A Perspective on Development of Future FBRs in India

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Dec. 7 – 11, 2009, Kyoto, Japan

Outline

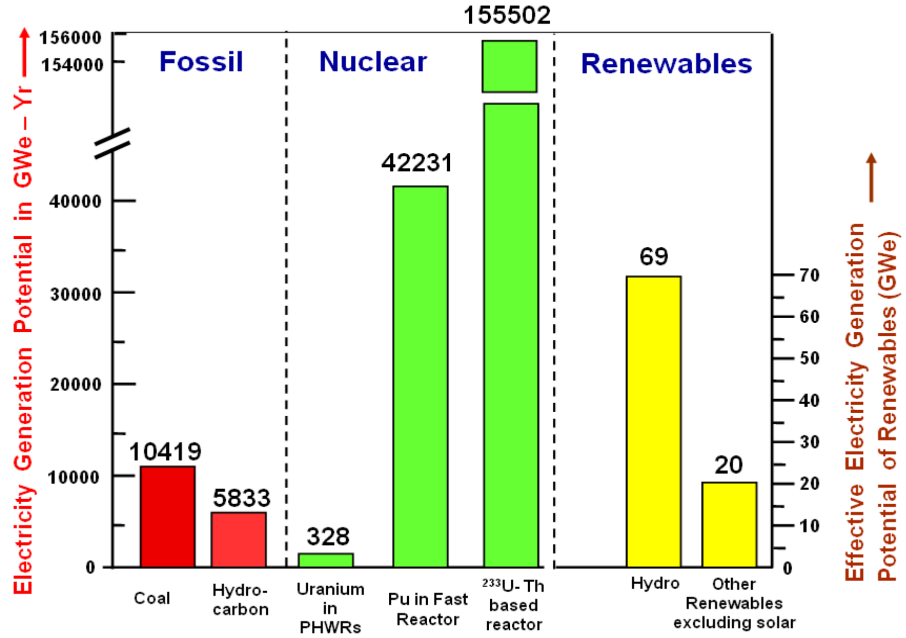
- Energy scenario in India
- Fast reactor programme
  - Fast breeder test reactor
  - Prototype fast breeder reactor
  - MOX based Commercial fast breeder reactors
  - Metal fuel fast reactors
- Summary

Current Indian energy position, resources & emerging scenario

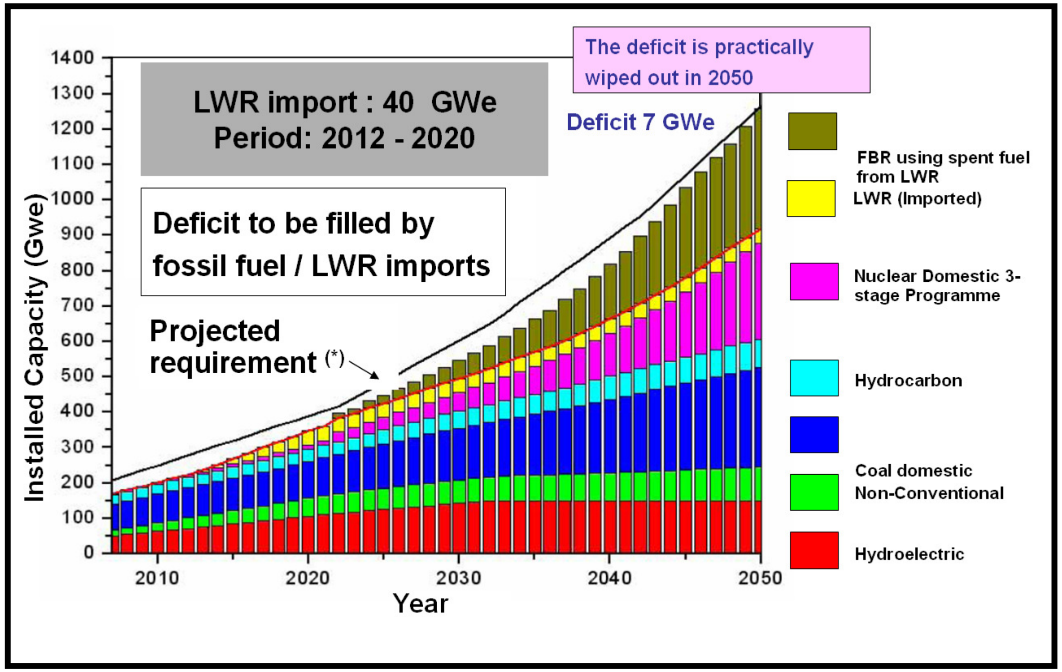
Current Indian Energy Position(*)

Fuel	Installed Capacity (MWe)	% Generation 2008-09
Coal	80,396	52.8
Gas	16,449	10.8
Oil	1,200	0.8
Hydro	36,885	24.2
Nuclear	4,120	2.7
RENEWABLE ENERGY SOURCES	13,310	8.7
Total	1,52,360	100

(*) Present Peak Deficit: 14.2%

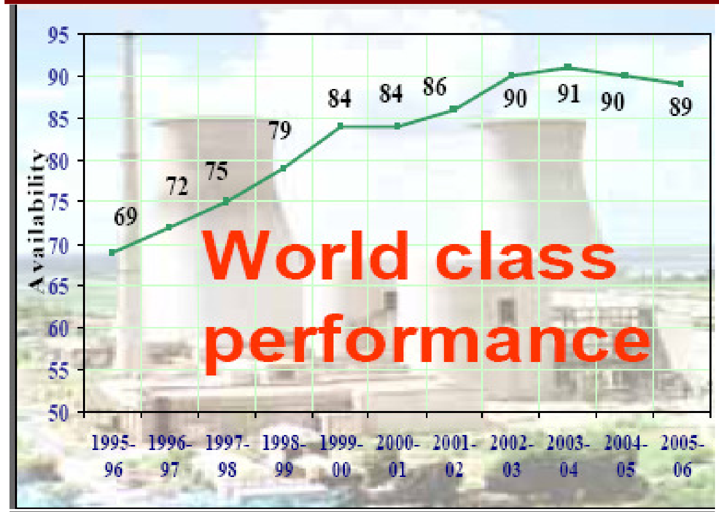


- Energy Resources Potential



- Domestic energy scenario including imported nuclear reactors

Three stage Indian nuclear power programme



- 16 – PHWRs Under Operation
- 2 - Under construction
- Several others planned
- Progressive scaling to 700MWe
- Gestation period reduced
- POWER POTENTIAL ≅10 GWe
- LWRs

  2 BWRs Operating

  2 VVERs under Construction

Fast Breeder Reactors

- 40 MWth FBTR - Operating since 1985
- Technology Objectives Realised
- 500 MWe PFBR -Under Construction
- TOTAL POWER POTENTIAL ≅530 GWe

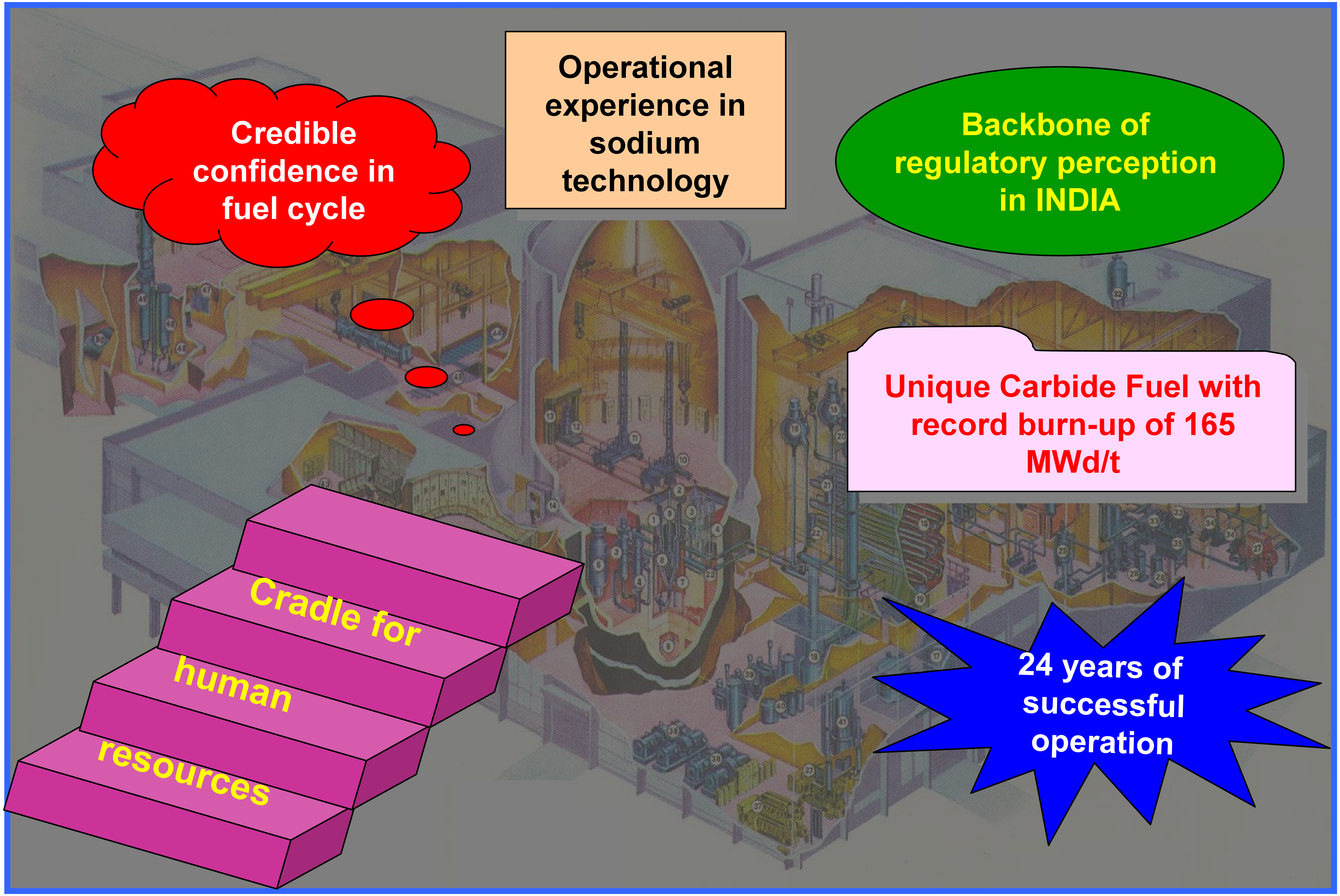
Thorium Based Reactors

- 30 kWth KAMINI-Operating
- 300 MWe AHWR-Under Development
- POWER POTENTIAL IS VERY LARGE

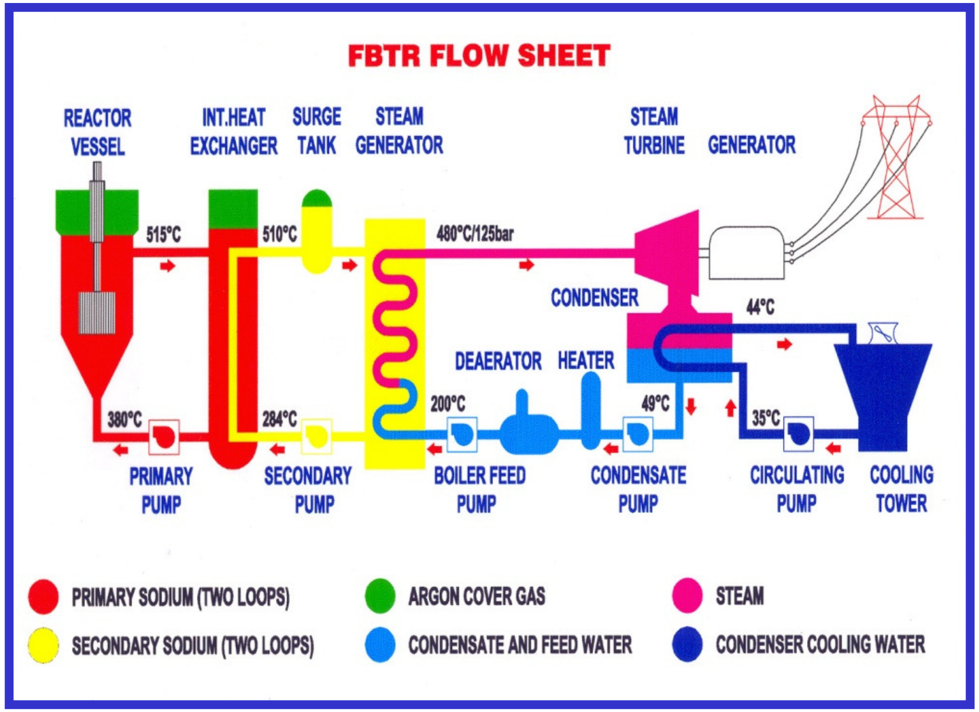
FBR programme in India

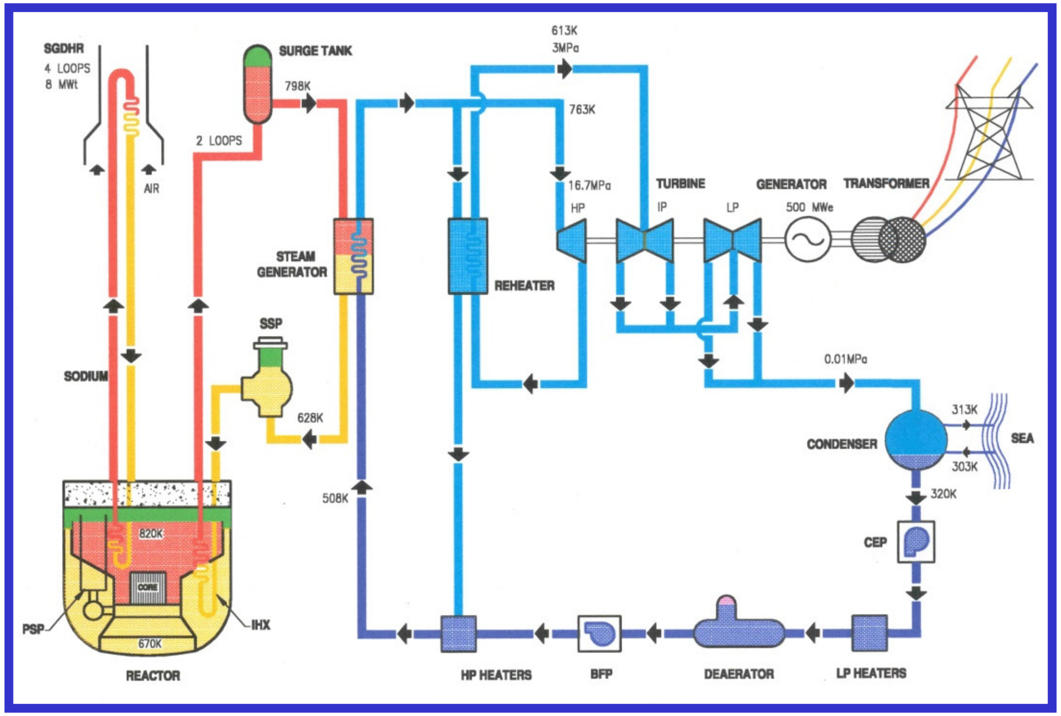
- India started FBR programme with the construction of FBTR (agreement signed with CEA, France in 1969)
- FBTR is a 40 MWt (13.5 MWe) loop type reactor. The design is as that of Rapsodie-Fortissimo except for incorporation of SG and TG.
- FBTR is in operation since 1985
- 500 MWe fast breeder reactor project (PFBR) through indigenous design and construction
- Govt. granted financial sanction for construction in Sep.2003
- Construction of PFBR is being carried out by BHAVINI
- PFBR will be critical by 2011
- Construction of 6 more reactors (2x500 MWe at Kalpakkam & 4x500 MWe at a new site) based on improvements in PFBR design in a phased manner (MOX fuel). Commercial operation of all six by 2023
- Beyond 2020, metallic fuelled sodium cooled reactors with 1000 MWe capacity

Fast Breeder Test Reactor



Approach to big leap in FBR programme





FBTR

40 MWt

13.5 MWe

Loop type

Fuel: PuC - UC

- 390 r-y worldwide FBR operational experience
- Rich experience with MOX fuel
- 30 y of focused R&D programme involving extensive testing and validation
- Material and Manufacturing Technology Development and Demonstration
- Science based technology
- Peer Reviews
- Synergism among DAE, R&D Institutions and Industries

PFBR

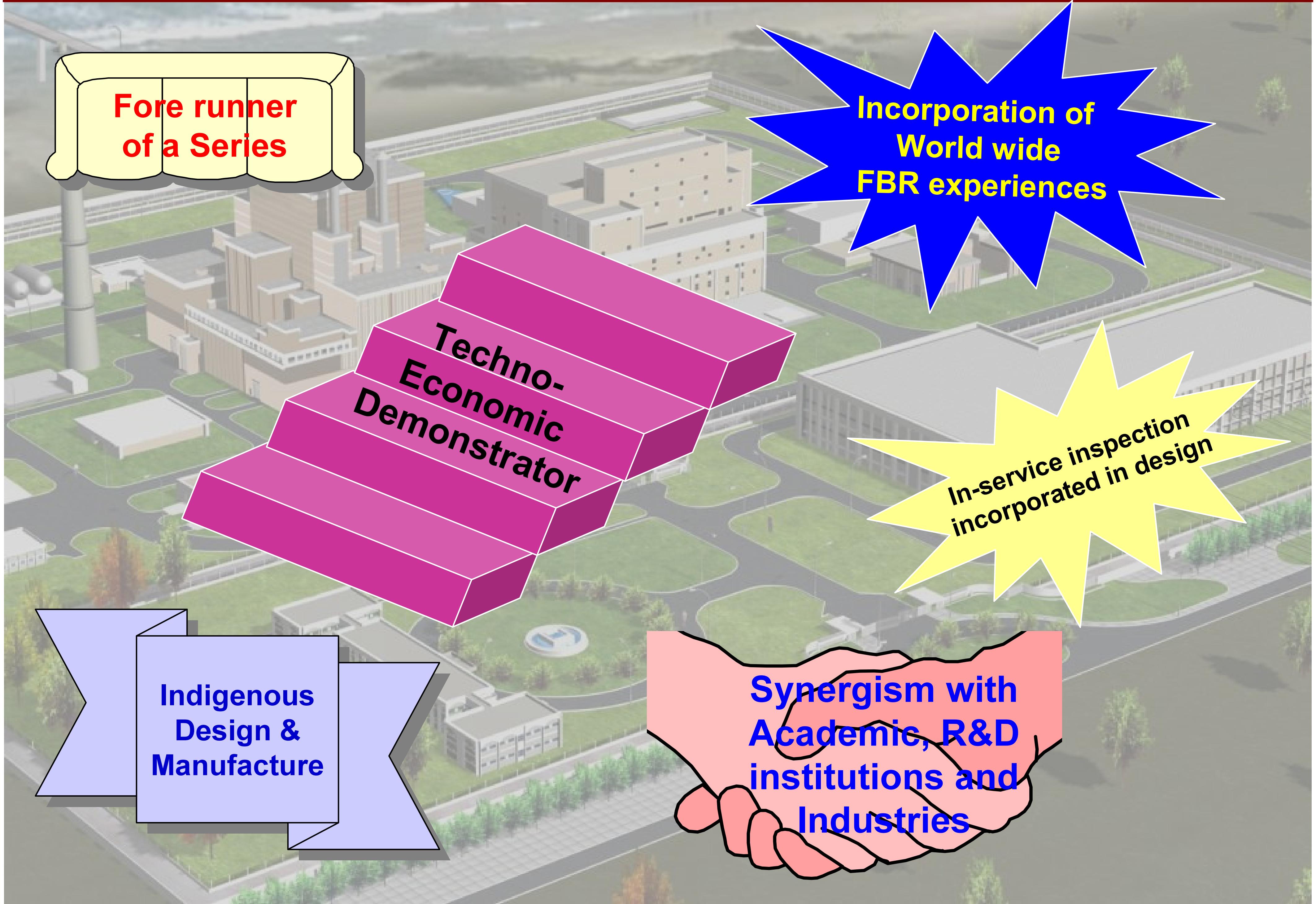
1250 MWt

500 MWe

Pool Type

Fuel: UO_2-PuO_2

Prototype Fast Breeder Reactor



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 critical by Sept 2011

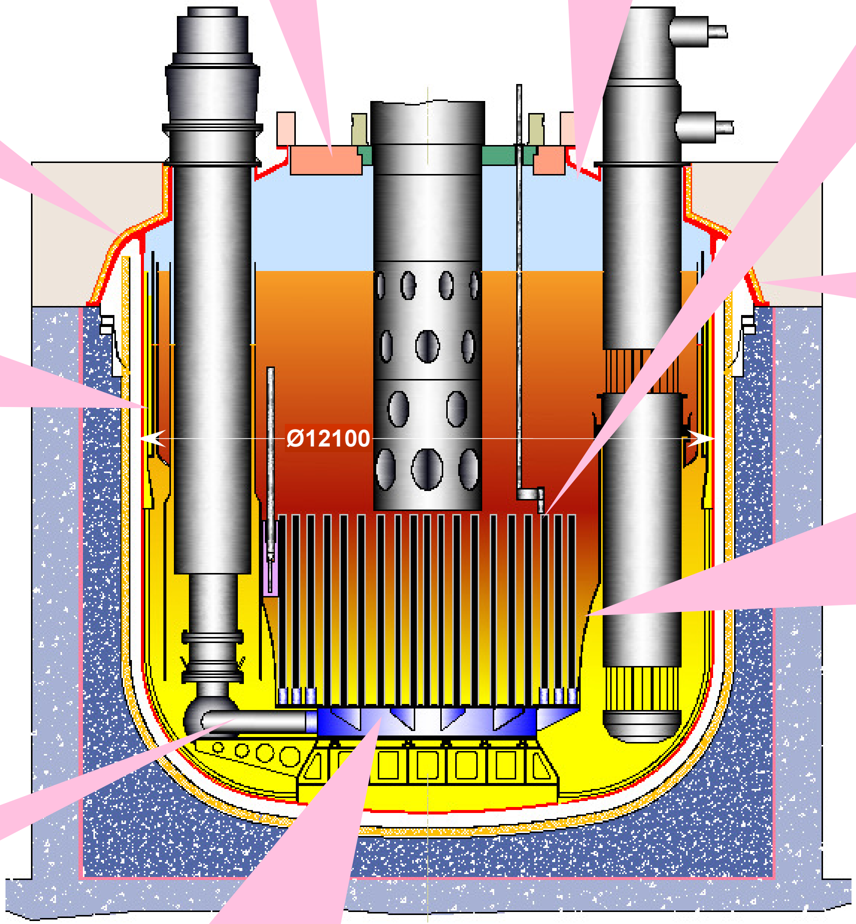
Design of Future FBRs – Approach & Directions

- **Plans to build 6 FBRs of 500 MWe each by 2023. Two FBRs at Kalpakkam to make use of co-located Fast Reactor Fuel Cycle Facility to reduce Fuel Cycle Cost. Site Selection Committee recommendations sent for Kalpakkam**
- **Cost Reduction consistent with enhanced safety will be main objectives.**
- **CFBR will incorporate lessons learnt from construction of PFBR, in particular, manufacturing specifications, material procurement, means to reduce manufacturing time and plant layout**
- **CFBR will have changes in design and safety requirements to reflect experience gained through regulatory review**
- **Revised Safety Criteria under review by safety committee**
- **Design options also governed by objective of reduction in import of wrought products**
- **Reduction in construction time**
- **Directions and innovations published on INPRO and GENIV reactor concepts would be given due considerations**
- **Well defined R&D tasks**

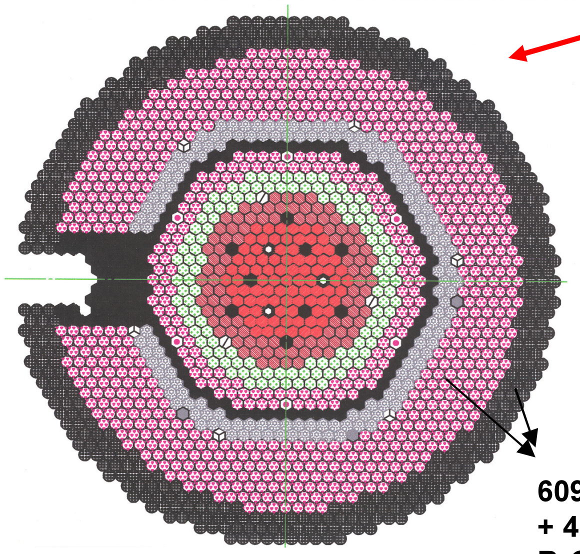
Basic design features

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

Innovative Reactor assembly design features



Bulk Shield Reduction through Advanced Shielding Material



PFBR Core

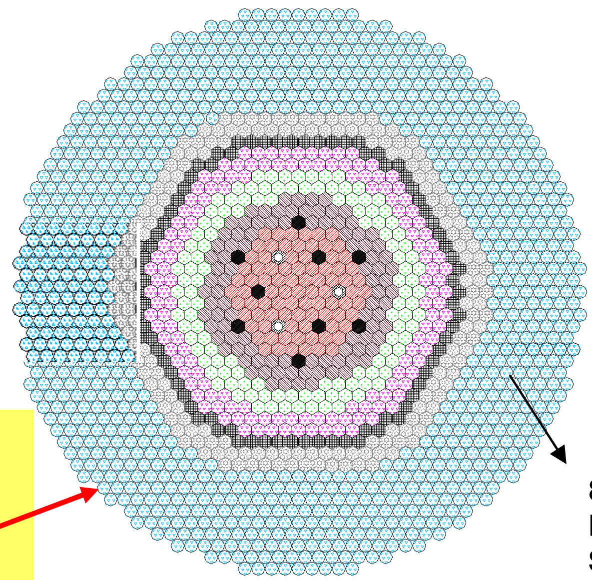
Radial Shields:

9 Rows (SS & B_4C)

CFBR Core

Radial Shields:

8 Rows (Ferroboron)



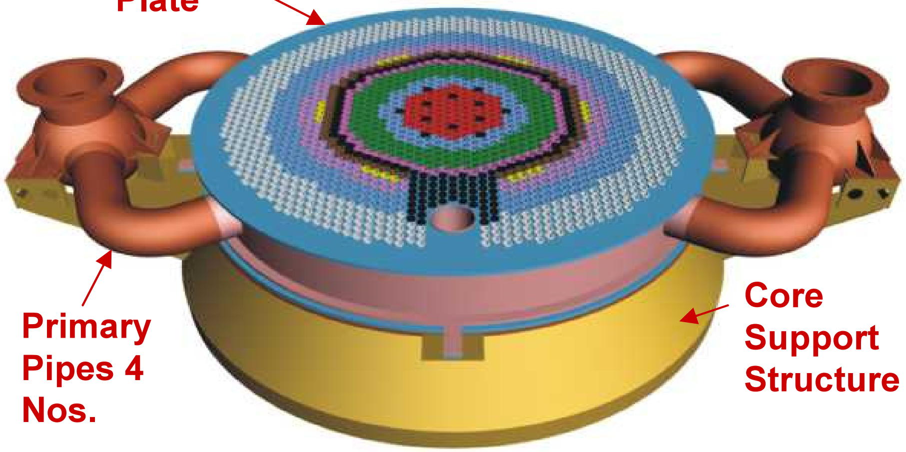
- **Ferroboron is used as a master alloy in steel industry as an additive for boron.**
- **Commercial ferroboron has 15-18 wt% boron**
- **Available in form of lumps, granules and powder**
- **Bulk density: ~4 g/cm^3**

Advantage of using ferroboron

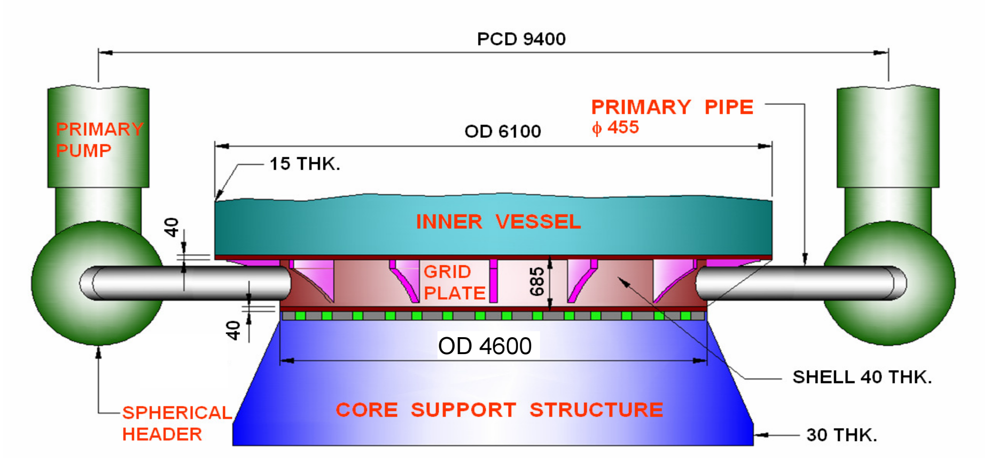
- **Reduction of 1 row of shielding SA**
- **Reduction in No. of Shielding SA: 145**
- **Reduction in diameter ~250 mm**

Grid Plate

PFBR

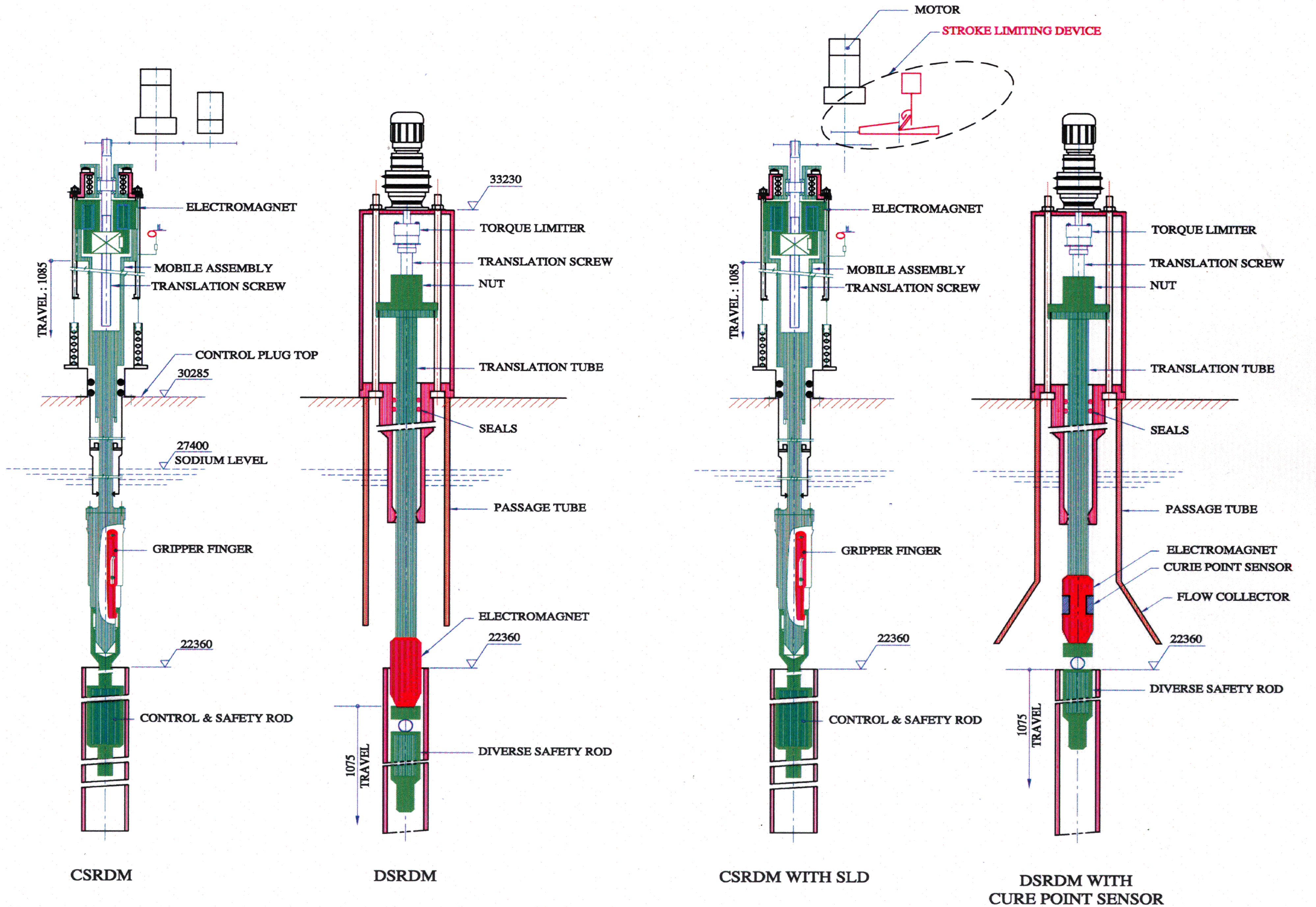


CFBR



Concept / Parameter	PFBR	CFBR
Type of construction	Bolted	Welded
Sleeves	Provided for all Core SA	Provided for only SA requiring flow. Peripheral SA supported through spikes
Overall Diameter x Ht	--	Reduction in height by 300 mm. Reduction cylindrical shell diameter by 2.2 m
No. of Pipes / Sodium pump	2	4
Core layout	Non-symmetric	Symmetric
Comparative weight	1	0.45

Shutdown Systems



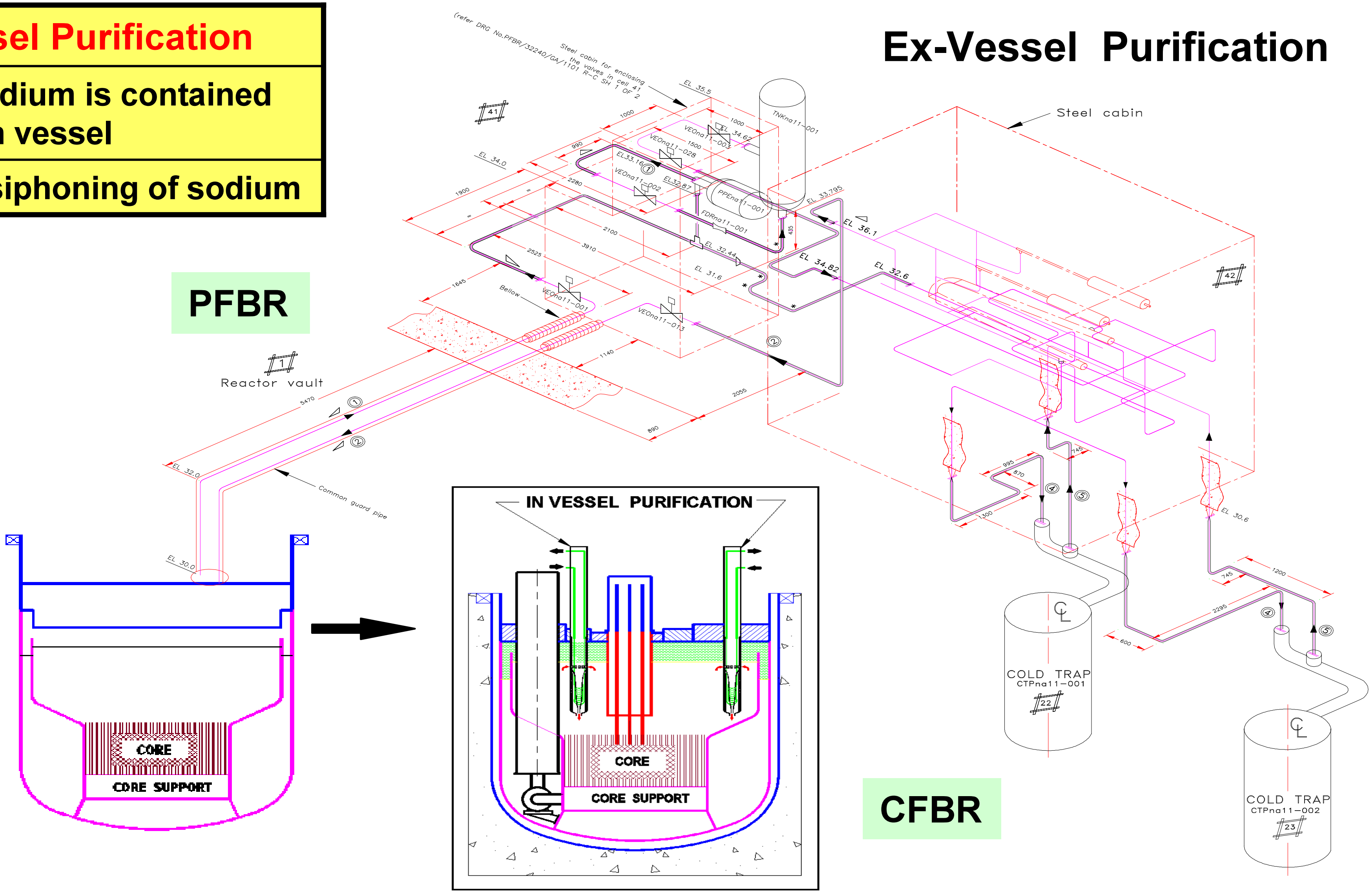
PFBR **CFBR**

Sodium purification

In-vessel Purification
Primary Sodium is contained within main vessel
No risk of siphoning of sodium

Ex-Vessel Purification

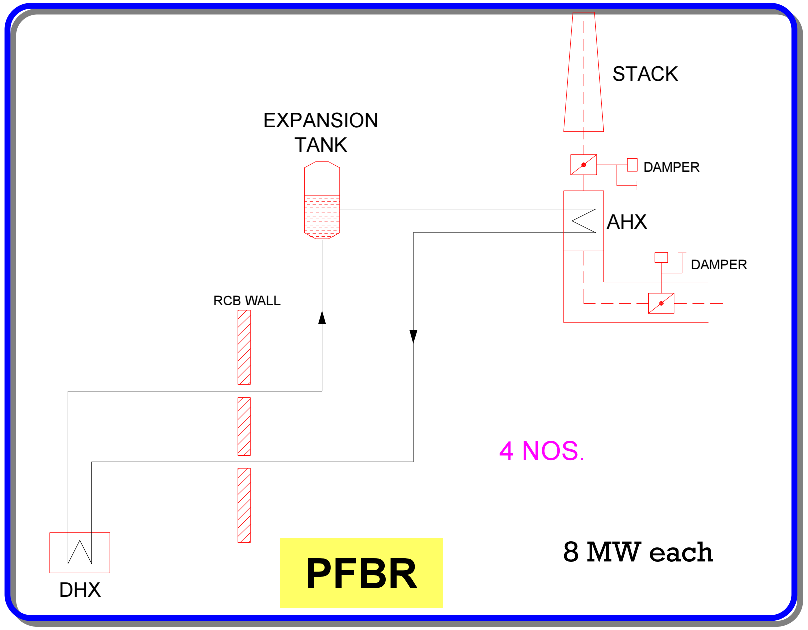
PFBR



CFBR

In-Vessel Purification

Decay Heat Removal

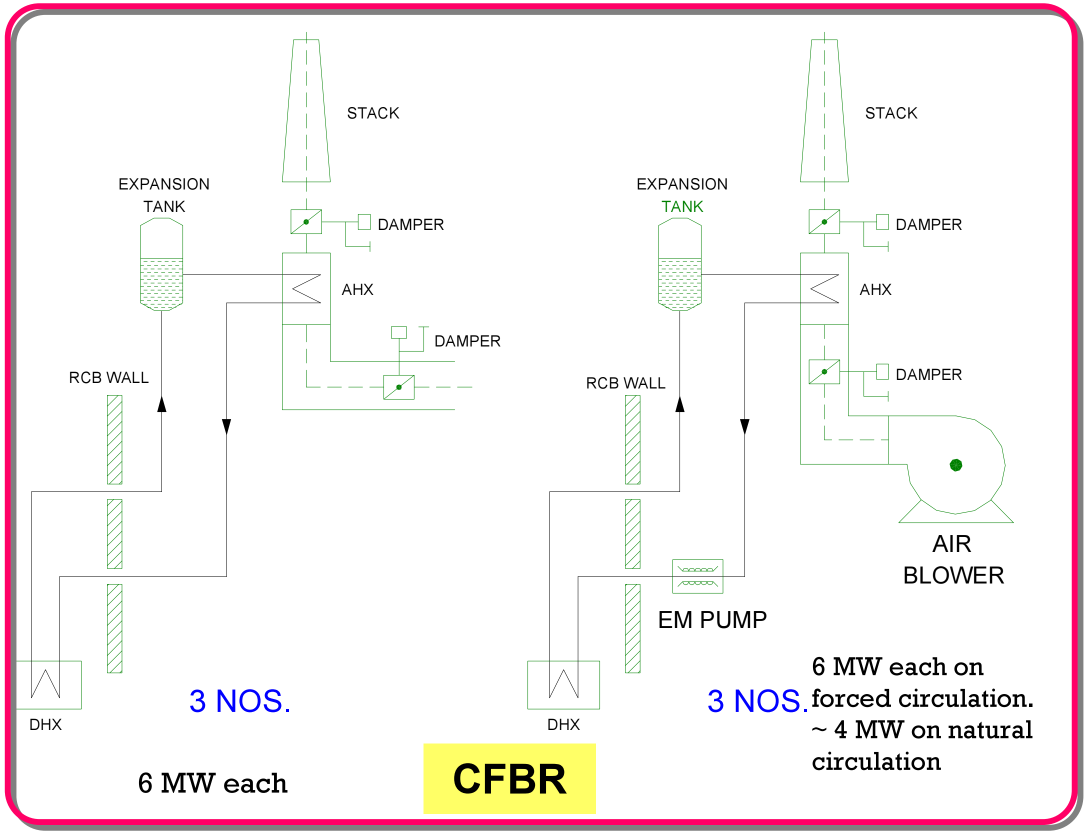


CFBR:

3 SGDHR circuits with forced cooling (2/3 of heat removal under natural convection)

&

3 SGDHR circuits with natural convection cooling each with a power removal capacity of 6 MWt

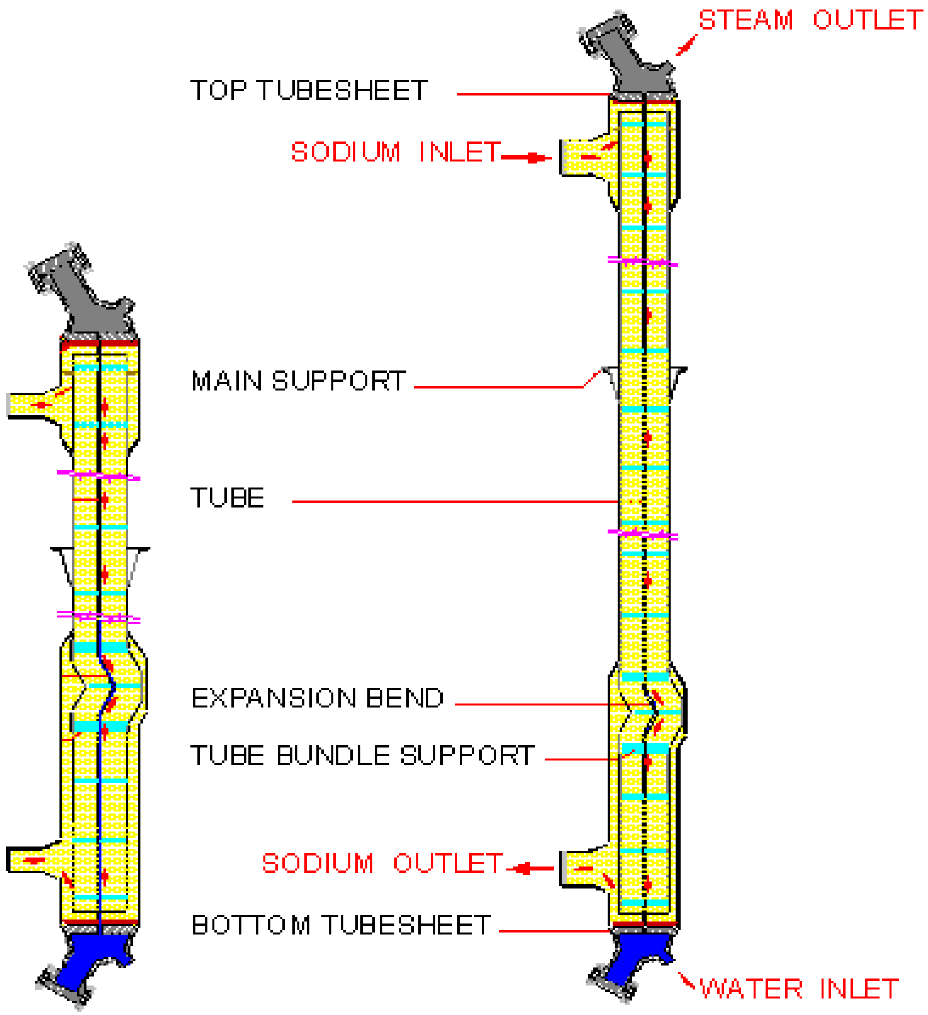


PFBR:

4 independent SGDHR loop each with 8 MW heat removal capacity

The SGDHRS is completely passive except for the dampers at the inlet and outlet of Air Heat Exchangers

Steam Generator



PFBR

- 547 tubes
- 17.2 OD X 2.3 WT
- Matl Gr 91
- No of welds
  547 X 16 = 8752

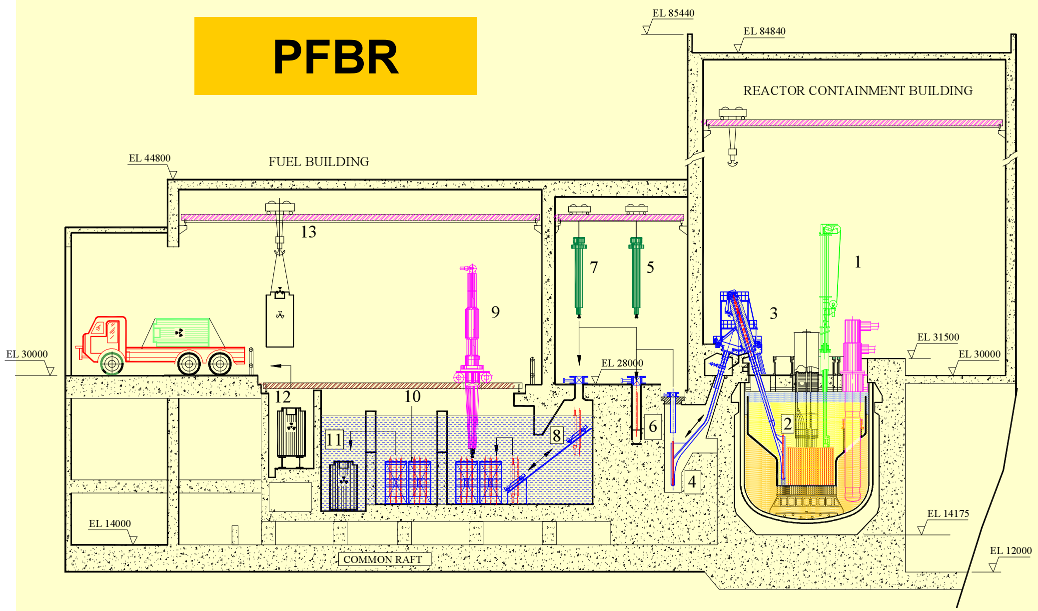
CFBR

- 475 tubes
- 17.4 OD X 2.4 WT
- Matl Gr 91
- No of welds
  475 X 12 = 5700

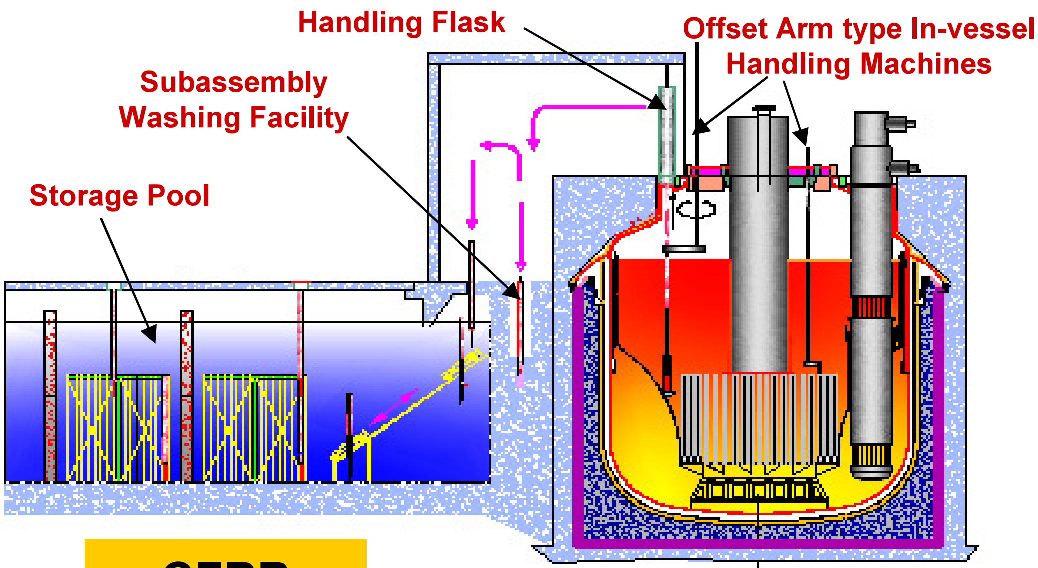
- Objective: To reduce the number of butt welds of tube to tube sheet raised spigot. This reduces manufacturing time, favourable impact on reactor schedule and enhances safety.
- Tube length increased from 23 to 30 m.
- Number of steam generators reduced from 8 to 6 (3 SG/loop for future reactors)
- Operation flexibility to run with 3 + 2 SG of affected loop

Fuel handling system

PFBR



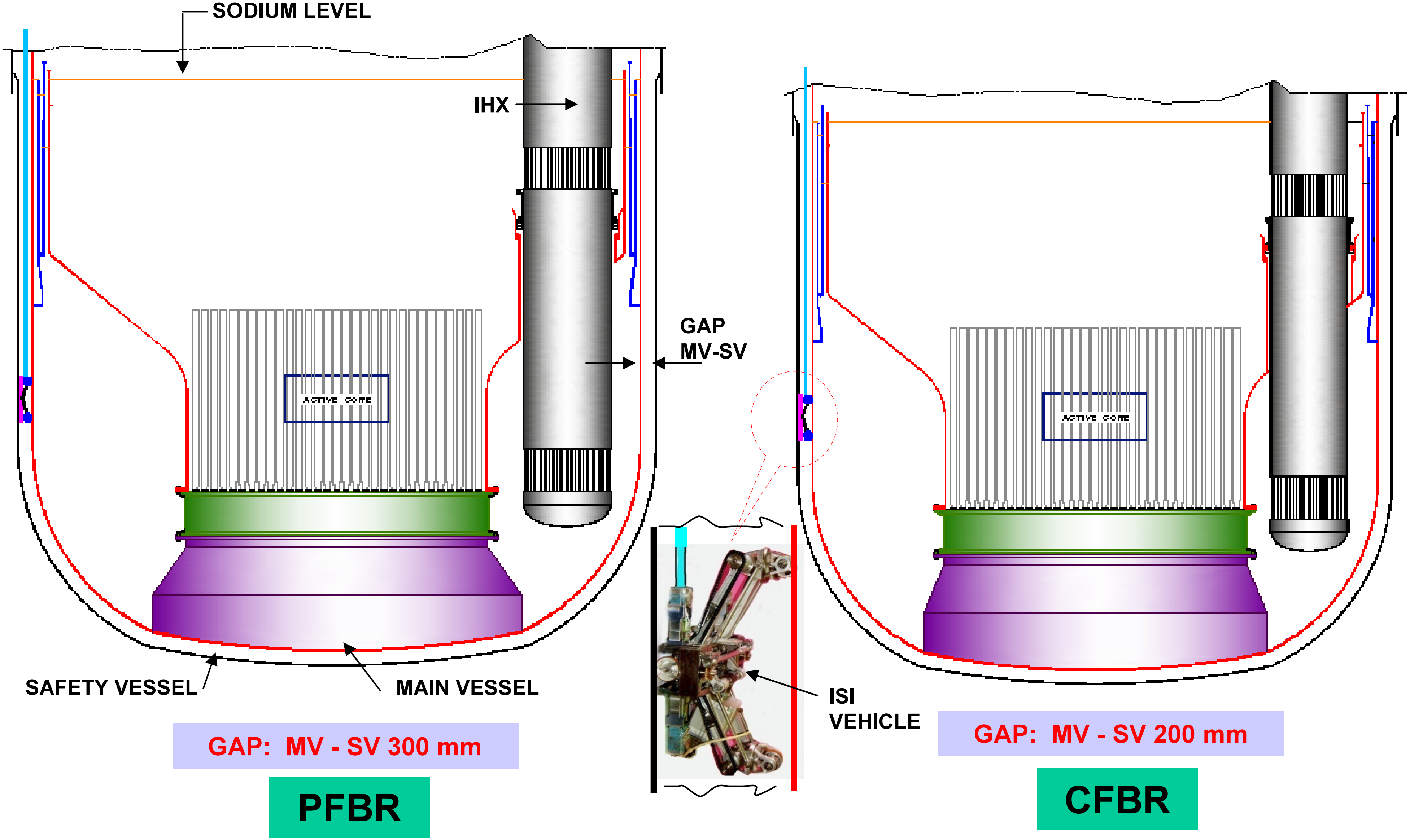
- 2 RP + 1 TA (Offset arm) for In-vessel handling + 1 Inclined fuel transfer machine (IFTM) for Ex-vessel handling



CFBR

- 2 RP + 2 TA (Offset arm) for In-vessel handling + 1 Flask (Straight Pull) for Ex-vessel handling

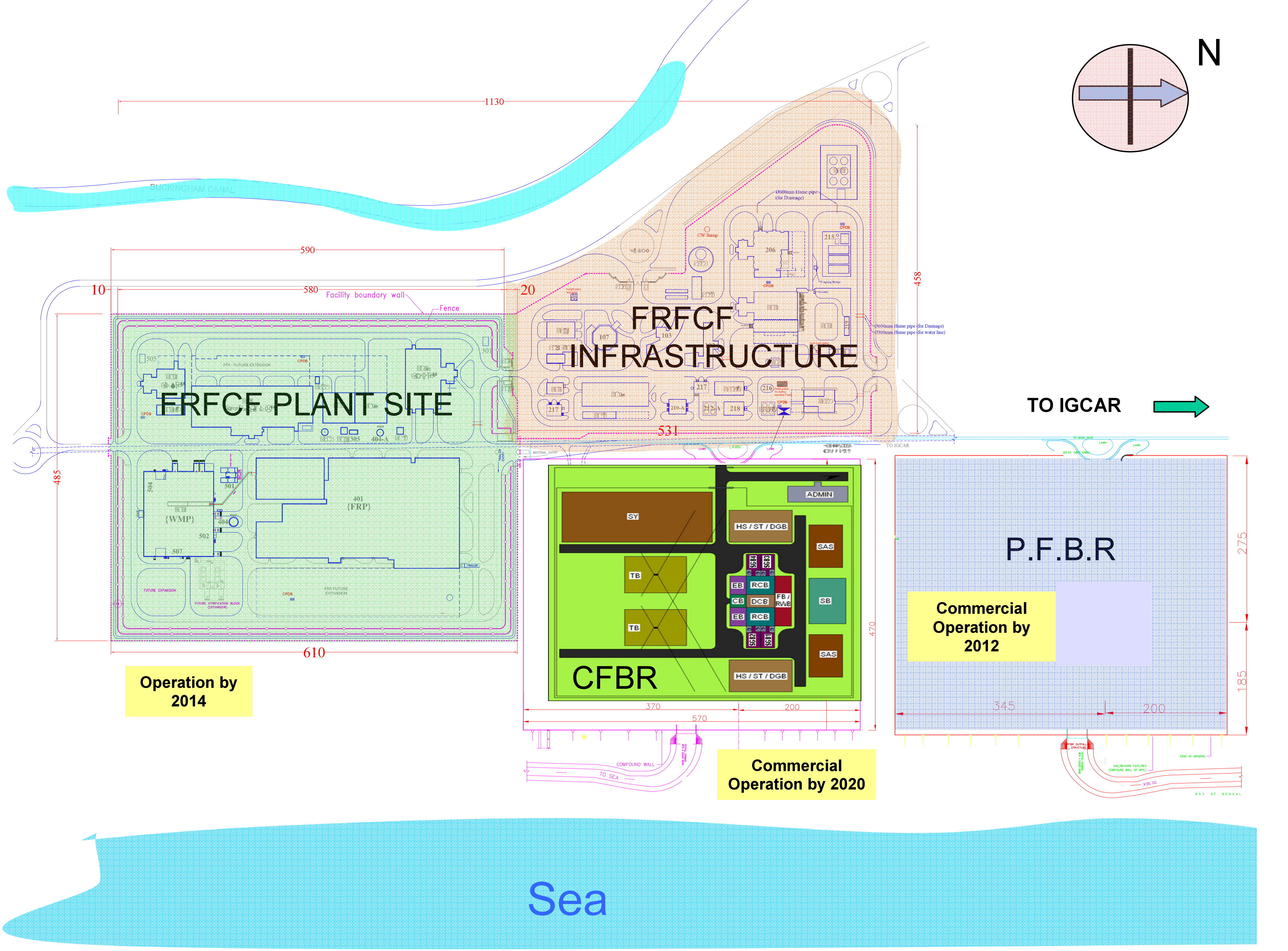
In-service inspection of Main vessel



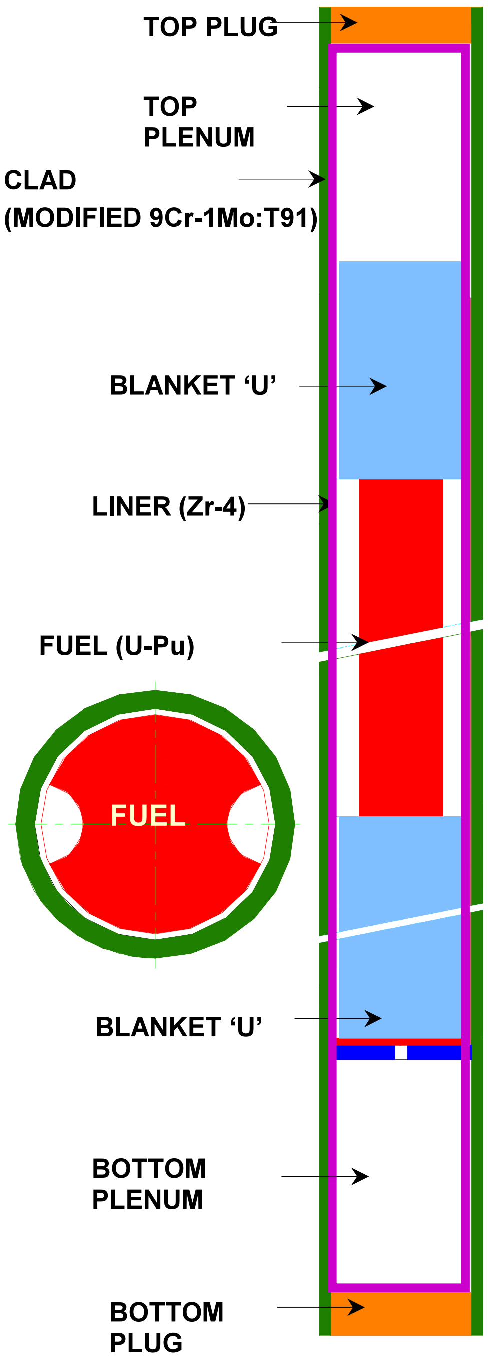
- **Advanced Techniques with gas-coupled ultrasonic testing using electro-magnetic acoustic transducers or phased-array ultrasonic testing using micro-electro-mechanical systems are under study**
- **Development of examination and crack detection / repair under sodium is also planned**

Material of Construction

Component	PFBR	CFBR
Clad	20% CW 15Cr-15Ni + Mo + Ti + Si ASTM A 771	• 20%CW 15Cr-15Ni + Mo + Ti + Si + B + P • ODS
Wrapper	-do-	9Cr-1Mo
Main vessel	316 LN	316 LN
Safety vessel	304 LN	Carbon steel (A48P2)
Grid plate, Core support structure	316 LN	Assessment towards using 304 LN
IHX	316 LN	316 LN
Steam generator	Modified 9Cr-1Mo (Gr.91)	Gr.91
Secondary sodium piping	316 LN	Study for Cr-Mo. Linked to availability of sodium valves in Cr-Mo
Sodium pumps, Sodium tanks	304 LN	304 LN

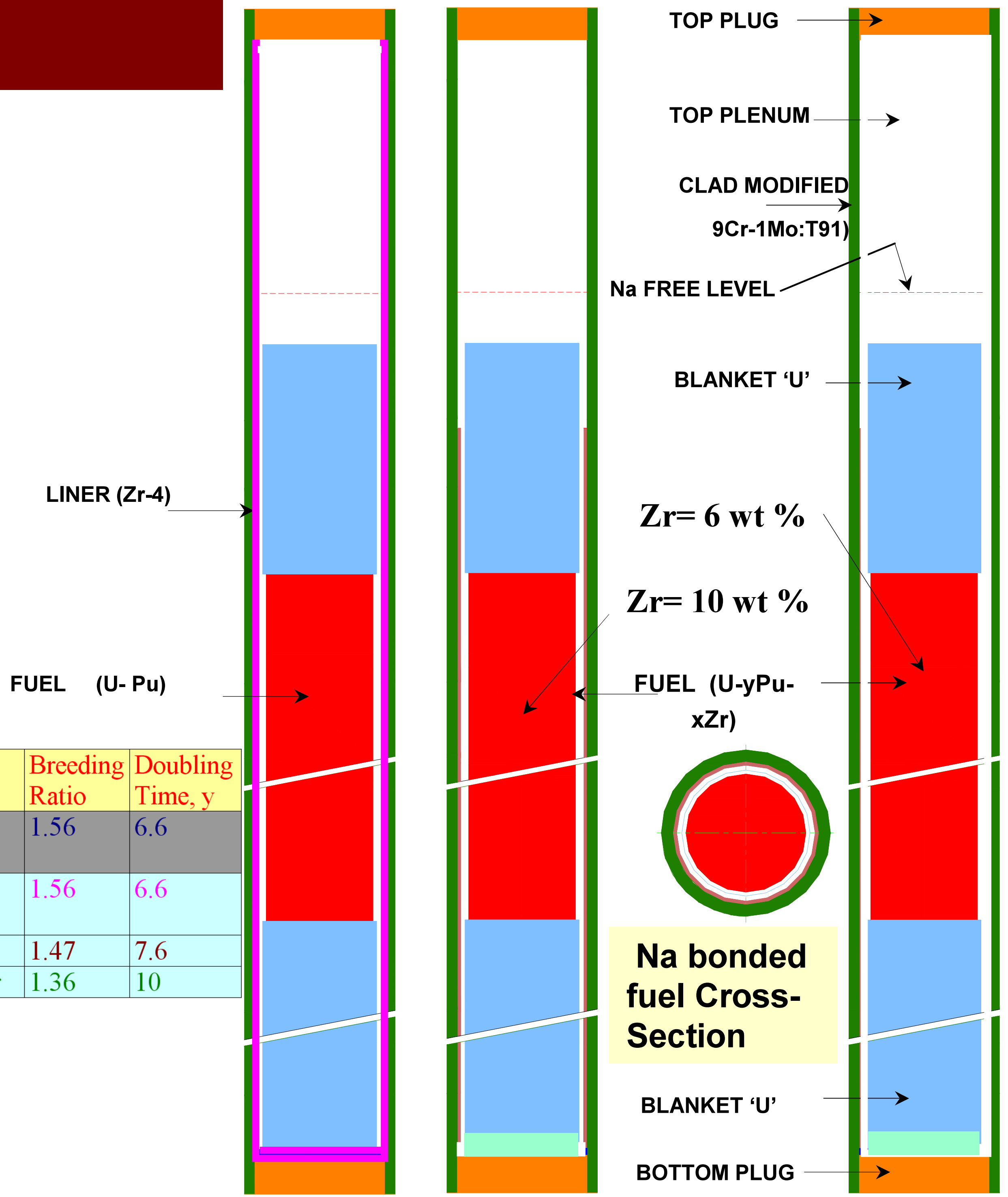

N
FRFCF INFRASTRUCTURE
FRFCF PLANT SITE
TO IGCAR
Operation by 2014
CFBR
Commercial Operation by 2020
P.F.B.R
Commercial Operation by 2012
Sea
1130
590
580
610
485
458
531
570
370
200
470
275
185
345
Facility boundary wall
Fence
{WMP}
{FRP}
ADMIN
SY
HS / ST / DGB
SAS
SB
TB
EB
RCB
CB
DCB
FB / RVVB

Metallic fuel



Mechanical bonded

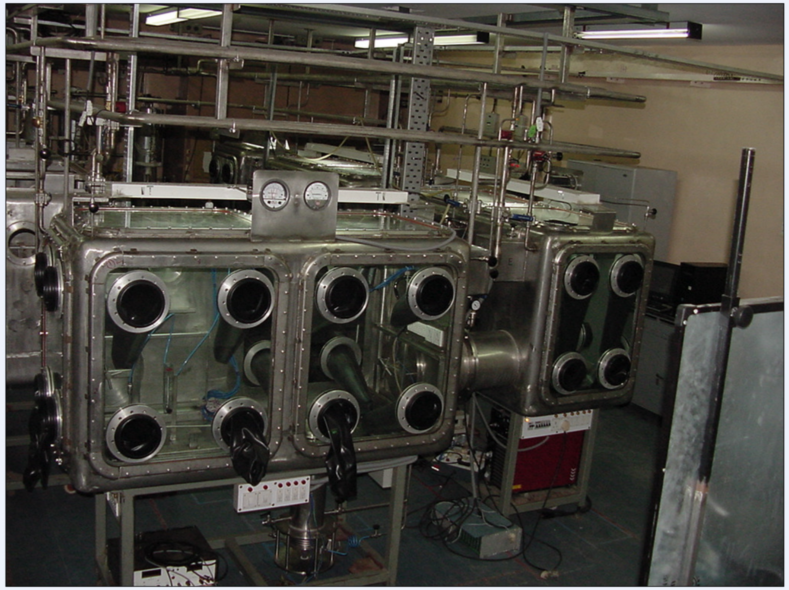
Bonding	Fuel	Breeding Ratio	Doubling Time, y
Mechanical	U- Pu + Zr- 4 liner	1.56	6.6
Sodium	U- Pu + Zr- 4 liner	1.56	6.6
	U- Pu- 6 % Zr	1.47	7.6
	U- Pu- 10 % Zr	1.36	10



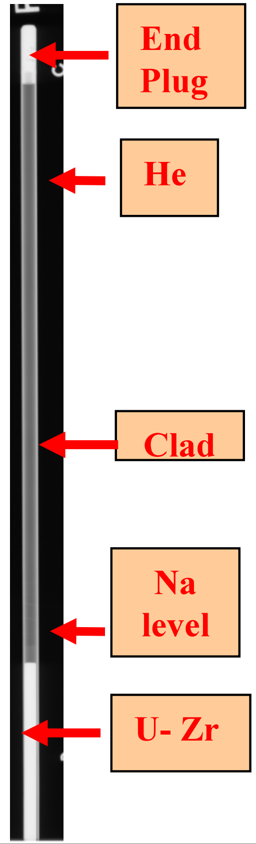
Sodium bonded

Metal fuel development

- Testing pins in FBTR
- 37-pin test SA in FBTR
- FBTR core conversion as predominantly metallic fuel
- Testing of few metallic fuel subassemblies in PFBR
- One 500 MWe CFBR to have flexible core (Oxide or metal)
- Construction of test reactor with metallic fuel core for testing of power reactor metal fuel subassemblies



Sodium bonded pin fabrication facility



Sodium bonded Metallic fuel pin

Pyro-Chemical reprocessing facility

Summary

- **Fast Breeder reactor with closed fuel cycle is an inevitable technology option for providing energy security for India**
- **PFBR is a techno-economic demonstrator and a fore runner in the series of FBRs planned**
- **Beyond PFBR, economic competitiveness is important for rapid commercial deployment of FBRs**
- **Several conceptual and rationalised design options are under consideration towards achieving enhanced safety and improved economy for the future FBRs**
- **Energy parks with multiple units and co-located fuel cycle facilities are planned from economic, operational and strategic considerations**
- **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**

Thank You