Safety Management and Effective Utilization of Indian Research Reactors APSARA, CIRUS and DHRUVA

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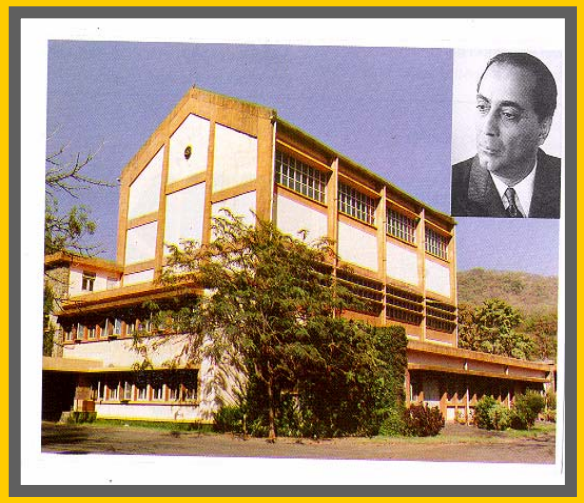
Research Reactors at Trombay

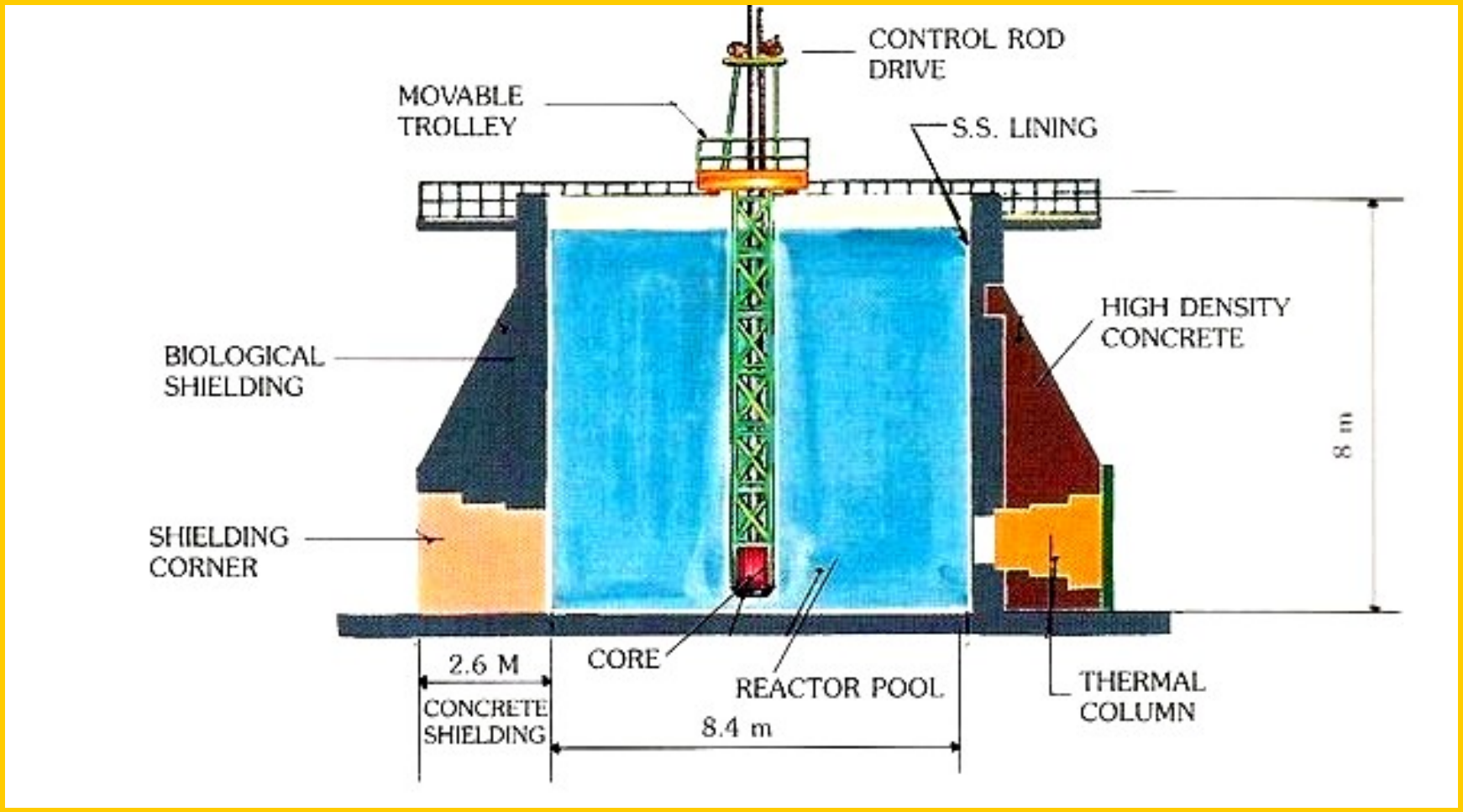


	APSARA	DHRUVA	CIRUS
TYPE	POOL	TANK	TANK
POWER	1 MWt	100 MWt	40 MWt
FUEL	En. U	NAT. U	NAT. U
COOLANT	LIGHT WATER	HEAVY WATER	LIGHT WATER
MODERATOR	LIGHT WATER	HEAVY WATER	HEAVY WATER
NEUTRON FLUX ($n/cm^2/sec$)	1×10^{13}	1.8×10^{14}	6.7×10^{13}

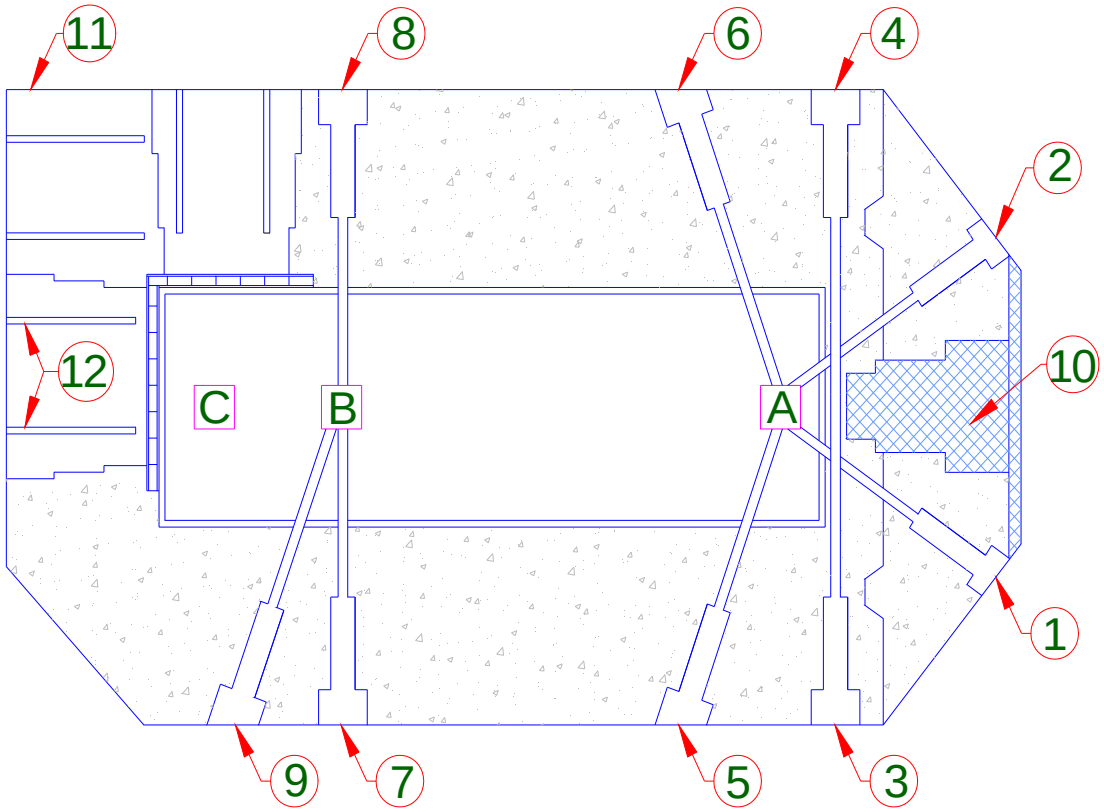
Research Reactors

	APSARA	**CIRUS**	**DHRUVA**
Reactor type	Pool type	Tank	Tank
Date of criticality	Aug 4, 1956	July 10, 1960	Aug 8, 1985
Nominal thermal power	1 MWt	40 MWt	100 MWt
Fuel	HEU in U-Al Alloy form-Al Clad Flat plate	Nat. U metal rods clad in Al	7 element cluster of Nat. U metal rods in Al clad
Fuel inventory	4.5 kg of U-235	10 Te	6.5 Te
Thermal neutron flux ($n/cm^2/s$)	1×10^{13}	6.5×10^{13}	1.8×10^{14}
Moderator / coolant	Light water	Heavy water / Light Water	Heavy water
Shutdown / Control devices	Cadmium plates	B_4C filled rods	Cadmium rods

APSARA


CONTROL ROD
DRIVE
MOVABLE
TROLLEY
S.S. LINING
HIGH DENSITY
CONCRETE
BIOLOGICAL
SHIELDING
8 m
SHIELDING
CORNER
2.6 M
CONCRETE
SHIELDING
CORE
REACTOR POOL
8.4 m
THERMAL
COLUMN

Apsara Reactor block



A, B & C - CORE POSITIONS

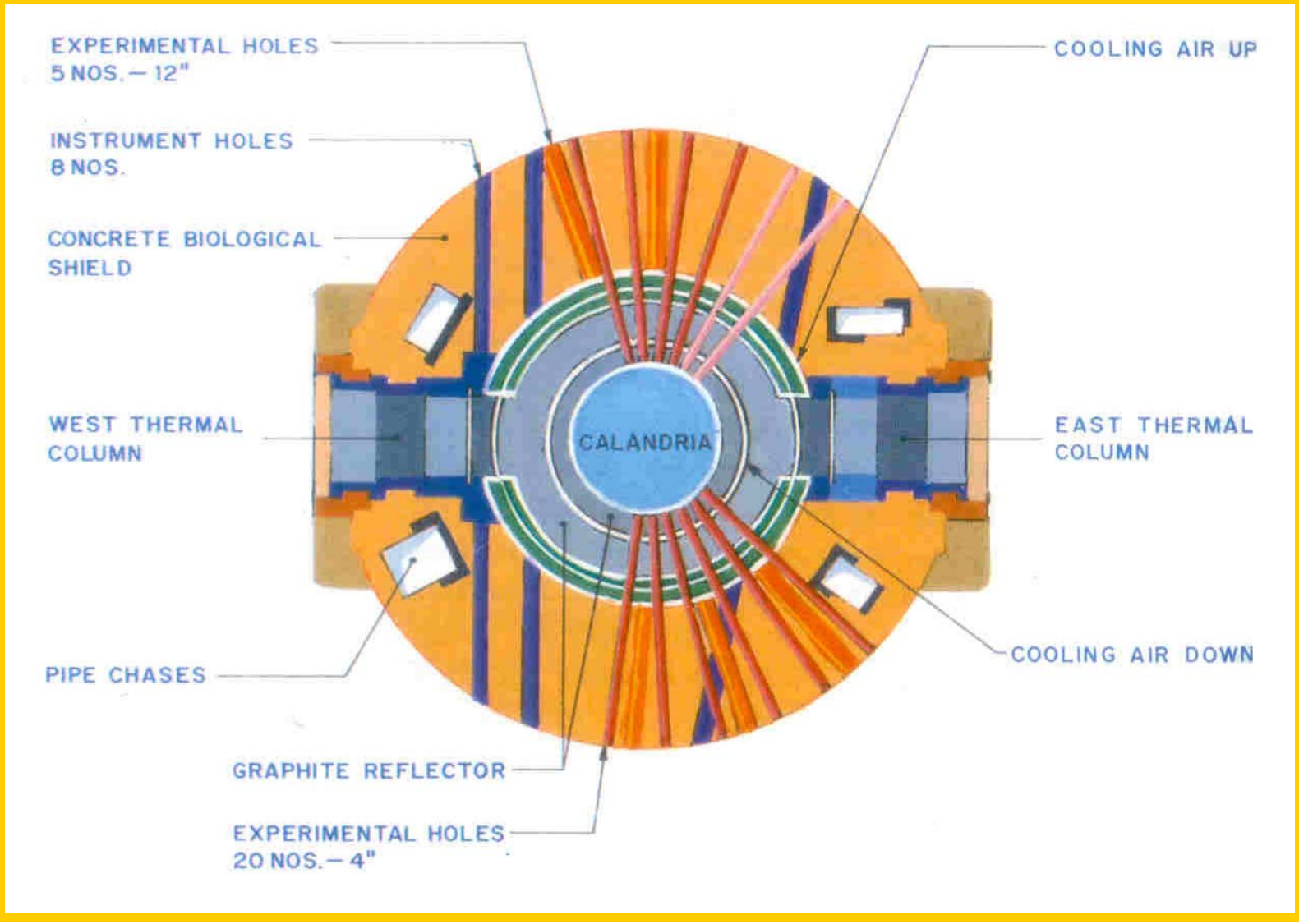
1 TO 9 - BEAM TUBES

10 - THERMAL COLUMN

11 - SHIELDING CORNER

12 - RAILS FOR MOVABLE SHIELDS

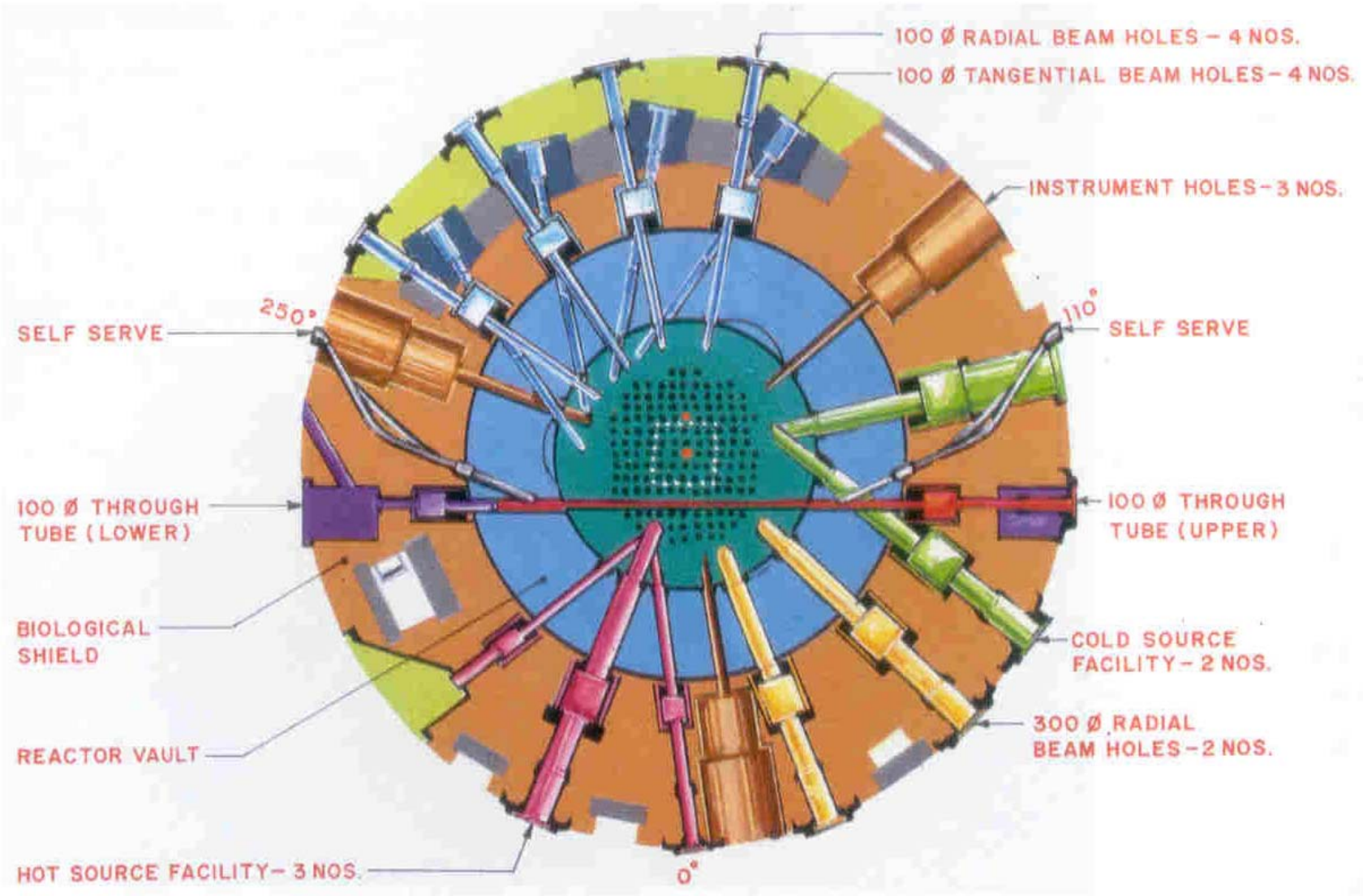
CIRUS – Experimental and Irradiation Facilities



CIRUS – Experimental and Irradiation Facilities

- Pressurized Water Loop – 400 kW, 2000 psig & 300^0C for irradiation testing of nuclear fuels, activity transport studies etc.
- Pneumatic Carrier Facility – Designed for pneumatically transporting the sample to the reactor for short term irradiation .
- Thermal Column Facility – Provides thermalised neutrons by replacing concrete shielding with graphite blocks in specified zones around reactor.
- 25 beam tubes and experimental holes

DHRUVA


100 Ø RADIAL BEAM HOLES – 4 NOS.
100 Ø TANGENTIAL BEAM HOLES – 4 NOS.
INSTRUMENT HOLES – 3 NOS.
250°
SELF SERVE
110°
SELF SERVE
100 Ø THROUGH TUBE (LOWER)
100 Ø THROUGH TUBE (UPPER)
BIOLOGICAL SHIELD
COLD SOURCE FACILITY – 2 NOS.
300 Ø RADIAL BEAM HOLES – 2 NOS.
REACTOR VAULT
HOT SOURCE FACILITY – 3 NOS.
0°

Experimental setup in Dhruva Reactor Hall

Dhruva – Experimental and irradiation facilities

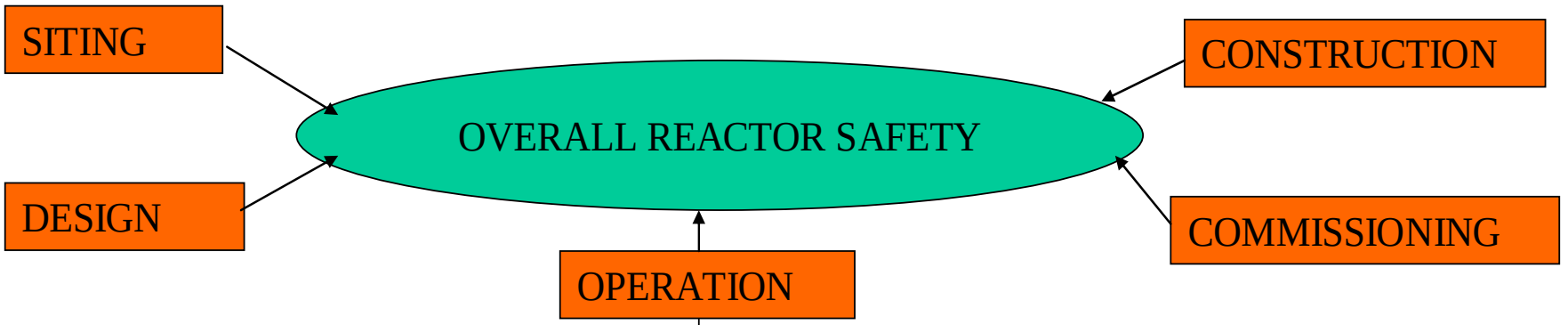
- Beam Tubes
  - 100 mm dia tangential and radial beam tubes - Four each
  - Two 300 mm dia radial beam tubes
  - Two through tubes of 100 mm dia beam tubes
  - One 300 mm dia cold neutron source beam tube
  - One 300 mm dia for installation of hot source beam tube
- 2 positions for isotope production and any lattice position can be used for installation of additional irradiation assemblies
- Pneumatic Carrier Facility – A short term irradiation facility for NAA
- 2 MW Pressurized Water Loop – operating at 100 kg/cm^2 & 290^0C for irradiation testing of nuclear fuels -- Being commissioned .
- Two Creep and Corrosion testing positions

Important Role Played By These Research Reactors

- Developing India's nuclear energy programme and in establishing the safety basis for the related activities
- Provided basic and essential facilities for
  - Training scientists and engineers
  - Neutron beams for conduct of research in many areas
  - Production and application of radio-isotopes in the field of medicine, agriculture and Industry
  - Generation of expertise in several other related fields such as radio-isotope processing, management of radioactive waste, fuel chemistry and radiochemistry, radiation protection and emergency preparedness

Safety, the Principle Goal

Principal goal of research reactor safety is to keep radiation exposure of plant personnel and members of public as low as reasonably achievable in all operational states and accident conditions



COMPLIANCE WITH OLC AND ASSURANCE OF LONG TERM SAFETY

MAINTENACE, SURVEILLANCE, INSPECTION

Preventive Maintenance
-Testing
-Servicing
-Replacement

- To minimise breakdowns
- Conducted at regular intervals based on periodic or predictive approaches
- Prolong service life of SSC

Surveillance
-Monitoring
-Functional tests
-Calibration checks

- Conducted at regular intervals
- To ensure compliance with OLC

In- Service Inspection
-Surface
-Sub-Surface
-Volumetric

- Conducted on a programmatic basis
- Aimed at assessing the condition of SSC subject to corrosion, erosion, stress, fatigue or other ageing effect

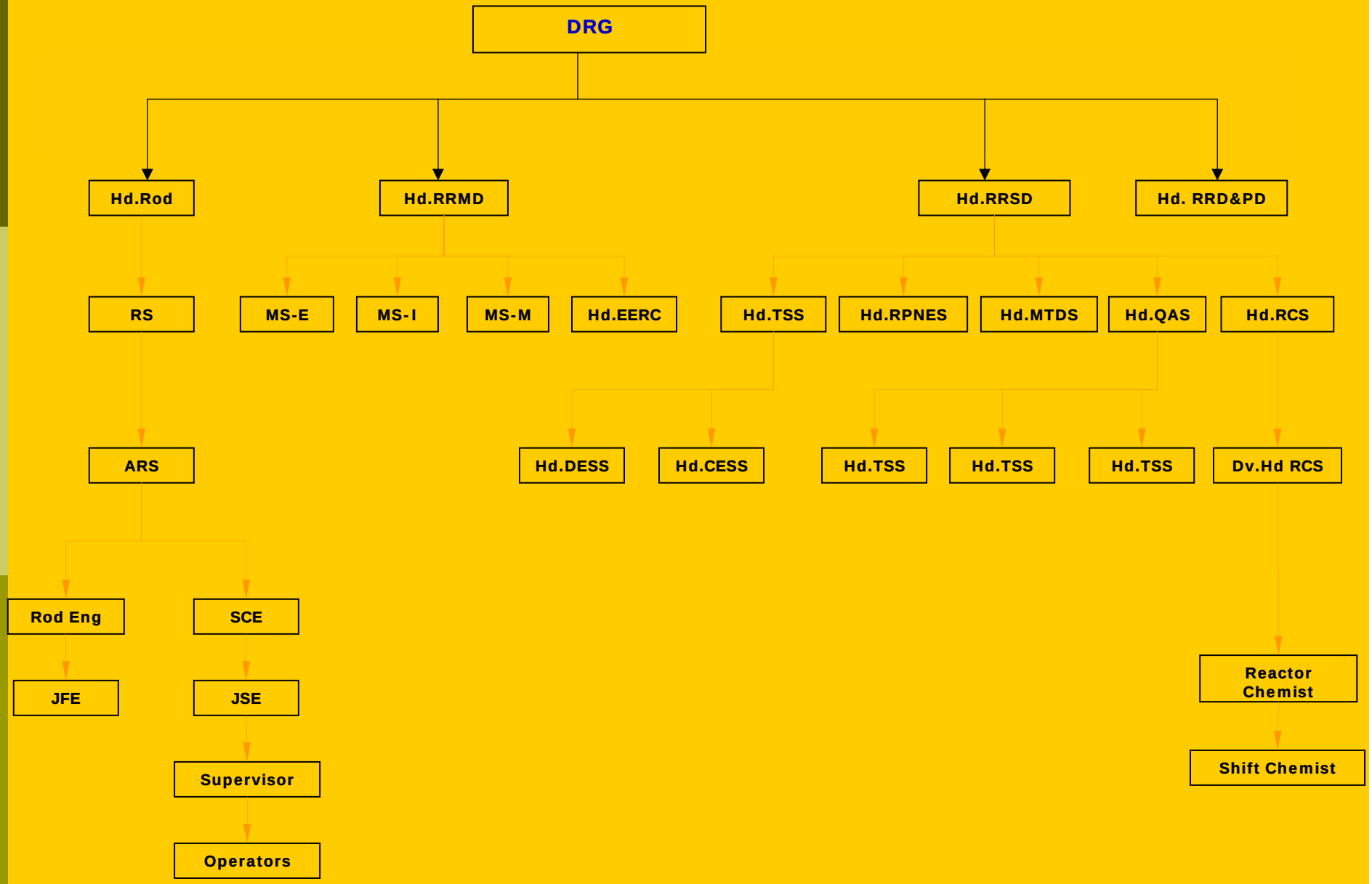
Safety Management of Apsara, Cirus and Dhruva

- **A well evolved and time tested system is in place**
- **Each constituent of safety management programme aims towards enhancing safety culture**

Operating Organization

- Structured organization set-up
- Well defined roles and responsibilities
- Well defined lines of communication and authority

Functional Organisation for Research Reactors



Documentation

Important documents

- **Design Basis reports covering design aspects**
- **Safety Analysis Report**
- **Technical Specification**
- **Quality Assurance manual**
- **In-Service Inspection Programme**
- **Emergency Operating Procedures**
- **Radiation Emergency Procedures**
- **Plan for the regular emergency exercises and tests**
- **Operating & maintenance procedures for normal operation**
- **Process & Instrumentation Diagram for all the process and safety systems**

These documents are reviewed and updated periodically.

Documentation

Technical Specifications for operation of the respective research reactor is the most important document

Contents

- Safety policy
- Operational Limits and Conditions (OLCs) for reactor systems
- Surveillance requirements and administrative controls.
  - The administrative controls cover functional organization chart, requirements of licensing for operating staff, O&M procedures, plant records, reporting, and functions of safety review committees

Technical Specifications

- Any change in this document requires approval of regulatory body.
- Strict adherence to the technical specification ensures operational safety of the research reactor.
- Any violation of the technical specification clause is taken seriously and reported promptly (within 24 hours) to the regulatory body.

Procedures and Practices

Good Operating Practices:

Work permits

- Maintenance work permit
  - Gas Cutting & Welding permit
  - Work and test permit
- Special work permits for special activities like jumpering of interlocks

Good Operating Practices: Contd.

- Written valve slips for effecting valve status changes
- Checklists for routine jobs requiring number of sequential activities
- Window forms for routine jobs
- Issuance of transfer slips for fuel movement
- Pile irradiation requests for irradiation of samples
- Approved fuelling agenda

Good Operating Practices: Contd.

- Close attention to chemistry of fluid systems
- Approved Emergency Operating Procedures for postulated off-normal conditions
- Duly approved special procedures for non-routine safety significant activities

These practices led to development of a strong safety culture wherein all plant personnel are conscious about safety importance of their actions and are proactive about maintaining and enhancing safety.

Procedures and Practices Contd.

Procedures

- Approved Emergency Operating Procedures for postulated off-normal conditions
- Duly approved special procedures for non-routine safety significant activities
- Care is taken in selecting such procedures to keep their number to a bare minimum to avoid dilution of their significance and the involvement of personnel in carrying out the procedures.
- Depending upon their safety significance some of these procedures are reviewed and approved by safety committees.

Procedures and Practices Contd.

- Our experience is that simple procedures written in collaboration with plant personnel highlighting the safety significance of each step are valued and are less likely to be bypassed compared to cumbersome procedures prepared in isolation.

Procedures and Practices

- Emergency Preparedness
  - Plant emergency and Site emergency
- Radioactive waste management
  - All discharges are monitored and recorded
  - All the activities related to radioactive waste management communicated to the regulatory authority periodically.
- Radiation safety
  - All radiation workers are monitored
  - An annual person mSv budget is prepared in advance and is approved by regulatory body. Assessment of the station dose is carried out periodically by Operation Review Committee to ensure dose consumption to be within budget.

Procedures and Practices contd.

- Reactor Utilization and modifications
  - Design of every proposed experiment and associated modification is done in accordance with the same principles that apply to the design of the reactor itself.
  - Utilization and modification proposals having major safety significance are subjected to an initial safety analysis to determine whether the change is within the operational limits and conditions
- Chemistry control
  - Stringent chemistry control of coolant and moderator system
    - Excellent condition of the pipelines in various systems of Cirus after 4 decades of service is credited to meticulous control of process systems chemistry

Training, Licensing and Re-Licensing

- Strong emphasis on formal training and licensing of personnel in research reactors
- Structured training programme
  - Class room lectures by senior and well qualified O & M staff members
  - On-the-job training in different plant areas
  - Systems checklists (a set of questions) signed by the authorized personnel.

Training, Licensing and Re-Licensing Contd.

Licensing process

- Written examination
  - Walk-through test
  - Assessment interview by an expert committee.
  - The license is valid for three years after which the person needs to be re-licensed by the expert committee.
  - In case a person remains absent from his licensed position for more than 35 days, he/she is required to get re-certified as per the established procedure before resuming his licensed position.

Incident Reporting

Caters to the requirements of reporting of operational anomalies and safety significant incidents

- For all operational events, a first information report is prepared immediately and is followed by a detailed report supplemented with Root Cause Analysis (RCA).

- Based on the RCA and subsequent reviews of the event by the safety authorities, necessary recommendations are formulated for implementation of measures that can prevent recurrence of such event.

Incident Reporting Contd.

- Reactor fault reports and system/equipment fault reports are also prepared in appropriate format for effective performance evaluation and initiation of timely corrective action to avoid translation of precursors into events/significant events.

- These reports after due investigation and incorporation of comments by the plant management are returned back to the O&M staff for discussion in crew meetings

Quality assurance and Internal Regulatory Inspection

Quality assurance programme includes

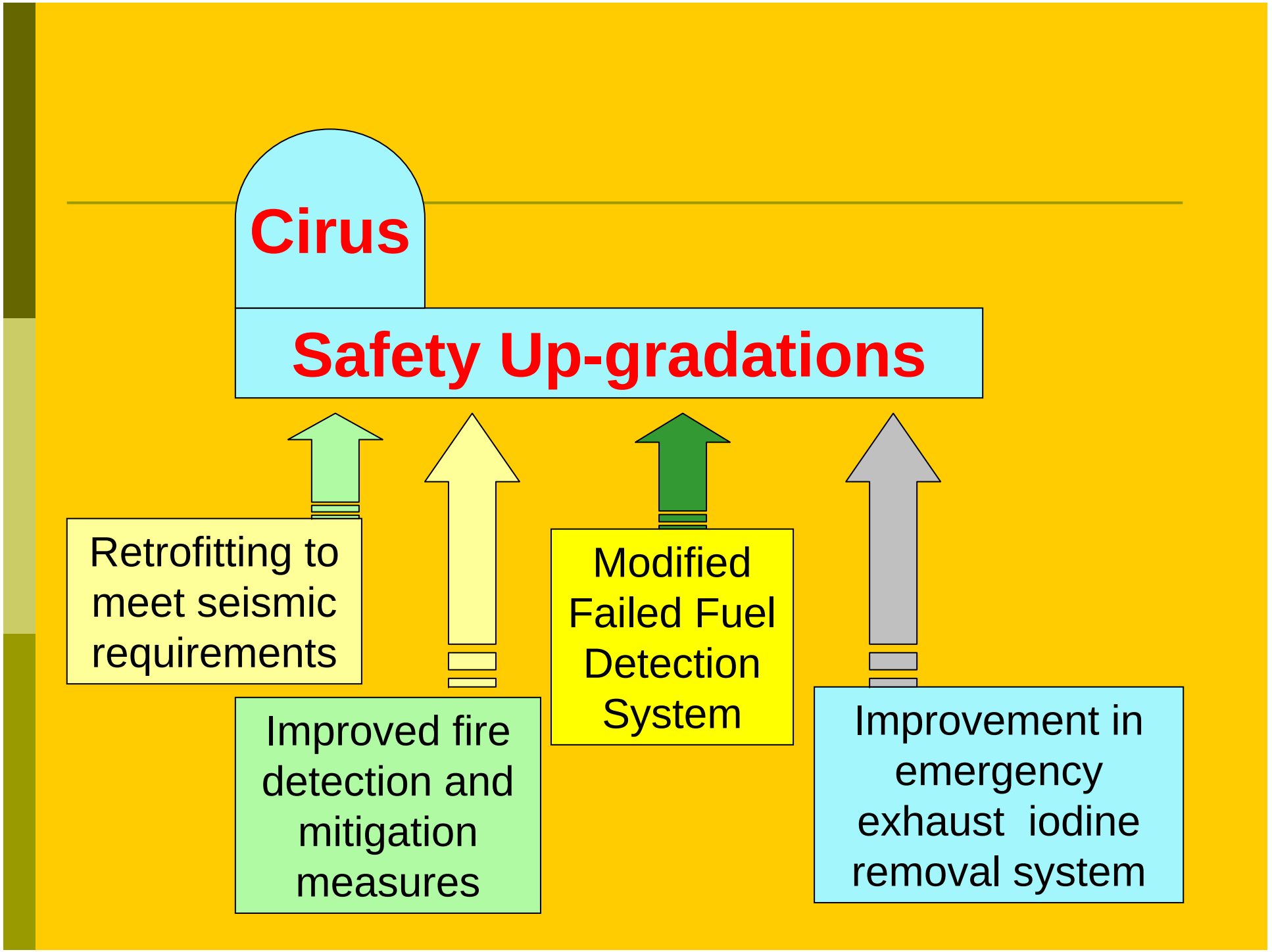
- Monthly technical audits of operational and maintenance activities
- Performance review of systems and equipments
- Checking compliance with technical specifications for all activities with specific emphasis on surveillance schedules
- Ensures implementation of recommendation of various safety committees and compliance with radiological and industrial safety measures in all O&M activities
- Periodic Internal Regulatory Inspections (IRI)

Ageing Management and Safety Upgrades

Ageing management aims at identifying refurbishment requirements and retrofit upgrades that need to be implemented to qualify systems, structures and components to current safety standards

CIRUS REFURBISHMENT – Major Activities

- REACTOR VESSEL – In Service Inspection
- REMOTE REPAIRS IN IN-ACCESSIBLE AREA
  - COVER GAS PIPE FLANGE JOINTS
  - LEAK RECTIFICATION OF ALUMINIUM THERMAL SHIELD COOLANT PIPE
- PRIMARY COOLANT PIPES
- LIFE ASSESSMENT OF EQUIPMENTS
- BALL TANK LEAK REPAIRS
- EXTENSIVE EXTERNAL CORROSION PROTECTION MEASURES


Cirus
Safety Up-gradations
Retrofitting to meet seismic requirements
Improved fire detection and mitigation measures
Modified Failed Fuel Detection System
Improvement in emergency exhaust iodine removal system

Life Extension and Ageing Management

Cirus Refurbishment

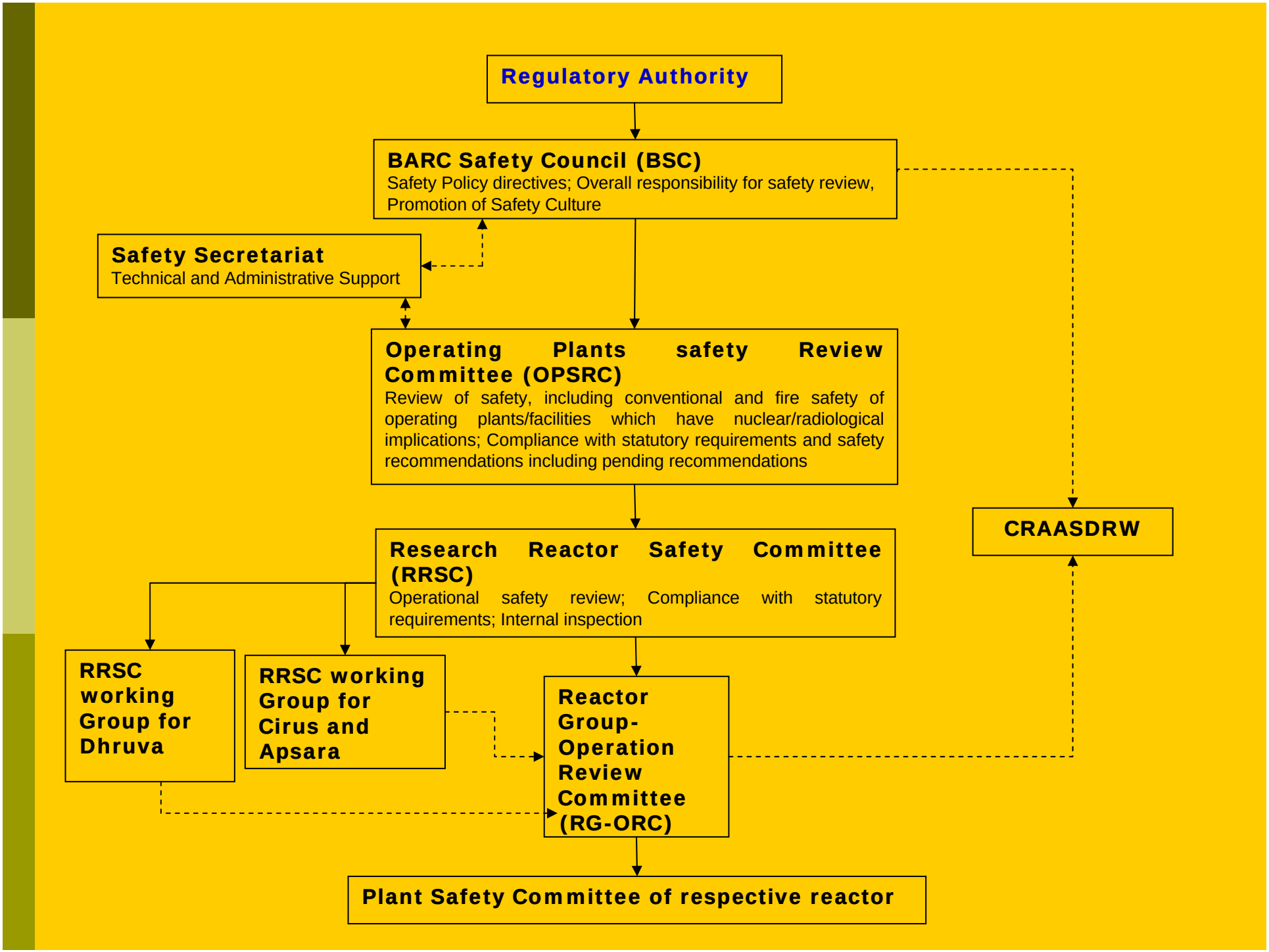
- Ageing studies
- Remote installation of split clamps on helium lines.
- Remote installation of hollow plug in cooling line of Aluminium thermal shield.
- Reconditioning / replacement of underground piping and cables.
- Repair of emergency water storage tank.
- Expertise acquired

Plan for Apsara Refurbishment and up-gradation

- To extend its useful life and to meet the current safety standards
- Upgrading the reactor to a 2 MW reactor to enhance the maximum available thermal neutron flux to 6.5 x 10^{13} $n/cm^2/s$.
- LEU plate type fuel in the form of U3Si2 dispersed in aluminium
- Beryllium oxide will be used as the reflector
- Reactor building and associated structure will be strengthened to meet the current seismic standards.

Regulatory Review and Control

- A multi-tier regulatory framework with clear assignment of responsibilities exists for regulatory review and control of research reactors
- First Review at ORC
- Second Level Review at RRSC
- Third Level Review at BSC
- Final Directive By Regulatory Authority


Regulatory Authority
BARC Safety Council (BSC)
Safety Policy directives; Overall responsibility for safety review, Promotion of Safety Culture
Safety Secretariat
Technical and Administrative Support
Operating Plants safety Review Committee (OPSRC)
Review of safety, including conventional and fire safety of operating plants/facilities which have nuclear/radiological implications; Compliance with statutory requirements and safety recommendations including pending recommendations
CRAASDRW
Research Reactor Safety Committee (RRSC)
Operational safety review; Compliance with statutory requirements; Internal inspection
RRSC working Group for Dhruva
RRSC working Group for Cirus and Apsara
Reactor Group-Operation Review Committee (RG-ORC)
Plant Safety Committee of respective reactor

Effective Utilization of Apsara, Cirus and Dhruva

Effective Utilization

- A large number of user groups are available within BARC.
- A users committee coordinates the utilization programme for our research reactors.
- The National Facility for Neutron Beam Research (NFNBR) at BARC, caters to the needs of the Indian scientific community
- Scientists from, universities and national laboratories also use these facilities in research reactors through collaborative research projects
- Many of these collaborations are being supported by University Grant Commission - DAE Consortium for Scientific Research (UGC-DAE CSR), Board of Research in Nuclear Sciences (BRNS), and other agencies

Utilization of Research Reactors

These reactors provide

- Neutron Beam Research
- Nuclear Physics Research
- Neutron Activation Analysis
- Fuel & Materials Testing
- Detector Testing
- Isotope Production
- Neutron Radiography
- Shielding Experiments
- Utilization of low temperature waste heat
- Nuclear techniques in Agricultural & Biological Applications

Concluding Remarks

- Safety management system practised in Apsara, Cirus and Dhruva is evolved with experience and is updated from time to time based on operational experience and new knowledge acquired.
- The excellent safety track record of research reactors in India over 150 reactor years of operation proves the effectiveness of our safety management system.

Concluding Remarks Contd.

- Ageing of old reactors has been managed by systematic assessments and refurbishing actions.
- The refurbishing outage has been also utilized for making several safety upgrades to meet present safety standards, as in the case of refurbishment of the Cirus reactor.
- Safety improvements have been made on a continuing basis based on operating experience and new knowledge.
- At times, these improvements have gone beyond the requirements of design and safety analysis giving credence to the slogan **AHARA "Safety – As High As Reasonably Achievable".**

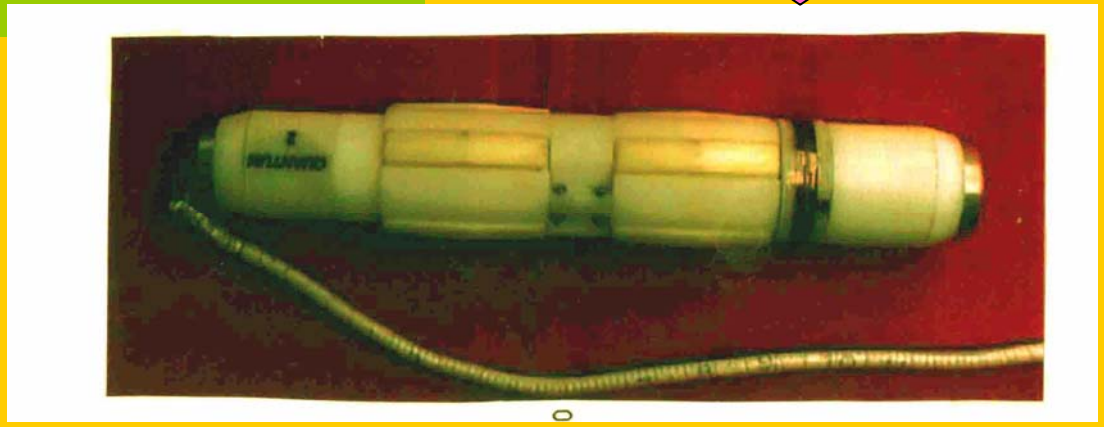
thankyou

Cirus Ageing Studies

Ageing studies were mainly focused on

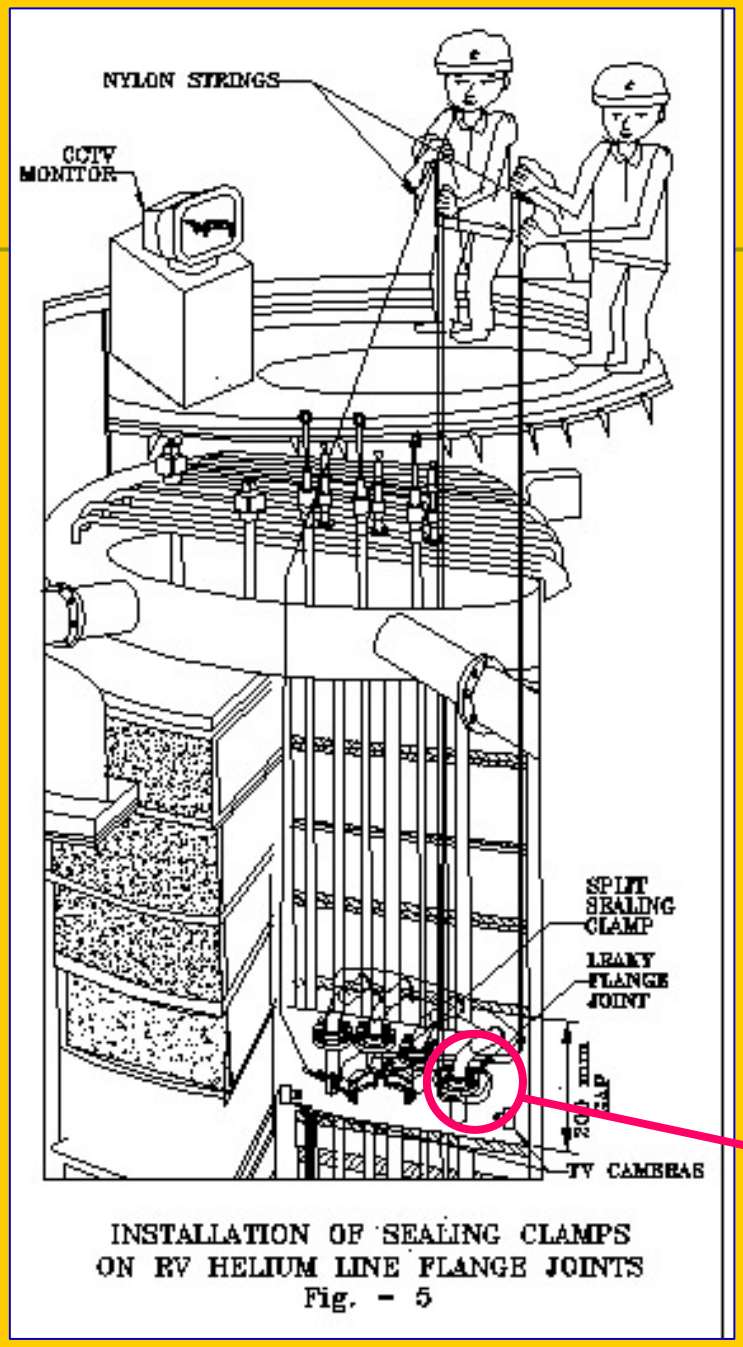
- In-core components
- Safety systems
- Important civil structures

ECT Probe for Cirus Calandria Tube Inspection



Helium pipe leak rectification

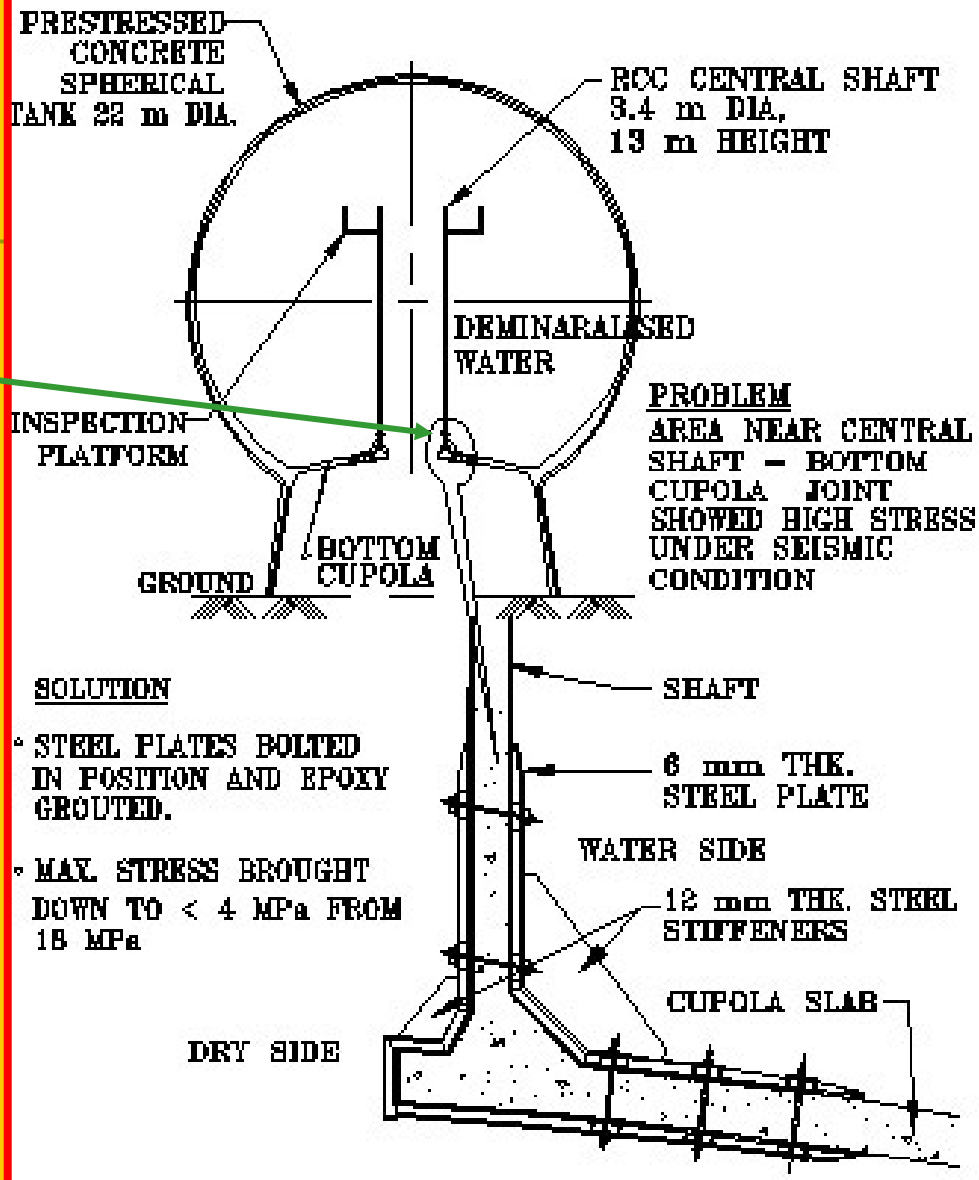
- Tongue and groove flange joints in helium pipe lines were experienced to be leaking
- Location: In an inaccessible area located 4.5 M below the working platform in a 200 mm vertical gap between steel thermal shield and biological shield
- For this repair encircling split clamps were developed and installed remotely



INSTALLATION OF SEALING CLAMPS
ON RV HELIUM LINE FLANGE JOINTS
Fig. - 5

Repair of Emergency Water Storage Tank

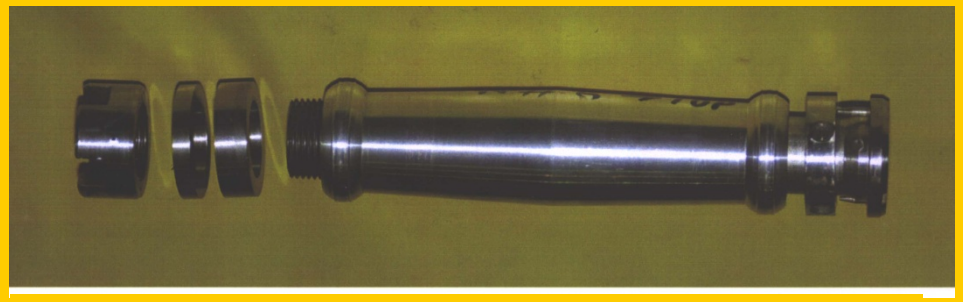
- A small leak had developed near the bottom of the central inspection shaft
- Repair work :
  - Strengthening of central shaft by steel jacketing to meet seismic qualification requirements
  - Pressure grouting by epoxy injection
  - Entire surface was coated with water proofing compound



STRUCTURAL RETROFITTING IN BALL TANK
Fig. – 8

Remote repair of leaky cooling line of Al-thermal shield

- Pressure testing indicated leak in the Al thermal shield in core region
- Remote inspection revealed that one of the joints in the coolant inlet pipe is leaking.
- Since the location was not accessible for repair, a hollow sleeve type plug as shown in the photograph was developed and installed inside the leaky pipe remotely after a full scale mock-up



Hollow plug used for arresting leakage from inlet pipe of Aluminium Thermal Shield.

Replacement and servicing activities during Cirus refurbishing

Replacement (Length)

Piping	4 Km
Power Cables	3 Km
Control Cables	4 Km
Thermocouple Cables	5 Km

Servicing (Nos.)

Valves	350
Electrical Motors	100
Thermocouples/RTDs	200
Control Valves	100
Assorted Inst. Items	200

Reconditioning of underground piping in primary cooling system of Cirus

Expertise acquired in Ageing Management

- Preservation of Systems Structures and Components during long outage
- Re-commissioning of refurbished systems
- Special startup of refurbished reactor
- Data generation for future decommissioning

DHRUVA Tray Section, Sample capsule & Self serve ball

NARO/ARO

REACTOR GROUP

M/E/I-

APSARA / CIRUS / DHRUVA REACTOR
WORK PERMIT FORM

Date

INITIATION

A Job :

Initiated by : (Name in Capital Letter)

Area :

Verified by : (Shift Engineer)

PREPARATION

B Observation by Maintenance

C Power supply isolation & Red Tag Installation

Requirement

Supply Isolation Required	Yes	Not required
Fuse removal	Yes	
Tag Installation	Yes	

Shift Engineer
Time : Hrs.

Execution at site

Supply Isolated	Yes	
Fuse removed	Yes	
Red Tag # ..... installed on breaker	Yes	

D

RHC / IS Clearance	Yes required	Not required
System Isolated	Yes	Not required
Gas Cutting / Welding Permit issued	Yes	Not required

Precautions :

Permit expires at ..... hrs. (unless specified, expires at the end of the day, 1630 hrs.)

It is mandatory for the maintenance staff to contact area operator for correct identification of the equipment before starting the job.

Does job involve Gas Cutting / Welding | Yes | No

Estimated Time ..... Hr

Maintenance Supervisor
Time : Hrs.

Shift Electrical Foreman
Time : Hrs.

Shift Engineer
Date : Time : Hrs.

RHC / INDUSTRIAL SAFETY CLEARANCE

E Name of the Maintenance Supervisor :

1. Radiation Safety Protection Gears :

Maximum time limit per person.....hrs./minutes

Coveralls	Wrist Badge	Plastic Suit	Dosimeter	Fresh Airline Respirator
Gloves	Head Badge	Urine Sample	Comfo Respirator	

2. Industrial Safety Protection Gears :

Rubber glove	Goggle	Life line	Medical fitness	Contact Safety Co-ordination Engineer **
Gum boot	Helmet	Safety belt	Fresh air respirator & face shield	
Face shield	Apron	Canvas shoe	Asbestos glove	

3. Special precautions for working in Apsara pool / core are to be taken | Yes
Any other precaution (change of coveralls etc.) :
** Comment & Signature of Safety Coordination Engineer, if required

Health Physicist / Time : Hrs.

EXECUTION AT SITE

F Job completed | Yes | No | Surplus maintenance material removed | Yes | No

Brief description of the work done :

Instructions, if any :

Maintenance Supervisor
Time : Hrs.

NORMALISATION

G Permit to resume power supply and removal of Red Tag

Resume Supply	Yes	
Install Fuse	Yes	
Remove Red Tag	Yes	

Shift Engineer
Time : Hrs.

Breaker put on	Yes		
Fuse Installed	Yes		NA
Supply resumed	Yes		NA
Red Tag # ..... & Stub Returned			

Shift Electrical Foreman / Time : Hrs.

H Report on job status

Surplus maintenance material is removed | Yes | No

Remarks :

Lead hand / Time : Hrs.

I Permit Clearance

Job completed | Yes | No

Gas Cutting / Welding Permit cleared, if issued | Yes | No

Remarks :

Shift Engineer / Time : Hrs.

CONTROL ROOM COPY

RENEWAL OF WORK PERMIT

Date	Receiving Officer	RHC Clearance	Time of Expiry	Shift Engineer	Day's Progress	Dose Received as per Dosimeter	Cleaning Officer	Shift Engineer

MAINTENANCE RECORD

1. Reason for equipment removal/maintenance PM/Overhaul/Breakdown
2. Status of equipment
3. Inspection Report of equipment / components
4. Equipment / Components replaced
5. Commissioning Report
6. Remarks

Signature :

Name :

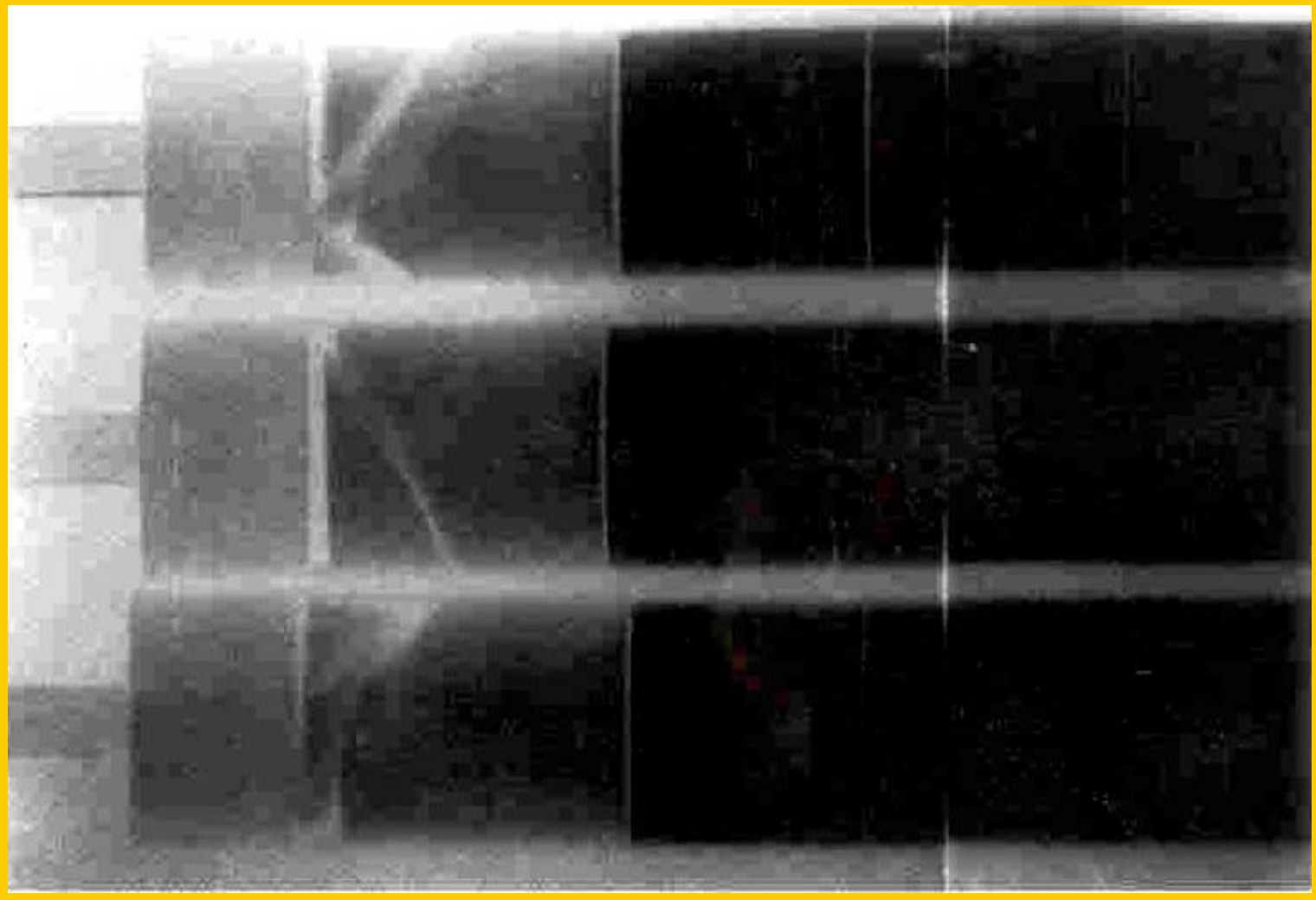
Section :

(Maintenance Supervisor) (Maintenance Engineer)

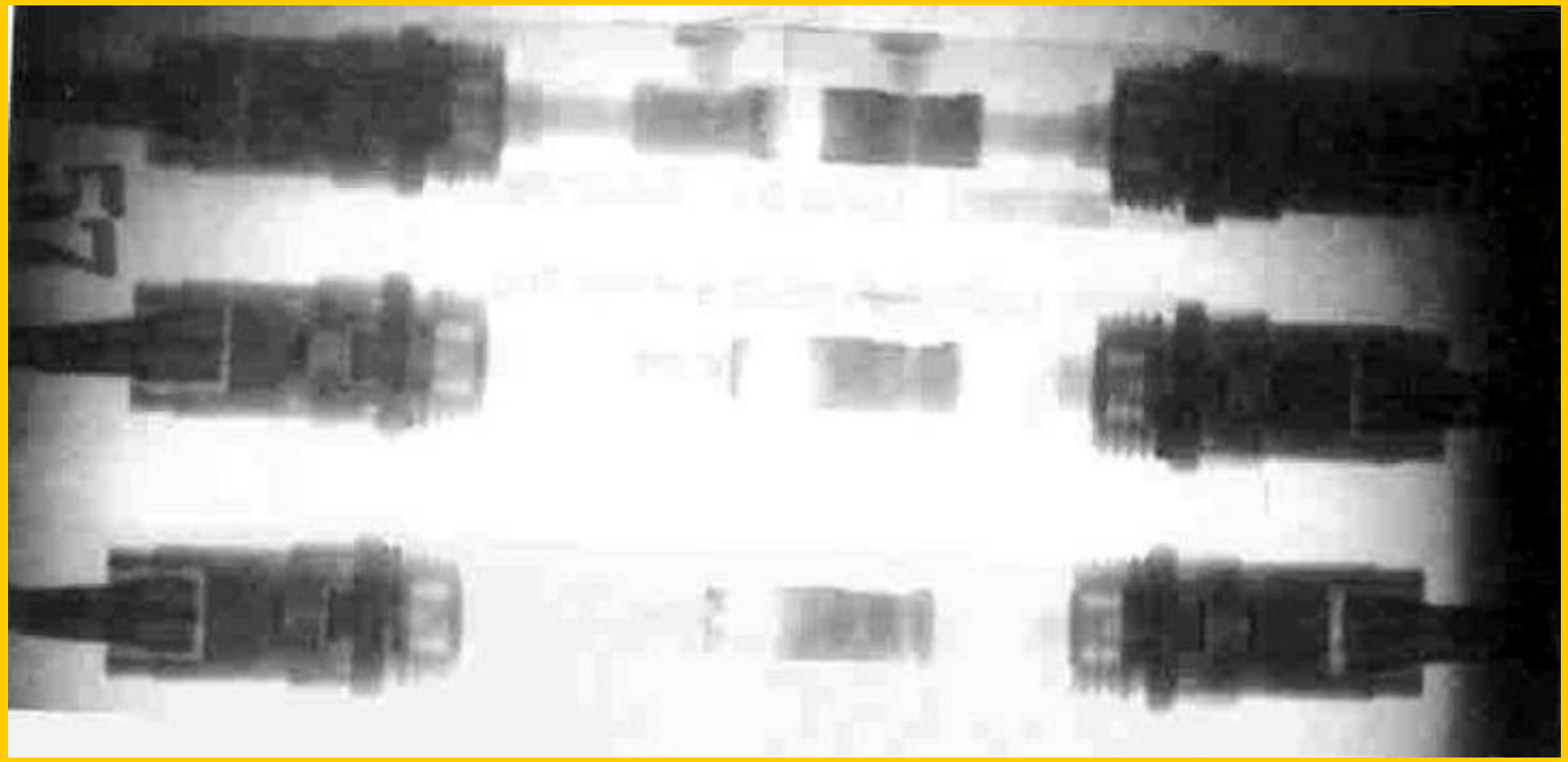
Red Tag


APSARA/CIRUS/DHRUVA
Tag No. 7801
DANGER
DO NOT OPERATE
खतरा
System/Eqipment
Work Permit No.
Date
SE'S Name
STUB
Tag No. 7801
Date
System/Equiment
Work Permit No.

Trombay Rice variety ‘Hari’, A Dwarf mutant induced with fast neutrons

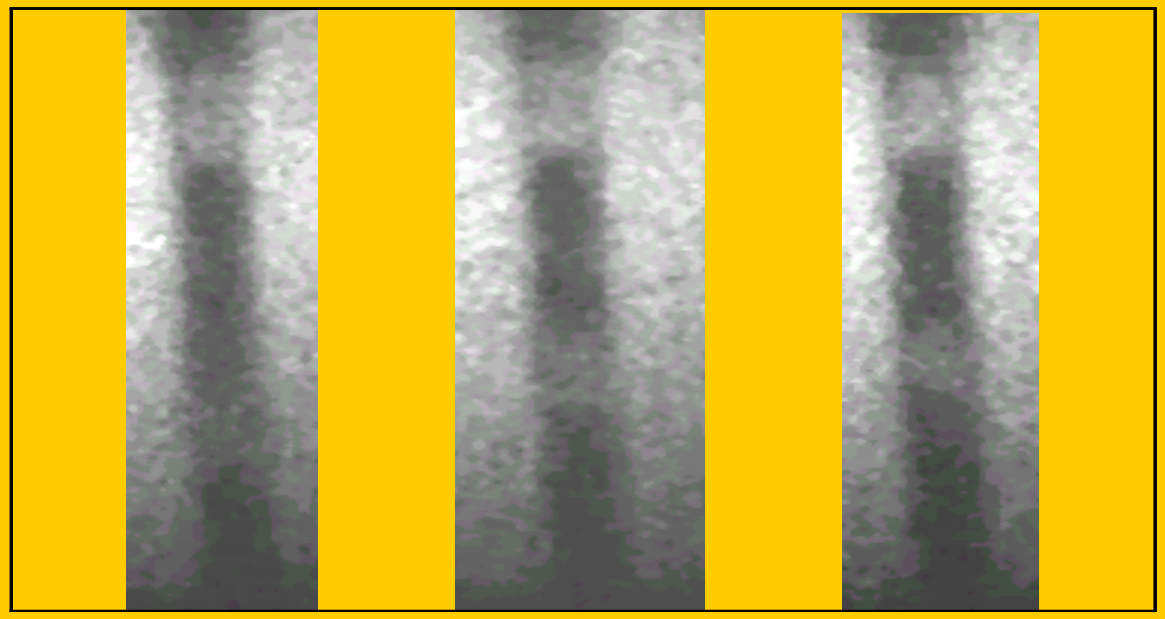


Neutron Radiograph of damaged thermal insulation pellets in MOX fuel pins



Neutron radiograph of cable cutters used for satellite solar panel deployment

Image of Neutron Radiography of Two phase flow



SPND for in-core applications in Nuclear Power Plants

Shielding Experiment Programme in APSARA

- **PFBR Shielding**
  - **Simulation of PFBR Blanket leakage neutron spectrum in Shielding corner using depleted uranium converter assemblies.**
  - **Six Radial and one Axial Bulk Shielding Experiments**
  - **Three radiation streaming experiments.**
  - **Bulk shielding experiments to study neutron and gamma attenuation through pure materials used in the fast reactor shielding.**
- **AHWR Shielding**
  - **Experiments for Evaluation of streaming through various sizes and types of channels and penetrations to be used for shielding design of Advanced Heavy water reactor (AHWR)**

Fuel Irradiation studies

- Towards development of Mixed Oxide (MOX) fuel, UO_2-PuO_2 fuel pins were test irradiated for stipulated burn up in Pressurized Water Loop (PWL) of Cirus reactor. Various design and manufacturing parameters were assessed through these tests
  - Particle size of Pu agglomerates and their distribution in pellets
  - Variation in pellet - cladding gap
  - Variation in cladding manufacture route
  - Variation in filler gas composition
- Towards utilization of Thoria based fuel in PHWRs an experimental assembly containing ThO_2-PuO_2 fuel pellets was successfully irradiated to a burn up of more than 15000 MWD/Te in PWL.
- Irradiation of intentionally defected fuel pin for Activity transport studies
- Studies contributed significantly to the development of Nat U oxide and Nat U-Pu MOX fuels for power reactors

Material Irradiation studies

- Zircaloy calandria tubes manufactured by different routes were test irradiated in Dhruva reactor to study their In-pile growth behaviour
- Assessment of radiation induced creep of Zirconium materials was carried out
- Radiation embrittlement studies of materials used in Indian PHWRs
- Studies on pressure vessel steel to measure post irradiation static and dynamic fracture toughness
- Studies resulted in finalization of manufacturing route for the PHWR pressure tubes and calandria tubes

Nuclear techniques in Agricultural & Biological Applications

- Neutron induced mutations to produce genotypes with high yield, improved quality, early or late maturity, tolerance to disease & pests.
- Induction and isolation of mutant varieties in different crops, plants and ornamentals.
- P^{32} labeled bimolecules for advanced work in genetic engineering
- Studies to confirm the Radiation Induced growth stimulation
- Study of Post irradiation effects to enhance shelf life of agro products

Development & Testing of Nuclear Instrumentation

- **Testing and Calibration of ion chambers, B-10 lined proportional counters from ECIL**
- **Calibration of variety of miniature neutron detectors for in-core applications in atomic power plants**
-
- **Start-up channel for Kamini reactor and Narora Atomic Power Plant (NAPP)**
- **Measurement of neutron sensitivity of Cobalt, Platinum, Vanadium SPNDs**
- **Self-Powered Neutron Detector amplifiers for 500 MWe PHWRs**

Neutron Activation Analysis

NAA used for detection of trace elements in variety of matrices such as geological, biological, archaeological, environmental, high purity materials, nuclear pure materials and forensic samples.

- Quick characterization of geological samples from GSI
- Study of rare earth elements in monazite sand and U & Th containing minerals
- Characterisation of ultra high purity silicon, gallium
- Analysis of biological and rock samples such as Basalt, Granite, Zircon, Monazite, Apatite, Limonite, etc.
- Chloride content of Zr - 2.5 % Nb material
- Forensic investigations

Neutron Radiography

- In the development of reactor fuels
  - Characterization of U-Pu MOX fuel pins.
  - Monitoring of compositional variation of PuO_2 in U-Pu MOX fuel pellets inside sealed fuel pins
- Assessment of hydriding on Zircaloy-2 pressure tube of Pressurised Heavy Water Reactors (PHWRs).
- Non-Destructive Testing of components used in aerospace e.g. cable cutters and pyrocharges, etc used for satellites
- Evaluation of Boron Carbide distribution in burnable poisons, poison rods and poison plates
- Study of flow pattern transition instability in boiling channels of Advanced Heavy Water Reactor (AHWR)

Utilization of low temperature waste heat for Desalination of seawater

- A 30 m^3/day seawater desalination plant based on low temperature vacuum evaporation process utilizing Cirus reactor waste heat coupled with Cirus and made operational
- High quality product water with low TDS obtained
- Technology will be utilized for recovery of moderator waste heat for desalination in future PHWRs located at coastal sites.

Radioisotope production

- **Isotope production programme started in mid fifties after setting up of Apsara**
- **The regular supply of isotope for various uses commenced in early sixties after Cirus became operational. Today the reactors cater to the needs of 1250 user institutions.**
- **Preparations of Mo^{99}, I^{131}, I^{125}, P^{32}, S^{35}, Cr^{51}, Co^{60}, Au^{198}, Br^{82}, Ir^{192} and other isotope are supplied to industrial, agricultural and medical institutions.**
- **Variety of nucleonic gauges for measurement of density, thickness, moisture content, bulk quantity, etc have been developed with wide acceptability in the industry.**

Radioisotope production (…Continued)

- **Variety of techniques developed for study of effluent dispersion in water bodies.**
- **Residence time measurement in chemical reactors, flow patterns in fluidized beds, entrainment and flooding patterns in distillation columns, silt movement studies, etc through radioactive tracer techniques**
- **Radiation processing including sterilization of medical products, sterilization of agricultural products, hygienisation of city sewage utilize isotopes produced in BARC**

Work and Test Permit

Work and Test Permit

(WT form should accompany the main work permit under which the maintenance was carried out, for jobs where equipment is to be tested before proceeding with further activities)

WT-1 Testing requirements

Main permit number :

Date and time of issue :

Brief description of job done :

Test details and duration of test :

Maintenance supervisor
Date and time

WT-2 Clearance for testing

Other permits on the said equipment are cleared :

Power supply resumption for only testing purpose :

System isolation done normalised for testing purpose :

Special precautions :

Permit expires at :

Shift engineer
Date and time

WT-3 Power supply resumption for testing

Other permits on the equipment cleared :

Power supply resumed for testing :

Under testing caution board displayed :

Shift electrical supervisor
Date and time

Work and Test Permit Contd..

WT-4 Test completion
Brief test results : Rework requirement : Remarks if any : Maintenance supervisor Date and time
WT-5 Power supply normalisation/isolation requirement
Power supply normalisation for regular operation as in column-G of main permit: Power supply isolation for further work: Red tag to be installed: Process side isolation requirements: Special precautions: Shift engineer Date and time
WT-6 Power supply normalisation/isolation status
Other permits on the equipment cleared : Power supply normalised: Red tag and caution boards removed: power supply isolated for further work and red tag installed : Shift electrical supervisor Date and time

Neutron Beam Tube Research

- Apsara, Cirus and Dhruva reactors are extensively used in the frontier areas of neutron beam research.
- Complete expertise developed in the area of neutron beam research in crystallography, magnetic scattering, and inelastic scattering which has yielded information on structures of amino acids, ferrites, magnetic alloys, high temperature super conductors, intermetallic compounds like Zr_2Ni for Hydrogen absorbing properties and other systems exhibiting phase transitions.
- Lattice dynamical studies of metals and complex ionic systems
- Small angle neutron scattering(SANS) to study nano-composites, soft matter (gel, colloids, polymers), ferro fluids, micellar formation using variety of surfactants including multi-head group surfactants, etc.
- Several instruments like Single crystal diffractometer, powder diffractometers, high-Q diffractometer, polarization analysis spectrometer, have been developed and a time-of-flight quasielastic spectrometer spin-echo spectrometer and ultra small angle instrument will be installed soon.

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Reactor Group

Form No. RG-2

APSARA/CIRUS/DHRUVA REACTOR
GAS-CUTTING & WELDING PERMIT

(Applies only to area specified below)

Ref : NARO/ARO Work Permit No. M/E/I _____ Dt : / / Issued to _____

Gas Cutting & Welding Permit No. _____ Date : / / Area / Location : _____

Description of work _____

Job Allocated to : (Welder / Cutter) _____

_____
(Work shop In-charge/Foreman)

TYPE OF GAS CUTTING	TYPE OF WELDING

PRECAUTIONS		Yes	No
Within 35 feet of work area / location (Open areas)			
1.	Floors swept clean of combustibles		
2.	Combustible floors wet down or covered with asbestos		
3.	No combustible or flammable liquids		
4.	Combustibles or flammable liquids covered with asbestos or metal shields		
5.	All wall and floor opening covered		
6.	Fire proof tarpaulins suspended beneath work to collect molten material / sparks		
Grounding of Welding Machine			
7.	Receptacle grounding		
8.	Job grounding		
Walls & Ceiling			
9.	Combustibles moved from opposite side of wall		
Enclosed Equipment / Confined Area (Pipe lines, Tanks, Ducts)			
10.	Equipment cleaned of all combustibles		
11.	Containers purged of flammable vapours and well ventilated		
General			
12.	Gas cutting & welding equipment in good condition		
13.	Portable and appropriate fire extinguishers available in good condition near job site		
Fire Watch			
14.	To be provided during and for 30 minutes after operation		
15.	Supplied with fire extinguisher		
16.	Trained in use of fire equipment and turning in an alarm		

The above location has been examined and the precautions mentioned above (1 to 16) have been taken to prevent fire.

_____
(Mech. Maint. Supervisor)

Approved to commence work

_____
(Shift Engineer)

Final Check-up before Clearing the Permit

Work area and adjacent areas to which fire sparks and heat might have spread (floors above and below and opposite sides of walls) were inspected for at least 30 minutes after work was completed, and were found fire safe.

Date & Time work completed : ___/___/___ : _____ Hrs.

_____
(Mech. Maint. Supervisor)

Permit Cleared : Yes / No

Date : / / Time : Hrs.

_____
(Shift Engineer)