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CONF-780440--1

THE ROLE AND PROGRESS OF THE CLINCH RIVER BREEDER REACTOR PLANT

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Prepared for Presentation at the

American Power Conference

Chicago, Illinois

April, 1978

This paper contains information developed in the course of work under US Department of Energy Contracts E4-76-C-15-2395 and E4-76-C-15-0003

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Introduction

The Clinch River Breeder Reactor Plant (CRBRP)* has a vital role in the development of the Liquid Metal Fast Breeder Reactor (LMFBR) as a viable energy source for future use. This role is multifaceted as shown by the following seven objectives:

Provide the evolutionary step in the design of plant equipment approximately midway between test reactors and commercial plants;

Develop the industrial equipment and manufacturing base with the associated reservoir of trained personnel necessary to support a commercial industry;

Demonstrate the LMFBR potential and advantages in meeting the necessary safety, licensing and environmental requirements;

Confirm that an LMFBR plant will meet performance objectives reliably, safely and with necessary availability in a utility operating environment;

Establish the potential for favorable economics of the Breeder Reactor;

Instill confidence in the ultimate customer, the utility industry, in the LMFBR through its direct participation in design construction and operation of the plant;

Provide the vehicle for later testing of advanced concepts for LMFBRs in a fashion analogous to the Shippingport Light Water Reactor.

The accomplishments of the Project to date demonstrate that these objectives are being met. The timely completion and operation of the CRBRP will complete the achievement of these objectives. To provide perspective, the accomplishments of the Project in design, licensing and manufacturing will be summarized followed by an assessment of the achievements toward these programmatic objectives.

Progress of the CRBRP

The most dramatic evidence of progress on the Clinch River Breeder Reactor Plant is in the system and component design and fabrication. All of the conceptual design and more than 90% of the preliminary design of the CRBRP is complete. The Project has completed approximately 50% of

*The CRBRP is a 975 MW Thermal Liquid Metal Fast Breeder Reactor which would be operated as part of the TVA system. A complete description of the design is found in the 1977 Technical Progress Report, CRBRP-ARD-0211.

the detailed design for the systems and components of the Nuclear Island. Even these achievements are overshadowed by the progress on the major component fabrication. To show this progress, certain of the components identified in Table I and shown in their in-plant locations in the cut away in Figure 1 will be discussed in some detail.

The reactor vessel (Figure 2), is a stainless steel vessel which is 20'3" in diameter and 54'8" long, weighing 470 tons dry. The inlet nozzle is 2' in diameter while the outlet nozzle is 3' in diameter. Babcock and Wilcox is the fabricator for this vessel. The Figure identifies the major elements that will be assembled and welded together. All of these elements have been fabricated. Figures 3 through 5 show various elements of the vessel in different stages of completion. Figure 3 shows the support ring, top flange, and Inconel shell during gun drilling of a dip seal maintenance port. Use of the Inconel transition to accommodate different rates of thermal expansion allowed the use of carbon steel for the top flange and support ring which reduced cost while providing additional strength. Figure 4 shows shell courses B and C being fitted to course D for welding. Note the 3' diameter outlet nozzles on shell course D. The reactor vessel lower shell assembly, comprised of the thermal liner support ring, the middle shell, core support ring and cone, and the lower shell, is also undergoing machining of welding preparations. Figure 5 shows the core support ring and core support cone assembled ready for welding. The reactor vessel is almost 50% complete.

The CRBRP core support structure is shown on Figure 6 with the key subassemblies identified. Allis Chalmers manufactured this 100 ton assembly which is 18' high and 13' in diameter, constructed entirely of stainless steel. The design of the core support structure, using lower inlet module liners which fit into the core plate assembly, provides the flexibility to accommodate a variety of core configurations without necessitating a change to the permanent structures of the plant. This allows the CRBRP to operate with the reference mixed oxide fuels or with other fuels, including thorium if so desired, as part of a later test program. Further, the use of gun drilling to provide the radial flow paths and connection to the upper plenum provides a simple design to insure hydraulic holddown of the fuel assemblies and provide by-pass flow for the shielding and vessel thermal liner. The core support structure is complete through the manufacturing process. Figures 7 through 9 show the core support structure in various stages of the fabrication. Figure 7 shows the upper assembly being tack welded to the lower assembly for the final girth weld of the unit which was completed on January 31, 1978. Figure 8 shows the core plate assembly on the horizontal boring machine during dimensional inspection which utilized a laser interferometer. Figure 9 shows the moduleliners being installed into the core plate assembly. The white coating is condensation frost which formed after cooling in liquid nitrogen prior to insertion.

The CRBRP closure head is composed of three rotating plugs. In conjunction with the fuel handling machines, these three rotating plugs provide the capability to reach any of the fuel assemblies in the core for refueling. The closure head also provides for biological and thermal shielding from the sodium and fuel in the reactor vessel itself. Figure 10 shows the major components of the CRBRP closure head. Chicago Bridge and Iron is responsible for the closure head assembly including risers, plug drives and bearings, which weighs 500 tons and is forged carbon steel. The plug thicknesses are 22". The large rotating plug is 21'6" in diameter while the intermediate plug is 14'8" and the small plug is 5'8" in diameter. Figure 11 shows the intermediate rotating plug with the holes for the small rotating plug, the upper internal structure columns and all but five control rod drive mechanisms completed. Machining is proceeding on the large rotating plug and the small rotating plug.

The intermediate heat exchanger shown on Figure 12 is being fabricated by Foster Wheeler. This stainless steel heat exchanger is 8'8" in diameter and 52'1" long and has a dry weight of 115 tons. The unit has a rating of 325 MW thermal with 2850 tubes per unit. Figure 13 shows the lower tube sheet during drilling of the tube sheet holes. The IHX bundle assembly, consisting of the upper tube sheet, the tubes, the distribution cylinder to insure proper flow distribution, and the downcomer strongback, has been assembled.

The steam generator is one of the key components for an LMFBR. The CRBRP steam generator module shown in Figure 14 is being fabricated by the Atomics International Division of Rockwell International. This "hockey stick" design enables accommodation of differential expansion between tubes and between the tube bundle and the shell. This unit is 65' long and 4'4" in diameter with a dry weight of 115 tons. It is a 2¼ chrome-1 moly steel material construction with 757 tubes per module. These units are interchangeable as a superheater or as an evaporator. There are two evaporator modules and one super heater module per heat transport loop. The rating for the super heater is 92 MW thermal while the rating for the evaporator is 116½ WM thermal. The preproduction tube sheet forging which is being used to develop machining methods is shown on Figure 15. The shroud is shown on Figure 16. The prototype steam generator is presently approximately 30% complete.

The CRBRP primary pump represents a simplification from the design of the pump for the FFTF. In particular, providing the stand pipe bubbler arrangement has allowed the shaft of the pump to be shortened considerably, thereby alleviating design problems and permitting better extrapolability for large plants. The primary pump is shown in Figure 17 and is being fabricated by Byron Jackson, Division of Borg Warner Corporation. The pump weighs approximately 82 tons and is 24' high, 8' in diameter, constructed of 304 and 316 stainless steel. The flow rate is 33,700 gallons per minute at 458' sodium head for the primary pump. The primary and intermediate pumps are of identical design. The sodium pump hydraulic model has been completed and tested verifying design parameters. A second assembly representing design changes required to accommodate thermal transient changes is nearly complete. The procurement of materials for the prototype pump is well underway.

In addition to the components specifically discussed above, fabrication has commenced on the others listed in Table I and progressed significantly on tanks and guard vessels which would be shipped this calendar year.

Further, the Project had made significant progress in the licensing arena. In February of 1977, the NRC issued the Final Environmental Statement (FES). In March, the Site Suitability Report (SSR) was issued by the NRC. The basic conclusions reached by the NRC in these two documents were that the CRBRP could be built on the Clinch River Site and operated to meet all safety and environmental requirements. Further, the environmental hearings schedule had been issued by the Atomic Safety and Licensing Board. These hearings would have provided the open public forum for airing the issues related to the CRBRP. Finally, the Project and NRC had supplied tremendous quantities of information to the intervenors in response to discovery requests. The documentation prepared by the Project for these Licensing efforts is estimated to exceed 50,000 pages.

Achievements in Meeting CRBRP Objectives

The CRBRP (975 MWt) provides the intermediate step between test reactors (e.g. FFTF -400 MWt) and prototype commercial reactors ($\sim$2400 MWt). The CRBRP components are two and one-half to three times larger capacity than those of the FFTF. Present designs indicate that components for the prototype large breeder reactor are approximately three times larger than those of the CRBRP. This technology scale-up of approximately a factor of three was successfully employed in the development of the Light Water Reactor. Further, the design conditions for the CRBRP are at least as stringent as those projected for the prototype commercial reactors. The design and fabrication techniques developed for the CRBRP will provide the basis for design of the commercial plant. (For example, the development of high temperature design criteria and analytical techniques provides the basis for design and evaluation of the large plant even if the outlet temperature is lower than that for the CRBRP.) The design of the CRBRP components has included consideration of their extrapolability to considerably larger sizes. (For example, the intermediate heat exchanger (IHX) design was modified from that of the FFTF to provide capability for later extrapolation to commercial size and to reduce the fabrication costs of the CRBRP.) Therefore, the CRBRP has served both the extrapolability function and the component simplification cost reduction function during the design process. Following successful operation of the components in the plant system, the CRBRP will have demonstrated the capability of the components themselves and the strong potential for successful extrapolation to commercial sizes with relatively low risk.

The CRBRP is developing the industrial equipment and manufacturing base necessary to support a commercial industry. It is anticipated that approximately 300 manufacturers from more than 35 states will supply equipment to the Project with more than 10,000 employees involved in the design and fabrication of this equipment. As detailed above, many of these manufacturers are deeply involved in the fabrication of key components now. The progress to date shows that the objective of building a manufacturing base is being met.

By virtue of the NRC issuance of favorable FES and SSR, the CRBRP has partially met the goal of demonstrating that the LMFBR is fully capable of meeting safety, licensing and environmental requirements. If the licensing process were resumed, many of the generic LMFBR environmental and safety issues would be treated in an open public forum as part of the CRBRP licensing. This should provide for early public participation and awareness of the advantages and disadvantages of the LMFBR and prevent later delays in licensing due to lack of public awareness of the issues.

Confirmation that performance objectives would be met can only be completed with operation of the plant. However, the data from development programs supporting CRBRP (e.g., fuel performance, thermal hydraulic behavior in fuel and plena, control rod performance, steam generator fabrication techniques) have already shown that component performance will meet objectives.

The potential for favorable economics would be fully established following operation. Even at this stage, the CRBRP has made significant progress. The Project has been able to negotiate and maintain fixed price contracts for many of the major contracts. Further, the fabrication schedule milestones have been met or exceeded for certain major components. This is the basis for confident assertion that LMFBR component fabrication costs will be predictable and subject to control to initial estimates.

Conclusions

The Clinch River Breeder Reactor Plant plays a vital role in the development of an LMFBR industry by demonstrating the technical performance, reliability, maintainability, safety, environmental acceptability and economic feasibility of an LMFBR central station power plant in a utility environment and confirms the value of the LMFBR in conserving natural resources. Activities already completed on the CRBRP Project have supported the attainment of these objectives in fulfilling the role of the CRBRP. In particular, the licensing interactions with the NRC leading to the issuance of a favorable or environmental acceptability (FES), the development of an industrial base of qualified component suppliers, and the completion of system and component designs, have all shown the ability of the CRBRP to meet its objectives. The most striking achievements on the CRBRP to date have been the completion of component designs and the considerable progress in component fabrication. Many of the major components are 50% or more through the fabrication process. The capability of the Project to maintain cost and schedule in these component procurements has been a major achievement and provides a solid basis for establishing the commercial viability of the LMFBR.

Table I. CRBRP Major Component Fabrication Summary

COMPONENT	TOTAL VALUE $ IN MILLIONS	PERCENT COMPLETE 12/31/77
• REACTOR VESSEL	28.2	55
• CORE SUPPORT STRUCTURE	3.6	96
• REACTOR VESSEL HEAD	10.4	40
• INTERMEDIATE HEAT EXCHANGER	36.5	66
• STEAM GENERATOR	67.9	33
• PUMPS	45.4	24
• PUMP DRIVE SYSTEM	17.3	13
• COLD LEG CHECK VALVE	4.9	80
• REACTOR GUARD VESSEL	3.3	53
• IHX GUARD VESSEL	3.0	62
• PUMP GUARD VESSEL	3.0	54
• EX-VESSEL STORAGE TANK	20.3	30
• EX-VESSEL TRANSFER MACHINE	7.4	4*
• IN-VESSEL TRANSFER MACHINE		
- PROTOTYPE/PLANT	2.4	42
- SPARE (IN-VESSEL SECTION)	1.0	–
• OVERFLOW TANK	2.1	38
• IN-CONTAINMENT/ EX-CONTAINMENT STORAGE TANKS	.9	55
• SODIUM DUMP TANKS	3.3	68
• SMALL SODIUM VALVES	3.9	20
• TURBINE GENERATOR	19.1	24
• PROTECTED WATER STORAGE TANK	.02	50
• OTHER	107.4	–
TOTAL	$ 391.5M	

*LONG LEAD MATERIALS

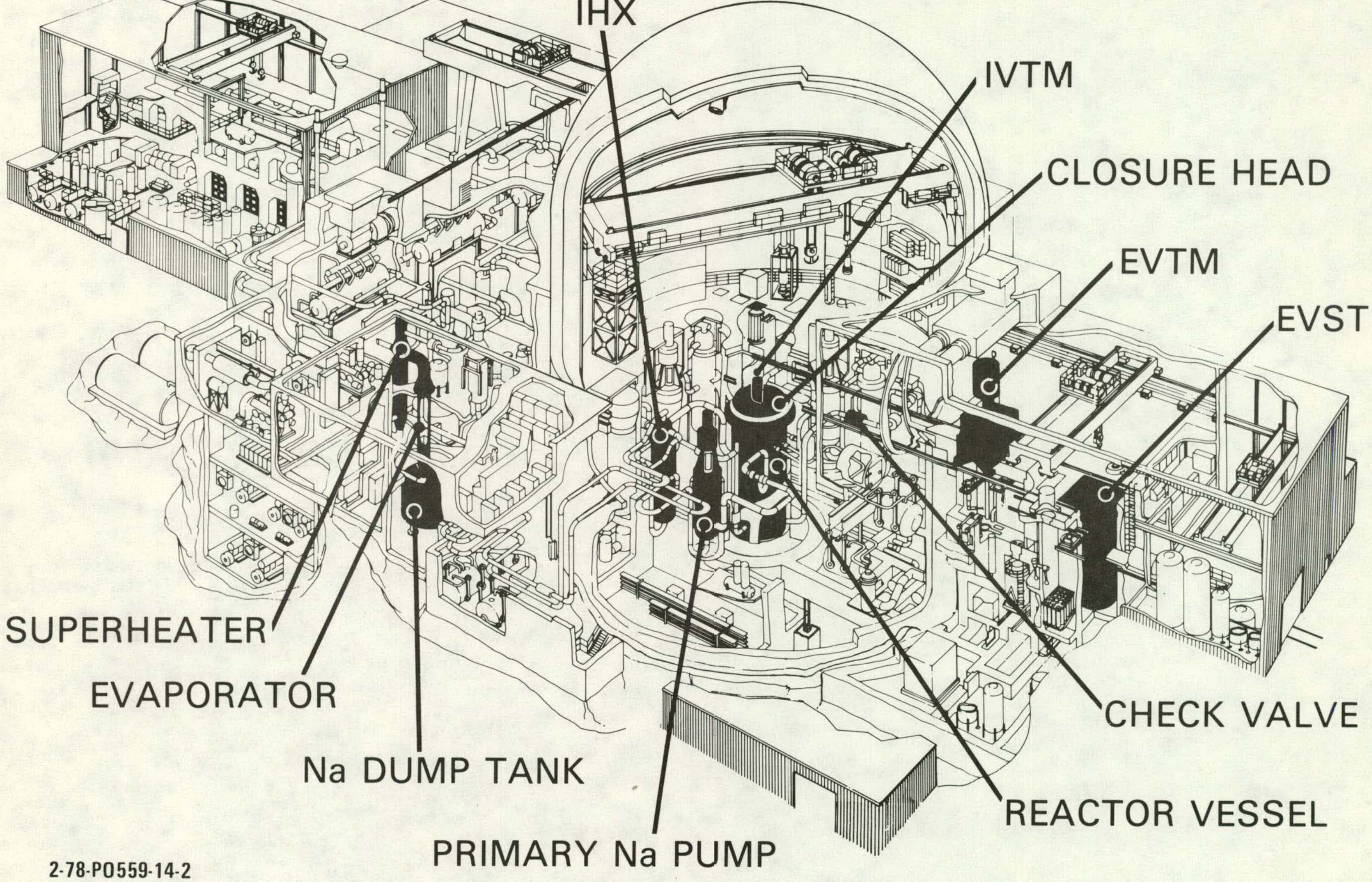

Figure 1. CRBRP Cutaway

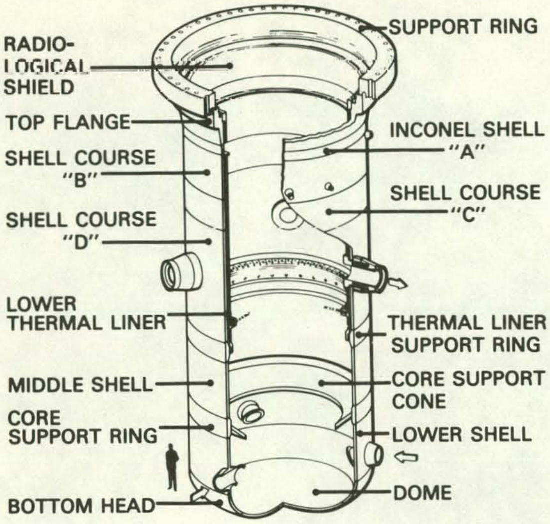

Figure 2. CRBRP Reactor Vessel

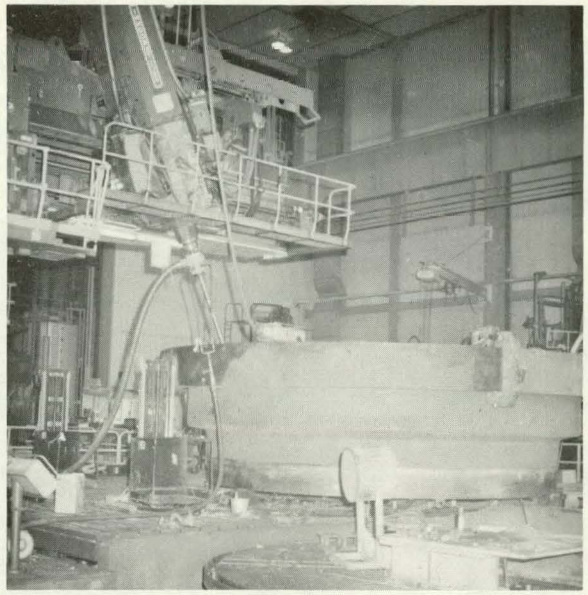

Figure 3. Reactor Vessel Support Ring

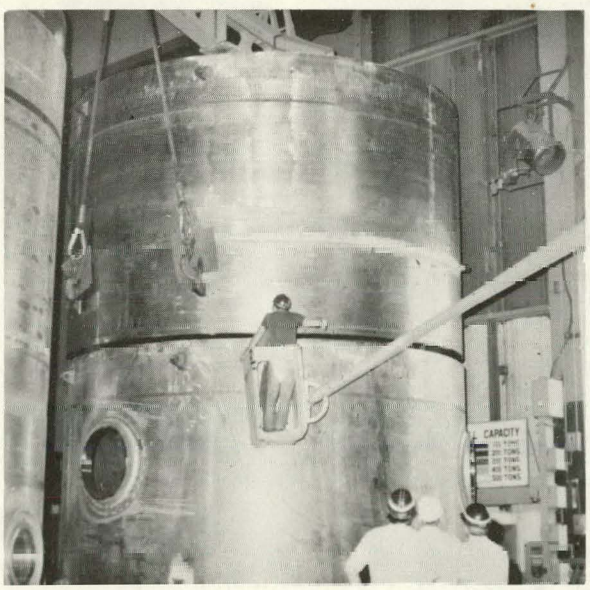

Figure 4. Reactor Vessel Shell Course

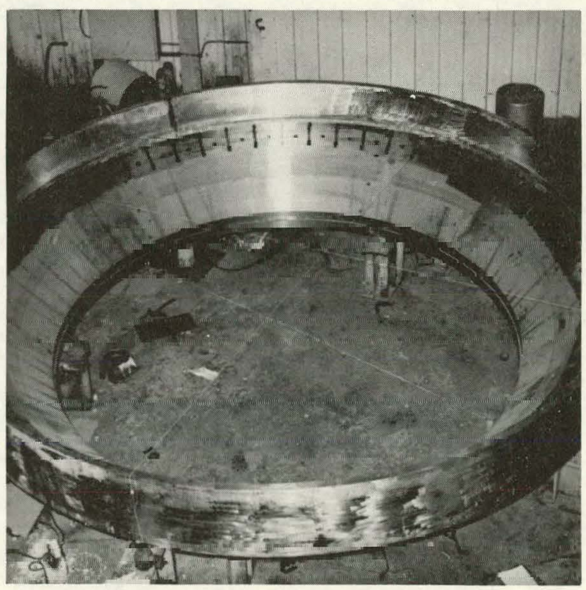

Figure 5. Reactor Vessel Core Support Cone & Ring

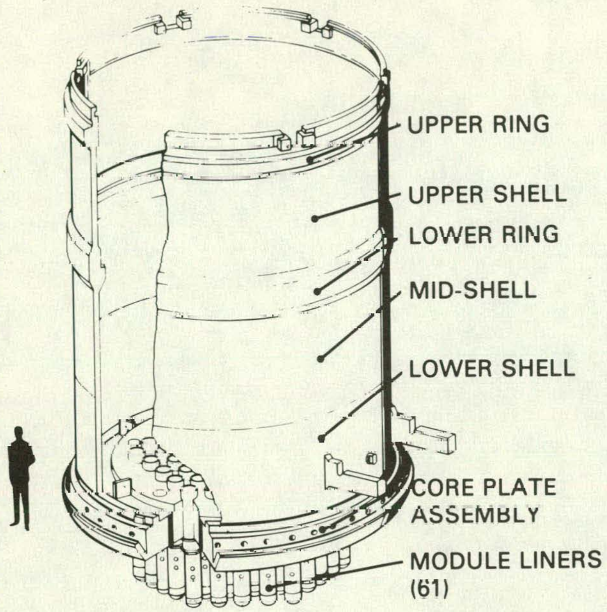

Figure 6. CRBRP Core Support Structure

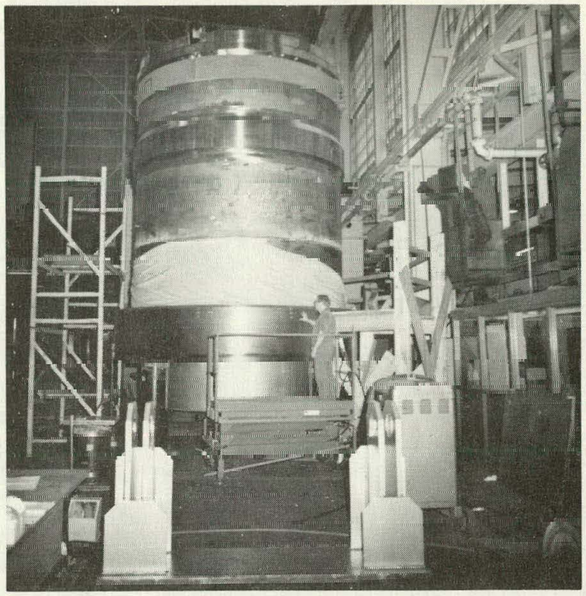

Figure 7. Core Support Structure Assembly

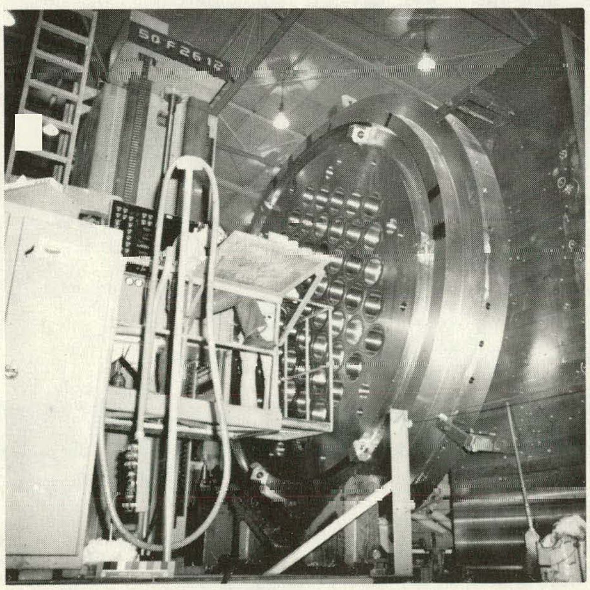

Figure 8. Core Plate Assembly

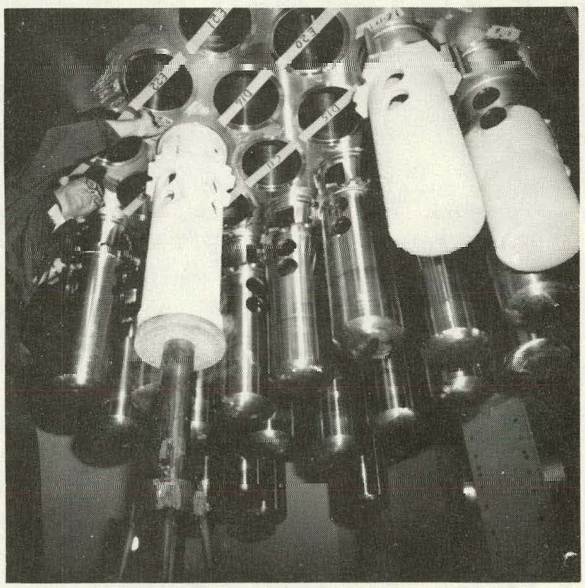

Figure 9. Core Plate and Module Liners

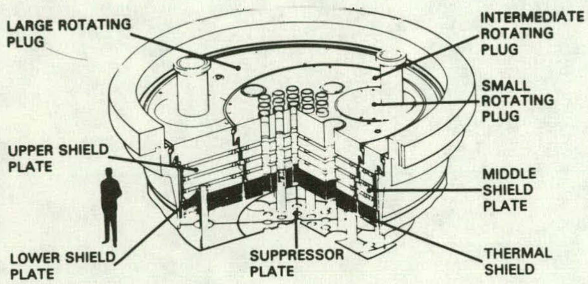

Figure 10. CRBRP Closure Head

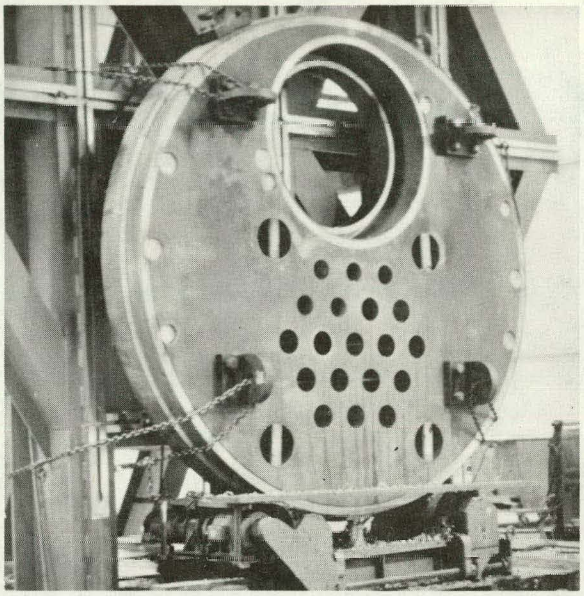

Figure 11. Intermediate Rotating Plug

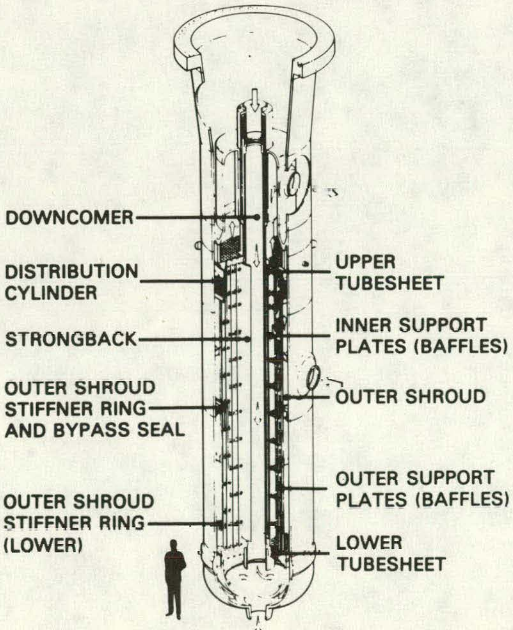

Figure 12. CRBRP Intermediate Heat Exchanger

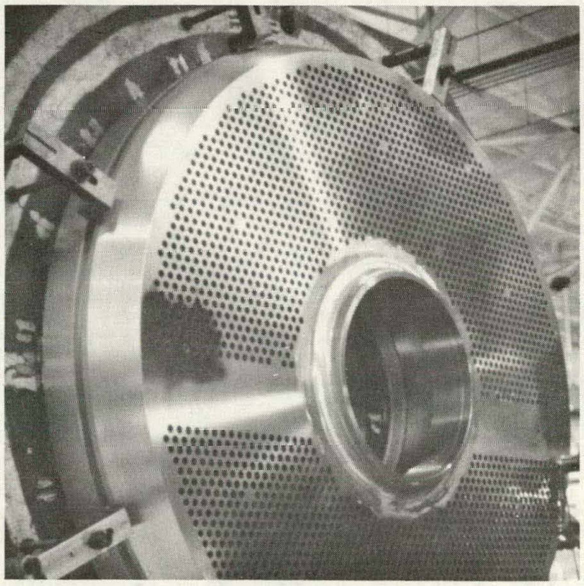

Figure 13. IHX Lower Tube Sheet

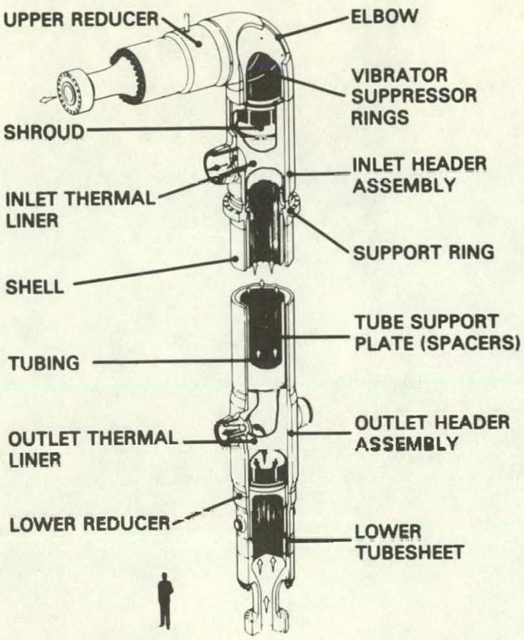

Figure 14. CRBRP Steam Generator

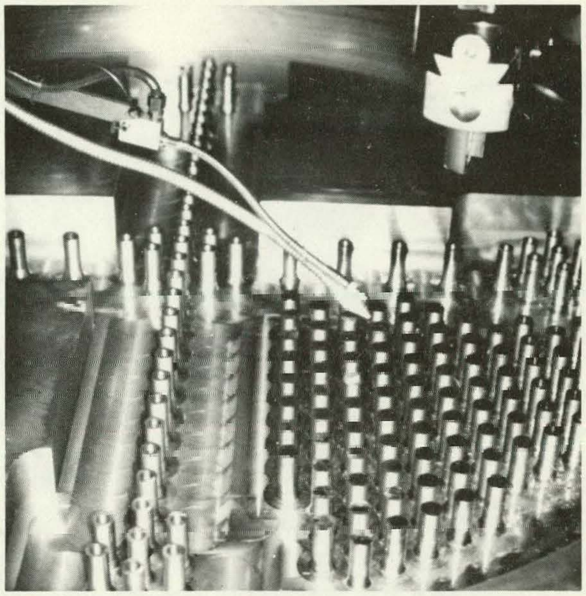

Figure 15. Steam Generator Tube Sheet

Figure 16. Steam Generator Shroud

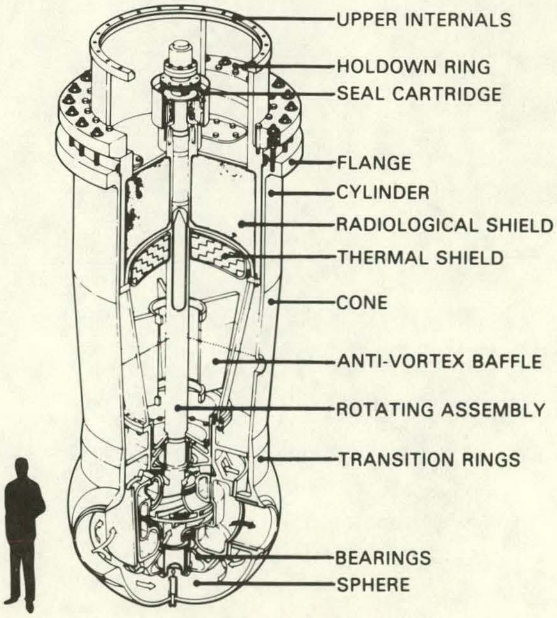

Figure 17. CRBRP Primary Pump