SODIUM-HEATED STEAM GENERATOR
DEVELOPMENT

THE BABCOCK & WILCOX CO.
BOILER DIVISION
BARBERTON, OHIO

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ABSTRACT

An evaluation of several alternate ways to redesign the Prototype Steam Generator to eliminate stainless steel pressure parts is being made. Recommendations will be made to the Commission. Fabrication of the Prototype is held up.

A draft of the Interim Report containing design criteria, steam generator preliminary cost trend curves and preliminary specifications has been submitted to the Commission for approval.
1.0 PREFACE

1.1 BACKGROUND

This Contract was received on March 20, 1963 and signed on April 3, 1963. The overall objective of this Contract is to develop large heat exchange equipment of improved design. This heat exchange equipment will be available for use in the Atomic Energy Commission Liquid Metal Fast Breeder Reactor Program which has the overall objective of developing reliable, economical, large central station nuclear power plants.

1.2 SCOPE:

The scope of work being done under this Contract is briefly as follows:
Task I - Steam generator development including prototype fabrication and testing:

This task includes the following major phases, some of which have been completed.

A - Preliminary design of a full size sodium heated steam generator
B - Supporting research and development work
C - Preliminary design of a 30 MWe Prototype Steam Generator
D - Detail design of the Prototype Steam Generator
E - Fabrication of the Prototype Steam Generator for Installation and testing at SCTI.
F - Preparation of operating instructions and test program
G - Analysis of test data from SCTI
H - Destructive examination of the Prototype Steam Generator following testing
I - Final report relating the results of the testing and destructive examination to the design of the full size...
steam generator.

Task II - Sodium to Steam Heat Exchanger Elements and Research:

This study is intended to integrate into the steam generator design things that have been learned so far in the detail design and fabrication of the Prototype Steam Generator in order to speed up as much as possible the turn around time for experience to be factored back into the design of a component. This Task has the following major phases:

A - Design Criteria, including preliminary cost trend curves and preliminary specifications.

B - Concept trade-off studies to establish the relative total evaluated cost of alternate steam generator configurations such as large units with coil type arrangement of heating surface, modular concepts, etc.

C - Optimization of the reference design in which the selected concept from the above study will be studied over a range of pressures and temperatures, etc.

D - Preliminary design which will include a design and detail cost estimate so that the relative costs that have been determined in the previous portions of this study can be reduced to absolute costs.

1.3 RELATIONSHIP TO OTHER PROJECTS:

This steam generator development program is generating design and cost information of value within the LMFBR program to the contractors having 1000 MWe plant studies, to those in the Commission, National Laboratories, and private industry doing development work on demonstration
plants and on full size commercial LMFBR plants. This program will produce a steam generator of demonstrated performance and reliability that will be available for use in the construction of LMFBR demonstration plants and full size commercial central station power plants.

2.0 TECHNICAL PROGRESS DURING REPORTING PERIOD:

2.1 TASK I - PROTOTYPE STEAM GENERATOR:

Fabrication of the Prototype Steam Generator has been held up as a result of an overheated spot discovered in one of the stainless steel superheater riser tubes that had been fabricated and was being made ready for installation in the steam generator. Careful checking of every tube in the steam generator disclosed three additional areas in the stainless steel superheater tubing where there were surface indications of small cracks under dye penetrant examination. A review was made of the problem of whether or not there might be areas of sub-surface damage that would not show up in dye penetrant examination, but which could cause a tube leak during testing at SCTI or could interfere with the interpretation of results of the destructive examination of the steam generator following testing.

On November 15, 1967 the Commission issued a program letter directed to solve this problem. Based on the Commission's consideration of the uncertainties in the quality of materials and workmanship in the Prototype Steam Generator the decision was made to defer further fabrication of the present design and to evaluate alternate courses of action to eliminate as far as possible the questionable areas with respect to the stainless steel superheater. In addition to eliminating the unknowns with respect to the present stainless steel tubing the objectives of the investigation of
the steam generator will be to eliminate the stainless steel portion of
the water-steam side of the steam generator which will eliminate the need
for stainless steel tubes and tubesheets, external cross-over connections,
dissimilar welds, and will thereby greatly simplify and streamline the
design. Also, the elimination of all stainless steel from the water-
steam side will avoid a concern as to whether the stainless steel super­
heater can be damaged through accidental upsets in the feedwater chemistry.

It has become possible to eliminate the need for a stainless steel
superheater because the system studies being carried out for 1000 MWe
study contracts are indicating the optimum steam temperature is somewhat
lower than the steam temperature for which the Full Size and Prototype
Steam Generators were originally designed. Lowering the steam temperature
to 950 F has resulted in a lower metal temperature in the superheater so
ferritic alloys can be used throughout both the boiler and superheater.

A study was begun to evaluate the several alternate ways that the
stainless steel superheater can be eliminated. These include the following:

1 - Use of existing Croloy 2-1/4 boiler bundle only, taking the
resulting reduction in performance.

2 - Replacement of the present stainless steel superheater bundle
with a Croloy 2-1/4 superheater bundle occupying the same place.

3 - Adding length to the existing Croloy 2-1/4 boiler bundle to achieve
the desired performance.

4 - Installing a new Croloy 2-1/4 bundle in the existing shell.

Another alternate, a whole new steam generator was evaluated but the
tube bundle was identical to Alternate 4 above so that it would fit into
the existing shell and there would be no reason to consider a new shell.
In addition to comparing the four alternate designs to eliminate the stainless steel superheater a brief review was made of alternate materials of construction to confirm if there is a material available that would be a better selection than Croloy 2-1/4 for this application. Of the materials that would be suitable for sodium service at this temperature, Croloy 2-1/4 still appears to be the best choice because there are more data available on its properties and its performance in sodium than on most of the alternate materials except austenitic stainless steel. Although other materials such as Incoloy 800 appear attractive, it is felt that the highest assurance of a satisfactory steam generator design at this time can be had by using Croloy 2-1/4.

The report on this study should be completed in January 1968. This report will contain the evaluation of these alternates and a recommendation including how much of the present unit can be used and what the performance of the recommended design will be. Also included will be a preliminary schedule for the design and fabrication of the revised prototype steam generator.

2.2 INSTRUMENTATION:

The sheathed thermocouples that were returned to the vendor for calibration have been calibrated and delivered to B&W. Arrangements had been made for calibration of the strain gages by the vendor. The vendor submitted a suggested procedure for calibration based on a bending bar technique of applying the strain to the gage. B&W suggested that the calibration procedure be changed to pure tension loading of the test bar to which the strain gages are attached because of inherent errors in the bending bar technique.
As a portion of the creep and drift test of a strain gage the method of sealing the strain gage leads into the protective hut is being investigated. There are small tubes protruding from the side of the strain gage hut through which the sheathed strain gage and thermocouple wires are inserted. Mock-ups of a number of these tubes were made and several techniques of brazing sheathed leads to these small tubes were tried. Both the single braze and double braze procedures appear to give lead free seals, but destructive examination of a number of these brazed joints showed porosity in some of the brazed joints that might result in leakage in the future, and that penetration of the brazing alloy into the space between the sheathed lead and outer tube is not uniform if the lead and outer tube are not carefully aligned.

2.3 TASK II - SODIUM TO STEAM HEAT EXCHANGER STUDY:

A draft of the Interim Report BAW-1280-46 containing cost trend curves and a preliminary set of steam generator specifications has been transmitted to the Commission for review and comment. The general arrangement of this steam generator is shown on Drawing 25590 F attached.

2.4 R&D PROGRAM:

EROSION IN TUBE BENDS:

This project is directed to determine if there will be a problem of erosion in once-through steam generators on the water side at the location where the steam quality is high—near the point of dryness. To find if there would be significant erosion it would be necessary to operate a test facility over a number of years so that measurable amounts of erosion could take place if in fact it will really occur. There is a gas fired model once-through steam generator at the B&W Alliance Research Center that
has operated at various loads, pressures, and outlet temperatures over approximately the past twelve years. It was felt that if samples of tubing were removed from a number of locations in this steam generator and examined for erosion it could be determined if erosion inside tubes having short radius bends will actually be a problem in service. It is planned to remove a number of bends from the bank of tubes at the steam outlet end of this steam generator because this location would have the highest steam side velocity and also is the section of the steam generator having the best instrumentation for determining exactly what the steam conditions were in the tubes. In addition it is planned to make a survey of all of the operating logs for this steam generator to determine the location where additional tube bends should be removed that would have operated most of the time with high qualities near the point of dryness. Replacement tubes have been fabricated for the outlet bank of this steam generator so that the samples can be removed and the new bank installed during the next outage of this equipment. The survey of the operating logs for this steam generator is scheduled to begin in January. Based on the results of this study the location for removal of the additional tube bend samples will be selected.

3.0 EXPECTED PROGRESS DURING NEXT REPORT PERIOD:

During the next three months it is expected that the recommendation on redesigning the Prototype Steam Generator would have been approved so the scheduling of the redesign and fabrication of the Prototype Steam Generator can proceed.