be reached, which is unlikely, the employee will be transferred to other duties for the remainder of the quarter or year.

DESIGN DOSE RATES IN THE " N.S. SAVANNAH "

Location	Operating conditions	Type of access	Whether controlled area	Design dose rate
1. Nearest point of access by passengers	50 MW power operation. No fission product activity in primary loop	Normal	No	500 millirem/ year
2. Nearest accessible crew spaces	50 MW power operation. No fission product activity in primary loop	Normal	Yes	5 rem/year
3. Areas outside secondary shield wall (crew work spaces)	50 MW power operation. No fission product activity in primary loop	Limited	Yes	100 millirem/ week
4. Cargo holds	1/5 maximum power. No fission product activity in primary loop	Normal	No	500 millirem/ year
5. Inside containment	Reactor operating	None permitted	Yes	
6. Inside containment	Reactor shut down half an hour or longer, with fission products removed from primary loop	Limited	Yes	200 millirem/ hour
7. Locations occupied during fuel transfer operations	Reactor shut down 10 days or longer. Refuelling operations	Limited	Yes	200 millirem/ hour transient conditions, 7.5 millirem/ hour continuing conditions
8. Adjacent to demineralisers for disconnection by crew	Reactor shut down several hours	Limited	Yes	200 millirem/ hour

[1] The roentgen is the unit of radiation that measures a certain dose in air due to X-rays.

The rem (Roentgen equivalent man) is the corresponding dose to body tissue. The dose in rems is dependent on the RBE (Relative Biological Effectiveness) of the particular ionising radiation (i.e. the ability of the radiation to damage body tissue). Different radiations such as alpha, beta, gamma and neutrons have different RBE's. The millirem is 1/1000 of a rem.

Inspection and Testing

Inspection and testing of the ship has been referred to several times ; it may be useful to summarise the general requirements.

The U.S. Coast Guard, the Atomic Energy Commission and the American Bureau of Shipping review and approve specifications prepared for all major systems and components. These agencies provide inspection services at the reactor plant and shipyard. Quality control is assured by tests required of the contractors and verified by Joint Group representatives and by the Oak Ridge National Laboratory.

All equipment must be fabricated in conformance with existing codes and regulations of the U S. Coast Guard and the American Bureau of Shipping, and the marine rules of the American Institute of Electrical Engineers. A Combined Test Committee has been established to supervise the preparation of the test procedures and the performance of the functional, pre-start-up, dockside, and sea tests. This Combined Test Committee consists of the reactor and ship builders, the operating contractor and the Joint Group. It will continue to function until its members have confidence that the ship is satisfactory and that the crew can handle it properly under all operating conditions.

Organisation and Training of the Crew

In general the ship's complement will be quite similar to that of a conventional ship of this type and a description of the departments is unnecessary.

Personnel with nuclear engineering competence is being added to the qualified marine staff of the shipping company which will operate the vessel. All ship operating personnel will be seasoned mariners fully qualified and documented by the U.S. Coast Guard ; they will also be given whatever nuclear training is necessary to enable them to assume the new duties required by the propulsion system.

With the full co-operation of the appropriate unions a programme of suitability checks and aptitude screening is being carried out on all persons assigned for training in operating the *N.S. Savannah.* In order to broaden the experience of the deck and engineering officers in the field of atomic energy, they will be given theoretical and brief practical instruction in many phases of the atomic energy industry. This is to be done for general familiarisation purposes, not as an attempt to make nuclear engineers or reactor physicists of these men.

The Master and First, Second, and Third Officers will take a training course of approximately one year in the following specialities :

(1) Twenty weeks in reactor technology and the propulsion system of the *N.S. Savannah.*

(2) Four weeks in radiation health physics and environmental health.

(3) Four weeks observing general reactor operation.

(4) Eight weeks of tutoring in management and supervisory functions at the Atomic Energy Commission and private reactor establishments.

(5) Eight weeks in the builder's shipyard during the period of installation and testing of nuclear and non-nuclear machinery.

The engineering officers have been selected from those available in the operator's fleet. Selection has been based upon experience at sea, academic performance and special aptitude examinations.

In order to be assured of a competent group at the time sea tests and trials are conducted in the spring of 1960, 15 officers initiated their training course in September 1958. It is planned that three trained groups of eight engineering officers each will be available for service on the *N.S. Savannah* during her first several years of operation. Those not immediately assigned to the vessel will be used by States Marine Lines on other ships, permitting rotation of the *Savannah's* engineering crew. This group will become the central core from which crews of additional nuclear ships can be drawn.

The training is being conducted by the reactor builder, the Babcock and Wilcox Company, with an academic period of approximately four months ; an on-the-job power plant orientation at the reactor builder's site of approximately four months, including substantial instruction on a simulator of the complete reactor system ; three months of field training at operating reactor facilities, principally under the regular supervisors of these reactors ; and four months of training and observation at the shipyard on the installation, operation, and maintenance of the ship's propulsion system.

Specialised training will be given in instrument operation and maintenance to two engineering officers and two unlicensed engineering department crew members. Similar special training in other nuclear equipment maintenance will be given to one officer and two unlicensed crew members. Other unlicensed engineering crewmen will receive from three to six weeks' training on those aspects of their normal duties that have been modified by virtue of the nuclear propulsion. The purpose of this training effort is to give the crew a sufficient understanding of this new propulsion technique to enable them to operate nuclear ships as easily as conventional ships.

Ship Operation

Selection of the operating agent for the *N.S. Savannah* was made from 47 shipping companies operating vessels under the United States flag. States Marine Lines, which will act as agent for the Government in operating the vessel, was chosen for its demonstrated marine capability and safety record.

Manuals of operating procedures will be developed for the ship as a unit, not for the reactor as an independent or superimposed system. All major procedures will be supplemented by comprehensive check lists. For instance, a reactor start-up procedure will include functional checks of safety and control equipment.

Refuelling and major repair operations would normally not be performed by crew members but rather in specialised shore facilities maintained for this purpose. Maintenance, however, will be of great importance to them and will be in accordance with standard marine practices as a minimum. Preventive maintenance will be facilitated by the use of replaceable, plug-in electrical and electronic components, and by shipboard spare parts provided in accordance with the relevant requirements of the American Bureau of Shipping and the U.S. Coast Guard.

Maintenance in zones where radiation or contamination is present or expected will be accomplished under standards laid down by the Atomic Energy Commission. Radiation zones will be locked and access will be controlled by the Captain. When such access is required, members of the crew will be guided by special radiation zone work procedures and, if necessary, will be under the surveillance of qualified monitors. The necessity of entering the containment at sea can be avoided by the use of reliable components, the ability to bypass malfunctioning equipment, and by accomplishing preventive maintenance on a prescribed schedule.

The pre-operational familiarisation and training programme will make the necessary operating manuals less complex and burdensome for the entire crew.

Voyages of the *N.S. Savannah* will be designed to afford the most useful practical data on the ship and, secondarily, to demonstrate this use of atomic energy to the maritime world.

Environmental Health and Safety

Extensive environmental health and personnel health physics programmes have been planned for the *N.S. Savannah* to provide radiological protection for the crew, passengers, stevedores and shipyard personnel. It is of particular significance that the *Savannah* will be the first major reactor plant generally accessible to the public, i.e. as passengers and as port visitors. The design, programming and criteria have been conservative, predicated upon the safest possible operation at all times. Complete containment, secondary shielding and fixed monitoring systems have been described ; they are an integral part of the personal protection system.

The shipboard health physics programme will encompass radiation surveillance and control of various shipboard areas through the use of the monitoring system described above and through the auditing of personal exposure. In addition to the fixed stations associated with the reactor compartment and the 14 health physics monitoring points, a third monitoring system consists of survey instruments and personal devices for the measurement of exposure.

Reference is again made to the design dose rates in the chart. The levels are predicated on measurement at the point of highest radiation, based on continuous exposure to an individual for the period covered. In actual practice, however, it is anticipated that the dose rates received by crew members will generally be approximately one-half of the design dose rate because crew members will not be working continuously in the area of highest radiation levels.

Members of the engineering department working in the machinery space and others who enter controlled areas will wear conventional film badges and pocket dosemeters for measuring beta, gamma and neutron exposure rates. Members of other departments are not expected to be required to enter controlled areas and will not therefore wear film badges or dosemeters.

In addition to supervising the control of designated areas and personnel monitoring, the health physics functions aboard ship will also include periodic area surveys to determine the presence of radioactive contamination in the vicinity of the reactor. In the event that tools or clothing should become contaminated, decontamination will be planned and monitored by the health physics personnel. Protective clothing and equipment such as overalls, caps, gloves and, if necessary, respirators, will be available to those performing decontamination work. Experience elsewhere in the premises of the Atomic Energy Commission indicates that little maintenance work involving radioactive components will be required of the crew. This work can be deferred until the ship reaches port and the reactor plant is shut down.

A general environmental programme has been undertaken with the aim of demonstrating that no deleterious release has taken place on land or at sea. The Coast and Geodetic Survey, Weather Bureau and Corps of Engineers have undertaken an integrated environmental analysis as an aid in planning the voyages, harbour routing and berth selection most suitable for the ship and for the land and estuarine environments. Work is proceeding to determine safe dispersion procedures for radioactive materials in sea water in the expectation that this data on oceanography will permit the discharge of low-level wastes to the ocean without hazard to the crew and the ship and without adverse effects upon marine life. The *N.S. Savannah*, it should be noted, will not discharge liquid or solid wastes in harbours or at sea.

It is believed that the environmental health and safety programmes can be reduced after a record has been made of the operating experience of the *N.S. Savannah*. However, these programmes are regarded as useful in the early development period as a means of obtaining acceptance by the maritime world of this new mode of propulsion.

International Acceptance of Nuclear Ships

In initiating the nuclear ship programme President Eisenhower stated—

> I should like to emphasise that the ship's reactor design will not be secret. The reactor will be built on an unclassified basis. It will be possible for engineers, not only of our own country but of other nations, to view the nuclear power plant and see at first hand this demonstration of the great promise of atomic energy for human betterment.

This policy has been extended. Full information on all aspects of the nuclear ship programme has been made available, as developed, to those who have sought information. This has included both foreign and domestic governmental, union and industrial officials. This has been done because it is hoped that sufficient confidence will be created to overcome any concern for the safety of nuclear ships in normal international commerce.

The publication and dissemination of technical reports for use by other nations has been the first effort in this direction. A symposium conducted by the Joint Group in 1957 presented to American atomic and marine industrialists the early plans of the nuclear ship contractors for the *N.S. Savannah*. The proceedings of the symposium were made available to the domestic and foreign public. In August 1958 a second symposium was held, to which were invited the shipping attachés of all maritime nations. Again the plans and progress of the *N.S. Savannah* were described. The proceedings of the symposium were made available to the public in January 1959.[1]

[1] *Proceedings of the 1958 Nuclear Merchant Ship Symposium* (Washington, D.C., Department of Commerce, Office of Technical Services, 1959).

Several nations interested in nuclear ship propulsion have taken steps towards the formulation of rules to be used in the design and construction of nuclear ships. For more than three years a panel of experts named by the Society of Naval Architects and Marine Engineers has studied the design, construction and operation standards that could be applied. This group, called the M-13 Panel, has also co-operated with the U.S. Coast Guard's Nuclear Committee, which is preparing recommendations for the 1960 Convention on Safety of Life at Sea. Informal discussions with the Nuclear Ship Safety Committee of the United Kingdom of draft rules on these subjects have revealed uniformity of views. Plans are being made for meetings with the principal maritime nations in the hope of securing uniform standards in these matters. It is anticipated that, if such agreement is reached, procedures for the international acceptance of nuclear ships can be simplified.

Conclusion

It has been the aim of the United States to construct a practical ship using nuclear propulsion. However, an overriding factor has been the desire to ensure safety of operation in the world's harbours. Complete containment, retention of all wastes and other safeguards have been used to achieve this; less stringent requirements can be incorporated in future ships after the *Savannah's* experimental years of service.

While engineering and economic factors and general approval of nuclear ships are important, the acceptance of such ships by their crews is more basic to the success of this new phase of the atomic energy industrial age.