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HEAVY-WATER CRITICAL ASSEMBLY

Tetsuya Ando
Akira Ide
Atomic Power Division

I. INTRODUCTION

Advenced Thermal Rreactor (ATR) and Fast Breeder Reactor have been selected for the national projects to develope new power reactors based on Japanese technology, and the activities on the development have been promoted by the Power Reactor and Nuclear Fuel Development Corporation (PNC). One aspect of this work is to erect a heavy-water critical test assembly mainly to determine experimentally the reactivity effect of the heavy water level, the flux distribution in the core, core parameters such as the buckling and equivalent reactivities of the control rods, etc. in order to understand the ATR reactor characteristics.

Fuji Electric who in cooperation with FAPIG has completed the the conceptual design work for this experimental assembly for the Japan Atomic Energy Research Institute. In December, 1968, an order was received, considerable efforts were required for the initial critical approach by the end of 1969, to maintain the overall ATR development schedule. Various difficulties were overcome and completion of the assembly was promoted through the efforts of FAPIG. Thanks to the guidance and support of PNC, the initial critical goal of December 28, 1969, was achieved successfully.

II. OUTLINE OF THE ASSEMBLY

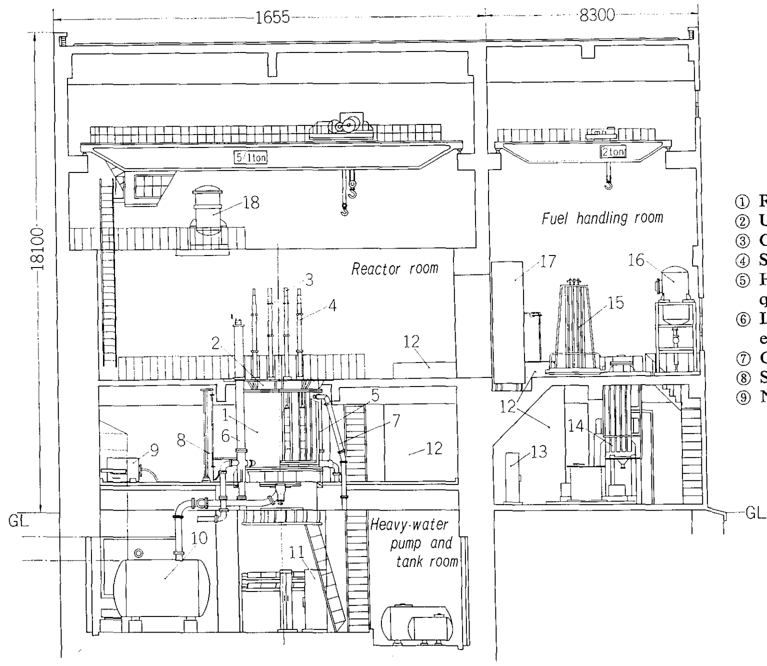
This assembly contains a core tank consisting of a tank, calandria tubes through which fuel elements in pressure tubes are inserted. There is also a heavy water system which supplies heavy water as a moderator into the tank. There are also a gas system for preventing deterioration of the heavy water and drying the inside of the tank, and a light water system which includes a heater and a cooler for measurement of the coolant temperature coefficient. The processing quantities of these are measured by process instruments and the conditions in the nuclear reactor are monitored by nucleonic instruments. Other components include the reactor control equipment for the control and safety rods and the fuel handling equipment. Three types of core lattice pitches can be achieved by changing the upper and lower grid plates. The upper grid plate can contain 4 safety rods and 2 control rods plus the driving devices for these rods.

The approach to critical of this equipment is performed by raising heavy water level and an overflow pipe is provided in the high and low speed heavy water supply system (one in each system) in order to prevent any abnormal rises in the water level. The specified level of these overflow pipes can be changed continuously so that the heavy water level does not exceed the specified level at an abnormal rate. When abnormal states are detected by the safety protective circuit, the heavy water can be dumped from the core tank very rapidly by means of 2 dump circuits.

The critical assembly are housed in an air-tight structure with 3 levels, one below the ground and 2 above the ground. The reactor room is on the level above the ground. The heavy water pump and tank room is below the ground level and the light water and gas system are arranged above the ground level adjacent to the reactor room. *Fig. 1* shows a

***Table 1* Parameters of heavy-water critical assembly**

1. Core tank	Material	Aluminum A.A. 5052
	Inner diameter	3 mϕ
	Height	3.5 m
	Thickness	10 mm (center part)
2. Coolant	Material	Heavy-water (80°C)
	Charging amount	15 tons
3. Fuel channels	Numbers	161 (Max.)
	Pitch	200 mm, 225 mm, 250 mm
4. No. of light water cooling channel		13
5. Moderator cover gas		N_2, 100 mm Aq.
6. Flux plotting equipment		Motor driven, remote control
	Drive speed	5 mm/sec
	Positioning accuracy	Less than ±1 mm
7. Control rod	Material	Cadmium
	Numbers	4
	Drive system	Motor driven ball screw
	Drive speed	5~20 mm/sec continuously variable
8. Safety rod	Material	Cadmium
	Numbers	4
	Drive speed	40 mm/sec and free drop



① Reactor tank
② Upper grid
③ Control rod driving gear
④ Safety rod driving gear
⑤ High speed overflow quipment
⑥ Low speed overflow equipment
⑦ Cover gas pipe
⑧ Servo manometer
⑨ Neutron source driving gear
⑩ Heavy-water storage tank
⑪ Heavy-water pump and valve control panel
⑫ Fuel disassembling pool
⑬ Fuel cleaning equipment control panel
⑭ Fuel assembling equipment
⑮ Fuel transporter
⑯ D_2O-H_2O mixing tank
⑰ Shielding door
⑱ H_2O surge tank

Fig. 1 Sectional view of heavy-water critical assembly

sectional view of the heavy-water critical assembly and *Table 1* gives the parameters for heavy-water critical assembly.

III. DETAILS OF EACH COMPONENT

1. Fuel

The used fuel is UO_2 pellets consisting of natural uranium and slightly enriched uranium. Each pellet has an outer diameter of 14.8 mm and a height of 20 mm. These pellet are contained in a cladding with an outer diameter of $16.65^{+0.16}_{-1}$ mm and an inner diameter of $15.00^{+0.16}_{-0}$ mm. The effective height of the meat is 2,000 mm and the interior is filled with helium gas. The fuel rods are seal welded at both ends with end plugs. The cladding is made of an aluminum alloy (A.A. 5052). It contains less than 10 ppm of boron, the degree of straightness is less than 1/2,000 and the helium leak rate in the seal welded parts is less than 10^{-6} ACC/sec. The fuel rods are arranged in clusters containing a total of 28 rods in three concentric circles (*Fig. 2*). Each rod is held in position by a plate-shaped grid. The dimensions of the grid perforations are $16.9^{+0.55}_{-0}$ and the error in the perforation pitch is less than ± 0.05 mm. The fuel clusters are loaded in the reactor so that they form a single unit with the pressure tubes. The pressure tubes are thin-walled pipe made of aluminum alloy (A.A. 5052). They have an inner diameter $116.8^{\pm 0.25}$mm, a thickness of $2.0^{\pm 0.15}$mm. The degree of straightness is 2/3,200 mm and the boron content is less than 10 ppm. Coolant can be inserted in the pressure tubes. The bottom

Fig. 2 Fuel element

of the tubes contains water-outlet drain and the coolant can be circulated in some tubes.

2. Core Tank

The core tank consists of the tank itself, upper and lower grids, a lower neutron absorber, calandria tubes, PNS (pulsed neutron source), a neutron source insertion tube, experimental tubes and a hollow portion passing through the center. The material used is aluminum alloy (A.A. 5052) except for the bolts, lower neutron absorber meat and the seal materials. The design temperature is 80°C but the seal contains 150°C resistant EPT rubber so that it can withstand the heat which occurs during drying. All the structures except for the tubes are made by welding and the grade of the welding of the parts

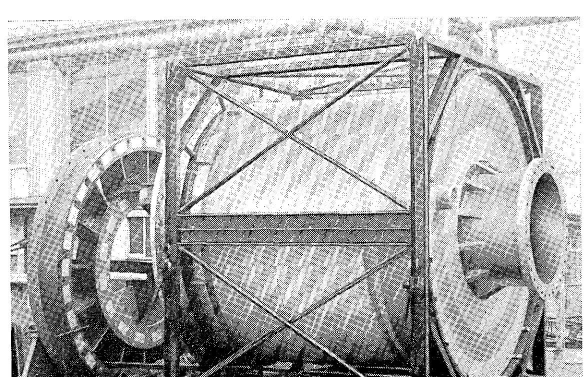


Fig. 3 Reactor tank

which come in contact with the heavy water is as specified in JIS Z 3105 Class A. The helium leak rate is less than 10^{-6} ACC/sec.

The tank (see *Fig. 3*) has an inner diameter of $3{,}005^{+12}_{-0}$ mm, a height of 3,100 mm and a wall thickness of 10 mm in the center part and 20 mm at the ends. The bottom plate has a hole passing through it with an inner diameter of 1,150 mm in the center. There are also two dump holes with diameters of 200 mm on the periphery of the bottom plate which is flat with a thickness of 30 mm. It is fixed to the steel support frame with glass fiber between the frame and the plate. Radial slots and bolts are used for fixing the tank in place in order to avoid the effects of thermal expansion and provide resistance to earthquakes. Except for the mechanically finished bottom plate and upper flange surfaces, all of the tank metal is unfinished. However, when parts which do not meet the JIS Class A welding standards are rewelded, troubles occured such as large dimensional changes due to contraction, but finally these dimensions could be kept within the specified tolerances.

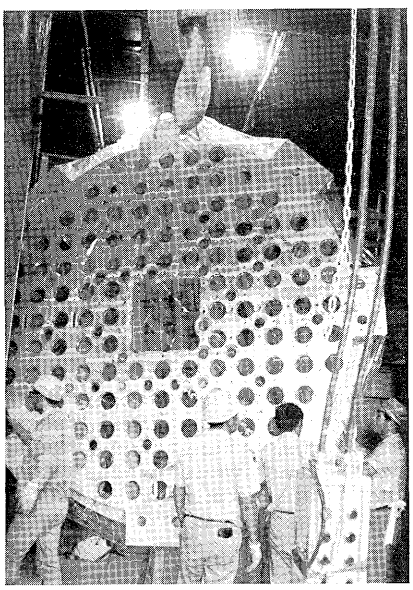


Fig. 4 Upper grid

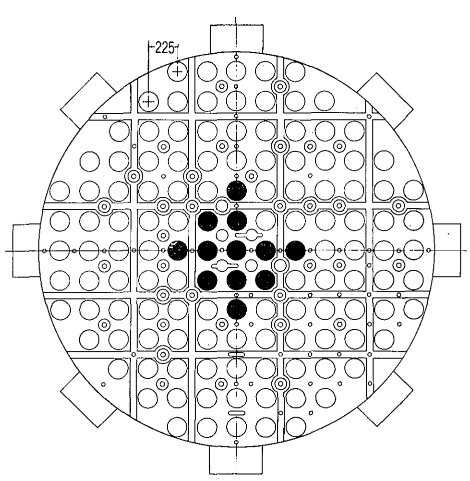


Fig. 5 Upper grid looked from bottom

The upper grid (*Fig. 4*) is a square grid having 129 holes of 146 mm in diameter with a pitch of 225 mm for positioning and supporting of the calandria tubes. It is fixed on the top of the tank body. It is possible to remove the central part consisting of nine-channels. Fuel assemblies weighing about 120 kg are lowered into each of the holes and to keep the deflection in the center less than 1 mm in respect to the total weight, ribs with thicknesses of 45 mm were welded on the upper plate. Therefore the total height became 400 mm. In addition to the above mentioned holes for the attachment of the calandria tubes, there are also thirty five 88 mm diameter holes for attachment of the control rod and safety rod drive equipment and fifty three 25 mm diameter experimental holes interstitially. Therefore, the ribs became complicated as shown in *Fig. 5* and there were difficulties in the manufacture but on the basis of data from preliminary experiments which will be described later, parts with different characteristics were combined and a structural analysis was performed as the plane frame structure. The results of this analysis were good.

The calandria tubes have outer diameters of $136.5^{\pm 0.5}$mm, thicknesses of 2 mm and straightnesses of 2 mm/total length. They are sealed between the upper grid by means of O-rings.

The lower neutron absorber is made of Boral plates enclosed in aluminum plates. It is fixed to the bottom plate of the tank with bolts and the lower grid is attached on the top of the absorber. The lower grid is intended for determing the position of the rods and the holes correspond with the holes in the upper grid. The Boral plates were imported from the United States.

3. Reactivity Control Equipment

1) Control rods and control rod drive equipment

(1) Control rods

The control rods are of two types with an outer diameter of 70 mm and an effective length of 1,700 mm, or an outer diameter of 8.5 mm and an effective length of 1,700 mm. The former type are cadmium of about 1 mm thickness in hollow aluminum cylindrical cladding and the latter are cadmium pellets in cylindrical stainless steel cladding. Both of these types can be connected to the same control rod drive equipment and are used for experimental purposes.

(2) Control rod drive equipment

The basic specifications are as follows:

Drive system: motor drive using ball screw
Stroke: 1,000 mm
Drive speed: 5–20 mm/sec. continuously variable
Control rod position detecting accuracy:
within 0.1 mm

Control rod position indication : digital, decimal system, 5 figures

In order to make the control rod drive speed continuously variable, a speed servo mechanism is used and the speed can be remote-controlled either automatically or manually from the control room. The effective stroke of the drive equipment is 1,000 mm but by using extended rods, it is possible to expand the operation range of the control rods.

The drive mechanism is located at the top of the equipment and consists of a servomotor, tachogenerator, speed reduction gear, electromagnetic brake and an A/D converter. Since all of the components are contained in an aluminum case, attachment and removal are easily performed.

The rotation of the servomotor is transmitted to the ball screws via the final reduction gear and move a ball and nut construction upwards and downwards. Two drive rods are lowered into the ball and nut system and the control rods are lowered directly or by attaching extended rods via the cross joint which is attached to the lower part of the drive rods. Limit switches are attached at both stroke ends of the ball and nut system and when these limit switches operate, the servomotor is stopped and the brake is engaged.

The control rods drive equipment is made mainly of stainless steel.

2) Safety rods and safety rod drive equipment

(1) Safety rods

These rods have an outer diameter of 70 mm and an effective length of 1,700 mm. They consist of cadmium of thickness of approx. 1 mm with hollow aluminum cylindrical cladding. There are a shock absorbing rubber attached to the top of the safety rod in order to dampen the dropping shock during reactor scram and a plated for adherence of the electromagnet. The bottom of the rods has a dash pot construction for the guide tubes.

(2) Safety rod drive equipment

The main specifications are as follows :

Drive system : motor (normal conditions) and free drop (emergency conditions)

Speed : 40 mm/sec.

Acceleration during free drop : more than 0.6 g average

The safety rod drive equipment consists of a drive motor, reduction gear, wire-wound drum and electromagnet. All of the components except the drive motor are housed in a stainless steel support cylinder with an outer diameter of approx. 140 mm.

Under normal conditions, the safety rods adhere to the electromagnet in the drive equipment but during reactor scram, the electromagnet is de-energized by the scram signal and the rods fall. Restoration of the fallen rods or up/down movement of the rods at times other than reactor scram is accomplished by the drive motor in the safety rod drive equipment. *Fig. 6* is a photograph of the safety rod drive mechanism.

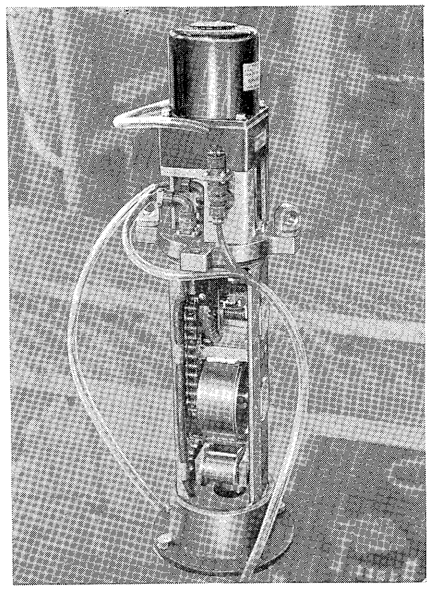


Fig. 6 Driving mechanism for safety rod

4. Accessories

1) Neutron source drive equipment

Except during start up the neutron source is housed in a container separated from the reactor tank. This container is a triple-walled cylinder consisting of iron, lead and boron-impregnated paraffin layers. The neutron source capsule is contained in the center part of this cylinder. Drive of the source during start up is performed by remote control from outside the reactor room using motor drive equipment.

2) Overflow pipe and drive equipment

The overflow pipe is provided to set the reactor tank water level and also to serve simultaneously as final safety equipment to prevent abnormal rises in the reactor tank water level. There are two types

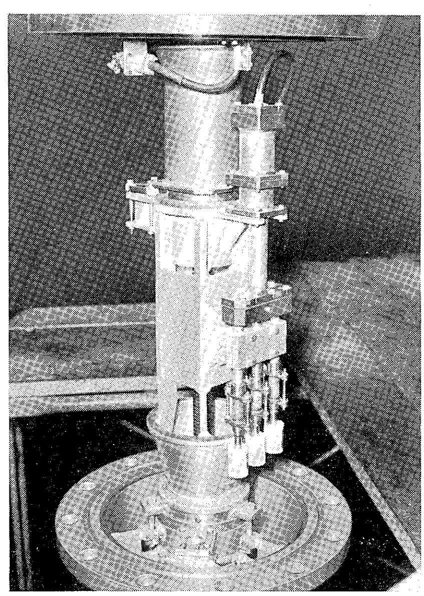


Fig. 7 Bell mouth end of overflow pipe

of overflow pipe: one for low speed and one for high speed water supply. Operation of both types of pipes is manual and in both cases, the set value is indicated both at the site and remotely (in the control room) using a selsyn motor. The drive handle is locked at the set value position. A photograph of the bell mouth end of the overflow pipe is shown in *Fig. 7*.

3) Flux plotting equipment

This equipment is operated automatically and remotely from outside the reactor room using a small BF_3 counter, etc. and is used for measuring the flux distribution within the reactor heavy water area. It is placed on the top of the upper reactor grid when measurements are required. Drive is by an electrical system in both the horizontal and vertical directions and is performed by rotating drive screw rods via a final reduction gear. A/D converters are provided for position indications in both the horizontal and vertical directions and the indications are given remotely in the control room.

5. Water and Gas Circuit System

The water and gas circuit system is divided into the following systems:

1) Heavy water system

This system is mainly for supplying the moderator (heavy water) to and removing it from the reactor tank. It includes also the drain line and purification system.

In the supply system, the heavy water is removed from the heavy water storage tanks (two aluminum tanks, each with a capacity of 12 m^3) by means of a high speed feed pump (12 *l*/sec, made of SUS) and supplied to the tank via the high speed overflow pipe (which sets the water level in the reactor tank and automatically stop the water supply at the set value. Even if it is not stopped, the overflow is returned to the heavy water storage tank and there is no abnormally high water level in the tank. The setting range is 700 to 2,400 m and the pipe is made of aluminum). This is a high speed system which can supply cooled water (cooling 19 m^3 of 80°C heavy water to 25°C in 5 hours) or heated water (heating 0°C heavy water to 25°C in 5 hours, maximum 80°C). There is also a low speed supply system in which heavy water is removed from the heavy water storage tank by means of the auxiliary tank supply pump (12 *l*/sec, made of SUS) and supplied to the auxiliary tank (200 *l*, made of A1). The low speed feed pump (21 *l*/sec, made of SUS) supplies the heavy water to the core tank to nearly the critical water level. Then the heavy water is supplied up to the critical level by the heavy water reactivity control pump (1 *l*/sec, also used as the low speed feed pump) or the heavy water level reactivity control pump (5 *l*/min). This low speed system operates completely via the low speed overflow pipe (functions are the same as the high speed pipe, setting range: 800 to 2,700 mm).

There are four types of heavy water effluent systems: the high speed effluent system (90 *l*/sec, effluent valves 4B and 6B opened simultaneously and heavy water transferred to heavy water storage tank), the low speed effluent system (2 *l*/sec, effluent valve 2B opened and heavy water transferred to heavy water storage tank), reactivity control effluent system (1 *l*/sec, valve 1–1/4B opened and water transferred to auxiliary tank) and the water level control effluent system (5 *l*/min, valve 1/2B opened and water transferred to auxiliary tank). In emergencies, water can also be removed by the dump valve (when level is 2,600 mm, two 8B valves opened simultaneously and heavy water returned to heavy water storage tank).

The drain line begins with the drain in the heavy water storage tank. The water is transferred to the aluminum heavy water drain tank (1 m^3) by the drain pump (0.1 m^3/sec) or by the slope of the drain line.

The purification system consists of purification of part of the water from the high speed supply system and the heavy water sent from the drain tank by the heavy water transfer pump (38 *l*/min). This purification is performed by a filter (1 m^3/hr, 10 μ mesh) and an ion exchange tower (1 m^3/hr, 1 $\mu℧$/cm). The water is returned to the heavy water storage tank. Deteriorated heavy water is returned to the heavy water storage tank. Deteriorated heavy water is transferred to the deteriorated heavy water tank (1 m^3) and is removed from the reactor room by means of a deteriorated heavy water pump (38 *l*/min).

In addition to the above, there are accessories including an aluminum new heavy water tank as a spare (1.5 m^3), a spare heavy water transfer pump for this tank (38 *l*/min, made of SUS), a new aluminum resin tank (0.6 m^3, also for the light water system) and a heavy water injection pump (45 *l*/min).

2) Gas system

This system employs nitrogen gas from high pressure nitrogen cylinders (ten 7m^3 cylinders) with the pressure reduced according to the application. The applications are described below.

The cover gas system reduces the pressure of the nitrogen gas inside the N_2 gas auxiliary tank (1.5 m^3, internal pressure: 100 mmAq) to approximately 20 mmAq and generally supplies nitrogen gas to each tank.

The air purge system successively reduces the pressures of the high pressure cylinders (15 kg/cm^2) to 1 kg/cm^2 and purges the air after rearrangement of the reactor tank.

The resin transfer system is used for pressure transfer of the new and disgarded resin. It can supply nitrogen gas at 1 kg/cm^2 when needed.

The drying system is used to dry the inside of the tanks at the time of tank rearrangement. It circulates the nitrogen gas from and back again to the N_2 gas auxiliary tank via the N_2 blower (12 m^3/min), the gas heater (heats 750 kg/h of N_2 gas from 20°C to 150°C), the dehumidifier (made of aluminum impregnated with activated alumina), the heavy water compressor (99% efficiency) and the reactor tank. This system can trap 99.7% of the water particles in the gas.

3) Light water system

Equipment which circulates cooled or heated water in the center 13 channels of the core tank depending on the experimental conditions is located. It also includes a pure water production system, a drain line and a water purification system.

The pure water production system changes filtered water into pure water by means of a pure water production device (1 m^3/h, 1 $\mu\mho$/cm). The pure water is stored in the pure water storage tank (2 m^3) and this water is supplied by the pure water pump (50 l/min) to the light water surge tank (1 m^3) for mixing with the resin transfer and for fuel handling.

The reactor tank circulation system supplies water from the light water surge tank to the reactor tank by means of the light water circulation pump (5 l/sec). The water is then again returned to the light water surge tank. Cooled water (cooling of 80°C light water to 25°C in one hour) and heated water (heating of 25°C light water to 80°C in 30 minutes) can be provided in accordance with experimental conditions.

The drain line transfers the water to the light water drain tank in accordance with the slope of the drain pipes. Occassionally, the water can be removed to the disposal tank outside the reactor room by means of the light water transfer pump (5 l/sec).

The water purification system purifies part of the water from the reactor tank circulation system by means of a filter (0.5 m^3/h, 10 μ mesh) and an ion exchange tower (0.5 m^3/h, 1 $\mu\mho$/cm). The purified water is taken in by the light water circulation pump and returned to the circulation system.

6. Control and Instrumentation

This equipment can be classified as nucleonic instruments, process instruments, safety circuits and control circuits. Except for one portion, all of these are attached or housed in the control desk and instrument panel in the control room. This makes the central monitoring and control possible (refer to to *Fig. 8*).

1) Nucleonic instrumentation

These circuits perform measurments required in start up operating and shut down. They consist of the following six channels and cover a measuring range from start up to maximum output.

Start-up channel	2 channels
Log d.c. channel	1 channel
Linear d.c. channel	1 channel
Safety channel	1 channel
Gamma ray channel	1 channel

Fig. 9 shown the nucleonic instrumentation. The nucleonic instrumentation is the only means by which

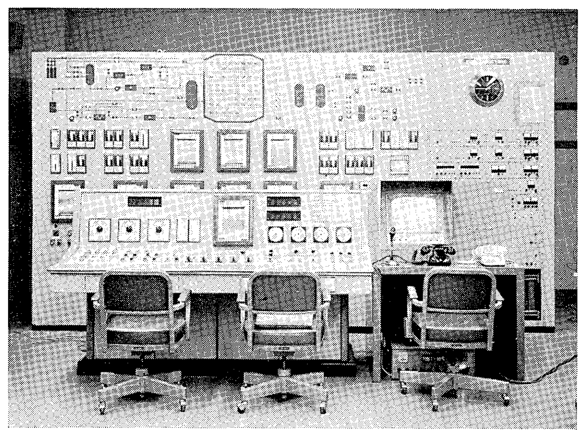


Fig. 8 Instrument panel and control desk

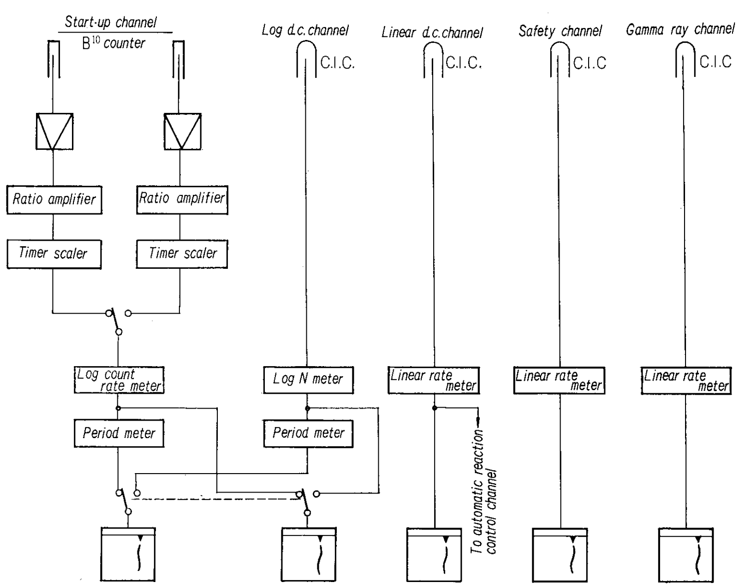


Fig. 9 Neucleonic instrumentation

the reactor output can be known directly. By detecting the high neutron flux, the short periods, etc., the scram signal is given out to the safety circuit. Because of its importance, the scram signal is given out even in cases when the nucleonic instrumentation power source is abnormal. In addition to scram signals, alarm and interlock signals are also produced when required. The nucleonic instrumentation is highly sensitive to noise since it must detect very weak signals and therefore considerable care must be taken with wiring, power source of grounding work, etc.

2) Process instrumentation

The process instrumentation measures the flow rates temperature, pressure, water level, etc. in the heavy water, light water and gas systems. The instruments perform recording and indication in the control room. One portion of the process values are indicated locally or on local panels.

Scram, interlock and alarm signals are given for the required process values. For measurements in the heavy water system, there are very severe limits in respect to leaks and all of the various types of transmitter for the pressure, flow rate, etc. are produced with special care given to leak-proofing for helium. SUS is used in parts in direct contact with heavy water to minimize rust caused by heavy water deterioration and corrosion of the metal due to diffierences in ionization tendencies.

3) Safety and protective circuits

The safety and protective circuits consist of interlock circuits, alarm circuits and scram circuits to insure safe and correct operation of the reactor. Some interlock and scram items can be partially bypassed, when required by experiments or tests, and the operations can be performed manually by key switches on the control desk on the basis of chief operator confirmation.

(1) Interlock circuits

The interlock circuits are used to insure safety of the reactor and its peripheral equipment during start up and operation. These circuits are as follows:

Start-up interlock circuit
High speed water supply interlock circuit
Low speed water supply interlock circuit
Control rod drive interlock circuit
Water level control system interlock circuit
Automatic control system closing interlock circuit
Heavy and light water systems interlock circuit

(2) Alarm circuits

The alarm circuits start a buzzer when the reactor or process system is not operating in the correct range. A lamp is also lit for the appropriate annunciater part in the semigraphic center on the instrument panel.

(3) Scram circuits

The scram circuits produce an alarm and simultaneously flicker the lamps of the annunciator parts concerned when the nucleonic instrumentation is out of order, the air supply for the instruments is low or some hindrance in operation has occurred due to an earthquake, etc. When the buzzer sounds, the magnet excitation circuit of the safety rods is opened, the four safety rods are dropped, and simultaneously the heavy water dumps by opening the dump valve copmletely. The reactor is then stopped immediately in the case of an emergency. The scram circuit are very important for safety and protection and therefore, after the scram signals are generated, it is necessary to stop the reactor as quickly as possible and a solid-state logic element is employed so that the signal transmission is delayed slightly. Thyristor switches are also used in the safety rod magnet release circuit so that the release time is shortened considerably.

4) Control circuit

The control circuit is used to control the reactivity. This can be done in two ways: by changing the position of the control rods and by changing the level of the heavy water in the tank. There are also two control systems: manual and automatic remote control from the control room. Safety rods and a heavy water dump circuit are also included for emergency control to stop the reactor.

7. Fuel Handling Equipment

This equipment is used to handle fuel for experiments and operation and the spent fuel taken from the reactor. This equipment has the following five components.

Fuel storage equipment:
fuel pellet storage box, fuel rod box, cluster storage, temporary storage for pressure tube stand assembly.

Fuel transport equipment:
fuel rod transporter, fuel rod storage transporter, transporter for inside reactor room, transporter for inside fuel storage, fuel transport conveyer

Fuel assembling equipment:
fuel rod assembling equipment, fuel cluster assembling equipment, fuel elements assembling equipment

Fuel disassembling equipment:
the diassembling equipment corresponding to those in above

Fuel cleaning equipment:
fuel cleaning and drying equipment

The fuel handling procedure is illustrated in *Fig. 10.* The fuel is transported between the various handling devices by means of various transporters and 1/2, 2 and 5/1t cranes provided in the handling area. An outline of the main devices for handling the fuel before loading into the reactor and also the spent fuel is given below.

1) Equipment for handling the fuel before loading into the reactor

(1) Fuel cluster storage

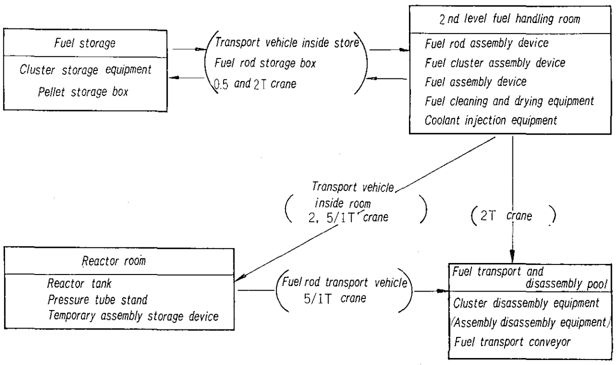


Fig. 10 **Fuel handling procedure**

The fuel storage contains a frame in the shape of a 4-line turret. The fuel clusters are lifted out by their tops and it is possible to store a maximum of 188 fuel clusters. Cadmium plates are provided along the clusters as a shield for the required parts of the frame in order to prevent a critical accident.

(2) Fuel rod storage box

This is synthetic resin cylinder arranged vertically and it is divided into 4 blocks per base with 24 rods per block. The rods are placed in this cylinder by means of the fuel handling transport system and normally, it is stored in the fuel storage.

(3) Fuel rod assembling device

The fuel rod assembly device is very simple and consists of a 1 m × 3.2 m assembly base, 6 V-blocks and L30 × 1 m V-shaped conduits. This assembling job is all performed manually.

(4) Fuel cluster assembling device

The fuel cluster assembling device assemble the fuel rods which project through the second floor of the handling room into a cluster using parts. It consists of fittings to grasp the tie plates and spacers and a steel frame with a scale to decide their positions. The procedure is performed on the second level and on the work frame on the first level of the handling room.

(5) Fuel cluster cleaning equipment

This equipment is used to clean the assembled fuel clusters when they are dirty. It consists of an SUS cylindrical shaped cleaning and drying tank, a hot water tank with heater and a hot-blast blower. It cleans by circulating pure water heated to 80°C and dries by means of blowing in filtered air at 60°C. This procedure is performed on the first level of the handling room and the fuel handling is carried out from the tank manhole on the second level of the handling room.

(6) Fuel element assembling equipment

This equipment consists of 6 aluminum cylinders projecting through to the second level of the fuel handling room. It is used to insert the fuel clusters into the pressure tubes placed inside the cylinders, and inject the coolant in order to produce the fuel assembly.

(7) Coolant injection equipment

This equipment consists of an aluminum mixing tank, a weight detector and a meter tank all arranged on the same frame. The mixing proportions are decided by the weight detector located in the mixing tank. An automatic valve receives signals from the setter and the mixture of light water, heavy water and light water and in some cases, only the heavy water is stored in the mixing tank. The free mixture is weighed by the direct level surface reading system in the weighing tank. The coolant is then injected into the fuel assembly. It is also possible to perform a cover of nitrogen gas with this equipment considering heavy water handling.

(8) Reactor room fuel transporter

This is a vehicle to transport the fuel assemblies or clusters. It moves on rails located between the reactor room and the handling room via a shielded door. Six fuel assemblies or clusters are handled at a time in the vertical position 6 and transported on this turret shaped vehicle.

(9) Fuel store transporter

This is a vehicle to remove the fuel clusters from the fuel storage. Three fuel clusters are hoisted vertically and transported on this turret shaped vehicle.

2) Handling eqipment for spent fuel

(1) Fuel rod transporter

This is a vehicle to transport the fuel rods removed from the reactor to the fuel handling room whenever required. It is provided with V-shaped conduits so that 6 fuel rods can be transported at one time. The bases of the V-shaped conduits can be turned so that the rods are handled horizontally and there is no bending load exerted on any rods in the vertical position.

(2) Fuel transfer and disassembling pool

This pool consists of an immersed conveyer for fuel transfer, the fuel cluster disassembly device and the accessory fuel rod box. The immersed conveyer for fuel transfer moves the fuel clusters from the reactor room to the handling room. The fuel carrier which is driven by an SUS chain is controlled by handles in both rooms. The fuel cluster disassembly device is made of SUS and is located in the handling room. It consists of arms for fixing the spacer parts of the fuel clusters and handles for moving these arms. It is operated at the pool surface. The disassembled fuel rods are stored in the fuel rod box which is similar to fuel rod storage boxes. When necessary disassembling of fuel assemblies is also possible. The above equipment for handling the fuel is all immersed in light water which acts as a shield.

(3) Fuel cleaning equipment

This epuipment is used for cleaning and drying of the disassembled fuel clusters, fuel rods, pressure tubes, etc. It is the same as the equipment described in Ⅲ. 7. 1). (5). The dried fuel rods are treated as fuel pellets after passing through the fuel scanning equipment etc. according to the purposes.

IV. OUTLINE OF MAIN DEVELOPMENT AND RESEARCH

The main points of development research carried out when this equipment was designed and manufactured are given below.

1) Photo-elastic and bending tests of upper grid pipe joint

As was described previously, the ribs of the upper grid are of a welded structure and include the so-called pipe joint for arrangement of the holes. The upper grid design has mainly determined by the strength and hardness of this part. Therefore, the optimum conditions during design and manufacture must be determined for dimensions within the permissible limits. A bending test was conducted on a 1/2 scale model and the maximum tension due to the surface photo-elasticity was compared with the calculated value.

2) Safety rod drop test

Drop tests were performed using dummy safety rods in order to determine the required safety rod drop time, the properties of the rubber and the dash pot used to dampen the shock caused by dropping and the maximum impact load. Since the safety rod drop distance is 2.45 m, the drop impact has considerable influence on the safety rods and the upper grid. Because of this, guidance was obtained from Professor S. Suzuki of the Engineering Faculty of Nagoya University. The results of the test indicated that the impact acceleration when the safety rods were dropped reached about 300G.

3) Overflow pipe characteristics test

The overflow pipe serves as a safety valve against increases in the reactor reactivity caused by rises in the heavy water level. Therefore, it is necessary to know accurately its hydraulic characteristics. Limits of the water level increase during overflow were confirmed using a full scale model.

4) Pressure tube water level setting and air bubble removal test

In order to investigate the method of setting the water level when the cooling water is inserted in the pressure tubes and its accuracy as well as the method for removing air bubbles which occur at that time, tests were performed using dummy fuel rods and acryl pressure tubes.

5) Safety and control rod

Since the safety rods consist of cadmium tubes sandwiched between aluminum, pre-manufacturing were conducted to establish their manufacturing conditions.

6) Tests on aluminum welding

In order to determine the influence of the aluminum welding method, conditions, etc. on the strength, dimensions, structure, etc., various tests concerning the tubes and plates especially were conducted. A welding method was established to satisfy design conditions on distortions, etc.

V. CONSTRUCTION WORK

In 1968, the construction of the buildings and design of the equipment was begun simultaneously. In February 1969, manufacture of a part of the equipment started and from August of the same year, assembly work at the site commenced. Commissioning tests lasted for about two months beginning in November, 1969. It was confirmed that the critical state was achieved at 4 : 30 p.m. on December 28, 1969.

At present, various experiments to get the nuclear properties of the ATR reactor are underway.