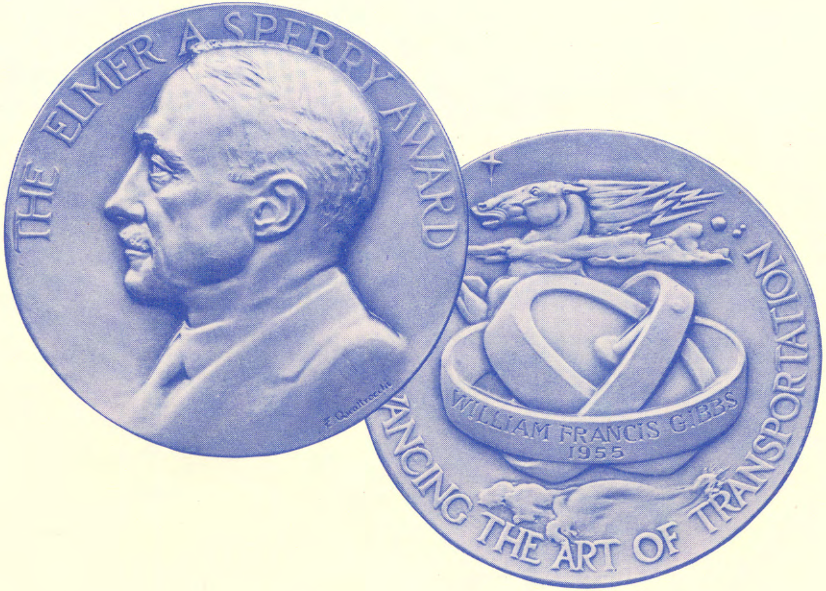
THE ELMER A. SPERRY AWARD FOR 1969



THE ELMER A. SPERRY AWARD MEDAL

In the words of Edmondo Quattrocchi, the sculptor of the medal . . .

"This Sperry medal symbolizes the struggle of man's mind against the forces of nature. The horse represents the primitive state of uncontrolled power. This, as suggested by the clouds and celestial fragments, is essentially the same in all the elements. The Gyroscope superimposed on these, represents the bringing of this power under control of man's purposes."

PURPOSE OF THE AWARD

The Elmer A. Sperry Award shall be given in recognition of —

"A distinguished engineering contribution which, through application, proved in actual service, has advanced the art of transportation whether by land, sea or air."

PRESENTATION OF THE

1969 ELMER A. SPERRY AWARD

To

DOUGLAS C. MAC MILLAN

M. NIELSEN

EDWARD L. TEALE, JR.

With Citations to Wilbert C. Gumprich and the organizations of George G. Sharp, Inc., Babcock and Wilcox Company and New York Shipbuilding Corporation.

By

The Board of Award under the sponsorship of

The American Society of Mechanical Engineers
Institute of Electrical and Electronics Engineers
Society of Automotive Engineers
The Society of Naval Architects and Marine Engineers
American Institute of Aeronautics and Astronautics

At the Seventy-seventh Annual Banquet of
The Society of Naval Architects and Marine Engineers

Thursday Evening, November 13, 1969
New York Hilton, New York, N. Y.

ELMER AMBROSE SPERRY
1860-1930

FOUNDING OF THE AWARD

The Sperry Award commemorates the life and achievements of Dr. Elmer A. Sperry (1860-1930) by seeking to encourage progress in the engineering of transportation. Much of the great scope of the inventiveness of Dr. Sperry contributed either directly or indirectly to advancement of the art of transportatation. His contributions have been factors in improvement of movement of men and goods by land, by sea and by air.

The award was established in 1955 by Dr. Sperry's daughter, Mrs. Robert Brooke Lea, and his son, Elmer A. Jr., and is presented annually.

1969 BOARD OF AWARD

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DOUGLAS C. MAC MILLAN

. . . for his direction and engineering contributions to all aspects of the preliminary studies and final design of the N. S. SAVANNAH.

Mr. MacMillan graduated from MIT as a Bachelor of Science in Naval Architecture in 1934. He joined George G. Sharp, Inc. in 1941, became President in 1951 and Chairman of the Board in 1969. He is a Vice President of SNAME, and was active on committees of that Society, and the U. S. Coast Guard, relating to the safety of nuclear merchant ships.

M. NIELSEN

. . . for the leadership he provided in guiding the entire SAVANNAH reactor project from conception through to final operation and specifically for his contributions to the solution of many novel problems involved in its manufacture.

Mr. Nielsen is Chairman and Chief Executive Officer of Babcock and Wilcox Company. He joined B&W in 1924 and advanced to his present position through the various steps including, chief of the Boiler Division, Executive Vice President and President.

EDWARD L. TEALE, JR.

. . . for his supervision and engineering contributions to the construction of the N. S. SAVANNAH and the installation and successful tests of its nuclear reactor.

Mr. Teale received his B.S. in Naval Architecture and Marine Engineering from Webb in 1934, joining the New York Shipbuilding Corporation in 1953 as Executive Vice President. He was a member of the Board of Directors and President from December 1955 until April 1965. He is now Senior Vice President of J. J. Henry Co., Naval Architects and Marine Engineers.

CERTIFICATES OF CITATION

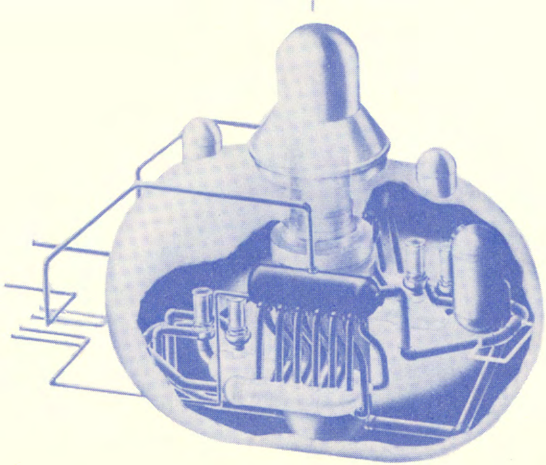
To Wilbert C. Gumprich for his leadership, engineering skill and contributions to the design of the SAVANNAH'S unique power plant.

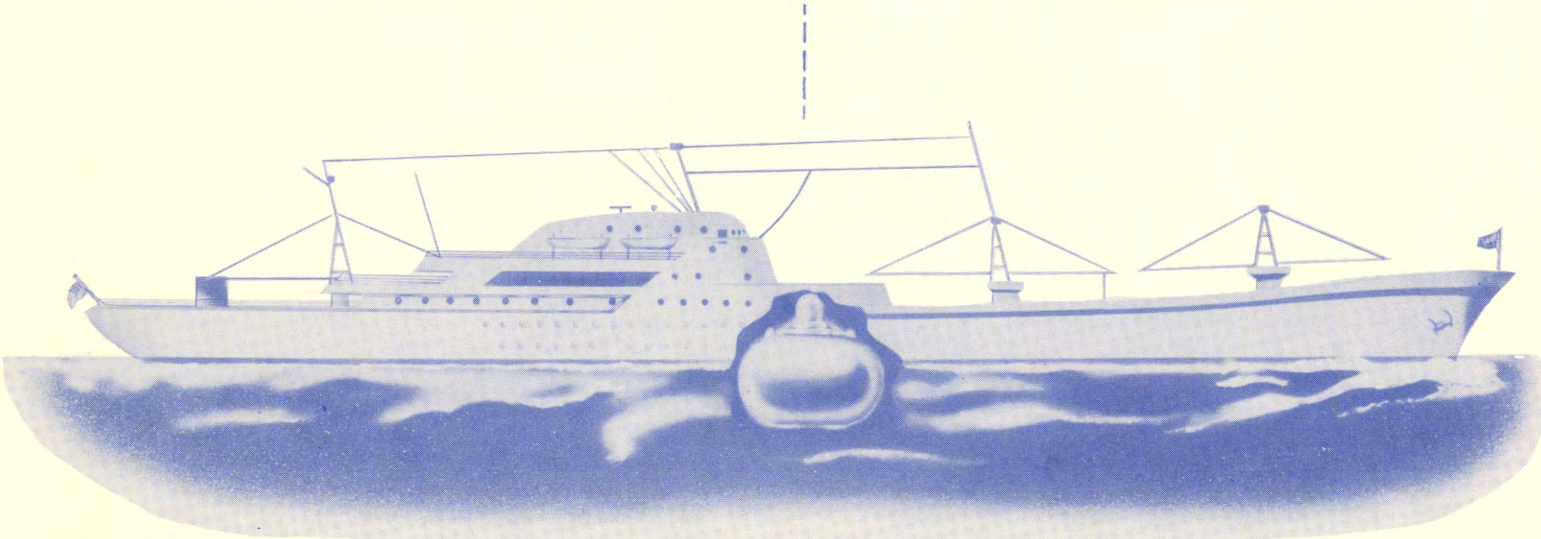
To the engineers and naval architects of George G. Sharp, Inc. responsible for the development of the design of the N. S. SAVANNAH.

To the engineering and production personnel of the Babcock & Wilcox Company for their work in the design and fabrication of the reactor of the N. S. SAVANNAH.

To the engineers and production staff of the New York Shipbuilding Corporation for the construction of the N. S. SAVANNAH, the installation of the nuclear reactor and the successful trials of the ship.

Heart of the
N. S. SAVANNAH'S
nuclear propulsion system lies within heavily shielded containment vessel (right) located amidships.





N. S. SAVANNAH

On May 22, 1819, a 320-ton vessel named SAVANNAH began the first transatlantic crossing using a steam engine as the source of power. This event clearly ushered in the steam age in ocean transportation, with the steam generated by the combustion of thermal fuels — wood, coal or oil.

One hundred and thirty-seven years later, in April, 1955, the world's first atomic-powered merchant ship was proposed by President Dwight D. Eisenhower as part of his Atoms-for-Peace Program, and was authorized by Congress in July 1956 as a joint project of the Atomic Energy Commission and the Maritime Administration. The initial contracts were awarded to Babcock and Wilcox for the reactor plant and to George G. Sharp, Inc. for the ship design in April 1957. The contract for the ship construction was awarded to New York Shipbuilding Corporation in December 1957.

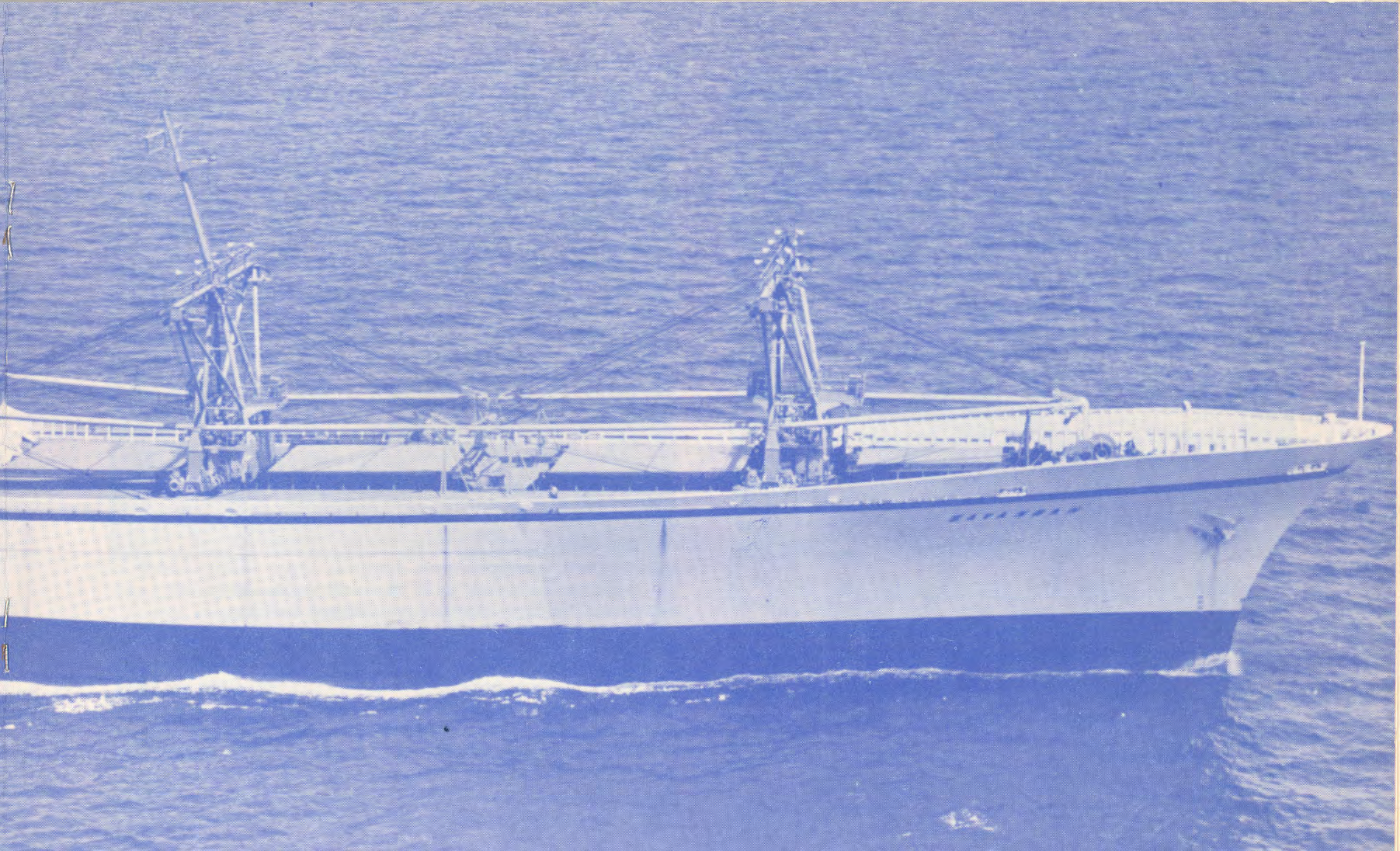
The keel was laid by Mrs. Richard M. Nixon on Maritime Day, May 22, 1958 and the ship was launched, with Mrs. Eisenhower as Sponsor, on July 21, 1959. After extensive public hearings on the safety of the ship and its nuclear system in March and April, 1961, and extensive testing of all sub-systems, the reactor was loaded with fuel on November 27-28, 1961, and went critical on December 21, 1961. Completely successful sea trials at full power were conducted in April 1962, and the ship was delivered to the Government in May 1962. This was followed by demonstration voyages to U. S. ports beginning in December, 1962. The first foreign trip was to Germany in June 1964, and the first foreign port entered was Bremerhaven. Commercial operation began in July 1965.

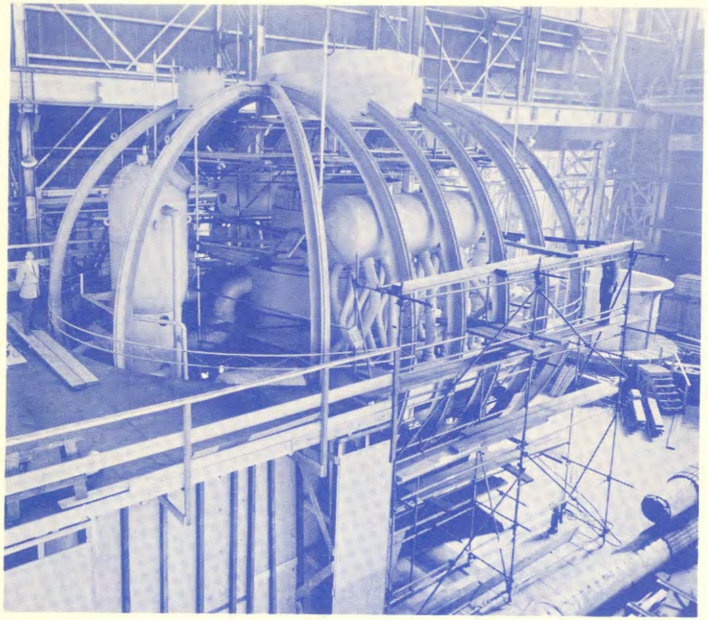
The SAVANNAH was envisioned by her sponsors as a major element in the Atoms-for-Peace Program and was to travel to major ports throughout the world as an instrument of goodwill and a visible demonstration of the benefits of peaceful use of nuclear energy. In addition, she was to provide a demonstration of the practical application of nuclear power to merchant ship propulsion, and pioneer the licensing and entry of such a ship into the important ports of the world. From its inception it was known that the SAVANNAH would not attain economical commercial operation, nor was she intended as a prototype.

George G. Sharp, Inc. started work on the preliminary studies for SAVANNAH in April 1957, and the preliminary design was submitted to the Maritime Administration in July followed by contract plans and specifications. From a naval architectural standpoint, the design requirements were most unusual. Instead of designing a ship to carry a specific number of passengers and quantity of cargo at a given speed, in this case it was to develop the design of a cargo-passenger ship suitable for a 22,000 shp nuclear power plant that would meet all safety requirements to be developed, and which could be built for a price within the program budget.

The result was a medium size passenger-cargo ship of distinctive design and appearance, having accommodations for sixty passengers and a capacity for 9250 tons of cargo. The ship is almost 600 feet long with a beam of 78 feet and weighs 21,850 long tons when fully loaded, and is propelled by a single propeller driven by a geared steam turbine, which operates on steam produced in two heat exchangers by the heat from the coolant of the nuclear reactor.

From a ship design standpoint, the presence of the nuclear power plant resulted in unusual requirements with respect to stability, distribution of weights and arrangement of machinery and access. It was necessary to place the reactor and containment vessel forward of the engine space because of size and stability considerations; i.e., it was too big





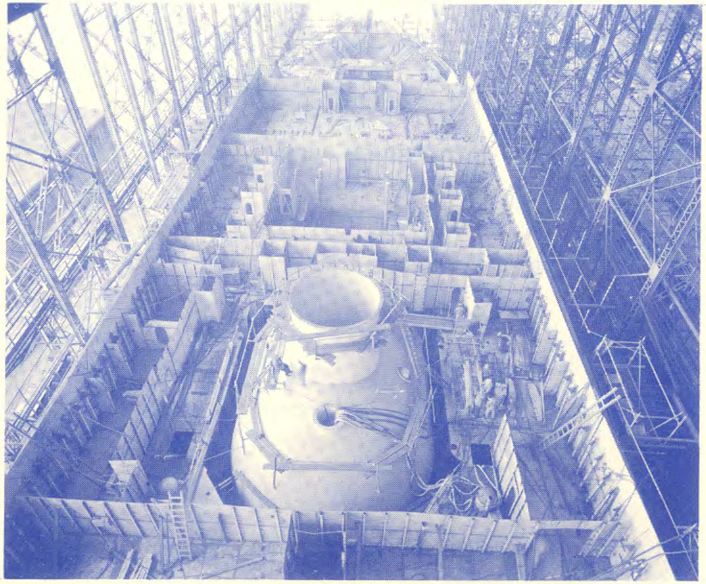
Size of the containment vessel required that it be built in three sections which were then assembled and welded in the ship. The cupola opening provided the only access for all major components of the primary nuclear plant.

to go above the propeller shaft without protruding through the main deck, and the increase in vertical center of gravity could not be tolerated from a stability standpoint. The longitudinal location was selected so that the ship, in the fully loaded condition, would have essentially even keel trim, and empty would trim by the stern. Refueling the reactor requires access for handling heavy weights so that an overhead system was selected, resulting in the superstructure being aft of the reactor hatch.

The principal problems introduced by nuclear propulsion were those relating to the safety of the ship, the personnel aboard, and the general community; and these were considered for conditions without precedence. The safety features of the nuclear power plant were the responsibility of Babcock & Wilcox. George G. Sharp, Inc. was principally responsible for the analysis of ship accidents and ship safety features.

The safety of the passengers, crew and cargo from the normal hazards of the sea was considered to be adequately secured by full compliance with existing rules. However, where severe ship accidents might result in damage to the nuclear plant, with possible release of radioactivity to the environment, special safety features were incorporated in the design. The analysis of the various types of ship acci dents resulted in a number of unusual features.

Although almost all ship collisions can be traced to errors in the judgment of responsible personnel, a thorough study of sixty major collisions was made to determine the mechanics of collision and to define the magnitude of damage to be expected, with particular reference to two potential sources of nuclear hazards, shock and penetration. The study disclosed that shock was not a problem, and was successful in correlating the penetration and damage with the kinetic energy of colliding ships. As a result, improved collision



Full scale model or mock-up of the containment vessel and the nuclear reactor system, constructed in the shipyard, served dual purpose of dimensioning size of units and assembly procedure, and training crew in maintenance procedures.

protection was provided in the structure and biological shielding outboard of the reactor to minimize the probability of containment rupture in a collision at sea, and to render it practically incredible in a harbor collision.

Babcock & Wilcox engineers generally say their most difficult challenge in the SAVANNAH project was the demonstration of the plant's safety to the complete satisfaction of the Maritime Administration, U. S. Coast Guard, U. S. Public Health Service, American Bureau of Shipping, and the Atomic Energy Commission's Division of Reactor Licensing and Advisory Committee on Reactor safeguards. A path was cleared through this unique regulatory complex that will lead the way for successors of the N. S. SAVANNAH.

The SAVANNAH was the first mobile nuclear power plant to be licensed by the Atomic Energy Commission. Guidelines had to be established for environmental protection aboard ship at sea, in port and at dockside for both normal and emergency conditions. Performance specifications were required for engineered safeguards, especially the reactor protection system, containment system, and an extensive filtering system for the reactor compartment ventilation. Special provisions were incorporated for fire protection including inerting the containment atmosphere with nitrogen.

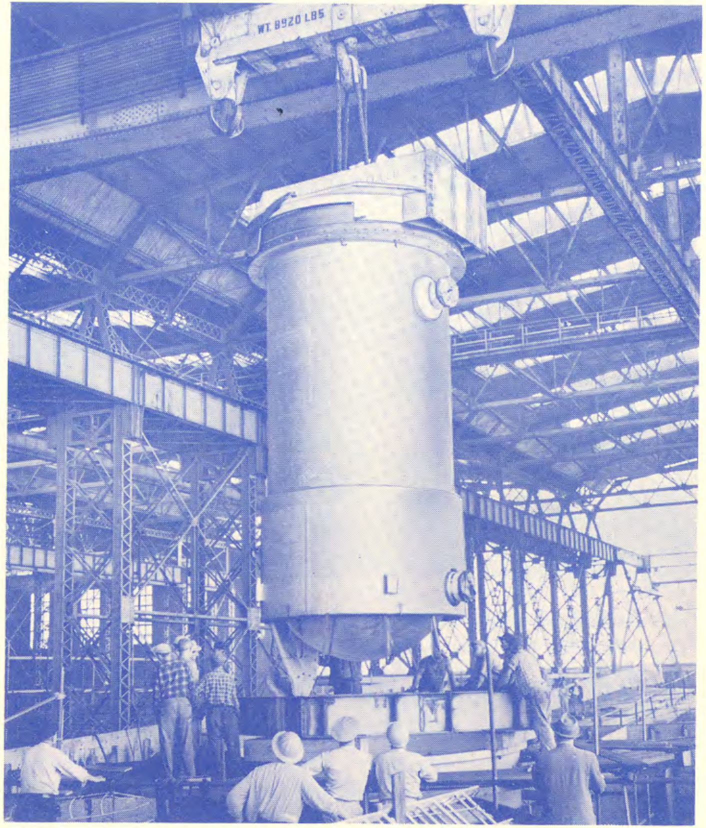
In addition to the licensing activities required for the ship and power plant, formal port entry and docking clearance were required for each port to be entered. Special reports were prepared analyzing SAVANNAH operations and providing assurance of environmental safety in each case. The goal was to provide a ship which would be acceptable for normal commercial entry and docking operation.

The paramount need for safety dictated conservatism in component design. The SAVANNAH has a pressurized water reactor system. Reactors of this general type were already operating at Shippingport and on the U.S.S. NAUTI-

LUS. However, the SAVANNAH design incorporated important differences from these reactors. In addition, the SAVANNAH's was the first reactor built for any type of marine service not to have a land-based prototype.

One of the major differences was the use of UO_2 ceramic fuel. This was the first marine application in the United States of a fuel form which has since become the standard for land-based pressurized water reactors. It offered the possibility of long core life between refueling operations, relatively low fabrication costs, and very stable core-performance under marine maneuvering conditions because of its inherent negative fuel temperature coefficient of reactivity. Each of the 32 fuel elements in the SAVANNAH core is made up of 164 stainless steel fuel pins containing uranium oxide slightly enriched in U235. In its 66 inch by 62 inch cylindrical volume, the core produces 75 megawatts of thermal power. Uniform fuel pin spacing is a critical requirement for proper core cooling and required Babcock & Wilcox to develop assembly fabrication techniques to achieve the necessary precision.

Reactor physics and design were not nearly as fully developed in the late fifties as they are today. Data for calculation of the fuel pin lattice, fissionable material loading, core power distribution, and determination of core control characteristics were obtained in an extensive series of zero power experiments at B&W's Critical Experiment Laboratory in Lynchburg, Virginia. The experiments included a hot exponential experiment in a specially built pressurized facility utilizing the B&W pool reactor as a neutron source; this experiment determined the effect of operating temperatures on the core's nuclear characteristics. Verification of the final design was accomplished at the laboratory through experiments with the actual SAVANNAH core before delivery to the shipyard.



The reactor vessel being lowered into position in the containment vessel. The core, within the reactor vessel was installed later.

The core is contained in a pressure vessel fabricated in B&W's Barberton, Ohio works. A removable head contains the control rod drive penetrations. The vessel's 6½ inch thick steel walls serve as part of an extensive steel, lead, concrete and polyethylene radiation shielding system. The control rod drive system presented a major development problem. Material for the rods themselves required extensive analysis and development. Hafnium, the only material then available with demonstrated service in water reactors, was in short supply and very expensive. As a result of a search for a material more suitable for commercial application, boron-stainless steel alloy plates were chosen; these were sheathed in stainless steel, forming rods of cruciform cross-section. The control rod drives were required to operate and "scram", that is, automatically shut down the reactor by rapid control rod insertion, in any ship attitude, and to achieve this a combination electro-mechanical-hydraulic system was chosen. These drives not only provide convenient stored energy to assure operation in any attitude after normal power failure, but included an automatic mechanical latch to prevent the rods from falling out of the core in the capsized position, or from being ejected by reactor pressure in event of failure of the hydraulic system. A comprehensive design, development and testing program in the vendor's shop, in B&W laboratories, and at the shipyard during installation was required to prove out these drives.

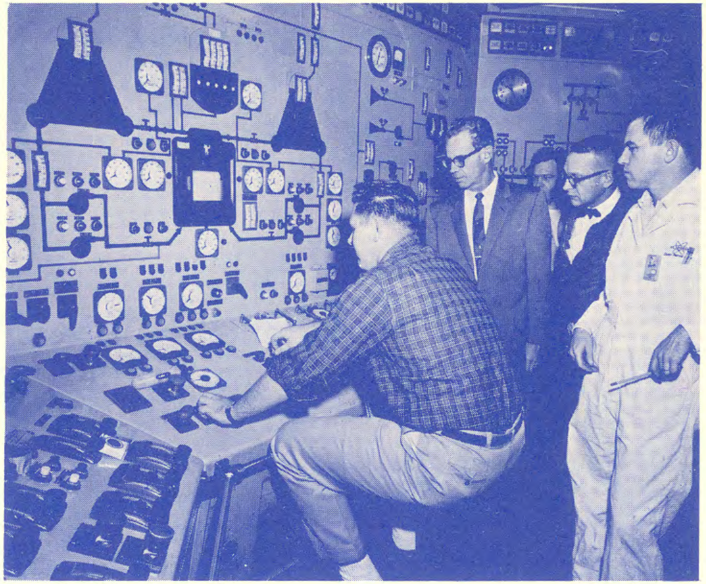
The containment system is one of the most unusual aspects of SAVANNAH design. A large steel pressure vessel containing the entire primary system functions as the ultimate engineered safeguard preventing the release of fission products to the environment in the event of a major reactor accident. Rupture of the primary system would flash a large amount of pressurized water to steam. Since a large volume containment of the type used for utility reactors is not practical on board ship, a compact high pressure containment

Lowering one of the 32 fuel elements into the reactor. This—and many other operations—had to be carried on under conditions of surgical cleanliness. Note plastic covering of element until entered into core, and the technicians' clothing.

was chosen. It is designed to withstand the 186 psi calculated to result from the loss of coolant accident. Faced with a limited containment volume B&W had to design for an extremely compact arrangement of the nuclear steam generating system components. The reactor, control rod drives and hydraulic system, two steam generators, reactor water-treatment systems, and electrically heated pressurizer, all primary system piping and pumps are laid out in a 35x25 foot area.

Maneuvering requirements more severe than those of conventional ships were specified for the power plant. This required substantial analysis and design development to produce a reactor control system which would perform in accordance with specifications. The system was proved out prior to installation by extensive use of analog computers and system simulation. Deck officers report that she responds more rapidly to engine orders than conventionally powered vessels. The reactor is automatically shut down, or scrammed, in the event of any of seven abnormal operating conditions. The frequency of scrams with power and research reactors was considered too high for efficient and safe marine operation. To reduce spurious scrams from minor instrument malfunctions, coincidence of unsafe indications from two independent instruments is relied on wherever possible. To date the only inadvertent scram on SAVANNAH under adverse conditions at sea resulted from a low hydraulic fluid reservoir level caused by roll of ship.

The work of all involved in the SAVANNAH project came together at the shipyard. It remained for the New York Shipbuilding Corporation to build a ship with many unique features, innovations and departures from usual practice, to install a radically different power plant within the confines of the containment vessel, to develop the necessary procedures and organization for inspection, quality control, health



Control room of the nuclear plant of the SAVANNAH shortly after the reactor was taken to criticality, December 21, 1961.

physics and nuclear technology, to create the organization to fuel the reactor, take it to criticality, and finally, make all power tests and sea trials up to delivery. To gain acceptance in the world's ports, it was necessary for the technical details of the SAVANNAH to be public information. This separated SAVANNAH from the highly classified Navy program and required developing procedures and safety assessment independently of the Navy Program. Whereas military necessity could be argued as justification of some features of naval procedure, the nuclear safety assessment of SAVANNAH required standards which would be acceptable, not only in the United States, but throughout the world. Organizations which have international stature, such as the American Bureau of Shipping, the U. S. Coast Guard and the U. S. Public Health Service have rules and inspection organizations, the satisfaction of which permit a conventional ship to be insured and to sail. The counterparts of these organizations throughout the world were offered the opportunity through the Department of State to be fully informed of the standards set and precautions taken. A notable example of international interest was the visit of a substantial Russian contingent, under Deputy Premier Koslov, to the shipyard during the construction period.

The fabrication, assembly and test of this containment vessel in the ship, by New York Ship, the installation and erection of the nuclear plant within this vessel and finally, the installation of the extensive shielding, presented numerous problems. The vessel is made up of a 35 foot diameter cylindrical section, with hemispherical heads and has an overall length of 50 feet. A 14 foot diameter cupola, located on top the cylindrical section, housing the control rod drives, was the access for installation of the components and equipment within the vessel.

Shielding on SAVANNAH serves the dual purpose of: (1) Limiting radiation outside the containment vessel 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 is divided into a primary shield, which surrounds the reactor itself, and the secondary shield which surrounds the containment vessel. In addition, both sides of the vessel are protected by a thick collision mat, constructed of alternate layers of steel and redwood. As a consequence of the size and shape of the vessel, the shield must be very large, very heavy — 2,000 tons — and of extremely awkward shape. Full account of this complex geometry was taken in the design of the shielding and development of shielding calculations by Sharp and B&W. It was further complicated by the effect of some 82 penetrations in the containment vessel shell for piping, electrical cables, pneumatic lines and access.

The exhaustive testing program conducted by New York Ship first included component tests followed by dummy runs in which the steam plant, electrical equipment, instrumentation and controls were tested to the fullest extent possible without full steam flow, and in the absence of nuclear radiation. The reactor fuel was then installed, one of the most delicate and carefully planned steps of the program, and criticality achieved. Testing to 10% full power was conducted at dockside in Camden, N. J.

The SAVANNAH was then moved to a site on the York River, near Yorktown, Va., which served as a base for further dockside tests to 40% full power, and for sea trials off the Virginia Capes. During the latter full power was achieved and all acceptance tests were completed. The Maritime Administration accepted the ship, at Yorktown, May 1, 1962.

There followed the Demonstration Phase of Operations, beginning with a voyage from Yorktown, Va., to Savannah, Ga. in August, followed by visits to other U. S. ports and then foreign ports. Through 1962-63 the N. S. SAVANNAH was operated by States Marine Lines under a General Agency Agreement. The demonstration phase was continued in 1964-65 by American Export Isbrandtsen Line, Inc. likewise under General Agency Agreement. Since 1965 to present, SAVANNAH has been in experimental commercial operation, under bare boat charter, to First Atomic Ship Transport, Inc.

On her sea trials, SAVANNAH exceeded her design power rating. She has compiled an excellent availability record, sailing 332,000 miles on her first core. Last year's replacement of four of the core's 32 fuel assemblies and a reshuffle of the other 28 is expected to provide power for another two and a half years of successful operation.

The N. S. SAVANNAH represents only the first short step down a long road that may hold promise for the use of nuclear power in commercial ships of the future. By transforming the concept of nuclear power for merchant ships into a reality, SAVANNAH has secured a place in Maritime history. The ultimate effect upon that history, however, awaits the decision of time.

Out of the technical experience derived from the design, construction and operation of N. S. SAVANNAH and the associated reactor development program have come designs for compact, new reactor systems. Operations to date have evolved a framework of regulations, procedures, standards and agreements that may lead to possible commercial use of nuclear-powered merchant ships in busy foreign and domestic ports. From SAVANNAH's training programs may flow personnel to meet the exacting demands for future nuclear ship operations.

But history does have a way of repeating itself. Few who saw that earlier SAVANNAH depart in 1819 foresaw the end of the days of sail. Years were to elapse before steamers drove the clippers off the high seas, and the first SAVANNAH, with her steam engine removed, spent the rest of her career as a conventional sailing vessel. It is to be hoped, in this day of greater acceptance of progress and change, that the promise of higher sustained speeds and prolonged periods of uninterrupted operations may prompt further development toward an economical nuclear powered ship.

PREVIOUS ELMER A. SPERRY AWARDS

1955 to WILLIAM FRANCIS GIBBS and his Associates for development of the S. S. United States.

1956 to DONALD W. DOUGLAS and his Associates for the DC series of air transport planes.

1957 to HAROLD L. HAMILTON, RICHARD M. DILWORTH and EUGENE W. KETTERING and Citation to their Associates for the diesel-electric locomotive.

1958 to FERDINAND PORSCHE (in memoriam) and HEINZ NORDHOFF and Citation to their Associates for development of the Volkswagen automobile.

1959 to SIR GEOFFREY DE HAVILLAND, MAJOR FRANK B. HALFORD (in memoriam) and CHARLES C. WALKER and Citation to their Associates for the first jet-powered aircraft and engines.

1960 to FREDERICK DARCY BRADDON and Citation to the Engineering Department of the Marine Division, SPERRY GYROSCOPE COMPANY, for the three axis gyroscopic navigational reference.

1961 to ROBERT GILMORE LETOURNEAU and Citation to the Research and Development Division, FIRESTONE TIRE AND RUBBER COMPANY, for high speed, large capacity, earth moving equipment and giant size tires.

1962 to LLOYD J. HIBBARD for application of the ignition rectifier to railroad motive power.

1963 to EARL A. THOMPSON and Citation to his Associates for design and development of the first notably successful automatic automobile transmission.

1964 to IGOR SIKORSKY and MICHAEL E. GLUHAREFF and Citation to the SIKORSKY ENGINEERING DEPARTMENT for the invention and development of the high-lift helicopter leading to the Sky Crane.

1965 to MAYNARD L. PENNELL, RICHARD L. ROUZIE, JOHN E. STEINER, WILLIAM H. COOK and RICHARDS L. LOESCH, JR. and Citation to the Commercial Airplane Division, THE BOEING COMPANY, for the concept, design, development, production and practical application of the family of jet transports exemplified by the 707, 720 and 727.

1966 to HIDEO SHIMA, MATSUTARO FUJII and SHIGENARI OISHI and Citation to the JAPANESE NATIONAL RAILWAYS for the design, development and construction of the NEW TOKAIDO LINE with its many important advances in railroad transportation.

1967 to EDWARD R. DYE (in memoriam), HUGH DeHAVEN and ROBERT A. WOLF and Citation to the Research engineers of Cornell Aeronautical Laboratory and the staff of the Crash Injury Research projects of the Cornell University Medical College.

1968 to CHRISTOPHER S. COCKERELL and RICHARD STANTON-JONES, and Citation to the men and women of the BRITISH HOVERCRAFT CORPORATION for the design, construction and application of a family of commercially useful Hovercraft.