REPORT NO. ESI-S-1

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MASTER

N S Savannah

Nuclear Merchant Ship

DESIGN REVIEW

SUMMARY REPORT

Prepared Under AEC Contract No. At (30-1)-2475

And Submitted to The United States Atomic Energy Commission

EBASCO SERVICES INCORPORATED

TWO RECTOR STREET

NEW YORK

JUNE 30, 1960

DISCLAIMER

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I - ABSTRACT

This report summarizes engineering services rendered by Ebasco Services Incorporated under contract AT(30-1)-2475 with United States Atomic Energy Commission for a survey covering the safety, adequacy and reliability of certain design and construction features pertaining to the N S Savannah nuclear power plant and related systems. Scope of the work was outlined to Ebasco under specific subjects and included eighteen (18) task assignments.

Authorization to start the design review on certain phases of the project assignment known as task No. 1 was given Ebasco in a telegram from AEC under date of November 16 1959.

Work completed by Ebasco as of June 30 1960 covered an independent review of data supplied by AEC such as design plans, specifications, reports, calculations, heat balances, system drawings, operating manuals, bills of material and equipment drawings.

Results and recommendations covering Ebasco work on this project were set forth in various preliminary or interim reports sent to AEC during its progress.

II - INTRODUCTION AND SUMMARY

A - PURPOSE AND SCOPE

In general, the purpose of the design review requested by AEC on the construction and operation of the N S Savannah was to survey the safety, reliability and adequacy of the ship's nuclear power plant and related systems. It was stated that suggestions for design changes, considered advisable, should also be included.

The scope of the project was limited to design review and included only those specific tasks assigned to Ebasco. The design review services rendered by Ebasco covered therefore only (1) a review of the design of the nuclear power plant and related service equipment and systems of the N S Savannah from the standpoint of reliability and adequacy (2) the suggesting of specific changes for improvement, and (3) a summary evaluation of the technical and safety considerations involving the present design and the suggested changes.

B - SUMMARY OF PROJECT

Interim reports were prepared covering the investigations and reviews made for each task. The material included in these interim reports is summarized in this report under Section III and covers work completed on the project as of June 30 1960. Also, during progress of the work on this project a total of six conferences were held with the United States Atomic Energy Commission at which time progress reports were submitted and task assignments discussed.

III - RESUME OF TASK ASSIGNMENTS

A - GENERAL

The various tasks assigned to Ebasco by the United States Atomic Energy Commission in connection with the design review for the N S Savannah were outlined in detail in a Task Assignment Schedule. Each of the tasks is also outlined in this Section of the report under the appropriate task number and a resume showing nature of work done is included.

B - REPORT OF TASK ASSIGNMENTS

Task No. 1 - Detailed Interconnection Diagrams

The purpose of this task was to prepare detailed interconnection diagrams of electrical wiring and pneumatic control as shown on B&W Flow and Instrumentation Drawings for the following systems:

Nuclear Instrumentation
Reactor Control System
Primary System
Primary Pressurizing System
Primary Relief System
Buffer Seal System
Hydrogen Addition System
Primary Purification System
Emergency Cooling System
Intermediate Cooling System
Shield Water System
Equipment Drain and Waste Collection System
Sampling System
Gaseous Waste Collection and Disposal and Absorption System
Containment Cooling System

Secondary System

Boiler Water Chemical Addition System

Radiation Monitoring System

Mechanical and electrical drawings were made after reviewing the Babcock & Wilcox Company, Bailey Meter Company, New York Shipbuilding Corporation, and other equipment manufacturers' drawings: such as flow diagrams, wiring diagrams, pneumatic tubing diagrams and various equipment details. The Ebasco system drawings present a composite of the different parts of each of the systems and, therefore, give complete pictures of the mechanical and electrical control for each system. As prepared, the Ebasco drawings will show the ship's operators the approximate physical location of instruments and control devices. In general, all drawings were made for the systems showing normal operating condition.

During the process of preparing these drawings, preliminary prints were issued to all interested parties for information and comments. Subsequent changes and revisions were made periodically as required.

A total of 33 drawings were made by Ebasco to cover the assignment under Task No. 1. A complete list of the drawings, separated as to systems, is included in Appendix A of this report.

Task No. 2 - Evaluation of Electrical & Pneumatic Control System Components

The purpose of this task was first, to evaluate the individual components for suitability and adequacy of service aboard the N S Savannah as they are used for control and instrumentation of the systems shown in Babcock & Wilcox Engineering Flow and Instrumentation Schematic Drawings and secondly, to study these components from a functional viewpoint in the systems in which they are installed and to analyze the relationship between these components to ascertain if their applications provide reliable and adequate controls. However, since the data available were not adequate to permit a complete evaluation, the Nuclear Instrumentation System, the Radiation Monitoring System and the Soluble Poison System were not reviewed.

The findings resulting from the engineering reviews, surveys and investigations are as follows:

(1) Generally, Bailey Meter Company pneumatic components as proposed for N. S. Savannah are functioning well in conventionally powered merchant vessels without unusual maintenance problems. They have excellent reliability and no significant record of failure. Bailey Meter Company controls are highly regarded for their performance by the Bureau of Ships of the Navy Department. Central power station applications have also shown many Bailey Meter Company components to be generally satisfactory.

(2) From a review of recorded component failures, provided by the Bureau of Ships, it appears that a possible source of operational difficulty may exist in the sylphon bellows of Bailey Meter Company transmitters. This is of no special significance, except for those transmitters not accessible during reactor operation where certain changes in location of transmitters should be made and backup controls should be provided to insure reliability of operation.

(3) Instrument or control air driers are considered necessary in central power stations and industrial applications, and newer and more advanced Navy shipboard applications, including nuclear submarines, require them. Although current merchant marine practice does not include such driers, it is felt that the more extensive and elaborate control systems of a reactor may require such driers and that they should be installed in the N.S. Savannah.

(4) Control components associated with Bailey Meter Company components, such as relays, switches, transformers, annunciators, lamps, push-buttons, meters, thermocouple switches, timers, pH instruments, Asco solenoid valves, Leslie control valves, and regulators for general service will probably be satisfactory. One exception is a Leslie angle needle valve, designated as buffer seal system differential pressure control valve LS-9V. This Leslie valve as presently installed may not provide reliable service for any appreciable time. It is felt that it should be replaced by an available and improved Leslie angle needle valve which has special design features suitable for this service.

(5) Sufficient spare parts should be provided to maintain and repair any malfunctioning control components on board ship. Also, a carefully selected set of spare components, including control valve topworks, should be stocked to enable replacement of vital components quickly and thus restore operational integrity while assemblies are repaired.

(6) Past experience indicates the importance of having the control components and related systems under the supervision of personnel trained in proper maintenance and repair methods. It is understood that such training has been provided for appropriate permanent members of the N.S. Savannah's operating staff.

(7) The controls and instruments provided are generally adequate and satisfactory for the services intended. However, full reliability and effectiveness is not being obtained from the control systems because of the manner of arrangement and interconnection of components. For instance, the isolation of duplicate electric circuits is insufficient, the branch feeder circuits serve too large segments of the control systems, and the alarm and annunciation signal initiating devices for variable conditions are not independent of the control devices themselves, with few exceptions. It is felt that these conditions should be remedied at the earliest practicable date or as experience may dictate.

(8) In the Safety System, the non-nuclear scram initiating circuits are not arranged to provide the positive action required since some false scrams may result from spurious signals and, in other cases, a scram may not result from proper signals. It is recommended therefore that all non-nuclear scram actuating signals be provided directly from each variable to the safety cabinet. These signals should be provided in sufficient quantities to establish a coincidence feature for each variable before any scram would be initiated. These signals should be of the "fail safe" type independent of any power supply external from the safety system and be entirely separate from the normal control circuit devices and wiring.

(9) In the Containment Isolation System the electric circuits therein are arranged and connected so that possible unnecessary activation of this system may shut off power from the reactor. These circuit arrangements should also be revised at the earliest possible date.

Task No. 3 - Structural Analysis

The purpose of this task was to make a structural analysis of (a) first and second cores, (b) core internals, (c) control rod drive structure, and (d) other equipment inside the containment.

In accordance with parts (a) and (b) of this task, the fuel container assembly of the first core (B&W core) was investigated for structural adequacy and possible maximum deflections due to thermal gradients, pressure drops and ship's motions. The thermal gradients were not taken as a straight line function but were calculated for their actual expected value, including the energy generated within the material due to gamma flux and interacting or capture neturons. Pressure drops were taken from B&W reports, as established by calculations and corrected by test results from the Research and Development Program. Accelerations and decelerations resulting from ship's motions were conservatively considered as working additively with other stresses on the core. Abnormal conditions investigated included the reactor operating at full power with only two pumps operating and the ship lying on its side with a value of 2 g total acceleration. These conditions were considered the most severe conditions at which the control and follower rods would have to be inserted. All clearances of the core were checked, including the maximum allowable machining, assembly and working tolerances to establish maximum allowable deflections. The material tensile strengths were investigated as to their aging, fatigue, work-hardening and notching effect characteristics under elevated temperatures.

It was determined that the deflection of the fuel containers under the most adverse conditions assumed will not interfere with the operation of the control rods and the structural strength is adequate for the life of the ship. The structural supports in the reactor vessel for the core were not reviewed so there are no comments.

The procedure for the analysis of the second core (GE replacement core) was substantially the same as the one described for the first core.

It was concluded that the deflections in the cans of the second core under the most adverse conditions assumed will not interfere with the operation of the control rods, and that the structural strength is adequate for the life of the ship.

For part (c) of this task the control rod drive structure was investigated to determine the maximum expected deflections under the following assumed independent conditions:

1. Normal operating conditions in heavy weather.
2. Abnormal condition with the ship lying on its side with an acceleration of 2 g total.
3. In port with the assumed effect of three reactor head bolt tensioners acting simultaneously on the structure.

The maximum expected stresses for the above conditions were also determined.

It was concluded that the support structure will prevent excessive deflection of the control rod drives and is structurally adequate. The design calculation sheets of the General Electric Company were also reviewed and appeared satisfactory.

For part (d) of this task, the stresses and moments due to thermal expansion on the primary piping system were investigated based on the worst temperature conditions to which the system can be subjected. In addition, the effects of weight and acceleration were reviewed to assure that the nozzles in the system are not over-stressed. This work also included structural analysis of the steam generators and pressurizer vessel. All design calculations of Babcock & Wilcox Company and those of the Electric Boat Division of the General Dynamics Corporation were reviewed and found satisfactory. Independent calculations were made when there was little or no margin in allowable stress values and also where there were disagreements with the basic assumptions or the assumptions were not stated by the designers. The piping calculations show the maximum stress occurs at the heat exchanger vestibule nozzle (material, ASTM-A182 Grade F304) which is welded to the pump casing (material, ASTM-A351 Grade CF8). Both materials have a minimum yield of 30,000 psi. Based on this minimum yield strength, a 2 g load with the ship on its side could produce a slight deformation of the pump casing and the vestibule nozzle.

It is believed, however, that this load condition is overly conservative, and if it were imposed only for a very short time the deformation would be imperceptable. Considering the severity of the design parameters and the conservative design approach, it is thought that the possibility of exceeding the yield strength in this case is not critical and, therefore, it is considered that the design is adequate, and does not exceed the maximum stress as allowed by applicable codes.

Task No. 4 - Primary Coolant Pumps
Task No. 4a - Purification System

Task No. 4 was to investigate the possibility of using buffer seal type pumps for the primary coolant system. However, this task was held inactive by instructions from the U.S. Atomic Energy Commission.

Task No. 4a was to review the adequacy of the purification system, consider effect on buffer seals and other components following postulated failure of resin beds including spread of resin through system.

From this study, it appeared that each demineralizer should have its own filter in a downstream series arrangement. In event of a sudden high-differential pressure across the filter in operation, indicative of a resin breakthrough the flow could then be shifted to another demineralizer-filter unit. If a cation unit were installed upstream of each demineralizer it would increase the life of the demineralizer resins. Other improvements suggested included; re-routing of the downstream filter bypass line to avoid resin breakthrough to the buffer seal tank, additional sampling connections, changes to the inaccessible diaphragm valve operators to a more reliable type of valve operator, an additional relief valve, interlocking of valves to protect the resins against possible high temperatures, and automatic flow equipment.

Task No. 5 - Babcock & Wilcox Co. Operating Manuals

The purpose of this task was to review and provide comments concerning the B&W operating manuals.

Ebasco started review of preliminary copies of individual Volume II Operating Manual as regards outline, content and format. Since it was decided that the operating manual had to be rewritten and brought up to date Ebasco was requested to stop further work and send in comments as of March 1, 1960.

Task No. 6 - Containment Vessel Environment

The purpose of this task was to make a study of the environment in the containment vessel in order to evaluate the effect of humidity, heat, pressure, etc. on the equipment therein (and the effects of nitrogen fixation and nitric acid attack), including evaluation of all electric cable inside the containment vessel.

All power and control cables specified for use inside the containment vessel were reviewed for suitability. Their physical location was also considered to evaluate accidental physical damage as well as damage from the environment. Also considered were the methods of support and guidance, construction details at penetrations, junction boxes and cable terminations, as well as actual installation procedure and workmanship as observed aboard the ship.

It was determined that polyvinyl sheaths for cables, while probably satisfactory for the present, should be checked for damage from time to time, and their use avoided in the future because of possible radiation damage and temperature limitation of the materials. The polyvinyl sheaths are adequate for the design conditions of 150 F but inadequate for an emergency temperature of 350 F. Cables with felted asbestos or glass fiber coverings over the conductor insulation should be installed with care and subsequently inspected to insure that terminations are properly sealed and that the sheath is undamaged. This would forestall moisture absorbtion in the layer of felted asbestos and/or glass fiber beneath the sheath; a condition which can lead to cable failure.

It was also determined that for upgrading purposes, consideration should be given to the use of extruded silicone rubber insulated, silicone rubber sheathed, armoured cables (non-portable) for all power and control sources within the containment vessel. The portable cable should have silicone rubber insulation and neoprene jacket, and all cable within primary shield tank wells should have polyethylene insulation and jackets. In the event of abnormal conditions care should be used to inspect and/or test all cables to determine which might require replacement.

Babcock & Wilcox Company's data and drawings relative to the reactor containment air-conditioning system were also studied in order to evaluate the adequacy and reliability of the design. The review was based on a detailed examination of the system specifications, engineering flow diagram, temperature, pressure and humidity conditions, equipment capacity, air distribution system, purge ventilation system and system controls. The review was supported by calculations, independent from those made by B&W, for heat load and air duct friction pressure loss.

It was found that the heat load conditions include reasonable margins of safety and equipment and materials were adequate. However, the use of aluminum for coil casing and duct work might prove advisable if it is found that a corrosion problem develops from the moisture within the containment. Manual presetting of the by-pass damper precludes adjustment for varying conditions. This deficiency could be circumvented by keeping the by-pass damper in the fully closed position and manually adjusting the valves in the cooling water lines to accommodate variations in load. Further improvement may be obtained by substituting automatic temperature control for these manually controlled valves. Provision for independent coil leakage detection is another desirable improvement. This would enable isolation of defective coils as required. Isolation of a coil by closure of the inlet and outlet valves means that the entrapped cooling water will expand due to increase in temperature. This objection could be overcome by installation of suitable pressure relief valves.

Atmospheric conditions within the containment vessel were also reviewed in order to evaluate the corrosive effect on the exposed surfaces of various metals. Effects with and without the presence of nitric acid on stainless and carbon steel, aluminum copper and copper alloy components were considered. Production of nitric acid by nitrogen fixation because of ionizing radiation was considered, especially acid production in the annulus surrounding the reactor vessel and acid production in the instrument thimbles within the primary shield tank. The escape into the containment of all the nitric acid produced in the annulus was assumed (although in reality there would be some retention in the fiberglass insulation) in order to establish the most unfavorable condition producing corrosion. The effect of nitric acid remaining in the annulus or in the instrument thimbles within the primary shield tank was also determined. In Appendix C, Figure 1 presents graphically the increase in corrosion that would occur in a normal temperature with increasing humidity. Although these air contaminants are sulfur dioxide and ammonium sulfate, the general corrosive effects of these compounds are very similar to the vapors of nitric acid. The production of nitric acid is presented in Figures 2 and 3.

It appeared that equipment and surfaces within the containment vessel will not be harmed by the containment atmosphere or by the nitric acid produced within the annulus surrounding the reactor vessel. Air circulation is adequate to prevent nitric acid from collecting and attacking the carbon steel, aluminum or copper alloys. If there is a problem Polyclad 933-1 and other protective coatings applied to surfaces add protection from nitric acid attack. Best practices should be used in applying protective coatings supplemented by thorough inspection. Care taken in the installation of instrument cans into thimbles will also help. Circulation of air, maintained during reactor operation, insures against concentration of acid. Air or helium purge through connections welded to the thimbles would facilitate the removal of acid and corrosion products through the outlet purge line. Provision for forced circulation of air through the insulation would drive off any acid which may have adhered thereto.

Task No. 7 - Alternate Control System

Although this task was to look into an alternate control system using transistorized components and packaged units with a view towards simplification, reliability and maintainability, this task was suspended by the United States Atomic Energy Commission since other parties were already assigned to this study.

Task No. 8 - Permanent Recording

Considering the mission of the N.S. Savannah, what data needed permanent recording and where could this equipment be located?

Babcock & Wilcox Company and Bailey Meter Company data, Bills of Material, Drawings and Specifications relative to instrumentation and control together with other pertinent data were reviewed and studied in order to determine the adequacy of the specified recorders for variable termperatures, flows, pressures and levels in the N.S. Savannah's power plant.

It is recommended from this review that additional recordings of variables are required to provide adequate operational and performance data as follows:

A. Nuclear Instrumentation - Continuous recording during start up operations of both BF_3 source range detector channels level and rate; auctioneered level and rate from the two fission chambers and auctioneered level and rate from the intermediate range compensated ionization chambers. This recording to be on three separate miniature type two pen recorders located on the main control console front panel.

B. Temperature - Addition of a single 16 point recorder as follows:

   1. Recording of four reactor shell differential temperatures to evaluate reactor warm-up and shut-down rates.
   2. The other twelve points to be used for variables in the propulsion system which would be required to calculate and check plant operation and efficiency. This temperature recorder could be located in control room on Auxiliary Panel "B".

C. Flow, Pressure and Level - Six existing variables in the reactor systems which are presently indicated and one new variable should be provided. All of these points could be accommodated in the existing recorder cases, in the main control room, which are presently utilized as indicators. Nine variables in the propulsion system should be recorded to facilitate analysis of plant operation. These recorders could be locally mounted in the machinery space.

D. Water Purity - Suspended solids in the buffer seal make-up and six points of conductivity throughout both the reactor and propulsion systems and two points of pH should be recorded. These recorders could be located in the sampling room with alarms brought back to the main console annunciator.

E. Miscellaneous Recorders - A two point miniature recorder should be added to the main switchboard for recording voltage and frequency of the vital instrumentation power supply bus. A multipoint "operations" recorder is recommended for recording of all actions which will result in loss of ship power. This recorder could be located in the nuclear instrumentation workshop.

Task No. 9 - Main Control Console

The purpose of this task was to study the main control console for time, motion and phychological factors.

In general, it was found that the main console is adequate for the mission intended. However, the console was found to be too large and should have been turned around so that the operator would face forward and have immediate access to the electrical switchboard as well as the main console. The control and annunciation for equipment not related to load changes or not needing continuous surveillance should not be located on the main console.

The use of indicating lamp colors, in our opinion, should have been standardized so their meanings would be consistent. Means for testing indicating lamps should also have been made consistent instead of the several methods employed on the main console.

Push button operation should have been delegated to certain specific functions such as lamp test or annunciator acknowledgement instead of being used for controlling the electrical circuits. It is felt that operation is further complicated by the use of momentary contact push buttons instead of rotary type control switches.

Nameplates were found to be generally inadequate and lacking effective descriptions.

The steam throttle control assembly appears to be unnecessarily large and may obstruct lateral movements on the console bench center section.

Task No. 10 - Chemical Cleaning

The purpose of this task was to investigate chemical cleaning of the plant by use of citric acid before the reactor goes critical. Also to determine whether such a cleaning method would help decontamination or reduce the amount of "crud" produced. However this investigation was suspended by the United States Atomic Energy Commission because reports from others indicated that the main primary pumps were susceptible to citric acid attack.

Task No. 11 - Safety System

This task was to prepare a coordinated Safety System drawing covering the various systems listed under Task No. 1.

Accordingly, Ebasco prepared a separate detailed interconnection diagram of the electrical wiring for the Safety System showing all the interconnections with the other B&W Reactor Systems which is ESI-drawing NI-80-E2 entitled, "Safety System - NI-80 - Interconnection Wiring Diagram."

Task No. 12 - Main Propulsion Plant

The purpose of this task was to review the main propulsion plant and its auxiliaries as follows:

(a) Check all New York Shipbuilding diagrams for flows, pressure drop, line sizes, piping design, control valve components, miscellaneous pump heads and capacities, extraction heaters, deaerator, and feed pumps. Review equipment specifications and check for adequacy.

(b) Check electrical system and control wiring for turbine generators and diesel generators for load control.

(c) Review main steam piping extraction lines, boiler feed piping and crossover steam piping for thermal stress conditions.

(d) Review power and control cable and components which include the following;

1 - Power Cable and Wiring Study - NYS Plan No. 529-302-15 through 25

2 - Review of Electrical Load Analysis - NYS Plan No. 529-302-9 Alt C Power System

3 - Review of Fault Current Analysis - NYS Plan No. 529-302-35 Alt B Power System

4 - Fuses, Breaker Coordination and Motor Overload Protection

5 - Group Control Centers and Motor Starters

6 - Switchboard

7 - Motors and Generators

8 - Miscellaneous Electrical Devices

9 - Electrical Distribution System - NYS Plan No. 529-302-13 Alt G, Power System Elementary Wiring Diagram

10 - Electrical Control Systems, Review control system for take-home motor and other controls in the propulsion plant

In accordance with parts (a) and (c) of this task, a design review of New York Shipbuilding Corporation diagrams and equipment specifications for the purpose of checking flows, pressure drop, line sizes, piping design, control valve components, miscellaneous pump heads and capacities, extraction heaters, deaerator, and feed pumps as used in the main propulsion systems was made. In addition, the main steam, extraction, boiler feed and cross-over steam piping systems were checked for thermal stress conditions. No back-up calculations were made.

It was found that the design documents and specifications for piping, valves, and equipment were satisfactory with the exception of a few minor drawing corrections. A general inspection of the thermal stress conditions for the main steam extraction, boiler feed and crossover steam piping indicated satisfactory flexibility.

In accordance with parts (b) and (d) of this task, the adequacy of the main propulsion plant and auxiliaries to provide satisfactory power for startup, normal, and emergency conditions was investigated. A check of the electrical system and control wiring for the turbine generators and the diesel generators for load control and a review of the power and control cables and components were also made.

Inspections were made on board ship, and the installation was found satisfactory insofar as workmanship is concerned. It was felt that cable trays could be used for grouping and supporting cables in congested areas in place of clamps and brackets to reduce initial and maintenance labor costs.

In general, it was determined that the electrical power system was satisfactory. However, it was found that the maximum short-circuit duty on the group control circuit breakers and power panel circuit breakers was greater than their interruption ratings. This can be corrected by operating the main switchboard as a split bus, or by addition of current limiting reactors in feeders to overdutied power panels and group control centers in which the breakers cannot be replaced.

Also calculations indicated that the voltage drop will be slightly less than 20 per cent when the fourth 300-hp primary pump is started with startup load on the two 750-kw diesel generators. The bus undervoltage relays can be set below 20 per cent so they will not operate falsely on startup. It is also suggested that more room should be allotted to electrical switchboard areas for future nuclear ships than was provided for the N. S. Savannah.

Task No. 13 - Casualty Analysis

The purpose of this task was to review the Babcock & Wilcox, "Casualty Analysis Report," dated July 15, 1959 to determine whether the functions and conditions described therein are correct, adequate, and in agreement with the latest interconnection wiring and control diagrams.

No corrections to drawings were made in the course of the review, but certain conditions were noted for future upgrading purposes. An analysis was made of the non-vital and vital instrumentation, electrical fuses, power supply and load distribution. A marked copy of the B&W analysis with certain comments, and corrections was submitted to the AEC.

This review indicated that the Casualty Analysis should be rewritten, brought up-to-date and certain important omissions added. It was noted that many instruments are tied together electrically, so that failure of a single fuse will cause loss of many duplicate instruments thus negating the purpose for their installation. In some cases, the annunciator signals are derived from pressure switches located at the ends of complex control systems. The loss of reliability in these instances is questioned.

Task No. 14 - Local Instrumentation

This task calls for listing and checking local instrumentation for each of the systems as listed under Task No. 1. Accordingly, all local instrumentation shown on Babcock & Wilcox and Bailey Meter Company's drawings are also shown on Ebasco's Pneumatic Instrument and Control drawings, and on the Control Equipment list which were prepared under Task No. 1

Task No. 15 - Engineering Flow Diagrams

The purpose of this task was to review and check the applicable flow diagrams for all of the mechanical systems as listed under Task No. 1 with respect to velocities, line sizes, pressure drops, pump capacities, pump heads, equipment adequacy, miscellaneous components and materials.

The Primary System was found consistent with system specifications. Review of welding details for temperature elements placed in the reactor inlet and outlet piping could not be done due to incomplete detailed information. With reference to the primary coolant pumps there is doubt as to whether they will operate satisfactorily under low flow range starting conditions.

The Relief System includes an effluent condensing tank and manifold assembly which should be tested at operating steam pressure to make certain that its design will not cause any undue shock or water hammer. Minor valve discrepancies should be corrected to be consistent with design requirements.

The Primary Pressurizing System was found satisfactory.

Several valves employed in the Buffer Seal System were found to deviate in part from the design specification. Furthermore the desurger location is not in accordance with pump manufacturer's recommendation. To avoid the possibility of water hammer, a relocation of the desurgers close to the pumps is desirable. A float control with a reasonably wide range should be installed at the desurger to have better control during the system pressurizing transient conditions.

The Hydrogen Addition System was found satisfactory, except for the fact that some operating valves are not shown on the drawing. It is noted that a check valve near the buffer seal tank is located below the water line. Its location may cause chattering due to low gas flow. With reference to the piping for this system, consideration should be given to the replacement of carbon steel pipe lines HA-9 and HA-10 with stainless steel material. Also, all safety relief valve vents should be located remote from air exhaust ducts, hot exhaust lines, passageways and above normal levels of personnel access.

A review of the design details of the control valves located in the Primary Loop Purification System indicates that improvements to benefit operation can be made. These include changing the existing inaccessible diaphragm valves to air cylinder type operators and provide interlocking between valves to protect the resins against possible high temperatures.

The Emergency Cooling System was found consistent with the specifications. However, a pressure relief valve should be installed on the cooling water piping, downstream of the emergency cooler, since inadvertent closing of the valves will result in a pressure build-up due to high temperature coolant.

In the Intermediate Cooling System the control valves CW-29V and CW-39V do not appear to have excessively high pressure drops as specified on data sheets so they may have been incorrectly specified. The two manually operated by-pass valves, CW-155V and CW-140V, located downstream of the buffer seal coolers and let-down coolers, respectively, do not seem to be equipped with any means to guide the operator for correct setting. It is suggested that a local pneumatic temperature indicator should be provided near each of the two valves.

The Equipment Drain and Waste Collection System was found satisfactory. Numerous cross connection and flow transfer points in the piping arrangement may require that operation instructions be written in sufficient detail to minimize errors by the operator. A twin strainer should be installed between the waste transfer pump and valve PD-69V to collect undissolved solid materials entering the pump.

A review of the design details of the Sampling System reveals several instances where improvements should be made, such as: replacement of Tygon tubing, with its 150F temperature limit, with stainless steel and redesigning breakdown orifices SA-F3 & SA-F10 to take the full pressure drop from 1750 psig to 75 psig and thus relieve valve SA-1V of throttling action.

The Gaseous Waste Collection and Disposal System was reviewed for adequacy of design and was found satisfactory.

No comments were made on the Gaseous Absorption Process Equipment System due to lack of adequate information.

The design documents and specifications relating to the Secondary System were found consistent with design specifications except for minor drawing corrections.

The Boiler Water Chemical Addition System was found satisfactory. The phosphate system and the sulfite system are adequately sized. However, there are some changes that can be made to improve the system.

Our experience with duplex positive displacement pumps, which are used for phosphate feed, has indicated a fall off in metering accuracy and higher maintenance costs with wear. We recommend the simplex type pump for this service. Diaphragm type shut off valves located between the containment and the secondary shielding are inaccessible during operation and should be replaced with the more reliable air cylinder type operator. Very probably, manual determination of phosphate and sulfite levels may suffice, but the inadequacy of such determinations in comparison with modern automatic analyzers, such as Larson-Lane, should be considered.

Due to lack of necessary information, the Soluble Poison System was not reviewed or evaluated.

Task No. 16 - Shield Test and Maintenance

The purpose of this task was (a) participate in shield test and evaluation of results and (b) study of maintenance procedure inside of containment vessel and review of drydock maintenance procedures (relating to radioactivity).

No work has been done on this task pending specific authorization from AEC.

Task No. 17 - Primary System Equipment Quality Control

The purpose of this task was as follows:

(a) Review estimated corrosion rates and maximum corrosion for reactor and primary system including the effect of nitrogen fixation.

(b) Review radiation effects on core materials, reactor vessel and primary system.

(c) Review of thermal insulation in contact with stainless steel piping and equipment for possible metal chloride contamination, stress corrosion cracking in primary system.

(d) Review welding procedures and stainless steel cladding procedures to insure against carbon migration and micro fissures in weld heat-affected zones for reactor vessel and primary loop.

(e) Review B&W activation calculations of primary coolant.

(f) Review B&W stress analysis of boiler and pressurizer for purpose of upgrading.

(g) Review B&W calculations to determine the temperature limitations of primary system materials and components and possible modes of malfunction that could endanger these limits.

For part (a), corrosion calculations as prepared by Babcock & Wilcox were reviewed to verify their validity. The corrosion rate used by B&W as a basis for calculation; 10 mg/dm^2 per month, was verified. This is the accepted rate for the 300 series stainless steel and it is not expected that corrosion during service will exceed it.

For part (b), radiation effects on core materials, reactor vessel and the primary system were reviewed.

With our present knowledge of the hardening effects of high intensity radiation on the stainless steel core materials, such effects should be minor so that no failure should result therefrom. Similarly the reactor vessel should not be affected. Since there should be no fast neutrons in the primary system, the piping should not be affected by radiation. There is some possibility of gamma heating of the primary system piping adjacent to the reactor. However, since the pipe always contains water, gamma heating should not cause abnormal thermal stresses.

For part (c), thermal insulation in contact with austenitic stainless steel was investigated to establish the probability for failure stemming from stress corrosion cracking. Stress corrosion cracks can occur in austenitic stainless steel when it is exposed to a moist environment containing oxygen and as little as 5 parts per million of chloride. Cracking has been observed in a temperature range of 650 F down to -130 F in a time as short as 30 minutes and as long as 7 years. N.S. Savannah insulation consists of commercial asbestos, fiberglas and other materials in which small amounts of chloride ions may be present. In addition, the insulation fire-resistive sealer, Benjamin Foster No. 30-72 contains 30 per cent chlorine. This sealer forms a waterproof coating around the outside of the insulation. Quantities of chlorine as an impurity in the insulation or as a major constituent in the sealer are sufficient to form the corrosive agent in the presence of moisture. Since the air temperature and humidity within the containment are controlled, no moisture should collect on or penetrate the insulation. Therefore, the chance of stress corrosion cracking occurring in normal operation is remote.

However, if moisture content should increase because of air conditioner failure, water leakage, or other means and the insulation sealer should become ineffective, stress corrosion may occur. Inspections within the containment should include examination of the insulation sealer, with removal and replacement of damaged portions scheduled for the next maintenance shutdown. The probability that stress corrosion cracking of the stainless steel will occur as a result of the above hypothesis is remote, and the Benjamin Foster No. 30-72 Sealer appears to be one of the best sealers available for this service.

For part (d), a review of B&W data and specified welding procedures for the incidence of carbon migration and microfissures in weld heat afflicted zones for the reactor vessel and the primary loop was attempted.

However, since B&W welding procedures are proprietary company information and so not available outside of the company, it was impossible for Ebasco to proceed with the task.

For part (e), B&W activation calculations were reviewed to establish their validity.

B&W calculations No. BAW-1126, dated December 1958, entitled, "NMSR Primary Coolant Activity," were found to be based on acceptable data and performed by a satisfactory method to give a reasonable answer.

For part (f), the B&W stress analysis of boiler and pressurizer were reviewed. The maximum pressures and stresses that could be experienced therein were also investigated.

On the basis of this analysis it was found that the pressurizer and steam generator are designed within USCG limitations as specified in CG-115 and that pressure or temperature increases are not probable beyond these limitations.

For part (g), an investigation to determine the temperature limitations of primary system materials and components, and possible modes of malfunction that could endanger these limits was made.

Materials, except for the heater wells in the pressurizer, are limited by design to 650 F since water in excess of this temperature would cause intergranular attack of sensitized austenitic stainless steel. Controls of the reactor and pressurizer do eliminate any danger of temperatures in excess of this value.

Task No. 18 - Wiring Diagrams

The original purpose of this task was to prepare elementary wiring diagrams and one-line wiring diagrams for B&W systems. As a further extension to this task, Ebasco was requested to prepare elementary wiring diagrams for the control rod drive system.

In accordance with the first part of the task, Ebasco prepared the required wiring diagrams covering the B&W systems. (See Appendix B of this report.) These drawings were prepared so as to develop wiring diagrams which show some of the complicated systems in elementary form. Also, they were prepared in such sizes that when they are reduced for insertion into the Testing and Operational Manuals they would remain legible. The Ebasco 480 volt one-line wiring diagram was based on New York Shipbuilding Corporation drawing No. 529-302-13 Alt G entitled, "Power System Elementary Wiring Diagram." The Ebasco

120 volt one-line wiring diagram and the elementary wiring diagrams were based on circuits developed by B&W and their subvendors.

The second part of this task (preparation of control rod drive system elementary wiring diagrams) was assigned to Ebasco on June 7, 1960 as an extension of Task No. 18. The work on this assignment has been started. However, the drawings were not finished by June 30, 1960 and the work will be continued into the new fiscal year. At present it is estimated that approximately 31 drawings will be required to cover this part of the assignment. These drawings are listed in Appendix B of this report.

IV - RESULTS AND CONCLUSIONS

The results and conclusions covering Ebasco's design review of the various tasks submitted for study were presented periodically to AEC in preliminary or interim reports. The comments in those reports included recommendations for modifications in equipment and/or design based on group classification as follows:

1 - Change should be made before startup to insure safety and/or reliability.

2 - Change in design is desirable to increase reliability of operation but not necessary before startup.

3 - Up-grading considerations for future improvements to be made at some later date.

The conclusions and recommendations presented in this resume are predicated solely upon review of the data and documents made available by direction of the AEC for our study. Any subsequent substitutions or deviations affecting either the specified material, the method of manufacture, the shop tests, or the governing specifications may void the conclusions and recommendations set forth. Workmanship and inspection during installation could similarly affect these conclusions and recommendations.

APPENDIX A

List of Ebasco Drawings
Prepared Under Task No. 1

LIST OF EBASCO DRAWINGS PREPARED UNDER TASK NO. 1 (Referred to by Systems)

Drawing Number	Title
a - Nuclear Instrumentation System:	
NI-80E1	Nuclear Instrumentation System - NI-80 - Interconnection Wiring Diagram
b - Reactor Control System:	
CR-86E1	Control Rod Drive System - CR-86 - Interconnection Wiring Diagram
CR-86E2	Control Rod Drive System - CR-86 - Interconnection Wiring Diagram
c - Primary System:	
PS-09M	Primary System - PS-09 Pneumatic Instrument & Control
PS-09E1	Primary System - PS-09 - Interconnection Wiring Diagram
PS-09E2	Primary System - PS-09 - Interconnection Wiring Diagram
PS-09E3	Primary System - PS-09 - Interconnection Wiring Diagram
PS-09L	Control Equipment List
d - Primary Pressurizing System:	
PE-15M	Primary Pressurizing System - PE-15 - Pneumatic Instrument & Control
PE-15E	Primary Pressurizing System - PE-15 - Interconnection Wiring Diagram
PE-15L	Control Equipment List
e - Primary Relief System:	
PR-18M	Primary Relief System - PR-18 - Pneumatic Instrument & Control
PR-18E	Primary Relief System - PR-18 - Interconnection Wiring Diagram
PR-18L	Control Equipment List
f - Buffer Seal System:	
SL-37M	Buffer Seal System - SL-37 - Pneumatic Instrument & Control

Drawing Number	Title
SL-37E	Buffer Seal System - SL-37 - Interconnection Wiring Diagram
SL-37L	Control Equipment List

g - Hydrogen Addition & Shield Water System:

HA-26E SW-60E	Hydrogen Addition System - HA-26 - Shield Water System - SW-60 - Interconnection Wiring Diagram
HA-26L	Control Equipment List Sheet No. 1 to 3 inclusive
SW-60L	Control Equipment List

h - Primary Purification System:

PP-21M	Primary Loop Purification System - PP-21 - Pneumatic Instrument & Control
PP-21E	Primary Purification System - PP-21 - Interconnection Wiring Diagram
PP-21L	Control Equipment List

i - Emergency Cooling System:

DK-48E	Emergency Cooling System - DK-48 - Interconnection Wiring Diagram
DK-48L	Control Equipment List

j - Soluble Poison System:

Due to lack of necessary information, no work was done on drawings for this system.

k - Intermediate Cooling System:

CW-47M	Intermediate Cooling System - CW-47 - Pneumatic Instrument & Control
CW-47E	Intermediate Cooling System - CW-47 - Interconnection Wiring Diagram
CW-47L	Control Equipment List

l - Equipment Drain and Waste Collection System:

PD-31M	Equipment Drain & Waste Collection System PD-31 - Pneumatic Instrument & Control
PD-31E	Equipment Drain & Waste Collection System PD-31 - Interconnection Wiring Diagram
PD-31L	Control Equipment List

Drawing Number	Title
m - Sampling System:	
SA-24M	Sampling System - SA-24 - Pneumatic Instrument & Control
SA-24E	Sampling System - SA-24 - Interconnection Wiring Diagram
SA-24L	Control Equipment List
n - Gaseous Waste Disposal and Adsorption System:	
WL-39M	Gaseous Waste Collection & Disposal System - WL-39 - Pneumatic Instrument & Control
WL-39E	Gaseous Waste Collection & Disposal System - WL-39 - Interconnection Wiring Diagram
WL-39L	Control Equipment List
o - Containment Cooling System:	
CC-49M	Containment Cooling System - CC-49 - Pneumatic Instrument & Control
CC-49E	Containment Cooling System - CC-49 - Interconnection Wiring Diagram
CC-49L	Control Equipment List
p - Secondary System:	
SS-11M	Secondary System - SS-11 - Pneumatic Instrument & Control
SS-11E	Secondary System - SS-11 - Interconnection Wiring Diagram
SS-11L	Control Equipment List
q - Boiler Water Chemical Addition System:	
BF-27E	Boiler Water Chemical Addition System - BF-27 - Interconnection Wiring Diagram
BF-27L	Control Equipment List
r - Radiation Monitoring System:	
RM-83E	Radiation Monitoring System - RM-83 - Interconnection Wiring Diagram
s - Miscellaneous Drawings:	
ESI-A-165262	List of Drawings

APPENDIX B

List of Ebasco Drawings
Prepared Under Task No. 18
and Extensions Thereto

LIST OF EBASCO DRAWINGS PREPARED UNDER TASK NO. 18 AND EXTENSIONS THERETO
(Referred to by Systems)

a - Nuclear Instrumentation System:

Nuclear Instrumentation Elementary Wiring Diagrams were not assigned to Ebasco under Task No. 18.

Drawing Number	Title
b - Safety System:	
NI-80ES	Safety System - NI-80 - Elementary Wiring Diagram

c - Reactor Control System:

Preparation of Control Rod Drive System Elementary Wiring Diagrams was assigned to Ebasco on June 7 1960 as an extension of Task No. 18. The work on this assignment has been started. However, the drawings will not be finished by June 30 1960 and the work will be continued into the new fiscal year.

At present it is estimated that approximately 31 drawings will be required to cover this new assignment. Individual drawing titles are as follows:

CR-86ES	Reactor Control System Elementary Wiring Diagram
CR-86ES1/31	Control Rod Drive System - CR-86-ROD E-1 - Elementary Wiring Diagram
CR-86ES2/31	Control Rod Drive System - CR-86-ROD C-1 - Elementary Wiring Diagram
CR-86ES3/31	Control Rod Drive System - CR-86-ROD D-1 - Elementary Wiring Diagram
CR-86ES4/31	Control Rod Drive System - CR-86-ROD E-2 - Elementary Wiring Diagram
CR-86ES5/31	Control Rod Drive System - CR-86-ROD C-2 - Elementary Wiring Diagram
CR-86ES6/31	Control Rod Drive System - CR-86-ROD D-2 - Elementary Wiring Diagram
CR-86ES7/31	Control Rod Drive System - CR-86-ROD E-3 - Elementary Wiring Diagram
CR-86ES8/31	Control Rod Drive System - CR-86-ROD C-3 - Elementary Wiring Diagram

Drawing Number	Title
CR-86ES9/31	Control Rod Drive System - CR-86-ROD D-3 - Elementary Wiring Diagram
CR-86ES10/31	Control Rod Drive System - CR-86-ROD E-4 - Elementary Wiring Diagram
CR-86ES11/31	Control Rod Drive System - CR-86-ROD C-4 - Elementary Wiring Diagram
CR-86ES12/31	Control Rod Drive System - CR-86-ROD D-4 - Elementary Wiring Diagram
CR-86ES13/31	Control Rod Drive System - CR-86-ROD A-1 - Elementary Wiring Diagram
CR-86ES14/31	Control Rod Drive System - CR-86-ROD B-1 - Elementary Wiring Diagram
CR-86ES15/31	Control Rod Drive System - CR-86-ROD A-2 - Elementary Wiring Diagram
CR-86ES16/31	Control Rod Drive System - CR-86-ROD B-2 - Elementary Wiring Diagram
CR-86ES17/31	Control Rod Drive System - CR-86-ROD A-3 - Elementary Wiring Diagram
CR-86ES18/31	Control Rod Drive System - CR-86-ROD B-3 - Elementary Wiring Diagram
CR-86ES19/31	Control Rod Drive System - CR-86-ROD A-4 - Elementary Wiring Diagram
CR-86ES20/31	Control Rod DRive System - CR-86-ROD B-4 - Elementary Wiring Diagram
CR-86ES21/31	Control Rod Drive System - CR-86-ROD X - Elementary Wiring Diagram
CR-86ES22/31	Control Rod Drive System - CR-86 - Control Power Distribution - Elementary Wiring Diagram
CR-86ES23/31	Control Rod Drive System - CR-86 - Automatic Group Demand Control - Elementary Wiring Diagram
CR-86ES24/31	Control Rod Drive System - CR-86 - Manual Group Control - Elementary Wiring Diagram
CR-86ES25/31	Control Rod Drive System - CR-86 - Hydraulic Pump 1, 2 and 3 - Elementary Wiring Diagram
CR-86ES26/31	Control Rod Drive System - CR-86 - Transducer, Pressure Switches & Alarms - Elementary Wiring Diagram
CR-86ES27/31	Control Rod Drive System - CR-86 - Annunciator & Indication Accumulator Liquid Detector and Lrive Motor High Temperature Elementary Wiring Diagram

Drawing Number	Title
CR-86ES28/31	Control Rod Drive System - CR-86 - Annunciator & Indication Low Accumulator Oil & Gas Pressure - Elementary Wiring Diagram
CR-86ES29/31	Control Rod Drive System - CR-86 - Reactor Scram Control - Elementary Wiring Diagram
CR-86ES30/31	Control Rod Drive System - CR-86 - Door Interlocks & Lamp Test Relays - Elementary Wiring Diagram
CR-86ES31/31	Control Rod Drive System - CR-86 - List of Symbols

d - Primary System:

PS-09ES1/5	Primary System - PS-09 - Elementary Wiring Diagram
PS-09ES2/5	Primary System - PS-09 - Elementary Wiring Diagram
PS-09ES3/5	Primary System - PS-09 - Elementary Wiring Diagram
PS-09ES4/5	Primary System - PS-09 - Elementary Wiring Diagram
PS-09ES5/5	Primary System - PS-09 - Elementary Wiring Diagram

e - Primary Pressurizing System:

PE-15ES1/2	Primary Pressurizing System - PE-15 - Elementary Wiring Diagram
PE-15ES2/2	Primary Pressurizing System - PE-15 - Elementary Wiring Diagram

f - Primary Relief System:

PR-18ES	Primary Relief System - PR-18 - Elementary Wiring Diagram

g - Buffer Seal System:

SL-37ES1/4	Buffer Seal System - SL-37 - Elementary Wiring Diagram
SL-37ES2/4	Buffer Seal System - SL-37 - Elementary Wiring Diagram
SL-37ES3/4	Buffer Seal System - SL-37 - Elementary Wiring Diagram
SL-37ES4/4	Buffer Seal System - SL-37 - Elementary Wiring Diagram

Drawing Number	Title

h - Hydrogen Addition and Shield Water Systems:

HA-26ES SW-60ES	Hydrogen Addition System - HA-26 - Shield Water System - SW-60 - Elementary Wiring Diagram

i - Primary Purification System:

PP-21ES	Primary Purification System - PP-21 - Elementary Wiring Diagram

j - Emergency Cooling System:

DK-48ES1/3	Emergency Cooling System - DK-48 - Elementary Wiring Diagram
DK-48ES2/3	Emergency Cooling System - DK-48 - Elementary Wiring Diagram
DK-48ES3/3	Emergency Cooling System - DK-48 - Elementary Wiring Diagram

k - Soluble Poison System:

Due to lack of necessary information, no work was done on this system.

l - Intermediate Cooling System:

CW-47ES1/2	Intermediate Cooling System - CW-47 - Elementary Wiring Diagram
CW-47ES2/2	Intermediate Cooling System - CW-47 - Elementary Wiring Diagram

m - Equipment Drain and Waste Collection System:

PD-31ES1/2	Equipment Drain & Waste Collection System - PD-31 - Elementary Wiring Diagram
PD-31ES2/2	Equipment Drain & Waste Collection System - PD-31 - Elementary Wiring Diagram

n - Sampling System:

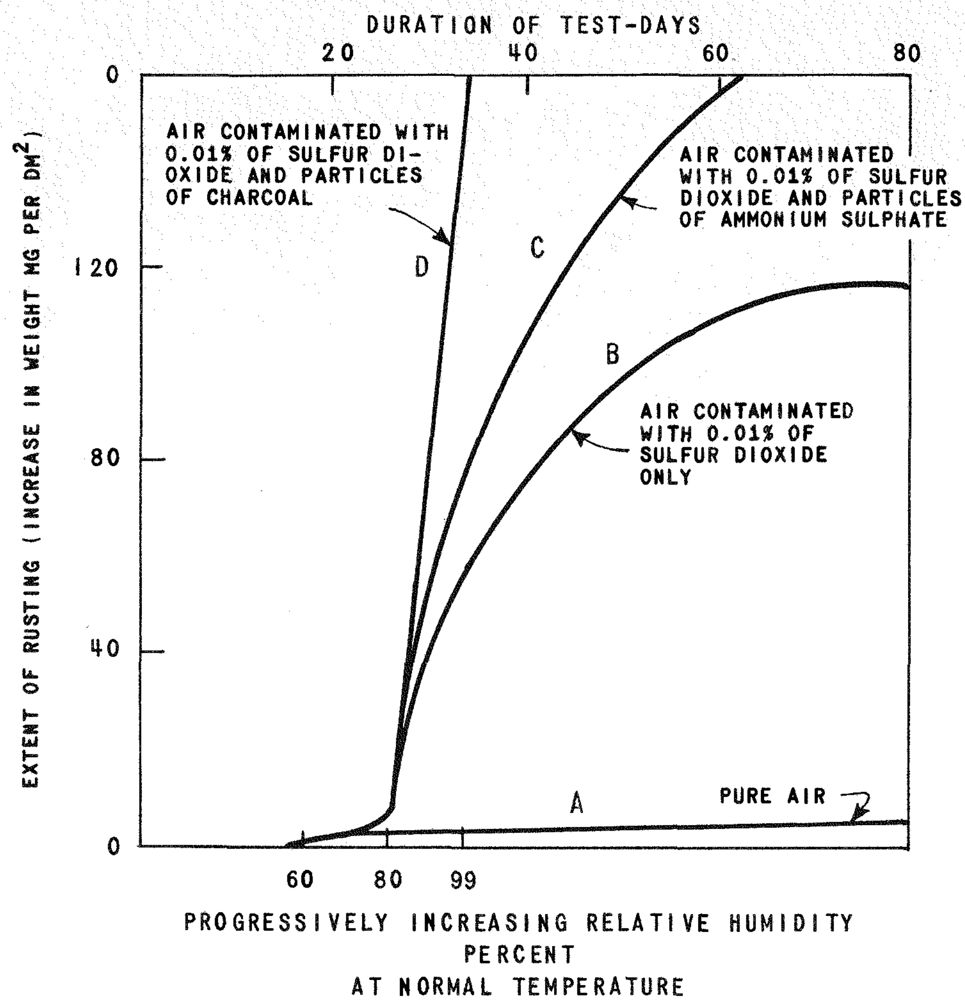
SA-24ES	Sampling System - SA-24 - Elementary Wiring Diagram

Drawing Number	Title
o - Gaseous Waste Disposal and Adsorption System:	
WL-39ES1/4	Gaseous Waste Collection & Disposal System - WL-39 - Elementary Wiring Diagram
WL-39ES2/4	Gaseous Waste Collection & Disposal System - WL-39 - Elementary Wiring Diagram
WL-39ES3/4	Gaseous Waste Collection & Disposal System - WL-39 - Elementary Wiring Diagram
WL-39ES4/4	Gaseous Waste Collection & Disposal System - WL-39 - Elementary Wiring Diagram
p - Containment Cooling System:	
CC-49ES1/3	Containment Cooling System - CC-49 - Elementary Wiring Diagram
CC-49ES2/3	Containment Cooling System - CC-49 - Elementary Wiring Diagram
CC-49ES3/3	Containment Cooling System - CC-49 - Elementary Wiring Diagram
q - Secondary System:	
SS-11ES1/2	Secondary System - SS-11 - Elementary Wiring Diagram
SS-11ES2/2	Secondary System - SS-11 - Elementary Wiring Diagram
r - Boiler Water Chemical Addition System:	
BF-27ES	Boiler Water Chemical Addition System - BF-27 - Elementary Wiring Diagram
s - Radiation Monitoring System:	
Radiation Monitoring Elementary Wiring Diagrams were not assigned to Ebasco under Task No. 18.	
t - Miscellaneous Drawings:	
ED-52ES1/3	Reactor Systems One-Line Wiring Diagram
ED-52ES2/3	Reactor Systems One-Line Wiring Diagram
ED-52ES3/3	Reactor Systems One-Line Wiring Diagram
	List of Symbols
	Lamp Test Circuit

APPENDIX C

GRAPHIC REPRESENTATION OF EFFECTS OF ATMOSPHERIC CORROSION AND NITRIC ACID PRODUCTION

ATMOSPHERIC CORROSION OF MILD STEEL



REFERENCE:

VERNON, W.H.J., TRANS. FARADAY SOC., 31, 1678, 1935

FIGURE 1

PRODUCTION OF NITRIC ACID IN THE AIR WITHIN
THE ANNULUS OF THE REACTOR VESSEL & PRIMARY SHIELD

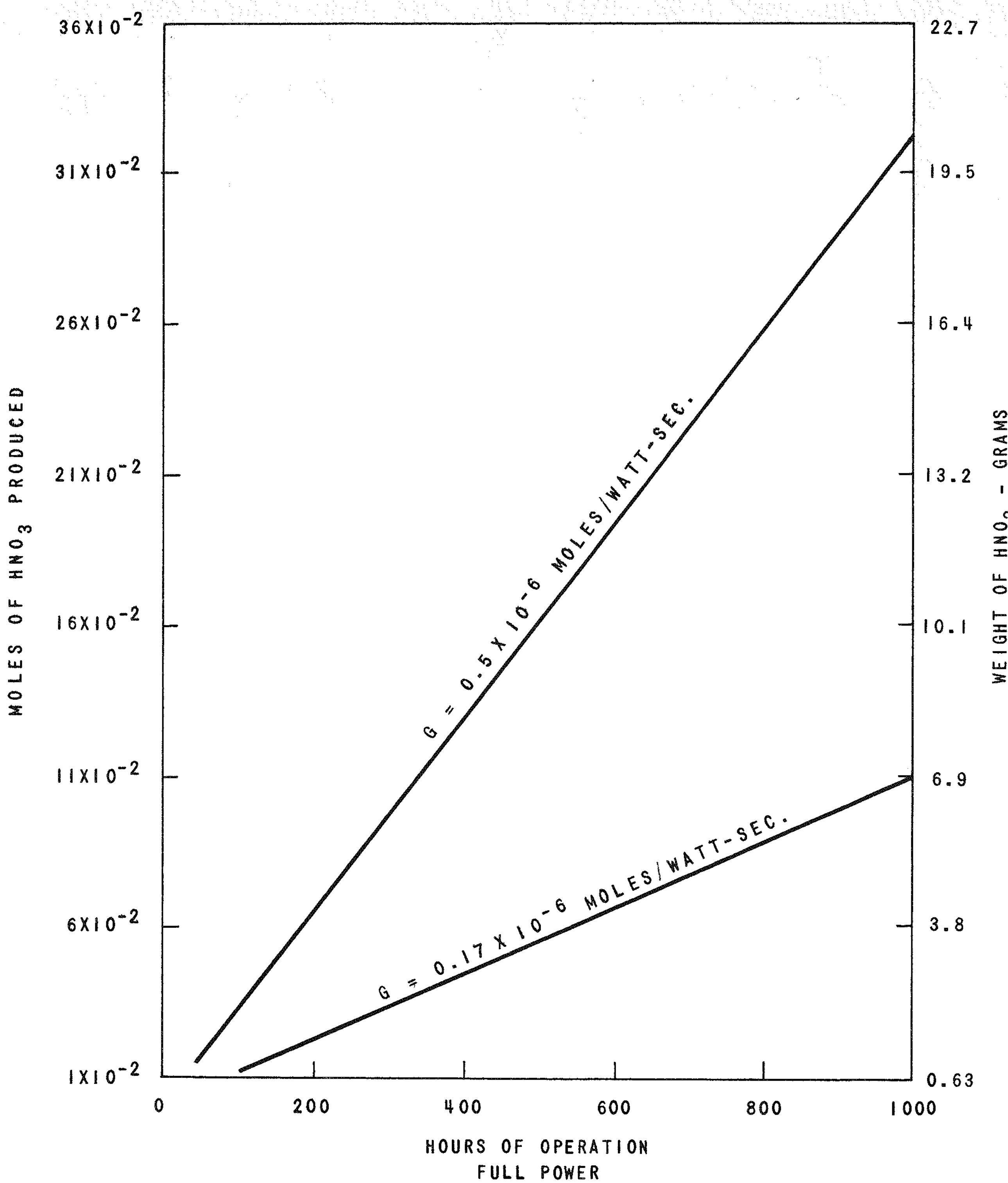


FIGURE 2

PRODUCTION OF NITRIC ACID IN THE AIR WITHIN
THE INSTRUMENTATION THIMBLES IN THE PRIMARY SHIELD TANK

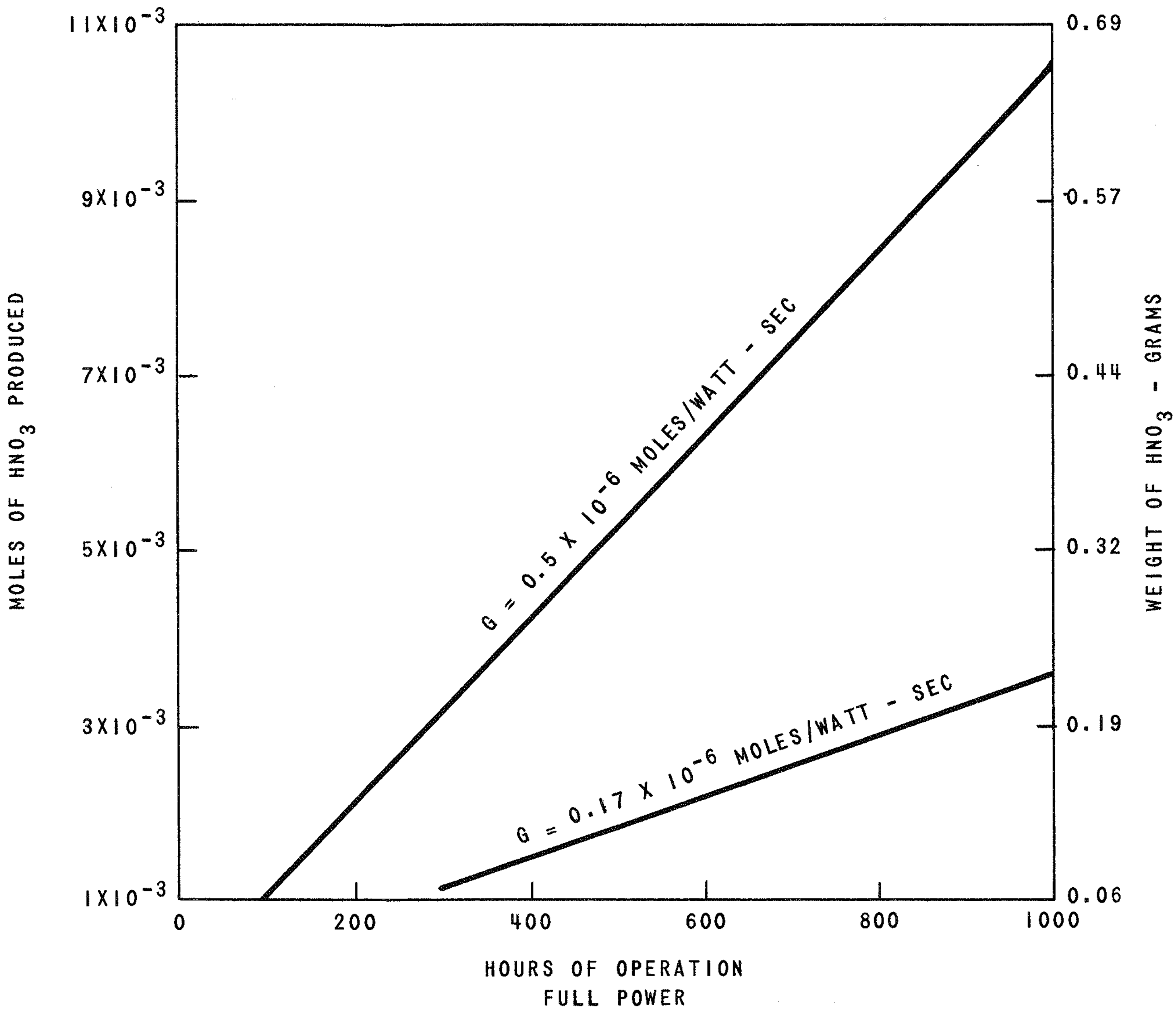


FIGURE 3