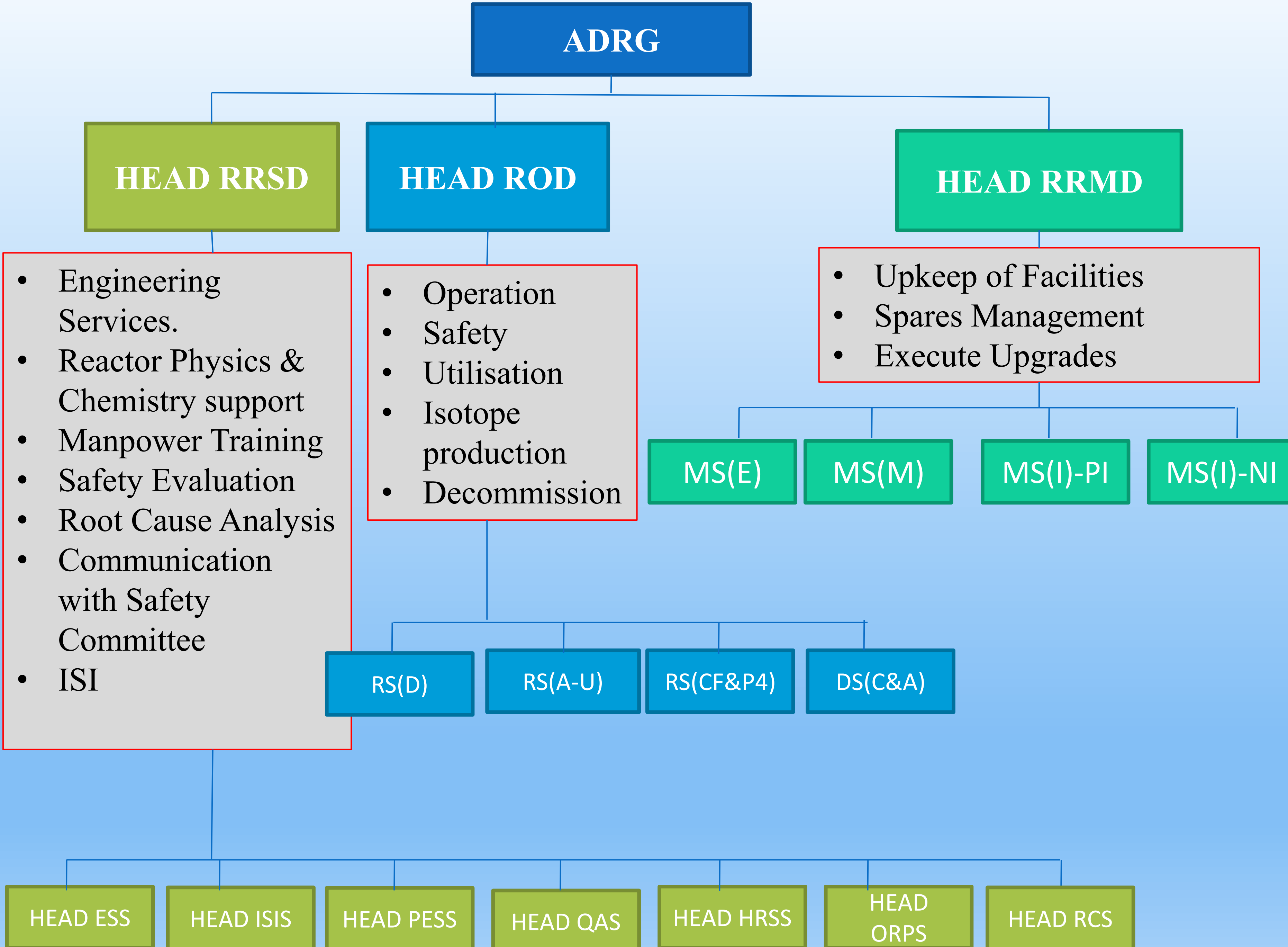
Reactor Group Activities

Reactor Group Mandate

- Safe and Efficient operation of Research Reactor at Trombay.
- Facilitating utilisation of Research Reactors for:
  - Engineering Experiments
  - Detector testing.
  - Material Testing
  - Fuel Testing
  - Beam Tube research
  - Neutron Activation Analysis
  - Basic Research
  - Physics Experiments
  - Etc.
- Isotope production.
- Decommissioning of Research Reactors


ADRG
HEAD RRSD
HEAD ROD
HEAD RRMD
• Engineering Services.
• Reactor Physics & Chemistry support
• Manpower Training
• Safety Evaluation
• Root Cause Analysis
• Communication with Safety Committee
• ISI
• Operation
• Safety
• Utilisation
• Isotope production
• Decommission
• Upkeep of Facilities
• Spares Management
• Execute Upgrades
MS(E)
MS(M)
MS(I)-PI
MS(I)-NI
RS(D)
RS(A-U)
RS(CF&P4)
DS(C&A)
HEAD ESS
HEAD ISIS
HEAD PESS
HEAD QAS
HEAD HRSS
HEAD ORPS
HEAD RCS

Interaction with other Groups of BARC

	Name of Group	Purpose of interaction
1	Nuclear Fuel Group (NFG)	Supply of fuel
2	Nuclear Recycle Group (NRG)	Fuel shipment, waste management
3	Radiochemistry & Isotope Group	Production of radio-isotopes
4	BARC Safety Council (BSC)	Safety committees
5	Reactor Design & Development Group (RD&DG)	Design, analysis & CDM support
6	Material Group	Corrosion Studies, RCA
7	Engineering Services Group (ESG)	Civil & Structural Engg. Support
8	Chemical Engineering Group (ChEG)	Heavy Water up gradation

Reactor Group Manpower

Division	Scientific Officers	Technical Staff	Administrative Staff	Auxiliary Staff
ROD	38	156	9	29
RRMD	38	184	4	5
RRSD	36	24	1	1
Total	**112**	**364**	**14**	**35**

Total 526

Facilities of RG

Apsara

Cirus

Critical Facility

Dhruva

Apsara-U

P-4

Apsara

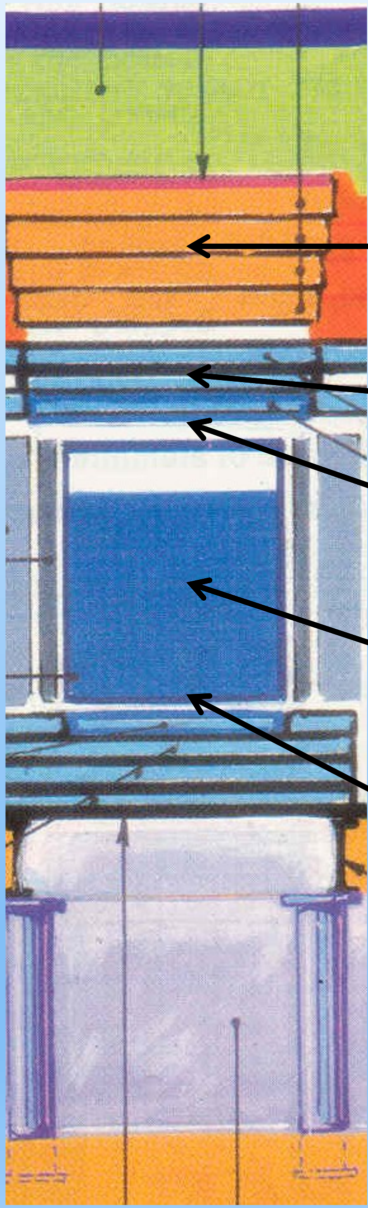
- India's First research reactor; Commissioned in 4th August 1956.
- Shut down on June 5th 2009.
- Defueled;
  - Fuel stored in AFR, Tarapur; Under IAEA Safeguards
- Reactor systems and associated components have been decommissioned.

- It is planned to strengthen the civil structure and convert the place into a museum, where we can display the heritage of BARC.

Cirus Reactor

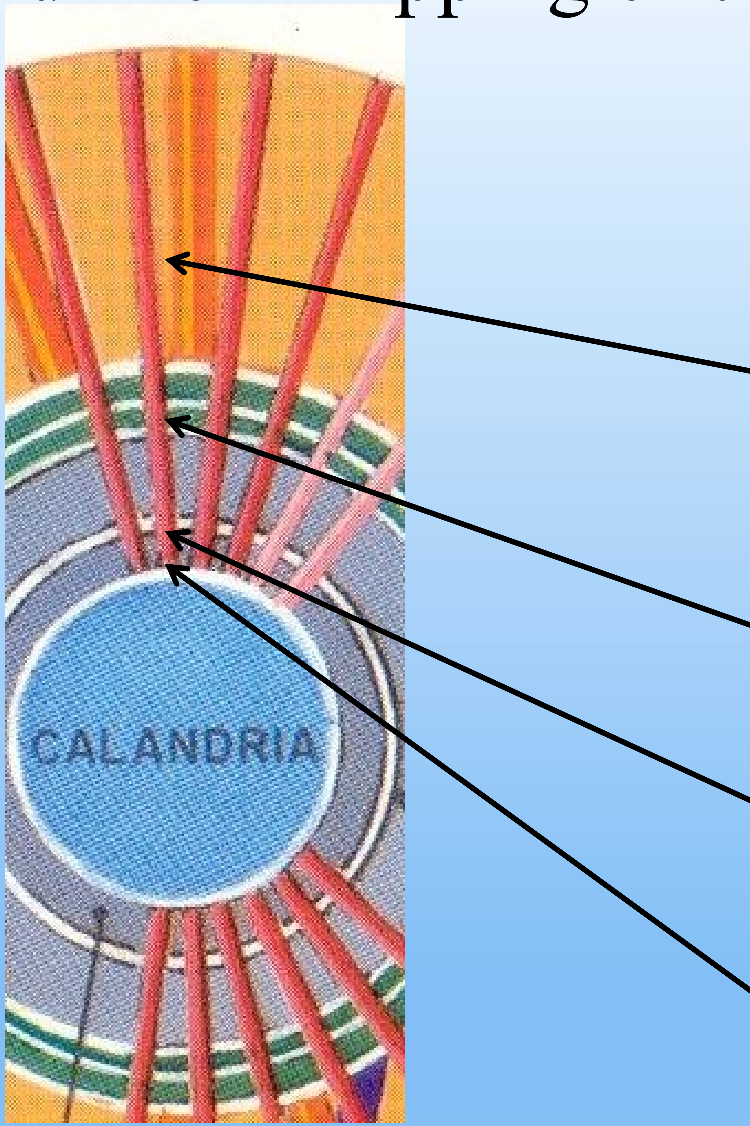
- A vertical tank type 40 MW_{th} reactor.
- Operational in 10th July 1960.
- Permanently Shut down on 31st Dec 2010 and is under decommissioning.
- Maintained in preservation mode
  - Core & SFSB defueled, (7-loop fuel)
  - New Tech Spec /surveillance /manpower
  - All process fluids drained.
  - Maintenance of civil structure
  - Crane / Stack / Ventilation
- Differed decommissioning
  - Core decommissioning may start some where in 2045.
- Peripheral decommissioning
  - Useful equipment used in other reactors.
  - Estimation and decontamination of waste.
  - In exempt category being disposed (with RHC clearance)
- Infrastructure is being used for supporting various BARC activities.
- RCB Uranium slurry removal
- Activities related to harvesting the locked up data of core structure.

Radiation Mapping of core: values are given in R/h



Location	2011	2013	2019
Upper biological shields	0.003-0.1	0.003-0.07	0.003-0.04
Upper Thermal Shields	70-300	50-100	50-70
7”gap above upper tube sheet	450-2500	1200 (max in 2016)	150-600
RV region	125-300	70-150	30-70
5”gap below lower tube sheet	300-1700 (3100 max)	200->1000 (max 1650 in 2016)	100-700

Radiation Mapping of core: values are given in R/h

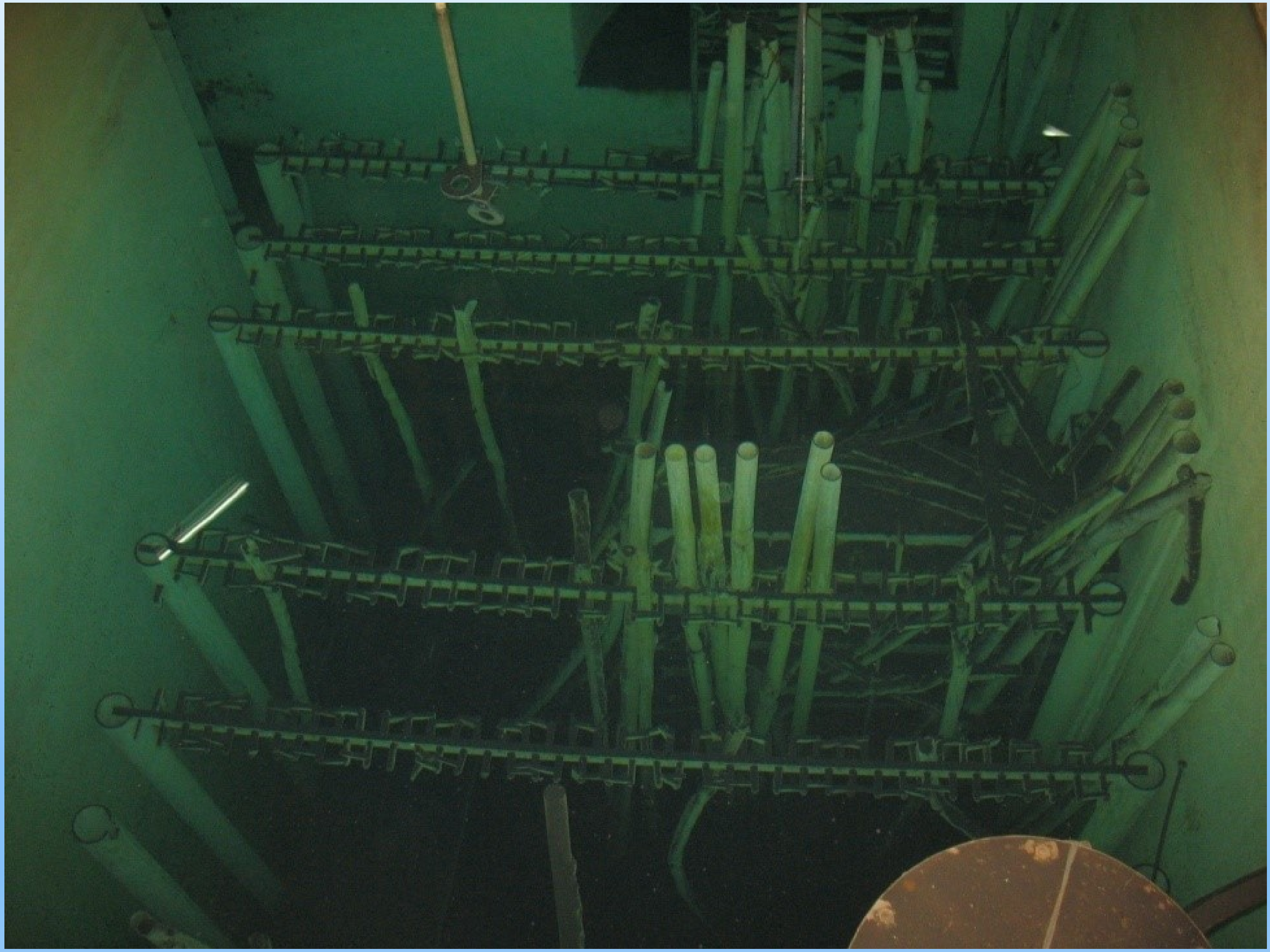


Location	2012 (R/hr)	2019 (R/hr)
Concrete Bio-shield	0.025-0.50	0.01-0.5
Cast Iron Thermal shields	100	40-50
Graphite Reflector	30-60	10-20
RV (on contact)	70-90	45-50

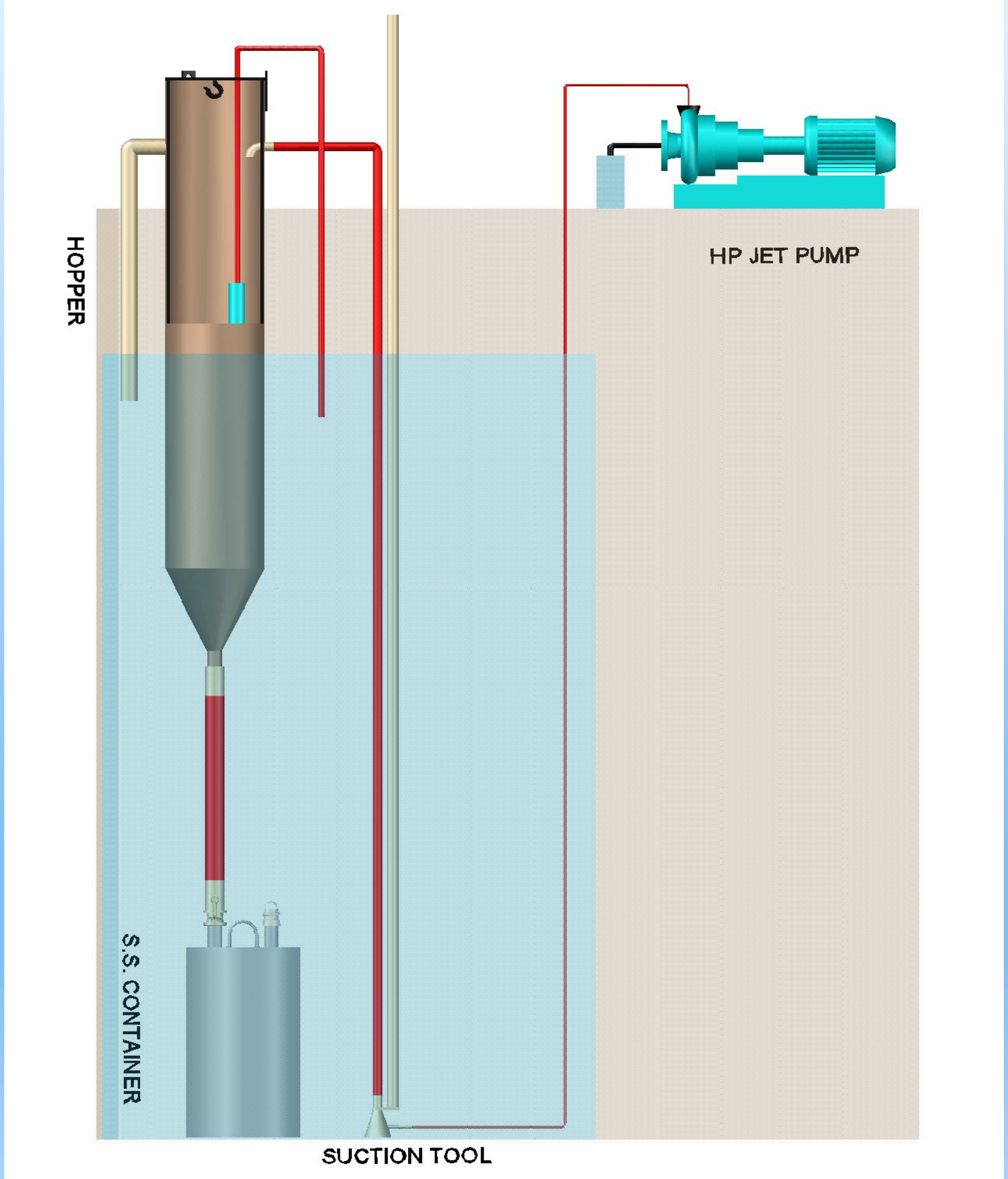
RCB (SFSB) Bay Cleaning

About 6.5 T of uranium is lying on the RCB floor.

Remote cutting tool under development for cutting and disposal of Alpha bearing Al sheaths of spent fuel rods to clear the bay for complete slurry collection.

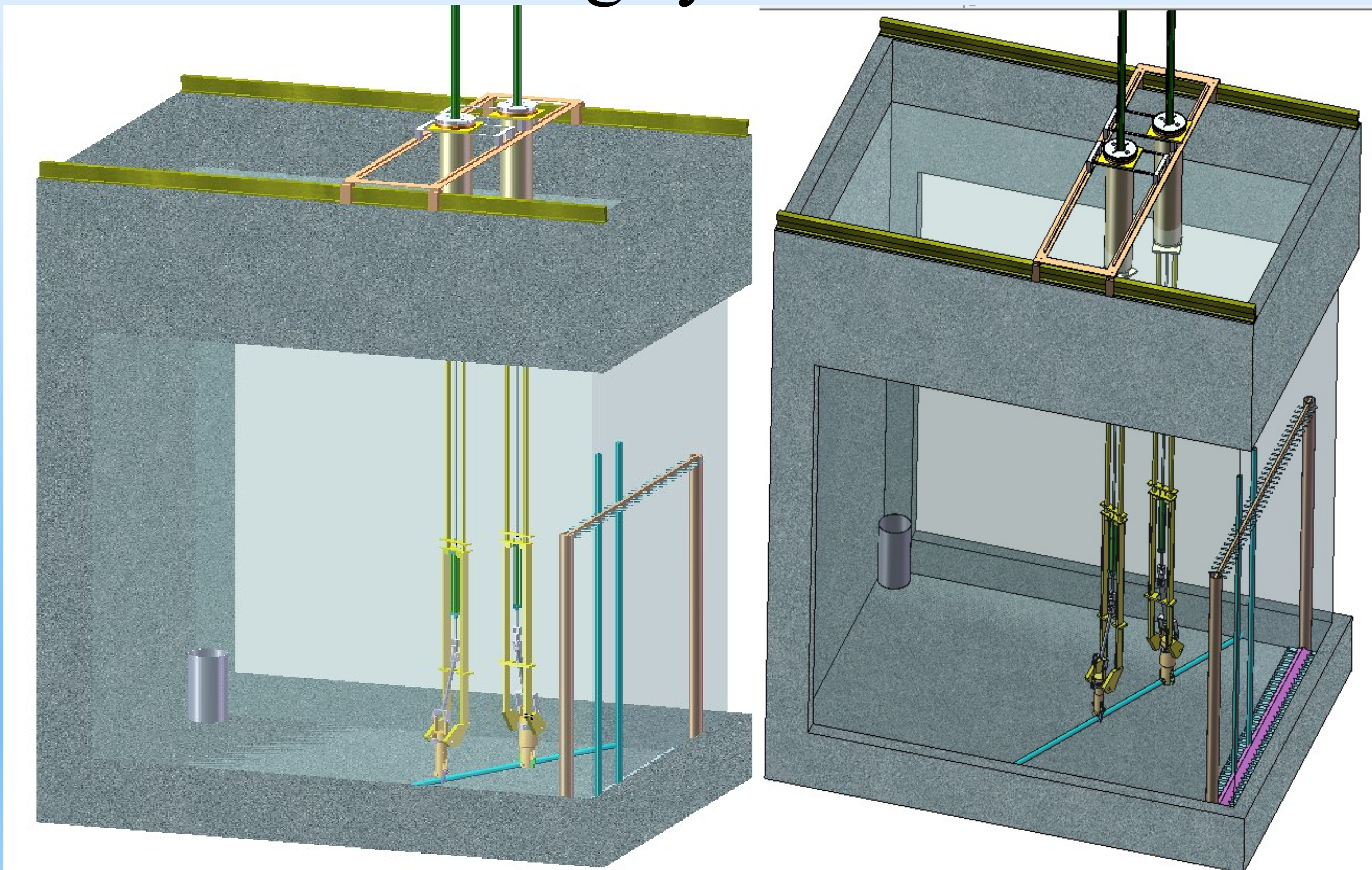


U-Slurry Collection Set-up

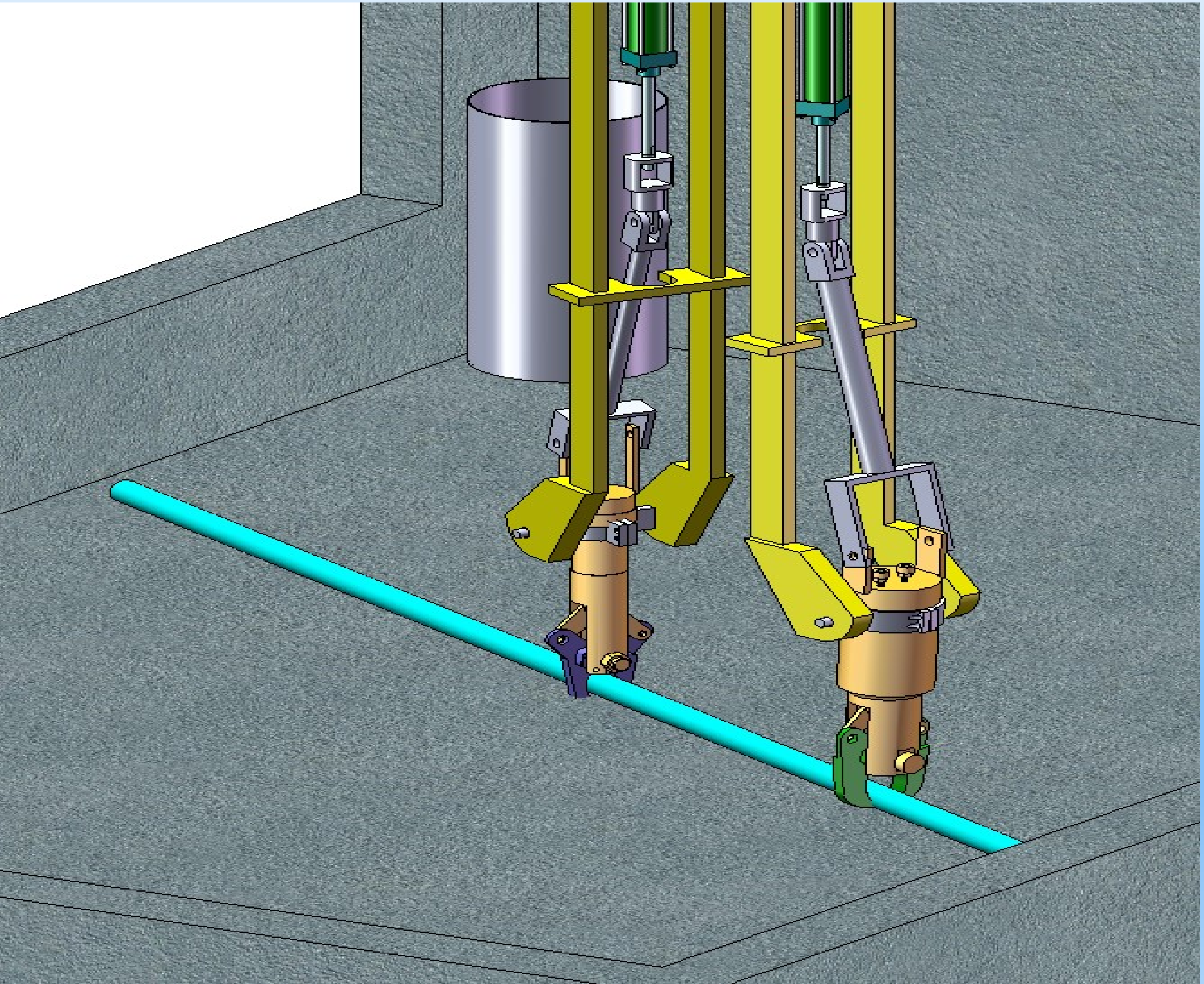


- Batch Process.
- Components:
  - High Pressure Jet Pump.
  - Suction Tool.
  - Muck Settling Hopper.
  - SS Container for Muck Collection.
  - Su-Pump for removal of water from hopper.
- All operations underwater.
- After filling, containers are capped and stored in RCB underwater.
- About 25% spent fuel slurry collected. (About 2.0 T)

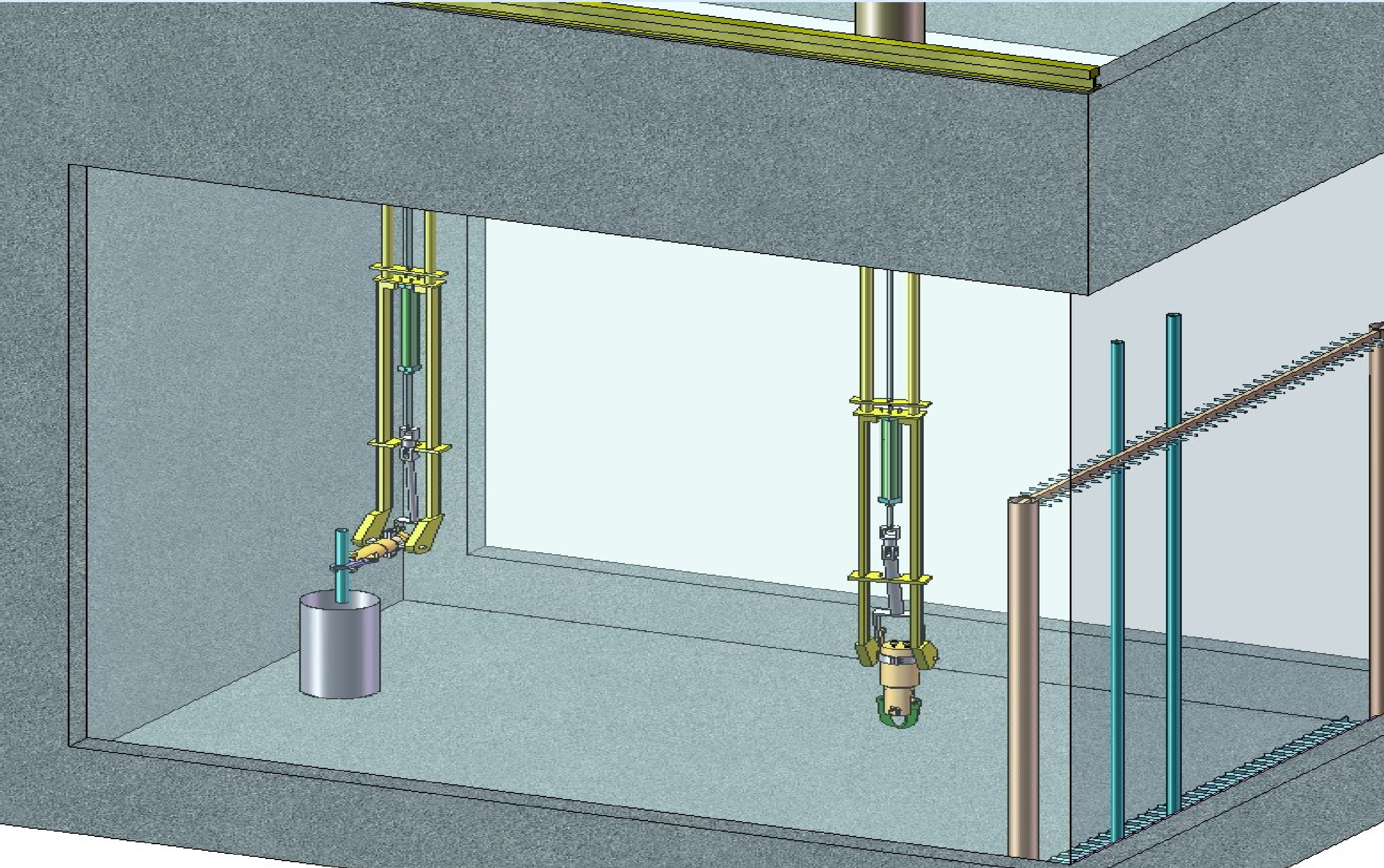
Al. Tube cutting system inside CRSB



Hydraulic Cutting and Gripping Device



Dropping of cut pieces into can/basket



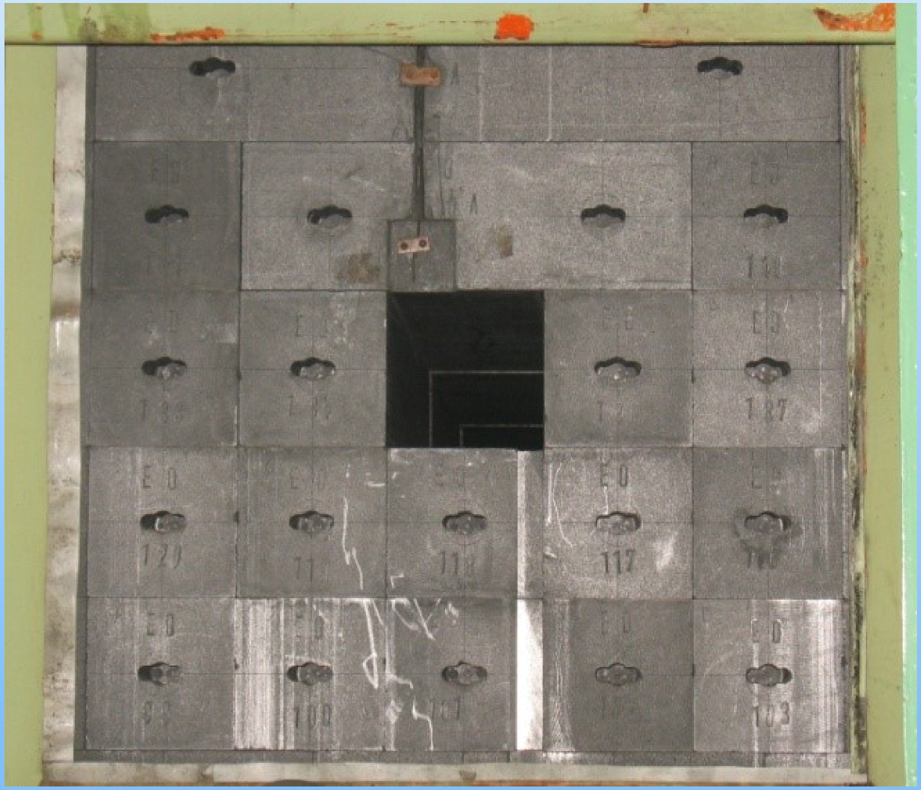
Cirus Waste Management

Ultrasonic decontamination machine

Waste Drum Scanning System (Co-60 & Cs-137 measurement)

- 450 M^3 Cat-I waste. (except pile block)
- 50 M^3 waste disposed off to WMD
- 45 M^3 will waste from pile block.

Graphite Plugs in Thermal Column



Graphite waste 55.0 T
C^{14} activity 5700 years

Utilization of Reactor Building

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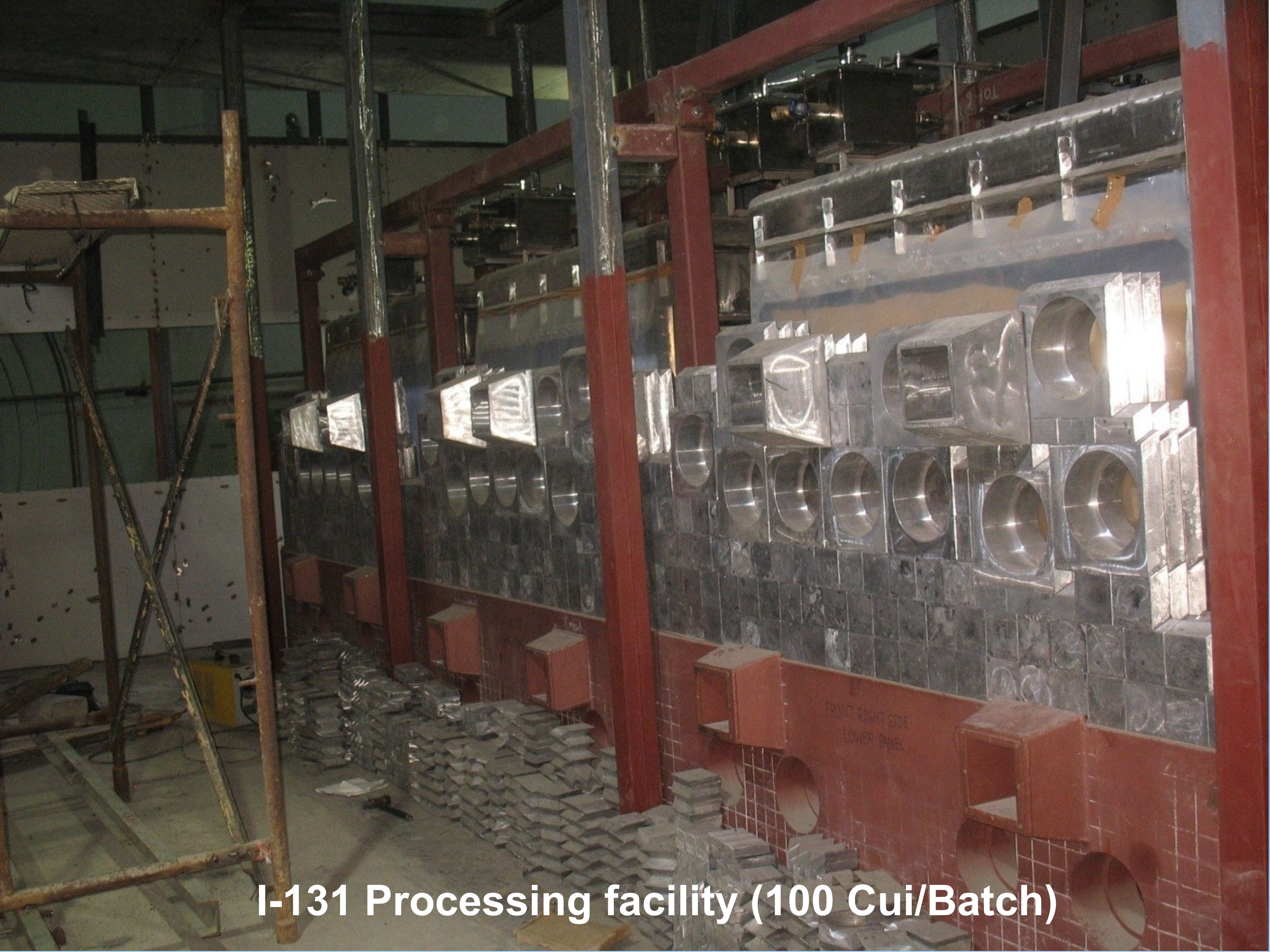


I-131 Processing facility (100 Cui/Batch)

Composition of Ageing Data Task Force

A task force of following officers is constituted for data mining of SSCs of Research Reactors Cirus, Apsara and Dhruva:

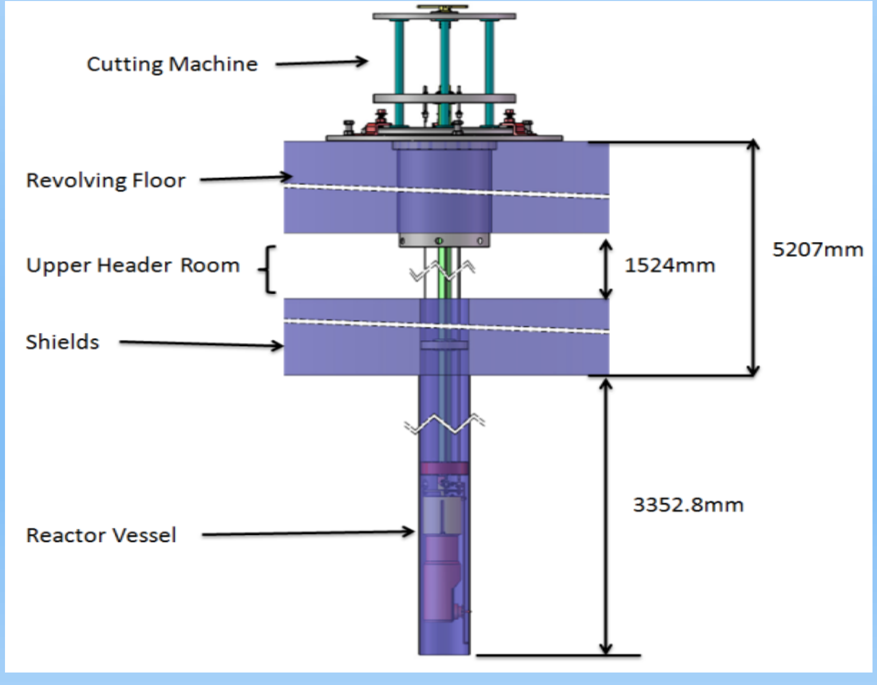
Shri Rakesh Ranjan, Decom Supdt., Cirus – Convener	
Dr. Suman Neogi, SO/G, MSD	Member
Shri R.S. Srivastav, SO/F, PIED	Member
Shri P.K. Mishra, SO/F, SED&FSFS, RTD	Member
Dr. Y.S. Rana, SO/G, RRSD	Member
Shri K. Ramavarma, SO/G, RRMD	Member
Shri Yogengra, TDD, NRG	Member
Shri Prasit Mandal, SO/G, ROD	Member-Secretary

The Task Force has co-opted Shri K.S. Babu (RHC, HPD), and Shri M.K. Ojha (ROD, Cirus).

Ageing Data Mining

Generation of data-base on degradation of mechanical and material properties of reactor SSCs in support of life extension of aging Research Reactors.

Al, Zircalloy, SS, Graphite, Concrete, Polymers, Cables are materials of interest.

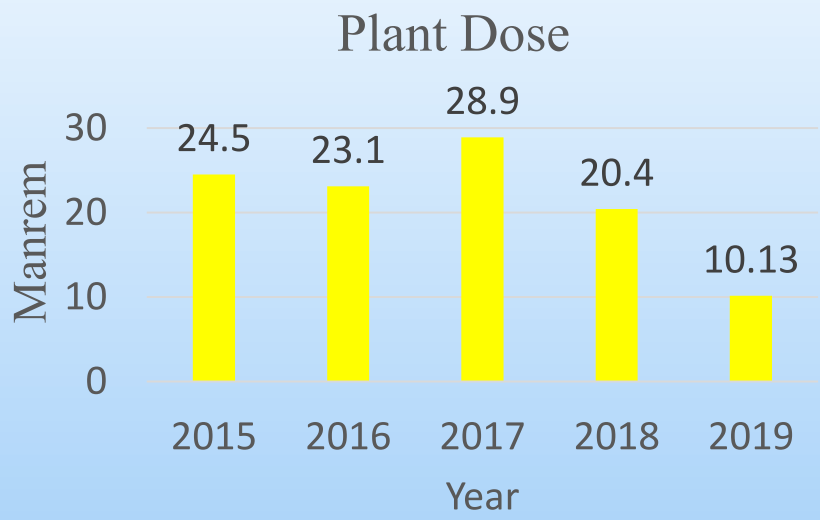


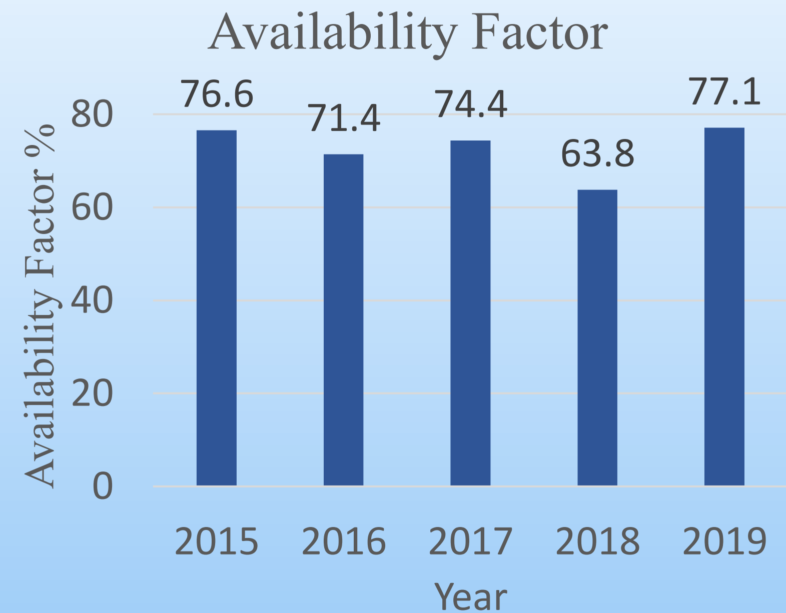
1S / ALCAN 6056 Al. Alloy Mechanical Properties

Sl. No.	Estimated Neutron Fluence, n/cm^2		Yield Strength MPa	Ultimate Tensile Strength MPa	Un-irradiated 1S Aluminium	
	Total	Fast (>1MeV)			YS MPa	UTS MPa
1	0.19×10^{21}	--	--	117.9	55	82
2	1.53×10^{21}	--	--	126.9		
3	2.16×10^{21}	--	--	115.1		
4	1.6×10^{22}	2.7×10^{21}	94.5	111.7		
5	7.02×10^{22}	1.54×10^{22}	102	163	ALCAN 6056	

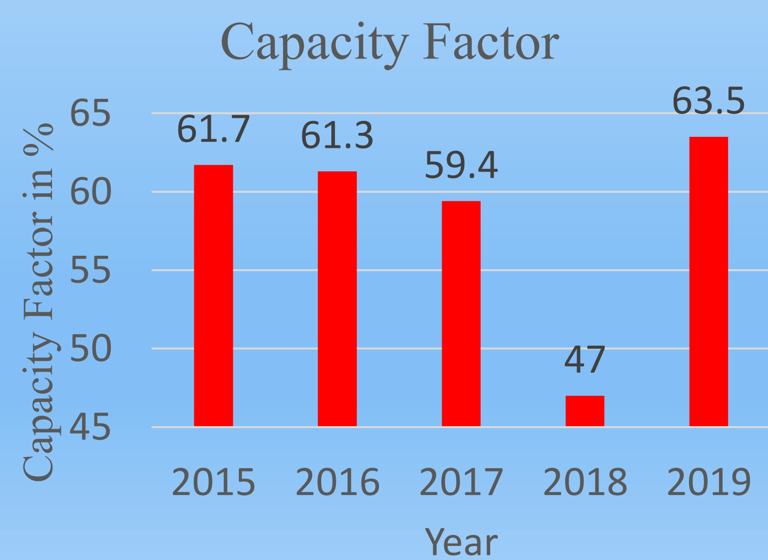
Dhruva Reactor

Dhruva Reactor Performance





- Highest Ever CF attained in 2019.
- AF & CF limited --shut down refuelling, highest AF possible is ~80% for 100 MW.
- Fuelling has increased from 180 to 300 /year.
- Lowest Ever plant Dose in 2019.
- Shipments to PP in a new shipping cask.
- Bay purification improved.
- Reduced fuel failure.
- ~370 TBq radioisotopes produced monthly.



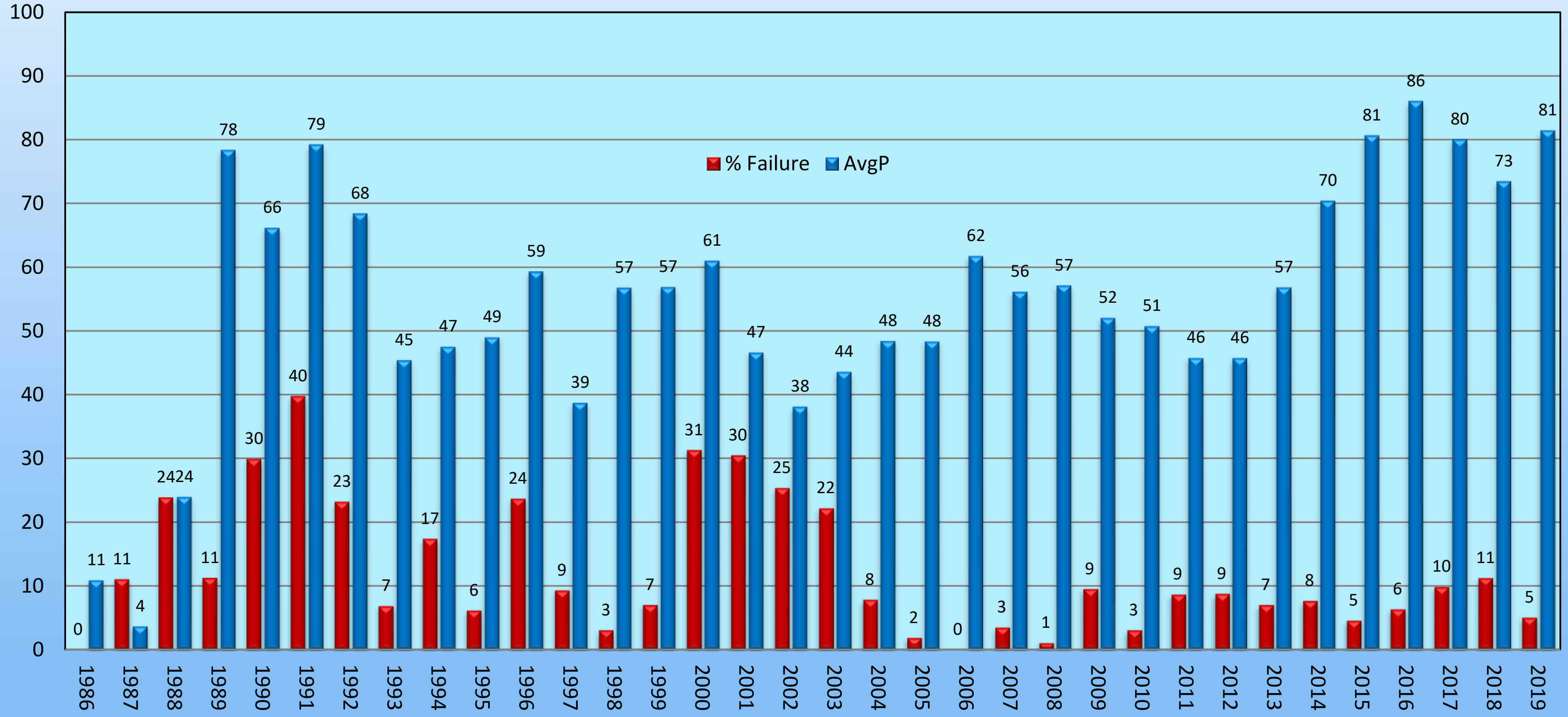
Dose Reduction

- Shipments PP in a new shipping cask.
  - 46 shipments (920 fuels) /yr
  - Dose per shipment 80 mRem from 300-400 mRem
  - 110 litre standalone IX resin hopper amenable to resin fixation by cementization.
  - Bay water activity 100Bq/ml from 1400Bq/ml.

SS lined Railings for SFSB

Decontamination Area was SS lined.

Avg.Power & Percentage Fuel Failure

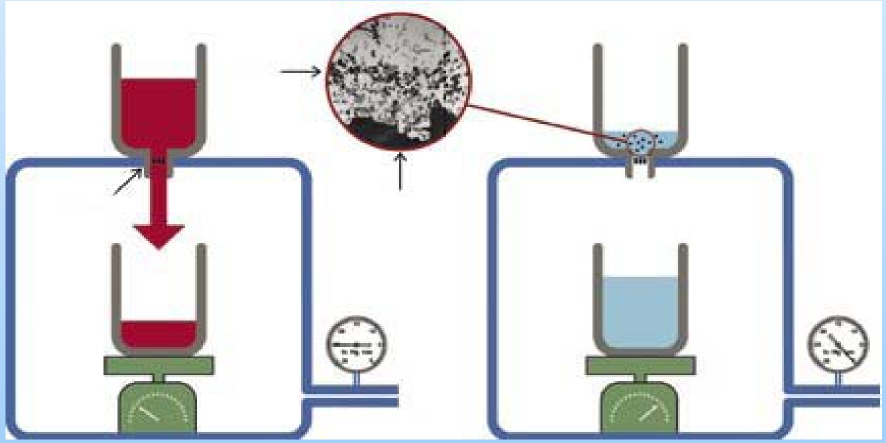


Change in Specifications of Aluminum

- NALCO was visited and matters were discussed with them.
- Trace impurity in Aluminium to know melt cleanliness by carrying out an evaluation using PoDFA (Porous Disc Filtration Apparatus).
- Also dissolved Hydrogen in molten Aluminium causes lot of porosity in the billets hence this specification was also added.
- Aluminum specifications were revised after NALCO visit, Hydrogen content to 0.2 ml / 100g Al and a PoDFA rating of 0.2 for all the new Aluminum was specified.
- 28 T of this material (99.8% pure) has been procured from NALCO to fix this parameter.

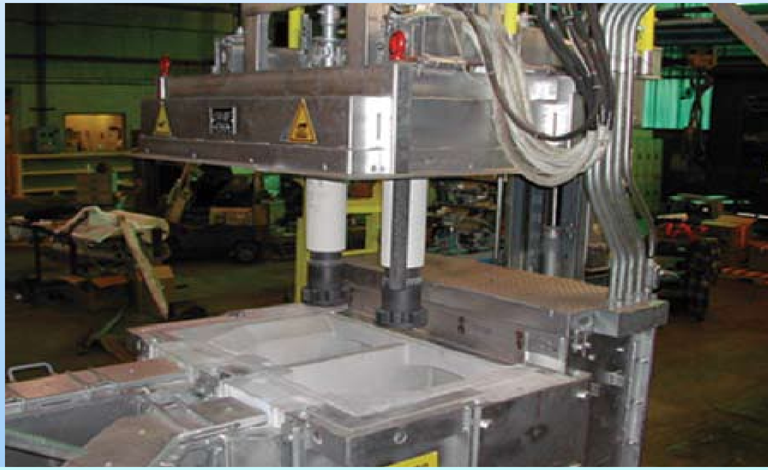
PoDFA

The sample is melted and passed through a filter. The residue on the filter is analyzed to obtain quantitative information on inclusion concentrations. Alcan's PoDFA (Porous Disc Filtration Apparatus) technique, is being used for assessing metal cleanliness at Nalco.



Additional mechanical filtration is done at the downstream of the degasser by Ceramic Foam Filter of 40 PPI (pores per inch) of Swiss make. The actual size of the pores was 1.6 mm to 2.1 mm. Excessive alkali metal (sodium, calcium, lithium) concentrations can cause edge cracking during slab rolling, and bar /rod breaks. Typical maximum alkali metal concentrations should not exceed 5 ppm for each element.

SNIFF Degasser (NALCO)



Hydrogen is removed from the molten aluminium by bubbling an inert gas through the metal. Argon and nitrogen are typically used, but argon is preferred for the best metal quality because of the tendency of nitrogen to form aluminium nitride inclusion.

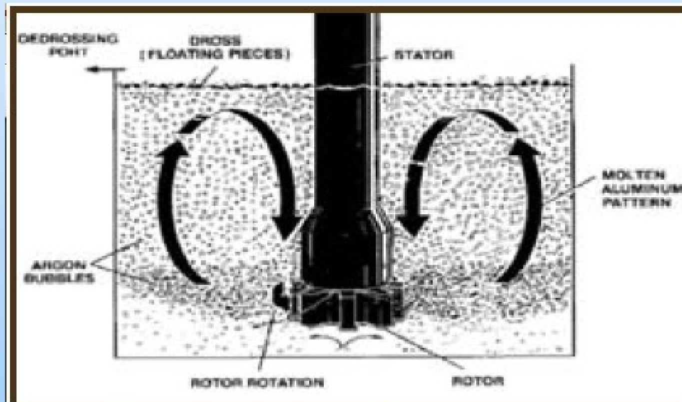


Figure 1: In-line degasser fundamentals

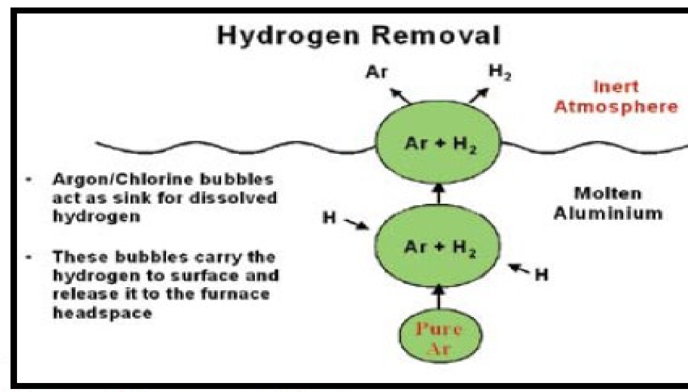
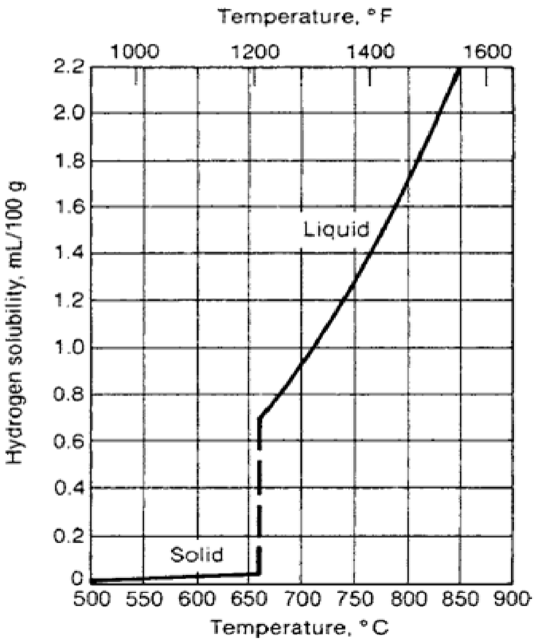


Figure 2: Hydrogen removal theory

Hydrogen Control



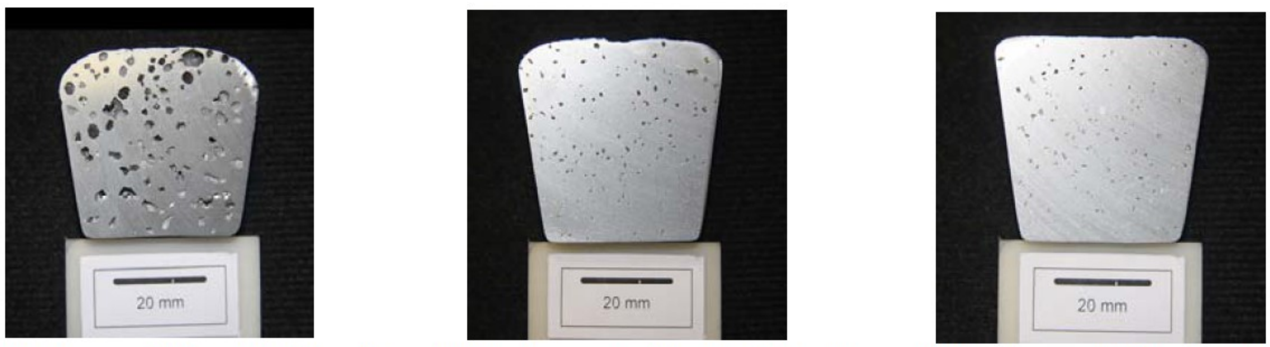
Solubility of hydrogen in aluminum at 1 atm hydrogen pressure

Hydrogen solubility decreases rapidly as the metal freezes during casting, and comes out of solution, causing porosity. Target dissolved hydrogen content depends on the final product application, and can range from 0.20ml / 100g Al for general extrusion and down to 0.10 ml / 100g Al for rolling slab for aerospace applications.

Analyser for Hydrogen in molten Aluminium

Just prior to getting solidified in the Billet Casting System, Hydrogen is analysed (M/s AlScan make analyser). This has two antennas at a predefined gap and voltage drop (in milli volts) across these two is measured which depends upon the amount of hydrogen in the molten metal.

Effect of Hydrogen on Aluminium



a) Hydrogen 0.92 ml / 100 g Al
Undercooling 1.58 C

b) Hydrogen 0.48 ml / 100 g Al
Undercooling 1.03 C

C) Hydrogen 0.27 ml / 100 g Al
Undercooling 0.92 C

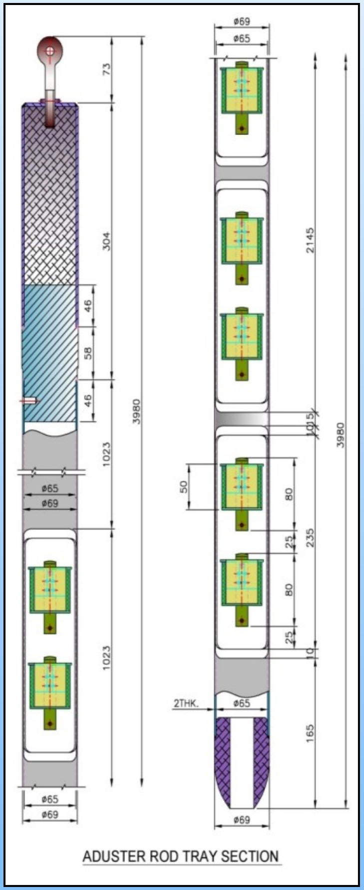
Figure 5 Photograph of sectioned specimens showing porosities due to dissolved hydrogen.

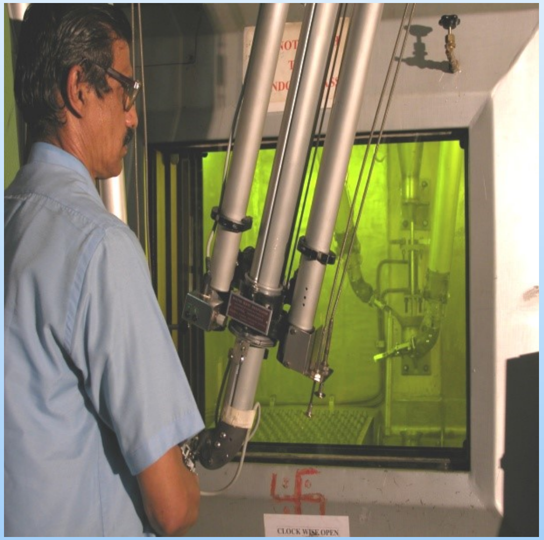
Reduction in Ductility-- Drawing Operation

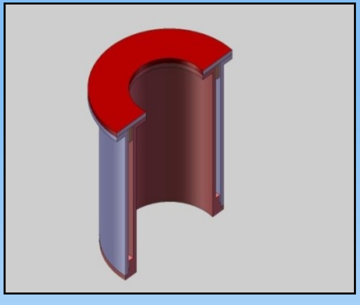
- During drawing operation Al Can on the Uranium fuel ductility of Clad drops from 35-40% to 15 % due to cold work.
- By modifying the fabrication process (changing the extrusion ratios) and annealing the clad tubes attempts are being made to keep the initial ductility of the clad before drawing to about 45-50% so that post canning it can remain ~20%.
- Initial trials have shown considerable reduction in fuel failure, with this.

Isotope Production

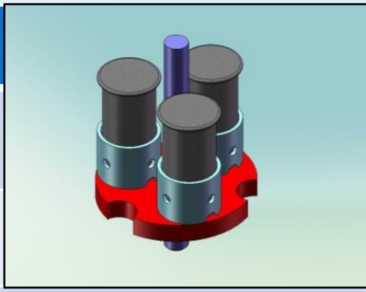
- Over 370 TBq (10,000 Ci) of various radioisotopes are processed to supply over 5000 consignments to more than 1900 user institutions in India and abroad on monthly basis.
- Two On-power Tray rods.
- 90 target samples each
- One Off Power tray rods for long term irradiation.
- Adjuster rod produces high Sp Activity Co^{60}. (up to 350 Ci/gm)
- Bi-weekly sample unloading, 90 - 100 loading / unloading per year.
- 700 isotope targets are irradiated per year.







MAJOR RADIO-ISOTOPES PRODUCED

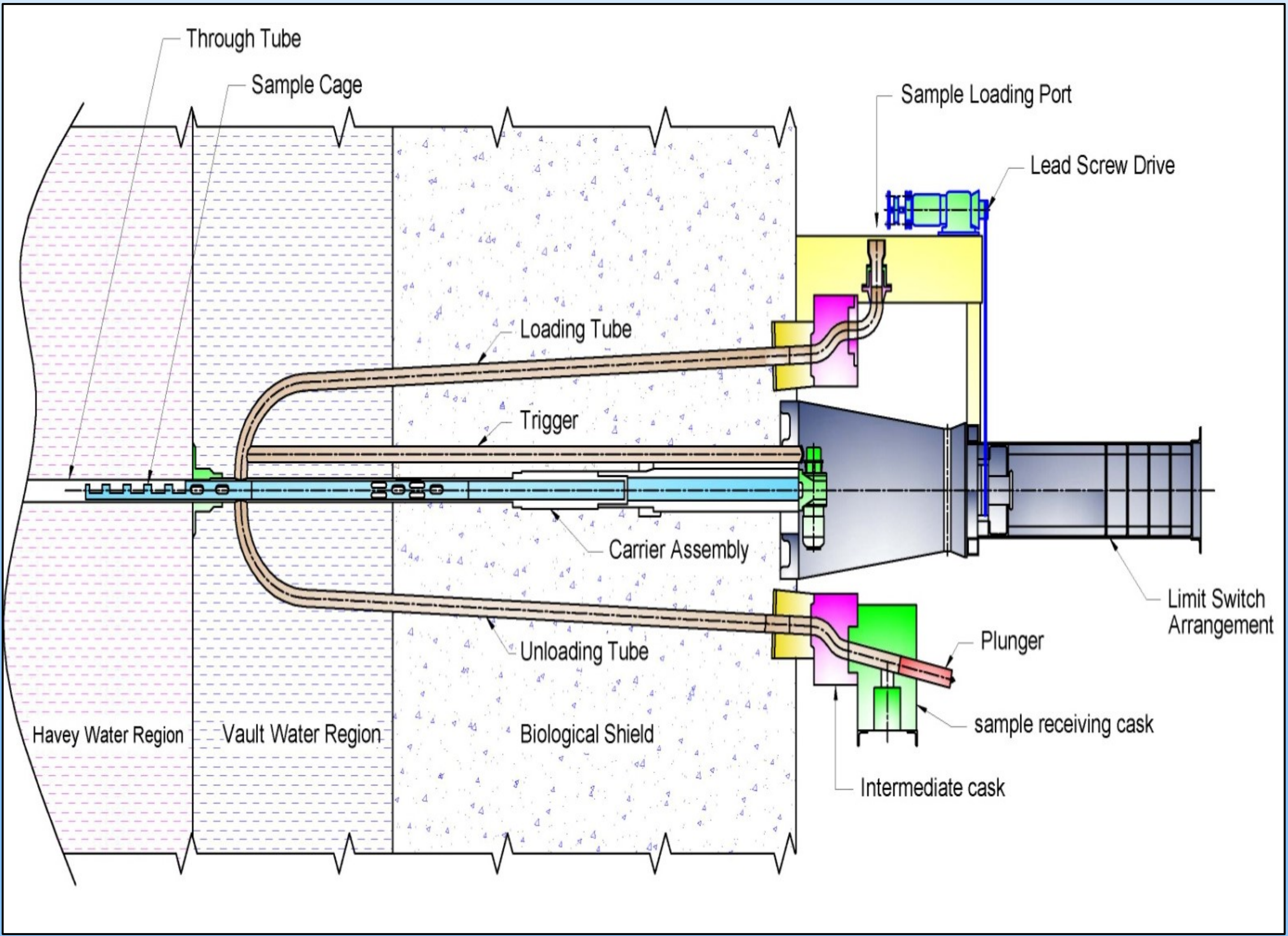


Radio nuclides	Target material	Amount and frequency	Application
Mo^{99}	Nat. MoO_3	(30-40 Ci/week	Medicine
I^{131}	Te	(40-60 Ci/week)	Medicine
P^{32}	Natural S	0.03 Ci/15 d	Medicine, Agriculture
Sm^{153}	Nat Sm_2O_3	10.8 Ci/month	Medicine
Lu^{177}	Enrich Lu^{176}	10.8 Ci/month	Medicine
I^{125}	Nat Xenon	0.8 Ci/2 month	Brach therapy, Radiometric assays
Br^{82}	Nat NH_4Br	As required	Research
Co^{60}	Nat. Cobalt	Long irradiation, as required	Industry, medicine, radiography etc
Ir^{192}	Nat Ir	1000 Ci/week	Radiography, medicine
S^{35}	Nat KCl	As required	Research

Self-Serve Facility for short term irradiation of targets

- Time of irradiation ranging from few hours to few days
- Flux levels : 5 x 10^{12} n/cm^2.sec

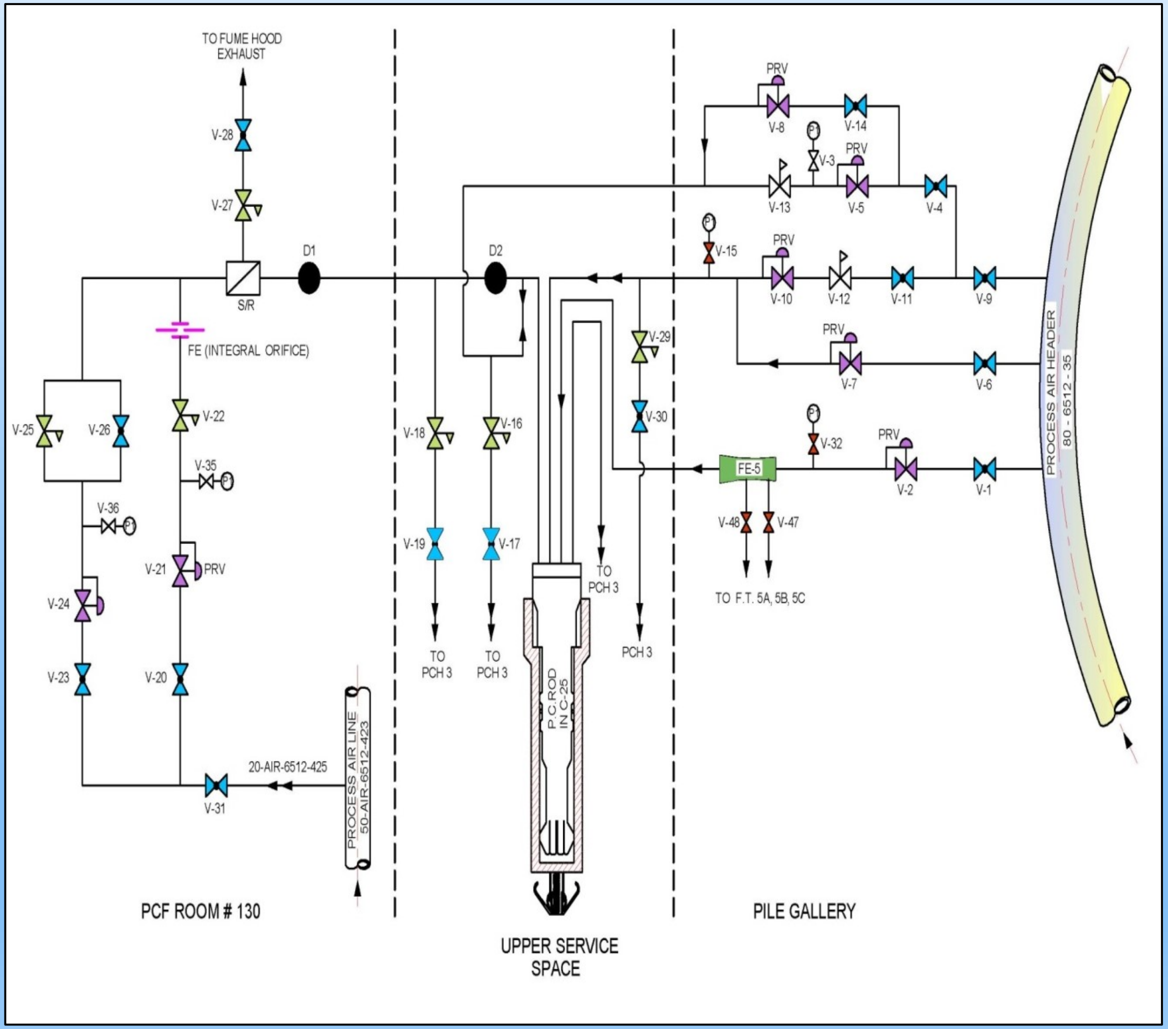
SELF SERVE BALL WITH CAPSULE



Pneumatic Carrier Facility (PCF) for irradiation of short-lived samples

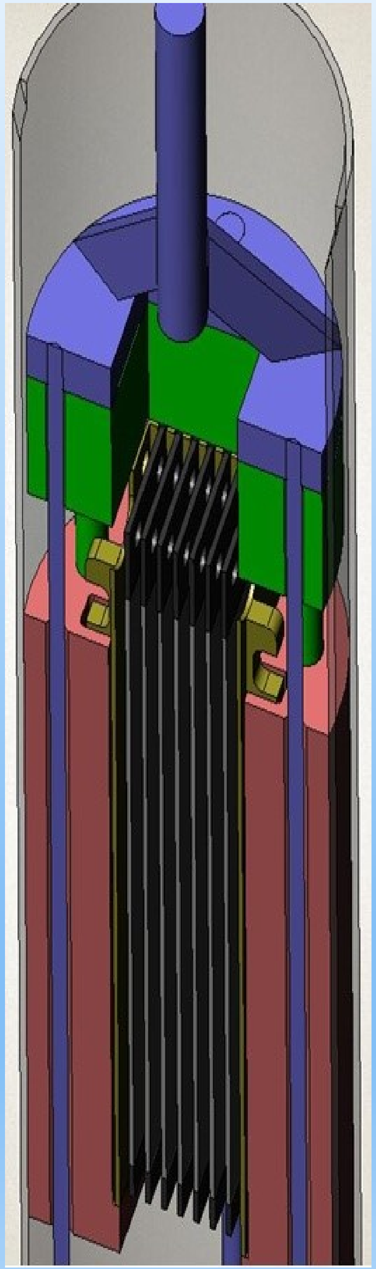
This facility is mainly used for neutron activation analysis for application in material sciences, environmental and life sciences, forensic science and archaeology.

This technique provides rapid quantitative simultaneous analysis down to ppb level.



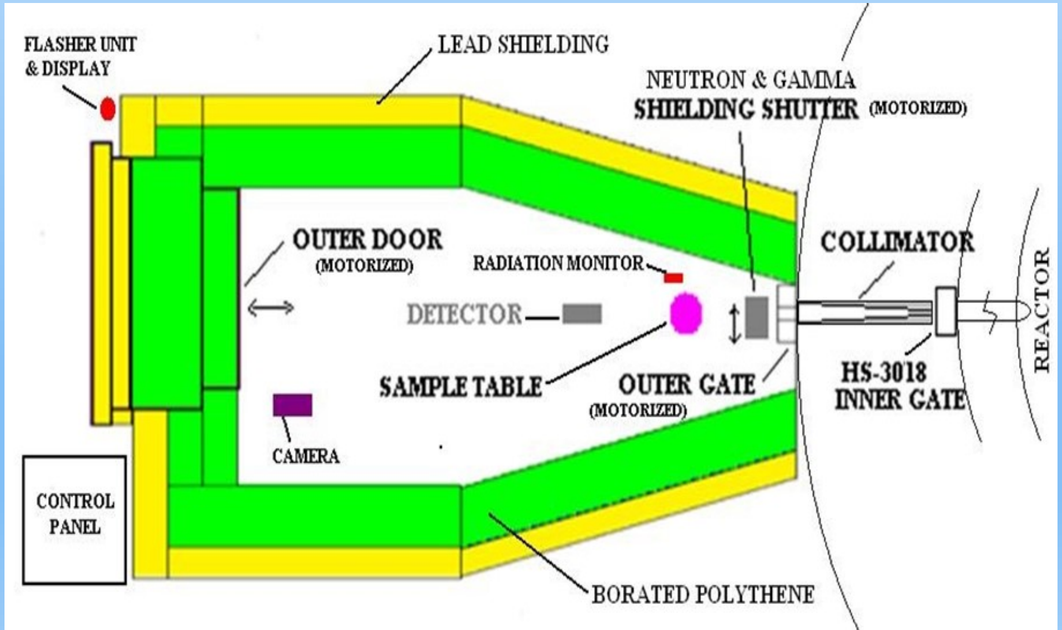
Irradiation of Fission Moly Target

- Commissioning of Tray Rod for LEU target irradiation towards Fission Moly production at Dhruva reactor is in progress (300 Ci/week)
- No. of LEU target plates: 13
- Fuel meat: Dispersed UAl_3 in Aluminium matrix (loading density: 2.55 g/cc)
- Design, fabrication & testing of tray section completed.
- Handling trials of the FTT cask carried out modifications pending.



Neutron Imaging Beamline At Dhruva

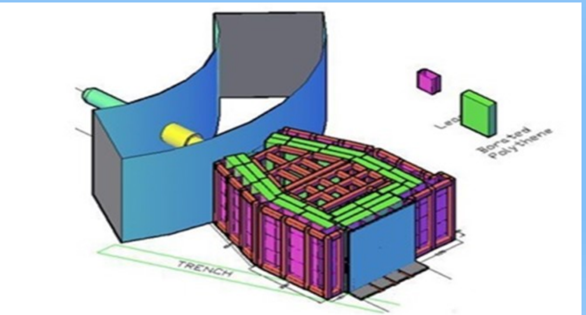
Advanced Neutron Imaging Beamline in Dhruva is a state-of-art imaging facility with neutron flux of nearly 4 x 10^7 n/(s-cm^2). It is utilized for neutron radiography, neutron tomography, real time imaging and neutron phase contrast applications.



Neutron Radiography Set-up at beam hole HS-3018 of Dhruva

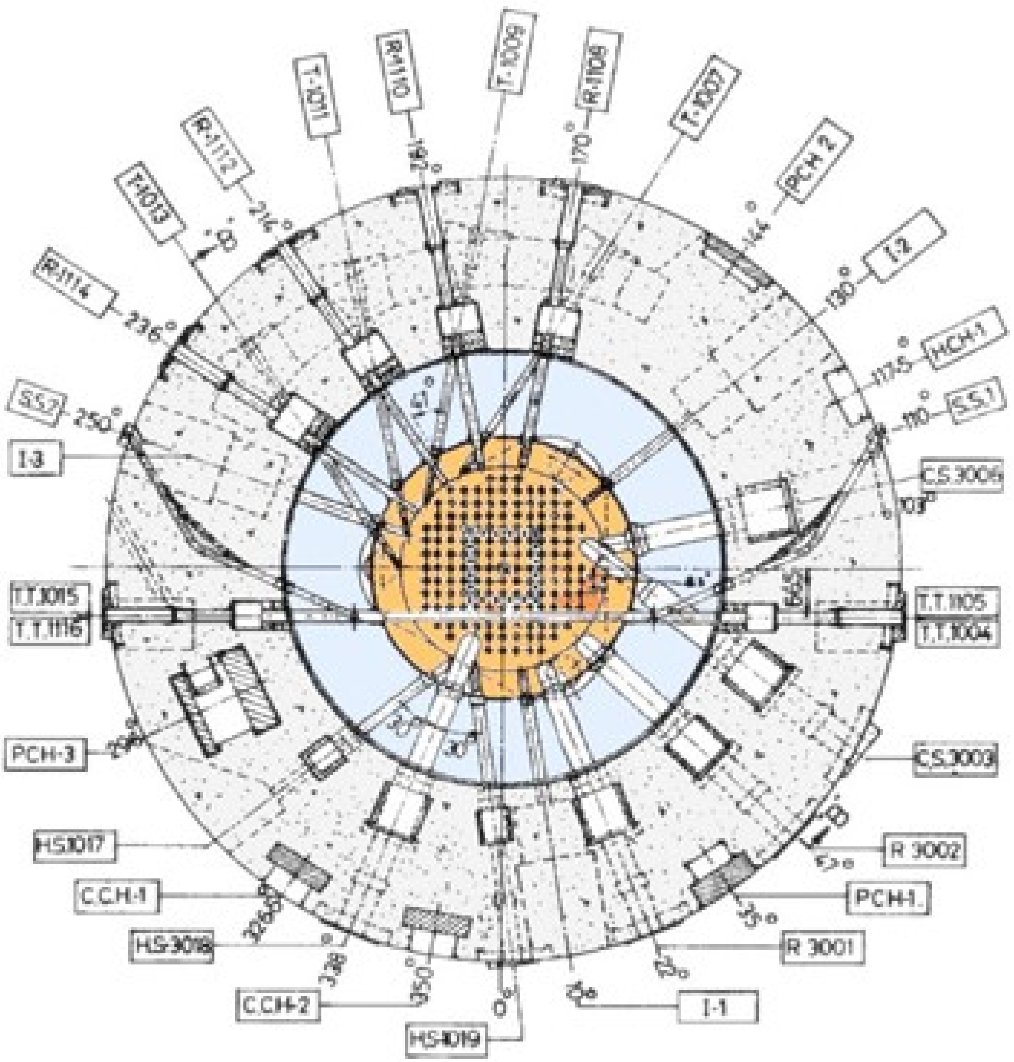
Neutron Imaging Beamline at HS-3018, Dhruva

Experimental hutch



Isometric View of Shielding Hutch
of Advanced Neutron Imaging Facility

Experimental And Irradiation Facilities



LEGEND

I	Ion chamber basket
R300	300 mm diameter Radial Beam Hole
PCH	Pile Chase
CS300	300 mm diameter Cold Neutron source
TT	Through Tube
SS	Self Serve facility for short duration irradiation
HCH	Helium Chase
T100	100 mm diameter Tangential Beam Hole
R100	100 mm diameter Radial Beam Hole
HS	Hot Neutron source
CCH	Cable Chase

S.No	Beam Hole	Size	Type	Elevation	Usage
1	R-3001	300 mm	Radial	33219	DURGA
2	R-3002	300 mm	Radial	33219	CTIF
3	CS-3003	300 mm	Cold neutron source	33371	-
4	CS-3006	300 mm	Radial Cold neutrons	33371	GT Lab
5	HS-3018	300 mm	Hot neutron source	33219	Neutron Radiography
6	T-1007	100 mm	Tangential	33219	SSPD
7	T-1009	100 mm	Tangential	33219	SSPD
8	T-1011	100 mm	Tangential	33219	SSPD
9	T-1013	100 mm	Tangential	33219	SSPD
10	HS-1017	100 mm	Hot neutron source	33219	SSPD
11	HS-1019	100 mm	Hot neutron source	33219	SSPD
12	R-1108	100 mm	Radial	34438	-
13	R-1110	100 mm	Radial	34438	-
14	R-1112	100 mm	Radial	34438	-
15	R-1114	100 mm	Radial	34438	-
16	TT-1015	100 mm	Radial (Through Tube)	33067	UGC-DAE CSR
17	TT-1004	100 mm	Radial (Through Tube)	33067	SSPD
18	TT-1116	100 mm	Radial UTT	34438	SS-2
19	TT-1105	100 mm	Radial UTT	34438	SS-1

Birds Eye view of experimental setups

Recent Major Safety upgrades

- Following safety upgrades have been recently carried out in the reactor.
  - Health assessment of civil structure.
  - Seismic re-evaluation to assess safety margins.
    - For SOR pseudo dynamic test is planned at CISR Chennai.
    - Rest of the components have adequate safety margins.
    - It is planned to provide a seismic trip on the reactor.
- Replacement of 3 DG sets with IEEE-387 qualified DG sets (750KVA)
  - 2 air cooled DG sets in a separate building, Seismically & DBFL Qualified.
  - One water cooled in existing building will be commissioned shortly

Recent Major Safety Upgrades

ECW system/OHST:

Lifeline of the reactor.

- Additional 10-inch make up line commissioned.
- DMZ tank converted to a pump house
- 2 additional New OHST make up pumps commissioned in DMZ tank

Additional down-comer from OHST to sub-basement through an independent route is being commissioned.

Modifications in the shut down cooling system

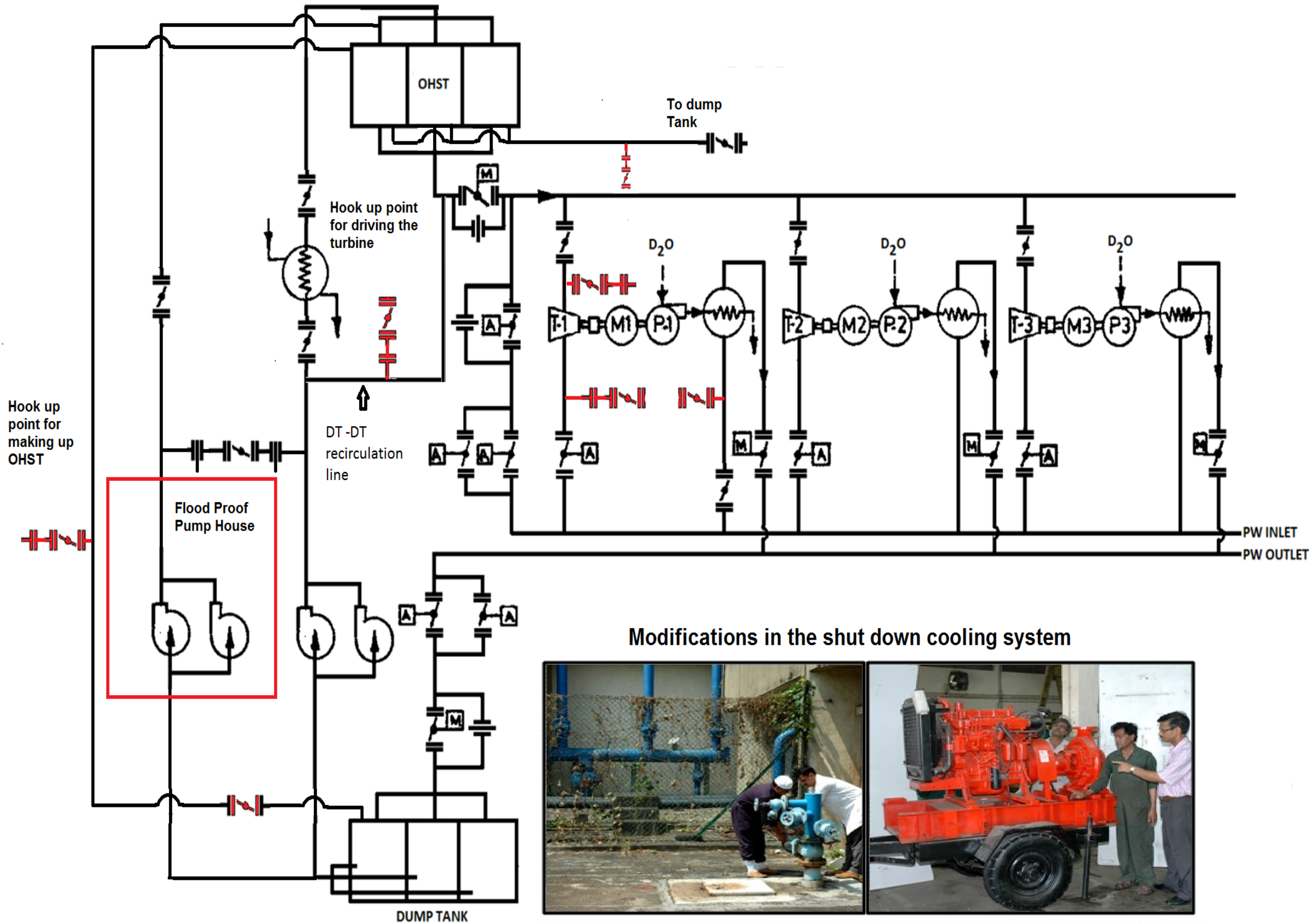


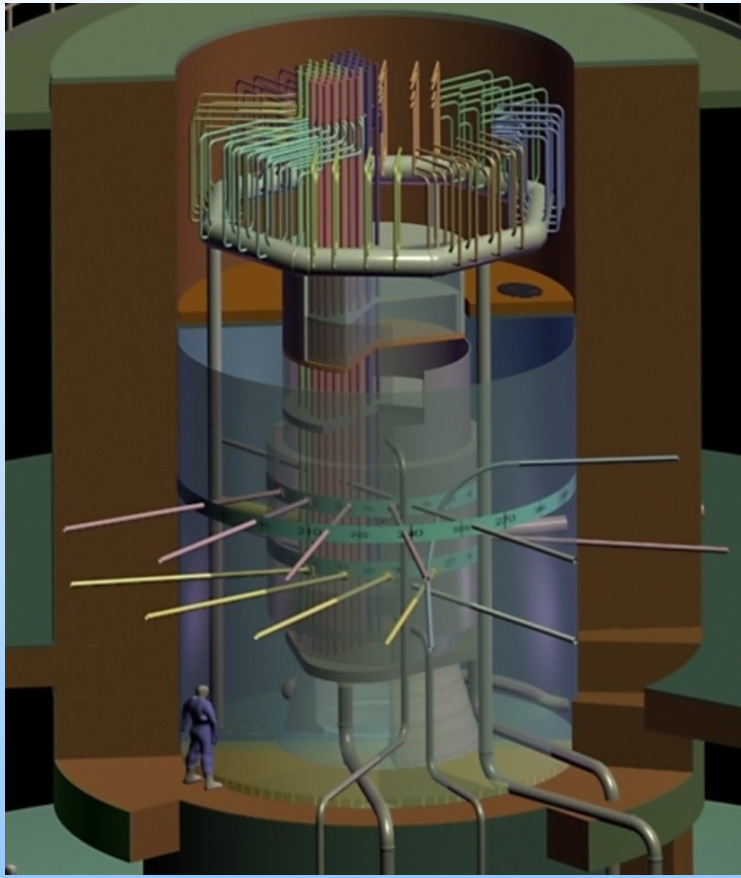
FIGURE SHOWING ECW LINE MODIFICATION WITH TROLLEY MOUNTED PUMP TO PUMP BACK UGDT WATER BACK TO OHST IN CASE OF EMERGENCY

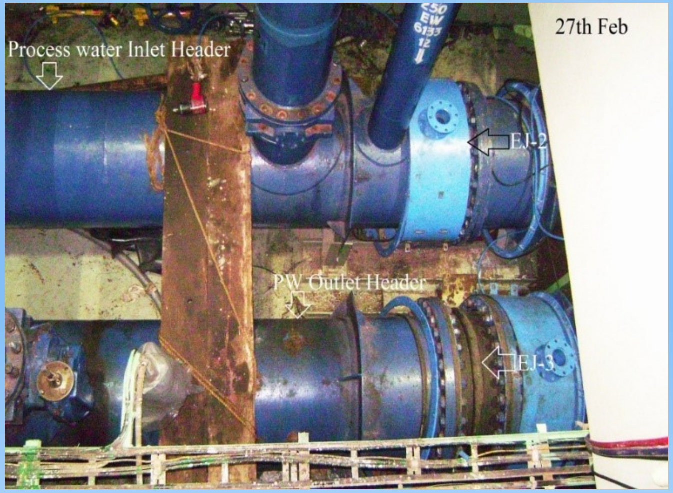
Several Other upgrades

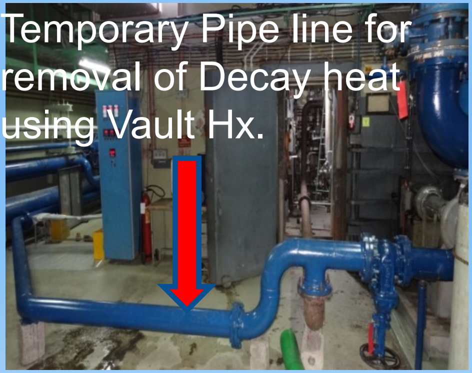
- To combat obsolescence, enhance safety and improve availability and maintainability several upgrades have been carried out such as:
  - Control room panels were replaced.
  - C& I Up grades were carried out in FM-A
  - Class-I, Class-II & Class-III power supply switch Gear were up graded.
  - Reactor Trip Logic System, Alarm Annunciator System, Start-up Logic System were changed from hard wired to computer based.
  - ECW Logic System is also being upgraded.
  - Supplementary Control room was provided to maintain shut down status of the reactor in case of non-availability of main control room.
  - Most of the pneumatic transmitters were replaced with electronics transmitters. (other than those required for redundancy)
  - Expansion joints in the non isolable region of the shut down cooling system were replaced.
  - ECCS drain line, embedded in the raft (1 meter below) which had got corroded due to sub soil seepage was repaired.
  - Engineering modifications carried out in Buggy Drive, FM-A main valve
  - New Motors have been procured for MCPs.

DHRS EJ Repair Plan Plan

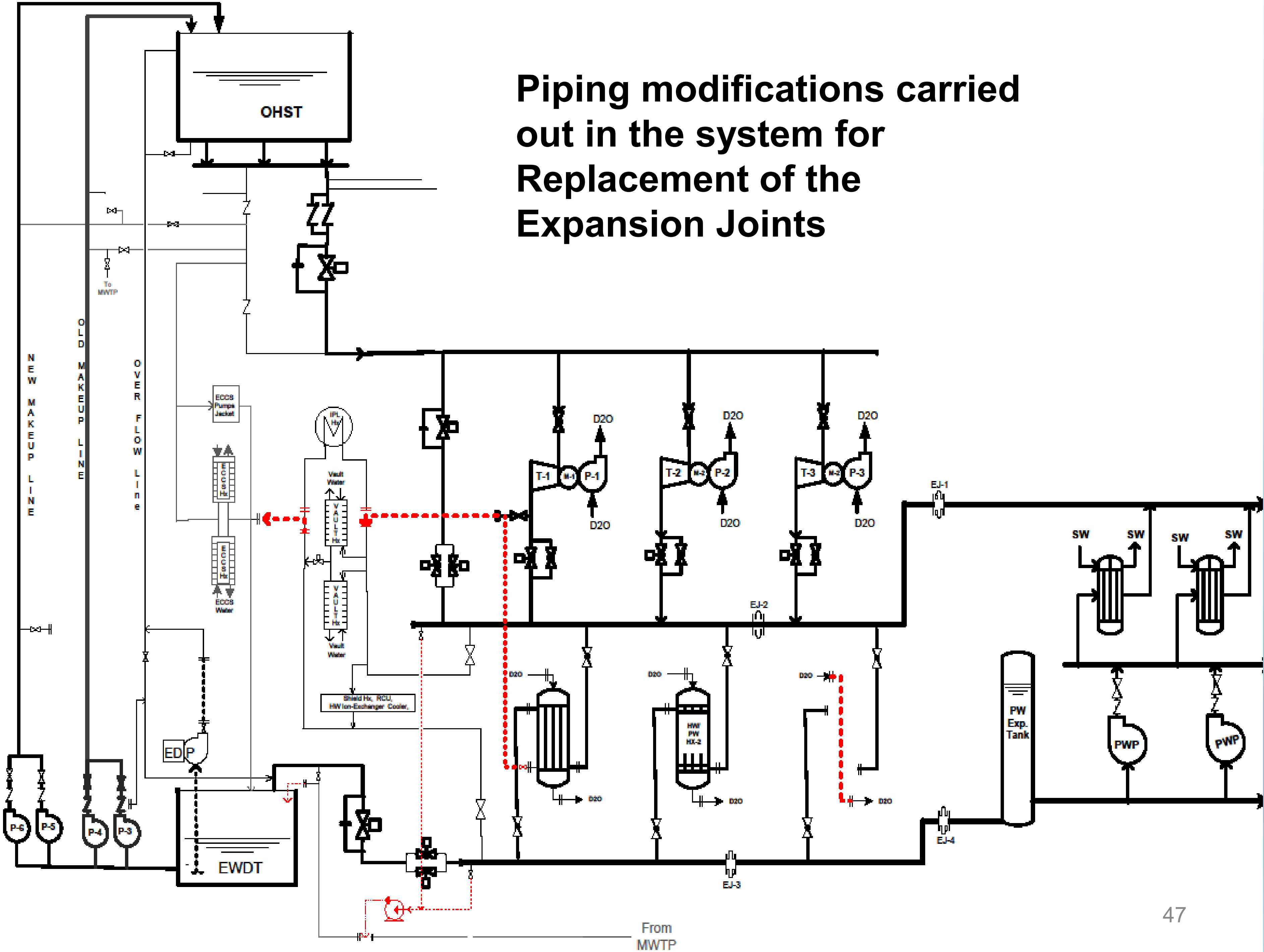
- After 10 days of Shut Down decay heat was ~ 116 kW.
- Secondary cooling was provided through two 750 kW Vault HXs, using specially laid CS 150 NB pipes.
- After 24 Hrs HW temperature stabilized at 37.4^{o}C/Limit was 50^{o}C.
- Subsequently all four EJs was replaced.







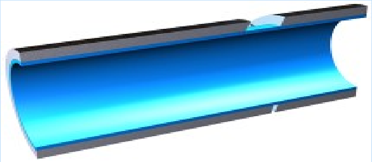
Piping modifications carried out in the system for Replacement of the Expansion Joints



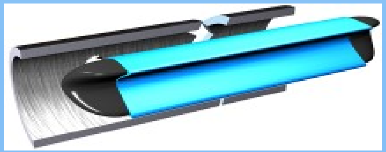
C & I Upgrades of Control Room and Fueling Machine

Supplementary
Control Panel

Flow Transmitters replaced with new
Electronics Transmitters



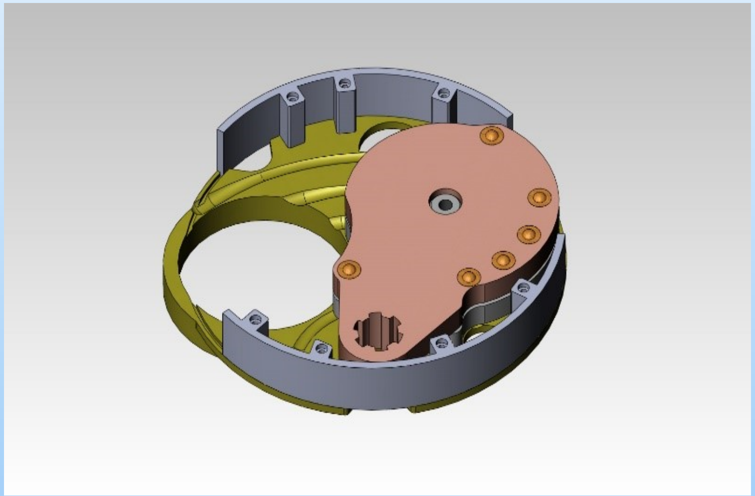
Lining Method



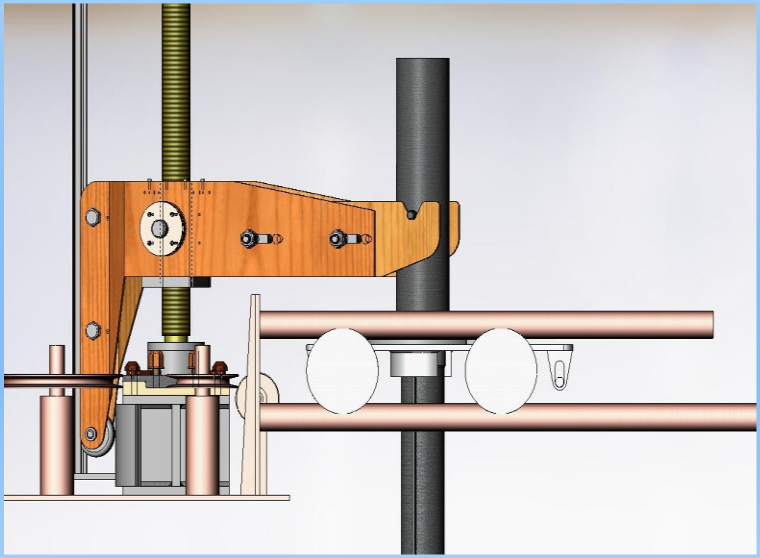
ECCS Drain Line Repair Plan

- Clean pipes using pneumatic tools /Hydro jetting and dry using hot air.
- Installation of liner along with bladder using existing access points and curing.
- Post Camera Inspection carried out

Important Activities at Dhruva...



- Testing, Installation & Commissioning of modified Main Valve mechanism



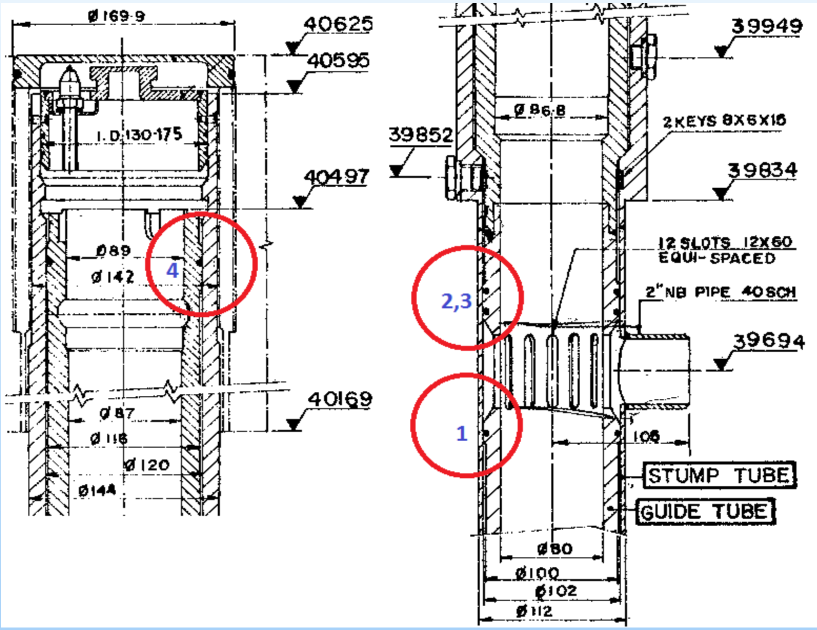
- Spent fuel transfer buggy for Dhruva reactor to enhance in-service life

Life Extension of Dhruva

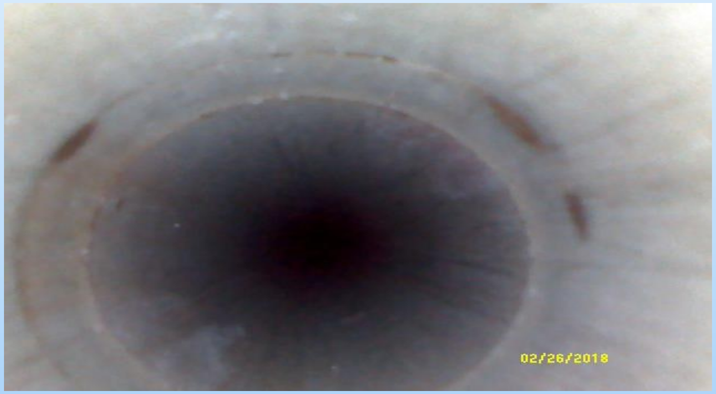
- Reactor has already seen more than 34 years of service.
- A systematic aging study has been initiated and it is felt that life of Dhruva Reactor can be extended for another 25-30 Years.
- For life extension, a long shut down requiring core unloading after 4-5 years is inevitable. May take ~ 1-1.5 year
- Systematic Ageing Management Plan is already in place.
  - A list of life limiting components of the reactor have been identified.
  - Their degradation mechanisms have been identified
  - Work to assess their condition is on hand.
- One of the major issues is to the cyclic loading seen by the reactor due to frequent starts and stops.
  - Originally these were limited due to on power fueling.
  - Till date Reactor has seen ~2000 cycles and at EOL it may see 5000 cycles.
  - ECW system is having more demands on it.
  - Change in category of system from mitigation to prevention. Hence needs upgradation.

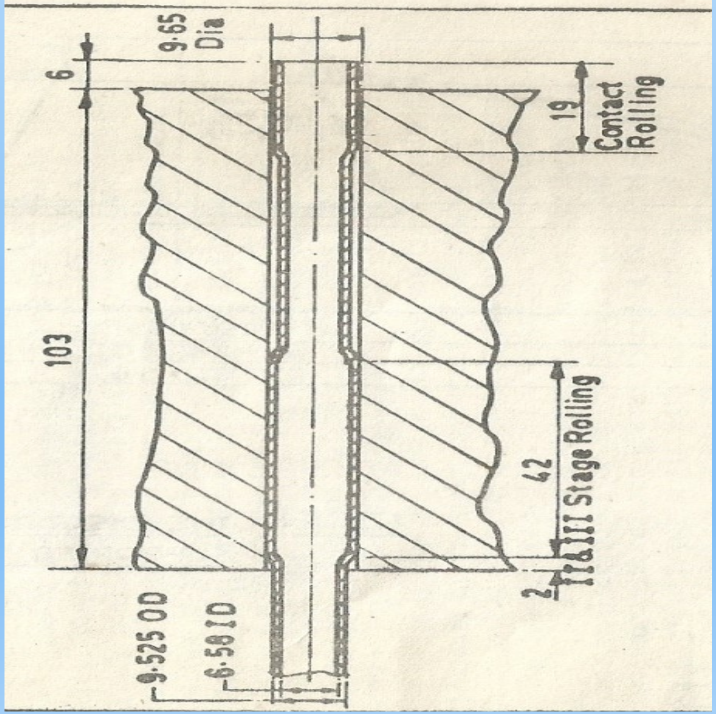
Major jobs

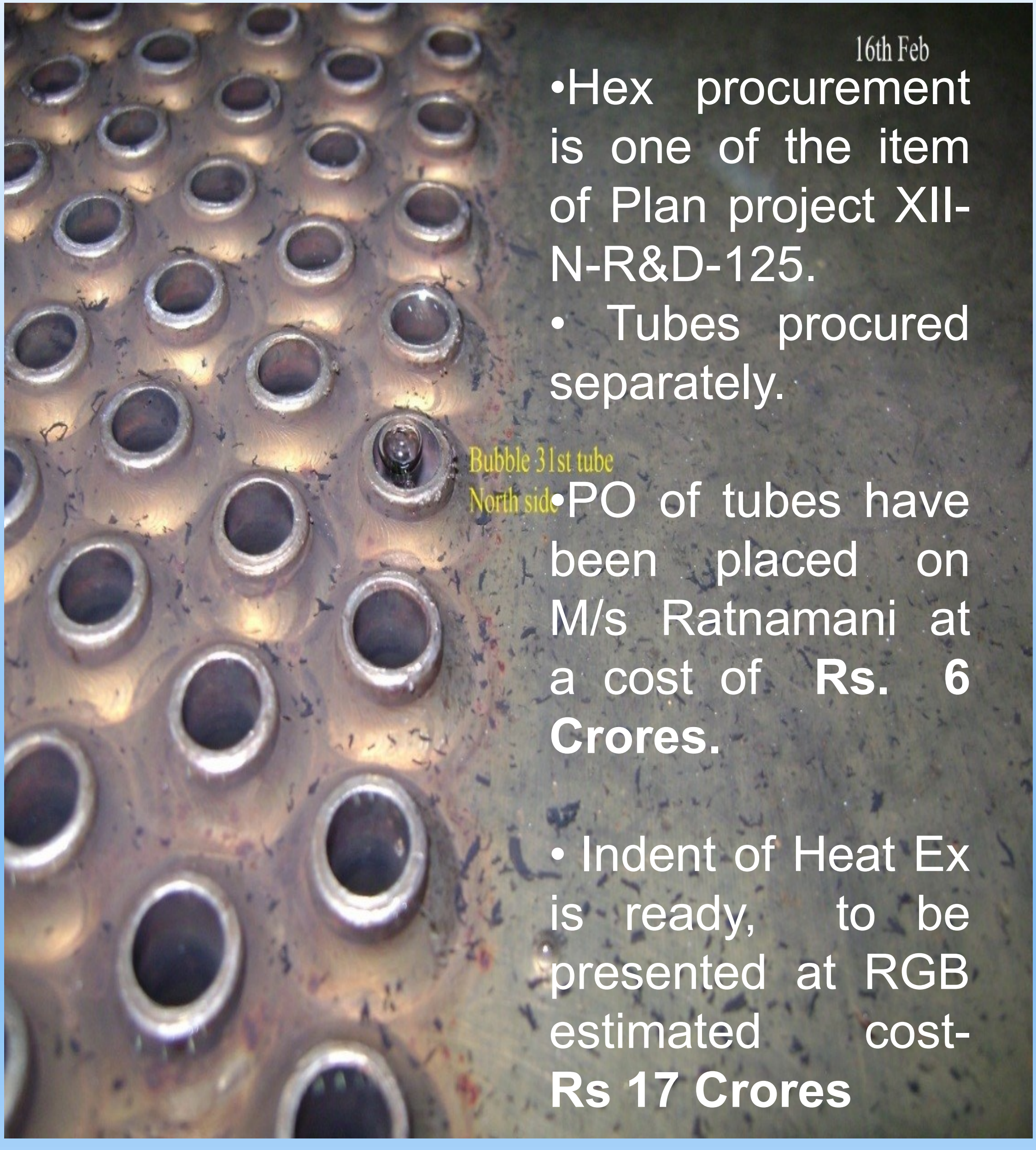
- Replacement of elastomers O-rings on guide tube.
- Procurement and commissioning of three new HW/PW Hxs.
- ISI of core internal structures.
- New SW jetty (requirement for reactor outage is roughly 2 -3 weeks)
- Repair / refurbish of ECW system
- Subsoil seepage from the Raft in subbasement.



HW Hx#3 Tube leak



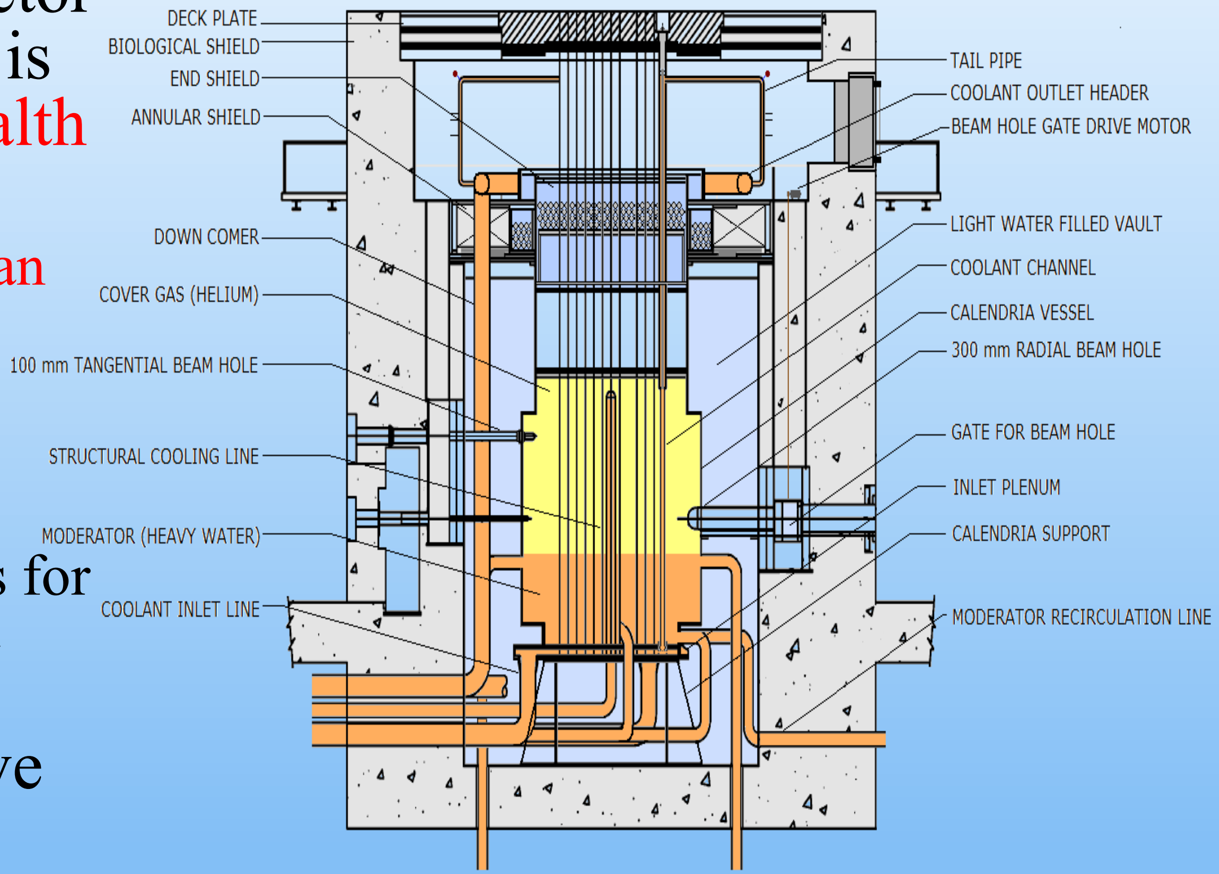




- Hex procurement is one of the item of Plan project XII-N-R&D-125.
- Tubes procured separately.
- PO of tubes have been placed on M/s Ratnamani at a cost of **Rs. 6 Crores.**
- Indent of Heat Ex is ready, to be presented at RGB estimated cost- **Rs 17 Crores**

ISI of Reactor internals

- There are several reactor internals where there is no provision their health assessment.
  - Zircalloy re-entrant can rolled joint.
  - Stump tube to top plenum SS-SS rolled joint.
  - Baffle diffusers plates for moderator inlet outlet nozzles.
- Some inspections have been carried out for:
  - Reactor vessel and inlet plenum. (due to fatigue loading)
  - Dissimilar weld joint between SS and CS in



General arrangement of Dhruva Reactor

Integrity evaluation of 300 mm Rolled Joint

- RED carried out thermo mechanical analysis for assessing residual life.
- It was concluded that the integrity of the rolled joint is not affected during normal operating conditions of the reactor.
- Following will also be done to ensure the healthiness of the rolled joints:
  - Visual inspection of rolled joint at site.
  - Helium leak test.
  - Cyclic testing on a mock rolled joint at RED for 5000 cycles.

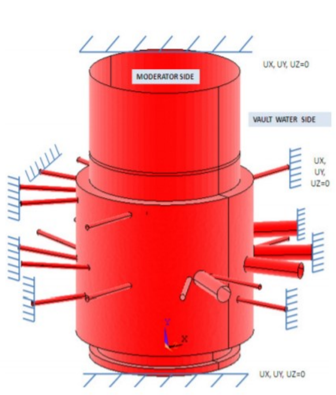


Fig.7. Boundary condition and loads for shell model

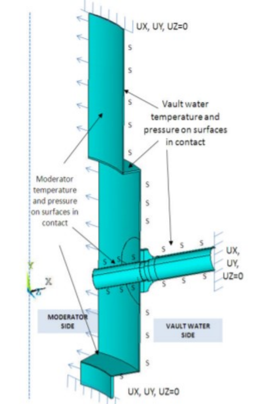


Fig.8. Boundary condition and loads for solid model

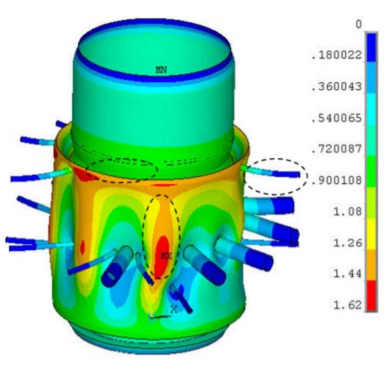


Fig.11. Contour plot of resultant displacement (mm) as obtained from the structural analysis of shell model

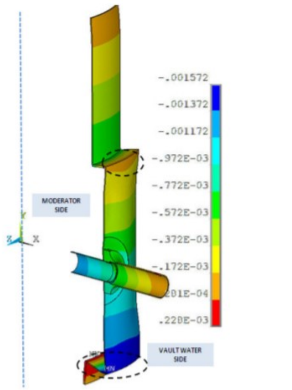
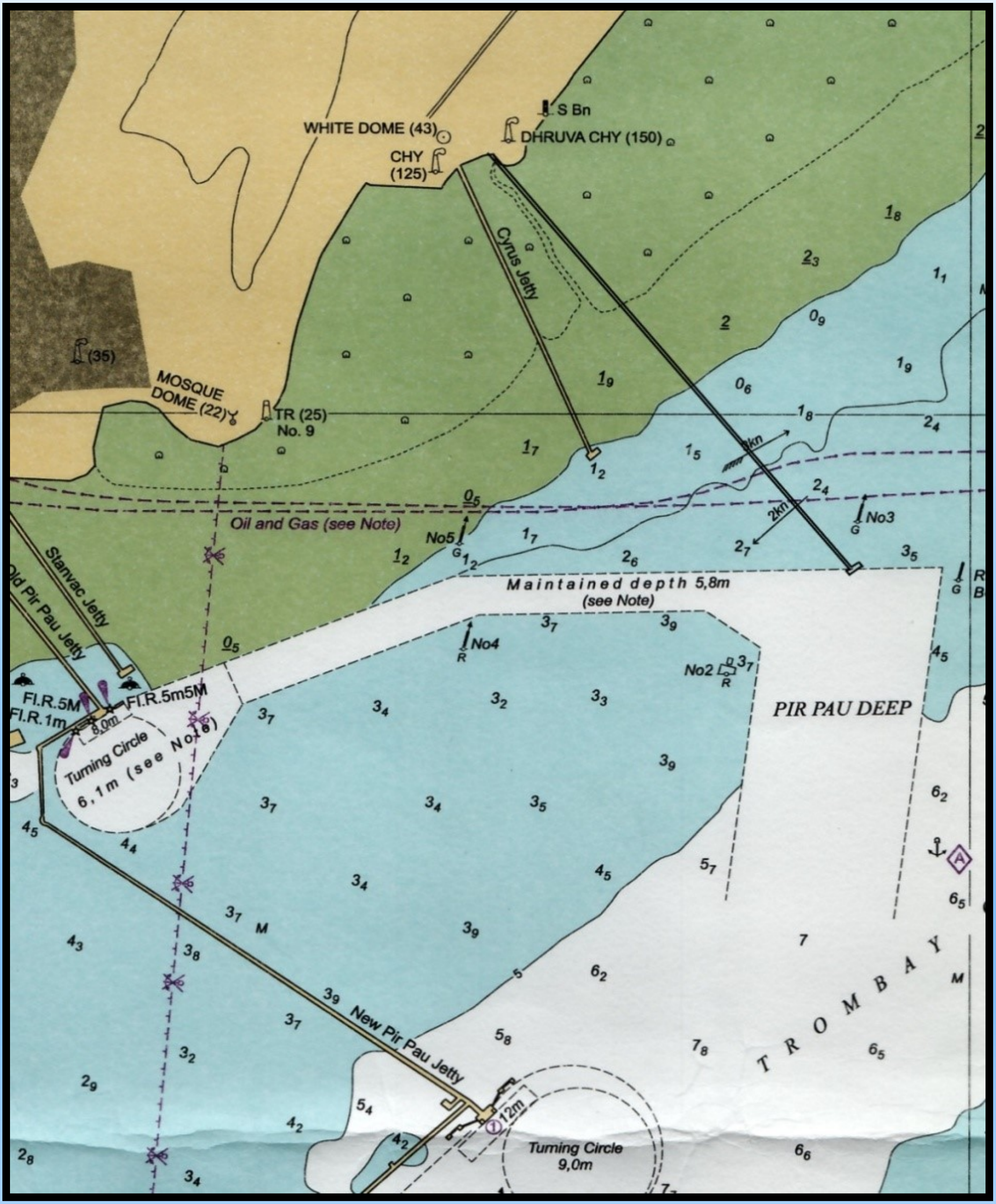


Fig.12. Vertical displacement (m) in the calandria as obtained from structural analysis of the solid model

Requirement for new jetty

- Existing jetty for Cirus was modified to cater to both Dhruva and Cirus reactor.
- Structure is more than 65 years old.
- Deterioration in civil structures.
  - Temporary Civil repair in consultation with CED carried out
- Accumulation of silt at the opening of chamber.
  - silt gets carried into pump chamber and damaging of radial bearings and jamming of pumps.
  - Periodic de-silting being carried out

Proposed Jetty



- 1.8 Km long and 7.0 m wide.
- Six pipe lines of ONGC, BPCL, Reliance are passing etc
- The same jetty can be utilized for proposed security requirement.
- Can cater to dilution requirement of ETP/WMD

Sub Soil Seepage Through Raft

- Water seepages at few places from Dhruva Reactor Building Raft. (Specially During rainy season)
- Seepages are from constructions joints and also at other places from the raft RCC slab.
- It is planned to repair the raft in Dhruva long shut down in consultation with A&SED/CED.

Sub-Soil Seepage in RCC RAFT/Joints

Critical Facility

- A low power Critical Facility is built to validate the physics design of the thorium based Advanced Heavy Water Reactor *(AHWR)*.
- All Experiments related to Ref . Core completed.
- Measurement of void coefficient of reactivity in AHWR experimental cluster was done.
- Large sample activation-for NAA & Detector testing is being done as per demand.
- ***Future Work Plan***
    - Experiments in AHWR representative core with (Th, Pu)MOX cluster for initial core.
    - Molten Salt Reactor(MSR) related experiments.

P-4

- **Cold Facility:**
- This is the facility were we carry out calibration of large number of in-core components of Compact light water reactors such as:
  - Burnable Poison Rods.(BPRs)
  - Emergency Protection Rods.(EPRs)
  - Compensating Grid Rods.(CGRs)
- **Hot Facility**
- We also carry out Criticality in the hot facility, for every 25°C step up to 300 °C.
- Subsequently reactor is operated up to 600 W.
- Power produced from the fuel assembly is assessed using gamma scanning of the fuel.
- This input is used for providing a flow orifice of the individual fuel assembly which are set here.
- Subsequently the core is delivered for its ultimate use on the platform.

P-4

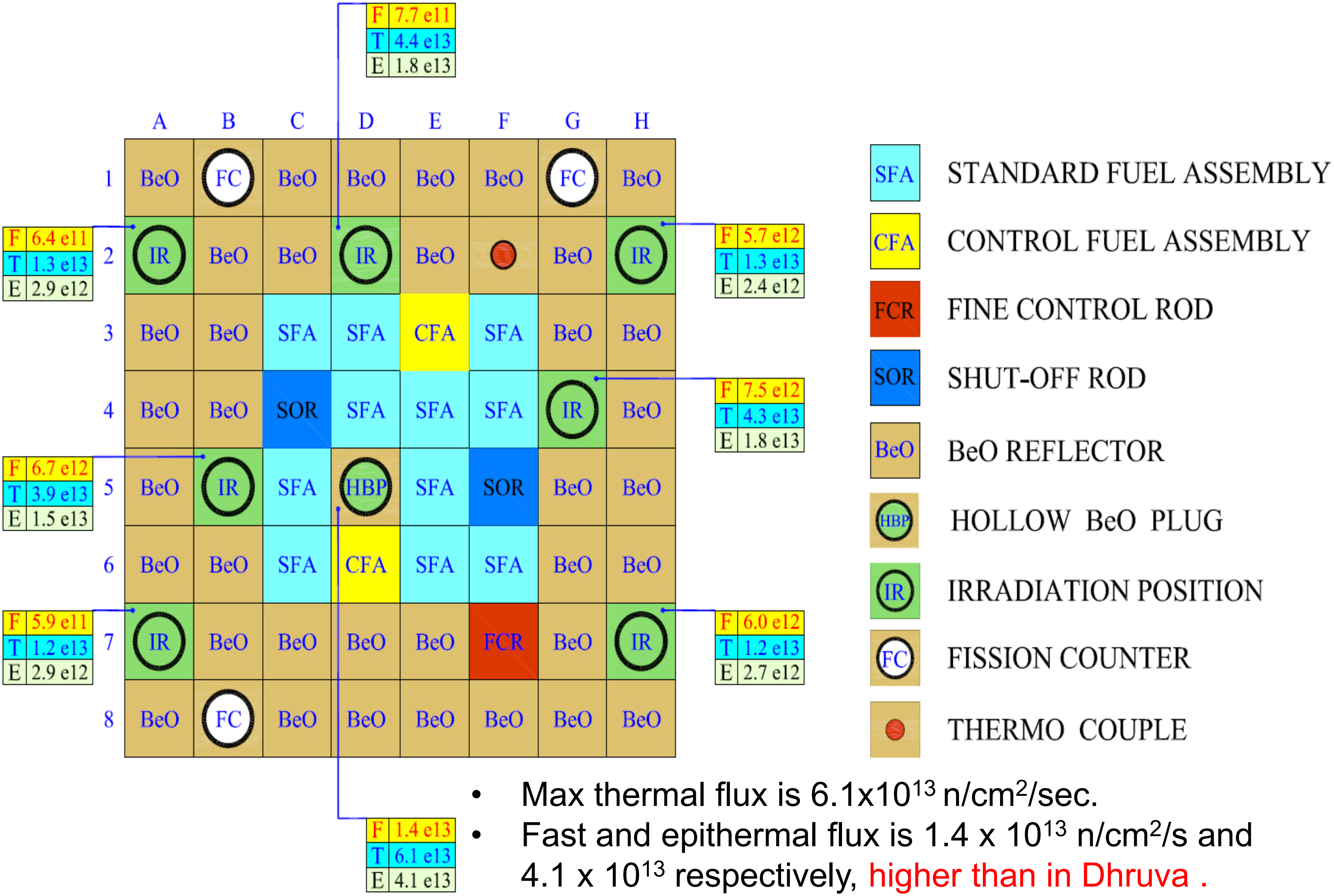
- **Completed Activities:**
- One core calibrated and delivered.
- Calibration of core components for next core (B-3 Type) - completed.
- Calibration of Compensating Grid Rods (CGRs) for four Internal Blocks (IB) of B-3 Type –completed.
- Calibration of Compensating Grid Rods (CGRs) for one Internal Blocks (IB) of B-11 Type is in progress.
- **Future Plan:**
- Commissioning of cold facility & physics experiment in cold facility for B-3 core.
- Commissioning of Hot facility & physics experiment in hot facility for B-3 core.
- Gamma scanning.
- Delivery of object by end of 2021.

APSARA-U REACTOR

Apsara-U Activities

Activity	Regulatory Clearance	Achievement
FAC and Low Power Experiments	2nd Sept. 2018	FAC: 10th Sept 2018 LPE : 19th Sept 2018 to 25th Sept 2018
High Power Operation Upto 600 kW	24th Dec 2018	18th Jan 2019
Changing the Core Configuration and Raising Power to 1.8 MW	2nd Apr 2019	22nd Apr 2019

Neutron Flux Distribution



- Max thermal flux is 6.1×10^{13} n/cm^2/sec.
- Fast and epithermal flux is 1.4×10^{13} n/cm^2/s and 4.1×10^{13} respectively, higher than in Dhruva .

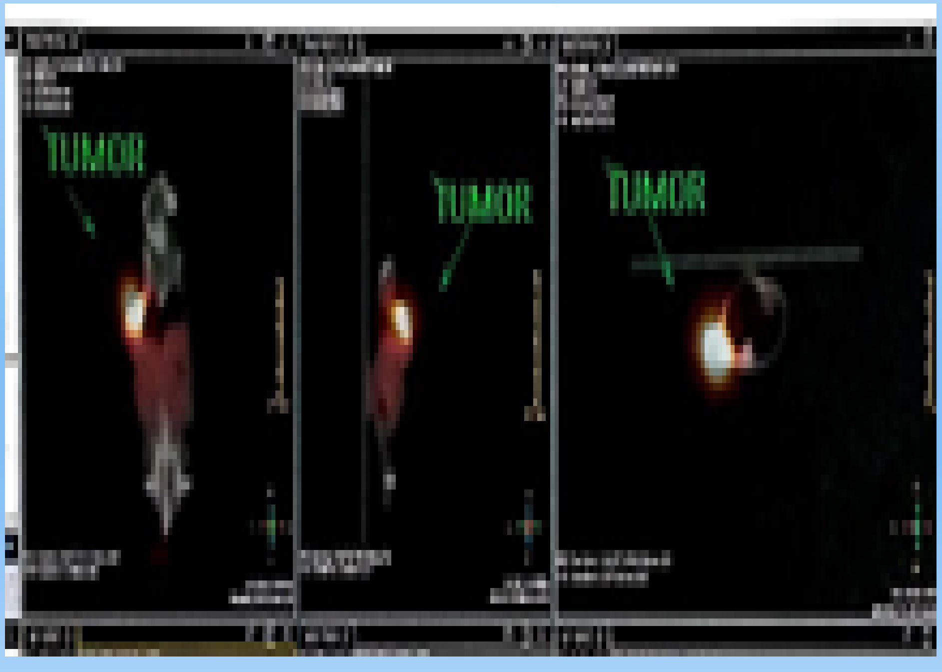
Provisions for Isotope Production in Apsara

- 8 irradiation positions in Apsara-U
- Provides for 110 samples at a time.
- 7 out-of-core irradiation positions
- 1 in-core irradiation position
- Special Tray Rod assemblies are provided in the reactor for production of radioisotopes.
- Each Tray Rod can accommodate 15 capsules of target material.

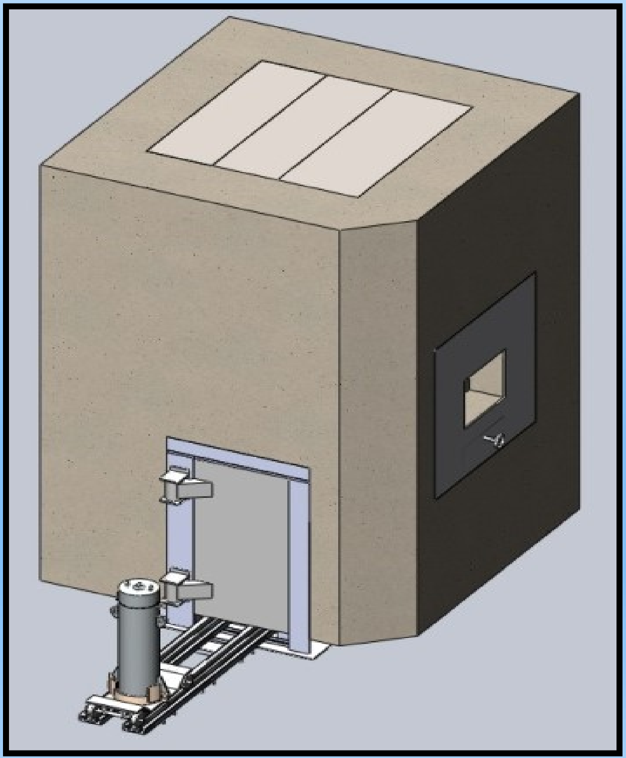
Handling trials of Isotope shielded flask in the Apsara pool .

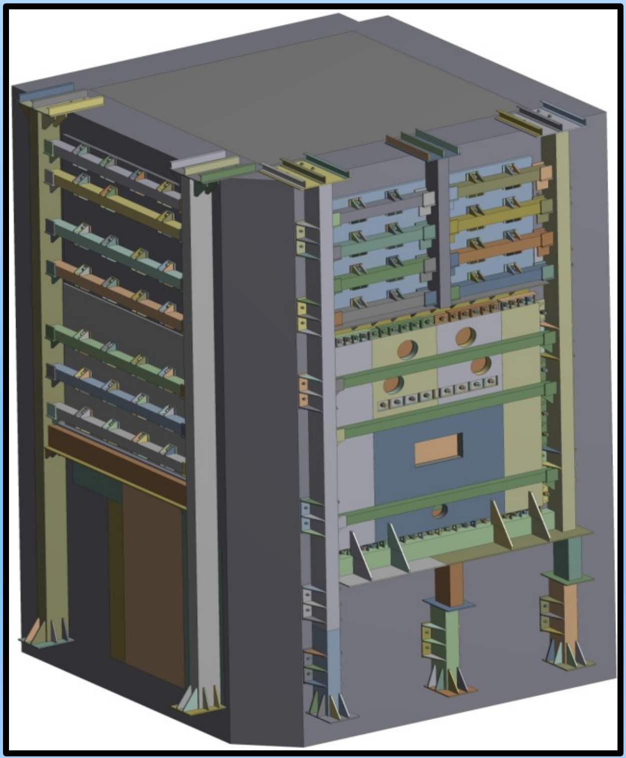
Isotope Production in Apsara-U

- Radioisotope production on trial basis commenced in **January, 2019.**
- Production of Cu-64 by irradiating Zn-64, utilizing higher fast flux available in Apsara-U carried out
  - Established production of NCA form Cu-64 for medical applications
  - Pre-clinical trials completed; showed promising results
- Feasibility of producing medically important radioisotopes being explored. [^{47}Sc, ^{117m}Sn, ^{166}Ho, etc]



- Trial samples being irradiated
  - Total 35 samples irradiated and delivered.
  - Target material:
    - Zn, MoO_3, Sm_2O_3, $HoCl_3$, Ge, Y_2O_3, Carbon fibre sample, geological samples etc.
- Augmentation of TRF shielding planned
  - For enabling handling of fission moly





Other Utilisation

Beam tubes

- Beam tubes allocated
  - Facilities being designed by researchers
    - Single-crystal Alignment Facility
    - Neutron Detector Test Facility
    - PGNAA, NAA
    - neutron imaging facility
- Flux mapping in one beam tube carried out
  - to be carried out in other beam tubes and irradiation facilities

Shielding Experimental Facility (SEF)

•Proposal received for initiating shielding experiments for compact light water reactors.

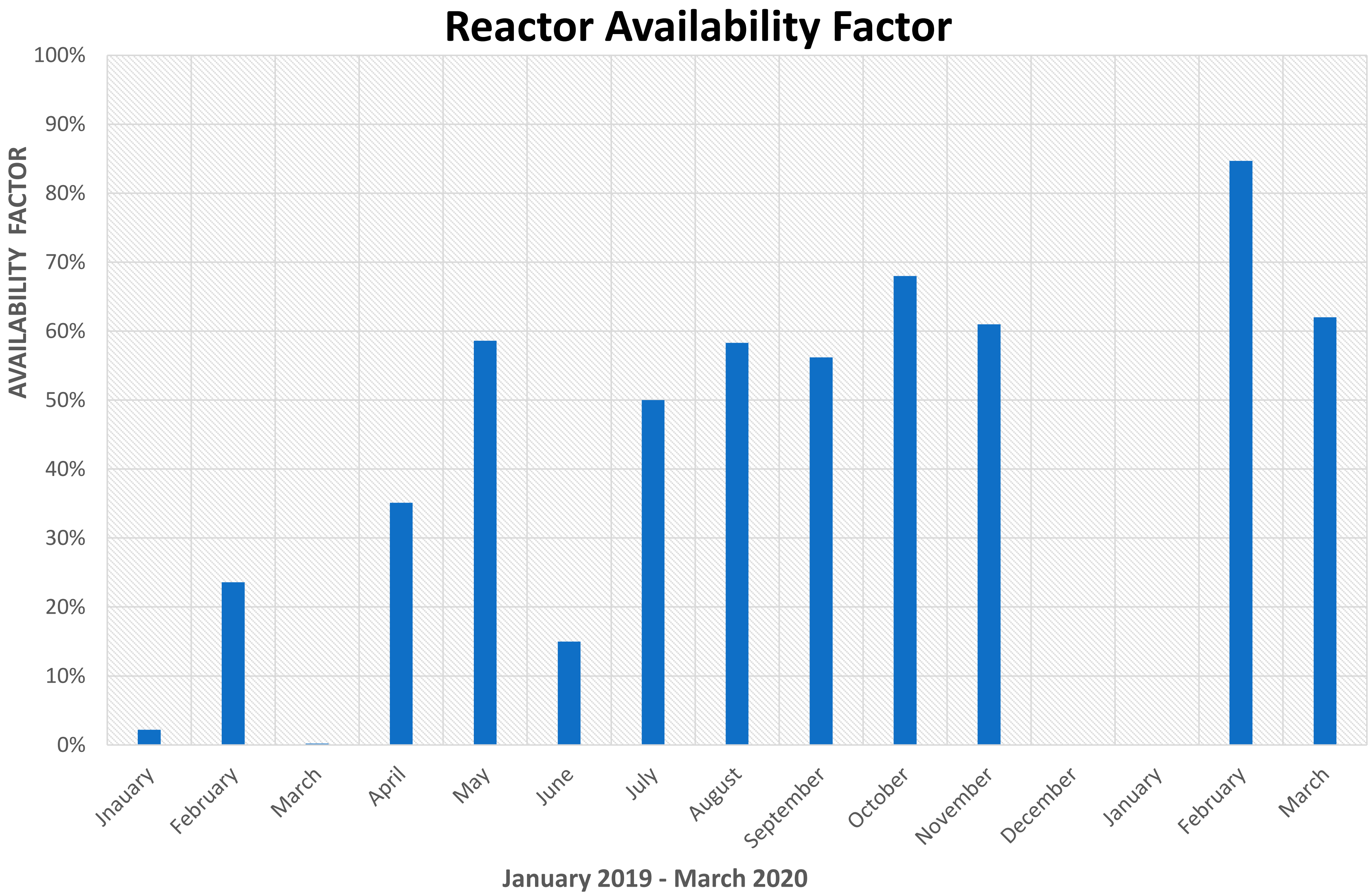
•Concrete bricks in Shielding trolleys replaced with cast RCC blocks

•Modifications to minimize radiation streaming through rail channels and floor gap is being implemented

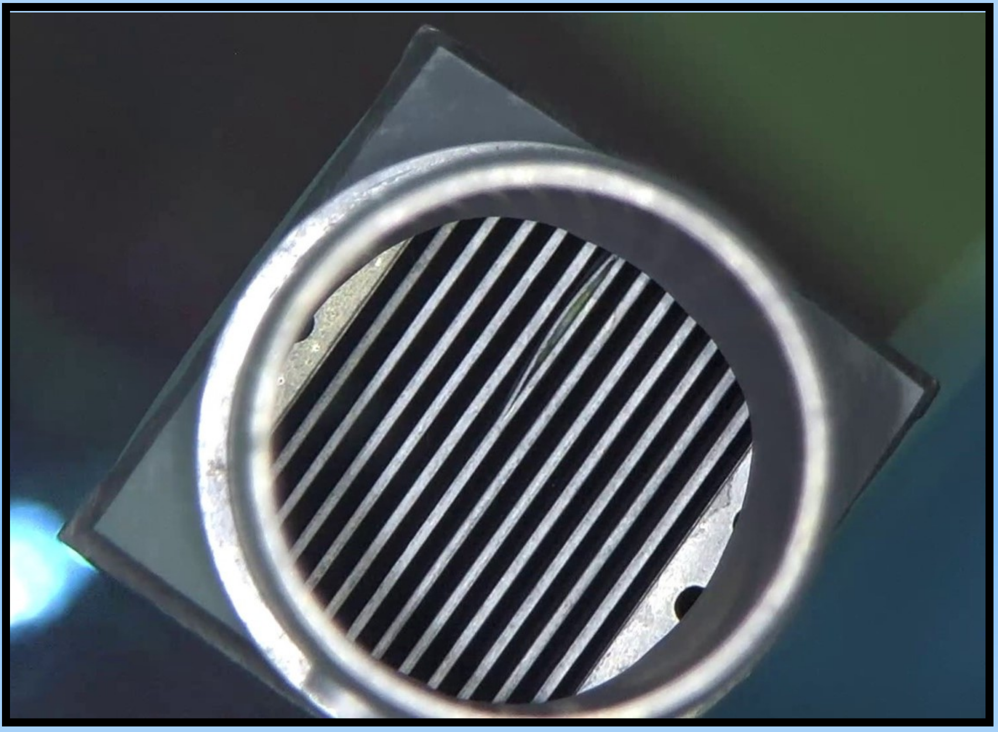
Thermal Column

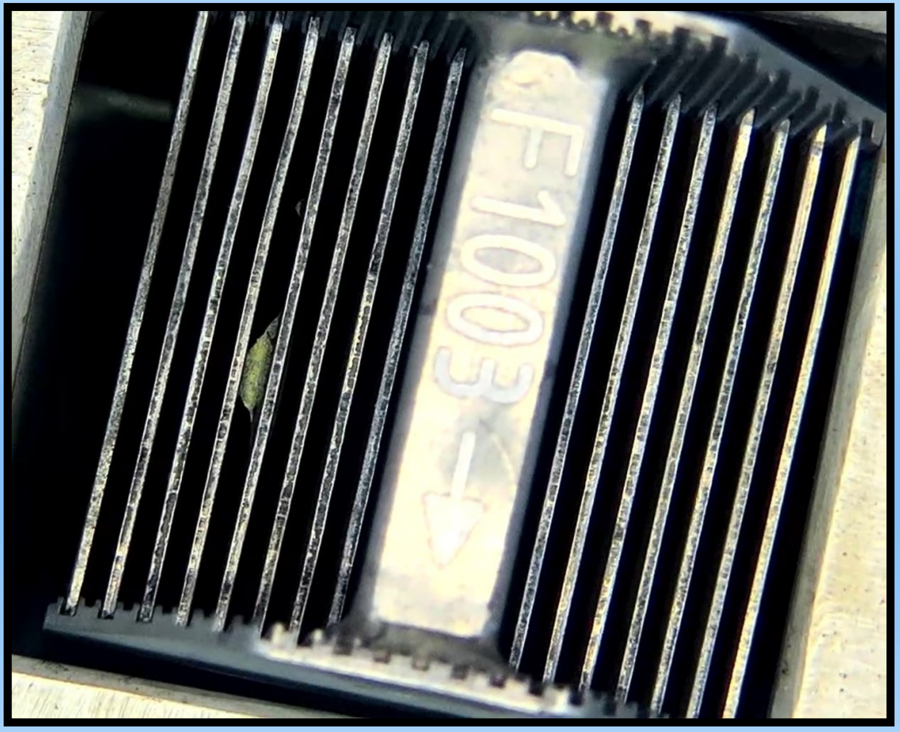
• Shielding plugs for augmenting shielding in experimental positions are being fabricated.

- **Reactor operating at NP-30% since August 2019**



- **Performance of all process systems satisfactory**
- **Radiological Status**
  - Area radiation fields < 0.1mR/hr (except on PCW pipelines and Heat exchanger in basement)
  - Exhaust effluent releases negligible
  - Personnel exposure insignificant; Collective dose for the year 2019: 0.60 person-mSv
- **Two fuel failures during reactor operation at 1.8 MW**
- **Reactor Power is limited to 600 kW for further observations**





- Remote visual inspection of fuel assemblies carried out within reactor pool

Further Plan on fuel...

- Inspection of failed fuel at PIED
  - Trials carried out for transportation carried out using dummy assembly
  - Cutting and inspection trials carried out at PIED
- Material Specifications, Fabrication process, QA checks being reviewed and new specifications have been drawn.
- New Fuel assemblies being fabricated
- Reprocessing of silicide fuel is to be planned.

Research and Development:
Computer Codes developed in ORPS

S/n.	Name of codes	Description
1.	ORPAC	Operational reactor physics analysis code.
2.	NEMSQR/NEMHEX	Diffusion theory code for square/hexagonal geometry using nodal expansion method
3.	RITAC	Point kinetics and thermal hydraulics coupled code for plate and pin type fuel geometry (up to sub-cooled boiling regime)
4.	SACRIT	Point kinetics and thermal hydraulics coupled code for plate and pin type fuel geometry (up to film boiling regime)
5.	IQSHEX/IQSSQR	Space-time kinetics and thermal hydraulics coupled code for hexagonal/square lattice cores of nuclear reactors using nodal expansion method based IQS
6.	DINHEX	Space-time kinetics and thermal hydraulics coupled code for hexagonal lattice cores of nuclear reactors using nodal expansion method based direct technique
7.	INVPK	Inverse point kinetics code for worth measurement of reactivity devices from power profile during rod drop
8.	DIFMC	Diffusion theory based analog Monte Carlo code for simulation of noise experiments
9.	SIGN	Neutron-gamma coupled shielding code for nuclear reactor
10.	MOC-T	Method of Characteristics (MOC) based neutron transport code for lattice level calculation