Critical facility for AHWR and PHWRs

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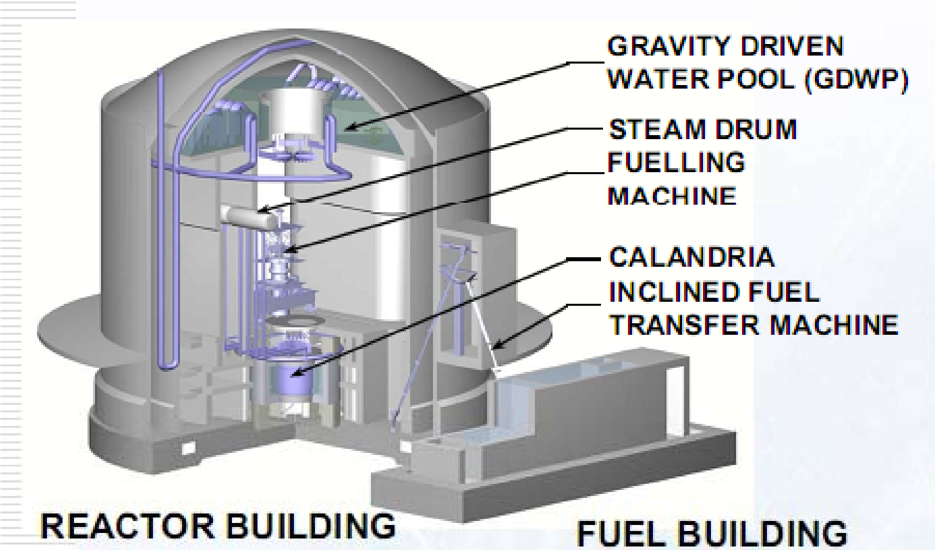
Critical facility

- India has large reserves of Thorium
- Utilisation of Thorium for power production is a thrust area of the Indian Nuclear Power Programme
- A Thorium based 300 MWe Advanced Heavy Water Reactor (AHWR) has been designed & developed at BARC. The reactor is designed to generate about 60% of its power from U^{233} which is bred in-situ from Th^{232} .
- Internationally, the nuclear data for Thorium cycle is less known as compared to that for Uranium & Plutonium
- A Critical facility has been built at BARC, for the validation of the calculational models and nuclear data used in the design of thorium based Advanced Heavy Water Reactor (AHWR)
- The facility is also designed to cater to the experimental requirements of future Pressurised Heavy Water Reactors

ADVANCED HEAVY WATER REACTOR (AHWR)



AHWR is a vertical pressure tube type, boiling light water cooled and heavy water moderated reactor using ^{233}U-Th MOX and Pu-Th MOX fuel.

Design Objectives

1. Thorium utilisation & Energy Security
2. Development of Passive Safety Systems
3. Plant location in a populated area
4. Electric Power output – 300 MWe
5. Design life of 100 years

Major Design Parameters

Reactor power	:	300 MWe with 500 m3/day desalinated water
Moderator	:	Heavy water
Coolant	:	Boiling light water under natural circulation
Coolant Channels	:	452 No.
Lattice pitch	:	225 mm square pitch
Fuel cluster- 54 pins	:	$(Th\text{-}Pu)O_2$: 24 pins $(Th\text{-}^{233}U)O_2$: 30 pins
Fuel burn up	:	38,000 MWd/Te (Avg)
Primary Shut Down System	:	37 Shut off rods
Secondary Shut Down System	:	Liquid poison injection in moderator

ADVANCED HEAVY WATER REACTOR (AHWR)

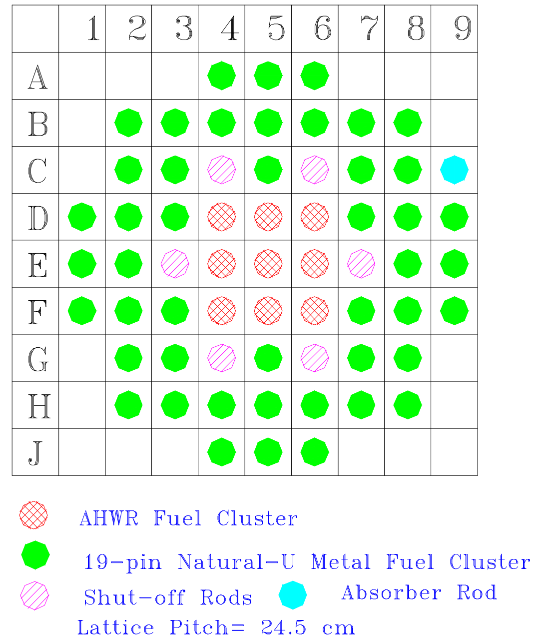
- Core heat removal by natural circulation during normal and shutdown conditions.
- Slightly negative Void coefficient of reactivity.
- Emergency Core Cooling during accident condition (LOCA) by direct injection of Coolant in the fuel from accumulators and Gravity Driven Water Pool (GDWP).
- Containment heat removal during LOCA by Vapour suppression in GDWP and Passive Containment Coolers suspended below GDWP.
- Containment isolation during LOCA by formation of water seal in ventilation ducts.
- Passive Poison Injection in Moderator during overpressure transient

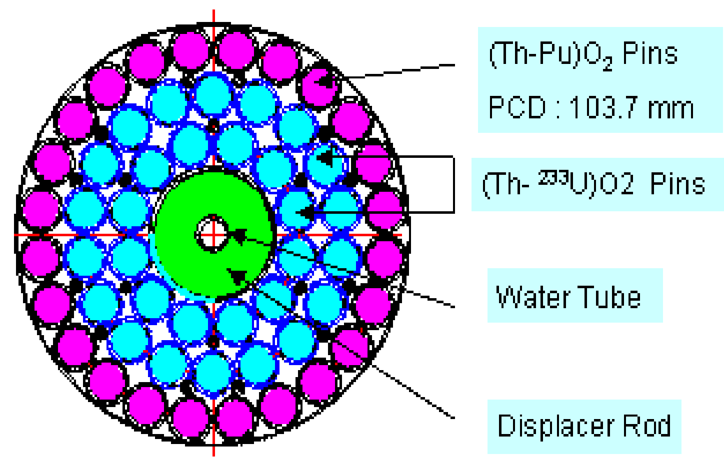
Salient Design Features of Critical facility

Nominal Power	100 Watts
Thermal Neutron Flux	~ 10^8 n/cm^2/s
Reactor tank	330 cm dia, 500 cm height
Lattice Pitch	Variable (minimum 215 mm)
Moderator	Heavy water
Cover gas	Nitrogen
Shutdown system	• 6 Cadmium Shut-off-rods • Moderator Dump
Reactor Control	Manual Moderator Level control

Different Type of Cores to be studied

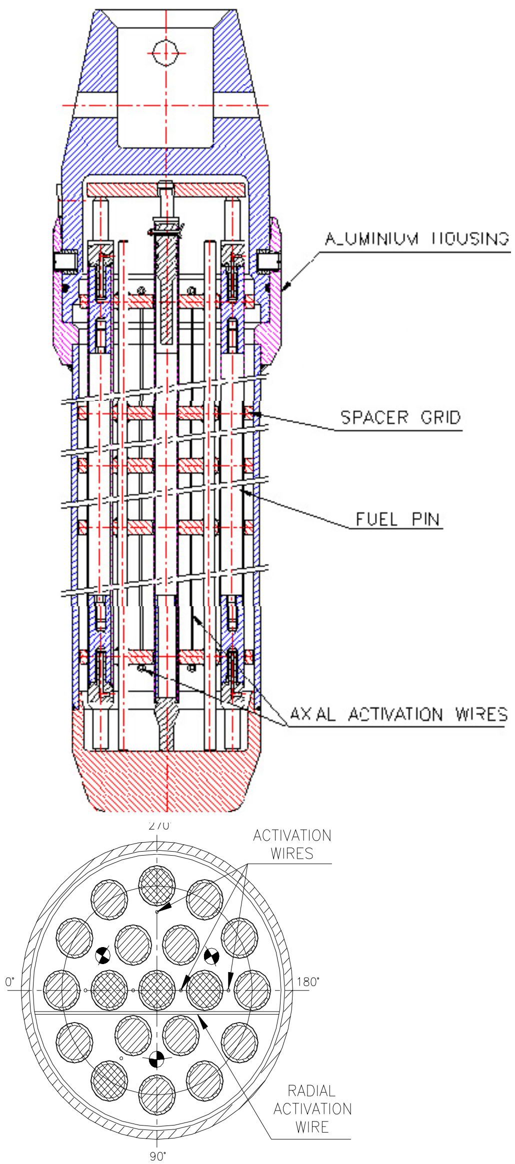
Reference Core	• **61 lattice positions** • **19 rod cluster of Natural Uranium** • **245 mm pitch**
AHWR Core	• 61 lattice positions • 54 pin AHWR cluster in 9 central positions of reference core • 245 mm pitch
PHWR Core	• 69 lattice positions • 37 rod fuel bundles • 286 mm pitch

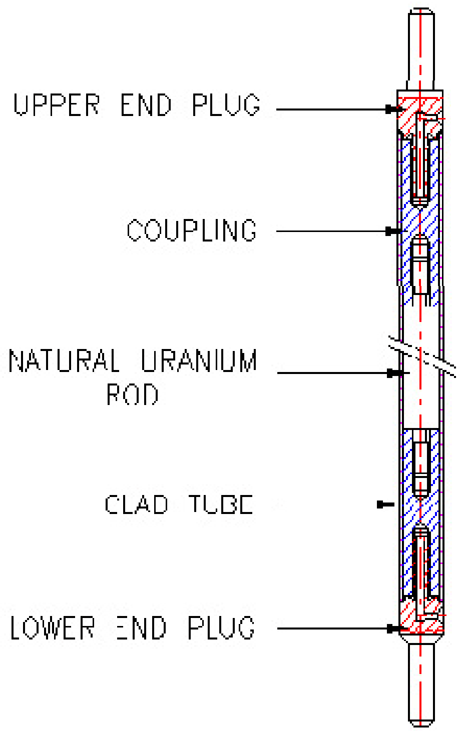




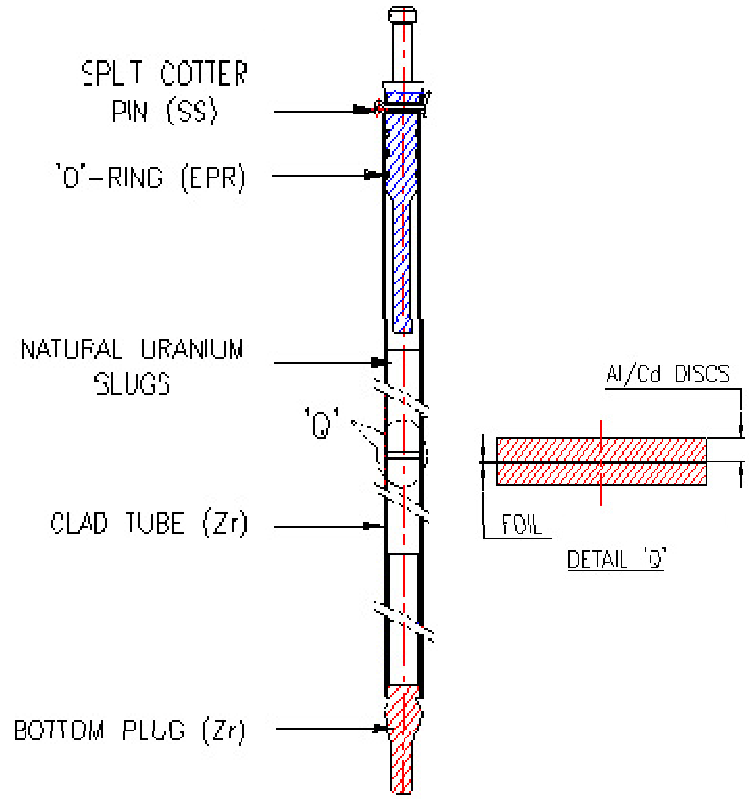
AHWR Fuel Cluster

Experimental Natural Uranium Cluster





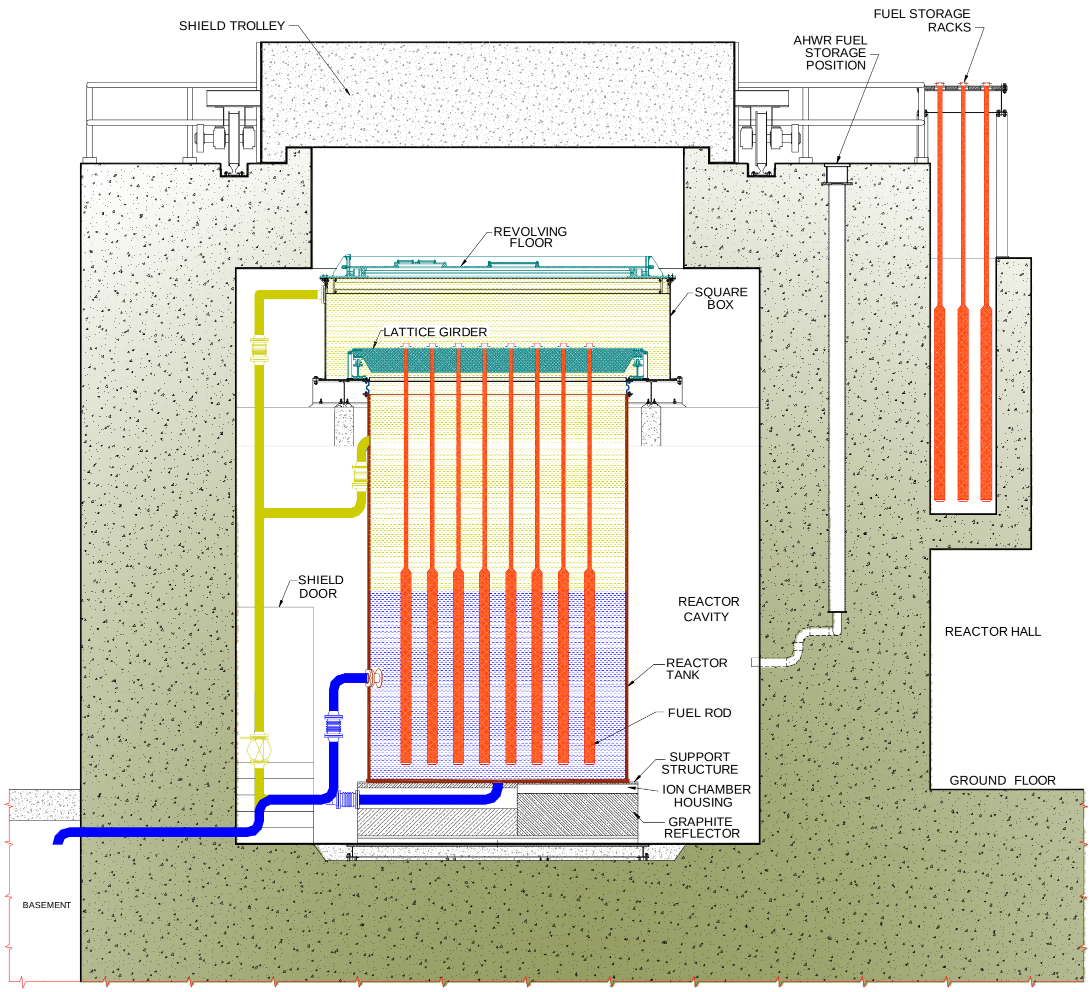
FUEL PIN
(Without Foils)



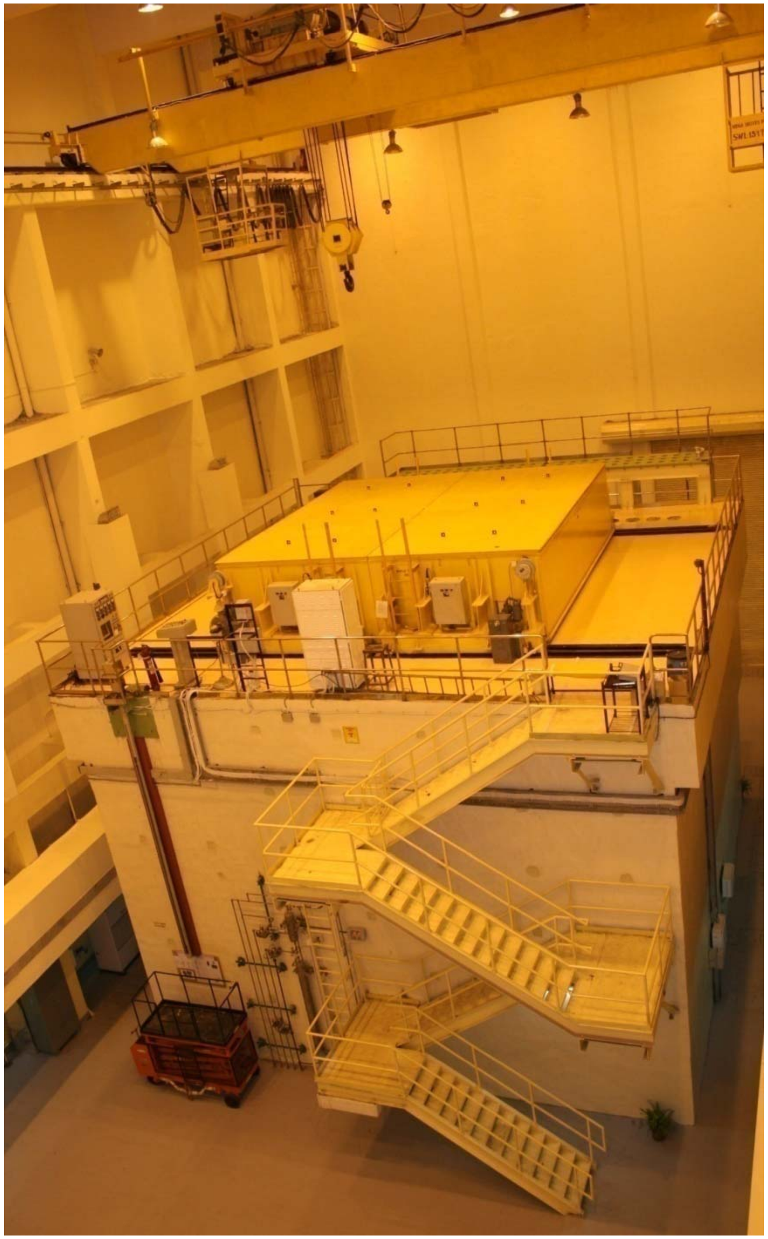
FUEL PIN
(With Foils)

Reactor Block

- The reactor tank & square box with revolving floor on the top housed inside a concrete reactor block
- Square box is connected to Reactor tank at top through an elastomeric expansion joint
- Lattice girders along with bridge plates support the Fuel assemblies and Shutoff rod assemblies
- The lattice pitch can be varied by adjusting lattice girder and bridge plate positions
- Top plate of square box has a central opening to allow access to lattice girders and the reactor tank
- An oil seal is provided between the fixed top plate of the square box and Revolving plate to avoid ingress of atmospheric air and moisture
- Two movable shield trolleys on top of the reactor block provide shielding in axial direction

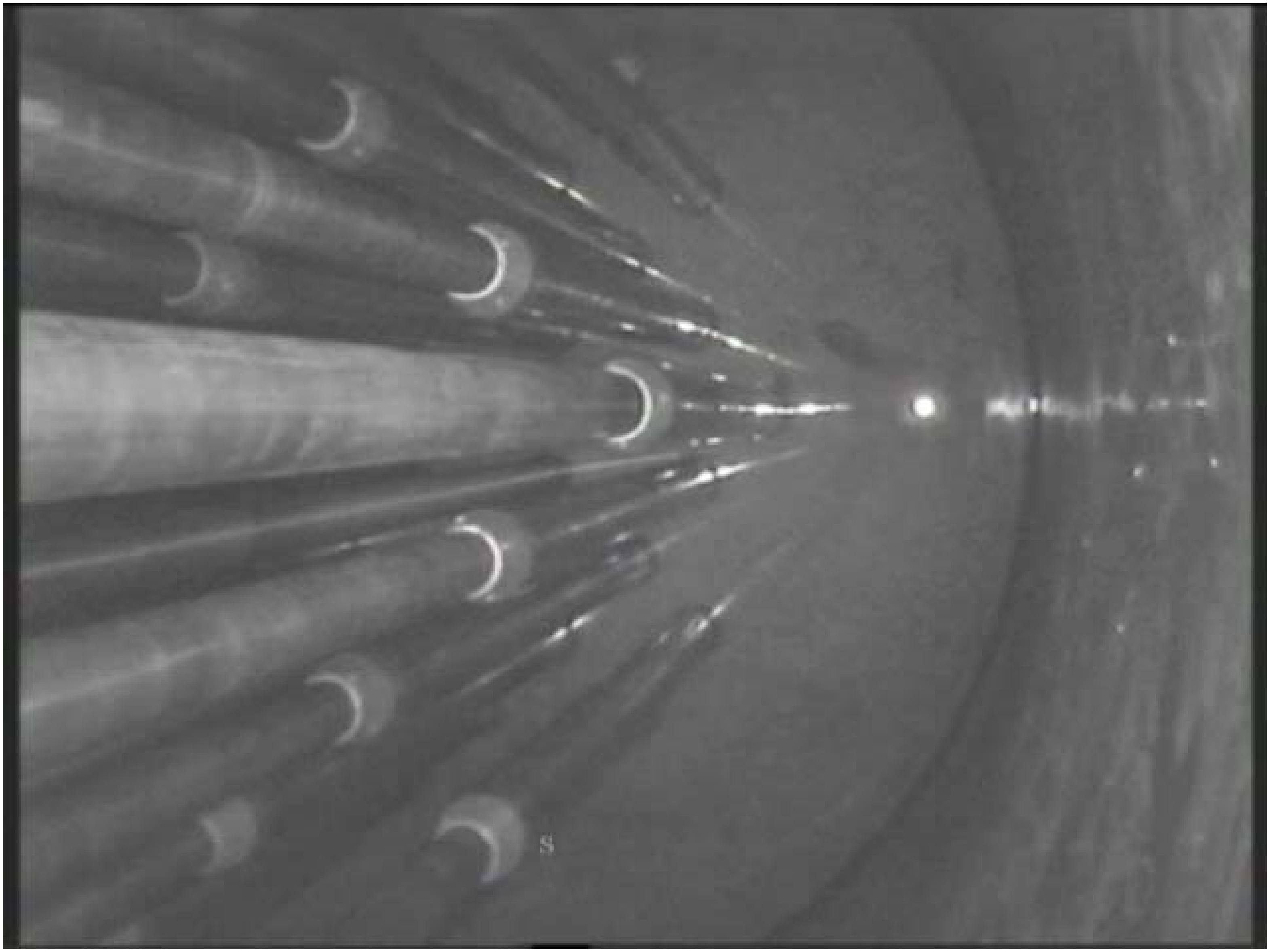


REACTOR BLOCK



REACTOR CORE

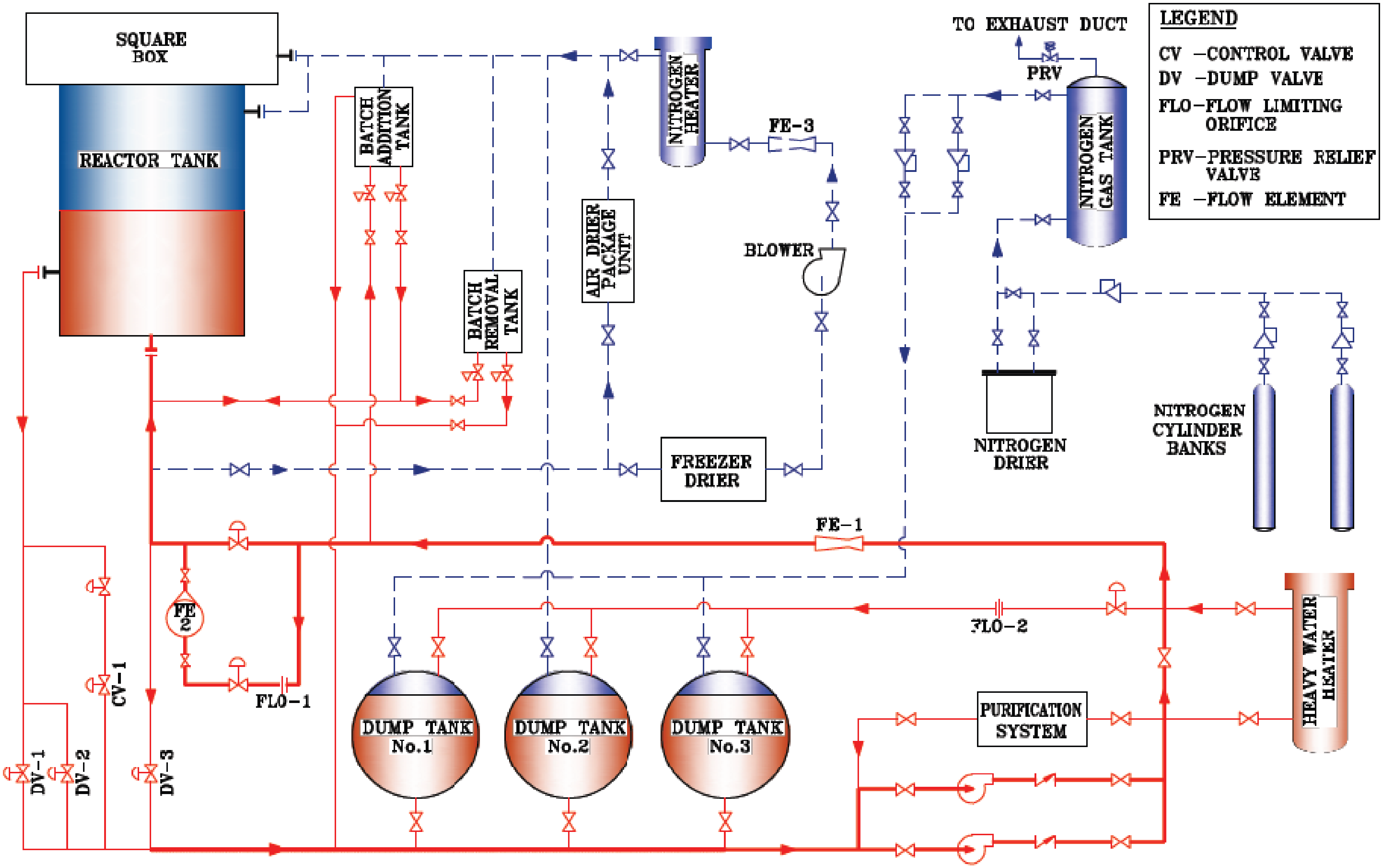
Reactor Tank With Fuel Assemblies



Moderator & Cover gas system

- The system is designed to supply the required inventory of heavy water in a controlled manner to the reactor tank
- Heavy water addition at a rate of 300 lpm till a preset moderator level in the reactor tank. Beyond the preset moderator level further heavy water addition is at a rate of 100 lpm.
- A batch addition and a batch removal facility are provided to permit addition or removal of exact quantity of moderator
- To limit the maximum reactivity that can be introduced in the system only limited inventory of Heavy water is maintained in the active system.
- Provision to carry out experiments at elevated moderator temperatures upto 60°C.
- The nitrogen cover gas system to maintain a dry gas blanket at a pressure of 5 to 8 cm water column (g) to prevent degradation of heavy water due to ingress of atmospheric moisture
- A nitrogen drying circuit provided for drying of the reactor tank, square box, heavy water equipment and connected piping to facilitate core reconfiguration.

Moderator & Cover gas system



Reactor Control & Protection system

- Criticality of the reactor is achieved by controlled addition of moderator into the reactor tank
- The neutron detectors are located in the graphite blocks below the reactor tank, to minimize the effects of variation of critical height on the incident neutron flux seen by the detectors
- Fast shut down of the reactor is achieved by gravity fall of a set of six cadmium shutoff rods into the core
- In addition to the insertion of the shutoff rods, moderator is also dumped from the reactor tank by opening of two fast acting dump valves
- Trip parameters are divided in two groups (Group – 1 & Group – 2) to provide two diverse chains of protection action.

Control & Instrumentation

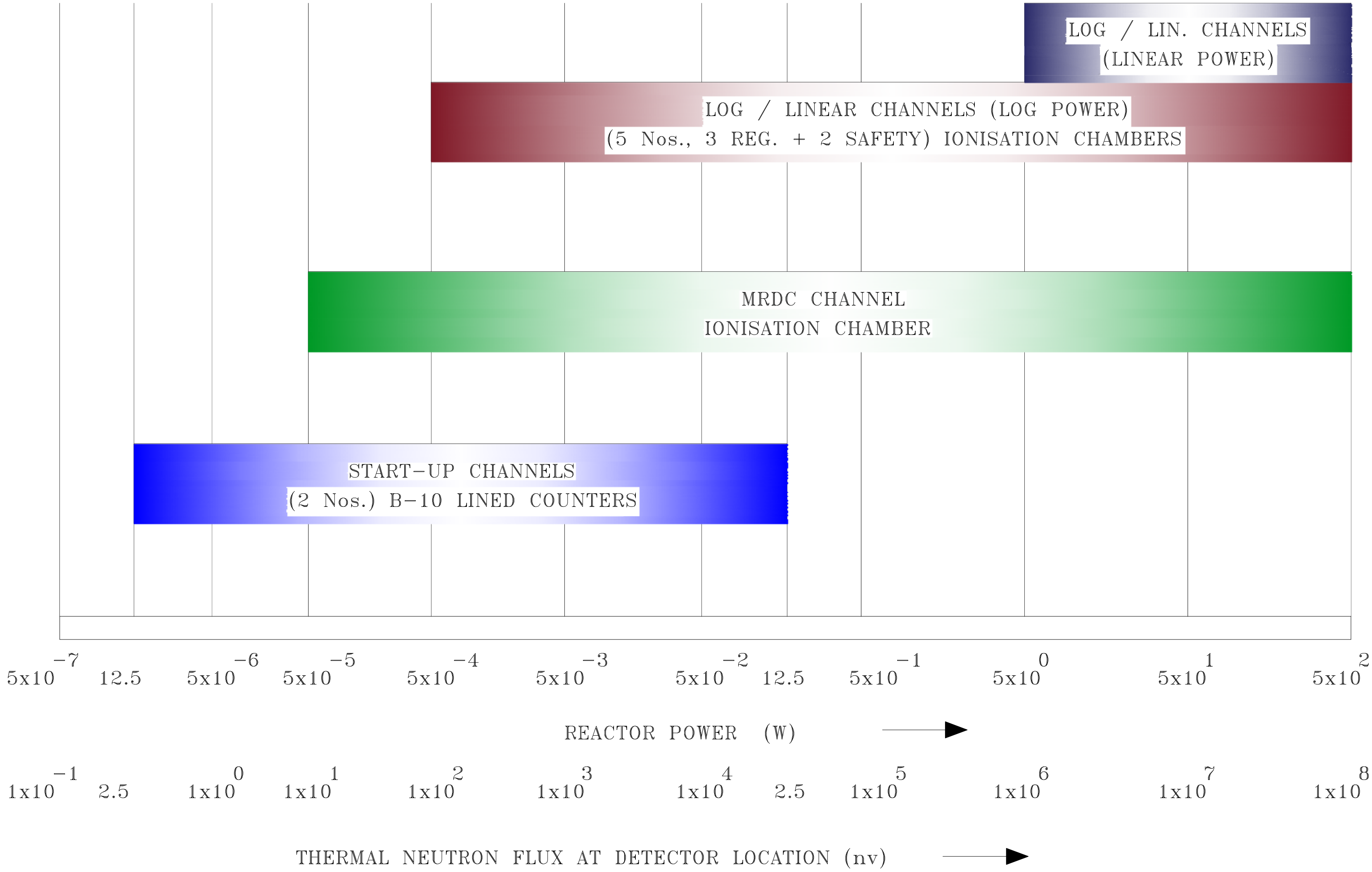
- For power measurements & protection in source range two pulse channels with B-10 lined proportional counters are provided. Each channel provides independent reactor trip through protection system
- In intermediate & power range six channels:
  - 3 Log/linear channels (B-10 lined uncompensated ion chambers) used to provide Log rate and Linear Power signals for manual regulation of reactor power
  - 2 Log/linear channels (B-10 lined Uncompensated ion chambers) are provided exclusively for reactor protection
  - 1 no. of B-10 lined compensated ion-chamber for MRDC.
  - MRDC (B-10 lined compensated ion-chamber) has seven ranges from 0 – 0.5 mW to 0 – 500 W on linear scale.
- On-line flux measurements by distributed set of Fission chambers

C&I - Range Overlap Diagram

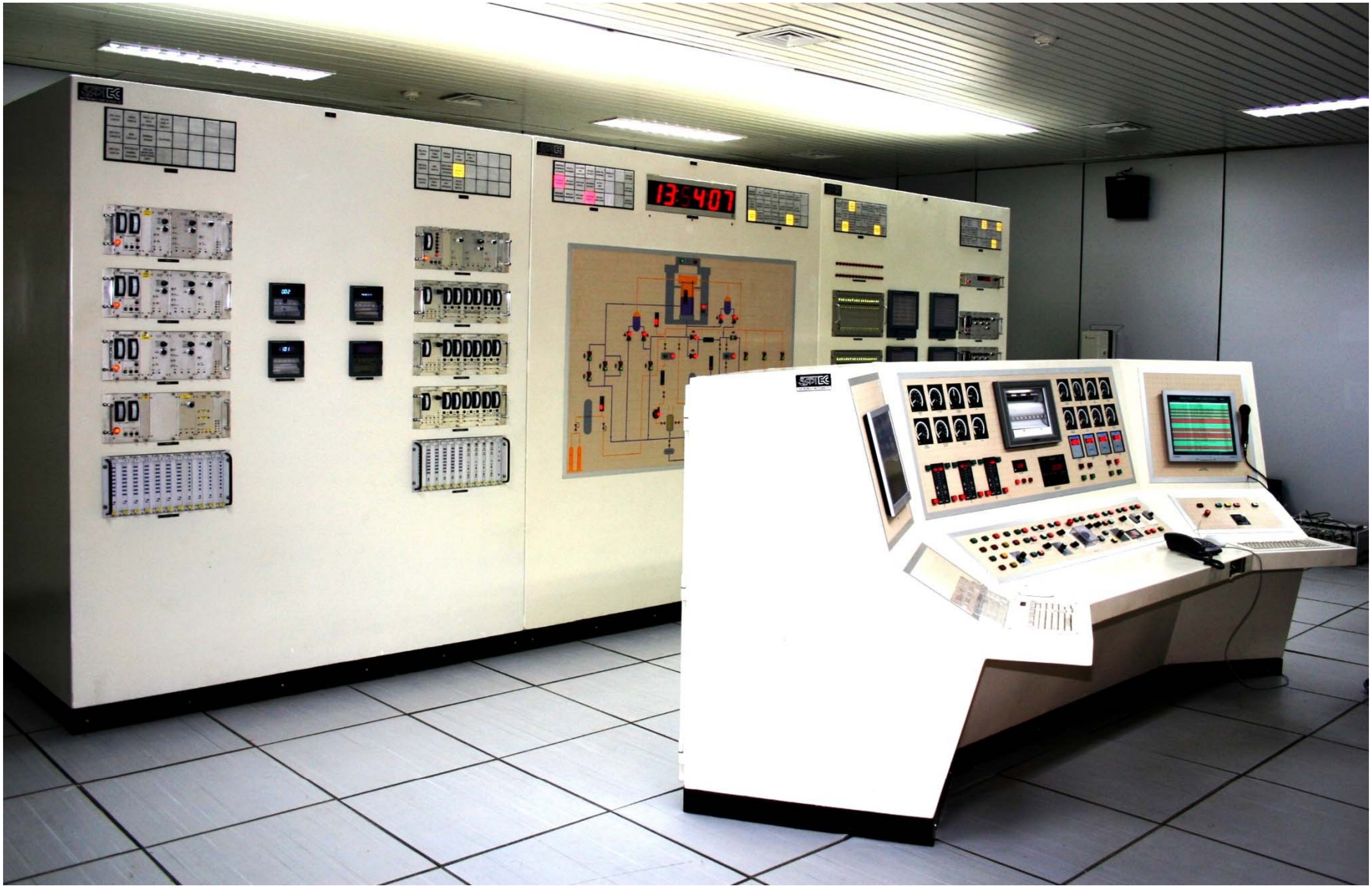
DETECTOR NEUTRON SENSITIVITIES

1) B-10 Lined Counters - 4 cps / nv

2) Uncompensated Ionisation Chambers - 2×10^{-14} A / nv



CONTROL ROOM



Experiments Carried out

- After commissioning Several experiments conducted for measurement of flux, reaction rates, neutron spectrum, flux disadvantage factor, ratio of epithermal to thermal neutron flux as also axial & radial flux profiles in the reactor.
- Measurement of combined and individual worth of Shut-off-rod(s).
- Measurement of level coefficient of moderator for the reference core.
- Measurement of reactivity worth and Calibration of Absorber rod
- An integral experiment for measuring critical height with the mixed cluster containing ThO_2 and Metallic Uranium pins loaded in the central location of the core.
- Fine structure flux measurement inside the central lattice

Planned Experiments for AHWR

- Critical height and level coefficient measurement with (Th-Pu)Oxide and (Th-U^{233})Oxide fuel
- Flux profile, reaction rates and the ring power factor inside the removable fuel pins of experimental fuel cluster.
- Worth of reactivity devices
- Assessment of coolant void reactivity
- Worth of Dysprosium burnable poison in ThO_2 & (Th-Pu)O_2 and (Th-^{233}U)Oxide in AHWR fuel cluster
- Reaction rate and initial conversion ratio measurements

Planned Experiments

- Experiments with an external neutron source using LEHIPA beam in sub-critical configuration of core planned to be carried out in CF as a part of ADSS programme. Desired level of sub-criticality will be achieved by changing moderator level / fuel loading.
- Planned to simulate one-way-coupled sub-critical region of proposed ADSS core. Two regions of core with different criticality properties will be assembled, separated by a buffer zone with a strong thermal neutron absorber. The source multiplication properties of such an arrangement will be validated.
- To study loosely coupled cores such as the 540 MWe PHWR by simulating decoupling (through water curtains etc). Dynamic experiments with such arrangement will be used to generate data for control stability evaluations

THANK YOU FOR THE ATTENTION