SST-1 Status & Plans

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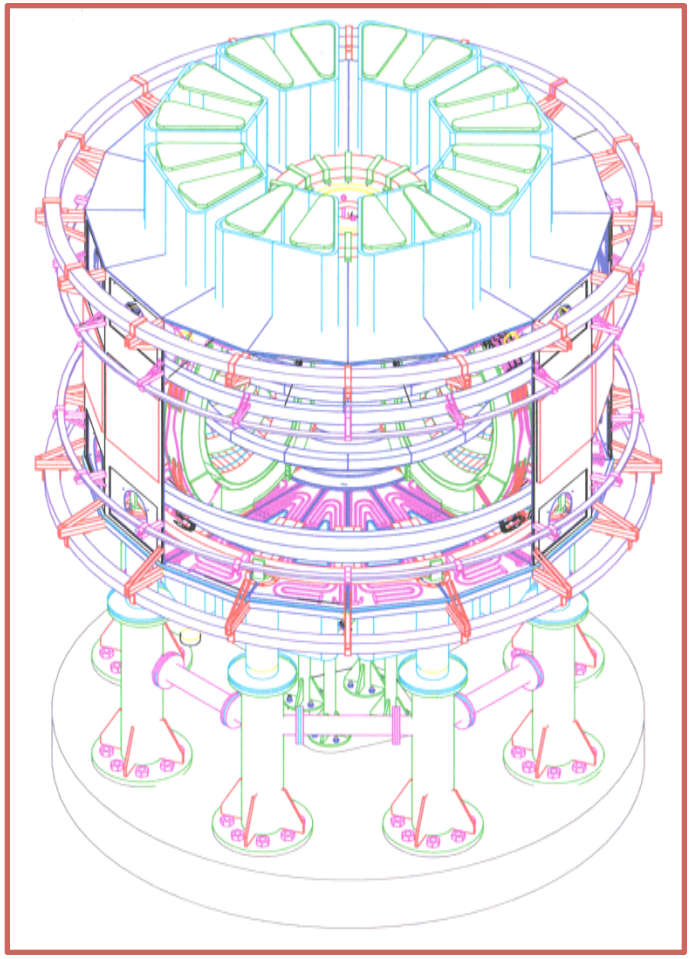
SST-1 Tokamak

SST1 MACHINE PARAMETERS

MAJOR RADIUS	:	1.1 m
MINOR RADIUS	:	0.2 m
ELONGATION	:	1.7-2
TRIANGULARITY	:	0.4-0.7
TOROIDAL FIELD	:	3T
PLASMA CURRENT	:	220 kA.
ASPECT RATIO	:	5.2
SAFETY FACTOR	:	3
AVERAGE DENSITY	:	1×10^{13} cm^{-3}
AVERAGE TEMP.	:	1.5 keV

PLASMA SPECIES	:	HYDROGEN
PULSE LENGTH	:	1000s
CONFIGURATION	:	DOUBLE NULL
	:	POLOIDAL DIVERTER
HEATING & CURRENT DRIVE:		
LOWER HYBRID	:	1.0 MW
NEUTRAL BEAM	:	0.8 MW
ICRH	:	1.0 MW
TOTAL INPUT POWER	:	1.0 MW
FUELLING	:	GAS PUFFING



ISOMETRIC CUT- VIEW OF SST-1

Commissioning of SST-1 Tokamak was partial & could NOT be completed in the earlier attempts.

SST-1 Project had targeted some broad physics & technology objectives

- Plasma characteristics in long pulses (steady state)
- Non-circular plasma studies
- Ohmic to CD (LHCD) assisted plasmas
- Feedback & Control physics in steady state plasmas
- Diverter physics in steady state plasmas
- Wall saturation studies in steady state plasmas etc

- Large Superconducting magnet technologies
- Large size cryogenic technologies
- Large size vacuum vessel associated technologies
- High Heat flux handling technologies
- Large AC/DC power supplies
- Auxiliary steady state heating technologies

Continuing, starting Jan 2009, SST-1 refurbishment has been recognized & accepted as a Mission

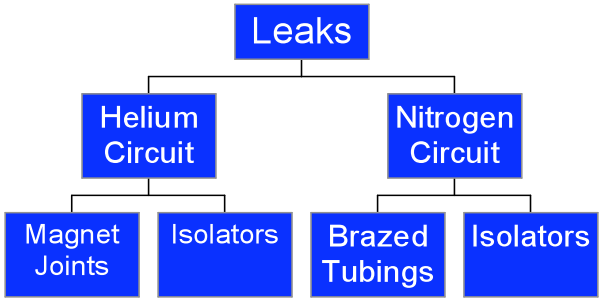
Mission Objectives (immediate)

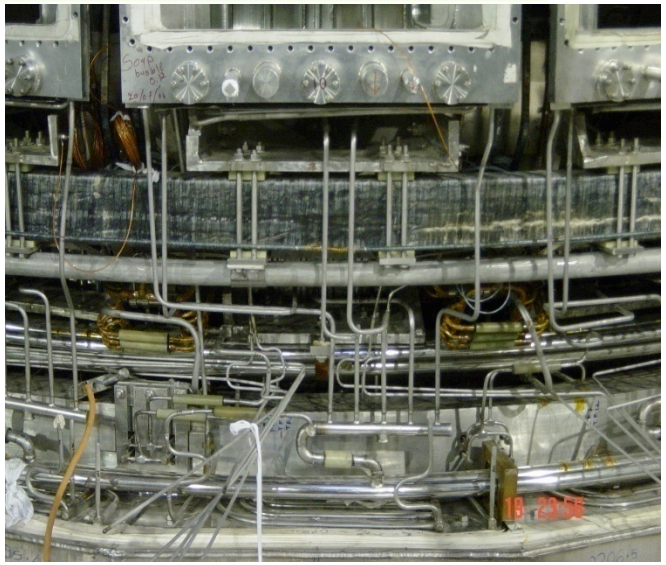
~100 kA, limiter assisted circular plasma with superconducting TF magnets & PF Magnets (plasma breakdown with V-s of OT system, equilibrium by BV magnets, expected duration ~ 300 ms TF field ~ 1.5 T, q ~ 3

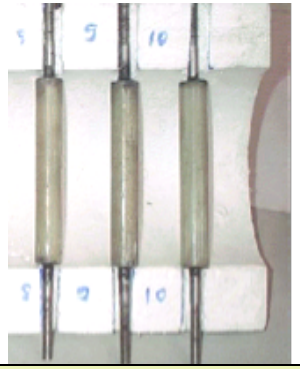
Prior to first plasma

- **All 16 assembled series connected TF Magnets Test in SHe flow (4 bar, 4.5 K, 1.25 g/s at inlet) producing 3 T at R =1.1 m & 5.1 T on the conductor without any Plasma but assembled in a cryostat vacuum of 10^-5 mbar or better.**
- **All SC PF magnets test in some envisaged operational scenario currents and ramp rates in SHe flow (4 bar, 4.5 K at inlet) & investigating the influence of reflected voltages on the magnets as well as on the PS**

Major SST-1 problem areas
(concluded from last campaign)







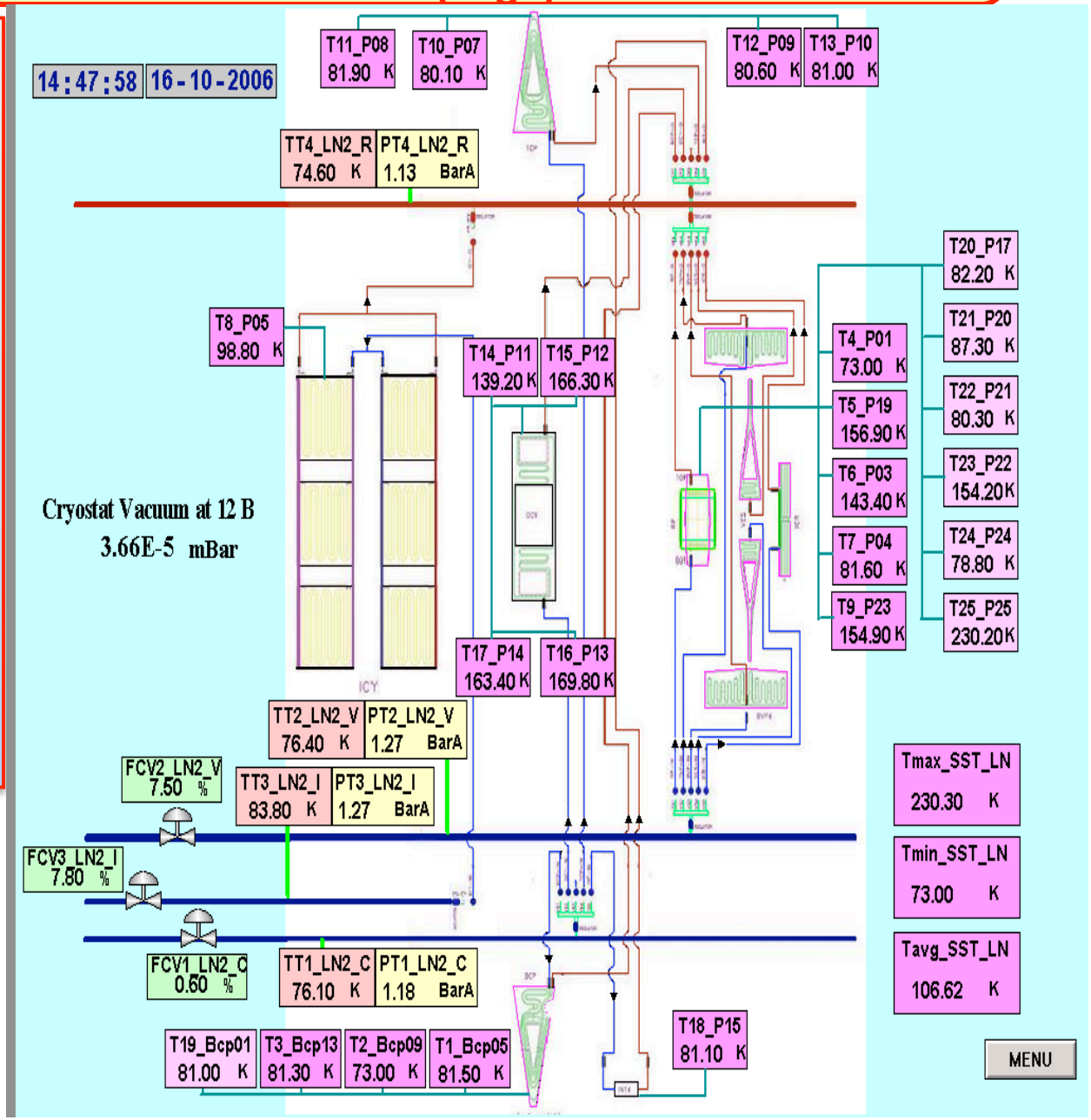
Leaks are unforgiving in a superconducting Tokamak & limits operations

SST-1 problem areas

(concluded from last campaign)

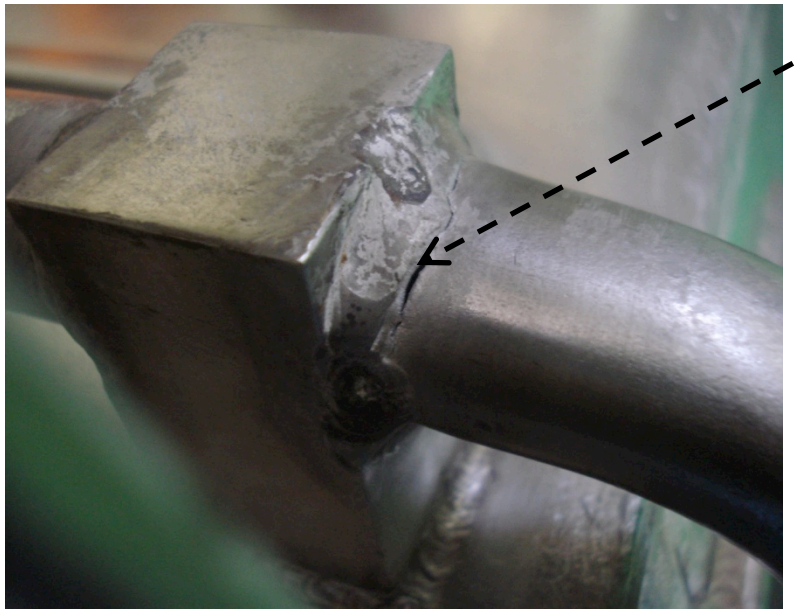
- Flow imbalances between various branches of the Nitrogen Circuit (Thermal Shield)
- Higher heat load on the Magnet System from the thermal shield.

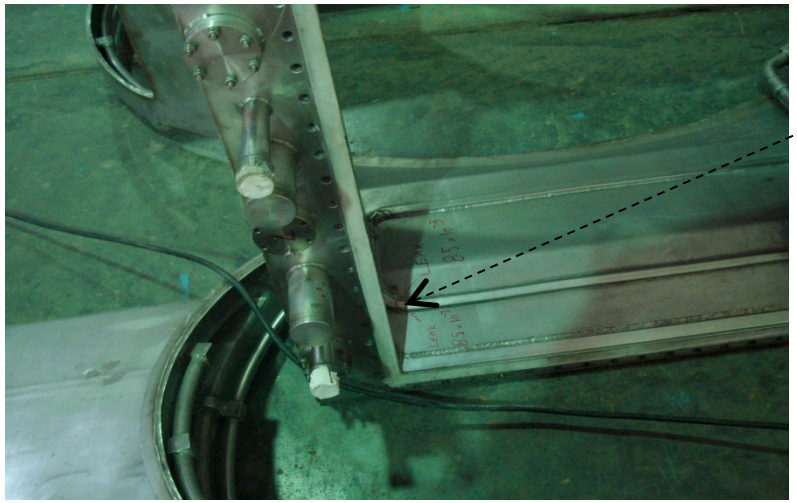
Flow imbalance & higher Temperature gradients in Thermal Shields are NOT Acceptable in a Superconducting Tokamak



SST-1 problem areas
(observed after the dismantling of the machine)

Channels for baking purposes (with hot N2) welded on the VV sectors has developed leaks at some locations.





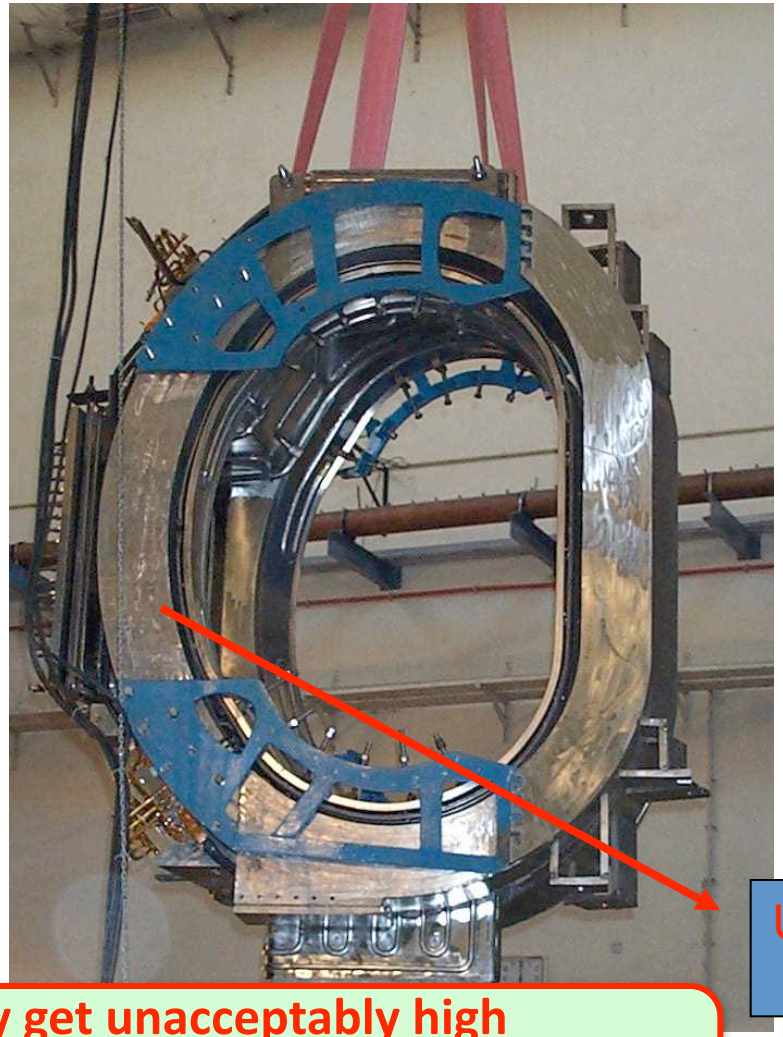
These leaks will limit the vessel vacuum, baking Temperature & plasma characteristics

SST-1 problem areas

(concluded from last campaign)

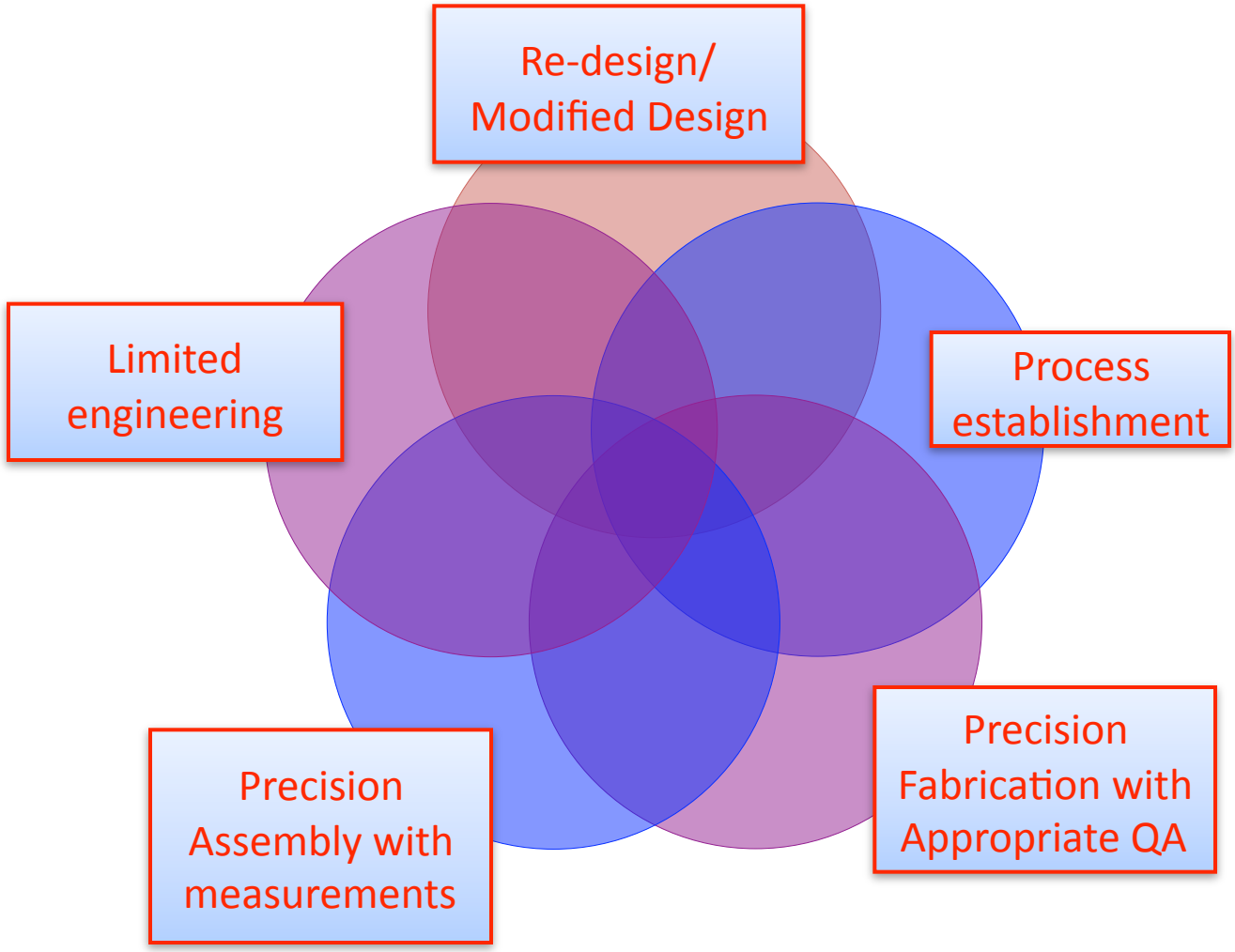
- TF Magnet cases and 5 K structures remain at a higher temperature (~ 40 K or more) as they are not actively cooled.

- Expected unforeseen events like plasma current disruption / VDE, eddy current induced heating in the inner case may heat up the edge pancakes of the TF winding packs.



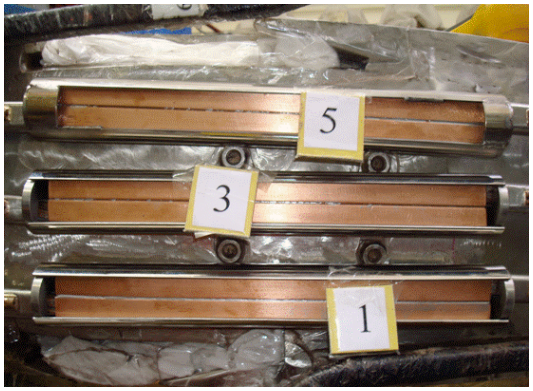
TF case facing the plasma may get unacceptably high heat load from disruption & VDE and may necessarily require dumping of the magnet.

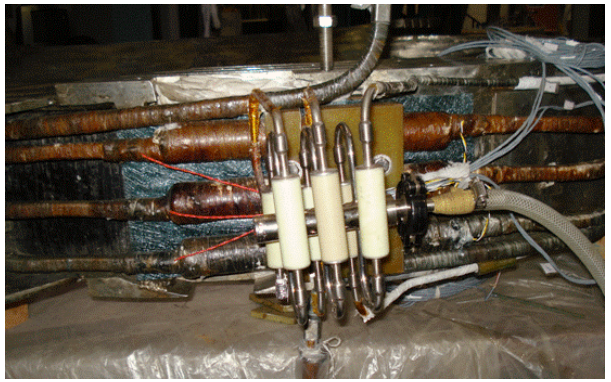
Spectrum of Refurbishment Characteristics

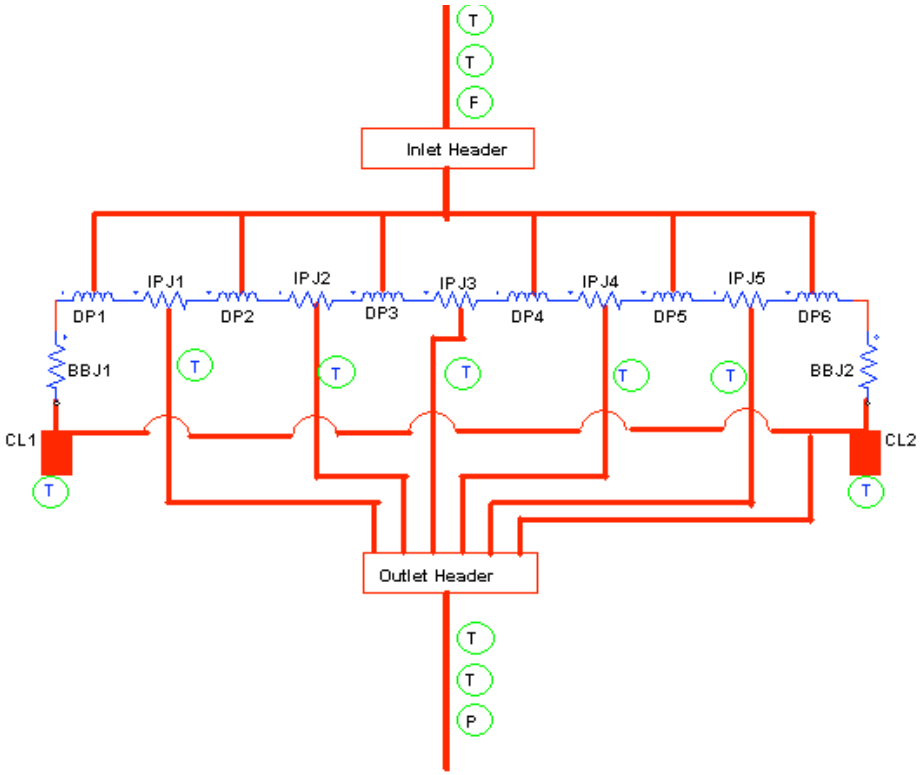


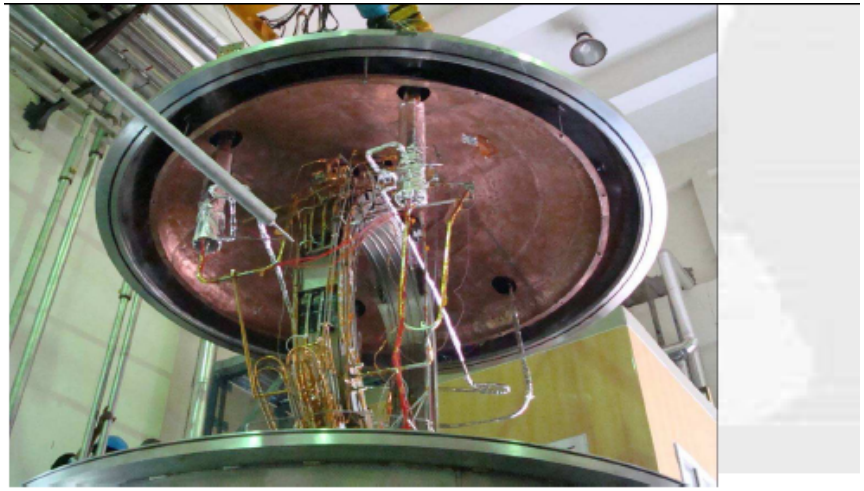
With emphasis on testing the components in representative conditions to the extent possible (often at multiple levels)

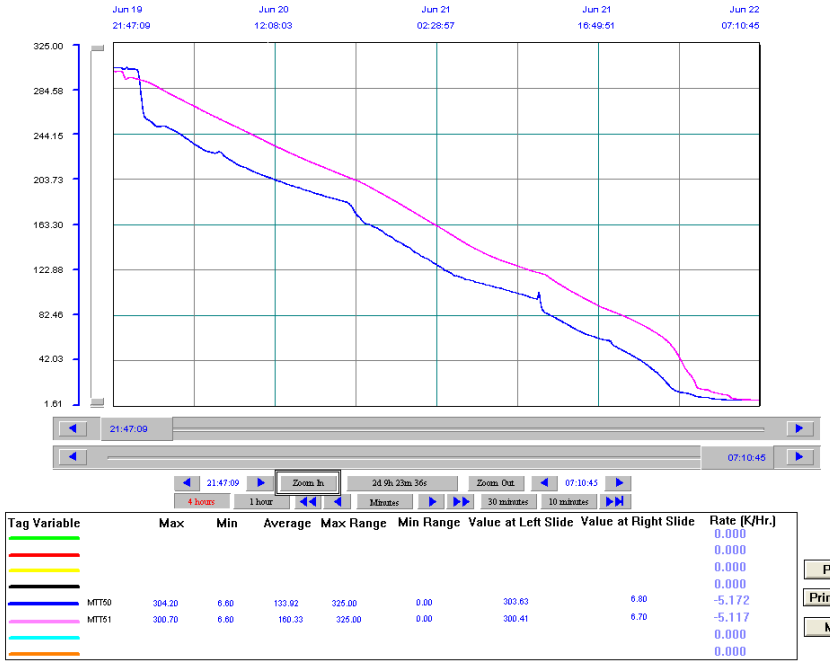
SST-1 Magnet System

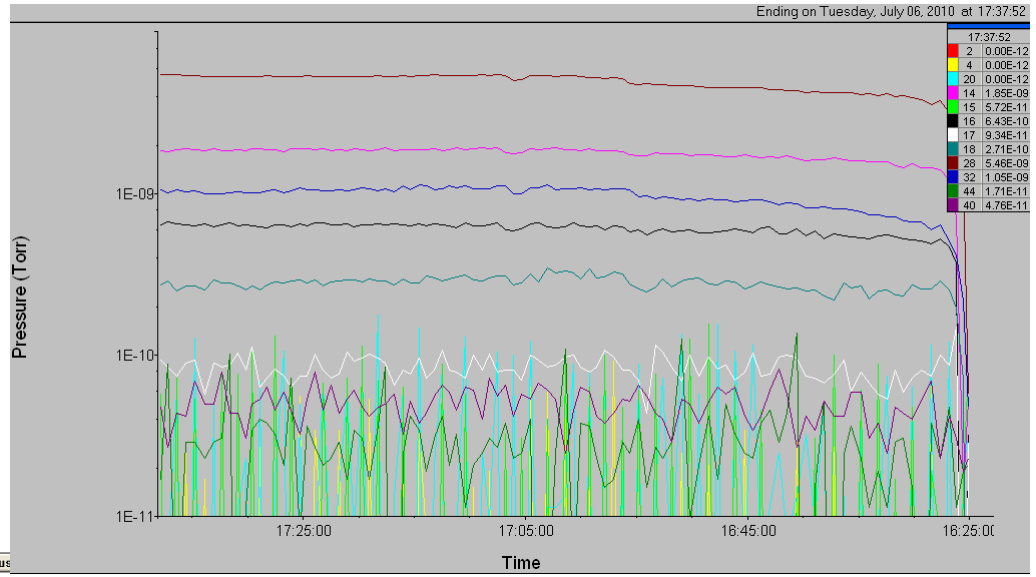


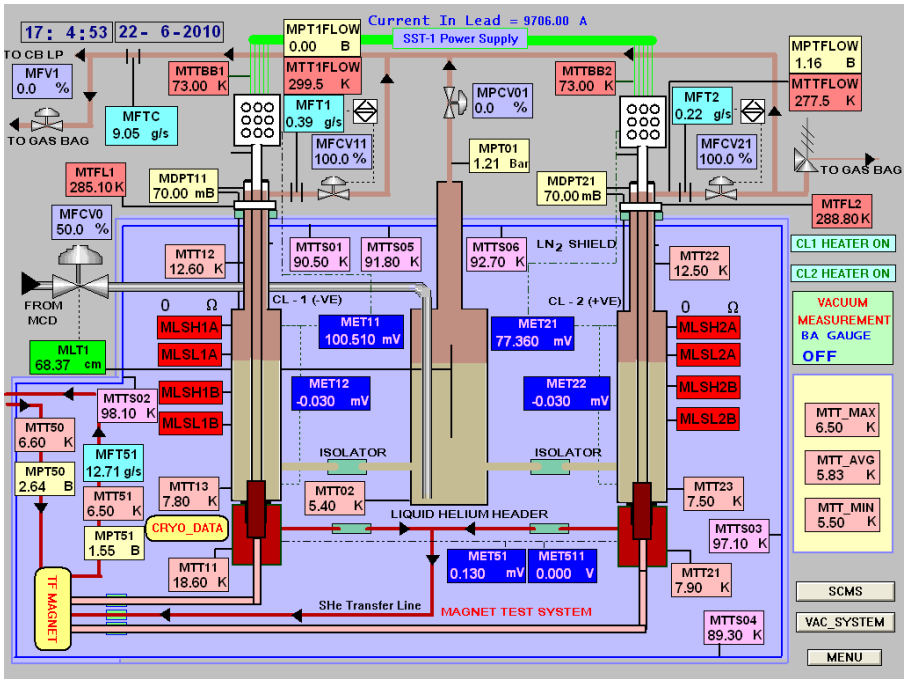












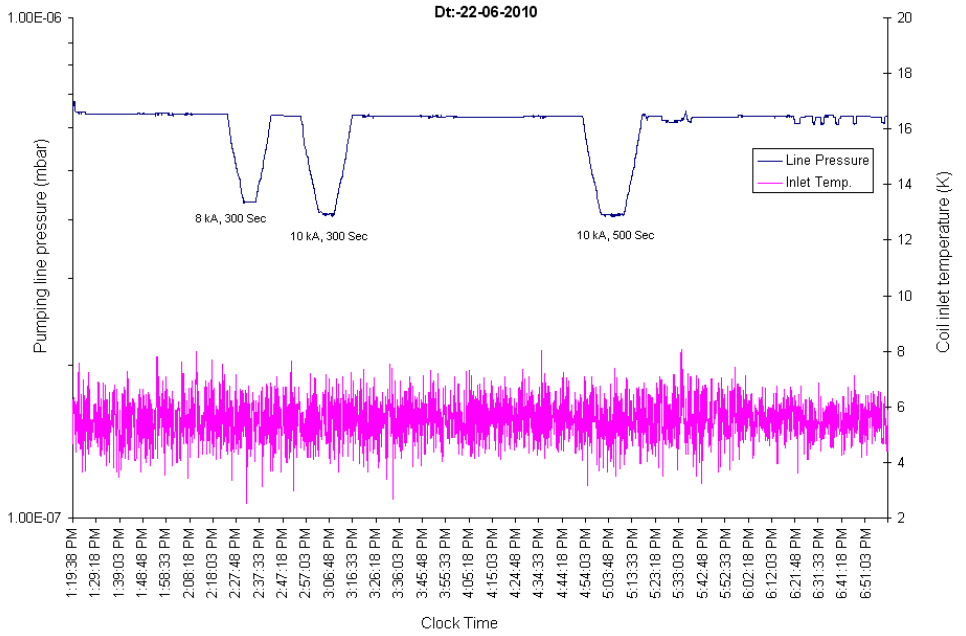
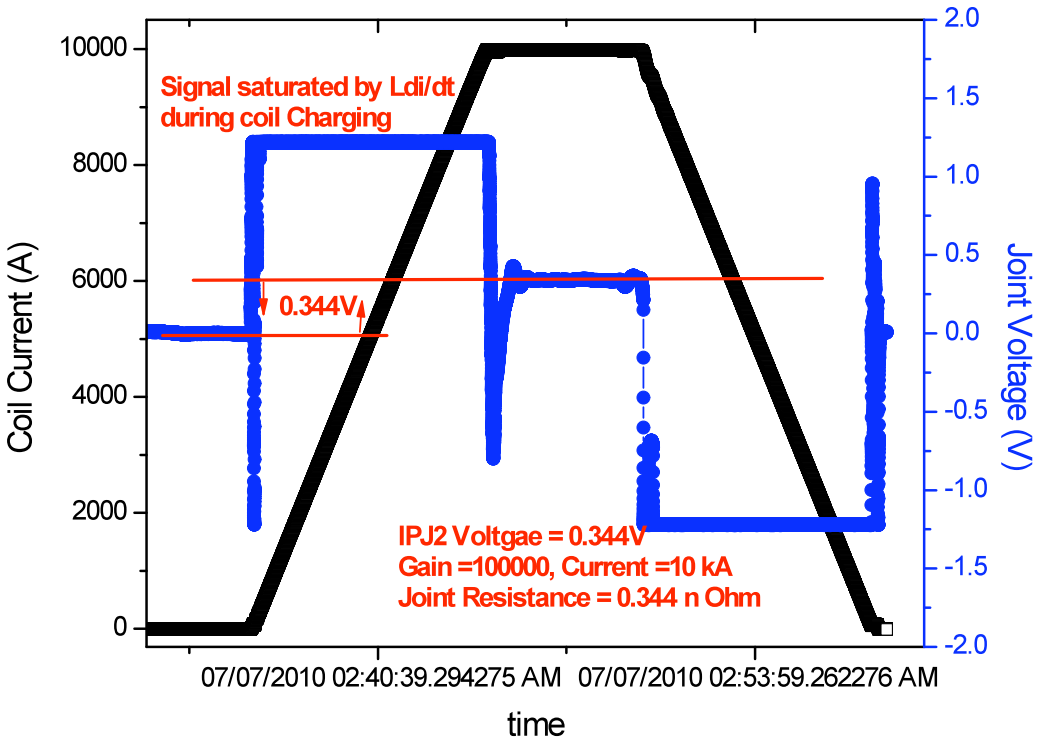
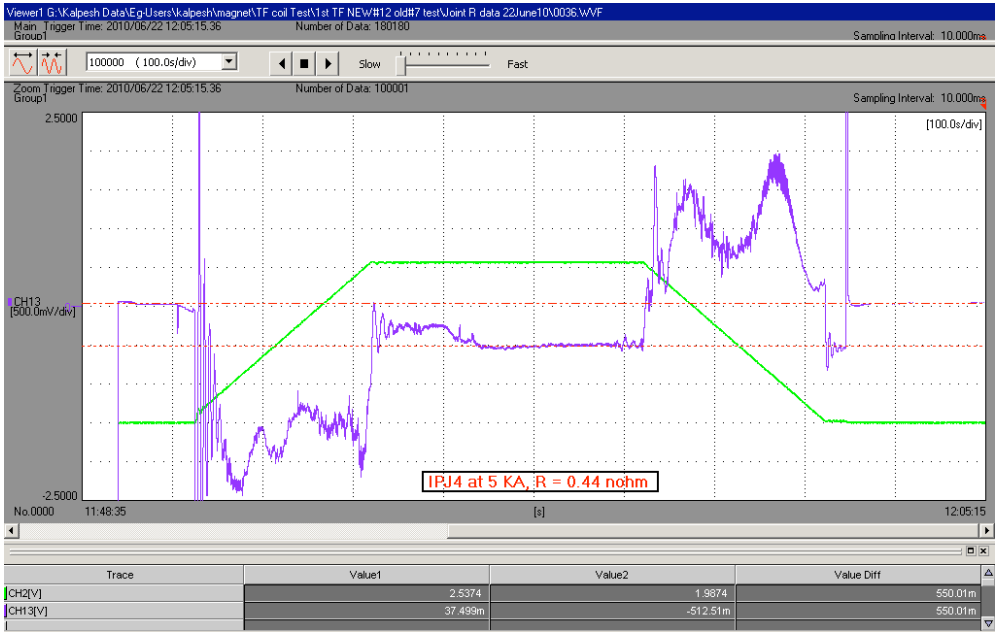
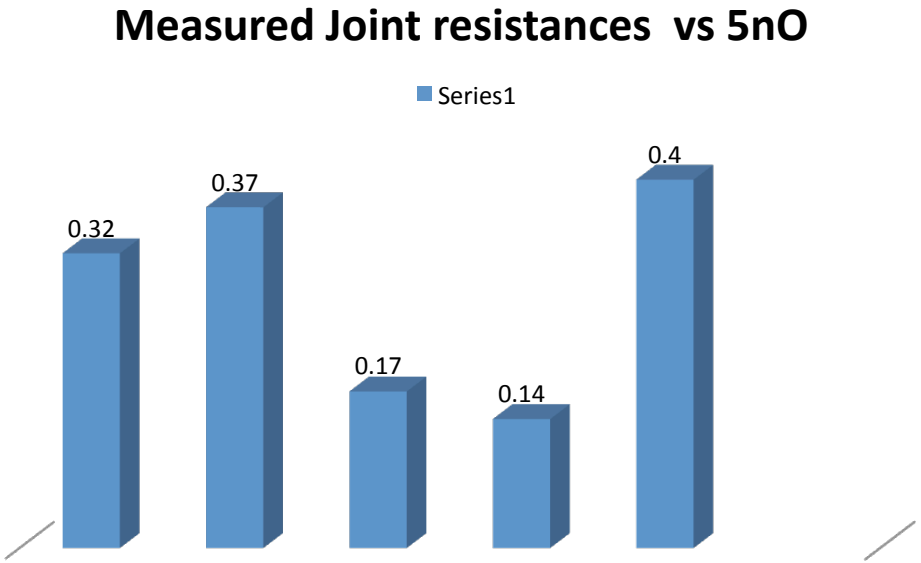


Figure - 2: Pressure and Temperaure curves during charging of TF # 12.



Coil	Joint Name	Joint Resistance
TF5	IPJ1	0.32 nΩ
	IPJ2	0.37nΩ
	IPJ3	0.17 nΩ
	IPJ4	0.14 nΩ
	IPJ5	0.40 nΩ



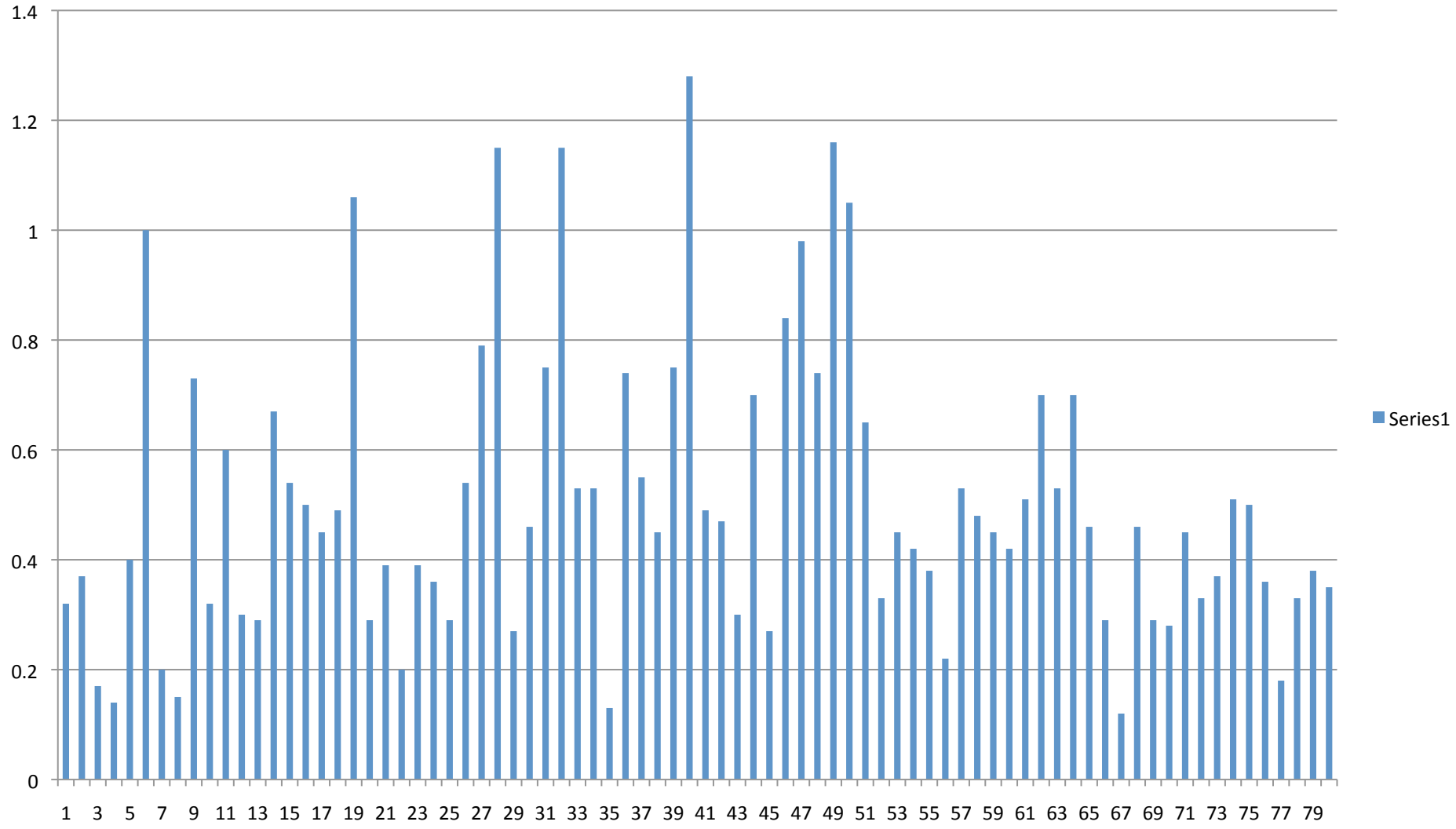


SST-1 TF Campaign statistics

- June 05,10-June 25,10
- June 26,10-Jul 10, 10
- Jul 11, 10-Jul 25, 10
- Jul 26, Aug 24, 10
- Aug 25, 10-Sep 02,10
- Sep 03,10-Sep 12, 10
- Sep 13,10- Sep 22, 10
- Sep 23,10- Oct 02, 10
- Oct 03,10-Oct 13,10
- Oct 14, 10- Oct 24, 10
- Oct 25, 10-Nov 05, 10
- Nov 07, 10-Nov 16, 10
- Nov 17, 10- Dec 03, 10
- Dec 04, 10-Dec 19, 10
- Dec 20, 10- Jan 07, 11
- Jan 08, 11- Jan 24, 11

- 1st Coil (two attempts)
- 2nd Coil
- 3rd Coil
- 4th Coil (two attempts)
- 5th Coil
- 6th Coil
- 7th Coil
- 8th Coil
- 9th Coil
- 10th Coil
- 11th Coil
- 12th Coil
- 13th Coil
- 14th Coil
- 15th Coil
- 16th Coil

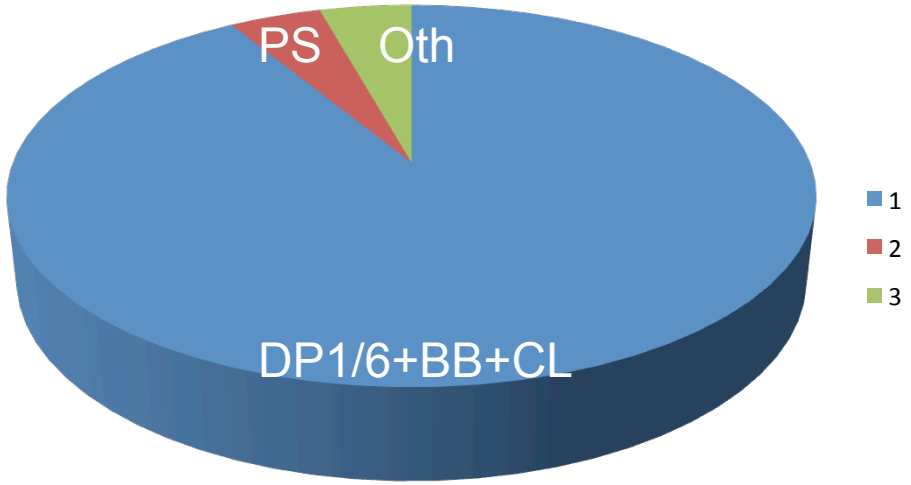
All Joints (of all 16 TF magnets)



06 # of joints above 1 n-Ohm, Joints Mean value: 0.5 n-Ohm

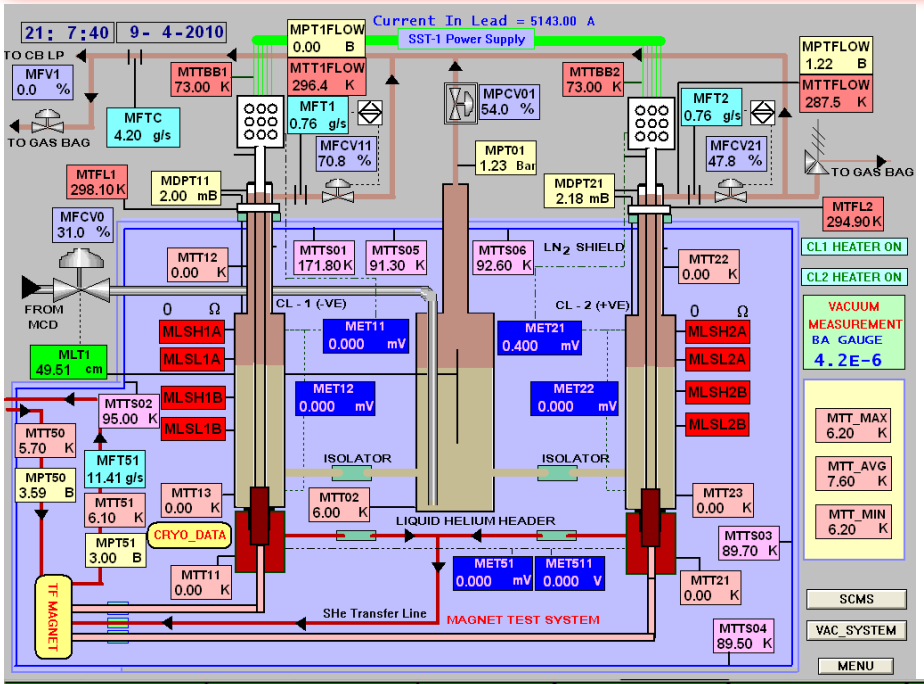
Quench Statistics

TF-1	0
TF-2	3
TF-3	2
TF-4	1
TF-5	2
TF-6	3
TF-7	0
TF-8	3
TF-9	0
TF-10	0
TF-11	2
TF-12	3
TF-13	1
TF-14	0
TF-15	3
TF-16	0



- In 21/23 cases, quench results from inadequate cooling of the BB-CL sections which were cooled with the exit helium of the edge (DP1/6) pancakes. These quenches can be avoided.
- In all quenches the quench detection & magnet protection systems worked as expected.
- Following the quenches, higher magnitudes of currents were flown as well as insulation was verified to be intact.

2. SST-1 Cryogenic System



Compressor		LN2 Precooling		Turbine Parameter	Turbine A Parameter		Turbine B Parameter		Turbine C Parameter	
PT230	14.01	DPT433	33.45	Inlet Pressure	PT522A	13.52	PT522B	5.30	PT522C	11.57
PT218	1.05	FCV432	11.81	Inlet Temp	TE441	37.95	TE455	16.00	TE450A	9.60
PT233	3.50	TT487	81.94	Outlet Pressure	PT523A	6.16	PT523B	1.08	PT523C	4.11
FT238(g/s)	138.03	TT347(C)	-2.45	Outlet Temp	TE476	32.75	TE457	15.15	TE479	8.96
PCV225 / 229	20.10	MCD Critical Parameter		Speed	ST540A	1747.00	ST540B	1463.00	ST540C	1252.00
JT198C	440.00	PT605	1.30	Bearing Temp	TT555A	6.75	TT555B	6.85	TT555C	16.85
JT198B	1.00	TT606	5.54	Bearing Pressure	PT525A	13.47	PT525B	13.44	PT525C	11.11
PCV223	12.50	LT607(mm)	280.40	Break Pressure	PT526A	10.60	PT526B	12.03	FCV428C	35.95
COMP C	100.64	LT607(ltr)	378.50	Cold Box			FCV428A	100.00	TT031	5.90
COMP B	0.31	WT601	195.70	Outlet Temp	TT479	8.96	OTHER		TT419	4.53
TT184(C)	16.40	FCV444	15.99	Outlet flowrate(g/s)	CL_FLOW	4.00	TT463	14.15	PT419	4.06
Purifier Pressure Drop		FCV446	15.17	CC Speed in Hz	ST410	0.02	FCV435	26.93	FT419	60.50
PT706	14.09	FCV443	0.00	Return Temp	TT451	121.18	FCV436	22.03	PT396	1.03
PT715A	13.96	FCV445	63.87	Return Pressure	PT338	3.06	FCV420	100.00	TT425	271.30
DIFF	0.13	FCV447	0.00	HP Pressure	PT353	13.60	FCV421	4.00	LT449	651.70

The 1.3 KW Refrigerator-Liquifier system works efficiently in either or mixed modes and has been into operation for more than 50 campaigns during SST-1 Mission till date in either Two phase or Supercritical mode of operations with or without cold circulator.

3. SST-1 80 K & 5 K System

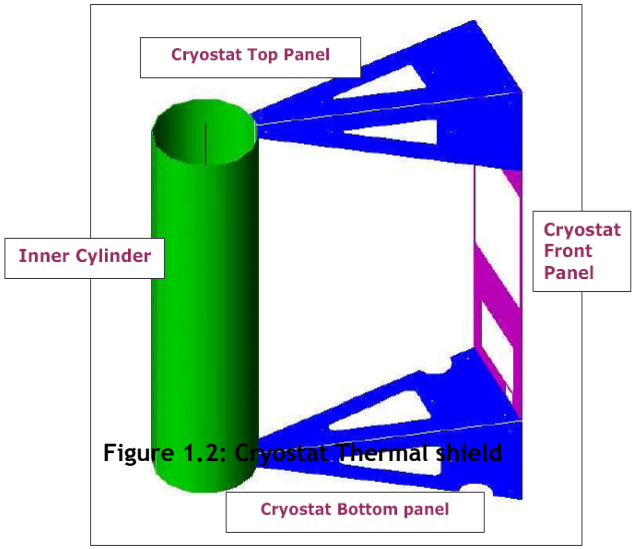
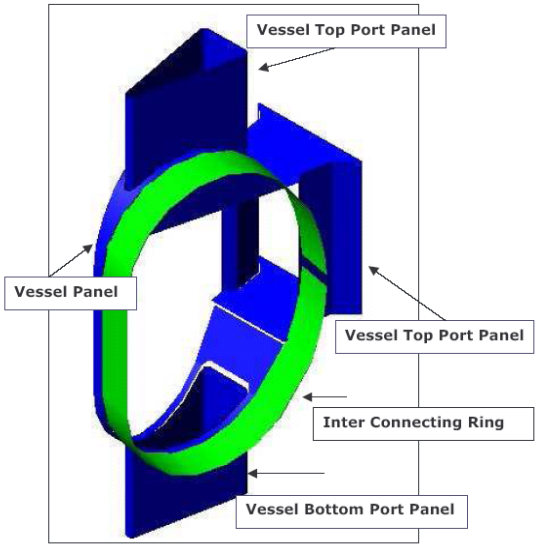
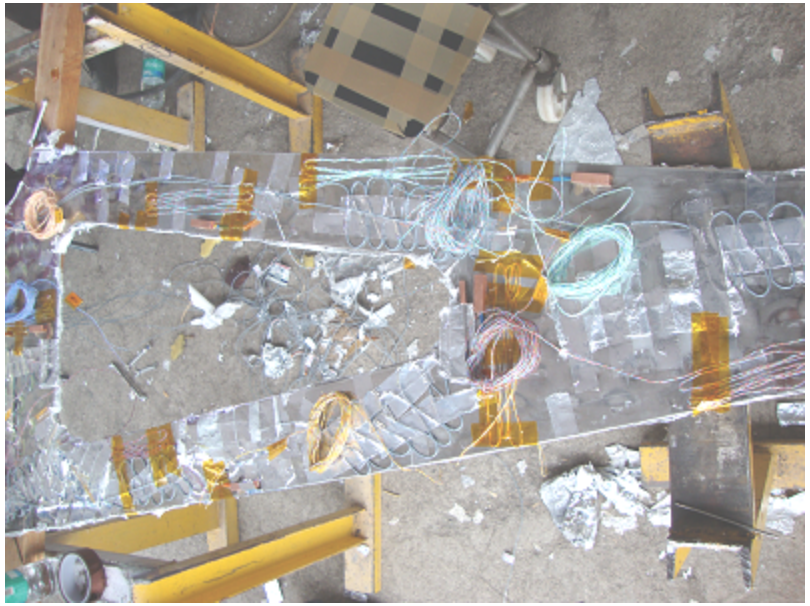


Figure 1.2: Cryostat Thermal shield

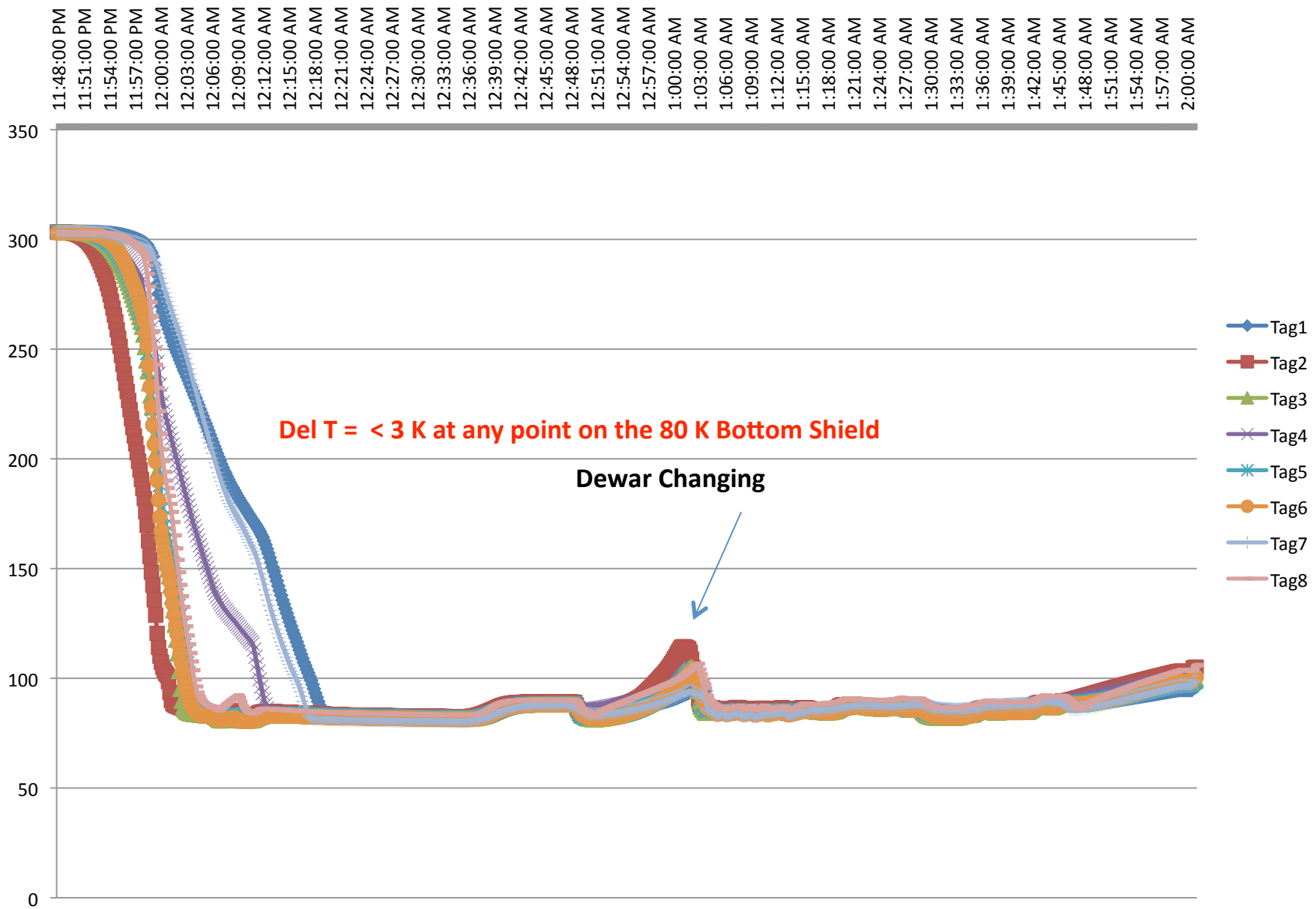
Cryostat Panels



Vessel Panels

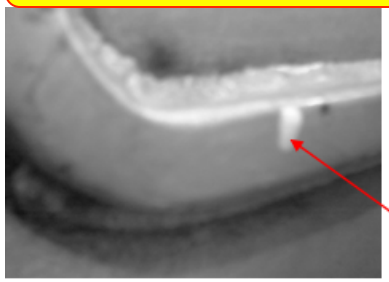


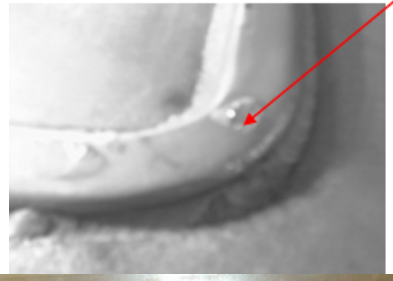
TEMPERATURE MEASUREMENT RESULTS



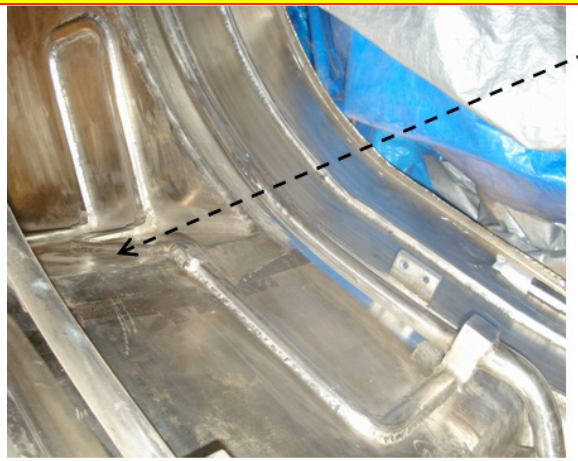
Results in these group tests have shown that the temperature uniformity is within the specified range of 5 K and the temperature anywhere on the surface of the panel is less than 90 K for a nominal flow rate of 19 g/s.

4. SST-1 Vacuum Vessel & First Wall

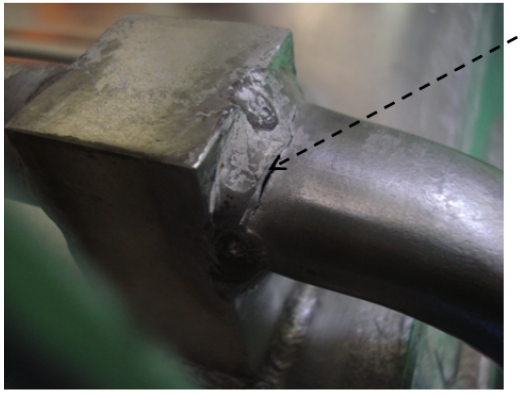


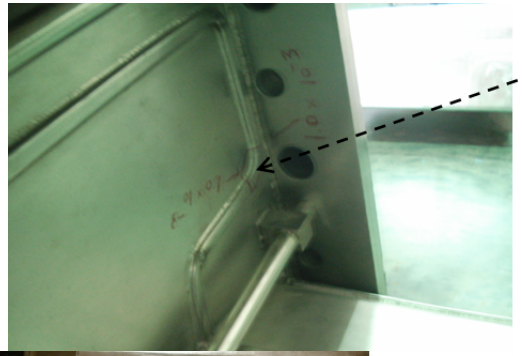


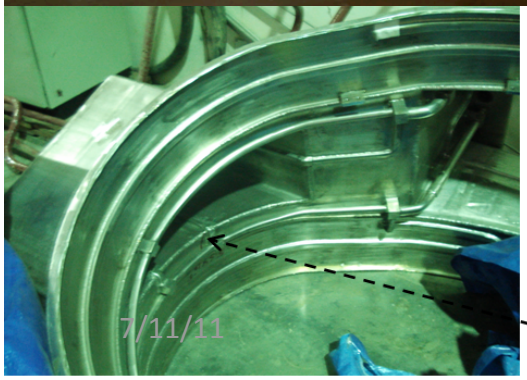
Leaks on the surfaces of the backing channels (8.0×10^{-5} mbar l/s).

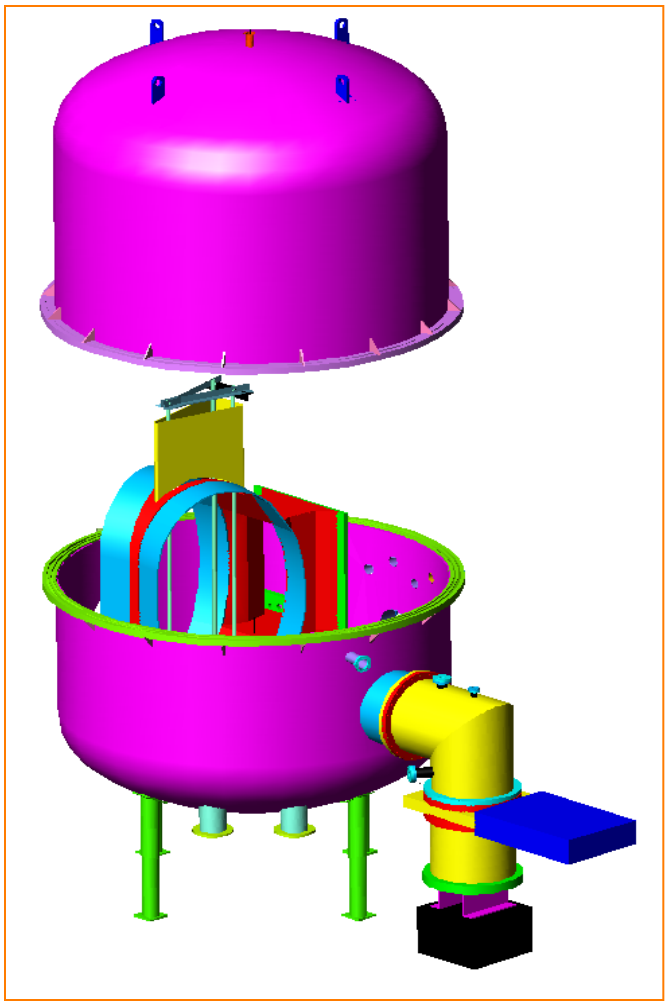


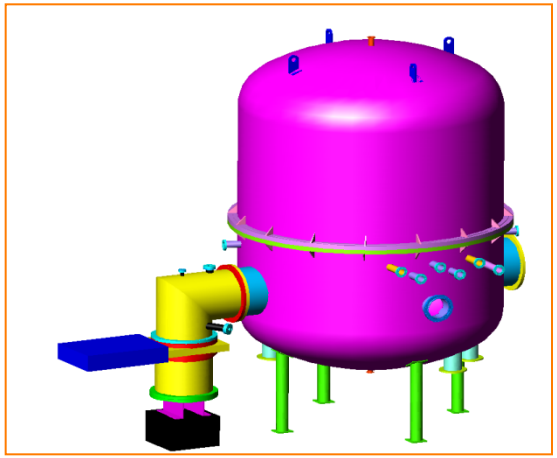
Two surface leaks (1.0×10^{-1} mbar l/s).

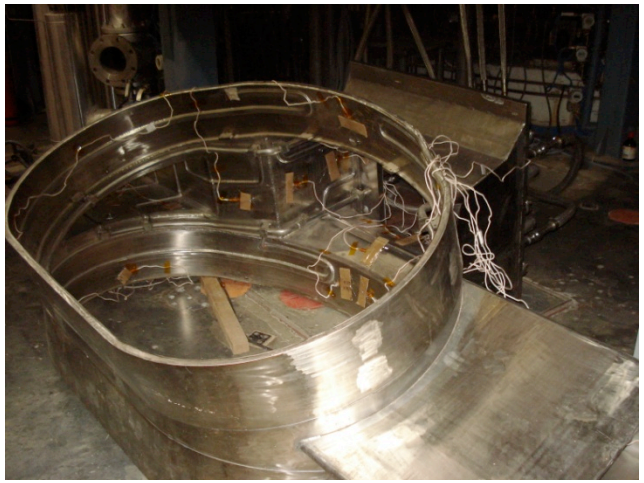






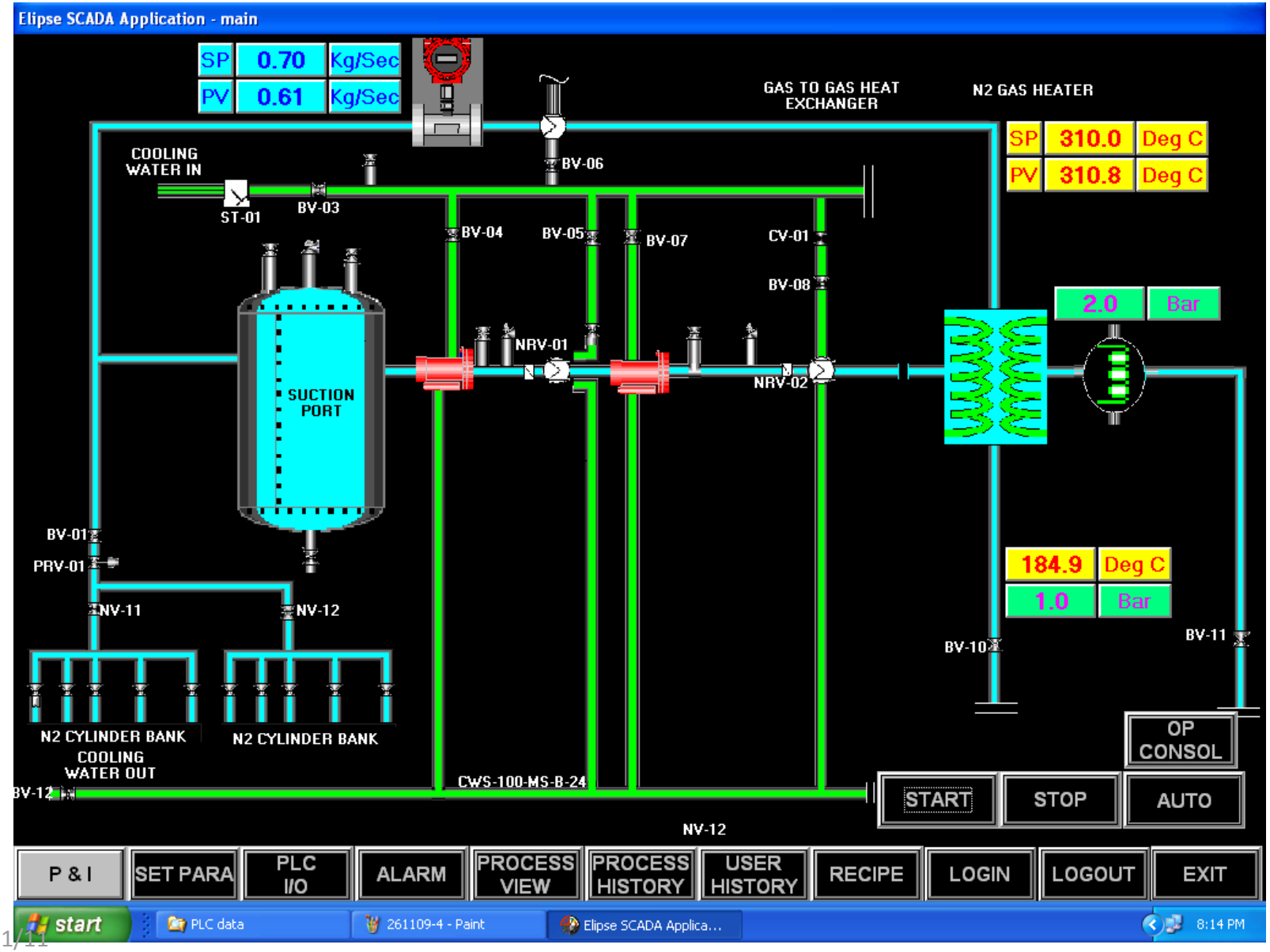


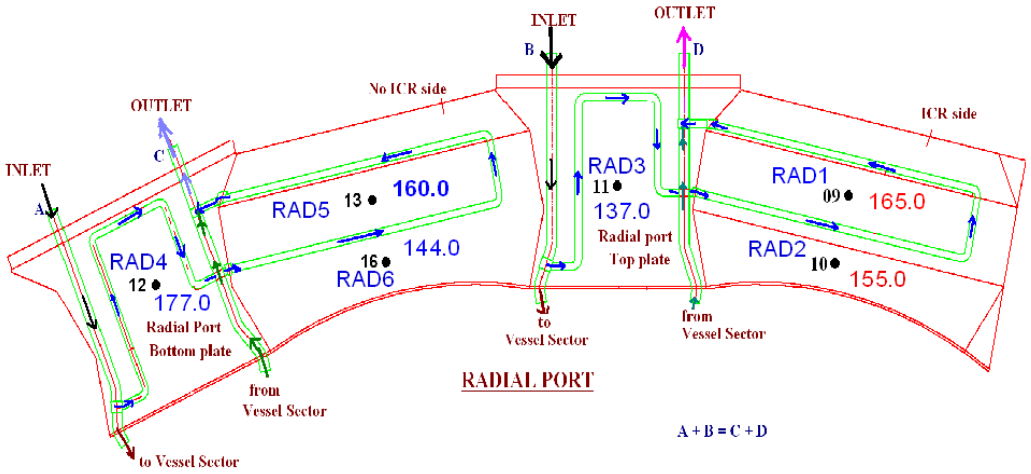


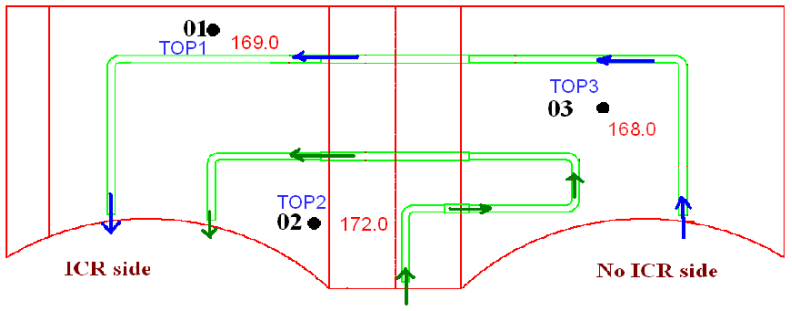


Each of the vessel sector and vessel module having baking channels are being tested in representative baking conditions

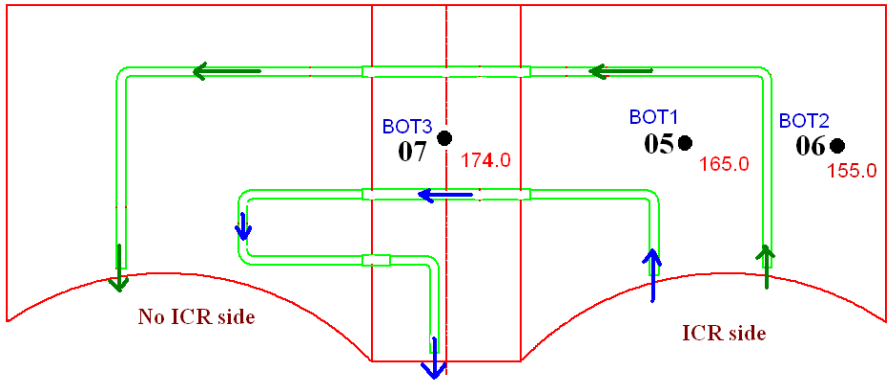
Final status of the system during baking flat-top (typical)



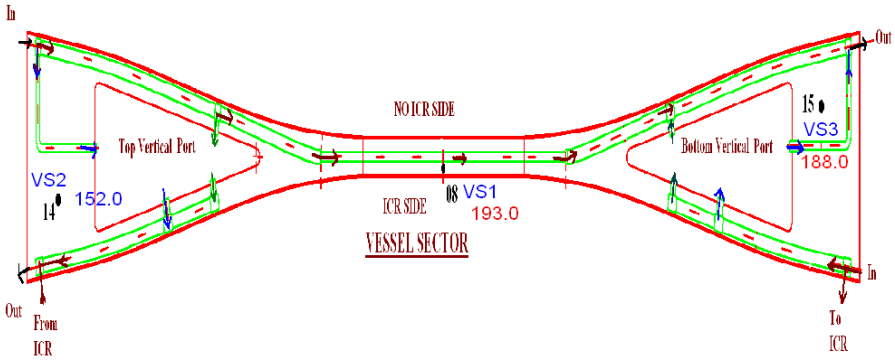


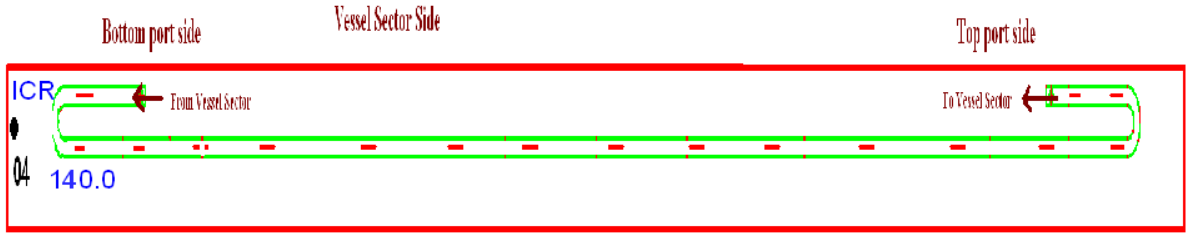


VERTICAL TOP PORT

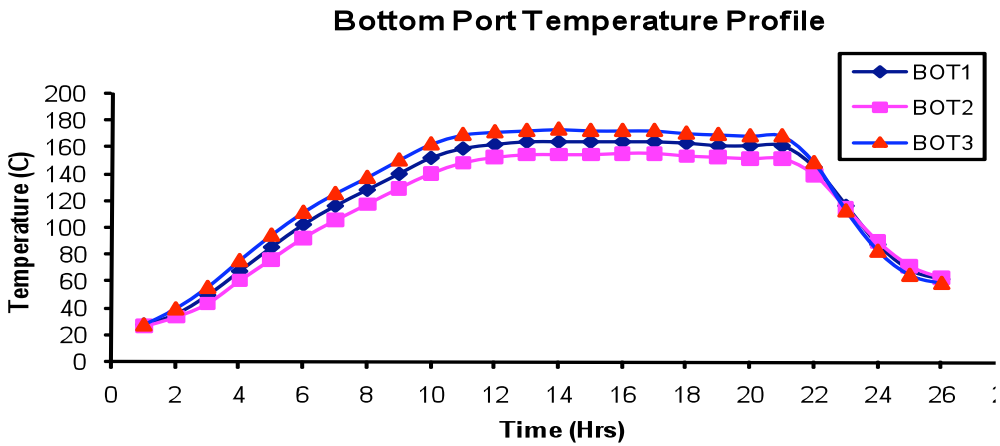


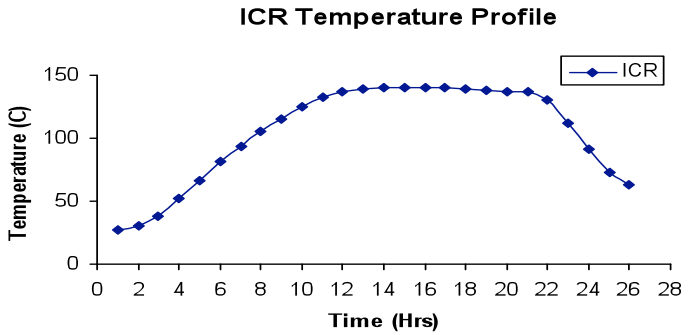
VERTICAL BOTTOM PORT

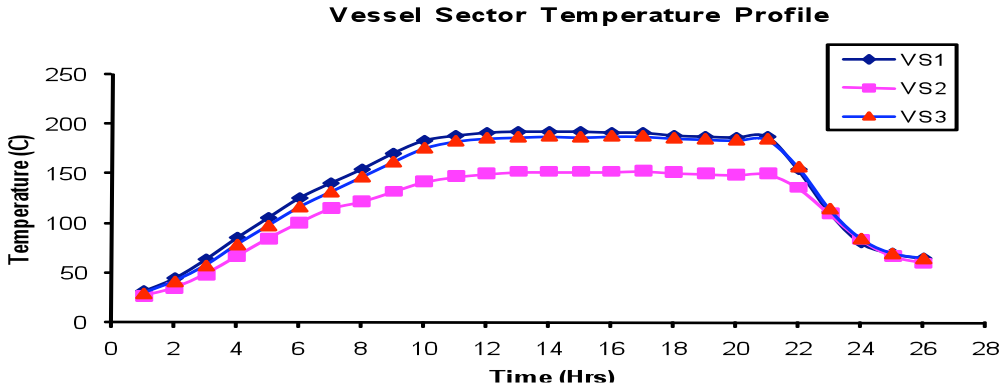


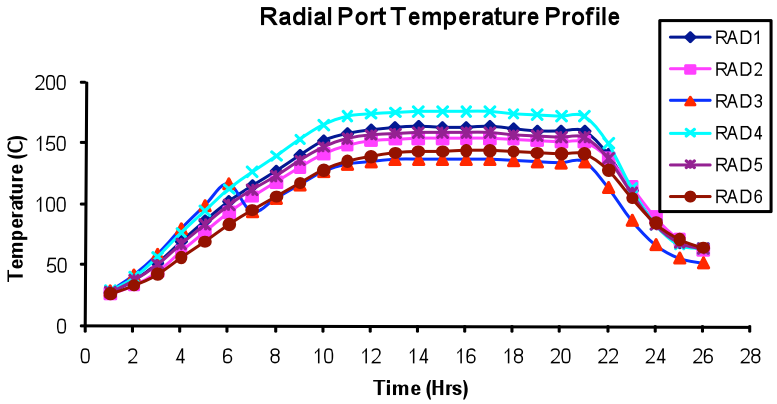


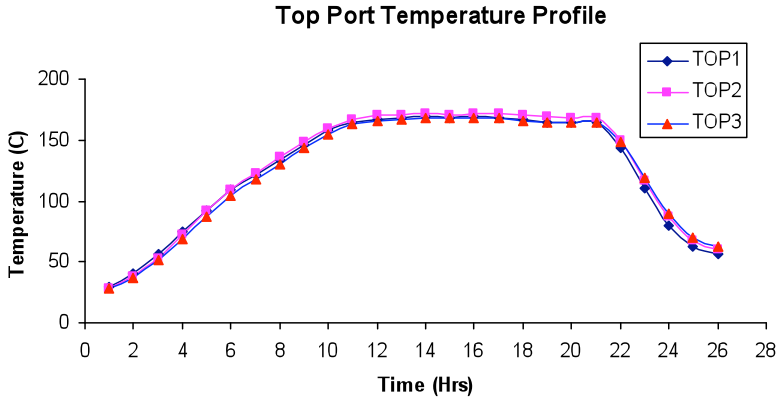
INTER CONNECTING RING


Bottom Port Temperature Profile
BOT1
BOT2
BOT3
Temperature (C)
Time (Hrs)

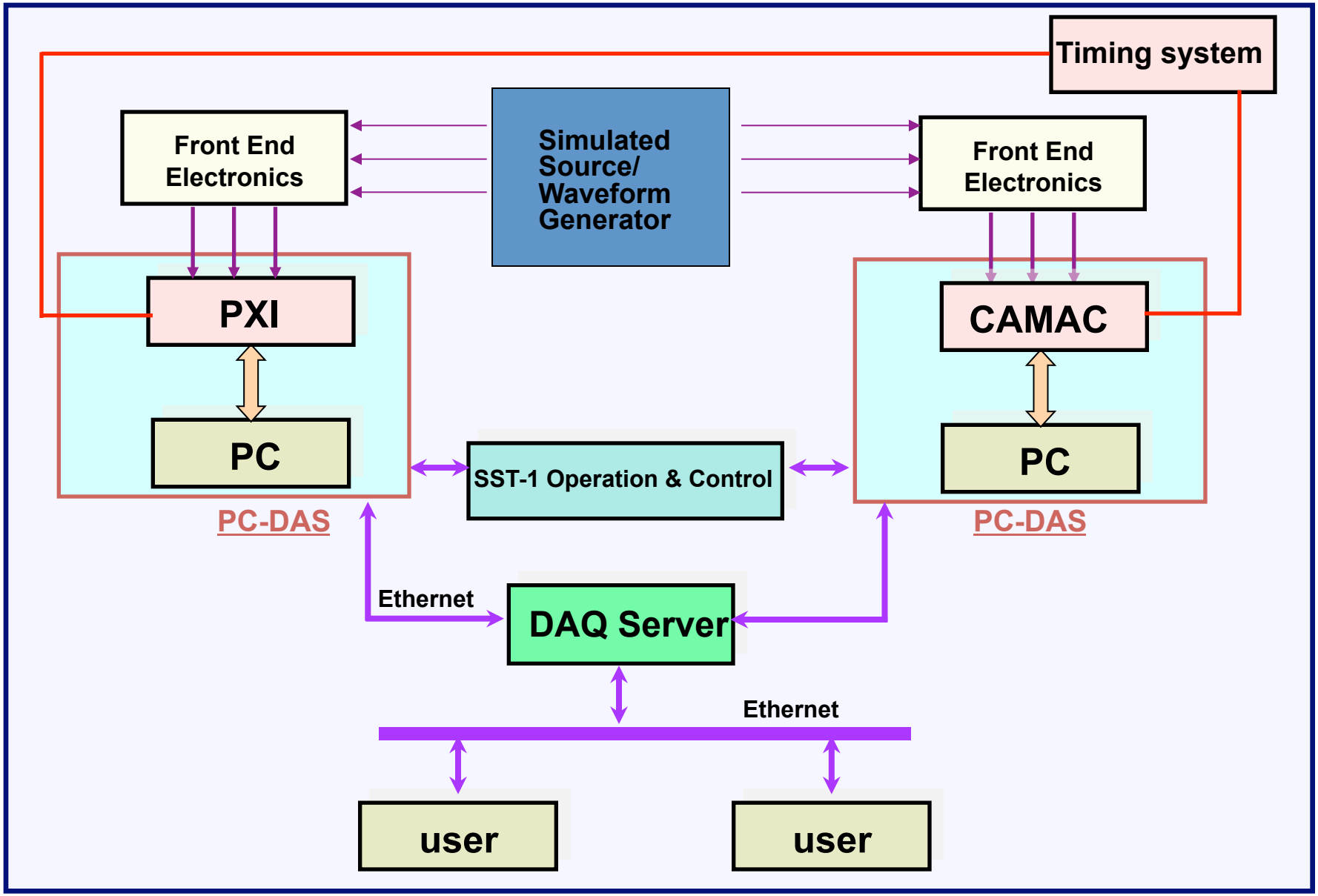

ICR Temperature Profile
ICR
Temperature (C)
Time (Hrs)

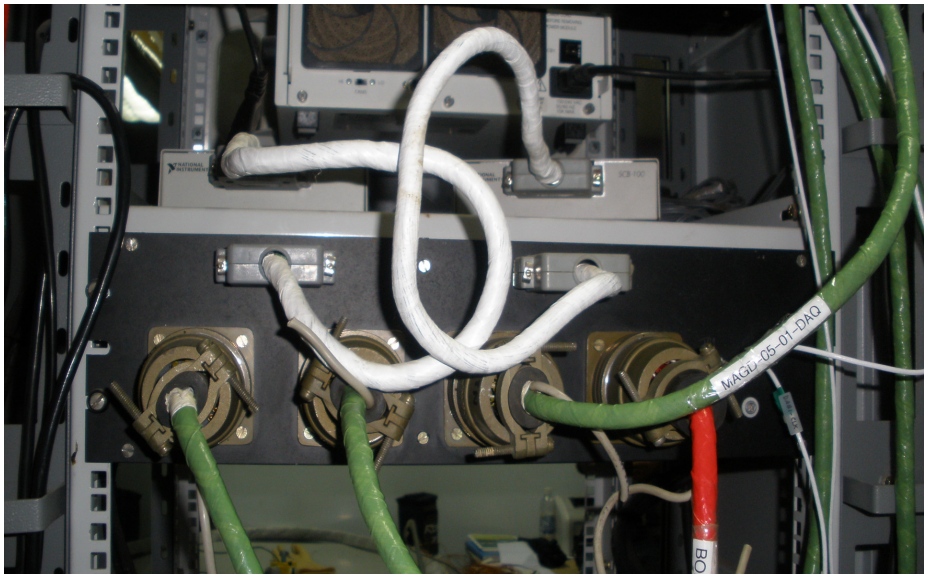

Vessel Sector Temperature Profile
VS1
VS2
VS3
Temperature (C)
Time (Hrs)


Radial Port Temperature Profile
RAD1
RAD2
RAD3
RAD4
RAD5
RAD6
Temperature (C)
Time (Hrs)

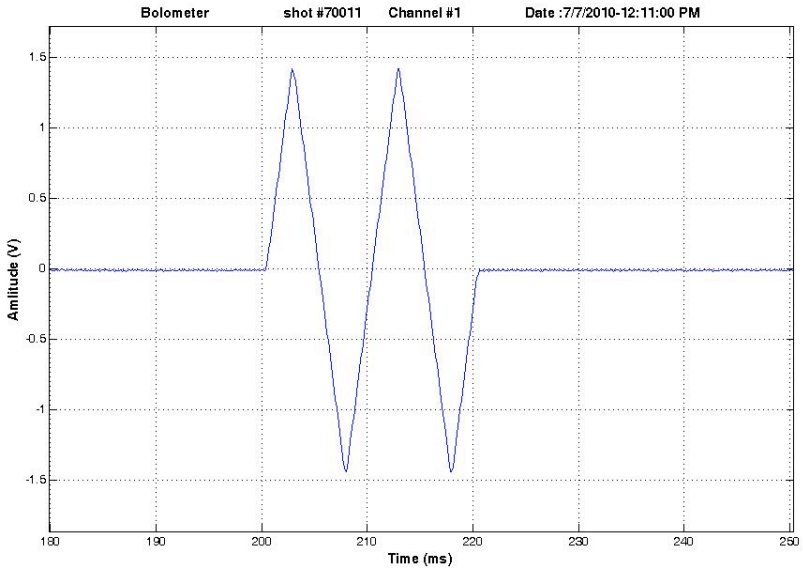

Top Port Temperature Profile
TOP1
TOP2
TOP3
Temperature (C)
Time (Hrs)

5. SST-1 DAQ Integrated Testing

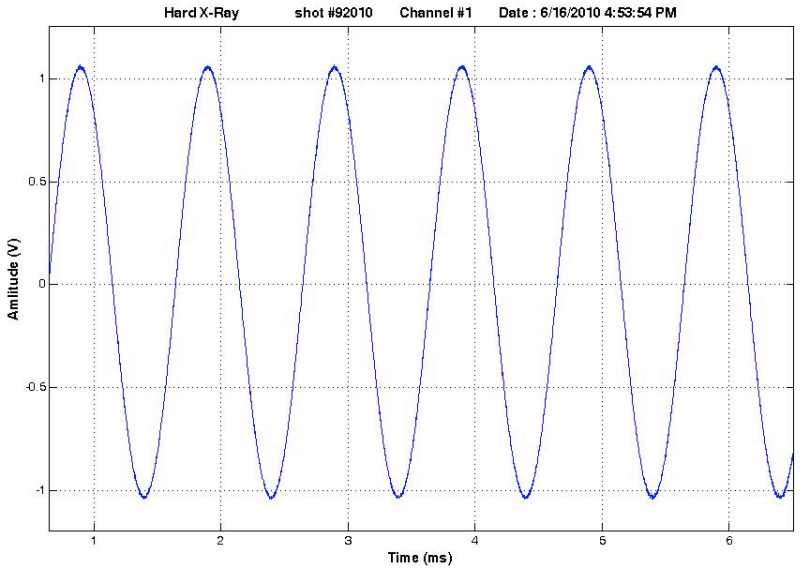




Integrated Testing - 2



Pre/Post Trigger Acquisition



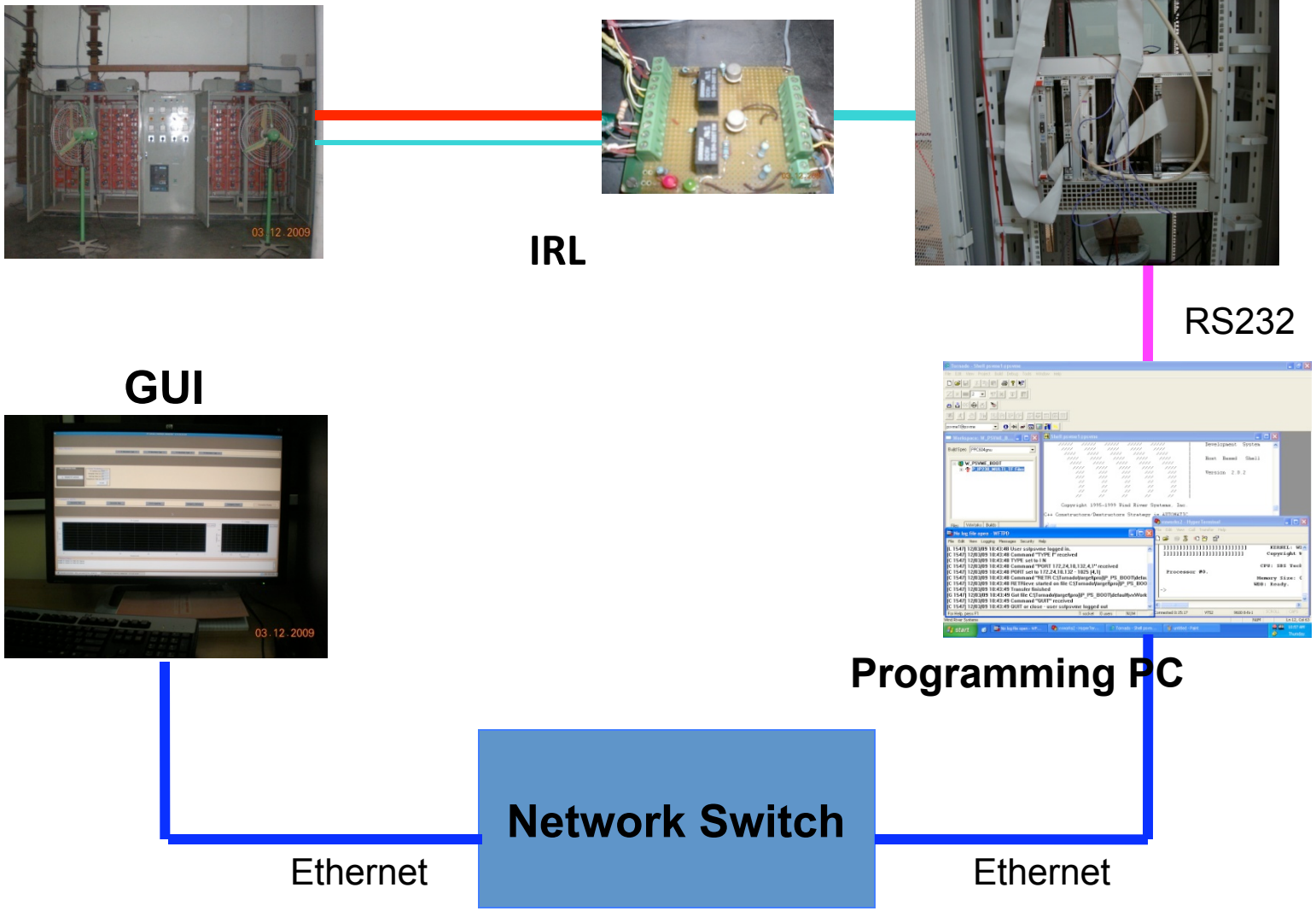
Continuous Acquisition

Important achievements till now.....

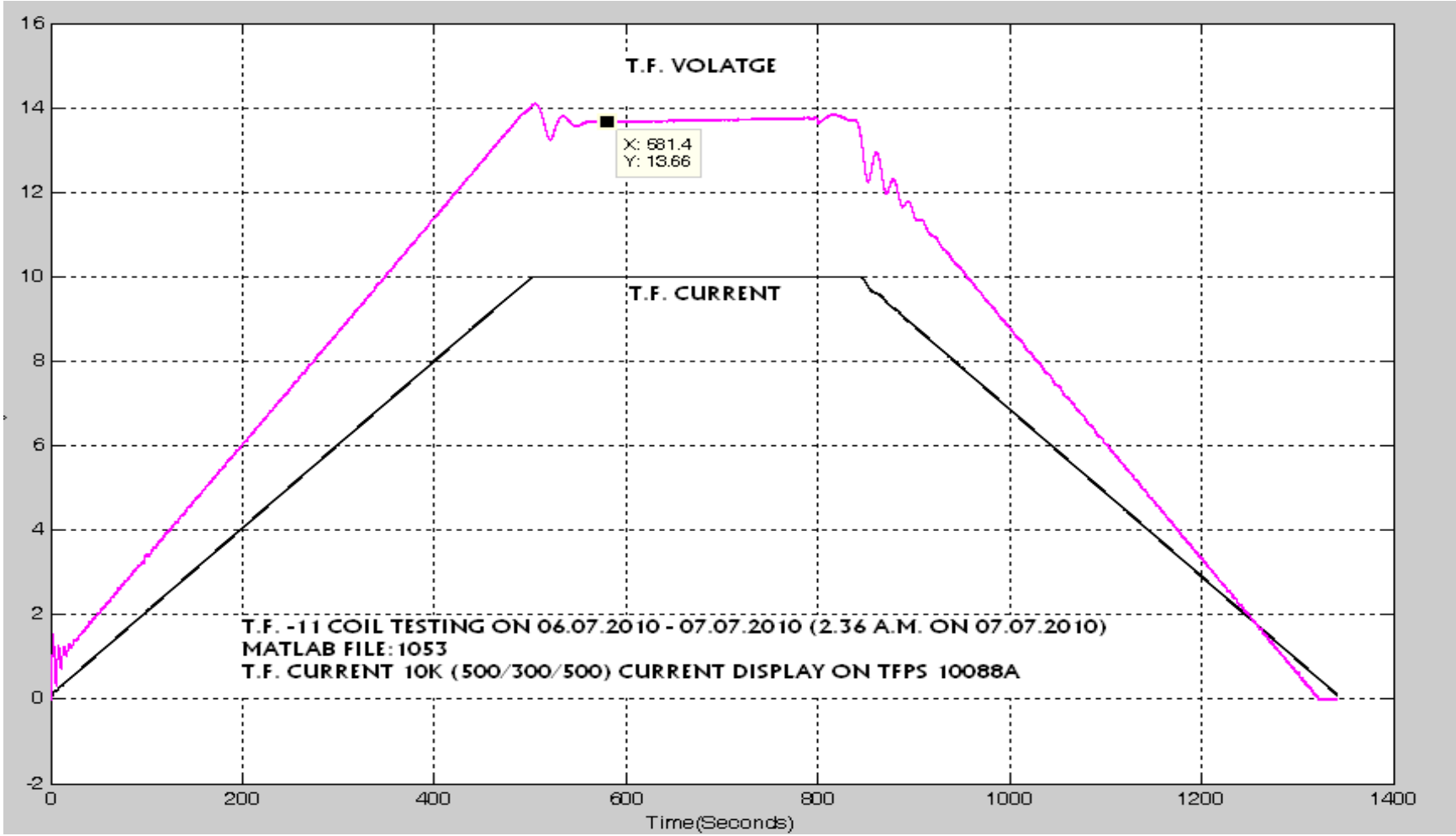
- Automatic Shot number based Configurations and Data Files generations at different locations.
- Communication Interface and interlocking among Electronics, SST-1 Data Acquisition and SST-1 Operation & Control Divisions.
- Nomenclature to each Diagnostic channel, signal cable, interface connector etc. for easy and quick channel tracing and debugging
- Automated Files generation, stored in DAQ Server for data analysis, of channel signal conditioning parameter details , Time Stamping information of Trigger etc. for each shot.

6. SST-1Power System

TF Topology

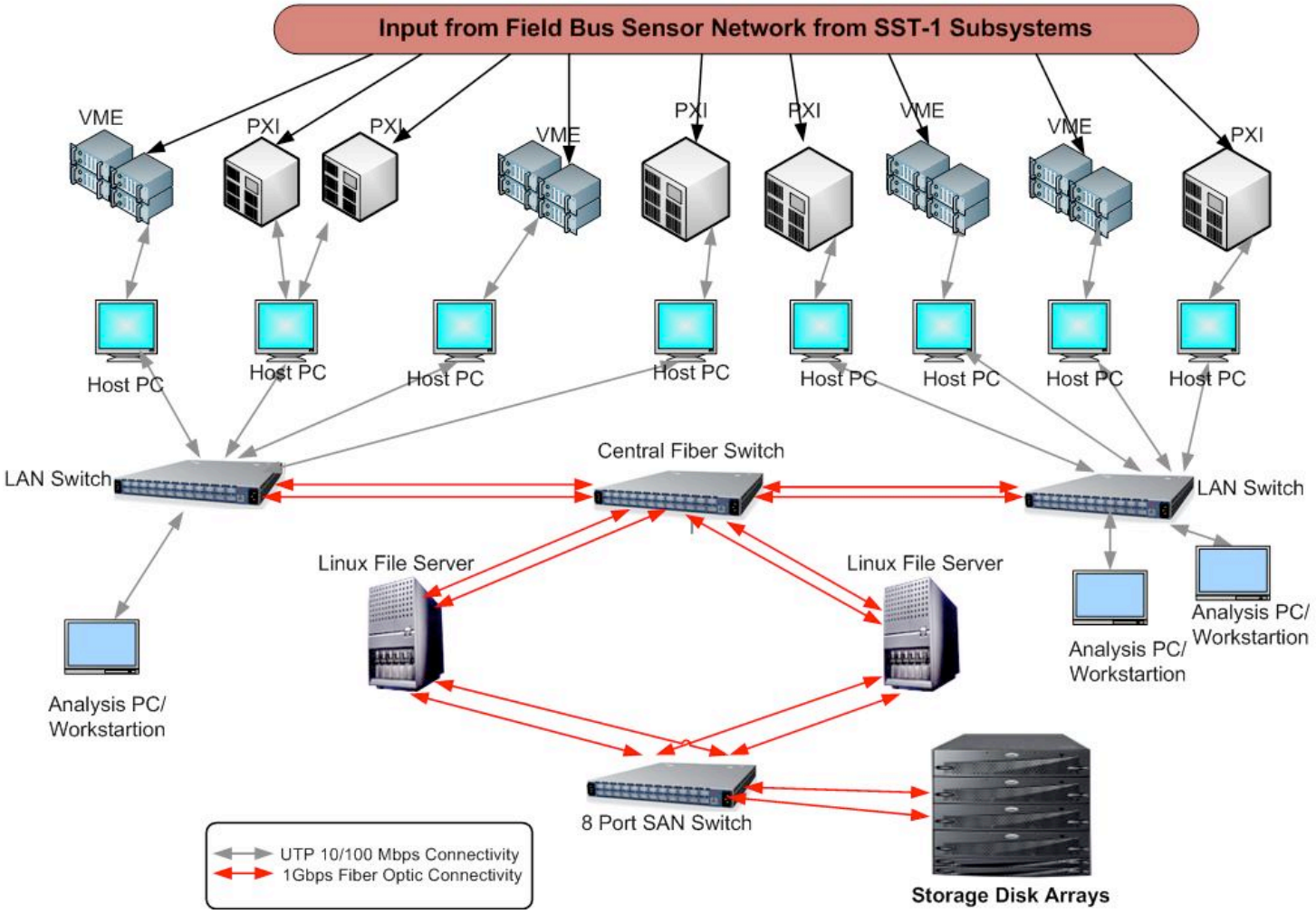


TF voltage and Current profile for TF coil testing



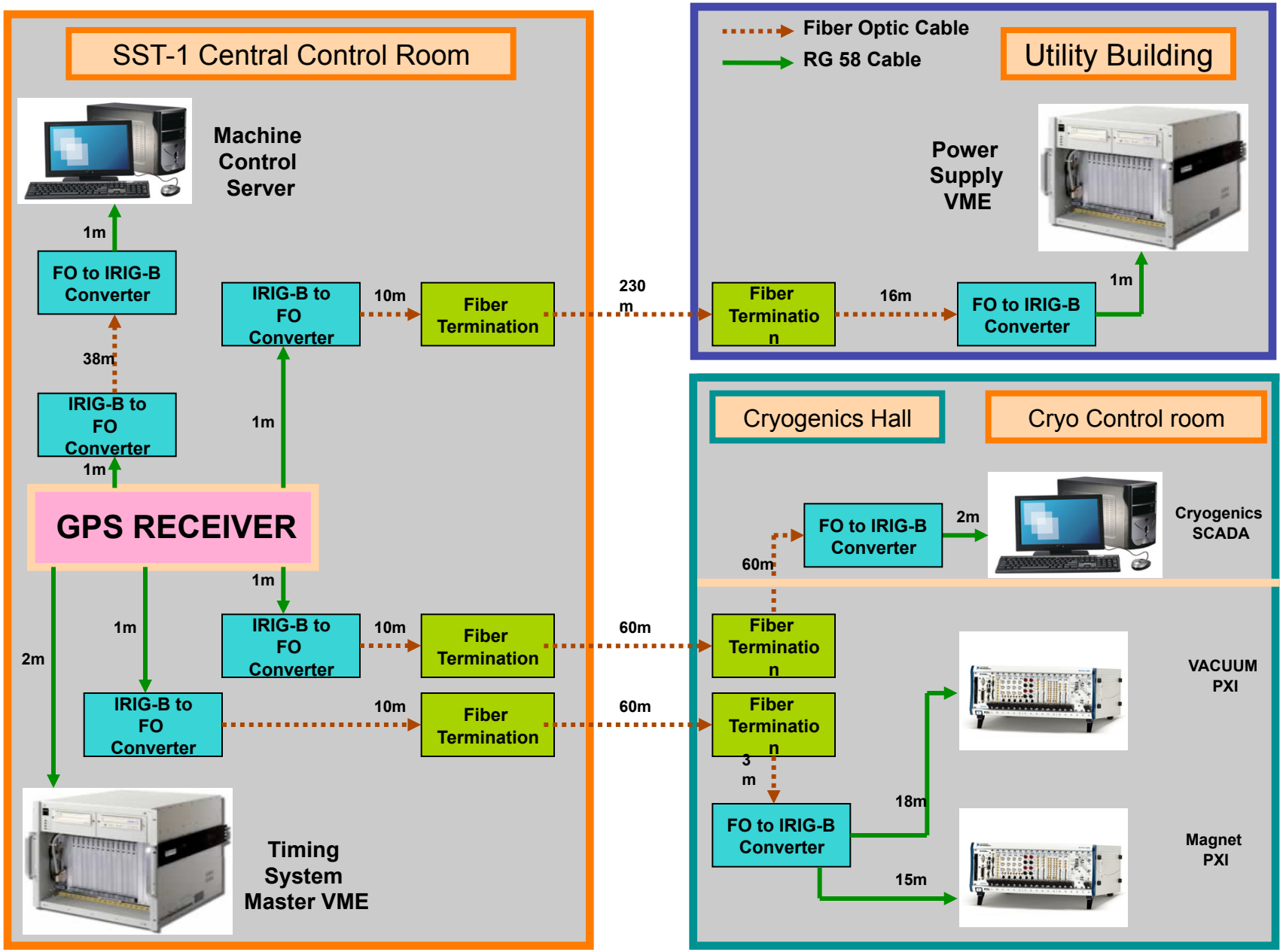
7. SST-1Central Control

Storage System Architecture for SST-1

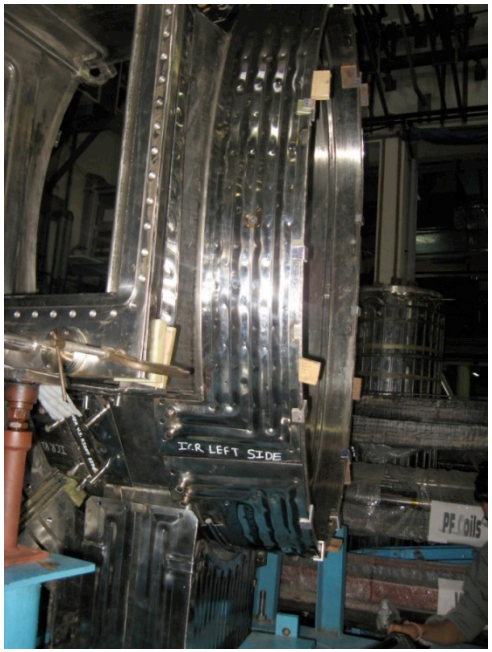


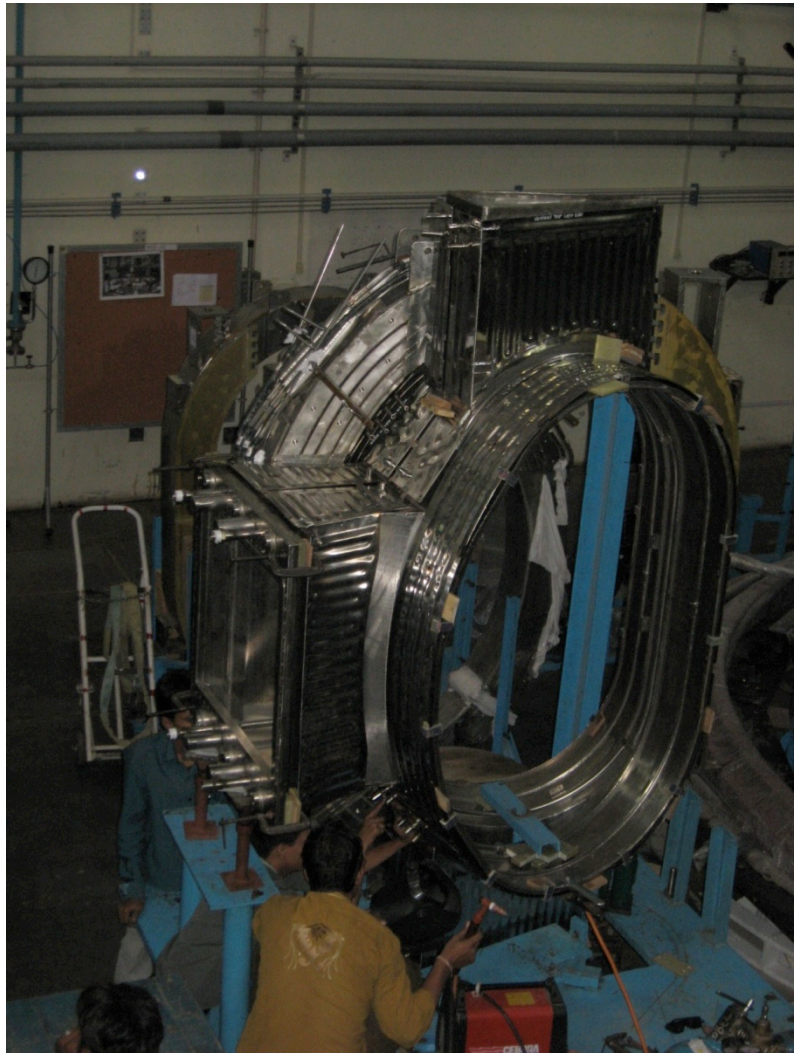
- **SAN** based Usable Storage Capacity of **3TB Online + 6 TB Near-Online**.
- **Salient features:** Modular, Fully redundant, no single point of failure, Active-Active configuration.

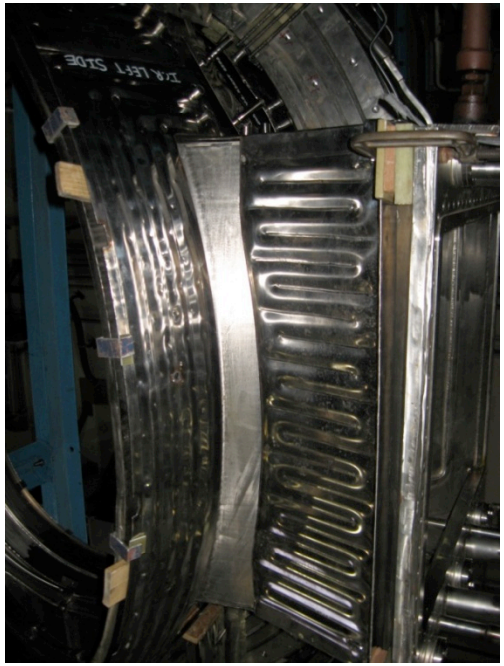
Network Diagram of Time Synchronization System of SST-1

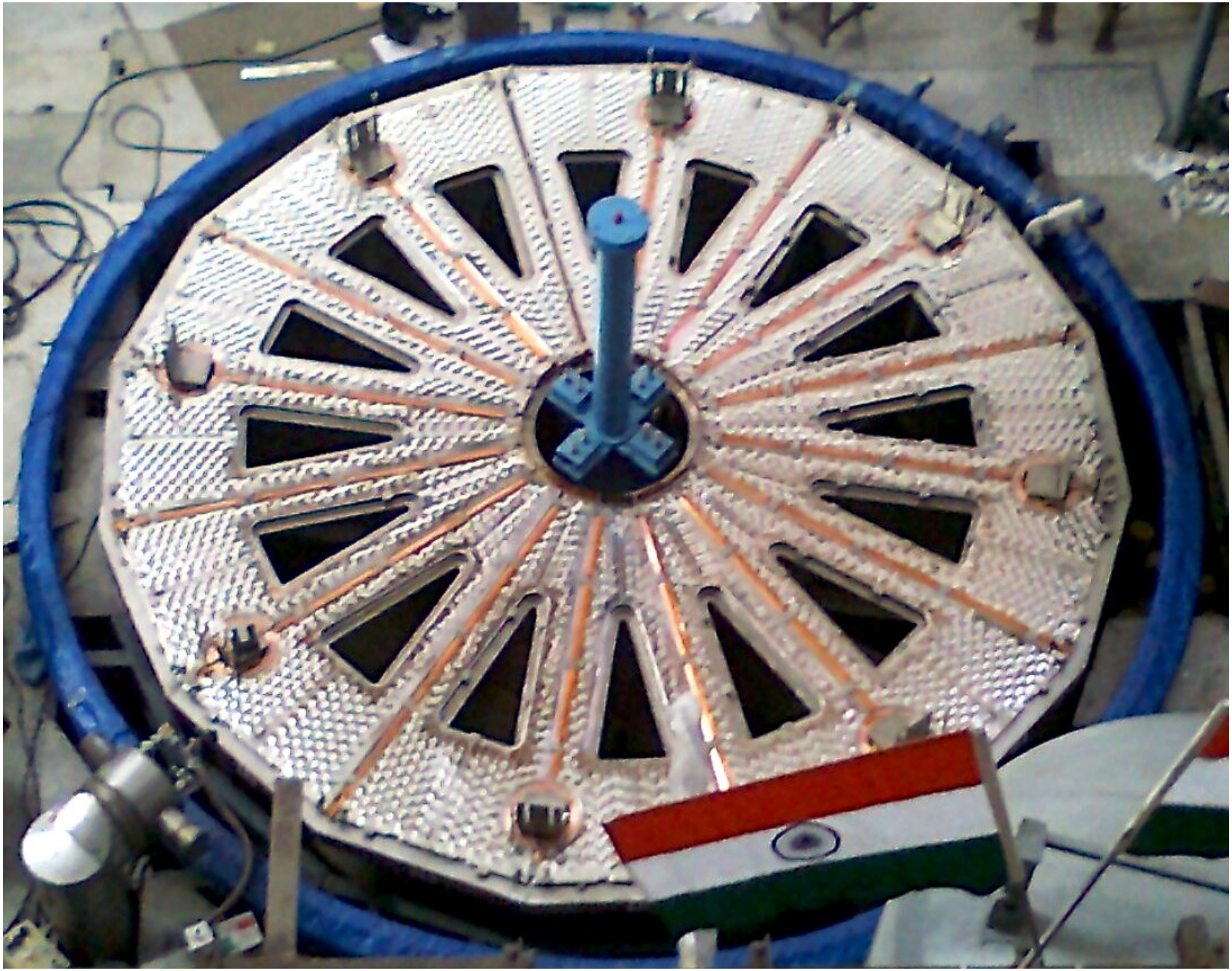


8. SST-1 Device Integration

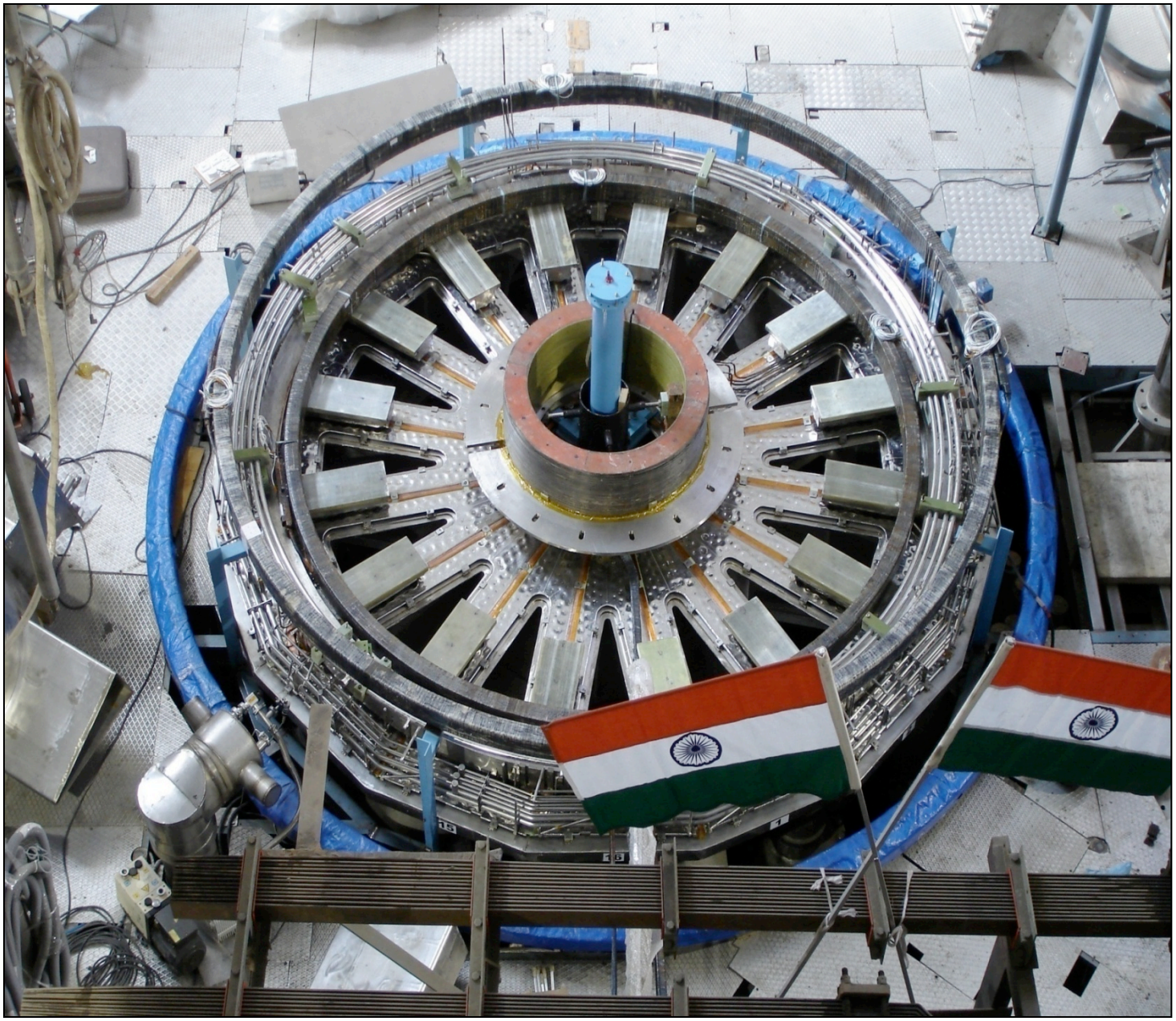




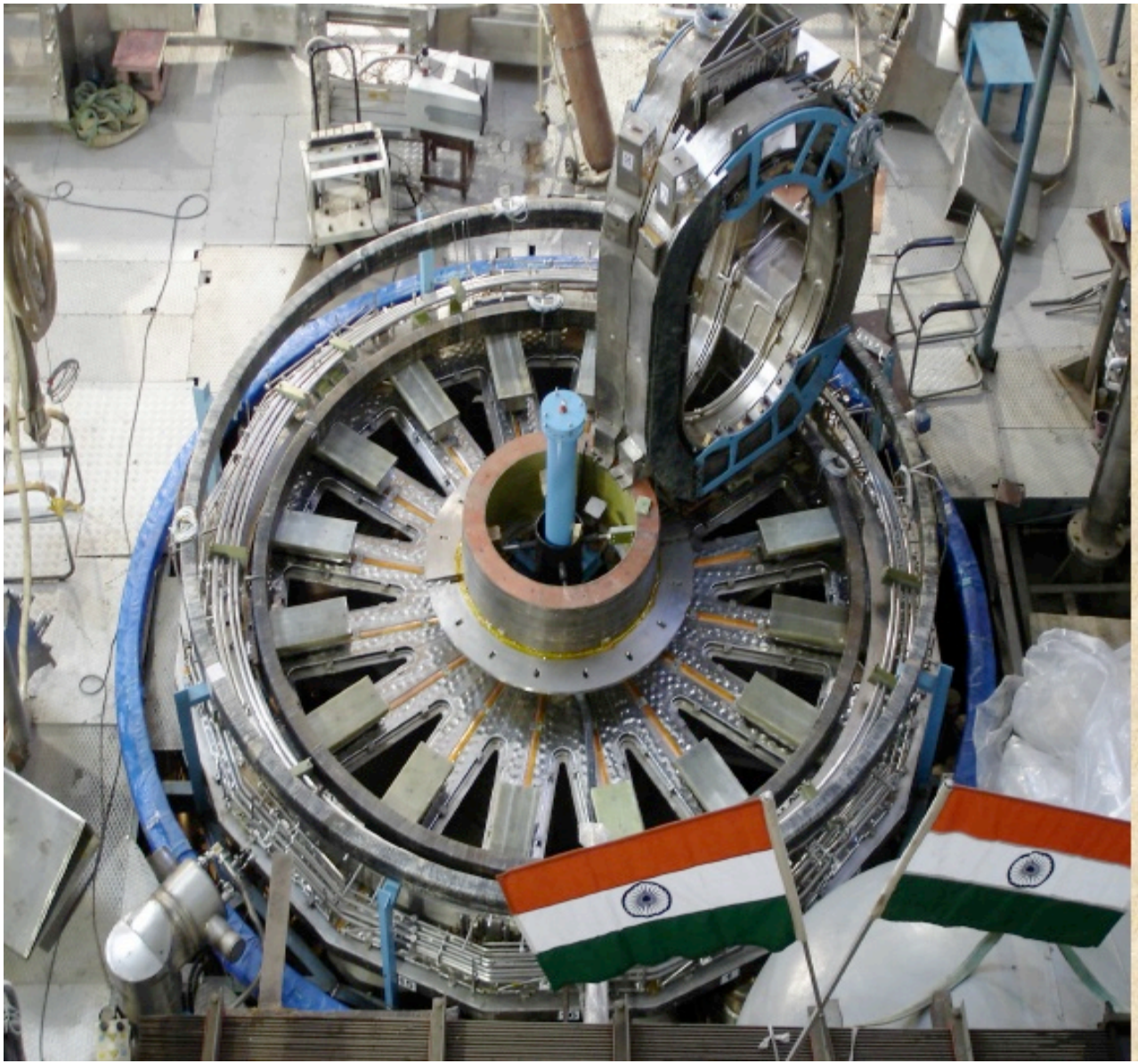




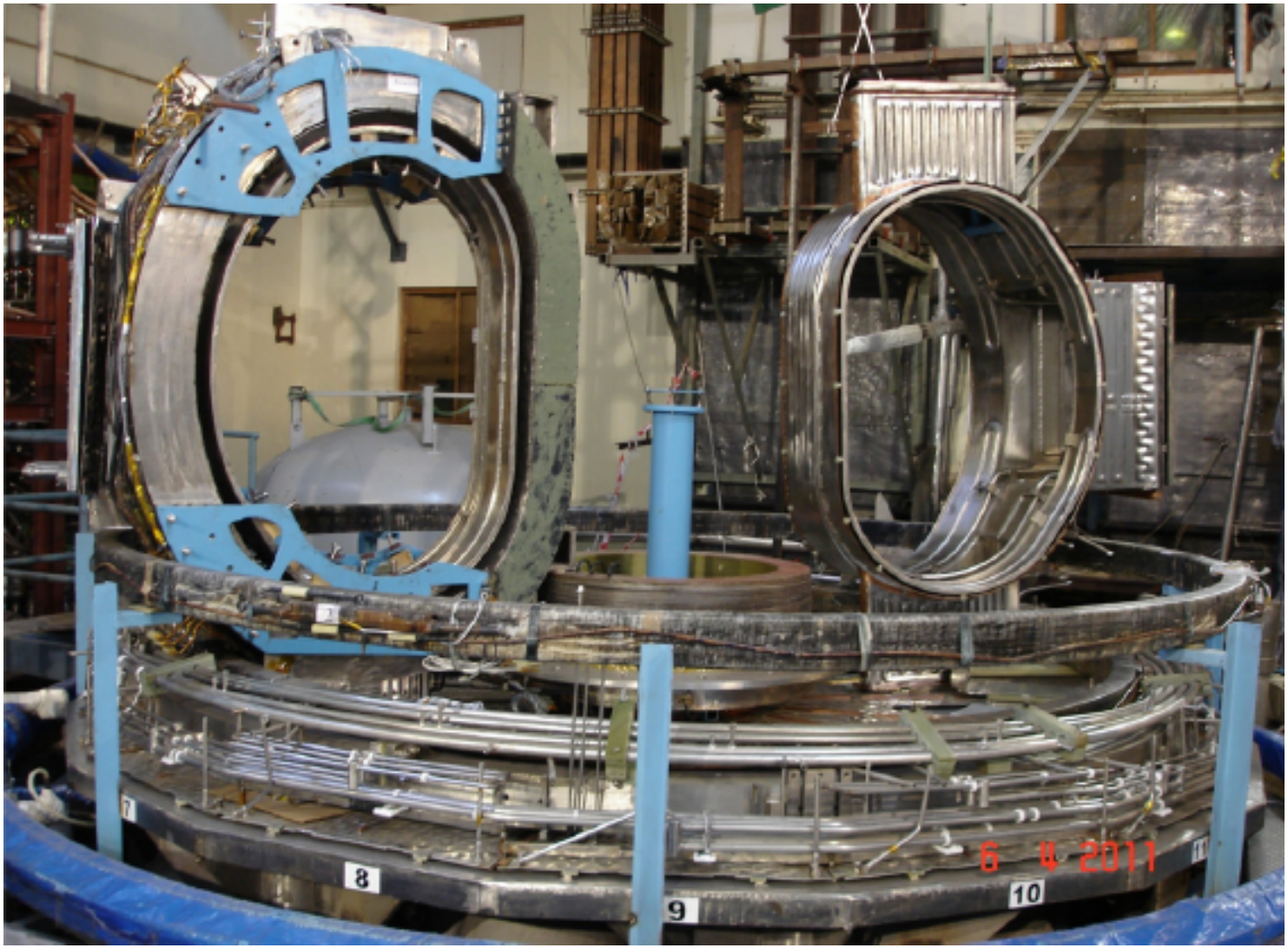
Jan 10, 2011



Feb 10, 2011



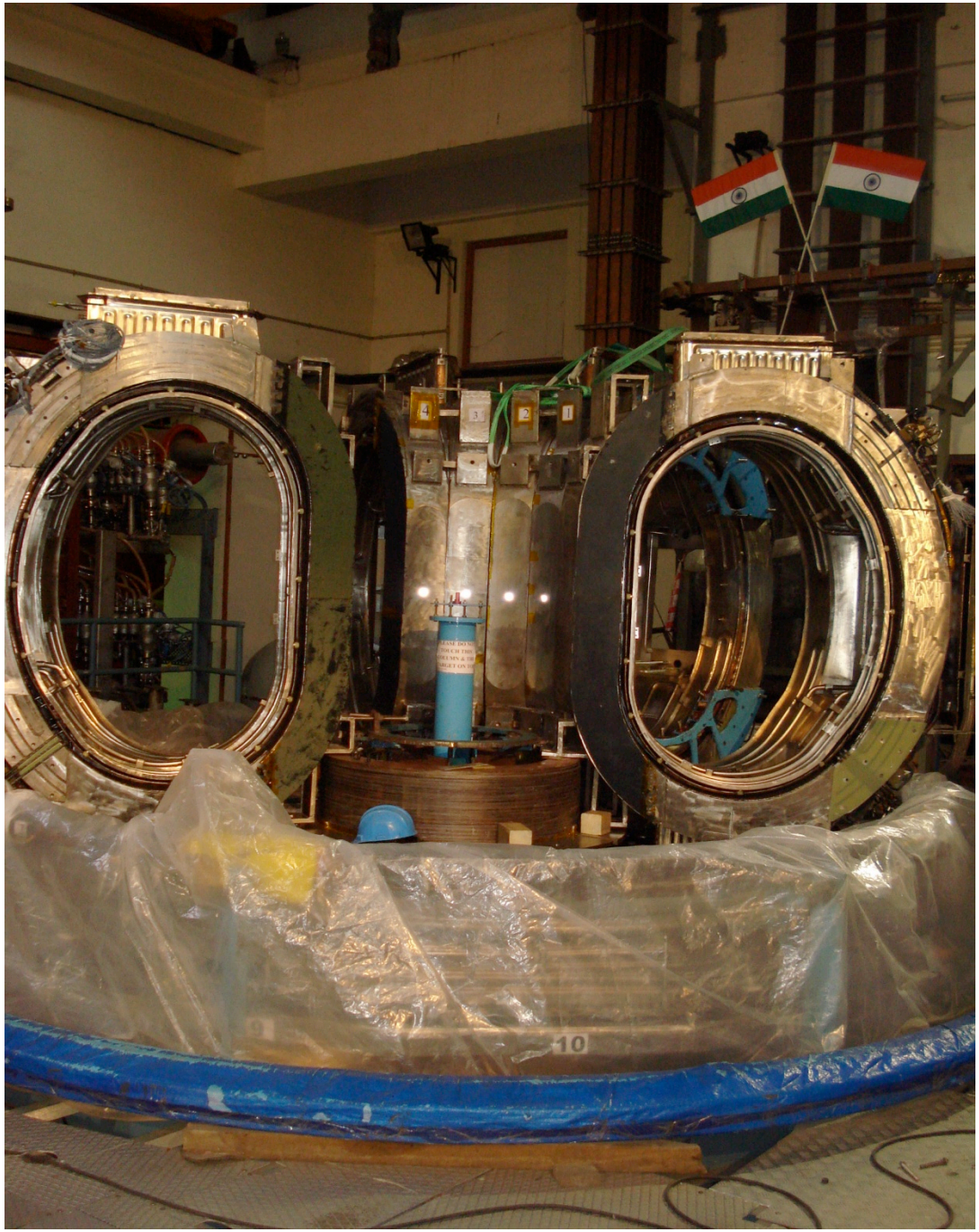
Mar 10, 2011



April 10, 2011

A view of the device assembly area

June 10, 2011



June 14, 2011

June 23, 2011

SST-1 Mission Schedule Projection

- The SST-1 Device Integration at present is ahead of the projected schedule.
- The cool-down of the assembled magnets in the cryostat is expected in Dec 2011.
- The engineering validations & First Plasma is expected in the first half of 2012.

Thank You