NUCL-13-70-55

Construction of the SRE Core

Here's how the core of the Sodium Reactor Experiment is being built. Description of the arrangement of the fuel, graphite, sodium flow, and core enclosures provides background for understanding the methods used to make the zirconium-canned moderator-reflector units

By R. L. OLSON
Nuclear Engineering & Manufacturing Department
North American Aviation, Inc.
Downey, California

INTENDED AS a 20-Mw (heat) pilot prototype for power reactors of the sodium-graphite type, the Sodium Reactor Experiment is being built at Santa Susana, California. It is scheduled for testing in 1956. Use of graphite moderator and sodium coolant, together with the need for interchangeability of experimental core components, results in a subdivided core in which low-enrichment uranium-metal fuel rods are located in the core assembly as shown in Figs. 1 and 2.

To limit the amount of graphite that could absorb any sodium that might leak through a thin-walled fuel-channel, the graphite assemblies are individually canned as shown in Fig. 3. These moderator-reflector units can be removed from the core and replaced with alternate experimental units.

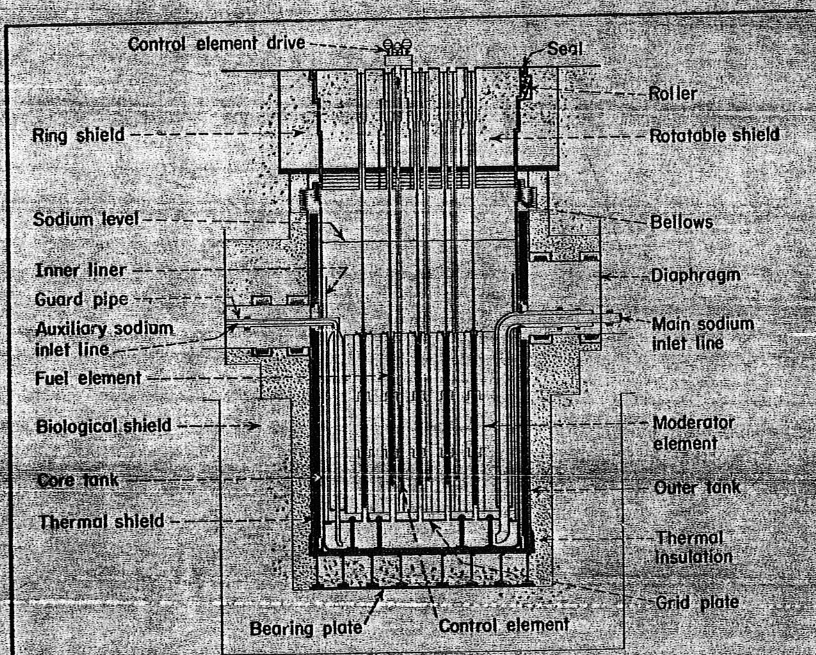

FIG. 1. SRE core, showing arrangement of fuel, moderator-reflector cans, coolant flow, containers, and control drives. Drive mechanisms fastened to outside of loading face actuate control elements through shield plugs, which form upper end of control-element thimbles. Both the core tank and outer tank assembly are welded, gastight, to upper shield through large stainless-steel bellows that accomodates vertical expansion of tanks. Two gallery seal boxes extending from outer tank assembly at level of sodium piping complete secondary envelope around expansion sections in upper portion of downcomer assemblies and discharge piping

Fuel, moderator, reflector. The 6-ft-long fuel rods, which are suspended in assemblies from plugs in the top shield, hang within as many as 57 zirconium tubes lining the inside of vertical holes through the centers of the graphite moderator stringers. Thimble tubes for control and safety elements extend downward from the top shield and fit into 17 3.21-in.-i.d. channels formed by the scalloped corners of three adjacent moderator cans.

The moderator volume is 6 ft high, 6 ft in diameter, and is surrounded by a graphite reflector 2 ft thick. Thus, over-all dimensions of the graphite assembly are 10 ft high by 10 ft in diameter. This moderator-reflector core assembly consists of 91 vertical hexagonal graphite prisms or "stringers" and 28 stringers that are less than full hexagons, as shown by Fig. 2. Each hexagonal stringer is about 11 in. wide across the flats and is "canned" in a zirconium sheet-metal envelope.

Between the reflector and the core tank is a type-304 stainless-steel liner that serves as a baffle to reduce temperature gradients along the tank wall.

Coolant flow. Sodium coolant at 500° F enters the core from downcomers into the plenum in lower head of core tank. It flows upward through fuel channels and into discharge pool above core. A smaller downcomer pipe supplies sodium to underside of core from where it flows upward in control channels and clearance spaces between cans. About 1,200 gpm of Na passes through the core; its mixed mean outlet is at 960° F. The inlet downcomers are concentric doublewalled pipe assemblies; the outer pipe is welded to the core tank wall; the inner sodium pipe joins the external sodium system just above upper reflector. A gas-filled annulus thermally insulates inlet sodium from sodium in core. There are a minimum number of critical welds in the sodium system at the core.

Reactor enclosures. The 49,000-lb type-304 stainless-steel core tank, which contains the moderator-reflector assemblage, fuel, and sodium coolant, has a 1½-in. wall and is 18 ft 10⅜ in. high with an 11 ft i.d. Its flat lower head supports a grid plate, which in turn supports the canned graphite.

The core tank is supported from below by the outer tank assembly, a flat-bottomed low-alloy steel (SA301 Grade B) vessel that provides a secondary envelope around the core. Shear lugs inside the bottom of the outer tank engage a slotted skirt on the core tank and allow for radial expansion while fixing the location of the core tank. Seven mild-steel rings, 138 in. i.d. by 5½ in. thick with a total weight of about 176,000 lb, stacked in the annulus between the core tank and the outer tank serve as thermal shields.

The outer tank is supported on a series of concentric cylinders that carry the core loads from the bottom of the core tank to circular bearing plates bolted to the reactor foundation slab. The cavity formed by the concrete foundation slab and side shield is lined with ¼-in. mild-steel plate. Actually, a core cavity-liner vessel with attached cooling coils is erected on the foundation slab and the side-shield concrete is poured against it. The spaces between the sides and bottom of the outer tank assembly and the cavity liner are filled with thermal insulation blocks.

Installation of the ring shield and loading-face shield completes the core enclosure. The underside of the loading face shield has a series of parallel, stainless steel, reflective-insulation sheets. All concrete facing the core contains cooling coils.

Fabrication

The methods used for making the zirconium hexagonal cans result from the close tolerances on the cross-section dimension, the limited width of the zirconium sheet readily available, and the desire to minimize cost and development time for tooling.

When tool fabrication was started, the tolerance on width across flats was

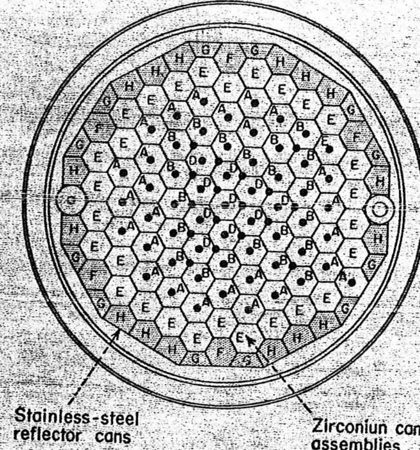

FIG. 2. Core arrangement of 86 zirconium-can graphite units of four types and 33 stainless-steel-can units of three types. Stainless-steel cans are used in outer reflector region where steel's greater neutron-capture cross-section does not appreciably affect fuel-enrichment requirements. Fuel rods hang in holes through centers of hex units; control and safety rods move in channels at corners of three adjacent cans

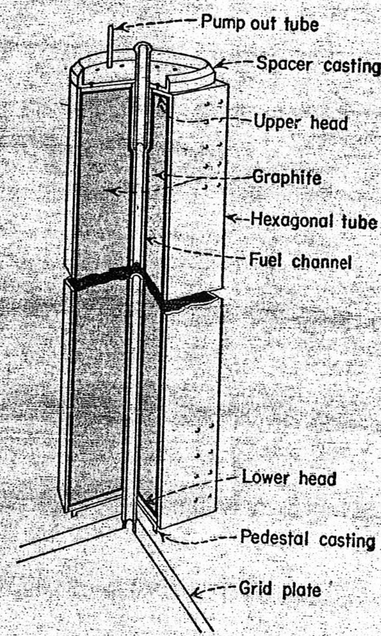

FIG. 3. Type-A can assembly uses a graphite stringer, 0.035-in.-sheet Zr for hexagonal tube, 0.10-in. Zr plate for upper and lower heads, 2.875-in.-o.d. × 0.035-in.-thick Zr tube for fuel channel, ½-in. o.d. × 0.035-in.-thick Zr for pump-out tube used to charge assembly with pressurized helium. Each can is supported on a grid plate by a type-304 stainless-steel pedestal casting, the flange of which is fastened to the lower head of can with 10 studs welded to can head. Upper ends of cans are spaced laterally by similar castings. Without pumpout tube, over-all height of unit is 120⅞₃₂ in.; outside width across flats is 10.872 in. Unit weighs 760 lb, of which Zr is 49 lb. Stainless-steel sheet 0.031 in. thick is used for the hex walls of the outer reflector units

±0.015. Later analysis relaxed this to ±0.026. The close tolerance results from heat-transfer limitations between the graphite and the can wall, and from the need for limiting the flow space between cans.

Experience in forming and welding stainless-steel and titanium sheet for aircraft and missile skins indicates more assurance of complying with design specifications and cost and time criteria if the hex tube of Zr is built by welding together several simple formed shapes rather than by the limited production of more complex shapes having fewer welds. Preliminary tests indicate high-quality zirconium welds can be achieved with available equipment.

Forming the Zr panels. Each hexagonal tube is built up from six separate panels as shown in Fig. 4. Final sizing of the panel is accomplished as shown in Fig. 5. The power brake presses dimples into the panel to insure clearance for sodium flow in case can warps during reactor operation. The straight-break panels are folded in break dies that are heavier than normal.

Building the tubes. The panels are welded into a hexagonal tubular sheath as shown in Fig. 6. Argon shielding gas (16 ft³/hr) is introduced around the electrode and to cover the welded area behind the electrode. A grooved copper chill strip is inserted along the stake top and helium backup gas (3 ft³/hr) is introduced through ports drilled in the botton of the groove. All welds are inspected using both die-penetrant and radiographic techniques.

Assembling the can. Limitations on size of available reactor-grade graphite require that each moderator or reflector stringer be prepared from three blocks. The fuel channel in the center of the graphite block is bored to a diameter of 2.920 +0.010/−0.000 in., machined across flats to 10.755 ± 0.010 in., and the ends are finished selectively to make a 10-ft stringer. Then the stringer is moved horizontally into the hex sheath.

Can heads with attached studs and

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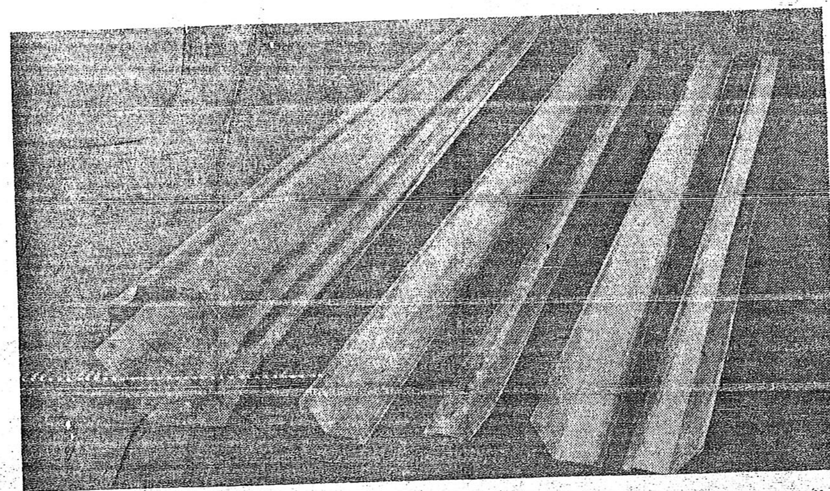

FIG. 4. Zirconium tubes are each built from six pieces made as "straight-break" panels or "scalloped" panels. Panel preparation begins by blanking 0.035-in. stock into strips 6.5 in. wide by 124 in. long. Tool pin holes are punched on ends of blank in sections later trimmed off. After panel is formed at room temperature with profile dies in power break, panel is clamped in stress-relieving fixture accurately machined to desired shape. It is held at 1,040° F for 15 min and permitted to cool in fixture. The slight oxidation is removed by blasting with fine alumina

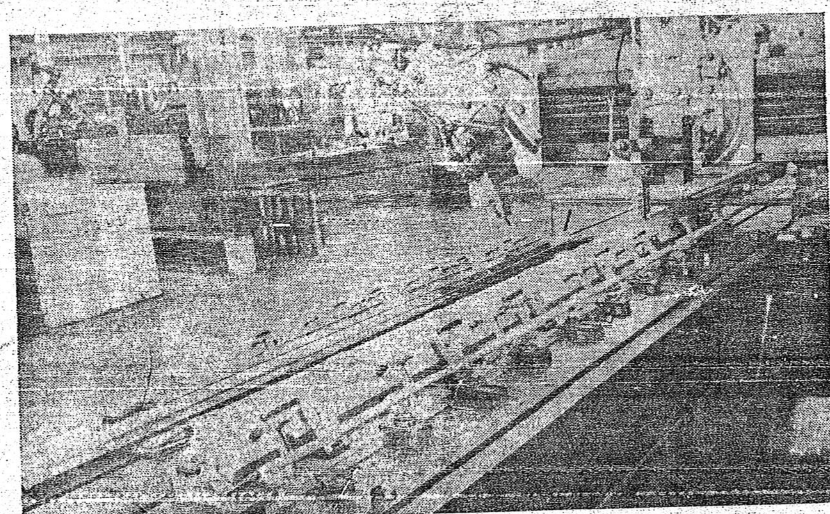

FIG. 5. Longitudinal edges of panels are planed to desired dimension with an alloy steel cutting tool used dry with a 3-deg clearance angle and 67-deg lip angle. Cutting speed of 40 ft/min produces very satisfactory results

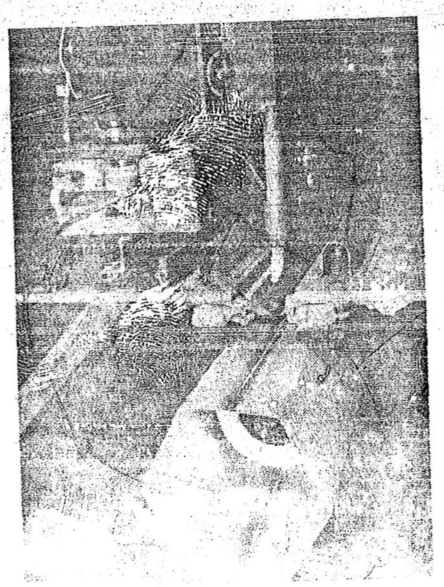

FIG. 6. Fixture and welding machine are used to form six panels into tubular sheath. Edges to be welded are cleaned by lightly buffing with emery cloth and wiping with acetone on an absorbent tissue. First part placed on stake is positioned to weld centerline by indexing planed edge with a locating gage. Mating part is butted to planed edge and held by clamps with 65-psi air. The 10-ft butt welds are made by power-driven automatic welding head moving at 4 in./min while stake or backup bar locates and supports panels and subassemblies. Welder uses tungsten electrode $\frac{3}{32}$ in. in diameter, tapered to sharp point over $\frac{1}{16}$ in. of tip. Starting tabs are either integral extensions of panel or tack-welded in place. High-frequency current is used to strike arc, then cut out as arc voltage is established at 10 volts for 40 amperes d-c, straight polarity. Wide range of settings give sound welds

the fuel-channel tube are fitted and manually welded in place using inert-gas-shielded tungsten arc. The welds joining the heads to the 0.035-in. material are run at about 8 in./min with a current of 60–70 amperes. The assembly sequence and the pumpout tube enable all welding to be backed up by inert gas.

After assembly, the can is leaktested with a helium mass spectrometer. Welds are inspected radiographically and with die penetrant. The completed can assembly is purged with helium, and the pumpout tube is pinched off and sealed by welding. The stainless-steel pedestal and spacer castings are assembled to the can heads using an alignment fixture to assure concentricity, and the stud nuts are secured with lock wire.

Putting cans into core. The moderator-reflector cans will be installed in the tank after installation of the core-tank bellows and ring shield.

After unpacking, final cleaning, and inspection in the reactor building, each can assembly will be lifted by the upper casting, lowered into the core tank, and fitted to the grid plate. The core assembly will proceed from the center and work outward. Careful gaging, checking, and recording of the center-to-center dimension of the units will insure proper fits under all conditions.

When the outermost cans are in place, adjustable locating bars fastened to the inside of the core tank at the elevation of the upper spacer castings will be set to girdle the core assembly. The top shield will be put in place by the 75-ton-capacity coffin-handling bridge and the core enclosure will be completed by sealing the joints.

Pilot production. Presently, we are completing a pilot quantity of cans to prove out or to indicate any necessary changes to the tooling and fabricating processes. This involves every step from material procurement to final assembly and testing. From this it has been determined that about 8,800 lb of zirconium ingot will be needed for cans for one core loading plus several experimental can units.

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Many groups have contributed to the engineering analysis, development, test, design, and careful workmanship for the SRE core. These include the Materials Research and Process Development Group of the Aerophysics Department and the Tooling, Reactor Components and Sheet Metal Departments in the Los Angeles plant of North American Aviation, Inc.