

# Completion and Installation of the ITER Lower Poloidal Field Coils PF5 & 6

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# Outline

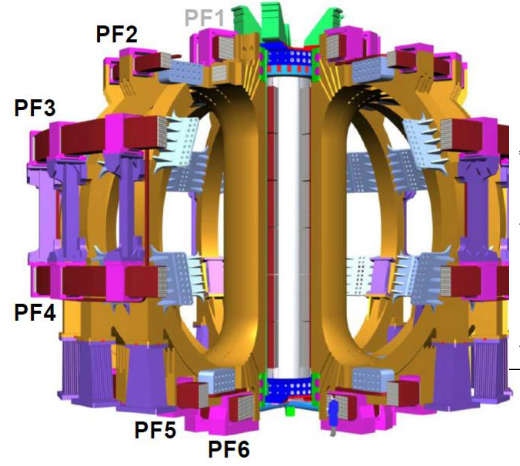
- Overview of the PF coils manufacturing
  - The challenge of the manufacturing process
  - Reproducibility and reliability of winding/insulation and cryogenic skills
  - Site acceptance test in Cadarache
- Assembly scenario of the PF5&6 coils
  - Lifting review for PF5 & 6 coils
  - Alignment of positioning from assembly hall to the tokamak pit
- Near future for PF5&6 coils Installation to TF

# Overview of the PF coil procurement



Presented by Alessandro Bonito Oliva at MT 26, on September 25<sup>th</sup>, 2019

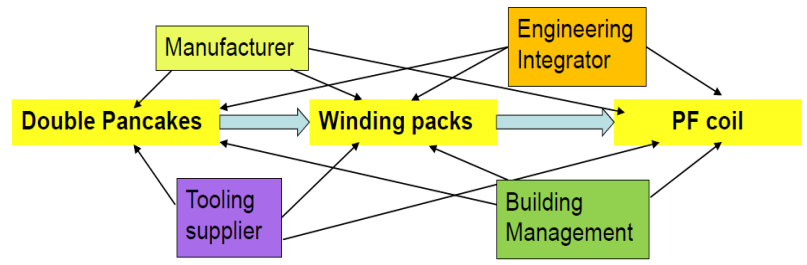
## How did we get here...



PF DIMENSIONS (MM)			
	Outer diameter (m)	Height (m)	Weight (t)
PF2	17.2	0.7	342
PF3	24.8	1.0	384
PF4	24.6	1.0	349
PF5	17.6	1.0	342
PF6	10.3	1.1	399

### ITER Poloidal Field (PF) Coils Procurement Strategy

- 1 by Russia, 5 by F4E.
- EU PF Procurement Arrangement (PA) overview:
  - PF2-PF6 PA annex B 1.1.P1A.EU.01
    - Signed June 2009 between ITER and F4E.
- PF6 outsourcing Procurement assigned on 2013 through international agreement to: Chinese Academy of Science (CAS) Institute ASIPP, located in Hefei (China).



### Lessons learned on Procurement configuration

- **Vertical** vs **horizontal** splitting of procurement
  - All contracts signed between 2013 and 2016.
- PF coils horizontal splitting: all contracts cover each production phase.
- **Multiple and complex interfaces for F4E to manage**
- PF2-PF5 Procurement split in 6 smaller contract, each task involved 4 suppliers

# PF manufacturing Status. PF2-6 coils

## Where we are...

- PF2-PF5 built in Cadarache
- PF3 & PF4 too large to be transported: built in Cadarache
- **PF5 & PF6 delivered simultaneously: 2 production lines**
- PF 6 Manufactured in China.

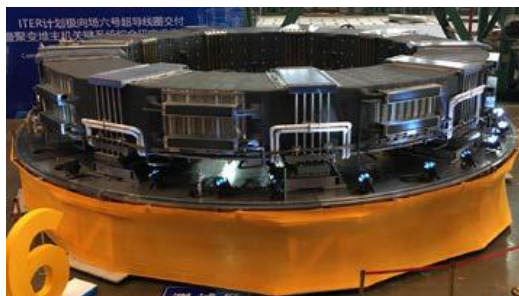
### PF5 status

- Delivered in 2021
- **Installed in Pit**



### PF6 status

- Delivered in 2021,
- **Installed in Pit in 2021**



### PF2 status

Cold test done. Moved out of the cryostat. Preparation for HV tests



### PF3 - 4 status

- PF 4: Winding of 8 DPs completed.
- PF3 : 4 DPs Impregnation finished.



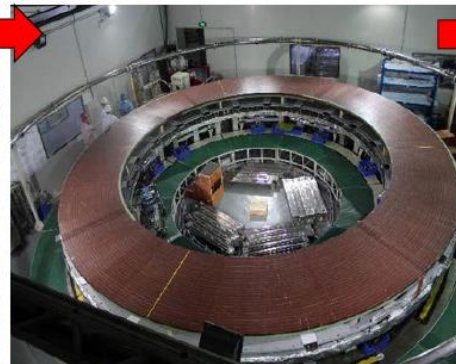
# The challenge of the manufacturing process

## Challenge:

- Several dozens of superconducting double pancakes, requiring bending, insulating and welding steps.
- Keep accuracy of a few mm on dimensions up to 25m.
- Reproducibility and reliability of magnet winding/insulation and cryogenic skills.
- Qualification and repair during manufacturing.



Double pancake winding and insulation



Double pancake Impregnation



Double pancakes stacking and WP insulation



PF thermal cycle to LN T + HV insulation test and leak checks



Hydraulic circuit and clamps assembly



Winding Pack Impregnation

# Site acceptance test in Cadarache

- Control Plan for cryogenic test of PF coil
- All test records traceability in manufacturing database

## 01 - Handling

Authorization To Proceed Point 010 - Issue of the Applicable Document List (procedure, documentation, drawings) (ATPP Cleared (IO))

## 02 - Electrical Connections

MAN-DA Authorization To Proceed Point 010 - Issue of the Applicable Document List (procedure, docum

## 03 - Cryogenic Test

MAN-DA Authorization To Proceed Point 010 - Issue of the Applicable Document List (procedure, docum

Authorization To Proceed Point 121 - Perform HV DC test @30kV (ATPP Cleared (IO))

Authorization To Proceed Point 250 - Paschen test the PF5 coil according to the applicable document list (ATPP Cleared (IO))

Authorization To Proceed Point 291 - Perform an integral leak test of the coil and the clamp (ATPP Cleared (IO))

Authorization To Proceed Point 360 - DC high voltage test (ATPP Cleared (IO))

Authorization To Proceed Point 380 - Record current and voltages value at 100A stable value (ATPP Cleared (IO))

Authorization To Proceed Point 390 - Record current and voltages value at 500A stable value (ATPP Cleared (IO))

Authorization To Proceed Point 400 - Leak test of the coil at 80K (ATPP Cleared (IO))

Authorization To Proceed Point 410 - Pressure drop test at 80K (ATPP Cleared (IO))

Authorization To Proceed Point 470 - Pressure drop test after warm up (ATPP Cleared (IO))

Authorization To Proceed Point 480 - Leak test of the coil after the warm up (ATPP Cleared (IO))

Authorization To Proceed Point 490 - HV DC test after warm up (ATPP Cleared (IO))

Authorization To Proceed Point 500 - Paschen test after the warm up (ATPP Cleared (IO))

Authorization To Proceed Point 530 - Perform the HV DC test at 30kV (ATPP Cleared (IO))

Authorization To Proceed Point 580 - Issue the final report for cryogenic test (ATPP Cleared (IO))

### Cold test

	Id ▲	Title
	340	Check coil temperatures to start with the cold test
	350	Check after 30s that the software is saving the data correctly
	360	DC high voltage test
	370	Visual check of connection quality, apply hand force to assess strength of connections
	371	Record 5 data sample at 0 current
	380	Record current and voltages value at 100A stable value
	381	Record 5 data sample at 0 current
	390	Record current and voltages value at 500A stable value
	400	Leak test of the coil at 80K
	410	Pressure drop test at 80K



File
<a href="#">MSC210314_CP340.pdf</a>
<a href="#">MSC210310_CP360.pdf</a>
<a href="#">MSC210313_CP380 - CP390.pdf</a>
<a href="#">MSC210313_CP380 - CP390.pdf</a>
<a href="#">MSC210311_CP400.pdf</a>
<a href="#">MSC210312_CP410.pdf</a>

File
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<a href="#">MSC210504_CP420.pdf</a>
<a href="#">cooldown_warm_up_from_2021_01_12_Vacuum600.csv</a>
<a href="#">MSC210505_CP430.pdf</a>
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<a href="#">MSC210506_CP440-CP460.pdf</a>
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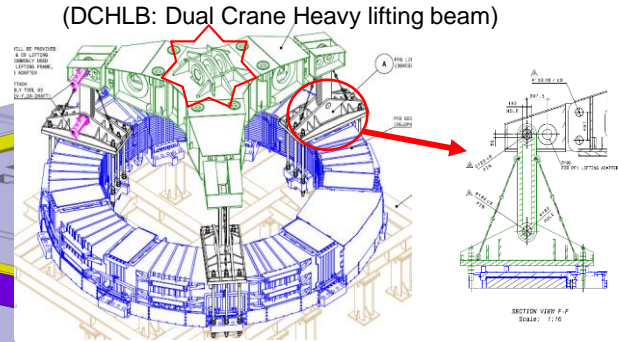
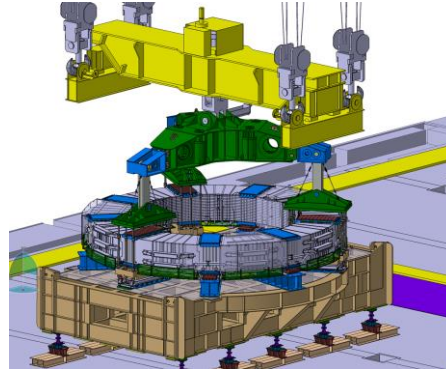
File
<a href="#">MSC210602_CP470_Pf5.pdf</a>
<a href="#">MSC210503_CP480_Leak_test_warm_up.pdf</a>
<a href="#">MSC210802_Final HV DC test at 29 kV on PF5 after warm-up.pdf</a>
<a href="#">MSC210601_CP500_Pf5.pdf</a>

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- Overview of the PF coils manufacturing
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  - Site acceptance test in Cadarache
- **Assembly scenario of the PF5 & 6 coils**
  - Lifting review for PF5 & 6 coils
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# PF 6 lifting milestone overview

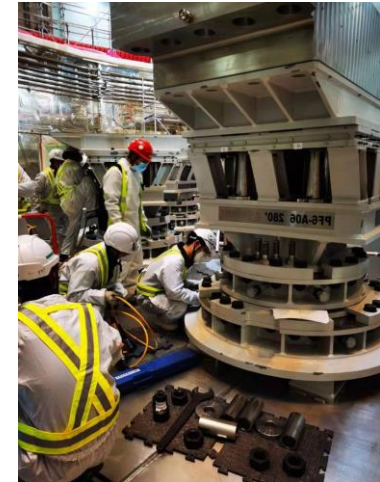
- PF6 Lift Preparation (IDM\_4NRWU6) in March,2021
- Objective: Lift the PF6 in safe conditions and No damage
  - Lifting process
  - Lifting tools design, manufacture and verification test;
  - Docs preparation (Lifting plan, Installation and test plan, Installation & Test record);
- PF 6 Lifting Review (March 04 -2021) (IDM\_4PD7KU)
- PF6 lifting review - Close-out Report (IDM\_52FKYU)
  - 17 follow up actions closed
  - 23 items for Risk analysis and mitigation plan
- Organization/coordination set-up for the lifting operation
  - Resource: 5 IO, 5 CMA, 40 CNPE TAC1 involved.
  - Tooling: 750T crane and DCHLB lifting beam as lifting tool.
- PF6 rest on temporary support in the Tokamak pit (21th April, 2021)
  - 20th- 21st, April, 2021: 4 hrs for lifting trial, 1 day for real lift.



Checking pins / holes dimensions

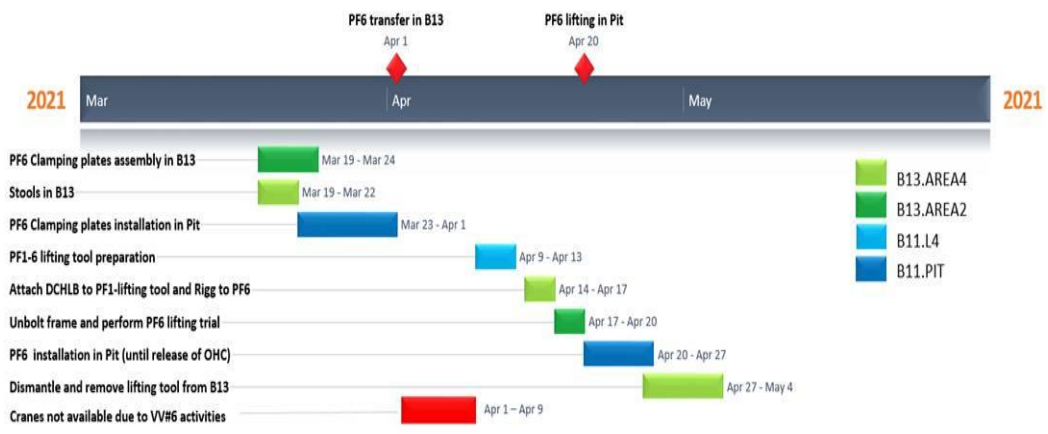
- Lifting adapters / links pins and holes
- Extensions / links pins and holes
- PF6 lifting frame / DCHLB pin

DocName	Rev	Title
TA1-UAS-P11-00030	A2	TA1 Procedure of Installation of Placement of PF6 on Temporary Supports
TA1-PTI-P11-00038	A1	TA1 ITP for installation of PF6 on Temporary Supports (CWP027)
TA1-UMH-P11-00011	A1	TA1 Lifting Procedure for Placement of PF6 on Temporary supports
TA1-PTI-P11-00041	A1	TA1 ITP for Lifting Trial of PF6 Coil (CWP027)
TA1-LXX-P11-00028	A2	TA1 ITR matrix and ITR template for CWP027
TA1-LXX-P11-00029	A2	TA1 List of Construction Objects for CWP027
TA1-PSA-P11-00012	A1	TAC 1 – HEALTH AND SAFETY SPECIFIC PLAN Addendum CWP 27 PPSPS FRAMATOME AND CNPE Europe Installation of Placement of PF6 on Temporary Supports
TA1-UAS-P11-00028	A1	TAC-1 Metrology procedure for placement of PF6 coil on temporary supports
TA1-ZDS-P00-00035	A1	TA1 PROJECT IWP DETAIL SCHEDULE OF Placement of PF6 on Temporary Supports





# PF 6 Lifting Logic Diagram and Schedule



## Challenges Overcome :

- Load test done with the tool fully assembled
- Asymmetry of load & a strategy to avoid tilting
- **Deflection check during lifting trial**
- **Mitigation plan for tilting, balancing weights during lift**
- Space and availability of the 750 t OHCs in assembly hall

**IO/ F4E/ CMA/ CNPE TAC1 team spirit !**

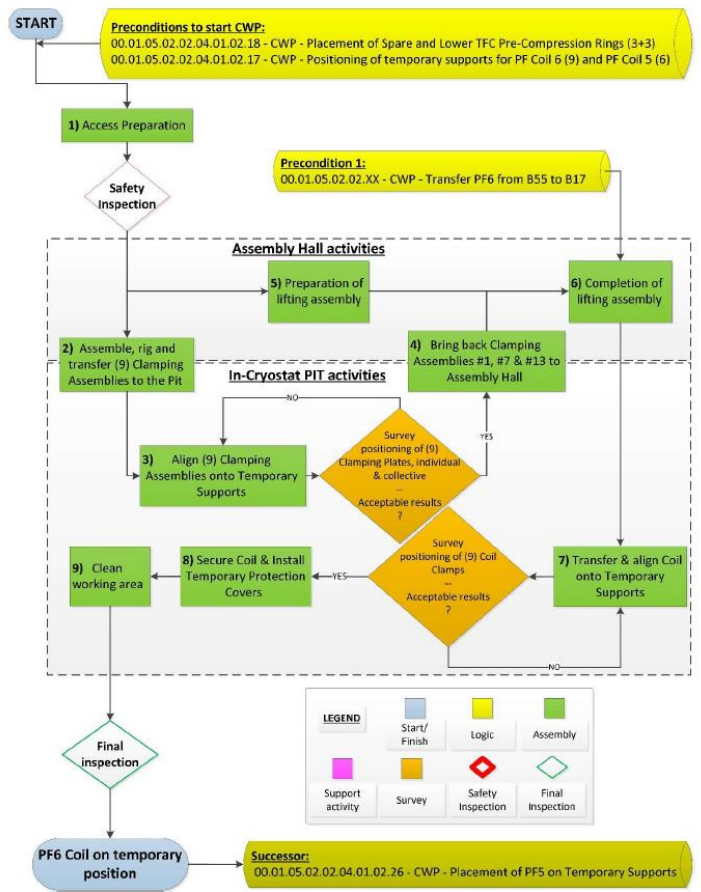
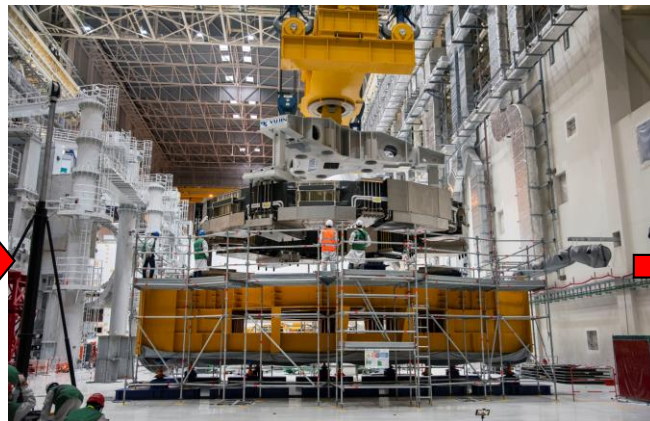


Figure 6.1-1 Installation sequence diagram

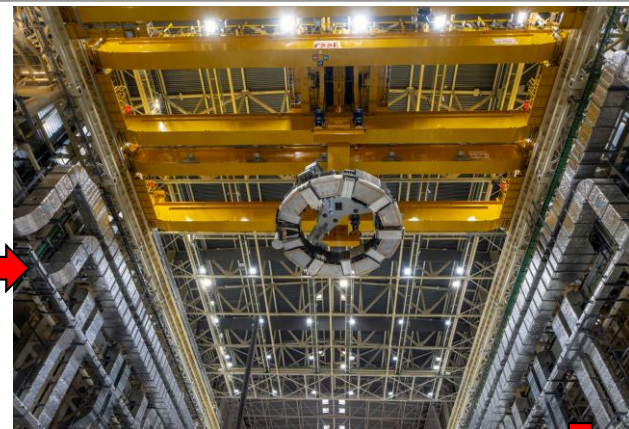
# Assembly scenario of PF 6 lifting and installation on temporary position



PF6 temporary supports in the PIT



PF6 pre lifting in assembly hall



PF6 UFO during the lifting



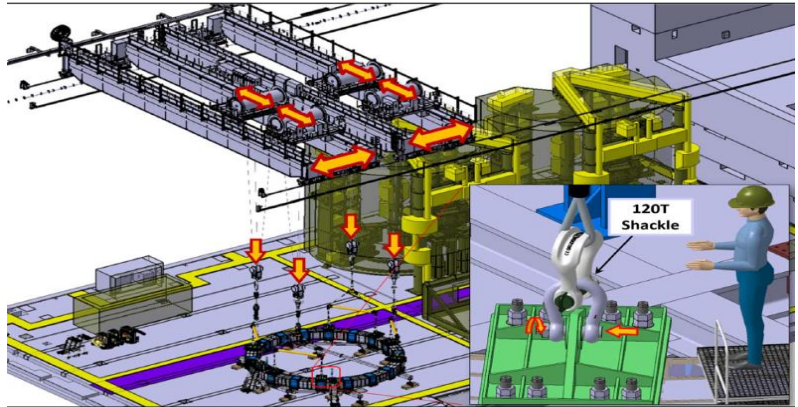
PF6 in PIT



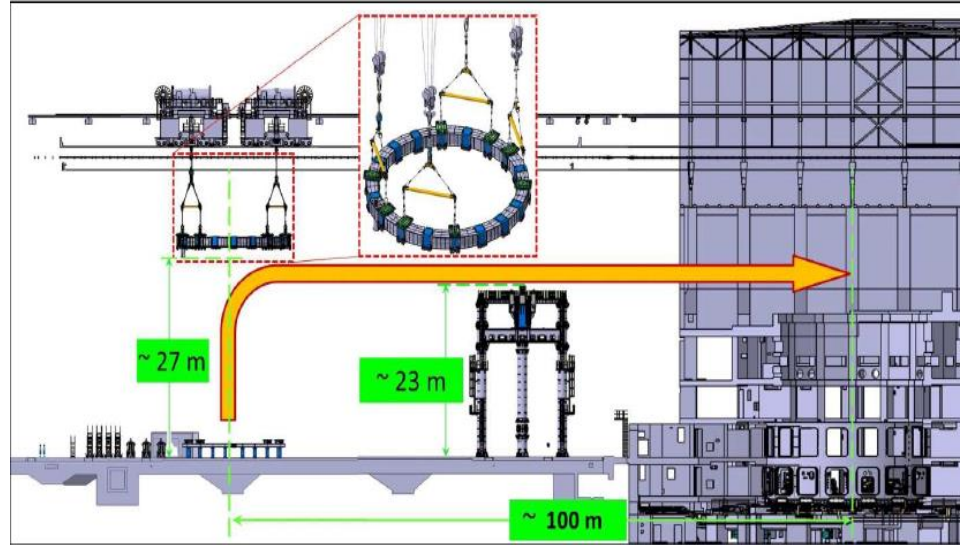
PF6 above PIT



PF6 above Sector Sub-Assembly Tool



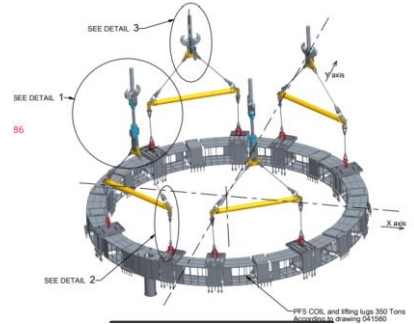
Connect Lifting Units to Lifting Adapters



Transfer PF5 Coil from AH to the Cryostat Base, land on Temporary Supports

PF5 Lifting Units

- Lifting Adapters to Dual Crane.
- Dual PF5 Coil weight and dimensions dimensions and capabilities due to PF5 Coil weight and dimensions

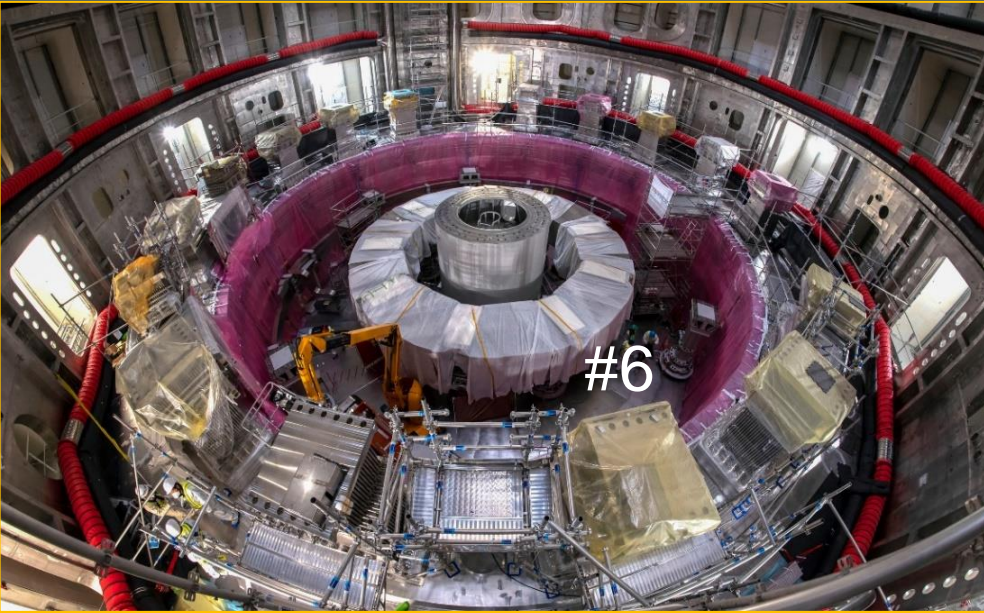


Challenges overcome: :

- Lifting height: 25 meters minimum
- Highest component to overcome: SSAT Tool - VV Align ~23m
- Transfer travel: ~100 meters along north direction
- **Crane issue moving under descent creep speed**

# Recent On site progress with the first 2 PF coils inserted

Welcome PF5 & 6 to arrive at new "home" in the tokamak pit



- Poloidal field coil # 6 was inserted in the assembly pit on 21 April 2021
- Poloidal field coil # 5 was inserted in the assembly pit on 15 September 2021

**within tolerance on temporary support**

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# Next step: Final position in few years after TF coils installation

- Raise the position of PF 5&6 coils and structure-clamp-plates to near-final position

Final positioning of PF coils, Reserve Engineering of customization shims

Bolt Clamp Plates to the TF structure

Remove: screw-jacks, stacking beams and Top-Plates, Temporary Supports

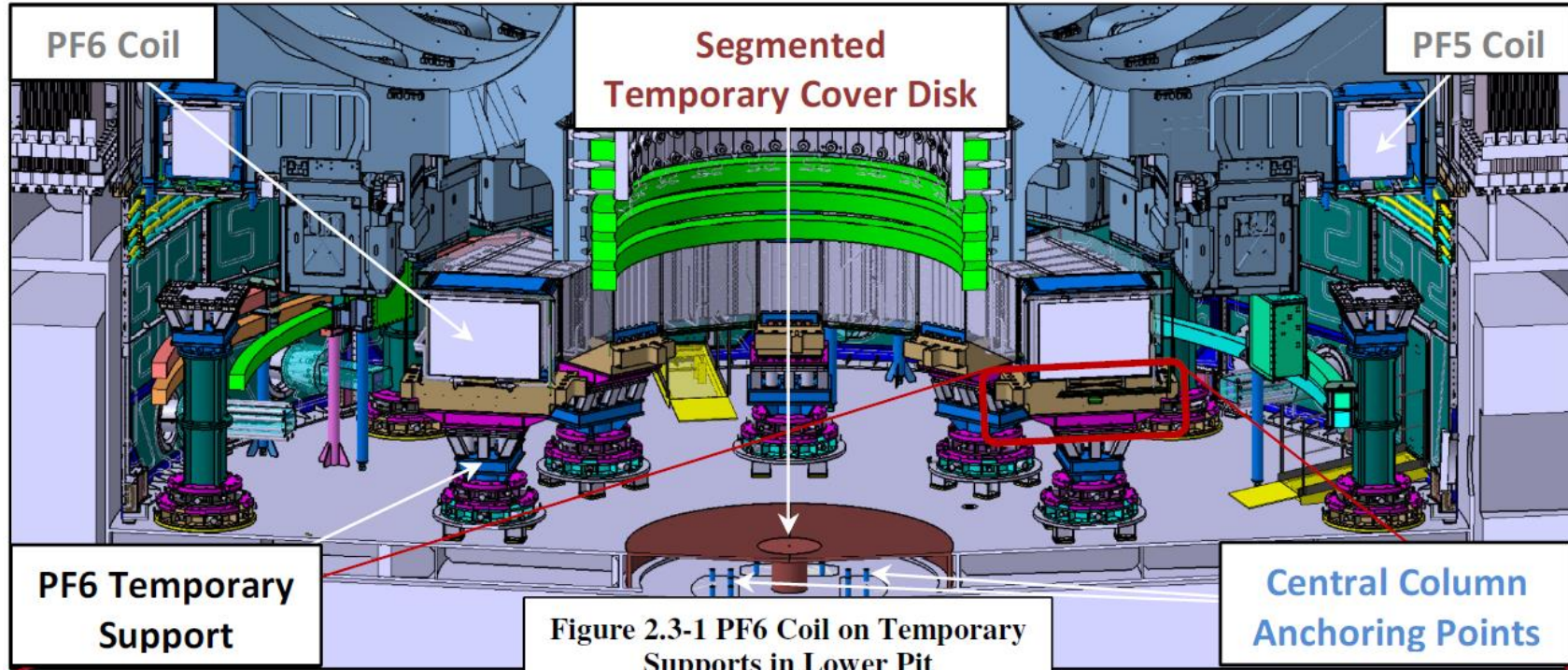


Figure 2.3-1 PF6 Coil on Temporary Supports in Lower Pit

# ITER

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*Thank you for your attention!*



ITER 2021,11