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Program:	Sodium Component Development
Program Manager:	D. T. Eggen
Reporting Period:	Fiscal Year 1965

I. PROGRAM OBJECTIVES

The general objective of this work is to provide reliable and economic heat-transfer components for large, economically competitive sodium-cooled power reactors. The specific objectives of this program are to develop and test prototype sodium heat-transfer components, such as sodium-to-steam generators, sodium-to-sodium heat exchangers, pumps, valves, flowmeters, and instrumentation. This program also investigates fundamental sodium technological problems such as heat transfer on shell and tube sides, corrosion-induced or enhanced by heat-transfer conditions on both the water and sodium sides, material property changes induced by impurities in the coolants, and mass transfer in systems containing mixed materials and large temperature gradients.

II. TECHNICAL PROGRESS DURING FISCAL YEAR 1965

A. SODIUM COMPONENT TEST INSTALLATION

Performance of the entire sequence of preoperational tests was completed. This means that both primary and secondary sodium systems have been filled with sodium, and main pumps operated; pilot burners have been used to add heat in the main gas-fired heater; the steam system has been chemically cleaned; preheated, and made ready for the generation of steam; and individual equipment components have all been determined to be properly installed, calibrated, and made ready for proper service. A new and larger tank was purchased for the primary system, and the existing secondary tank was replaced with the original primary tank.

Performance of the preoperational testing program revealed a number of deficiencies in the plant, which have been corrected. Performance of the step-by-step preoperational test program made manifest a number of engineering and construction oversights which, if left uncorrected, would prevent proper operation or adequate control of the plant. Successful conclusion of all of the preoperational tests has rendered the plant ready for experimental operations. Procedures for the plant performance tests have been completed. Step-by-step procedures for steady-state and transient testing of the ALCO/B-L-H steam generator are approximately one-half done.

A number of additional standard operating procedures were written. A new plant description was written, and a table of the design specifications giving the operating limits of major equipment and of the various systems has been compiled.

All construction work required for placement of the ALCO steam generator, i. e., installation of steam and sodium piping, placement of heaters, thermocouples, and instruments and installation of associated electrical gear was

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completed. Subsequent to the installation of the steam generator, the connecting piping and the steam generator were hydrostatically tested. A gas chromatograph was put into operation.

A larger (7500-gal) tank was purchased and installed for use as a primary fill/drain tank. The original primary tank was substituted for the secondary tank. The plant is finished. The project objectives have been satisfied.

B. FABRICATION OF THE MODULAR STEAM GENERATOR

Fabrication of the modules was completed with no major problems. The welding and x-ray inspection of the tube-to-tubesheet welds has presented little or no difficulty. Tube-to-tubesheet welding procedures which were developed during the design phase of this project were used in the fabrication of the modules. Of the first 37 tube-to-tubesheet welds made, two were considered questionable. Both were rerun and reinspected and found to be within the limits of the specification. The entire Cr-Mo tubesheet and welds were placed in a furnace for postheat treatment, then the tube bundle was assembled to the shell by placing the shell in pit. In making the tube-to-tubesheet welds on the superheaters, a short tube was accidentally installed in a tube bundle. It appeared advisable to cut off the short tube and replace it with a tube of correct length. Examination revealed that a guide "bullet" used in inserting the tube had not been removed, causing excessive internal gas pressure during the welding operation. A modified procedure was used to weld the tube to the splice piece. In any future tube-to-tubesheet welding operations of this nature, a pressure control device will be utilized.

Initial welding done on the upper shell required an unusual amount of rework. As the welders gained experience, the rework required became consistently less. Fewer difficulties were encountered in welding of the shell assemblies for the superheaters.

In the design of any future modular steam generators, consideration should be given to changing the cone reducers to standard concentric reducers. This would allow welding and radiography in straight sections of equal diametric with no change in section. Postheat treatment of the evaporator shell welds was done. Review of the assembly operations of the first evaporator and the cost of inserting the tube bundle in the shell showed that this operation should be changed. Assembly time was considerably reduced and radiography made easier with less possibility of damage to the tubes.

After completion of the entire unit, hydrostatic testing, rinsing, and drying were accomplished. Upon completion of the hydrostatic test, the outside of the evaporator modules was wire-brushed, given two coats of primer paint, and shipped to storage. The thermocouples which will be used to measure the individual tube outlet steam temperatures were clamped to the evaporator tubes. Calculations made indicated the thermocouple installation was adequate for determination of any flow instabilities. Fatigue tests on a module head were completed, and additional tests on standard bar type specimens showed that 5 Cr - 1/2 Mo is superior to 2-1/4 Cr - 1/2 Mo.

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C. INSTRUMENT DEVELOPMENT

Since inception of this project in March 1965, a detailed plan of action for the work effort has been prepared to perform a limited number of pilot tests of the more promising commercially available electric resistance strain gages, and to inspect the production facilities of strain gage manufacturers and vendors manufacturing special high-temperature strain gage wire. Pilot evaluations include the following.

- a) Apparent strain versus temperature characteristics at 900, 1000, 1100, and 1200°F
- b) Stability (drift) versus time characteristics at 900, 1000, 1100, and 1200°F (for periods up to 6 mo before and after thermal shocking)
- c) Repeatability characteristics at 1000 and 1200°F
- d) Resistance to thermal shock at rates up to 50°F per sec and temperatures up to 1200°F
- e) Variation in gage factor as a function in temperature.

The lack of strain gage reliability is probably often due to inadequate quality control, showing a need for improvement in techniques for casting the bars from which the wire is drawn and for maintaining more adequate quality control during the drawing operations. Too much lot-to-lot variation in commercial wire filament strain gages for accurate or meaningful strain measurement at temperatures above 750°F is evident. Development of procedures to make more reliable wire-filament strain gages, development of better weld joints, use of more stable alloys for 1200°F gages, and development of specifications for strain gages with considerably improved performance and reliability above 750°F, under steady-state and thermal shock conditions, is required. With such development, it should be possible to build high-temperature nuclear components and accessory equipment having far greater structural reliability with respect to creep, fatigue, stress-rupture, etc., than is possible today.

D. MECHANISMS IN SODIUM

Testing of bellows at a stroke to compressed length ratio of 4:1 in 1200°F liquid sodium was reinitiated using test equipment and candidate bellows reclaimed from previous bellows work. A Bellmetrics, Type 316 stainless steel bellows, previously exercised in 1200°F sodium, failed at 43,000 cycles, representing 430% of design life.

Bench testing of a motion-multiplying (4x) mechanism which consists of a 2-stage differential rack system was started. This mechanism contains no bearings as such, and shows great promise for applications where a long output stroke with a short input is desired, i. e., control elements and fuel handling. Approximately 4200 cycles have been logged by the test mechanism, with no sign of degradation.

Disassembly and inspection of a mechanism which utilized a sodium-vapor condensing and thermal barrier zone below a conventional rubber O-ring (rotary seal) in a pool of sodium at 1200°F for 5252 hr were completed. The condensing plates were very effective. Internal to the rotary shaft were two actuator shafts (one within the other) which could be moved axially through a 4-in. stroke. It was concluded that, in time, both shafts would have accumulated sufficient amount of sodium compound to induce binding.

The excellent performance of the Belmetrics bellows alleviates to a great extent reservations concerning the use of bellows as seals in liquid sodium. Moving parts in a sodium vapor environment will eventually become bound if a temperature gradient extending below the freezing point of sodium exists in the part-clearance spaces.

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Program: Sodium Component Development	
Project: Operation of Sodium Component Test Installation	
Project Engineer: J. A. Leppard	
Reporting Period: Fiscal Year 1965	AEC Category: 04-01-04-31
General Order: 7593	Subaccount: 1322

I. PROJECT OBJECTIVES

The project objective is to operate the Sodium Components Test Installation and to test, obtain data on, and evaluate the performance of prototype intermediate heat exchangers and prototype steam generators.

II. TECHNICAL PROGRESS DURING FISCAL YEAR 1965

Performance of the entire sequence of preoperational tests was completed. This means that both primary and secondary sodium systems have been filled with sodium, and main pumps operated; pilot burners have been used to add heat in the main gas-fired heater; the steam system has been chemically cleaned, preheated, and made ready for the generation of steam; and individual equipment components have all been determined to be properly installed, calibrated, and prepared for proper service.

During preparation of procedures for filling the primary sodium system, new calculations revealed that the fill and drain tanks installed for both the primary and secondary systems were too small. A new and larger tank was purchased for the primary system, and the existing secondary tank was replaced with the original primary tank. A total of 41,000 lb of sodium is contained in the primary system, and 36,600 lb in the secondary.

As a result of the tank capacity problem, the schedule for the completion of preoperational testing was extended to very nearly the end of the fiscal year. In order to optimize manpower utilization, the sequence of preoperational tests was altered to expedite testing of those parts of the plant which were not affected by tank construction work.

Performance of the preoperational testing program revealed a number of deficiencies in the plant which have been corrected. Typical of these problems was the addition of safety valves, sampling locations, and safety features.

Planned activities subsequent to the completion of the preoperational test program include plant performance tests and component tests. Procedures for the plant performance tests, the objective of which is to determine the operating characteristics of the SCTI as a plant, have been completed. Similar step-by-step procedures for steady-state and transient testing of the ALCO/BLH steam generator are approximately one-half done.

During this year, a number of additional standard operating procedures were written. A new plant description was written, and a table of the design specifications giving the operating limits of major equipment and of the various systems

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has been compiled. All of these documents are part of the SCTI operations manual, which has been in preparation for two years, and is now essentially complete.

III. EVALUATION OF EFFORT DURING FISCAL YEAR 1965

Performance of the step-by-step preoperational test program made manifest a number of engineering and construction oversights which, if left uncorrected, would have prevented proper operation or adequate control of the plant. Action required to rectify these problems absorbed considerable time, but was considered necessary. It should be recognized that the purpose of the preoperational test program was to uncover these very conditions during system checkout and initial operation. Successful conclusion of all of the preoperational tests has rendered the plant ready for experimental operations.

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Program: Sodium Component Development

Project: Installation of ALCO Steam Generator

Project Engineer: J. A. Leppard

Reporting Period: Fiscal Year 1965

AEC Category: 04-01-04-31

General Order: 7593

Subaccount: 4125

I. PROJECT OBJECTIVES

The project objective is to install the ALCO steam generator, design and effect plant modifications, and complete the modular steam generator installation design package.

II. TECHNICAL PROGRESS DURING FISCAL YEAR 1965

All construction work required for placement of the ALCO steam generator, i. e., installation of steam and sodium piping, placement of heaters, thermocouples, and instruments, and installation of associated electrical gear was completed. Subsequent to installation of the steam generator, the connecting piping and the steam generator were hydrostatically tested. A gas chromatograph, installed to monitor steam generator cover gas for hydrogen, was put into operation.

Concurrently with the preoperational test program (reported under 1322), a design and construction review was conducted to locate and correct plant discrepancies. As a result of these studies, several plant modifications were made, and all construction work connected with it has been finished. Included with these modifications were the following.

- 1) Provision of additional screen gates between the cooling tower and main circulating pump to permit cleaning the screens without shutting down the circulating water system
- 2) Installation of a jib crane adjacent to the cooling tower to facilitate handling of screens, pump parts, or other heavy equipment
- 3) Addition of sample holders for metallurgical determination of impurities in the sodium system
- 4) Change in location and in placement of additional steam and feed water sampling lines
- 5) Addition of several relief valves on the high-pressure steam piping required to meet ASME code
- 6) Addition of a cold-trap system with connections to both primary and secondary sodium systems completed with a plugging meter and an in-line sodium sampling station for each loop

A larger (7500-gal.) tank was purchased and installed for use as a primary fill/drain tank. The original primary tank was substituted for the secondary tank.

Design of the modular steam generator installation package was completed. Some of the structural steel required for this installation was placed in position, and much of the equipment required was purchased and placed in storage.

III. EVALUATION OF EFFORT DURING FISCAL YEAR 1965

With completion of the ALCO steam generator installation and plant modifications, and termination of all other construction work at the SCTI, the plant is finished. The project objectives have been satisfied.

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Program: Sodium Component Development

Project: Fabrication of Modular Steam Generator

Project Engineer: D. T. Eggen

Reporting Period: Fiscal Year 1965

AEC Category: 04-01-04-31

General Order: 7593

Subaccount: 4121

I. PROJECT OBJECTIVES

The project objective is to design and fabricate a 37-tube, low-temperature evaporator and high-temperature superheater module capable of providing 2400 psi, 1050°F steam at the turbine throttle. The modules will be fabricated for installation and test in the SCTI. The necessary design work for installation of the modules in the SCTI will be completed, and the necessary equipment for installation of the modules in the SCTI will be ordered.

II. TECHNICAL PROGRESS DURING FISCAL YEAR 1965

A. FABRICATION

Fabrication of the two evaporator and two superheater modules were completed. Details of the fabrication are reported in NAA-SR-11410, "Fabrication of Modular Steam Generator for the SCTI." Details of the design are reported in NAA-SR-9826, "Final Design of Sodium Heated Modular Steam Generator for the SCTI." Figure 1 shows the two completed superheater units on their storage rack.

1. Tube-to-Tube Sheet Welds

The tube-to-tube sheet welding procedures developed during the design phase of this project for 2.25% Cr - 1% Mo, 5% Cr - 0.5% Mo, Type 347 and Type 304 stainless steel were used in fabrication of the modules.

The procedures for the tube-to-tube sheet welding were: (1) the tube to be welded was brought to the tube stub on the tube sheet; (2) the copper chill and external gas manifold were positioned aligning the tube-to-tube stub; (3) a ball of stainless steel wool was inserted well below the weld to avoid intermixing of inert gas and atmosphere; (4) the weld head was positioned in the tube sheet bore to be welded; (5) the gas lines, power cables, and power supply were checked; (6) the weld cycle was initiated; (7) upon completion of the entire weld cycle, the weld head and chill were removed; and (8) the ball of stainless steel wool was removed. This completed the weld.

Tube-to-sheet welding was accomplished by use of a weld head similar to the one developed earlier for this program. This head was an improved model, in that the drive motor was integrally mounted and the locating plate was simplified. Power was provided by the same power supply and programmer as used in the early development efforts. All tube-to-tube sheet welding was performed with the units in a vertical position. This was accomplished by installing the units in a steel-lined pit approximately 50 ft deep, in the assembly area floor.

7593-2501 -
Figure 1. Superheater Units on
Storage Rack

The procedure for setup was the same for both the evaporators (5% Cr - 0.5% Mo) and the superheaters (Type 321 stainless steel). The welding parameters were determined and the welding procedure specified for each alloy. The weld procedures specified the equipment to be used, the type of shielding gas, gas flow, electrode description, all of the automatic programming parameters and detailed step-by-step setup instructions, plus a sketch of the weld joint setup.

During the initial tube bundle assembly 15 tube-to-tube sheet welds were made on a mockup of the tube-sheet configuration. One mockup was made from 5% Cr - 0.5% Mo steel, the other from Type 321 stainless steel. Welds were made using the same weld procedures, respectively, as those to be used on the modules. The samples made of chrome-moly steel were postheat-treated by the same procedure as intended for that tube sheet. These samples were then submitted to Quality Control for x-ray dye penetrant, helium leak check, and finally metallographic examination.

Upon acceptance by Quality Control, the tube-to-tube sheet welding operations were started. Porosity and inclusion allowances were established by using a specially prepared comparison plate allowing approximately one-third the inclusions and/or pores of that allowed by Section VIII of the ASME Boiler and Pressure Vessel Code, for 1/4-in. plate material. Thinning, undercut, offset, or tungsten inclusions were not permissible. By welding from the middle row of tubes outward, radiography was performed upon

completion of every second row of welds. This permitted access to both rows of tubes. It also permitted dye penetrant inspection of the outside and inside of the welds.

a. Evaporator Units

Of the first 37 tube-to-tube sheet welds made, two were considered questionable because of pores or inclusions upon evaluation of the x-ray film. Both welds were rerun and reinspected and found to be within the limits of the specification. X-ray of the tube-to-tube sheet welds was done by double wall exposure. Shooting at a vertical angle of approximately 30° shows the image of the weld as an ellipse on the film. Two shots were made from opposite horizontal

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angles so that the weld could be fully exposed on film. When an area was questionable, additional shots were made to clearly define that area. The x-ray machine enclosures were fabricated of lead, thus providing shielding for personnel to within 13 ft when the equipment was in operation.

After welding, the tube bundle was removed from the pit and the entire Cr-Mo tube sheet and welds placed in a furnace for postheat treatment. Such treatment of the 5% Cr - 0.5% Mo evaporator module was accomplished by heating at a maximum rate of 400° per hr to 1325 to 1375° F, holding for 1 hr and cooling at a rate of 250 to 500° F per hr to below 600° F. Heating was monitored by clamping six thermocouples in the tubes at the weld joints and four additional thermocouples randomly placed around the tube sheet. Temperatures were recorded on tape for the record. During heat treatment, the entire heated area was purged with argon gas.

The welds were cleaned, helium-leak tested, and dye-penetrant inspected. The tube bundle was assembled to the shell by placing the shell in the pit, then lowering the tube bundle into the shell in a vertical position. The tube ends were faced to equal lengths by means of a spot facing tool in a drill press mounted over the end of the bundle. The tube sheet was mounted in position for welding of the lower end. Welding and inspection both proceeded much more rapidly and without difficulty. Since the tubes were now fixed at the opposite end, welding and inspection required lateral springing of the tubes for operator access. This proved to be no obstacle and caused no damage to the tubes. Three sets of spacers, the 32-in. shell section, a cone reducer, and the lower cross were left off the assembly for this purpose, thus allowing over 60 in. of free tube length.

The first major discrepancy occurred on the second evaporator module. The 35th weld on the second end had been completed; a setup was made for the 36th weld. The weld head was erroneously replaced in the 35th position. Without the protection of the combination external chill and gas backup, the weld was burned through.

After evaluation of the damage, it was decided to attempt a salvage operation. The tube stub on the tube sheet was backfaced to remove all cast metal, approximately 1/8 in. Two inches of the tube end were removed. The then existing end of the tube was prepared for welding and a 2-1/8-in. splice section also prepared for welding. The splice section was welded to the tube sheet using the original weld procedure. The tube was welded to the splice piece using a modified weld procedure.

b. Superheater Unit

Later in making the tube-to-tube sheet welds on the superheaters, a short tube was accidentally installed in a tube bundle. This tube was not discovered until after it had been welded. Rather than make a splice on the opposite tube sheet, it appeared advisable to cut off the short tube and replace it with a tube of correct length. A new tube was inserted in the tube bundle without removing it from the pit. The tube stub on the tube sheet was refaced and prepared for welding. In welding, the weld joint was "blown" into the gas annulus of the external chill. Examination revealed that a guide "bullet" used in inserting the tube had not been removed, causing excessive internal gas pressure during the welding operation.

Salvage required reshaping of the tube stub to nearly its original configuration, using specially ground cutters and preparing a new splice section. This section was welded to the tube sheet using the original weld procedure. A modified procedure was used to weld the tube to the splice piece. To assure control of the internal gas flow, a small loosely welded ball of stainless steel wool is inserted several inches below the weld joint. At this weld, a second ball was left in the tube and again caused excessive gas pressure resulting in a "blown" weld. This weld was also removed and a second splice section prepared and welded in place without incident (see Figure 2).

7593-2502
Figure 2. Welded Tube
Splice

While a slight thinning in wall thickness was expected at the weld joints, most welds showed a slight reinforcement on the outside of the tube. This reinforcement was apparently due to a slight restraint exerted by the tooling in welding. Boroscopic examination and also checks with a plug gage showed the welds to be generally flush with the ID of the tubes.

2. Shell Welds and Assembly

Prior to any shell welding, several welders were certified for welding both 5% Cr - 0.5% Mo and Type 321 stainless steel under Section IX of the ASME Boiler and Pressure Vessel Code. Weld samples were prepared for both the shell section and the tube sheet to nozzle section. The samples of 5% Cr - 0.5% Mo were postheat-treated in accordance with the recommended heat cycles for the sample thicknesses. Additional samples were sectioned and examined by Quality Control and found satisfactory.

Initial welding was done on the upper shell sections without consumable inserts. Early welds required an unusual amount of rework. Procedures were changed to use a consumable insert in making the root pass, which helped considerably in controlling the "drop through" in the inside of the shell sections. Several different weld rods were used as filler; 508-18 rod produced the cleanest weld deposit. Later, as the welders gained experience, the rework required became consistently less.

Fewer difficulties were encountered in welding of the shell assemblies for the superheaters. This material was Type 304 stainless steel, on which alloy all welders had years of experience. Due to the limited clearance between the inside diameter of the shell and the tube bundle, control of "drop through" caused some problems. Weld shrinkage, particularly on the superheater shells, while within the tolerance, caused interference in the insertion of the spacer and support rod assembly into the shell. However, once the spacers passed the girth welds they were free and without interference from the shell.

In both the evaporator and superheater the design of the cone reducer caused the most difficulty. The weld joint being located at the break point on both ends of the reducer. X-ray film showed a sharp line at the edge of the weld. Grinding to blend caused thinning in shell section. Alignment of the joint often proved

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difficult. Again, interpretation of the film caused much disagreement. Often this line was interpreted to be lack of fusion or undercut. Visual examination of the weld was often impossible in final stages of assembly because the areas in question were hidden by the tube bundle. The only solution was to remove the area of weld in question and reweld.

Postheat-treatment of the evaporator shell welds was done by coiling the area with electrically insulated copper wire, and wrapping with an insulation blanket. Each joint was monitored with calibrated thermocouples. Power was supplied with conventional welding power supplies. The heat cycle was manually controlled by varying the power output of the power supplies as required by the time-temperature cycle.

Review of the assembly operations of the first evaporator and the cost of inserting the tube bundle in the shell showed that this operation should be changed. The spacers and support rods were assembled and inserted into the center shell section. The diffusers, cone reducers, and fittings were added, except for the lower cross and split shell section. The tubes were now inserted. Assembly time was considerably reduced and radiography made easier, with less possibility of damage to the tubes.

B. HYDROSTATIC TEST

Preliminary planning included a hydrostatic test immediately after completion of the tube-to-tube sheet weld. It was intended to hold a closure plate over the tube sheet end by clamping to a collar below the neck of the tube sheet. The extreme torque required to seal the closure plate caused the collar to indent the sheet surface in the neck area. Rather than risk damage to the tube sheet, this method of test was abandoned.

After completion of the entire unit, plugs were welded in the nozzle extensions, the shell sealed with closure plates and hydrostatic-tested. The units were then rinsed and dried. Test of the tube-to-tube sheet welds was monitored by observing shell side pressure while the tube side was under test pressure.

Upon completion of the hydrostatic test and acceptance by the State Inspector, the outside of the evaporator modules were wire-brushed and given two coats of primer paint.

The evaporators were originally sealed by clamping closure plates over the shell nozzles and then coating them with a fiberglass epoxy. Movement and temperature changes caused these seals to leak. Therefore, a plate was fitted over the nozzles and fused to the weld preparation of the nozzle. The units were then again purged with dry gas.

C. EVAPORATOR MODULE OUTLET STREAM TEMPERATURE MONITORING THERMOCOUPLES

In order to provide maximum integrity to the tubes in the evaporator modules, the thermocouples which will be used to measure the individual tube outlet steam temperatures were clamped to the evaporator tubes. Calculations made indicated that the temperature errors which would be experienced due to the clamping of

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the thermocouples would be 8°F or less. Since temperature changes of the order of 20 to 50°F would be expected if unequal flow-of-significance occurred, the thermocouple installation was considered adequate for determination of any flow instabilities.

D. FATIGUE TESTS

Fatigue tests on a module head were completed, and additional tests on standard bar type specimens comparing 2.25% Cr - 1% Mo and 5% Cr - 0.5% Mo, showed the latter to be superior. These tests are reported in NAA-SR-9827, "Fatigue Testing of 37-Hole Modular Steam Generator Head."

E. CONTROL STUDY

The control study using a variable node length model for the once-through steam generator was terminated early in the fiscal year due to a stability problem in the variable node length model. This problem has since been corrected by using a different method of solution on the analog computer. No attempt was made to rerun the control study due to the nearness of the project completion date. A summary of the work done relative to the control study and variable node length was documented.

F. INSTALLATION OF MODULES IN THE SCTI

The design drawings necessary for installation of the modules in the SCTI (based on the Modular Steam Generator being installed first) were completed.

The necessary equipment for installation of the modules in the SCTI has been received and stored.

III. EVALUATION OF EFFORT DURING FISCAL YEAR 1965

The fabrication of the modules was completed with no major problems. The welding and x-ray inspection of the tube-to-tube sheet welds presented little or no difficulty. In the design of any future modular steam generator, consideration should be given to changing the core reducers to standard concentric reducers. This would allow welding and radiography in straight sections of equal diameter with no change in section. In any future tube-to-tube sheet welding operations where the weld configuration is dependent on the internal and external pressure of the shielding gas, a pressure control device should be utilized.

The report NAA-SR-9828, "Test Program for 2400 psi, 37 Tube, 20 Mwt, Modular Steam Generator" has been deferred to take advantage of information to be gained in the ALCO/BLH Steam Generator Test Program.

The project has met its objective of the design and fabrication of a sodium heated steam generator for high-quality steam. The modular steam generator concept with the related special manufacturing processes developed, appears to be economically competitive with other designs while providing the following.

- 1) Minimum possibility of caustic stress corrosion
- 2) Generation of 950 to 1050°F steam consistent with reliable performance

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- 3) Possibility of generation of high pressure steam to exploit associated lower plant heat rates
- 4) Isolation and removal from service without major outage
- 5) Steam generator fabrication and installation schedules which will not govern the plant construction schedule.

Proof of performance of the modular steam generator has yet to be demonstrated, since the present schedule is for the modules to be tested in the SCTI after the ALCO steam generator test. With the modular steam generator being the second installation in the SCTI, additional design work will be required to modify the installation drawings. This added work will be given a separate subaccount.

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Program: Sodium Component Development	
Project: High-Temperature Strain Measurements	
Project Engineer: W. J. Hallett	
Reporting Period: Fiscal Year 1965	AEC Category: 04-01-04-31
General Order: 7593	Subaccount: 1328

I. PROJECT OBJECTIVES

The objective of this project is to develop suitable, reliable, high-temperature strain gages for experimental stress or strain measurements, or for application in process instrumentation components. Commercially available gages will be tested to determine their limits, applicability, and reliability as analytic instruments for use on component test loops and systems, and as sensing elements in pressure transducer and force-arm applications. Suitable high-temperature strain gages will be developed, as well as application techniques for high temperature use. Methods of accomplishing temperature compensation and sealing of the sensitive element will be investigated to permit use in contact with sodium or sodium vapor.

II. TECHNICAL PROGRESS DURING FISCAL YEAR 1965

Since inception of this project in March 1965, effort has been directed towards preparation of a detailed plan of action for the work effort, during which preparation of a limited number of pilot tests were performed on the more promising, commercially available electric resistance strain gages. Production facilities of strain gage manufacturers and vendors manufacturing special high-temperature strain gage wire were inspected in order to identify gaps in strain gage technology and manufacturing. The pilot evaluation includes the following.

- 1) Apparent strain versus temperature characteristics at 900, 1000, 1100, and 1200°F.
- 2) Stability (drift) versus time characteristics at 900, 1000, 1100, and 1200°F (for periods up to 6 mo before and after thermal shocking)
- 3) Repeatability characteristics at 1000 and 1200°F.
- 4) Variation in gage factor as a function in temperature.

Results from the pilot evaluations are not complete. However, it was clearly ascertained that gages from one lot of commercially available 1200°F electric resistance strain gages were found defective due to improperly welded joints between the grid and the lead tabs. Their stability was extremely poor. Gages of this same type, from the same manufacturer but from a different lot evaluated earlier, showed excellent stability with respect to drift, even at 1200°F. This indicates that the lack of strain gage reliability is probably often due to inadequate quality control. Also, inspection of the facilities and procedures of the vendor furnishing strain gage wire, of the type used in manufacturing these gages,

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indicated a need for improvement in techniques for casting the bars from which the wire is drawn, and for maintaining more adequate quality control during the drawing operations.

Additional information from the pilot investigation, including evaluation of a full-bridge, 900°F sheathed type commercial gage for use in steam, etc, is currently being completed.

III. EVALUATION OF EFFORT DURING FISCAL YEAR 1965

On the basis of information obtained during this brief period, it is plain that there is too much lot-to-lot variation in commercial wire filament strain gages with respect to electrical characteristics and reliability for accurate or meaningful strain measurement at temperatures above 750°F. In part, due to the lack of sufficient quality control during fabrication of the gage, and in using alloys developed for manufacture of potentiometers or other less critical electric components.

The so-called metal-film or etched-foil gages, which have gained considerable popularity in the past several years, do not require making critical weld joints between the 0.001-diameter grid wire and the heavier lead tabs, since the grid and lead tabs are etched as a unit. In this respect, they are more predictable and reliable than the wire-wound gages which do require critical weld joints. Unfortunately, metal-film or etched-foil gages cannot be flame-spray bonded to the structure without damage to the gage. They require the use of ceramic cements which are more electrically conductive and more fragile as a bonding material than the aluminum oxide used in the flame spray process, and thus have been found inferior to flame-spray bonded electric resistance strain gages.

Procedures will be developed to make more reliable wire-filament strain gages, with particular emphasis on the development of better weld joints. More stable alloys will be used for gage materials, such as the Fe-Cr-Al alloys, which are not now being used in commercially available 1200°F wire strain gages. This special wire is already on hand as well as the fixtures for fabricating pilot gages for further evaluation. The state-of-the-art survey carried out several years ago will be updated. Specifications will be developed for procurement of strain gages with considerably improved performance and reliability at temperatures above 750°F, under steady-state and thermal shock conditions. With such gages, it should be possible to develop high-temperature nuclear components and accessory equipment having far greater structural reliability with respect to creep, fatigue, stress-rupture, etc, than is possible today.

ATOMICS INTERNATIONAL
A Division of North American Aviation, Inc.

Program: Sodium Component Development

Project: Mechanisms in Sodium

Project Engineer: W.J. Hallett

Reporting Period: Fiscal Year 1965

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I. PROJECT OBJECTIVES

The objective of this project is to evaluate materials, configurations, and surface treatments for use in high-temperature liquid sodium or sodium vapor. Information generated in this project will be applicable to the designs of mechanisms such as control elements, handling equipment, and variable orifices which must operate in sodium cooled reactors.

II. TECHNICAL PROGRESS DURING FISCAL YEAR 1965

Testing of bellows at a stroke-to-compressed length ratio of 4:1 in 1200°F liquid sodium was reinitiated using test equipment and candidate bellows reclaimed from previous bellows work. A Belmetrics, 316 stainless steel bellows, which had previously been exercised in 1200°F sodium, was additionally tested and failed at 43,000 cycles (3-in. compression and extension stroke). The cycles attained represent 430% of design life. Preparations for testing an identical bellows in the test rig were nearly completed.

Bench testing of a motion-multiplying (4x) mechanism which consists of a 2-stage differential rack system was started. This mechanism contains no bearings as such, and shows great promise for applications where a long output stroke with a short input is desired, i. e., control elements and fuel-handling equipment. The test mechanism has been placed on continuous operation for cycling a 100-lb load over an 80-in. distance with a 20-in. input stroke. Cycling in this mode will continue until failure occurs, to provide basic information concerning problem areas associated with rack and pinion drives having motion ratios of 1:4. Approximately 4200 cycles have been logged by the test mechanism, with no sign of degradation.

Disassembly and inspection of a mechanism which utilized a sodium-vapor condensing and thermal barrier zone below a conventional rubber O-ring (rotary seal) were completed. This mechanism had been adapted to a vessel containing sodium, and the internals exposed to a pool of sodium at 1200°F for 5252 hr. The inspection revealed that the condensing plates (Figure 1) were very effective, in that no sodium vapor had reached the seal area, or the annulus between the rotary member and the housing. Internal to the rotary shaft were two actuator shafts (one within the other) which could be moved axially through a 4-in. stroke. The smaller shaft (3/8-in. diameter) was supported by the larger shaft (5/8-in. diameter) so that there was no relative motion between the two shafts when the larger was exercised. When the smaller shaft was raised and then lowered to its seat position, relative motion between shafts did occur. At disassembly, a narrow band of sodium compound was found to have been deposited within the shaft annuli. The locations corresponded to a level where the estimated temperature was 250°F.

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Figure 1. Sodium Vapor Condensing Plates on Rotary Seal

Figure 2. Rotary Seal Actuator Shafts

Externally, the two shafts (Figure 2) exhibited distinct lines of demarcation in the area of the sodium deposit. Above the deposits, the shafts were clean and smooth. Below the deposits, there was light frosting for a short distance which diminished to discolored, but otherwise clean surfaces again. It was concluded, that in time, both shafts would have accumulated sufficient amounts of sodium compound to induce binding.

III. EVALUATION OF EFFORT DURING FISCAL YEAR 1965

The excellent performance of the Belmetrics bellows alleviates to a great extent reservations concerning the use of bellows as seals in liquid sodium. Although this bellows did not duplicate the extraordinary performance of a similar bellows which had been tested during FY 1963, the 43,000 cycles reached is still a significant accomplishment. Test results from a third bellows of this type will provide additional data for the evaluation of bellows for use as seals in liquid sodium. Results from the inspection of the O-ring test mechanism indicate that moving parts in a sodium vapor environment will eventually become bound if a temperature gradient extending below the freezing point of sodium exists in the part-clearance spaces.