



The HL-LHC High Order Correctors for Corrector Package #1

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on behalf of Marco Statera and the LASA team

INFN Milano - LASA



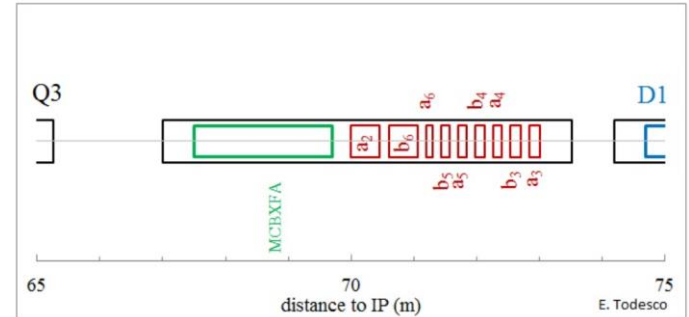
CERN – March 15th 2022

Content

- Introduction
- Overview of the selected HOC magnets for CP1
- Main NCs affecting several magnets of CP1
- Review of each of the 9 magnets
 - Magnet story & NCs
 - Fabrication at SRV (FAT v1)
 - Powering tests at cold
- Conclusion

Introduction

- So far: 4 deliveries from LASA
- 30 HOC magnets at CERN and 28 accepted
- 9 HOC magnets in the corrector package
- 1st cold mass assembly in 180 already started
- *Today: Gedankenexperiment ☺*



HOC magnets for CP1

HOC magnets for CP1

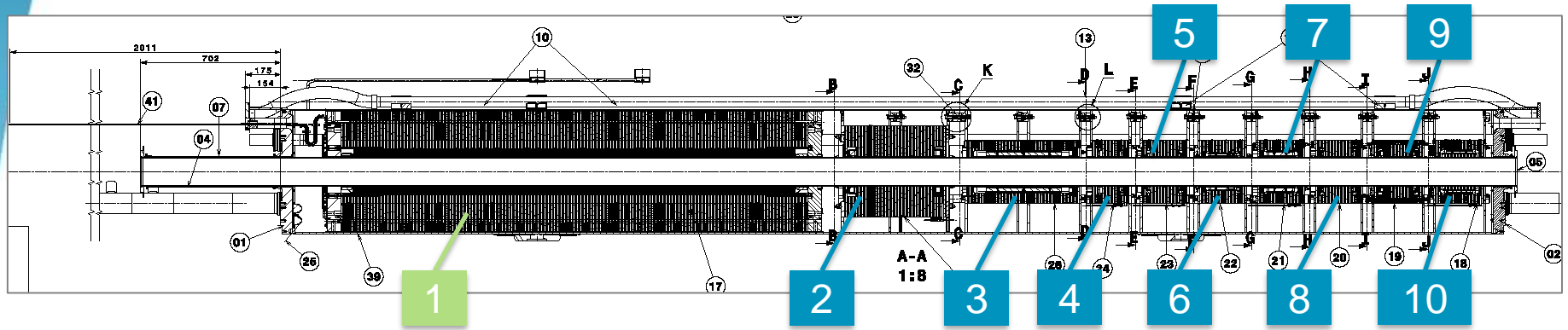
HOC magnets selected from the 1st and 2nd deliveries:

Magnets	Location	Batch	CD	Delivery	Status
MQSXF2	CERN 180	1b	4	2	accepted
MQSXF3	CERN 180	2	6	2	accepted
MCSXF01b	CERN 180	1a	CERN	1	accepted
MCSXF02	CERN 180	1a	4	2	accepted
MCSXF03	CERN 180	1b	3	1	accepted
MCSXF04	CERN 180	1b	CERN	1	NCR burr
MCSXF05	CERN 180	2	5	2	accepted
MCSXF06	CERN 180	2	6	2	accepted
MCOXF03	CERN 180	1b	3	2	accepted
MCOXF04b	CERN 180	1b	6	2	accepted
MCOXF07	CERN 180	2	6	2	accepted
MCDXF01b	CERN 180	1a	CERN	1	accepted
MCDXF02b	CERN 180	1a	CERN	1	accepted
MCDXF04	CERN 180	1b	CERN	1	accepted
MCDXF05	CERN 180	2	CERN	1	accepted
MCDXF06	CERN 180	2	CERN	1	accepted
MCTXF1b	CERN 180	1a	CERN	1	NCR lam.
MCTXF2	CERN 180	1b	3	1	accepted
MCTSXF1	CERN 180	1a	5	2	accepted
MCTSXF2	CERN 180	1b	5	2	accepted



Corrector Package #1	
MQSXF2	S
MCSXF01b	N
MCSXF02	S
MCOXF03	N
MCOXF04b	S
MCDXF01b	N
MCDXF02b	S
MCTXF2	N
MCTSXF1	S

HOC magnets for CP1



- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10

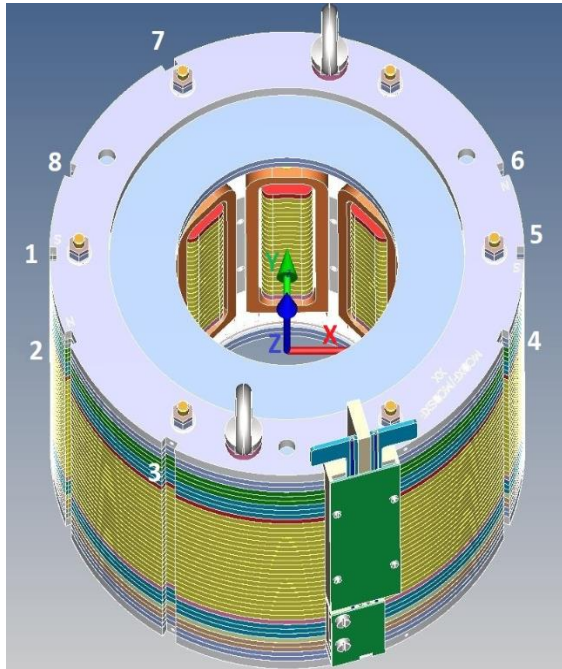
MCBXFA | MQSXF2 | MCTXF2 | MCTSXF1 | MCDXF01b | MCDXF02b | MCOXF03 | MCOXF04b | MCSXF01b | MCSXF02

Main non-conformities

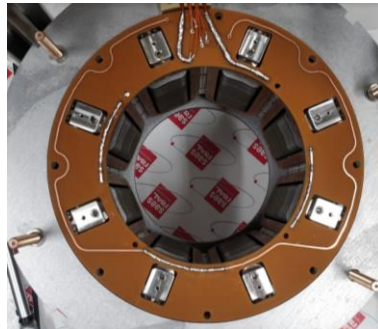
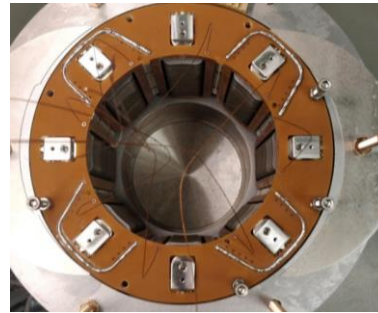
A bit of background history about the upgrades and changes of design affecting several magnets of CP1

Reminder – PCB box

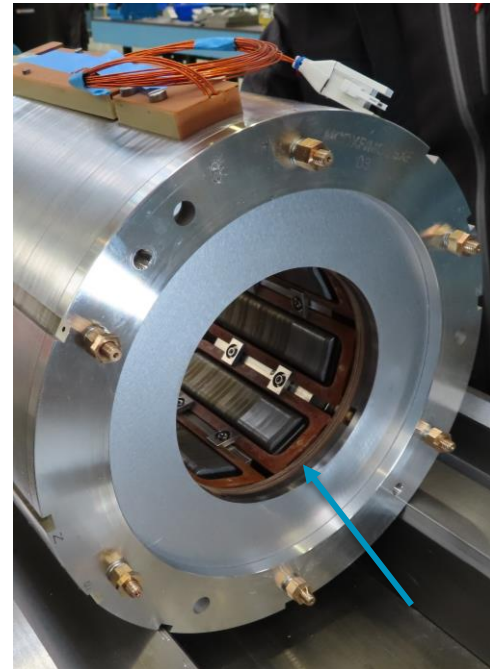
Example of an octupole:



PCB bottom/top:

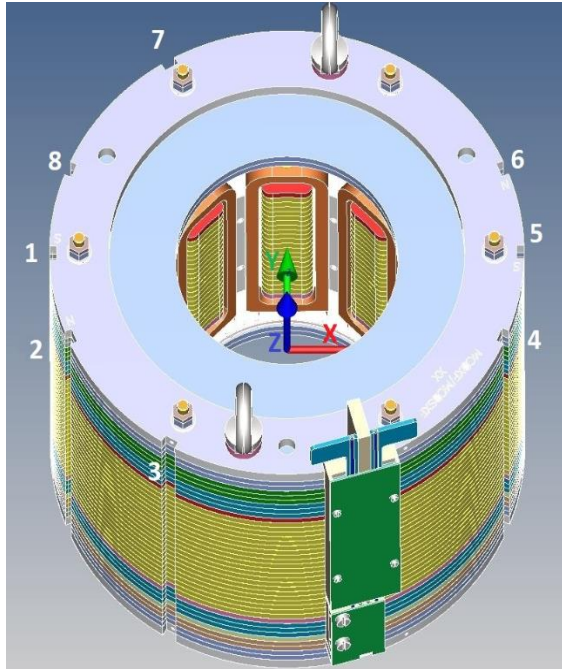


PCB final:



Reminder – Wedges & Supports

Example of an octupole:

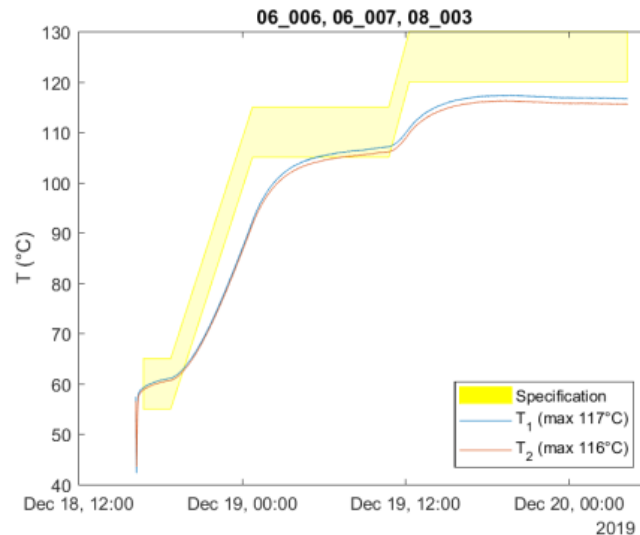


Supports

Wedge

Lower curing temperature (37 coils)

- Temperature of 125°C +/- 5°C required for the post-curing not met for 37 coils (6P, 8P, 10P)
- Average of 117°C (between ~110-120°C)
- Preventive actions:
 - Control point by supplier before & after curing
 - Temperature cycle to be tuned with measurements
- Decision: **coils can be used as they are**
 - No mechanical properties' changes but T_g slightly below the spec (independent study made by CTD)
 - Micro-photography of cross section 06_002 shows no sign of degradation that could be attributed to a thermal cycle at lower temperature



Example of thermal cycle at lower temperature

→ 3 Magnets of CP1 affected (11 coils):

MCSXF01b	MCSXF02	MCOXF03
4/6 coils	5/6 coils	2/8 coils

Wedge movement in MCOXF1 and MCTXF1

- Test of MCOXF1: 6/8 wedges fell towards the bottom
- Test of MCTXF1: 2/12 wedges fell towards the bottom
- No impact on the performance
- Preventive actions:
 - RT preloads recalculated [EDMS 2454023](#)
 - All series magnets shall have the new torque values to the wedges
- **9 magnets to send back to SRV to be partially reassembled and increase the torque on wedges:**
MQSXF1, MCSXF01*, MCSXF02, MCOXF01*, MCOXF02, MCDXF01*, MCDXF02*, MCTXF1*, MCTSXF1.
- (*) Magnets already tested shall be retested with the increased torque value

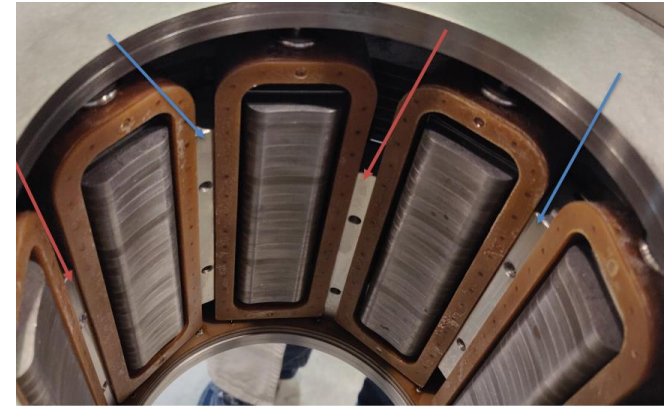


Figure 1 Inner view of HCMCOXF001-X5000001's coils and wedges. In red arrows: moved wedges

→ 5 Magnets of CP1 affected:

MCSXF01b	MCSXF02	MCDXF01b	MCDXF02b	MCTSXF1
Repair & retest (b)	Repair before test	Repair & retest (b)	Repair & retest (b)	Repair before test

Wedge movement in MCOXF1 and MCTXF1

- RT preload recalculated → increased value of the torque [EDMS 2454023](#) :

Table II Nominal torques values to be applied on the wedges after the reported calculation. The errors of the tools in use at the company are also reported. For comparison the previous vales are also reported.

Magnet	Torque [n. x Nm]	Range [Nm]	Tool		Previous value [n. x Nm]
			1 range 0.20-0.50 Nm	2 range 0.50-2.00 Nm	
4P	2 x 1.00	0.94-1.06		2	2 x 0.8
6P	2 x 0.44	0.40-0.48		1	2 x 0.2
8P	2 x 0.55	0.52-0.58		2	2 x 0.25
10P	2 x 0.35	0.32-0.39		1	2 x 0.20
12P S	2 x 0.49	0.45-0.53		1	2 x 0.35
12P N	2 x 0.31	0.28-0.34		1	2 x 0.20

Design change for wedge supports (4P* & 8P)

- Movement of wedges after test in octupoles with upgraded torque values in MCOXF03 ([NC 2489174](#)), MCOXF04 ([NC 2515856](#))
 - From 0 to 2 supports for wedges + 3 washers
 - Applicable for all octupoles
- Supports not properly tightened after the test of MQSXF1 ([NC 2611005](#))
 - From 4 to 2 supports for wedges + 3 washers
 - (*) Applicable for MQSXF1, MQSXF3, MQSXF5

→ 2 Magnets of CP1 affected by DPR :

MCOXF03	MCOXF04b
Single wedge movement observed: additional 2 supports added in LASA (no retest)	Wedges' movement observed: additional 2 supports added in LASA (retest b)

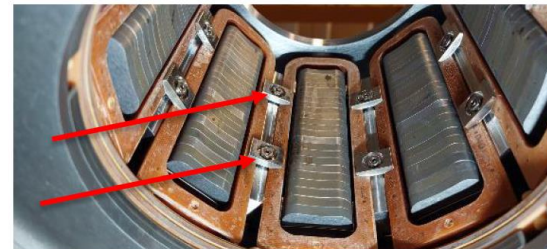


Fig. 1 – Octupole MCOXF04 – Intermediate solution

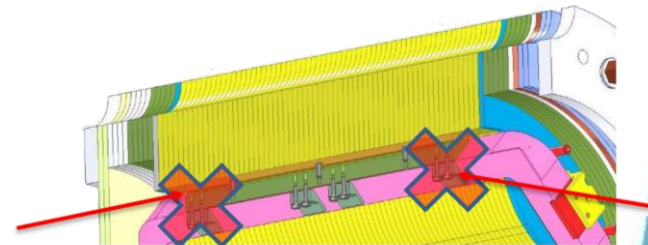


Fig. 3 – Wedges supports removed in 2 places

NB: 1 Magnet of CP1 *not* affected by DPR

MQSXF2

Accepted with previous design (i.e. 4 supports)

MQSXF2

MQSXF2 | MCTXF2 | MCTSXF1 | MCDXF01b | MCDXF02b | MCOXF03 | MCOXF04b | MCSXF01b | MCSXF02

Corrector Package #1	
MQSXF2	S
MCSXF01b	N
MCSXF02	S
MCOXF03	N
MCOXF04b	S
MCDXF01b	N
MCDXF02b	S
MCTXF2	N
MCTSXF1	S

Magnet story

<https://edms5.cern.ch/equipment/HCMQSF001-X5000002>

- Magnet directly delivered with increased torque values
- Powering test at LASA in Mar 2021 (CD4)
- 4 wedge supports and 1 washer per screw (first series design)
 - DPR 2559921 not applicable
- No extra step, no repair/upgrade
- No NC

Equipment Identifier: HCMQSF001-X5000002
Other Identifier: MQSXF2
Description: Single Aperture (150 mm) Skew Quadrupole (a2)

Main						
Made of		Equipment data		Manufacturing	Operation	Documents
History						
Map						
Actions: Add extra step						
Workflow Diagram						
No workflow diagram is defined for this equipment						
Workflow Steps						Last Repeated
Step	IR/E	Other name	Description	Status	Result	NC
10		()	Mechanical Assembly	Done	Ok	
20		()	Electrical Test	Done	Ok	
30		()	Dimensional Check	Done	Ok	
40		()	Acceptance by LASA	Done	Ok	
50		()	Shipping to LASA	Done	Ok	
60		()	Cold Test	Done	Ok	
70		()	Magnetic Measurements	Done	Ok	
80		()	Acceptance by CERN for shipping	Accepted	Ok	
90		()	Shipping to CERN	Done	Ok	
100		()	Visual Inspection @CERN	Done	Ok	
110		()	Electrical test @CERN (*)	Done	Ok	
120		()	Acceptance by CERN	Accepted	Ok	

NB: the magnet was firstly manufactured with low torque value, and reassembled directly in LASA before delivery (1 FAT only) – not in the NC

Magnet	NCs
MQSXF2	N/A (accepted with old design i.e. 4 supports)

Fabrication at SRV (FAT v1)

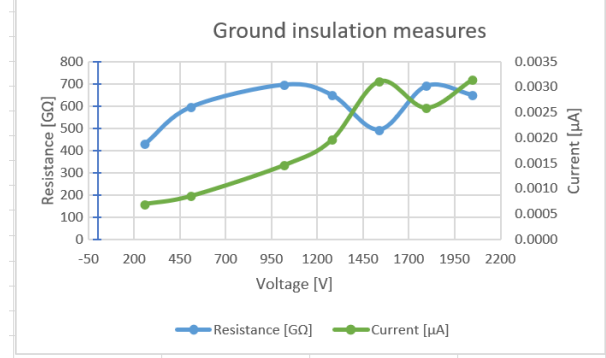
- Central core length of 386.16 mm
→ **1 core lamination added**
- Final PCB box planarity of **0.9 mm**:
“In a 20mm circular sector there is a gap of 0.2mm between the layers of the PCB BOX. This gap is within the acceptability criteria.”
- Residual Gap between closing disc bottom plane and the top surface of the Duratron screw's head: **0.5 mm**
- CMM max deviation: **0.030 mm** for slot 1; **0.029 mm** for slot 4. (acceptability 0.15 mm)
- Leak current @ 2000 V: 0.00315 μA ($\leq 10 \mu\text{A}$)

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [$\text{G}\Omega$]
250	256	0.001	429
500	510	0.001	597
1000	1022	0.001	697
1250	1278	0.002	651
1500	1537	0.003	495
1750	1793	0.003	691
2000	2049	0.003	650

Acceptability criteria:
The leakage current at 2000V DC must be below 10 μA .

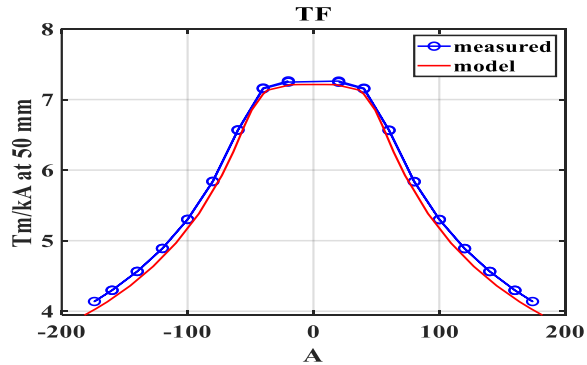
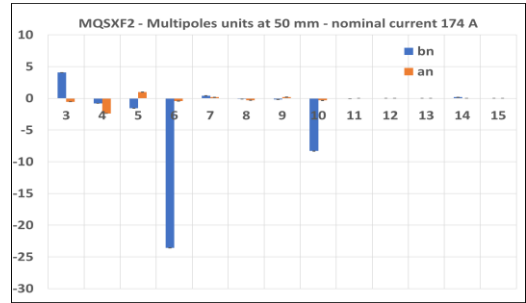
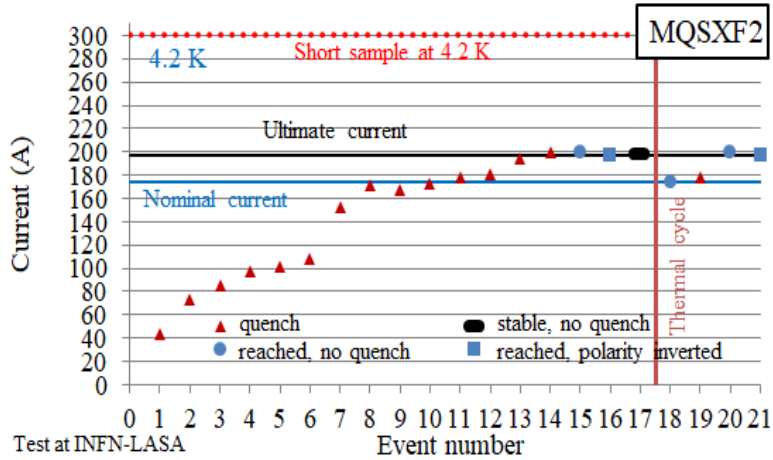
Remarks:
The measures have been taken after 30s from the reaching of the set voltage. Yellow values indicate out of scale or under range.

Resistance of the circuit:
Measured with a multimeter [Ω]: **202**



Powering tests at LASA (MQSXF2)

- Powering test at LASA in Mar 2021 (CD4)
- Magnetic Measurements

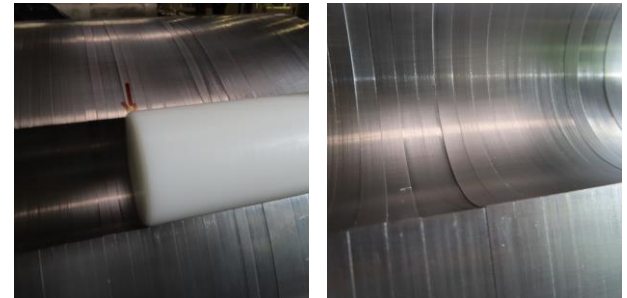


CURRENT [A]	BdL [Tmm] Calc.	BdL [Tmm] Meas.	Δ[%]
174 A	700.0	720.0	2.9
197 A	753.2	772.4	2.6



Reception at CERN

- Visual inspection at CERN:
 - 4 supports for wedges (design v1 as agreed)
 - Rust on some laminations
 - All dimensions within tolerances (± 3 mm for the lengths; $+0.5/-0.0$ mm for the diameters)
 - S grooves aligned (jig 9.92 mm)
 - Aperture diameter ok (jig $\varnothing 149$)
 - Line X half through holes ok (jig $\varnothing 61$)
- Dielectric insulation test at 200 V after powering test at cold : 100 G Ω



MCSXF01b

MQSXF2 | MCTXF2 | MCTSXF1 | MCDXF01b | MCDXF02b | MCOXF03 | MCOXF04b | **MCSXF01b** | MCSXF02

Corrector Package #1	
MQSXF2	S
MCSXF01b	N
MCSXF02	S
MCOXF03	N
MCOXF04b	S
MCDXF01b	N
MCDXF02b	S
MCTXF2	N
MCTSXF1	S

Magnet story

<https://edms5.cern.ch/equipment/HCMCSXF001-X5000001>

- Magnet firstly manufactured and tested with low torque values
- 1st powering test at LASA in Nov 2020 (CD2)
- Sent back to SRV for partial reassembly with increased torque values on wedges
- 2nd powering test at CERN in Apr-May 2021
- No support for wedges (6P)

Equipment Identifier: HCMCSXF001-X5000001

Other Identifier: MCSXF01b

Description: Single Aperture (150mm) Sextupole (b3) MCSXF

Main Made of Equipment data **Manufacturing** Operation Non-conformities Documents History Map

Actions: [Add extra step](#)

Workflow Diagram

No workflow diagram is defined for this equipment

Workflow Steps						Last Repeated
Step #	IR/E	Other name	Description	Status	Result	INC
10	()		Mechanical Assembly	Done	Ok	
11	E		no conformity	Cancelled	Cancelled	
20	()		Electrical Test	Done	Ok	
30	()		Dimensional Check	Done	Ok	
40	()		Acceptance by LASA (*)	Done	Ok	
50	()		Shipping to LASA	Done	Ok	
60	()		Cold Test	Done	Ok	
70	()		Magnetic Measurements	Done	Ok	
72	E		Upgrade in SRV (*)	Done	Ok	
74	E		Shipping to LASA	Done	Ok	
80	()		Acceptance by CERN for shipping	Accepted	Ok	
90	()		Shipping to CERN	Done	Ok	
92	E		Cold Test	Done	Ok	
94	E		Magnetic Measurements	Done	Ok	
100	()		Visual Inspection @CERN	Done	Ok	
110	()		Electrical test @CERN (*)	Done	Ok	
120	()		Acceptance by CERN (*)	Accepted	Ok	

Non-Conformities: 5

Magnet	NCs
MCSXF01b	<ul style="list-style-type: none">• Lower curing temperature for 4 coils (2323155): use as is.• Rectangular shape hole larger on the PCB (2419524): use as is.• Wire slightly bent (2419508): use as is; PCB support for the next magnets.• Not complete closure of the PCB box (2419512): use as is; PCB support for the next magnets.• Increase of the torque after wedge movement observed in MCOXF01 and MCTXF1 (2440962): repair and increase torque (after first test), and retest with upgraded torque (test b).

Fabrication at SRV (FAT v1)

- Central core length of 150.18 mm
 → **nominal number of laminations**
- 1 remark for coil assembly step: “Problem with the tightening of the screws for Centeing and Spacer block. Screws were too tight and they bended Spacers causing gaps. The problem was solved removing the screws and then replacing them with a gentle tight.”
- Planarity of PCB:
 - **0.2mm** Gap between PCB and Upper Arlon Layer. (NC 2419512)
 - **SC Cable of 06_007 bent** between Coil and PCB. (NC 2419508)
- CMM max deviation: **0.018 mm** for slot 1; **0.020 mm** for slot 5; **0.014 mm** for slot 2; 0.021 mm for slot 6 (acceptability 0.10 mm)
- Leak current @ 1500 V: 0.00143 μ A

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μ A]	Resistance [G Ω]
250	256	0.0003	500
500	510	0.0005	966
1000	1021	0.0009	1137
1250	1277	0.0012	1039
1500	1537	0.0014	1074

Acceptability criteria:

The leakage current at 1500V DC must be below 10 μ A.

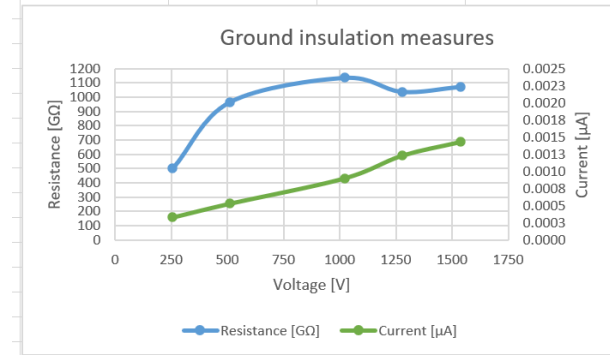
Remarks:

The measures have been taken after 30s from the reaching of the set voltage. Yellow values indicate out of scale or under range.

Resistance of the circuit:

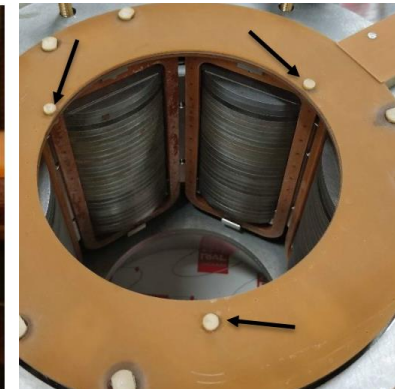
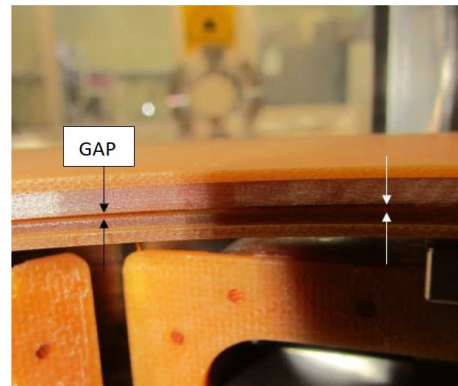
Measured with a multimeter [Ω]

102.1

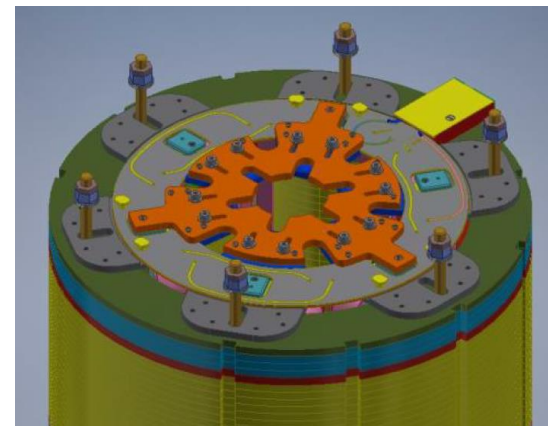


Not complete closure of the PCB box

- PCB Box not completely closed: **0.7 mm gap**
- **Extra holes added** close to the inner circumference of the PCB Box to tight it with 3 Duratron bolts
 - **gap reduction from 0.7 to 0.2 mm.**



- Preventive actions:
 - **PCB support** designed and produced (keep the flatness of the PCB during brazing)
 - **Set of extra holes and extra Duratron bolts** have been added in the design of the PCB box for all series magnets except 10P



Wire slightly bent and resoldered

- 1 wire of coil 06_007 is bent between coil and PCB
- The PCB was bent because not supported (cf NC 2419512) along the internal diameter, so the SC cables have been de-soldered from the PCB; and resoldered when the PCB flatness was partially recovered → **bent wire observed then.**
- Magnet can be **accepted as it is:**
 - Bent wire not damaged
 - Validation of performance during test at cold

NB: more magnets with bent wires accepted (no NCR due to bent wire since recurrent observation, but traceability in the FAT and visual inspection at CERN).



Figure 1- front view coil ID 06_07

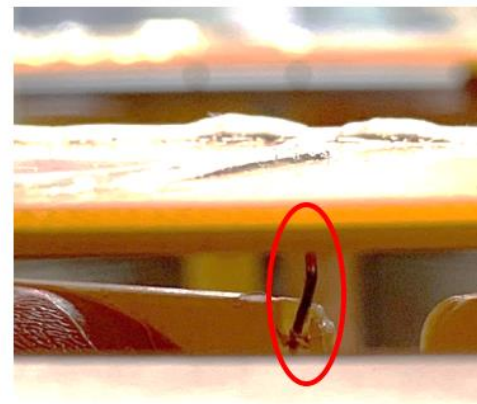
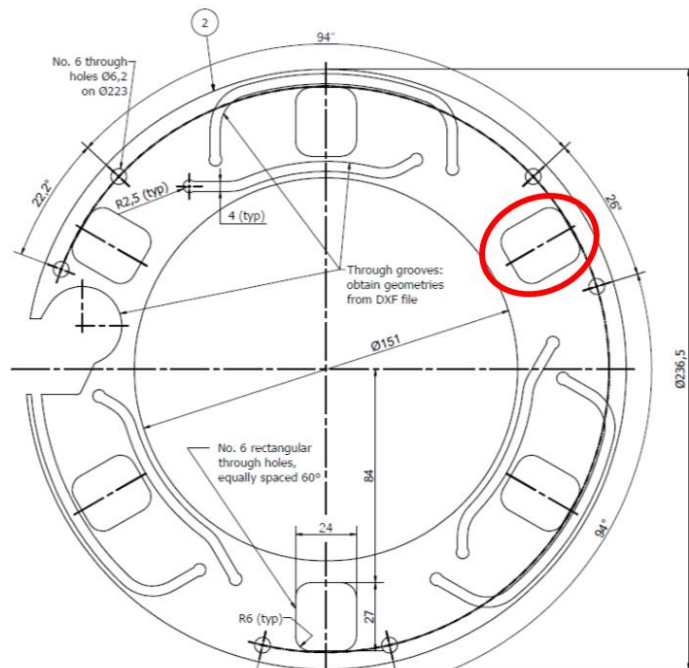


Figure 2-back view coil ID 06_07

Larger rectangular hole in PCB box

- Measurements: 29.1 x 26.12 mm
- Nominal values: 27 x 24 mm
- **No functional impact → use as is.**
- Preventive actions:
 - Supplier to correct milling program
 - Improved Quality Control at the manufacturer



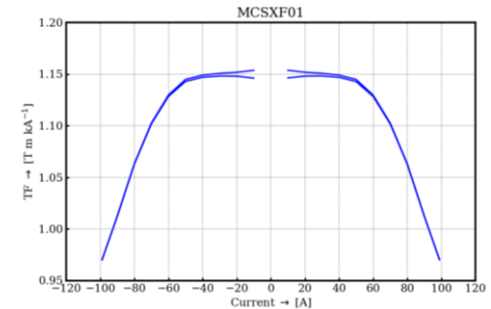
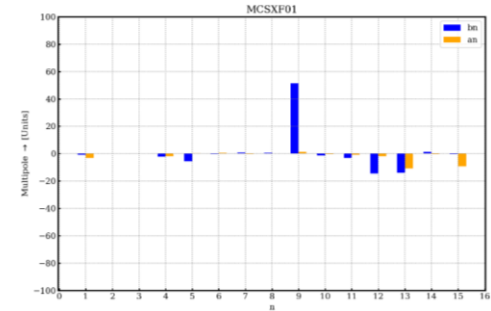
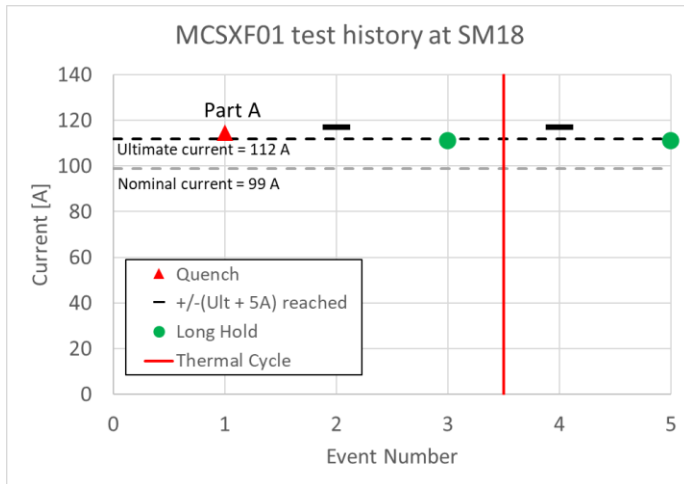
Partial reassembly at SRV (FAT v2)

- **Reassembly of the NCS** only to increase the torque during the wedge assembly
(0.2 → 0.44 Nm)
- The CS has not been reassembled (same planarity of the PCB as before i.e. gap of 0.2 mm + 1 bent wire)
- CMM max deviation: **0.016 mm** for slot 1; **0.021 mm** for slot 5; **0.015 mm** for slot 2; **0.019 mm** for slot 6 (acceptability 0.10 mm)
- Leak current @ **100 V (magnet already tested at cold)** : 0.00019 μA ($\leq 10 \mu\text{A}$)

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [G Ω]
100	101	0.0002	>100
Acceptability criteria:			
The leakage current at 1500V DC must be below 10 μA .			
Remarks:			
The measures have been taken after 30s from the reaching of the set voltage. Yellow values indicate out of scale or under range. The maximum voltage has been set to 100V because the magnet has already undergone to the cold test			
Resistance of the circuit:			101.9
Measured with a multimeter [Ω]			

2nd powering test at CERN (MCSXF01b)

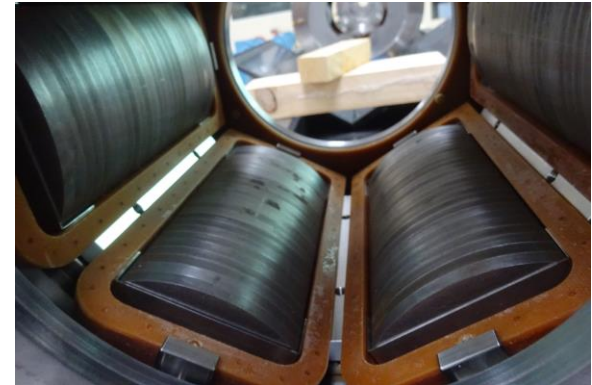
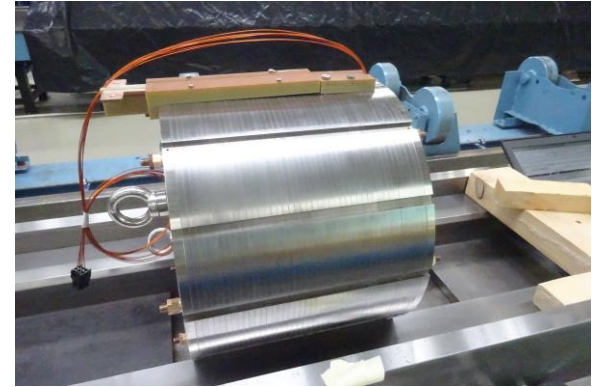
- 2nd powering test at CERN in Apr-May 2021
- Magnetic Measurements



Reception at CERN

- Visual inspection at CERN:
 - Rust on some laminations
 - 1 bent wire (NC 2419508)
 - All dimensions within tolerances (+/- 3 mm for the lengths; +0.5/-0.0 mm for the diameters)
 - N and S grooves aligned (jig 9.92 mm)
 - Aperture diameter ok (jig \varnothing 149)

- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω



MCSXF02

Corrector Package #1	
MQSXF2	S
MCSXF01b	N
MCSXF02	S
MCOXF03	N
MCOXF04b	S
MCDXF01b	N
MCDXF02b	S
MCTXF2	N
MCTSXF1	S

MQSXF2 | MCTXF2 | MCTSXF1 | MCDXF01b | MCDXF02b | MCOXF03 | MCOXF04b | MCSXF01b | **MCSXF02**



Magnet story

<https://edms5.cern.ch/equipment/HCMCSXF001-X5000002>

- Magnet firstly manufactured with low torque values
- Before first test, sent back to SRV for partial reassembly with increased torque values on wedges
- Powering test at LASA in Mar 2021 (CD4)
- No support for wedges (6P)

Equipment Identifier: HCMCSXF001-X5000002

Other Identifier: MCSXF02

Description: Single Aperture (150mm) Sextupole (b3) MCSXF

Main Made of Equipment data **Manufacturing** Operation Non-conformities Documents History Map

Actions: [Add extra step](#)

Workflow Diagram

No workflow diagram is defined for this equipment

Workflow Steps

Step ID	IR/E	Other name	Description	Status	Result	Last Repeated INC
10		()	Mechanical Assembly	Done	Ok	
20		()	Electrical Test	Done	Ok	
30		()	Dimensional Check	Done	Ok	
40		()	Acceptance by LASA	Done	Ok	
50		()	Shipping to LASA	Done	Ok	
52	E	()	Upgrade in SRV (*)	Done	Ok	
54	E	()	Shipping to LASA	Done	Ok	
60		()	Cold Test	Done	Ok	
70		()	Magnetic Measurements	Done	Ok	
80		()	Acceptance by CERN for shipping	Accepted	Ok	
90		()	Shipping to CERN	Done	Ok	
100		()	Visual Inspection @CERN	Done	Ok	
110		()	Electrical test @CERN	Done	Ok	
120		()	Acceptance by CERN	Accepted	Ok	

Non-Conformities: 4

Magnet	NCs
MCSXF02	<ul style="list-style-type: none">• Lower curing temperature for 5 coils (2323155): use as is.• Internal BT-S2 degluing in 1 coil (2316887): use as is.• Rectangular shape hole larger on the PCB (2419524): use as is.• Increase of the torque after wedge movement observed in MCOXF01 and MCTXF1 (2440962): repair before test, and test with upgraded torque directly.

Fabrication at SRV (FAT v1)

- Central core length of 150.25 mm
→ **nominal number of laminations**
- 1 remark for coil assembly step: “Problem with the tightening of the screws for Centeing and Spacer block. Screws were too tigh and they bended Spacers causing gaps. The problem was solved removing the screws and then replacing them with a gentle tigh.”
- PCB support used for soldering the wires.
- CMM max deviation: **0.015 mm** for slot 1; **0.020 mm** for slot 5; **0.013 mm** for slot 2; **0.020 mm** for slot 6 (acceptability 0.10 mm)
- Leak current @ 1500 V: 0.0013 μA ($\leq 10 \mu\text{A}$)

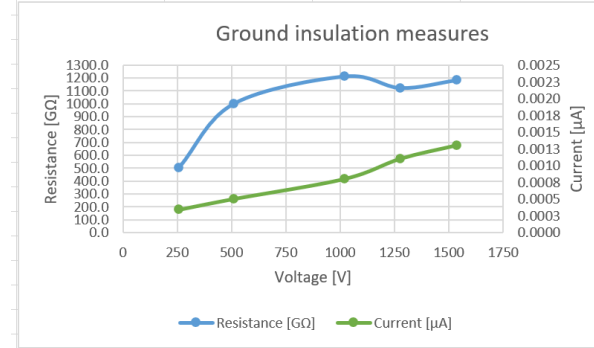
Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [$\text{G}\Omega$]
250	257	0.0003	500.0
500	510	0.0005	1000.0
1000	1022	0.0008	1213.0
1250	1278	0.0011	1123.0
1500	1538	0.0013	1184.0

Acceptability criteria:
The leakage current at 1500V DC must be below 10 μA .

Remarks:
The measures have been taken after 30s from the reaching of the set voltage. Yellow values indicate out of scale or under range.

Resistance of the circuit:
Measured with a multimeter [Ω]

102.0



Internal BT-S2 de-gluing on 1 coil

- Presence of a small delamination area of the internal BT-S2 strip
- **Coil can be used as is.**
- Preventive action:
 - Review of the **internal BT-S2 strip design by adding two more rows of holes** to reduce the residual stress and enhance the resin adhesion

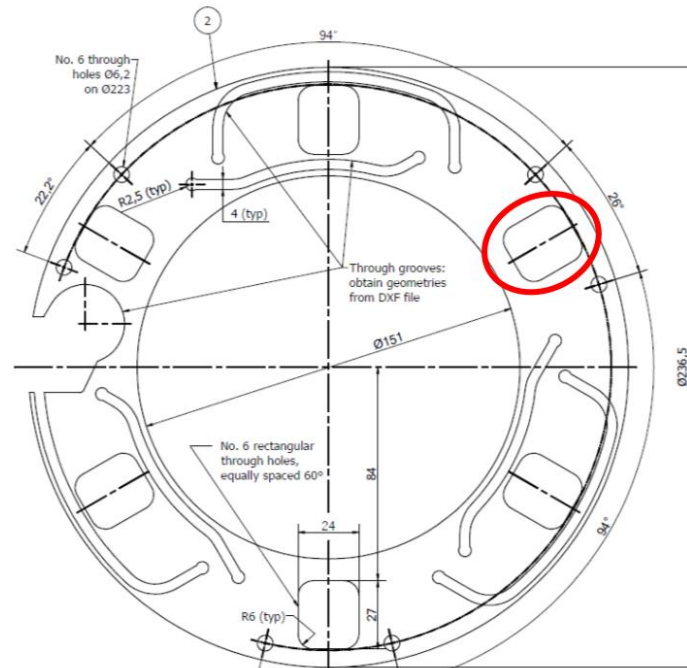


Larger rectangular hole in PCB box

- Measurements: 29.1 x 26.12 mm
- Nominal values: 27 x 24 mm

- **No functional impact → use as is.**

- Preventive actions:
 - Supplier to correct milling program
 - Improved Quality Control at the manufacturer



Partial reassembly at SRV (FAT v2)

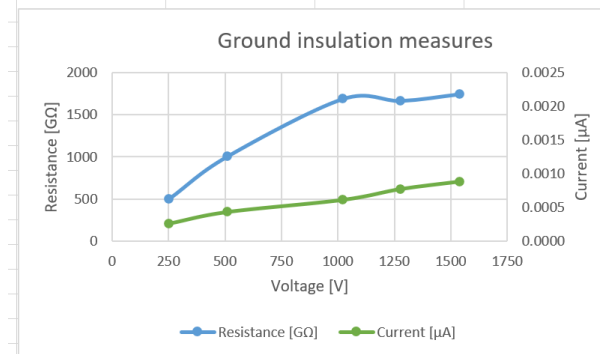
- Reassembly of the NCS only to increase the torque during the wedge assembly (0.2 → 0.44 Nm)
- CMM max deviation: **0.017 mm** for slot 1; **0.018 mm** for slot 5; **0.016 mm** for slot 2; **0.017 mm** for slot 6 (acceptability 0.10 mm)
- Leak current @ **1500 V** : 0.00088 μA

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [GΩ]
250	254	0.0003	500
500	510	0.0004	1000
1000	1022	0.0006	1684
1250	1278	0.0008	1661
1500	1538	0.0009	1740

Acceptability criteria:
The leakage current at 1500V DC must be below 10 μA.

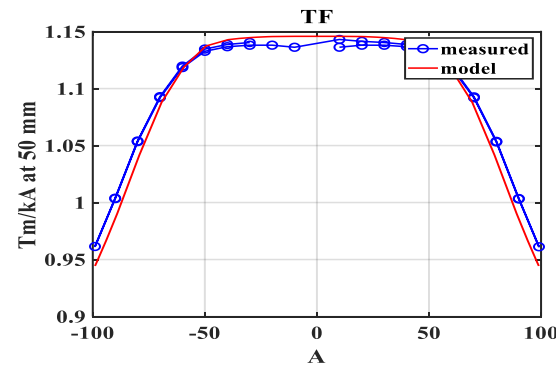
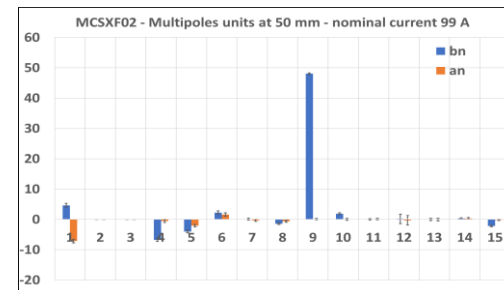
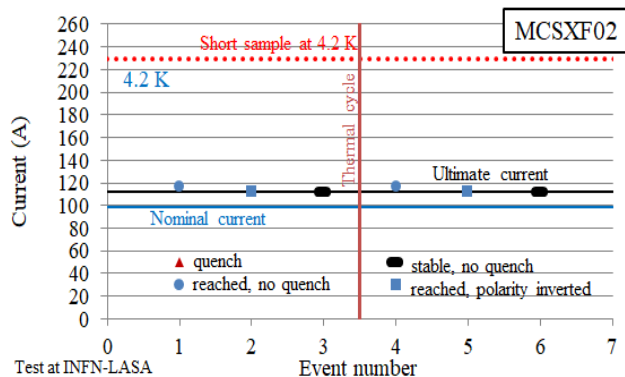
Remarks:
The measures have been taken after 30s from the reaching of the set voltage. Yellow values indicate out of scale or under range.

Resistance of the circuit:
Measured with a multimeter [Ω] **101.9**



Powering test at LASA (MCSXF02)

- Powering test at LASA in Mar 2021 (CD4)
- Magnetic Measurements



CURRENT [A]	BdL [Tmm] Calc.	BdL [Tmm] Meas.	Δ[%]
99 A	93.5	95.2	1.8
112 A	100.5	101.8	1.3

Reception at CERN

- Visual inspection at CERN:
 - Rust on some laminations
 - 4 wires slightly bent → accepted as agreed
 - All dimensions within tolerances (+/- 3 mm for the lengths; +0.5/-0.0 mm for the diameters)
 - N and S grooves aligned (jig 9.92 mm)
 - Aperture diameter ok (jig $\varnothing 149$)
- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω



MCOXF03

MQSXF2 | MCTXF2 | MCTSXF1 | MCDXF01b | MCDXF02b | **MCOXF03** | MCOXF04b | MCSXF01b | MCSXF02

Corrector Package #1	
MQSXF2	S
MCSXF01b	N
MCSXF02	S
MCOXF03	N
MCOXF04b	S
MCDXF01b	N
MCDXF02b	S
MCTXF2	N
MCTSXF1	S

Magnet story

<https://edms5.cern.ch/equipment/HCMCOXF001-X5000003>

- Magnet directly manufactured with increased torque values
- Powering test at LASA in Jan 2021 (CD3)
 - movement of 1 wedge by 7mm
- 2 wedge supports added directly in LASA (intermediate design) – no retest

Equipment Identifier: HCMCOXF001-X5000003

Other Identifier: MCOXF03

Description: Single Aperture (150 mm) Octupole (b4) MCOXF

Main Made of Equipment data **Manufacturing** Operation Non-conformities Documents History Map

Actions : [Add extra step](#)

Workflow Diagram

No workflow diagram is defined for this equipment

Workflow Steps				Last Repeated		
Step#	IR/E	Other name	Description	Status	Result	INC
10		()	Mechanical Assembly	Done	Ok	
20		()	Electrical Test	Done	Ok	
30		()	Dimensional Check	Done	Ok	
40		()	Acceptance by LASA	Accepted	Ok	
50		()	Shipping to LASA	Done	Ok	
52	E	()	Upgrade in SRV (*)	Pending		
54	E	()	Shipping to LASA	Pending		
60		()	Cold Test	Done	Ok	
70		()	Magnetic Measurements	Done	Ok	
72		()	Upgrade in SRV (*)	Pending		
74	E	()	Shipping to LASA	Cancelled		
80		()	Acceptance by CERN for shipping	Accepted	Ok	
90		()	Shipping to CERN	Done	Ok	
100		()	Visual Inspection @CERN	Done	Ok	
110		()	Electrical test @CERN	Done	Ok	
120		()	Acceptance by CERN	Accepted	Ok	

Steps being updated

Non-Conformities: 2

Magnet	NCs
MCOXF03	<ul style="list-style-type: none">• Lower curing temperature for 2 coils (2323155): use as is.• Small wedge movement observed after test (2489174): repair with 2 additional supports in LASA but no retest.

Fabrication at SRV (FAT v1)

- Central core length of 132.5 mm
→ **nominal number of laminations**
- Torque on wedges: 0.55 Nm
- Final PCB box flatness of **0.4 mm**
- Residual gap between closing disc bottom plane and top surface of the Duratron screw's head : negative gap of **-0.3 mm**
→ not critical thanks to the hollow closing lamination
- CMM max deviation: **0.019 mm** for slot 1; **0.020 mm** for slot 5; **0.016 mm** for slot 2; **0.013 mm** for slot 6 (acceptability 0.10 mm)
- Leak current @ 1500 V: 0.00147 μA ($\leq 10 \mu\text{A}$)

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [Ω]
250	256	0.0003	500.0
500	510	0.0006	795.0
1000	1021	0.0011	969.0
1250	1277	0.0012	1040.0
1500	1537	0.0015	1044.0

Acceptability criteria:

The leakage current at 1500V DC must be below 10 μA .

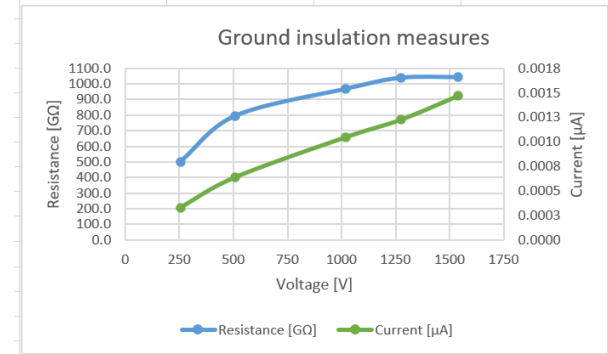
Remarks:

The measures have been taken after 30s from the reaching of the set voltage. Yellow values indicate out of scale or under range.

Resistance of the circuit:

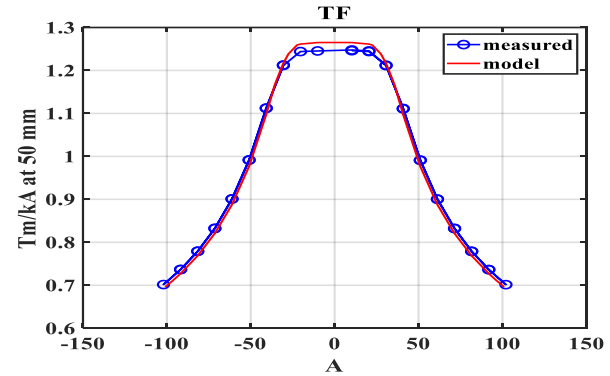
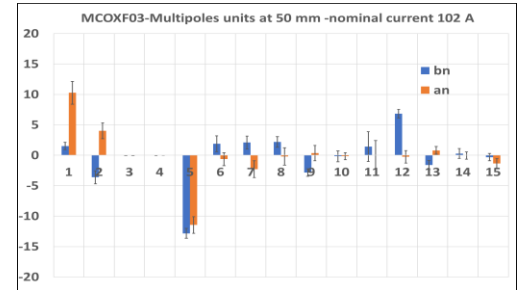
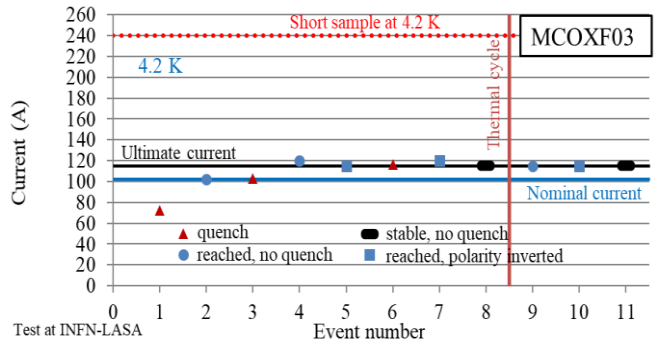
Measured with a multimeter [Ω]

144.8



Powering test at LASA (MCOXF03)

- Powering test at LASA in Jan 2021 (CD3)
- Magnetic Measurements



CURRENT [A]	BdL [Tmm] Calc.	BdL [Tmm] Meas.	Δ[%]
102 A	70.7	71.6	1.3
115 A	75.7	77.2	1.9



Wedge supports added in LASA

- After powering test, 1 wedge is displaced downwards of 7 mm. Could be moved by hand. (NC 2489174)
 - Repair **directly done in LASA**
 - **No retest required**
- 2 Additional supports per wedge are installed** (intermediate solution; no need of reassembly)

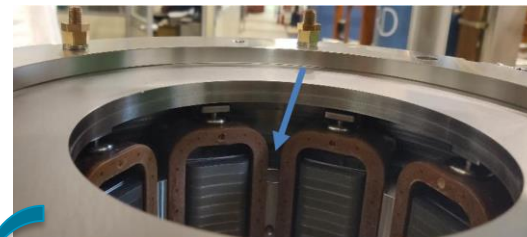
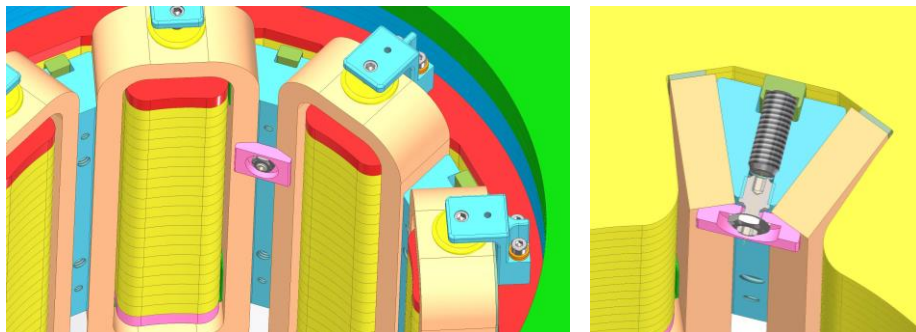
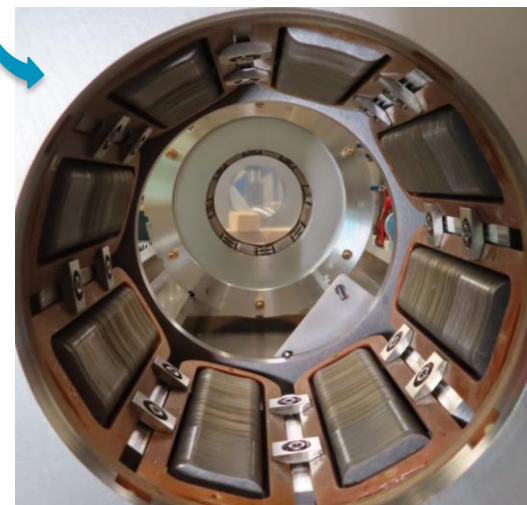
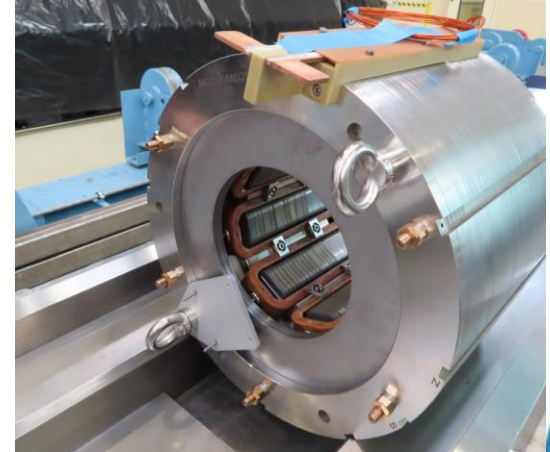


Figure 1 Inner views of HCMCOXF001-X5000003. The displaced wedge is highlighted.



Reception at CERN

- Visual inspection at CERN:
 - Rust on some laminations
 - 1 wires slightly bent → accepted as agreed
 - All dimensions within tolerances (+/- 3 mm for the lengths; +0.5/-0.0 mm for the diameters)
 - N and S grooves aligned (jig 9.92 mm)
 - Aperture diameter ok (jig $\varnothing 149$)
- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω



MCOXF04b

MQSXF2 | MCTXF2 | MCTSXF1 | MCDXF01b | MCDXF02b | MCOXF03 | **MCOXF04b** | MCSXF01b | MCSXF02

Corrector Package #1	
MQSXF2	S
MCSXF01b	N
MCSXF02	S
MCOXF03	N
MCOXF04b	S
MCDXF01b	N
MCDXF02b	S
MCTXF2	N
MCTSXF1	S

Magnet story

<https://edms5.cern.ch/equipment/HCMCOXF001-X5000004>

- Magnet directly manufactured with increased torque values
- 1st powering test at LASA in Mar 2021 (CD4)
 - movement of wedges observed
- 2 wedge supports added directly in LASA (intermediate design)
- 2nd powering test at LASA in Jun 2021 (CD6)

Equipment Identifier: HCMCOXF001-X5000004
Other Identifier: MCOXF04b
Description: Single Aperture (150 mm) Octupole (b4) MCOXF

Actions: Add extra step

Workflow Diagram

No workflow diagram is defined for this equipment

Workflow Steps				Last Repeated		
Step ID	R/E	Other name	Description	Status	Result	INC
<u>10</u>			Mechanical Assembly	Done	Ok	
<u>20</u>			Electrical Test	Done	Ok	
<u>30</u>			Dimensional Check	Done	Ok	
<u>40</u>			Acceptance by LASA	Done	Ok	
<u>50</u>			Shipping to LASA	Done	Ok	
<u>52</u>	E		Upgrade in SRV (*)	Pending		
<u>54</u>	E		Shipping to LASA	Pending		
<u>60</u>			Cold Test	Done	Ok	
<u>70</u>			Magnetic Measurements	Done	Ok	
<u>72</u>	E		Upgrade in SRV (*)	Pending		
<u>74</u>	E		Shipping to LASA	Cancelled		
<u>76</u>	E		Cold Test	Pending		
<u>78</u>	E		Magnetic Measurements	Pending		
<u>80</u>			Acceptance by CERN for shipping	Accepted	Ok	
<u>90</u>			Shipping to CERN	Done	Ok	
<u>100</u>			Visual Inspection @CERN	Done	Ok	
<u>110</u>			Electrical test @CERN	Done	Ok	
<u>120</u>			Acceptance by CERN	Accepted	Ok	

Steps being updated

Non-Conformities: 1

Magnet	NCs
MCOXF04b	<ul style="list-style-type: none">• Wedge movement observed after thermal cycle (2515856) : repair with 2 additional supports and retest (test b)

Fabrication at SRV (FAT v1)

- Central core length of 133.12 mm
→ **nominal number of laminations**
- Torque on wedges: 0.55 Nm
- Final PCB box flatness of **0.38 mm**
- Residual gap between closing disc bottom plane and top surface of the Duratron screw's head : negative gap of **-0.1 mm**
→ not critical thanks to the hollow closing lamination
- CMM max deviation: **0.017 mm** for slot 1; **0.018 mm** for slot 5; **0.016 mm** for slot 2; **0.016 mm** for slot 6 (acceptability 0.10 mm)
- Leak current @ 1500 V: 0.002 μA ($\leq 10 \mu\text{A}$)

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [$\text{G}\Omega$]
250	253	0.0004	500
500	510	0.0006	857.0
1000	1021	0.0011	904.0
1250	1277	0.0014	920.0
1500	1537	0.0017	910.0

Acceptability criteria:

The leakage current at 1500V DC must be below 10 μA .

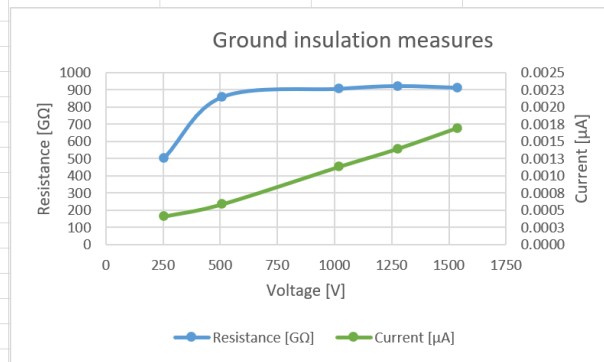
Remarks:

The measures have been taken after 30s from the reaching of the set voltage.
Yellow values indicate out of scale or under range.

Resistance of the circuit:

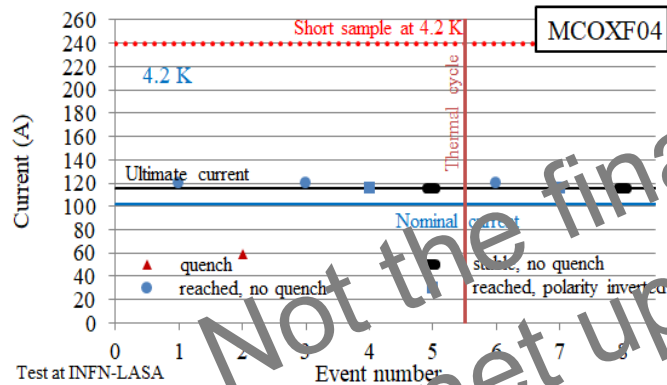
Measured with a multimeter [Ω]

143.6

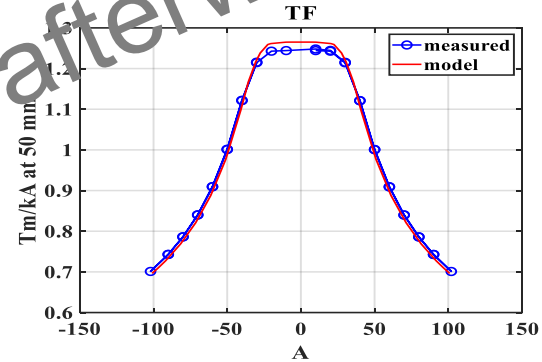
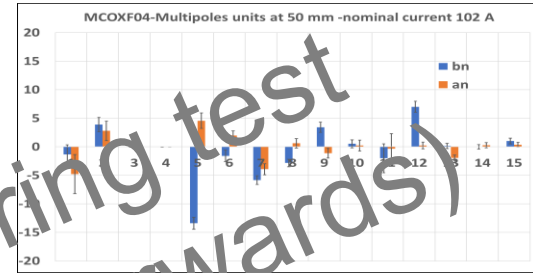


1st powering tests at LASA (MCOXF04)

- 1st powering test at LASA in Mar 2021 (CD4)
- Magnetic Measurements



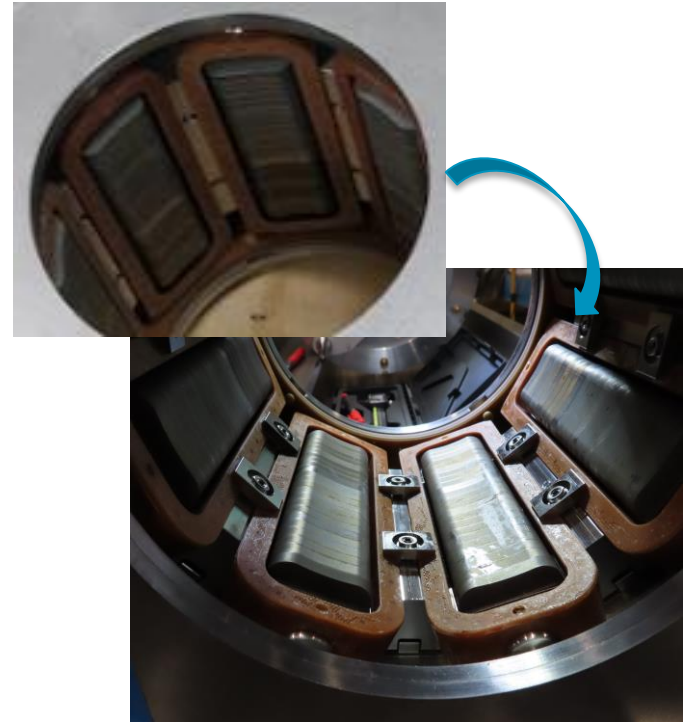
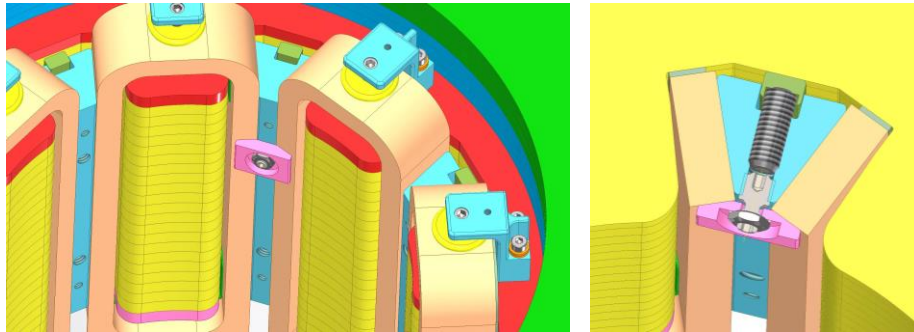
Not the final powering test
(magnet upgrade afterwards)



CURRENT [A]	BdL [Tmm] Calc.	BdL [Tmm] Meas.	Δ[%]
102 A	70.7	71.5	1.2
115 A	75.7	76.4	1.0

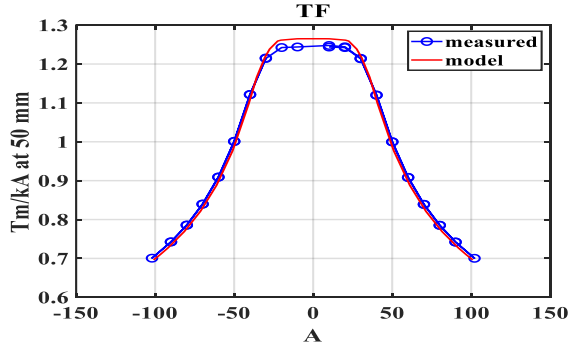
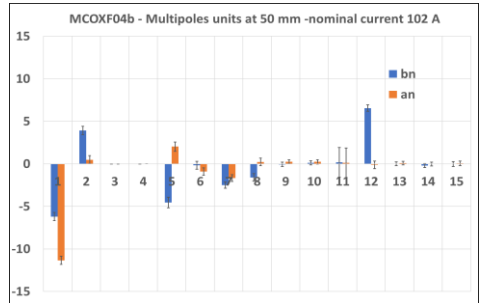
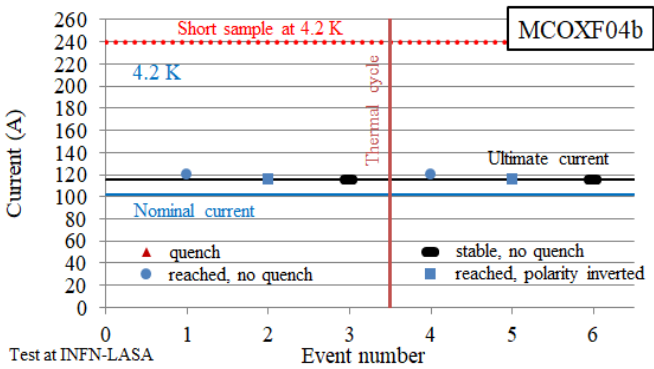
Wedge supports added in LASA

- After powering test, all the wedges are displaced downwards. Could be moved by hand. (NC 2515856)
 - Repair **directly done in LASA**
 - **Retest required (test b)**
- **2 Additional supports per wedge are installed** (intermediate solution; no need of reassembly)



2nd powering tests at LASA (MCOXF04b)

- 2nd powering test at LASA in Jun 2021 (CD6)
- Magnetic Measurements



CURRENT [A]	BdL [Tmm] Calc.	BdL [Tmm] Meas.	Δ[%]
102 A	70.7	71.5	1.1
115 A	75.7	76.4	0.9



Reception at CERN

- Visual inspection at CERN:
 - Rust on some laminations
 - All dimensions within tolerances (+/- 3 mm for the lengths; +0.5/-0.0 mm for the diameters)
 - N and S grooves aligned (jig 9.92 mm)
 - Aperture diameter ok (jig \varnothing 149)
- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω



MCDXF01b

MQSXF2 | MCTXF2 | MCTSXF1 | **MCDXF01b** | MCDXF02b | MCOXF03 | MCOXF04b | MCSXF01b | MCSXF02

Corrector Package #1	
MQSXF2	S
MCSXF01b	N
MCSXF02	S
MCOXF03	N
MCOXF04b	S
MCDXF01b	N
MCDXF02b	S
MCTXF2	N
MCTSXF1	S

Magnet story

<https://edms5.cern.ch/equipment/HCMCDXF001-X5000001>

- Magnet firstly manufactured and tested with low torque values
- 1st powering test at LASA in Jul 2020 (CD1)
- Sent back to SRV for partial reassembly with increased torque values on wedges
- 2nd powering test at CERN in Apr-May 2021
- No support for wedges (10P)

Equipment Identifier: HCMCDXF001-X5000001

Other Identifier: MCDXF01b

Description: Single Aperture (150 mm) Decapole (b5)
MCDXF

Main Made of Equipment data Manufacturing Operation Non-conformities Documents History Map						
Actions: Add extra step						
Workflow Diagram						
No workflow diagram is defined for this equipment						
Workflow Steps						Last Repeated
Step ID	IR/E	Other name	Description	Status	Result	INC
10		()	Mechanical Assembly	Done	Ok	
20		()	Electrical Test	Done	Ok	
30		()	Dimensional Check	Done	Ok	
40		()	Acceptance by LASA	Accepted	Ok	
50		()	Shipping to LASA	Done	Ok	
60		()	Cold Test	Done	Ok	
70		()	Magnetic Measurements	Done	Ok	
72	E	()	Upgrade in SRV (*)	Done	Ok	
74	E	()	Shipping to LASA	Done	Ok	
80		()	Acceptance by CERN for shipping	Accepted	Ok	
90		()	Shipping to CERN	Done	Ok	
92	E	()	Cold Test	Done	Ok	
94	E	()	Magnetic Measurements	Done	Ok	
100		()	Visual Inspection @CERN	Done	Ok	
110		()	Electrical test @CERN	Done	Ok	
120		()	Acceptance by CERN	Accepted	Ok	

Non-Conformities: 1

Magnet	NCs
MCDXF01b	<ul style="list-style-type: none">• Increase of the torque after wedge movement observed in MCOXF01 and MCTXF1 (2440962): repair and increase torque (after first test), and retest with upgraded torque (test b).

Fabrication at SRV (FAT v1)

- Central core length of 132.63 mm
→ **nominal number of laminations**
- CMM max deviation: **0.018 mm** for slot 1; **0.016 mm** for slot 5; **0.026 mm** for slot 2; **0.020 mm** for slot 6 (acceptability 0.10 mm)
- Leak current @ 1500 V: 0.0020 μA ($\leq 10 \mu\text{A}$)

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [$\text{G}\Omega$]
250	256	0.0005	500.0
500	509	0.0007	749.0
1000	1020	0.0012	802.0
1250	1276	0.0016	771.0
1500	1535	0.0020	753.0

Acceptability criteria:

The leakage current at 1500V DC must be below 10 μA .

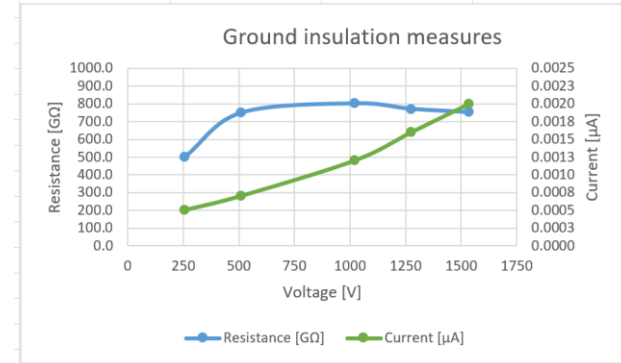
Remarks:

The measures have been taken after 30s from the reaching of the set voltage.
Yellow values indicate out of scale or under range.

Resistance of the circuit:

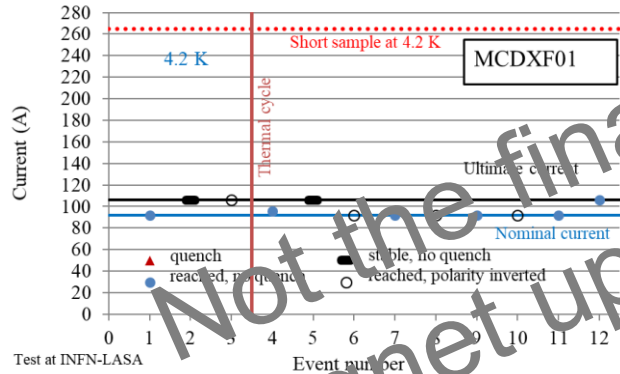
Measured with a multimeter [Ω]

103.6

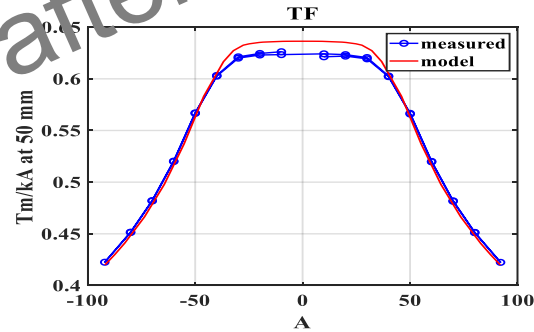
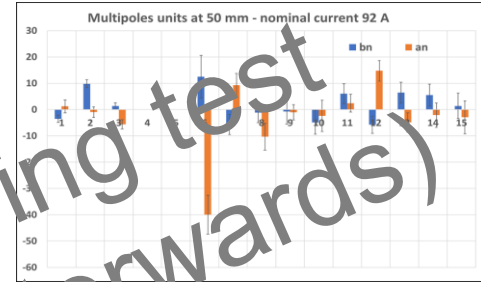


1st powering tests at LASA (MCDXF01)

- 1st powering test at LASA in Jul 2020 (CD1)
- Magnetic Measurements



Not the final powering test
(magnet upgrade afterwards)



CURRENT [A]	BdL [Tmm] Calc.	BdL [Tmm] Meas.	Δ[%]
92 A	38.7	38.9	0.6
106 A	41.8	42.0	0.5

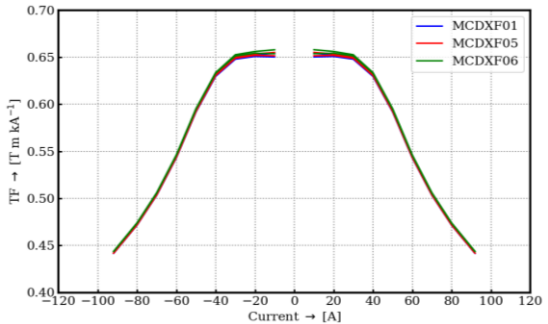
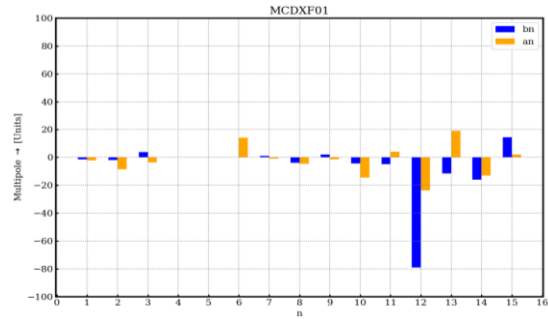
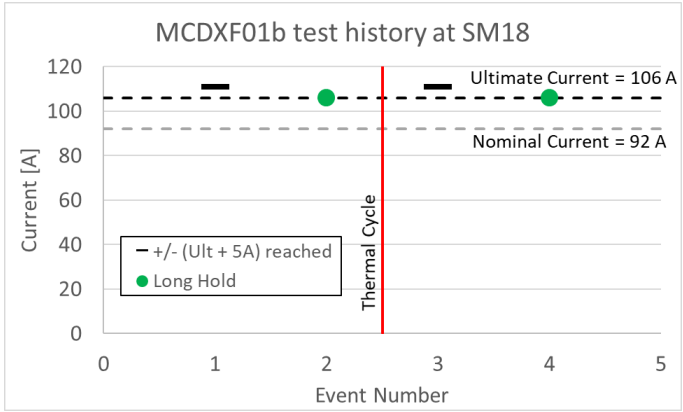
Partial reassembly at SRV (FAT v2)

- **Reassembly of the NCS only**, to increase the torque during the wedge assembly (**0.2 → 0.35 Nm**)
- The CS has not been reassembled
- CMM max deviation: **0.018 mm** for slot 1; **0.016 mm** for slot 5; **0.012 mm** for slot 2; **0.016 mm** for slot 6 (acceptability 0.10 mm)
- Leak current @ **100 V (magnet already tested at cold)**: 0.0002 μA ($\leq 10 \mu\text{A}$)

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [G Ω]
100	101	0.0002	>100
Acceptability criteria:			
The leakage current at 1500V DC must be below 10 μA .			
Remarks:			
The measures have been taken after 30s from the reaching of the set voltage. Yellow values indicate out of scale or under range. The maximum voltage has been set to 100V because the magnet has already been undergone a cold test.			
Resistance of the circuit:		103.5	
Measured with a multimeter [Ω]			

2nd powering tests at CERN (MCDXF01b)

- 2nd powering test at CERN in Apr-May 2021
- Magnetic Measurements

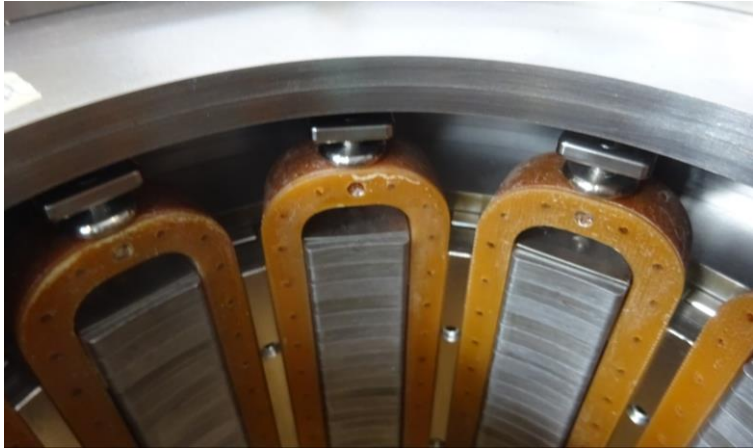
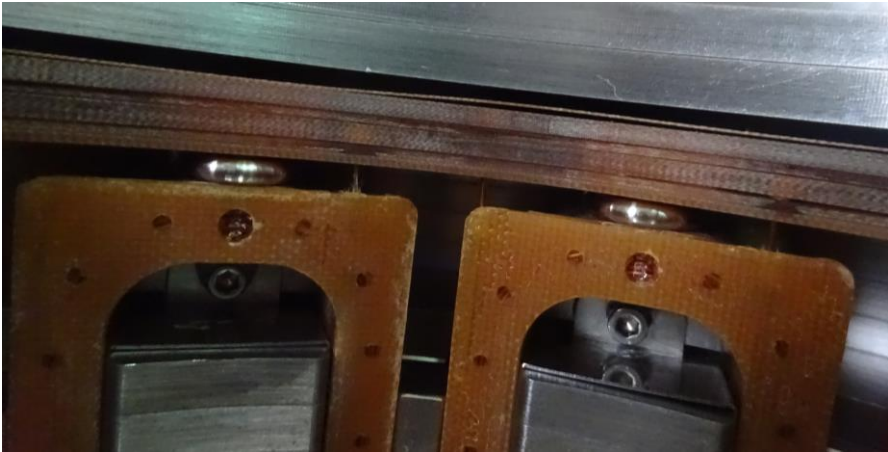


Reception at CERN

- Visual inspection at CERN:
 - Rust on some laminations
 - All dimensions within tolerances (+/- 3 mm for the lengths; +0.5/-0.0 mm for the diameters)
 - N and S grooves aligned (jig 9.92 mm)
 - Aperture diameter ok (jig $\varnothing 149$)
- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω



Reception at CERN



MCDXF02b

MQSXF2 | MCTXF2 | MCTSXF1 | MCDXF01b | **MCDXF02b** | MCOXF03 | MCOXF04b | MCSXF01b | MCSXF02

Corrector Package #1	
MQSXF2	S
MCSXF01b	N
MCSXF02	S
MCOXF03	N
MCOXF04b	S
MCDXF01b	N
MCDXF02b	S
MCTXF2	N
MCTSXF1	S

Magnet story

<https://edms5.cern.ch/equipment/HCMCDXF001-X5000002>

- Magnet firstly manufactured and tested with low torque values
- 1st powering test at LASA in Nov 2020 (CD2)
- Sent back to SRV for partial reassembly with increased torque values on wedges
- 2nd powering test at CERN in Apr-May 2021
- No support for wedges (10P)

Equipment Identifier: HCMCDXF001-X5000002
Other Identifier: MCDXF02b
Description: Single Aperture (150 mm) Decapole (b5) MCDXF

Actions : Add extra step

Workflow Diagram
No workflow diagram is defined for this equipment

Step ID	IR/E	Other name	Description	Status	Last Repeated	
					Result	INC
10		()	Mechanical Assembly	Done	Ok	
20		()	Electrical Test	Done	Ok	
30		()	Dimensional Check	Done	Ok	
40		()	Acceptance by LASA (*)	Accepted	Ok	
50		()	Shipping to LASA	Done	Ok	
60		()	Cold Test	Done	Ok	
62	E	()	Upgrade in SRV (*)	Done	Ok	
64	E	()	Shipping to LASA	Done	Ok	
66	E	()	Cold test	Done	Ok	
70		()	Magnetic Measurements	Cancelled		
80		()	Acceptance by CERN for shipping	Accepted	Ok	
90		()	Shipping to CERN	Done	Ok	
92	E	()	Cold Test	Done	Ok	
94	E	()	Magnetic Measurements	Pending		
100		()	Visual Inspection @CERN	Done	Ok	
110		()	Electrical test @CERN (*)	Done	Ok	
120		()	Acceptance by CERN	Accepted	Ok	

Steps being updated

Non-Conformities: 1

Magnet	NCs
MCDXF02b	<ul style="list-style-type: none">• Increase of the torque after wedge movement observed in MCOXF01 and MCTXF1 (2440962): repair and increase torque (after first test), and retest with upgraded torque (test b).

Fabrication at SRV (FAT v1)

- Central core length of 133.2 mm
→ **nominal number of laminations**
- CMM max deviation: **0.017 mm** for slot 1; **0.020 mm** for slot 5; **0.017 mm** for slot 2; **0.023 mm** for slot 6 (acceptability 0.10 mm)
- Leak current @ 1500 V: 0.0015 μA ($\leq 10 \mu\text{A}$)

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [$\text{G}\Omega$]
250	256	0.0005	500.0
500	510	0.0006	904.0
1000	1020	0.0012	875.0
1250	1276	0.0013	987.0
1500	1535	0.0015	1006.0

Acceptability criteria:

The leakage current at 1500V DC must be below 10 μA .

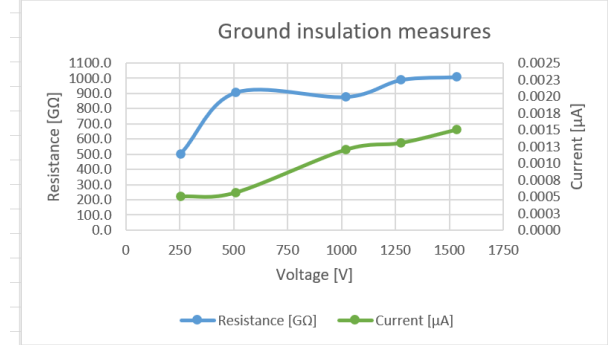
Remarks:

The measures have been taken after 30s from the reaching of the set voltage. Yellow values indicate out of scale or under range.

Resistance of the circuit:

Measured with a multimeter [Ω]

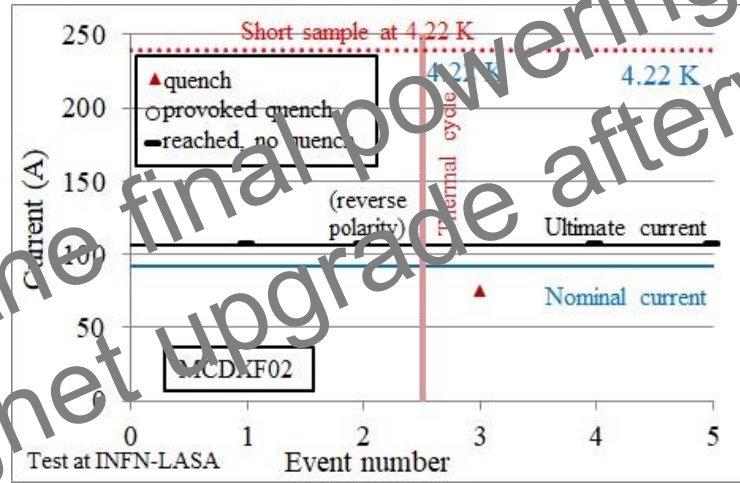
103.5



1st powering tests at LASA (MCDXF02)

- 1st powering test at LASA in Nov 2020 (CD2)
- No Magnetic Measurements

Not the final powering test
(magnet upgrade afterwards)



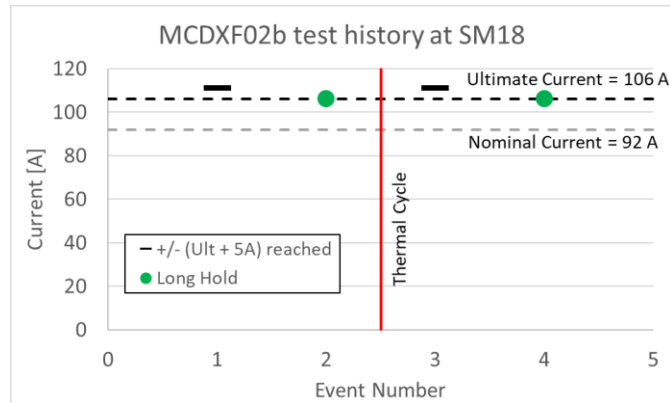
Partial reassembly at SRV (FAT v2)

- **Reassembly of the NCS only**, to increase the torque during the wedge assembly
(0.2 → 0.35 Nm)
- The CS has not been reassembled
- CMM max deviation: **0.016 mm** for slot 1; **0.020 mm** for slot 5; **0.017 mm** for slot 2; **0.019 mm** for slot 6 (acceptability 0.10 mm)
- Leak current @ **100 V (magnet already tested at cold)**: 0.0010 μA ($\leq 10 \mu\text{A}$)

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [$\text{G}\Omega$]
100	101	0.0001	>100
Acceptability criteria:			
The leakage current at 1500V DC must be below 10 μA .			
Remarks:			
The measures have been taken after 30s from the reaching of the set voltage. Yellow values indicate out of scale or under range.			
The maximum voltage has been limited to 100V because the magnet has been already undergone to cold test at LASA.			
Resistance of the circuit:			103.3
Measured with a multimeter [Ω]			

2nd powering tests at CERN (MCDXF02b)

- 2nd powering test at CERN in Apr-May 2021
- Magnetic Measurements but the data were corrupted due to a malfunction of the shaft motor.



Reception at CERN

- Visual inspection at CERN:
 - Rust on some laminations
 - All dimensions within tolerances (+/- 3 mm for the lengths; +0.5/-0.0 mm for the diameters)
 - N and S grooves aligned (jig 9.92 mm)
 - Aperture diameter ok (jig $\varnothing 149$)
- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω



Reception at CERN



MCTXF2

MQSXF2 | **MCTXF2** | MCTSXF1 | MCDXF01b | MCDXF02b | MCOXF03 | MCOXF04b | MCSXF01b | MCSXF02

Corrector Package #1	
MQSXF2	S
MCSXF01b	N
MCSXF02	S
MCOXF03	N
MCOXF04b	S
MCDXF01b	N
MCDXF02b	S
MCTXF2	N
MCTSXF1	S

Magnet story

<https://edms5.cern.ch/equipment/HCMCTXF001-X5000002>

- Magnet directly delivered with increased torque values
- Powering test at LASA in Jan 2021 (CD3)
- No support for wedges (12P)
- No longitudinal pushers (12P)

- No extra step, no repair
- No NC

Equipment Identifier: HCMCTXF001-X5000002
Other Identifier: MCTXF2
Description: Single Aperture (150 mm) Dodecapole (b6)

Main						Made of		Equipment data		Manufacturing		Operation		Documents		History		Map		
Actions : Add extra step																				
Workflow Diagram																				
No workflow diagram is defined for this equipment																				
Workflow Steps												Last Repeated								
Step #	R/E	Other name	Description	Status	Result	INC														
10		()	Mechanical Assembly	Done	Ok															
20		()	Electrical Test	Done	Ok															
30		()	Dimensional Check	Done	Ok															
40		()	Acceptance by LASA	Accepted	Ok															
50		()	Shipping to LASA	Done	Ok															
60		()	Cold Test	Done	Ok															
70		()	Magnetic Measurements	Done	Ok															
80		()	Acceptance by CERN for shipping	Accepted	Ok															
90		()	Shipping to CERN	Done	Ok															
100		()	Visual Inspection @CERN	Done	Ok															
110		()	Electrical test @CERN	Done	Ok															
120		()	Acceptance by CERN	Accepted	Ok															

NB: the magnet was firstly manufactured with low torque value, and reassembled directly in LASA before delivery (1 FAT only) – not in the NC

Magnet	NCs
MCTXF2	N/A

Fabrication at SRV (FAT v1)

- Central core length of 460.722 mm
→ **1 core lamination added**
- Torque on wedges: 0.31 Nm
“The wedges have been first tightned at 0.2Nm and blocked with epoxy. In order to increase the tightening torque they were then disassembled and replaced with new ones. Finally each wedge has been tightened to the new nominal torque defined by INFN (0.31Nm) and blocked with epoxy.”
- Final PCB box planarity of **0.47 mm**
- Residual gap between closing disc bottom plane and top surface of the Duratron screw's head : **1.13 mm** (≥ 0.2 mm)
- CMM max deviation: **0.013 mm** for slot 1; **0.012 mm** for slot 5 (acceptability 0.12 mm)
- Leak current @ 2000 V: 0.0184 μA (≤ 10 μA)

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [$\text{G}\Omega$]
250	254	0.0010	254.0
500	510	0.0025	203.0
1000	1022	0.0049	207.0
1250	1278	0.0059	215.0
1500	1538	0.0105	146.5
1750	1793	0.0155	115.6
2000	2049	0.0184	111.1

Acceptability criteria:

The leakage current at 2000V DC must be below 10 μA .

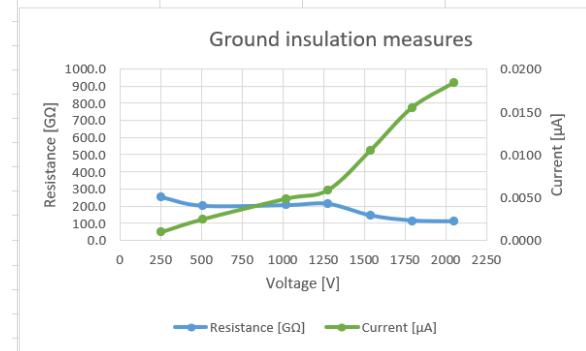
Remarks:

The measures have been taken after 30s from the reaching of the set voltage. Yellow values indicate out of scale or under range.

Resistance of the circuit:

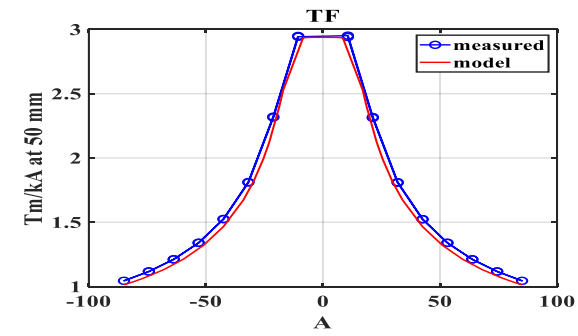
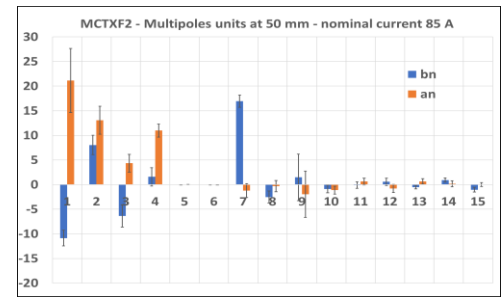
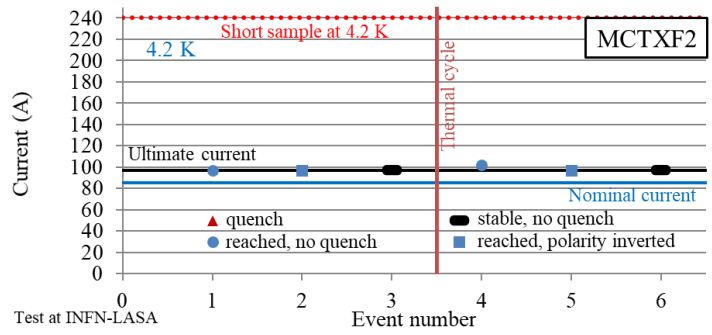
Measured with a multimeter [Ω]

646.7



Powering tests at LASA (MCTXF2)

- Powering test at LASA in Jan 2021 (CD3)
- Magnetic Measurements



CURRENT [A]	BdL [Tmm] Calc.	BdL [Tmm] Meas.	Δ[%]
85 A	86.1	88.8	3.2
97 A	92.9	95.8	3.2

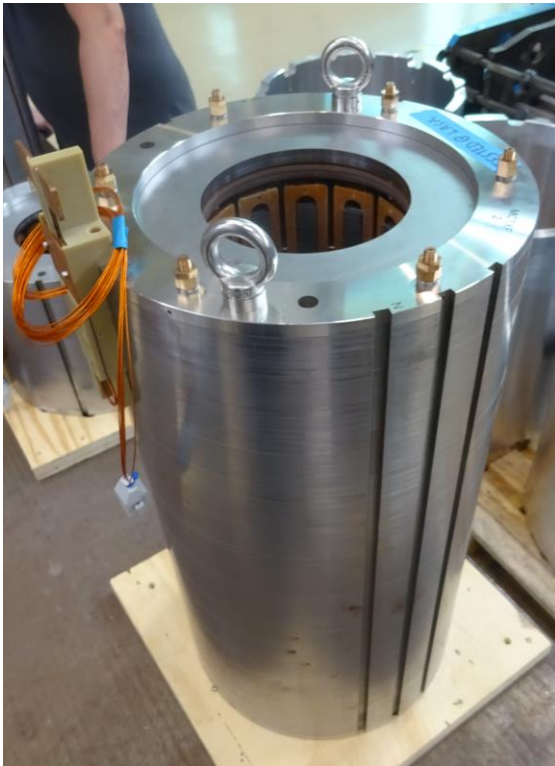


Reception at CERN

- Visual inspection at CERN:
 - Rust on some laminations
 - Resin delamination in one coil on the return side
 - 1 wire bent → accepted as agreed
 - All dimensions within tolerances (± 3 mm for the lengths; $+0.5/-0.0$ mm for the diameters)
 - N grooves aligned (jig 9.92 mm)
 - Aperture diameter ok (jig $\varnothing 149$)
- Dielectric insulation test at 150 V after powering test at cold : 66.1 G Ω



Reception at CERN



MCTSXF1

MQSXF2 | MCTXF2 | **MCTSXF1** | MCDXF01b | MCDXF02b | MCOXF03 | MCOXF04b | MCSXF01b | MCSXF02

Corrector Package #1	
MQSXF2	S
MCSXF01b	N
MCSXF02	S
MCOXF03	N
MCOXF04b	S
MCDXF01b	N
MCDXF02b	S
MCTXF2	N
MCTSXF1	S

Magnet story

<https://edms5.cern.ch/equipment/HCMCT SXF001-X5000001>

- Magnet firstly manufactured with low torque values
- Before first test, sent back to SRV for partial reassembly with increased torque values on wedges
- Powering test at LASA in Apr 2021 (CD5)
- No support for wedges (12P)
- No longitudinal pushers (12P)

Equipment Identifier: HCMCT SXF001-X5000001
Other Identifier: MCT SXF1
Description: Single Aperture (150 mm) Skew Dodecapole (a6)

Main						
Made of						
Equipment data						
Manufacturing						
Operation						
Non-conformities						
Documents						
History						
Map						
Actions : Add extra step						
Workflow Diagram						
No workflow diagram is defined for this equipment						
Workflow Steps						Last Repeated
Step ID	IR/E	Other name	Description	Status	Result	INC
10			Mechanical Assembly	Done	Ok	
20			Electrical Test	Done	Ok	
30			Dimensional Check	Done	Ok	
40			Acceptance by LASA	Accepted	Ok	
50			Shipping to LASA	Done	Ok	
52	E		Upgrade in SRV (*)	Done	Ok	
54	E		Shipping to LASA	Done	Ok	
60			Cold Test	Done	Ok	
70			Magnetic Measurements	Done	Ok	
80			Acceptance by CERN for shipping	Accepted	Ok	
90			Shipping to CERN	Done	Ok	
100			Visual Inspection @CERN (*)	Done	Ok	
110			Electrical test @CERN	Done	Ok	
120			Acceptance by CERN	Accepted	Ok	

Non-Conformities: 1

Magnet	NCs
MCTSXF1	<ul style="list-style-type: none">• Increase of the torque after wedge movement observed in MCOXF01 and MCTXF1 (2440962): increase torque before test, and test with upgraded torque directly.

Fabrication at SRV (FAT v1)

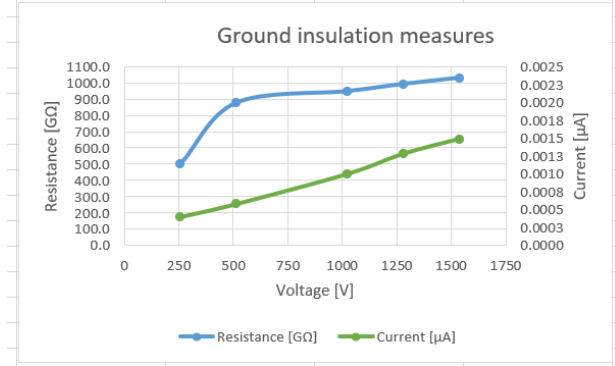
- Central core length of 80.865 mm
→ **nominal number of laminations**
- Final PCB box planarity of **0.4 mm**
- Residual gap between closing disc bottom plane and top surface of the Duratron screw's head : **1.4 mm** (≥ 0.2 mm)
- CMM max deviation: **0.017 mm** for slot 1; **0.020 mm** for slot 3 (acceptability 0.10 mm)
- Leak current @ **1500 V**: 0.00149 μ A (≤ 10 μ A)

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μ A]	Resistance [G Ω]
250	256	0.0004	500.0
500	510	0.0006	878.0
1000	1022	0.0010	951.0
1250	1278	0.0013	995.0
1500	1538	0.0015	1034.0

Acceptability criteria:
The leakage current at 1500V DC must be below 10 μ A.

Remarks:
The measures have been taken after 30s from the reaching of the set voltage. Yellow values indicate out of scale or under range.

Resistance of the circuit: 165.5
Measured with a multimeter [Ω]



Partial reassembly at SRV (FAT v2)

- Reassembly of the NCS only, to increase the torque during the wedge assembly
(0.35 → 0.49 Nm)
- The CS has not been reassembled
- CMM max deviation: **0.015 mm** for slot 1; **0.019 mm** for slot 3 (acceptability 0.10 mm)
- Leak current @ **1500 V**: 0.001 μA ($\leq 10 \mu\text{A}$)

Ground insulation test on the magnet assembly			
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [μA]	Resistance [$\text{G}\Omega$]
250	256	0.0003	>500
500	510	0.0004	>1000
1000	1021	0.0007	1430.0
1250	1277	0.0009	1431.0
1500	1537	0.0010	1511.0

Acceptability criteria:

The leakage current at 1500V DC must be below 10 μA .

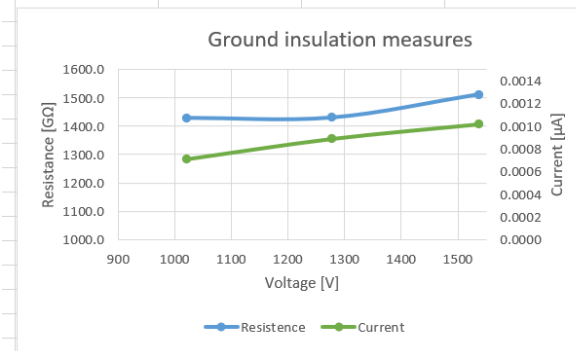
Remarks:

The measures have been taken after 30s from the reaching of the set voltage.
Yellow values indicate out of scale or under range.

Resistance of the circuit:

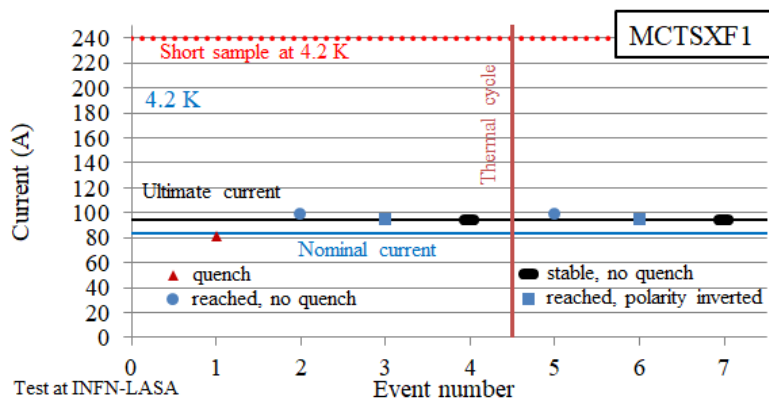
Measured with a multimeter [Ω]

163.9



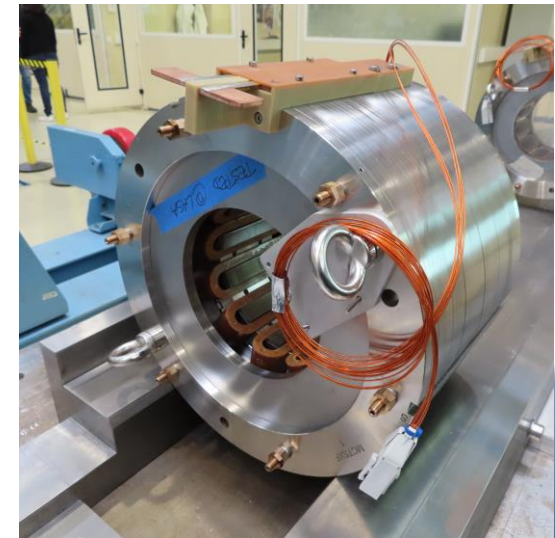
Powering tests at LASA (MCTSXF1)

- Powering test at LASA in Apr 2021 (CD5)
- No Magnetic Measurements

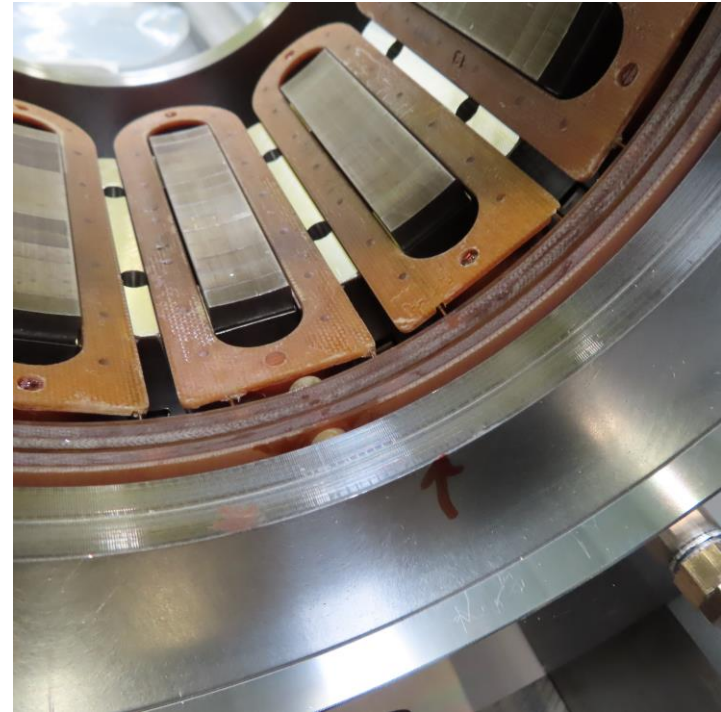
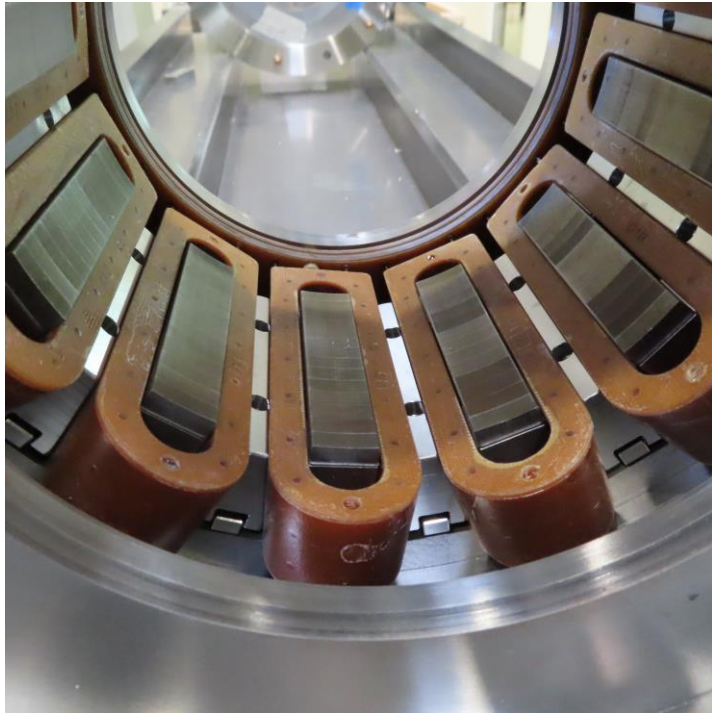


Reception at CERN

- Visual inspection at CERN:
 - Rust on some laminations
 - 1 wire bent → accepted as agreed
 - All lengths within tolerances (+/- 3 mm)
 - Diameters CS and NCS smaller by 0.1-0.2 mm (tol.+0.5/-0.0 mm) → accepted with smaller diameters since no problem for cold mass assembly
 - S grooves aligned (jig 9.92 mm)
 - Aperture diameter ok (jig \varnothing 149)
- Dielectric insulation test at 150 V after powering test at cold : 35.1 G Ω



Reception at CERN



Conclusions

Summary

- 8 Non-Conformities (1x criticality 4; 2x criticality 3 ; 5x criticality 2)
- 1 Deviation Permit Request affecting 2 magnets

- 7 magnets with NCs
- 11 coils with NCs

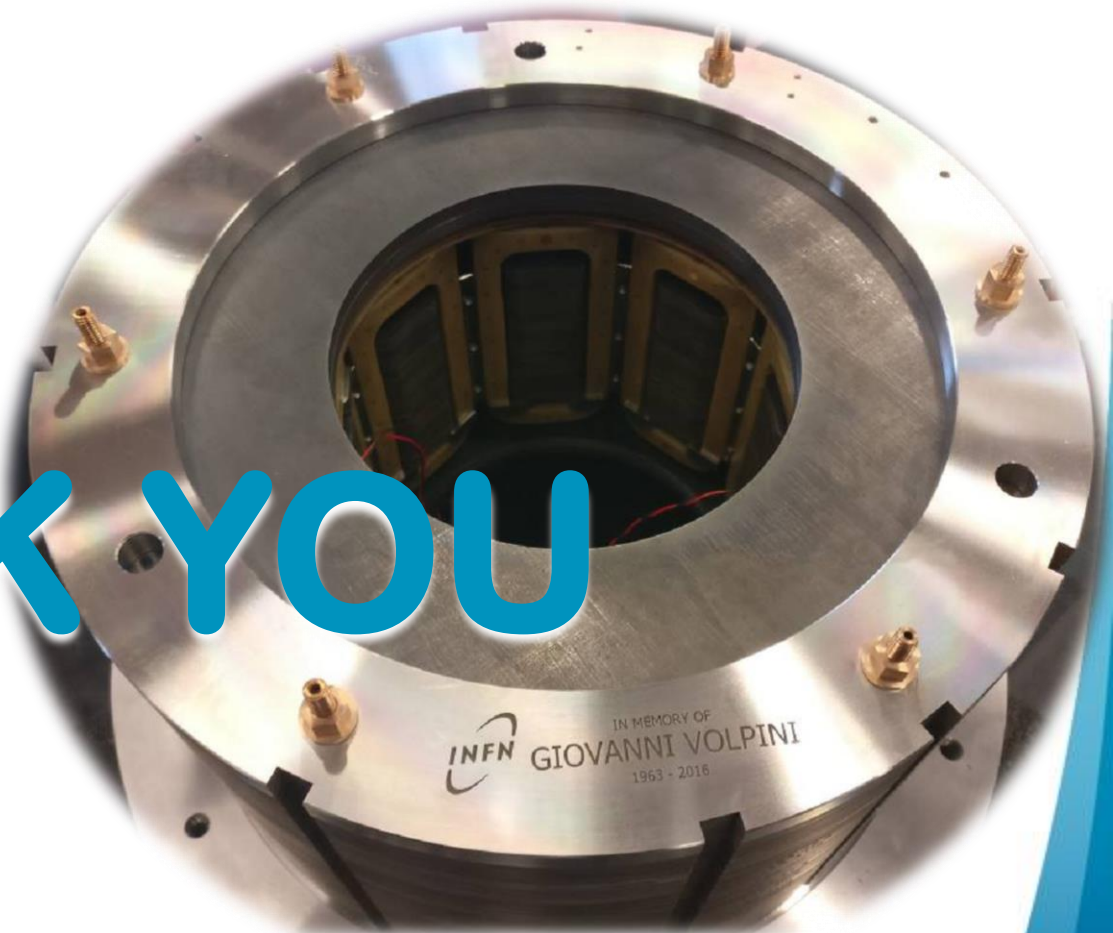
- All magnets performed well during powering tests at cold.
- All magnets were accepted by CERN.



THANK YOU

LASA team

F. Broggi, E. De Matteis, S. Mariotto,
A. Paccalini, A. Palmisano, A. Pasini,
D. Pedrini, A. Leone, M. Quadrio, M. Prioli,
M. Sorbi, M. Statera, M. Todero, C. Uva



Current status

- HO Correctors series production test ongoing
 - 54 HO Correctors produced by SAES Rial Vacuum
 - 37 magnets compliant
 - Quench protection crosscheck ongoing
- 30/54 magnets at CERN
- 2 magnets to be tested in SM18 in April

NC 2323155

NC 2323155	Criticality 4	Lower curing temperature						
MQSXF2	MCSXF01b	MCSXF02	MCOXF03	MCOXF04b	MCDXF01b	MCDXF02b	MCTXF2	MCTSXF1
04_008	06_007	06_001	08_013	08_025	10_005	10_014	12_024	13_002
04_009	06_009	06_006	08_018	08_026	10_006	10_017	12_025	13_003
04_010	06_012	06_008	08_034	08_027	10_007	10_018	12_026	13_005
04_012	06_017	06_011	08_046	08_028	10_009	10_020	12_028	13_006
	06_020	06_014	08_048	08_038	10_010	10_022	12_029	13_007
	06_024	06_021	08_049	08_039	10_011	10_023	12_030	13_011
			08_050	08_040	10_015	10_024	12_031	13_012
			08_051	08_047	10_016	10_026	12_032	13_013
					10_021	10_027	12_033	13_014
					10_025	10_028	12_034	13_016
							12_035	13_017
							12_036	13_018