NUCLEAR ELECTRIC G.S. TECHNICAL TRAINING COURSE

5 - NPD Systems

3 - Reactor Boiler & Auxiliaries

1 - Reactor

0 - General

0.0 INTRODUCTION

This lesson will deal with the physical components of the reactor only. The theory of operation of the reactor will be covered in other lessons.

1.0 INFORMATION

1.0 General

The design of the NPD reactor in general embodies the following features:

1. A horizontal cylindrical construction.
2. An unpressurized heavy water moderator.
3. A pressurized heavy water coolant.
4. Unpressurized, aluminum calandria tubes.
5. Pressurized, reactor coolant tube of zirconium alloy.
6. On-power refuelling from opposite ends of fuel channels.

There are a total of 132 fuel channels. Each fuel channel constitutes a lattice position. The fuel channels are spaced on a square lattice having a pitch of 10¼ inches, that is the distance from the center of one channel to the other.

The fully loaded reactor weighs approximately 200 tons.

1.1, Calandria

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 cylindrical aluminum alloy vessel with double side and end walls. It contains the heavy water moderator and reflector within the inner walls, and the light-water reflector and shield between the inner and outer walls.

The calandria is penetrated axially by 132 aluminum calandria tubes. The pressurized coolant tubes are centrally located within the calandria tubes.

The calandria is provided with a dump port on its lower side which provides a minimum area of 20 square feet for rapid removal of heavy water from the calandria. The port arrangement also provides the gas liquid interface which supports the heavy water moderator.

The calandria is located in the reactor vault, Room 203. It is positioned such that its axial centerline is in a east-west direction.

The total weight of the fully loaded calandria is supported by hanging the calandria structure from four 3½ inch diameter steel rods. The rods are 13 feet long. The rods are carried from four steel columns anchored to the walls and floor of the reactor vault. The support rods are fastened to the calandria in such a manner that the North-East corner of the calandria is rigid but the other three corners of the structure are free to move at the support plates where the support rods are fastened. This was done to allow thermal expansion of the reactor components during operation.

The outside diameter of the calandria is 17 feet, but including the dump assembly it is 19 feet.
The length from end fitting to end fitting is 15 feet.

1.1.1 Side Walls

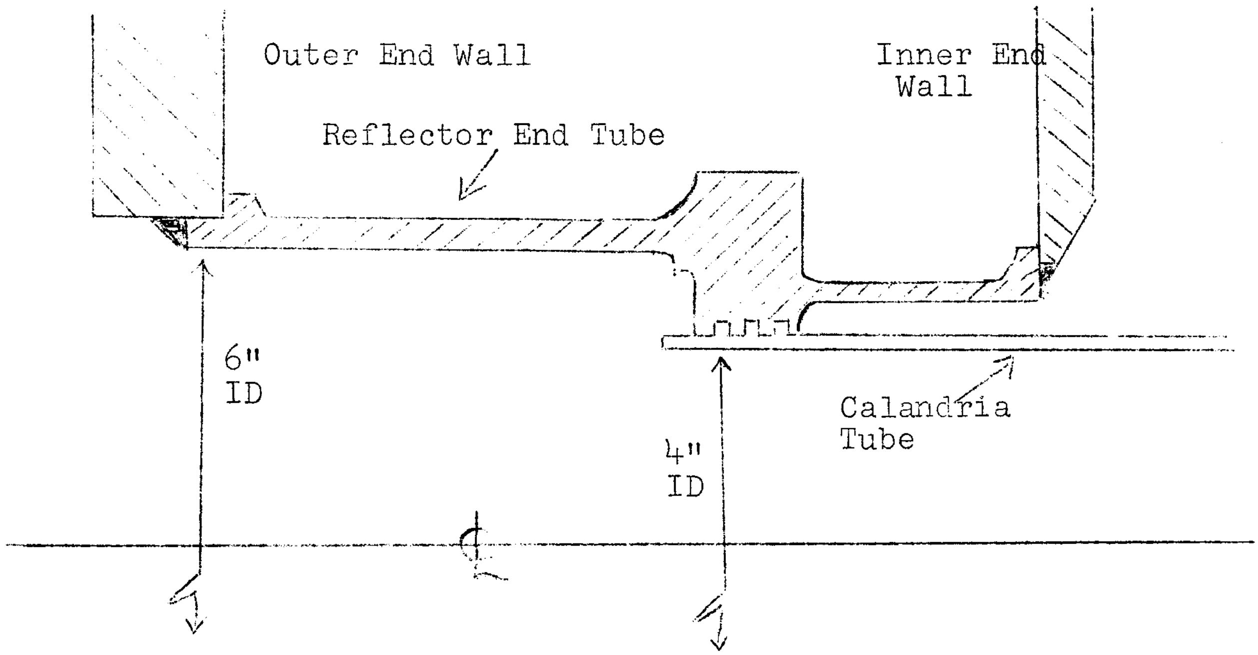
The outer side wall of the calandria is made of ½ inch aluminum plate. It forms the outer wall of the light water reflector annulus and forms the main structural component of the reactor core assembly. Heat is generated in the outer side wall by radiation. This heat is removed by the light water reflector and the vault ventilation system.

The inner side wall of the calandria is made ¼" aluminum plate. It forms the boundary between the light water reflector and the heavy water moderator. The vessel formed by the inner side wall has a maximum diameter of approximately 15 feet tapering to a minimum diameter of 12 feet at each end giving it a barrel-like shape. This was done to reduce the volume of heavy water moderator-reflector required. The inner side wall is cooled by contact with the moderator and light water reflector.

A number of stiffening rings are used between the inner and outer walls to give rigidity to the calandria structure. The rings have holes in them to permit cross circulation of reflector water.

1.1.2 <u>End Walls</u>

The outer end walls of the calandria are made of 2 inch thick aluminum plate. While the inner end walls are of $\frac{1}{2}$ inch aluminum plate. The end walls serve as tube sheets into which the calandria tubes are rolled. The outer end walls form the main radial structural components of the calandria and also support the coolant tube assemblies. There are 132 reflector end tubes which span the one foot space between the outer and inner end walls. These end tubes serve as a penetration through the end walls at each fuel site; See Figure I.



Cross Section of End Wall
at Reflector End Tube

<u>Figure I</u>

The ring boss shown on the section of reflector end tube serves as a seat against which the calandria tube is rolled in. The reflector end tubes, in this manner, serve as supports for the thin inner end wall, transferring stresses back to the heavy outer end wall.

1.1.3 Calandria Tubes

Spanning the length of the calandria between the inner end walls are one hundred and thirty two 4 inch aluminum calandria tubes. The ends of the tubes are rolled into the reflector end tubes. Rolled joints were chosen so that they could be more easily removed and replaced by remote maintenance methods.

The net result of the calandria and end reflector stepped-tube installation is the provision of one hundred and thirty-two horizontal holes completely through the calandria. The coolant tubes are located within these holes and are centralised within the calandria tubes by internal annular spacers at the centre of each tube. An air space is provided between the coolant tube and the calandria tube to insulate the moderator from the hot coolant.

1.1.4 Coolant Tube Assembly

The purpose of the coolant tube assembly is:

(a) To support the fuel in the correct position within the lattice arrangement.
(b) To contain the pressurized heavy-water coolant.
(c) To provide access for fuel changing.
(d) To provide means of adjusting the coolant flow.

The main components of the coolant tube assembly are:

(a) The coolant tube of zircaloy, 13 feet 9 inches long having an ID of $3\frac{1}{4}$ inches.
(b) The stainless steel end fitting.
(c) The end fitting support and clamping block.

The end fitting supports are clamped to the reactor outer end wall with the clamping blocks. The end fittings are then mounted in the end fitting supports and the coolant tubes rolled into the end fittings.

The coolant tube assemblies are fixed at the East end of the reactor but are allowed to expand toward the West as the temperature is increased. The coolant tube is supported centrally within the calandria tube by means of the end fittings at each end and at its centrepoint by means of a garter spring spacer that fills the gap between the coolant and calandria tubes. An air space is thus provided between the coolant tube and the calandria tube.

Interchangeable flow orifices are inserted in each end fitting providing means of adjusting the coolant flows.

1.1.5 Dump Arrangement

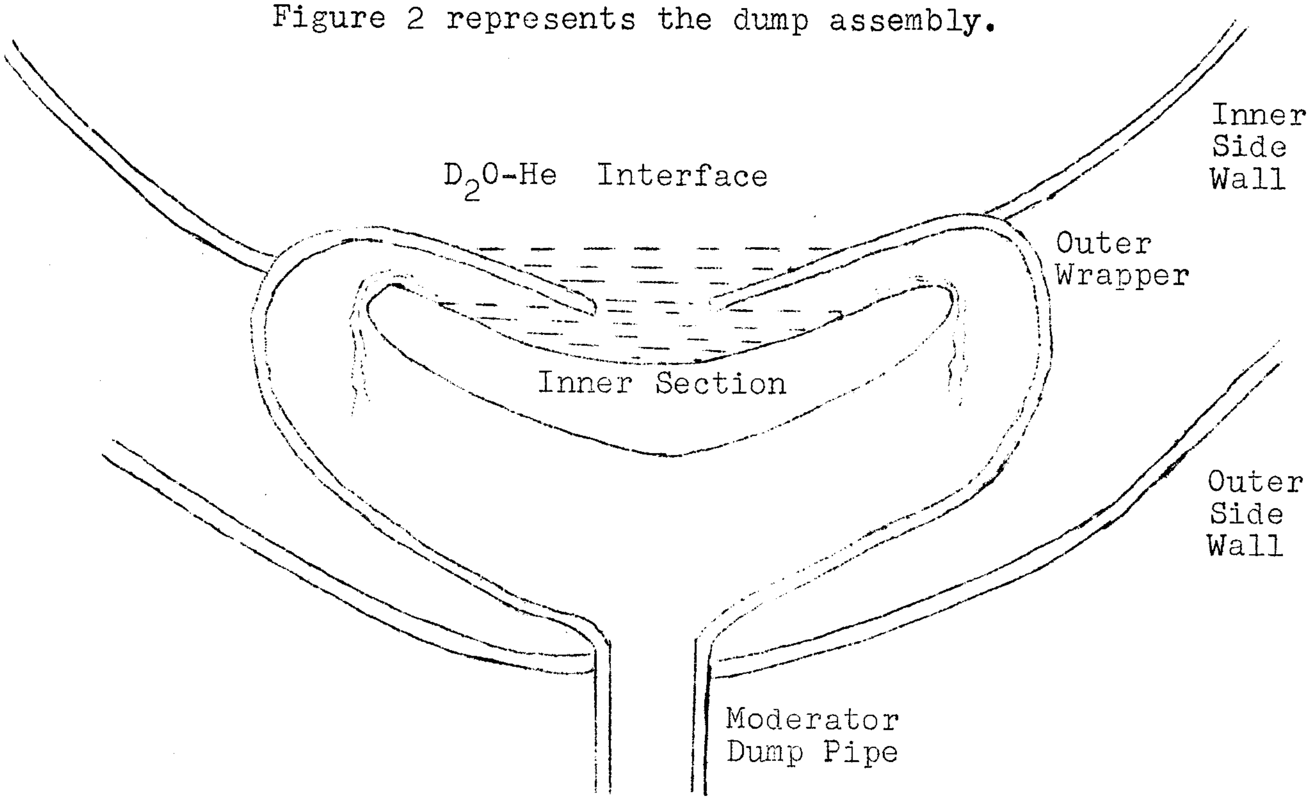
The dump arrangement provides the heavy-water to Helium interface to support the moderator within the calandria. It also provides a large opening, 20 square feet, for rapid dumping of the moderator to the dump tank in the event of a reactor trip.

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 fold-up.

The dump assembly consists of an inner section which is built up of a number of ribs covered with a wrapper of 3/8" aluminum.

The inner section is surrounded by an outer wrapper which is spaced out from it by a number of outer ribs.

Figure 2 represents the dump assembly.



Inner and Outer Dump Assembly
Cross Section at Dump Pipe

Figure 2

1.1.6 Vessel Penetrations

A number of calandria vessel penetrations are made to facilitate reactor control.

Please refer to Figures 3 (a), 3 (b), and 4 at the end of the lesson.

1.1.6.1. Light Water Connections

Light water enters the reflector vessel through three horizontal inlet headers which run the full length of the calandria. The light water reflector leaves the reflector volume through two horizontal outlet headers which run along the top of the calandria for its full length.

1.1.6.2. Heavy Water Connections

Heavy water is admitted to the moderator vessel through two inlet pipes in the bottom of the calandria. Heavy water beyond the requirements of moderator level is spilled over the dump slot weir and returned to the dump tank.

Heavy water is also admitted at the top of the calandria by six pipe headers called spray headers. They are shaped to conform to the barrel shape of the inner side wall. The spray headers provide spray cooling to the calandria tubes when they are not immersed in moderator water.

The booster rod tube enters the side of the calandria mid-way up on the circumference and extends through to the opposite inner side wall. Heavy water enters the calandria continually through this tube.

1.1.6.3. Miscellaneous Connections

A 16 inch helium gas balance line is located on the vertical center line of the calandria. This pipe extends into the inner moderator vessel, passing through the reflector. It enters at the top of the calandria.

During startup experiments a vertical access tube was provided. The tube is a long thimble inserted on the vertical centerline of the calandria near its center, and extends down the full diameter of the calandria.

This tube allowed an ion chamber to be inserted directly into the reactor core. The residual neutron flux is now adequate and the access tube has been capped.

Neutron windows are required to allow thermal neutrons to escape from the core for power measurement purposes. The neutron windows consists of three reentrant cans penetrating the outer and inner side walls at three points below the horizontal centerline of the calandria.

Two instrument connections are required to measure the height of heavy water moderator-reflector in the inner vessel. Both instrument connections go through the inner and outer side walls.

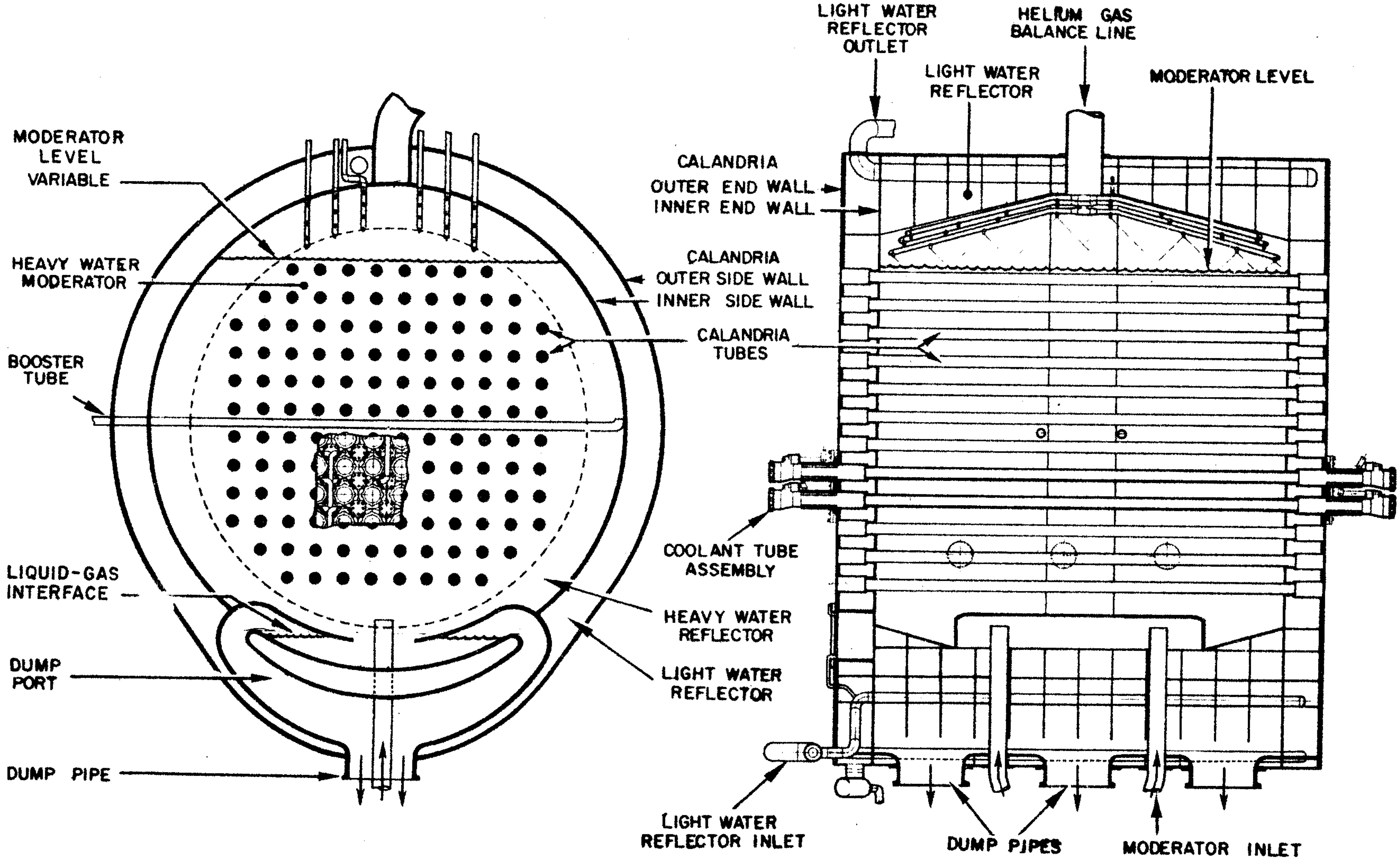
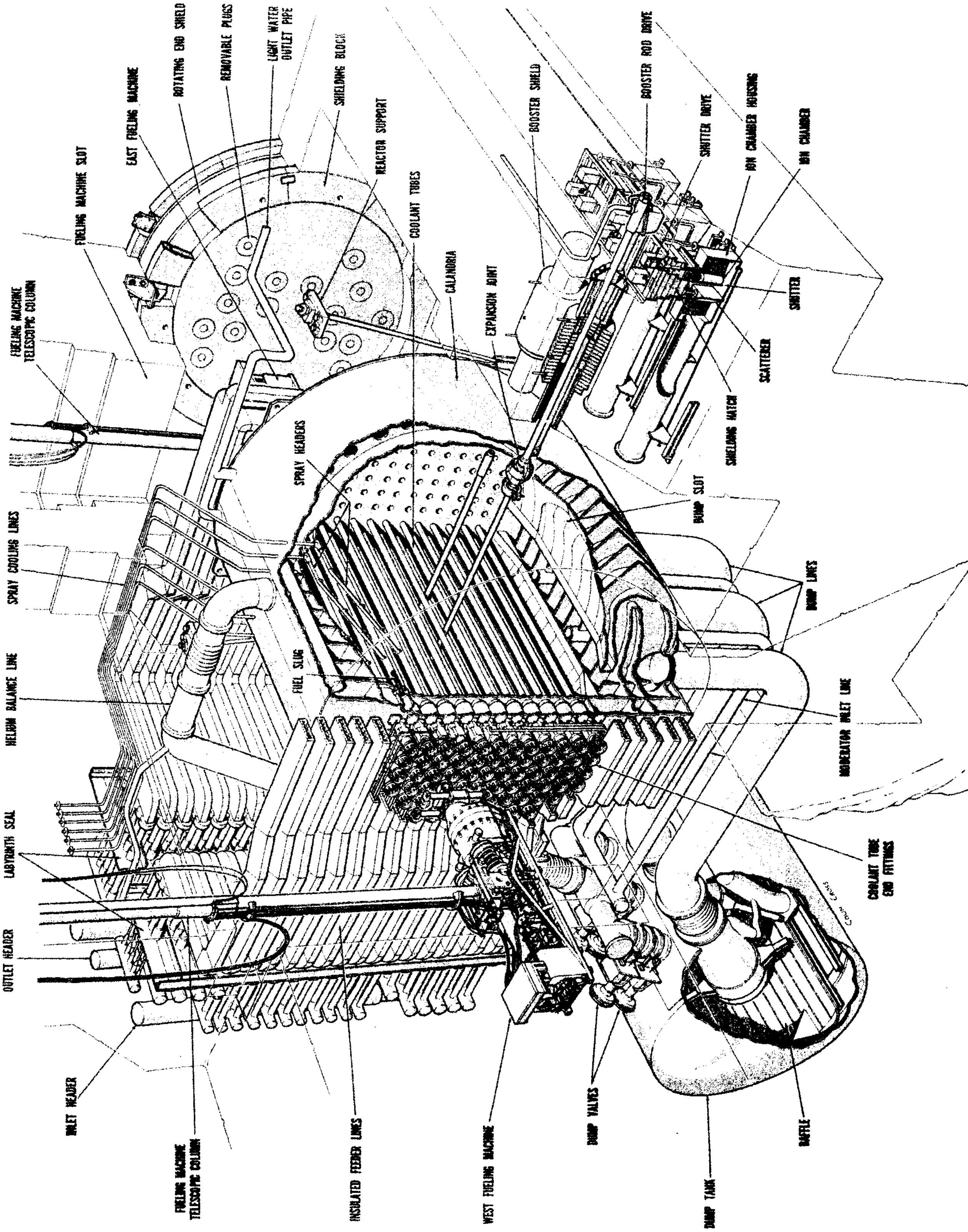

MODERATOR LEVEL VARIABLE
HEAVY WATER MODERATOR
BOOSTER TUBE
LIQUID-GAS INTERFACE
DUMP PORT
DUMP PIPE
CALANDRIA
OUTER END WALL
INNER END WALL
CALANDRIA
OUTER SIDE WALL
INNER SIDE WALL
CALANDRIA TUBES
COOLANT TUBE ASSEMBLY
HEAVY WATER REFLECTOR
LIGHT WATER REFLECTOR
LIGHT WATER REFLECTOR INLET
LIGHT WATER REFLECTOR OUTLET
LIGHT WATER REFLECTOR
HELIUM GAS BALANCE LINE
MODERATOR LEVEL
DUMP PIPES
MODERATOR INLET

Fig. 3 (a)

Fig. 3 (b)



NPD-2 REACTOR CUT-AWAY

Figure 4