US ITER 11102-CM0001-R00
PA 1.1.P4A-B.US.01

Interface Control Document for the Interface between the Central Solenoid Insert Coil and the Test Facility

May 2011

INTERFACE CONTROL DOCUMENT FOR THE INTERFACE BETWEEN THE CENTRAL SOLENOID INSERT COIL AND THE TEST FACILITY

Alexandre Smirnov
Yoshihiko Nunoya
Nicolai Martovetsky

Prepared by
US ITER Project Office
Oak Ridge, Tennessee

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6283
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

INTERFACE CONTROL DOCUMENT
FOR THE INTERFACE BETWEEN
THE CENTRAL SOLENOID INSERT COIL AND THE TEST FACILITY

	Signature	Date
Prepared by:	Alexandre Smirnov	05/19/11
Approved by: CS Systems Manager	Christopher Rey	5-23-11
Magnet Systems Chief Engineer	Nicolai Martovetsky	5/19/11
WBS Team Leader	Wayne Reiersen	5/20/11
Chief Engineer	Brad Nelson	5/20/11
Quality & ES&H Manager	Frank Casella	5/24/11

REVISION RECORD

Number: US ITER 11102-CM0001

ICD for ITER Central Solenoid Insert

Revision No.	Description of Revision	Date Revised	Revision Written by:	Revision Approved by:*
	DRAFT	12/10/2010	Alexandre Smirnov	Nicolai Martovetsky
00	Technical editing	12/30/2010	Walter Koncinski	Nicolai Martovetsky

*Approval must be at the level of the work breakdown structure manager or above.

CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

ACRONYMS

BPS	brazing procedure specifications
CSCI	Central Solenoid Conductor Insert
CSI	Central Solenoid Insert Coil
CSMC	Central Solenoid Model Coil
DA	domestic agency
DC	direct current
EDA	engineering design activities
GKG	glass-Kapton-glass
HAZ	heat-affected zone
ICD	Interface Control Document
IDD	Interface Design Document
JADA	Japanese ITER Domestic Agency
JAEA	Japan Atomic Energy Agency
JCT	Joint Central Team
JHPSL	High-Pressure Gas Safety Law
KHK	the High-Pressure Gas Safety Institute of Japan
METI	Ministry of Economy, Trade and Industry of Japan
NBBI	National Board of Boiler and Pressure Vessel Inspectors
PQR	procedure qualification record
SHe	supercritical helium
SRD	Systems Requirement Document
USIPO	US ITER Project Office
WPS	welding procedure specifications

ABSTRACT

This document provides the interface definition and interface control between the Central Solenoid Insert Coil and the Central Solenoid Model Coil Test Facility in Japan.

1. INTRODUCTION

As part of the engineering design activities for ITER, the Central Solenoid Model Coil (CSMC), including insert coils, has been manufactured and has been tested at the Japan Atomic Energy Agency (JAEA) CSMC Test Facility. The tests were conducted to obtain experimental data, to demonstrate reliable operation of superconducting coils, and to prove the design principles proposed for the ITER superconductors.

This document defines interfaces between the new Central Solenoid Insert (CSI) and the CSMC Test Facility. Inspections required to receive the CSI coil to the test facility are also described in this document.

The supplier who will manufacture CSI in order to test it in the Test Facility shall design the CSI according to interface control drawings as listed in Sect. 5.

2. GENERAL CONFIGURATION

2.1 CONFIGURATION OF THE TEST FACILITY

The JAEA CSMC Test Facility photo is shown in Fig. 1.

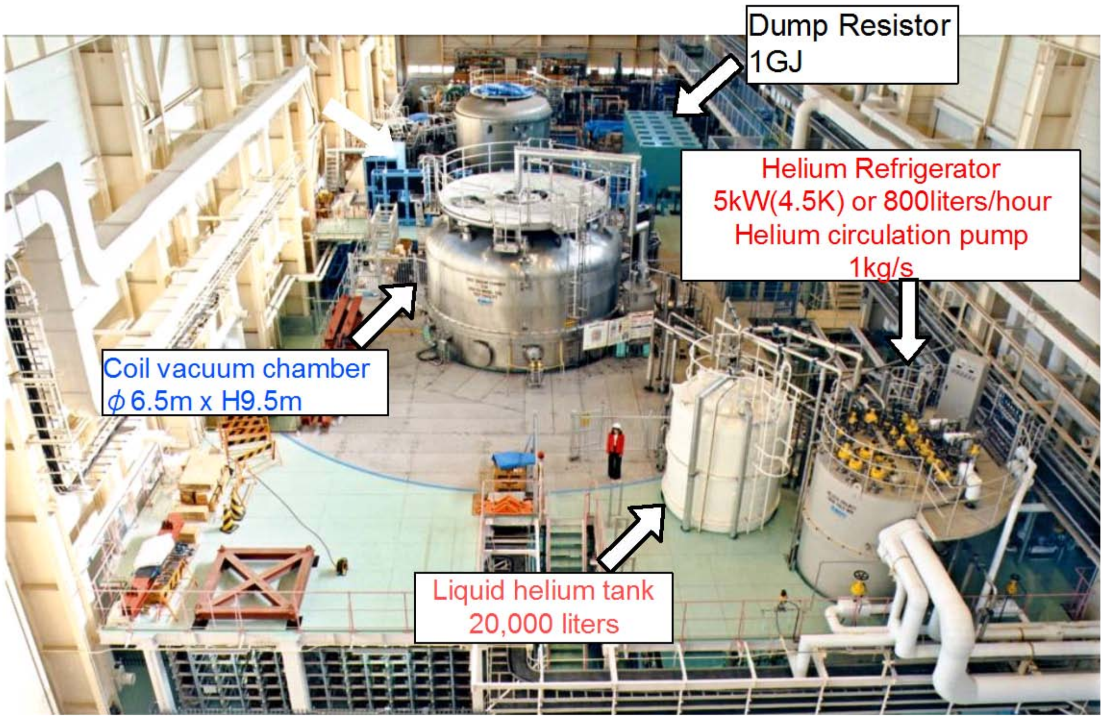


Fig. 1. Test Facility photo.

A bird's-eye view of the Test Facility is shown in Fig. 2.

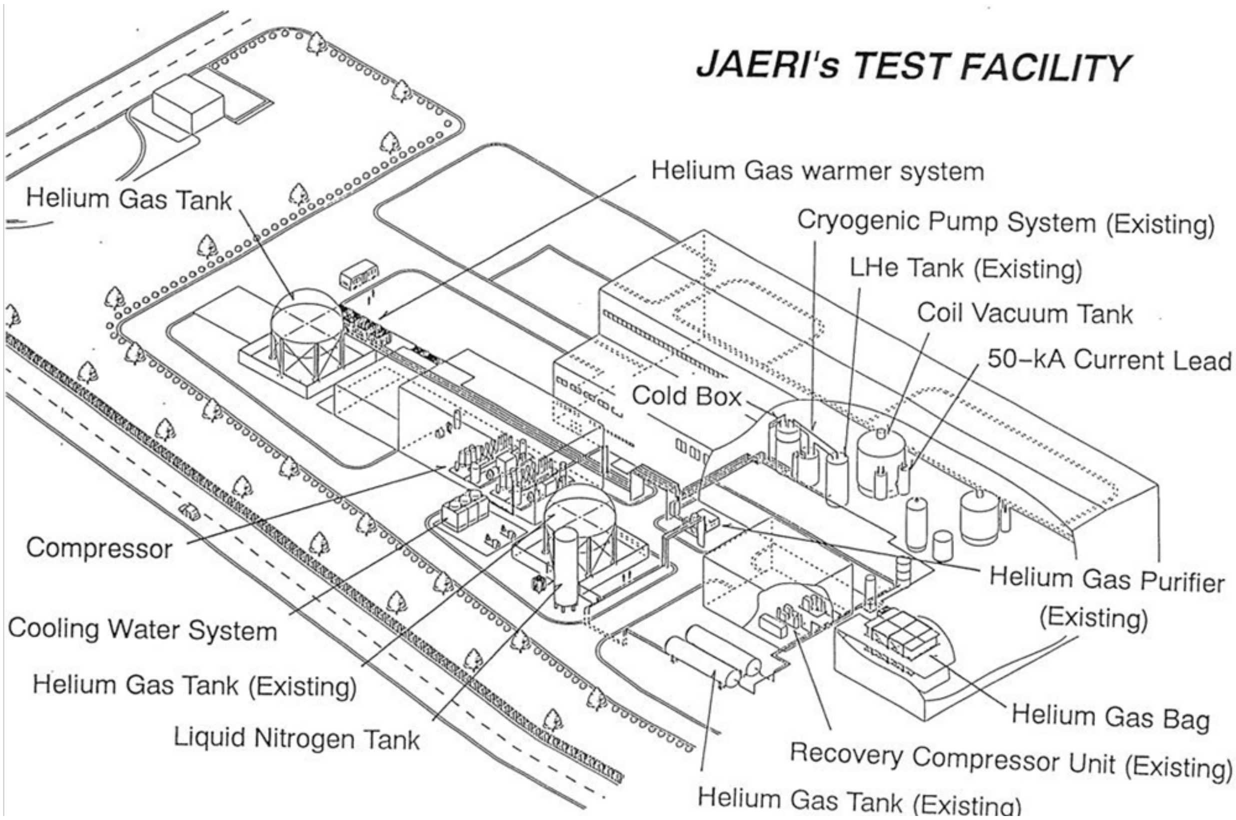


Fig. 2. Test Facility bird's-eye view.

The Test Facility consists of the following components, equipment, and systems shown on the ground floor and second floor layouts (see Figs. 3 and 4):

- cryogenic system
- direct current (DC) power supply 1
- DC power supply 2
- pulse power supply
- discharging resistors
- circuit breakers
- current leads
- bus bars and switching units
- coil protection and control system
- vacuum chamber and pumping units
- data acquisition system
- instrumentation cables between feedthroughs and data acquisition system
- 60 ton crane
- equipment in the vacuum tank (e.g., CSMC with piping, control valves, instrumentation cables, 4K legs, 4K gravity base)

The CSMC Test Facility was built to test large conductors for fusion under the most relevant conditions (temperature, strain, magnetic field, and current) to verify the design parameters.

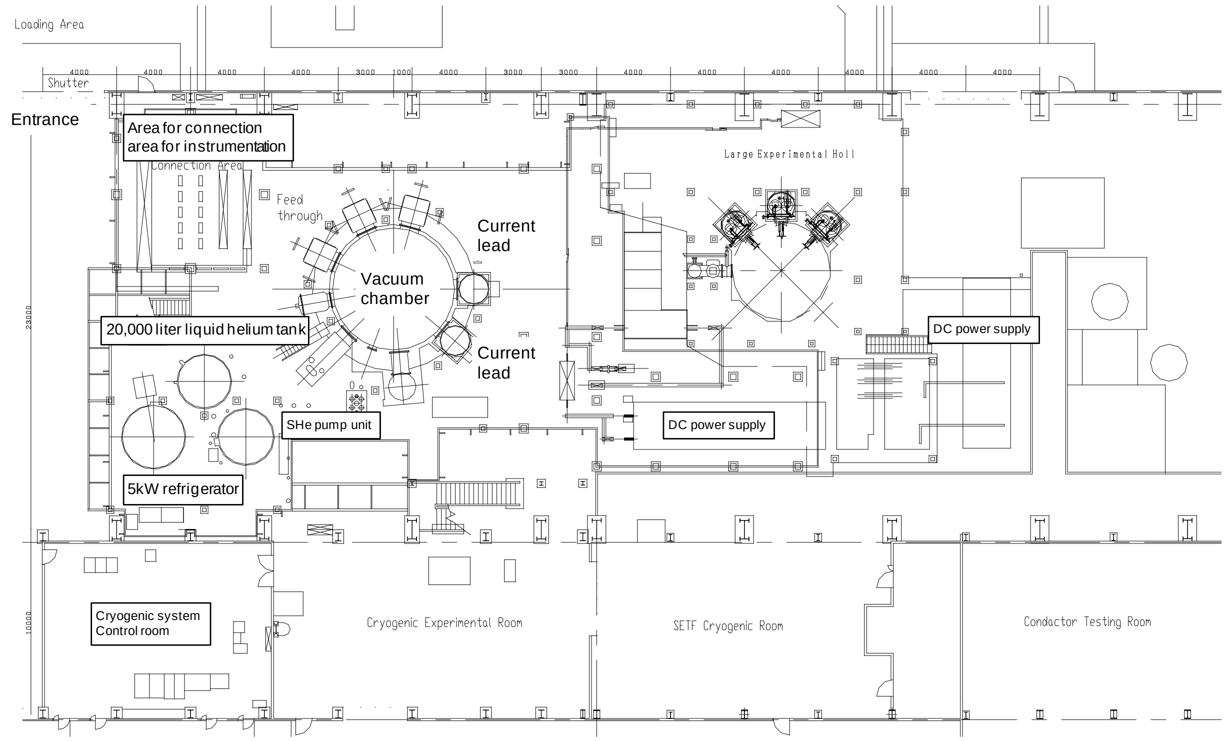


Fig. 3. Test Facility, ground floor layout.

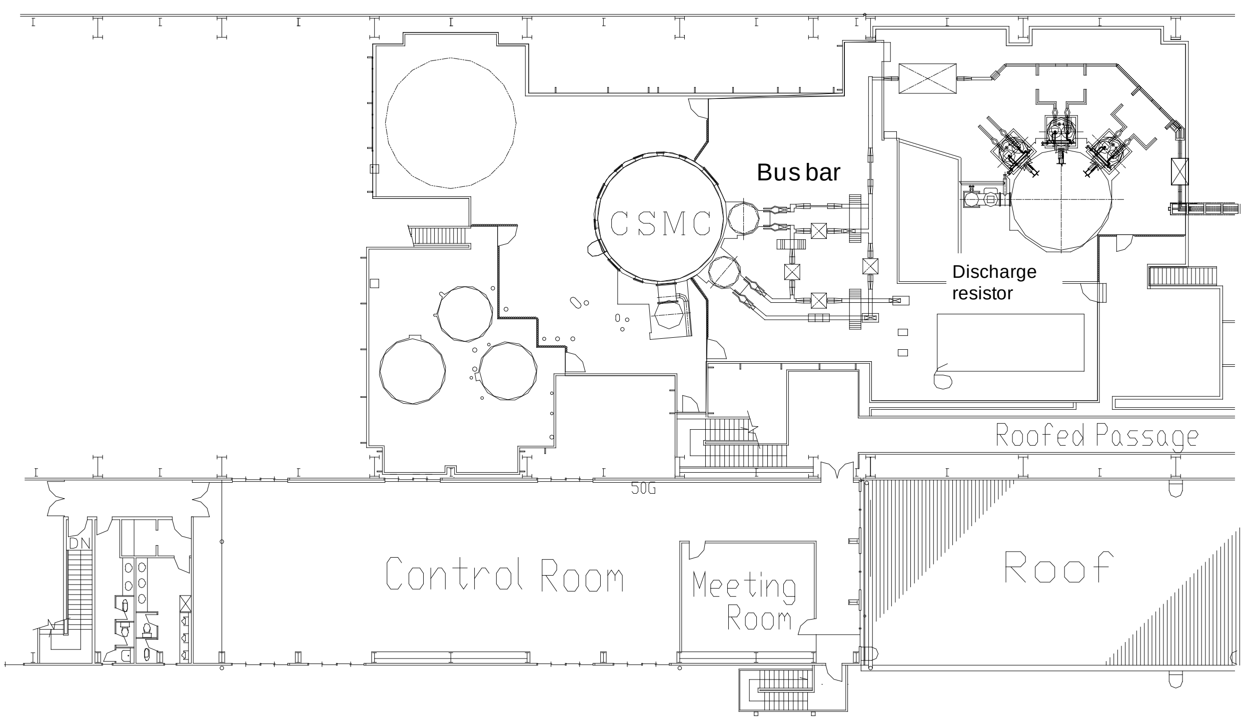


Fig. 4. Test Facility, second floor layout.

3-D generated image of the CSMC with the CSI installed and with the electrical and plumbing interface without cryogenic vessel shown in Fig. 5.

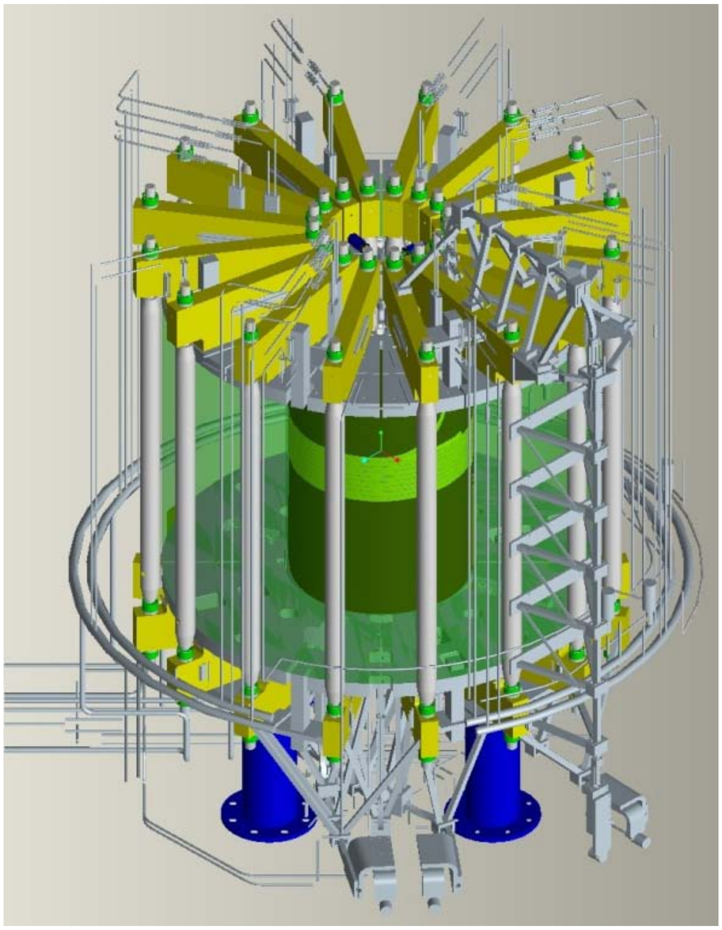


Fig. 5. 3-D generated CSI/CSMC Interface (outer module shown in transparent green).

Table 1 show the space envelope that the CSI needs to fit. The terminations of the CSI need to fit the terminations from the facility buses.

Table 1. Space envelope of the CSI

Geometrical Parameters	
Main winding envelope - Inner diameter - Outer diameter - Height	 1417 mm 1535 mm 496.5 mm
- Length of conductor	< 44.6 m
- Number of turns	8.875
- Number of layers	1
Total height with terminations	4445

Drawing of the Envelope (see Fig. 6) to show what allowable space exists for the Central Solenoid Insert.

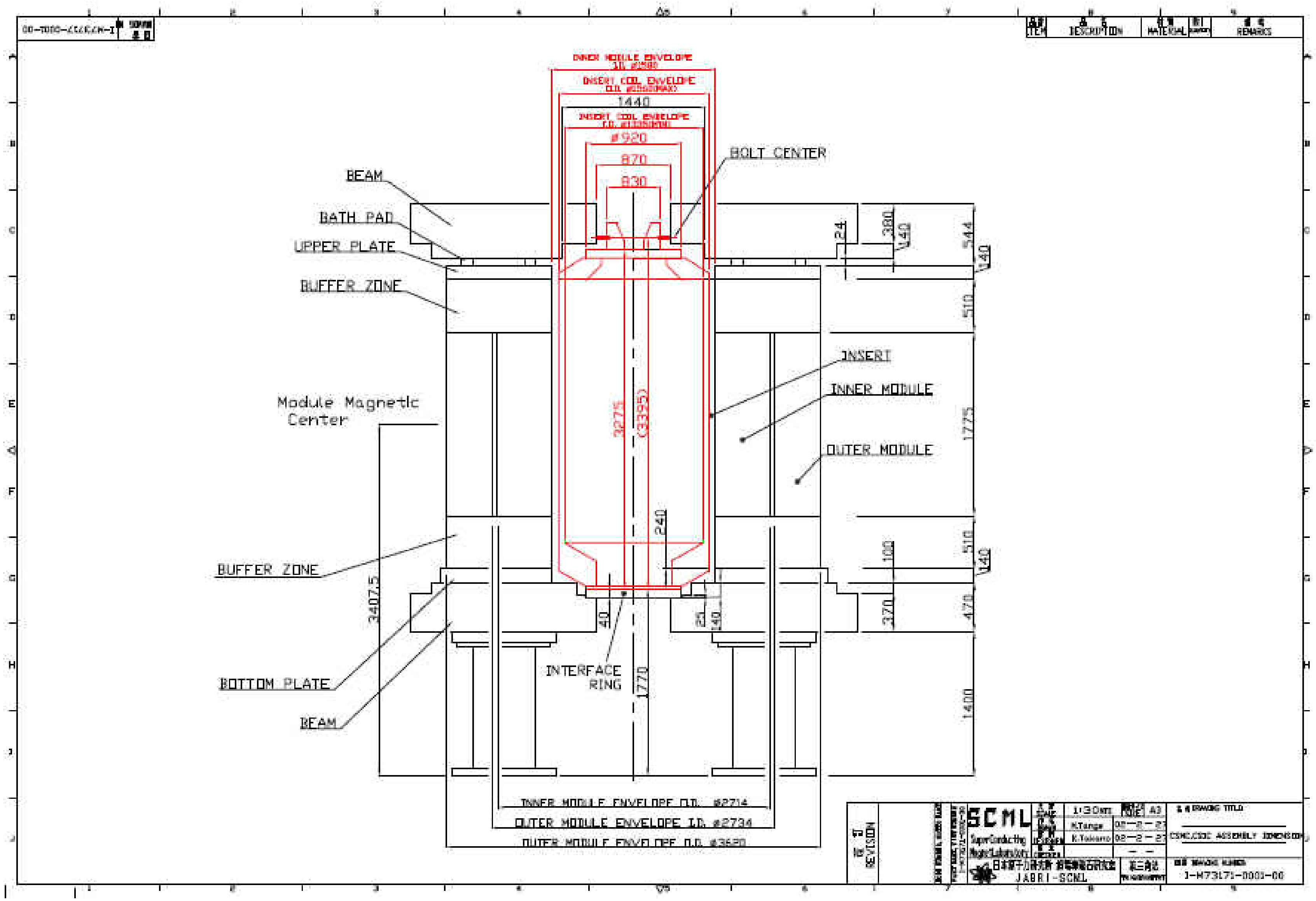
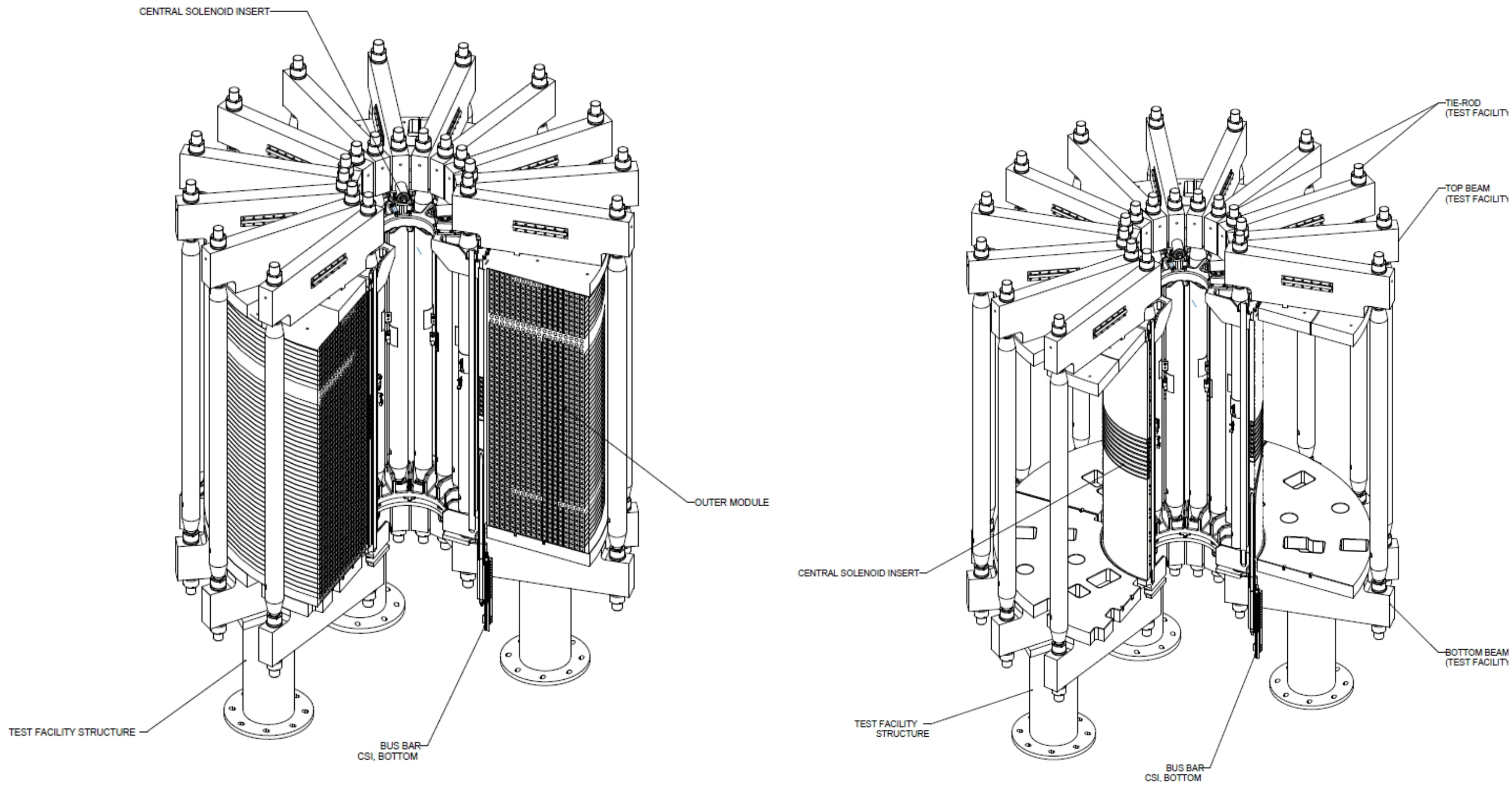


Fig. 6. CSI/CSMC Interface envelope drawing.

The main parts of the CSMC in-vessel systems are shown in Figs. 7, (a) and (b).



(a) (b)

Fig. 7. The main parts of the in-vessel system. CSI inside the CS Model Coil.

2.2 CONFIGURATION OF THE INSERT COIL

The configuration of the CSI is as follows:

- A single layer coil, including insulation. The winding is embedded in stainless steel cylinders (spacers); the ground insulation system consists of glass-Kapton-glass (GKG) to meet high-voltage requirements; for low voltage (less than 1 kV), the Kapton barrier may be omitted.
- Support structure with cooling piping.
- Sensors installed in the CSI with instrumentation cables and connectors.

Figure 8 shows the configuration of the winding pack and the pre-compression structure. The pre-compression structure is shown in Fig. 9.

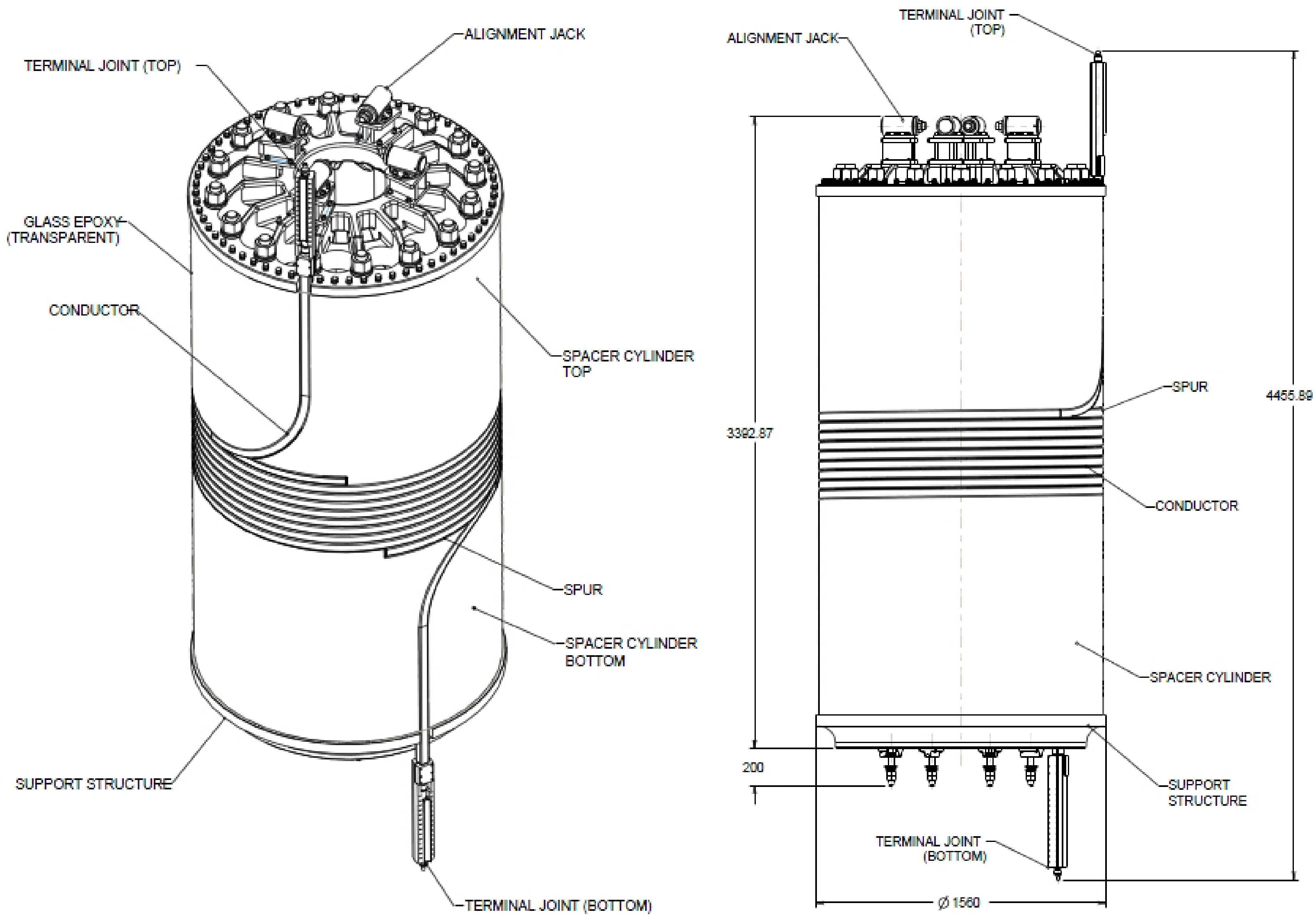


Fig. 8. CSI assembly drawing.

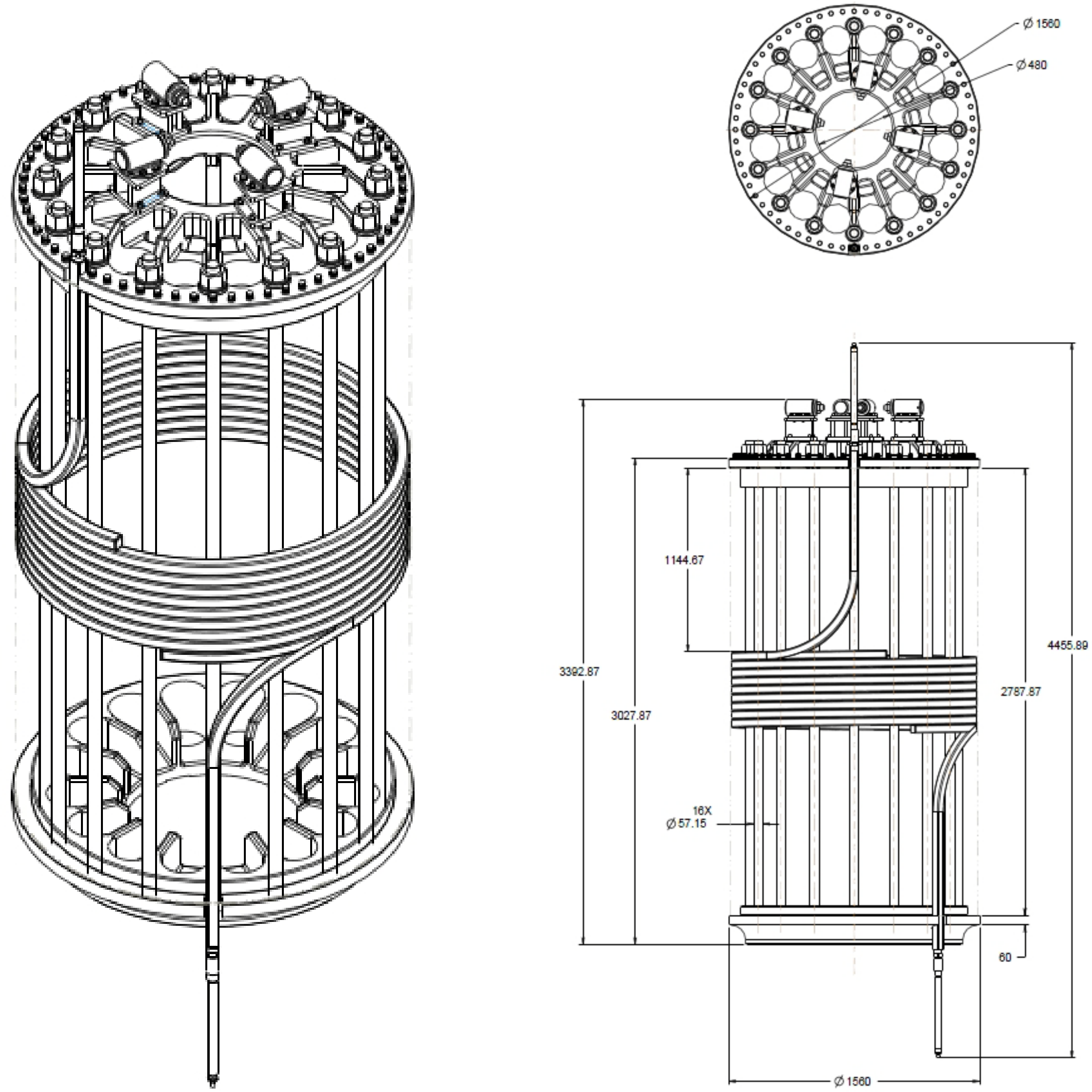


Fig. 9. CSI support structure drawing.

3. TEST FACILITY TECHNICAL SPECIFICATION

The technical specifications of the CSMC Test Facility are determined from the requirements of the ITER Joint Central Team and are given in the Task Agreement “Preparation of ITER CS Model Coil Test Facility (N 13 TT 19 93-10-12 FJ).”

3.1 COOLING PARAMETERS

The Test Facility provides the capabilities summarized in Table 2.

Table 2. CSMC Test Facility capabilities

Purifier time (days)	5 (target 3)
Cool down time (days)	40 (target 20)
Operating temperature (K)	4.5
Helium flow rate, channel (g/s)	10
Helium flow rate, coil (g/s)	350
Max. operating pressure (bar)	7
Max. pressure drop (bar)	4
Average pump work (W)	400 (into a cold circuit)
Max. helium volume in coil (L)	2000

3.2 ELECTRICAL PARAMETERS

The inductances of 800 mH for the CSMC and 2 mH for only the CSI are postulated from the given conditions (total energy of 1 GJ, current of 50 kA, and maximum field of 13 T). The components needed to conduct performance tests of the CSI are summarized in Table 3.

Table 3. Components needed to test the CSI

Component	Rating
Two DC power supplies	50 kA
Discharging resistor	1 GJ, 0.04 Ω
Circuit breaker	50 kA-2.5 kV
Current leads (2 pairs)	50 kA
Bus bars and switching units	50 kA

4. TEST FACILITY CONFIGURATION COMPONENTS

4.1 CRYOGENIC SYSTEM

4.1.1 Configuration of the Components

The configuration of the cryogenic system is shown in Fig. 10. Components are listed in Table 4.

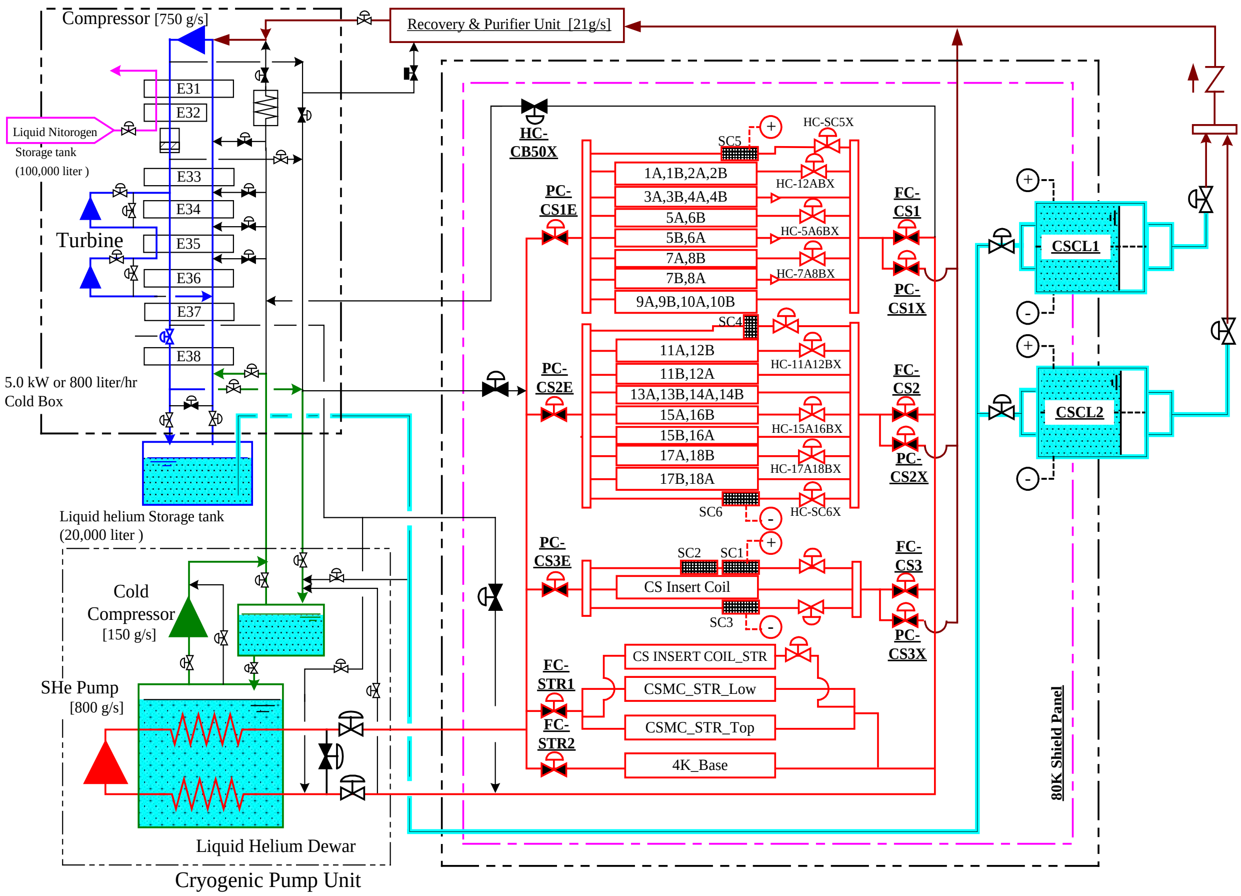


Fig. 10. Cryogenic system configuration.

Table 4. Components of the CSMC Test Facility cryogenic system

Component	Rating
Cold box	
Refrigeration power	5 kW at 4.5 K
Liquefaction power	800 L/h
Helium compressor	
Total mass flow rate	600–750 g/s
Suction pressure	Around 0.1 MPa
Discharge pressure	1.6 -1.8 MPa
Isothermal efficiency	Better than 55%
Type	Oil injection screw type

Purifier	
Inlet gas contamination	1000 ppm
Outlet gas contamination	Less than 1 ppm
Inlet water contamination	Saturated
Outlet water contamination	Less than -60^{o}C
Recovery unit	
Recovery helium gas storage	700 m^3, 2.0 MPa
Recovery mass flow	20 g/s
Primary liquid helium storage tank	
Storage capacity	20,000 L
Auxiliary cold box	
SHe flow rate	500 g/s
SHe temperatures	As low as 4.1 K
SHe pressure	0.5 - 1.0 MPa
SHe circulation head	As high as 0.2 MPa
Liquid nitrogen tank	
Storage capacity	100,000 L

4.1.2 Cryogenic Parameters

The CSMC cryogenic system can serve the following cryogenic conditions to the CSI.

4.1.2.1 Coil supply temperature, pressure, and mass flow rate

The CSI shall be cooled by supercritical helium (SHe). The SHe conditions as the coil supply temperature, pressure, and mass flow rate are listed in Table 5.

Table 5. Supercritical helium conditions

Condition	Temperature (K)	Pressure (MPa)	Mass flow rate (g/s)
Rated	4.5	0.5–1.0	150–500
Minimum temp	4.0	0.5–1.0	less than 300[a]
Maximum temp	8.0	0.5–1.0	less than 100. Partially[b]

[a]The minimum supplying temperature depends on the mass flow rate. It is possible to reduce the temperature if the mass flow rate is reduced much more.

[b]The maximum temperature will be produced and controlled by using electric heater. The temperature also depends on the supplying mass flow rate. High temperature can be partially supplied to the winding part, if such system is equipped.

4.1.2.2 Pressure drop through the coil

Pressure drop conditions are shown in Table 6.

Table 6. CSMC pressure drop conditions

Acceptable pressure drop through the coil when the SHe pump operated (MPa)	< 0.2
Pressure drop measurement without SHe pump operation (MPa)	0.4 for a few flow channels in the coil

4.1.2.3 Cooldown conditions

Cooldown conditions are summarized in Table 7.

Table 7. CSMC cooldown conditions

Condition	Temperature (K)
Cooldown capacity (kW)	
50	~100
5	4.5
Mass flow rate capacity (g/s)	
50–150	300–100
150–300	100–4.5
Available cooldown control	
Automatic	300–100
Manual	100–4.5

4.1.2.4 Proof pressure

The proof pressure is more than 1.5 times the design pressure in each temperature region. The design pressure of the cryogenic system is 2.0 MPa. Accordingly, the proof pressure of the cryogenic system is 3.0 MPa. Therefore, the CSI design pressure can be as high as 2.0 MPa.

4.1.2.5 Helium leakage

The cryogenic system will be fabricated to have the helium leakage of less than 1.0×10^{-7} mbar L/s with the design pressure at room temperature. Thus, the same criterion of the helium leakage will be requested to the CSI.

4.2 POWER SUPPLY SYSTEM

The power supply system of the Test Facility has two DC electrical circuits and a pulsed electrical circuit that uses a part of the DC circuit in common (see Fig. 11).

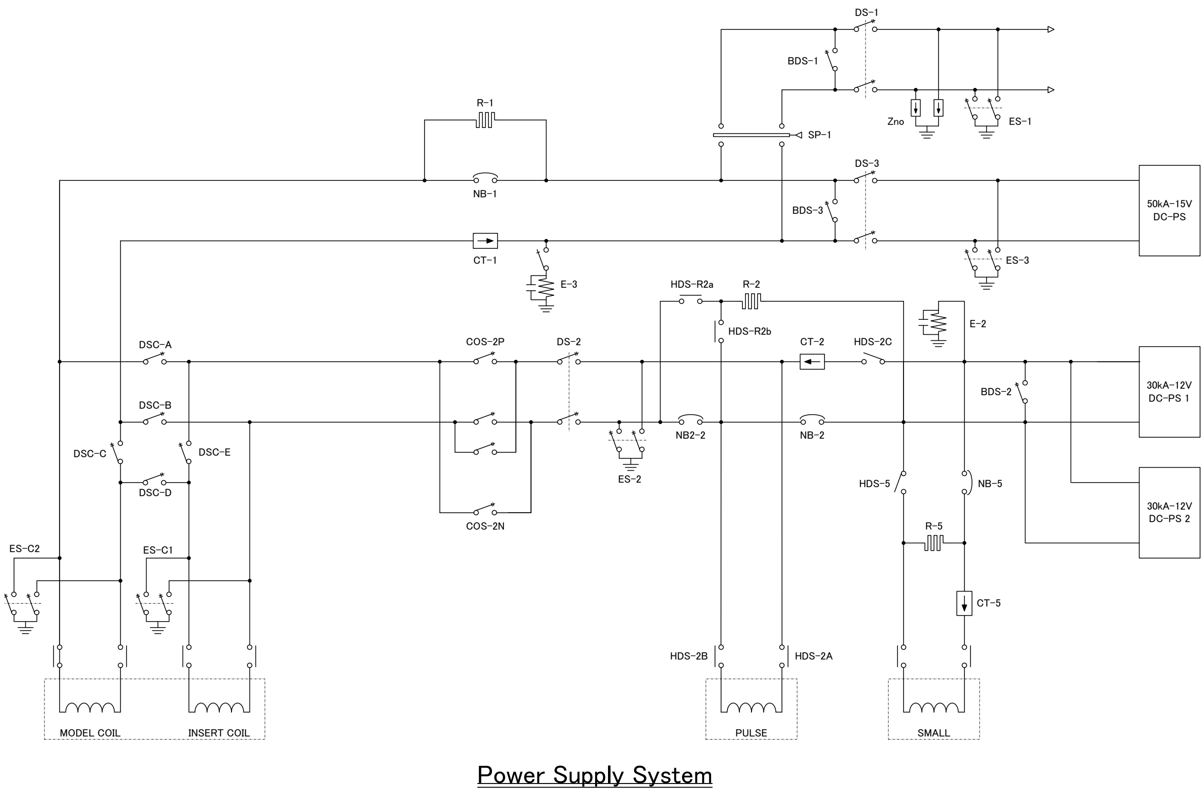


Fig. 11. Power supply system for the CSMC and Test Facility.

Each electrical circuit consists of a power supply, a circuit breaker, a discharging resistor, a pair of current leads, bus bars, and switching units. The possible operation modes of CSMC with the power supply system is shown in Fig. 12 and summarized in Table 8.

Table 8. Modes of the CSMC Test Facility power supply system

Mode name	Power Supply	Coil	Protection
DA	50kA DC PS	Model coil + Insert	50kA,10kV,600MJ
D2	50kA DC PS	Model coil	50kA,10kV,600MJ
B1	60kA DC PS	Insert	60kA,1.5kV,110MJ
MA	50kA DC PS 60kA DC PS	Model coil Insert	50kA,10kV,600MJ 60kA,1.5kV,110MJ

Several operating modes will be provided in order to carry out the performance tests of the CSMC. All the available operating modes of the CSMC will be specified by the Japanese ITER Domestic Agency (JADA).

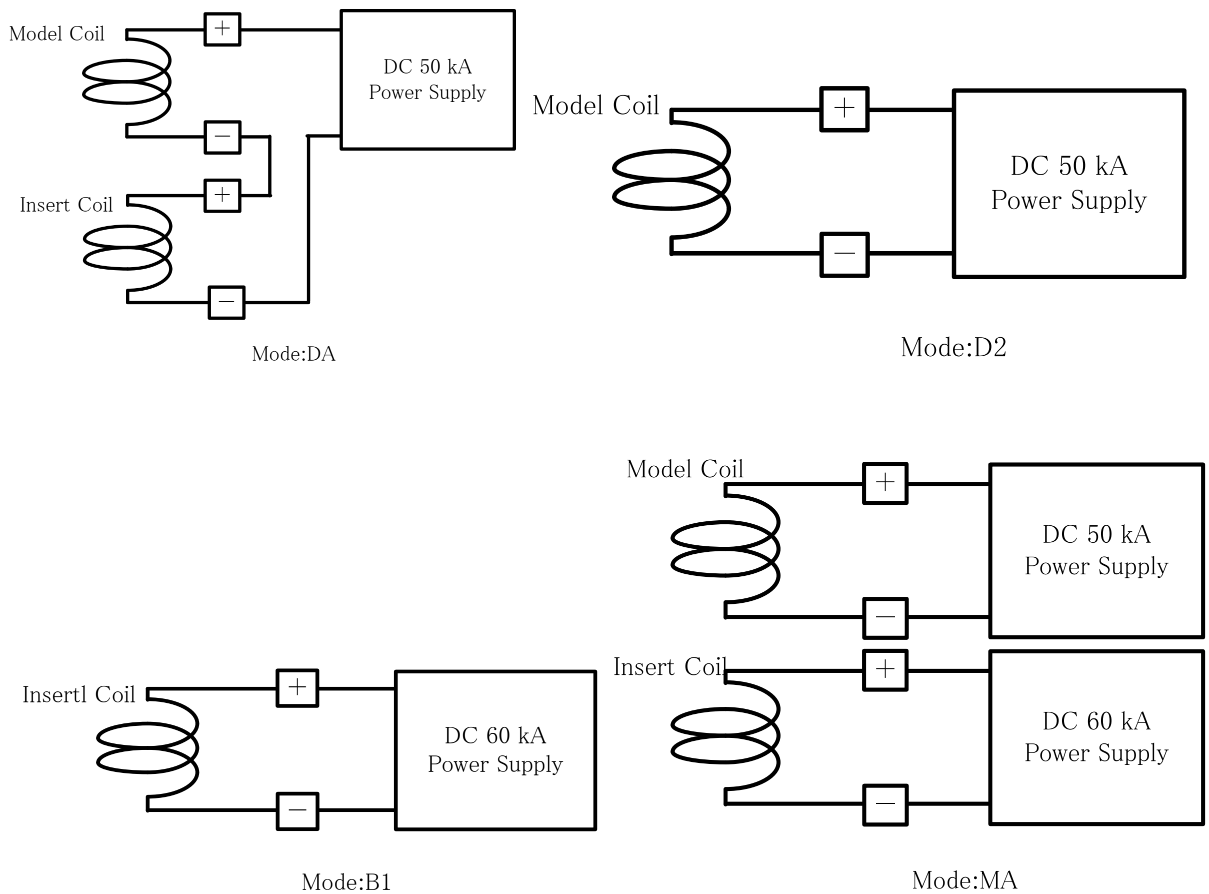


Fig. 12. Operation mode for the CSMC and CSI.

4.2.1 Electrical Circuit for the CSMC

The CSMC will be charged up to 50 kA in the DC test by using this circuit. These circuit components are listed in Table 9.

Table 9. DC test circuit components

DC power supply 1	
Maximum current (kA)	50
Maximum voltage (V)	15
Discharging resistor	
Discharging resistance (Ω)	0.01, 0.02, 0.04, 0.05, 0.1, 0.2 (for 1 GJ)
DC Circuit breaker	
Maximum current (kA)	50
Maximum voltage (kV)	10
DC Current leads	
Transport current (kA)	50
Insulation voltage (kV)	10 (to the ground)
DC Bus bars	
Transport current (kA)	50

4.2.2 Electrical Circuit for the CSI

The insert will be charged up to 50 kA in DC test and will be fatigue tested by using this circuit. The capacity of this circuit is 30 kA continuous, or 50 kA under the condition of charging time (3 min with an interval of 10 min). The polarity of a current can be changed by the switching units in the circuit. Circuit components are listed in Table 10.

Table 10. Components for CSI test circuit

DC power supply			
	50kAPS	30kAPS1+30kAPS2	
Maximum current	DC50kA	DC60kA	
Maximum voltage	±15V	±12V	
Ripple	10-3 rms	10-4 rms	
Circuit breaker			
	NB-1	NB2+NB2-2	
Rated breaking current	±50kA	+60kA	
Maximum breaking voltage	±10kV	+1.5kV	
Delay time	0.5sec	0.2sec	
Components	VCB+DS	ACB+ACB	
Discharge resistor			
	R-1	R-2	
Component	50mΩ×21units	12.5mΩ×8units	
Resistance value	0.02Ω-0.2Ω	0.7mΩ-0.1Ω	
Maximum capacity of resistor	1GJ	110MJ	
Maximum discharge current	50kA	60kA	
Switching unit			
	DS-1, 2, 3, DCS-A, B, C, D, E	BDS-2,3	COS-2P・2N
Operating current	DC50kA, DC30kA, DC15kA	DC50kA, DC30kA	DC30kA
Mechanism	pressurized air	pressurized air	pressurized air
Dead time	open < 2sec close <3.5sec	open <0.4sec close <0.6sec	open <2sec close <3.5sec
Bus bar			
	50kA Bus Bar	30kA Bus Bar	
Rated current	DC50kA-8h	DC30kA-8h	
Rated voltage	AC6.6kV	DC1.5kV	
Short-time rated current	-	DC60kA-1h	
Rounding resistor			
	E-2	E-3	
Resistor	20Ω	100Ω	
Capacitor	50μF	100μF	
Rated voltage	DC1.5kV	AC6.6kV	
DC-Current transformer			
	CT-1	CT-2	
Maximum Current	60kA	60kA	
Detection	shunt resistor	hall DC current transformer	
Accuracy	±0.15%	±0.45%	

4.3 COIL PROTECTION AND CONTROL SYSTEM

Quench detectors to protect the CSMC are installed in the Test Facility and have the capability of reliable and fast detection of a coil quench. A control system is installed to perform safe and reliable operation of the Test Facility and the CSMC and to initiate discharge in case of a coil quench.

4.3.1 Low-Voltage Operation

In low-voltage operating mode, two DC power supplies (DC power supply 1 and 2) are available. There are many interlocks between the control system and the important components, such as the DC power supplies, DC circuit breakers, disconnecting switches for the bus bar, and the doors to the high-voltage area. Two kinds of quench detectors will be installed in the Test Facility. One will detect an appearance of resistivity using a compensated voltage. The other will detect a change of mass flow rate. The control system will open the DC circuit breakers due to the signals from these detectors in order to protect the CSMC.

4.4 VACUUM CHAMBER

The degree of vacuum in the vacuum chamber will be maintained not to exceed 1.3×10^{-2} Pa (1.0×10^{-4} Torr) during CSMC operation. A liquid-nitrogen-cooled cold wall will be mounted on the inner surface of the vacuum chamber; its temperature will be maintained at 80 K. The vacuum chamber's available inner diameter will be about 5.6 m; its inner height will be about 6.0 m.

4.5 DATA ACQUISITION SYSTEM

A computer-controlled data acquisition system will be installed for data acquisition, display, storage, and retrieval. The system will be accessible via local, domestic, or international networks.

4.6 INSTRUMENTATION

Instrumentation includes signal conditioners, wiring between sensors and signal conditioners in the control room, and equipment for selection of sensors.

4.6.1 Available Channels

The available number of sensors for CSI is listed in the document: I-M73174-0001-01.

4.6.2 Cryogenic Valve

JADA can provide 25 feedthroughs and helium gas for valve control if cryogenic valves to control SHe flow rate are requested.

The other type of the cryogenic valves, piping, and valve controller will be prepared by DA as a part of an additional request.

4.7 CRANES AND LIFTING EQUIPMENT

The capacity of the existing crane in the test facility is about 60 tons (see Figs. 13 and 14). The capacity of the existing crane is extended easily up to 62 tons. Additional lifting equipment would be requested if the weight of the largest single unit to be assembled into the vacuum chamber exceeds the crane capacity.

In that case, temporary lifting equipment would be used, and the building would need to be modified (for example, removal of the roof of the building) to install the unit. A large amount of money and time would be required.

Fig. 13. Lifting of the Toroidal Field (TF) Insert Coil.

Fig. 14. TF Insert Coil turnover procedure during installation into a center hole of the CSMC.

4.8 HEATER POWER SUPPLY

4.8.1 Resistive Heating Power Supply

Two sets of resistive heating power supplies are available to raise the SHe inlet temperature so that the current-sharing temperature can be measured. The power supplies can provide 400 V, 20 A DC output.

4.8.2 Inductive Heating Power Supply

An inductive heating power supply is available to raise the temperature of strands so that a stability margin can be measured. Output of the inductive heating power supply is summarized in Table 11.

Table 11. CSMC Test Facility inductive heating power supply output

Maximum current (A)	1000
Maximum voltage (V)	600
Resonance frequency (kHz)	1–5
Output duration (ms)	5–40
Load inductance (mH)	50–100

5. INTERFACE

Interfaces between the CSI and the Test Facility are described in this section. The interface drawings are provided by JADA.

5.1 STRUCTURAL INTERFACE

Drawings related to structural interface are listed in Tables 12a and 12b.

Table 12. Structural interface drawings list

JAEA		
Number	**File**	**Title**
I-M73171-0001-00	AutoCAD/.DWG	CSMC, CSI Assembly Dimension
I-M73171-0002-00	AutoCAD/.DWG	Insert Coil Bolt Bottom Structure
I-M73171-0003-00	AutoCAD/.DWG	Insert Coil M30 Bolt
I-M73171-0004-00	AutoCAD/.DWG	Insert Coil Self-aligning Washer
I-M73171-0005-00	AutoCAD/.DWG	Insert Coil Key Bottom Structure
I-M73171-0006-00	AutoCAD/.DWG	Insert Coil Key and Bushing
I-M73171-0007-00	AutoCAD/.DWG	TF Insert Coil Upper Bracket
I-M73171-0008-00	AutoCAD/.DWG	Insert Radial Envelope
USIPO		
Number	**File**	**Title**
11101-OR-0290-R00	PRO-E/PDF	CSI Assembly Total
11101-OR-0291-R00	PRO-E/PDF	CSI Module after VPI
11101-OR-0292-R00	PRO-E/PDF	CSI Conduit
11101-OR-0293-R00	PRO-E/PDF	CSI Support Structure w/Conduit

5.2 LIFTING TOOL

An installation of the CSI is performed by the lifting equipment available in the Test Facility building. (See Sect. 4.7).

The CSI will be equipped with appropriate hardware for lifting. The US ITER Project Office (USIPO) will provide standing frame and parts for turning over for the CSI.

5.3 CRYOGENIC INTERFACE

The cryogenic interface between the CSI and the cryogenic system (See Sect. 4.7) described in details as follows.

5.3.1 The CSI Coil

Three pairs of SHe supply and return line will be prepared for the CSI by the Test Facility. The inner module, the outer module, and the insert will have respective flow control valves in the SHe supply line.

The Central Solenoid Conductor Insert (CSCI) piping and the interface piping are fabricated from 304L or 316L stainless steel. The same material shall be chosen for the CSI piping. The piping will be joined by welding. Relevant drawings are listed in Tables 13a and 13b.

5.3.2 The CSI Structure

A structure cooling supply line and its return line will be prepared by the Test Facility. The maximum supply mass flow of supercritical helium will less than 100 g/s. See Tables 13a and 13b for a drawing of plumbing layout and interface conditions.

5.3.3 The Pressure Taps

The pressure taps are located at the low voltage piping area, outside the insulation joint. Specifications of the pressure taps are follows: material is SS304L or SS316L; diameter is around 1/8B size, connection type is welding.

Table 13. Cryogenic interface drawings list

JAEA		
Number	**File**	**Title**
Overall CSMC flow diagram		
I-M73172-0001-00	AutoCAD/.DWG	CSMC Flow Diagram
CSMC plumbing diagrams		
I-M73172-0002-00	AutoCAD/.DWG	Insert Coil Plumbing Inlet for Insert Coil
I-M73172-0003-00	AutoCAD/.DWG	Insert Coil Plumbing Outlet for Insert Coil
I-M73172-0005-00	AutoCAD/.DWG	Insert Coil Structure Plumbing
Plumbing layout and interface conditions		
I-M73172-0005-00	AutoCAD/.DWG	Insert Coil Structure Plumbing
USIPO		
Number	**File**	**Title**
11101-OR-0294-R00	PRO-E/PDF	CSI Support Structure without Conduit, with Cooling Line
11101-OR-0299-R00	PRO-E/PDF	CSI Cooling Line Layout

5.4 ELECTRICAL INTERFACE

Two pairs of current lead terminals are prepared near an 80 K shield panel. The geometrical position of the current lead terminals is shown in Figs. 6 and 7. The superconducting busbars are components of the CSMC and have a terminal that can be directly connected to the current lead terminal by several bolts. The plane for the connection between the superconducting busbar and the current lead is in parallel to the 80 K shield panel.

The busbars at the top and bottom form the terminal joints between the CSMC and CSI. (Details of the interface requirements for terminal joint will be included in a later revision of this document.)

Drawings related to the electrical termination interface are listed in Tables 14a and 14b.

Table 14. Electrical termination interface drawings list

Number	File	Title
JAEA		
Number	**File**	**Title**
I-M73173-0001-00	AutoCAD/.DWG	Insert Conductor Termination/Bus Bar Joint (top)
I-M73173-0002-00	AutoCAD/.DWG	Insert Conductor Termination/Bus Bar Joint (bottom)
I-M73173-0003-00	AutoCAD/.DWG	Allowable Terminal Structure Area
I-M73173-0004-00	AutoCAD/.DWG	Saddle
I-M73173-0005-00	AutoCAD/.DWG	Bus Bar Half Clamp
I-M73173-0006-00	word/.doc	Thermal Contraction Accommodation
USIPO		
Number	**File**	**Title**
11101-OR-0290-R00	PRO-E/PDF	CSI Assembly Total
11101-OR-0298-R00	PRO-E/PDF	CSI Terminal Sleeve Assembly

5.5 INSTRUMENTATION

5.5.1 Interface Drawing Documents

USIPO will prepare instrumentation for the CSI according to the following interface drawing documents (See Table 15).

Table 15. CSMC sensors

Number	File	Title
Number of sensors		
I-M73174-0001-00	EXCEL/.xls	The Mounting Sensor Number for the Insert Coil
Dimensions of instrumentation cable		
I-M73174-0002-00	EXCEL/.xls	Dimension of the Cable
Signal conditioner (prepared by JADA)		
I-M73174-0003-00	word/.doc	Specification of Signal Conditioner Amplifier and Power Supply for Heater (4 pages)
Feedthrough specifications (prepared by JADA)		
I-M73174-0004-00	word/.doc	Specification of Feedthrough
Sensor Naming rule		
I-M73174-0005-00	EXCEL/.xls	Sensor Naming Rule
Feedthrough assignment for voltage tap, quench detection, and compensation coil		
I-M73174-0006-00	EXCEL/.xls	Voltage Tap for Meas. and Q.D. and Compensation Coil Feedthrough Assignment
High-voltage thermometer feedthrough assignment		
I-M73174-0007-00	EXCEL/.xls	High-voltage Thermometer Feedthrough Assignment
Low voltage instrumentation connector assignment (e.g., thermometer, strain gage, displacement sensor. Hall probe and acoustic emission)		
I-M73174-0008-00	EXCEL/.xls	Thermometer Connector Assignment
I-M73174-0009-00	EXCEL/.xls	Strain Gauge Connector Assignment

I-M73174-0010-00	EXCEL/.xls	Displacement Sensor Connector Assignment
I-M73174-0011-00	EXCEL/.xls	Hall Prove Sensor Connector Assignment
I-M73174-0013-00	EXCEL/.xls	Acoustic Emission Sensor connector assignment
Assignment of board for pickup coil and voltage of resistive heater terminal		
I-M73174-0012-00	EXCEL/.xls	Pick Up Coil and Voltage of Resistive Heater Terminal Board Assignment
Feedthrough assignments of inductive and resistive heaters		
I-M73174-0014-00	EXCEL/.xls	Inductive Heater and Resistive Heater Feedthrough Assignment
Physical position of interface of instrumentation in vacuum chamber		
I-M73174-0015-00	PowerPoint/.ppt	Interface
Specification for Feedthrough (voltage tap)		
I-M73174-0016-00	PowerPoint/.ppt	Specification for Feedthrough (Voltage Tap)
Specification for high-voltage cable connection		
I-M73174-0017-00	PowerPoint/.ppt	Specification for High Voltage Cable Connection
Specification for Winchester connector for low voltage sensor and board and feedthrough for heater		
I-M73174-0018-00	PowerPoint/.ppt	Specification for Connector
I-M73174-0019-00	PowerPoint/.ppt	Specification for Terminal Board
I-M73174-0020-00	PowerPoint/.ppt	Specification for Feedthrough (Heater)
Estimation of wiring route and length		
I-M73174-0021-00	Visio/.vsd	Estimation of Wiring (High Voltage tap)
I-M73174-0022-00	Visio/.vsd	Estimation of Wiring (High Voltage Thermometer to Feedthrough)
I-M73174-0023-00	Visio/.vsd	Estimation of Wiring (High Voltage Thermometer to Cable Joint)
I-M73174-0024-00	Visio/.vsd	Estimation of Wiring (Low Voltage Sensor)
I-M73174-0025-00	Visio/.vsd	Estimation of Wiring (Heater)
I-M73174-0026-00	AutoCAD/.DWG	Estimation of Root and Cable Length of the Wiring

5.5.2 The Voltage Taps and Wiring Diagram for the CSI

The voltage taps and wiring diagram for the CSI instrumentation is given in the Fig. 15.

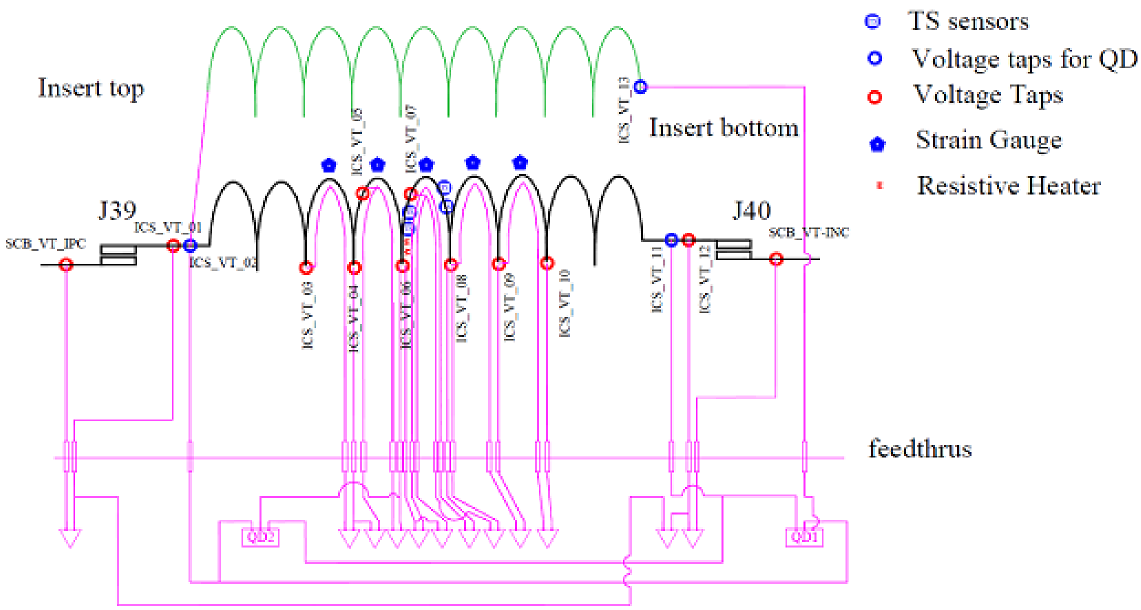


Fig. 15. CSI instrumentation diagram.

5.5.3 The Plumbing and Hydraulic Instrumentation for the CSI

The plumbing and hydraulic instrumentation for the CSI is shown in Fig. 16.

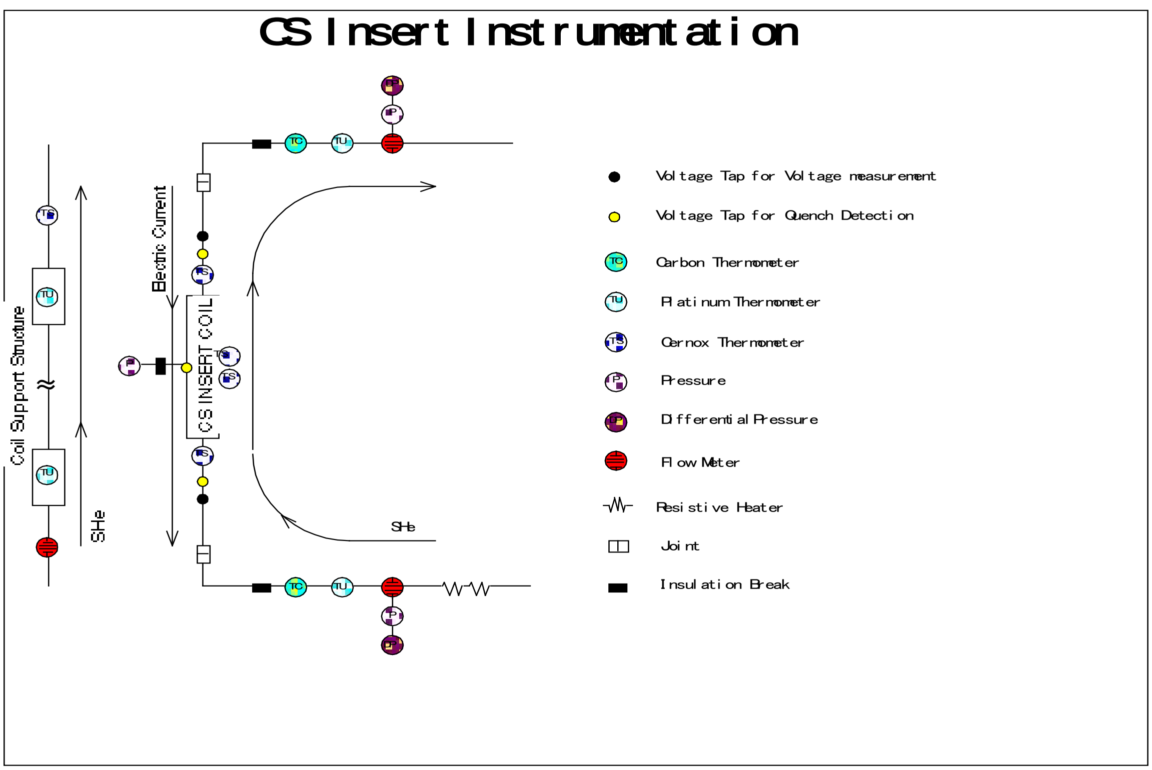


Fig. 16. Plumbing instrumentation for the CSI.

The list of sensors is given in Tables 16 and 17 below. The sensors (Facility) or (F) mean that these sensors are already part of the CSMC facility plumbing.

Table 16. CSI sensors

Sensor	Number
Voltage tap	18 (from 10 locations)
Voltage tap for QD	3
CGR thermometer (Facility)	2
Cernox thermometer	4
Pt-Co thermometer (Facility)	2
Strain gauge	5
Flow meter (Facility)	2
Pressure meter (Facility)	2
Differential pressure meter (F)	1
Pressure tap (F)	2
Resistive heater	2
Inductive heater	0
Hall probe for current distribution measurement	0
Compensation coil	1

Table 17. Sensors for CSI structure

Sensor	Number
Cernox thermometer (F)	1
Pt-Co thermometer (F)	8
Flow meter (F)	1
Pressure tap (F)	2
Strain gauges on the rods	4

6. SAFETY REGULATION

The CSMC combines high-pressure gas equipment with a cryogenic system, and a safety regulation is required for the use of high-pressure gas. Because the CSI is to be tested by at the CSMC Test Facility at JADA, it will be regulated by the Japanese government under the Japanese Gas High Pressure Safety Law (JHPSL). The JHPSL determines some technical requirements and inspection regulation for only pressure-retaining parts (called "Designated Equipment" in the law) of the high-pressure equipment such as the CSI. The following sections describe the procedure for application of the JHPSL to the CSMC.

6.1 APPLICATION PROCEDURE FOR THE JAPANESE SAFETY REGULATION

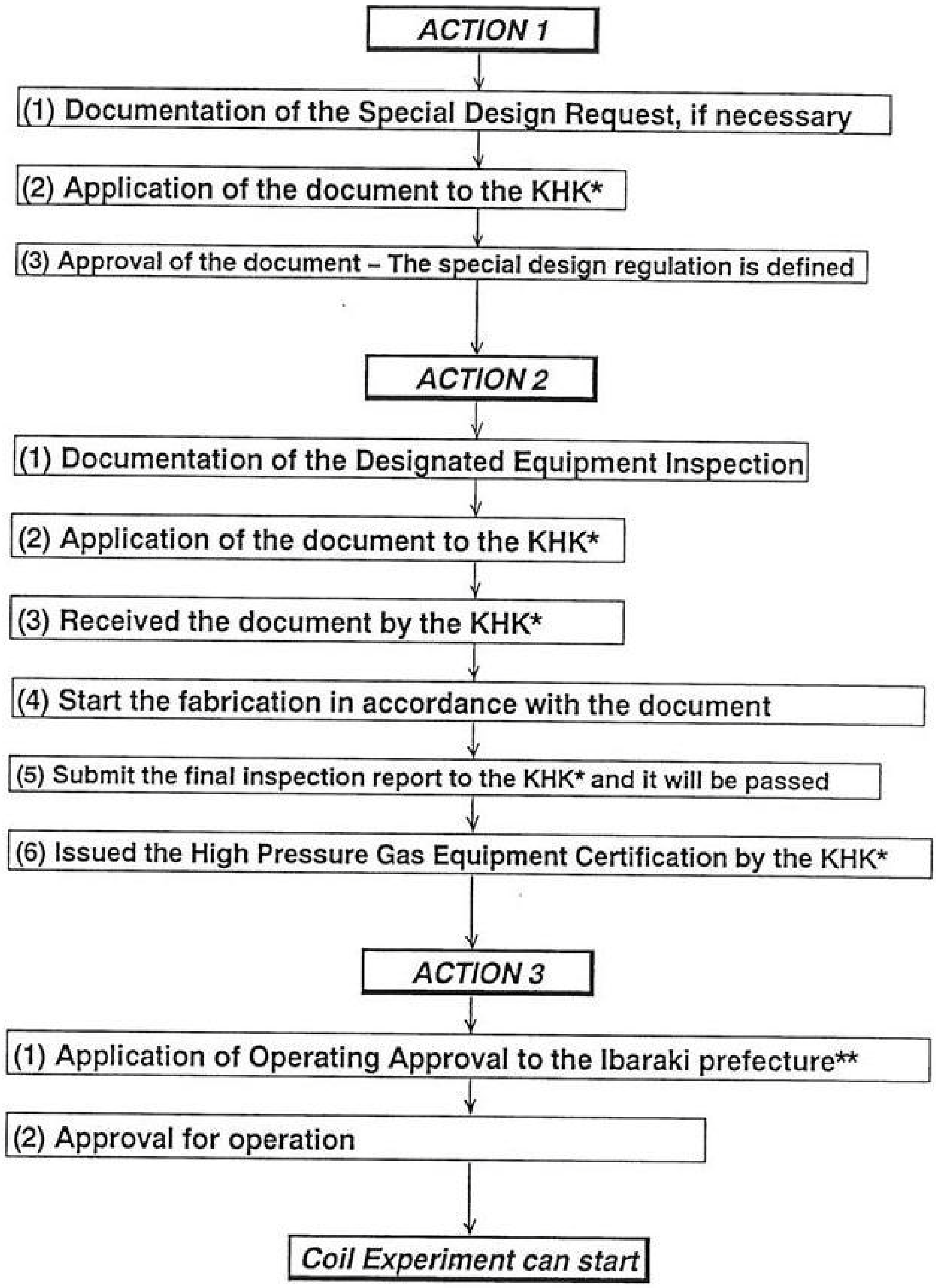
The pressure vessel specified in the JHPSL is classified both by design pressure *P* (megapascals) and volume *V* (cubic meters). Cable-in-conduit conductor is categorized as "pressure vessel (Designated)" (see Table 18).

Table 18. JHPSL requirements for CSMC components

Items	General (PV < 0.004)	Designated (PV > 0.004)
Components in SC magnet system	Plumbing, etc.	Coil
Special design request for deviation	Required	Required
Inspection during fabrication by the agency	Not required	Required
Site Inspection at JAEA by the Ibaraki Prefecture Office	Required	Required

With regard to importing high-pressure gas equipment for the CSI, USIPO shall comply with the requirements detailed in *Application and Inspection of Imported High-Pressure Gas Equipment* [the High-Pressure Gas Safety Institute of Japan (KHK)].

The USIPO shall comply with the JHPSL for design, fabrication, inspection, and documentation of the CSI except for conductor fabrication. The procedure for application of JHPSL is shown as a flow diagram in Fig. 17.



*: The kind of the branch of the MITI at the Japanese government, which controls the high pressure equipments.

**: The Japanese prefecture where the JAERI is located.

Fig. 17. The procedure for application of JHPSL.

6.1.1 Code to be used for Manufacturing

The applicable codes for welding and testing the pressure-retaining parts of the CSI are the Japanese industrial welding and inspection standards.

6.1.2 Special Design Request

- The pressure retaining parts of the CSI shall be designed and fabricated in accordance with the JHPSL. However, it is possible to deviate from the specified technical requirements in the event of having acquired the special approval of the government [the Ministry of Economy, Trade and Industry of Japan (METI)].

- The coil terminal parts may use special materials that are not specified in JHPSL. In that case, 4K test data for the material are indispensable to demonstrate strength and ductility; allowable stress for the material can be determined from the 4K data.

- The coil terminal parts use various joining methods (e.g., tungsten-inert gas welding, brazing, electron beam, friction, hot isostatic pressing). Mechanical strength of the joint at 4K also shall be demonstrated.

- Because electromagnetic force is the dominant force in a superconducting magnet, cyclic operation of the superconducting magnets will be followed by analyses for stress and fatigue to determine the effect of electromagnetic force.

- If the CSI has some “special designs” (deviations from the JHPSL), special approval is required before the CSI is fabricated. It would take about three months from the time of application for approval. After that, a special regulation for the special design is defined.

6.1.3 Application of the Designated Equipment Inspection

The JHPSL specifies inspection regulations for designated equipment. Therefore, after special design approval from is obtained from METI, an application to KHK (a branch of METI) for fabrication of the CSI will be required. The fabrication of the CSI shall be started after KHK receives the application.

6.1.4 Inspection of the Designated Equipment during Manufacturing

The fabrication of the CSI shall be started after the application of the designated equipment inspection. The CSI shall be subjected to inspection by KHK in accordance with the JHPSL for each stage of construction (e.g., design, quality verification of materials, fabrication, welding).

6.1.5 Issue of the High Pressure Gas Equipment Certificate

The KHK issues a high pressure gas equipment certificate when the CSI passes all the inspections.

6.1.6 Operation Approval

An application for construction and operating approval shall be performed to the Ibaraki Prefecture Office to test the CSI at the CSMC Test Facility. After approval is obtained, the CSI shall be tested at the test facility.

6.2 APPLICATION REGARDING THE LAW

JADA will process all applications regarding the JHPSL and requires the submission of information regarding the design, quality verification of materials, fabrication, welding, and their inspection. The DAs, which are in charge of the fabrication of the pressure-retaining parts of the CSI, shall report the information to JADA and need to get the approvals before the fabrication can begin. The following information is required:

- manufacturer
- drawing of coil
- drawing of terminal joint
- material and method of joint
- schedule

If the supplied information is not enough, JADA will ask USIPO to provide further information. Based on the information, JADA will check the design of the CSI to ensure that it conforms to the JHPSL. If there is deviation, JADA may ask USIPO to modify the design and to provide data for the special design request. The report shall include the following items.

6.2.1 Design Approval

To obtain special design approval, the following information shall be provided to JADA:

- fabricator
- brief fabrication schedule
- design pressure and temperature
- operating pressure and temperature
- capacity of the coil (physical volume)
- general arrangement drawings with representative dimensions and design specifications such as pressure and temperature
- detailed drawings of all pressure-retaining parts (including welded parts) that illustrate the materials, dimensions, tolerances, and welding methods
- information regarding the materials to be used, including weld metal and heat affected zone (HAZ) (e.g., chemical compositions, mechanical properties at room temperature, and mechanical properties at cryogenic temperatures)
- information regarding allowable stress of the materials used, including a definition of the allowable stress, the weld metal, and the HAZ
- a calculation of stress for the pressurized load and the electromagnetic load on all the pressure-retaining parts, including welded parts
- information regarding the inspection method and specification of joint parts (e.g., weld, brazing, transition joint)
- information regarding mechanical tests to guarantee the integrity of the base material and joint at room and cryogenic temperatures

6.2.2 Inspection Approval

The following information shall be provided to JADA in an application for inspection of designated equipment:

- Specifications for the inspection:

- The types and forms of the tests and inspection records shall be clearly specified.
- The required procedures and judgment standards for the tests and inspections shall be clearly specified.

- Schedule of inspection procedures: The content of the inspection to be undertaken by the overseas inspection organization (witness or document examination) shall be cleanly specified for each inspection item.
- Strength calculation sheet: In principle, strength calculation shall be completed in accordance with the standard strength calculation format provided by the JADA.
- Assembly drawings and detailed parts drawing: The drawings shall include design specifications (e.g., design pressure, design temperature, materials to be used, dimensions of each part used for strength calculations, requirements for nondestructive examination, requirement for postweld heat treatment, and corrosion allowance).
- Welding procedure specifications (WPSs) and brazing procedure specifications (BPSs) and welding qualification records (PQRs) and brazing PQRs: The WPSs, BPSs, and the approved PQRs for welded parts shall be submitted. If no approved PQR is available, it shall be obtained.
- Drawing of the cutting plan for the mechanical samples: The drawing shall include the cutting plan of the samples and sample shape and dimensions.
- Proof sample test: Proof sample tests for butt welding, tensile test of proof sample at room temperature is required.
- Other documents considered necessary by the KHK as required: Documentation such as a quality control manual, actual results of manufacturing, procurement documentation for structural materials and welding materials, the present conditions on the factory approval shall be submitted in accordance with KHK's request.

6.3 INSPECTION OF THE PARTS FABRICATED BY THE USDA

The parts of the CSI fabricated by DAs shall be treated as “imported designated equipment” as defined in the JHPSL and thus subject to an inspection. A special exception may be made (the inspection can be dispensed with) if the items are described in documents that the KHK has specified as being necessary. For example, in lieu of an inspection, JADA would accept performance certificates issued by neutral warranted overseas inspection organizations such as the National Board of Boiler and Pressure Vessel Inspectors (NBBI) (USA) or the Technischer Űberwachugs-Verein (Germany).

The United States Domestic Agency (USDA), which will fabricate a part of the CSI, shall submit to JADA the documentation specified by the KHK, including performance certificates issued by organizations registered with the NBBI. JAEA will consult with the KHK about the documentation required for KHK to certify the equipment. Therefore, the final contents of the documentation will not have been specified. At a minimum, the USDA shall provide the following certificates, drawings, and test results with procedures and judgments, and certificates signed by the NBBI for the components that it delivers for the CSMC:

- Quality verification of the materials:
  - mill sheet;
  - detailed drawings in which the pressure-retaining parts and material codes, including the heat number, are described; and
  - a material certificate that describes the correspondence between a seamless tube number and a material heat number (mill sheet number).

- Documentation of inspection during fabrication: Records of groove inspections that describe visual inspection results and measurement results of the dimensions to ensure that
  - there are no harmful defects on the groove,
  - groove shape is correct, and
  - alignment of the butt joints that can be observed before welding is within the tolerance.

- Welding inspection:
  - WPS;
  - welding PQR;
  - welding records for all welded joints that describe an actual conditions (e.g., welding condition, identified number of the welded joint) to verify that the employed welding procedure conformed in accordance with the WPS;
  - welded joint position drawings with the name of welder;
  - certificates to verify that surface of the welding was free cracks, undercuts, overlaps, craters, slags, or any other harmful defects; and
  - certificates to verify that alignment of butt joints observed after welding is within the value specified by the regulation.

- Mechanical tests of butt welding: Certificates document the following tests using the machined specimens treated with the same condition (cold working and Nb_3Sn reaction heat treatment) as the conductor:
  - tensile test at room temperature,
  - tensile test at liquid helium temperature,
  - root bend test at room temperature,
  - face bend test at room temperature, and
  - fracture toughness test at liquid helium temperature.

- Nondestructive tests:
  - results and certificates for radiographic tests conducted for the entire length of the butt welds and
  - results and certificates for penetration tests or magnetic particle tests conducted for entire length of all welds.

- Pressure-proof tests: Results and certificate of pressure-proof test conducted at the hydraulic or the pneumatic pressure of 1.5 times the design pressure (does not include pressure rise due to quench)
- Leakage tests:
  - results and certificate for air tight test conducted at the pneumatic pressure of more than the design pressure (does not include pressure rise due to quench) and
  - results and certificates for helium leakage test.

- Dimension measurement: Results and certificate of dimension measurements (specifically, thickness) of pressure retaining parts
- Proof sample test for butt weld: If a butt weld is used during coil manufacturing, a proof sample shall be made and a tensile test shall be performed. If the joint diameter is less than 50 mm, a full-size tensile test is required.

7. ELECTRICAL SAFETY REGULATION

The Japanese safety regulation for electrical devices requires a high pot test. Test conditions are summarized in Table 19.

Table 19. Japanese high-pot test criteria

Test duration: 10 min

Test item	Test voltage (× max operating voltage)	
	AC	DC
Conductor to ground	1.5	3
Conductor to low-voltage sensor	1.5	3
Conductor to inductive heater	1.5	3

8. DOCUMENT FOR INSTALLATION OF THE COIL

The USDA shall prepare a document regarding the handling, cabling, and piping required for the installation of the CSI at the CSMC Test Facility.

9. TEST FOR INSTALLATION OF THE CSCI

The following tests of the CSCI will be performed to ensure its safe operation in the test facility:

- confirmation of certificates and documents described in Sects. 6, 7, and 8
- a visual inspection
- an inspection of dimensions
- pressure proof test
  - condition: 2.5 MPaG, 10 min
  - criteria: no observable deformation
- Helium leak test
  - condition: 2.0 MPaG, sensitivity <E-7 Pam3/s
  - criteria: no indication of leak
- high pot test
  - condition: DC 2Vop + 1kV (coil-ground), 10 min
  - criteria: no discharge
- ground insulation test
  - condition: DC 1kV (coil-ground)
  - criteria: > 5 M ohm
- a sensor check

10. INSTALLATION PROCESS AND SCHEDULE

A typical schedule for installation of an insert coil in CSMC Test Facility is shown (in weeks) in Fig. 18. Figures 19, 20, and 21 shows photos during a coil insert installation at the Test Facility.

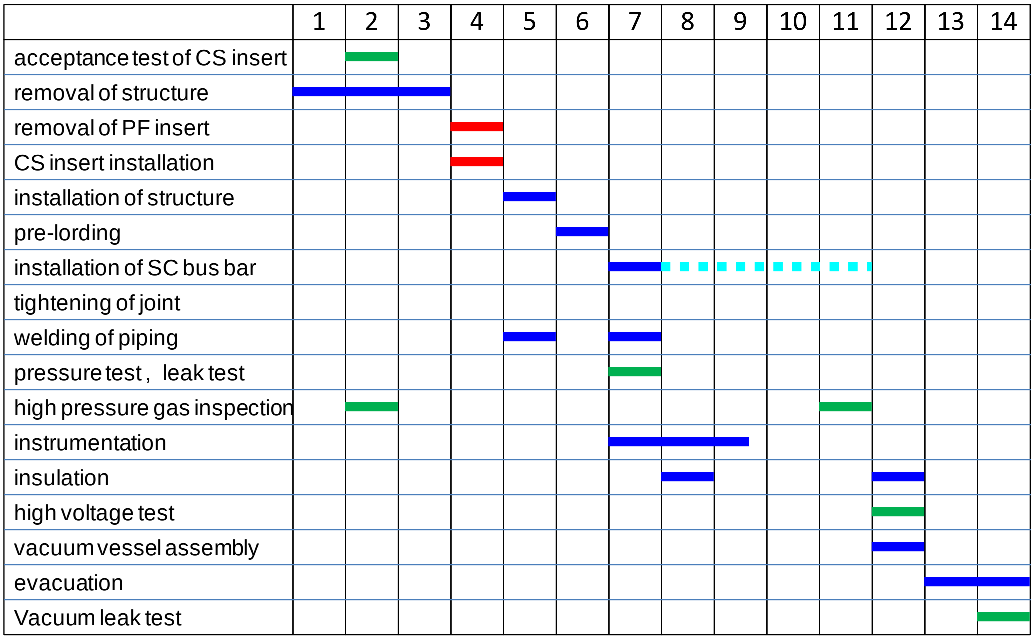


Fig. 18. Installation schedule for the CSI.

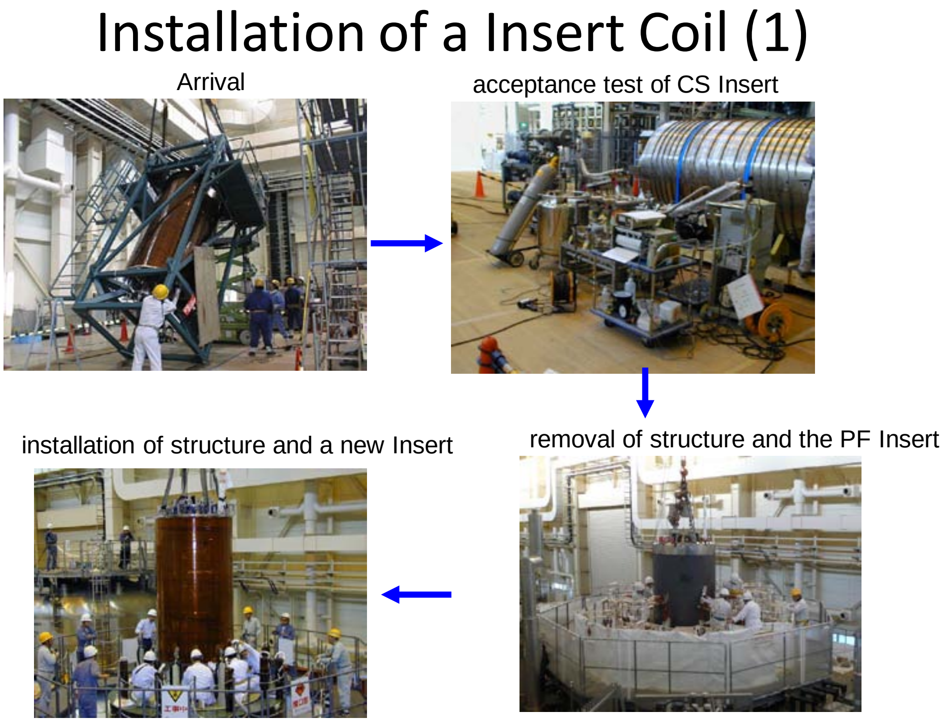


Fig. 19. Installation of the CSI (1).

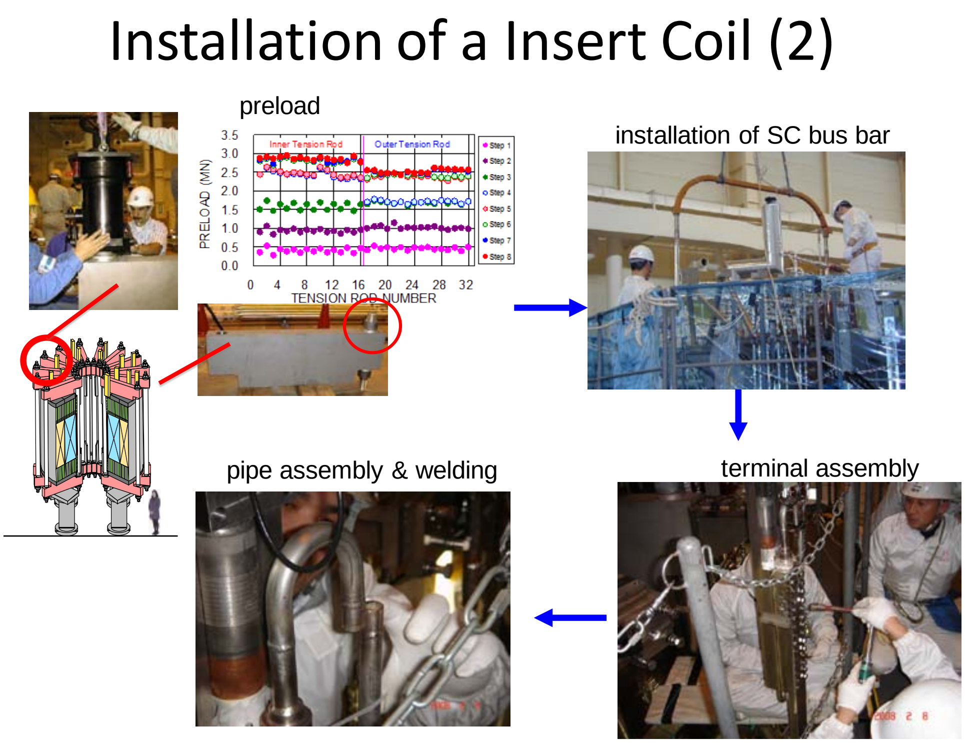


Fig. 20. Installation of the CSI (2).

Installation of a Insert Coil (3)

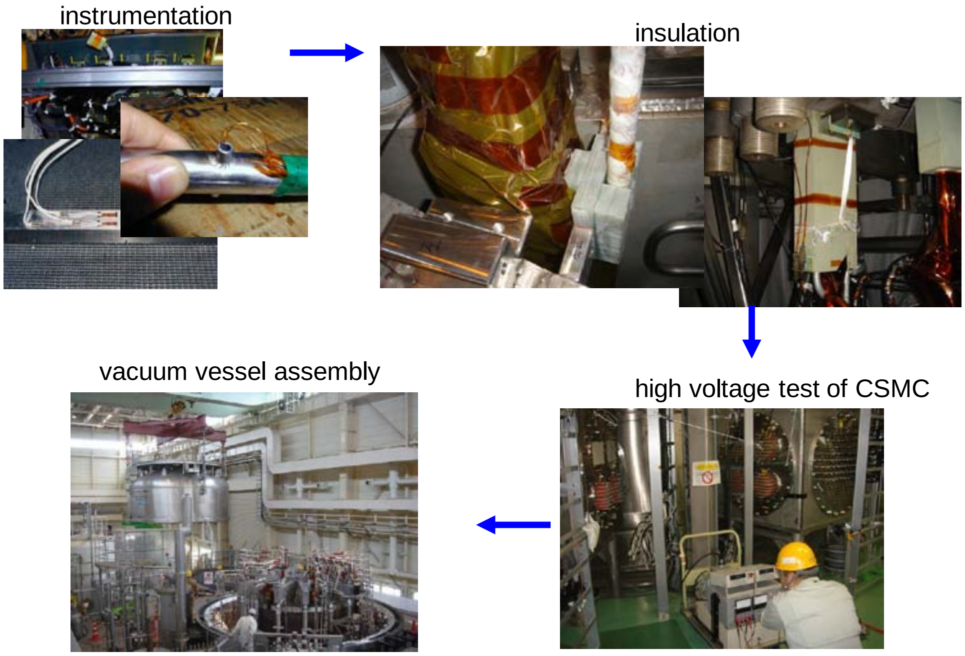


Fig. 21. Installation of the CSI (3).

11. PARTS AND RESPONSIBILITY LIST

Parts required for installation of the CSI at the test facility and the parties responsible for their fabrication are listed in Table 20.

Table 20. Parts and fabrication responsibility list

Item	Quantity	Responsibility	
Top and bottom joint			
Half clamp (Insert side)	2		US
Half clamp (Bus bar side)	2	JA	
Saddle pieces (Insert side)	2		US
Saddle pieces (bus to bus)	1	JA	
Silver plating of saddle pieces (Insert side)	2		US
Silver plating of saddle pieces (bus to bus)	1	JA	
Silver plating of coil terminals	2		US
Silver plating of bus bar terminals	5	JA	
Bolts (M10) for clamp			US
Nuts (M10)			US
Indium wire	Proper quantity	JA	
Insulation box			
Semi cases	2		US
Bus bar support (fiber-reinforced polymer blocks)	2	JA	
Bus bar support (SUS plate)	2	JA	
Bolt interface			
M30 studs	4		US
M30 nuts	8		US
A set of self-aligning washers for top	4		US
A set of self-aligning washers for bottom	4		US
Washer for M30	8		US
Disk spring washer for M30	4		US
Shim for the height adjustment	Proper quantity		US
Key interface			
Keys	4		US
Bushings	4		US
Register interface			
Register	4		US
Bolts for register			US
Nuts for register			US
Instrumentation			
Wires of high and low pot sensors			US
Winchester connector			US
& Pin and its terminal assembly		(JA)	US
Others			
Frame for standing			US
Parts for turning over			US

INTERNAL DISTRIBUTION

1. F. Casella, ORNL
2. D. Hatfield, ORNL
3. N. Martovetsky, ORNL
4. C. Rey, ORNL
5. W. Reiersen, ORNL
6. A. Smirnov, ORNL
7. File-USIPO DCC-RC

EXTERNAL DISTRIBUTION

8. P. Libeyre, ITER Organization
9. C. Lyraud, ITER Organization
10. N. Mitchell, ITER Organization
11. Y. Nunoya, JAEA