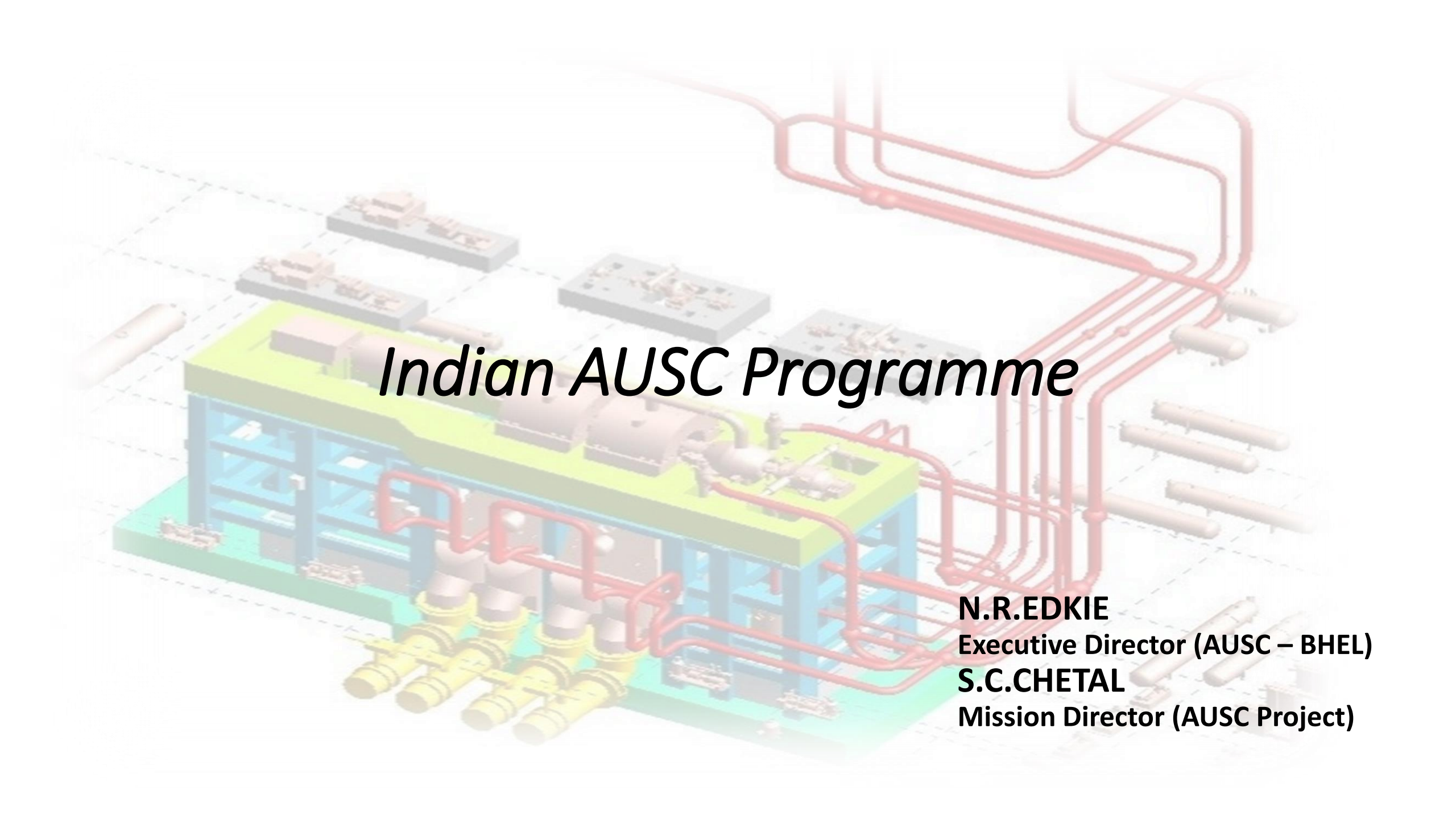
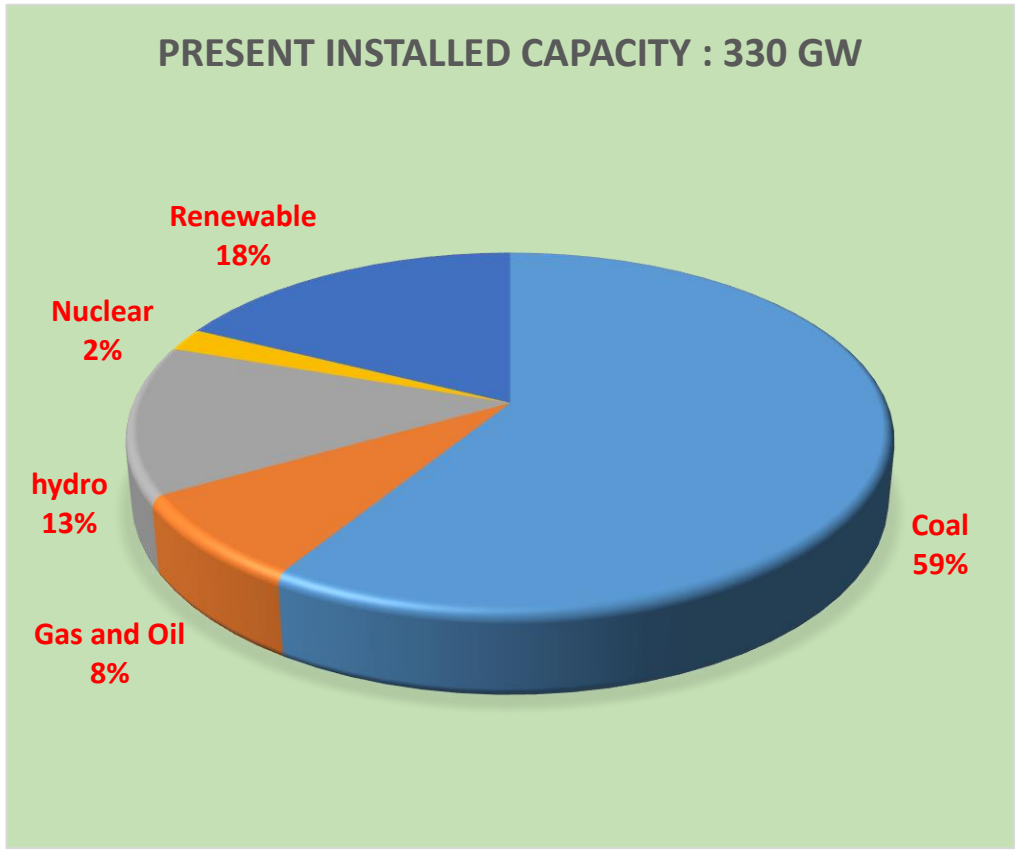


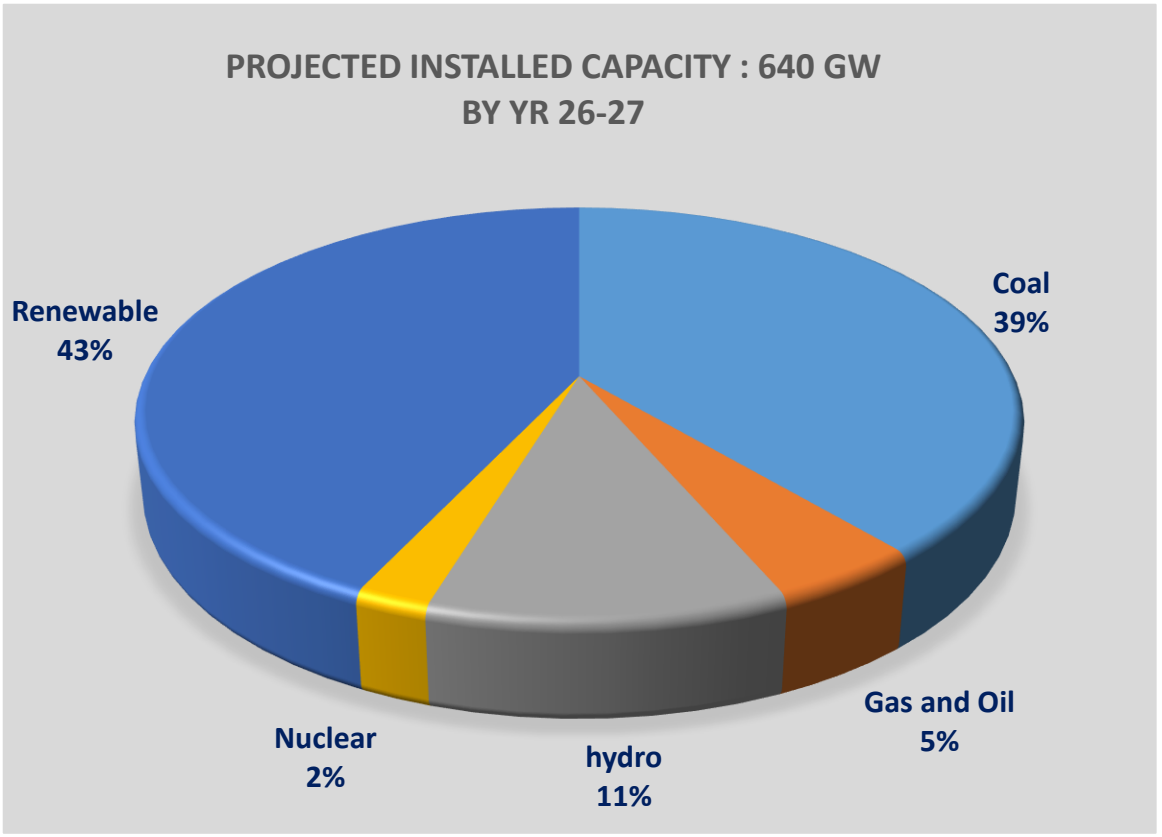
Indian AUSC Programme

N.R.EDKIE
Executive Director (AUSC – BHEL)
S.C.CHETAL
Mission Director (AUSC Project)

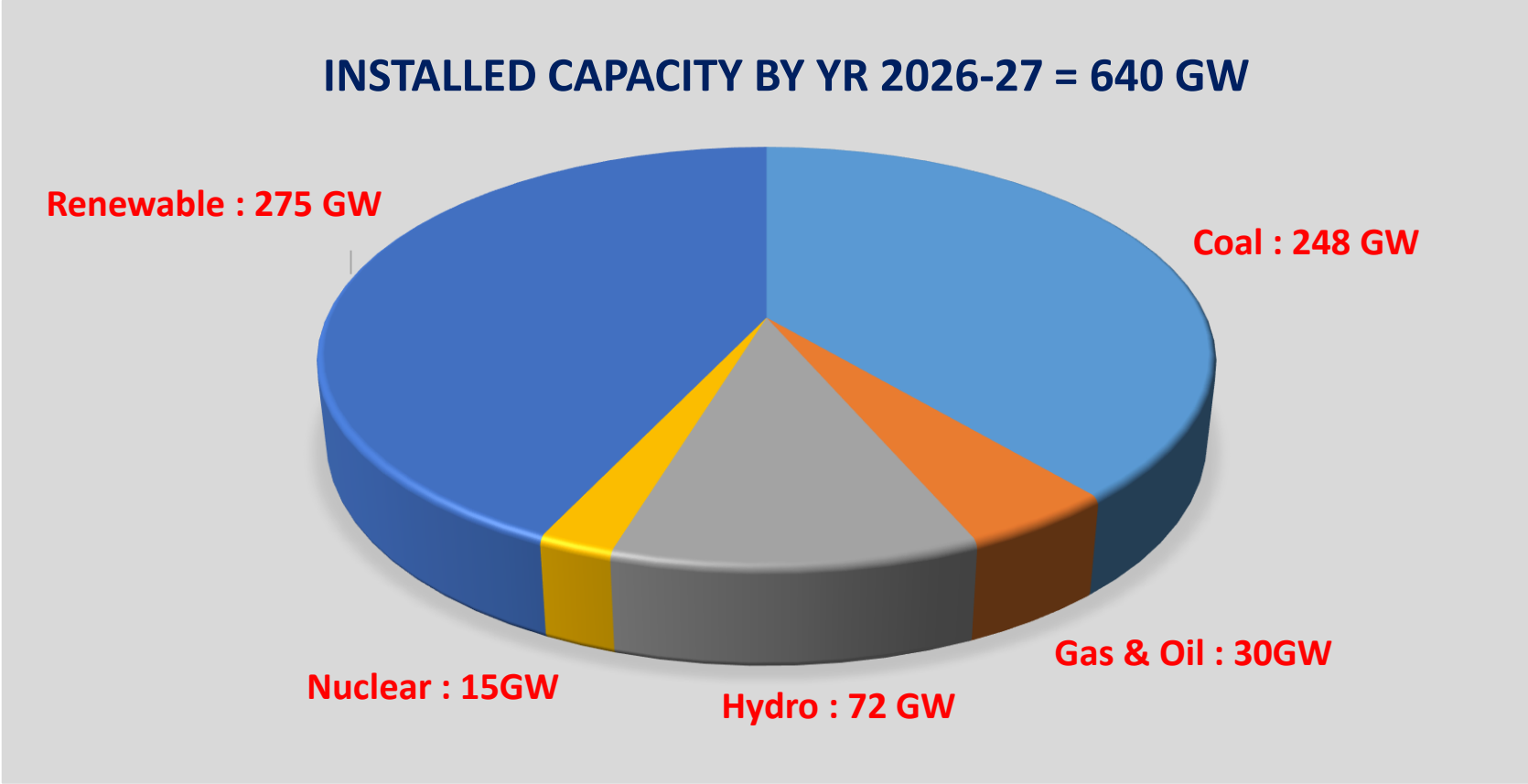
Indian Installed Capacity Mix

(as per Electricity plan by CEA)





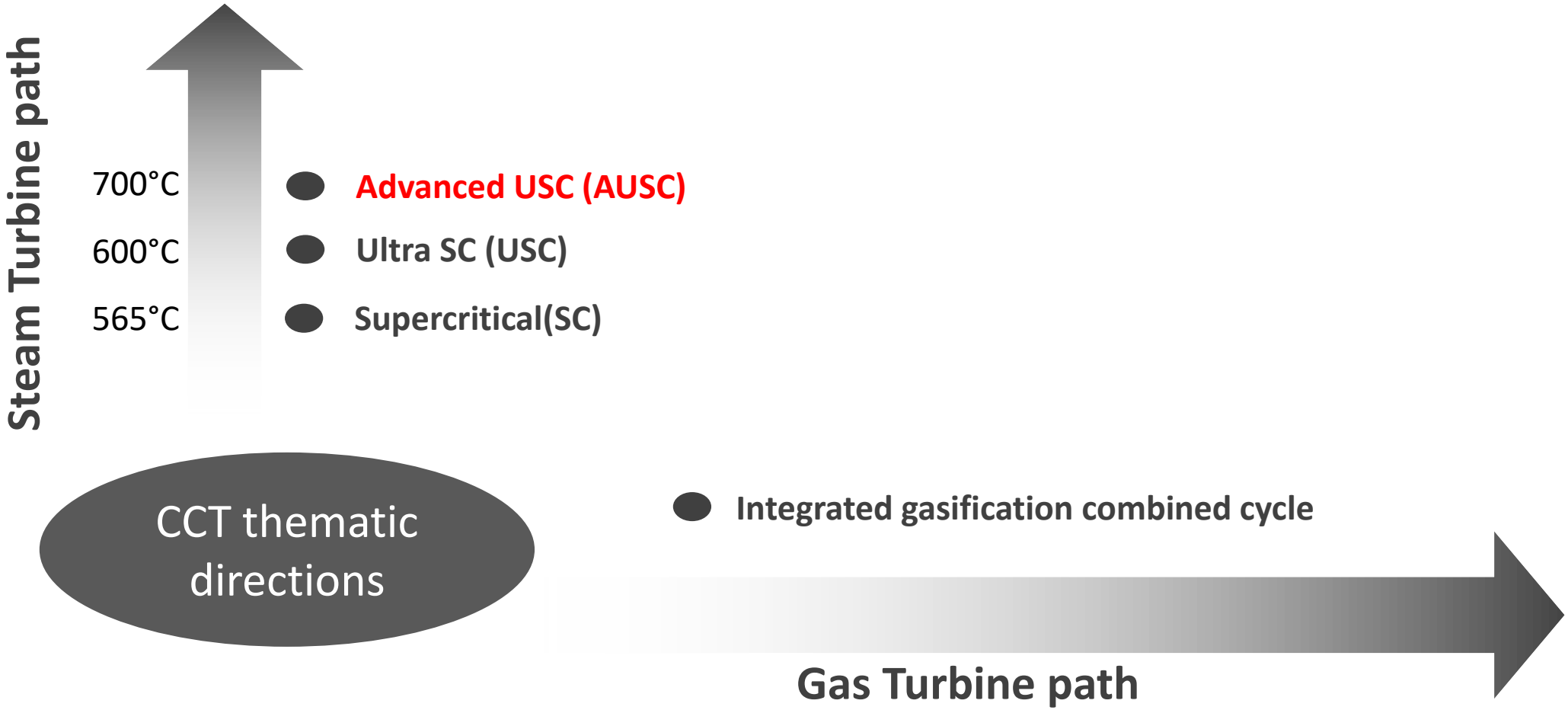
Coal to remain integral to India's energy security



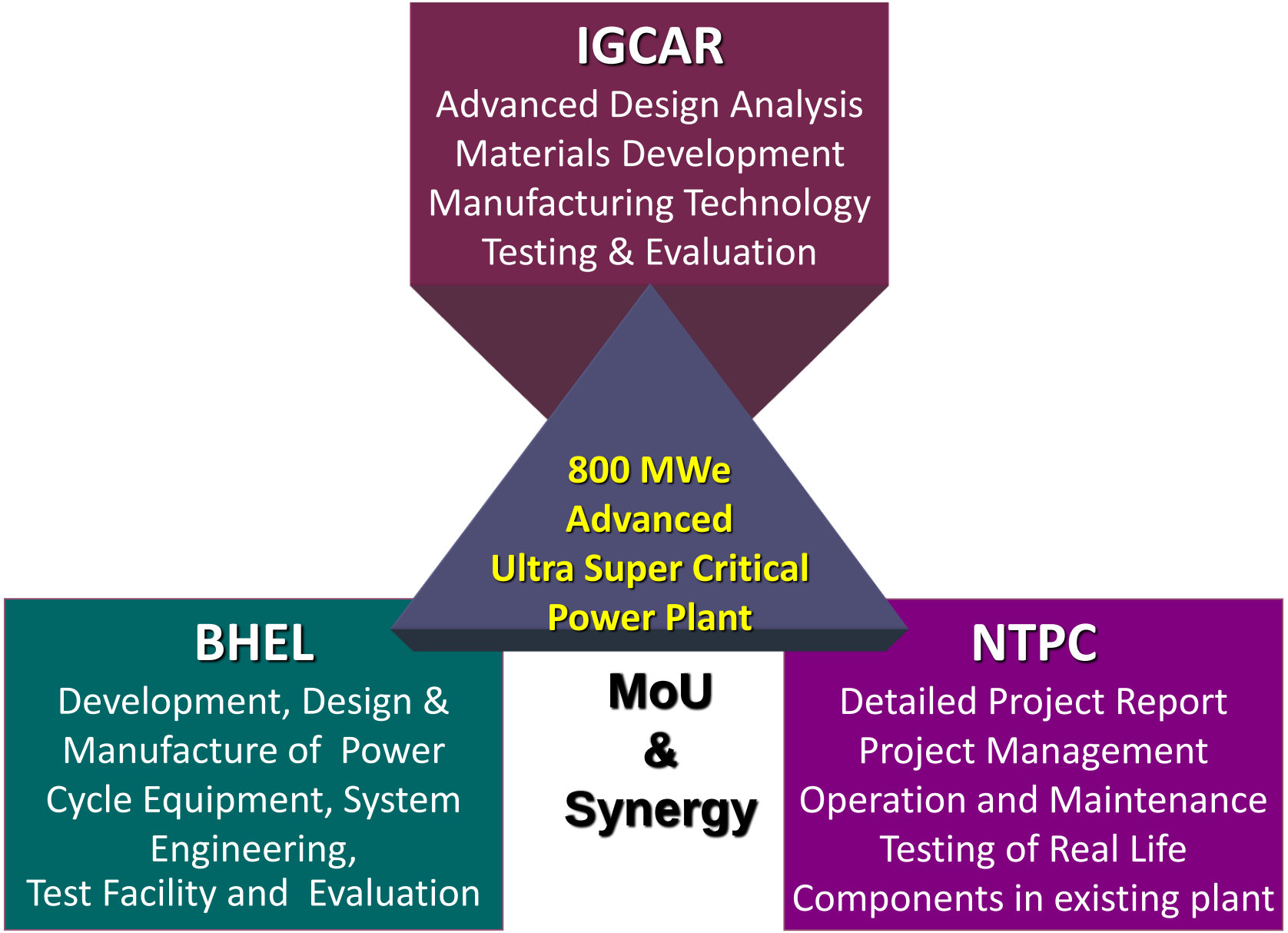
Growth Drivers for Coal Based TPS

- India has great push for renewable energy (RE) (40-45% in energy mix by 2027). However "cyclic behaviour" of RE, again calls for baseline capacity of coal based generation for stability.
- Availability of abundant coal reserves, vital for energy security of the country.
- Old sub-critical plants will be replaced phase-wise with high efficiency PCC plants

Approach for Clean use of Coal



Consortium for Indian AUSC Mission Program



Organizational Structure

- **Dedicated organization established to execute Mission in Research, Development & Demonstration mode**
- **Full time Mission Director appointed in May, 2017**
- **Mission Director is fully empowered for selection of manpower and financial structure**
- **Nominees from BHEL, NTPC, IGCAR on deputation at senior levels**
- **Design, Development, Manufacturing & Testing being done in different industries & institutes with subject expertise**
- **High level steering committees review the project progress periodically**

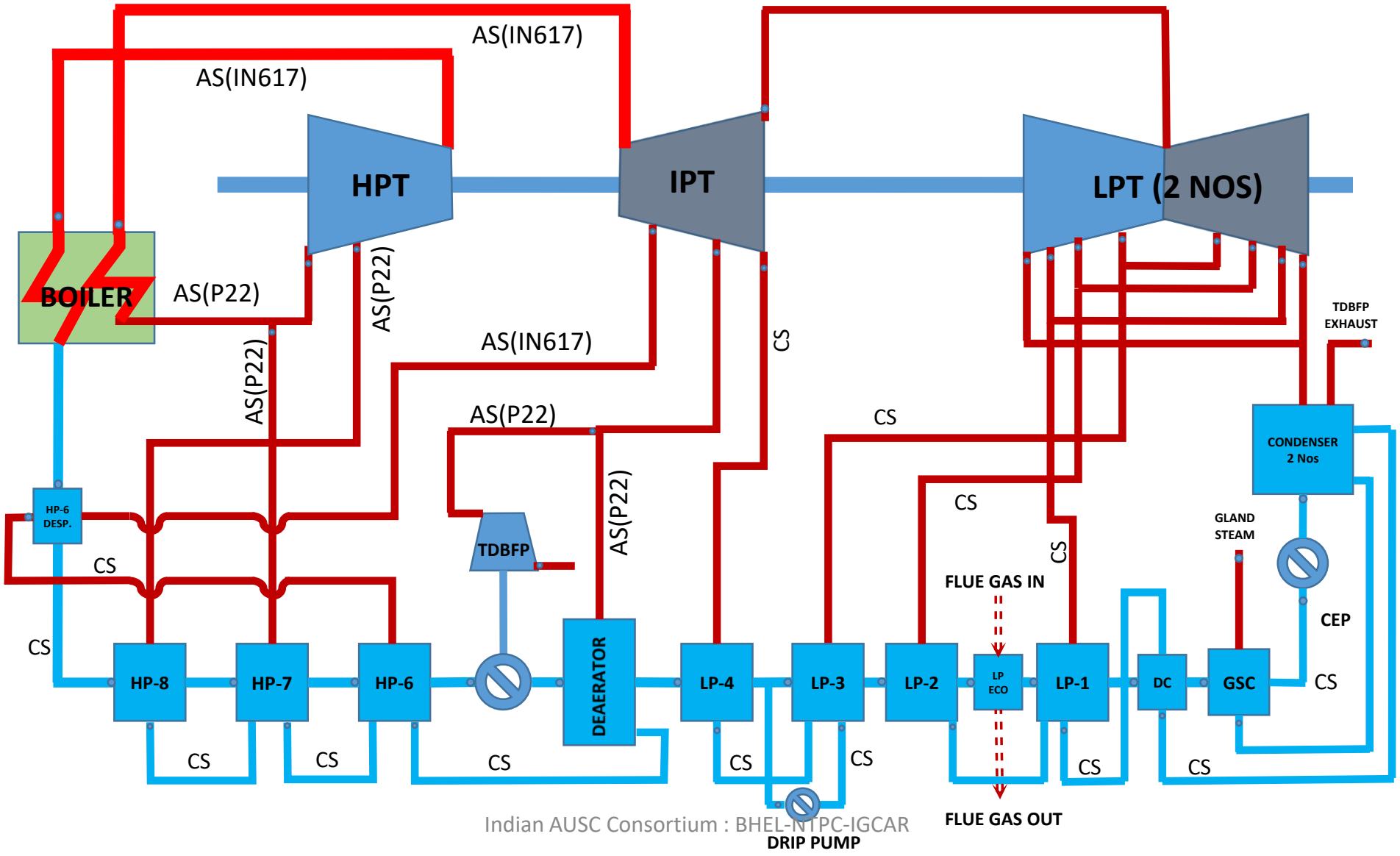
Stages of Development

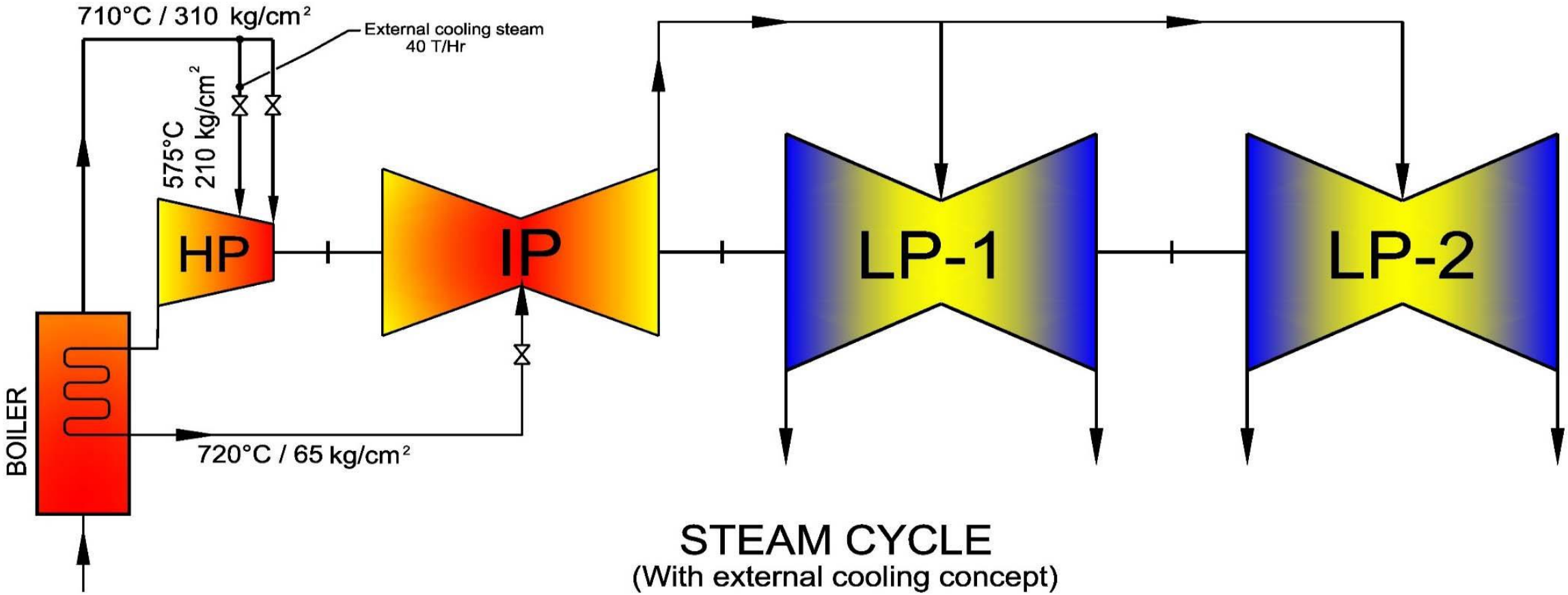
- Selection of steam parameters and optimization of steam cycle
- Design and development of equipment such as steam generator, steam turbine, feed water heater, system deign & layout
- Selection and development of materials, testing and evaluation under simulated conditions at existing or new plants
- Development of welding, welding consumables and fabrication technologies
- Manufacturing and Testing facilities to be established

Salient Parameters for Indian AUSC Project

Parameter	Value	Unit
Main Steam Temperature	710	°C
Main Steam Pressure	310	Kg/Cm^2
Main Steam Flow	1850	TPH
RH steam Temperature (Single Reheat)	720	°C
Reheat Pressure	65	Kg/Cm^2
Cooling water temperature	32	°C
Temperature rise across condenser	6.5	°C
Final Feed Water Temp	305	°C
Efficiency on HHV	46	%

800MW ADVANCED ULTRA SUPER CRITICAL THERMAL CYCLE





STEAM CYCLE
(With external cooling concept)

Material Selection Basics

***Adequate mechanical strength at high temperature such as Creep, tensile, LCF, structural stability leading to reduced effect of thermal aging**

***High temperature Corrosion and oxidation resistance (water chemistry important)**

***Weldability and machinabality**

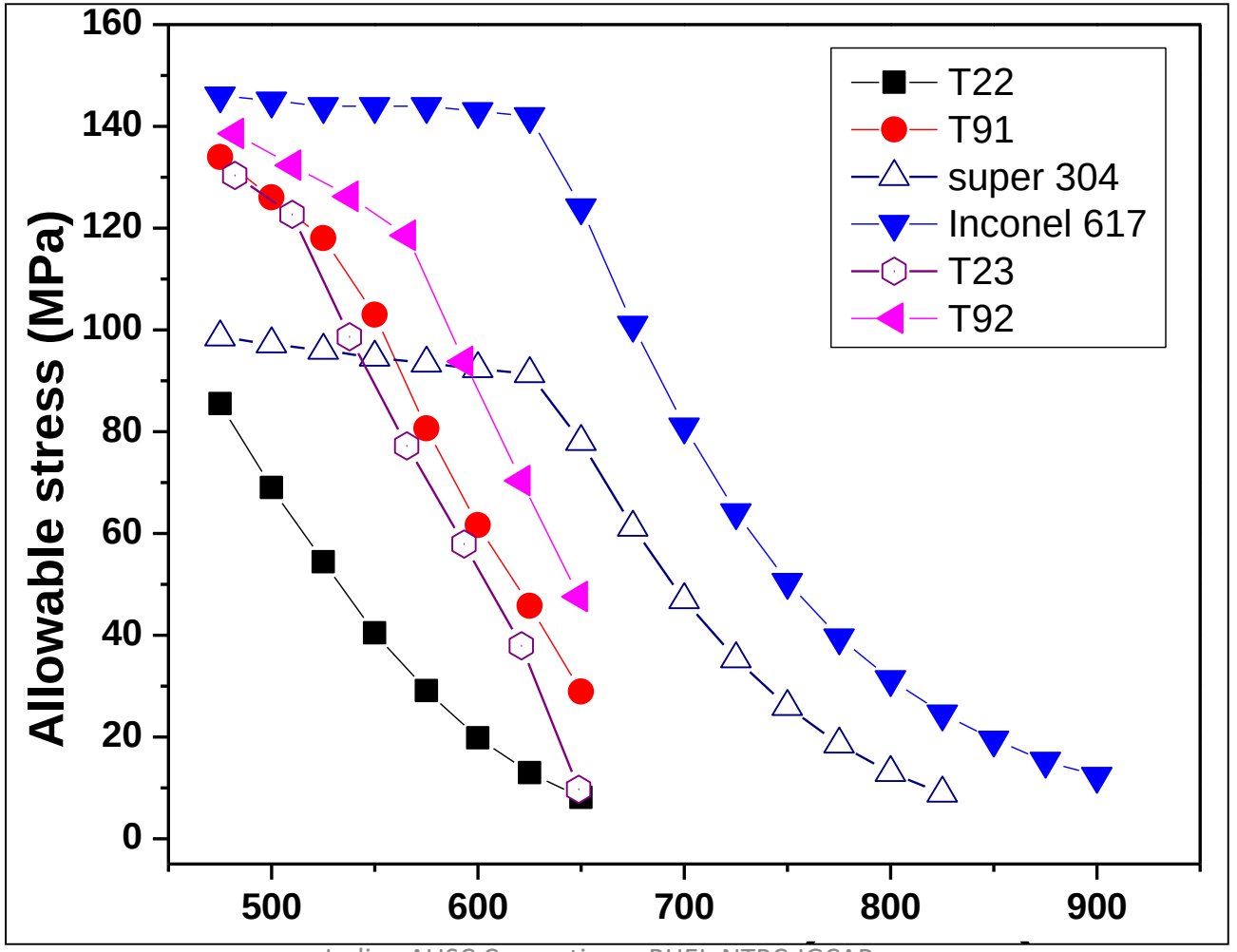
***Operating experience for similar application and design conditions**

***Availability of materials in required sizes**

***Inclusion in design codes and allowed by regulatory body**

***Overall economics**

ASME allowable stresses as a function of temperature for T22, T23, T91, T92, Super 304H & Inconel 617



Maximum Recommended Metal Temperature

- **Maximum recommended design metal temperature is governed by creep properties and corrosion behaviour(both steam side and fire side)**
- **Corrosion behaviour: loss in metal thickness, scale formation leading to increased metal temperature and concern for scale exfoliation.**
- **Maximum recommended design temperature for a few grades**

Grade	Maximum temperature C
T22,T23,T24	560-570
T91	590
T92	610
SS347	650
Super 304H	670 (Shot peened condition)
Alloy 617	750

Material for Evaporator tubes

Choice between T91 and T92 for boiler tubing as an a example

- **AUSC plant with tube design mid-wall temperature of 600C**
- **Benefit of higher admissible stress leading to lower tube thickness in case of T92 to be weighed against higher cost of T92.**
- **T92 will be around 13% lower in thickness.**
- **However, cost of T92 tubing is typically 20% higher than T91.**
- **Overall economics in such a case of boiler tubing is in favour of T91.**
- **Besides, there is an apprehension that formation of Laves phase (Fe_2W) & their rapid coarsening on long term exposure may decrease creep strength.**

Material for Steam Header

- **Steam header working temperature ~ 710°C.**
- **For AUSC main steam header, the materials could be either austenitic stainless steel or nickel base alloys.**
- **Super 304 H is not suitable due to temperature limitation.**
- **Solid solution strengthened nickel base Superalloy having adequate temperature capability for creep are suitable for the application.**
- **The relative thermal fatigue resistance for Inconel 617 will be far better than austenitic stainless steels.**
- **As such, Alloy 617 has been selected for the main steam header.**

Material for Casings

- **For hot portion of turbine casing, the choice for castings is primarily between Inconel 617 and Inconel 625.**
- **Inconel 617 is not included in ASME for castings and hence choice becomes Inconel 625 as it is included as material specification in ASME. (SA-494M Gr CW6MC)**
- **Limited experience available in the world for turbine casing in Inconel 625.**
- **Nickel base alloy-21Cr-9Mo-3.5Nb**
- **Material data to be generated for design for castings though data available in ASME for wrought products.**
- **Design is to reduce content of Inconel 625 in the turbine casing from economics, being very expensive material**

Materials for Indian AUSC - Boiler

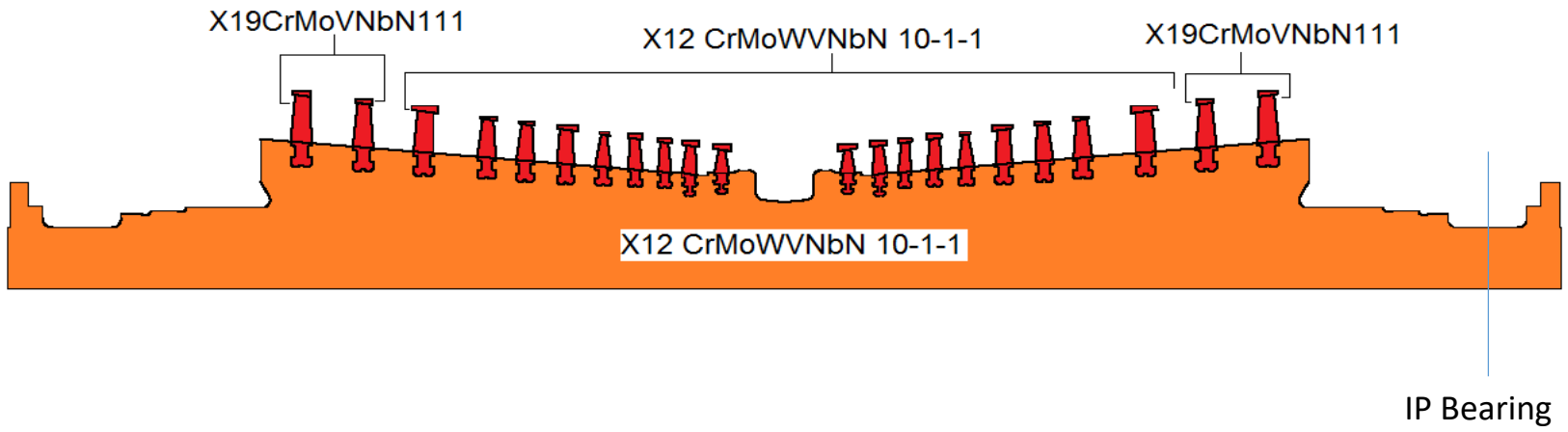
Component		Material
Header inlet	Superheater 1, 2, 3 and 4	P91, Alloy 617 AND Alloy 617
	Reheater 1.1 and 1.2	P22, alloy 617
Header outlet	Superheater 1, 2, 3 and 4	Alloy 617
	Reheater 1.1 and 1.2	Alloy 617
Pipes	Superheater 1	P91, Alloy 617
	Superheater 2	Alloy 617
	Superheater 3	Alloy 617
	Reheater 1.1	Alloy 617
	Reheater 1.2	Alloy 617

Materials for Indian AUSC - Turbine

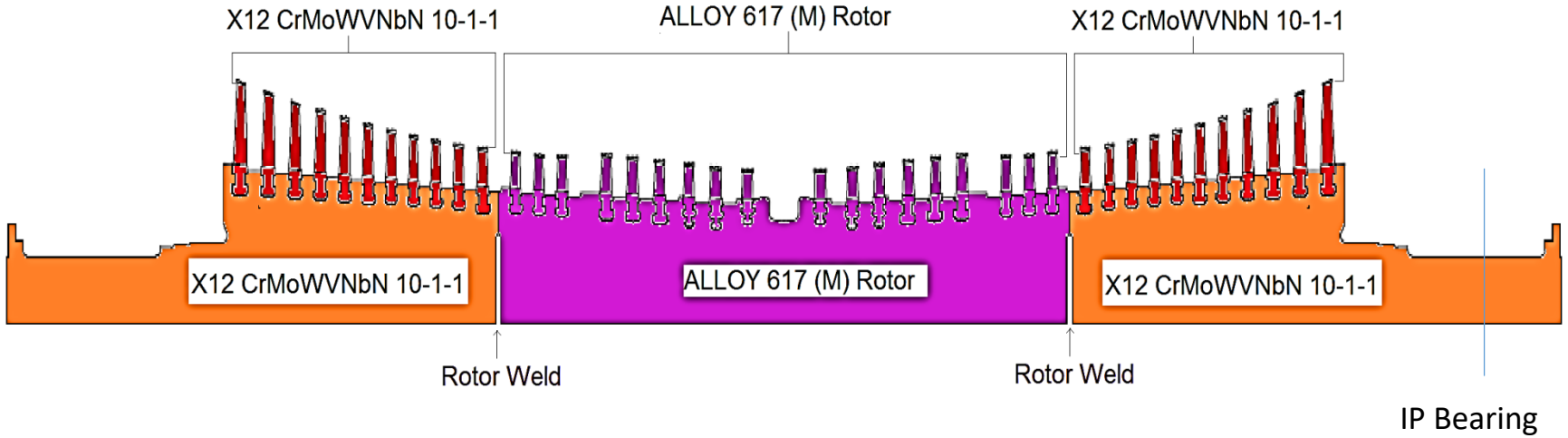
Component		Material
Casing	Outer Casing	HP-GP91 (GX12)+ A356(GS17)
	Inner Casing	Cast Alloy 625 welded with GP91 (GX12)
Valve	Casing	HP-Alloy 617M, IP-Cast Alloy 625
	Weld on ends	Alloy 617M
Rotor	HP and IP	Alloy 617M welded with 10 Cr
Blades	HP and IP	Alloy 617M, X12, X19, X22

COMPARISON ON 660 MWE SUPERCRITICAL ROTOR & 800 MWE AUSC IP ROTOR

660 MW Super Critical IP Rotor - Indian (Schematic)*

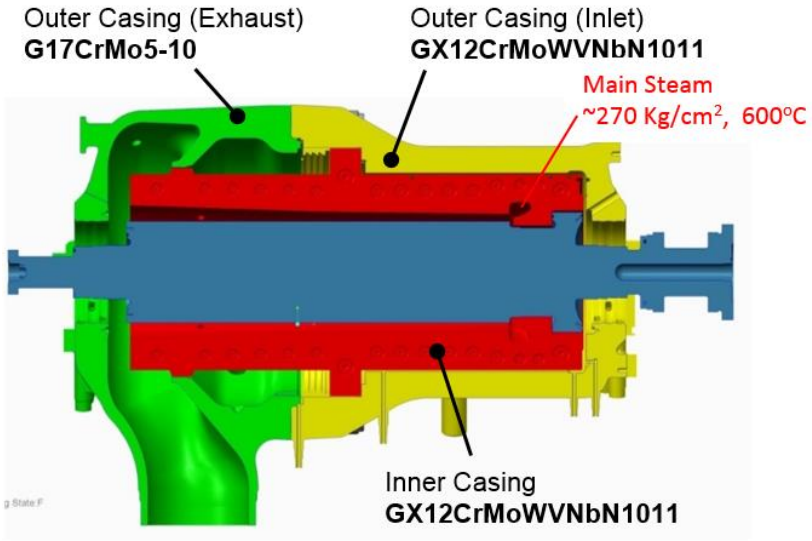


800 MWe AUSC IP Rotor (Schematic)*



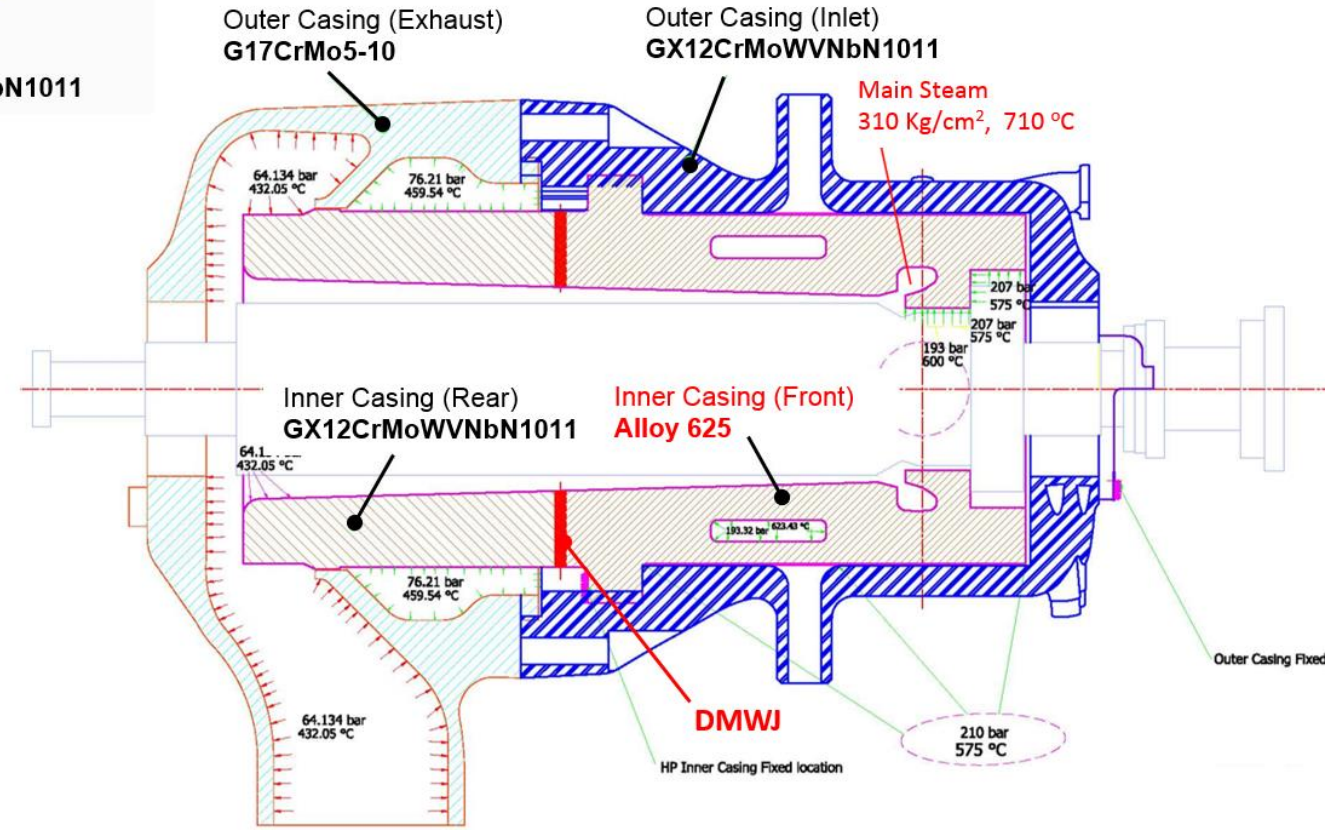
** The above schematic is for representation purposes only. Actual rotor configuration may vary from the depiction above*

HP Turbine Section Design – Material Comparison



USC Turbine Casings

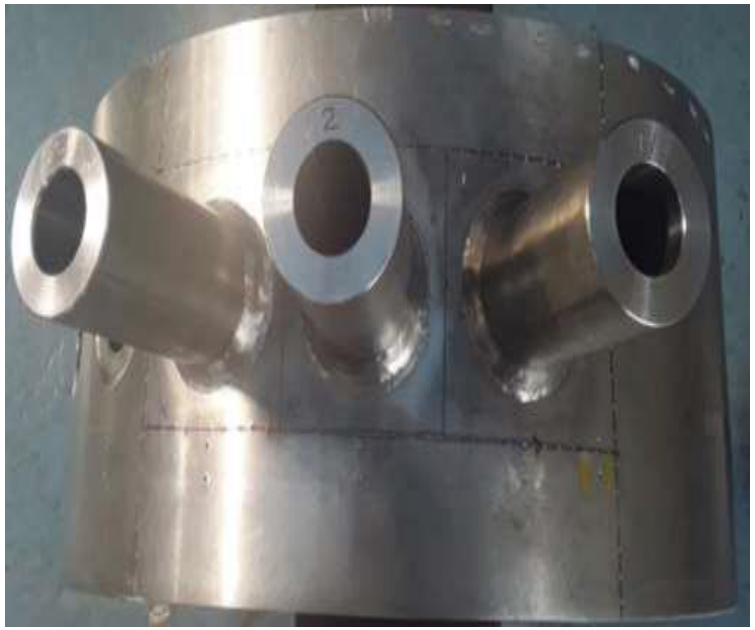
AUSC Turbine Casings



AUSC FABRICATION

Superheater Header

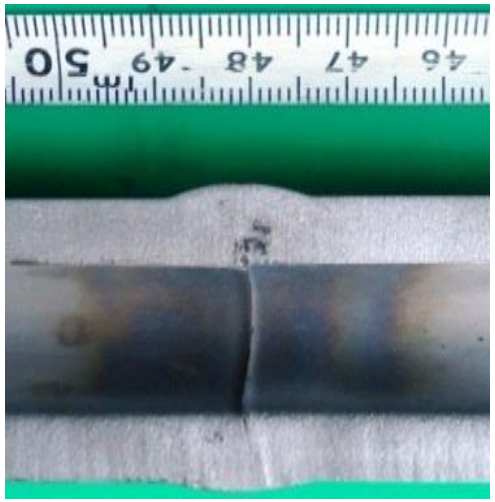
Alloy 617 Mock up SH header welding
Narrow Gap Hot Wire GTAW



Header pipe with Alloy 617stub weld
(Stub size – 51 x11.9 mm)
Inside - Mechanical TIG w/o filler wire
Outside -Manual TIG with filler wire

Header to Header Weld & Header to end Cover Weld (Header Size : 457 x 120 mm)

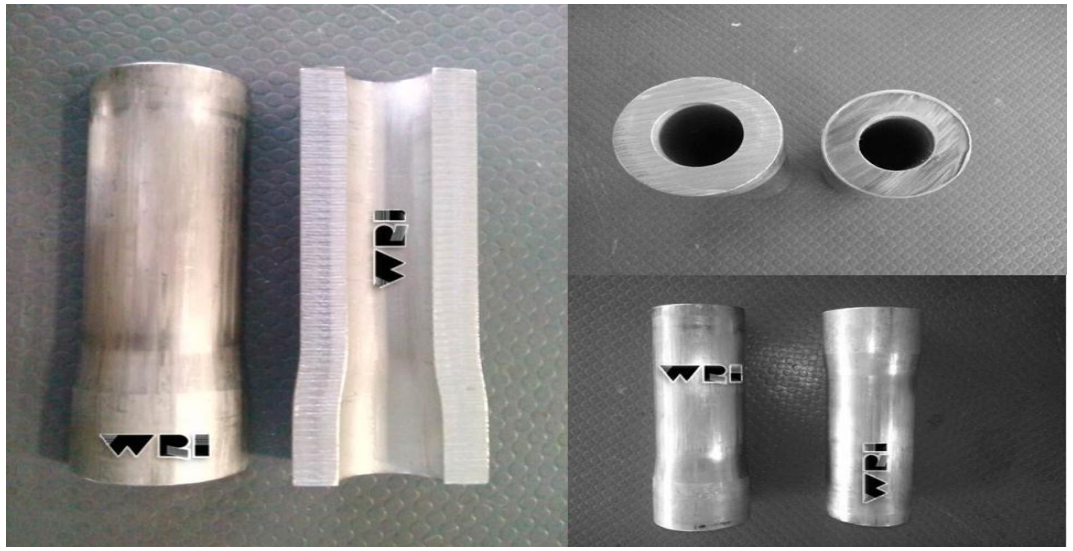
Tube bending & welding



Tube butt joint Super 304H, Inconel 617, Haynes 230

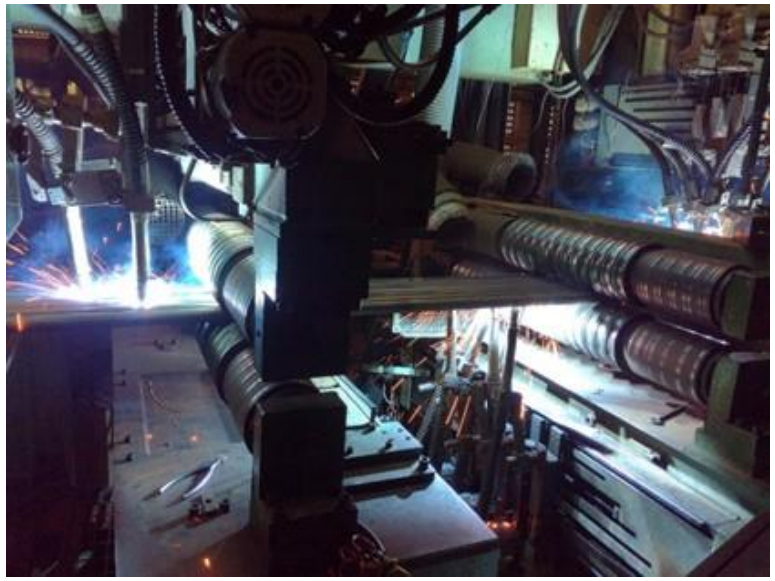
Cold Bending of Alloy 617 tubes for Dia 52 x 11.9 mm

Hot Squeezing of Alloy 617 tubes



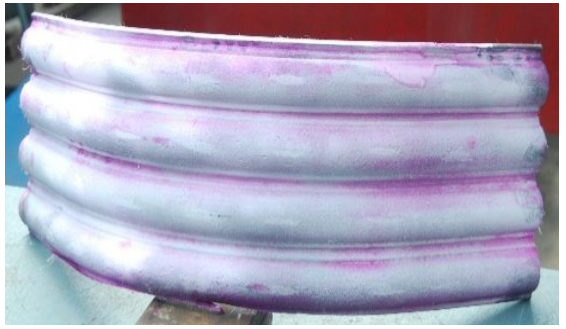
Cold Swaging of Alloy 617 tubes

Gr 91 Panel Fabrication



Gr91 Panel MAG Welding 20T Auto Welding

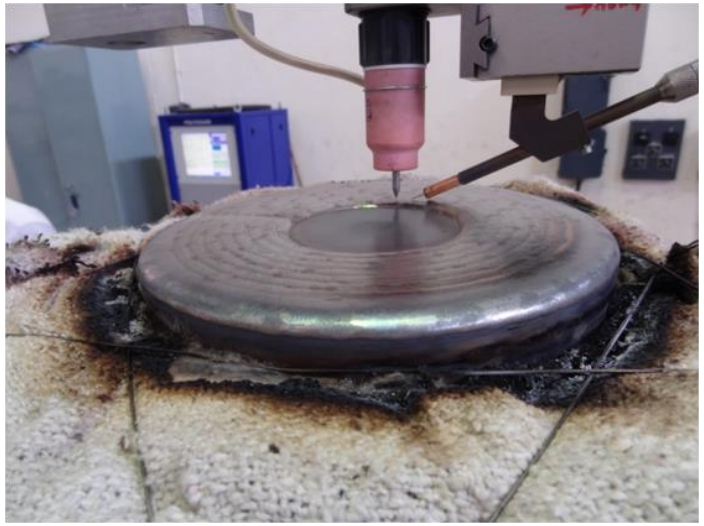
Welded Panel

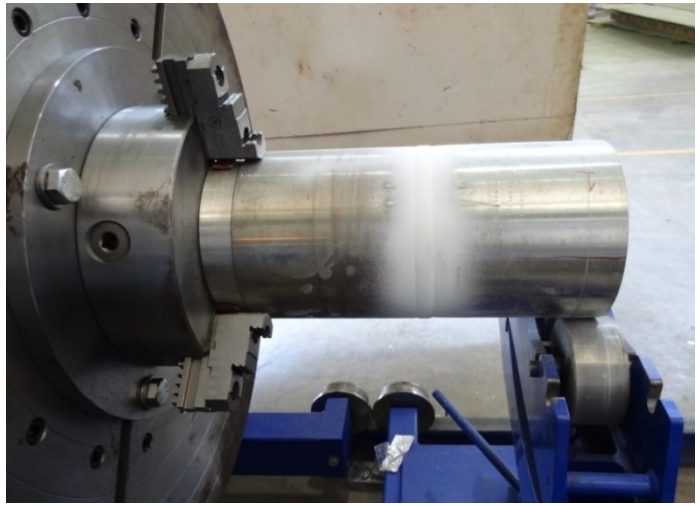


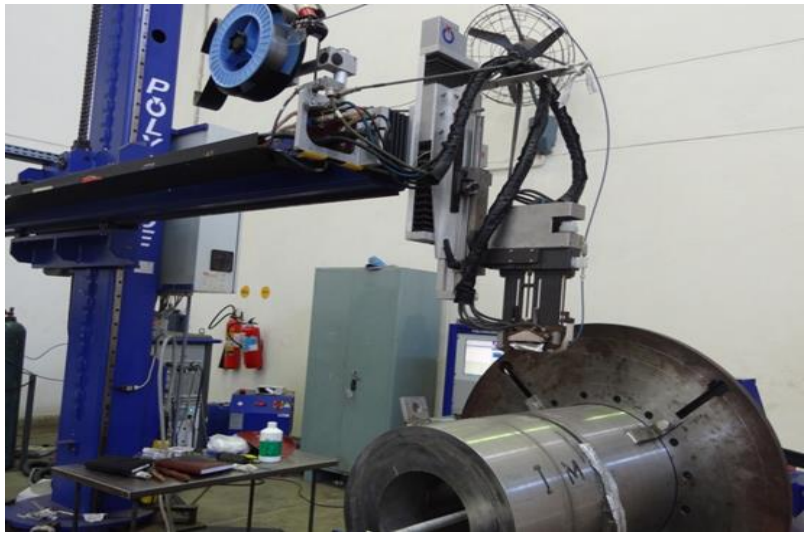
Gang Bending of Panels

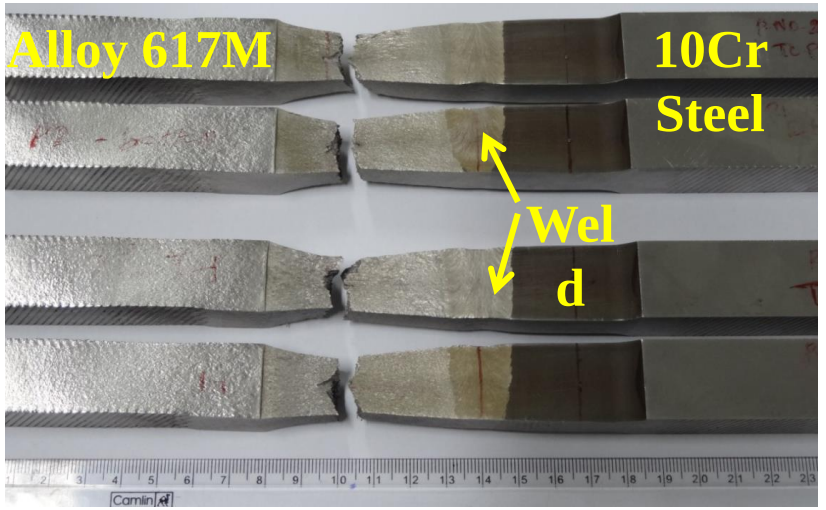
Spiral wall & Vertical wall Tubing

Bimetallic Rotor Mock-up Welding





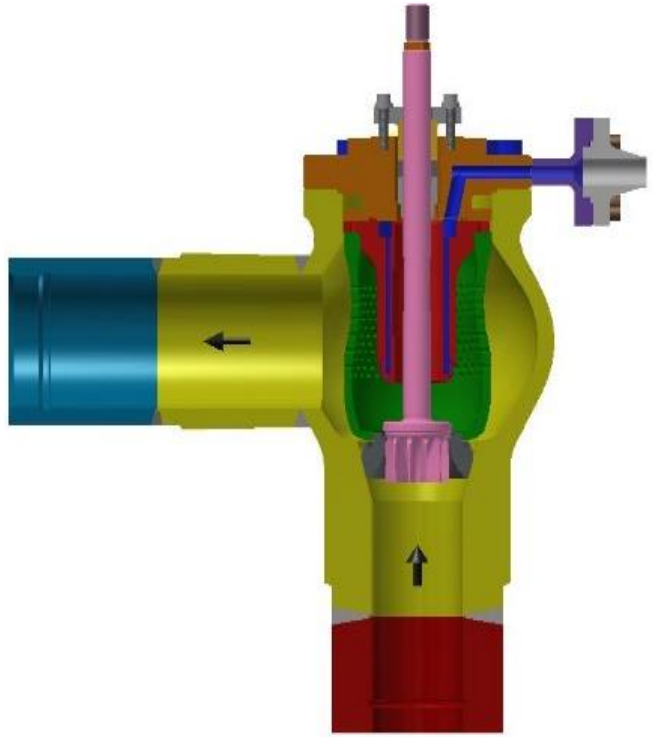




Development of High Pressure Bypass Valve for HP turbine

Highlights :

Parameter	Upstream	Downstream
Pressure, $kg/cm^2(g)$	337.5	78.3
Temperature, °C	718	650 (Transient)



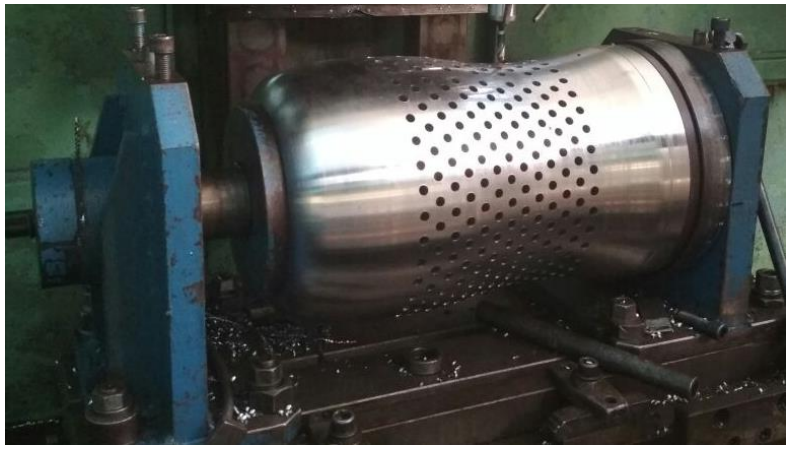
- Pressure testing 1.5 time design pressure ~ 506 Kg/Cm^2
- In-house Design
- Indigenous manufacturing with Nickel alloy 617M.
- Valve seat stellite coated by PTAW process
- Valve stem Chromium coated by HVOF process
- Completion Target Dec 2017

HP Valve components under manufacturing

Inconel 617

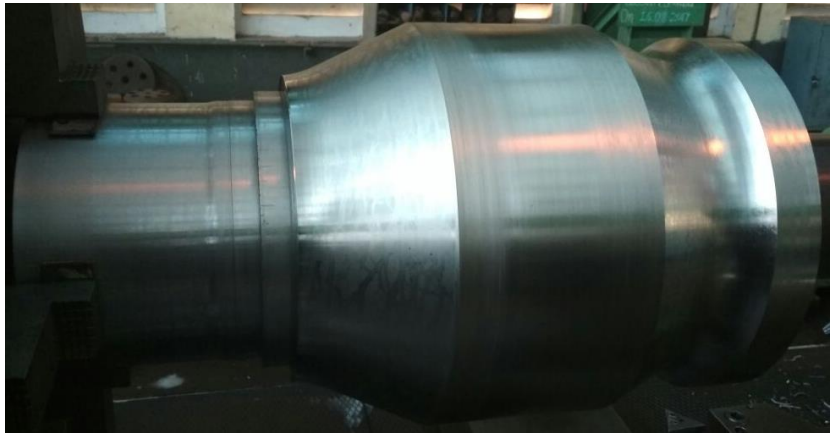
F91

F22



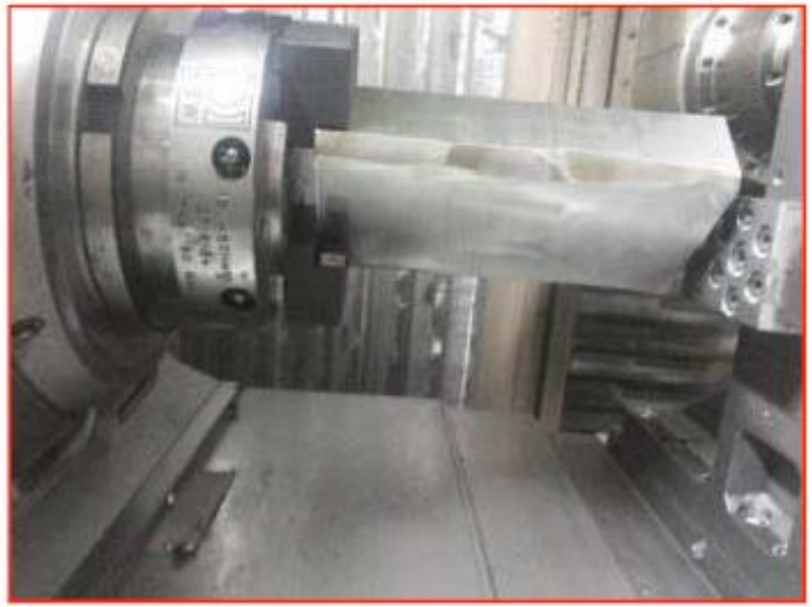
Jetcage

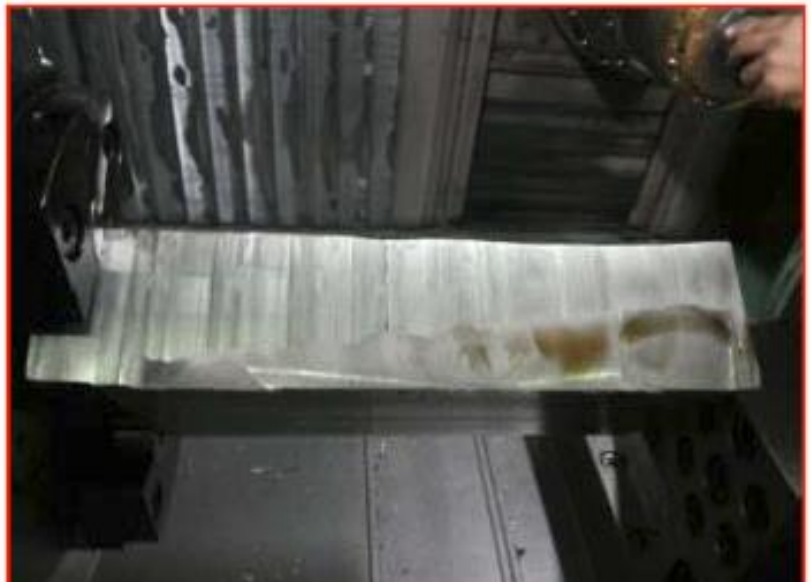
Outlet Nozzle



Body

Machining of blade in 5-Axis Machine with various tools





Material Testing on AUSC materials

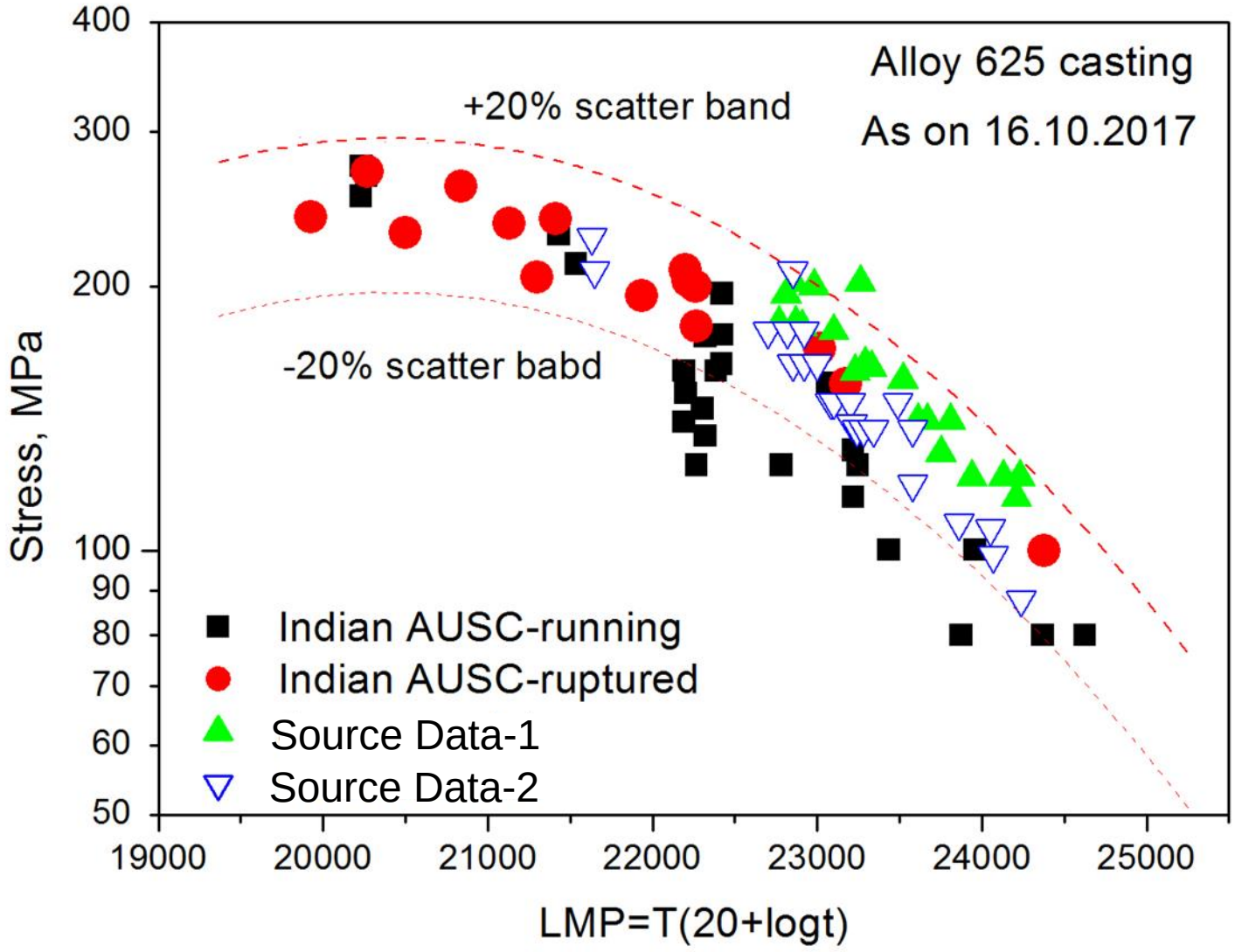
Exhaustive Material Testing Programme is under progress at different labs of IGCAR, BHEL, NTPC & MPA, Stuttgart.

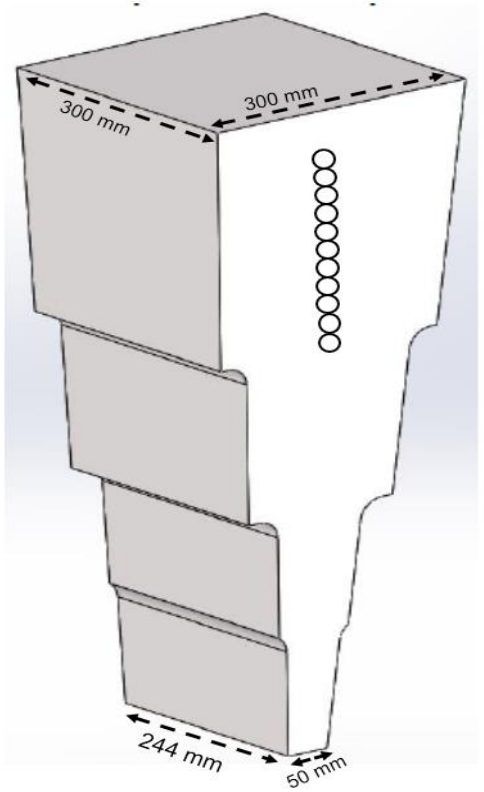
Broad categorization of the tests:

- **Hot tensile tests upto 750°C**
- **Creep properties for design data evaluation at specified stress level & for design temperature of 700°C for $1.5x10^5$ hours through accelerated short term**
- **Creep properties for material properties evaluation through accelerated short term for Norton Bailey Coefiicient, Isochronus Stress-Strain curves etc.**
- **Creep Deformationproperties upto 10000 hours & beyond**
- **Low cycle fatigue at various strain ranges upto 720°C**
- **High cycle fatigue UPTO 700°C**
- **Creep-fatigue interaction**
- **Round Robin Testing of Tensile, creep & LCF at IGCAR, BHEL, NTPC & MPA**
- **Microstructural stability study on thermal, creep and fatigue exposures**

Creep testing on alloy 625 casting

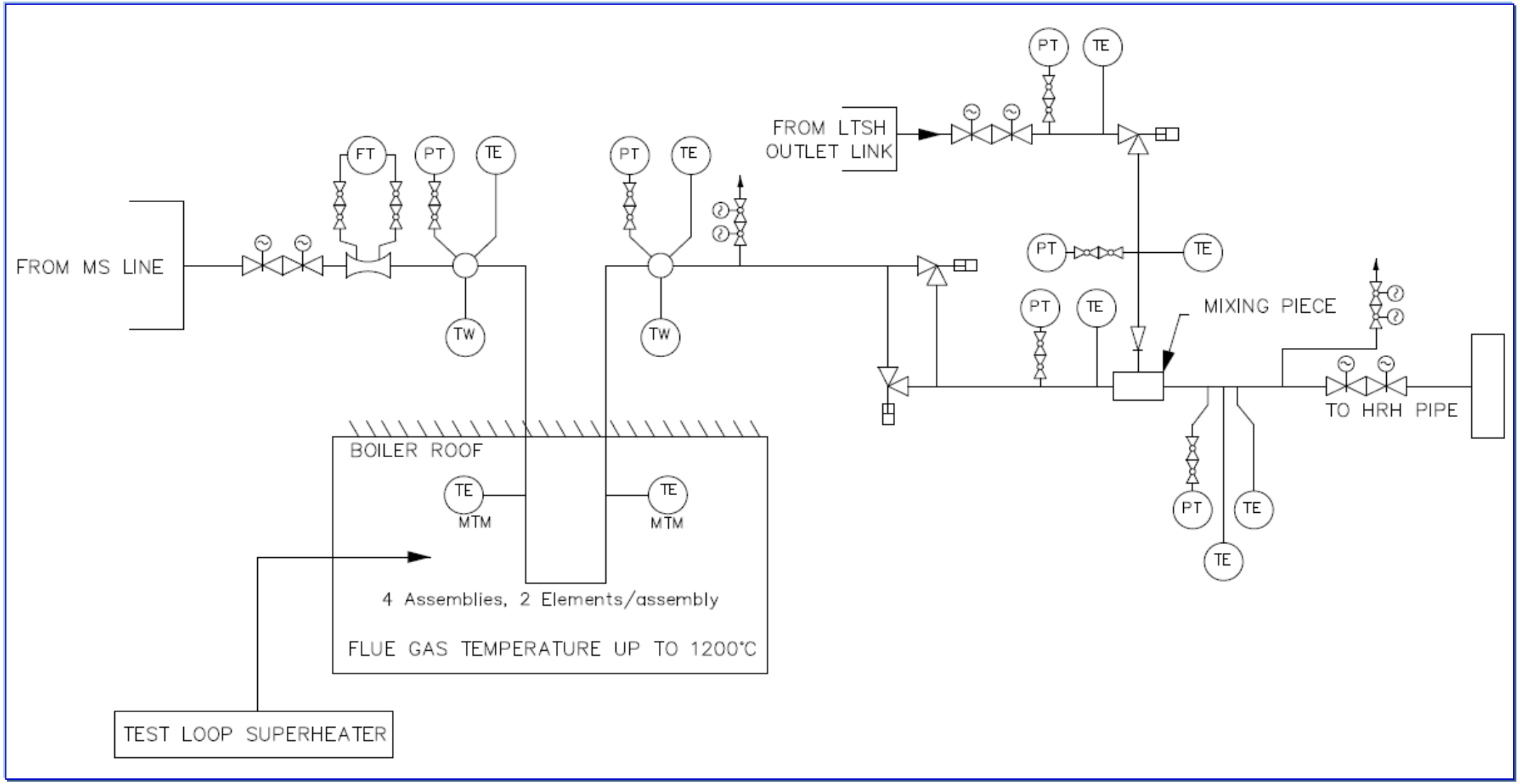
Testing institute: BHEL R&D, NTPC NETRA & IGCAR





42 tests at different stages of completion, some short term tests are completed. Preliminary results show that the cast has creep rupture strength Comparable to those reported by Japanese and Goodwin Castings.

Fire Side Corrosion Test Rig – Schematic

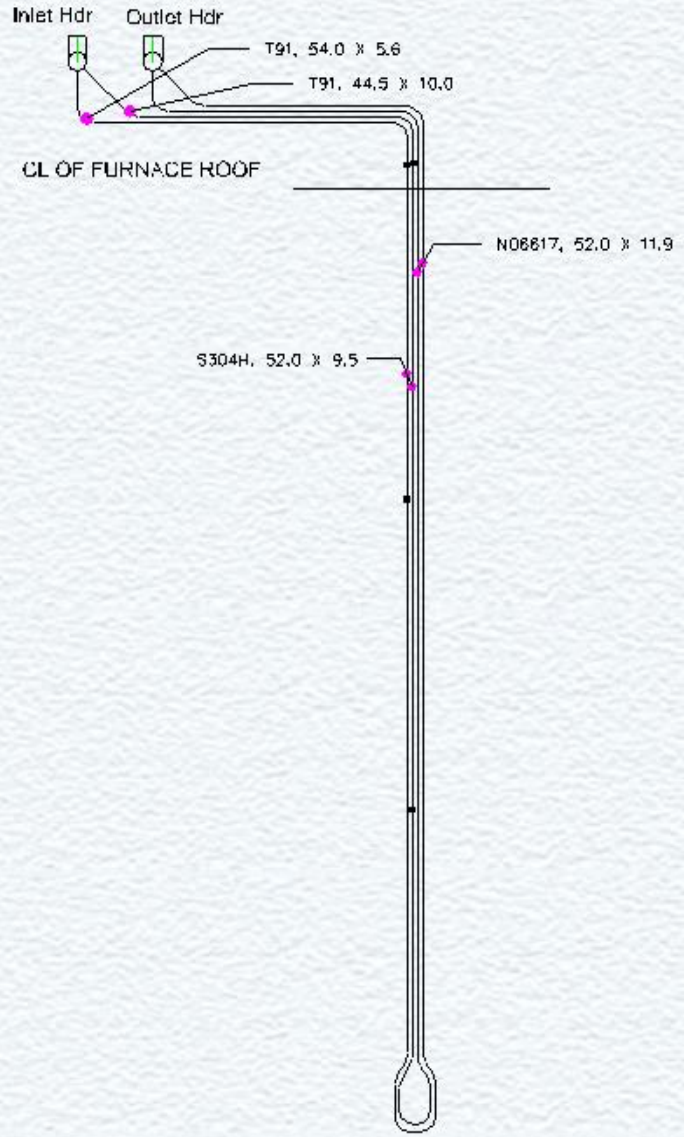


Test loop for testing the Fire-side Corrosion property of Advanced Materials (Super 304H & Inconel 617)

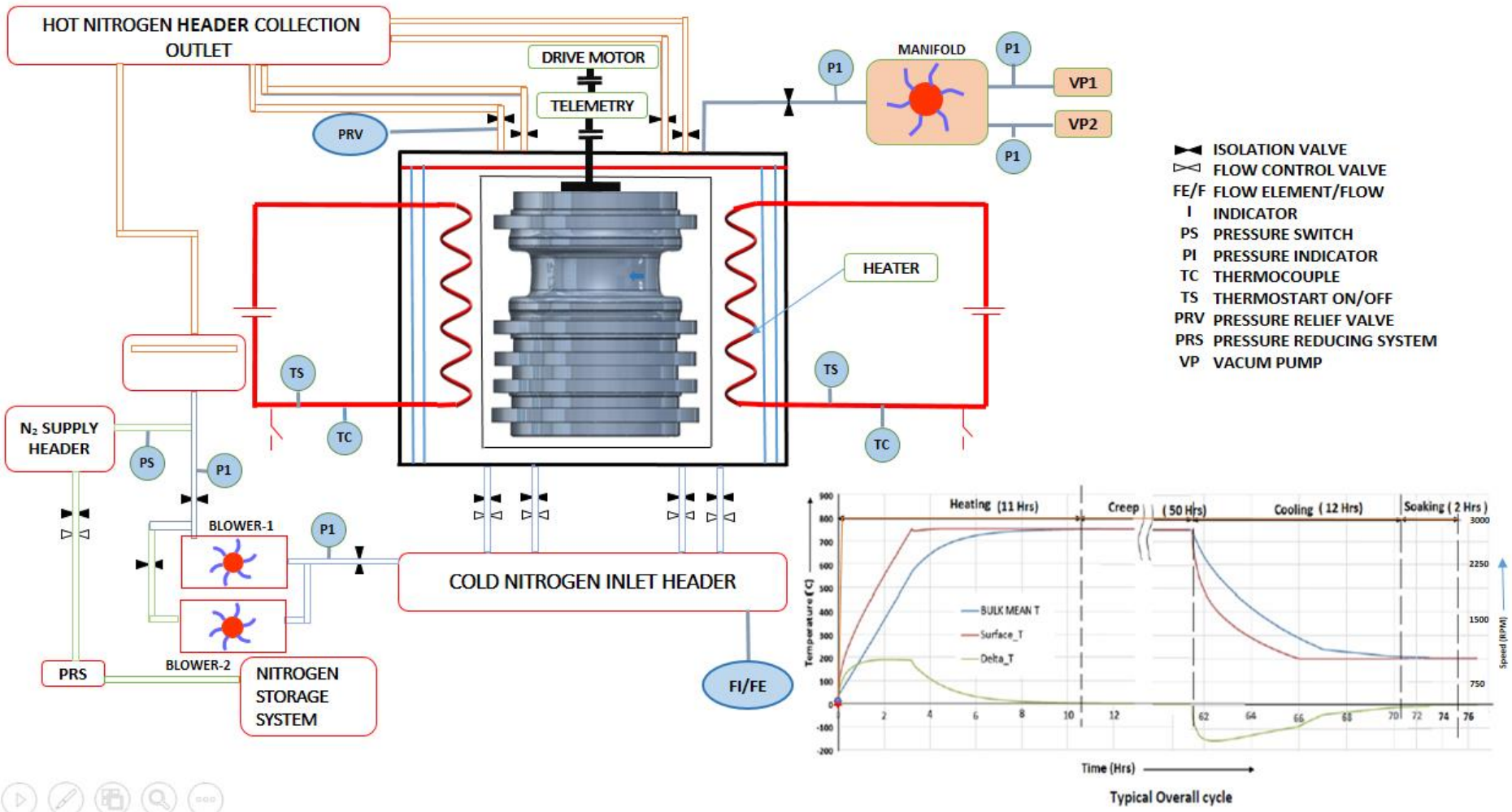
- The test loop will be placed in the open upper furnace of 210 MW unit which is in Radiation zone
- NTPC Dadri 210 MW boiler is identified for incorporating the test loop

Test Loop Tubing

TEST LOOP TUBING		
Tube OD, mm	Thk., mm	ASME Spec.
52.0	11.90	NO6617
52.0	9.50	SA 213 S304H
54.0	5.60	SA 213 T91
44.5	10.00	SA 213 T91
No. of Assemblies = 4 No. of elements per assembly = 2		



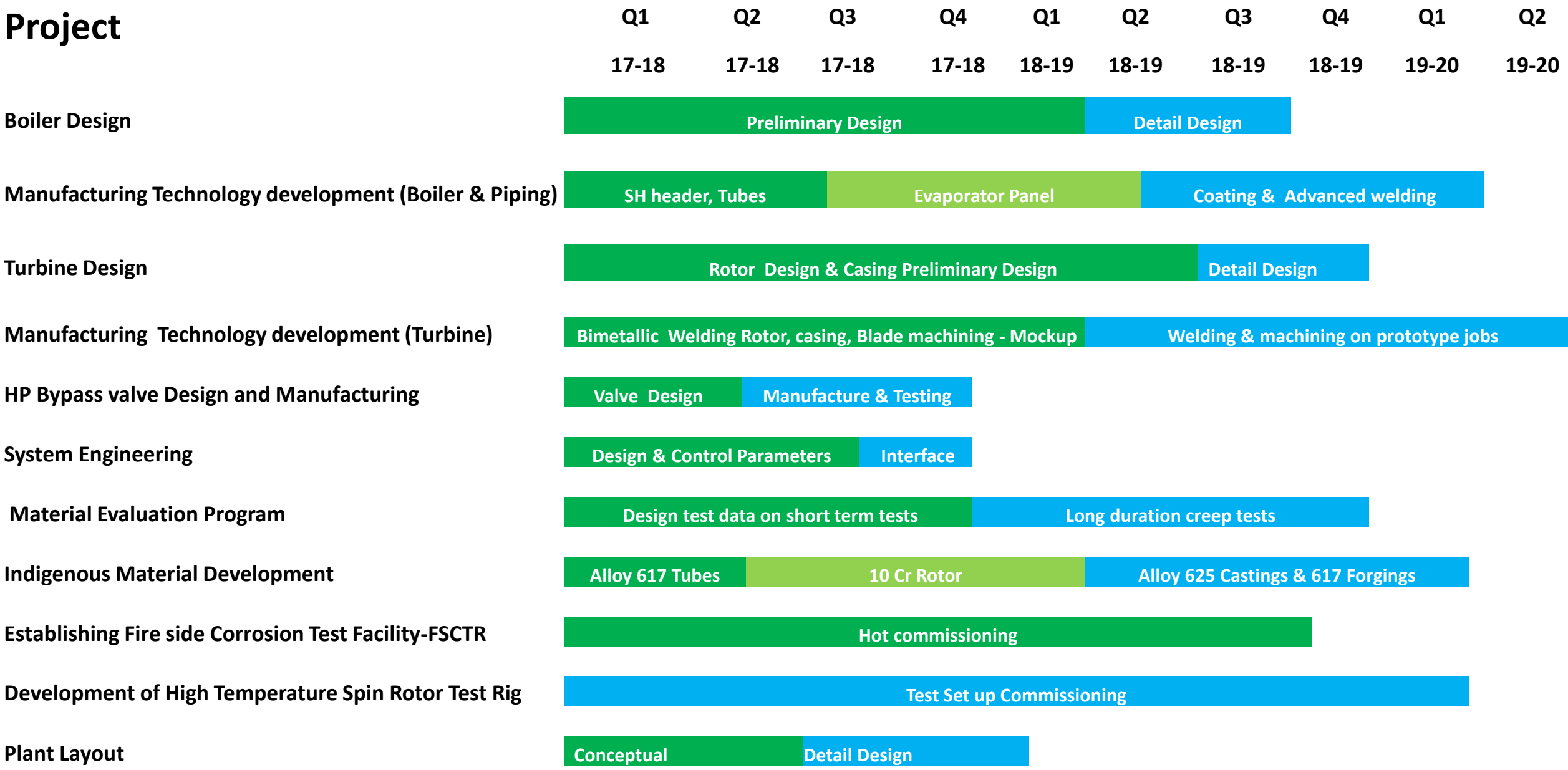
Schematic Arrangement for High Temperature Spin Test Rig



Cost Economics of AUSC technology

- **Design to minimize usage of expensive Nickel base alloy**
- **Turbine layout- HP turbine on different floor and IP-LP on different elevation for overall economy to reduce the cost associated with Inconel 617 piping**
- **Bimetallic rotor and casting.**

Project Schedule



Thank you!