construction of the sodium reactor experiment

S R E

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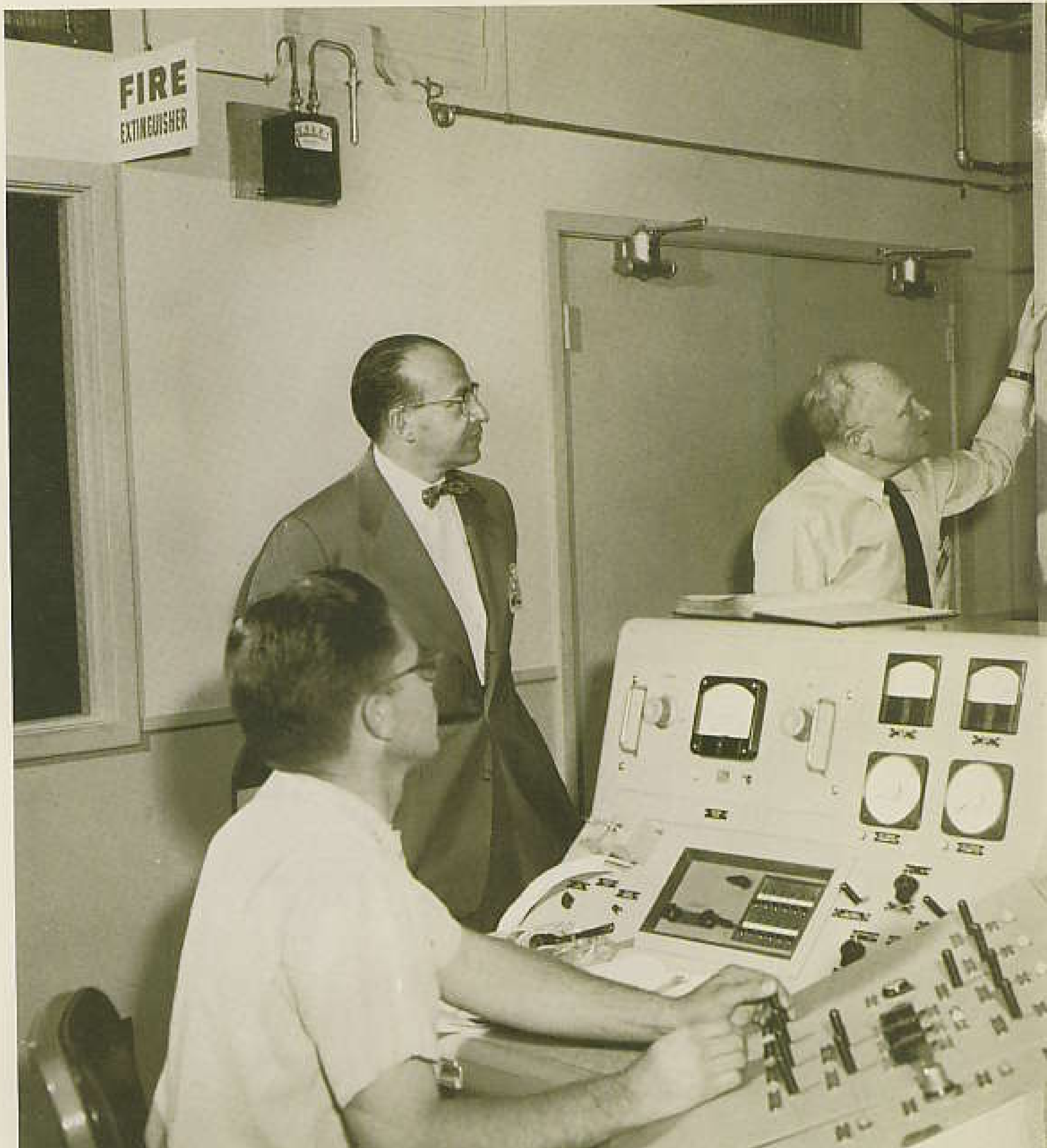
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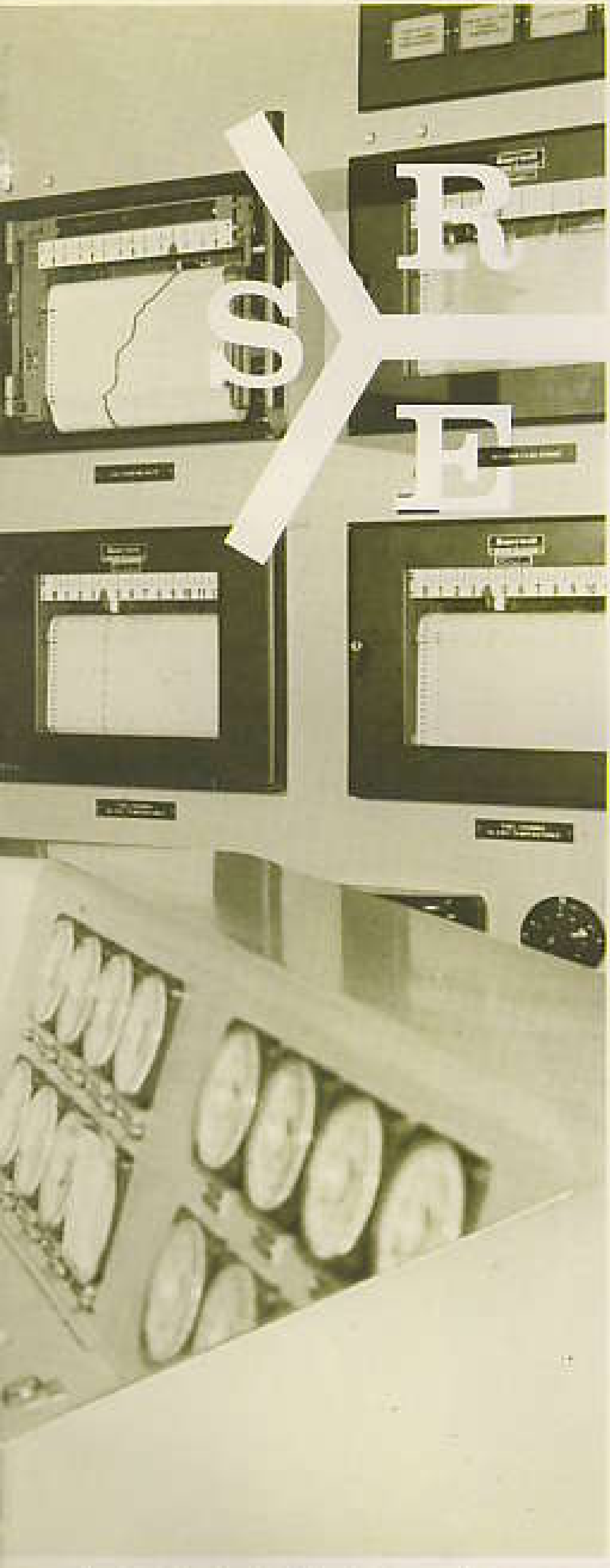


1 **Criticality Of The SRE, April 25, 1957.** As the log counting rate recorder indicates reactor criticality, the culmination of several years of research, development, and construction is being observed by Dr. Chauncey Starr, Vice-President of North American Aviation and General Manager of Atomics International (center), and Dr. Sidney Siegel, Technical Director of A.I. (right).

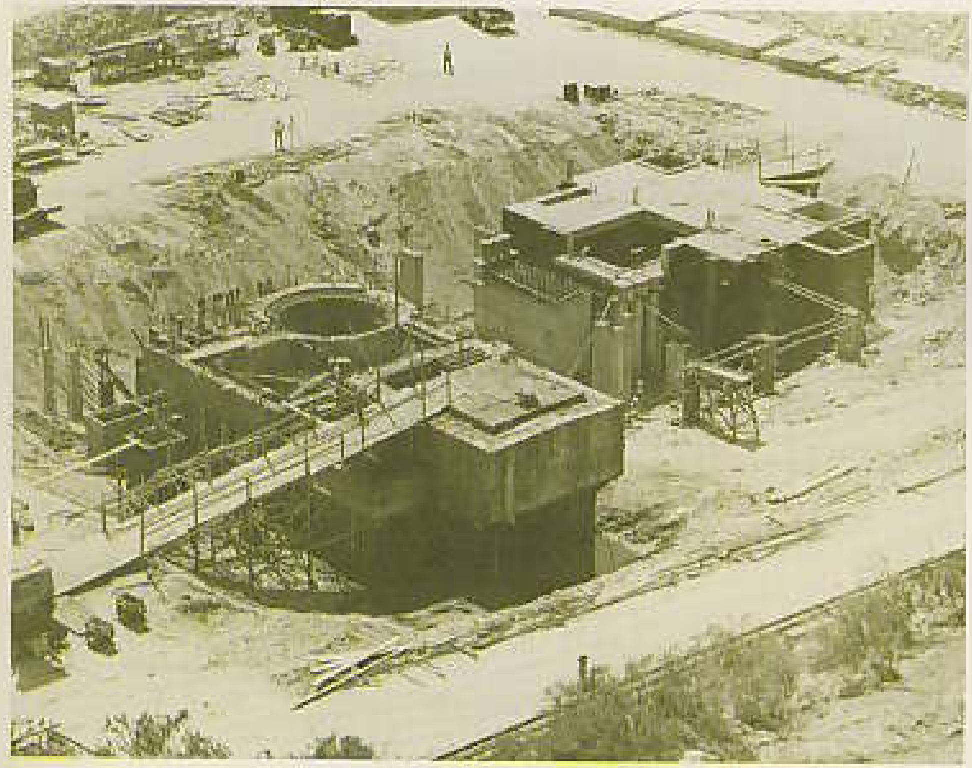
sodium reactor experiment

On June 25, 1954, Atomics International entered into a contract with the United States Atomic Energy Commission for a program of development leading to the construction of the Sodium Reactor Experiment (SRE). The broad aspects of this program included the development of the basic technology for the use of sodium as a reactor coolant and the use of graphite as the moderator and reflector. The SRE itself was designed to produce 20,000 kilowatts of heat. It was originally planned to dissipate this heat into the atmosphere through air-cooled heat exchangers. Subsequently, however, an agreement was reached with the Southern California Edison Co. whereby a steam-electric plant, to be erected by that company, would utilize the heat generated by the reactor to produce about 6,500 kilowatts of electricity to be fed into the Southern California Edison distribution system.

The Sodium Reactor Experiment is located in the Santa Susana Mountains, approximately 30 miles northwest of the center of Los Angeles, and about 10 miles northwest of Canoga Park, California.

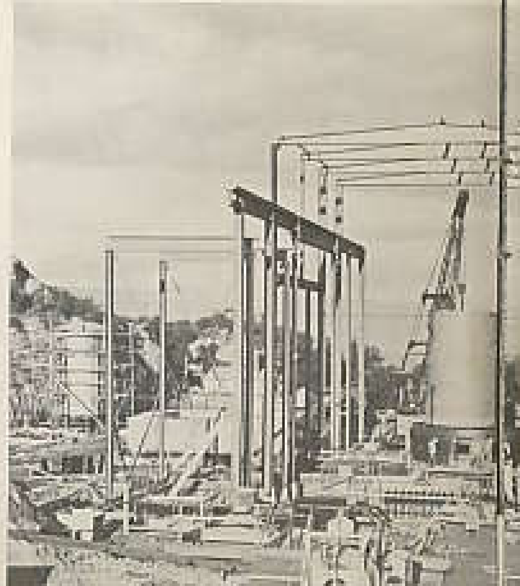
This booklet contains a number of photographs and diagrams, tracing the construction progress of the SRE, detailing a number of its important components and illustrating some of its technology and a part of the research required to develop this technology.

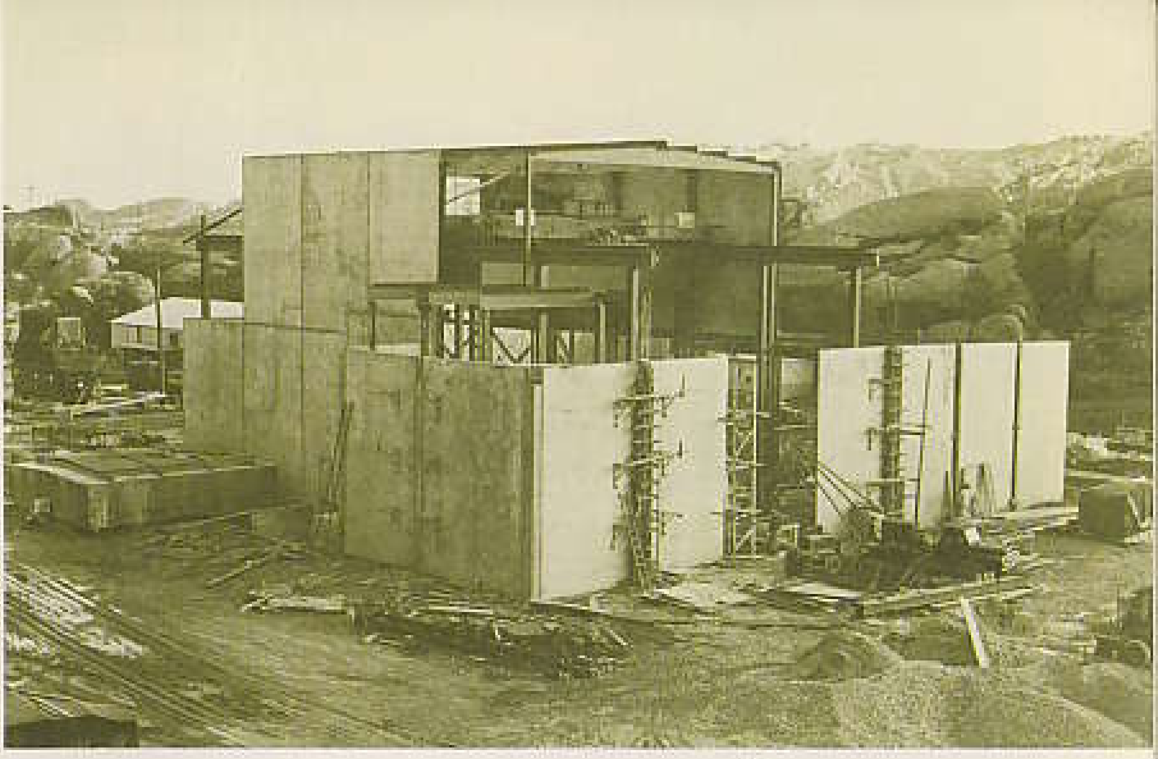
2 **Site Excavation, March 1955.** The circular cavity to the left will contain the foundation for the reactor core; those to the right are for the fuel storage cells, the fuel element cleaning cells, and the hot cell.



3 **Main Sub-Floor Structural Components.** The block to the left contains the core cavity liner and the vaults for the primary sodium loop and the primary sodium fill tank. The block to the upper right contains the hot cell basement room. Visible between the two blocks are the three fuel element cleaning cells, the 96 irradiated-fuel storage cells and the three moderator-can storage cells.

4 **The Structural Steel Framework For The Reactor Building** having been completed, the outer tank of the reactor core is being lowered into place. The tank to the far left is the core tank, awaiting installation.

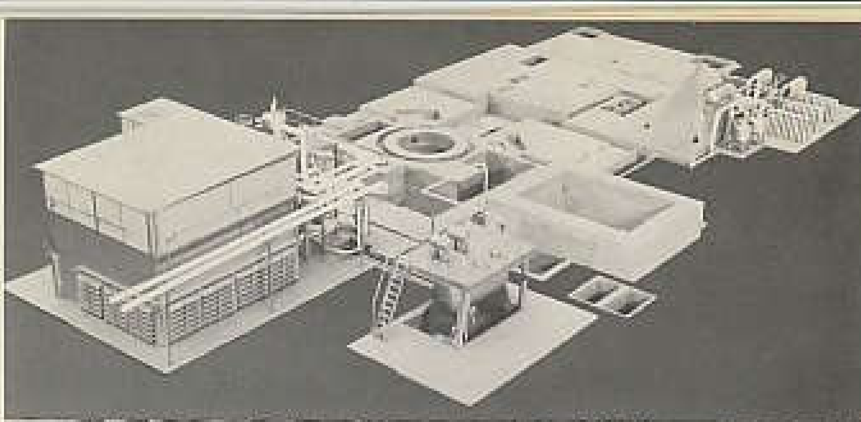




5 **The Reactor Building Under Construction.** A tilt-up, concrete slab method of construction was used.

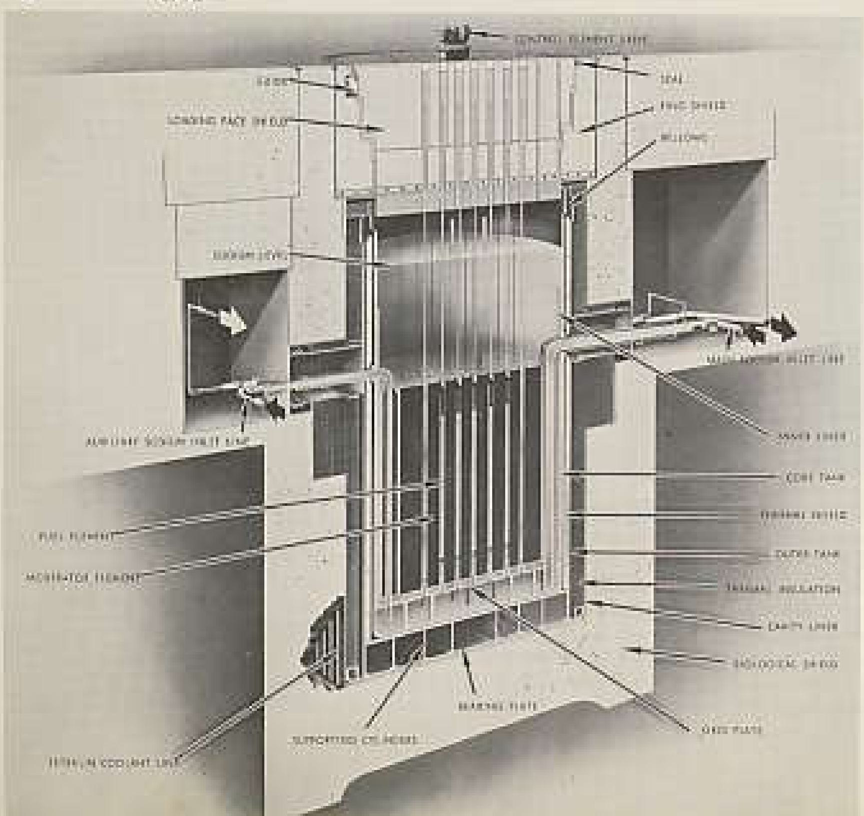
site and buildings

6 **SRE Site** at completion of construction in March, 1957, at which time pre-operational tests were already being carried out. The large building to the right of the photograph contains the reactor and its associated equipment and controls. The structure immediately to its left is the sodium-air heat exchanger. From the reactor building, sodium piping leads across the roadway, left, to the steam generator of the electrical generating plant. At lower left is the power plant control building. Other buildings shown in the left center part of the photograph are engineering development laboratories.



7 **Model Of The SRE** shows the position of the reactor core in relation to the rest of the plant. The galleries which contain the primary sodium system are inside the building and adjacent to the reactor. The piping of the secondary sodium system is designed to allow the sodium to flow from the building to the sodium-air heat exchanger, or to by-pass the sodium-air heat exchanger and flow to the steam generator of the steam-electric plant (not shown in the model).

8 **Cross-Sectional Drawing Of The Reactor** with details on its various components. The liquid sodium enters the lower plenum beneath the grid plate at a temperature of approximately 500° F and flows upward through the fuel-element channels as well as between the moderator cans, reaching the upper sodium reservoir at a temperature of approximately 960° F. The reactor atmosphere pressure of the helium above the upper sodium reservoir is 3 pounds per square inch gage.



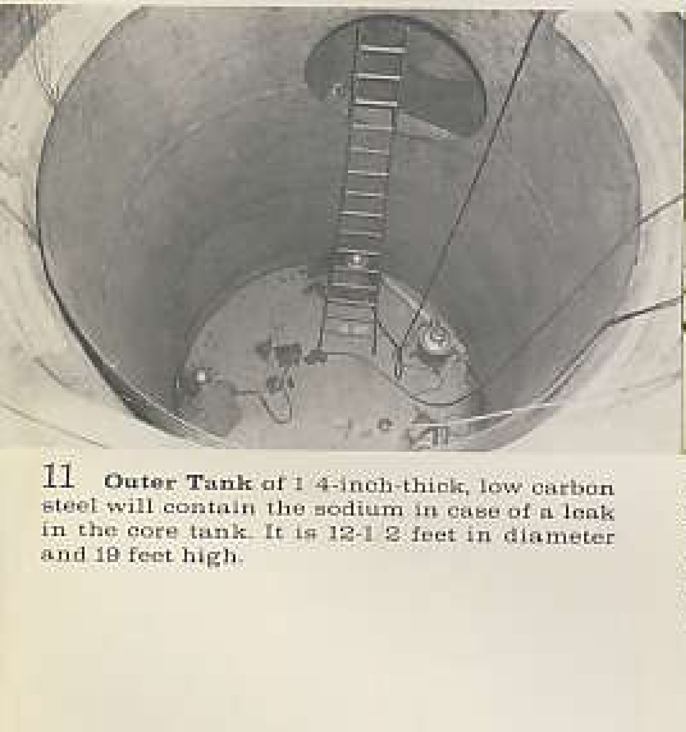
the reactor

The heart of the SRE is the reactor itself. The following section shows the various components of the reactor, starting with the cavity liner, inside of which are consecutively fitted the insulating blocks, the outer tank, the thermal shield rings, and the core tank. The core proper contains the graphite moderator assemblies, the fuel elements, and the control and safety elements.

9 **Cavity-Liner** of the reactor core, showing the tetralin coolant lines to remove heat from the concrete shielding which will surround this tank. The large hole, left of center, will contain the sodium inlet and outlet pipes.

10 **Thermal Insulating Blocks** being installed inside cavity liner.

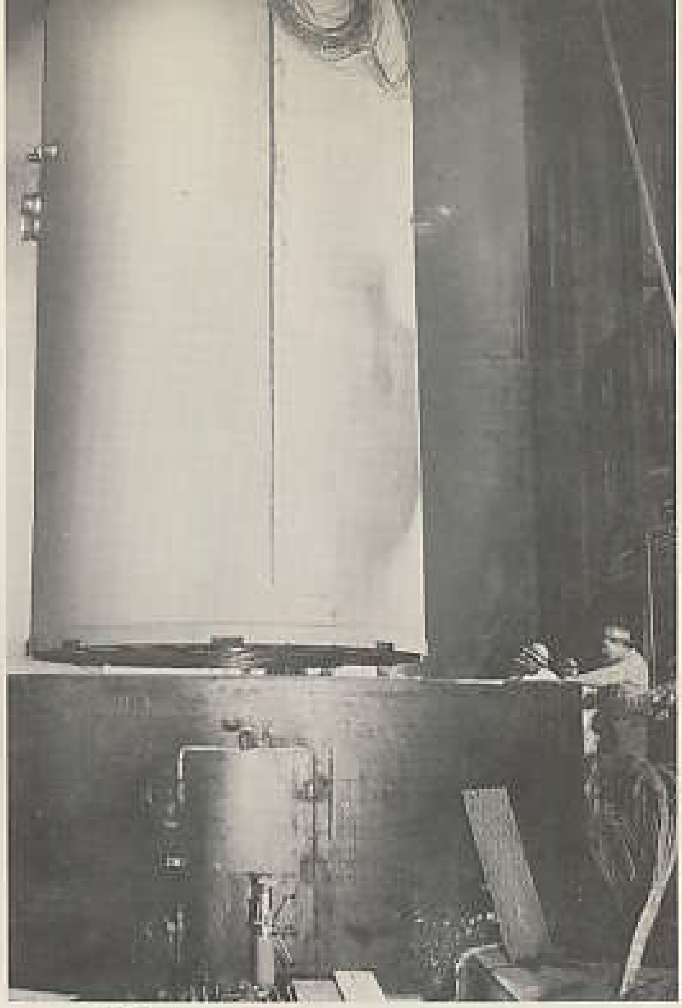
S R E the reactor



11 **Outer Tank** of 1/4-inch-thick, low carbon steel will contain the sodium in case of a leak in the core tank. It is 12-1/2 feet in diameter and 19 feet high.

12 **Thermal Shield Rings** of cast steel, 5-1/2 inches thick, are being lowered into place inside the outer tank. The rings are not welded to each other and the bottom ring simply rests on the bottom of the outer tank to permit free thermal expansion.

13 **Stainless Steel Core Tank** sections being welded together.



14 **Core Tank**, being lowered into position, is 11 feet in diameter and 19 feet in height. (The circular wall surrounding the sub-floor-level reactor area is a temporary construction safeguard.)

15 **Bottom Grid Plate** inside the core tank. Sodium enters the core tank into the plenum beneath this grid plate. Pedestals at the bottom of each canned graphite moderator assembly fit into the holes in this grid plate, thus positioning the can. In addition, the pedestal has a circular channel along its axis which directs the sodium from the lower plenum up through the coolant tube in the moderator can assembly.

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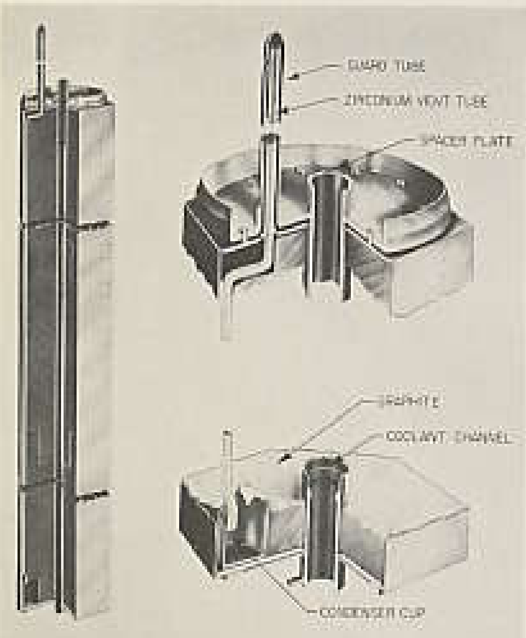
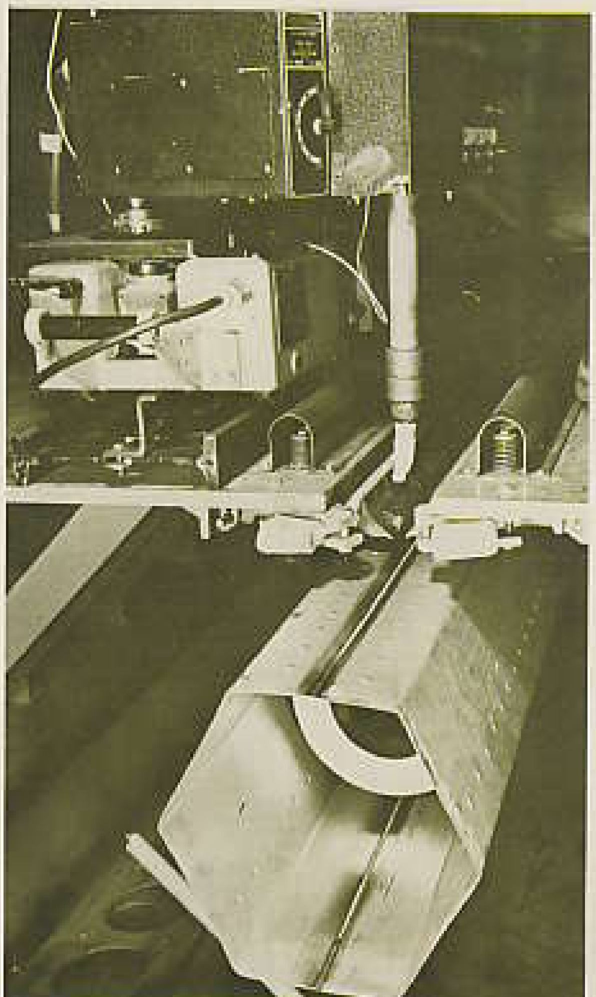
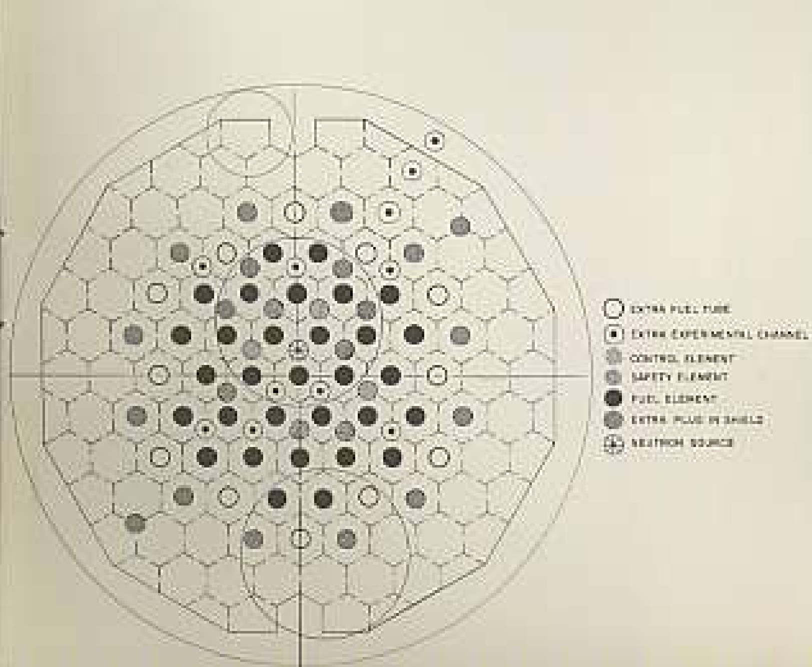


16 **Canned Graphite Moderator And Reflector Assembly** shown in this cutaway drawing, is hexagonal in shape, 11 inches across the flats and 10 feet long, with a center coolant channel 2.8 inches in diameter, The fuel element is inserted into the center coolant channel so that the liquid sodium coolant, flowing upward through the channel, removes the heat from the fuel element. The vent tube is provided to allow escape of any absorbed gases in the graphite.

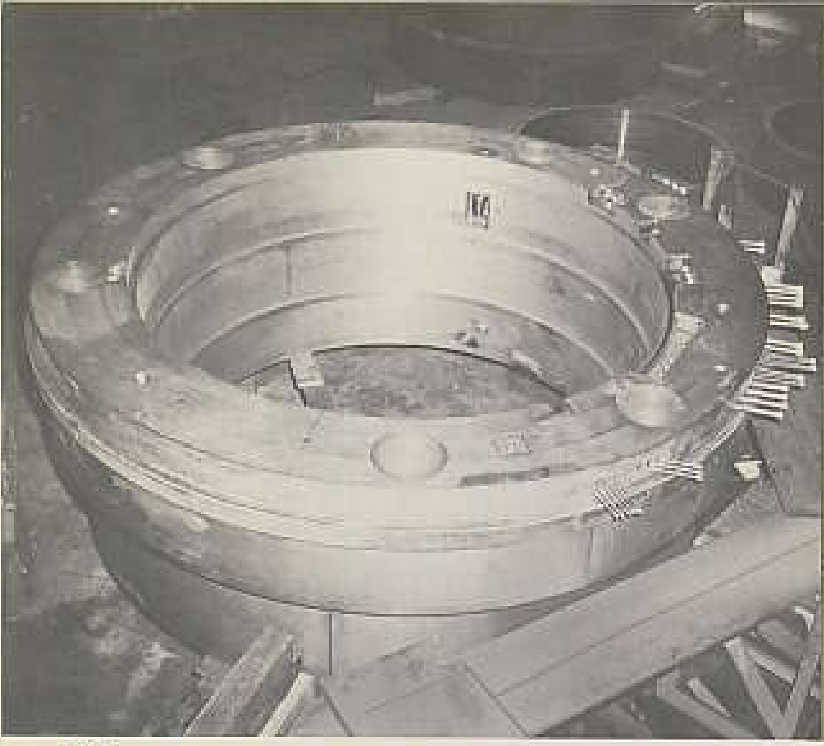


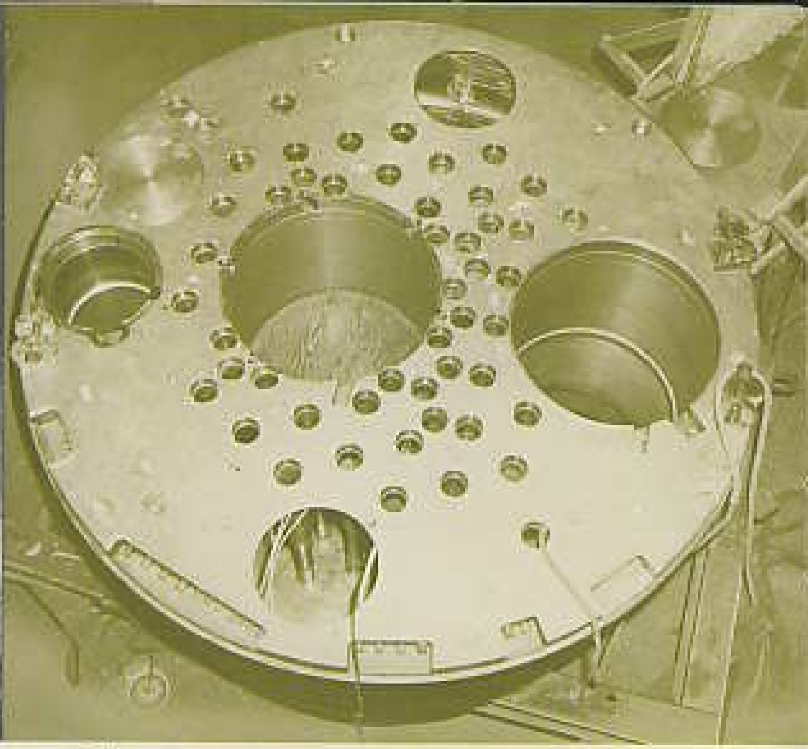
17 **Zirconium Moderator Can,** formed of six side-panels which are joined by a completely automatic heliarc weld. The zirconium sheet is 0.035 inches in thickness and is dimpled to provide a space between adjacent cans through which sodium may flow.

18 **Completion of Loading** of canned graphite moderator assemblies. The vent tubes will extend from the moderator cans to the space above the sodium pool. The core holds 119 cans containing graphite, of which 57 are zirconium moderator cans with center coolant channels. Of the 62 reflector cans, 29 are identical to the moderator cans except that there are no center coolant channels. The other 33 are made of stainless steel and range in shape from full to half hexagon.



19 **Loading Pattern** of reactor core. Thirty-one fuel elements are located near the center of the core while 12 extra fuel channels are provided for flexibility of loading.





20 **Ring Shield,** 15 feet in diameter, is pictured prior to installation. It is stepped to receive the rotatable loading-face shield and to prevent radiation streaming. The entire shield is filled with dense concrete for shielding purposes.

21 **Rotatable Loading-Face Shield,** 11-1/2 feet in diameter, has a total of 81 small plugs extending through it for access to all of the fuel elements, the control and safety elements, and the experimental channels. There are also three large plugs so located to provide access to any graphite assembly within the core tank when the shield is rotated to the proper position. All plugs are stepped to prevent radiation streaming. Like the ring shield, this loading-face shield is also filled with dense concrete.

22 **Checking Alignment Of The Reactor Loading-Face After Installation.**

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S the reactor

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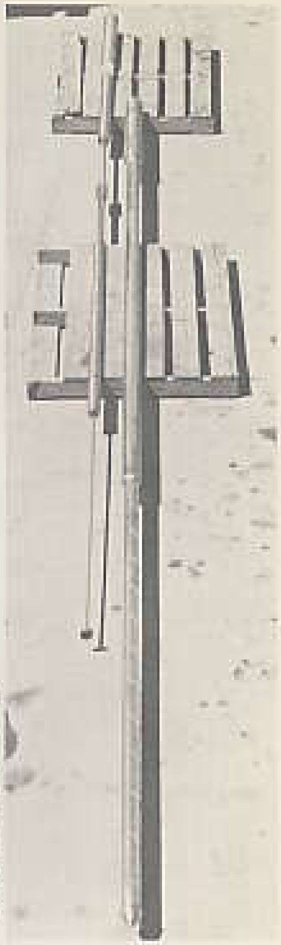
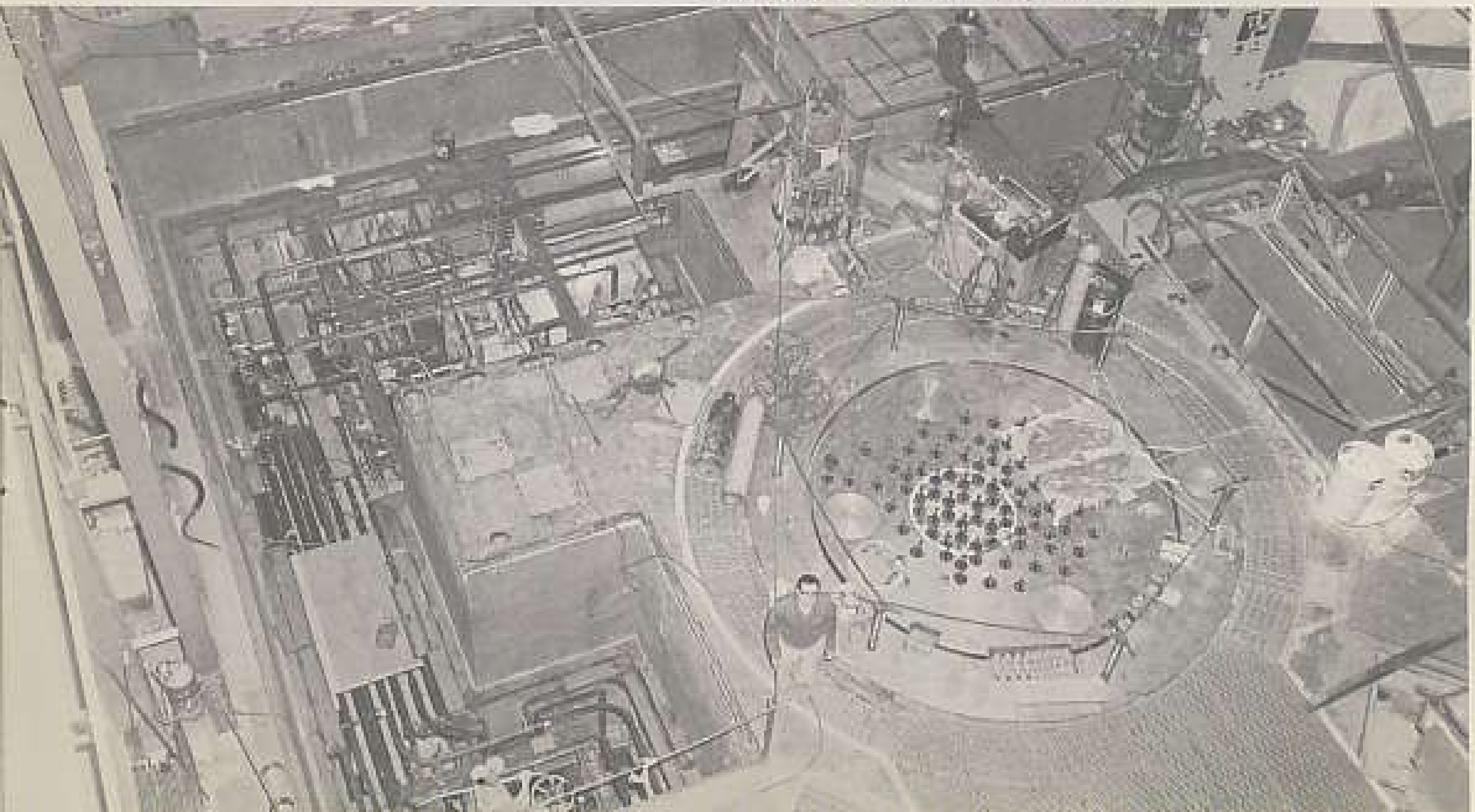
23 **Experimental Loading Of SRE Fuel Element** into core. The element is made up of seven rods, each rod consisting of twelve 6-inch long uranium slugs, in a thin-walled stainless-steel jacket-tube. The six outside rods are spirally wrapped with stainless-steel wire to maintain spacing between the rods and to assure mixing of the sodium as it flows through the inner passages just surrounding the central rod, and through the outer passages surrounding the six rods. At the bottom of the rods is a locating guide and an orifice plate for controlling the flow of the sodium as required for each particular coolant tube. The entire fuel element is attached to a plug in the loading-face shield by a hanger rod.



24 **Control Element,** disassembled. The right-hand rod is the thimble into which the control element is fitted. The neutron absorbing material is made up of 18 rings of boron-nickel alloy. There are a total of four control elements in the reactor, each of which controls 1.6 per cent of reactivity. Drive motors are capable of controlling the movement of the control elements at speeds of either 0.24 or 3.0 feet per minute.

25 **Interior View Of Reactor Building** showing reactor loading-face and primary sodium circuit galleries before installation of concrete shielding blocks.



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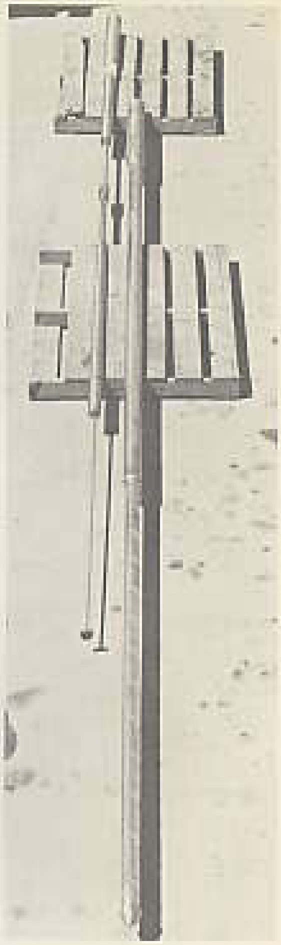

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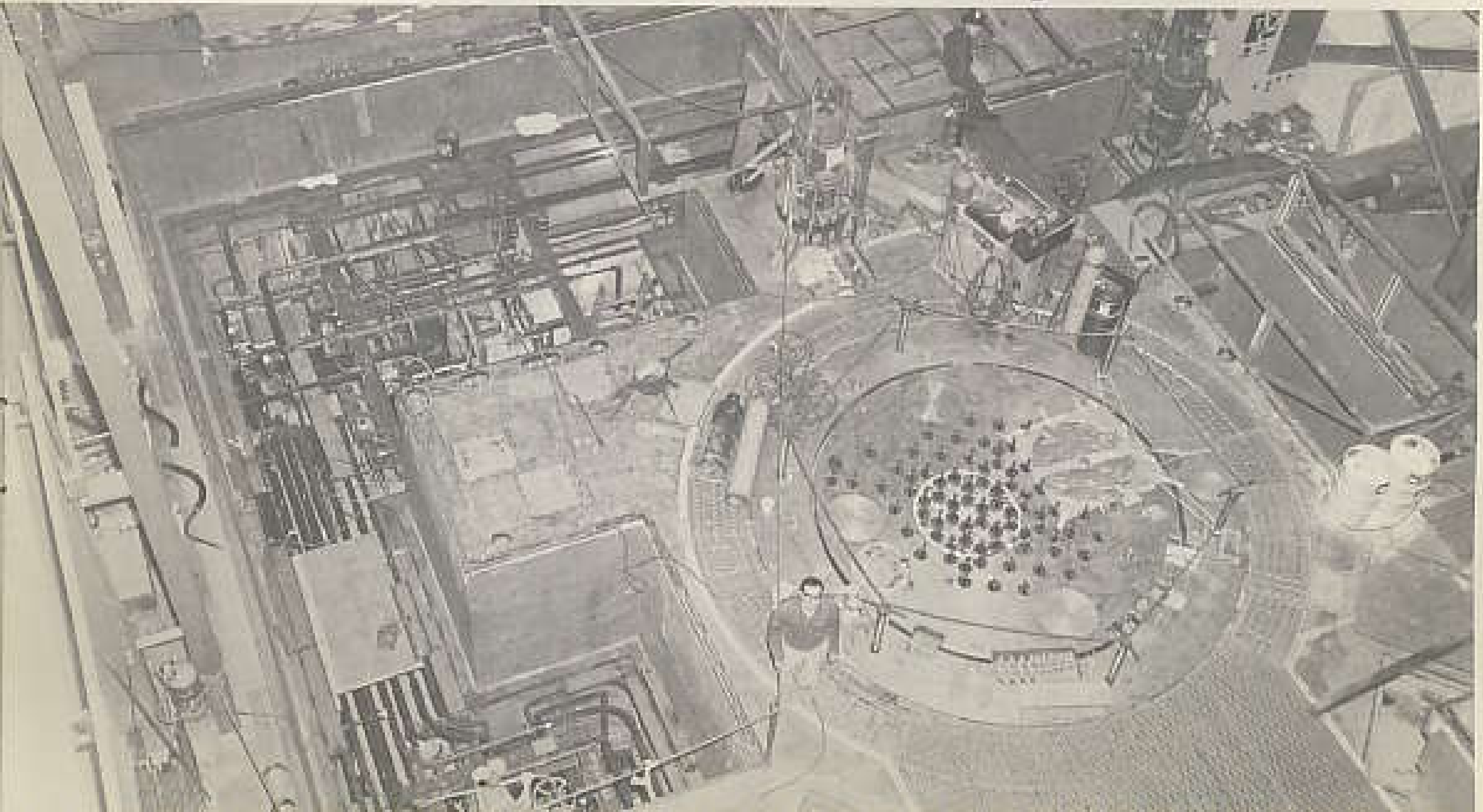


26 Dense Concrete Shielding Block is being lowered into place over primary sodium circuit gallery. These blocks are 5-1/2 feet thick and form a gastight seal with the edge of the adjacent floor.

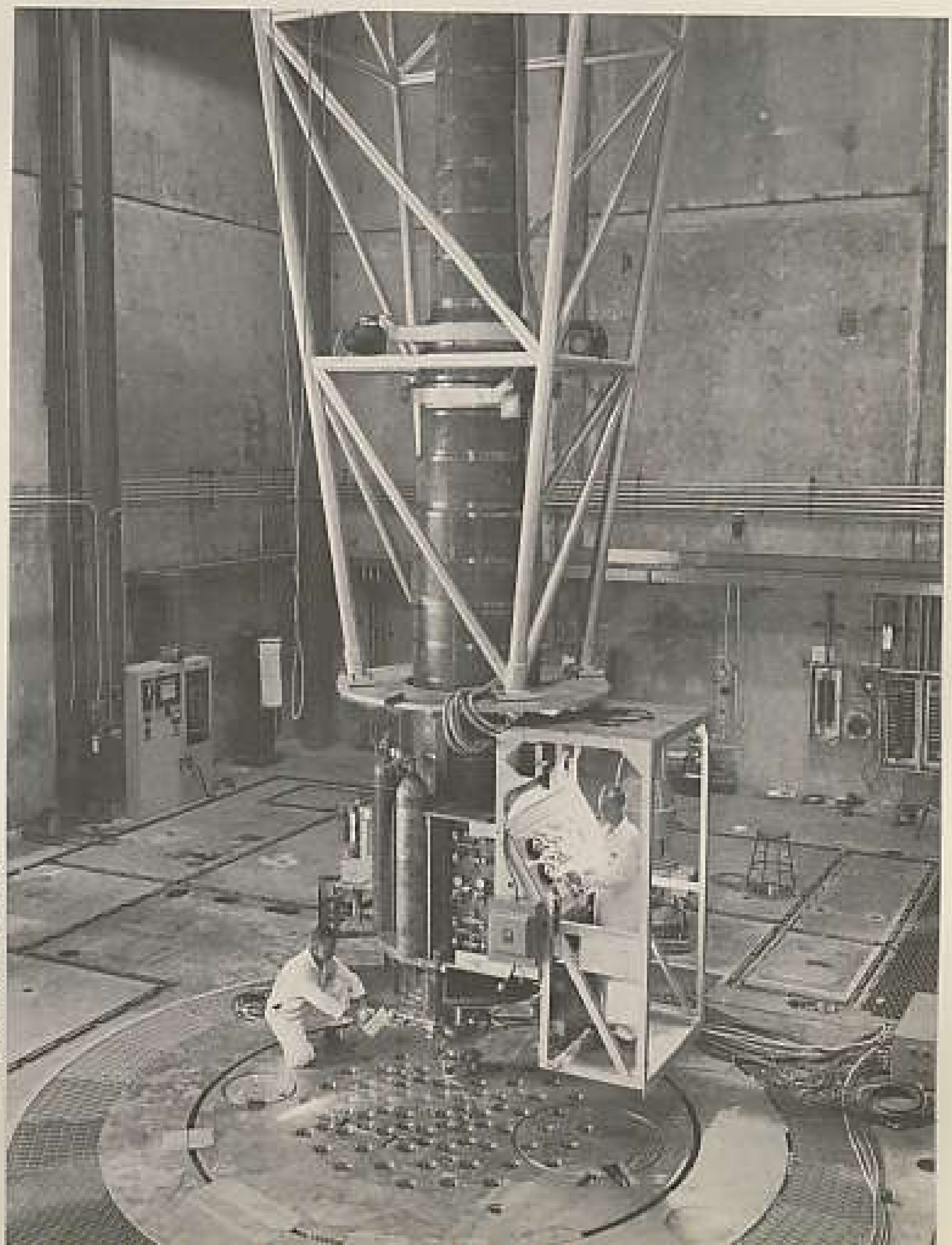
SRE the reactor

27 Control Room, showing control console and a part of the bank of recording and indicator instruments.

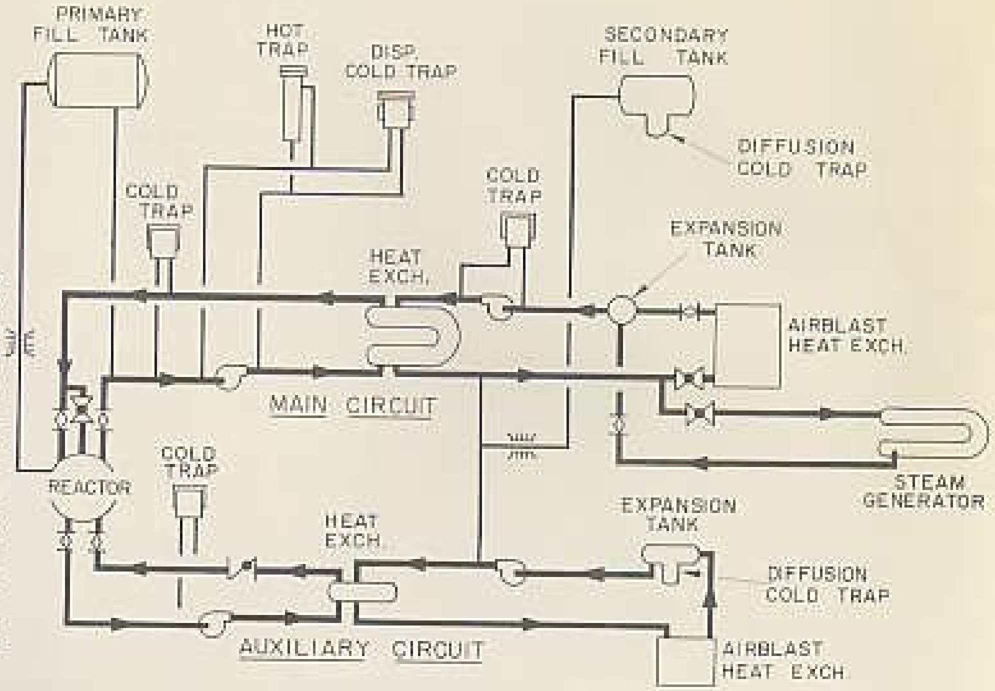
To change a fuel element, the cask is located over the desired plug in the loading-face shield. A gastight seal is formed between the cask and the top shield. Following this, a large lead shield skirt is lowered to the surface of the loading-face shield. The plug with its attached fuel element is removed and lifted into the cask. A separate mechanism then rotates the fuel-element lifting assembly bringing a new fuel element into position. After the new element and shield plug are lowered into place, the spent element is transported to the cleaning cells and then to the storage cells.

SRE

fuel handling



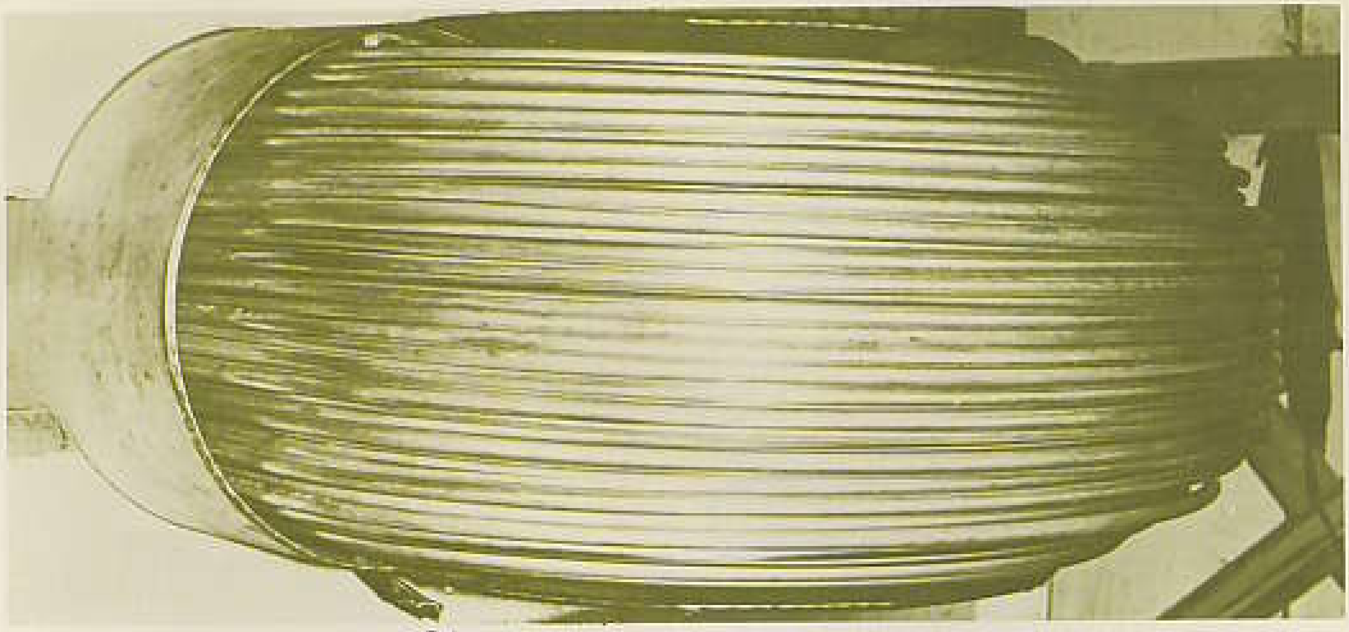
28 **Fuel Handling Cask** over the loading-face shield. The cask is carried on a handling bridge, and is capable of being moved as required within the reactor room. This cask is 35 feet in overall height and weighs 50 tons. There is a maximum thickness of 9 inches of lead-shielding near its base, tapering to a thickness of 1/2 inch near the top.



29 **Sodium System Of The SRE.** The radioactive sodium in the main primary circuit leaves the reactor, passes through the intermediate heat exchanger and returns to the reactor. The nonradioactive sodium in the main secondary circuit is heated in the intermediate heat exchanger and travels to the steam generator (or to the sodium-air heat exchanger during experimental operations) before returning to the intermediate heat exchanger. The auxiliary circuit operates simultaneously with the main circuit in order to assure heat removal capability in the event of component failure in the main circuit.

the sodium system and its

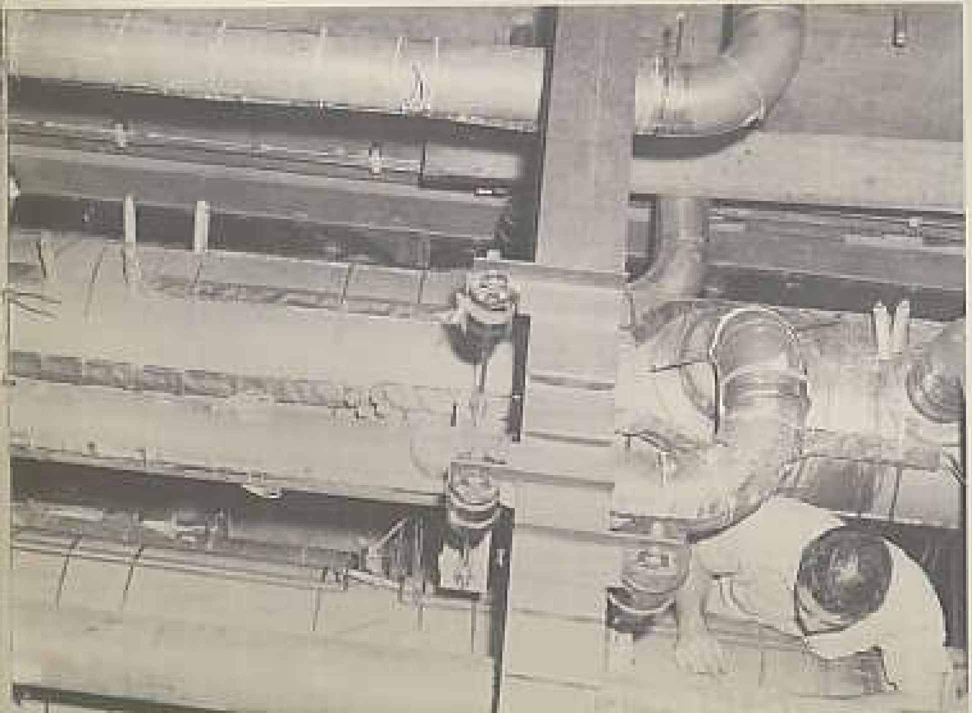
30 **Primary Sodium Fill Tank** from which sodium is directed to the reactor core. Sodium is first introduced to the fill tank from drums at two different melt stations. A similar fill tank exists for the secondary sodium circuit. The small tank atop the fill tank is a sodium vapor trap.

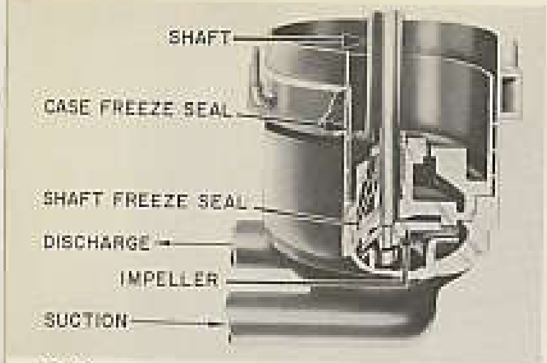


31 **Tube Bundle** of the main intermediate heat exchanger, during construction. There are 316 U-shaped tubes which have a total heat exchange area of 1155 square feet. The primary sodium flows through the tubes while the secondary sodium counterflows around the tubes.

components

32 **Main Intermediate Heat Exchanger.** Tubular-type heaters are strapped to the heat exchanger and to the sodium piping and vessels of the sodium system to heat them prior to filling with sodium and to keep the sodium liquid until heat is generated within the reactor itself.





33 **Sodium Pumps** have special sodium freeze seals. A shaft freeze is made at a cooled gland inserted in the space normally provided for pump packing, and another sodium freeze seal exists at the pump casing. Tetralin coolant is circulated through the glands to keep the sodium frozen.

34 **Main Primary Liquid Sodium Pump** being lowered into position. This pump has a long shaft extending through the vault shield so that during operation the motor will remain accessible above floor level.

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S the sodium system

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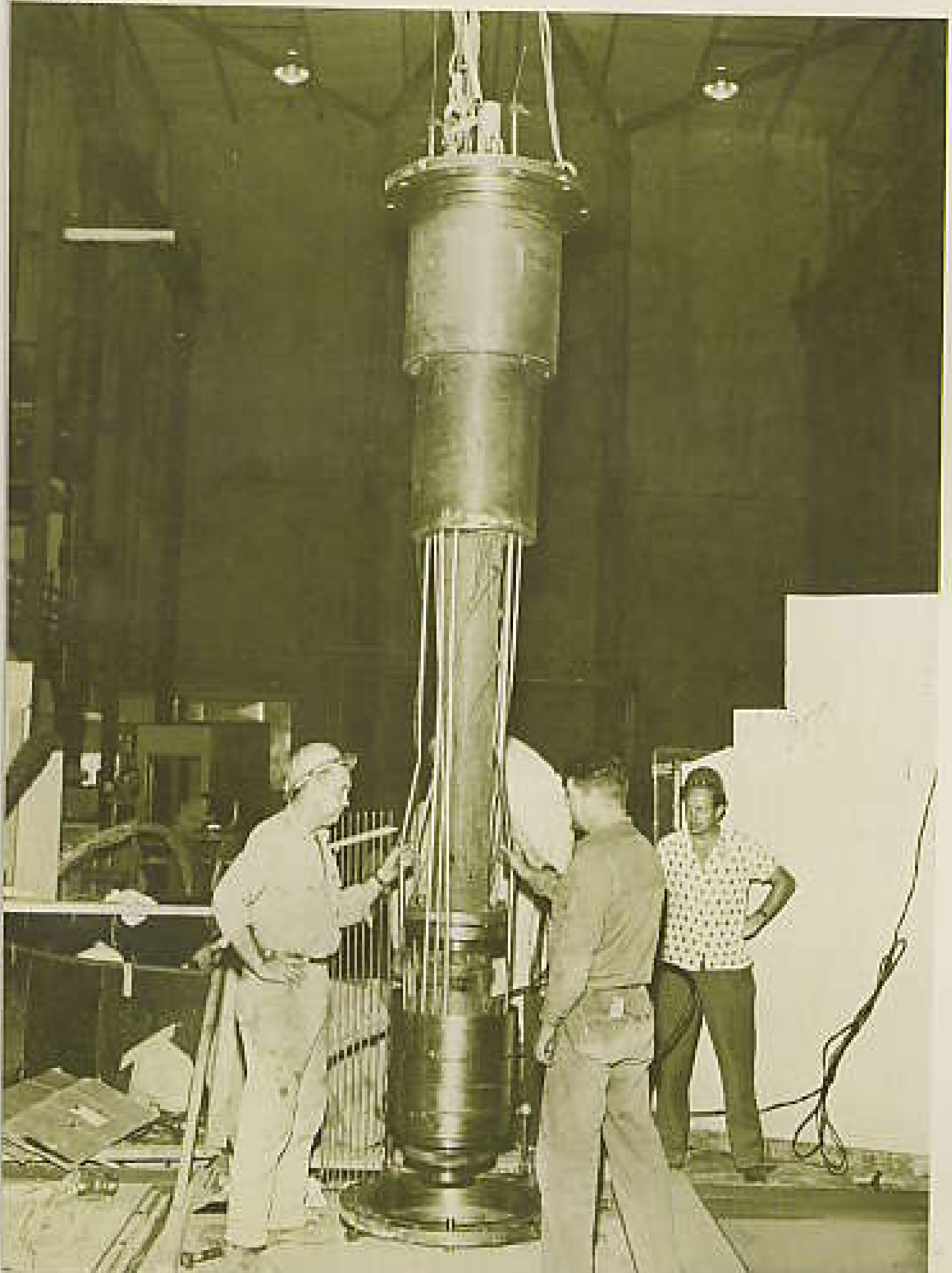
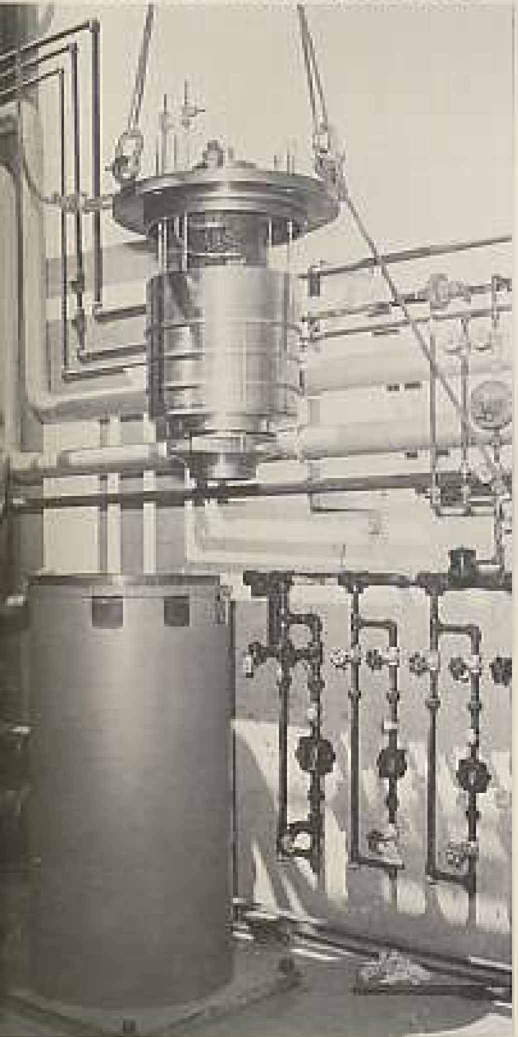


and its components

35 **Main Secondary Liquid Sodium Pump Being Installed.** This pump has a short shaft because the secondary coolant does not become radioactive and shielding is not required.

Equipped with 50-horsepower drive-motors, these sodium pumps are capable of delivering 1285 gallons per minute. All of the pump motors are variable-speed drive.

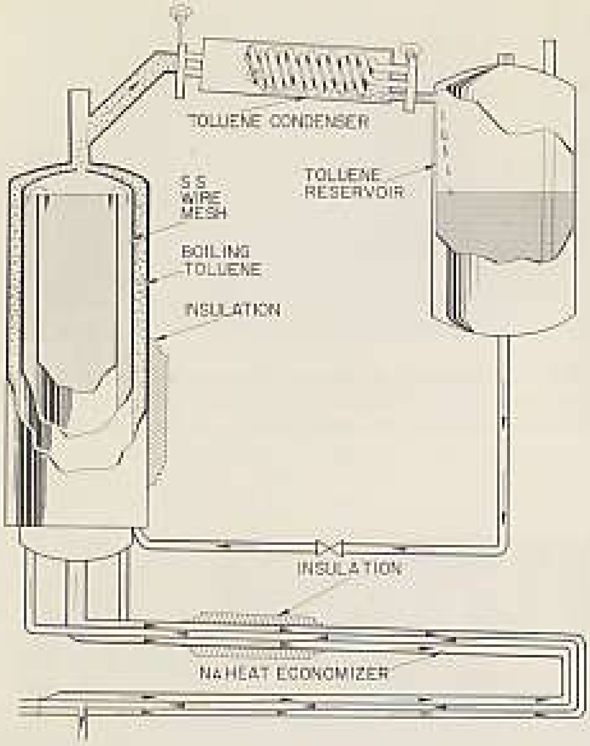


36 **Sodium-Air Heat Exchanger** distributes the secondary sodium through banks of U-tubes which are cooled by air current.

37 **Finned Tube Banks** of the sodium-air heat exchanger, during installation. A total of four banks of these tubes provides 23,600 square feet of heat removal surface.

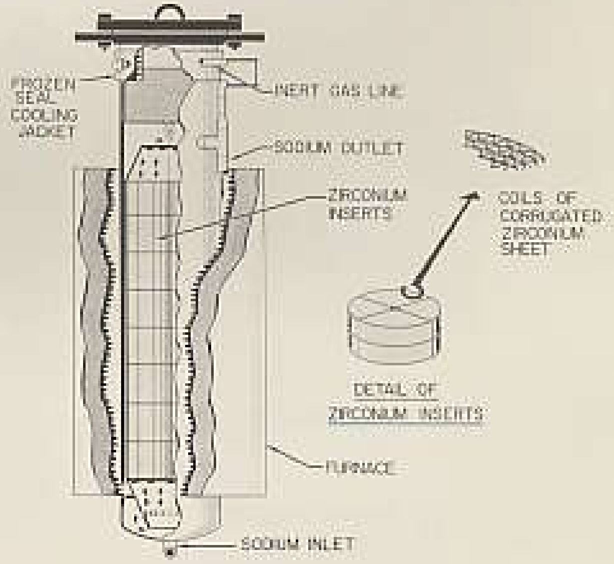
38 **Fan** for the sodium-air heat exchanger. There are two fans, each driven by a 50-horsepower, variable-speed motor.

39 **Cold Trap** provides a region where the sodium temperature is decreased below the sodium-oxide precipitation point, thus removing the greater part of the sodium oxide from the system. The cold traps are capable of reducing the oxygen content to about 15 parts per million.



40 **Cold Trap** installed in secondary system.

41 **Hot Traps** are used to remove the small amount of sodium oxide not removed by the cold trap. The sodium and zirconium in the hot trap are heated to about 1200° F. At this temperature, zirconium becomes an excellent absorber of oxygen and other gaseous impurities, and removes them from the sodium. The hot traps reduce the oxygen content to approximately 2 parts per million.



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42 **Corrugated Zirconium Foil** being inserted into the hot trap during construction.

43 **Hot Trap Installation.**

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the sodium system and its components

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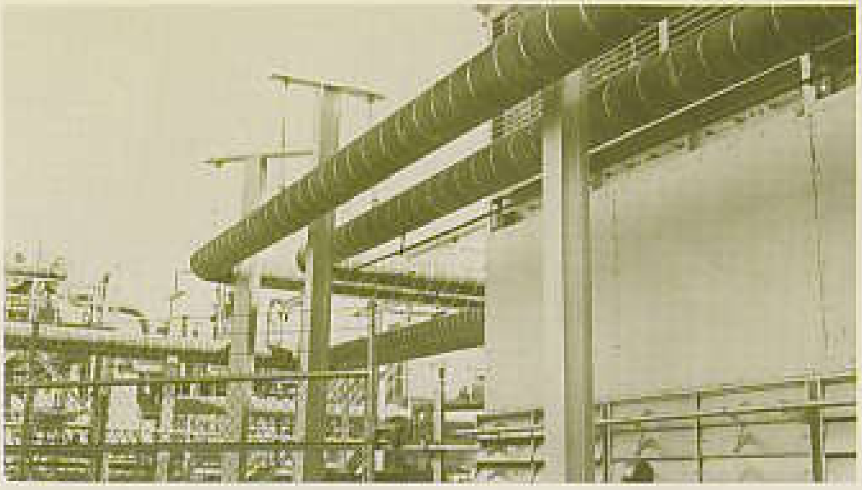
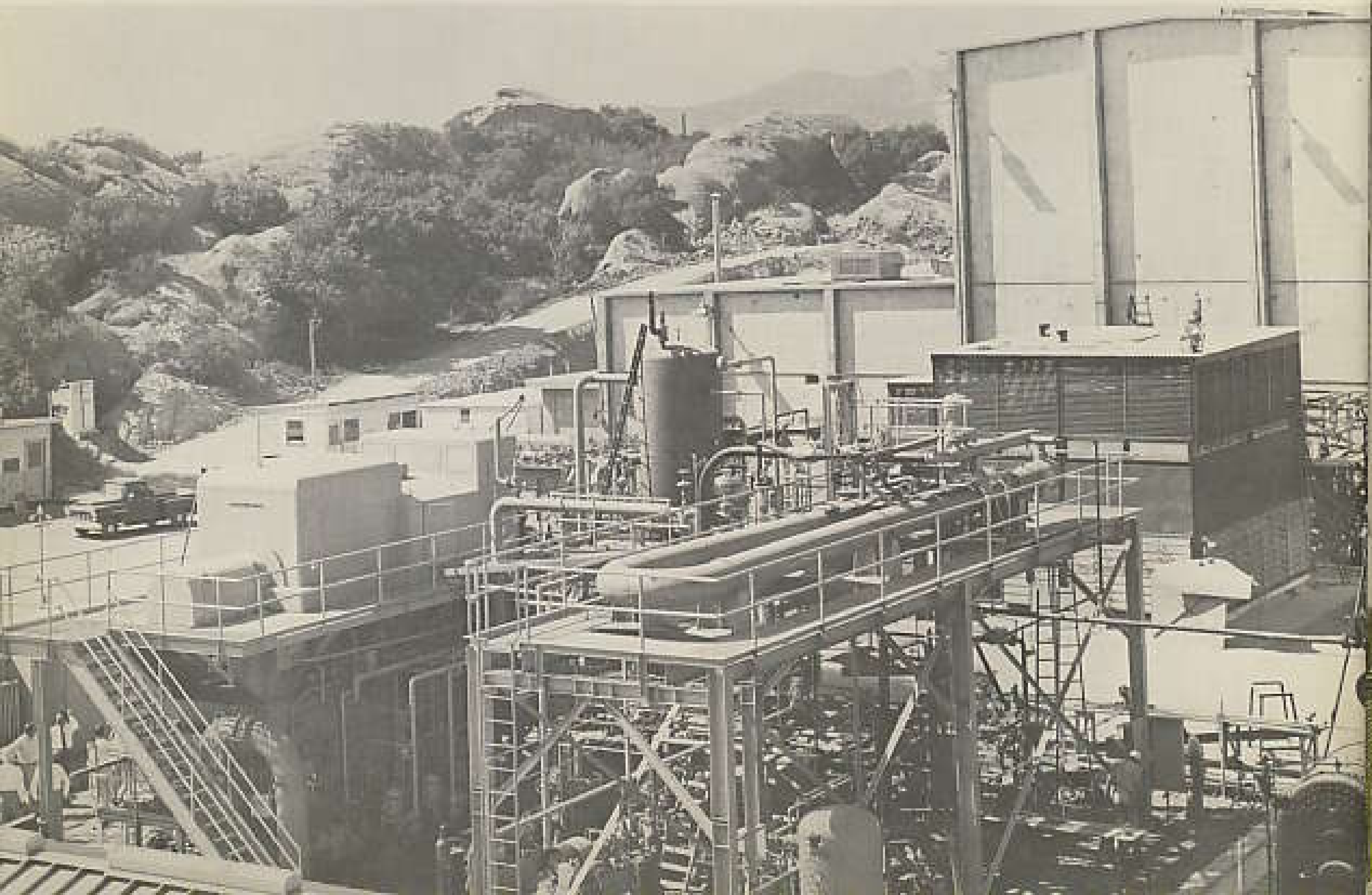
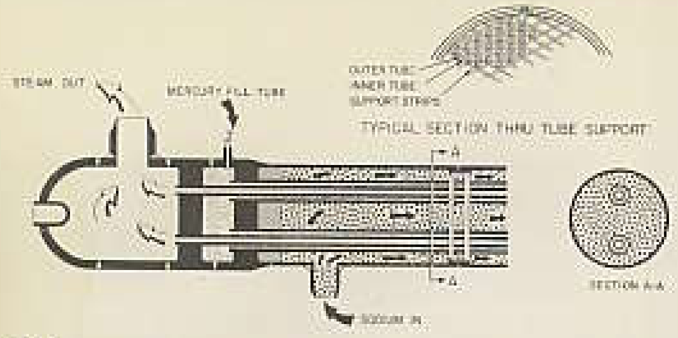


44 **Secondary Sodium Lines** lead out to the steam-electric plant. These lines are 6 inches in diameter and carry nonradioactive sodium to the steam generator at 900° F and 50 pounds per square inch absolute, returning the sodium at 440° F. The sodium velocity is 13 feet per second.

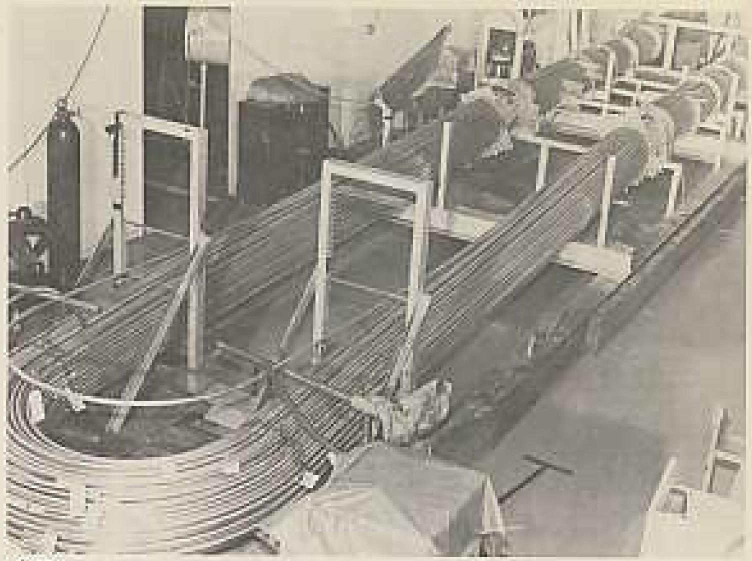
The electric power generation facility, installed by the Southern California Edison Company, is rated at 7500 kilowatts. Temperature and pressure conditions at the turbine throttle are similar to those encountered in modern fossil-fuel plants. In other respects it is as similar to a conventional steam plant as the special requirements of a reactor-heated system will allow. The major departure is the **once-through** steam generator.

45 **Complete Steam-Electric Plant Showing** the U-shaped **once-through** steam generator in the center foreground and the turbine generator to its left. The steam generator produces 88,700 pounds per hour of steam at a pressure of 620 pounds per square inch and at a temperature of 825° F.





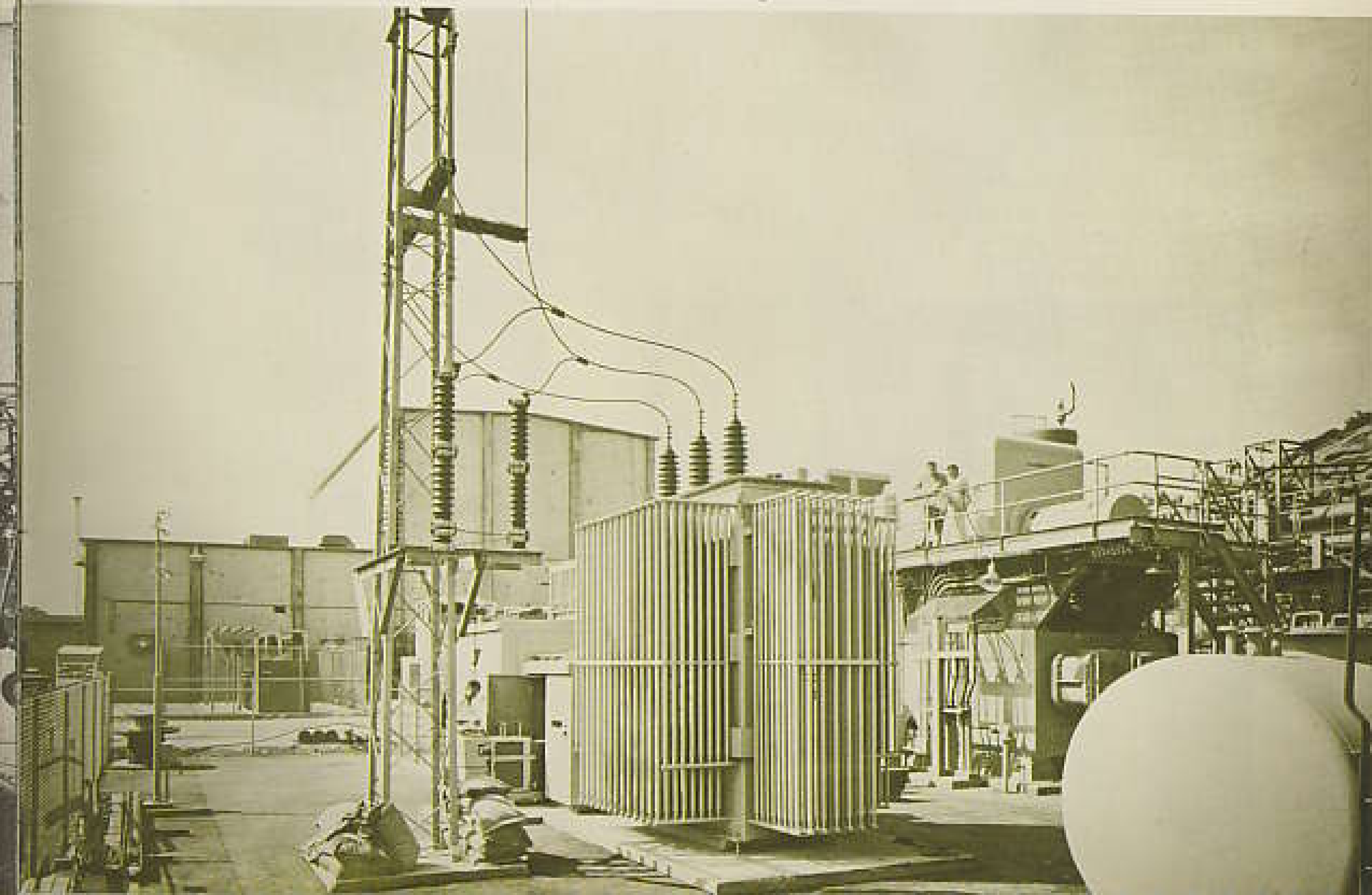
46 **Cutaway Drawing Of The Steam Generator** showing the double-walled tubes. The annular space between the tubes is filled with mercury pressurized at 190 pounds per square inch which serves as a monitoring fluid for detection of tube failure. The mercury further serves as a separating medium between the steam and the sodium. A leak in an outer tube would result in a movement of mercury into the low pressure sodium, while a leak in an inner tube would allow passage of 620 pounds per square inch steam into the mercury.

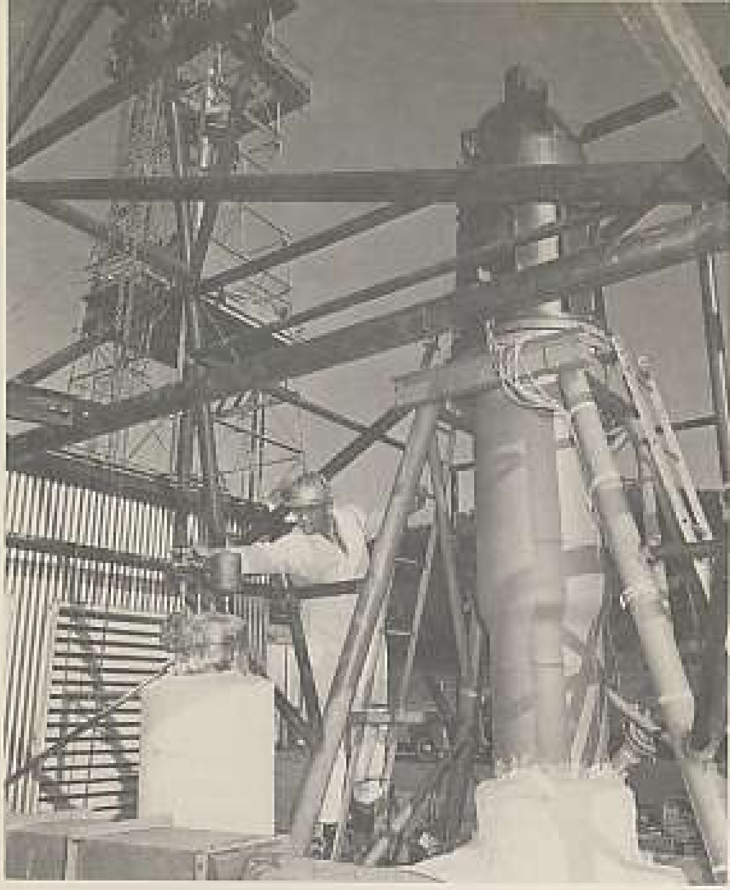


47 **Tube Bundle Of Steam Generator** during construction. Each double-walled tube is about 80 feet in length.

the steam-electric plant

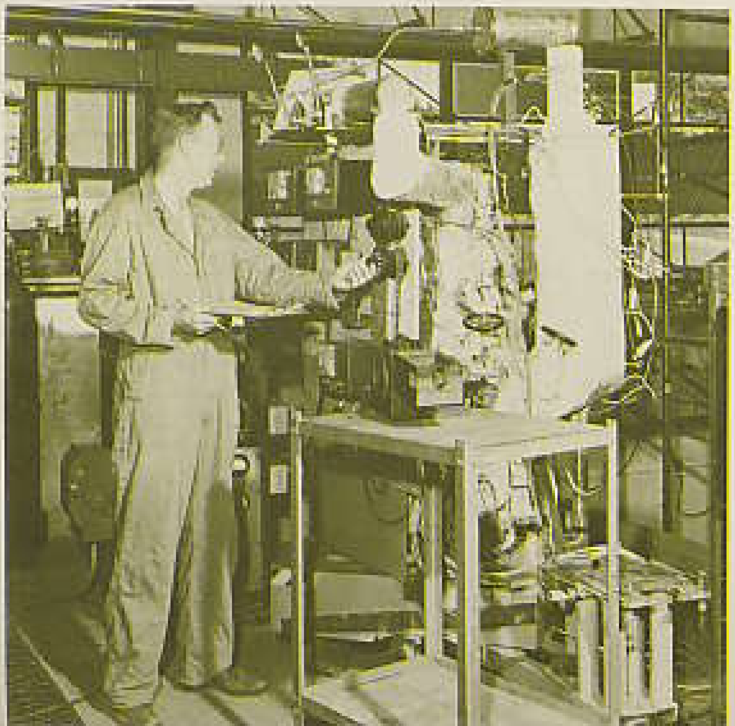
48 **Step-Up Transformers** increase the output voltage to 69,000 volts for transmission into the Edison system. The steam-electric plant and the reactor building are in the background.



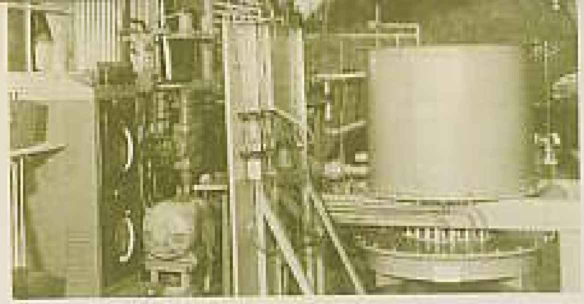


49 **Liquid Sodium Pump**, with a capacity of approximately 1200 gallons per minute and capable of producing a head of 50 pounds per square inch, is installed in a sodium test loop to determine the pump's characteristics and to study the performance of its sodium freeze seal and its lubrication system. The test loop is also used to simulate the reactor heat transfer system. Other components tested were flow meters, plugging meters, pressure gages and cold traps. (In the background is the SRE component test tower. An operating platform on the test tower corresponds to a reactor operating floor. Below this level are cleaning cells and a heated pipe containing sodium. A fuel handling cask is suspended from a carriage which traverses the work area and permits a fuel element to be inserted into the desired cell.)

50 **Sodium Test Pot** for testing of reactor components in liquid sodium at operating temperatures. The test in progress is part of a program for development of liquid-sodium level indicators.



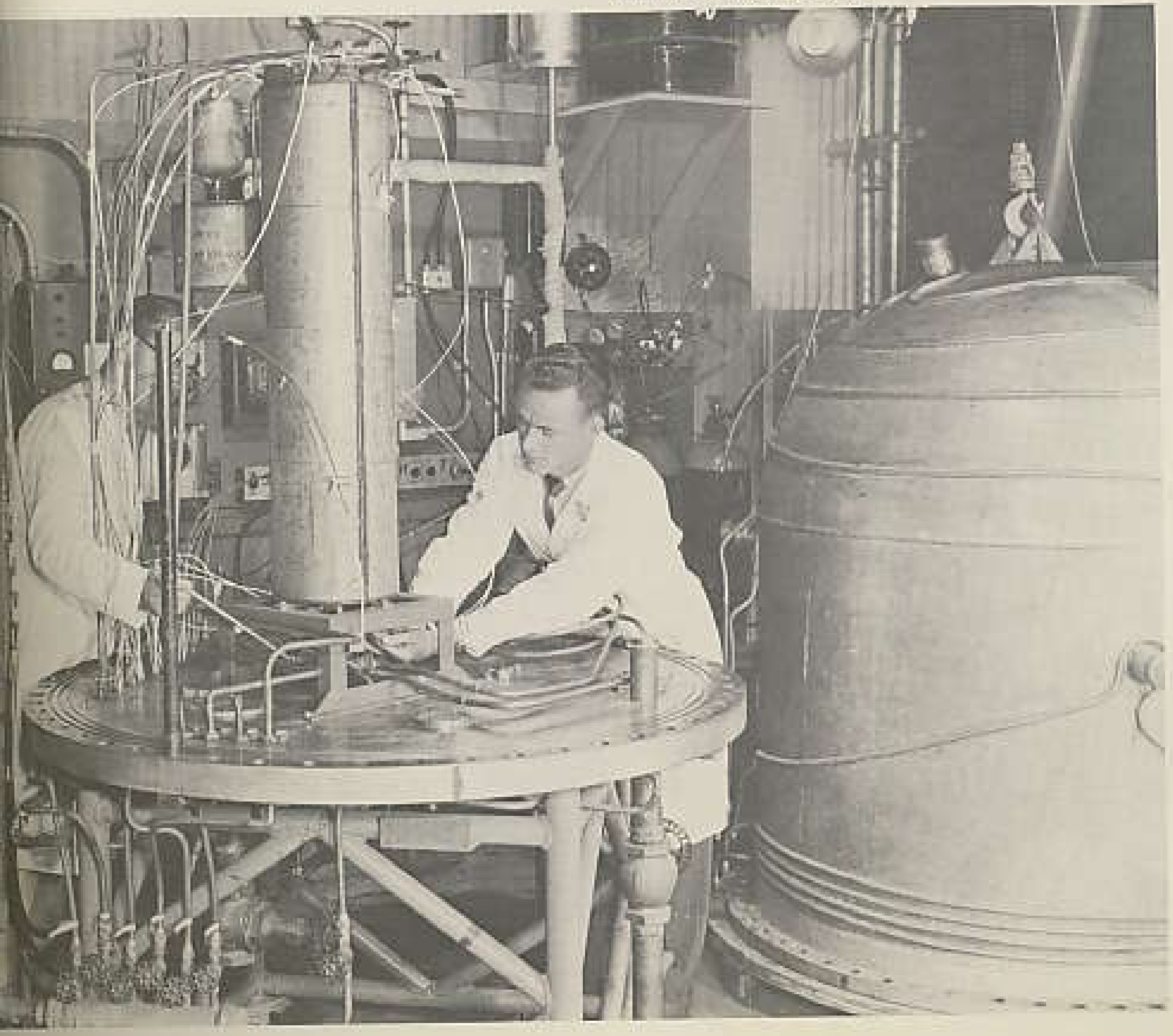
The SRE research and development program is intended to expand the area of information covering sodium-graphite technology. Primarily, the aim is to experimentally demonstrate the reliability of reactor components, to extend their performance limits by design variations, and to apply the information developed to further improvements of the SRE.



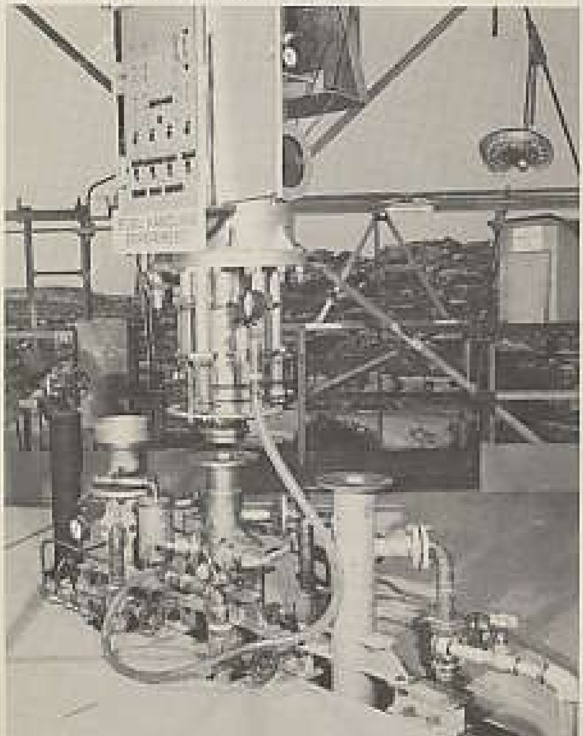
51 **Hydraulic Experiment.** A scale model of the reactor core tank was used to determine coolant flow patterns and pressure drops in the reactor core, employing heated water to match the Reynolds number of liquid sodium.

research and development

52 **Control Element Heat Transfer Experiment,** performed to determine the rate of heat transfer from the neutron absorber rings, to assure adequate cooling. A gastight tank surrounds the apparatus.



53 **Fuel Element Handling Experiment**, located on the operating platform of the component test tower. Typical reactor operations were carried out and the performance of the equipment evaluated. Prototype fuel elements were inserted into the molten sodium in a fuel channel and were removed for cleaning by use of the remotely-operated cask.



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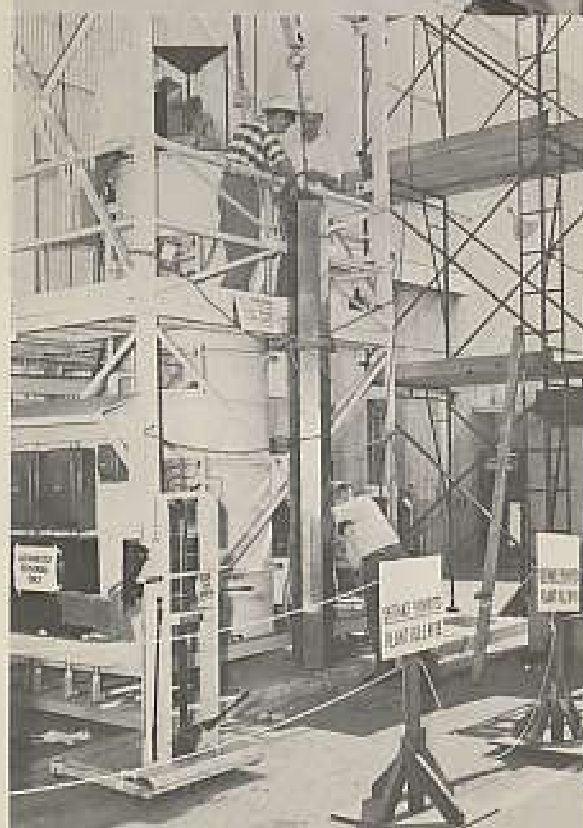

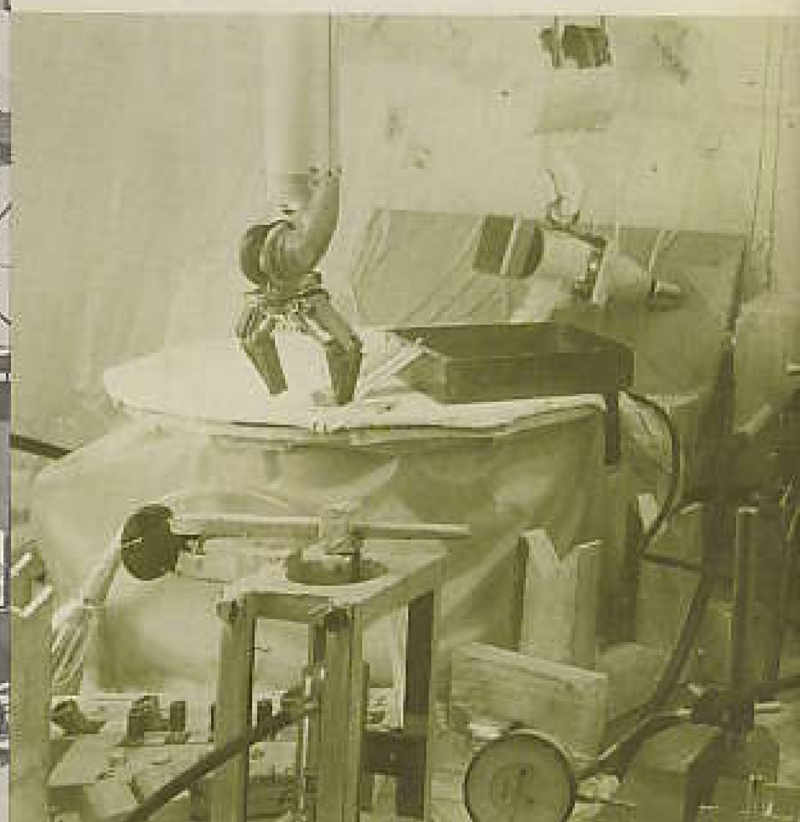

54 **Moderator Assembly Test Furnace** used for vacuum annealing of zirconium and for performing outgassing experiments on graphite to determine pick-up of gases by zirconium. Men are engaged in the removing of zirconium cladding after completion of a test.

R

research and development

E

55 Interior View Of An SRE Hot Cell during an experiment where irradiated fuel samples of various types of uranium alloys were examined to determine dimensional change due to radiation damage.

56 Hot Cell Manipulators. The operator observes the experiment through 42 inches of lead-glass plates. The hot cell, located below floor level at one end of the reactor room, is equipped with three sets of manipulators and viewing windows, and provides a facility for the examination of any radioactive components removed from the reactor.

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