Fusion technology development in India to ensure ITER deliverables ^{ID:1341} M.J. Singh^{1,2}, Ujjwal Baruah^{1,2}, A.K. Chakraborty^{1,2}, Girish Gupta^{1,2}, Ajith Kumar^{1,2}, Vinay Kumar^{1,2,3}, Aparajita Mukherjee^{1,2}, Hitesh Pandya^{1,2,3}, Shrishail Padasalagi¹, S.L. Rao^{1,2}, N.P. Singh^{1,2}, Rajesh Kumar Trivedi^{1,2}, Hitensinh Vagehla^{1,2}, Indranil Bandyopadhyay^{1,2,3} ¹ITER-India, Institute for Plasma Research, Gandhinagar ²Institute for Plasma Research (IPR), Gandhinagar 382428, India ³ Homi Bhaba National Institute (HBNI), Mumbai 400094, India mahendrajit@iter-india.org

ABSTRACT

- Indian domestic agency contributes nine procurement packages to the ITER machine.
- R&D route to manufacturing through prototypes
- Dedicated laboratories to test Cryolines, ICRH sources, Diagnostic neutral beam line parameter establishment, integrated performance of ECRH sources, Power supply and ITER diagnostic development
- Till date more than 90% manufacturing of components related to supporting first plasma operation completed and include cryostat, cooling water, cryolines and cryodistribution and vacuum vessel in wall shields

R&D PERFORMANCE INTENSIVE SYSTEMS ITER India LAB

SOURCES FOR ION CYCLOTRON RESONANCE HEATING (ICRH)

Indigenous development of 3 dB hybrid combiner to demonstrate 2.5 MW/VSWR 2:1/36-60 MHz/CW using two amplifier chains. Tested in splitter mode to with one 1.5 MW amplifier chain



The technological developments and the laboratory R&D activities and the present status of each of the nine procurement packages is presented and discussed.

CHALLENGES, METHODS & IMPLEMENTATION

- Several first of kind components large size, special material, tight tolerances and quality and safety requirements as per applicable codes and standards
- R&D activities in several institutes, relevant industries, experiments in ITER India laboratory

CRYOSTAT

- Manufacturing activities at L&T Hazira India ended in Nov. 2020 • Base section, lower cylinder and upper cylinder assembled at ITER India workshop at ITER site section the • Base first component to be installed in the TOKAMAK pit as per desired tolerances
- The lower section, placed on the base section and ~ 100 m welding circumferential implemented



Activities continue in the ITER workshop towards assembly of top lid segments

	Power level (kW) (c)						_				
Frequency (MHz)	Input power ~1000kW at Port 3			Input power ~1500kW at Port 3			-		150	oluv.	
	Output power Port 1	Output power Port 4	Isolated port power Port2	Output power Port 1	Output power Port 4	Isolated port power Port2	-2.50			VNA_S13	(d)
36	466	565	4.10	708	856	6.13	- (m) -2.70 -2.80 -2.90	-			
40	487	543	1.17	734	812	1.89	E -3.00		**		
45	508	524	2.08	766	788	3.76	-3.20 -3.30				-
50	507	511	0.37	769	777	0.56	-3.40	*			
55	513	532	0.60	763	802	1.07	35	40) 45 Free	50 Juency (MHz)	55
60	470	531	3.10	703	803	4.83	- <u>L</u>				

DIAGNOSTIC NEUTRAL BEAM (DNB) COMPONENTS

Steady progress in the manufacturing of the DNB components

Compressive strain (Extension) [mm/mn

- Auxiliary systems for Indian test facility (INTF) under installation and integration in DNB lab
- Experiments on ROBIN restart after a disassembly, cleaning and reassembly operation. Cs to be injected in coming months

MANUFACTURING EXPERIENCES

Hot Helium leak tests failure led to ED layer characterization Reduced mechanical strength at elevated temperatures



0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2 essive strain (Extension) [mm/mm

Problems encountered with EBW over 30 mm depth for U shaped connector welding to residual ion dump panels

COOLING WATER SYSTEM

• >90% of the deliveries effected and accepted by ITER



Pipe in pipe concept to accommodate thermal expansion in buried piping

Cooling tower FRP structure



- Several trails with different configuration and EBW parameters unsuccessful ; Lack of fusion, fissures
- Alternate configuration tests currently underway







INTEGRATED TESTING OF EC SOURCES

170 GHZ 1 MW gyrotrons currently under factory acceptance tests at M/s Gycom Russia Facility in ITER India laboratory to perform integrated tests ready and interfaced with auxilliaries



at the ITER site





DIAGNOSTIC SYSTEMS FOR ITER



Installation of the group-Y cryolines, warmlines and their supports - Area 53

Cold circulator cartridges under inspection at IO

- A total of 16 circuits of Group Y cryolines and 48 circuits of warmlines have been successfully pressure tested in Cryoplant area using gaseous nitrogen with the last test being performed for longest circuit of WDH-1 warmline on during the first quarter of 2021
- The largest of the seven distribution cold boxes, the 20 m long, 3.5 m diameter and 70 tonne cryoplant termination cold box (CTCB) has been manufactured, assembled and installed at ITER

IN-WALL SHIELDS FOR VACUUM VESSEL



ACKNOWLEDGEMENTS

- blocks manufactured and assembled :tolerance range 0.1 – 0.15 mm
- Corrosion properties of IWS material studied using electro-chemical immersion technique and polarisation techniques
- 100% IWS components successfully manufactured and delivered to KODA and EUDA for their installation in the vacuum vessel sectors

All participating industries, research institutes and scientific and technical staff at ITER India and ITER IO



- Negligible loss in transmission for signals from ECE diagnostic for relative humidity values upto 1% • Development of a prototype polariser splitter unit for ECE diagnostic
- Development and Qualification of Boron Carbide (B4C) as a Neutron Shielding Material
- Modifications in the design of XRCS-Edge system in Upper Port -09' include a cut out through DFW and DSM in the UP 09 port plug, a 1.5 m long pipe evacuated sight tube for X-ray transport and Be window as primary vacuum barrier and operational barrier

RF GENERATOR AND MULTI MEGAWATT POWER SUPPLIES

Scenario development and operational	Indigenous 40 kW solid state	3 MW operation supported		
support to 100 kV power supply	RF generator development	by Dual output ICHVPS. 70		
operations at SPIDER, RFX Padua	Configuration optimization	hours of operation		
Issues resolved through experiment	through operation on ROBIN	Confirmed final specification of ICHVPS for IO deliveries		
/simulation on the Indian test bed	and TWIN –ve ion test beds			