

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

Emma Gautheron on behalf of Marco Statera and the LASA team INFN Milano - LASA



CERN – March 15th 2022

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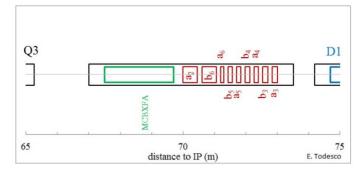
- Introduction
- Overview of the selected HOC magnets for CP1
- Main NCs affecting several magnets of CP1
- Review of each of the 9 magnets
 - Magnet story & NCs
 - Fabrication at SRV (FAT v1)
 - Powering tests at cold
- Conclusion



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 ☺







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HOC magnets for CP1



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HOC magnets for CP1

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

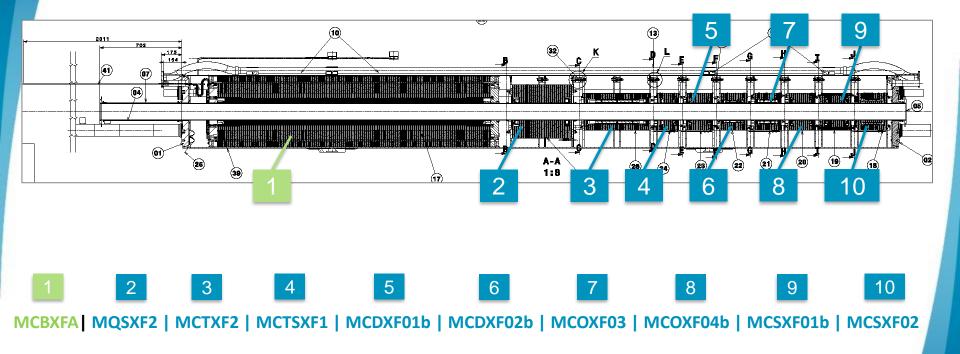
	Magnets	Location	Batch	CD	Delivery	Status
Ľ	MQSXF2	CERN 180	1b	4	2	accepted
	MQSXF3	CERN 180	2	6	2	accepted
Г	MCSXF01b	CERN 180	1a	CERN	1	accepted
L	MCSXF02	CERN 180	1a	4	2	accepted
	MCSXF03	CERN 180	1b	3	1	accepted
	MCSXF04	CERN 180	1b	CERN	1	NCR burr
	MCSXF05	CERN 180	2	5	2	accepted
_	MCSXF06	CERN 180	2	6	2	accepted
Г	MCOXF03	CERN 180	1b	3	2	accepted
L	MCOXF04b	CERN 180	1b	6	2	accepted
	MCOXF07	CERN 180	2	6	2	accepted
Г	MCDXF01b	CERN 180	1a	CERN	1	accepted
L	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.
Ľ	MCTXF2	CERN 180	1b	3	1	accepted
Ľ	MCTSXF1	CERN 180	1a	5	2	accepted
	MCTSXF2	CERN 180	1b	5	2	accepted

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



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HOC magnets for CP1





Main non-conformities

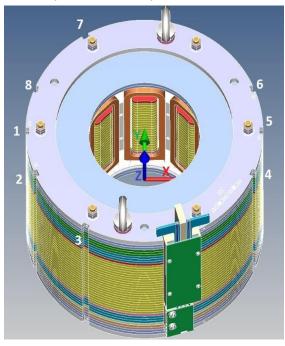
A bit of background history about the upgrades and changes of design affecting several magnets of CP1



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Reminder – PCB box

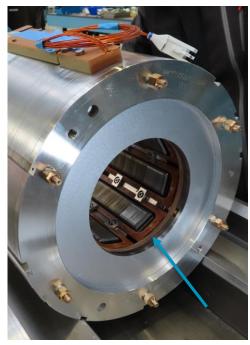
Example of an octupole:



PCB bottom/top:



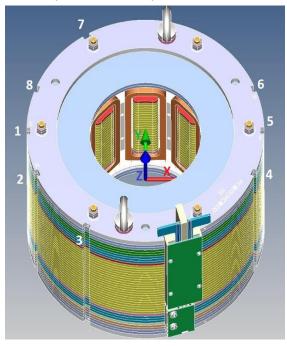
PCB final:





Reminder – Wedges & Supports

Example of an octupole:







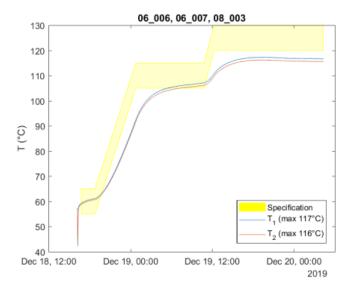
Lower curing temperature (37 coils)

- 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:

NC 2323155

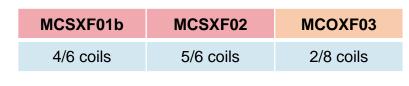
(criticality 4)

- 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 Tg 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

 \rightarrow 3 Magnets of CP1 affected (11 coils):





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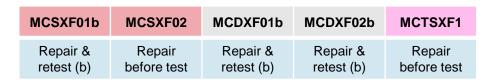
NC 2440962 NC 2619741 (criticality 3) Wedge mouvement in MCOXF1 and MCTXF1

- 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

 \rightarrow 5 Magnets of CP1 affected:



11

NC 2440962 NC 2619741 (criticality 3)

Wedge mouvement in MCOXF1 and MCTXF1

RT preload recalculated \rightarrow 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 1 range 0.20-0.50 Nm 2 range 0.50-2.00 Nm	Previous value [n. x 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 (<u>NC 2489174</u>), MCOXF04 (<u>NC 2515856</u>)

 \rightarrow From 0 to <u>2 supports</u> for wedges + 3 washers

 \rightarrow Applicable <u>for all octupoles</u>

- Supports not properly tightened after the test of MQSXF1 (<u>NC 2611005</u>)
 - \rightarrow From 4 to <u>2 supports</u> for wedges + 3 washers
 - \rightarrow (*) Applicable for MQSXF1, MQSXF3, MQSXF5
 - \rightarrow 2 Magnets of CP1 <u>affected</u> by DPR :

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



DPR

2559921

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Corrector Pack	age #1
MQSXF2	S
MCSXF01b	Ν
MCSXF02	S
MCOXF03	Ν
MCOXF04b	S
MCDXF01b	Ν
MCDXF02b	S
MCTXF2	Ν
MCTSXF1	S

MQSXF2

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



Magnet story

https://edms5.cern.ch/equipment/HCMQSXF001-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)
 - \rightarrow DPR 2559921 not applicable
- No extra step, no repair/upgradeNo NC

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orkflow S ⁱ tep 13 R <u>10</u> <u>20</u>	No t	-	•••		
tep L1 R <u>10</u> <u>20</u>	teps	-	•••		
tep L1 R <u>10</u> <u>20</u>		Description			
tep L1 R <u>10</u> <u>20</u>		Description			
10 20	/E Other name				
20	0	Mechanical Assembly	Status Done	Result Ok	NC
	0	Electrical Test	Done	Ok	
	0	Dimensional Check	Done	Ok	
<u>30</u> 40	0	Acceptance by LASA	Done	Ok	
<u>40</u> 50	0	Shipping to LASA	Done	Ok	
60	0	Cold Test	Done	Ok	
70	0	Magnetic Measurements	Done	Ok	
80	0	Acceptance by CERN for shipping	Accepted	Ok	
90	0	Shipping to CERN	Done	Ok	
100	0	Visual Inspection @CERN	Done	Ok	
110	0	Electrical test @CERN (*)	Done	Ok	
	0			Ok	

NB: the magnet was firstly manufactured with low	
orque 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)

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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 circolar 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 (≤ 10 μA)

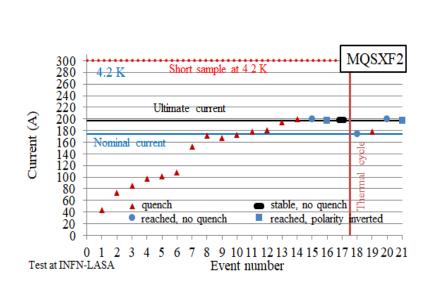
Set parameter		Measured values	
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ]
250	256	0.001	429
500	510	0.001	597
1000	1022	0.001	697
1250	1278	0.002	651
1500	1537	0.003	495
1750	1793	0.003	691
2000	2049	0.003	650
The leakage curre			
Remarks: The measures hav	ve been taken after 30 dicate out of scale or e circuit:	s from the reaching under range.	of the set voltage.
Remarks: The measures hav Yellow values inc Resistance of the	ve been taken after 30 licate out of scale or e circuit: multimeter [Ω]	s from the reaching under range.	02
Remarks: The measures hav Yellow values inc Resistance of the	ve been taken after 30 licate out of scale or e circuit: multimeter [Ω]	s from the reaching under range.	02
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Remarks: The measures hav Yellow values inc Resistance of the Measured with a	ve been taken after 30 licate out of scale or e circuit: multimeter [Ω]	s from the reaching under range.	02 Ires 0.0035 0.0030 0.0025 g
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Remarks: The measures hav Yellow values ind Resistance of the Measured with a 800	ve been taken after 30 licate out of scale or e circuit: multimeter [Ω]	s from the reaching under range.	02 Ires 0.0035 0.0030 0.0025 [4] 0.0025 [4] 0.0025 [4] 0.0025 [4] 0.0025 [4] 0.0025 [4] 0.0025 [4] 0.0035

istance [GO] ———Current [uA

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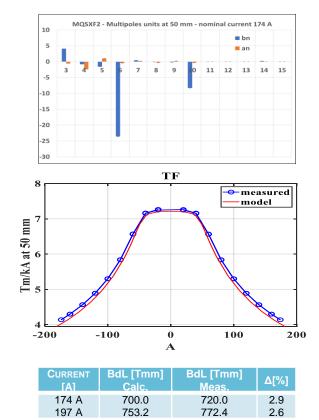


Powering tests at LASA (MQSXF2)



Powering test at LASA in Mar 2021 (CD4)

Magnetic Measurements

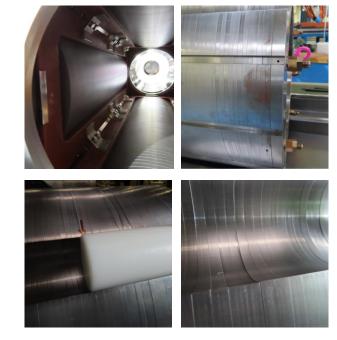


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Reception at CERN

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 Ø149)
- Line X half through holes ok (jig Ø61)
- Dielectric insulation test at 200 V after powering test at cold : 100 G Ω





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

MCSXF01b

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



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)

Other Id	dentifier:	MCSXF01b		
MCSXF	<i>tion.</i> Sing	le Aperture (150mm) Se	extupole (DS	·)
 Ρ	0	H 🔍 H	Q	TP .
	Equipment data	Manufacturing Operation Non-conformit	ties Documents Hi	istory Map
ions: Add extr				
orkflow Diagra				
	No	workflow diagram is defined for this	equipment	
orkflow Steps				Last Repe
	Other name	Description	Status	Result
10	. ()	Mechanical Assembly	Done	Ok
11 🕒	0	no conformity	Cancelled	Cancelled
20	0	Electrical Test	Done	Ok
20	() ()	Electrical Test Dimensional Check	Done Done	Ok Ok
20 30	Ő	Dimensional Check	Done	Ok
20 30 40	0 0	Dimensional Check Acceptance by LASA (*)	Done Done	Ok Ok
20 30 40 50 60 70	0 0 0	Dimensional Check Acceptance by LASA (*) Shipping to LASA Cold Test Magnetic Measurements	Done Done Done	Ok Ok Ok Ok Ok
20 30 40 50 60 70	0 0 0 0 0 0	Dimensional Check Acceptance by LASA (*) Shipping to LASA Cold Test Magnetic Measurements Upgrade in SRV (*)	Done Done Done Done	Ok Ok Ok Ok Ok Ok
20 30 40 50 60 70 72 72 74	0 0 0 0 0 0 0	Dimensional Check Acceptance by LASA (*) Shipping to LASA Cold Test Magnetic Measurements Upgrade in SRV (*) Shipping to LASA	Done Done Done Done Done Done Done	Ok Ok Ok Ok Ok Ok Ok
20 30 40 50 60 70 72 74 80	0 0 0 0 0 0 0 0	Dimensional Check Acceptance by LASA (*) Shipping to LASA Cold Test Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping	Done Done Done Done Done Done Done Accepted	Ok Ok Ok Ok Ok Ok Ok Ok
20 30 40 50 60 70 72 6 74 8 80 90		Dimensional Check Acceptance by LASA (*) Shipping to LASA Cold Test Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping Shipping to CERN	Done Done Done Done Done Done Accepted Done	Ok Ok Ok Ok Ok Ok Ok Ok
20 30 40 50 60 70 72 6 74 80 90 92 6		Dimensional Check Acceptance by LASA (*) Shipping to LASA Cold Test Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping Shipping to CERN Cold Test	Done Done Done Done Done Done Accepted Done Done	Ok Ok Ok Ok Ok Ok Ok Ok Ok Ok
20 30 40 50 60 72 72 80 90 92 94 94		Dimensional Check Acceptance by LASA (*) Shipping to LASA Cold Test Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping Shipping to CERN Cold Test Magnetic Measurements	Done Done Done Done Done Done Accepted Done	Ok Ok Ok Ok Ok Ok Ok Ok Ok Ok
20 30 40 50 60 70 72 6 74 80 90 92 6		Dimensional Check Acceptance by LASA (*) Shipping to LASA Cold Test Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping Shipping to CERN Cold Test Magnetic Measurements Visual Inspection @CERN	Done Done Done Done Done Done Accepted Done Done	Ok Ok Ok Ok Ok Ok Ok Ok Ok Ok Ok Ok
20 30 40 50 60 72 72 80 90 92 94 9 9 9 9 9 9 9 9 9 9 9 9 9		Dimensional Check Acceptance by LASA (*) Shipping to LASA Cold Test Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping Shipping to CERN Cold Test Magnetic Measurements	Done Done Done Done Done Done Accepted Done Done Done Done	Ok Ok Ok Ok Ok Ok Ok Ok Ok Ok



15.03.2022

Non-Conformities: 5

Magnet	NCs
MCSXF01b	 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 µA

Set paramete	er	Measured values	
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ]
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 of The leakage cu	riteria: rrent at 1500V DC mus	t be below 10 µA.	
Remarks:			
Yellow values Resistance of t	ave been taken after 30 indicate out of scale or he circuit: a multimeter [Ω]	under range.	2.1
Yellow values Resistance of t	indicate out of scale or he circuit: a multimeter [Ω]	under range.	2.1
Yellow values : Resistance of t Measured with	indicate out of scale or he circuit: a multimeter [Ω]	under range.	2.1
Yellow values Resistance of t	indicate out of scale or he circuit: a multimeter [Ω]	under range.	2.1



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

 \rightarrow gap reduction from 0.7 to 0.2 mm.

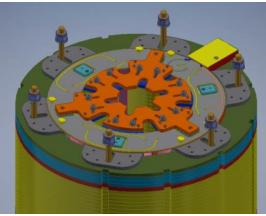
Preventive actions:

NC 2419512

(criticality 3)

- **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

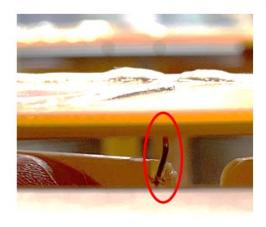


Figure 2-back view coil ID 06_07

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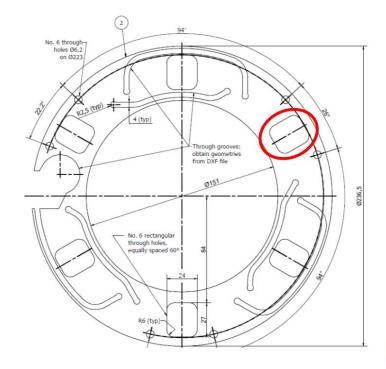
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Larger rectangular hole in PCB box

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

No functional impact \rightarrow use as is.

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

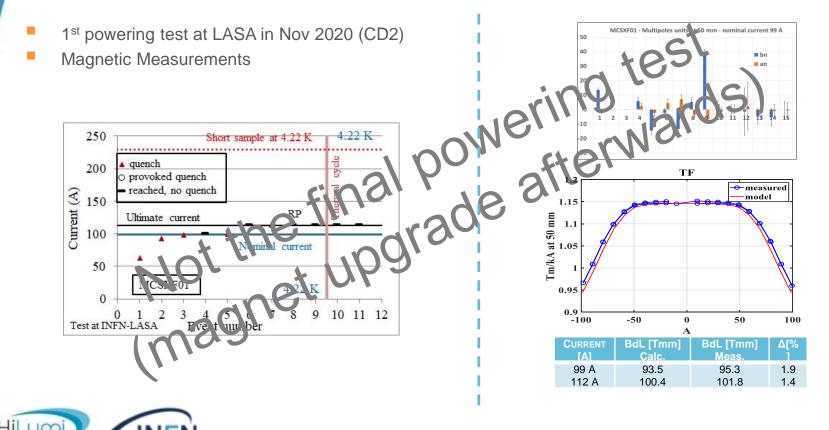




NC 2419524

(criticality 2)

1st powering test at LASA (MCSXF01)



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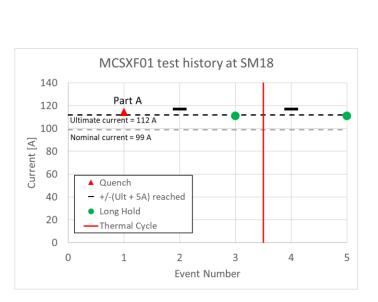
Partial reassembly at SRV (FAT v2)

- 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 (≤ 10 μA)

Grou	nd insulation test	on the magnet ass	embly	
Set parameter		Measured values		
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ]	
100	101	0.0002	>100	
Acceptability crite	eria: t at 1500V DC mus	t be below 10 μA.		
Remarks:				
Yellow values indic	ate out of scale or	is from the reaching under range. The ma nas already undergo	aximum voltage has	
	circuit:	10	1 0	
Resistance of the	Measured with a multimeter [Ω]		101.9	

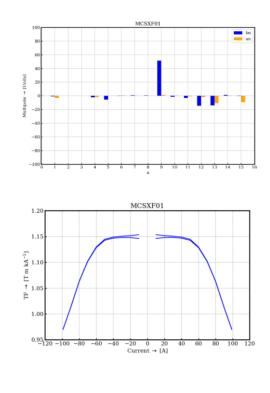


2nd powering test at CERN (MCSXF01b)



Magnetic Measurements

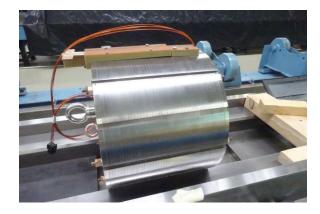
2nd powering test at CERN in Apr-May 2021

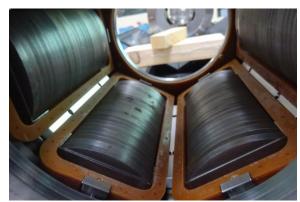




Reception at CERN

- 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 Ø149)
- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω







E. Gautheron | HOC magnets for Corrector Package #1

Corrector Pack	age #1
MQSXF2	S
MCSXF01b	Ν
MCSXF02	S
MCOXF03	Ν
MCOXF04b	S
MCDXF01b	Ν
MCDXF02b	S
MCTXF2	Ν
MCTSXF1	S

MCSXF02

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)

Description: Single Aperture (150mm) Sextupole (b3) MCSXF Manufacturing Operation Non-conformities Documents History Map ns: Add extra step Add extra step Non-conformities Documents History Map kflow Diagram No workflow diagram is defined for this equipment Istatus IResult 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 51 () Cold Test Done Ok 60 () Cold Test Done Ok 70 () Acceptance Vy CERN for shipping Accepted Ok 80 () Acceptance by CERN for shipping Accepted Ok 90 () Shipping to CERN Done Ok 90 () Visual Inspection @CERN Done	Ōŧ	her I	dentifier:				
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Kflow Diagram No workflow diagram is defined for this equipment kflow Steps Last R IP II [R/E [Other name IDescription IStatus Result 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 51 () Upgrade in SRV (*) Done Ok 54 () 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	n Ma	ide of 🔨	Equipment data	Manufacturing Operation Non-conformities	Documents Hist	ory Map	
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Last R kflow Steps Last R pt3 IR/E IOther name IDescription IStatus IResult 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 () Upgrade in SRV (*) Done Ok 54 () Shipping to LASA Done Ok 54 () Shipping to LASA Done Ok 50 () 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	kflow	Diagr					
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100 0) Acceptance by LASA Done Ok 50 0) Shipping to LASA Done Ok 52 0) 0) Upgrade in SRV (*) Done Ok 54 0) 0 Shipping to LASA Done Ok 54 0) 0 Shipping to LASA Done Ok 60 0) Cold Test Done Ok 70 0 Magnetic Measurements Done Ok 80 0) Acceptance by CERN for shipping Accepted Ok 90 0) Shipping to CERN Done Ok 100 0) Visual Inspection @CERN Done Ok	ep 🖬 👘		Other name			Result	
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52 6 0 Upgrade in SRV (*) Done Ok 54 6 () 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	pt: <u>10</u> <u>20</u>		Other name () ()	Mechanical Assembly Electrical Test	Done Done	 Result Ok Ok	
52 6 () Upgrade in SRV (*) Done Ok 54 () 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	pti <u>10</u> <u>20</u> <u>30</u>		Other name () () ()	Mechanical Assembly Electrical Test Dimensional Check	Done Done Done	Result Ok Ok Ok	Repe
54 C) 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	pti <u>10</u> <u>20</u> <u>30</u> <u>40</u>		Other name () () ()	Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA	Done Done Done Done	Result Ok Ok Ok 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	10 10 20 30 40 50	R/E	Other name () () () () () ()	Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA	Done Done Done Done Done	Result Ok Ok Ok Ok Ok	
80 () Acceptance by CERN for shipping Accepted Ok 90 () Shipping to CERN Done Ok 100 () Visual Inspection @CERN Done Ok	pti 10 20 30 40 50 52	R/E	Other name () () () () () () () ()	Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*)	Done Done Done Done Done Done	Result Ok Ok Ok Ok Ok Ok	
OD O Dependence Dependence Dependence 90 () Shipping to CERN Done Ok 100 () Visual Inspection @CERN Done Ok	10 20 30 40 50 52 54	R/E	Other name () () () () () () () () ()	Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*) Shipping to LASA	Done Done Done Done Done Done Done	IResult Ok Ok Ok Ok Ok Ok Ok	
100 () Visual Inspection @CERN Done Ok	10 20 30 40 50 52 54 60	R/E	Other name () () () () () () () () () ()	Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*) Shipping to LASA Cold Test	Done Done Done Done Done Done Done Done	Result Ok Ok Ok Ok Ok Ok Ok Ok	
100 () Visual Inspection @CERN Done Ok	10 20 30 40 50 52 54 60 70	R/E	Other name 0 0 0 0 0 0 0 0 0 0 0 0 0	Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*) Shipping to LASA Cold Test Magnetic Measurements	Done Done Done Done Done Done Done Done	Result Ok Ok Ok Ok Ok Ok Ok Ok	
	10 20 30 40 50 52 54 60 70 80	R/E	Other name 0 0 0 0 0 0 0 0 0 0 0 0 0	Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*) Shipping to LASA Cold Test Magnetic Measurements Acceptance by CERN for shipping	Done Done Done Done Done Done Done Done	Result Ok Ok Ok Ok Ok Ok Ok Ok Ok	
110 () Electrical test @CERN Done Ok	10 20 30 40 50 52 54 60 70 80 90	R/E	Other name 0 0 0 0 0 0 0 0 0 0 0 0 0	Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*) Shipping to LASA Cold Test Magnetic Measurements Acceptance by CERN for shipping Shipping to CERN	Done Done Done Done Done Done Done Done	Result Ok Ok Ok Ok Ok Ok Ok Ok Ok Ok	



Non-Conformities: 4

Magnet	NCs
MCSXF02	 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.



10

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 (≤ 10 µA)

010	und insulation test o	-	mbly
Set parameter		Measured values	
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ]
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 crit	eria:		
The leakage curren	t at 1500V DC must	be below 10 µA.	
Remarks:			
Resistance of the Measured with a n		10	2.0
1300.0 1200.0 (1100.0 (1100.0 0 0 0 0 0 0 0 0 0 0 0 0 0	Ground in	sulation measu	0.0025 0.0023 0.0020 0.0018 <

15.03.2022

E. Gautheron | HOC magnets for Corrector Package #1

NC 2316887 (criticality 2)

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





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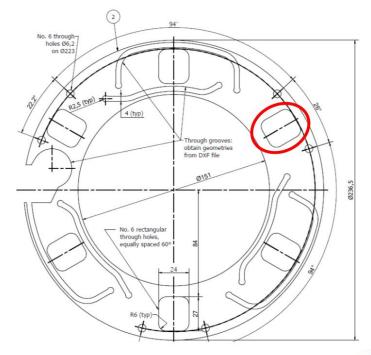
10

Larger rectangular hole in PCB box

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

No functional impact \rightarrow use as is.

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





NC 2419524

(criticality 2)

10

Partial reassembly at SRV (FAT v2)

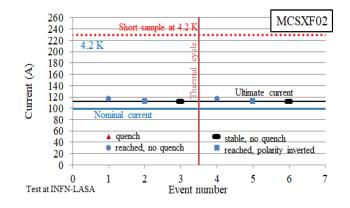
- Reassembly of the NCS only to increase the torque during the wedge assembly
 (0.2 → 0.44 Nm)
- CMM max deviation: 0.017 mm for slot 1; 0.018 mm for slot 5; 0.016 mm for slot 2; 0.017 mm for slot 6 (acceptability 0.10 mm)
- Leak current @ 1500 V : 0.00088 μA

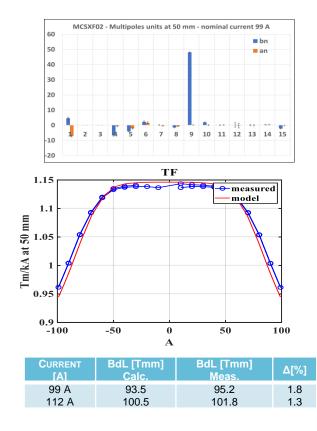
Gro	und insulation test o	-	mbly
Set parameter		Measured values	
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ]
250	254	0.0003	500
500	510	0.0004	1000
1000	1022	0.0006	1684
1250	1278	0.0008	1661
1500	1538	0.0009	1740
Acceptability crit	eria:		
The leakage curren	t at 1500V DC must	be below 10 µA.	
Remarks:			
Measured with a m		LU sulation measu	1.9
			100
2000			0.0025
			0.0025
			0.0025
			0.0025
			0.0025
ل ع ع			0.0025 0.0020 0.0015
U 1500 U 1000 U 500			0.0025 0.0020 0.0015 UT 0.0010 0.0010 0.0005
G 1500 av 1000 tsis 500 0 0	250 500 750	1000 1250 1500	0.0025 0.0020 0.0015 0.0010 0.0000 0.0000
G 1500 ev 1000 tsis 500 0 0	250 500 750 Voltag		0.0025 0.0020 0.0015 0.0010 0.0000 0.0000
G 1500 ev 1000 tsis 500 0 0			0.0025 0.0020 0.0015 0.0010 0.0000 0.0000



Powering test at LASA (MCSXF02)

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





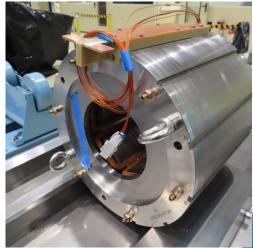


10

Reception at CERN

- Visual inspection at CERN:
 - Rust on some laminations
 - 4 wires slightly bent \rightarrow 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 Ø149)
- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω







E. Gautheron | HOC magnets for Corrector Package #1

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

MCOXF03

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



Magnet story

- 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





Non-Conformities: 2

Magnet	NCs
MCOXF03	 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
 - ightarrow 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 (≤ 10 µA)

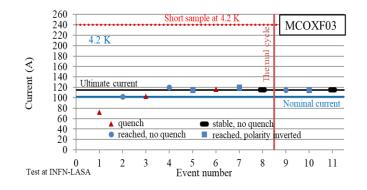
Set parameter		Measured values	
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ]
250	256	0.0003	500.0
500	510	0.0006	795.0
1000	1021	0.0011	969.0
1250	1277	0.0012	1040.0
1500	1537	0.0015	1044.0
Acceptability crit	eria: nt at 1500V DC mus	t he helow 10 µA	
Remarks:	in at 1500 V DC inu:	πος σειόν το μΑ.	
Yellow values ind Resistance of the	icate out of scale or circuit:		of the set voltage
Yellow values ind	icate out of scale or circuit:	under range.	
Yellow values ind Resistance of the	icate out of scale or circuit: nultimeter [Ω]	under range.	4.8
Yellow values ind Resistance of the	icate out of scale or circuit: nultimeter [Ω]	under range.	4.8
Yellow values ind Resistance of the Measured with a 1 1100.0 1000.0	icate out of scale or circuit: nultimeter [Ω]	under range.	4.8
Yellow values ind Resistance of the Measured with a r 1100.0 900.0	icate out of scale or circuit: nultimeter [Ω]	under range.	4.8 res
Yellow values ind Resistance of the Measured with a r 1100.0 900.0	icate out of scale or circuit: nultimeter [Ω]	under range.	4.8 res 0.0018 0.0015 0.0013 3
Yellow values ind Resistance of the Measured with a r 1100.0 900.0	icate out of scale or circuit: nultimeter [Ω]	under range.	4.8 res 0.0018 0.0015 0.0013 3
Yellow values ind Resistance of the Measured with a 1 1100.0 1000.0 900.0 0 800.0 0 800.0 0 800.0 0 800.0 0 1000.0 100	icate out of scale or circuit: nultimeter [Ω]	under range.	4.8 res 0.0018 0.0018 0.0013 0.0013 0.0010
Yellow values ind Resistance of the Measured with a 1 1100.0 1000.0 900.0 G 800.0 0 700.0 900.0 900.0 9	icate out of scale or circuit: nultimeter [Ω]	under range.	res 0.0018 0.0015 0.0013 0.0013 0.0010 0.0008 E
Yellow values ind Resistance of the Measured with a 1 1100.0 1000.0 900.0 0 800.0 0 800.0 0 800.0 0 800.0 0 1000.0 100	icate out of scale or circuit: nultimeter [Ω]	under range.	res 0.0018 0.0015 0.0015 0.0013 0.0010 0.0008 0.0008 0.0008
Yellow values ind Resistance of the Measured with a 1 1100.0 1000.0 900.0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 9	icate out of scale or circuit: multimeter [Ω] Ground in 250 500 750	under range.	4.8 res 0.0018 0.0013 0.0013 0.0013 0.0013 0.0003 0.0000 0.0003 0.0003 0.0003 0.0003 0.0003 0.0003 0.0003

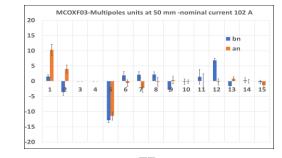


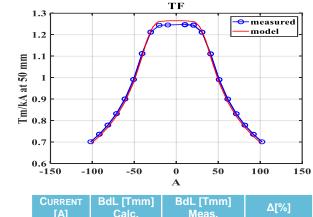
Powering test at LASA (MCOXF03)

Powering test at LASA in Jan 2021 (CD3)

Magnetic Measurements







CURRENT	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)
 - \rightarrow Repair directly done in LASA
 - \rightarrow No retest required
- **2 Additional supports per wedge are installed** (intermediate solution; no need of reassembly)

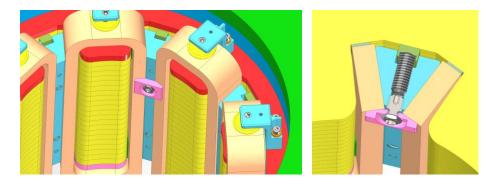




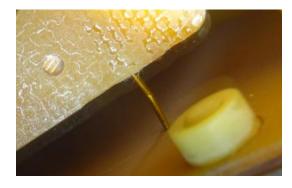
Figure 1 Inner views of HCMCOXF001-X5000003. The displaced wedge is highlighted.

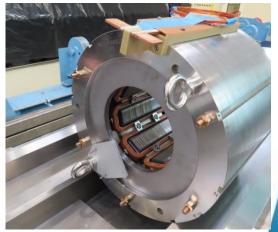




Reception at CERN

- Visual inspection at CERN:
 - Rust on some laminations
 - 1 wires slightly bent \rightarrow 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 Ø149)
- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω







E. Gautheron | HOC magnets for Corrector Package #1

Corrector Pack	age #1
MQSXF2	S
MCSXF01b	Ν
MCSXF02	S
MCOXF03	Ν
MCOXF04b	S
MCDXF01b	N
MCDXF02b	S
MCTXF2	Ν
MCTSXF1	S

MCOXF04b

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



Magnet story

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

Equipment Identifier: HCMCOXF001-X5000004 (†) Other Identifier: MCOXF04b Description: Single Aperture (150 mm) Octupole (b4) MCOXF Main Made of KEquipment data Manufacturing Operation Non-conformities Documents History Map Actions : Add extra step Workflow Diagram Workflow Steps Last Repeate Step 🖬 IR/E |Other name Description Status Result INC 10 Mechanical Assembly Done Ok 20 Done Ok Electrical Test Ok 30 0 **Dimensional Check** Done Ok 40 update Done Acceptance by LASA <u>50</u> 52 Done 0k 0 Shipping to LASA Pendina 0 Upgrade in SRV (*) 54 0 Shipping to LASA Pendina 60 Cold Test Done Ok 70 72 Magnetic Measure Ok Done Pending Upgrade 74 76 78 80 Cancelled ē Pending ignetic Measurements Pending Accepted Ok Acceptance by CERN for shipping 90 Ok Done Shipping to CERN Ok 100 Done Visual Inspection @CERN Done Ok 110 Electrical test @CERN Ok 120 Accepted Acceptance by CERN



- 1st powering test at LASA in Mar 2021 (CD4)
 - ightarrow movement of wedges observed
- 2 wedge supports added directly in LASA (intermediate design)
- 2nd powering test at LASA in Jun 2021 (CD6)

HILUMI INFN

Non-Conformities: 1

Magnet	NCs
MCOXF04b	 Wedge movement observed after thermal cycle (2515856) : repair with 2 additional supports and retest (test b)



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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

 \rightarrow not critical thanks to the hollow closing lamination

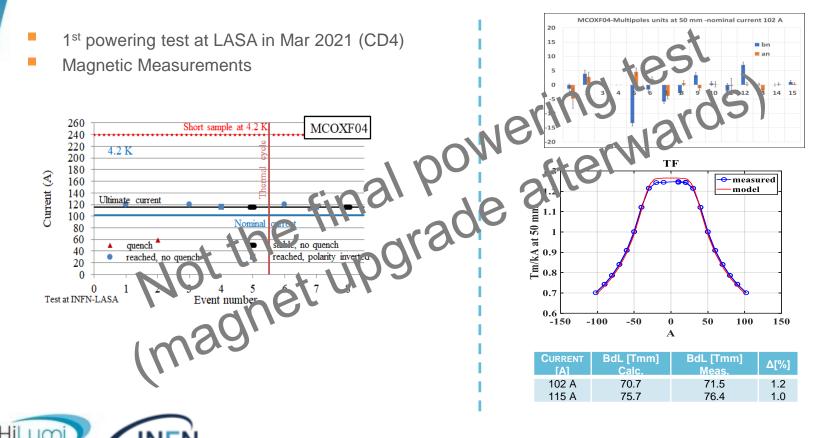
- CMM max deviation: 0.017 mm for slot 1; 0.018 mm for slot 5; 0.016 mm for slot 2; 0.016 mm for slot 6 (acceptability 0.10 mm)
- Leak current @ 1500 V: 0.002 µA (≤ 10 µA)

Grou	ind insulation test of	on the magnet asse	mbly
Set parameter		Measured values	
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ]
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 crite	ria:		
The leakage current	at 1500V DC must	be below 10 µA.	
Remarks:			
Yellow values indic		nder ränge.	
Resistance of the c	ircuit:	1/	26
	ultimeter [Ω]		3.6
1000 900 900 900	ultimeter [Ω]	14 sulation measu	

15.03.2022

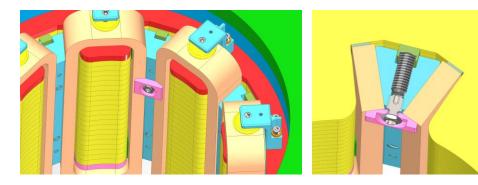
E. Gautheron | HOC magnets for Corrector Package #1

1st powering tests at LASA (MCOXF04)



Wedge supports added in LASA

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



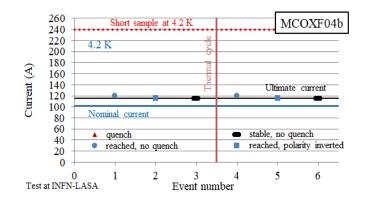


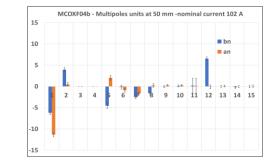


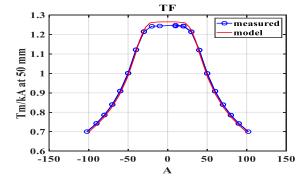
E. Gautheron | HOC magnets for Corrector Package #1

2nd powering tests at LASA (MCOXF04b)

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







CURRENT	BdL [Tmm]	BdL [Tmm]	Δ[%]
[A]	Calc.	Meas.	
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 Ø149)
- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω





Corrector Package #1			
S			
Ν			
S			
Ν			
S			
Ν			
S			
Ν			
S			

MCDXF01b

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



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)

The states	Other I	dentifier:	<i>fier:</i> HCMCDXF001-X50 MCDXF01b e Aperture (150 mm) E		ft
	0				
Main	Made of	Equipment data	Manufacturing Operation Non-conformi	ties Documents Hist	ory Map
ctions	: Add ext	ra step			
Vork	flow Diagr	am			
	, and the second s		orkflow diagram is defined for this	equipment	
			5		
Vork	flow Steps				Last Repea
Step I		Other name	Description	Status	Result N
	0	0	Mechanical Assembly	Done	Ok
	0	0	Electrical Test	Done	Ok
	0	0	Dimensional Check	Done	Ok
	0	0	Acceptance by LASA	Accepted	Ok Ok
		0	Shipping to LASA	Done	Ok Ok
5					
6	0	0	Cold Test		
<u>6</u> 7	0	0	Magnetic Measurements	Done	Ok
6 7 7	0 2 2 2 3 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3	0	Magnetic Measurements Upgrade in SRV (*)	Done Done	Ok Ok
6 7 7 7	0 2 2 4 3 3 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3	0 0 0	Magnetic Measurements Upgrade in SRV (*) Shipping to LASA	Done Done Done	Ok Ok Ok
6 7 7 7 8	0 20 22 34 30	0 0 0 0	Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping	Done Done Done Accepted	Ok Ok Ok Ok
6 7 7 7 8 9	0 70 72 74 74 80 90	0 0 0 0 0	Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping Shipping to CERN	Done Done Done Done Accepted Done	Ok Ok Ok Ok Ok
6 7 7 8 9 9	0 2 3 4 30 10 10 10 10 11 12 12	0 0 0 0 0 0	Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping Shipping to CERN Cold Test	Done Done Done Accepted Done Done	Ok Ok Ok Ok Ok Ok
6 7 7 8 9 9	0 12 12 12 13 14 15 14 15	0 0 0 0 0 0 0	Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping Shipping to CERN Cold Test Magnetic Measurements	Done Done Done Accepted Done Done Done	Ok Ok Ok Ok Ok Ok Ok
6 7 7 7 8 9 9 9 9	0 2 30 4 50 4 50 4 50 4 50 4 50 50		Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping Shipping to CERN Cold Test Magnetic Measurements Visual Inspection @CERN	Done Done Done Accepted Done Done Done Done	Ok Ok Ok Ok Ok Ok Ok Ok
6 7 7 8 9 9 9 10	0 12 12 12 13 14 15 14 15	0 0 0 0 0 0 0	Magnetic Measurements Upgrade in SRV (*) Shipping to LASA Acceptance by CERN for shipping Shipping to CERN Cold Test Magnetic Measurements	Done Done Done Accepted Done Done Done	Ok Ok Ok Ok Ok Ok Ok



Non-Conformities: 1

Magnet	NCs
MCDXF01b	 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

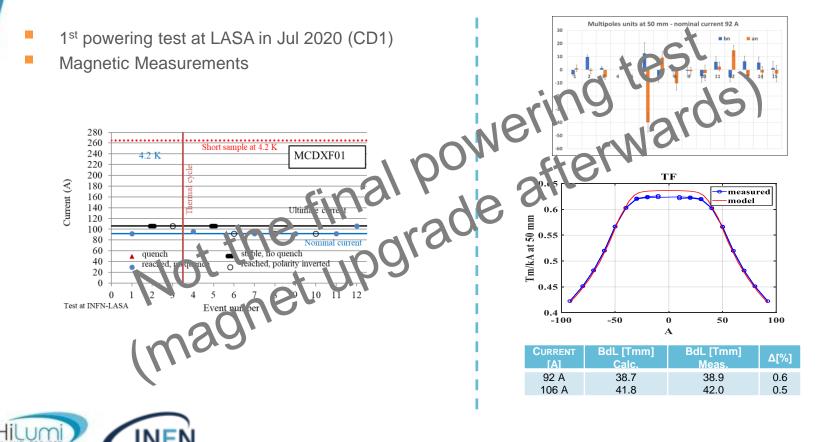
CMM max deviation: 0.018 mm for slot 1; 0.016 mm for slot 5; 0.026 mm for slot 2; 0.020 mm for slot 6 (acceptability 0.10 mm)

Leak current @ 1500 V: 0.0020 µA (≤ 10 µA)

Set parameter		Measured values	
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GC
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 crite	eria:		
The leakage current	at 1500V DC must	t be below 10 μA.	
Remarks:			
Measured with a mu	altimeter [Ω]	10	3.6
1000.0	Ground ir	sulation measu	0.0025 0.0023



1st powering tests at LASA (MCDXF01)



E. Gautheron | HOC magnets for Corrector Package #1

Partial reassembly at SRV (FAT v2)

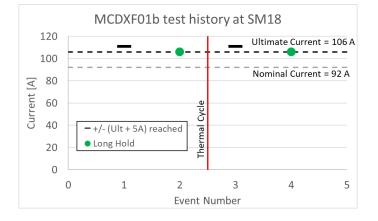
- Reassembly of the NCS only, to increase the torque during the wedge assembly
 (0.2 → 0.35 Nm)
- The CS has not been reassembled
- CMM max deviation: 0.018 mm for slot 1; 0.016 mm for slot 5; 0.012 mm for slot 2; 0.016 mm for slot 6 (acceptability 0.10 mm)
- Leak current @ 100 V (magnet already tested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

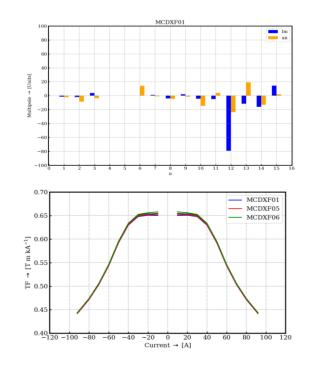
Grour	nd insulation test	on the magnet ass	embly
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ]
100	101	0.0002	>100
Acceptability crite			
The leakage current	at 1500V DC must	t be below 10 μA.	
Remarks:			
The measures have Yellow values indica been set to 100V be	ate out of scale or a	under range. The ma	aximum voltage has
Resistance of the	circuit:	10	2 E
Measured with a multimeter $[\Omega]$		103.5	



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 Ø149)
- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω





Reception at CERN







E. Gautheron | HOC magnets for Corrector Package #1 15.03.2022

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

MCDXF02b

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



Magnet story

- 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 Operation Non-conformities Documents History Map Made of KEquipment data Manufacturing Actions : Add extra step Workflow Diagram Workflow Steps Last Repeate Step LI IR/E |Other name Description Status Result INC 10 0 Mechanical Assembly Done Ok Ok 20 Electrical Test Done 30 Dimensional Check Done Ok upda 40 Accepte Ok Acceptance by LASA (*) Ok **50** Shipping to LASA Done Cold Test Ok <u>60</u> Done Ok <u>62</u> Upgrade in SRV (*) 🏷 Done ŏ <u>64</u> Done Ok 66 Cold test 🦰 Done Ok 70 Cancelled Measurements 80 Accepted Ok CERN for shipping Done Ok 90 ipping to CERN <u>92</u> Done Ok a Cold Test 94 Magnetic Measurements Pending 100 Done Ok Visual Inspection @CERN Done Ok 110 Electrical test @CERN (*) 120 Accepted Ok Acceptance by CERN



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

Non-Conformities: 1

Magnet	NCs
MCDXF02b	 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)

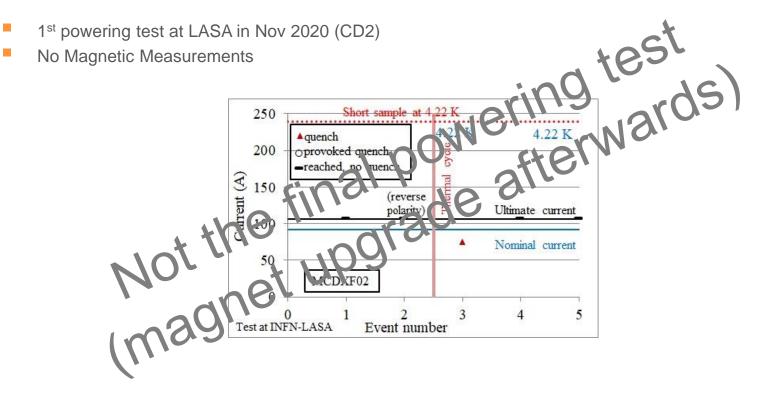
Leak current @ 1500 V: 0.0015 µA (≤ 10 µA)

	ind insulation test of	on the magnet asse	mbiy
Set parameter		Measured values	
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ
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 crite	ria:		
The leakage current	at 1500V DC must	be below 10 µA.	
Remarks:			
Resistance of the c	ircuit:	10	
Resistance of the c Measured with a mu		10	3.5
Measured with a m 1100.0 1000.0 900.0 00.0	ultimeter [Ω]	10. sulation measu	res 0.0025 0.0023 0.0013 0.0015 0.0015 0.0015 0.0015 0.0015 0.0003 0.0000 0.0000 0.0000



E. Gautheron | HOC magnets for Corrector Package #1

1st powering tests at LASA (MCDXF02)



E. Gautheron | HOC magnets for Corrector Package #1 15.03.2022

Partial reassembly at SRV (FAT v2)

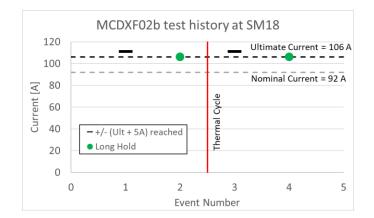
- Reassembly of the NCS only, to increase the torque during the wedge assembly
 (0.2 → 0.35 Nm)
- The CS has not been reassembled
- CMM max deviation: 0.016 mm for slot 1; 0.020 mm for slot 5; 0.017 mm for slot 2; 0.019 mm for slot 6 (acceptability 0.10 mm)
- Leak current @ 100 V (magnet already tested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

Grou	nd insulation test	on the magnet asse	embly
Set parameter	Measured values		
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ]
100	101	0.0001	>100
Acceptability crite	ria:		
The leakage current	at 1500V DC mus	t be below 10 µA.	
Remarks:			
The measures have Yellow values indica The maximum volta already undergone t	ate out of scale or u ge has been limited	inder range. I to 100V because t	C
Resistance of the c	ircuit:	10	2.2
Measured with a multimeter $[\Omega]$		103.3	



2nd powering tests at CERN (MCDXF02b)

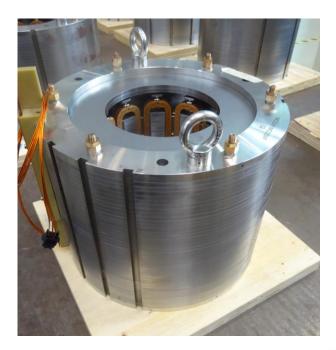
- 2nd powering test at CERN in Apr-May 2021
- Magnetic Measurements but the data were corrupted due to a malfunction of the shaft motor.





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 Ø149)
- Dielectric insulation test at 150 V after powering test at cold : 100 G Ω





Reception at CERN





E. Gautheron | HOC magnets for Corrector Package #1 15.03.2022

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

MCTXF2

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



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

History 🗙 Map

- 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

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

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

Made of KEquipment data Manufacturing Operation Operation

Actions : Add extra step

Workflow Diagram

Workflow	V Step	5			Last R	epeated
Step 🖬	R/E	Other name	Description	Status	Result	NC
10		0	Mechanical Assembly	Done	Ok	
20		0	Electrical Test	Done	Ok	
30		0	Dimensional Check	Done	Ok	
40		0	Acceptance by LASA	Accepted	Ok	
50		0	Shipping to LASA	Done	Ok	
60		0	Cold Test	Done	Ok	
70		0	Magnetic Measurements	Done	Ok	
80		0	Acceptance by CERN for shipping	Accepted	Ok	
90		0	Shipping to CERN	Done	Ok	
100		0	Visual Inspection @CERN	Done	Ok	
110		0	Electrical test @CERN	Done	Ok	
120		0	Acceptance by CERN	Accepted	Ok	

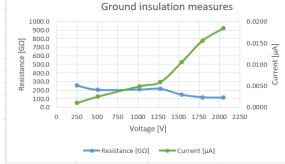
Fabrication at SRV (FAT v1)

- 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)

Grou	nd insulation test	on the magnet asse	embly	
Set parameter		Measured values		
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ]	
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 crit	eria:			
The leakage curren	t at 2000V DC mus	t be below 10 μA.		
Remarks:				
	been taken after 30 ate out of scale or 1	s from the reaching under range.	of the set voltage.	
Resistance of the	circuit:	64	6.7	
Measured with a m	ultimeter [Ω]	04	0.7	



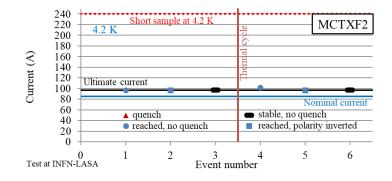
15 03 2022

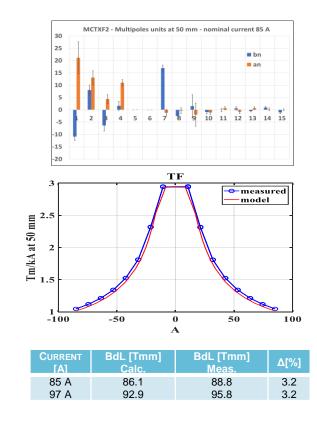
E. Gautheron | HOC magnets for Corrector Package #1

Powering tests at LASA (MCTXF2)

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

Magnetic Measurements







- Visual inspection at CERN:
 - Rust on some laminations
 - Resin delamination in one coil on the return side
 - 1 wire bent \rightarrow 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 Ø149)
- Dielectric insulation test at 150 V after powering test at cold : 66.1 G Ω

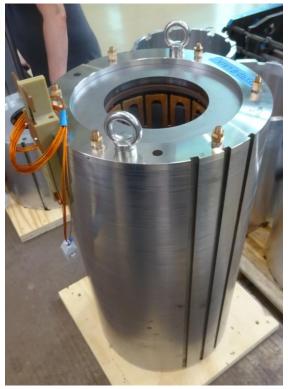






E. Gautheron | HOC magnets for Corrector Package #1

15.03.2022









E. Gautheron | HOC magnets for Corrector Package #1

15.03.2022

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

MCTSXF1

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



https://edms5.cern.ch/equipment/HCMCTSXF001-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)

Other Id	lentifier:	i fier: HCMCTSXF001-X500 MCTSXF1 le Aperture (150 mm) Sk		f) oole	
(a6)			~		_ ا
fain Made of	Equipment data	Manufacturing Operation Non-conformitie	s Documents Hist		
tions: Add extr		Manufacturing Coperation & Non-Comornide	s a Documents a Hist	согу у мар	
	<u> </u>				
orkflow Diagra					
	No v	workflow diagram is defined for this eq	luipment		
orkflow Steps	No v	workflow diagram is defined for this eq	luipment	l ast l	Reneate
	No v	Norkflow diagram is defined for this eq	luipment	Last I	Repeate INC
		5			
Step 🖬 🛛 🛛 🛛 🖓 🗛	Other name	Description	Status	Result	
<u>10</u> <u>20</u>	Other name	Description Mechanical Assembly	Status Done	 Result Ok	
Step L1 R/E 10	Other name () ()	IDescription Mechanical Assembly Electrical Test	 Status Done Done	 Result Ok Ok	
Step L1 R/E 10	Other name () () ()	IDescription Mechanical Assembly Electrical Test Dimensional Check	 Status Done Done Done	Result Ok Ok Ok	
Step L1 R/E 10	0ther name () () () () ()	IDescription Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA	Status Done Done Done Accepted	Result Ok Ok Ok Ok	
Step L3 R/E 10 20 30 40 50 52	Other name 0 0 0 0 0	IDescription Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA	Istatus Done Done Done Accepted Done	Result Ok Ok Ok Ok Ok	
Step L3 R/E 10 20 30 40 50 52 54 6	Other name 0 0 0 0 0 0	IDescription Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*)	Status Done Done Accepted Done Done	Result Ok Ok Ok Ok Ok Ok	
Step L3 R/E 10 20 30 40 50 52 54 60	0ther name 0 0 0 0 0 0 0	IDescription Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*) Shipping to LASA	IStatus Done Done Done Accepted Done Done Done	Result Ok Ok Ok Ok Ok Ok Ok	
itep 11 R/E 10 20 30 40 50 52 54 60 70 70	0ther name 0 0 0 0 0 0 0 0 0	IDescription Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*) Shipping to LASA Cold Test	Status Done Done Accepted Done Done Done Done	Result Ok Ok Ok Ok Ok Ok Ok	
itep t1 R/É 10 20 30 40 50 52 54 60 70 80	Other name 0 0 0 0 0 0 0 0 0 0	IDescription Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*) Shipping to LASA Cold Test Magnetic Measurements	IStatus Done Done Accepted Done Done Done Done Done Done	Result	
itep L1 R/F 10 20 30 40 50 52 6 54 6 70 80 90 90	Other name 0 0 0 0 0 0 0 0 0 0 0 0 0	IDescription Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*) Shipping to LASA Cold Test Magnetic Measurements Acceptance by CERN for shipping Shipping to CERN	IStatus Done Done Done Accepted Done Done Done Done Done Done Done Done	Result	
itep t1 R/É 10 20 30 40 50 52 54 60 70 80	Other name 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	IDescription Mechanical Assembly Electrical Test Dimensional Check Acceptance by LASA Shipping to LASA Upgrade in SRV (*) Shipping to LASA Cold Test Magnetic Measurements Acceptance by CERN for shipping	JStatus Done Done Accepted Done Done Done Done Done Accepted Done	Result Ok Ok Ok Ok Ok Ok Ok Ok Ok Ok	



Non-Conformities: 1

Magnet	NCs
MCTSXF1	• 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 µA (≤ 10 µA)

Set parameter		Measured values			
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GQ]		
250	256	0.0004	500.0		
500	510	0.0006	878.0		
1000	00 1022 0.0010		951.0		
1250	1278	0.0013 995.			
1500	1538	1538 0.0015			
Acceptability crit	teria:				
The leakage curren	nt at 1500V DC must	be below 10 μA.			
Remarks:					
	Ground in	sulation measu	res		
1100.0 1000.0 0.0000 0.00000 0.0000 0.0000			0.0025 0.0023 0.0020 0.0018 0.0015 0.0013 0.0013		



Partial reassembly at SRV (FAT v2)

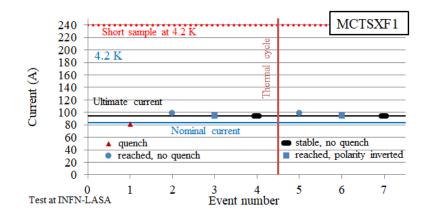
- Reassembly of the NCS only, to increase the torque during the wedge assembly (0.35 → 0.49 Nm)
- The CS has not been reassembled
- CMM max deviation: 0.015 mm for slot 1; 0.019 mm for slot 3 (acceptability 0.10 mm)
- Leak current @ **1500 V**: 0.001 μA (≤ 10 μA)

Gro	und insulation test	on the magnet ass	embly
Set parameter		Measured values	i
Voltage [V]	Voltage [V]	Current [µA]	Resistance [GΩ]
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 cri	teria:		
The leakage curre	nt at 1500V DC mus	t be below 10 µA.	
Remarks:			
Measured with a r	nultimeter [Ω]	16	3.9
Measured with a 1	nultimeter [Ω]	16	3.9
Measured with a r		16	
1600.0			0.0014
1600.0			0.0014 0.0012
1600.0 <u>5</u> 1500.0 <u>1400.0</u>			0.0014 0.0012 0.0010 <u>§</u>
1600.0 <u>5</u> 1500.0 <u>1400.0</u>			0.0014 0.0012
1600.0 <u>5</u> 1500.0 <u>1400.0</u>			0.0014 0.0012 0.0010 <u>4</u> 0.0008 <u>4</u>
1600.0 1500.0 1400.0 1400.0 1300.0			0.0014 0.0012 0.0010 0.0008 0.0006
1600.0 G 1500.0 G 1400.0 ²⁰ 1300.0 ²⁰ 1300.0 ²⁰ 1300.0 ²⁰ 1000.0 ²⁰ 1000.0	Ground ir	isulation measu	0.0014 0.0012 0.0010 0.0008 0.0004 0.0004 0.0004 0.0002 0.0000
1600.0 1500.0 CC 1400.0 0 1400.0 1300.0 1300.0 1300.0 1300.0 1100.0	Ground ir	D 1300 1400	0.0014 0.0012 0.0010 [v] 0.0008 0.0004 0.0004 0.0004
1600.0 G 1500.0 G 1400.0 ²⁰ 1300.0 ²¹ 1200.0 1100.0 1000.0	Ground ir	isulation measu	0.0014 0.0012 0.0010 0.0008 0.0004 0.0004 0.0004 0.0002 0.0000
1600.0 G 1500.0 G 1400.0 ²⁰ 1300.0 ²¹ 1200.0 1100.0 1000.0	Ground ir Ground ir	D 1300 1400	0.0014 0.0012 0.0010 0.0008 0.0004 0.0004 0.0004 0.0002 0.0000



Powering tests at LASA (MCTSXF1)

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





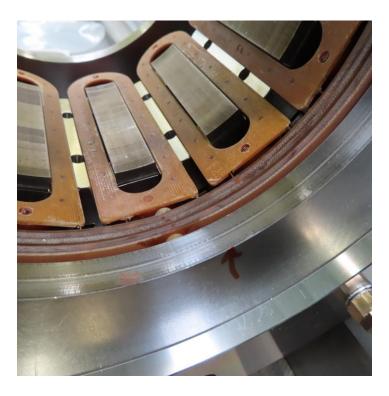
- Visual inspection at CERN:
 - Rust on some laminations
 - 1 wire bent → accepted as agreed
 - All lengths within tolerances (+/- 3 mm)
 - Diameters CS and NCS smaller by 0.1-0.2 mm (tol.+0.5/-0.0 mm) → accepted with smaller diameters since no problem for cold mass assembly
 - S grooves aligned (jig 9.92 mm)
 - Aperture diameter ok (jig Ø149)
- Dielectric insulation test at 150 V after powering test at cold : 35.1 G Ω













E. Gautheron | HOC magnets for Corrector Package #1 15.

15.03.2022

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

LASA

INFN

LASA team

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E. Gautheron | HOC magnets for Corrector Package #1

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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

