3. Reactor Boiler and Auxiliaries

1. Reactor

2. Calandria Assembly

0.0 INTRODUCTION

The calandria is a complex structure whose basic functions are to contain the moderator and reflector liquids and to serve as the structural form for the whole reactor.

The calandria is a horizontal, cylindrically-shaped, double-walled aluminum vessel which is penetrated axially by 132 calandria tubes and which has a dump port on its lower side. The inner vessel contains the heavy water moderator. The outer vessel contains the light water reflector. The calandria tubes surround the coolant tubes which contain the uranium oxide and heavy water coolant. The end wall assemblies support the inner and outer side walls, calandria tubes, and dump port, support the coolant tube assemblies, and transfer the hydrostatic and hydrodynamic loadings and piping and component reactions to the reactor supports. The dump port provides the liquid-gas interface necessary to support the moderator with a differential pressure and the opening necessary for rapid discharge of the moderator for reactor shutdown. Calandria vessel penetrations such as booster tubes, vertical access tube, neutron windows, and moderator level connections facilitate reactor control.

The calandria is located in the Reactor Vault, Room 203, with its axial centerline at elevation 383 ft. 6 in. in an east-west direction. The end of the calandria at which the reflector pipes enter and leave faces east.

Heavy water is admitted to the moderator vessel from the moderator circuit (DM 321) through the two moderator inlets in the bottom of the calandria, the booster tube in the side of the calandria, and six spray headers in the top of the calandria. Heavy water drains from the moderator vessel to the moderator dump tank through three dump pipes connected to the calandria dump port. A dump vent pipe maintains the helium gas pressure in the dump port equal to that of the dump tank. The moderator is supported in the calandria by the pressure differential which is maintained between the near-atmospheric pressure dump slot and the sub-atmospheric pressure helium balance line by a system of valves and blowers which form a part of the moderator helium system (D.M. 323)

Light water from the reflector circuit (D.M. 341) is admitted to the bottom of the reflector vessel by three internal headers and is removed from the top of the reflector vessel through two internal headers. The reflector is maintained at slightly greater than atmospheric pressure.

The calandria is supported by four reactor support rods (D.M. 314) which transfer the calandria weights and loadings to the reactor vault structure.

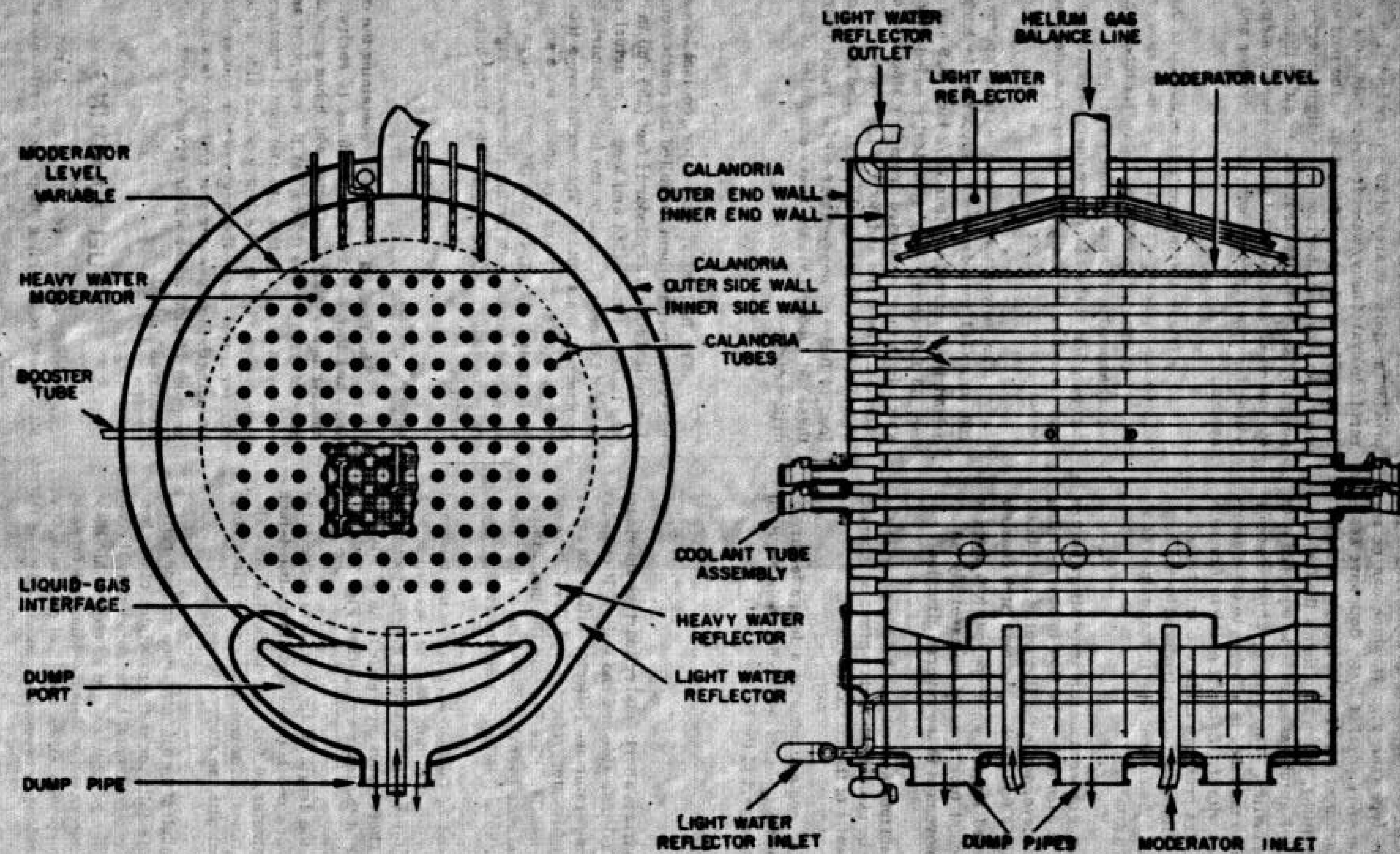


Fig. 8 N P D-2 Reactor Arrangement

OUTER SIDE WALL

PURPOSE:

The outer side wall has two main purposes. First of all, it serves as the outer wall of the light water reflector annulus which surrounds the inner side wall. Secondly, it forms the main axial structural component of the core assembly. It was chosen to be the structural member because it is outside the light water reflector where the thicker aluminum plates required to give it strength do not have any appreciable effect as far as neutron capture is concerned.

GENERAL DESCRIPTION

The outer side wall is made of ½" aluminum (C54S) plate except for a top plate which is 3/4" thick and a keel plate which is 1" thick. The top and keel plates provide extra strength where the large openings of the gas balance line and the moderator dump pipes enter the calandria. The top plate is approximately 17" wide and the keel plate is approximately 38" wide. Both run the full length of the side wall.

OPERATIONAL STRESSES

The outer side wall is stressed by a combination of the following loadings:

1. Internal pressure of light water reflector.
2. Axial loading from reflector pressure reaction on end walls and from inner side wall reaction on end walls
3. Vertical shear and bending movement considering the outer side wall as a beam simply supported at its ends and loaded by calandria, moderator, reflector and fuel weights.

4. Reactor support reaction acting parallel to the calandria axial outerline.

5. Circumferential bending moments transferred from the stiffening rings.

The worst case stresses resulting from combinations of the above are within code allowable stresses.

Heat is generated in the outer side wall by radiation. This is removed by the cooling effect of the light water reflector which flows from three inlet headers at the bottom of the calandria to two outlet headers at the top. Some heat is also removed by the reactor vault atmosphere. The outer side wall temperature is expected to be normally within 1 or 2°F of the reflector temperature.

STIFFENING RINGS

PURPOSE

The stiffening rings support the thin inner side wall, assist in tying the dump port assembly into the calandria structure, and contribute to the rigidity of the calandria structure.

GENERAL DESCRIPTION

There are 11 stiffening rings spaced 12 5/8" apart axially along the length of the calandria structure between the two end walls. They span the radial gap between the inner and outer side walls and at the bottom, between the outer wrapper of the dump port and the outer side wall. They are made of ¼" aluminum plate except at special locations where extra strength is required such as at large openings where they are made of ½" thick plate. They are backed around their outer periphery with a strip of aluminum 1" X ¼". Each stiffening ring is perforated with 14 holes 8" in diameter spaced around the circumference. These holes are to permit cross circulation of reflector water.

OPERATIONAL STRESSES

Each stiffening ring, together with 12" wide circumferential strips of the inner and outer side walls, form a hoop with an "I" shaped cross section. These hoops are subjected to bending moments which produce tension at the inner periphery and compression along the outer periphery due to the differential pressures between the reactor vault atmosphere, the reflector water and the moderator reflector heavy water.

The stiffening rings are immersed in the reflector water and are cooled by it.

PURPOSE

The inner side wall forms the boundary between the light water reflector and the heavy water moderator reflector.

GENERAL DESCRIPTION

The inner side wall is comprised of a center cylindrical section approximately 2' long and two frustra of right circular cones tapering from a maximum diameter of approximately 14' - 8" to a minimum of 12' at the ends giving it a barrel like appearance. Total length of the inner vessel is approximately 12½ feet. The ends were tapered in this way to reduce the volume of D_2O moderator reflector required. The saving was approximately 20,000 lbs., the advantage of which will be partly offset by reduced burnup at the ends of the fuel channels because of a 2 mk. loss in reactivity.

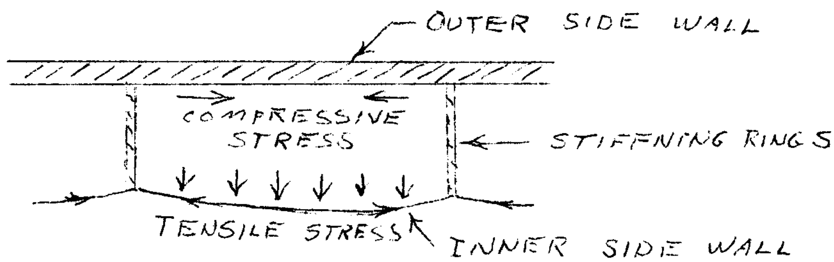
The inner side wall is interrupted at the bottom by the outer dump slot wrapper which forms the bottom wall of the inner volume. The material of the inner side wall is ¼" thick aluminum plate except at places where there are openings through it. At these places it is ½" thick. It is supported within the outer side wall by means of the stiffening rings.

OPERATIONAL STRESSES

The inner side wall is loaded by the external light water reflector pressure and by the internal sub-atmospheric pressure required to support the heavy water. The difference in these two pressures plus differential expansion set up by differences in temperature between moderator and reflector subject the inner side wall plate to varying stresses.

The inner side wall between stiffening rings is a very short large diameter cylinder of very thin ($\frac{1}{4}$") material. Taken as a cylinder subjected to external pressure it is overloaded and would collapse. However, each cylinder is secured at its ends (by the outer side wall and stiffening rings) and these ends are therefore not free to move longitudinaly. This longitudinal movement is necessary for the cylinder to collapse so that in this way the inner side wall is supported by the outer side wall.

Consider an axial element of the inner and outer side wall as shown below:



For an element of the inner side wall the depth to length ratio is very small so the load carried by resistance to bending is very small and was not considered. Tensile strength and resistance to elongation were assumed to provide the entire resistance to external pressure. The combined bending and tensile stress in the region of the supports makes these points the most critical.

The inner side wall is cooled by contact with the moderator and reflector.

END WALLS

PURPOSE

The end walls provide containment for the reflector at the ends and end closures of the calandria to contain the moderator reflector heavy water. They also serve as tube sheets into which the calandria tubes are rolled and as the main radial structural components to position and support the coolant tube assemblies.

GENERAL DESCRIPTION

Each end wall is composed of the following:

(1) An outer end wall of 2" thick aluminum plate. It is roughly circular in shape but distended on the lower end to suit the shape of the calandria dump slot assembly. 132 holes are drilled through the outer end wall on a rectangular lattice of $10\frac{1}{4}$" pitch. It is provided with two lifting lugs near the top which will be used for handling the calandria prior to installation and two projections below the horizontal centerline where the calandria support rods are attached.

(2) An inner end wall of $\frac{1}{2}$" thick aluminum plate to match the outer end wall. The 132 lattice holes are smaller in diameter, however, and there are no lifting lugs or projections for the reactor support rods.

(3) 132 reflector end tubes which span the space between the two end walls as shown in the attached sketch.

The end tubes serve as a penetration through the end walls at each fuel site.

The ring boss shown on the section of reflector end tube serves as a seat against which the calandria tube is rolled in.

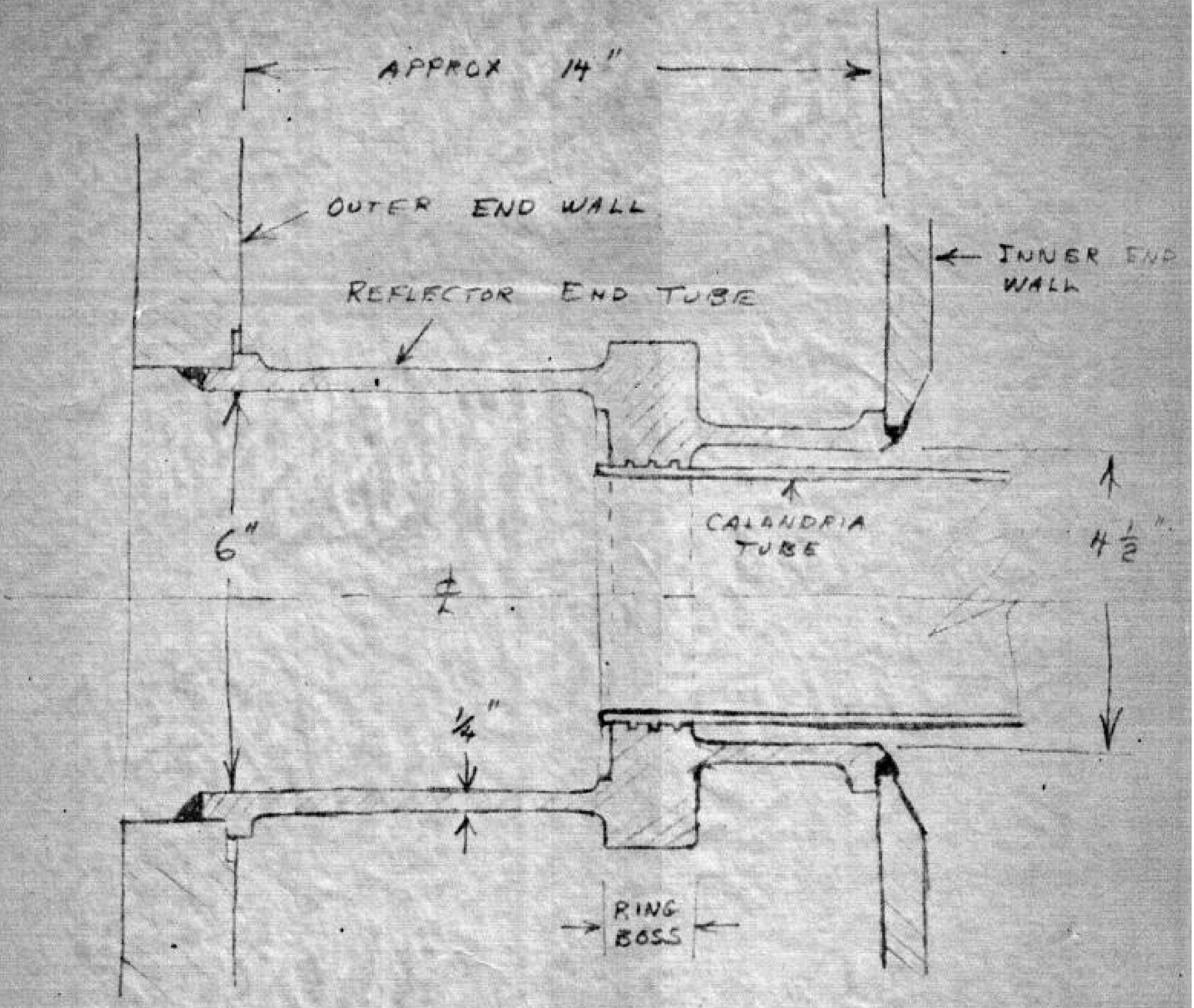
This arrangement has two main advantages. First is the avoidance of dimensional change and subsequent distortion of the inner end wall which would have occured had it been used as the tube sheet. Secondly only about two or three inches of the light water adjacent to the inner side and end walls is effective as a reflector. For this reason, keeping the necessarily heavy rolled-joint ring bosses a few inches out from the plane of the end walls increases the efficiency of the light water reflector.

The reflector end tubes also serve as supports for the thin inner end wall, transferring stresses back to the heavy outer end wall.

(4) Dump slot and inner side wall extensions. These are extensions of the inner and outer wrappers of the dump slot assembly and of the inner side wall. They span the space between the inner and outer end walls to transfer the tensile stresses set up in the inner side wall and dump slot wrappers to the heavy outer end wall.

(5) Shear plates. These are welded between the outer and inner end walls, one at each outer reflector end tube position, except those across the bottom. These shear plates are ½" thick and their purpose is to provide rigidity to the end wall structure. See attached sketch.

(6) The intermediate end wall. This is a series of short plates assembled in the form of a polygon. The plates span the space between the inner and outer side wall and serve as a support to



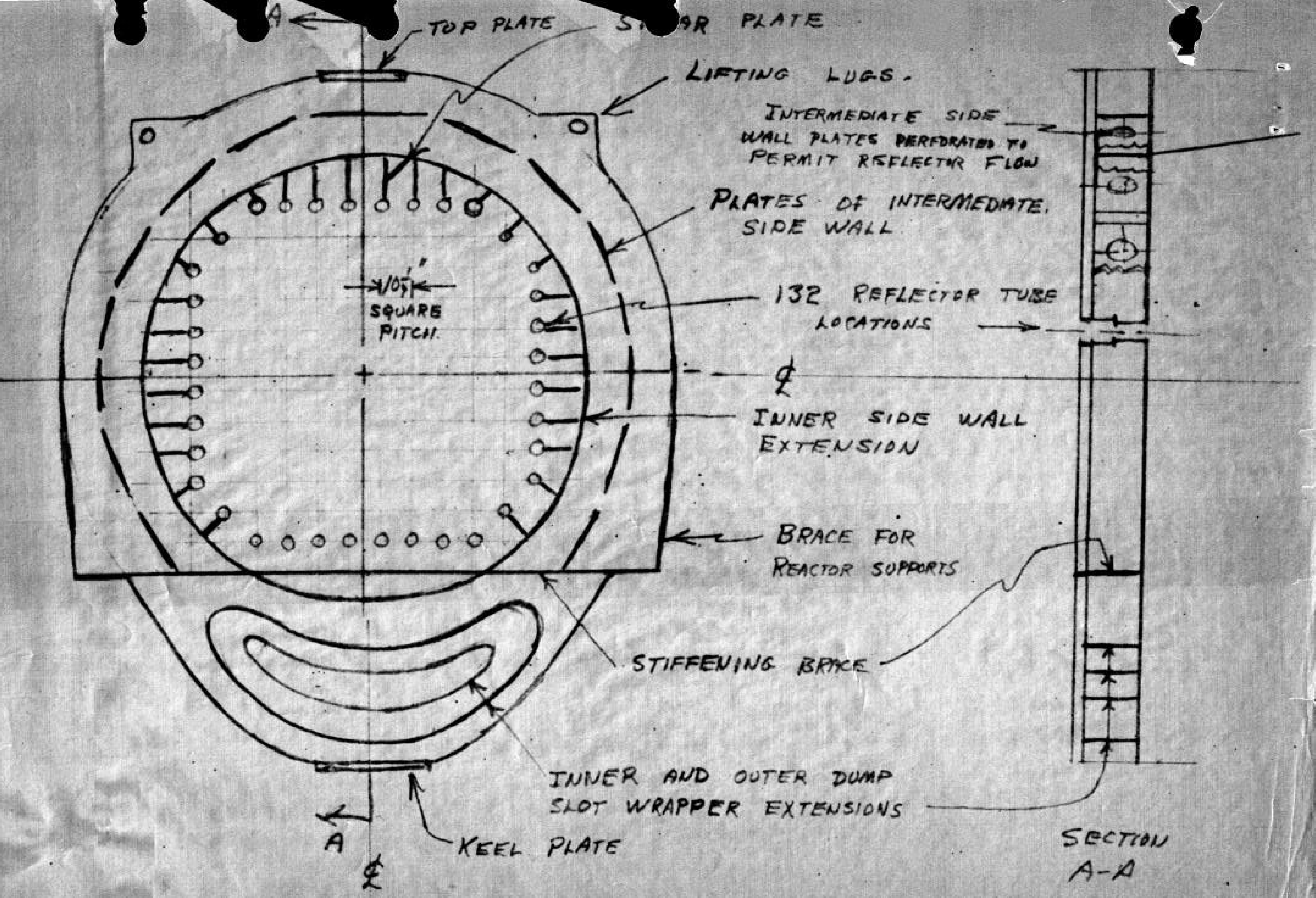
CROSS SECTION OF END WALL AT REFLECTOR END TUBE

NOTE: SECTION AT RING BOSS BETWEEN DOTTED LINES WAS MACHINED OUT AFTER CALANDRIA ASSEMBLY.

the inner side wall around a circumference roughly half way between that of the inner side wall extension and the outer side wall.

(8) A stiffening brace. This brace spans the space between inner and outer side wall and is oriented horizontally across the end wall below the centre line between the support pads. It provides extra strength in the end wall to resist the horizontal components of the support reactions.

A sketch is attached to clarify the relative positions of the various components of the end wall structure.


A
TOP PLATE
LIFTING LUGS.
INTERMEDIATE SIDE WALL PLATES PERFORATED TO PERMIT REFLECTOR FLOW
PLATES OF INTERMEDIATE SIDE WALL
132 REFLECTOR TUBE LOCATIONS
SQUARE PITCH
℄
INNER SIDE WALL EXTENSION
BRACE FOR REACTOR SUPPORTS
STIFFENING BRACE
INNER AND OUTER DUMP SLOT WRAPPER EXTENSIONS
A
KEEL PLATE
℄
SECTION A-A

DUMP ARRANGEMENT

PURPOSE

The dump arrangement provides the D_2O to He interface to support the moderator within the calandria. Also, it provides a large opening (20 sq. ft.) for rapid dumping of the moderator.

GENERAL DESCRIPTION

The dump slot assembly is contained within the distension along the lower side of the calandria. The configuration was designed to minimize as much as possible, the amount of heavy water hold-up.

It consists of an inner section which is built up of eleven ribs ¼" thick spaced axialy on 12 5/8" centerlines. The ribs are located at the same cross sections as the stiffening rings.

An inner wrapper of 3/8" thick aluminum completely encloses this space which is filled with reflector light water. The ribs are relieved at the ends to permit light water to flow from this volume back into the end walls. One of the three reflector inlet headers at the bottom of the calandria enters this section as shown.

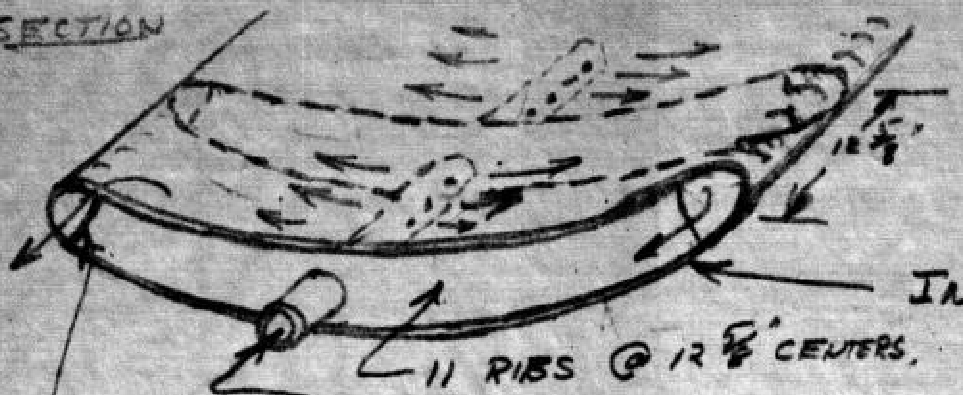
This inner section is surrounded by an outer wrapper which is spaced out from it by eleven outer ribs. These outer ribs are ¼" thick and are spaced 12 5/8" apart on the same sections as the stiffening rings.

All surfaces of the dump slot assembly are in contact on one side at least, with either the reflector or moderator and are kept cool in this way.

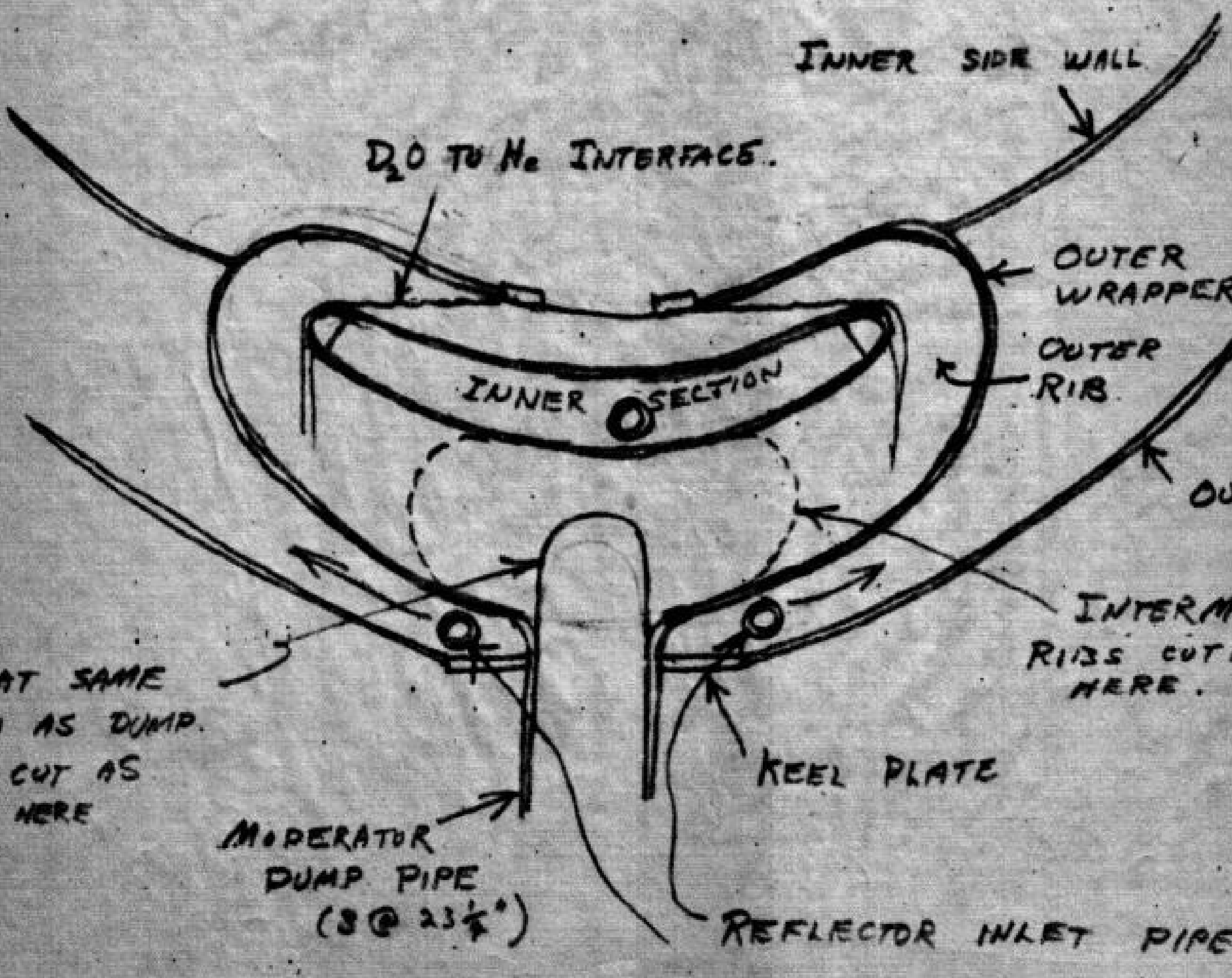
See attached sketch for assembly of the components mentioned above.

Also considered as part of the dump arrangement is the gas balance line which runs from the top of the moderator vessel, through the top plate to the helium system which maintains the differential pressure between the interface in the dump slot assembly and the top of the moderator. It is 16" dia. and is welded to the top plate and the inner side wall where it passes through the reflector. It is located on the vertical center line of the calandria.

INNER SECTION



INNER AND OUTER SECTIONS.
CROSS SECTION AT DUMP PIPE.



CALANDRIA TUBES

PURPOSE

The calandria tubes provide an insulating annular air gap between the coolant tube and the moderator and assist in supporting the coolant tube at its mid point.

GENERAL DESCRIPTION

The 132 calandria tubes are roll expanded into the ring bosses of the reflector end tubes. Rolled joints were chosen so that they could be more easily removed and replaced by remote maintenance methods. After boring the ring bosses out to slightly less than the outer diameter of the coolant tubes, they were pre-rolled to an inner diameter slightly greater than the calandria tubes. This was done to work hard en the face against which the tubes were then rolled. Three annular grooves were machined onto the surface of the ring bosses before rolling. During the roll the calandria tube wall is forced into the three grooves as it is expanded. This feature added to the pull out strength of the rolled joint which consistently exceeded 18,000 lbs. during development.

OPERATIONAL STRESSES

The calandria tube acts as a fixed end beam loaded with the following:

(1) The coolant tube reaction of approximately 115 lbs. at its center point through a garter spring spacer in the air gap.

(2) The uniformly distributed load of its own weight. The tube also acts as a pipe with internal atmospheric pressure and an external pressure depending on the moderator level and the Helium pressure above the moderator.

The calandria is also subjected to the following axial stresses:

1. Tie-tube action of the calandria tubes between the end walls.
2. Stresses induced by differential thermal expansion between the calandria tube and the outer side wall.

The combined stresses due to these loadings must not exceed the code allowable stress. If the combined loading reaches the yield stress of the metal, the tubes will collapse. On this basis, the minimum pressure that will collapse the tubes is 31 psi with the other stresses at their maximum operational values.

The greatest external pressure that can occur on the calandria tubes is on the bottom row at the instant of dump. At this instant the total pressure is equal to the head of D_2O on the tube plus a rapid increase in the helium pressure on the top of the moderator. This maximum pressure has been calculated to be 5.8 psi.

The calandria tubes are cooled by the moderator and may be completely immersed, partially immersed and partially cooled with spray or completely cooled by spray.

SPRAY SYSTEM

PURPOSE:

The spray system cools calandria tubes and inner side and end walls which are not immersed in moderator either during operation or shutdown condition.

The spraying system consists of six pipe headers orientated parallel to the calandria tubes and shaped to conform to the barrel shape of the inner side wall. The headers contain "Fulljet" nozzles for spraying exposed calandria tubes and "Flooding" nozzles for spraying the exposed inner side wall. The "Fulljet" nozzles produce a full cone spray pattern with uniform distribution and the "Flooding" nozzles produce a flat spray pattern with a wide spray angle. The "Flooding" nozzle imparts a low impact velocity to the water which helps it to adhere to the inner side walls.

The two innermost headers each contain seven "Fulljet" nozzles spraying directly onto the calandria tubes and two "Flooding" nozzles spraying tangentially onto the center-top portion of the inner side wall. The two "middle" headers each contain eight "Fulljet" nozzles directed at the calandria tubes. The outer pair of headers each contain eight "Fulljet" nozzles - six directed on the calandria tubes and two at either end directed on both the outer top portions of the inner side wall and the calandria tubes.

The type 304 stainless steel nozzles are all screwed into bosses on the spray headers and locked in place. The spray headers are connected to the calandria at their inlet pipe and at their ends.

The spray headers are fed from the moderator system with a flow totalling 250 IGPM (depends on moderator pressure). The sprays operate continuously during all conditions of reactor operation.

A preliminary design alternative was whether or not to make the spray nozzles replaceable in the event that they would become plugged. The spray nozzles were made a permanent part of the calandria structure for the following reasons: The calandria structure would have been more complex. The filters in the moderator demineralizer system will remove particles of 40 microns and larger; the nozzle orifices are approximately 3/8 inches diameter; therefore, the possibility of the nozzles plugging is very remote. The nozzle spray patterns overlap such that with one or more nozzles plugged adequate spray coverage is still given.

Tube rows beneath the upper row are cooled by the water dripping off the row above (cascading downward).

Extensive development tests were performed on a mocked-up spray system to study the effects of surface cleanliness, nozzle plugging temperature, and calandria tube deflection, on spray and drip distribution. Surface cleanliness affects spray effectiveness significantly. The overlapping of nozzle-coverage areas showed that the plugging of one nozzle was not serious. Temperature variation, within the expected range, had no significant effect. The mid-point deflection of calandria tubes did not cause the dripping coolant to flow to the calandria tube mid-points and starve the tube ends.of coolant.

PURPOSE

The purpose of the coolant tube assembly is to support the fuel in the correct position within the lattice arrangement, to contain the coolant which is held at a pressure of 1236 to 1183 psi and 485 to 530°F, to provide access for fuel changing and adjustment of coolant flow.

COMPONENTS

The main components of the coolant tube assemblies are:

1) Coolant tube of zircaloy, 13'-9" long, 3.250" ID and 0.151" wall thickness
2) Stainless steel end fittings
3) End fitting supports
4) Clamping blocks
5) Garter spring

GENERAL DESCRIPTION

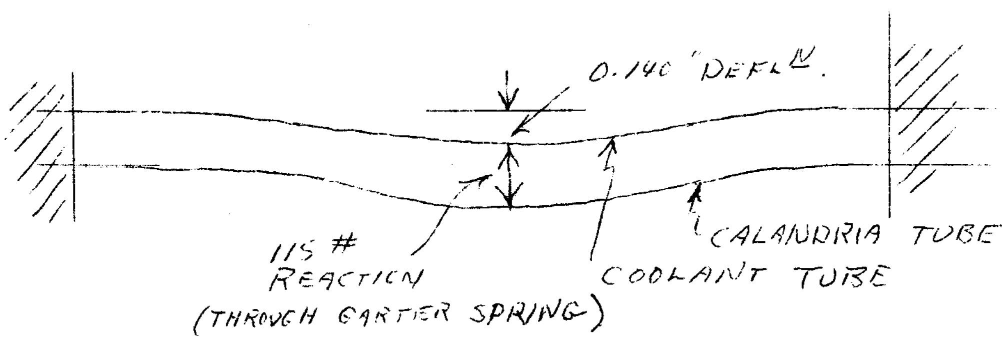
The coolant tubes are rolled into the end fittings. The tube will be rolled into one end fitting and then the tube and end fitting will be installed within the calandria tube. The second end fitting will then be installed and the second rolled joint made in place. A rolled joint between the coolant tube and end fitting was used because of the lack of technology to produce a satisfactory zircaloy to stainless weld.

The assemblies are supported centraly within the calandria tubes at the ends by means of end fitting supports clamped to the reactor face with clamping blocks and at their centre point by means of a garter sping spacer which fills the gap between the coolant and calandria tubes.

The method of supporting the end fittings provides a rigid connection to the heavy outer end wall of the calandria which resists the bending moments within the coolant tube due to its own weight and the weight of fuel and coolant. The rigid connection also transfers the reaction due to expansion of the feeder pipes through the outer end wall to the reactor supports.

For the physical arrangement of the end fittings and supports see the attached sketch.

The coolant tube and calandria tube were, for the purpose of stress analysis, considered as a composite beam with fixed end supports.

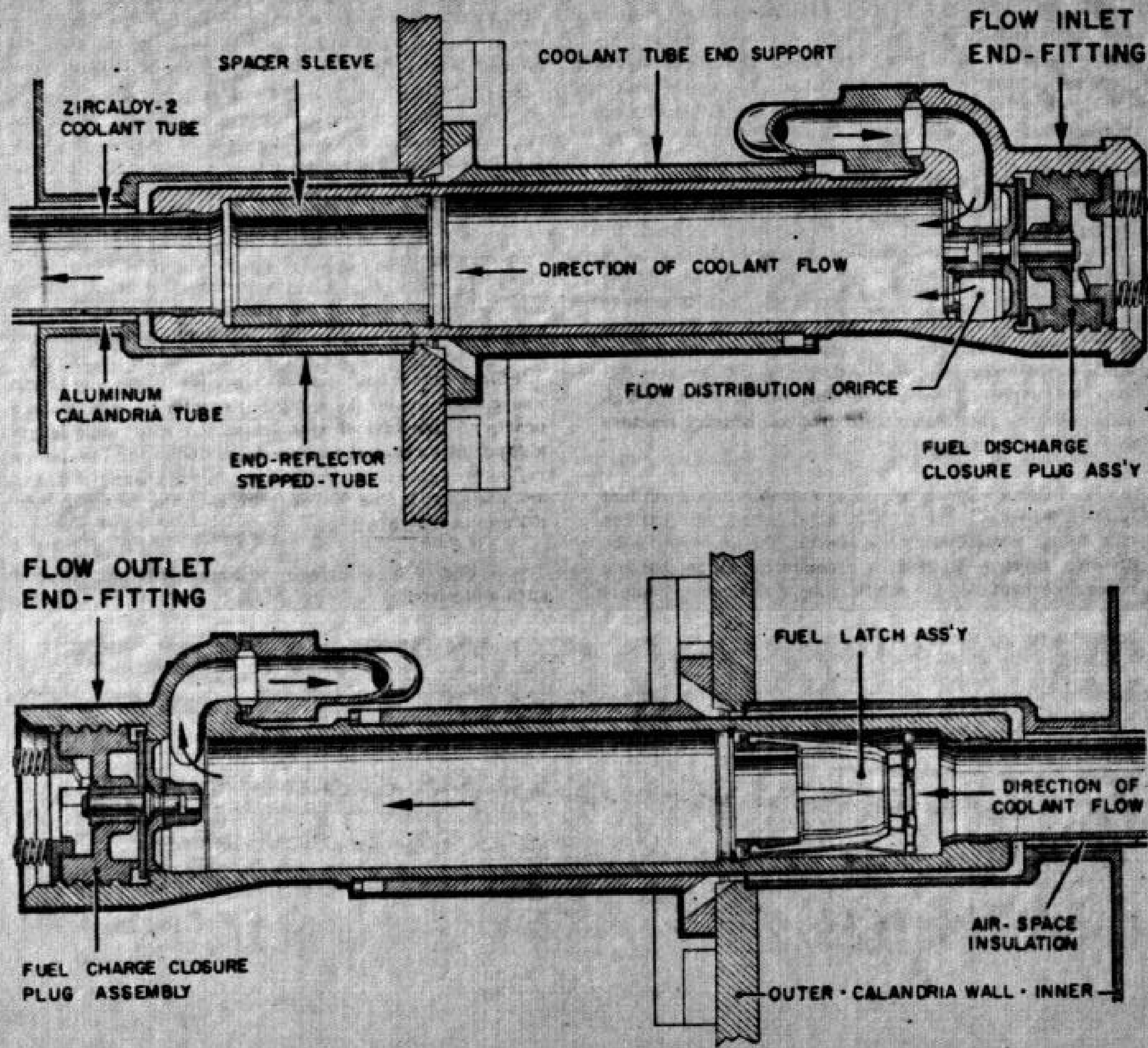


The calandria tube takes part of the weight of the coolant tube through the garter spring space. The total coolant tube, calandria tube deflection is calculated to be 0.140 inches.

Locking rings are installed in annular groves in the end fittings and end fitting supports to locate the coolant tubes axially within the calandria. The coolant tube assemblies are fixed at the east end of the reactor. At the west end, however, the annular groves in the end fitting supports were machined wider than the locking ring to permit growth of the coolant tube to the west as its temperature increases.

The east end was chosen as the fixed end for the coolant tubes since this is also the fixed end for the calandria (see D.M. 314). As the longer feeder pipes associated with the west end of the reactor lengthen the coolant tubes also expand in the same direction, minimizing thermal stress from this source.

The garter spring consists of a toroid of wire of approximately 3/16" cross-sectioned diameter and a major inner diameter of $3\frac{1}{2}$". The wire is of Inconel "X" and is of square cross section .020" x .040". The advantage of the square cross section is that wear on the coolant and calandria tubes is reduced.


FLOW INLET
END-FITTING
SPACER SLEEVE
COOLANT TUBE END SUPPORT
ZIRCALOY-2
COOLANT TUBE
DIRECTION OF COOLANT FLOW
ALUMINUM
CALANDRIA TUBE
END-REFLECTOR
STEPPED-TUBE
FLOW DISTRIBUTION ORIFICE
FUEL DISCHARGE
CLOSURE PLUG ASS'Y
FLOW OUTLET
END-FITTING
FUEL LATCH ASS'Y
DIRECTION OF
COOLANT FLOW
AIR-SPACE
INSULATION
FUEL CHARGE CLOSURE
PLUG ASSEMBLY
OUTER · CALANDRIA WALL · INNER

INLET AND OUTLET HEADERS

PURPOSE

Heavy water is admitted to the moderator vessel through the booster tube, spray headers, and moderator inlet pipes.

GENERAL DESCRIPTION

The moderator inlet pipes pass up through the dump port and terminate just inside the moderator vessel. The moderator pipes are divided for most of their length by a diametral rib which corresponds to and maintains the continuity of the dump port ribs and the stiffening rings.

Heavy water beyond the requirements of moderator level is spilled over the dump port weir and returns to the dump tank.

The objective of the light water reflector inlet and outlet system is to produce a uniform bottom-to-top flow through the annular side and end reflector vessels. This flow is required to remove generated radiation heat and to prevent stagnation corrosion.

Light water enters the reflector vessel through three horizontal inlet headers which run the full length of the calandria. The inlet headers enter the calandria at the bottom of one end wall. Two headers project directly into the reflector space between the dump port outer wrapper and the outer side wall. The flow from these headers travels from the bottom to the top of the annular reflector vessel. The third header jogs up inside the end wall and runs inside the dump port inner wrapper. The flow from this header travels both ways to the lips of the wrapper, down the lips into the end walls and up through the end walls to the top of the annular reflector vessel.

Light water leaves the reflector volume through two horizontal outlet headers which run along the top of the calandria for its full length. These headers leave the calandria through the outer side wall close to the end wall containing the light water inlets.

The flow leaves the inlet headers and enters the outlet headers through two axial rows of holes in each header. The rows are orientated and the holes spaced to give **uniform** flow distribution.

NEUTRON WINDOWS

PURPOSE

The neutron windows allow thermal neutrons to escape from the reacting core for power measurement purposes.

GENERAL DESCRIPTION

The neutron windows consist of three reentrant cans penetrating the outer and inner side walls at three points below the horizontal centerline of the calandria. The centerlines of the cans slope down from the center of the calandria to prevent collection of pockets of water which could dissolve nitrogen oxides from the reactor vault air and form corrosive nitric acid.

VERTICAL ACCESS TUBE

PRUPOSE

A nautron flux approximately 10^{-3} that of the full power neutron flux is required if reactor startup is to be monitored by the power ion chambers. Since this neutron flux will not be available during startup experiments, a vertical access tube has been provided to allow an ion chamber to be inserted directly into the reactor core.

GENERAL DESCRIPTION

The vertical access tube is a long thimble which is inserted on the vertical centerline of the calandria near its center, and which travels the full diameter of the calandria. The vertical access tube enters the calandria through a sleeve welded to the calandria inner and outer walls. The sleeve is fitted with a special "Marman" coupling which holds the vertical access tube in place and which allows the connection of an extension tube which projects up into the Fuelling Machine Room 405.

An O-ring seal between the access tube lip and the sleeve coupling prevents the inleakage of air when the moderator vessel is at sub-atmospheric pressure. The vertical access tube and therefore the rubber O-ring will be in place only during low-flux startup experiments and therefore will not be subject to radiation damage.

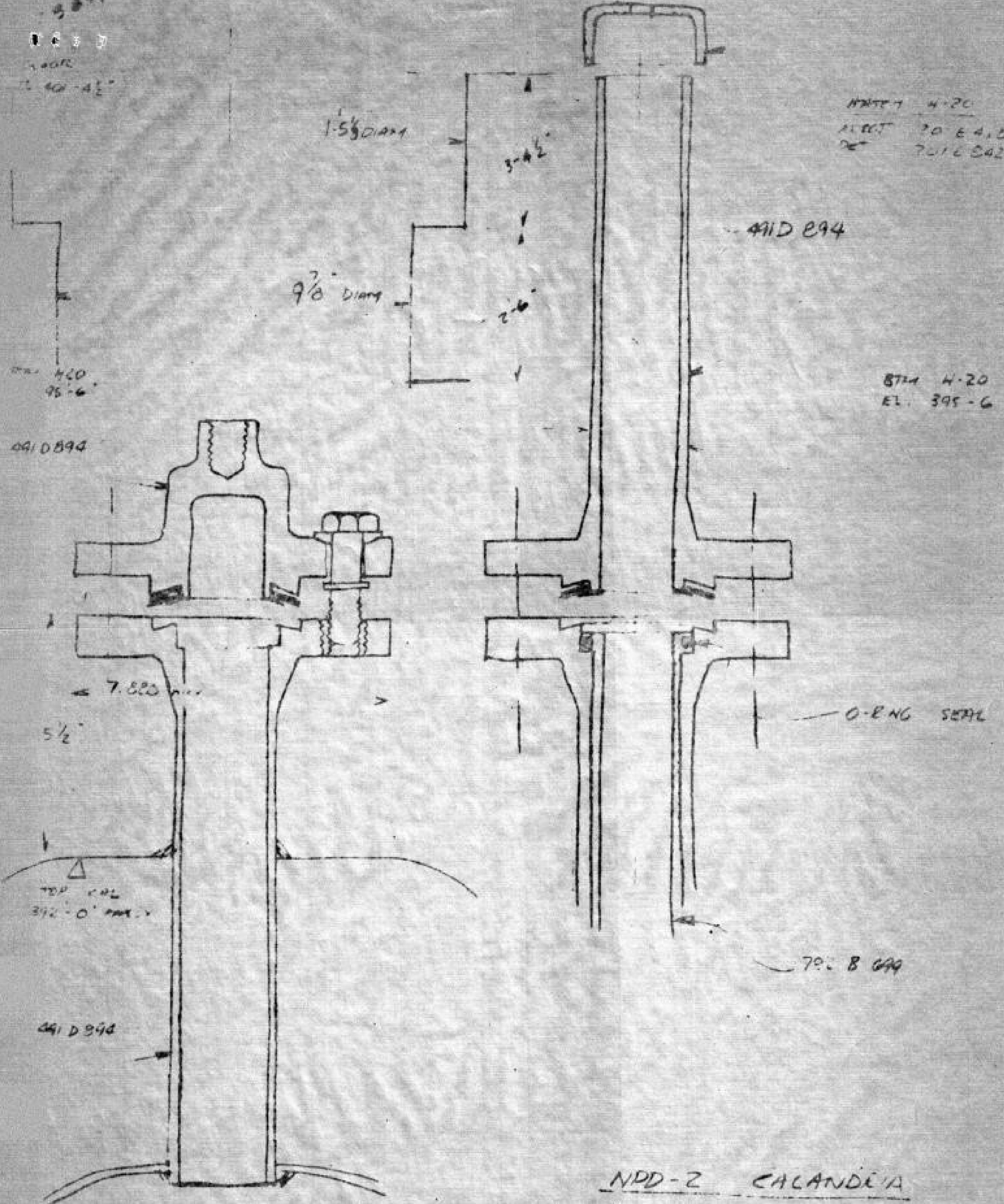
The lower end of the vertical access tube is held in place by a conical sleeve bracket mounted from one of the moderator inlet pipes.

When the residual neutron flux is adequate to permit continual measurement by the power ion chambers, the vertical access and extension tubes will be removed and the sleeve capped with a "Marman" coupling cap. The tube is designed so these operations can be performed remotely.

After removal of the access tube, the vertical access hole will always be available for internal inspection of the calandria.

The vertical access tube is filled with air at atmospheric pressure.

See attached sketch.



NPD-2 CALANDRIA

VERTICAL ACCESS TUBE

DETAILS

SEE DRAWINGS AS REFERENCED.

22 MAR. 61

BOOSTER TUBE

PURPOSE

The booster tube supports and guides and contains the coolant for the booster rod. The booster rod is a fissile assembly which is inserted into the reactor core to increase reactivity.

GENERAL DESCRIPTION

Provision has been made for the installation of two booster tubes, although only one will be installed initially. The booster tube enters the calandria on its horizontal centerline near its mid-point through a sleeve welded to its inner and outer side walls. The booster tube is located axially by a lip on its outer end which fits into and is held by a groove in the female coupling on the booster tube sleeve. The inner end of the booster tube is supported by a bracket mounted on the inner side wall opposite the point of entry of the booster tube. The bracket has a funnel-shaped opening to facilitate entry of the booster tube and an elbow to direct the booster rod covering flow upward into the moderator vessel to make sure that the booster tube is full.

The booster tube sleeve is normally connected by its coupling to the booster tube extension (D.M. 313). The booster tube sleeve which is not in use is closed with a coupling cap.

The booster tube with its method of support and type of couplings is designed for remote replacement.

The vacant booster tube sleeve can be used for internal inspection of the calandria if necessary.

A booster rod cooling flow of 100 IGPM passes through the booster tube and is discharged to the moderator vessel.

VENTS AND DRAINS

PURPOSE

Vents and drains are required to permit complete filling and drainage of both the moderator and reflector vessels.

HEAVY WATER

The space above the heavy water in the moderator vessel is vented by the gas balance line. The space above the heavy water in the dump port is vented by the dump vent.

The moderator vessel is inherently self-draining except for pockets formed by the dump port. Drain pipes are provided from the pockets formed at the center of the moderator vessel where the inner side wall intersects the dump port outer wrapper and from the large pocket formed by the shape of the dump port inner wrapper.

LIGHT WATER REFLECTOR

The many compartments formed by the ribs in the dump port inner wrapper and by the stiffening rings in the annular reflector vessel are all provided with vents and drains. The reflector inlet and outlet headers are equipped with drains at both ends.

All gas is vented from the reflector vessel through the vent on the top of the calandria outer wall which leads to the reflector head tank.

All light water may be drained from the reflector vessel through the reflector drain located on the bottom of the calandria outer wall.

INSTRUMENT CONNECTIONS

PURPOSE

Two instument connections are required to measure the height of heavy water moderator/reflector in the moderator vessel.

GENERAL DESCRIPTION

The top instrument connection enters the inner side wall at the top center of the moderator vessel, travels tangentically through the outer side wall and terminates in a socket-weld coupling.

The bottom instrument connection enters the middle section of the inner side wall just above the inner-side-wall-to-dump-port-outer-wrapper intersection. It then runs radially through the outer side wall and terminates in a socket-weld coupling.

OPERATIONAL LIMITS AND/OR HAZARDS

Allowable Temperatures and Temperature Differentials

Allowable temperatures and temperature differentials in the calandria are based on allowable thermal stresses in the calandria structure.

The calandria tube, inner side wall, and outer side wall all attempt to attain different lengths dependent upon their temperature of operation. If we assume that the end walls are rigid and that the relatively thick outer side wall governs the position of the end walls, then the stress in the inner side wall and the calandria tubes is proportional to the difference between their temperatures and that of the outer side wall.

Heat transfer calculations indicate the following relative temperature differences:

> Outer side wall temperature within 1 or 2°F of reflector temperature. Inner side wall temperature intermediate between moderator and reflector temperatures. Portions of the inner side wall above the moderator surface and exposed to spray cooling may be 3 to 4°F above the intermediate temperature.
>
> Calandria tube temperatures approximately 12°F above moderator temperature when completely immersed or 8 to 10°F above when spray-cooled.

The maximum temperature difference and therefore the maximum thermal stress will occur in the calandria tubes. If we make the reasonable assumption that the combined stresses induced by bending and internal temperature gradients in a half-submerged calandria tube with spray cooling on its top periphery approach 70 percent of the code allowable stress of 6200 psi for Alcan aluminum alloy 57S at 200°F, then the remaining allowable 30% of the code stress could be caused by a temperature difference of 14°F between calandria tube and outer side wall.

Considering the previous metal temperatures and the calandria tube thermal stress allowable differential, then the allowable differential between moderator and reflector becomes -9°F to +23°F, i.e. the reflector temperature can never be more than 9° colder than the moderator temperature but may exceed it by up to 23°F. The moderator and reflector circuits have been designed with this temperature difference in mind.

If emergency conditions necessitate shutting off the spray system when the moderator has been dumped, the difference between the mean reflector and mean coolant temperatures when the spray system is shut off determines the thermal stress imposed on the calandria tubes.

If the difference between coolant and reflector mean temperatures is 35°F, the combined mechanical and thermal compressive stress will equal the code allowable stress of 6200 psi.

If the difference between coolant and reflector mean temperatures is 70°F, the combined mechanical and thermal compressive stress will equal the yield point of 11,000 psi.

If the temperature difference between coolant and reflector mean temperatures is 185°F, the combined mechanical and thermal compressive stress is equal to the minimum ultimate stress of 26,000 psi.

When the yield point is exceeded, some tube deformation may occur. As the ultimate stress is approached, the possibility of the tube failing in compression or of the calandria tube rolled joint pulling out increases.

Under emergency conditions, bringing the reflector temperature to its maximum will reduce the differential temperature between coolant and reflector mean temperatures.

Allowable Pressures and Pressure Differentials

The moderator vessel, reflector vessel, and calandria tubes will withstand, either internally or externally a full vacuum or a pressure of 15 psig.

The maximum allowable pressure differential across the inner side wall, inner end wall, and the calandria tube wall is 15 psi.

The critical external pressure for collapse of the calandria tube is 31 psig. The calandria tube is protected from excessive external pressure by a rupture disc in the moderator helium system designed to fail at 20 psig.

REACTOR CALANDRIA ASSEMBLY

EQUIPMENT DATA LIST

1. CALANDRIA GENERAL

Form: Horizontal Cylinder

Nominal Diameter: 17 ft. 0 in.

Nominal Length: 15 ft. 0 in.

Inner Wall Thickness: Sides $\frac{1}{4}$ in.
Ends $\frac{1}{2}$ in.

Outer Wall Thickness: Sides $\frac{1}{2}$ in.
Ends 2 in.

Calandria Tube Inside Diameter: 4.000 inches

Calandria Tube Wall Thickness: 0.054 inches

Dry Weight per Drawing 201E318: 40,500 lb.

Volume Moderator Vessel: 1721 cubic ft.

Volume Reflector Vessel: 1500 cubic ft.

Center of Gravity per 201E318: 19 $\mp$ 1" below axial at center.

2. OUTER SIDE WALL

Nominal Outside Diameter: 17 ft. 0 in.

Nominal Length: 15 ft. 0 in.

Nominal Depth: 18 ft. 8 9/16 in.

Wall Thicknesses: Top Plate: 3/4"
Side Plates: 1/2"
Keel Plate: 1"

Material : ASTM B 209-58T GR40A-0 (Alcan C54S-0)

3. STIFFENING RINGS

Number: 11

Nominal Spacing: 12 5/8 in. centers

Nominal Outside Diameter: 16 ft. 11 in.

Nominal Inside Diameter: At Center: 14 ft. 8½ in.

At Ends: 12 ft. 6½ in.

Wall Thickness: Nominal: ¼ in.

As Noted: ½ in.

Reflector Circulation Holes: 14 per ring

8 in. diameter

Backing strips: 1" X ¼" approx.

Material: ASTM B209-58T GR40A-0 (Alcan C54S-0)

4. INNER SIDE WALL

Nominal Inside Diameter: At Center: 14 Ft. 8 in.

At Ends: 12 ft. 0 in.

Length of Center Cylinder: 2 ft. 1¼ in.

Length of Cone Frustra: 5 ft. 2 7/8 in.

Nominal Inside Length: 12 ft. 7 in.

Wall Thickness: ¼ in.

Reinforcing Plate Thickness:

At Gas Balance Line: 1 in.

At Neutron Window: 3/4"

At Dump Port and Slot: 1/2"

Material: ASTM B209-58T GR40H-0 (Alcan C54S-0)

5. END WALLS

Nominal Outside: Diameter: 17 ft. 0 in.

Nominal Depth: 10 ft. 2 9/16 in.

Distance Between Outer and Inner Wall: 14 7/8 in.
(to outside faces)

Outer Wall Thickness: Nominal 2 in.

Spot-faced Area: 1½ in. min.

Inner Wall Thickness: ½ in.

Shear Brace Thickness: ½ in.

Inner Side Wall Extension Thickness: ½ in.

Intermediate Side Wall Thickness: ¼ in.

Dump Port Extension Thickness: 3/8 in.

Openings in Inner End Wall to
Reflector Vessel: 26 holes, 6 in. diameter

Inside Diameter of Left Lug Holes: 2 in.

Left Lug Capacity: 48,000 lb. individual direct tensile taking ult. shear = 18,000 psi, factor of safety = 6

End Tube I.D. at Outer Wall: 6 in.

End Tube I.D. at Inner Wall: 4½ in.

End Tube I.D. at Boss: After Machining: 4.050 in.

After Pre-rolling: 4.120 in.

End Tube Wall Thickness: Nominal: ¼ in.

At Boss: 1½ in. approx.

Tube Rolling Grooves: .045 in. wide, .025 in. deep spaced on ¼ in. centers.

Support Stiffening Rib: Length: 12 ft. 3 in.

Width: 12½ in.

Thickness: 1½ in.

Web Plate Thickness: 1½ in.

Support Pad: Thickness: 3 in.

Dowel Holes: 2½ in. diam.

U-Gusset Thickness: 1½ in.

Bottom of Support Pads to Horizontal of Calandria: 63¼ in.

Material: ASTM B209-58T GR40A-0 (Alcan C54S-0)

Threaded Insert Holes: 157 sets of 4 holes located 4 around each lattice position.

Threaded Inserts: Hele-Coil Screw Lock Insert No. 3591 - 14CN x 7/8 in. Tang broken off.

Threaded Insert Material:

6. DUMP ARRANGEMENT

6.1 Gas Balance Line

Nominal Diameter: 14 in.

Inside Diameter at Calandria: 16 in.

Elbow: 14 in. L.R. elbow, .375 in. wall

Flange: Marman Female Flange 53701/B

Bolt Lightening Torque: 10 ft. lb.

Material: Flange ASTM GS11A-T6 (AA 6061-T6)

All other: ASTM B209-58T GR40A-0

6.2 Dump Port

Length of Dump Port: 12 ft. 7 in.

Area Dump Slot: 20 ft^2

Total Area Dump Pipes: 8.85 ft.^{2}

Overall Discharge Coefficient: Within the range 2.1 to 3.5 with the velocity taken as 13.5 ft/sec.

Inner Wrapper Thickness: 3/8 in.

Inner Wrapper Ribs: Thickness: Nominally: ¼ in.
at Dump Pipes: ½ in.

Number: 11

Spacing: 12 5/8 in. centers.

Outer Wrapper Thickness: Top: 1/4 in.

Bottom: 3/8 in.

Outer Wrapper Ribs: Thickness: Nominally: 1/4"

At Dump Pumps: 1/2 in.

Number: 11

Spacing: 12 5/8 in. centers.

Dump Pipes: 23¼ in. inside diam., 0.375 in. wall

Dump Pipe Transitions: Inlet I.D. 31 3/4 in.

Outlet I.D. 23 ¼ in.

Material: ASTM B209-58T GR40A-0 (Alcan C54S-0)

7. CALANDRIA TUBES

Outside Diameter: 4.112 ∓ .008 in.

Wall thickness: 0.054 ∓ .004 in.

Length: 13 ft. 3 in.

Material: ASTM B210-57T* GR 20A- (Alcan 57S-H12)

8. SPRAY SYSTEM

Total Capacity: 272 IGPM

Headers: Number: 6

Size: 1½ in. sch. 40 pipe

Overall Length: 12 ft. approx.

Header Spacing: 10¼ in.

Approximate Nozzle Spacing: 20 in. approx.

Material: ASTM B235 58T-GR40A-0

Calandria Tube Nozzles:

Type: Spraying Systems Co. "Fulljet" Nozzle 3/4"in. HH 7 (5.84 IGPM)

Rated Capacity 7 USGPM at 7 psig header pressure.

Conical Spray Included Angle: 89° at 7 psig.

Total Number Installed: 46
Material: Type 304 Stainless Steel

Inner Side Wall Nozzles:

Type: Spraying Systems Co. "Flooding" Nozzle 3/4 in K120

Rated Capacity: 10 USGPM (8.33 IGPM) at 7 psig header pressure

Flat Spray Included Angle: 120°F.

Total Number Installed: 4

Material: Type 304 Stainless Steel.

9. INLET AND OUTLET HEADERS

9.1 Moderator Inlets

Number: 2

Size: 6 in. sch. 40, 56 in. long.

9.2 Reflector Inlets

Number: 3

Size: 4 in. sch. 40

Flow Distribution Holes:

Reflector Header: 2 rows of 84 - 3/8 in diam. holes per header

Dump Port Inner Wrapper Header: 2 rows of 73 - 3/8 in diam. holes per header.

9.3 Reflector Outlets

Number: 2

Size: 6 in. sch. 40

Flow Distribution Holes: 2 rows of 94 - 1/2 in diam. holes per header.

10. VENTS AND DRAINS

10.1 Moderator Vents

Dump Vent Pipe: 1½" dia. Extra Strong, 27 in. long.

Dump Vent Pipe Cap: 2 in. std. welding cap.

10.2 Moderator Drains

Dump Port Inner Wrapper: 3 - 3/4 in Extra Strong pipes, 10 1/8 in. long.

Inner Side Wall - Dump

Port Inner Wrapper: 2 - 3/4 in. Extra Strong Pipes, 16½ in. long.

10.3 Reflector Vents

Main Vent: Socket weld coupling for 1 in. pipes

10.4 Reflector Drains

Main Drain: 6 in. sch. 40 pipe 4¼ in. long

Inlet Header Drain: 2-3/8 in. diam. holes per header

Outlet Header Drain: 2 - ½ in. diam. holes per header.

11. NEUTRON WINDOWS

Location: Horizontal: 45 in. below

Vertical: 38 in. centers, offset 6 in. toward reflector inlet end of calandria.

Inside Diameter: 8½ in.

Nominal Length: 41 7/16 in.

Distance from End of Window to Vertical Calandria: 52 in.

Wall Thickness: ¼ in.

End Plate Thickness: ¼ in.

Axis Slope: $\frac{1}{2}^{\circ}$ down from calandria

Material: ASTM B209-58T GR40A-0 (Alcan C54S-0)

12. BOOSTER TUBE

Location: On calandria horizontal , 15 in. either side of traverse

Number: Installed: 1

Provision for: 2

Sleeve: Inside Diameter: 3.093 in.

Overall Length: 11 ft. 6 in.

Flange: Marman Male Flange 54321 with Marman Gasket 54052-3-5

Cap: Size: $3\frac{1}{2}$ in. O.D., **drilled hole in end for handling**

Flange: Marman Male Flange 54321 with Marman Gasket 54052-3-5

Material: Flanges and Bolts: ASTM GS11A-T6 (AA6061T6)

Flange Gasket: ASTM GS11A-0 (AA 6061 0)

All other: ASTM B210-58T GR40A-0 (Alcan C54S-0)

Lightening Torque for Marman Coupling:

Bolts: 800 in-lb.

14. INSTRUMENT CONNECTIONS

Size: Top: 3/4 in. Extra strong Pipe, 57 in. long.

Bottom: 3/4 in. Extra strong Pipe, 24 in. long.

Material: ASTM B235-58T GR40-A0 (Alcan C54S-0)

Sleeve: Outside Diameter: 3.596 in.

Length: 21½ in.

Flange: Marman Female Flange 55282

Projection Beyond Calandria Outer Wall: 3¼ in.

Tube: Inside Diameter: 2 3/4 in.

Outside Diameter: 3 in.

Length (including lip): 15 ft. 7 in.

Lip: 3.245 in O.D. pts. inside Marman Flange.

Cap: Marman Male Cap Flange 55283 with Marman Gasket 54052-3-5

Materials: Flange and Cap: ASTM GS 11A-T6 (AA6061-T6)

Gasket: ASTM GS 11A-0

All other: ASTM B209-58T GR40A-0 (Alcan C54S-0)

13. VERTICAL ACCESS TUBE

Lacation: On calandria vertical centerline, 19 in. to the west side of the lateral centerline.

Depth of Penetration - Approx. 15'

Sleeve: Size: 3 in. diam. sch. 40

Projects 5½ in. above top of calandria

Overall Length: 22 in.

Flange: Marman Female Flange 54322

Access Tube: Inside Diameter: 2 3/4 in.

Wall Thickness: 1/8 in.

Length: 15 ft. 4 in.

End Cap Thickness: 1/4 in.

Lip Outside: Diameter: 3.497 in.

Access Tube O-ring: Parker #2-236 Compound 47-74-1

Extension Tube: Size 3 in. sch. 40 pipe