

CRBRP GEFR-SP 241

DATE 5-29-81

CONF-811008--2

TITLE: The Protected Air-Cooled Condenser for the Clinch River Breeder Reactor Plant

AUTHORS: R. Louison/C.E. Boardman

Prepared for presentation at

**MASTER**

ASME/IEEE Joint Power Generation Conference  
Conference

Held in St. Louis, MO  
City, State

On Oct. 5, 1981  
*H. J.* Date

**DISCLAIMER**  
This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This paper contains material  
resulting from work performed  
for CRBRP

Under Contract No. 54-7A0-192909BP

Under DA N/A

*This paper has been authored by a contractor of the U.S. Government under Contract No. DE-AC15-76CL50003. Accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes.*

ADVANCED REACTOR SYSTEMS DEPARTMENT • GENERAL ELECTRIC COMPANY  
SUNNYVALE, CALIFORNIA 94086

**GENERAL  ELECTRIC**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

*EHB*

## **DISCLAIMER**

**This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.**

## **DISCLAIMER**

**Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.**

THE PROTECTED AIR-COOLED CONDENSER FOR  
THE CLINCH RIVER BREEDER REACTOR PLANT

- R. Louison      Senior Engineer, Advanced Reactor Systems Department,  
General Electric Company, Sunnyvale, California, Mem. ASME
- C. Boardman    Principal Engineer, Advanced Reactor Systems Department,  
General Electric Company, Sunnyvale, California

The long term residual heat removal for the Clinch River Breeder Reactor Plant (CRBRP) is accomplished through the use of three protected air-cooled condensers (PACC's) each rated at  $15\text{MW}_t$  following a normal or emergency shutdown of the reactor. Steam is condensed by forcing air over the finned and coiled condenser tubes located above the steam drums. The steam flow is by natural convection. It is drawn to the PACC tube bundle from the steam drum by the lower pressure region in the tube bundle created from the condensing action.

The concept of the tube bundle employs a unique patented configuration which has been commercially available through CONSECO Inc. of Medford, Wisconsin. The concept provides semi-parallel flow that minimizes subcooling and reduces steam/condensate flow instabilities that have been observed on other similar heat transfer equipment such as moisture separator reheaters (MSRS). The improved flow stability will reduce temperature cycling and associated mechanical fatigue. The PACC is being designed to operate during and following the design basis earthquake, depressurization from the design basis tornado and is housed in protective building enclosure which is also designed to withstand the above mentioned events.

## INTRODUCTION

The Clinch River Breeder Reactor Plant (CRBRP) is the nations first large-scale demonstration breeder nuclear power plant to be located in Oak Ridge, Tennessee. The plant will have an electric generating capacity of 375 megawatts and operate as part of the Tennessee Valley Authority System.

The Project evolved from the need to develop the Liquid Metal Fast Breeder Reactor (LMFBR) to assure a long-term nuclear fuel source. The breeder will complement the light water reactor-now the principal source of nuclear power. Its deployment would make it unnecessary to mine lower quality and more costly ore and would extend present uranium resources for centuries. The LMFBR will create more fuel than it consumes as it generates electricity.

CRBRP was established to demonstrate that the breeder can operate reliably and safely in a utility environment and to serve as a major step in the successful transition from technology development efforts to large-scale commercial LMFBR plants.

The primary coolant used for the reactor is liquid sodium. Sodium is also used to transfer heat through intermediate heat exchanger(s) (IHX's) to the intermediate loop. Heat is then transferred from the sodium of the intermediate loop to the water and steam of the steam generators and superheaters.

There are three independent loops for this heat transfer path from the reactor to the superheaters. The steam from the steam generator is separated in the steam drum prior to being superheated. Three protected air-cooled condensers (PACC's), one for each loop, are used to remove from the plant the long term decay heat by condensing the steam drawn off the steam drum. This paper will describe the general background of the PACC, the design requirements, the basic design and the outstanding features of the PACC.

## GENERAL BACKGROUND

The PACC's are sized to remove the entire plant sensible and decay heat load within one hour after a normal or emergency shutdown. To meet the need for operation during and after an emergency, the PACC is classified as part of the plant safety equipment and is designed to perform its functions during and after the specified abnormal conditions. Other PACC system components such as valves, piping and electrical supply are similarly classified and designed. Two of the PACC's are powered by the two separate plant emergency diesel generators. The third PACC is powered by the plant emergency battery. The PACC condenses steam by forcing ambient air over a finned condenser tube bundle that contains the

steam drawn from the steam drum. As the PACC's are part of the plant safety system, it differs from the conventional dump heat exchanger in that they are housed in a protective enclosure. The Steam Generator Building in which the PACC's are housed is designed to withstand design basis earthquakes, design basis tornadoes, and tornado generated missiles. The PACC's are also classified as Seismic Category 1 components, designed to remain functional during and after the design basis earthquake in order to remove the plant decay heat. The tube bundle and supports are constructed to ASME Boiler and Pressure Vessel Code, Nuclear Power Plant Components, Division 1, Class 3. The electrical motor and control are Class 1E in accordance with IEEE and Project requirements.

The PACC's are sized to remove 15 Mwt ( $51.2 \times 10^6$  BTu/hr) when the saturated steam from the steam drum is at 1400 psig (98 kg/cm<sup>2</sup>) and 588°F (309°C). At these conditions, the steam is being condensed at the rate of 89,500 lb/hr (40,600 kg/hr).

The PACC's are located on the top floor of the Auxiliary Bay of the Steam Generator Building. The three cells in which the PACC's are located are identical, with air inlets on the south wall and exhaust stack above the roof. Both the air inlets and the exhaust stacks provide shielding to prevent a direct hit on the PACC's from tornado generated missiles. The three steam drums, from which the saturated steam flows to the condensers, are located on the floor immediately beneath each of the three PACC's in the Auxiliary Bay. The condensate is returned to the steam drum. When the steam in the tube bundle is condensed, it causes a collapse of the steam volume and creates a low pressure region in the tube bundle. This low pressure allows the steam to flow up from the steam drum to the PACC tube bundles through natural convection.

#### ISOLATION OF THE PACC DURING NORMAL PLANT OPERATION

A study was performed utilizing two concepts for isolating the PACC's the steam-side isolation and the air-side isolation. In the steam-side isolation concept, the steam supplies and condensate returns are valved off, thus isolating the tube bundles from the steam drums. In this case the tube bundles will be at ambient pressure and temperature during normal plant operation. In the air-side isolation concept, the PACC is on hot standby during normal reactor operation. The tube bundle is not valved off from the steam supply. Instead, the tube bundle is isolated from the ambient air by an insulated plenum. The plenum may have either doors or louvers that open upon initiation of PACC operation.

Since the air-side isolation concept avoids the material and transient problems inherent in the steam-side isolation concept and provides more reliable operation by simplifying the startup and shutdown procedures, the air-side isolation approach was selected and the equipment specification was written on this basis.

## DESIGN REQUIREMENTS

In addition to the previously discussed requirements for decay heat removal during and following the design basis earthquake, the following are other major design considerations. Each PACC is subdivided into two half size units to eliminate the possibility of a single failure that may cause a loss of a complete PACC and that loop to lose its long term heat removal capability. This also reduces the size of the tube bundle for shipping. Each half is separately operable and controllable with redundant fan, motor, air flow control and shutoff devices. Attached figures provide the overall arrangement of the PACC.

Heat losses from the PACC during normal plant operation is limited to 3% of rated PACC duty. This requires that the plenum and the louvers or dampers be insulated and that air leakage through the louvers and insulation joints be held to a minimum. For improved heat transfer, dump heat exchangers are usually finned. For the PACC application, either mechanically embeded fins or welded fins were acceptable. Section III of the ASME Code does not specifically allow welded fin attachment to a pressure boundary, therefore an inquiry with ASME Code Committee was initiated to gain acceptance of welded fins. The inquiry resulted in Code Case N-160 (1797) which allows welding of carbon steel or stainless steel fins to tubes made of similar material.

## PACC DESIGN

The PACC design uses a cylindrical tube bundle concept that had been developed for heat exchanger equipment with vertical headers as shown in the attached figures. This results in a compact tube bundle configuration thus reducing the overall size of the unit. Fins are first attached to the 2.0 in. (5.08cm) O.D. heat transfer tubes by welding. The tube is then spirally wound around a mandrel four times forming a conically shaped coil.

Each coil is attached to the inlet and the outlet headers. For the PACC application, the cone is inverted so the steam inlet is on the outside and condensate return is lower and inside. Because the air flow through the coils is radially inward, the unit incorporates partial parallel heat transfer characteristics and reduces the subcooling potential.

Each coil has an outside diameter of 100 in. (2.54m) and an inside diameter of 69.5 in. (1.76m) and consists of 89 ft. (27.1m) of finned tube length. Each tube bundle consists of 46 coils and 20,792 ft<sup>2</sup> (1932m<sup>2</sup>) of external heat transfer surface. The total surface area includes a 10% margin over that required for the rated capacity of 7.5 Mwt per half size unit. The coils are formed so that when stacked the tubes nest into a triangular pattern. The overall heat transfer coefficient is estimated to be 4.5 Btu hr ft<sup>2</sup> (2.2 cal/hr cm<sup>2</sup>c) with a log mean temperature difference of 306°F (153°C).

One axial fan with variable pitch blades is used for each tube bundle. Each fan is capable of 75,000 SCFM ( $2.1 \times 10^6$  SLM) at 53 HP with a turn down ratio of 10:1.

Two louvers are used to isolate each half of the PACC. One shutoff louver at the fan discharge or the inlet to the plenum area and one at the plenum discharge. The louvers are insulated to reduce the heat loss during normal plant operation. The inlet louver also serves to protect the fan motor from being overheated by the tube bundle when the PACC is on standby.

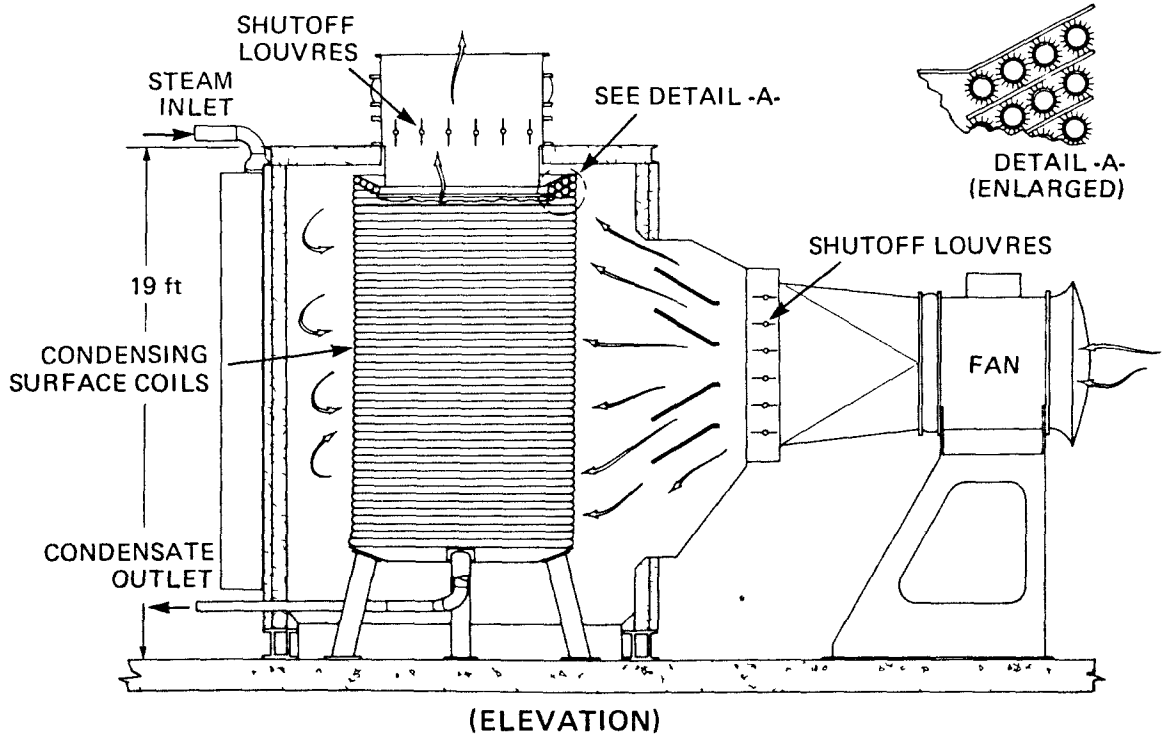
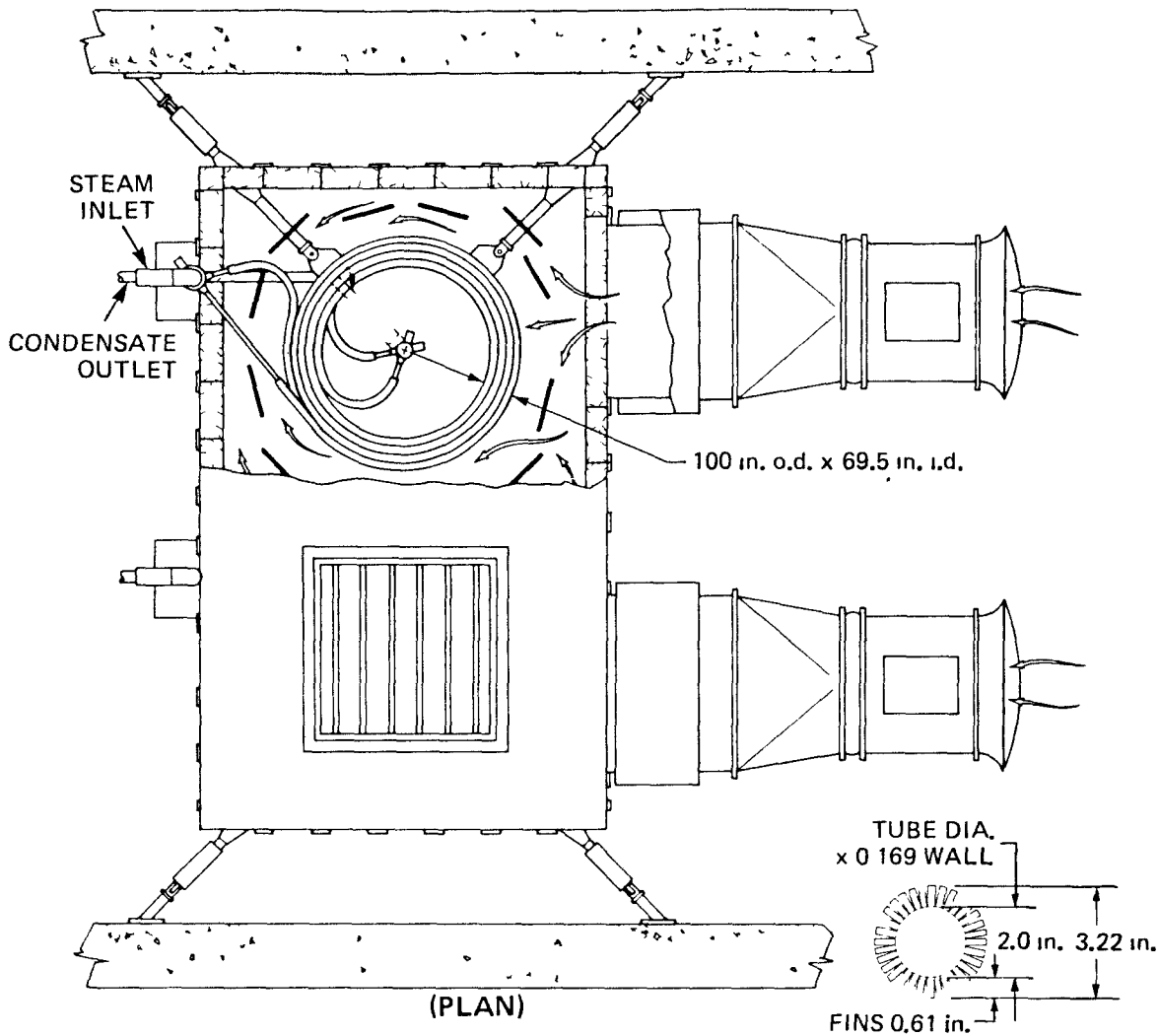
Air flow vanes are used to minimize air flow maldistribution. At the entrance to each tube coil, an orifice is added to increase the steam side pressure drop insuring equal and steady steam flow through each coil. These provisions to improve airside and steam/condensate flow distribution and the low subcooling nature of the unit will reduce steam/condensate flow instabilities which have been observed on other similar heat transfer equipment, most notably moisture separator reheaters (MSRs). Unstable flow coupled with subcooled condensate is the main cause for fatigue failures of the tubes. Towards this end, extensive analytical effort and model testing as necessary are being undertaken to assure that the initiating mechanisms for flow instabilities are minimized.

Seismic design for the unit is of major importance in the design effort. To support the tube bundle, horizontal restraints throughout the height of the tube bundle are being incorporated into the design and modeled for dynamic computer analysis.

To measure the performance of the PACC in the plant operation a venturi type flowmeter is used to measure the condensate flow. The condensate temperature and the steam temperature are also measured for the performance assessment.

Following the fabrication of the first unit, a complete PACC is to be assembled and tested to demonstrate its mechanical and heat transfer capability using live steam.





PROTECTED AIR COOLED CONDENSER