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# Clinch River Breeder Reactor Plant Project

# Summary Edition 1980 Technical Progress Report

**(October 1979 Through September 1980)**

EMOWEX

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## THE CRBRP PROJECT

This is the first annual report in the decade of the 1980's on the technical progress of the Clinch River Breeder Reactor Plant (CRBRP) Project. The United States could have an operating breeder reactor before the end of this decade, as the Project's work is directed toward achievement of plant criticality in September 1988. Upon full operation, 375 megawatts of electrical power—sufficient for the domestic needs of 200,000 people—will flow from this demonstration plant over the Tennessee Valley Authority distribution system.

Even more important, operation of the plant will demonstrate economic conversion of uranium-238 into reactor fuel. Uranium-238 is a by-product of the enrichment process used to prepare fuel for conventional (light-water) nuclear power plants. It has been accumulating at the enrichment facilities of the U.S. Department of Energy since the end of World War II. It is estimated that this fuel source, if used in breeder plants, could satisfy all of the United States' electricity needs for centuries to come.

The CRBRP, as it is to appear when completed, is shown in Figure 1. It is to be located on a 100-acre portion of a 1364-acre site in Oak Ridge, Tennessee.

The CRBRP Project is a partnership venture of government, industry, and electric utility companies in the United States. The 753 participating utilities are contributing $257 million to the Project.

Plant design was approximately 75 percent complete at the end of this report period, and research and development related to the Project were approximately 90 percent complete. The cost of plant equipment completed and on order totaled $530 million, of which $118.1 million worth of major components had been completed and were in storage (Table 1).

The CRBRP construction site is not developed as a storage location, so several locations are being used for interim storage as shown in Table 1. The size and weight of some components make it uneconomical to move them to interim storage locations; those components are stored on the vendor's property and will be moved to the construction site when needed.

The plant design incorporates the most advanced technology available worldwide. It has been updated by the latest technical improvements and scientific advances, including lessons learned from the Three Mile Island incident, so as to keep it at the forefront of fast breeder reactor development. The design has benefited from foreign fast breeder experience, but it also includes advanced features not yet achieved in foreign designs. A prime example is the heterogeneous core configuration, which improves the "breeding" capability of the reactor (the ratio of fuel produced to fuel consumed). Another example is application of advanced high-temperature design techniques for the sodium systems. Moreover, alternate fuel cycles have been examined to permit the CRBRP to serve as a test bed for advanced fuel designs for future plants in the nation's on-going LMFBR programs.

More than 4100 persons in 24 states and the District of Columbia are employed in the Project. Peak construction manpower at Oak Ridge is expected to be 3050 workers. Total Project expenditures were $932 million at the end of this report period, and the total plant cost estimate was $2.886 billion (year-of-expenditure dollars).

This technical progress report on the CRBRP Project describes the objectives, design decisions, and major accomplishments achieved in the planning, organizing, design, and execution of the Project during the period October 1, 1979, through September 30, 1980. It is a summary of the 1980 CRBRP Technical Progress Report, which was prepared by the Advanced Reactors Division of Westinghouse Electric Corporation, the Lead Reactor Manufacturer for the Clinch River Breeder Reactor Plant Project, in fulfillment of contract requirements with the United States Department of Energy. It includes inputs from the CRBRP Architect-Engineer (Burns and Roe, Inc.), from the Constructor (Stone & Webster Engineering Corporation), and from the supporting Reactor Manufacturers (Atomics International Division of the Energy Systems Group of Rockwell International Corporation, the Advanced Reactor Systems Department of General Electric Company, and the Advanced Reactors Division of Westinghouse Electric Corporation).

## PRIOR WORK

Project management requirements and scopes of responsibility were defined in 1973. In 1974, major plant system concepts were selected, a reference plant design was established and documented, and major system design descriptions and key equipment specifications were completed. Orders were placed for critical long-lead materials starting in 1975, and quotes were requested on major plant components. An integrated Project Office was established at Oak Ridge, Tennessee, in 1975.

The Environmental Report was submitted to the Nuclear Regulatory Commission (NRC) in 1974 and docketed in 1975. The Preliminary Safety Analysis Report was submitted and docketed in 1975. There was much interchange with the NRC before the environmental hearings process was suspended in April 1977, after NRC's publication

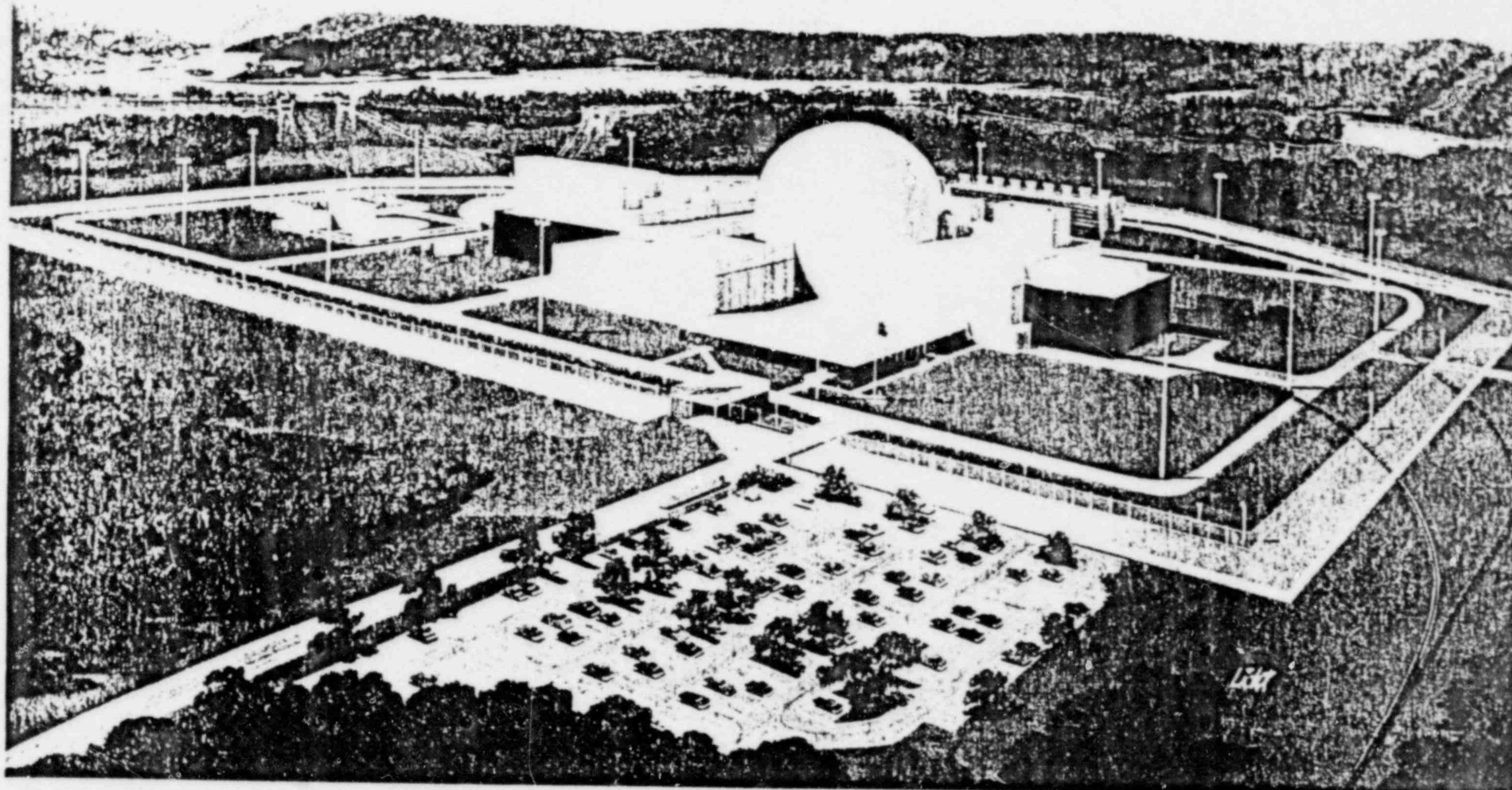

Figure 1. Artist's Concept of the Clinch River Breeder Reactor Plant, Looking East.

TABLE 1. MAJOR COMPONENT DELIVERIES THROUGH SEPTEMBER 1980

| Component | Delivery Date | Approximate Cost[1] ($ Million) | Storage Location |
|---|---|---|---|
| Cold-Leg Check Valves (3 of 3) | 11/78 | 5.0 | Oak Ridge, Tennessee |
| Prototype Sodium Pump Drive System | 12/78 | 2.9 | Vernon, California |
| Secondary Control Rod System Prototype (1 of 4) | 12/78 | 3.0 | San Jose, California |
| Intermediate Heat Exchanger Guard Vessels (3 of 3) | 1/79 | 3.3 | Memphis, Tennessee |
| Reactor Guard Vessel | 1/79 | 3.7 | Memphis, Tennessee |
| Sodium Pump Guard Vessels (3 of 3) | 2/79 | 3.7 | Memphis, Tennessee |
| In-Vessel Transfer Machine Prototype and Control System | 5/79 | 3.0 | Santa Susana, California |
| Reactor Closure Head Plug Drive and Control System | 5/79 | 1.2 | Memphis, Tennessee |
| Primary Sodium Overflow Vessel | 10/79 | 2.2 | Memphis, Tennessee |
| Reactor Vessel (Including Core Support Structure) | 12/79 | 27.7 | Mt. Vernon, Indiana |
| Sodium Dump Tanks (3 of 3) | 1/80 | 3.2 | Memphis, Tennessee |
| Reactor Closure Head Bull Gear and Bearing Assemblies (3 of 3) | 4/80 | 1.0 | Memphis, Tennessee |
| Ex-Vessel Storage Tank Guard Vessel | 5/80 | 1.9 | Memphis, Tennessee |
| Reactor Closure Head Risers, Welded and Bolted (1 Set of 3) | 5/80 | 2.8 | Memphis, Tennessee |
| Deaerator | 5/80 | 0.3 | Oak Ridge, Tennessee |
| Ex-Vessel Storage Tank Bull Gear and Bearing Assembly | 5/80 | 1.0 | Yokohama, Japan |
| Secondary Control Rod System Prototype (2 of 4) | 7/80 | 3.1 | San Jose, California |
| Condensate Pumps (3 of 3) | 7/80 | 0.3 | Oak Ridge, Tennessee |
| Sodium Pump Drive Components | 9/80 | 10.7 | Oak Ridge, Tennessee |
| Intermediate Heat Exchangers (3 of 3)[2] | 9/80 | 38.1 | Oak Ridge, Tennessee |
| Estimated Total Cost of Components Listed | | 118.5 | |

[1] These approximate costs vary somewhat from values shown elsewhere because they are rounded off and also because they include, in addition to manufacturing costs, the charges for preparation for storage and shipping to storage.

[2] The third intermediate heat exchanger was received just after the close of this report period (in October 1980).

of a favorable Final Environmental Statement and Site Suitability Report in February and March 1977. All prerequisites for commencement of public hearings had been completed, and a date had been set for the hearings when the National Energy Plan of April 1977 called for cancellation of the Project in the interest of retarding breeder development and reprocessing of spent light-water-reactor fuel worldwide. The Project was continued thereafter with the limitation that the design of the plant and the fabrication of hardware already on order would continue, but direct pursuit of the construction permit was suspended during the national policy debate about the future of the Project. The Project continued to update its licensing documents, submit new information to the NRC, and develop information for use in resolution of licensing questions but without direct interchange with the NRC.

Site geology surveys were completed in 1977.

Fabrication of the prototype steam generator and many plant components was undertaken in 1976. The three cold-leg check valves, and electronic signal conditioning equipment for the reactor upper internals structure, were completed and stored in 1978. The prototype sodium pump drive system was tested and delivered to the pump vendor in 1978 for pump testing.

Much of the basic design and documentation had been completed and refined by 1979, and analysis and testing methods were improved and applied to many components. Design and analysis effort was applied in 1979 to the heterogeneous reactor core design—an arrangement of fuel and blanket assemblies that improves the breeding ratio, reduces peak neutron flux levels, and reduces the number of fuel and control assemblies required as compared with the original homogeneous core design.

The guard vessels for the reactor, intermediate heat exchangers, and primary sodium pumps were completed and shipped to storage in 1979. The major components of the prototype sodium pump were completed in 1979, a water test facility for the pump was completed, and preparations for the water test were being made.

The primary sodium overflow vessel was completed in 1979. The in-vessel transfer machine for the Reactor Refueling System also was completed; dry testing of the machine was completed, and wet (sodium) testing was begun. The refueling computer was completed and delivered for testing at the Energy Technology Engineering Center in 1979. The plug drive and control system for the reactor closure head was completed and delivered to storage.

All major components of the prototype electromagnetic sodium pump were fabricated and assembled in 1979 except for the throat section. The prototype six-inch liquid-metal check valve was completed and successfully tested with nitrogen. Seven of the eight prototype thermal-transient liquid-metal valves were fabricated and were in testing. All of the one-inch and smaller prototype liquid-metal valves were fabricated and successfully tested with nitrogen.

Final design reviews were conducted for many components in 1979, including the fuel and blanket assemblies, the reactor vessel, the primary control rod drive mechanisms, the bull gear and bearings for the reactor closure head, and the horizontal baffle assembly for the reactor vessel. Research and development proceeded with testing of the primary and secondary control rod drive systems, qualification testing of the in-vessel transfer machine, water testing of a radial blanket assembly model, mechanical properties testing of cell liner materials, concrete testing in the high-temperature range, and evaluation of data from critical experiments conducted in the Zero-Power Plutonium Reactor.

## ACCOMPLISHMENTS

*Component Fabrication, Testing, and Delivery* — During this report period, fabrication and shipment of components continued. The reactor vessel, for example, (the major component of the reactor coolant system) was completed at a cost of $27.7 million, which includes the core support structure (Figure 2). All major components of the reactor vessel closure head were fabricated, and the assembly of the head was well along in preparation for testing.

All fabrication of the plant-unit primary control rod drive mechanisms and primary control rod drivelines was completed, and acceptance testing was begun. Development and reliability testing showed the primary control rod system to be a highly reliable reactor shutdown system.

Testing of a prototype of the secondary control rod drive system demonstrated design adequacy and led to improvements in materials, fabrication methods, and maintenance capabilities. Those improvements were incorporated into the second prototype, and testing was begun (Figure 3).

Many components of the Reactor Refueling System either were completed or were in fabrication. Testing of the in-vessel transfer machine in a sodium environment demonstrated reliability of operation (Figure 4). The ex-vessel storage tank guard vessel was completed (Figure 5). Validation tests of software for the refueling control system were performed successfully.

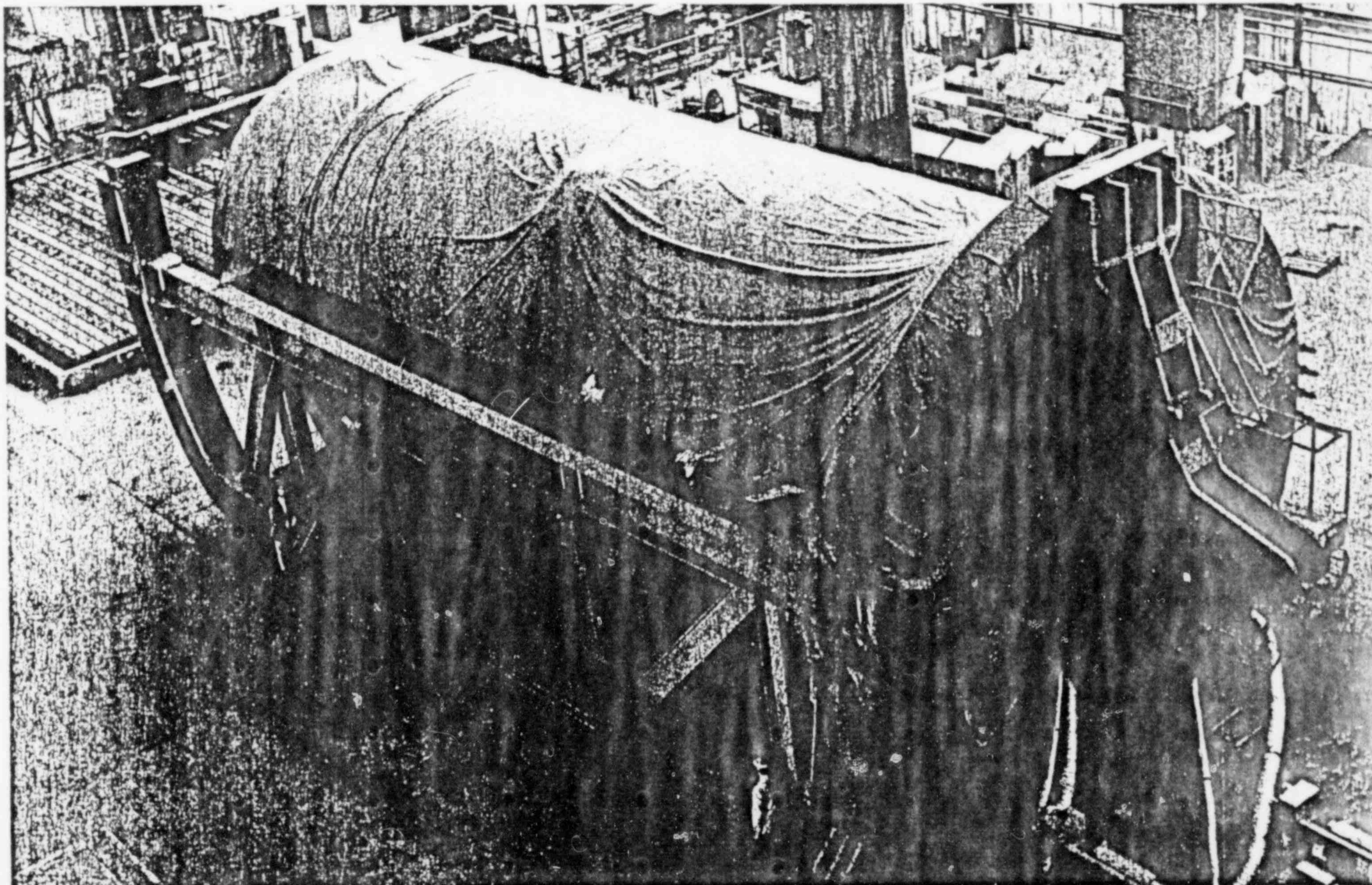

Figure 2. Reactor Vessel in Storage in the J-Frame That Will Be Used for Transporting and Erecting It.

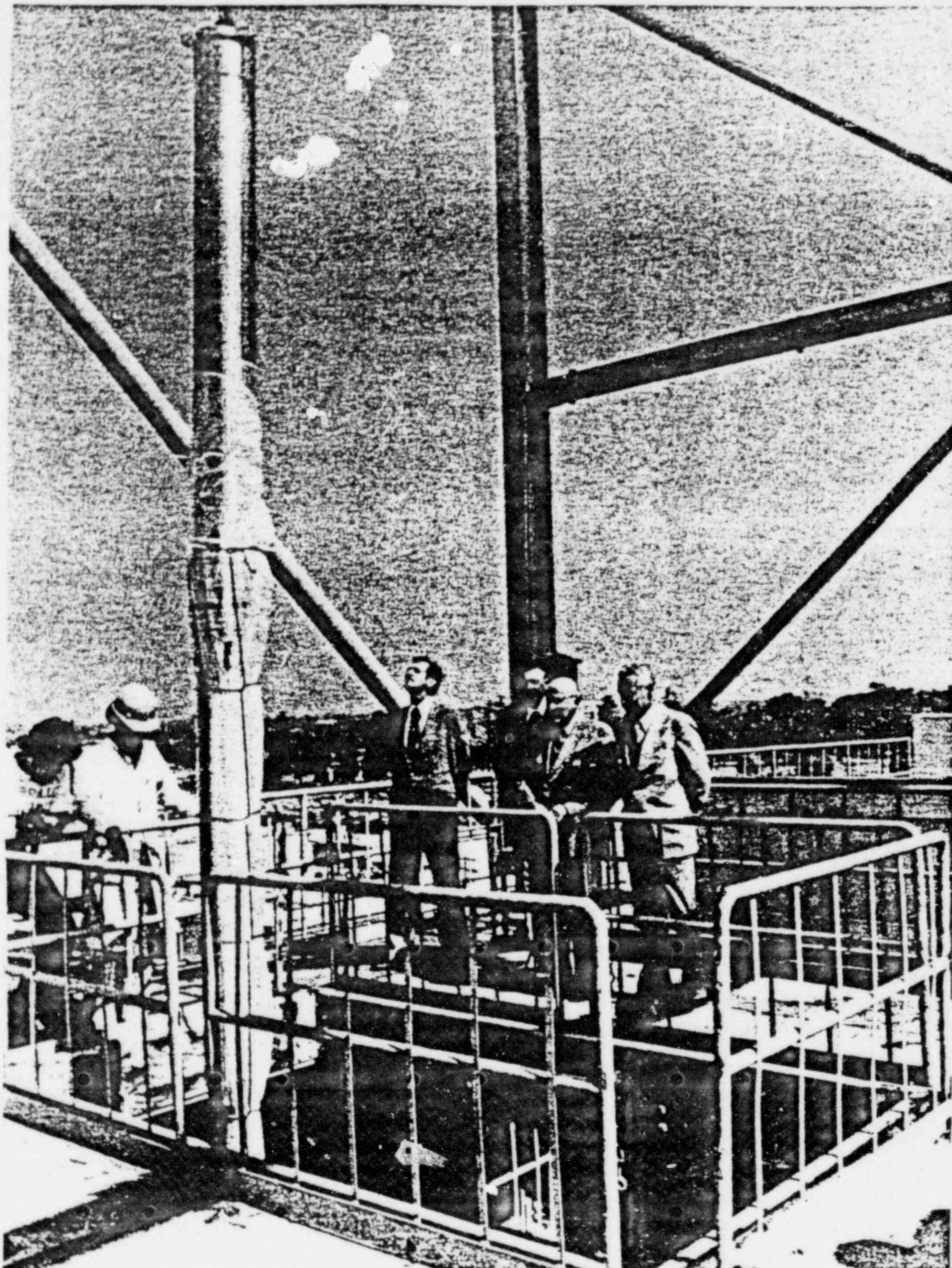

Figure 3. Second Prototype of the Secondary Control Rod Drive System Being Installed in Sodium Test Loop.

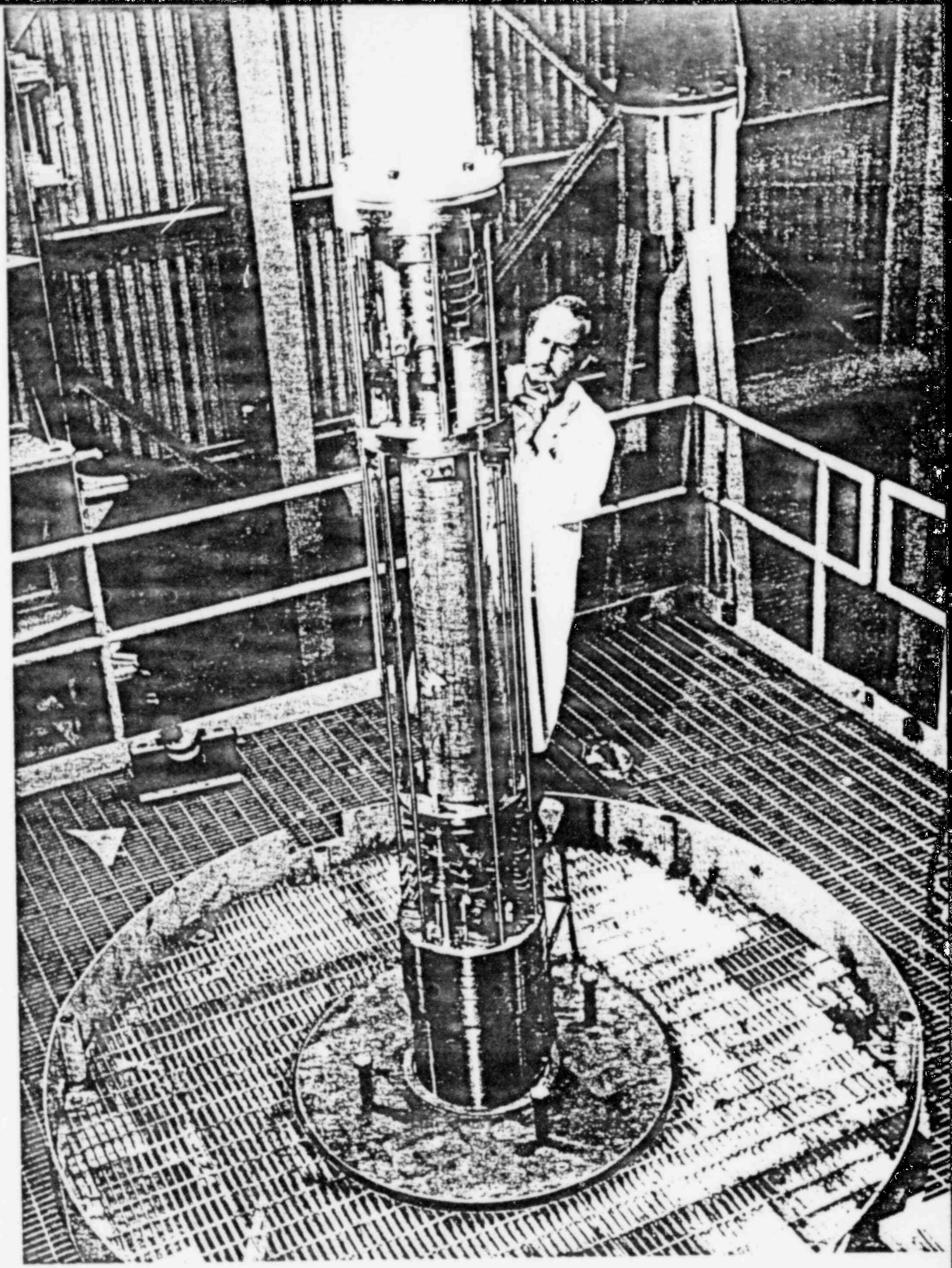

Figure 4. In-Vessel Transfer Machine of the Reactor Refueling System Being Prepared for Sodium Testing.

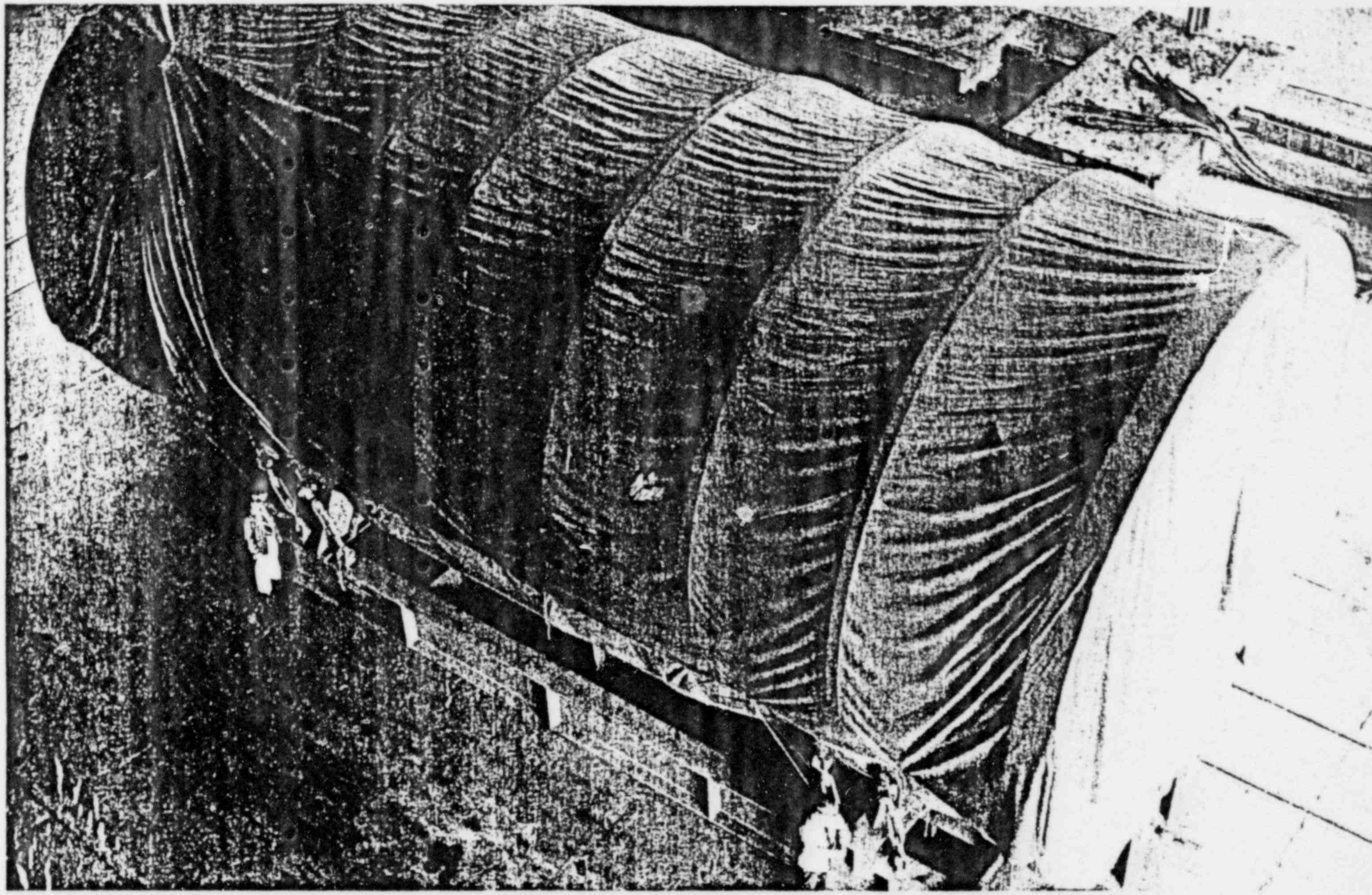

Figure 5. Ex-Vessel Storage Tank Guard Vessel for the Reactor Refueling System.

Components of the prototype primary system sodium pump were completed, and the pump was assembled (Figure 6). The pump with its drive motor attached was installed in a test facility, and water testing was begun (Figure 7).

The three intermediate heat exchangers were completed, and two of them were delivered to storage near the plant site (Figure 8). The third was scheduled for delivery soon after the end of the report period.

The tube bundle assembly for the prototype steam generator was completed (Figure 9). Fabrication of other parts of the prototype was in progress.

Prototype and plant subsystems and components of the Plant Protection System were fabricated. Test results were used to improve designs and manufacturing practices (Figures 10 and 11).

Figure 12 shows the plant locations of some of the major components that have been completed.

*Engineering* — Design of the CRBRP containment vessel progressed to within three months of the date for final release for fabrication. This vessel, which encloses the entire Primary Heat Transport System and auxiliaries, is the largest component in the plant. Release for fabrication will be a major milestone for the Project.

Many stress analyses and associated studies for reactor systems components were conducted. Discussions of those activities are included where applicable in the component sections of the 1980 CRBRP Technical Progress Report.

Emphasis was placed on completion of the final fuel and control assembly enrichment specifications. The specifications for cores 1 and 2 were released to the Project Office for review and approval.

Analysis and test efforts were continued to finalize the core restraint system design. Mechanical tests continued in the full-scale Core Restraint Test Facility and with in-reactor experiments at the Experimental Breeder Reactor II. Development of computer codes for the prediction of core restraint performance neared completion.

The characteristics of thermal striping conditions in the core outlet plenum, and the cyclic damage caused by thermal striping on reactor structural components, were investigated by analyses and model tests.

Significant progress was made in the Nuclear Steam Supply System (NSSS) availability program. The purpose of that program is to provide a quantitative assessment of the ability of the NSSS to support electric power production. The assessment will include predictions of the individual system contributions to NSSS availability and to reductions in unavailability due to maintenance, refueling, in-service inspection, and lack of spares.

Tests verified the ability of the cell liner design to withstand a large spill of sodium coolant. Final calculations for the cell liner vent system were completed as well as the preliminary pipe routings and modeling for the system.

The CRBRP model, which depicts the major buildings and their contents, neared completion at the Architect-Engineer's facility (Figure 13). It is used to analyze the spatial effects of new design concepts and engineering changes.

*Key Systems Design Reviews* — A major review of the CRBRP designs was initiated by the Project in April 1979. This effort, known as the Key Systems Design Reviews, was organized into a number of task teams. The task teams were composed of personnel from different disciplines and organizations under the guidance of a senior management Steering Group. They conducted rigorous reviews of the operation, maintenance, and testing outlines of the key systems of the plant. The reviews continued until October 1980. They emphasized the man/machine interfaces, protection of plant equipment, multiple failures and recovery, potential releases of radioactivity, and the protection of plant personnel and public health and safety.

All of the task teams defined potential areas for improvement in the operation of the systems, mainly in the areas of improved man/machine interfaces, improved instrumentation and control capability, system-to-system interface definition, and improved operating procedures. The overall conclusion of the task team efforts was that, with the satisfactory resolution of the task teams' findings, the CRBRP design will meet the design requirements and can be operated without undue risk to the operating staff or to the health and safety of the public.

The efforts of eight of the ten Key Systems Review Task Teams were completed, and final reports of the results were issued. Those reviews covered the following topics:

- Decay Heat Removal,
- Spent Fuel Transport, Storage, and Cooling,
- Sodium/NaK Leaks,
- Thermal Margin Beyond Design Base,
- Control Room,
- Radioactive Waste,
- Liquid-Metal/Water Reactions,
- Containment Isolation.

The Inert Gas Processing and Integrated Cooling Systems reports were to be issued early in 1981.

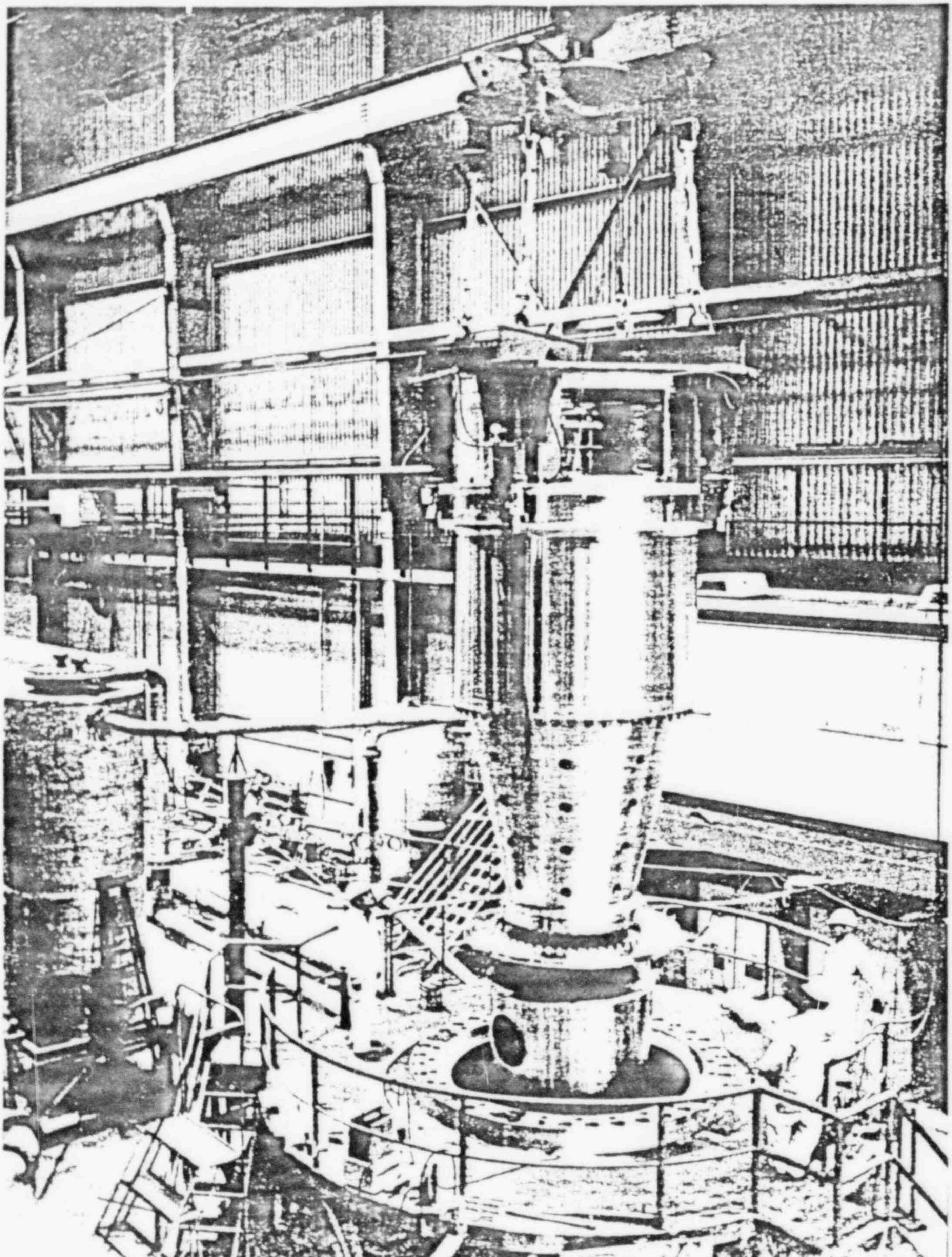

Figure 6. Prototype Primary System Sodium Pump Being Assembled.

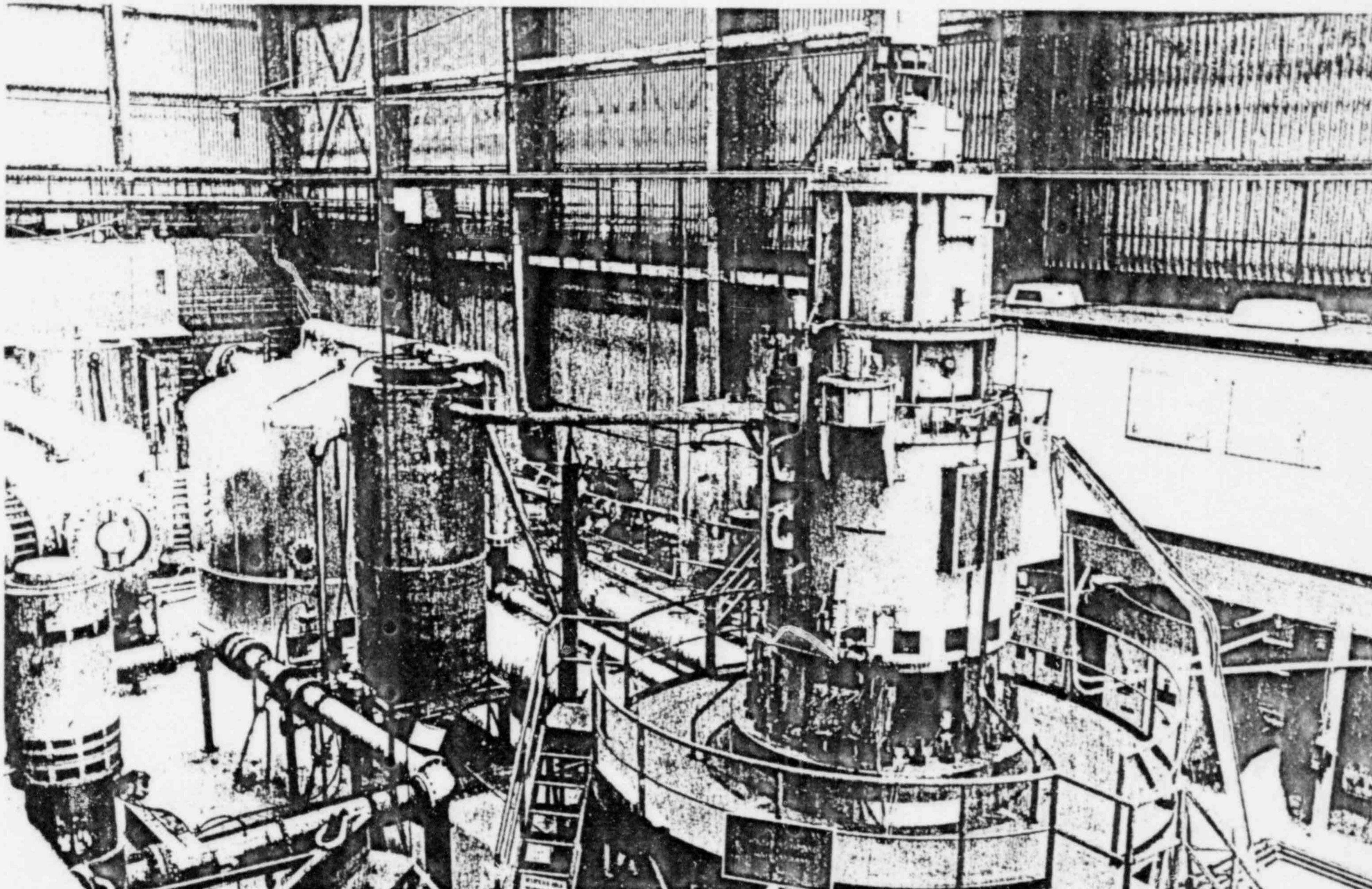

Figure 7. Prototype Primary System Sodium Pump, and Its Drive Motor, Ready for Testing.

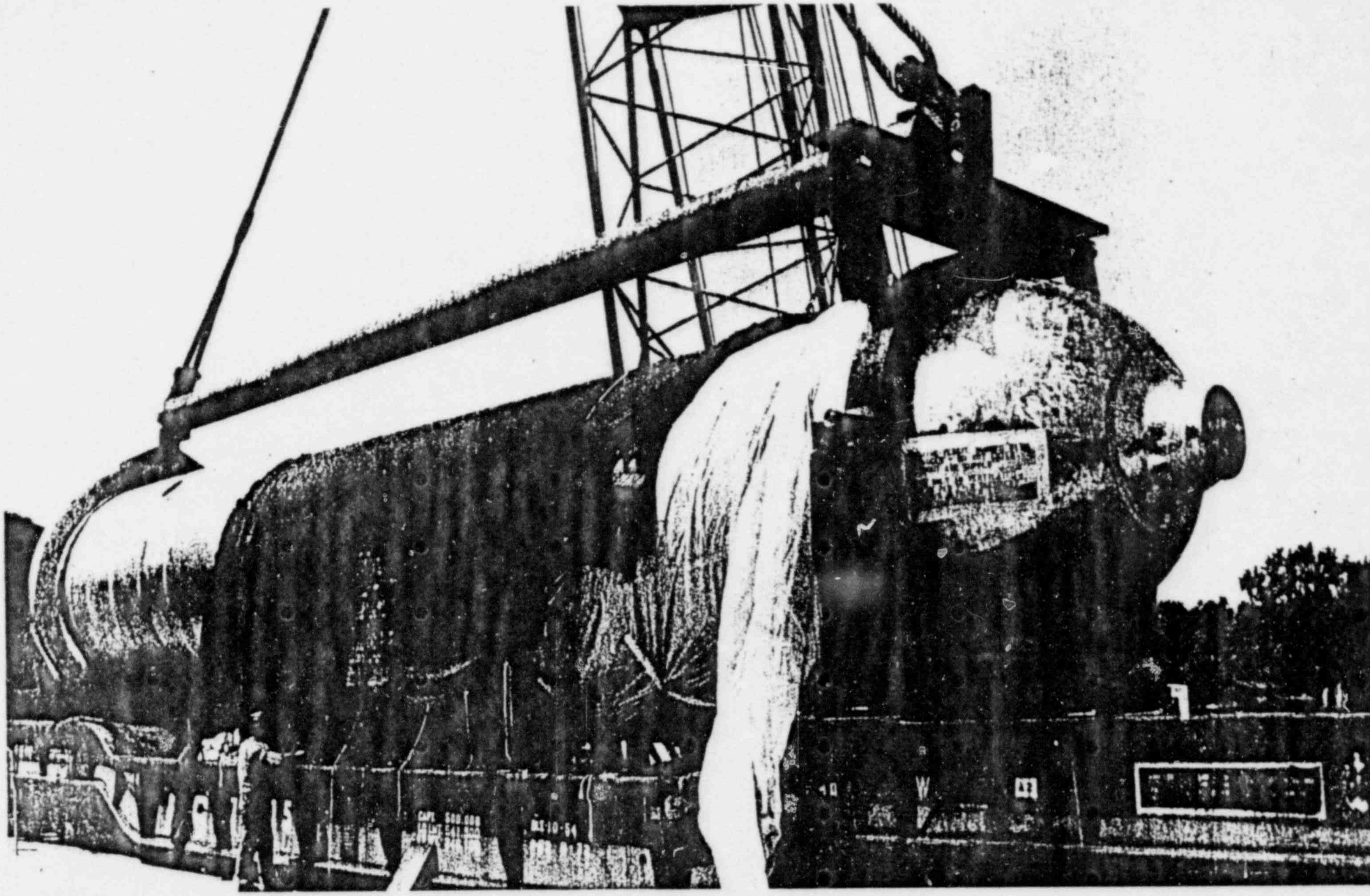

Figure 8. One of the Three Intermediate Heat Exchangers Being Unloaded for Storage.

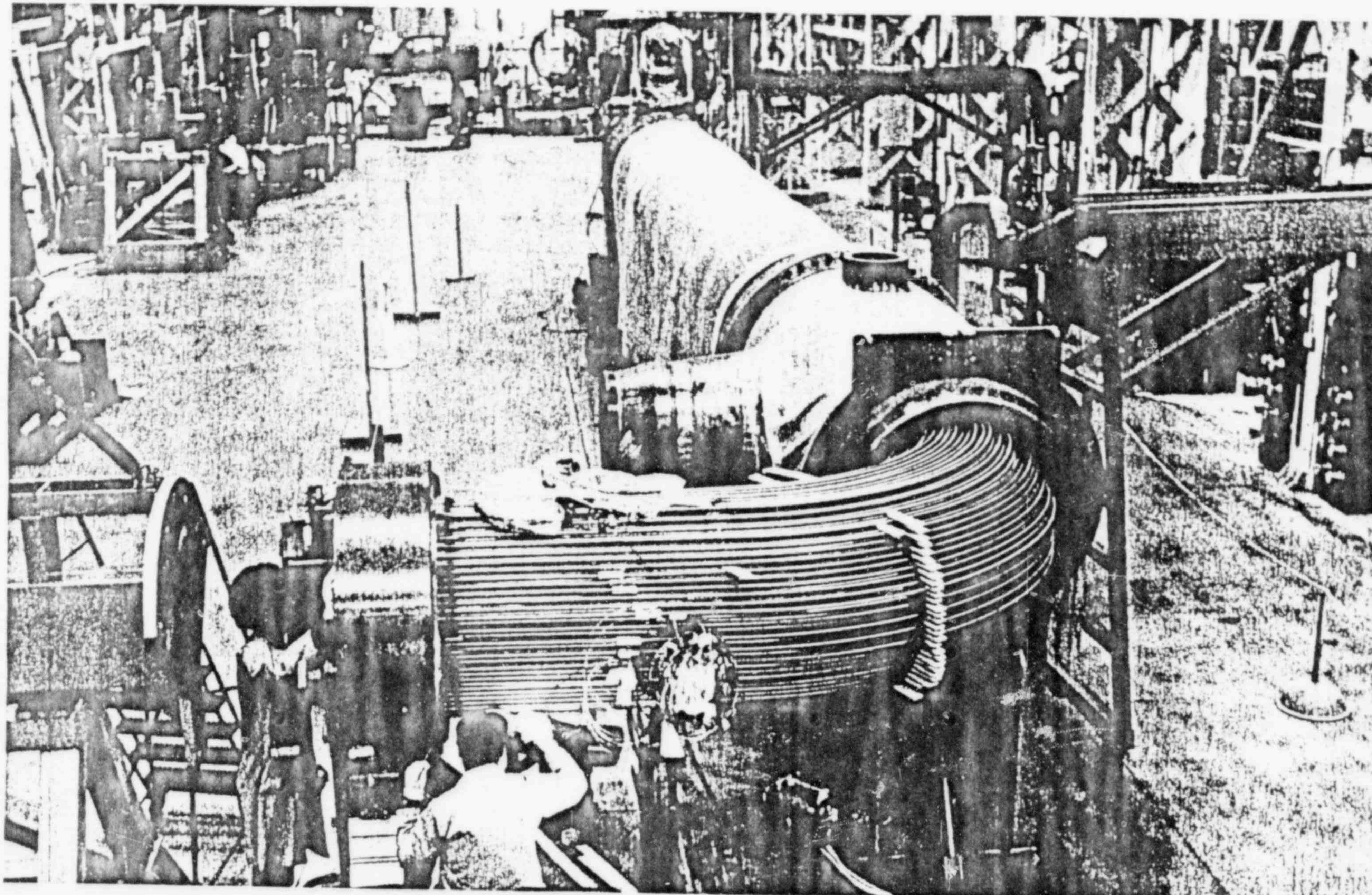

Figure 9. Completing the Tube Bundling Operation for the Prototype Steam Generator.

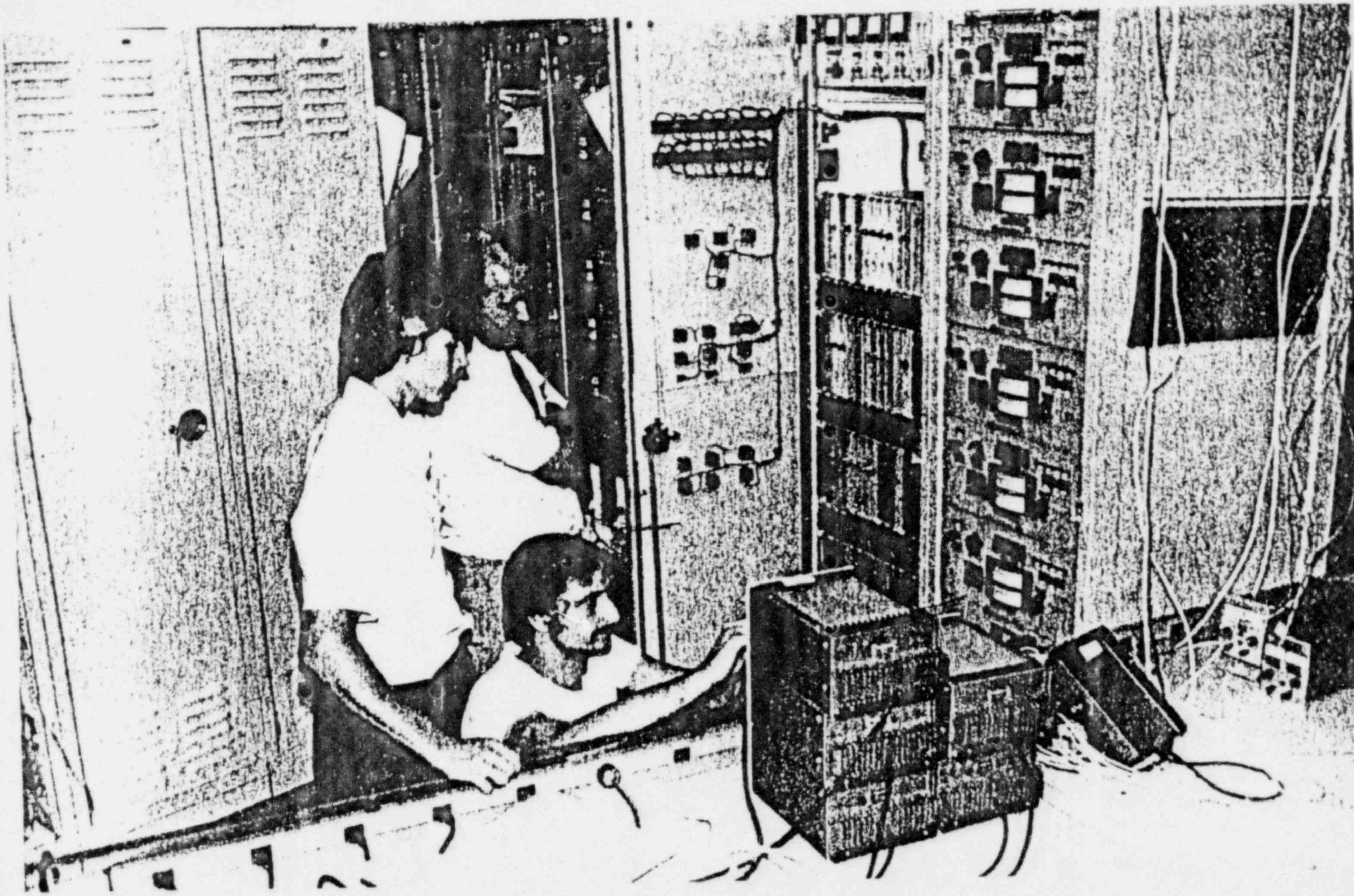

Figure 10. Final Acceptance Tests of the Secondary Reactor Shutdown System of the Plant Protection System.

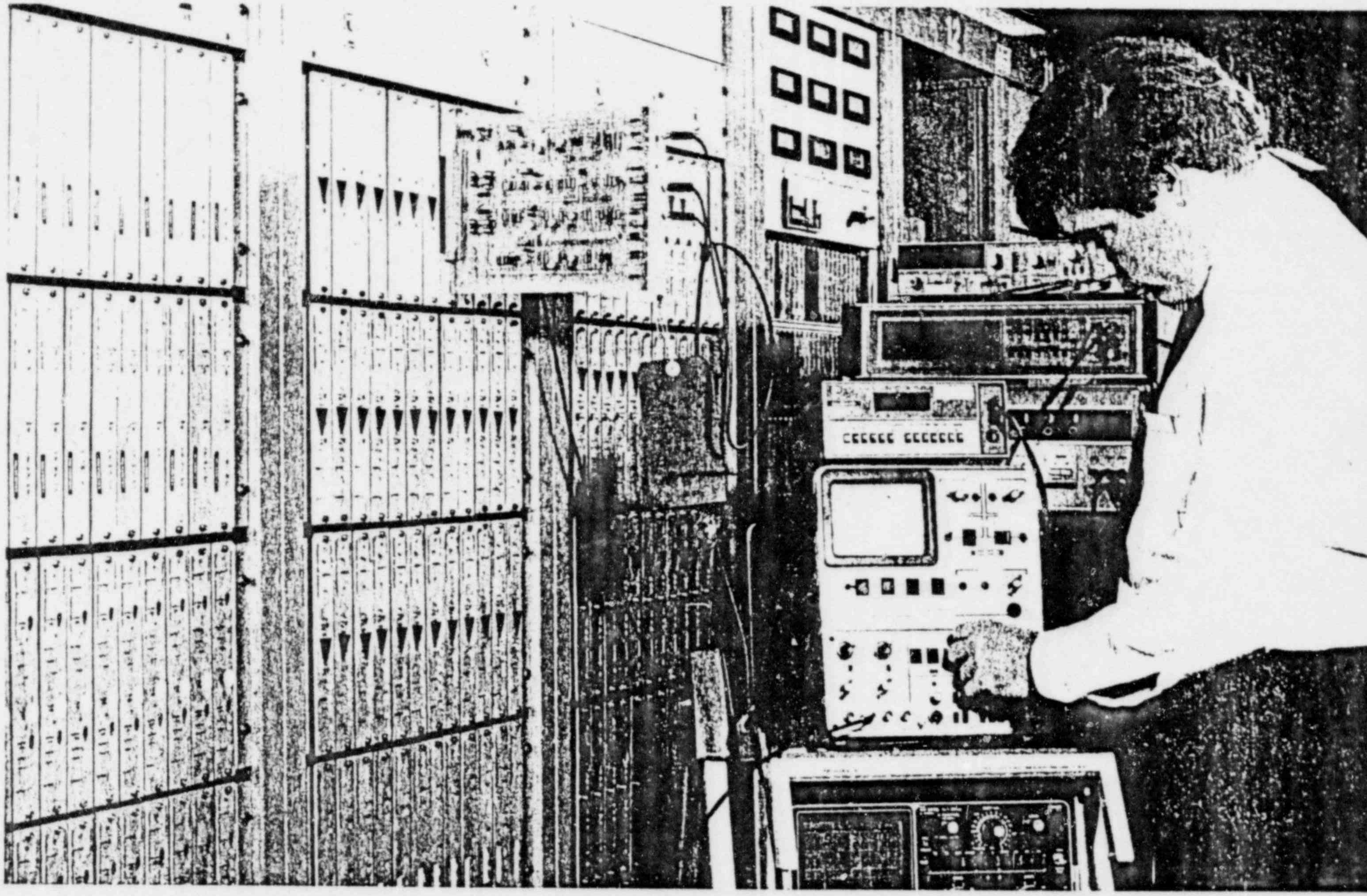

Figure 11. Plant Protection System Components Being Analyzed in the Reliability Test Facility.

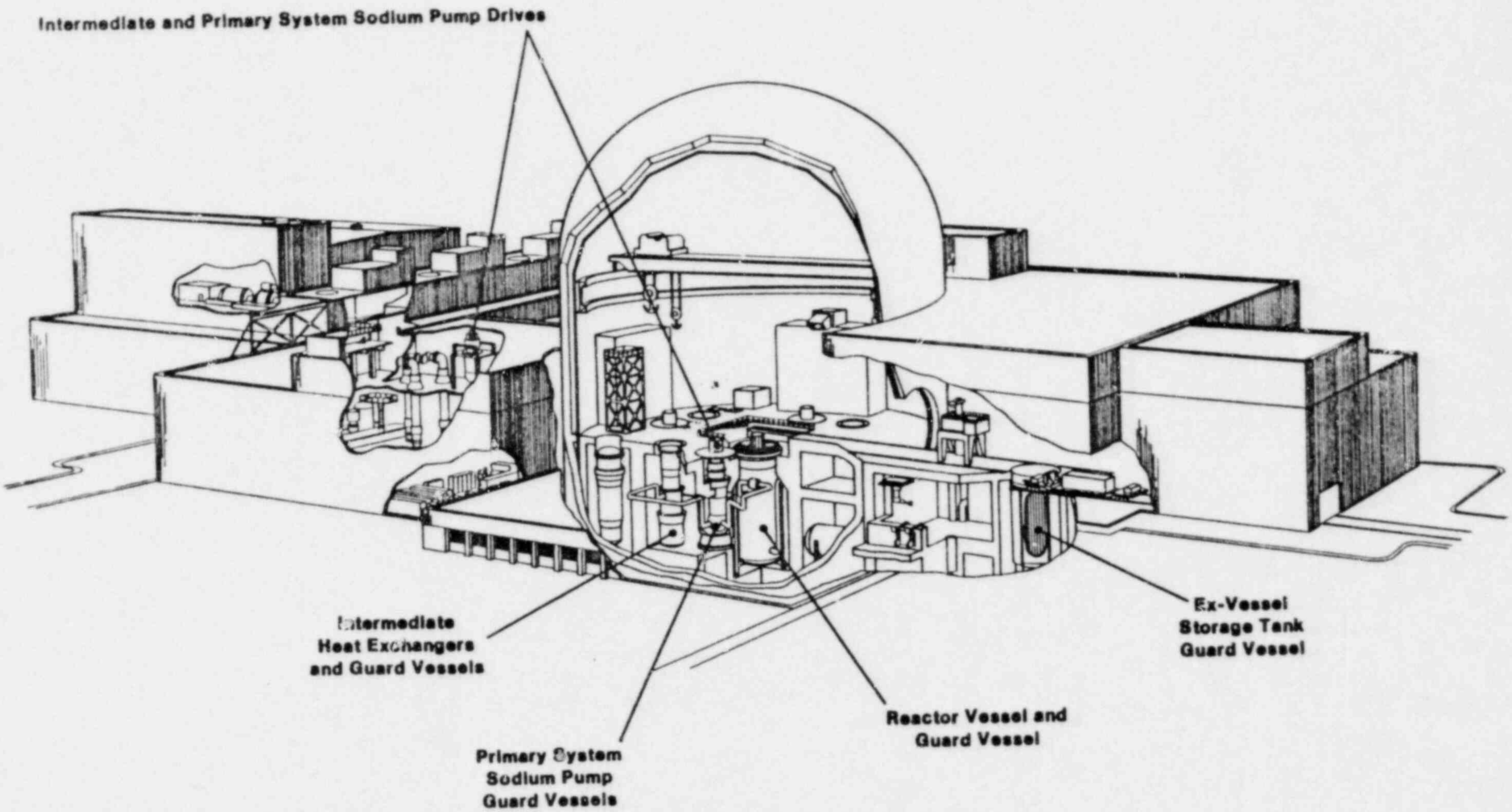


Figure 12. CRBRP Plant Concept, Indicating Locations of Some of the Major Components That Have Been Completed.

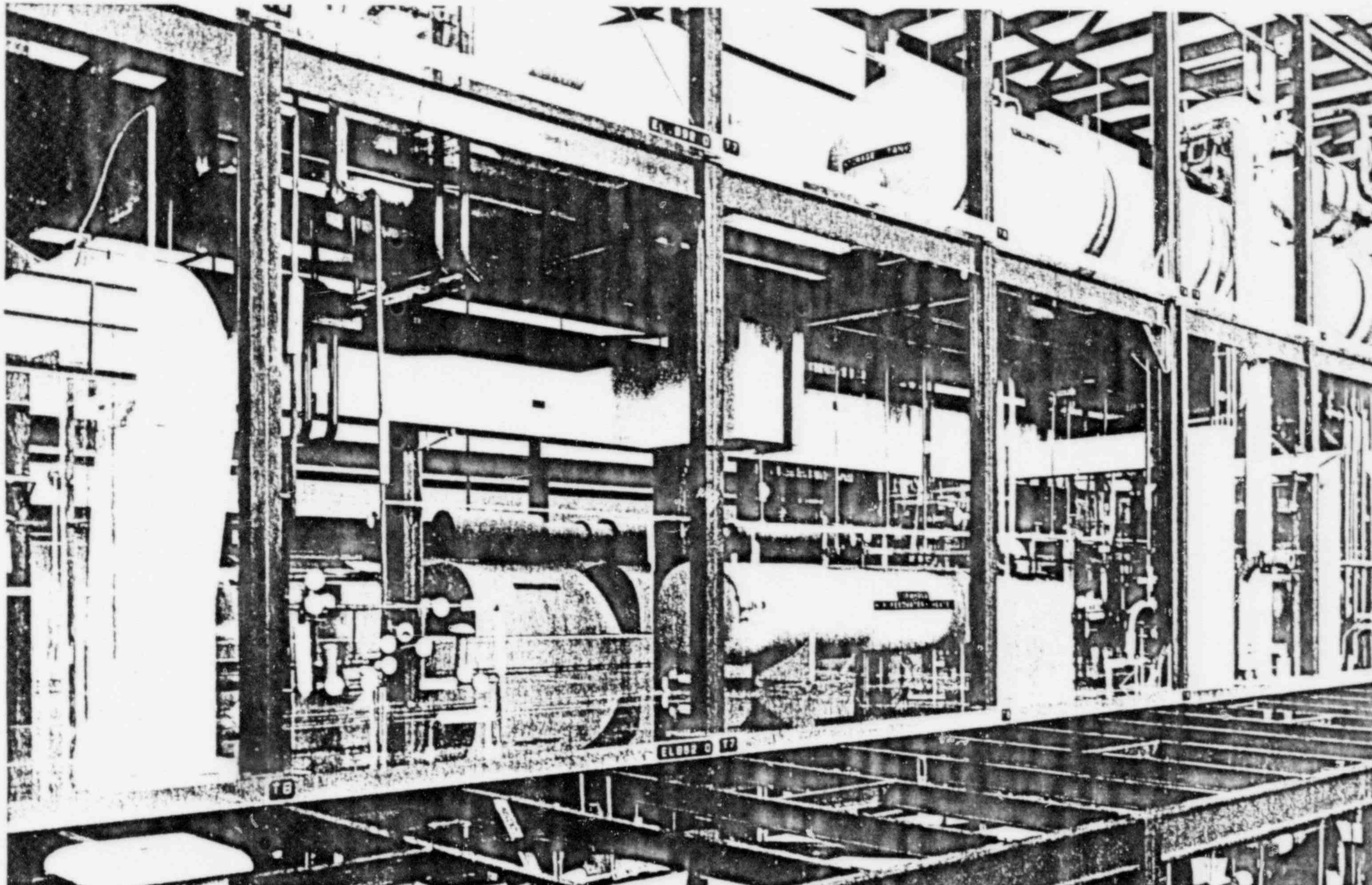

Figure 13. Turbine Generator Building as Modeled in the CRBRP Model.

*Project Management* — Activities of the Project Quality Assurance Program included program management reviews, quality verification reviews, quality assurance program audits, personnel training, and improvement of the plans and procedures of all participants.

The Systems Integration function continued its activities in the technical interfacing, scheduling, and control of Nuclear Island design activities, the interfacing of those activies with the Balance of Plant activities under the control of the Architect-Engineer, and the assuring of proper utilization of FFTF experience.

The Total Plant Cost Estimate was revised to reflect the effects of the construction delays caused by the national policy debate on the Project. The Constructor updated the preconstruction estimate and related schedules to include design improvements, revised material and labor costs, delays in delivery of components, and delay in the start of construction.

*Licensing* — The Project provided technical reports and amendments of the Preliminary Safety Analysis Report to the NRC for safety and licensing review. Further actions in the environmental public-hearing process will not be initiated until a national policy decision to complete the Project is made. Plant safety analyses continued to yield design improvements. Qualitative and quantitative analyses continued in the Safety-Related Reliability Program.


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