Status of Fast Reactor Programme in India

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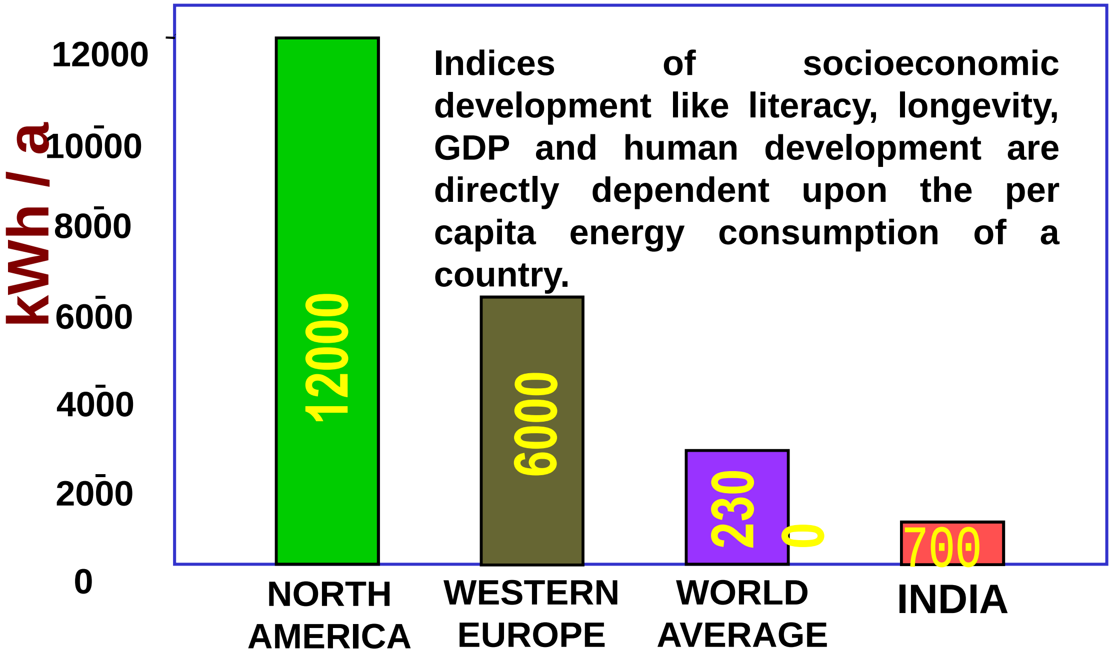
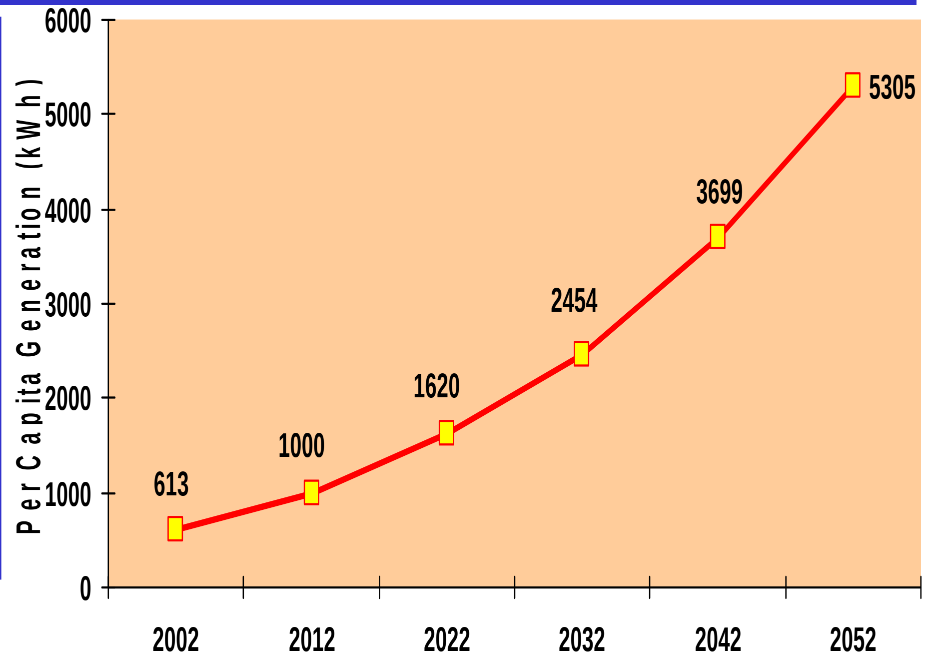
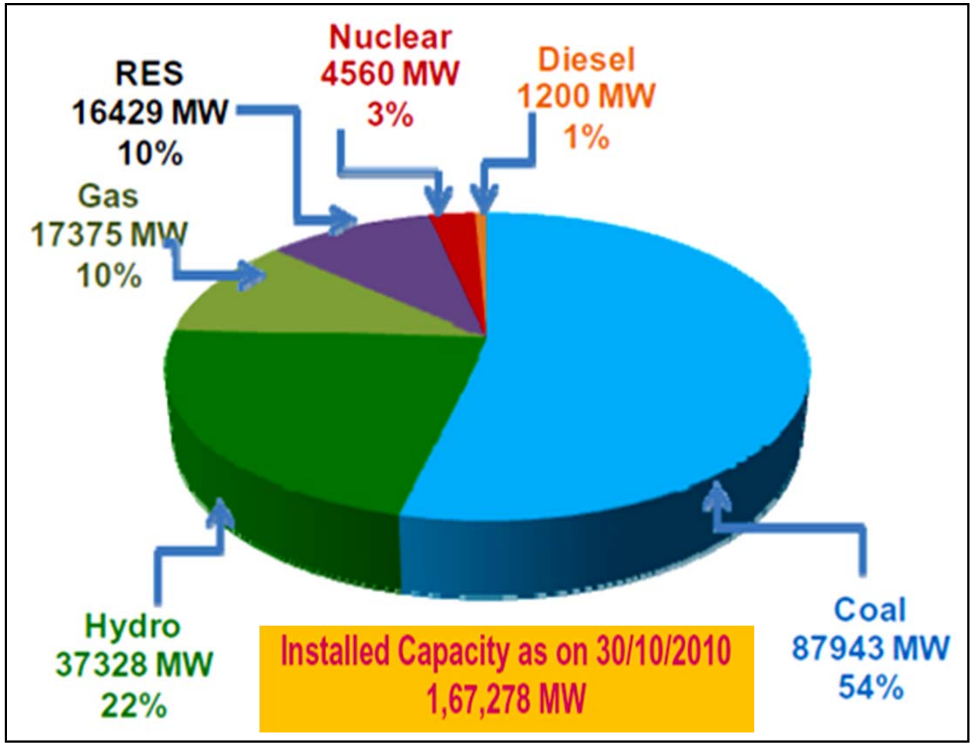
Status of Fast Reactor in World

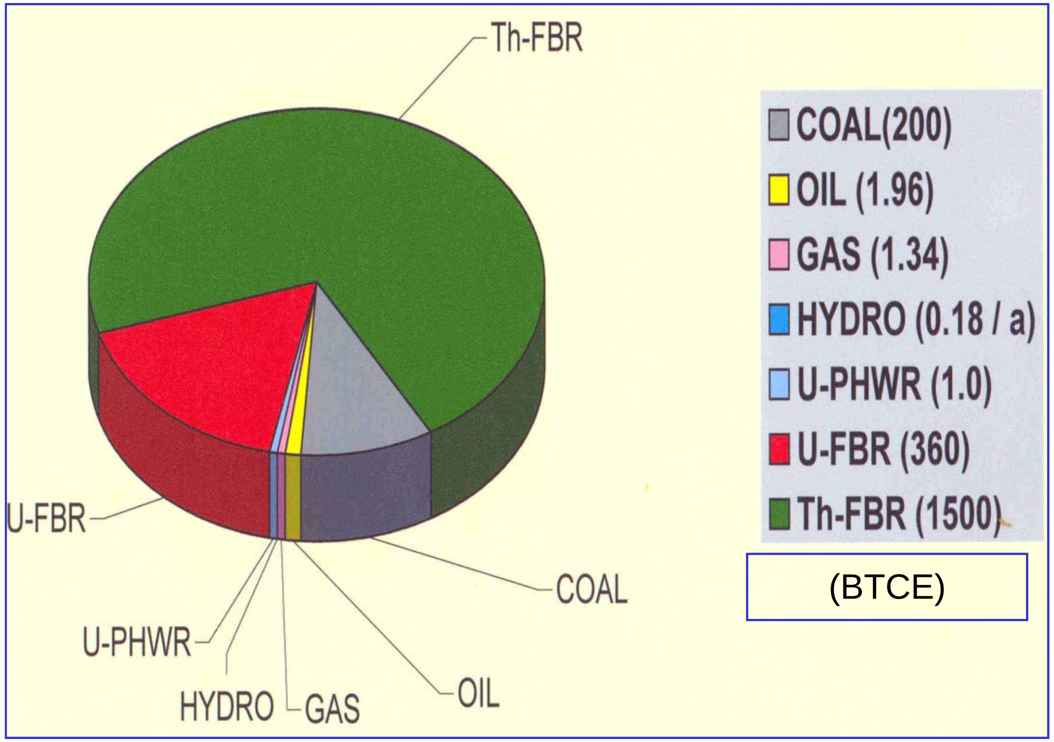
8th March 2012, TSuruga

Role of Nuclear for Energy Security of Nation

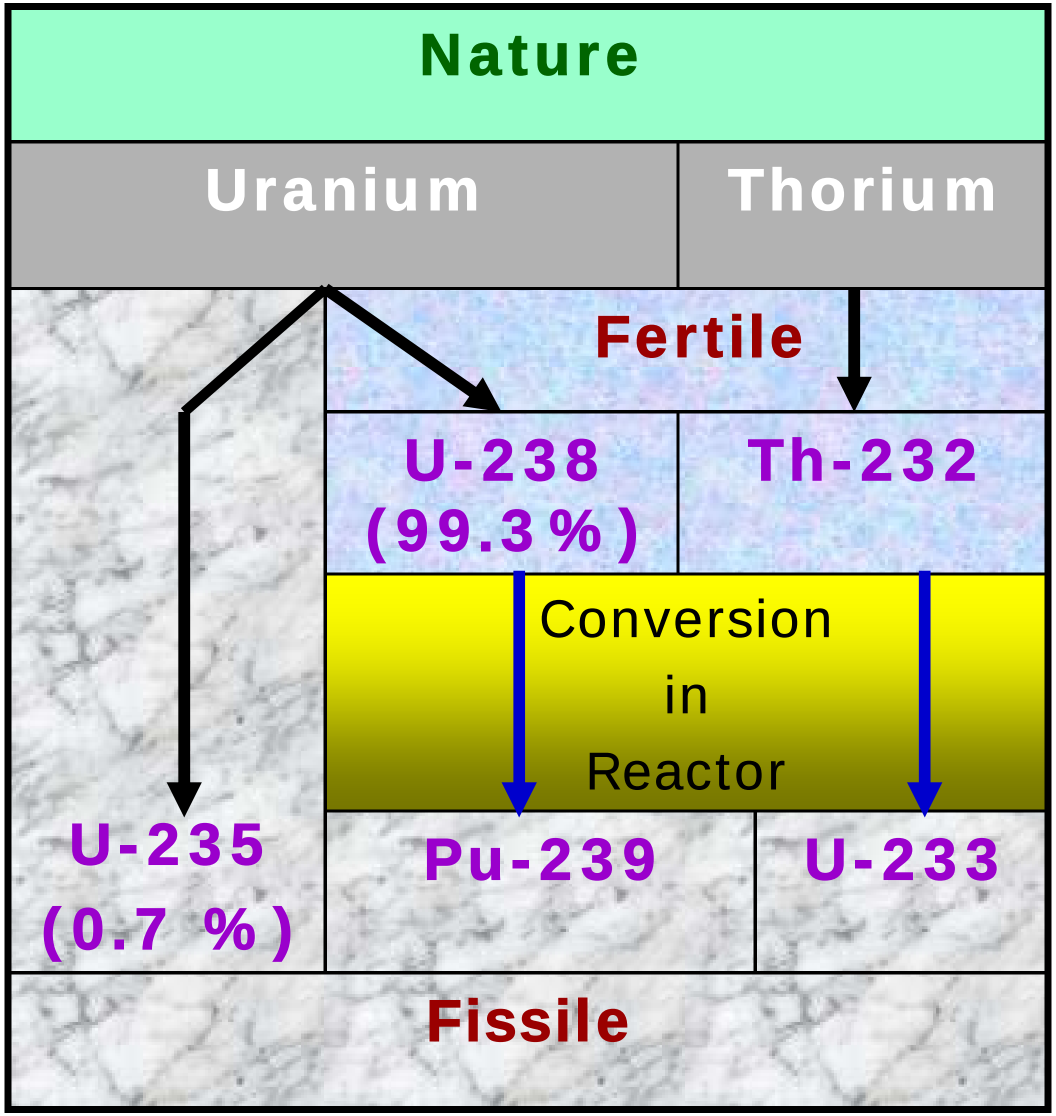








Pathways for utilisation of nuclear fuel resources

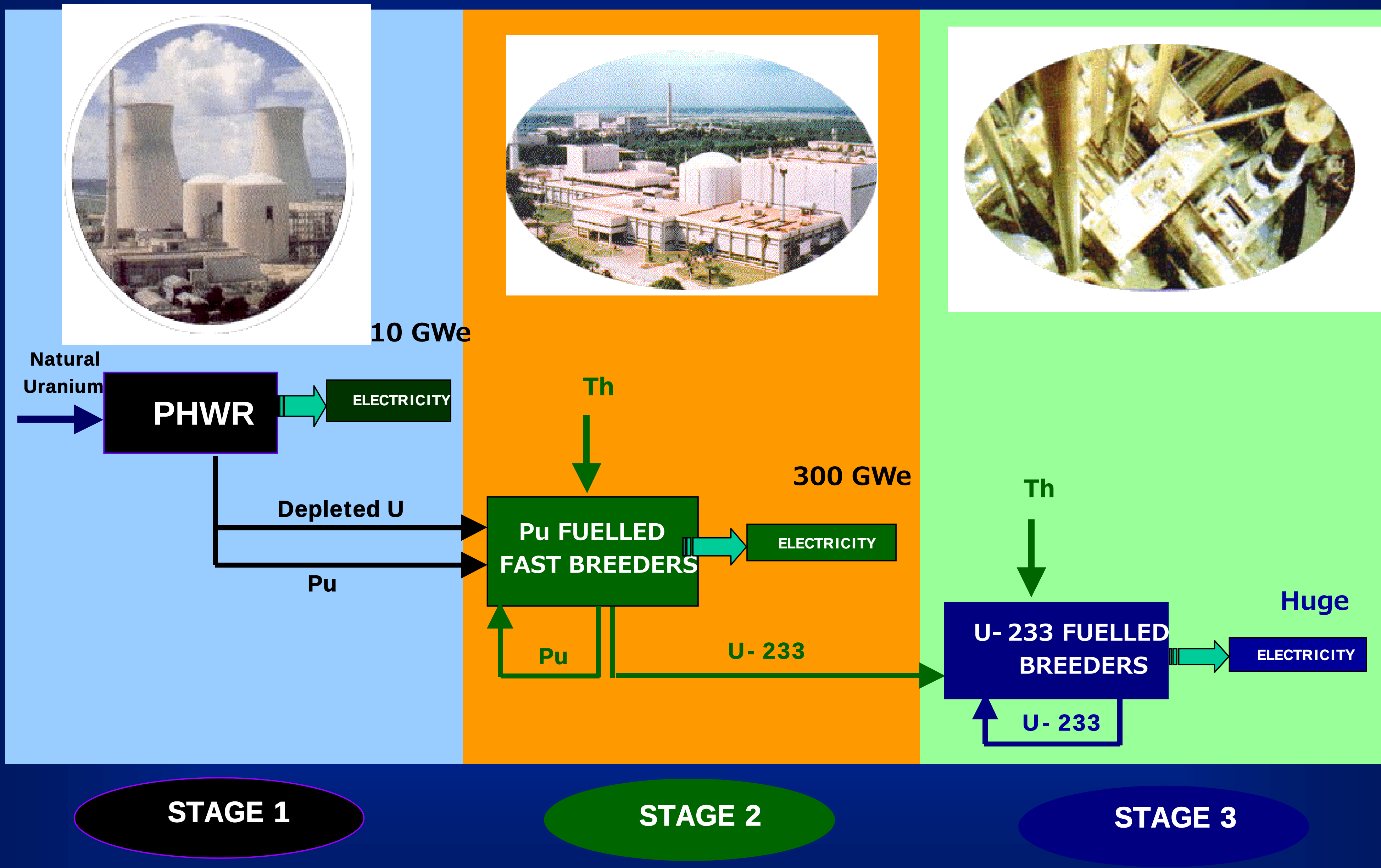


India has abundant thorium, however thorium cannot straightway be used as nuclear fuel as it has no fissile isotopes.

Fast Breeder Reactors operating with Plutonium as fuel,
produce more Plutonium than they consume. However, they require almost three times more fissile materials to get started, as compared to thermal reactors.

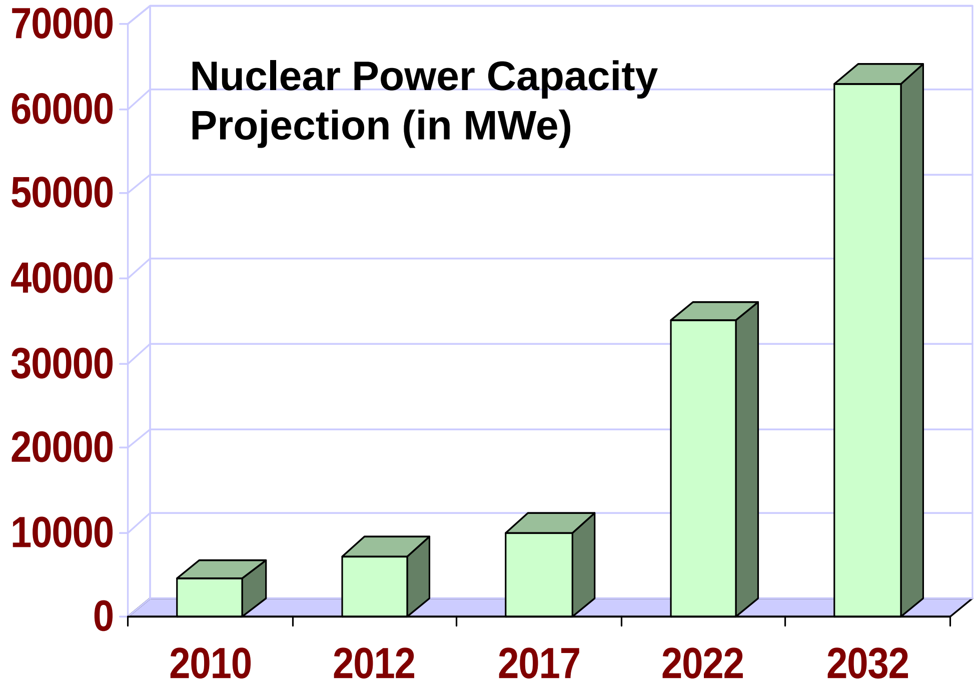
Thermal Reactors require moderator. With heavy water as moderator, even natural uranium can serve as nuclear fuel. Enriched uranium is needed if light water is used as moderator.

Three Stage Nuclear Power Programme



India's Nuclear Roadmap

- PHWRs from indigenous Uranium
- PHWRs from imported Uranium
- Imported LWR to the max. extent of 40 GW(e)
- PHWRs from spent enriched U from LWRs (*undersafeguard)*
- FBRs from reprocessed Pu and U from PHWR
- FBRs from reprocessed Pu and U from LWR *(undersafeguard)*
- U-233-Thorium Thermal / Fast Reactors



- India has indigenous nuclear power program (4780 MW out of 20 reactors) and expects to have 20,000 MWe nuclear capacity on line by 2020 and 63,000 MWe by 2032.
- **Foreign technology and fuel are expected to enhance India's nuclear power plans considerably. All plants will have high indigenous engineering content.**
- India has a vision of becoming a world leader in nuclear technology due to its expertise in fast reactors and thorium fuel cycle.

Features of Fast Breeder Reactors

- Effectively utilizes the natural uranium (nearly 80 %)
- Consumes the depleted fuel discharged from thermal reactors
- Breeds more fissile material (plutonium) than consumed

- With a large number of thermal reactors operating and planned worldwide, the limited available natural uranium would be consumed very fast. On the other hand, with FBRs, energy supply can be ensured over a few centuries.

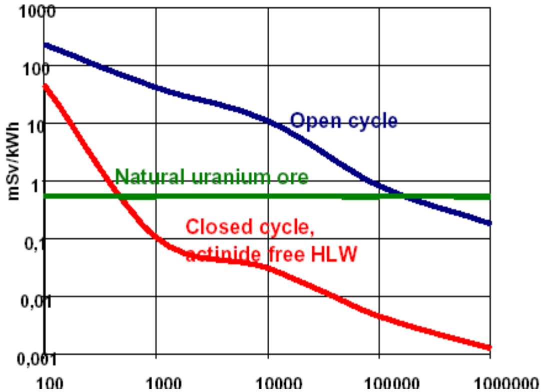
- FBR is important from waste management and environmental considerations.

- Burns actinides and long lived radioactive fission products. Generation of precious metals such as Cs, Pd etc which have many important societal applications and can be extracted from its waste (wealth from waste).

Uncertainties in oil prices and available uranium resources bring FBR with closed fuel cycle to focus

Energy Potential

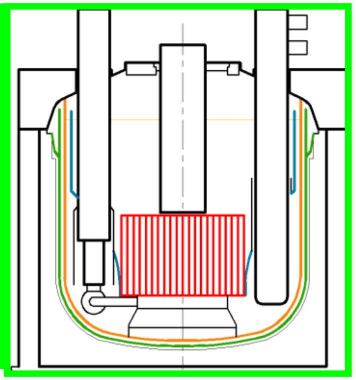
1 kg of coal	3 kWh	
1 kg of oil	4 kWh	
1 kg U (natural)	50,000 kWh	in PHWR
(if reprocessed)	3,500,000 kWh	in FBR



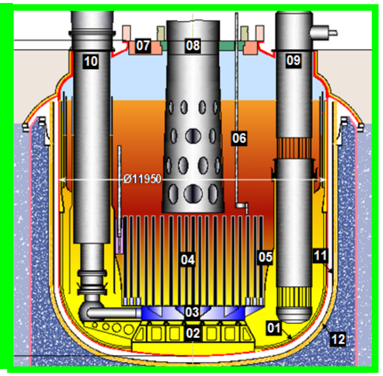
FBR Programme in India

- Indigenous Design & Construction
- Comprehensiveness in development of Design, R&D and Construction
- High Emphasis on Scientific Breakthroughs
- Synthesis of Operating Experiences
- Synthesis of Emerging Concepts (Ex.GENIV)
- Focus on National & International Collaborations
- Emphasis on high quality human resources
- Creation of environment for enabling innovations
- Marching towards world leadership by 2025

Future FBR
- 1000 MWe
- Pool Type
- Metallic fuel
- Serial constr.
- Indegenous
- Beyond 2025

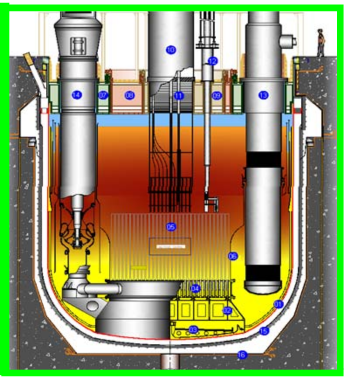


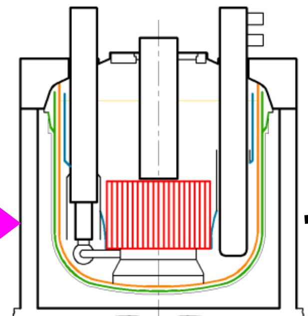
CFBR
- 500 MWe
- Pool Type
- UO2-PuO2
- 3 twin units
- Indigenous
- From 2023…



FBTR
- 40 MWt
- 13.5 MWe
- Loop type
- PuC – UC
- Design: CEA
- Since 1985

PFBR
- 1250 MWt
- 500 MWe
- Pool Type
- UO2-PuO2
- Indigenous
- From 2013..

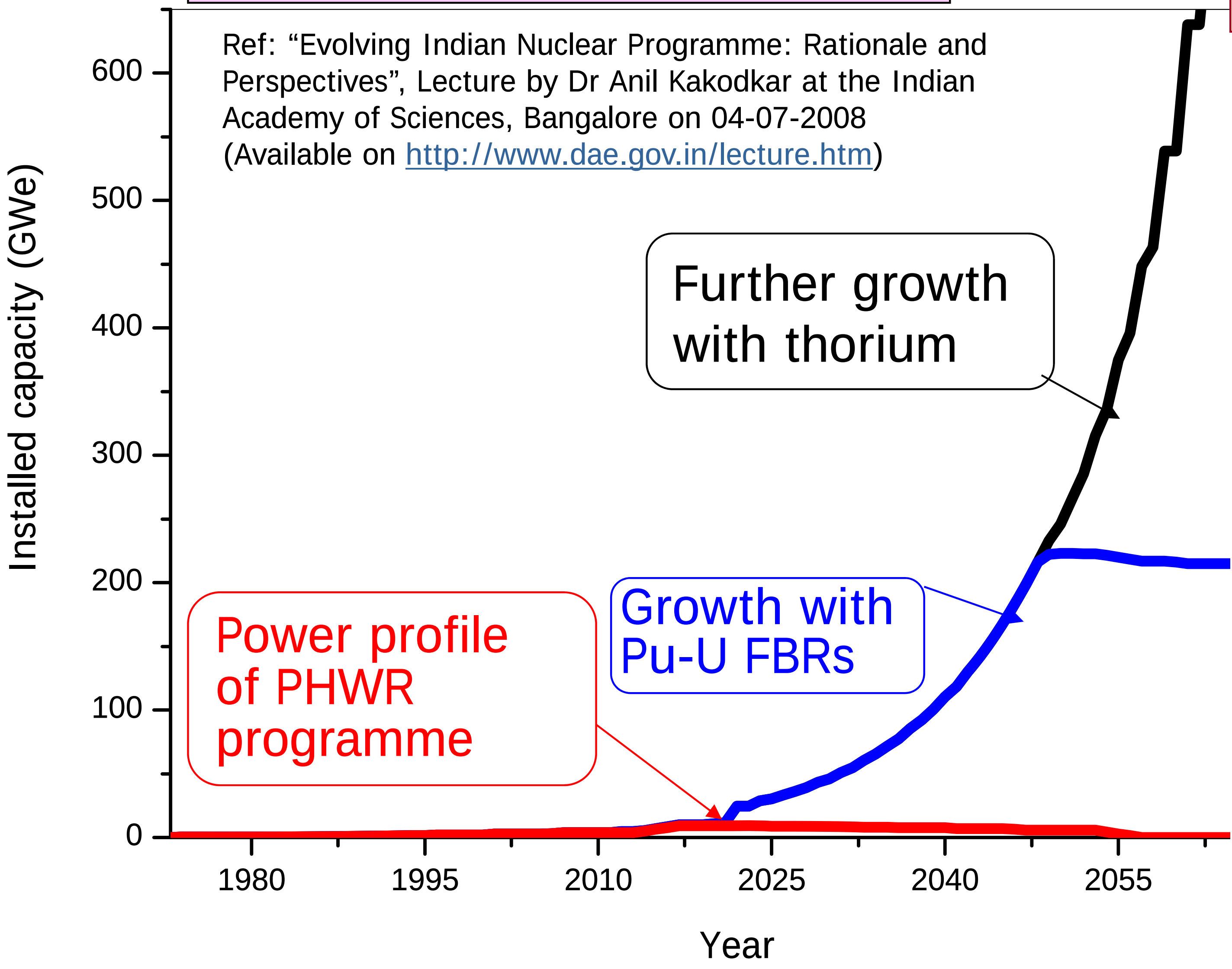




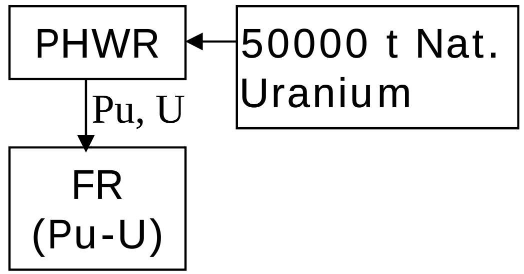
MFTR (120 MWe)

With fast breeders and thorium utilisation, much higher targets can be met in a sustainable manner

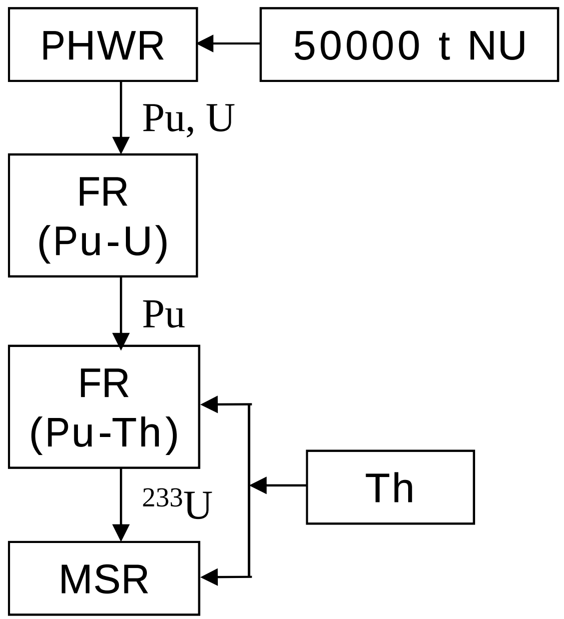
Results of a typical case study



Reactor Chain for use of recycled U-Pu in FBRs



Reactor chain of U-Pu and Th-Pu FBRs + Th-U233 reactors



FBR Fuel Cycle

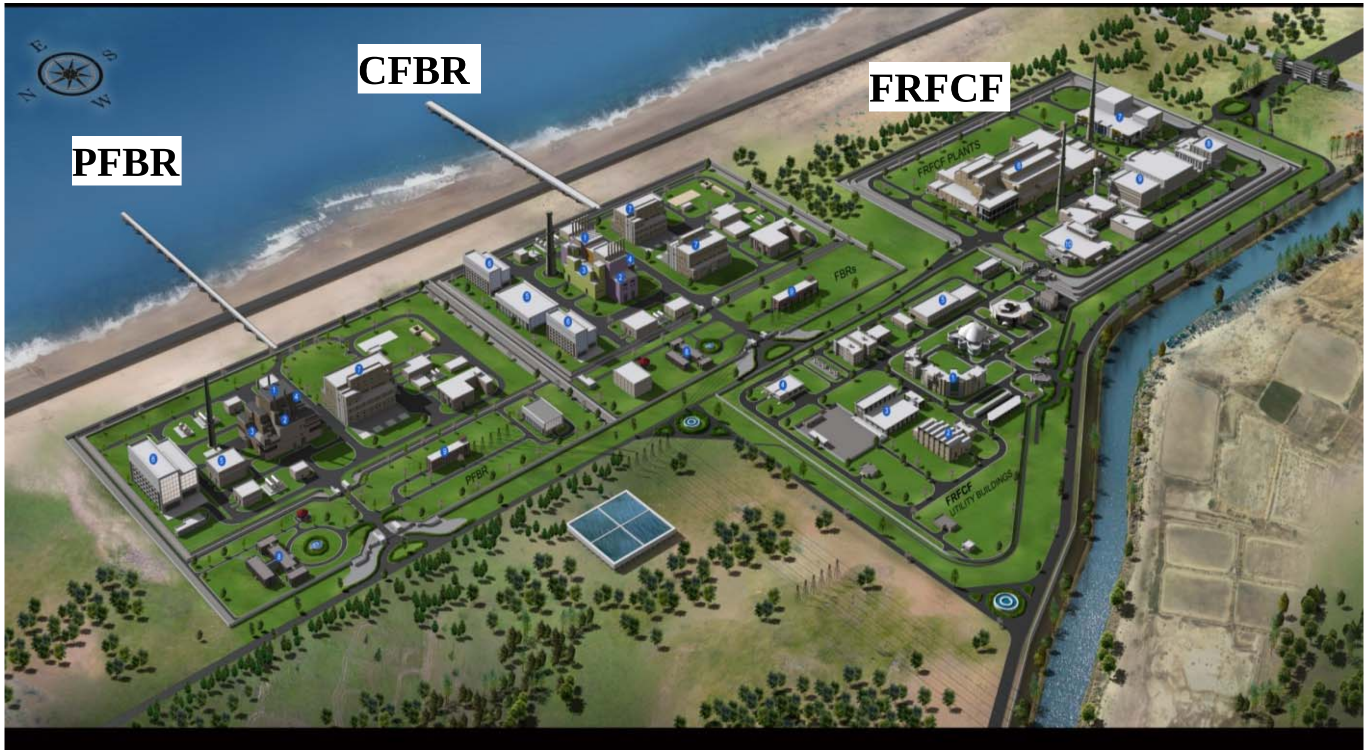
Fuel discharged from FBTR reprocessed in CORAL. Fuel with burn-up of 150 GWd/t has been successfully reprocessed

Next ……
Technology demonstration in DFR Plant
Commercial demonstration in PFBR fuel reprocessing plant

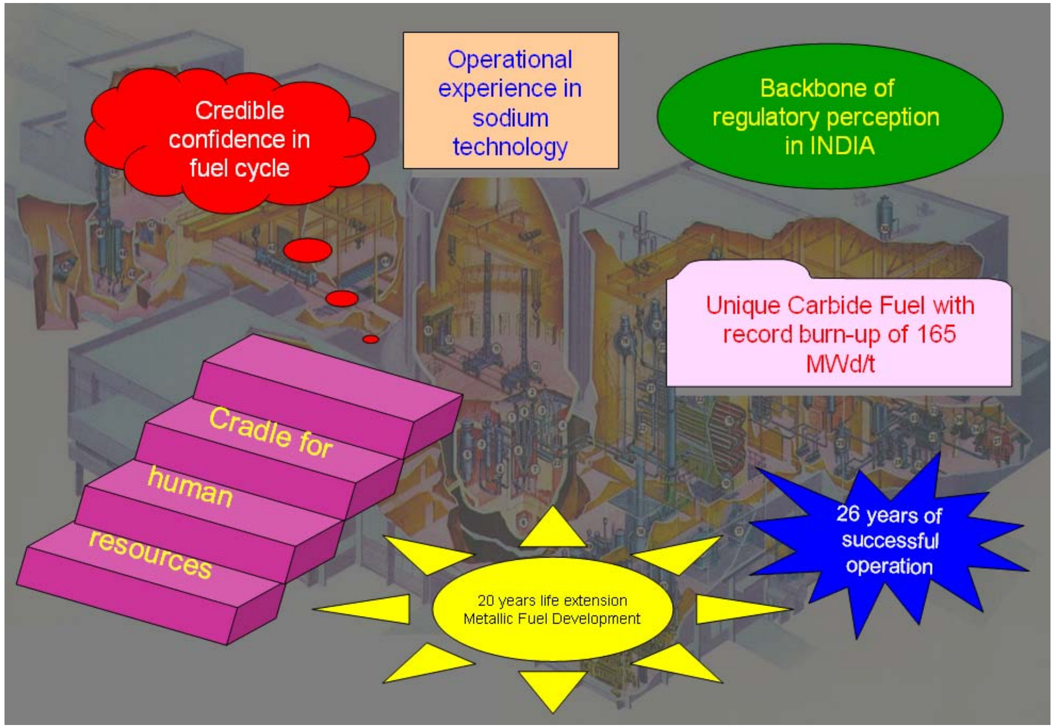
Fast Reactor Fuel Cycle Facility (FRFCF)

Co-located facility with all facilities for recycling the fuel from PFBR, including fuel fabrication, assembly, reprocessing and waste management.

Layout is planned in such a way that future expansion is possible to cater the needs of two more 500 MWe FBRs, to be built at Kalpakkam



FBTR today



FBTR, in operation since 1985, is test bed for FR fuels & materials.

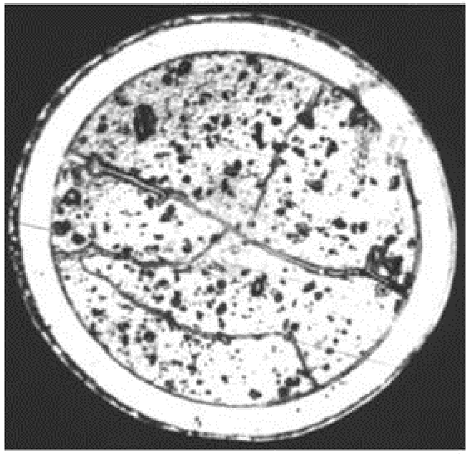
It has completed 18 irradiation campaigns .

Its unique carbide fuel has set an int. record in burn-up (165 GWd/t)

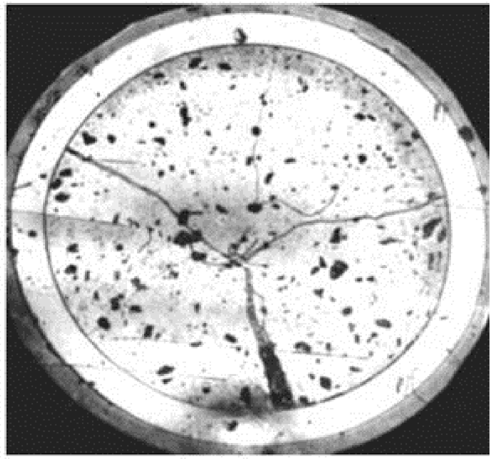
PFBR test fuel is completed irradiation at FBTR and seen 112 GWd/t burn-up.

Performance of sodium systems for the past 26 years has been excellent.

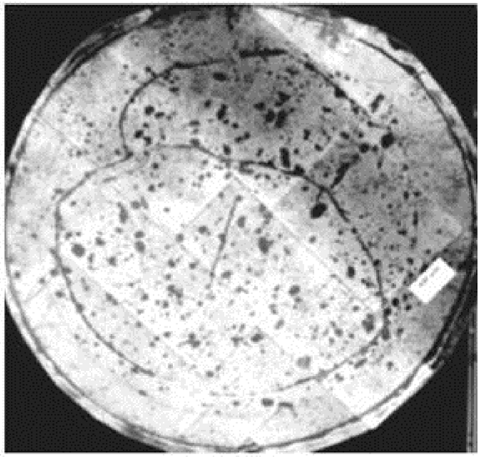
Steam generators have performed without a single leak incident



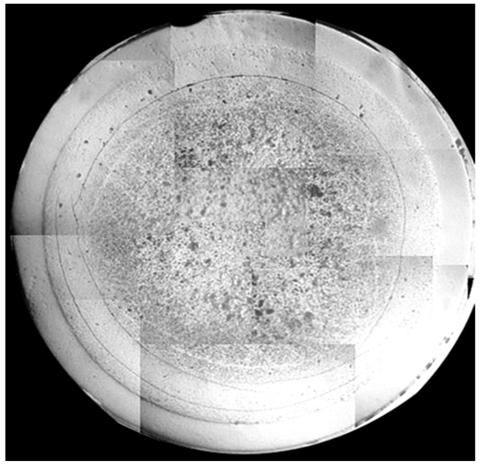
25 GWd/t BURN-UP



50 GWd/t BURN-UP



100 GWd/t BURN-UP

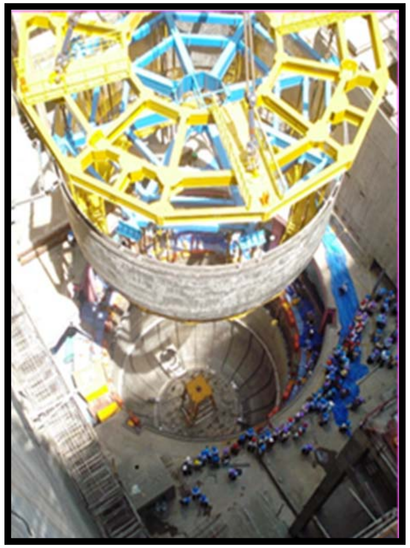


154 GWd/t BURN-UP

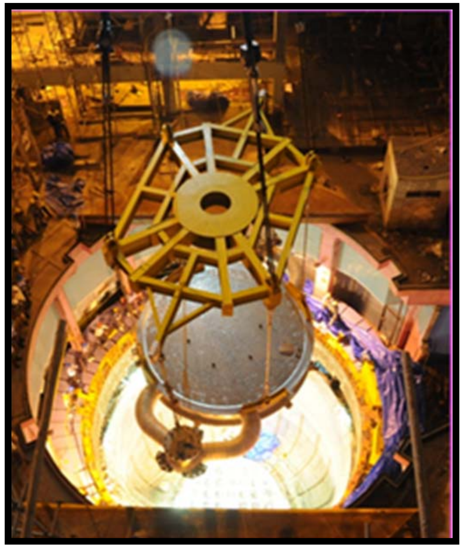
Current Status of PFBR Project

Safety vessel

Main vessel

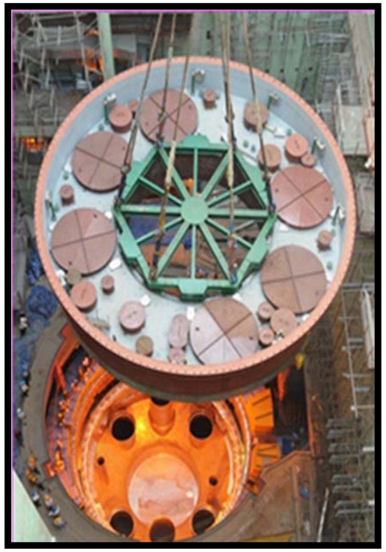


Thermal baffles



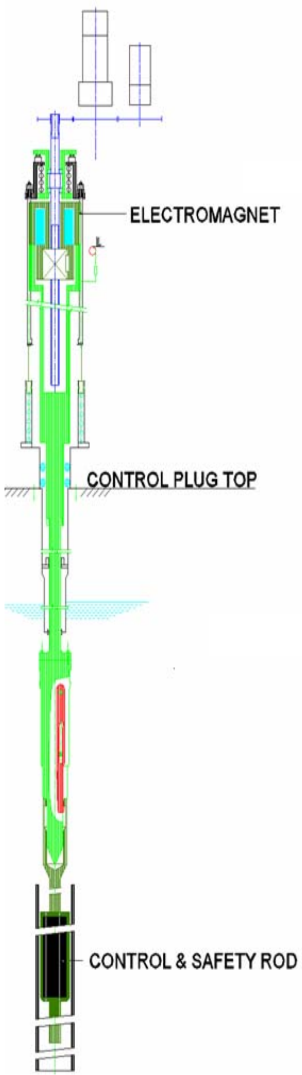
Grid plate

Inner vessel



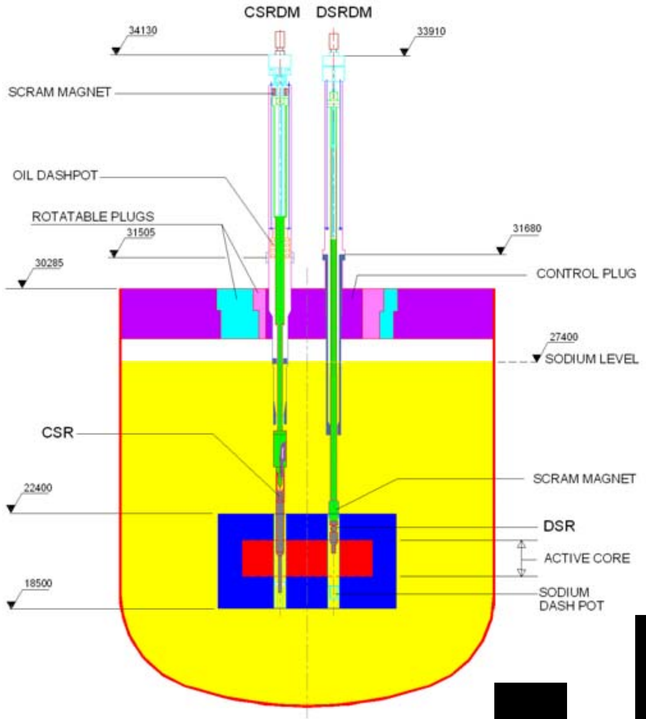
Roof slab

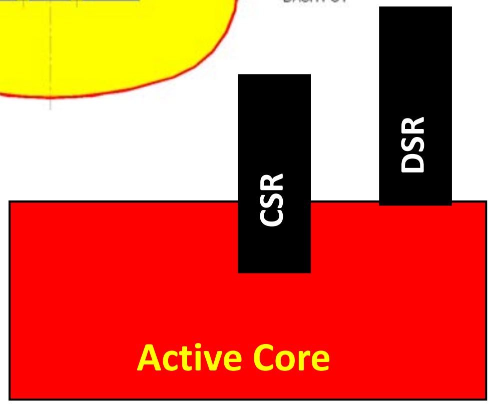
Testing of Shutdown Systems of PFBR

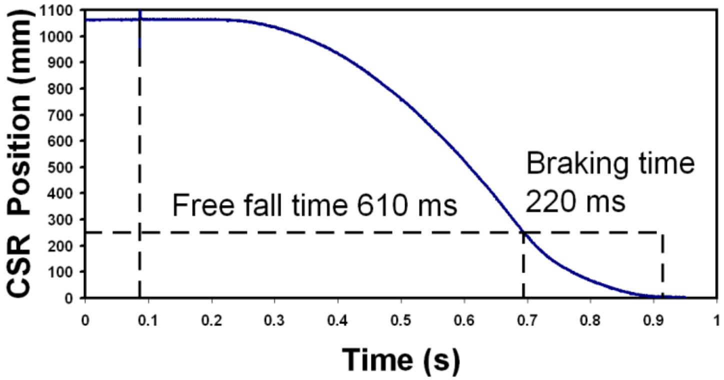


CSR & CSRDM

Upper & Lower Parts of CSRDM

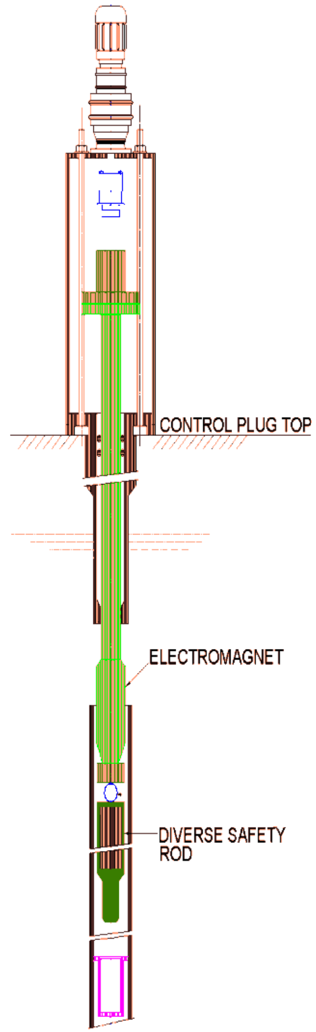






Drop time of CSR : 610 ms < 1 s

Upper & Lower Parts of DSRDM



DSR & DSRDM

No. of Scram cycles tested in Na

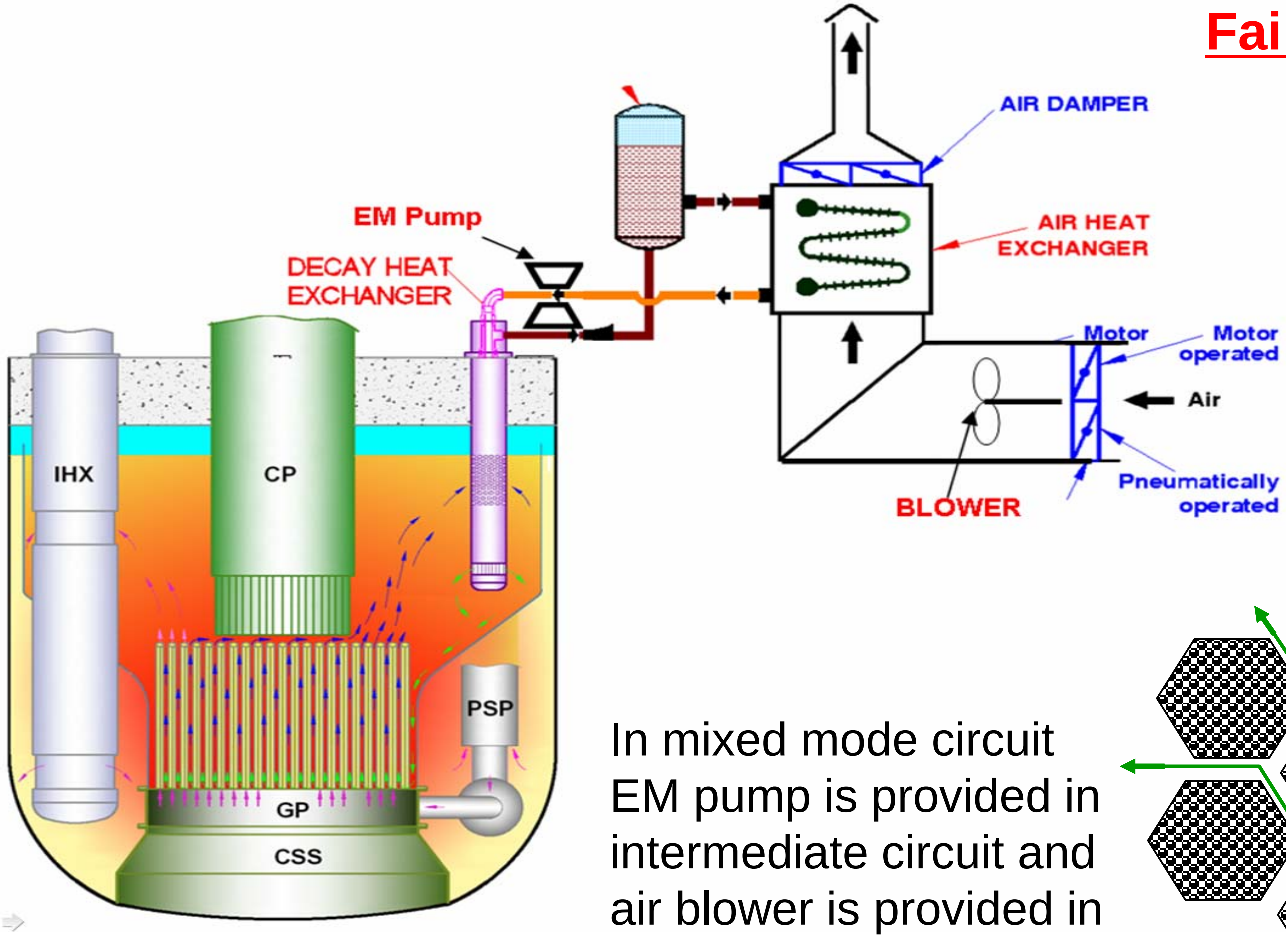
at 803 K	: 500
at 823 K	: 1093

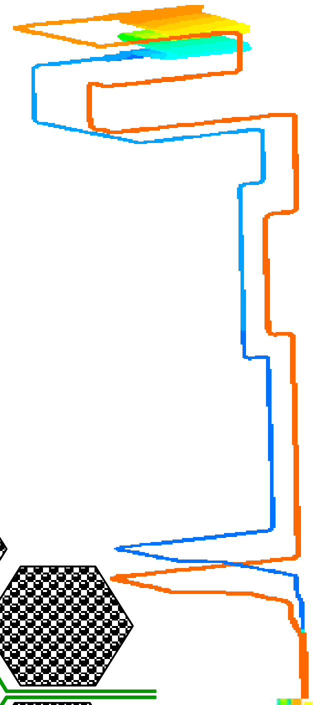
No. of cycles tested in Na

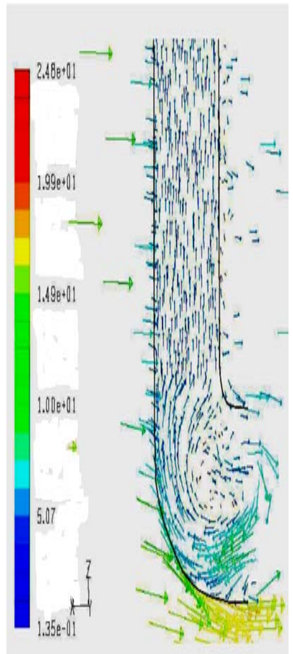
(Scram) at 773 K	: 186
(Translation) at 670 K	: 986

Safety Grade Decay Heat Removal System

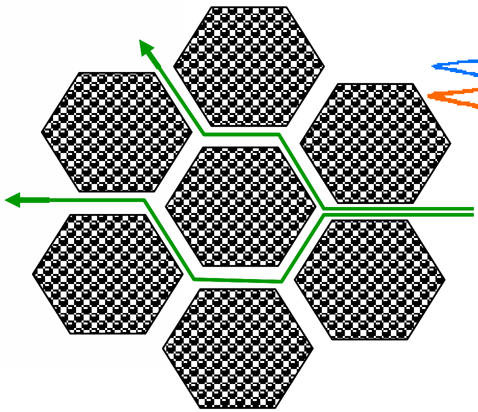
Failure of all Pumps



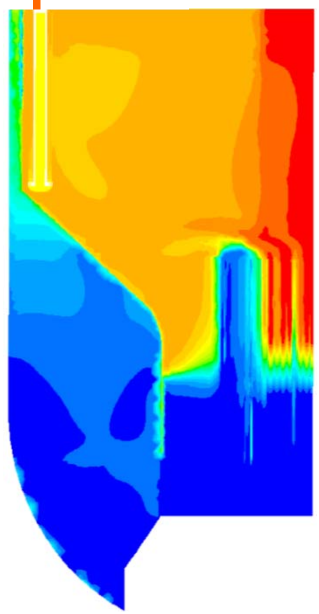




In mixed mode circuit EM pump is provided in intermediate circuit and air blower is provided in air circuit.



Inter Wrapper Flow



Analysis with multi-dimensional model for pools with inter-wrapper space (StarCD) and 1-D model for equipments and piping (DHDYN).

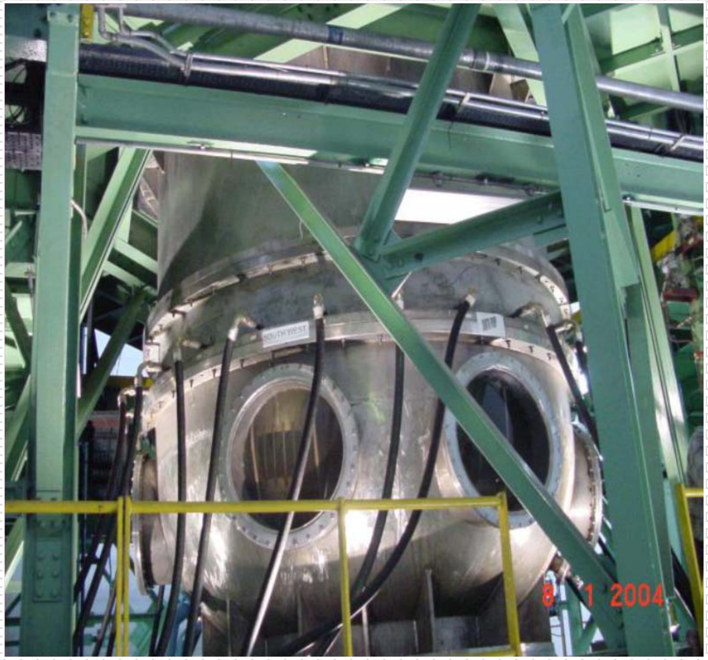
Availability any two circuits for 7 h and one circuit subsequently with primary circuit under natural convection is sufficient to limit the temperatures below category 4 limits

Performance Evaluation of DHR Capability

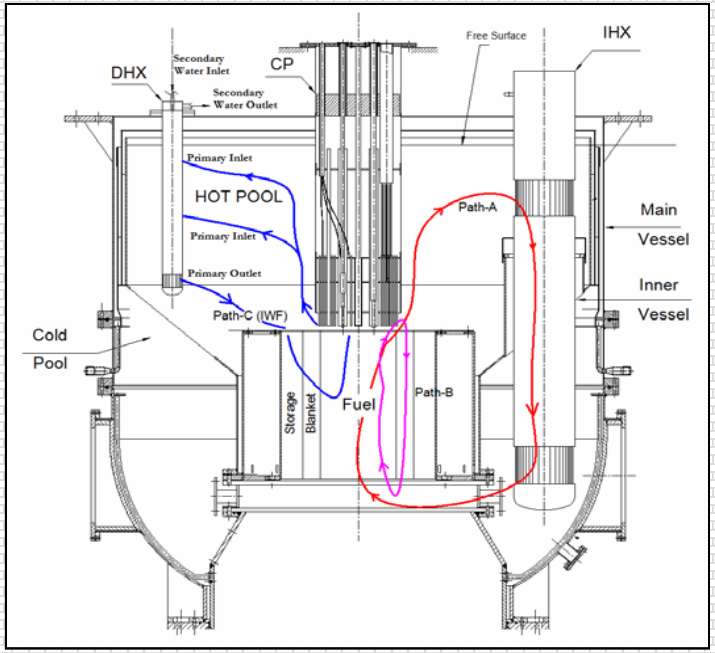
- Temperature & flow distributions in the hot pool
- Confirmation of SGDHR system Performance
- Assessment of Inter Wrapper Flow contribution

Facilities Utilized

FBTR, SAMRAT and SADHANA



SAMRAT Model (1/4 scale)



Natural convection flow paths

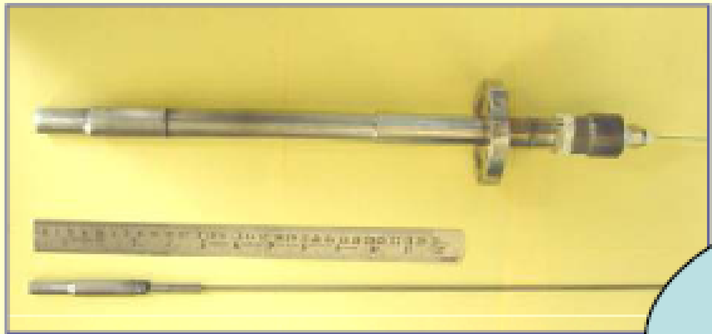
SADHANA loop

Sensors for sodium systems

Electrochemical sensor for hydrogen in sodium

P_{H_2}(sample) // Electrolyte // P_{H_2}(reference)

Solid electrolyte: $CaBr_2$-CaHBr



Detection limit: ≤ 50ppb

Resolution: 10 ppb change over 50ppb background

Simple instrumentation and inexpensive

Chosen for PFBR and one sensor incorporated in Phenix reactor, France

Sensor for trace hydrogen in argon cover gas

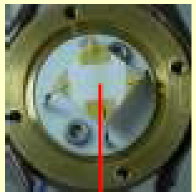
Required for steam leak detection during reactor start up and low power operation

Operation in FBTR since 12 years and chosen for PFBR

Thermal conductivity detector for detection of hydrogen

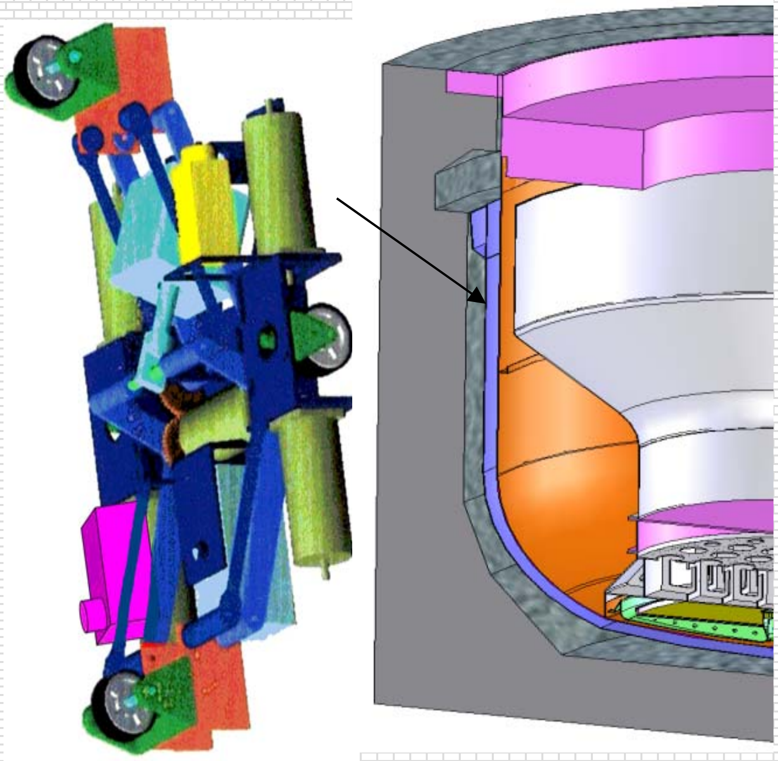
Lowest detction limit: 30 ppm H_2
(PFBR Spec.: 100ppm)

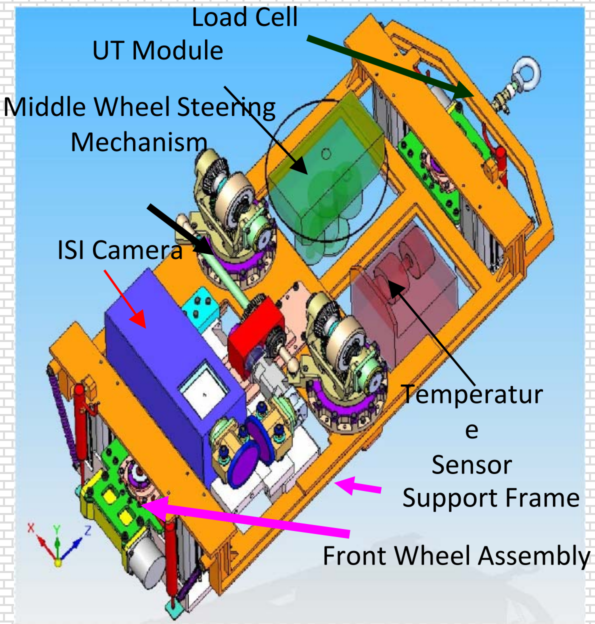
Thin film sensor for measurement < 30 ppm H_2

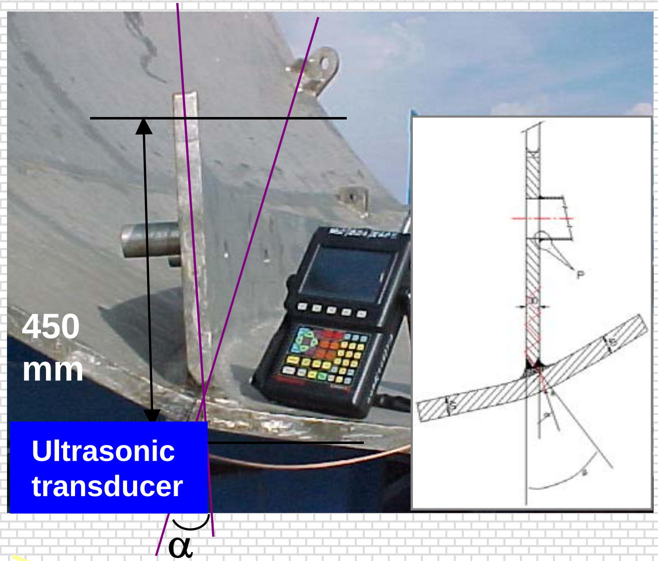


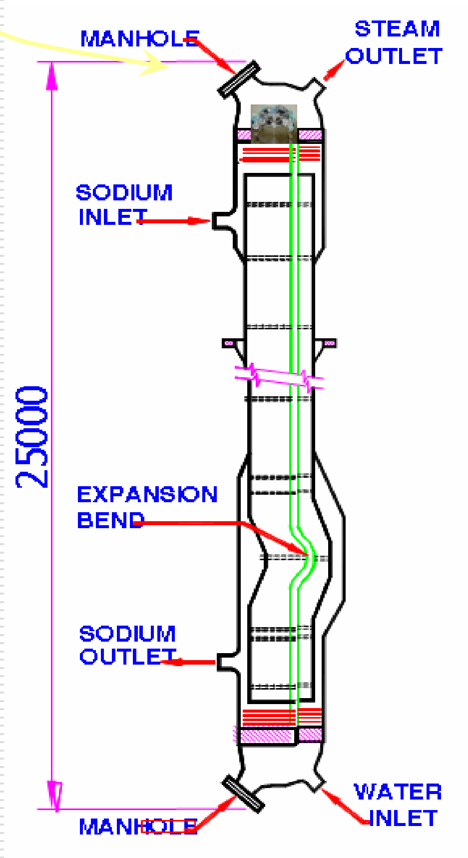
Robust Technologies for In-Service Inspection (ISI)

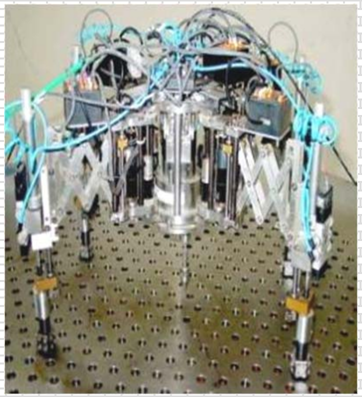
ISI of main vessel including core support structure







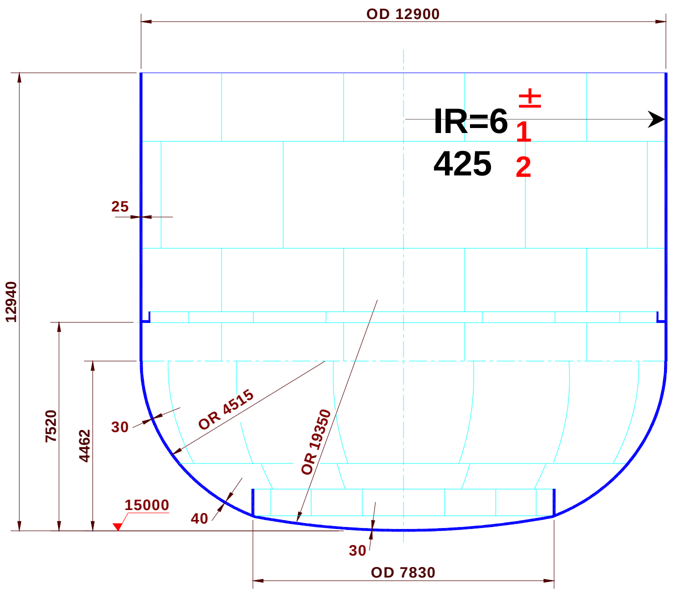


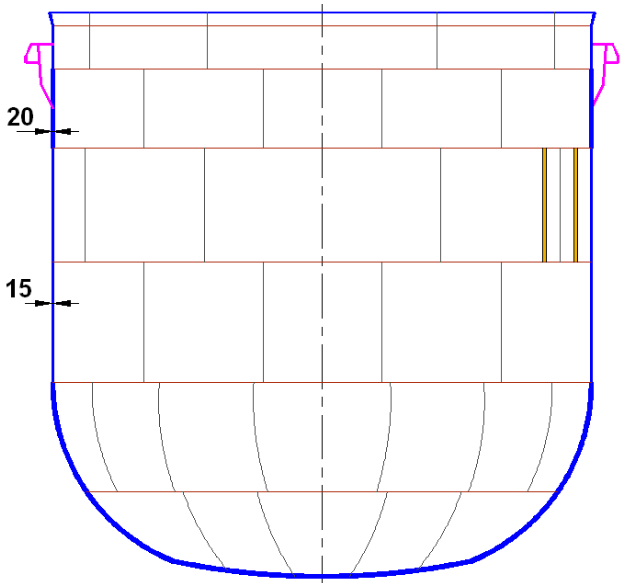


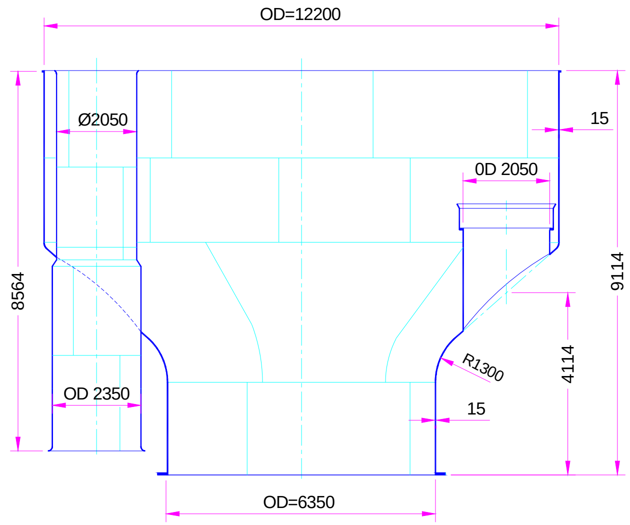
ISI of steam generators of PFBR – In-house developed Remote field eddy current testing technology

Form Tolerance Achieved for Large Diameter Thin Shells

Component	ASME	Form Tolerance on Radius (mm)		
	$(ID_{Max} - ID_{Min})$	RCC-MR	PFBR	
			Specified	Achieved
Main Vessel	± 70	± 50	± 12	< ± 12 (during fit up) < ± 18 (at isolated locations)
Safety Vessel	± 70	± 50	± 12	± 12 (at majority locations) ± 18 (at isolated locations)
Inner Vessel	± 67	± 50	± 12	< ± 8 (during fit up) < ± 20 (at isolated locations)



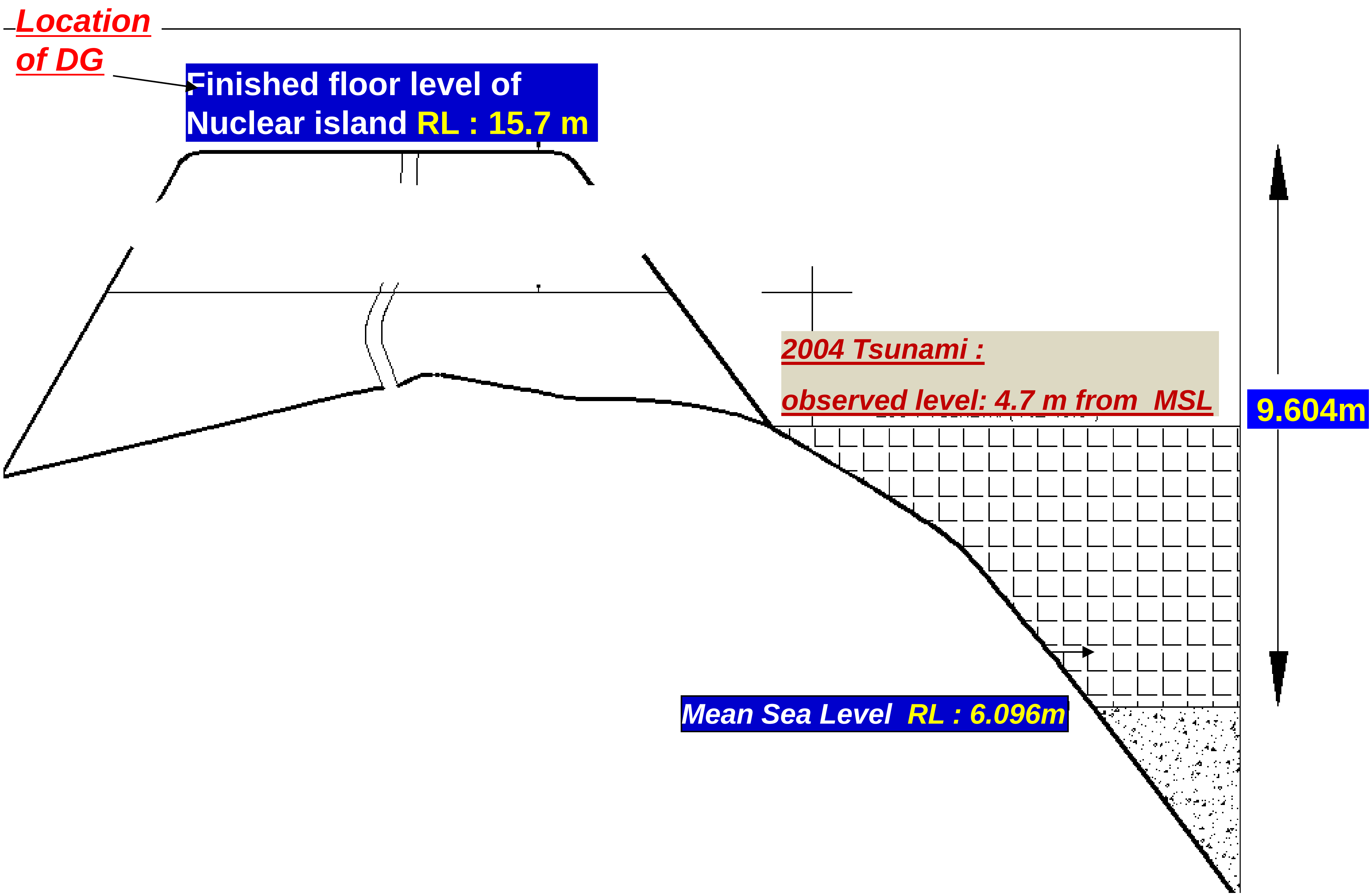




SECTION-AA

MATERIAL : SS 316 LN

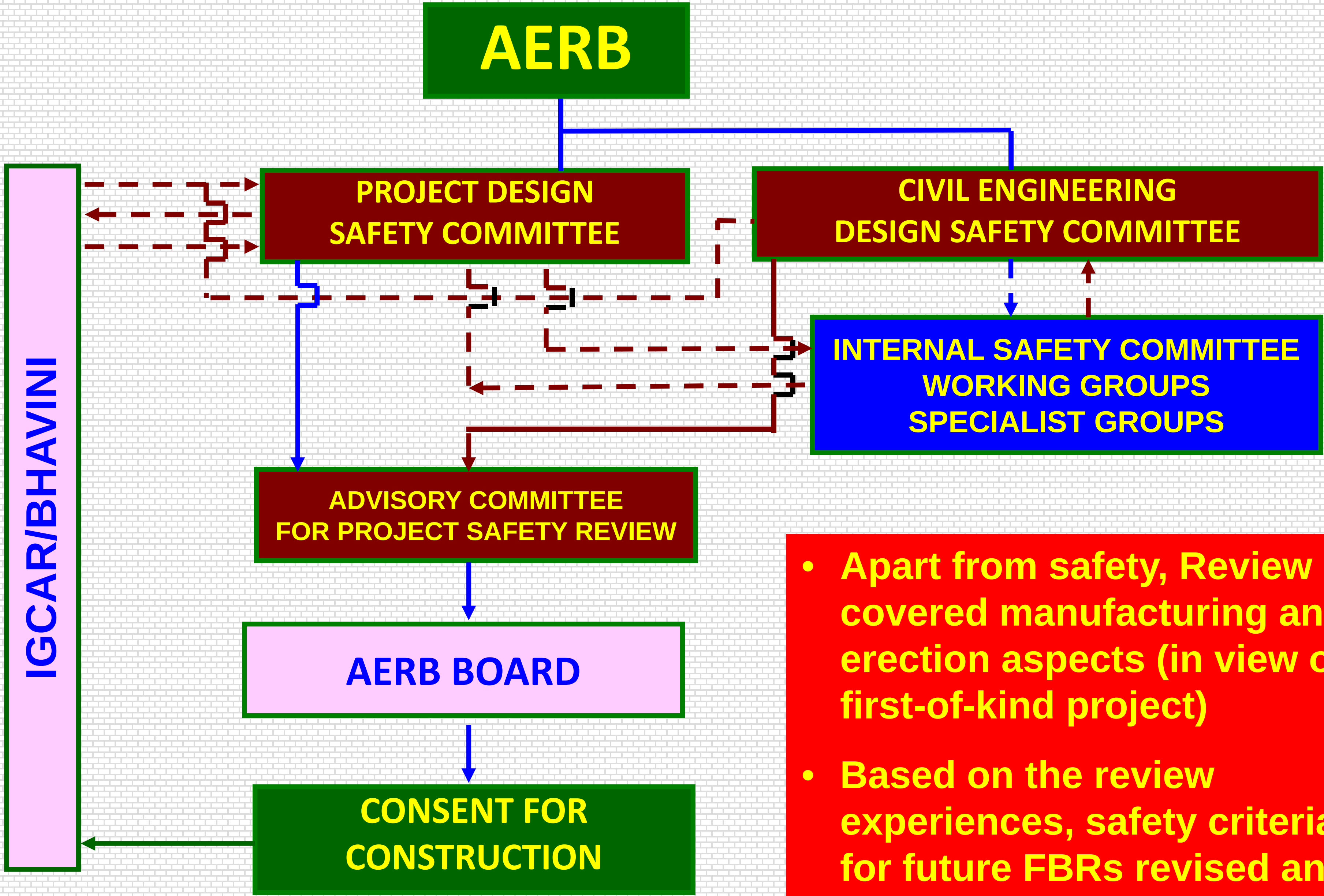
Protection Against Tsunami



POST- FUKUSHIMA ACTIONS PLANNED

- Reactor trip on seismic event
- Augmenting DG Diesel oil storage day tank capacity
- Air cooled Mobile DG set (SBO DG)
- Additional Battery Bank
- Additional water supply hook up for spent fuel storage pool
- Provision of water tight doors/shutters for Steam Generator Buildings, DG Buildings etc.
- Additional Stores
- Sealing the penetrations of cables and pipelines to NICB and Power Island to prevent water entry
- Provide alternate approach road to Kalpakkam site
- Emergency Preparedness Plan to handle events at PFBR due to Natural calamities

Authorization for PFBR Construction



- Apart from safety, Review covered manufacturing and erection aspects (in view of first-of-kind project)
- Based on the review experiences, safety criteria for future FBRs revised and under review by regulators

Confidence on PFBR Project

- Technology with strong R&D backup
- Manufacturing technology development completed prior to start of project
- Capability of Indian industries to manufacture high technology nuclear components demonstrated (main vessel, safety vessel, steam generator, grid plate etc..)

IGCAR

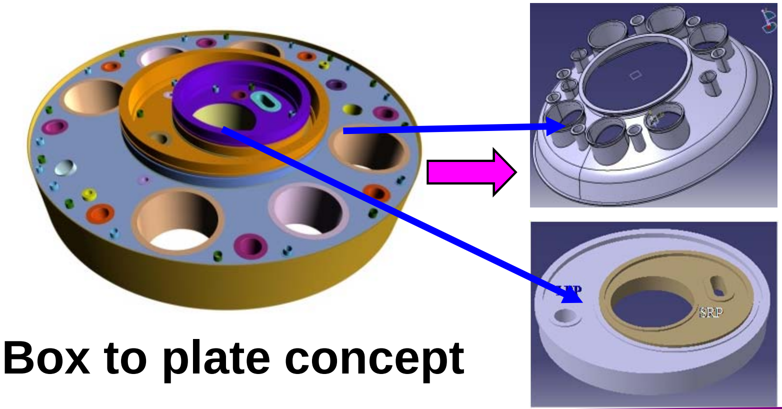
BHAVINI

PFBR will be commissioned by Mar 2013

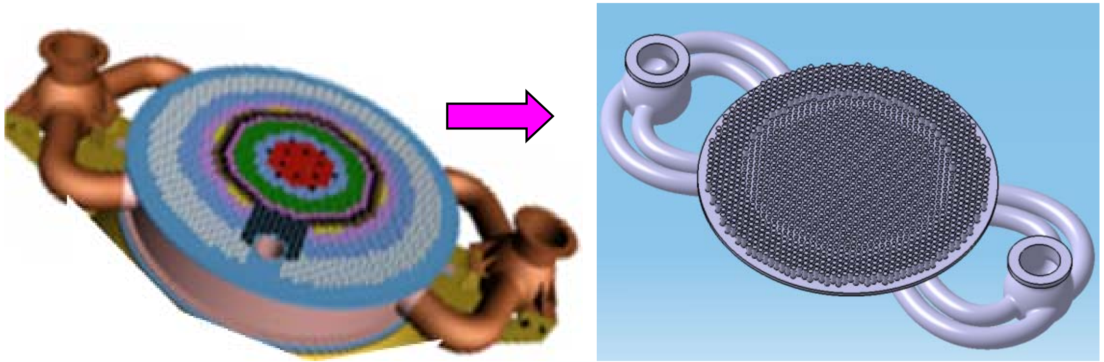
Basic Design Features

PARAMETER	CFBR	PFBR
Power MWe	500	500
Design Life	60 Calendar years	40 Calendar years
Primary Circuit	Pool With No Primary Sodium Outside Pool	Pool External Purification
Fuel	MoX	MoX
Fuel Burn-up	200 GWd/t (in phased manner)	100 GWd/t
Load Factor	85% Load Factor	75% Load Factor
Unit	Twin	Single
Number of Primary Pumps Secondary Pumps IHX/Loop SG/Loop	 2 2 2 3	 2 2 2 4
SG Design	Tube Length 30 m	23 m
Spent Fuel Storage	Water	Water
No. of thermocouples/FSA	3	2

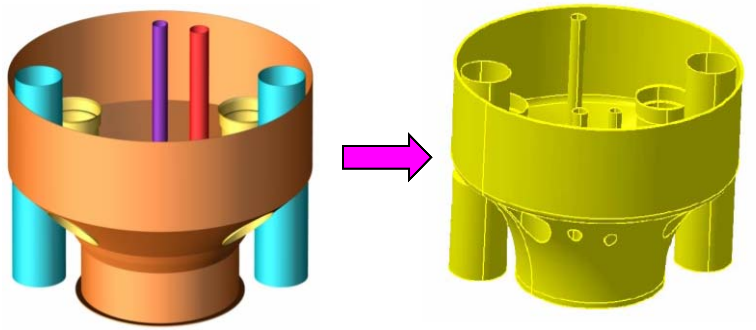
Design Evolutions: PFBR to CFBR



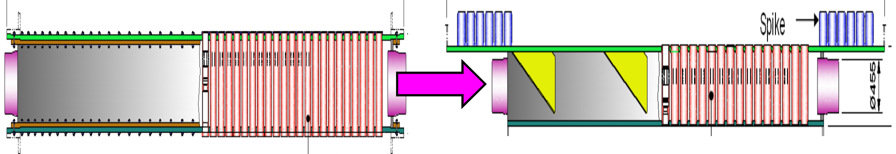
Box to plate concept



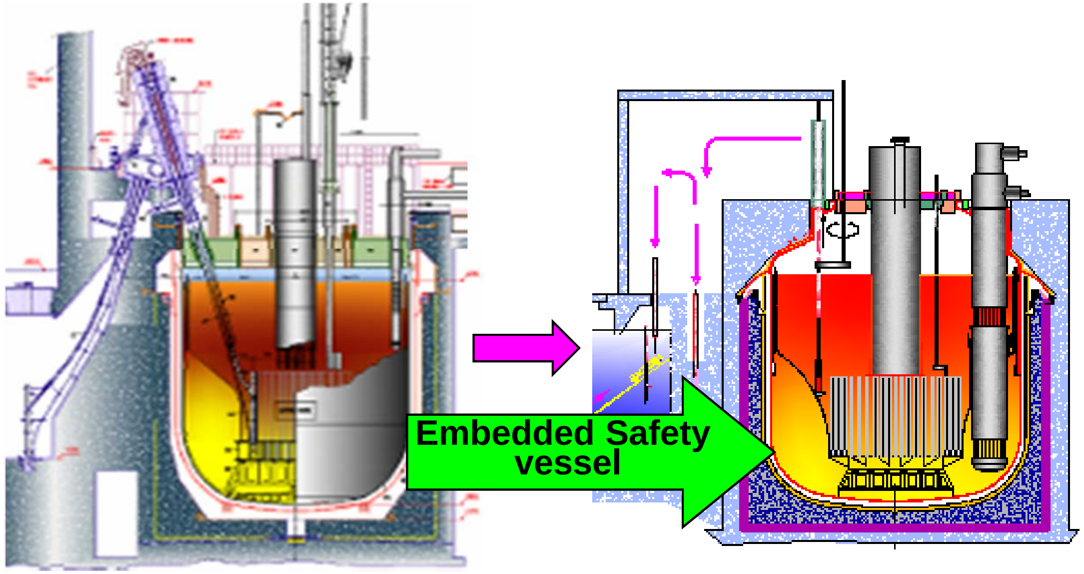
Four to eight primary pipes



Cone with torus to single torus



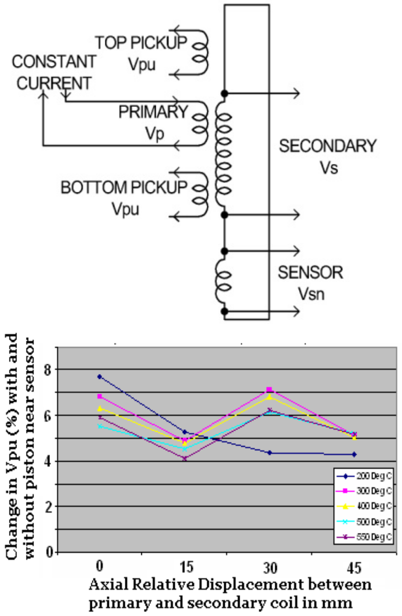
Large plenum to smaller plenum
Bolted structure to welded structure



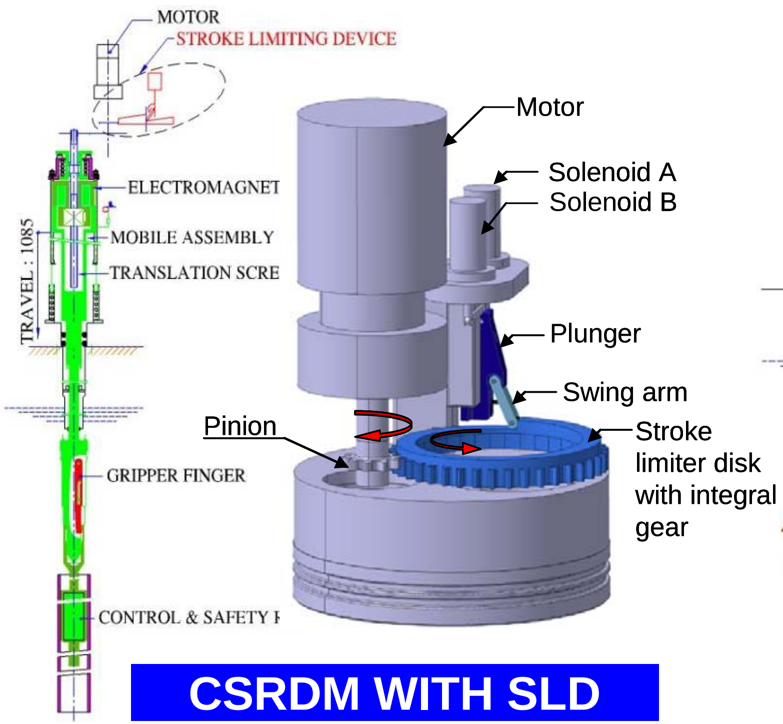
Elimination of Inclined fuel transfer machine

Material inventory reduction~ 25% , Simplified fuel handling scheme, Reduced manufacture time, Enhanced safety

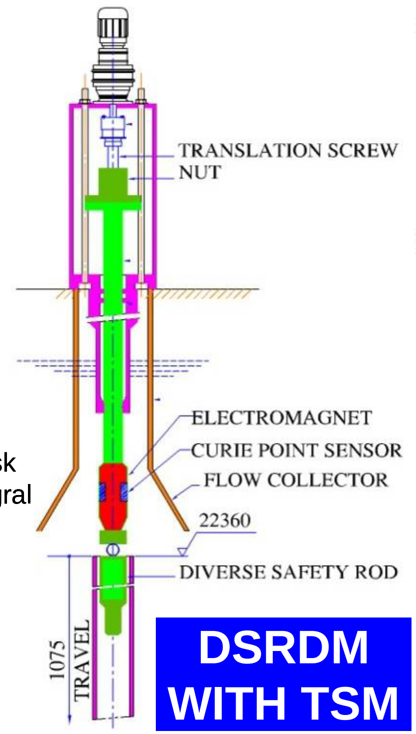
Enhancing Reliability of Shutdown System



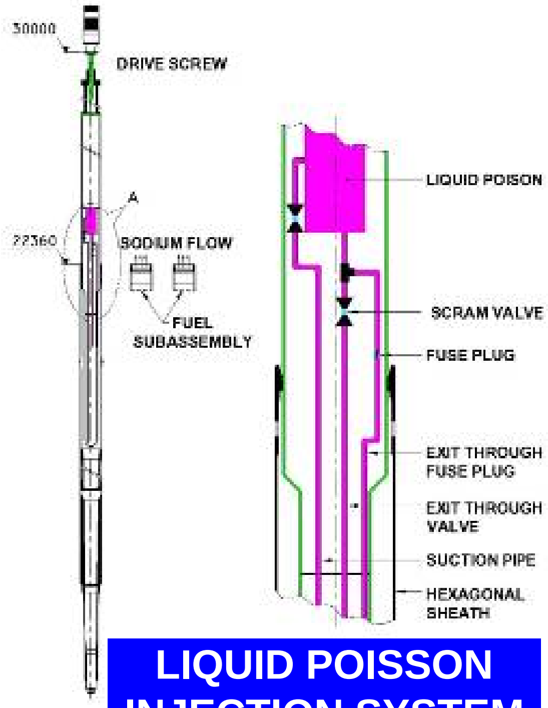
DROP TIME USING ECPS



CSRDM WITH SLD



DSRDM WITH TSM



LIQUID POISSON INJECTION SYSTEM

Reliable Drop Time Measurement

Multiple techniques (Eddy Current, Kalman Filter & Accoustics) developed

Safety enhancements

(i) **Stroke limiting device in CSRDM to minimise probability of occurrence of inadvertent withdrawal of Control & Safety Rod**

(ii) **Temperature Sensitive Electro Magnet in DSRDM to minimize failure of SD system due to instrumentation failure**

(iii) **Additional Liquid Poisson Injection System**

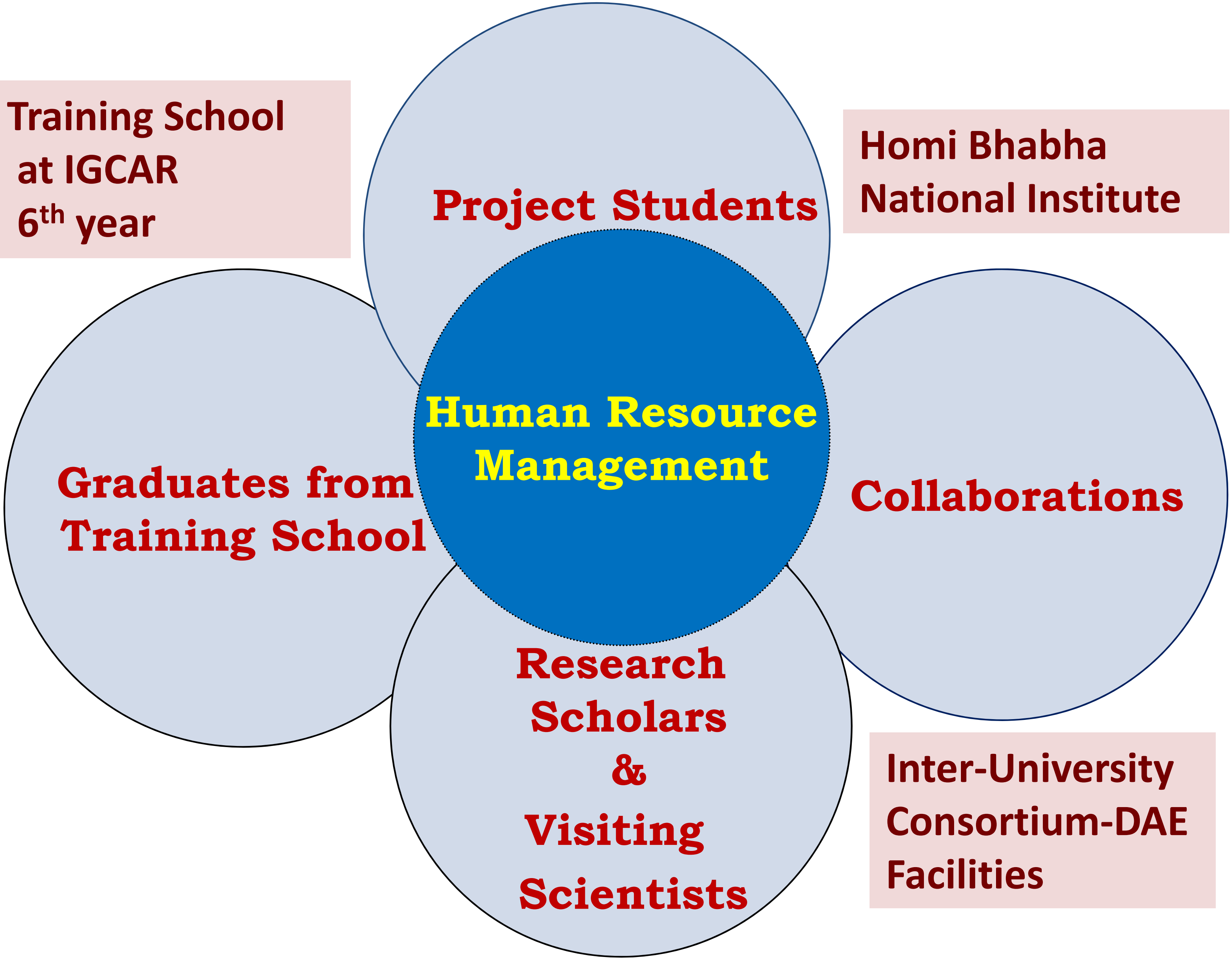
OBJECTIVE : Enhanced reliability by one order of magnitude

Human Resource Management

Attracting & Empowering Young Talent

Training School
at IGCAR
6^{th} year

Homi Bhabha
National Institute



Inter-University
Consortium-DAE
Facilities

Summary

- FBR with closed fuel cycle is an inevitable technology option for providing energy security for India
- FBTR has provided substantial and valuable operating and maintenance experience of SFR systems
- PFBR is a techno-economic demonstrator and a fore runner in the series of FBRs planned
- Beyond PFBR, six 500 MWe (3 twin) units and 120 MWt metallic fast test reactor would be commissioned by 2020
- Roadmap for large scale deployment of FBR and systematic introduction of metallic fuel reactors with emphasis on breeding gain and co-located fuel cycle facilities based on Pyro-chemical reprocessing is laid
- Emphasis on scientific innovations / breakthroughs and & high quality scientific human resource development

Fast Reactors for Energy Security