Design Features of Reactor Assembly Components of Future FBRs

P.Chellapandi

Director-Safety Group

Indira Gandhi Centre for Atomic Research

Kalpakkam-603 102

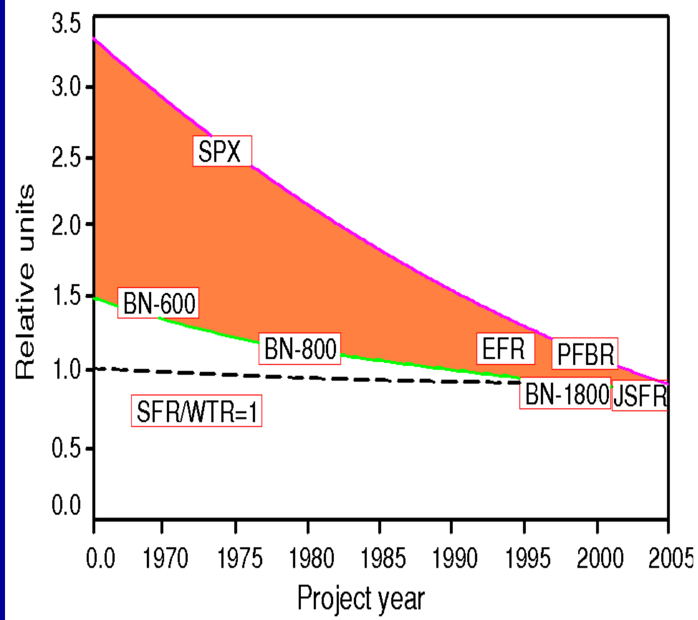
Preface

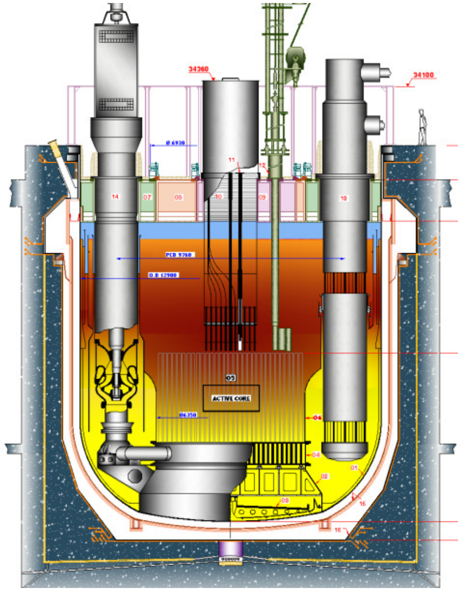
- 500 MWe Prototype Fast Breeder Reactor is under construction at Kalpakkam
- PFBR will be commissioned in Sep 2011
- Beyond PFBR: 6 units of 500 MWe FBR with improved economy and enhanced safety would be commissioned in 2020
- One twin unit consisting of 2x500 MWe reactors will be constructed at Kalpakkam, near PFBR

Motivation For Improvements For Reactor Assembly

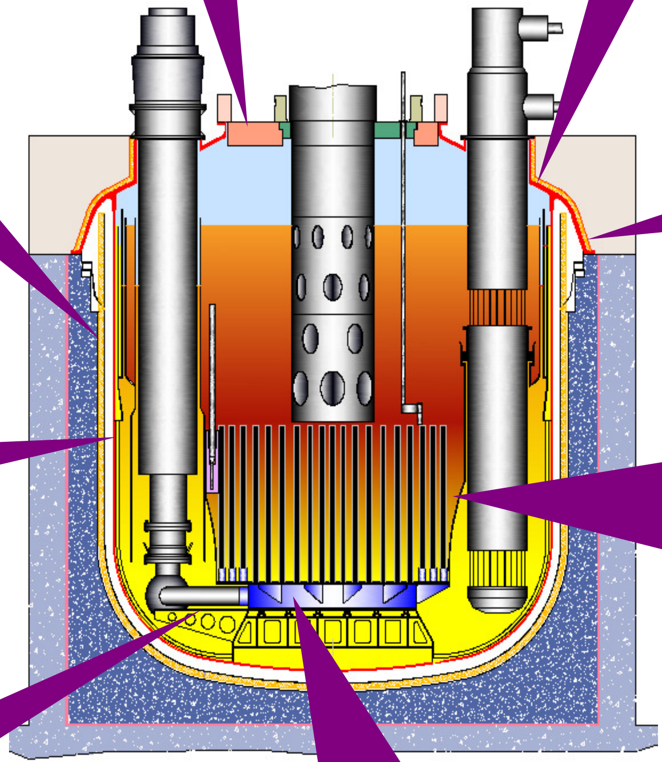
- PFBR design is reasonably optimised with 2 loop configuration
- Scope exits for reducing material consumption for reactor assembly components
- Feed back from design, manufacture and erection of PFBR Components
- International trend for innovative reactors
- Economic targets fixed for future FBRs

Evolution of SFR/WTR specific cost





Improvements Proposed For Reactor Assembly



No change in Reactor Vault Concept

Reduction of Main Vessel Diameter

- ✓ **Radial spacing at core level, radial spacing at top shield and circumferential spacing at top shield level decide the vessel diameter.**

- ✓ **PCD of pump/IHX can be reduced to 9400 mm and roof slab diameter to 12010 mm with measures such as**

  (i) use of integrated control plug with SRP

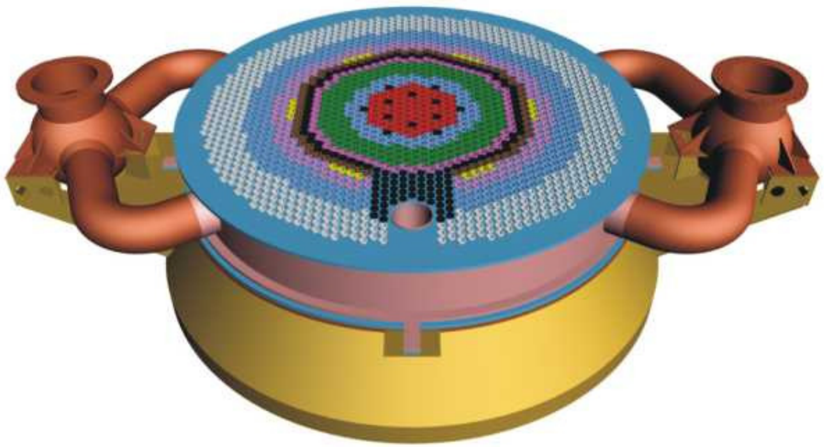
  (ii) Reducing the gap between the flanges (possible due to the dome shaped roof slab).

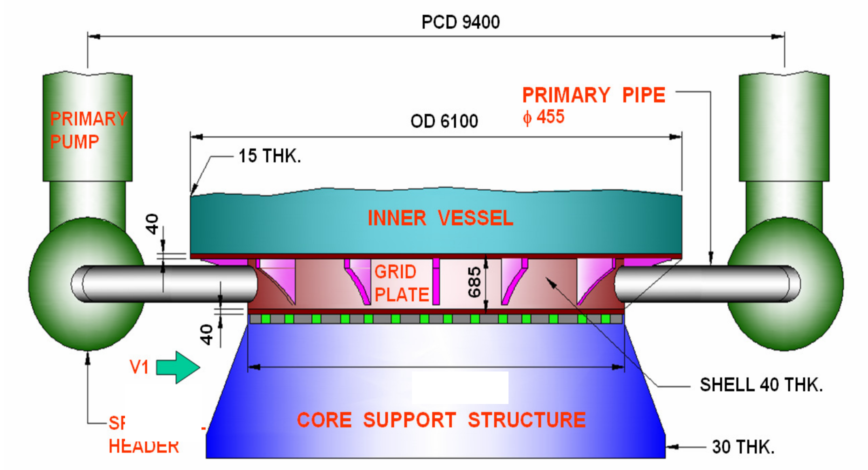
  (iii) Machining of penetration shells in roof slab.

- ✓ **Reduction in the annular gaps between inner vessel/thermal baffles/main vessel from the experience gained from PFBR component manufacture.**

Main vessel diameter would be reduced from 12.9 m 12.01 m

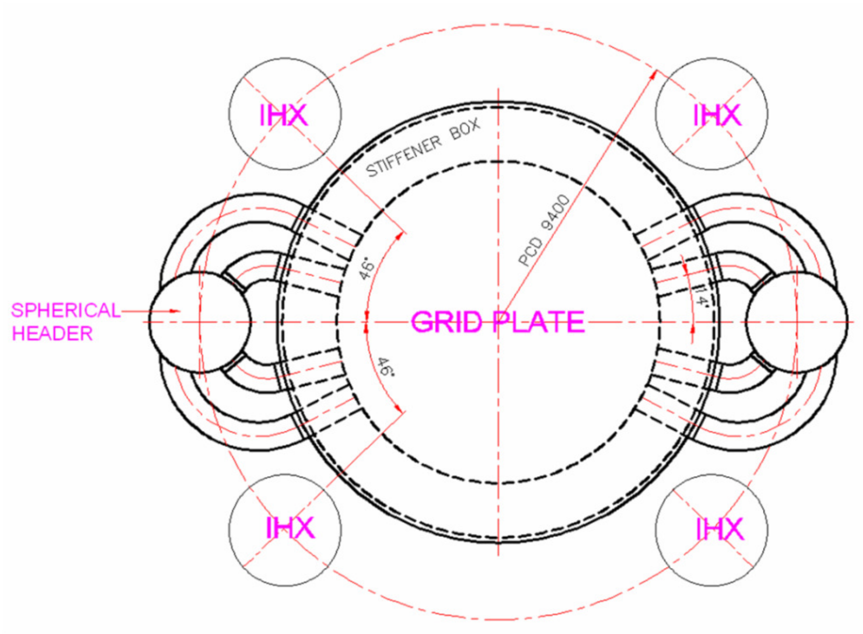
Welded Grid Plate

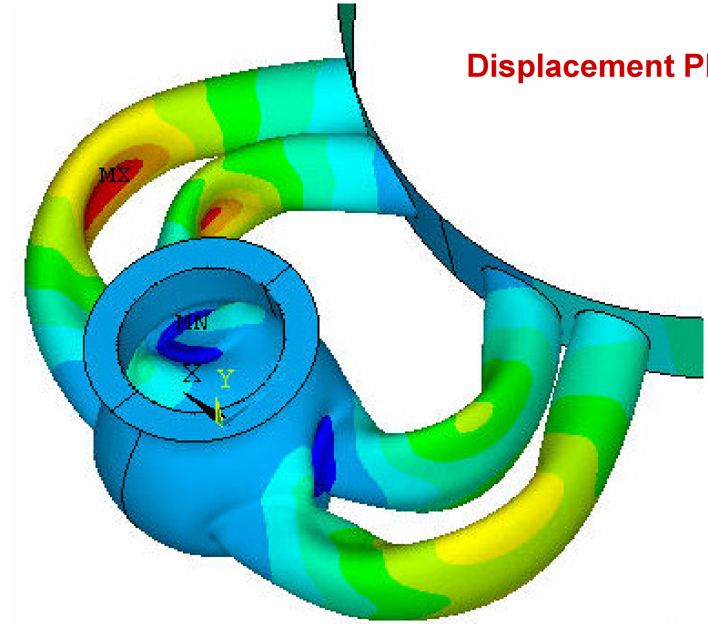




- Welded joints for shell-to-plates joints / sleeves-to-plates joints – No leakage, Flanges & Fasteners eliminated, diameter reduced and better thermo-mechanical behaviour
- Sleeves provided only for subassemblies that require forced cooling – Shell & Bottom plate diameters reduced and sleeves reduced from 1758 to 660.
- Availability of space for accommodating more number of pipes
- Symmetric core layout by shifting IVTP shell shifted to inner vessel
- Shell diameter reduction by 2.2 m and Height reduction by 300 mm
- Weight reduction by 55%
- Manufacturing simplifications

Increased Number of Primary Sodium Pipes

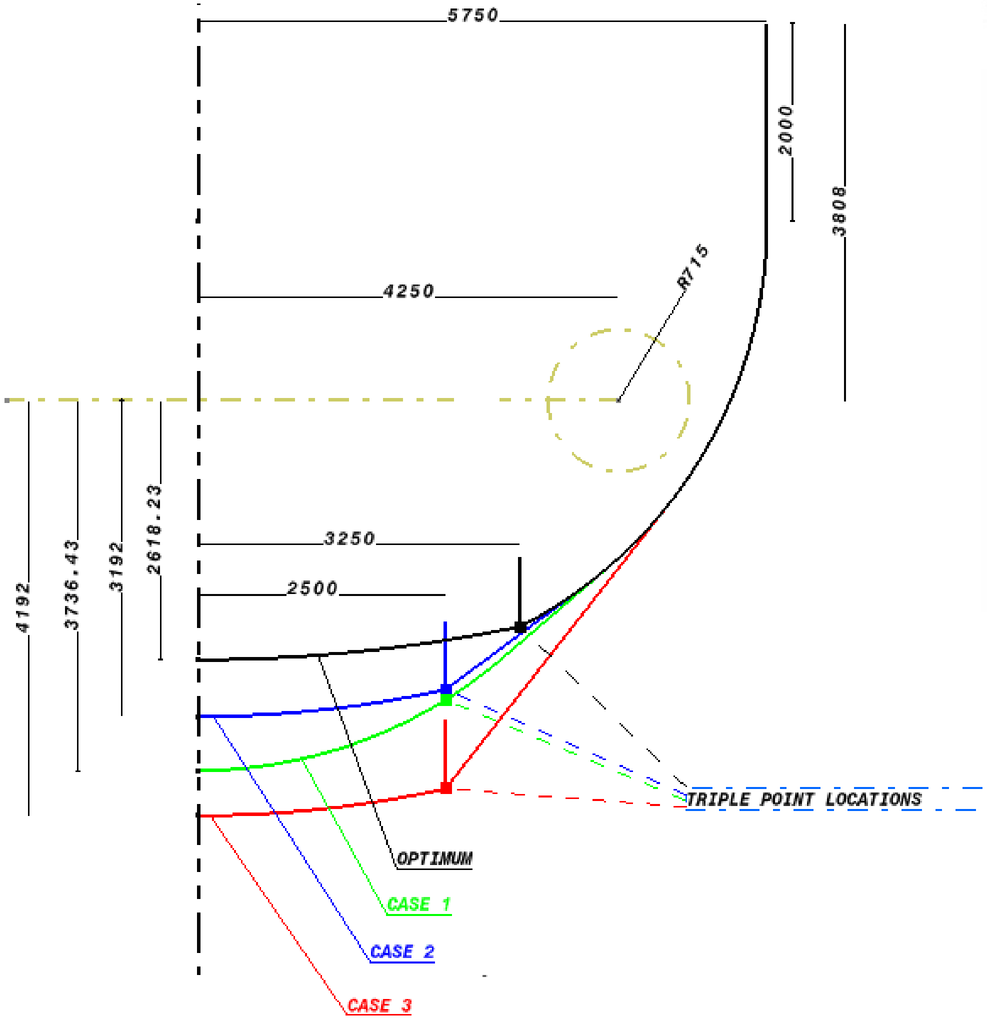


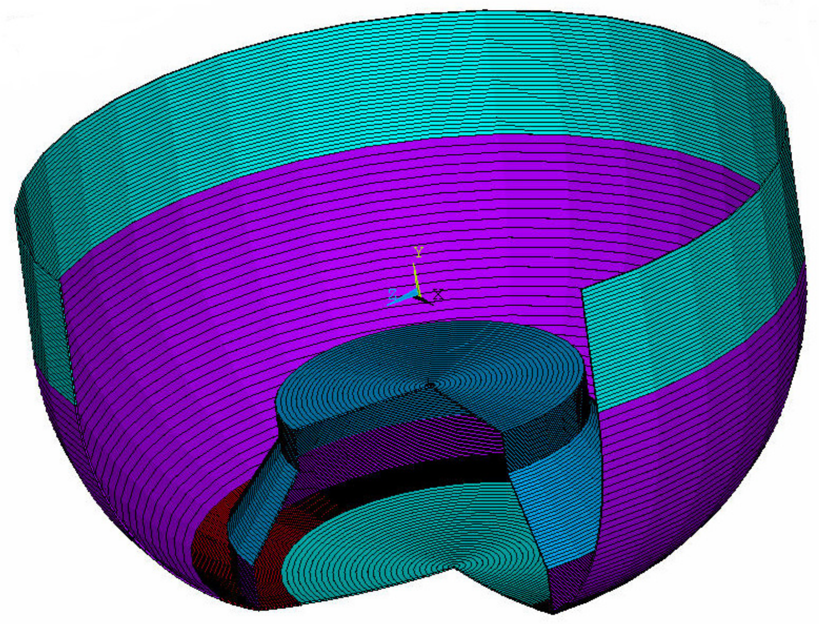


- **Number of pipes increased from 4 to 8**
- **Coolant flow reduction to core is reduced consequent to one pipe rupture (enhanced safety margin)**
- **Pipe size is reduced (600 mm to 400 mm): Grid plate height is reduced**
- **Flow and temperature uniformity in the grid plate during transient**

Optimisation of Main Vessel Dished End

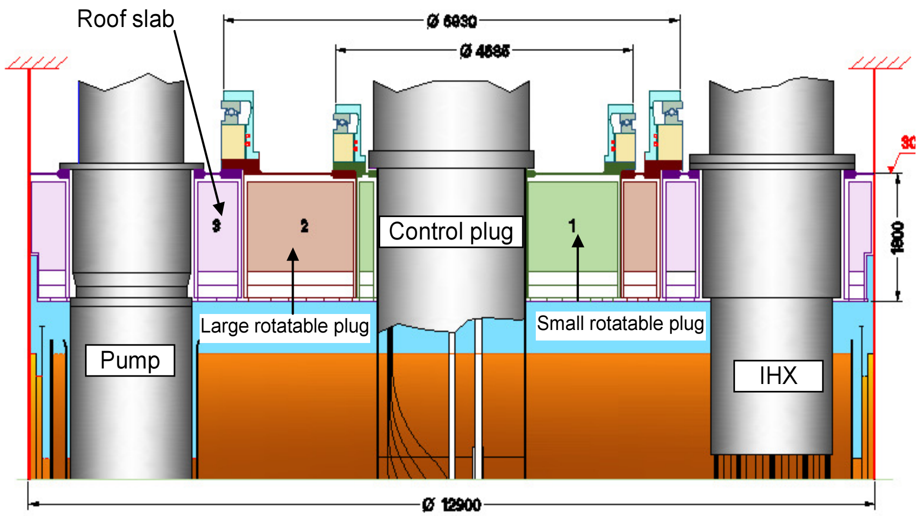
Introduction of conical portion between the knuckle and crown

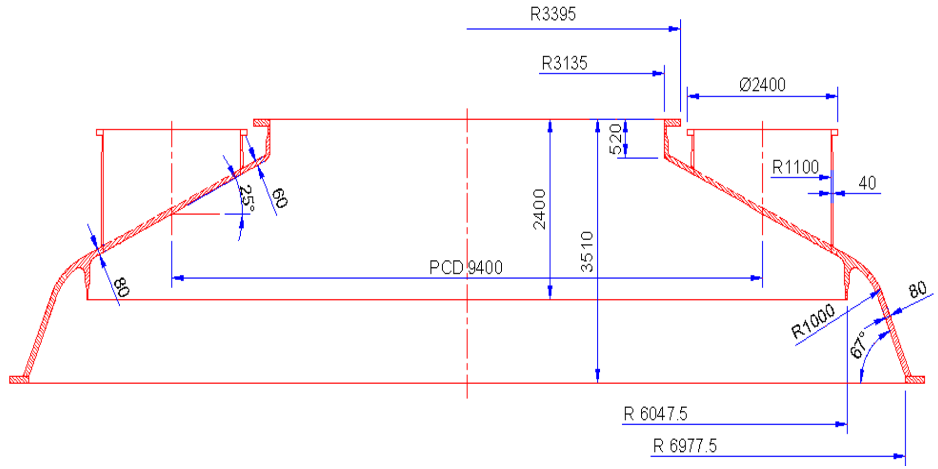




Optimisation from deflection, primary stress, buckling of knuckle portion and post accident heat removal considerations.

Dome Shaped Roof Slab
with Skirt Support under Compression





- **Large box type structure with many penetrations - Fabrication of box type structure is a very complex, time consuming and difficulty to handle laminar tearing problems and to meet dimensional requirements due to its large dimensions**
- **Dome shape calls for reduced wall thickness,**
- **Shielding can be decoupled from RS and transferred directly to the reactor vault.**
- **Higher energy absorption potential under sodium slug impact due to CDA**
- **Through machining , it is possible to have minimum annular spaces (diameter reduction and mitigate the sodium release to RCB**

Thick Plate Cocept for Rotatable Plugs

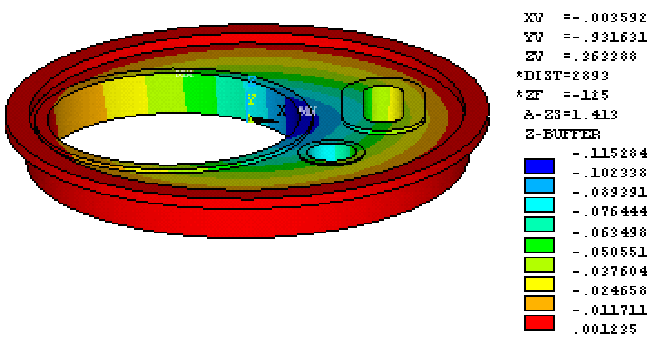
Advantages over box type design

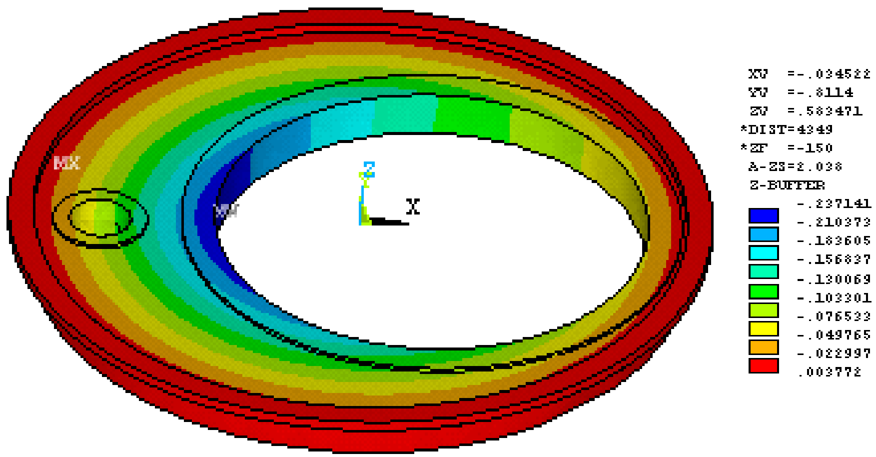
Machined annular gaps in SRP & LRP

- Reduction in diameter of SRP and LRP
- Reduction in overall diameter of reactor vessel
- Economy

Reduction in height of SRP & LRP

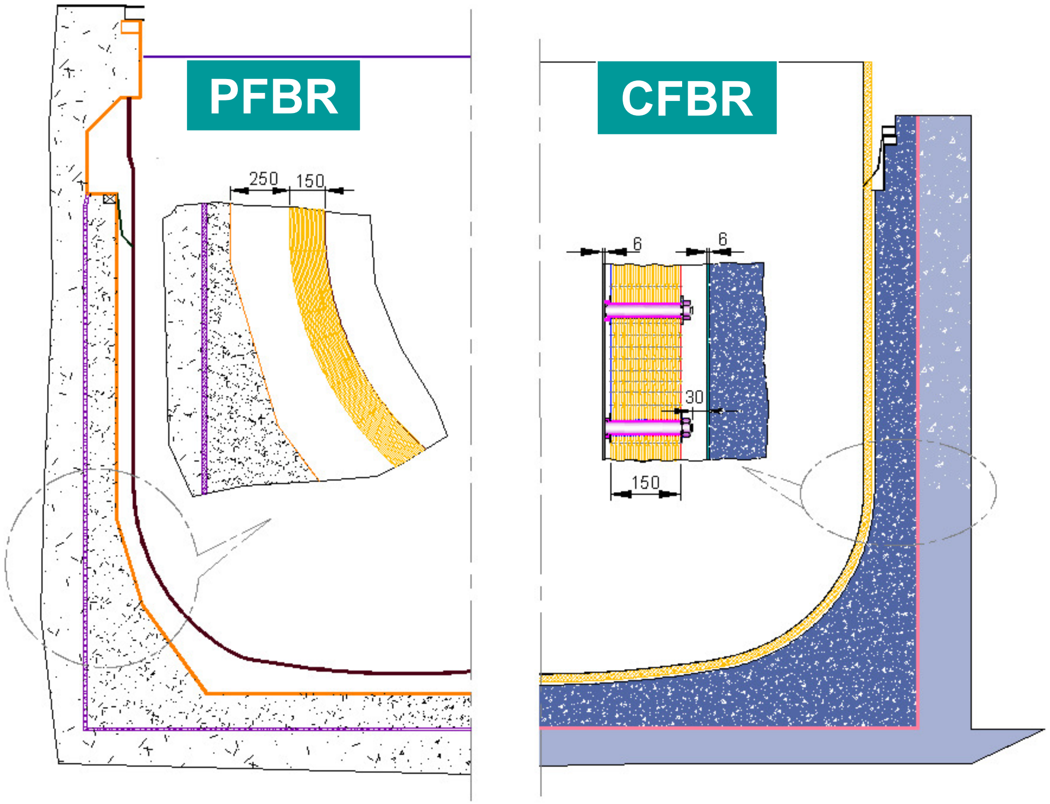
- Saving in length of the components penetrating SRP & LRP
- Economy





Deflection Contours of SRP & LRP

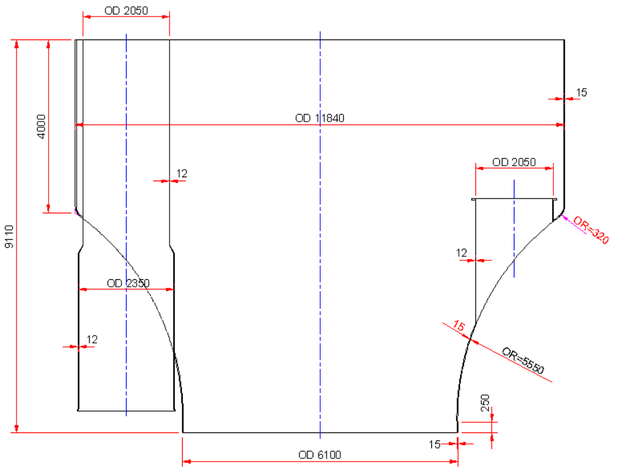
Anchored Safety Vessel

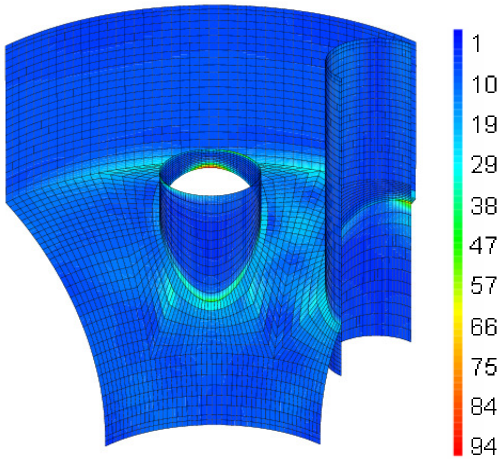


- Gap between SV and inner reactor vault is eliminated, thus reducing vault dimensions.
- Thickness of SV to be reduced to 6 mm
- Material changed to carbon steel
- Erection simplicity and economy

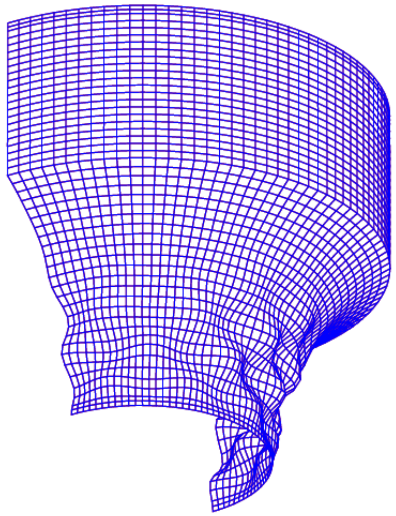
Inner Vessel with Single Toroidal Shell

- Diameter of IV at lower portion reduced by 250 mm due to reduction in GP diameter
- Radon portion changed to single toroidal shell due to its inherent higher buckling strength over conical shell
- Due to new geometry, thickness reduced from 20 mm to 15 mm
- Diameter of upper shell reduced by 360 mm due to reduction in PCD of stand pipes subsequent to reduction in corresponding annular gaps in top shield
- Reduction in thickness and overall dimensions result in reduced weight of 43 t compared to 65 t in PFBR
- Can accommodate the IVTP

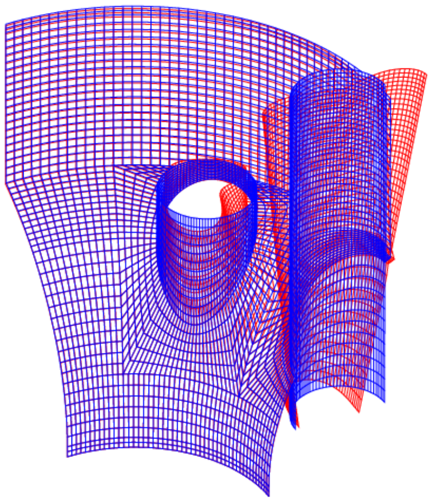




Von Mises stress intensity distribution

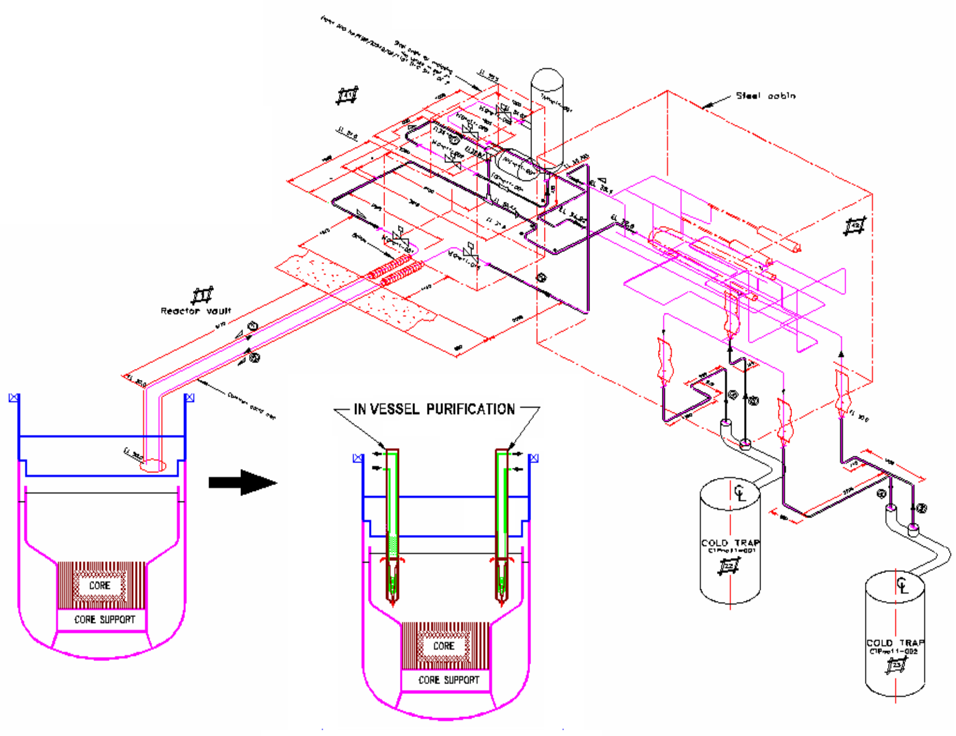


Critical buckling mode shape without stand pipes (buckling factor = 74)



Critical buckling mode shape with stand pipes (buckling factor = 29)

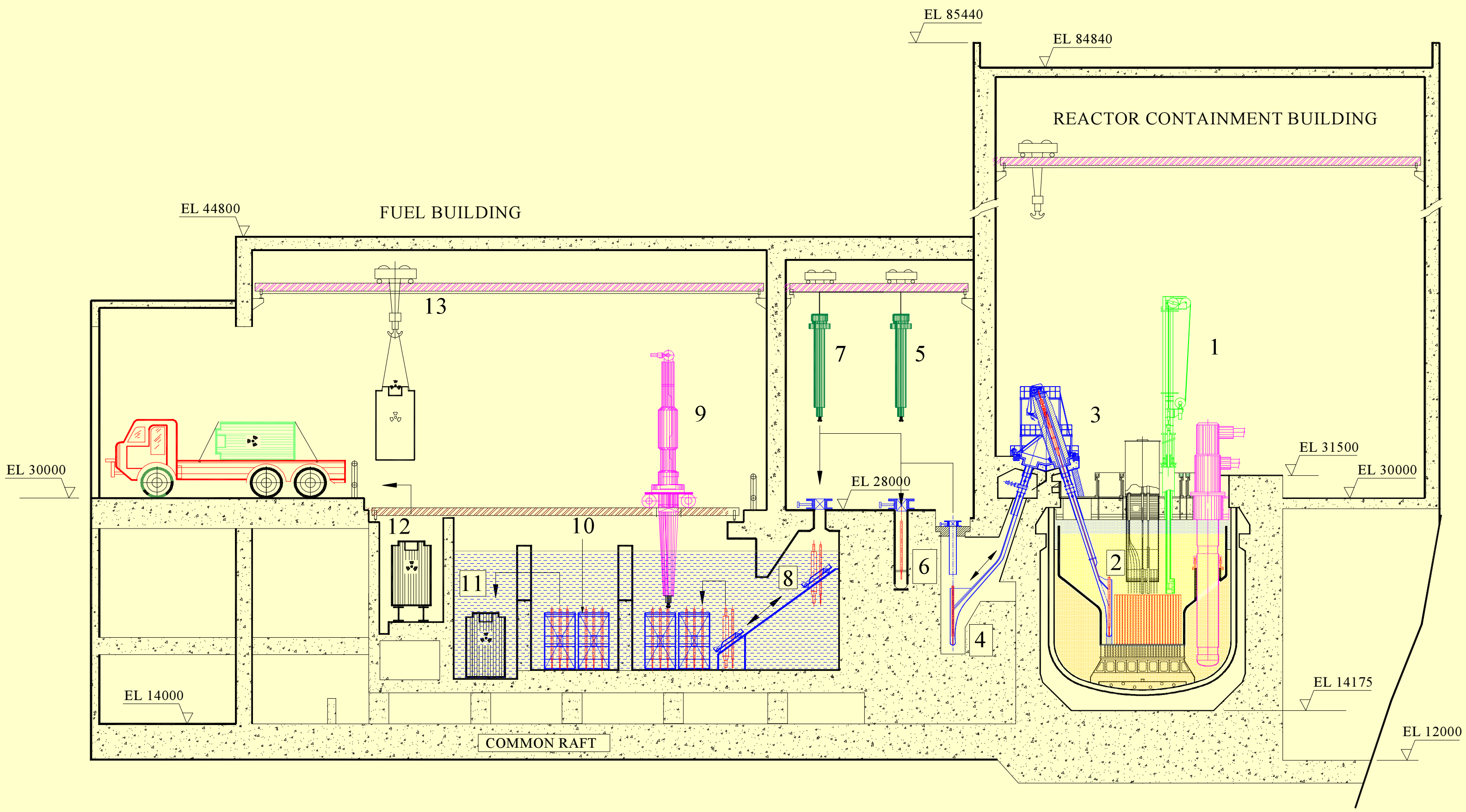
In-vessel Sodium Purification



Advantages:

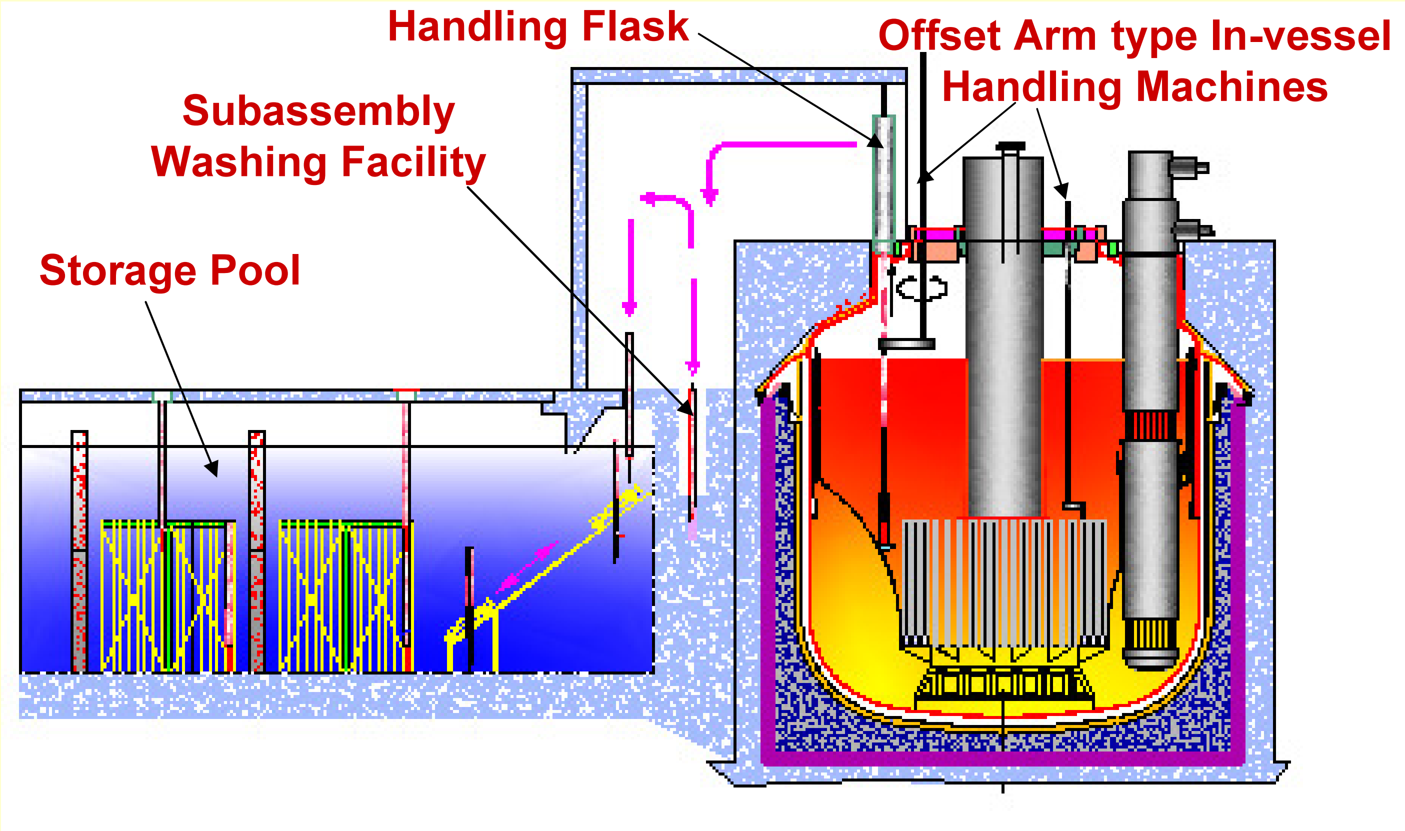
- No need of separate concrete cell
- Separate shielding for cold trap
- No risk of siphoning of sodium
- No sodium piping shielding
- No need for separate inert atmosphere

PFBR- Fuel Handling System



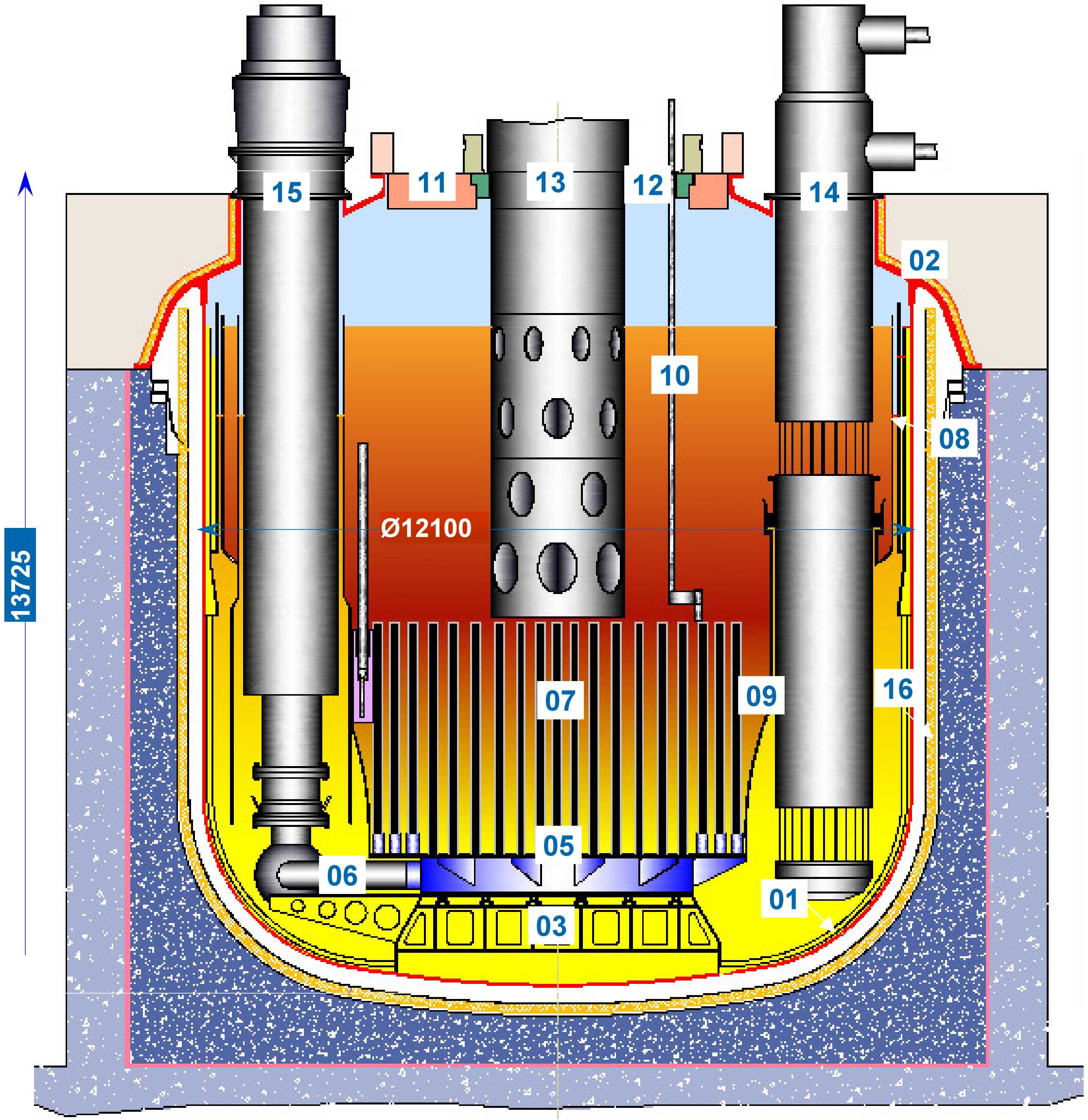
- ❖ 2 RP + 1 TA (Offset arm) for In-vessel handling + 1 Inclined fuel transfer machine (IFTM) for Ex-vessel handling
- ❖ IFTM costly and time consuming to construct

CFBR- FUEL HANDLING SYSTEM



- 2 RP + 2 TA (Offset arm) for In-vessel handling
- Inclined Fuel Transfer Machine Eliminated
- Ex-vessel Handling by one simple Straight Pull machine with flask

SCHEMATIC OF CFBR REACTOR ASSEMBLY



Sl. No	Components	Weight in t		
		PFBR	CFBR	Average in %
01	Main Vessel	134	85	- 36
02	Roof Slab	275	110	- 60
03	Core Sup. Structure	45	35	- 22
04	Core Catcher	21	15	- 28
05	Grid Plate	85	34	- 60
06	Primary Pipe	5	5	0
07	Core	513	420	- 18
08	Thermal Baffle	65	75	+ 15
09	Inner Vessel	61	55	-10
10	Transfer Arm	22	22	0
11	LRP + Support	73	106	+ 45
12	SRP + Support	45	40	- 11
13	Control Plug	78	78	0
14	IHX- 4 Nos.	172	172	0
15	Primary Pump- 2Nos.	143	143	0
16	Safety Vessel + Thermal Insulation	154	122	- 20

PRELIMINARY ESTIMATES OF SAVINGS IN REACTOR ASSEMBLY

(A) Material savings

		PFBR	CFBR
Total weight (tonnes)	with core	2156	1685
	without core	1643	1234
Specific steel consumption for RA (t/MWe)	with core	4.31	3.37 (21.9% reduction)
	without core	3.29	2.47 (25.0% reduction)

(B) Primary Sodium Inventory

1100 t in PFBR reduces to ~ 1000 t in CFBR (10 % reduction)

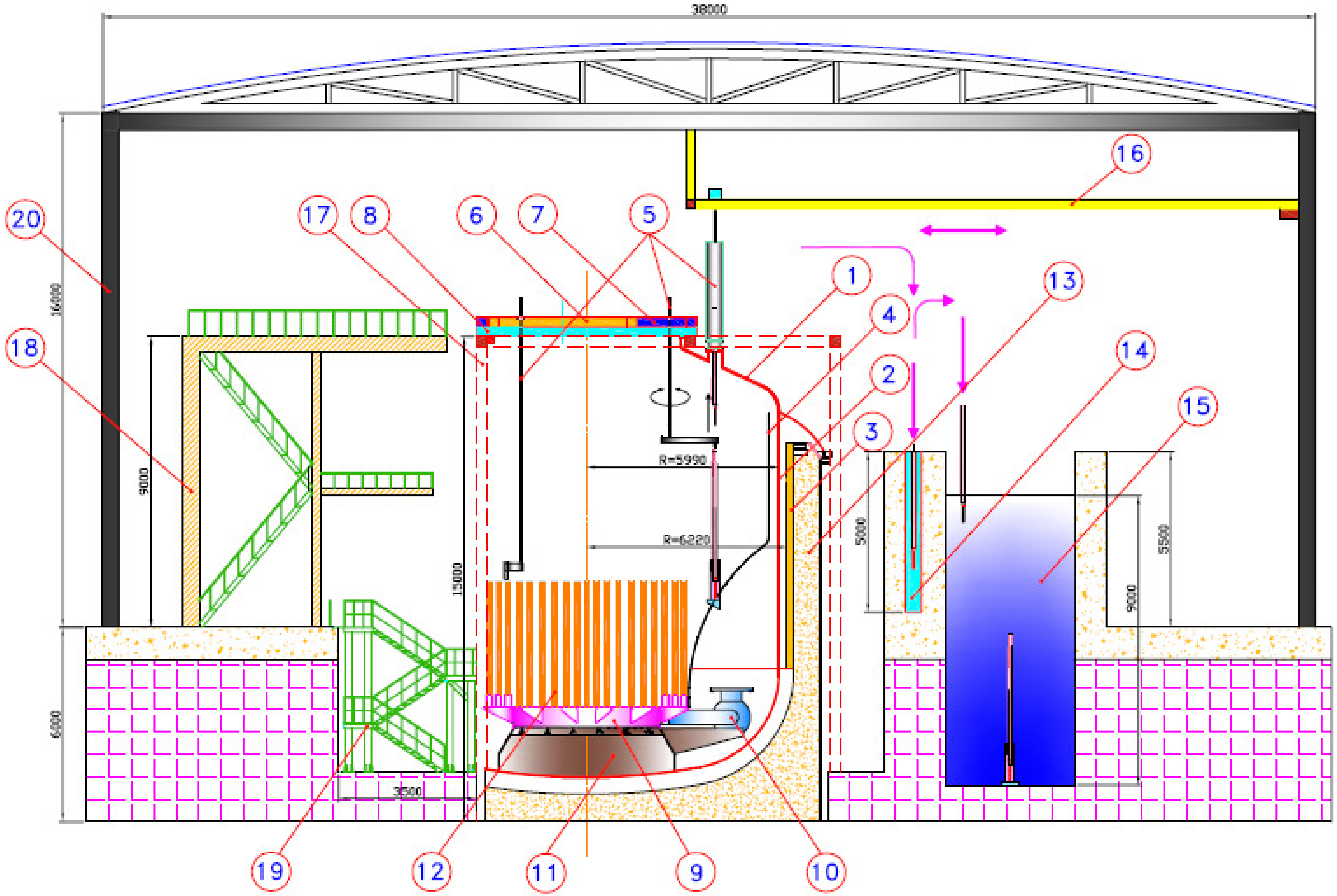
(C) Cost of Reactor Assembly

60 million euro for PFBR reduced to ~50 million euro for CFBR

Challenges and Approach

Improvements	Challenges
Thickness reduction	Elimination of OBE
Welded Grid Plate	Technology Development
Dome Shaped Roof Slab	Availability of Large diameter Forged ring
Single Torus Inner Vessel	Technology Development
Anchored Safety Vessel	Sodium resistance concrete and construction issues
Thick plate LRP and integrated Control plug and SRP	Availability of forged plates (A48 P2)
In-vessel Purification	Qualification of cold trap at high temperature environments
Simplified FH System	Demonstration of operations

Integrated Test Facility for CFBR



Approach

- Involvement of Young Engineers from IGCAR (Responsible for Design) and BHAVINI (Responsible for construction)
- Involvement of Academic Institutions for Design optimisation and Analysis
- Technology Development involving Multiple Industries
- Well Defined Road Map for the execution of R&D
- Robust Review Mechanisms starting from Conceptual Stage


Thank You