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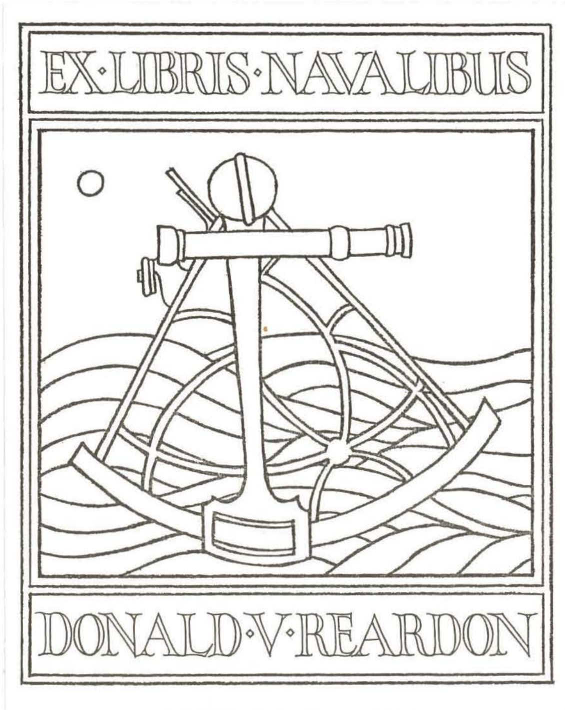
TECHNICAL, OPERATIONAL AND ECONOMIC REPORT ON THE N. S. SAVANNAH FIRST YEAR OF EXPERIMENTAL COMMERCIAL OPERATION

1965 - 1966

SAVANNAH

PREPARED BY
OFFICE OF RESEARCH AND DEVELOPMENT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TECHNICAL, OPERATIONAL AND ECONOMIC REPORT ON THE N.S. SAVANNAH FIRST YEAR OF EXPERIMENTAL COMMERCIAL OPERATION 1965 - 1966

U.S. DEPARTMENT OF COMMERCE
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N.S. SAVANNAH on Drydock at Her Nuclear Service Facility
Todd Shipyards Corporation, Galveston, Texas

ACKNOWLEDGMENT

This report has been prepared under the direction of Delma L. Crook, Manager, Nuclear Ship Research & Development (R&D) Program. Special credit is given to the SAVANNAH Project Engineers: John D. Neidlinger, Charles P. Patterson, Tom M. Christian, and Frank R. Kesterman of the Maritime Administration, and to F. Norman Watson of the Atomic Energy Commission for their contribution in their areas of expertise in the development of this report.

Special mention should be made to First Atomic Ship Transport Inc. and the Nuclear Division of Todd Shipyards Corporation for their diligent collection and submission of the basic technical data included in this report.

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INTRODUCTION

The first year of experimental commercial operation of the Nuclear Ship (N.S.) SAVANNAH began on August 20, 1965, at the Nuclear Service Facility located at Todd Shipyards in Galveston, Texas. A Bareboat Charter Agreement effective on that date, between the Department of Commerce, Maritime Administration, and First Atomic Ship Transport Inc. (FAST), a wholly owned subsidiary of American Export Isbrandtsen Lines, Inc., of New York, provided for her operation on an experimental basis in commercial service.

Initially designed as a vehicle to demonstrate one of the peaceful uses of the atom, and as a test bed for the application of nuclear power for merchant vessel propulsion, she has met many challenges and passed all tests.

In the minds of those responsible for the SAVANNAH's operation during the demonstration phase, one question remained: How would the ship do in commercial operation? In the initial design, demonstration features were given consideration over commercial features. Moreover, the SAVANNAH was designed for round-the-world passenger/cargo service in 1957. Consequently, such things as a blind cargo hold arrangement, limitations in cargo gear, large public spaces and passenger quarters, which could not be utilized in commercial operation, would hamper overall commercial performance. Also, her design features required higher manning levels than the requirements of similar ships of a standardized commercial design, and she would be in

competition with time tested cargo vessels and long established port operating modes.

Even with the inherent design limitations, the financial advantages of experimental commercial operation, seemed to offer the one method by which the SAVANNAH could continue her research and development function while reducing the cost to the Government by an estimated $4,000,000 per annum.

In the following pages, our purpose was to set forth a description and the results of that first year of operation which ended on August 19, 1966, including 7 successful voyages and a 30-day annual outage at Todd Shipyards in Galveston, Texas. The report is intended to be self-critical as well as informative.

1. DEMONSTRATION PHASE OF OPERATION

Completed in 1962, the SAVANNAH was built by the United States Government as a prototype vessel at a cost of about $55 million. A joint project of the Maritime Administration and the Atomic Energy Commission, the ship was designed to demonstrate to the world the sincere desire of the United States to use atomic power for peaceful purposes, and to determine the practicability of applying nuclear energy to the operation of commercial cargo and passenger vessels.

After extensive sea trials, the SAVANNAH undertook a series of eleven domestic port visits in 1962 and 1963, beginning with a visit to her namesake city of Savannah, Georgia. The ship was then being operated for the U. S. Government by States Marine Lines (SML) under a General Agency agreement, with Commodore Gaston DeGroote as Captain. During the initial domestic voyage she visited Atlantic and Gulf ports, transited the Panama Canal, and called at Hawaiian and U. S. West Coast ports.

In over 90,000 miles of operation, the SAVANNAH used up only 33 pounds of enriched uranium fuel, about enough to fill a man's hat. By comparison, a conventionally powered vessel traveling the same distance would require more than 17,000 tons of fuel oil. Such very small fuel consumption, without accompanying smoke pollution, is one good reason that nuclear propulsion may be desirable for merchant ships of the future.

After returning to her servicing facility at Galveston in 1963, labor troubles, caused by pay differentials between the engine and deck departments, culminated in a strike which could not be settled. It became necessary for the U. S. Government to start all over again with a new General Agent having contracts with different maritime unions. This required training a new crew complement while the ship remained immobilized for a year.

When the SAVANNAH resumed operation in May 1964, she was operated by American Export Isbrandtsen Lines (AEIL), with Captain David B. McMichael as Captain. The vessel made a second voyage to a series of domestic ports and then made her maiden Atlantic crossing, the first of five demonstration voyages between foreign and domestic ports.

When the Nuclear Ship SAVANNAH returned to her servicing facility at Galveston, Texas, on March 10, 1965, she had visited a total of 55 ports, been viewed by 1,500,000 people, and traveled the equivalent of nearly four trips around the world.

The SAVANNAH, in her two years of operations, had established an internationally accepted pattern of marine operations for atomic commercial ships that might follow. The ship had carried cargo and passengers in domestic and foreign waters, and, in addition to the impression made on ship's visitors, had

influenced the acceptance of atomic energy for peaceful purposes by millions of people who saw, heard, and read about the SAVANNAH in newspaper, magazine, television and radio accounts of the port visits.

2. EXPERIMENTAL COMMERCIAL PHASE OF OPERATION - FIRST YEAR

With the successful completion of the demonstration phase of the SAVANNAH's operation, the experimental commercial phase was initiated to develop routine operation and prepare the world's maritime community for acceptance of nuclear-powered cargo vessels in commercial service. A second purpose was to establish operational data as to the reliability and safety of nuclear ships for use in planning for any advanced nuclear-powered cargo vessel designs of the future. Further, plans were made to eliminate problems created by the use of nuclear power that placed greater restrictions on such vessels than on those using nonnuclear systems. Continued operation would also provide a nucleus of trained personnel for employment in the key positions aboard any future nuclear vessels and for shore support of such vessels.

2.1 Operation

A company capable of directing the operation of the SAVANNAH was organized and incorporated under the laws of the State of New York as First Atomic Ship Transport Inc., a wholly owned subsidiary of American Export Isbrandtsen Lines, Inc.

On August 5, 1965, a three-year Operating License (NS-1), the first for nuclear-powered merchant vessels, was issued to FAST by the U. S. Atomic Energy Commission (USAEC), Division of Reactor Licensing, for the operation of the SAVANNAH reactor.

A Bareboat Charter Agreement for a three-year period, effective on August 20, 1965, was executed by the Maritime Administration, U. S. Department of Commerce, and First Atomic Ship Transport Inc. (FAST). A Bareboat Charter is, basically, a standard document used by the Maritime Administration to allow ship operators to operate government owned vessels in a manner virtually identical to the way they would operate privately owned vessels.

Government support for the vessel's operation was determined by the operating costs in excess of estimated revenues. Since the vessel was constructed as a combination passenger-cargo ship, passenger quarters, passenger dining facilities, extra crew and trainee quarters, and the location of some of the storage and shop areas took up space which would normally be used for cargo. The SAVANNAH, due to its many innovations, has a larger crew than a conventionally powered ship of comparable size, and its maintenance and supply costs are higher. To compensate for these features, the Bareboat Charter for the first year of operation provided that FAST would be reimbursed on a base amount of $1.339 million for estimated operating losses, plus an allowance for actual FAST nuclear shore staff expenses up to a maximum of $473,000. As an incentive feature to keep operating costs to a minimum, and to encourage revenue producing efforts, the charter provided that if operating costs (expenses less revenues) were less

than $1.339 million, a "profit" would result, with FAST and Maritime receiving equal shares up to a maximum of $200,000 for FAST. All "profit" above $400,000 would go to Maritime. On the other hand, if the estimated operating costs were more than $1.339 million, a "loss" would result, with FAST and Maritime sharing equally up to the first $200,000; FAST sharing one-quarter and Maritime three-quarters between $200,000 and $600,000; and Maritime bearing all losses in excess of $600,000.

2.1.1 FAST Nuclear Shore Staff

Nuclear shore staff funding to FAST was provided by Maritime up to a maximum amount of $473,000 for the first year on a direct reimbursable basis. The shore staff requirements and functions are set forth in general terms below:

President (1) - Responsible for overall corporate management.

Vice Presidents (2) - Responsible for the overall administration of the FAST operation, as required by the President and/or Board of Directors.

Reactor Engineer (1) - Responsible for reactor safety, reactor operation, systems accountability, and health physics activities on the vessel.

Mechanical Engineer (1) - Responsible for the operation, maintenance and surveillance of the control rod drive system and associated supporting equipment, in addition to assisting

the Administrative Staff in matters pertaining to the mechanical systems on the vessel.

<u>Instrument/Electronics Engineer (1)</u> - Responsible for surveillance of the nuclear, nonnuclear, and electrical instrumentation aboard ship.

<u>Staff Health Physicist (1)</u> - Responsible for health physics activities aboard the vessel, and direction of contractors retained to assist in implementing the shipboard health physics program.

<u>Port Engineer (1)</u> - Responsible for maintaining the vessel, scheduling outage work, accounting for services rendered, and preparing timely reports of vessel operations.

<u>Port Operations Officer (1)</u> - Responsible for coordinating arrangements for vessel entry into and departure from domestic and foreign ports. He assists local authorities in the development of port operating plans, and directs port security arrangements for the vessel.

<u>Port Survey Officer</u> - Assists the Port Operations Officer in vessel port requirements, and surveys current and future port areas for information applicable to preparation and updating of Port Operating Plans.

The FAST shore staff also includes two secretaries who are responsible to the two Vice Presidents, an Administrative Assistant responsible for the timely preparation of performance data and coordination of administrative activities, and

a Counsel who provides legal advice and service in developing port entry arrangements with foreign governments in cooperation with the Department of State and the Maritime Administration. Contractor services are provided by several organizations for technical support of the program, and security and special watchman services are contracted for as required.

Some of the positions described above were not immediately filled, as personnel with the required capabilities were not available, placing a heavy burden on the other staff members.

Expenditures for the first year were approximately $305,000, rather than the maximum $473,000 estimated in the Bareboat Charter.

2.1.2 Cargo Operations

The SAVANNAH was integrated into regular operation of the American Export Isbrandtsen Lines fleet on Trade Routes 5, 7, 8, 9 and 10 (U. S. Atlantic ports to Europe and the Mediterranean). The operation is best classified as a normal breakbulk type, with some deck capacity for container cargo.

An assessment of the operational capability of the ship, as well as problems encountered by the ship's Master and Officers follows:

Booms and Cargo Gear Arrangement

The ship is equipped with "Ebel" type cargo gear utilizing the

offset topping lift, an excellent rig which has been installed on other new freighters. Many gang hours of stevedore time have been saved with this rig. Unfortunately, however, problems have arisen from the general layout of the SAVANNAH's cargo gear.

The low height of the trusses causes a steep pull-down angle of the topping lifts and vang guys. This creates a problem of boom support and control of the turning axis at the goose neck when working in a high boom position. This has led to instances of goose neck and boom yoke damage and failure.

The tilt back design of the "A" frame type masts has proven not to be very practical. Booms rigged on the after side of the masts are prevented from being topped to the proper height to work the forward end of the hatch efficiently. The broad support frames which are positioned ahead of the heel of the booms also prevent the booms from being topped and swung inboard to work the after end of the hatch. The limit switches on the forward side of the mast support frames, which are there to prevent boom damage when the forward booms are swung inboard, require constant attention to perform this function properly.

Not only is it possible to damage the yardarms on Nos. 2 and 3 masts with the after set of booms on these masts when they are topped high, but frequently shore cranes work up against these yardarms while loading and discharging the forward ends of No. 4 and No. 7 holds.

The booms are too short for the normal reach required on many piers, the desirable onshore reach being at least 18 feet from the vessel's side when the boom is at a 30-degree angle.

The shorter SAVANNAH boom lengths, coupled with the broad beam of the SAVANNAH (78 feet) makes the maximum obtainable onshore reach about 12 to 14 feet, or from 4 to 6 feet less than the desirable reach.

There seems to be no simple or economical solution to this cargo gear problem. The best solution would be to add booms of a more practical design at hatches Nos. 2, 3, 4 and 6, with heavy-lift gear between Nos. 2 and 3 hatches. There is a large cubic capacity in these holds. To take full advantage of this capacity, double sets of booms would be advantageous on these hatches.

There is an especial need for heavy-lift gear when carrying military cargo. The Department of Defense desires and often requires that a vessel be self-sustaining. Installation of heavy-lift gear would be most feasible between Nos. 2 and 3 hatches, utilizing a type similar to "Stoelken" gear. This arrangement allows one heavy-lift boom to service these two hatches. The necessary king post required for heavy-lift gear could also support two sets of conventional booms, thereby doubling up cargo gear at Nos. 2 and 3 hatches.

Winches

The performance of the hydraulic cargo winches, both in capacity and maintenance free operation, falls below the standard required today on a modern freighter. The 3.3 ton capacity of the cargo winches is inadequate for lifting such cargoes as containers, steel, military vehicles, agricultural equipment, tractors, etc., which are common cargo for most freighters. In the light of present day needs, 5-ton winches are a minimum, and 10-ton winches are desirable.

The hydraulic system has not been reliable. When trouble occurs, it often results in at least four hours downtime. Leaks in these systems have required excessive maintenance. The use of shore cranes and immediate attention by the ship's crew to the hydraulic systems as trouble develops has prevented excessive stevedoring costs. There is, however, a need for a more reliable system.

Excessive rigging time is required, usually by the deck gang. Double rigging or single rigging from a double rigged condition almost always adds additional stevedore gang hours because of the low capacity of the winches. The normal fork-lift used to handle cargo in the hold weighs about 7,000 pounds, which is above the capacity of a singled-up boom. Quite often double rigging is employed for the sole purpose of placing a fork-lift into a hatch.

The winch problem is a serious design deficiency, which would have to be corrected should the SAVANNAH continue in operation as a commercial cargo ship for extended periods.

Cargo Holds

The SAVANNAH's usable cargo holds are adequate in cubic capacity, while the cargo gear is on the marginal side. The many 'tween decks offer advantages for cargo stowage. Low ventilation ducts in the 'tween decks and location of hatch cover controls are disadvantages which should be corrected on any future designs.

The ventilation system for the cargo holds appears to be inadequate during the winter months. Sweat damage to cargo and considerable sweating in the upper and lower 'tween deck spaces has been found on almost every voyage during the winter months. Dehumidification equipment has been recently installed in Holds Nos. 3 and 4, which will correct this sweating condition and also permit the vessel to solicit highly lucrative cargo requiring humidity control.

Hatch Covers

The hydraulic hatch covers in use on the SAVANNAH have been a source of considerable trouble, attributable to their light construction. Careful operation has not prevented damage to wheels, wheel brackets, and hinge-pin bushings. The light construction results in considerable racking and warping from the smallest obstruction on the trackways. This is especially true of the 'tween deck covers. Keeping these trackways

sufficiently clean for free and smooth operation is difficult. The limited clearance and tolerance allowed in the original shipfitting installation did not allow for enough normal lateral movement of the cover; therefore, binding occurs quite often. If this is not immediately recognized by the operator, hatch cover damage occurs. Hydraulic leaks and water leaks through the main deck gaskets are a recurring problem.

Trim

Contrary to early predictions, the vessel's trim has not been a problem. If, however, the SAVANNAH should carry a full homogeneous cargo, such as grain, with the large cubic capacity forward of her tipping center (472,759 cu.ft. forward and 160,551 cu.ft. aft), some ballasting might be necessary. This would cause some loss in deadweight capacity. Except for unusual cargo, careful pre-stow planning can prevent or reduce this potential loss of cargo carrying capacity.

Tonnage Performance

Figures on tonnage averages per unit time are not readily available in most domestic ports and never in foreign ports. Domestic stevedore rates are based on net payable tons (usually measurement tons). For the SAVANNAH, the domestic performance is about 25 net payable tons per gang hour for normal general and Department of Defense cargo.

Several methods to increase tonnage outturn have been tried. A single whip increases the hook speed, but the hook is idle

quite often awaiting movement of cargo. This is especially true in foreign ports. The double-up whip arrangement is preferred, because it provides a safer operation at little or no loss of tonnage performance. The swinging boom arrangement is required when weights approach the limits of the winches, but close supervision by ship's officers is a necessity during this mode of operation to prevent injury to personnel and damage to equipment.

As previously pointed out, while the SAVANNAH's cargo gear leaves much to be desired, she has many good basic design features. The large cubic capacity, the spacious clear deck space suitable for deck cargo, the many 'tween decks which allow for good port segregation of cargo, and the faster cruising speed all helped the SAVANNAH perform creditably on highly competitive schedules during the first year of experimental commercial operation.

How well the disadvantages were surmounted by FAST is shown in the following performance table.

	Eastbound	Westbound	Total
Four Voyages (TR 5, 7, 8 & 9 Europe)			
*Long Tons	10,664	5,420	16,084
**Cubic Utilization	76%	57%	67%
Three Voyages (TR 10 Mediterranean)			
*Long Tons	12,236	6,481	18,717
**Cubic Utilization	94%	67%	81%
Total Voyages (First Year)			
*Long Tons	22,900	11,901	34,801
**Cubic Utilization	85%	62%	74%

* 2,240 lbs.

** Based on approximately 630,000 total cubic feet available. The percentage excludes cargo carried on deck.

2.1.3 Plant Operations and Performance

In the first year of commercial operation, the SAVANNAH traveled approximately 72,000 miles, with its reactor logging approximately 3400 Effective Full Power Hours (EFPH). While the reactor operated at power levels as high as 72 MWt (Megawatt Thermal) during the year, the average power level over the period was 19 MWt. This includes approximately one month of shutdown time during the annual outage at Galveston. Based on a maximum usable power level of 74 MWt, the utilization factor for the reactor was about 0.39. Of significant interest is the fact that the power plant responded satisfactorily to more than 700 changes in load, not unusual for a cargo vessel power plant, but certainly unique in operating histories of land-based utility power reactors.

N.S. SAVANNAH's first year of experimental commercial operation has provided tentative answers to two very crucial questions. These are:

1. How reliable is a nuclear ship?
2. What are annual maintenance and repair costs and other voyage expenses for a nuclear ship?

The answers to both these questions have been more favorable than expected.

Availability of reactor power at sea has been virtually 100%. The only loss of power at sea occurred on Voyage 6. Considerable difficulty (noisy or erratic operation) had been experienced

with Channel 9 of the nuclear instrumentation system after the ship departed from New York at the beginning of the voyage; consequently the channel was isolated for necessary repairs. As the channel was being returned to service, high voltage was accidentally applied to the signal lead of one of the other two level-safety channels and a scram (reactor shutdown) occurred. On this occasion, the take-home motor was engaged in less than 10 minutes; the reactor was again critical in about 23 minutes after the scram occurred.

The reactor was critical 81 per cent of the time; was shut down on a scheduled basis 15 per cent of the time; and was shut down on an unscheduled basis 4 per cent of the time. A total of 26 scrams occurred during the year. Of these, one occurred at sea, and only 6 scrams occurred while the reactor was at power levels in excess of 10 per cent full power.

Radiation control was obtained without significant difficulty. The average personnel exposure for the crew was 88 milli-roentgen equivalent man (mrem) for the one-year period. The highest single exposure for the year was 1140 mrem. The maximum permissible exposure level is 5000 mrem/yr, as specified in the Code of Federal Regulations, Title 10.

There was no spread of contamination on the ship outside the normal health physics control areas, except on one occasion during the annual outage. In this instance, a manufacturer's representative brought contamination onto the ship from

another facility. This was discovered at the containment health physics checkpoint. After the man's shoes were found to be seriously contaminated, they were destroyed, and the passageways were successfully decontaminated.

On one occasion, while a sample system relief valve was being decontaminated in the hot chemistry laboratory, several drops of contaminated water fell onto the tile deck in the laboratory. Because of the nature of the tile floor, washing was ineffective, and the level of radiation activity on the floor remained at about 2500 disintegrations per minute (DPM). The tile was subsequently removed and replaced by a low porosity linoleum type floor covering which can be more readily decontaminated.

Radiochemistry tests of the primary water were made daily. Principal isotopes in the water were Manganese-54, Cobalt-60, Cobalt-58, Iron-59 and Chromium-51. The 15-minute gross beta-gamma degassed activity remained at about 0.01 microcurie/cc, about the same as was found during initial sea trials in 1962. Radioiodine levels remained at about 10^{-4} microcuries/cc. Argon-41 levels were at 10^{-4} to 10^{-3} microcuries/cc. Resins in one of the three primary system demineralizers were renewed once during the year, during the outage in June 1966.

A total of 98,000 gallons of liquid waste, containing 9000 microcuries of radioactivity, was discharged to shoreside tank cars for disposal or to the Atomic Servant for processing. It was not necessary to discharge radioactive liquid wastes in any port waters.

The SAVANNAH control rod drive system, a source of concern because of its complexity and uniqueness, continued to perform very satisfactorily during the year. There were no failures to scram. The hydraulic oil leakage rate (all leaks combined) amounted to less than one-tenth of 1 per cent of the total capacity. Periodic visual inspection of selected buffer seal shafts revealed no noticeable change. As a result of carbon steel tanks being replaced with stainless steel tanks and other upgrading efforts prior to the start of the FAST operation; hydraulic oil cleanliness was superior to that experienced in previous periods. Scram time tests indicated time of 0.48 to 0.52 seconds, well below the Technical Specifications value of 1 second.

The containment vessel integrity remained at a high level during the year. In each of five measurements of the leakage rate at 60 psig, the rate was found to be between 0.5 and 0.8% per day, well below the Technical Specifications value of 1.2% per day. (For the SAVANNAH, the peak post-MCA (Maximum Credible Accident) containment vessel pressure is expected to be no greater than 173 psig, and the average pressure in the first two hours after an MCA is expected to be less than 60 psig, even if little or no pressure suppression is exercised.)

The reactor space ventilation system filters were tested quarterly during the year. In only one case was it necessary to replace a filter because it failed to meet the requirements

of the Technical Specifications. The results of all other tests of particulate removal capability and iodine removal capability were well above the Technical Specifications values of "A removal factor of at least 1000 for DOP" (dioctyl phthalate). In the one unacceptable filter, an iodine removal factor of 51 was observed. A prefilter and absolute filter were replaced after completion of Voyage 3, but this was because of high pressure drop and not for lack of particulate removal capability.

A major concern during the year was the incidence of high chlorides in the secondary side of the steam generators. Throughout the year, there were 10 instances of chlorides in excess of 1 parts per million (ppm) in the boilers, three of which were in excess of 5 ppm. The maximum chloride level found was 28.75 ppm. The chloride problem does not pertain to the secondary side of the steam generators, which are of carbon steel construction. The problem is on the primary side, which has Type 304 stainless steel tubes and liners on all surfaces in contact with primary water, and is very susceptible to chloride stress corrosion. Oxygen control is obtained by maintaining 20-30 ppm of sodium sulfite in the water on the secondary side of the steam generators. During all of the high chloride incidents, the sodium sulfite concentration was satisfactory. It is believed, therefore, that no instance of high chlorides and high oxygen content occurred simultaneously.

The occurrence of high chlorides in the boiler water was thought to be caused primarily, if not entirely, to occasional unstable operation of the No. 1 low pressure sea water evaporator, one of two evaporators used to furnish make-up water to the secondary system. Actions taken to minimize the likelihood of recurrence of high chloride concentrations and to provide greater capability to deal effectively with the problem include:

(a) Shutting down or tripping out the evaporators in anticipation of steam plant-load changes or heavy weather.

(b) Piping the evaporator air ejector condenser drains to the boiler feed tank, rather than to the atmospheric drain tank, so that these drains cannot feed into the secondary system without passing through the plant make-up demineralizer.

(c) Frequent check of operability and calibration of evaporator salinity cell and trip valve.

(d) Increase in the length of pipe between the salinity cell and the dump valve on the salt water heater drain to accommodate the lag time between cell trip and dump valve operation.

(e) Relocation of the Quantichem analyzer from the lower engine room to the chemistry lab. This provides a better environment for the analyzer and facilities operation and maintenance by the water chemist.

(f) Conversion of No. 4 centerline ballast tank to use as a reserve boiler feed tank with a capacity of 150 tons of water.

2.1.4 Maintenance and Repair

A nitrogen atmosphere is maintained in the containment vessel to eliminate the possibility of any fire hazard in this area. Thirteen times during the year the containment vessel was

purged of nitrogen to permit maintenance, testing, and repairs. The major items of maintenance and repair will be discussed later.

During its entire operating history, the SAVANNAH has experienced difficulties with the two main feedwater pumps. In the first year of experimental commercial operation, some repair of one or both of the main feed pumps was necessary on each voyage. Primary difficulties have been in the bearings and governors. These are steam-turbine-driven pumps which are rated at 735 gallons per minute. In the June 1966 outage, the old pumps were replaced with new, more compact pumps, which necessitated rerouting of steam and water piping. The operating experience with the new pumps is as yet insufficient to permit evaluation of their reliability.

The SAVANNAH pressurizer is equipped with 160 electric heaters, connected in five groups of 12, 12, 24, 40 and 72 heaters per group. Four of these heaters required replacement during the period.

The buffer seal system, which supplies high pressure water for in-leakage at the control rod drive sliding seals, includes, among other things, three desurger tanks located downstream from the three charge pumps. Electrical heaters are wrapped around each desurger tank, and during reactor operation the heaters maintain a steam pocket in the upper portion of the tanks. On the second voyage of the year, it was found that one of these tanks was heavily bulged and immediate repair

was considered necessary; a second tank was bulged to such an extent that replacement was scheduled for the annual outage. This condition was attributed to a malfunction in the electric heater control and alarm.

During reactor operation, the ship's compartment in which the containment vessel is located is maintained at a negative pressure. This compartment is called the reactor space, and the ventilation system serving that compartment is called the reactor space ventilation system (RSVS). Each of the two filters in this system consists of a demister, a prefilter, an absolute filter, a silver-plated copper mesh filter, a deep charcoal bed, and a second silver-plated copper mesh filter.

Major Maintenance Record RSVS Filters

Voyage	Maintenance
2	Replace charcoal unit - RSVS No. 2 Filter
3	Replace Prefilter & Absolute Filter - RSVS No. 1 Filter
'66 Outage	Install new gasketed access plate on each RSVS filter housing

On several occasions, maintenance of pneumatic lines and fittings inside the containment vessel was necessary in order to reduce air in-leakage to the containment vessel. While maintenance of the lines and fittings is not a major item in itself, the necessary purging and re-inerting of the containment vessel makes this maintenance costly and time-consuming. This

experience shows that pneumatic instruments and actuators should not be used inside reactor containment.

Three hydraulic oil pumps supply high pressure oil to the control rod drive system. A sheared coupling on one of these pumps was replaced, and the pump itself was later replaced. This was the first occurrence of this type of failure in SAVANNAH operating experience, and no satisfactory explanation for the failure has been found.

2.1.5 Annual Outage

The June 1966 annual outage was scheduled to last one month. Although this was the shortest annual outage ever planned for the ship, it was felt that there would be sufficient time to accomplish the required work if a concerted effort was made by all parties. The N.S. SAVANNAH arrived at her service facility, Todd Shipyards Corporation, in Galveston, Texas, on June 2, 1966, and departed July 1, 1966. The ship was down for repair and annual inspection a total of 29 days. This included a one-day sea trial and five days drydocking time. The ship then resumed the planned normal experimental commercial operating schedule.

Several of the more important jobs which were performed during the outage are discussed below:

The pneumatic-operated pressurizer relief valve PR-3V, which had been a source of leakage into the effluent condensing tank,

was replaced with a new design pilot-operated valve. Evaluation of the valve is part of the research and development program being carried out on the ship. At this time, its performance is exceeding expectations.

New vibration snubbers were installed on the pressurizer. Utilizing a Belleville spring arrangement, the snubbers were designed by Savannah Technical Staff engineers and were thoroughly tested in a mockup rig on the Nuclear Servicing Vessel (N.S.V.) ATOMIC SERVANT prior to the ship's arrival. The snubbers were adjusted and test performed during the sea trials. The tests showed that they were performing as designed.

Alternate circuits were developed to improve the safety system. The improvements consisted essentially of the addition of parallel scram circuits. These were installed and tested during the outage. The installation included not only the operational equipment, but also modification of all spare equipment and the updating of drawings affected by the modification.

New electrical penetrations were installed in containment vessel Boxes 50 and 52. Penetration in all of the other boxes had been installed previously. This completed the program of installation of the new improved seal type penetrations, which has significantly reduced leakage from the containment vessel.

The port steam drum isolation valve SS-4V was replaced with a valve of a new design. The starboard valve had been replaced

during the previous annual outage.

To improve navigation aboard the ship, a new Loran A/C unit was installed to replace an older Loran C unit.

Dehumidification Equipment Installation for Cargo

A dehumidification system for cargo was installed in Holds No. 3 and No. 4. This system allows complete control over temperature and humidity in the holds and makes it possible for the SAVANNAH to procure highly profitable cargo requiring humidity control, such as tobacco. The decision to start engineering and ordering material was made in April. The engineering portion included a complete redesign of the cargo hold ventilation system to make it compatible with equipment units. Because of its size and the late date of authorization, the installation could not be completely finished. It was approximately 80% completed during the outage, and was to be finished during the ship's normal stops in the New York area, involving no delay in the ship's operating schedule.

Cathodic Protection System

A cathodic protection system for the hull of the vessel was installed. The system produces controlled electrical currents, suppressing the local galvanic currents generated between the hull and sea water, thereby minimizing corrosion of the hull itself.

The underwater portion of the system was installed while the ship was on drydock. This involved cutting holes for the necessary hull penetrations and installation of the anodes.

The remainder of the system was installed and tested while the ship was tied up to the pier.

Water Chemistry Equipment

The Quantichem unit aboard the ship was designed to sample secondary water at several locations in the reactor plant and to analyze this water for chloride content. It was originally installed in the lower engine room space. During the outage the unit was relocated to the water chemistry laboratory adjacent to the control room. During the move, the unit was completely overhauled and upgraded by installing constant head vessels with level switches and new sample cells. The unit was calibrated during sea trials.

Salinity in the secondary system had been measured in several locations by the use of Larson Lane units. The units were located individually throughout the engine room. During the outage, these units were overhauled and relocated to the same area as the Quantichem. Also, the secondary system pH meter was relocated to this area. These changes centralized the equipment and made for better control of the water chemistry.

Reactor Space Ventilation System

The reactor space ventilation system modification, which entailed the installation of a recirculation mode, was completed during the outage. This system had previously been designed and the installation engineering completed by the Savannah Technical Staff. A preliminary checkout of the

system was performed. A final check and further extensive testing of the system was to take place later.

Main Boiler Feed Pump Installation

The main boiler feed pumps originally installed on the ship required extensive and frequent maintenance. During the outage, the old feed pumps were removed and new feed pumps were installed. The engineering for the installation of the pumps, performed by the Savannah Technical Staff, included preparation of several drawings and detailed installation procedures. As a part of the new installation, the auxiliary feed piping was eliminated. The port feed pump retains auxiliary feed system capabilities.

In order to complete the installation during the limited time available, a great deal of preparatory work was done. This included procurement of all material, excluding the pumps. The logic control panel, which permits operation of the pumps from the control console, was fabricated and tested prior to the ship's arrival.

The pump installation was completed during the outage. Shipboard operation of the pumps demonstrated the need for additional work on pump controls. This was begun in December 1966 and was to continue until satisfactory operation was attained.

Control Rod Drive System

During the June 1966 outage, all the "O" ring seals in 189 panel-mounted valve assemblies and 21 flow orifice assemblies

in the control rod drive system were replaced. This "O" ring replacement could be classified as preventive maintenance because many of the "O" rings had exceeded manufacturer's recommended life. This replacement reduced the hydraulic oil leakage mentioned previously to an insignificant amount of less than a pint per day.

2.1.6 Port Entry

In the demonstration phase of operation of the SAVANNAH by the Maritime/AEC Joint Group through American Export Isbrandtsen Lines, Inc. acting as General Agent for the United States, agreements were made between the United States and various other countries regarding the use of foreign ports and waters by the SAVANNAH. These agreements usually covered safety assessments, port arrangements, inspection, disposition of radioactive wastes, maintenance, repair and servicing, and public liability. Countries with which agreements were made include Belgium, Denmark, Federal Republic of Germany, Greece, Ireland, Italy, The Netherlands, Norway, Portugal, Spain, Sweden, and the United Kingdom of Great Britain and Northern Ireland. Ports in France were also opened to the SAVANNAH, but without a formal agreement.

The Atomic Energy Commission provided the Maritime Administration with an indemnity agreement under the Price-Anderson Act during the period of government operation of the ship in the demonstration phase. The agreement indemnifies and holds harmless

the operators of the SAVANNAH against claims for public liability arising from a nuclear incident up to 500 million dollars.

As operator of the SAVANNAH under bareboat charter in her experimental commercial operation, First Atomic Ship Transport Inc. is licensed by the Atomic Energy Commission and has a similar arrangement for equivalent indemnification under the Price-Anderson Act.

Since the agreements between the United States and other countries for use of their ports and waters were effective only while the vessel was being operated by the Government, it was necessary for FAST to make new arrangements with each country. FAST officials have indicated that foreign port demonstration visits of the SAVANNAH, when operated by the Government, did not have a lasting effect of keeping the ports open for the ship. They found different circumstances and problems in getting permission to call at foreign ports under the experimental commercial operation, as opposed to the U. S. Government sponsored demonstration visits.

Maritime and the Department of State have cooperated in an effort to assist in obtaining favorable responses from those countries (on trade routes permitted by the Charter) to which FAST expressed a desire to schedule port calls. The State Department asks the U. S. Embassy in a country to be visited to inform the appropriate officials of that country of the intention of FAST to send the SAVANNAH to the country's ports.

The Embassy offers to furnish any additional information and to assist representatives of FAST when they call on the country's officials. State advises Maritime of the reaction of the foreign officials, and Maritime gives this information to FAST. FAST's representatives may then call on the appropriate foreign officials to continue the entry negotiations. State and Maritime cooperate in providing the Embassy with additional information or assistance to enable it properly to reflect the interest of the United States and the protection afforded under the Price-Anderson Act.

FAST has obtained permission for the SAVANNAH to call at ports in Germany, Portugal, Spain, Belgium, Netherlands, and Italy. The SAVANNAH has also called at ports in France without a formal agreement.

Following is a list of the countries where action is pending for port entry of the SAVANNAH:

- Turkey
- Greece
- The Netherlands
- Belgium
- Yugoslavia
- Libya
- Tunisia

In accordance with licensing requirements of the AEC, FAST developed Port Operating Plans based on FAST-2, "N.S. SAVANNAH Port Operation Criteria." The plans for each port were to be

submitted to the AEC, Division of Reactor Licensing, and the U. S. Coast Guard for review and approval prior to the initial port entry by the SAVANNAH. Port operating plans developed by FAST were prepared and approved for 11 domestic ports and 18 foreign ports during the first year of experimental commercial operation. The vessel entered and departed, without mishap, a total of 71 ports during the first year; thus furthering the acceptance of the ship as a standard commercial carrier. The opening of seven new ports of call in the first year and the plans to initiate service to an additional six ports of call in the second year reflected the increasing acceptance of this vessel in an important trade area. A list of ports for which Port Operating Plans were prepared and approved is included as Appendix A.

3. NUCLEAR VESSEL SERVICING FACILITY - GALVESTON, TEXAS

3.1 Savannah Technical Staff

The Savannah Technical Staff (STS) was originally set up in 1962, when States Marine Lines (SML) operated the ship. At that time it was known as the combined staff. Upon the termination of SML's contract, the STS, comprised of Todd Shipyards Corporation (Todd) and The Babcock & Wilcox Company (B&W), was formally established.

During the period of this report, Todd's Nuclear Division supplied an average of 29 trained and experienced Administrators, Design Engineers, Health Physicists, and Maintenance Engineers for the STS.

The B&W contribution varied from three people in August of 1965 to none in August 1966. B&W provided additional support from its Lynchburg facilities.

The staff represented a unique capability, in that it was a technically oriented group, thoroughly familiar with the SAVANNAH and her systems and capable of servicing her at any port in the world.

The SAVANNAH's servicing base in Galveston, Texas, consisted of a combination of Todd's repair yard and facilities and special Government facilities arranged to perform refueling and major nuclear repairs as well as normal maintenance. The following page summarizes STS capabilities and services.

SERVICES

ENGINEERING AND DESIGN

Reactor components and systems.

Reactor instrumentation and devices and systems.

Radiation monitoring systems.

Reactor equipment handling devices and systems.

Reactor fuel handling tools and equipment

Remotely operated equipment for handling, storage and disposal of radioactive material.

FABRICATION, INSTALLATION AND MAINTENANCE

Reactor components and systems.

Reactor instrumentation devices and systems.

Reactor handling equipment.

Reactor fueling and refueling tools and equipment.

Remote handling equipment for measuring storage, and disposal of radioactive material.

Radiation monitoring systems.

SPECIAL SERVICES

Consulting services in connection with any of the listed services.

Health physics training programs and manuals for management, supervisors, technicians and monitors.

Calibration and repair of radiological safety instrumentation.

Leak testing of radioactive sources.

Decontamination of facilities and equipment.

Health physics personnel for emergency assistance.

3.2 Work Program

The work described below was accomplished by STS during the SAVANNAH's first year of experimental commercial operation, August 20, 1965 to August 19, 1966. It also included the support given to First Atomic Ship Transport Inc. under the group's contract with FAST.

3.2.1 Pump Repairs

After four trouble-free years of operation, two of the N.S. SAVANNAH's four canned rotor primary coolant pumps unexpectedly failed, and the condition of the other two pumps was suspect because of intermittent high current drain. This breakdown occurred as the N.S. SAVANNAH was nearing the end of the 1965 annual outage, just prior to her experimental commercial operation.

While the exact cause of the failures was uncertain, they apparently occurred during a 60 psi leak rate test of the containment vessel. The mechanism of the failure was believed to have been the inward deformation of the thin Inconel stator can because of lower pressure in the primary system than was present in the stator can. As a result, a hole was worn in the can wall, permitting primary system water to enter the stator windings, shorting out the pump motor.

All four of the primary system pumps were replaced, after minor mechanical alterations required by differences in the design of the spare pumps.

The nature of these pumps makes their repair a complex and sophisticated job. Repairs of this type had never before been performed outside the vendor's fabrication shop. Under the direction of the Todd Nuclear Division personnel, repair of the pumps was substantially completed at the end of the period covered by this report.

3.2.2 Drawing Upgrading

A major effort of the staff was the drawing upgrading program required to comply with AEC regulations, to assist efficient operation of the ship by FAST, to provide training aids, and to maintain the various systems. This involved making detailed corrections to the original ship drawings to bring them into conformity with the current ship systems and equipment.

3.2.3 Refueling Preparations

Preparations were started for the future refueling of the SAVANNAH. This included writing detailed procedures and preparation of a safety analysis which would be required to obtain a license.

The need for several new pieces of equipment for refueling, as well as modifications to existing equipment, were discovered as a result of writing the procedures.

The safeguards report for the refueling license was started, and Sections I and II, Facilities and Equipment, and Description of Operations, were completed. Section III, Hazards Analysis, was started. A study was initiated, as a part of the Hazards

Analysis, on the effect of possible accidental dropping of the refueling equipment on the reactor vessel and the subsequent release of radioactive material.

3.2.4 Facilities

The servicing facilities were used for the pump repairs and the annual outage during the year. In connection with the SAVANNAH refueling and storing of the removed core, the facilities outfitting work was continued and many of the planned additions were completed.

A completely enclosed decontamination room, measuring 20 ft. square by 34 ft. high, was designed and constructed within the Nuclear Facilities Building. The room contains facilities for decontamination of radioactive equipment that might be removed from the ship during refueling or primary system repairs.

The decontamination room has its own ventilation exhaust system. The exhaust air duct intake contains both a particulate roughing filter and an absolute filter, with the exhaust duct discharging through a louver on the roof. Should the normal power fail in the facilities building, a 75 kilowatt, 440 volts alternating current, 3 phase, 60 cycle diesel generator is provided to supply various emergency lights, radiation monitoring equipment, and several drop cord outlet circuits. Supplemental power is also provided by the emergency generator to allow restricted operation of the building overhead crane; the restriction being that only two of three movements (hoist, carriage, bridge) can

be made at one time.

A demineralized water heating system and an alarm and detection system were designed and installed. The latter system includes smoke detectors, flame detectors, and a high radiation alarm. It also includes an audible alarm located outside the building and an alarm panel located in the guard's office, where personnel are on duty twenty-four hours a day.

The spent fuel pit was being filled to the top when it was observed that the level of water in the liner sump was rising, indicating a leak in the pit liner. Samples of the water in the pit were found to contain approximately 100 ppm of chlorides, and on this basis the entire contents of the fuel pit were pumped into Galveston Bay. No discharge of radioactivity was involved. A crack approximately 15 ft. long was found in the northeast corner weld of the liner.

Inspection of the side of the plate next to the concrete showed that spot corrosion had occurred between the plate and the concrete. It was determined that there was no known practical method to stop further corrosion of the liner, and it was decided to replace the aluminum liner with a stainless steel liner.

A study was made which indicated the need for some cooling when a depleted core would be first loaded in the spent fuel pit. Preliminary design and sizing work for installing the

cooling equipment was completed.

Approximately 3,100 gallons of waste had been generated during the previous outage and by the pump repairs, and was stored aboard the N.S.V. ATOMIC SERVANT. A study was initiated to determine the most economic method for disposal of this waste. A combination of filtering and continuous dilution was decided upon. A filter was installed in the waste process system on the ATOMIC SERVANT, which reduced the activity of the waste by a factor of two. Todd's radioactive material license from the State of Texas was revised to allow the continuous discharge of liquid waste from the ATOMIC SERVANT assaying more than 10^{-7} microcuries per cc. The revision provides that the waste be metered into the discharge of a sea water pump whose flow would be such that the actual discharge into the ship channel would assay less than 10^{-7} microcuries per cc. Approximately 6,300 gallons of waste were discharged by this method, and continual analysis of the bay indicated no change in radioactivity.

A fenced storage area was constructed to meet license requirements for storage of radioactive material. At present Government owned radioactive material from Lynchburg is stored within this area. One Government owned trailer was modified to serve as a storage building for flammables and located within this area. This permitted highly flammable materials to be removed from the regular warehouse, greatly reducing the fire hazard.

As a further safety measure, a door was installed in the west

end of the Facilities Building to allow ready access and exit at either end of the building in the event of fire, radiation, or other emergency. A 1½-inch aluminum line was installed from the Facilities Building to a point approximately 300 feet out on pier "E". This line permits ready transfer of primary grade water from the Facilities Building to the SAVANNAH and vice versa. A 2-inch waste line was installed on pier "E" for discharge of diluted liquid radioactive waste from the ATOMIC SERVANT, eliminating the need to move the barge to the end of the pier to discharge waste to Galveston Bay as had been required previously.

Several pieces of equipment were designed and fabricated for use during refueling for the handling of radioactive equipment, i.e., upper flow baffle, upper grid plate and fuel bundles into the spent fuel pit. They included support stands for the internals handling cask and fuel element-control rod cask, a transfer assembly, and spent fuel storage racks.

3.2.5 Health Physics Training

A review of the routine health physics surveys and analyses performed aboard the N.S. SAVANNAH was made to determine if any reduction in the work load could be made without sacrificing radiological safety coverage or required data.

The outcome included deleting several items and reducing the frequency of others. A tentative schedule of work, reflecting

these changes, was prepared. The staff provided a health physics training officer to sail on Voyage No. 4 to conduct training classes for members of the deck and engine departments.

3.2.6 Marvel-Schebler Control Rod Drive System

The final draft of Marvel-Schebler (MS) Safeguards Report, Volume II, was completed.

A modification was made to the MS Logic Power Wiring which added a fail-safe feature.

All material required for the MS training program, including drawings and a training manual, were completed and stored.

Monthly battery checks were made on the logic and standby batteries, and desiccant was replaced in the cabinets as required.

The periodic six month exercise of the system was performed in July 1966. The twenty-four hour operation was completed, and no faults occurred in the electronic system. A full-out scram was performed to check for the presence of particulate in the mockup vessel, and none was observed.

Work was started on preparation of metal "O" ring pressure caps for installation. This involved testing the vent valves, which were sent to the vendor for repair and resurfacing.

3.2.7 General

A complete revision of the Safety Assessment was made during

the year. This document, Revision II, consists of 450 pages, 135 figures, and 73 foldout drawings.

A microfilm system was installed in central files. All drawings were filmed and subsequently placed on IBM cards. This allows the cards to be kept on hand while the film is kept in a bank safety deposit box. There are approximately 12,000 cards in the system.

The 36 Core II fuel elements, 4 Core I spare elements, and miscellaneous hardware were transferred from storage at Medina Air Force Base to the Army storage facilities at Killeen, Texas. The transfer was accomplished in five days and was supervised by the staff. At this time, each element was inspected, purged with dry nitrogen, and the desiccant was replaced.

Several technical reports were written and issued during the year. These included:

STS-62, "Fuel Management Report."

STS-69, "Operation With Failed Fuel Element."

STS-70, "February-August Operations Report."

STS-71, "Multi-channel Analyzer Calibrations Report."

BAW-1303, "5000 EFPH Physics Report."

BAW-1306, Rev. 1, "Nuclear Instrumentation and Safety System."

"Technical Information for the Master" was prepared in draft form and submitted to FAST and MARAD for comments. The comments were being incorporated in the document and the report is expected to be issued shortly.

3.3 Nuclear Shore Staff (FAST) Support

The staff furnished support for First Atomic Ship Transport Inc. during the year in the form of backup personnel sailing aboard the ship, preparation of engineering information packages, preparation of procedures and supervision of work during the annual outage.

The major support furnished came during the annual outage in which the staff engineered certain jobs, prepared drawings, obtained appropriate regulatory approvals, prepared procedures, and supervised installations aboard the ship. The most significant of these included:

1. Installation of two five gallon per minute pumps in the charge pump rooms to facilitate pumping the charge pump room bilges and leak-off tanks to waste tanks PD-T5 and PD-T6.
2. The flanging of primary purification relief valves to allow bench testing during the annual United States Coast Guard inspection.
3. Installation of additional access plates to the reactor space ventilation system filter housing to improve filter maintenance.
4. Installation of boiler blowdown isolation valves outside the containment vessel to allow maintenance of the boiler blowdown valves.
5. Fabrication of two charge pump desurgers.
6. Installation of charge pump desurger SL-T4.
7. Thorough overhaul of the control rod drive system.
8. Inspection and calibration of nuclear instrumentation.

4. TRAINING

The Bareboat Charter Agreement between First Atomic Ship Transport Inc. and the Maritime Administration provided for the Government to direct and finance the training necessary to meet vessel manning requirements caused by crew attrition, and to maintain a pool of shipboard personnel trained in nuclear procedures.

Licensed marine engineers and deck officers recruited by FAST through the Brotherhood of Marine Officers were selected by a panel for reactor operator training on the basis of their scholastic background, professional experience, age, and aptitude tests.

4.1 Training Program

The following is a description of the Savannah Training Program conducted during the first year of experimental commercial operation. This training is designed to prepare reactor operator trainees to manipulate the controls of the SAVANNAH's reactor and operate her propulsion plant in a competent and safe manner. Deck officer trainees are trained to manage a nuclear reactor site in accordance with the Technical Specifications, Port Operation Criteria, and other applicable regulations.

A summary of the numbers of persons trained or in training in each category is given in the following table for the first year of operation.

	Trained	In Training
Reactor Operators	13	0
Senior Reactor Operators	13	8
Deck Officers	4	0
Water Chemistry	17	0
Health Physics	8	13
Instrumentation	2	1
Nuclear Advisor	7	0

4.1.1 Reactor Operator Training

The academic phase of instruction, for a period of 4-5 months, was conducted at the United States Merchant Marine Academy at Kings Point. The courses of instruction provided the participants with a background in nuclear science, and with a detailed knowledge of the N.S. SAVANNAH nuclear propulsion system. Extensive use of the N.S. SAVANNAH simulator provided training for understanding the reactor system and steam plant system behavior and control. The subjects covered are listed below:

- Nuclear Physics
- SAVANNAH Systems
- Electronics
- SAVANNAH Electrical
- Applied Mathematics
- SAVANNAH Simulator Laboratory
- Nuclear Instrumentation
- Reactor Engineering
- Reactor Management and Safeguards

The shipboard phase of instruction, for a period of 4-5 months, was conducted aboard the N.S. SAVANNAH under the guidance of an experienced Training Officer. This phase of the program consisted of classroom review of academic subjects, familiarization with shipboard arrangements, and operational practice. The subjects covered are listed below:

SAVANNAH Systems and Procedures
Reactor Engineering
Radiation Monitoring
Physics Review
Nuclear Instrumentation
Electrical Systems
Control Rod Drives

Shipboard familiarization included a program of systems check-out in which the trainees individually determined the location and operating sequence of each component in the various systems. The trainees gained operating experience during this phase of the program by standing watches in a training status.

A total of thirteen reactor operator trainees completed their training, and all passed the reactor operator license examinations given by the Atomic Energy Commission. The perfect record attained by this group was most satisfying and showed an economy in training costs. It was attributed to improved training based on the experience of earlier trainees. Examination results showed areas of weakness in former groups, and additional

instruction was given to the trainees in this most recent group.

After six months' experience as a reactor operator, an engineer with a second engineer's license or higher may be qualified to take the senior reactor operator's license examination given by the AEC. Upon receipt of a senior reactor operator license, a man is qualified to be in charge of the engine room watch at sea.

4.1.2 Deck Officer Training

Shipboard training was conducted aboard the SAVANNAH for deck officer trainees for a period of two voyages, or approximately four months, under the guidance of the Training Officer and Chief Officer. Upon successful completion of the shipboard training, the trainee was certified as qualified by the ship's Master to be in charge of a deck watch. Courses aboard ship were undertaken and completed in the following subjects:

- Nuclear Physics
- Reactor Engineering
- SAVANNAH Systems
- Health Physics
- Legal and Regulatory Aspects of Nuclear Vessel Operations

Shipboard familiarization included a program of deck officer functions checkout in which the trainees individually learned their duties by standing watches and performing work in a training status.

A total of four deck officers were trained under the program,

and all were certified as qualified SAVANNAH deck officers by the ship's Master.

4.1.3 Special Training

Specialized training was conducted both aboard the SAVANNAH and ashore in the following areas: Water Chemistry, Health Physics, Nuclear Instrumentation, and Nuclear Advisor. The training was given to provide the reactor operator engineers with these capabilities in order to reduce crew manning by the elimination of persons performing these duties as a specialty.

Water Chemistry

This training was given to a total of seventeen reactor operator engineers to provide them with the capability of performing water chemistry functions on the primary, secondary, and other systems while on watch. This training was conducted by Bull & Roberts, Inc. aboard the SAVANNAH, and ashore at the Calgon Corporation in Pittsburgh.

Health Physics

This training was given to a total of twenty-one reactor operator engineers and deck officers. Seven reactor operator engineers and one deck officer completed the training. Instruction in Health Physics Theory was given by Todd instructors aboard the SAVANNAH. Health physics functions were performed in a training status by the trainees under the guidance of the Staff Health Physicists.

Nuclear Instrumentation

Two reactor operator engineers were trained in nuclear instrumentation. The training was conducted at the U. S. Army Nuclear Instrumentation School at Fort Belvoir, Virginia, for a period of approximately eight months. The training they received has qualified them to analyze, service, and maintain the nuclear and nonnuclear instrumentation aboard the SAVANNAH.

Nuclear Advisor

The Nuclear Advisor must be an experienced engineer with detailed knowledge of the SAVANNAH's nuclear propulsion plant, its operation, and construction. His duties are to collect information and offer advice to the ship's Master on the specific conditions of the nuclear plant and potential shipboard and environmental hazards resulting from an abnormal plant condition.

A total of seven Babcock & Wilcox Company nuclear engineers were trained to perform this function aboard the SAVANNAH.

5. FINANCIAL

5.1 Revenues and Operating Costs

As previously indicated, the SAVANNAH was not designed to compete on an economic basis with other ships of her size in the carriage of cargo. Nuclear power is most likely to be practical on large ships (with twice the cubic capacity of SAVANNAH) and of very high speed ships (30 knots and above), designed to carry containerized cargo on long trade routes.

The following table is a summary of revenues received and operating expenses incurred by the SAVANNAH during the first year of experimental commercial operation. It should be understood that the data are preliminary in that some bills chargeable to the first year's operation had not yet been completely processed. Further, all FAST accounting in this area is subject to Government auditing which had not been completed for the first year. The figures in the table, however, are expected to approximate the final figures.

N.S. SAVANNAH Revenues and Operating Costs
First Year of Commercial Operation - Preliminary

Voyage Record			
Sea days	168		
Port days	197		
Total Number Days		365	
Voyage Revenue			
Freight - Eastbound		$1,399,757.74	
- Westbound		907,554.02	
Total		$2,307,311.76	
Mail		44,390.45	
Total Revenue			$2,351,702.21
Voyage Expenses			
Wages		$1,114,118.70	
Subsistence		40,122.47	
Stores & Equipment		148,704.47	
Fuel (Oil)		8,440.31	
Maintenance & Repair		375,370.10	
Insurance (P&I)		158,056.13	
Other Vessel Expense		14,471.16	
Total			$1,859,283.34
Port Charges			
Agency Fees		$ 14,546.88	
Wharfage		81,873.13	
Port Expense		240,553.20	
Other		73,343.20	
Total			$ 410,316.41
Cargo Charges			
Stevedoring		$ 513,661.83	
Other Cargo Expenses		215,470.04	
Brokerage-Freight		31,719.14	
Other		36,590.34	
Total			$ 797,441.35
Total Operating Expenses			$3,067,041.10

Other Expenses

Overhead to FAST	$ 197,100.00	
Shore Staff	305,409.00	
Total		$ 502,509.00
Total Expenses		$3,569,550.10

First Year Cost Summary

	Estimated	Actual
Total Operating Expense	$2,905,456	$3,067,041
Total Revenues	1,764,000	2,351,702
Operating Loss	$1,141,456	$ 715,339
Reduction in Estimated Loss	---	416,117
FAST Profit	---	200,000
Government Savings	---	226,117
Net Operating Loss	1,141,456*	915,339**
Overhead to FAST	197,100*	197,100**
Nuclear Shore Staff (FAST)	473,000*	305,409**
Total Cost to Government (FAST)	1,811,556	1,417,848

* and ** items included in total cost

The following comments may be helpful:

The FAST profit of $200,000 is based on a reduction of operating costs and improved revenue beyond that originally estimated in the agreement for the first year of operation. An overall operating deficit was projected for the accounting period and any reduction of these losses is equally shared between FAST

as a profit and the Government as a reduction in operating cost up to a limit of $400,000. Thereafter, any further savings are for the sole account of the Government. Conversely, losses or costs in excess of the anticipated figure are proportionately shared by both parties according to a mutually acceptable formula. The indicated revenue is good for a ship of SAVANNAH's cubic capacity hold arrangements and cargo gear. In preparation of the Bareboat Charter, estimates of probable revenues ranged from $1.4 million to $1.8 million. A number of questions influencing revenues were considered, such as:

1. Could we expect shippers to be reluctant to use a nuclear ship?
2. How much cargo would a single ship service attract?
3. Would tug requirements increase turnaround time?
4. Would P&I insurance and cargo insurance be higher?

All these questions indicated a conservative estimate.

The 197 days in port includes a 30-day scheduled outage because of the experimental nature of the SAVANNAH. After more experience is gained, a reduction in down-time would be expected, thereby giving an annual inspection period more comparable with that of a similar oil-fired vessel.

The annual maintenance and repair costs include those incurred for the annual inspection period, as well as voyage repairs, and include about $50,000 in what are considered nonrepetitive costs. The total M&R cost of $375,000 is substantially below

the estimate of $487,000 used in preparation of the Bareboat Charter, which was based on operational experience during the demonstration phase.

The overhead figure of $197,100 is based on a prorated cost per cargo vessel for the overall parent company (American Export Isbrandtsen Lines) fleet operation.

Crew wages reflect the high manning (66 personnel) on board SAVANNAH as a result of the safety and operational requirements for this first-of-a-kind ship. A list of the SAVANNAH's manning schedule for the first year of experimental commercial operation is included as Appendix B.

The data above do not include capital investment costs, nuclear fuel costs, or Price-Anderson nuclear indemnity charges. Other costs involving shoreside servicing facilities, support, and training are separately funded by the Government, and are covered in the following paragraphs.

5.2 Facilities and Support Costs

For the purposes of this report a composite work program was assembled from Fiscal Year Work Programs 65, 66 and 67 to reflect the budgeted cost for this period. This resulted in a work program for the first year of experimental commercial operation of $1,032,000. The total money expended during this period was $1,011,800, or $20,200 less than estimated.

Todd's Nuclear Division portion of the Savannah Technical Staff worked 42,145 man-hours at a total cost of $375,492, for an average man-hour cost of $8.90, including overhead and fee. The Todd Galveston Division's average rate for performing the repairs of the vessel was $5.85 per hour.

5.2.1 Outage Costs

Maritime expenditures for the annual outage were $228,232, which amounted to 22.5% of the total expenses for the year. A substantial portion of these costs were for ship improvements, many of which were discussed in previous sections. The most significant of these items of cost included:

Main Boiler Feed Pump Replacement - $53,114

PE-3V Replacement - $15,607

Cathodic Protection System - $31,041

Partial Dehumidification Equipment - $88,726

Replacement of SS-4V - $10,736

In summary, the total outage cost was approximately $500,000. Of this amount, $228,000 was for the Maritime account, and $272,000 was for the FAST account. The maintenance and repair costs were approximately $224,000, and the improvement costs were approximately $279,000. Costs associated directly with the nuclear plant were approximately $221,000. Although most of the costs were considered to be repetitive, studies are underway to determine how these costs could be reduced.

5.3 Training Costs

The total cost for training during the first year of experimental commercial operation was expected to approximate $282,000 upon completion of audit. This is approximately $40,000 less than the amount estimatedin the budget. The saving is attributed to training program improvements, management control, and revised trainee selection criteria.

6. SUMMARY

A summary of data derived from the first year of experimental commercial operation of the N.S. SAVANNAH follows:

6.1 Technical Data

6.1.1 General

Trade Routes	5, 7, 8, 9 North Atlantic and 10 Mediterranean
Number of Voyages:	7
Total Number of Domestic Port Entries:	36
Total Number Foreign Port Entries:	36
New Ports Not Previously Visited:	Rota Cadiz Cartagena Bilbao Genoa Marseilles Leghorn
Public Opposition or Picketing:	None
Number of Miles Traveled:	72,000
Effective Full Power Hours Operation:	3,400
Average Utilization Factor (including annual outage)	39% full power
Number of Load Changes:	More than 700
Total Number of Scrams:	26
Scram at Sea:	1
Scrams from 10 or Greater % of Full Power:	6
Per Cent of Time Reactor Critical:	81

Per Cent of Time Shut Down - Scheduled:	15
Per Cent of Time Shut Down - Unscheduled:	4
Fuel Failures:	None
Rod Drive Failures:	None
Number of Containment Integrity Tests:	5 at 60 psig
Containment Leak Rate - % per day at 60 psig:	0.5 to 0.8
(Tech. Spec. limit is 1.2% per day at 60 psig)	

6.1.2 Health Physics

Average Radiation Exposure of Crew:	88 mrem
Maximum Exposure of a Crew Member:	1,140 mrem
Exposure to Members of Public:	None
(Title-10-CFR limit is 5000 mrem/yr)	
Radioactive Liquid Waste Disposal:	
To Port Waters:	None
To Sea 12 Miles Offshore:	
Gallons at $3x10^{-4}$ micro-curies/cc or less	98,000
Total microcuries	9,000
Accidental Releases:	
To Hydrosphere	None
To Atmosphere	None

6.2 Achievements

It is always a difficult task to assess the true value of research and development in a program such as the SAVANNAH. The SAVANNAH is the forerunner of at least one additional nuclear ship (the German ship OTTO HAHN) and may in future years be looked upon as the forerunner of a nuclear merchant fleet. In the meantime, the SAVANNAH can claim the following achievements: SAVANNAH has -

1. Demonstrated that a nuclear merchant ship can operate safely and reliably in a regularly scheduled service.
2. Developed the framework for acceptance and entry and opened new ports to any future nuclear ships.
3. Demonstrated a favorable reaction on the part of shippers toward using nuclear transportation.
4. Produced information that could lead to reduced cost of operation of any future nuclear ships.
5. Produced and maintained a reservoir of marine engineers trained and licensed to operate a seagoing nuclear power plant.
6. Added to the prestige of the United States through demonstrations of an advanced type ship.
7. Demonstrated to the world the sincerity of United States efforts to use nuclear power for peaceful purposes.
8. Kept maritime regulatory problems before the regulatory bodies and industry, thus stimulating efforts to establish optimum requirements which will be applicable to any future nuclear merchant ships.

APPENDIX A

Approved Port Operating Plans

APPROVED PORT OPERATING PLANS
August 20, 1965 to August 19, 1966

Port	Plan Numbers
Philadelphia	FAST 100
Baltimore (Including the Chesapeake & Delaware Canal)	FAST 101
Hoboken	FAST 102
Rotterdam	FAST 103
Antwerp	FAST 104
Bilbao	FAST 105
LeHavre	FAST 106
Bremerhaven	FAST 107
Hamburg	FAST 108
Bayonne, New Jersey	FAST 109
Brooklyn	FAST 110
Hampton Roads	FAST 111
Boston and Cape Cod Canal	FAST 112
Marseilles	FAST 113
Charleston, S. C.	FAST 115
Genoa	FAST 116
Leghorn	FAST 117
Cadiz	FAST 118
Rota	FAST 119
Naples	FAST 120
Barcelona	FAST 123
Lisbon	FAST 124
Cartagena	FAST 125

Valencia	FAST 127
Pier 84, New York	FAST 133
Galveston	FAST 134
Venice	FAST 136
Trieste	FAST 137
Pier 13, Staten Island	FAST 139

APPENDIX B

N.S. SAVANNAH Manning Schedule

First Year Experimental Commercial Operation

N.S. SAVANNAH Manning Schedule
First Year of Experimental Commercial Operation

Deck		Staff	
1	Master	1	Nuclear Advisor
1	Chief Officer	1	Health Physics Technician
1	Second Officer	1	Radio Operator
3	Third Officer	1	Purser/Pharmacist Mate
1	Boatswain	4	
2	Deck Utility		
6	AB		
3	OS		
18			

Engine		Steward	
1	Chief Engineer	1	Chief Steward
1	Senior First Assistant	1	Chief Cook
1	First Assistant	1	Second Cook
3	Second Assistant	1	Chief Baker
9	Third Assistant	1	Third Cook
2	Instrument/ Electronic Officers	2	Bedroom Steward
1	Water Chemist	3	Steward Utility
2	Electricians	2	Officer Messmen
3	Oiler	1	Crew Messmen
1	Plumber/Machinist	2	Galley Utility
1	Engine Utility	2	Utility
2	Wipers	17	
27			

66 Total Crew