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ANNEX D: Available Documents of Quality Assurance Plan (QAP) for the LHC Project

Please refers to the attached CD-ROM (CERNDOCS Version 2.0): “CERN Official Documents: quality assurance, safety, purchasing, etc…”

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G1: *LHC-MMS/98-198/G01*
Technical Specification for the Supply of Copper Wedges for the Cold Masses of the LHC Superconducting Dipole Magnets.
G2: *LHC-ICP/01-242/FRM*
Technical Specification for the Supply of Quench Heaters for the series LHC Superconducting Main Dipole Magnets. (NOT YET AVAILABLE)
G3: *LHC-MMS/98-198/G03*
Technical Specification for the Supply of Austenitic Steel Strips for the Collars for the Cold Masses of the LHC Superconducting Dipole Magnets.
G4: *LHC-MMS/98-198/G04*
Technical Specification for the Supply of Fine-Blanked Austenitic Steel Collars for the cold masses of the LHC Superconducting Dipole Magnets.
G5: *LHC-MMS/98-198/G05*
Technical Specification for the Supply of Cold Bore Tubes for the LHC Main Dipole and Quadrupole Superconducting Magnets.
G6: *LHC-MMS/98-198/G06*
Technical Specification for the Supply of Fine-Blanked Austenitic Steel Yoke Laminations for the Cold Masses of the LHC Superconducting Dipole Magnets.
G7: *LHC-MMS/98-198/G07*
Technical Specification for the Supply of Fine-Blanked Low-Carbon Steel Yoke Laminations for the Cold Masses of the LHC Superconducting Dipole Magnets.
G8: *LHC-MMS/98-198/G08*
Technical Specification for the Supply of Austenitic Stainless Steel Shells for the Cold Masses of the LHC Superconducting Dipole Magnets.
G9: *LHC-MMS/98-198/G09*
Technical Specification for the Supply of Austenitic Steel End Covers for the Cold Masses of the LHC Superconducting Dipole Magnets.
G10: *LHC-MMS/98-198/G10*
Technical Specification for the Supply of Oxygen-Free Copper Helium Heat Exchanger Tubes for the LHC Main Dipole and Quadrupole Magnets. (NOT YET AVAILABLE)
G11: *LHC-CRI/BS/cl/*
Technical Specification for the Supply of LHC Bellows Expansion Joints.
G12: *LHC-MMS/98-198/G12*
Technical Specification for the Supply of Austenitic Steel Strips for the non-magnetic Laminations of the Cold Masses of the LHC Superconducting Dipole Magnets.
G13: *LHC-MMS/98-198/G13*
Technical Specification for the Supply of Coil Inter-Layers for the Cold Masses of the LHC Superconducting Dipole Magnets.

G14:	*LHC-MMS/99-202* *Technical Specification for the Supply of Polyimide Film for the Cable and Ground Insulation of the LHC Superconducting Magnets.*
G15:	*LHC-MMS/98-180* *Technical Specification for the Supply of Three Hydraulic Presses for Assembling and Welding the LHC Superconducting Dipole Magnets.*
G16:	*LHC-MMS/98-184* *Technical Specification for the Supply of Pole Measuring Machines for the LHC Superconducting Dipole Magnets.*
G17:	*LHC-MMS/99-199* *Technical Specification for the Supply of Portable 3-D Measuring Systems allowing the on-site Dimensional Inspection of the Cold Masses of the LHC Dipole Magnets.*
G18:	*LHC-MMS/99-209* *Technical Specification for the Supply of End Spacers sets of the LHC Dipole Magnets.*
G19:	*LHC-MMS/2001-229* *Technical Specification for the Supply of Helium filling pieces for the Cold Masses of the LHC Dipole Magnets. (NOT YET AVAILABLE)*

ANNEX A: TENDER DRAWINGS

1. AVAILABILITY OF TENDER (AND MANUFACTURING) DRAWINGS

As mentioned in Section 4.2.4, all the tender drawing will be available in "HPGL" format.

This shall also apply to the manufacturing drawings and their revisions.

The native CAD files (AutoCAD™ or Euclid 3™) of all the drawings produced by CERN are made available in order to limit the cost of the preparation of the Manufacturing Drawings by the Contractor.

The "HPGL" format is the only valid format as regards contractual aspects.

2. APPROVAL, REGISTERING AND STORING OF THE CONTRACTOR'S MANUFACTURING DRAWINGS

The approval procedure for the Contractor's Manufacturing Drawings is fully described in the LHC QAP Document: LHC-PM-QA-609 rev.1.0 "Storing of Contractor Drawings in EDMS/CDD" attached to this Technical Specification (please refer to the Drawings CD-ROM).

In addition to the procedure described, CERN requires that the following drawing codes are used and indicated in the double drawings identification. At the position seven (the position marked with "X"), the Contractor will write a specific letter (that will be communicated at the Contract signature) that will identifying the different Contractor. The four (digit) position marked "xxxx" shall be the number of the reference original drawing released by CERN following the nomenclature as explained in the next section.

3. CERN NOMENCLATURE FOR THE TENDER AND MANUFACTURING DRAWINGS

3.1. Active Part:

1.	Common Drawings for Dipole Type A and B:	LHCMB_XAxxxx
2.	Specific Drawings for Dipole Type A	LHCMBAXAxxxx
3.	Specific Drawings for Dipole Type B	LHCMBBXAxxxx

3.2. He Vessel:

1.	Common Drawings for Dipole Type A and B:	LHCMB_XSxxxx
2.	Specific Drawings for Dipole Type A	LHCMBAXSxxxx
3.	Specific Drawings for Dipole Type B	LHCMBBXSxxxx

3.3. Electrical Connections:

1.	Common Drawings for Dipole Type A and B:	LHCMB_XExxxx
2.	Specific Drawings for Dipole Type A	LHCMBAXExxxx
3.	Specific Drawings for Dipole Type B	LHCMBBXExxxx

3.4. Busbar Assemblies (these drawings are not supposed to be re-produced as Contractor Manufacturing Drawings)

1.	Dipole Busbars Drawings for Dipole Type A and B:	LHCDCBHAxxxx
2.	Quadrupole Busbar Drawings for Dipole Type A	LHCDCQHAxxxx
3.	Auxiliary Busbar Drawings for Dipole Type B	LHCDCCHAxxxx

4. ORGANIZATION CHART FOR THE LHC DIPOLE TENDER AND MANUFACTURING DRAWINGS

4.1. General assembly drawings

The General Assembly Drawings for the 4 types of delivered cold mass are the following:

- LHCMBA_S0001 “General Assembly cold mass TYPE A – Standard Test configuration”
- LHCMBA_S0007 “General Assembly cold mass TYPE A – Full Test configuration”
- LHCMBB_S0001 “General Assembly cold mass TYPE B – Standard Test configuration”
- LHCMBB_S0007 “General Assembly cold mass TYPE B – Full Test configuration”

4.2. Flow chart of the drawing nomenclature and numbering

The flow chart for a “TYPE A - Full Test Configuration” cold mass is shown in the file named: “flowchart.xls” annexed to the Drawings CD-ROM.

5. LIST OF TENDER DRAWINGS

Number	Revision	Subject	CAD Tool	Format	English Title	Creation Date	First Designer	Controlled by	Released by	Arch. State
LHCMB__A0001	AF	Act Part	AUTOCAD	A0	ACTIVE PART SECTIONS TYPE A & B - COLLARED COILS ASSEMBLY	1999-07-21	R.REY	M.GENET	D.PERINI	Archived
LHCMB__A0002	..	Act Part	AUTOCAD	A0	ACTIVE PART SECTIONS TYPE A & B - CONDUCTOR DISTRIBUTION	1999-07-09	P.MARTINS	R.REY	D.PERINI	Archived
LHCMB__A0003	AE	Act Part	AUTOCAD	A0	ACTIVE PART SECTIONS TYPE A AND B - LEFT HALF YOKE ASSEMBLY	2000-02-01	J.FORESTIER	M.GENET	D.PERINI	Archived
LHCMB__A0004	..	Act Part	AUTOCAD	A0	ACTIVE PART SECTIONS TYPA A AND B - RIGHT HALF YOKE	2001-03-14	P.MARTINS	M.GENET	D.PERINI	Archived
LHCMB__A0009	..	Act Part	EUCLID	A2	REFERENCE SYSTEME - FOR THE APERTURES	1999-08-05	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0010	AC	Act Part	AUTOCAD	A0	COLLARED COILS ASSEMBLY - COIL ASSEMBLY	1999-07-21	R.REY	M.GENET	D.PERINI	Archived
LHCMB__A0011	AB	Act Part	AUTOCAD	A0	COIL ASSEMBLY - COIL INNER LAYER	1999-07-21	R.REY	M.GENET	D.PERINI	Archived
LHCMB__A0012	AC	Act Part	AUTOCAD	A0	COIL ASSEMBLY - COIL OUTER LAYER	1999-07-21	R.REY	M.GENET	D.PERINI	Archived
LHCMB__A0013	AA	Act Part	AUTOCAD	A2	COIL ASSEMBLY - LAYER JUMP SPACER & BOX ASSEMBLY	1999-07-09	P.MARTINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0014	AA	Act Part	AUTOCAD	A1	COIL ASSEMBLY - INTER-LAYER SPACERS ASSEMBLY	1999-07-09	P.MARTINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0015	AA	Act Part	AUTOCAD	A1	COLLARED COILS ASSEMBLY - AUSTENITIC STANDARD COLLAR PACK	1999-08-03	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0016	AA	Act Part	AUTOCAD	A1	COLLARED COILS ASSEMBLY - AUSTENITIC ENDS COLLAR PACK	1999-08-03	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0017	AA	Act Part	AUTOCAD	A1	COLLARED COILS ASSEMBLY - AUSTENITIC LAYER JUMP COLLAR PACK	1999-08-03	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0020	AB	Act Part	AUTOCAD	A0	COLLARED COILS ASSEMBLY - GROUND INSULATION FOR COIL HEADS	1999-07-15	J.FORESTIER	R.REY	D.PERINI	Archived
LHCMB__A0021	AA	Act Part	AUTOCAD	A0	COLLARED COILS ASSEMBLY - GROUND INSULATION STRAIGHT PART	1999-08-06	P.MARTINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0022	AB	Act Part	AUTOCAD	A0	COLLARED COILS ASSEMBLY - GROUND INSULATION LAYER JUMP UP	1999-08-03	P.MARTINS	R.REY	D.PERINI	Archived
LHCMB__A0023	AB	Act Part	AUTOCAD	A0	COLLARED COILS ASSEMBLY - GROUND INSULATION LAYER JUMP DOWN	1999-08-05	P.MARTINS	R.REY	D.PERINI	Archived
LHCMB__A0024	AA	Act Part	AUTOCAD	A1	COLLARED COILS ASSEMBLY - GROUND INSULATION FOR COIL TERMINALS	1999-07-21	R.REY	P.MARTINS	D.PERINI	Archived
LHCMB__A0025	..	Act Part	AUTOCAD	A0	COLLARED COILS ASSEMBLY - QUENCH HEATER TYPE 1	2000-04-14	O.CRETTIEZ	P.MARTINS	D.PERINI	Archived
LHCMB__A0026	..	Act Part	AUTOCAD	A0	COLLARED COILS ASSEMBLY - QUENCH HEATER TYPE 2	2000-04-14	O.CRETTIEZ	P.MARTINS	D.PERINI	Archived
LHCMB__A0028	AA	Act Part	AUTOCAD	A0	COIL ASSEMBLY - ENDS INNER LAYER	1999-07-21	R.REY	P.MARTINS	D.PERINI	Archived
LHCMB__A0029	AB	Act Part	AUTOCAD	A0	COIL ASSEMBLY - ENDS OUTER LAYER	1999-07-21	R.REY	R.REY	D.PERINI	Archived
LHCMB__A0030	AB	Act Part	AUTOCAD	A1	HALF YOKE ASSEMBLY - LAMINATION STANDARD PACK	1999-07-28	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0031	AD	Act Part	AUTOCAD	A1	HALF YOKE ASSEMBLY - COMPENSATION LAMINATION PACK	1999-07-28	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0032	AC	Act Part	AUTOCAD	A0	HALF YOKE ASSEMBLY - CS & NCS LAMINATION PACK	1999-11-25	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0033	AA	Act Part	AUTOCAD	A1	HALF YOKE ASSEMBLY - TEMPERATURE SENSOR LAMINATION PACK	2000-01-11	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0034	AC	Act Part	AUTOCAD	A3	ACTIVE PART SECTIONS TYPE A & B - INSERT STANDARD PACK	1999-06-11	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0035	AC	Act Part	AUTOCAD	A2	ACTIVE PART SECTIONS TYPE A & B - COMPENSATION INSERT PACK	1999-06-11	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0036	AE	Act Part	AUTOCAD	A2	ACTIVE PART SECTIONS TYPE A & B - AUSTENITIC INSERT PACK	1999-06-11	S.DESCOINS	P.MARTINS	D.PERINI	Archived

LHCMB__A0037	AE	Act Part	EUCLID	A0	ACTIVE PART SECTIONS - END PLATE CONNECTION SIDE	1999-08-02	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0038	AD	Act Part	EUCLID	A0	ACTIVE PART SECTIONS - END PLATE LYRES SIDE	1999-08-02	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0039	..	Act Part	AUTOCAD	A3	ACTIVE PART LONGITUD. SECTIONS - BOLT	1999-08-05	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0040	..	Act Part	AUTOCAD	A4	ACTIVE PART LONGITUD. SECTIONS - BOLT SUPPORT	1999-08-04	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0041	AA	Act Part	AUTOCAD	A2	COLLARED COILS ASSEMBLY - COLLARED COIL END PLATE NCS	1999-10-01	S.DESCOINS	M.GENET	D.PERINI	Archived
LHCMB__A0042	AC	Act Part	AUTOCAD	A2	COLLARED COILS ASSEMBLY - COLLARED COIL END PLATE CS	1999-07-29	S.DESCOINS	M.GENET	D.PERINI	Archived
LHCMB__A0043	AC	Act Part	AUTOCAD	A3	COLLARED COILS ASSEMBLY - INSULATED HALF RING	1999-10-01	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0044	AC	Act Part	AUTOCAD	A4	COLLARED COILS ASSEMBLY - CENTRAL LOCKING ROD	1999-11-11	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0045	AC	Act Part	AUTOCAD	A4	COLLARED COILS ASSEMBLY - LATERAL LOCKING ROD	1999-11-11	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0046	AA	Act Part	AUTOCAD	A3	COIL INNER LAYER - CONDUCTOR INNER LAYER	1999-07-15	P.MARTINS	R.REY	D.PERINI	Archived
LHCMB__A0047	AA	Act Part	AUTOCAD	A3	COIL OUTER LAYER - CONDUCTOR OUTER LAYER	1999-07-15	P.MARTINS	R.REY	D.PERINI	Archived
LHCMB__A0048	..	Act Part	AUTOCAD	A4	COIL INNER LAYER - LAYER JUMP CABLE STABILIZATION	1999-08-06	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0049	..	Act Part	AUTOCAD	A4	COIL INNER LAYER - CABLE STABILIZATION	1999-08-11	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0050	..	Act Part	AUTOCAD	A4	COIL OUTER LAYER - CABLE STABILIZATION	1999-08-11	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0051	..	Act Part	AUTOCAD	A2	COIL INNER LAYER - CU-WEDGE INSULATED. INNER LAYER-III/IV	1999-08-03	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0052	..	Act Part	AUTOCAD	A2	CU WEDGE INS. INNER LAYER III/IV - CU-WEDGE NAKED. INNER LAYER-III/IV	1999-08-03	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0053	..	Act Part	AUTOCAD	A2	COIL INNER LAYER - CU-WEDGE INSULATED. INNER LAYER-IV/V	1999-08-03	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0054	..	Act Part	AUTOCAD	A2	CU WEDGE INS. INNER LAYER IV/V - CU-WEDGE NAKED. INNER LAYER-IV/V	1999-08-03	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0055	..	Act Part	AUTOCAD	A2	COIL INNER LAYER - CU-WEDGE INSULATED. INNER LAYER-V/VI	1999-08-03	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0056	..	Act Part	AUTOCAD	A2	CU WEDGE INS. INNER LAYER V/VI - CU-WEDGE NAKED. INNER LAYER-V/VI	1999-08-03	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0057	..	Act Part	AUTOCAD	A2	COIL OUTER LAYER - CU-WEDGE INSULATED. OUTER LAYER-I/II	1999-08-03	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0058	..	Act Part	AUTOCAD	A2	CU WEDGE INS. OUTER LAYER I/II - CU-WEDGE NAKED. OUTER LAYER-I/II	1999-08-03	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0059	AA	Act Part	EUCLID	A2	COIL INNER LAYER - END POLE NCS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0060	AA	Act Part	EUCLID	A2	COIL INNER LAYER - SPACER 5-6 NCS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0061	AB	Act Part	EUCLID	A2	COIL INNER LAYER - SPACER 4-5 NCS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0062	AA	Act Part	EUCLID	A2	COIL INNER LAYER - SPACER 3-4 NCS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0063	AA	Act Part	EUCLID	A2	COIL INNER LAYER - END PIECE NCS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0064	AA	Act Part	EUCLID	A2	COIL INNER LAYER - END POLE CS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0065	AB	Act Part	EUCLID	A2	COIL INNER LAYER - SPACER 5-6 CS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0066	AA	Act Part	EUCLID	A2	COIL INNER LAYER - SPACER 4-5 CS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0067	AB	Act Part	EUCLID	A2	COIL INNER LAYER - SPACER 3-4 CS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0068	AC	Act Part	EUCLID	A2	COIL INNER LAYER - END PIECE CS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0069	..	Act Part	EUCLID	A3	COIL INNER LAYER - SPACER CS	1999-07-26	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0070	AA	Act Part	EUCLID	A2	COIL INNER LAYER - CHIP NCS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0071	AA	Act Part	EUCLID	A2	COIL INNER LAYER - WEDGE TIP A CS	1999-07-26	J.DELCROIX	M.GENET	D.PERINI	Archived
LHCMB__A0072	AB	Act Part	EUCLID	A2	COIL INNER LAYER - WEDGE TIP B CS	1999-07-26	J.DELCROIX	R.REY	D.PERINI	Archived

LHCMB__A0073	AC	Act Part	EUCLID	A2	COIL INNER LAYER - WEDGE TIP C CS	1999-07-26	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0074	..	Act Part	EUCLID	A3	COIL INNER LAYER - END POLE TOOL CS	1999-07-26	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0075	..	Act Part	EUCLID	A3	COIL INNER LAYER - END POLE TOOL NCS	1999-07-26	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0076	..	Act Part	EUCLID	A2	COIL OUTER LAYER SHIP CS	1999-07-26	B.FERAL	R.REY	D.PERINI	Archived
LHCMB__A0077	AB	Act Part	EUCLID	A2	COIL OUTER LAYER - END POLE A CS	1999-07-26	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0078	AC	Act Part	EUCLID	A2	COIL OUTER LAYER - END POLE B CS	1999-07-26	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0079	AB	Act Part	EUCLID	A2	COIL OUTER LAYER - SPACER 1-2 CS	1999-07-26	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0080	AC	Act Part	EUCLID	A2	COIL OUTER LAYER - END PIECE CS	1999-07-27	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0081	AB	Act Part	EUCLID	A2	COIL OUTER LAYER - END POLE NCS	1999-07-27	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0082	AB	Act Part	EUCLID	A2	COIL OUTER LAYER - SPACER 1-2 NCS	1999-07-27	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0083	AD	Act Part	EUCLID	A2	COIL OUTER LAYER - END PIECE NCS	1999-07-27	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0084	..	Act Part	EUCLID	A3	COIL OUTER LAYER - SPACER CS	1999-07-27	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0085	..	Act Part	EUCLID	A3	COIL OUTER LAYER - END POLE TOOL NCS	1999-07-27	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0086	AA	Act Part	EUCLID	A3	COIL OUTER LAYER - END POLE TOOL CS	1999-07-27	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0087	AB	Act Part	EUCLID	A2	COIL OUTER LAYER - WEDGE TIP CS	1999-07-27	J.DELCROIX	R.REY	D.PERINI	Archived
LHCMB__A0088	..	Act Part	EUCLID	A2	COIL OUTER LAYER SHIP NCS	2000-07-20	B.FERAL	R.REY	D.PERINI	Archived
LHCMB__A0089	AB	Act Part	AUTOCAD	A1	LAYER JUMP SPACER & BOX ASSEMBLY - LAYER JUMP BOX	1999-07-09	P.MARTINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0090	AA	Act Part	AUTOCAD	A3	LAYER JUMP SPACER & BOX ASSEMBLY - LONG LAYER JUMP SPACER	1999-07-14	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0091	..	Act Part	AUTOCAD	A4	LAYER JUMP SPACER & BOX ASSEMBLY - PIN	1999-07-13	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0092	AA	Act Part	AUTOCAD	A3	COIL ASSEMBLY - SHORT LAYER JUMP SPACER	1999-07-14	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0093	AB	Act Part	AUTOCAD	A2	INTER-LAYER SPACERS ASSEMBLY - STANDARD INTER-LAYER SPACER	1999-08-11	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0094	AA	Act Part	AUTOCAD	A1	INTER-LAYER SPACERS ASSEMBLY - C.S. AND N.C.S. END INTER-LAYER	1999-08-05	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0095	AA	Act Part	AUTOCAD	A2	INTER-LAYER SPACERS ASSEMBLY - LEFT INTER-LAYER SPACER	1999-08-12	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0096	AA	Act Part	AUTOCAD	A2	INTER-LAYER SPACERS ASSEMBLY - RIGHT 1 ADJUST. INTER-LAYER SPACER	1999-08-11	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0097	AA	Act Part	AUTOCAD	A2	INTER-LAYER SPACERS ASSEMBLY - LAYER JUMP INTER-LAYER SPACER	1999-08-12	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0098	AA	Act Part	AUTOCAD	A2	INTER-LAYER SPACERS ASSEMBLY - RIGHT 2 ADJUST. INTER-LAYER SPACER	1999-08-19	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0099	AB	Act Part	AUTOCAD	A0	AUSTENITIC STANDARD COLLAR PACK - AUSTENITIC STEEL COLLAR A. TYPE 1	1999-07-27	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0100	AB	Act Part	AUTOCAD	A1	AUSTENITIC STANDARD COLLAR PACK - AUSTENITIC STEEL COLLAR A. TYPE 2	1999-08-02	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0101	AB	Act Part	AUTOCAD	A4	AUSTENITIC COLLAR PACK - ROD	1999-07-15	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0102	AA	Act Part	AUTOCAD	A2	AUSTENITIC ENDS COLLAR PACK - AUSTENITIC STEEL COLLAR B. TYPE 1	1999-07-16	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0103	AA	Act Part	AUTOCAD	A2	AUSTENITIC ENDS COLLAR PACK - AUSTENITIC STEEL COLLAR B. TYPE 2	1999-07-16	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0105	AA	Act Part	AUTOCAD	A2	AUSTENITIC LAYER JUMP COLLAR PACK - AUSTENITIC STEEL COLLAR C. TYPE 1	1999-07-19	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0106	AA	Act Part	AUTOCAD	A2	AUSTENITIC LAYER JUMP COLLAR PACK - AUSTENITIC STEEL COLLAR C. TYPE 2	1999-07-19	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0124	AB	Act Part	AUTOCAD	A2	QUENCH HEATER TYPE 1 & 2 - QUENCH HEATER STRIP	1999-10-20	P.MARTINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0125	AA	Act Part	AUTOCAD	A3	QUENCH HEATER TYPE 1 & 2 - HEATER ELEMENT	1999-10-20	P.MARTINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0126		Act Part	AUTOCAD	A3	QUENCH HEATER TYPE 1 & 2 - CONNECTOR	2000-04-05	O.CRETTIEZ	P.MARTINS	D.PERINI	Archived

LHCMB__A0129	AA	Act Part	AUTOCAD	A4	HALF YOKE ASSEMBLY - RING	1999-10-04	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0130	AA	Act Part	AUTOCAD	A4	HALF YOKE ASSEMBLY - STANDARD ANTITORSION BAR	2000-02-08	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0131	AA	Act Part	AUTOCAD	A4	HALF YOKE ASSEMBLY - END ANTITORSION BAR	2000-02-08	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0132	AA	Act Part	AUTOCAD	A4	HALF YOKE ASSEMBLY - TIE ROD YOKE	2000-02-08	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0133	AC	Act Part	AUTOCAD	A0	LAMINATION STD PACK & COMPENSATION - LAMINATION. TYPE A	1999-07-21	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0134	AB	Act Part	AUTOCAD	A1	LAMINATION STD & ADJUSTMENT PACK - LAMINATION TYPE C	1999-07-14	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0135	AB	Act Part	AUTOCAD	A4	LAMINATION STANDARD PACK - BEARING PIPE	1999-08-12	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0136	AC	Act Part	AUTOCAD	A0	COMPENSATION LAMINATION PACK - LAMINATION SHIM. TYPE AA	1999-10-01	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0137	AB	Act Part	AUTOCAD	A4	COMPENSATION LAMINATION PACK - BEARING PIPE	1999-08-12	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0139	AB	Act Part	AUTOCAD	A0	LAYER JUMP + CS & NCS LAMINATION PACK - AUSTENITIC LAMINATION. TYPE B	1999-10-07	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0140	AB	Act Part	AUTOCAD	A0	LAYER JUMP AND CS & NCS LAMINATION PACK - LAMINATION. TYPE D	1999-10-07	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0141	AD	Act Part	AUTOCAD	A0	CS & NCS LAMINATION PACK - LAMINATION. TYPE D1	1999-10-07	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0142	AC	Act Part	AUTOCAD	A0	CS & NCS LAMINATION PACK - LAMINATION. TYPE A1	1999-10-05	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0143	AB	Act Part	AUTOCAD	A4	CS & NCS LAMINATION PACK - BEARING PIPE	1999-08-12	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0144	AA	Act Part	AUTOCAD	A4	CS & NCS LAMINATION PACK - TAP ROD	1999-12-10	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0145	AA	Act Part	AUTOCAD	A4	CS & NCS LAMINATION PACK - KEY	2000-01-07	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0146	AB	Act Part	AUTOCAD	A0	C.S. & N.C.S. LAMINATION PACK - LAMINATION. TYPE A2	2000-01-10	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0147	AB	Act Part	AUTOCAD	A0	CS & NCS LAMINATION PACK - LAMINATION. TYPE A3	1999-08-12	J.FORESTIER	P.MARTINS	D.PERINI	Archived
LHCMB__A0148	AC	Act Part	AUTOCAD	A1	COMPENSATION & STANDARD INSERT PACK - INSERT	1999-07-19	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0149	AC	Act Part	AUTOCAD	A1	COMPENSATION INSERT PACK - ADJUSTMENT INSERT	1999-07-19	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0150	AB	Act Part	AUTOCAD	A4	INSERT STANDARD PACK - ROD	1999-07-13	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0151	AB	Act Part	AUTOCAD	A4	COMPENSATION INSERT PACK - ROD	1999-07-13	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0152	AC	Act Part	AUTOCAD	A1	AUSTENITIC INSERT PACK - AUSTENITIC INSERT	1999-07-19	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0153	AC	Act Part	AUTOCAD	A4	AUSTENITIC INSERT PACK - ROD	1999-07-13	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0155	AB	Act Part	AUTOCAD	A3	INSTRUMENTATION DRAWINGS - MB INSTRUMENTATION COLD MASS-OUTGOING WIRES	1999-09-07	S.DESCOINS	G.BRUN	J.BILLAN	Archived
LHCMB__A0156	AB	Act Part	AUTOCAD	A0	INSTRUMENTATION DRAWINGS - DIAGNOSTICS EQUIPMENTS LOCATIONS	1999-10-25	S.DESCOINS	G.BRUN	D.PERINI	Archived
LHCMB__A0158	AB	Act Part	AUTOCAD	A1	CONTROL DRAWINGS - COLLAR A TYPE 1. SPC CHECK POINTS	1999-07-14	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0159	..	Act Part	AUTOCAD	A2	CONTROL DRAWINGS - COLLAR A TYPE 2. SPC CHECK POINTS	1999-07-14	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0160	AB	Act Part	AUTOCAD	A2	CONTROL DRAWINGS - LAMINATION TYPE A. SPC CHECK POINTS	1999-11-15	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0161	AA	Act Part	AUTOCAD	A2	CONTROL DRAWINGS - AUST. LAMIN. TYPE B. SPC CHECK POINTS	1999-11-25	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0162	AB	Act Part	AUTOCAD	A2	CONTROL DRAWINGS - LAMINATION TYPE D. SPC CHECK POINTS	1999-11-26	R.ASKOVIC	P.MARTINS	D.PERINI	Archived
LHCMB__A0163	AA	Act Part	AUTOCAD	A3	CONTROL DRAWINGS - AUSTENITIC INSERT. SPC CHECK POINTS	1999-11-10	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0164	AA	Act Part	AUTOCAD	A3	CONTROL DRAWINGS - INSERT. SPS CHECK POINTS	1999-11-11	S.DESCOINS	P.MARTINS	D.PERINI	Archived
LHCMB__A0166	..	Act Part	AUTOCAD	A4	DIPOLE COLD MASS ASSEMBLY - STOP	2000-06-21	O.CRETTIEZ	M.GENET	D.PERINI	Archived
LHCMB__A0167	..	Act Part	AUTOCAD	A4	DIPOLE COLD MASS ASSEMBLY - LOCKING DEVICE	2000-06-21	O.CRETTIEZ	M.GENET	D.PERINI	Archived

LHCMB__A0170	AA	Act Part	AUTOCAD	A4	ACTIVE PART CROSS SECTION TYPE A & B - CYLINDRICAL FILLER PIECE	2000-08-07	O.CRETTIEZ	M.GENET	D.PERINI	Archived
LHCMB__A0171	AA	Act Part	AUTOCAD	A4	ACTIVE PART CROSS SECTION TYPE A & B - RECTANGULAR FILLING PIECE	2000-08-07	O.CRETTIEZ	M.GENET	D.PERINI	Archived
LHCMB__A0173	..	Act Part	AUTOCAD	A4	DIPOLE COLD MASS ASSEMBLY - STOP	2000-12-04	O.CRETTIEZ	M.GENET	D.PERINI	Archived
LHCMBA_A0001	AD	Act Part	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - ACTIVE PART CROSS-SECTION TYPE A	1999-07-21	R.REY	M.GENET	D.PERINI	Archived
LHCMBA_A0002	AE	Act Part	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - ACTIVE PART LONG. SECTIONS TYPE A	1999-07-21	R.REY	M.GENET	D.PERINI	Archived
LHCMBA_A0003	AD	Act Part	AUTOCAD	A2	INSTRUMENTATION DRAWINGS - VOLTAGE TAPS MBA - DESIGNATION AND LOCATION	1999-09-02	S.DESCOINS	G.BRUN	J.BILLAN	Archived
LHCMBB_A0001	AD	Act Part	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - ACTIVE PART CROSS-SECTION TYPE B	1999-07-21	R.REY	M.GENET	D.PERINI	Archived
LHCMBB_A0002	AE	Act Part	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - ACTIVE PART LONG. SECTIONS TYPE B	1999-07-21	R.REY	M.GENET	D.PERINI	Archived
LHCMBB_A0003	AD	Act Part	AUTOCAD	A2	INSTRUMENTATION DRAWINGS - VOLTAGE TAPS MBB - DESIGNATION AND LOCATION	1999-09-02	S.DESCOINS	G.BRUN	J.BILLAN	Archived
LHCDCBHA0001	AC	Bus Bars	EUCLID	A0	DIPOLE COLD MASS ASSEMBLY - BUSBARS MB TB INSTALLATION	1999-09-03	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCBHA0002	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TB	1999-09-17	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0003	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TB EXT INSULATED	1999-09-17	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0004	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TB INT INSULATED	1999-09-17	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0005	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TB EXT COPPER/SUPRA	1999-09-17	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0006	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TB INT COPPER/SUPRA	1999-09-17	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0007	AC	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TB EXT COPPER	1999-09-17	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0008	AC	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TB INT COPPER	1999-09-17	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0009	AC	Bus Bars	EUCLID	A0	DIPOLE COLD MASS ASSEMBLY - BUSBARS MB TA INSTALLATION	1999-09-20	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCBHA0010	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD ASSEMBLY - BUSBARS ASSY MB TA	1999-09-22	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0011	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TA EXT INSULATED	1999-09-22	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0012	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TA INT INSULATED	1999-09-22	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0013	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TA INT COPPER/SUPR	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0014	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMLY - BUSBAR ASSY MB TA EXT COPPER/SUPRA	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0015	AB	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TA INT COPPER	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0016	AB	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TA EXT COPPER	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0017	AC	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR MB TB EXT COPPER-STABILIZER	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0018	AC	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR MB TB INT COPPER-STABILIZER	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0019	AB	Bus Bars	AUTOCAD	A1	BUSBAR ASSY MB T.A INT COPPER - COPPER-STABILIZER	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0020	AB	Bus Bars	AUTOCAD	A1	BUSBAR ASSY MB T.A EXT COPPER - COPPER-STABILIZER	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0023	AB	Bus Bars	AUTOCAD	A1	BUSBAR ASSY MB T.A EXT COPPER - FLEXIBLE DIODE BUSBAR (LEFT)	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0024	AA	Bus Bars	EUCLID	A4	BUSBAR MB COPPER - SECTION	1999-09-23	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCBHA0025	AC	Bus Bars	AUTOCAD	A3	BUSBAR ASSY MB COPPER - FIXED POINT	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0026	AC	Bus Bars	AUTOCAD	A1	BUSBAR ASSY MB TB INT COPPER - FLEXIBLE DIODE BUSBAR (RIGHT)	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0027	AD	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TB COIL OUTLET	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0028	AB	Bus Bars	AUTOCAD	A1	BUSBAR ASSY MB TB COIL OUTLET - FLEXIBLE DIODE BUSBAR (LEFT)	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived

LHCDCBHA0029	AC	Bus Bars	AUTOCAD	A1	BUSBAR ASSY MB TB COIL OUTLET - STABILIZER	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0030	AD	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY MB TA COIL OUTLET	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0031	AC	Bus Bars	AUTOCAD	A1	BUSBAR ASSY MB T.A COIL OUTLET - FLEXIBLE DIODE BUSBAR (RIGHT)	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0032	AC	Bus Bars	AUTOCAD	A1	BUSBAR ASSY MB TA COIL OUTLET - STABILIZER	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0033	AB	Bus Bars	AUTOCAD	A3	BUSBAR ASSY MB COPPER - INT LYRE	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0034	AB	Bus Bars	AUTOCAD	A3	BUSBAR ASSY MB COPPER - EXT LYRE	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0038	AA	Bus Bars	AUTOCAD	A3	DIPOLE COLD MASS ASSEMBLY - BODY SPOUT'S	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0039	AA	Bus Bars	AUTOCAD	A3	DIPOLE COLD MASS ASSEMBLY - COVER SPOUT'S	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0041	AA	Bus Bars	AUTOCAD	A3	DIPOLE COLD MASS ASSEMBLY - SHEET	1999-09-23	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0043	AC	Bus Bars	AUTOCAD	A3	BUSBAR ASSY MB TB INT - CONNECTING PLANK B	1999-12-13	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0044	AC	Bus Bars	AUTOCAD	A3	BUSBAR ASSY MB TA EXT - CONNECTING PLANK A	1999-12-13	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCBHA0047	..	Bus Bars	EUCLID	A3	DIPOLE COLD MASS ASSEMBLY - SHEET	2000-03-28	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCBHA0048	..	Bus Bars	EUCLID	A3	DIPOLE COLD MASS ASSEMBLY - LOCK	2000-03-28	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCBHA0049	..	Bus Bars	EUCLID	A3	DIPOLE COLD MASS ASSEMBLY - SHEET	2000-03-28	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCBHA0050	..	Bus Bars	EUCLID	A3	DIPOLE COLD MASS ASSEMBLY - LOCK	2000-03-28	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCBHA0051	..	Bus Bars	EUCLID	A3	INSULATING SPOUT (POLYIM. 0.05) - E SECTION	2000-05-29	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCDCBHA0052	..	Bus Bars	EUCLID	A3	INSULATING SPOUT (POLYIM. 0.05) - RECTANGULAR SECTION	2000-05-29	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCDCBHA0054	..	Bus Bars	EUCLID	A3	MAGNET BENDING BUSBARS ASSY. - INSULATING SPOUT (POLYIM. 0.05)	2000-05-30	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCDCBHA0055	..	Bus Bars	EUCLID	A2	DIPOLE COLD MASS ASSEMBLY - BUSBARS ASSY SET. TYPE A	2000-11-09	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCBHA0056	..	Bus Bars	EUCLID	A2	DIPOLE COLD MASS ASSEMBLY - BUSBARS ASSY SET. TYPE B	2000-11-09	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCCHA0001	AB	Bus Bars	AUTOCAD	A0	BUSBARS MQF/AUXIL.ASSY TA - AUXIL.BUSBARS LINE M1 EXT TA	1999-09-24	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCCHA0002	AB	Bus Bars	AUTOCAD	A0	BUSBARS MQF/AUXIL.ASSY TA - AUXIL.BUSBARS LINE M1 INT TA	1999-09-24	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCCHA0003	AB	Bus Bars	AUTOCAD	A0	BUSBARS MQD/AUXIL.ASSY TA - AUXIL.BUSBARS LINE M2 EXT TA	1999-09-24	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCCHA0004	AB	Bus Bars	AUTOCAD	A0	BUSBARS MQD/AUXIL. ASSY TA - AUXIL. BUSBARS LINE M2 INT TA	1999-09-24	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCCHA0005	AA	Bus Bars	AUTOCAD	A4	DIPOLE COLD MASS ASSEMBLY - AUXILIARY BUSBAR SECTION	1999-09-24	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCCHA0006	AA	Bus Bars	EUCLID	A3	DIPOLE COLD MASS ASSEMBLY - AUX. BUSBARS INSULATION PRINCI	2000-09-28	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCDCCHA0007	..	Bus Bars	AUTOCAD	A0	BUSBARS MQF/AUXIL. ASSY TB - AUXIL. BUSBARS LINE M1 EXT TB	2001-01-09	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCCHA0008	..	Bus Bars	AUTOCAD	A0	BUSBARS MQF/AUXIL. ASSY TB - AUXIL. BUSBARS LINE M1 INT TB	2001-01-09	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCCHA0009	..	Bus Bars	AUTOCAD	A0	BUSBARS MQD/AUXIL. ASSY TB - AUXIL. BUSBARS LINE M2 INT TB	2001-01-10	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCCHA0010	..	Bus Bars	AUTOCAD	A0	BUSBARS MQD/AUXIL. ASSY TB - AUXIL. BUSBARS LINE M2 EXT TB	2001-01-10	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0001	AB	Bus Bars	EUCLID	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR INSTALLATION MQF/MBA	1999-09-03	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCQHA0002	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBARS MQF/AUXILIARY ASSY TA	1999-09-16	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0003	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.FOC. EXT INSULATED	1999-09-16	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0004	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.FOC. INT INSULATED	1999-09-16	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0005	AD	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.FOC.EXT COPPER/SUP	1999-09-16	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0006	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.FOC.INT COPPER/SUP	1999-09-16	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived

LHCDCQHA0007	AB	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.FOC.EXT COPPER	1999-09-16	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0008	AB	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.FOC.INT COPPER	1999-09-16	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0009	AB	Bus Bars	EUCLID	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR INSTALLATION MQD/MBA	1999-09-20	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCQHA0010	AB	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBARS MQD/AUXILIARY ASSY TA	1999-09-24	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0011	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.DEFOC. EXT INSULAT	1999-09-24	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0012	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.DEFOC. INT INSULAT	1999-09-24	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0013	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.DEFOC.EXT COPPER/S	1999-09-24	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0014	AC	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.DEFOC.INT COPPER/S	1999-09-24	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0015	AB	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.DEFOC EXT COPPER	1999-09-27	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0016	AB	Bus Bars	AUTOCAD	A1	DIPOLE COLD MASS ASSEMBLY - BUSBAR ASSY QUAD.DEFOC.INT COPPER	1999-09-27	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0017	AA	Bus Bars	EUCLID	A4	QUADRUPOLE BUSBAR COPPER - SECTION	1999-09-27	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCDCQHA0018	AB	Bus Bars	AUTOCAD	A1	BUSBAR ASSY QUAD.FOC. INT COPPER - COPPER STABILIZER	1999-09-27	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0019	AC	Bus Bars	AUTOCAD	A1	BUSBAR ASSY QUAD.FOC. EXT COPPER - COPPER STABILIZER	1999-09-27	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0020	AB	Bus Bars	AUTOCAD	A1	BUSBAR ASSY QUAD.DEFOC. INT COPPER - COPPER STABILIZER	1999-09-27	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0021	AB	Bus Bars	AUTOCAD	A1	BUSBAR ASSY QUAD.DEFOC. EXT COPPER - COPPER STABILIZER	1999-09-27	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0022	AC	Bus Bars	AUTOCAD	A3	BUSBAR ASSY QUADRUP COPPER - FIXED POINT	1999-09-27	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0023	AB	Bus Bars	AUTOCAD	A3	BUSBAR ASSY QUADRUP COPPER - INT LYRE	1999-09-27	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0024	AC	Bus Bars	AUTOCAD	A3	BUSBAR ASSY QUADRUP COPPER - EXT LYRE	1999-09-27	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0026	AA	Bus Bars	AUTOCAD	A2	BUSBARS QUAD./AUXILIARY ASSY - INSULATOR GUIDE	1999-09-27	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0027	AA	Bus Bars	AUTOCAD	A2	BUSBARS QUAD./AUXILIARY ASSY - INSULATOR GUIDE	1999-09-27	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0034	..	Bus Bars	EUCLID	A3	INSULATING SPOUT (POLYIM. 0.05) - U SECTION	2000-05-29	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCDCQHA0036	..	Bus Bars	EUCLID	A3	QUADRUPOLE BUSBARS ASSY. - INSULATING SPOUT (POLYIM. 0.05)	2000-05-30	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCDCQHA0037	AA	Bus Bars	EUCLID	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR INSTALLATION MQD/MBB	2000-12-04	B.FERAL	M.GENET	J.PERINET-MARQ	Archived
LHCDCQHA0038	AA	Bus Bars	EUCLID	A0	DIPOLE COLD MASS ASSEMBLY - BUSBAR INSTALLATION MQF/MBB	2000-12-04	B.FERAL	M.GENET	J.PERINET-MARQ	Archived
LHCDCQHA0040	..	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY-BUSBARS MQF/AUXIL. ASSY TB	2000-12-12	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCDCQHA0041	..	Bus Bars	AUTOCAD	A0	DIPOLE COLD MASS ASSEMBLY-BUSBARS MQD/AUXIL. ASSY TB	2000-12-12	BUDKER	P.IVANOV	J.PERINET-MARQ	Archived
LHCMB__E0002	AF	El. Connection	AUTOCAD	A0	POSITIONING TOOL ASSEMBLYFOR SEXTUPOLE - SEXTUPOLES SUPPORT	1999-10-19	SENER	H.NEMOZ	J.PERINET-MARQ	Archived
LHCMB__E0004	..	El. Connection	AUTOCAD	A3	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - CENTERING SCREW	1999-10-19	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0005	AB	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - SUPPORTS&WIRING ASS. LYRA S. A&B	2000-05-05	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0006	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - CONNECTION COIL YOKE	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0007	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - CONNECTION COIL WEDGE	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0008	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - CONNECTION COIL SPACER	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0009	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - INS. HALF BOX CONNECTION COIL	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0010	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - OUT. HALF BOX CONNECTION COIL	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0011	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - CONNECTION COIL SPACER BLOCK	1999-10-19	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0012	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - CONNECTION COIL COVER	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived

LHCMB__E0013	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - SUPRACONDUCTOR JUNCTION GUIDE	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0014	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - SUPRACONDUCTOR JUNCTION WEDGE	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0015	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - JUNCTION COILS YOKE	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0016	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - JUNCTION COILS WEDGE	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0017	..	El. Connection	EUCLID	A3	SUPPORTS & WIRING ASS. LYRE S. - MAGNET BENDING BUSBAR WEDGE	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0018	..	El. Connection	EUCLID	A3	SUPPORTS & WIRING ASS. LYRE S. - MAGNET BENDING UPPER GUIDE	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0019	..	El. Connection	EUCLID	A3	SUPPORTS & WIRING ASS. LYRE S. - MAGNET BENDING BUSBAR LOWER GUIDE	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0020	..	El. Connection	EUCLID	A3	SUPPORTS & WIRING ASS. LYRE S. - QUADRUPOLE BUSBAR GUIDE	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0021	..	El. Connection	EUCLID	A3	SUPPORTS & WIRING ASS. LYRE S. - QUADRUPOLE BUSBAR WEDGE	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0026	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - BUSBAR DIODE SEPARATING SUPPORT	1999-10-20	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0027	AA	El. Connection	AUTOCAD	A0	COLD MASS ASSEMBLY - POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE	1999-10-22	SENER	H.NEMOZ	J.PERINET-MARQ	Archived
LHCMB__E0028	AA	El. Connection	AUTOCAD	A3	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - ASSEMBLY TABLES FOR ADJUSTIN	1999-10-22	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0029	AA	El. Connection	AUTOCAD	A0	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - FRAME SUPPORT	1999-10-22	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0030	..	El. Connection	AUTOCAD	A2	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - PLATE	1999-10-22	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0031	..	El. Connection	AUTOCAD	A3	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - CENTERING CLAW	1999-10-22	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0032	..	El. Connection	AUTOCAD	A3	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - FIXED BUSH	1999-10-22	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0033	..	El. Connection	AUTOCAD	A3	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - SLIP BUSHING	1999-10-22	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0034	..	El. Connection	AUTOCAD	A3	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - FLOATING BUSH	1999-10-22	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0035	..	El. Connection	AUTOCAD	A4	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - LOCK SCREW	1999-10-22	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0036	..	El. Connection	AUTOCAD	A4	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - WASHER	1999-10-22	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0037	..	El. Connection	AUTOCAD	A4	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - LOCK WASHER	1999-10-22	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0038	AB	El. Connection	AUTOCAD	A4	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - STUD	1999-10-22	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0042	AA	El. Connection	AUTOCAD	A4	POSITIONING TOOL ASSEMBLY FOR SEXTUPOLE - CENTERING WASHER	1999-11-12	SENER	H.NEMOZ	F.SAVARY	Archived
LHCMB__E0044	..	El. Connection	EUCLID	A3	COLD MASS ASSEMBLY - SPACER	2000-03-03	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0045	..	El. Connection	EUCLID	A3	COLD MASS ASSEMBLY - SPACER	2000-03-03	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0046	..	El. Connection	EUCLID	A4	ELECTRICAL CONNECTION - SOLDER-TYPE LUG	2000-03-20	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0047	AB	El. Connection	EUCLID	A2	COLD MASS ASS. - ELECT.CONNECTION - UPPER INSULATING PLATE	2000-05-05	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0048	..	El. Connection	EUCLID	A3	WIRING ASS. CONNECTION S. - WIRING SUPPORT	2000-06-05	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0049	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - LOCK PLATE 14X50	2000-06-21	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0050	..	El. Connection	AUTOCAD	A4	DIPOLE COLD MASS ASSEMBLY - INSULATING PROFILE FOR INSTRUMENTAT	2000-08-10	O.CRETTIEZ	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0053	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - LOCK PLATE 10X20	2000-08-29	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0054	..	El. Connection	AUTOCAD	A4	AUXILIARY BUSBAR SUPPORT - COVER	2000-09-04	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0055	..	El. Connection	AUTOCAD	A4	AUXILIARY BUSBAR SUPPORT - INSULATING BOX	2000-09-04	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0057	AA	El. Connection	AUTOCAD	A2	BUSBAR SUPPORT FOR LINE M1/M2 LYRA SIDE - ASSEMBLY	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0058	..	El. Connection	AUTOCAD	A2	BUSBAR SUPPORT FOR LINE M3 LYRA SIDE - ASSEMBLY	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived

LHCMB__E0059	..	El. Connection	AUTOCAD	A3	BUSBAR SUPPORT FOR LINE M1/M2 OR M3 - SUPERIOR COVER	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0060	..	El. Connection	AUTOCAD	A3	BUSBAR SUPPORT FOR LINE M1/M2 OR M3 - INFERIOR COVER	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0061	..	El. Connection	AUTOCAD	A3	BUSBAR SUPPORT FOR LINE M1/M2 OR M3 - BELT	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0062	AA	El. Connection	AUTOCAD	A3	BUSBAR SUPPORT FOR LINE M3 - BUSBAR INSULATING FOR LINE M3	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0063	AA	El. Connection	AUTOCAD	A3	BUSBAR SUPPORT FOR LINE M1/M2 - BUSBAR INF. INSULATING LINE M1/M2	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0064	AA	El. Connection	AUTOCAD	A3	BUSBAR SUPPORT FOR LINE M1/M2 - BUSBAR CENTR. INSULATING LINE M1/M2	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0065	..	El. Connection	AUTOCAD	A3	BUSBAR SUPPORT FOR LINE M1/M2 - BUSBAR SUP. INSULATING LINE M1/M2	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0066	..	El. Connection	AUTOCAD	A4	BUSBAR SUPPORT FOR LINE M3 - SPRING	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0067	..	El. Connection	AUTOCAD	A4	BUSBAR SUPPORT FOR LINE M1/M2 - SUPERIOR SPRING	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0068	..	El. Connection	AUTOCAD	A4	BUSBAR SUPPORT FOR LINE M1/M2 - INFERIOR SPRING	2000-10-25	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0069	..	El. Connection	EUCLID	A1	MAGNET BENDING COLD MASS ASS. - DIODE CONNECTION ASS.	2000-11-17	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0070	..	El. Connection	EUCLID	A2	MAGNET BENDING COLD MASS ASS. - INSULATION TUBING	2000-11-17	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0071	..	El. Connection	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - INSULATION WALL	2000-11-17	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0072	..	El. Connection	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - CLAMP ASSEMBLY	2000-11-17	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0073	..	El. Connection	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - CONNECTOR BLOCK	2000-11-17	D.GALHAUT	G.BRUN	J.BILLAN	Archived
LHCMB__E0074	..	El. Connection	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - CONNECTOR BLOCK COVER	2000-11-17	D.GALHAUT	G.BRUN	J.BILLAN	Archived
LHCMB__E0075	..	El. Connection	AUTOCAD	A2	BUS BAR SUPPORT FOR LINE M1/M2 CONNEXION SIDE - ASSEMBLY	2000-12-11	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0076	..	El. Connection	AUTOCAD	A2	BUS BAR SUPPORT FOR LINE M3 CONNEXION SIDE - ASSEMBLY	2000-12-11	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0077	..	El. Connection	EUCLID	A3	DIODE CONNECTION ASSY. - LEFT INSULATOR PLATE	2000-12-19	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0078	..	El. Connection	EUCLID	A3	DIODE CONNECTION ASSY. - RIGHT INSULATOR PLATE	2000-12-19	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0079	AA	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - JUNC. AUX. BUS. LYRE S. - FULL TEST	2001-02-21	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0080	..	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - JUNC. AUX. BUS. CONNE. S. - FULL TEST	2001-02-21	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__E0081	..	El. Connection	AUTOCAD	A3	TOOLING FOR DIODE INSTALLATION - DIODE HANDLE	2001-03-28	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0001	AB	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASSY - CONN.SIDE - GENERAL ASSY(+CORR	1999-10-06	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0002	AC	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASSY. - SUPPORTS ASS. CONNEC. S. TYPE A	2000-04-06	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0003	AB	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASSY - LYRE SIDE - GENERAL ASSY(+CORR	1999-10-06	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0004	AB	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - WIRING ASS. CONNECTION S. TYPE A	1999-10-06	I.NIKITINE	G.BRUN	J.BILLAN	Archived
LHCMBA_E0005	AA	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASSY - ELECTRICAL CONNECTIONS (TYPE A	1999-10-06	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0009	AF	El. Connection	EUCLID	A0	CONNECTION SIDE COMPONENTS - DECAPOLE OCTUPOLE SUPPORT	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0010	AB	El. Connection	EUCLID	A2	COLD MASS ASS. - ELECT. CONNECTION - LOWER INSULATING PLATED TYPE A	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0011	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - V1 COIL OUTLET BUSBAR WEDGE	2000-09-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0012	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - V1 COIL OUTLET BUSBAR CLAMP	2000-09-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0013	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - V2 COIL OUTLET BUSB. THIN WEDGE	2000-09-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0014	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - V2 COIL OUTLET BUSB. THIN CLAMP	2000-09-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0016	AA	El. Connection	AUTOCAD	A0	COLD MASS ASSEMBLY - POSITIONING TOOL ASSEMBLY FOR DECAPOLE/OCTUPOLE	1999-11-17	SENER	M.GENET	J.PERINET-MARQ	Archived

LHCMBA_E0017	AA	El. Connection	AUTOCAD	A0	POSITIONING TOOL ASSEMBLY FOR DECAPOLE/OCTUPOLE - FRAME SUPPORT	1999-11-17	SENER	H.NEMOZ	J.PERINET-MARQ	Archived
LHCMBA_E0018	..	El. Connection	AUTOCAD	A2	POSITIONING TOOL ASSEMBLY FOR DECAPOLE/OCTUPOLE - PLATE	1999-11-17	SENER	H.NEMOZ	J.PERINET-MARQ	Archived
LHCMBA_E0019	AA	El. Connection	EUCLID	A1	DIPOLE COLD MASS ASSY. TYPE A - ELECTRI. CONNECT. SPOOL FULL TEST	1999-12-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0020	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - V2 COIL OUTLET BUSBAR WEDGE	2000-09-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0021	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - V2 COIL OUTLET BUSBAR CLAMP	2000-09-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0022	..	El. Connection	AUTOCAD	A4	AUXILIARY BUSBAR SUPPORT - COVER	2000-09-04	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0023	..	El. Connection	AUTOCAD	A4	AUXILIARY BUSBAR SUPPORT - INSULATING BOX	2000-09-04	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMBA_E0024	..	El. Connection	AUTOCAD	A3	AUXILIARY BUSBAR SUPPORT - BOX SUPPORT	2000-09-04	S.DESCOINS	M.GENET	J.PERINET-MARQ	Archived
LHCMBB_E0001	AB	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASSY - CONNECTIONS SIDE - GENERAL ASS	1999-10-06	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCMBB_E0002	AC	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - SUPPORTS ASS. CONNEC. S. TYPE B	2000-04-19	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBB_E0003	AA	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASSY - LYRE SIDE - GENERAL ASSY(+CORR	1999-10-06	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCMBB_E0004	AB	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - WIRING ASS. CONNECTION S. TYPE B	1999-10-06	I.NIKITINE	G.BRUN	J.BILLAN	Archived
LHCMBB_E0005	AA	El. Connection	EUCLID	A0	MAGNET BENDING COLD MASS ASSY - ELECTRICAL CONNECTIONS (TYPE B	1999-10-06	I.NIKITINE	M.GENET	J.PERINET-MARQ	Archived
LHCMBB_E0008	AB	El. Connection	EUCLID	A2	COLD MASS ASS. - ELECT. CONNECTION - LOWER INSULATING PLATE TYPE B	1999-10-19	J.DELCROIX	M.GENET	J.PERINET-MARQ	Archived
LHCMBB_E0009	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - V2 COIL OUTLET BUSBAR WEDGE	2000-09-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBB_E0010	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - V2 COIL OUTLET BUSBAR CLAMP	2000-09-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBB_E0011	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - V1 COIL OUTLET BUSBAR WEDGE	2000-09-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBB_E0012	..	El. Connection	EUCLID	A3	SUPPORTS ASS. CONNECTION S. - V1 COIL OUTLET BUSBAR CLAMP	2000-09-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMBB_E0015	AA	El. Connection	EUCLID	A1	DIPOLE COLD MASS ASSY. TYPE B - ELECTRI. CONNECT. SPOOL FULL TEST	1999-12-01	D.GALHAUT	M.GENET	J.PERINET-MARQ	Archived
LHCMB__S0001	AA	Helium Shell	EUCLID	A1	DIPOLE COLD MASS ASSEMBLY - ACTIVE PART - GEOMETRY	1999-07-06	D.GALHAUT	R.REY	F.SAVARY	Archived
LHCMB__S0002	..	Helium Shell	AUTOCAD	A0	SUPPORT FIT EQUIPMENT - SUPPORT ASSEMBLY WITH RING	2000-05-05	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0003	..	Helium Shell	AUTOCAD	A0	SUPPORT FIT EQUIPMENT - SUPPORT ASSEMBLY WITH MONORAIL	2000-05-05	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0004	AA	Helium Shell	AUTOCAD	A0	DIPOL COLD MASS ASSEMBLY - COLD BORE TUBE ASSEMBLY	1999-07-26	T.SAHNER	M.GENET	F.SAVARY	Archived
LHCMB__S0005	AE	Helium Shell	EUCLID	A0	DIPOLE COLD MASS ASSEMBLY - IFS ASSEMBLY	1999-08-17	T.RENAGLIA	G.TRINQUART	F.SAVARY	Archived
LHCMB__S0006	AB	Helium Shell	EUCLID	A0	DIPOLE COLD MASS ASS. - DIODE CONTAINER SEQUENCE ASS.	1999-07-06	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0007	AF	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - LYRE SIDE END COVER	1999-07-06	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0008	AF	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - CONNECTION SIDE END COVER	1999-07-06	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0012	AB	Helium Shell	EUCLID	A1	MAGNET BENDING COLD MASS ASS. - SUPPORT	1999-07-06	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0015	AB	Helium Shell	EUCLID	A0	DIPOLE COLD MASS ASSEMBLY - IFS TUBE	1999-09-01	T.RENAGLIA	G.TRINQUART	F.SAVARY	Archived
LHCMB__S0016	..	Helium Shell	EUCLID	A3	DIPOLE COLD MASS ASSEMBLY - TUBE #.01 88.9	1999-09-01	T.RENAGLIA	C.MENOT	D.BOZZINI	Archived
LHCMB__S0017	AB	Helium Shell	EUCLID	A3	DIPOLE COLD MASS ASSEMBLY - INSULATING TUBE	1999-09-02	T.RENAGLIA	C.MENOT	D.BOZZINI	Archived
LHCMB__S0018	AB	Helium Shell	EUCLID	A0	DIPOLE CAPILLARY ASSEMBLY - COLD MASS CURVING TOOL	1999-10-08	T.RENAGLIA	C.MENOT	D.BOZZINI	Archived
LHCMB__S0019	AB	Helium Shell	EUCLID	A0	DIPOLE CAPILLARY ASSEMBLY - SQUARE TOOL	1999-10-15	T.RENAGLIA	C.MENOT	D.BOZZINI	Archived
LHCMB__S0020	..	Helium Shell	EUCLID	A0	DIPOLE CAPILLARY ASSEMBLY - EQUIPMENT TOOL	1999-10-15	T.RENAGLIA	C.MENOT	D.BOZZINI	Archived
LHCMB__S0021	..	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASSY. - CAPILLARY TRANSPORT TOOL ASSY.	2000-11-13	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0022	..	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASSY. - DIODE BOX WELDING TOOL	2000-09-20	D.GALHAUT	M.GENET	F.SAVARY	Archived

LHCMB__S0023	..	Helium Shell	EUCLID	A1	DIPOLE CAPILLARY ASSEMBLY - HAND CURVING TOOL	1999-10-18	T.RENAGLIA	C.MENOT	D.BOZZINI	Archived
LHCMB__S0024	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - UNIONS FLANGE	2001-02-23	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0025	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - UNIONS FLANGE	2001-02-23	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0028	AB	Helium Shell	EUCLID	A2	WELDING FLANGE - MALE WELDING RING	1999-12-01	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0029	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - BACK ASSEMBLY FLANGE	2001-02-06	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0030	AA	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - PRESSURE RING	2001-01-05	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0031	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - BACK ASSEMBLY FLANGE	2001-02-06	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0032	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - FRONT ASSEMBLY FLANGE	2001-02-06	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0033	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - BACK RESTRAINT HALF FLANGE	2000-01-11	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0034	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - RESTRAINT THREAD ROD	2000-01-14	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0035	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - NUT	2001-02-06	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0038	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - MALE WELDING NOZZLE	2000-03-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0039	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - FRONT ASSEMBLY FLANGE	2001-02-07	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0042	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - BACK ASSEMBLY FLANGE	2000-01-12	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0043	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - FRONT ASSEMBLY FLANGE	2000-01-10	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0044	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - BACK RESTRAINT HALF FLANGE	2000-01-11	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0045	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - FRONT RESTRAINT HALF FLANGE	2000-01-11	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0075	AB	Helium Shell	EUCLID	A2	WELDING FLANGE - FEMALE WELDING RING	1999-12-01	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0083	AB	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASSY. - END COVER - US INSPECTION DRAW	1999-12-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0084	AD	Helium Shell	EUCLID	A2	MAGNET BENDING COLD MASS ASS. - M1. M2. M3 TYPE BELLOWS ASS.	2000-02-03	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0085	AD	Helium Shell	EUCLID	A2	M1. M2. M3 TYPE BELLOWS ASS. - EQUIPED BELLOWS	2000-02-03	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0086	AC	Helium Shell	EUCLID	A2	M1. M2. M3 TYPE BELLOWS ASS. - BELLOWS' PROTECTION	2000-02-03	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0087	AD	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - X TYPE INTERNAL EQUIPED BELLOW	2000-02-03	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0088	AC	Helium Shell	EUCLID	A3	X TYPE INTERNAL EQUIPED BELLOW - LEFT ADAPTOR	2000-02-03	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0089	AC	Helium Shell	EUCLID	A3	X TYPE INTERNAL EQUIPED BELLOW - RIGHT ADAPTOR	2000-02-03	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0090	AD	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - X TYPE EXTERNAL EQUIPED BELLOW	2000-02-03	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0091	..	Helium Shell	EUCLID	A0	MAGNET BENDIG COLD MASS ASSEMBLY - ASSEMBLY MANIFOLD M1-M2/N	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0092	..	Helium Shell	EUCLID	A2	MAGNET BENDING COLD MASS ASSEMBLY - CLAMP LINE M1-M2 ASSEMBLY	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0093	..	Helium Shell	EUCLID	A1	MAGNET BENDING COLD MASS ASSEMBLY - SHORT-CIRCUIT LINE M3 ASSEMBLY	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0094	..	Helium Shell	EUCLID	A2	MAGNET BENDING COLD MASS ASSEMBLY - END CLOSING LINE M3 ASSEMBLY	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0095	..	Helium Shell	EUCLID	A4	ASSEMBLY MANIFOLD M1-M2/N - COLLAR DIAMETRE 98	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0096	..	Helium Shell	EUCLID	A4	ASSEMBLY MANIFOLD M1-M2/N - COLLAR DIAMETER 66-53	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0097	..	Helium Shell	EUCLID	A4	ASSEMBLY MANIFOLD M1-M2/N - TRANSITION DIAMETER 60.3 / 50	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0098	..	Helium Shell	EUCLID	A2	ASSEMBLY MANIFOLD M1-M2/N - TUBE FOR AUXILIAIRY MANIFOLD	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0099	..	Helium Shell	EUCLID	A4	ASSEMBLY MANIFOLD M1-M2/N - SHEET MAINTENANCE CENTRAL TUBE	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0100	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASSY. - M1-M2 LINE SOCKET	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived

LHCMB__S0101	..	Helium Shell	EUCLID	A3	MAGNER BENDING COLD MASS ASSY. - N LINE SOCKET	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0102	..	Helium Shell	EUCLID	A2	CLAMP LINE M1-M2 ASSEMBLY - BASE CLAMP	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0103	..	Helium Shell	EUCLID	A2	CLAMP LINE M1-M2 ASSEMBLY - MEDIUM SHEET	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0105	..	Helium Shell	EUCLID	A3	CLAMP LINE M1-M2 ASSEMBLY - UPPER SHEET	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0106	..	Helium Shell	EUCLID	A3	CLAMP LINE M1-M2 ASSEMBLY - CLAMPING FLANGE	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0107	..	Helium Shell	EUCLID	A3	CLAMP LINE M1-M2 ASSEMBLY - CENTRING PIN FOR CLAMP	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0108	..	Helium Shell	EUCLID	A2	SHORT-CIRCUIT LINE M3 ASSEMBLY - LENGHTENING BUS-BAR	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0109	..	Helium Shell	EUCLID	A4	SHORT-CIRCUIT LINE M3 ASSEMBLY - TIGHTENING FLANGE	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0110	..	Helium Shell	EUCLID	A3	SHORT-CIRCUIT LINE M3 ASSEMBLY - ISOLATING HALF FLANGE	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0111	..	Helium Shell	EUCLID	A4	SHORT-CIRCUIT LINE M3 ASSEMBLY - ANGLE CLAMP SUPPORT	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0112	..	Helium Shell	EUCLID	A4	SHORT-CIRCUIT LINE M3 ASSEMBLY - STOP CENTRING	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0113	..	Helium Shell	EUCLID	A2	END CLOSING LINE M3 ASSEMBLY - END CLOSING LINE M3	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0114	..	Helium Shell	EUCLID	A2	END CLOSING LINE M3 ASSEMBLY - ISOLATING TUBE	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0115	..	Helium Shell	EUCLID	A4	END CLOSING LINE M3 ASSEMBLY - ISOLATING RING	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0116	..	Helium Shell	EUCLID	A3	SHORT-CIRCUIT LINE M3 ASSEMBLY - SHEET BRAZED SUPRA	2000-02-07	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0118	..	Helium Shell	AUTOCAD	A0	SUPPORT FIT EQUIPMENT - SYNOPTIC	2000-03-07	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0119	AB	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASSY. - DIODE CONTAINER SUPPORT	2000-03-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0120	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASSY. - GUIDE RING	2000-03-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0121	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASSY. - WELDING FLARE	2000-03-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0122	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASSY. - MALE WELDING NOZZLE	2000-03-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0123	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASSY. - COVER	2000-03-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0127	..	Helium Shell	EUCLID	A3	MAGNET BENDIND COLD MASS ASSY. - WELDING COVER	2000-03-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0128	..	Helium Shell	EUCLID	A2	MAGNET BENDING COLD MASS ASSY. - DIODE CONTAINER TEE	2000-03-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0129	AA	Helium Shell	EUCLID	A1	MAGNET BENDING COLD MASS ASSY. - DIODE CONTAINER	2000-03-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0130	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASSY. - DIODE CONTAINER TEE PLUG	2000-03-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0131	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASSY. - DIODE CONTAINER PLUG	2000-03-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0142	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASSY. - CONCAVE SHELL - STT WELDING	2000-03-29	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0143	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASSY. - CONVEX SHELL - STT WELDING	2000-03-29	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMB__S0144	AA	Helium Shell	AUTOCAD	A1	SUPPORT FIT EQUIPMENT - SLIDE	2000-03-30	J.FORESTIER	M.GENET	F.SAVARY	Archived
LHCMB__S0145	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - ROLLER	2000-03-30	J.FORESTIER	M.GENET	F.SAVARY	Archived
LHCMB__S0146	AA	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - AXLE	2000-03-30	J.FORESTIER	M.GENET	F.SAVARY	Archived
LHCMB__S0147	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - SPACER	2000-03-30	J.FORESTIER	M.GENET	F.SAVARY	Archived
LHCMB__S0148	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - CENTRING (MONORAIL)	2000-03-30	J.FORESTIER	M.GENET	F.SAVARY	Archived
LHCMB__S0149	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - HEXAGON SOCKET HEAD SHOULDER SCREW	2000-03-30	J.FORESTIER	M.GENET	F.SAVARY	Archived
LHCMB__S0150	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - PIN FOR CENTRING (RING)	2000-03-30	J.FORESTIER	M.GENET	F.SAVARY	Archived
LHCMB__S0151	..	Helium Shell	AUTOCAD	A0	SUPPORT FIT EQUIPMENT- MAIN SUPPORT FOR RING	2000-03-30	J.FORESTIER	M.GENET	F.SAVARY	Archived

LHCMB__S0152	..	Helium Shell	AUTOCAD	A0	SUPPORT FIT EQUIPMENT - MAIN SUPPORT FOR MONORAIL	2000-03-30	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0153	..	Helium Shell	AUTOCAD	A2	SUPPORT FIT EQUIPMENT - RING SUPPORT PLATE	2000-03-30	J.FORESTIER	M.GENET	F.SAVARY	Archived
LHCMB__S0154	..	Helium Shell	AUTOCAD	A2	SUPPORT FIT EQUIPMENT - MONORAIL SUPPORT PLATE	2000-03-30	J.FORESTIER	M.GENET	F.SAVARY	Archived
LHCMB__S0155	..	Helium Shell	AUTOCAD	A1	SUPPORT FIT EQUIPMENT - OUTSIDE CYLINDER GUIDE FOR FOOT	2000-03-30	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0156	..	Helium Shell	AUTOCAD	A2	SUPPORT FIT EQUIPMENT - INSIDE CYLINDER GUIDE FOR FOOT	2000-03-30	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0157	..	Helium Shell	AUTOCAD	A3	SUPPORT FIT EQUIPMENT - CENTRING PLATE FOR FOOT	2000-03-30	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0158	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - ADJUSTING SCREW FOR FOOT PLANE	2000-03-30	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0159	..	Helium Shell	AUTOCAD	A3	SUPPORT FIT EQUIPMENT - SHIM FOR FOOT SUPPORT	2000-03-30	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0160	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - SUPPORT FOOT LINEAR GUIDANCE PIN	2000-03-30	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0161	..	Helium Shell	AUTOCAD	A2	SUPPORT FIT EQUIPMENT - TAPPED HOLE MACHINING M24X2	2000-03-30	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0162	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - AXLE FOR PAD	2000-03-30	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0163	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - MECHANICAL STOP UNIT FOR MONORAIL	2000-03-30	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0164	..	Helium Shell	AUTOCAD	A2	SUPPORT FIT EQUIPMENT - FRAME FOR CEMENT (MONORAILS & RING)	2000-03-30	J.FORESTIER	M.GENET	F.SAVARY	Archived
LHCMB__S0165	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - KNUCKLE MODIFICATION	2000-07-19	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0166	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - HEADLESS GUIDE BUSH FOR KNUCKLE	2000-07-21	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0167	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - SQUARE FOR ROTATION LOCKING	2000-07-20	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0168	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - SQUARE FOR TRANSLATION LOCKING	2000-07-21	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0169	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - STOP FOR SLIDE ADJUST	2000-07-25	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0170	..	Helium Shell	AUTOCAD	A1	SUPPORT FIT EQUIPMENT - MODIF OF TURNING ROLLER TYPE CZB40 - ASSEMBLY	2000-07-28	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0171	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - MODIFICATION OF TURNING ROLLER - HAUNCH	2000-07-28	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0172	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT -MODIFICATION OF TURNING ROLLER -PLATE FOR SCREW	2000-07-28	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0173	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - MODIFICATION OF TURNING ROLLER - FIXING ROUND	2000-07-28	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0174	..	Helium Shell	AUTOCAD	A3	SUPPORT FIT EQUIPMENT - SLIDE BASEPLATE BEFORE WELDING	2000-08-17	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0175	..	Helium Shell	AUTOCAD	A3	SUPPORT FIT EQUIPMENT - SLIDE ALONGSIDE PLATE BEFORE WELDING	2000-08-17	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0176	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - ROUND SLIDE AXLE BEFORE WELDING	2000-08-17	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0177	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASSY - CLAMP LINE M1 ASSEMBLY	2000-09-04	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0178	..	Helium Shell	EUCLID	A2	MAGNET BENDING COLD MASS ASSY - CLAMP LINE M2 ASSEMBLY	2000-09-04	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0179	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASSY - END CLOSING LINE M1	2000-09-04	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0180	..	Helium Shell	EUCLID	A2	MAGNET BENDING COLD MASS ASSY - END CLOSING LINE M3	2000-09-04	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0181	..	Helium Shell	EUCLID	A1	MAGNET BENDING COLD MASS ASSY - M3 CLAMP ASSEMBLY	2000-09-04	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0182	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - FIXING PLAT FOR STOP (SLIDE ADJUST)	2000-09-01	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0183	..	Helium Shell	EUCLID	A1	MAGNET BENDING COLD MASS ASSY - END CLOSING MANIFOLD M2	2000-09-05	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0186	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - SPACER TUBE	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0184	..	Helium Shell	EUCLID	A1	MAGNET BENDING COLD MASS ASS. -CLOSING SLEEVE	2001-09-05	O.CHOISNET			
LHCMB__S0190	..	Helium Shell	EUCLID	A2	MAGNET BENDING COLD MASS ASSY - N LINE SUPPORT ASS.	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived

LHCMB__S0192	..	Helium Shell	EUCLID	A2	N LINE SUPPORT ASS. - ANGLE SUPPORT	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0193	..	Helium Shell	EUCLID	A2	N LINE SUPPORT ASS. - COLLAR SUPPORT TUBE DIAM. 70	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0194	..	Helium Shell	EUCLID	A2	M3 CLAMP ASSEMBLY - INSULATION CLAMP	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0195	..	Helium Shell	EUCLID	A3	M3 CLAMP ASSEMBLY - EXTENSION BUS-BAR CLAMP LINE M3	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0196	..	Helium Shell	EUCLID	A2	MAGNET BENDING COLD MASS ASSY - EXTENSION BUS-BAR LINE M3	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0197	..	Helium Shell	EUCLID	A4	LENGHTENING ASSEMBLY- BRAZING PART	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0198	..	Helium Shell	EUCLID	A3	BRAZING CLAMP LINE M3 - TIGHTENING SHEET	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0199	..	Helium Shell	EUCLID	A3	LENGHTENING CLAMP LINE - CLOSING CLSMP	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0200	..	Helium Shell	EUCLID	A2	INSULATION CLAMP - HALF UPPER CLAMP	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0201	..	Helium Shell	EUCLID	A2	INSULSTION CLAMP - HALF LOWER CLAMP	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0202	..	Helium Shell	EUCLID	A2	CLAMP LINE M2 ASSEMBLY - UPPER SHEET	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0203	..	Helium Shell	EUCLID	A3	CLAMP LINE M2 ASSEMBLY - HALF SHEET LEFT	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0204	..	Helium Shell	EUCLID	A3	CLAMP LINE M2 ASSEMBLY - HALF SHEET RIGHT	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0205	..	Helium Shell	EUCLID	A2	CLAMP LINE M2 ASSEMBLY - MEDIUM SHEET 2	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0206	..	Helium Shell	EUCLID	A2	CLAMP LINE M2 ASSEMBLY - LOWER SHEET	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0207	..	Helium Shell	EUCLID	A3	CLAMP LINE M2 ASSEMBLY - STOP SHEET	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0208	..	Helium Shell	EUCLID	A3	CLAMP LINE M1 ASSEMBLY - UPPER SHEET	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0209	..	Helium Shell	EUCLID	A3	CLAMP LINE M1 ASSEMBLY - HALF SHEET RIGHT	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0210	..	Helium Shell	EUCLID	A2	CLAMP LINE M1 ASSEMBLY - MEDIUM SHEET	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0211	..	Helium Shell	EUCLID	A2	CLAMP LINE M1 ASSEMBLY - LOWER SHEET	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0212	..	Helium Shell	EUCLID	A3	CLAMP LINE M1 ASSEMBLY - HALF SHEET LEFT	2000-09-06	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0213	..	Helium Shell	AUTOCAD	A3	SUPPORT FIT EQUIPMENT - HYDRAULIC JACK	2000-09-12	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0214	..	Helium Shell	EUCLID	A2	END CLOSING FLUSHING M3 ASSY - TUBE ASSEMBLY	2000-10-04	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0215	..	Helium Shell	EUCLID	A3	END CLOSING FLUSHING M3 ASSY - COVER	2000-10-04	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0217	..	Helium Shell	AUTOCAD	A3	SUPPORT FIT EQUIPMENT - TURNING DEVICE SUPPORT FLAT	2000-11-17	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0218	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - AXLE FIXING FOR TURNING DEVICE	2000-11-17	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0219	..	Helium Shell	AUTOCAD	A3	SUPPORT FIT EQUIPMENT - PRICE INQUIRY FOR TURNING DEVICE	2000-11-20	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0235	..	Helium Shell	EUCLID	A2	DIPOLE CAPILLARY ASSEMBLY - END CAP FIXATION PIECE	2001-01-17	T.RENAGLIA	C.MENOT	D.BOZZINI	Archived
LHCMB__S0236	..	Helium Shell	EUCLID	A3	LYRE S. FLUSHING ASS. LINE M2 - CLOSING FLANGE	2001-01-26	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0237	..	Helium Shell	EUCLID	A3	N LINE SUPPORT ASS. - BASE SUPPORT	2001-01-29	R.PERRET	M.GENET	F.SAVARY	Archived
LHCMB__S0238	..	Helium Shell	EUCLID	A4	N LINE SUPPORT ASS. - SPACER FOR BASE	2001-01-29	R.PERRET	M.GENET	F.SAVARY	Archived
LHCMB__S0239	..	Helium Shell	AUTOCAD	A1	SUPPORT FIT EQUIPMENT - MODIF OF TURNING ROLLER TYPE CZC40 - ASSEMBLY	2001-02-02	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0240	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT -MODIF OF TURNING ROLLER CZC40-HEIGHTENING PLATE	2001-02-02	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0241	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - MODIF OF TURNING ROLLER CZC40 - PLATE	2001-02-02	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0242	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - MODIF OF TURNING ROLLER CZC40 - SUPPORT PLATE	2001-02-05	S.DESCOINS	M.GENET	F.SAVARY	Archived

LHCMB__S0243	..	Helium Shell	EUCLID	A3	M3 CLAMP ASSEMBLY - LENGTENING ASSEMBLY	2001-02-05	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0244	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - N LINE PLUG	2001-02-14	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0245	..	Helium Shell	EUCLID	A3	MAGNET BENDING COLD MASS ASS. - N LINE EXTREMITY ASS.	2001-02-14	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0246	..	Helium Shell	EUCLID	A4	ENS. EXTREMITE LIGNE N - EMBOUT D'EXTREMITE	2001-02-14	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0247	..	Helium Shell	EUCLID	A4	N LINE EXTREMITY ASS. - ADAPTATOR #1.1 48/#1.1 66	2001-02-14	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0248	..	Helium Shell	EUCLID	A3	N LINE EXTREMITY ASS. - ROTATING FLANGE	2001-02-14	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0249	..	Helium Shell	AUTOCAD	A4	SUPPORT FIT EQUIPMENT - ROUND OF SPACING ADJUSTING OF THE SLIDES	2001-02-15	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0250	..	Helium Shell	AUTOCAD	A3	SUPPORT FIT EQUIPMENT - HYDRAULIC SCHEME	2001-02-21	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0252	..	Helium Shell	AUTOCAD	A0	SUPPORT FIT EQUIPMENT - ASSEMBLY OF TOOLING FOR TWIST ADJUS	2001-02-26	S.DESCOINS	M.GENET	F.SAVARY	Archived
LHCMB__S0253	..	Helium Shell	EUCLID	A2	CAPILLARY TRANSPORT TOOL ASSY. - HALF CLAMP	2001-02-28	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0254	..	Helium Shell	EUCLID	A0	CAPILLARY TRANSPORT TOOL ASSY. - GALLOWS	2001-02-28	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0255	..	Helium Shell	EUCLID	A3	CAPILLARY TRANSPORT TOOL ASSY. - HALF CLAMP	2001-02-28	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0256	..	Helium Shell	EUCLID	A1	CAPILLARY TRANSPORT TOOL ASSY. - PROTECTION TUBE CONTAINER	2001-02-28	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0257	..	Helium Shell	EUCLID	A2	CAPILLARY TRANSPORT TOOL ASSY. - LATERAL SUPPORT TUBE	2001-02-28	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0258	..	Helium Shell	EUCLID	A1	DIODE BOX WELDING TOOL - SPLIT COLLAR ASSY.	2001-03-09	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0259	..	Helium Shell	EUCLID	A3	DIODE BOX WELDING TOOL - SPACING SCREW TOOL	2001-03-09	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMB__S0261	..	Helium Shell	EUCLID	A2	DIODE BOX WELDING TOOL - SUPPORT SHEET	2001-03-25	O.CHOISNET	M.GENET	F.SAVARY	Archived
LHCMBA_S0001	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - GENERAL ASS. TYPE A - STD TEST	1999-07-07	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBA_S0002	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - LYRE S. TYPE A ASS. STD TEST	1999-07-07	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBA_S0003	AC	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - LYRE S. TYPE A ASS. STD TEST	1999-07-07	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBA_S0004	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - CONNECT. S. TYPE A ASS. STD TEST	1999-07-07	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBA_S0005	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - CONNECT. S. TYPE A ASS. STD TEST	1999-10-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBA_S0007	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - GENERAL ASS. TYPE A - FULL TEST	2000-11-24	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBA_S0008	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - CONNECT. S. TYPE A ASS. FULL TEST	2000-11-30	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBA_S0009	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - CONNECT. S. TYPE A ASS. FULL TEST	2000-11-30	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBA_S0010	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - LYRE S. TYPE A ASS. FULL TEST	2000-11-30	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBA_S0011	AC	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - LYRE S. TYPE A ASS. FULL TEST	2000-11-30	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBB_S0001	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - GENERAL ASS. TYPE B - STD TEST	1999-07-07	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBB_S0002	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - LYRE S. TYPE B ASS. STD TEST	1999-07-07	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBB_S0003	AC	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - LYRE S. TYPE B ASS. STD TEST	1999-07-07	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBB_S0004	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - CONNECT. S. TYPE B ASS. STD TEST	1999-07-07	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBB_S0005	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - CONNECT. S. TYPE B ASS. STD TEST	1999-10-08	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBB_S0007	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - GENERAL ASS. TYPE B - FULL TEST	2000-11-24	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBB_S0008	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - CONNECT. S. TYPE B ASS. FULL TEST	2000-11-30	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBB_S0009	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - CONNECT. S. TYPE B ASS. FULL TEST	2000-11-30	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCMBB_S0010	AB	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - LYRE S. TYPE B ASS. FULL TEST	2000-11-30	D.GALHAUT	M.GENET	F.SAVARY	Archived

LHCMBB_S0011	AC	Helium Shell	EUCLID	A0	MAGNET BENDING COLD MASS ASS. - LYRE S. TYPE B ASS. FULL TEST	2000-11-30	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCDCCAA0028	AB	Miscellaneous	AUTOCAD	A3	POWERING SHEME OF SPOOL CORRECTORS - MCD. MCO. AND MCS VERSION 6.1	1999-02-03	D.GROS	M.GENET	P.PROUDLOCK	Archived
LHCDCCMA0008	..	Miscellaneous	EUCLID	A4	FLANGE - AUXILIARY BUS BAR LINE	1998-05-22	V.PETROV	T.RENAGLIA	J.TOCK	Archived
LHCDCCMA0040	AB	Miscellaneous	EUCLID	A3	FLEXIBLE HOSE - AUXILIARY BUS BAR LINE	1999-04-26	V.PETROV	T.RENAGLIA	B.SKOCZEN	Archived
LHCDCCMA0041	..	Miscellaneous	EUCLID	A3	SUPPORTS OF LINE N - -	1999-04-26	V.PETROV	T.RENAGLIA	B.SKOCZEN	Archived
LHCDCCMA0042	..	Miscellaneous	EUCLID	A4	CLAMP - FOR SLIDING SUPPORT	1999-04-26	V.PETROV	T.RENAGLIA	B.SKOCZEN	Archived
LHCDCCMA0043	..	Miscellaneous	EUCLID	A4	CLAMP - FOR FIXING SUPPORT	1999-04-26	V.PETROV	T.RENAGLIA	B.SKOCZEN	Archived
LHCDCCMA0072	AA	Miscellaneous	EUCLID	A2	AUXILIARY BUS BAR LINE - FOR MB	2000-01-28	S.NIKITINE	T.RENAGLIA	A.JACQUEMOD	Archived
LHCDCCMA0073	AA	Miscellaneous	EUCLID	A3	BENDING MAGNET & QUADRUPOLE - N LINE TUBE #1 53	2000-03-02	D.GALHAUT	M.GENET	F.SAVARY	Archived
LHCDQDDP0002	AC	Miscellaneous	AUTOCAD	A1	DIPOLE DIODE-ASSEMBLY	1998-05-06	ACROTECNA	J.FRAIGNE	D.HAGEDORN	Archived
LHCLBA_S0003	..	Miscellaneous	AUTOCAD	A0	CROSS SECTION X-X ON TWIN SUP. SIDE - -	2000-06-08	O.CRETTIEZ	M.GENET	J.TOCK	Archived
LHCMB_TW0003	..	Miscellaneous	AUTOCAD	A0	TOOL PRESS FOR WELDING. TYPE A - WELDING PRESS ASSEMBLY	1998-02-02	T.SAHNER	M.GENET	G.SPIGO	Archived
LHCMCDOA0001	AA	Miscellaneous	AUTOCAD	A0	DECAPOLE/OCTUPOLE CORRECTOR MAGNET - GENERAL ASSEMBLY	1999-04-30	SENER	G.LAURENT	M.KARPPINEN	Archived
LHCMCSMG0001	AB	Miscellaneous	AUTOCAD	A0	GENERAL ASSEMBLY - .	1999-06-11	H.DURAND	G.LAURENT	A.IJSPEERT	Archived
LHCMMWED0008	AA	Miscellaneous	AUTOCAD	A4	WARM MAGNETIC MEASUREMENT - SPACE FOR MAGNETIC MEASUREMENT	1998-03-17	N.MERMILLOD	G.PATTI	J.BILLAN	Archived
LHCQBX_P0004	AC	Miscellaneous	EUCLID	A2	DIPOLE COLD MASS ASSEMBLY - HELIUM HEAT EXCHANGER TYPE MBP	1997-09-26	P.TRILHE	W.CAMERON	F.SAVARY	Archived
LHCVCC__0001	AB	Miscellaneous	EUCLID	A3	MAGNET BENDING AND QUADRUPOLE - COLD BORE TUBE #1.01 53 - TYPE 1	1998-06-12	V.KLEIMENOV	M.GENET	F.SAVARY	Archived

ANNEX B: PROCUREMENTS, PROCEDURES AND TESTS UNDER THE RESPONSIBILITY OF THE CONTRACTOR

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B2: Inspection and Test Plan (ITP) for dipole cold mass
B3: Requirements for the clean area
B4: Requirements for the superconducting cable during electrical insulation
B5: Insulation of copper wedges
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B24: Definition of the longitudinal bevelling of the half-cylinders
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ANNEX B1: MAGNETIC FIELD CHARACTERISTICS

1. SCOPE OF THE MEASUREMENTS

The purpose of field quality measurements at the Contractor's premises is:

- To allow the possibility of fine-tuning the magnetic length, by adjusting the number of magnetic laminations in the yoke blocks (maximum 5 laminations).
- To detect assembly errors or faulty components at an early stage of the production in order to allow remedial actions.

The aim is also to detect drifts in the evolution of field quality, to steer the production. For this reason, magnetic measurements carried out at the Contractor's premises shall be sent to CERN by e-mail within 24 hours to ensure an on-line analysis and, if needed, a fast feedback.

CERN will take full responsibility for the field quality of magnets that have followed the correct assembly procedure. Magnetic field measurements are summarised in the next Section. Tolerances on the magnetic length and corrective actions are analysed in Section 3. Acceptance windows for the multipoles to detect assembly errors or faulty components are given in Section 4.

CERN may find it necessary to fine-tune the field quality during production, by small changes of the pole shim thickness or of the geometry of the copper wedges in the coil layers. CERN will take full responsibility for defining these changes, for supplying the components under its responsibility and for the subsequent field quality obtained. Such fine-tuning will not affect the Contractor tooling. Tolerances and corrective procedures for fine-tuning are described in Section 5, which is given for information and has no contractual validity.

2. DEFINITIONS OF MAGNETIC MEASUREMENTS

2.1. Definitions

The field quality in the main LHC dipoles determines the envelope of stable particle trajectories and therefore it affects the performances of the machine. The relative difference in the main magnetic fields provided by the different dipoles (for the same current value) must not differ by more than a few 10^{-4} to provide the correct orbit to the beam. Relative deviations of the magnetic field from the ideal one must also be of the order of 10^{-4} to give a sufficiently wide stability domain around the nominal orbit.

The field quality is expressed by a power series, whose coefficients are called the multipolar (or harmonic) field errors. They are given in relative units of 10^{-4} with respect to the main dipole field, that is the order of magnitude needed for the good performances of the machine. Multipolar errors are normalised at a reference radius of 17 mm, that approximately corresponds to 2/3 of the magnet aperture. The definition of the apertures, the field errors and the reference system used can be found in the attached document LHC-M-ES-0001 "Field error naming conventions for LHC magnets" (Annex F1).

The magnetic field is therefore characterised by the sequence of the multipolar coefficients b_n and a_n, where n is order of the component. The coefficients b and a are called the normal and skew terms respectively. Please note that for symmetry reasons linked to the two-in-one design of the dipole cold masses, the even terms $b_{2,}\, b_{4,}\, b_{6\,.}$ …change sign from Aperture 1 to Aperture 2, whilst the odd terms $b_{3,}\, b_{5,}\, b_7$…have the same sign in both apertures. Components up to order n=11 are considered, the higher orders having little influence on beam dynamics.

2.2. Magnetic measurements at the Contractor’s premises

Magnetic measurements provide the values of the magnetic length, of the main field, of its direction, and the multipolar components. In each aperture the integral value in 20 consecutive sections along the 15 m axis of the magnet is measured. Then, an integral value for the whole aperture is worked out. Magnetic measurements are carried out for the collared coil, and for the assembled cold mass. They are specified in Annex B18

2.3. Influence of the deviations from nominal geometry on field errors

Field errors measured at the Contractor are due to misplacements of conductors and other components with respect to the nominal geometry. Therefore, the field quality is a relevant indicator of the capability of the Contractor of achieving the nominal design within the specified geometrical tolerances. Contributions to field imperfections can be split in three parts.

- Odd normal multipoles $b_{3,}\ b_{5,}\ b_7 \ldots$ are due to contributions that respect the up-down and the left-right symmetry. They are mainly determined by the positioning of the conductors in the collared coil. The iron yoke gives an additional contribution to $b_{3.}$
- Even normal multipoles $b_{2,}\ b_{4,}\ b_6 \ldots$ are due to contributions that do not respect a left-right symmetry. They are mainly determined by the positioning of the iron yoke and insert.
- Skew multipoles $a_{2,}\ a_{3,}\ a_4 \ldots$ are determined by contributions following other symmetries.

Odd normal multipoles are expected to be mainly determined by the collared coil, whilst the main contribution to even normal multipoles is expected to be due to the assembled cold mass. Non-zero values of the odd normal multipoles are chosen in the design to compensate the contribution of persistent currents that appear when the conductor reaches the superconductive state.

3. TOLERANCES ON MAIN FIELD MODULE AND DIRECTION

The integrated field is defined as the sum of the main field B_1 along the magnet axis $\int_{-\infty}^{+\infty} B_1(s)ds$.

The magnetic length is defined as $L_m = \frac{\int_{-\infty}^{+\infty} B_1(s)ds}{B_0}$, where B_0 is the main field in the central part.

The integrated field may vary due to

- the variation in the yoke packing factor (± 0.25 %, see also Annex B20);
- the variation in the coil length (± 3 mm over 15 m, see the relevant drawings);
- the tolerance on the colinearity of the bending field in the two magnet apertures.

The standard deviation of the relative variation of the field integral must not exceed $5\ 10^{-4}$ the main field. The average magnetic length of the cold masses shall be 14343 mm with a tolerance of ± 15 mm. The angle between the average direction of the main field and the midplane of the cold mass has a tolerance of ± 1 mrad. The local value of the angle measured over 750 mm has a tolerance of ± 3 mrad.

The acceptance criteria for the magnetic length of the cold masses will be based on a (expected) standard distribution. Referring to the Figure B1.1, the magnetic lengths of the cold masses shall be distributed following the population inherent to a standard distribution with a sigma of less than 5 mm.

Example: for a production of 4 octants (i.e. 624 cold masses), the acceptable population for:

– the sectors III	(for each area)	would be less than 15 cold masses
– the sectors II	(“)	would be less than 85 cold masses
– the sectors I	(“)	would be more than 212 cold masses

For the example (production of 4 octants) the acceptance criteria on the production would be:

- Total number of cold masses in each area III ≤ 15
- Total number of cold masses in two adjacent areas II and III ≤ 100

Under these conditions, the total number of cold masses in area I shall be larger than 212.

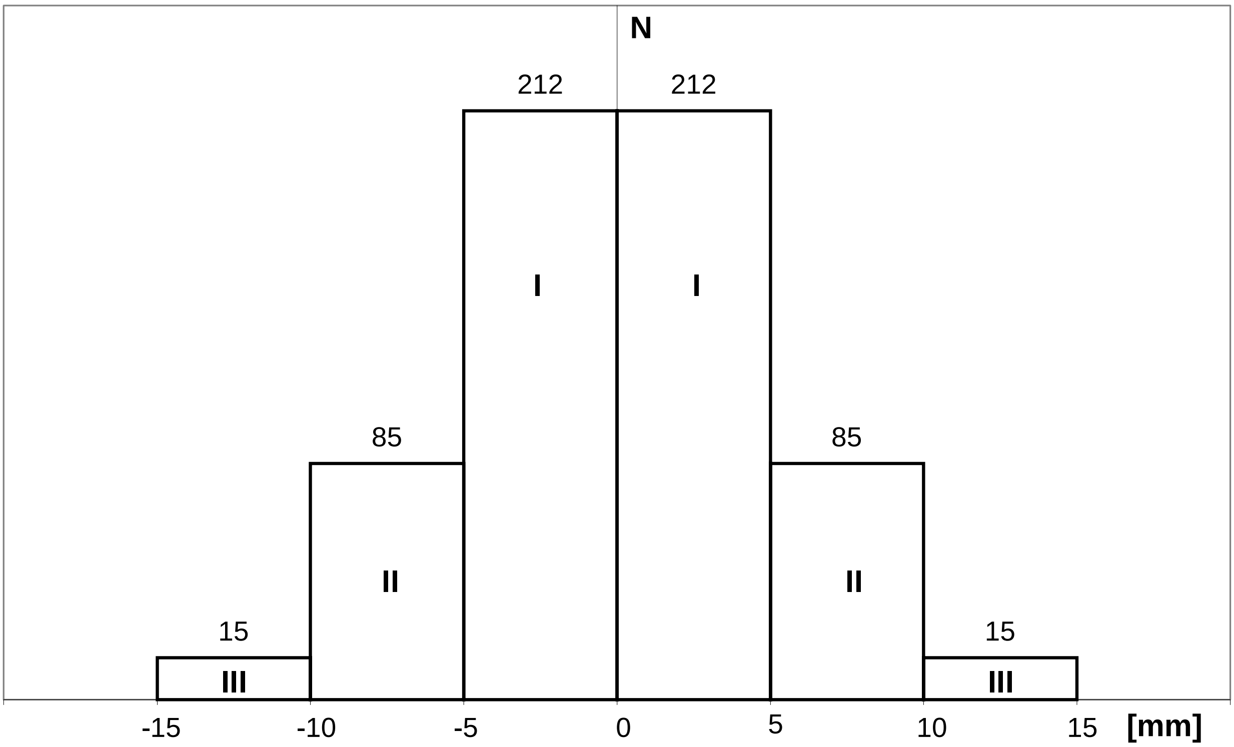

Figure B1.1 – Acceptable distribution for the magnetic length of the produced cold mass

3.1. Corrective action for field integral

Field integral can be controlled on the basis of the magnetic measurements carried out on the collared coil. Iron laminations can be added to or removed from a yoke pack to match the constraint on the standard deviation of the field integral (the method is described in Annex B19).

4. TOLERANCES ON MULTIPOLES TO DETECT ASSEMBLY ERRORS OR FAULTY COMPONENTS

The allowed range for the magnetic multipoles measured in the collared coil and in the assembled cold mass are given in Table B1.1 and in Table B1.2 respectively. Multipole values beyond these limits imply a fault in the assembling procedures or in the component geometry: in this case, either the collared coil or the assembled cold mass shall be taken out of the manufacturing line and the non conformity investigated in collaboration between CERN and the Contractor.

According to the experience acquired with the prototype programme, the iron yoke and the iron insert only produce a shift in the low-order odd normal components b_3 (+ 3.2 units), b_5 (+ 0.2 units) and b_7 (- 0.2 units). Results concerning the available measurements on the P2 prototypes are given in Annex F3 (LHC Project Report 467). The specified values will be updated using the measurements of pre-series magnets.

Examples of assembly errors which can be detected immediately after collaring are the use of incorrectly sized coils, wrongly placed copper wedges, incorrect thickness of polyimide insulation, incorrect sizing of the pole shims, incorrect geometry of the coil end regions, incorrect collaring procedures. An example of an assembly error detectable after welding the shrinking cylinder is a cold mass twist.

Table B1.1 – Acceptance limits for the multipoles measured in the collared coils, in units of 10^{-4} at 17 mm reference radius.

	Min	Max		Min	Max
b_1	-10.0	10.0	a_1	-10.0	10.0
b_2	-2.1	2.1	a_2	-2.1	2.1
b_3	-7.4	1.0	a_3	-1.5	1.5
b_4	-0.9	0.9	a_4	-0.9	0.9
b_5	-2.0	1.0	a_5	-0.6	0.6
b_6	-0.3	0.3	a_6	-0.3	0.3
b_7	0.5	0.9	a_7	-0.2	0.2
b_8	-0.2	0.2	a_8	-0.2	0.2
b_9	0.2	0.4	a_9	-0.1	0.1
b_{10}	-0.1	0.1	a_{10}	-0.1	0.1
b_{11}	0.7	0.9	a_{11}	-0.1	0.1

Table B1.2 – Acceptance limits for the multipoles measured in the assembled cold mass, in units of 10^{-4} at 17 mm reference radius.

	Min	Max		Min	Max
b_1	-10.0	10.0	a_1	-10.0	10.0
b_2	-2.1	2.1	a_2	-2.1	2.1
b_3	-4.2	4.2	a_3	-1.5	1.5
b_4	-0.9	0.9	a_4	-0.9	0.9
b_5	-1.8	1.2	a_5	-0.6	0.6
b_6	-0.3	0.3	a_6	-0.3	0.3
b_7	0.3	0.7	a_7	-0.2	0.2
b_8	-0.2	0.2	a_8	-0.2	0.2
b_9	0.2	0.4	a_9	-0.1	0.1
b_{10}	-0.1	0.1	a_{10}	-0.1	0.1
b_{11}	0.7	0.9	a_{11}	-0.1	0.1

5. REQUIRED FIELD QUALITY AND CORRECTIVE ACTIONS (FOR INFORMATION ONLY)

Field quality requirements to ensure the nominal performance of the accelerator are tighter than the ranges defined in Tables B1.1 and B1.2 to detect assembly errors or faulty components. CERN may find it necessary to fine-tune field quality during production, taking full responsibility of the actions taken.

5.1. Tolerance on multipoles required by beam dynamics

We assume that the multipoles follow a Gaussian distribution. Maximal values for the standard deviation of each multipole and optimal values for the averages for the collared coil are given in Table B1.3. The table is provisional and will be updated on the base of the experience acquired during the pre-series. The average values of the produced dipoles must agree with the optimal average within one sigma, with the exception of the b_5 case where an agreement within 1/3 of sigma is required.

For the assembled cold mass the same criteria is required, with the same sigma and averages with the exception of b_3 (average 0), b_5 (average - 0.3) and b_7 (average 0.5). Corrective actions may be taken during the production to steer the average within these control limits.

Table B1.3 – Field quality requirements from beam dynamics for the multipoles measured in the collared coil, in units of 10^{-4} at 17 mm reference radius.

	Average	Sigma		Average	Sigma
b_2	0.0	0.7	a_2	0.0	0.7
b_3	-3.2	1.5	a_3	0.0	0.5
b_4	0.0	0.3	a_4	0.0	0.3
b_5	-0.5	0.4	a_5	0.0	0.2
b_6	0.0	0.1	a_6	0.0	0.1
b_7	0.7	0.1	a_7	0.0	0.1
b_8	0.0	0.1	a_8	0.0	0.1
b_9	0.3	0.1	a_9	0.0	0.1
b_{10}	0.0	0.1	a_{10}	0.0	0.1
b_{11}	0.8	0.1	a_{11}	0.0	0.1

5.2. Corrective actions for odd normal multipoles

These actions can be taken at the level of the fabrication of the collared coil. The choice of shim thickness has a strong impact on odd normal multipoles, thus allowing to steer the production within a certain range. Shims are also used to impose the right azimuthal pre-stress in the coil. The allowed window of ± 15 MPa in the azimuthal pre-stress corresponds to a range of ± 0.12 mm variation of the shim thickness; the impact of a decrease in the shim thickness by 0.1 mm has been measured at CERN on short prototypes, and it is shown in Table B1.4. One can see that relevant actions to steer the average of the low-order odd multipoles b_3, b_5 and b_7 on the optimal values can be taken.

Table B1.4 – Influence on odd multipoles of a shim thickness reduced by 0.1 mm.

	Inner shim	Outer shim
Δb_3	-1.84	-1.36
Δb_5	0.24	0.05
Δb_7	-0.11	0.00
Δb_9	0.04	0.00
Δb_{11}	0.00	0.00

It is recalled here that in the event of decollaring and recollaring, quench heaters, ground insulation, shim retainers and coil protection sheets shall be scrapped and replaced by new ones without exception (see also Section 6.4.2).

5.3. Corrective actions for even normal multipoles

Even normal multipoles are given by the contribution of the iron yoke and of the insert. Modifications of the insert shape can be used to change b_2 and b_4. Different types of modifications have been tested on some prototypes and the results are summarised in the Annex F3 (LHC Project Report 467).

5.4. Corrective actions for skew multipoles

Skew multipoles are determined by asymmetries in the coils or in the components placed around them. In the magnets measured up to now they are shown to be not critical. Drifts in these components should be corrected by a control of the assembling procedures and sorting procedures (B.13) and of the geometric dimensions of the magnet components.

ANNEX B2: INSPECTION AND TEST PLAN FOR THE DIPOLE COLD MASS

NOTE: Important remarks

1. The ITP is concerning only the MANDATORY TESTS. The other type of tests (Recommended by CERN or applied by the Contractor)) are NOT listed.

2. ALL the below listed tests includes DATA storage (and transfer to CERN) of the measured values

Step N.	Component name	P.B.S.Number	Test Description	6. TEST SPECIFICATION	Test Status	Title of report	Control test preformed by	Name of controller	Date of Test	Name of Supervisor	Date of Approval	Approval Notes	Remarks
1	Insulation of Copper wedges	1.1.1.1	Electrical Test	LHC-MMS/98-198 Rev.2.0 Annex B5: Insulation of copper wedges- Electrical checks									
2	Superconducting cable	1.1.1.1	Electrical Test during the cable insulation	LHC-MMS/98-198 Rev.2.0 Annex B7: Electrical Test during cable insulation- polyimide splicing and repair.									
3a	Inner/Outer Layers	1.1.1.1	Electrical -Test after curing - Measurement of DC resistance	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
3b	Inner/Outer Layers	1.1.1.1	Electrical -Test after curing – Complex impedance	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
3c	Inner/Outer Layers	1.1.1.1	Electrical -Test after curing – Insulation Resistance of Copper wedges	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
3d	Inner/Outer Layers	1.1.1.1	Electrical -Test after curing – Discharge (interturn voltage) test	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
4	Inner Layer	1.1.1.1.1.1	Inner layer measuring (sizes)	LHC-MMS/98-198 Rev.2.0 Annex B9: Mechanical tests and tolerances of the layers, poles and collared coils.									
5	Outer Layer	1.1.1.1.1.2	Outer layer measuring (sizes)	LHC-MMS/98-198 Rev.2.0 Annex B9: Mechanical tests and tolerances of the layers, poles and collared coils.									

6	Inner/Outer Layers	1.1.1.1	Electrical test of Layer jump and ends region under pressure	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
7a	Assembled Poles	1.1.1.1	Electrical tests after layers assembly – Insulation Resistance before splice soldering	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
7b	Assembled Poles	1.1.1.1	Electrical test of layers assembly - DC resistance	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
7c	Layer Jump	1.1.1.1	Electrical test after layers assembly – Resistance [DC] of the brazed joint	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
7d	Assembled Poles	1.1.1.1	Electrical test after layers assembly – complex impedance	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
7e	Assembled Poles	1.1.1.1	Electrical - Discharge (interturn voltage) test.	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
8	Assembled Poles	1.1.1.1	Poles measuring (sizes)	LHC-MMS/98-198 Rev.2.0 Annex B9: Mechanical tests and tolerances of the layers, poles and collared coils.									
9a	Collared Coils	1.1.1.1.1	Electrical Test after collaring - DC resistance of windings	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
9b	Collared Coils	1.1.1.1.1	Electrical Test after collaring - DC resistance of Q.H.	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
9c	Collared Coils	1.1.1.1.1	Electrical Test after collaring – complex impedance	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
9d	Collared Coils	1.1.1.1.1	Electrical Test after collaring - Capacity to Ground.	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
9e	Collared Coils	1.1.1.1.1	Electrical Test after collaring - Capacitance to dipole	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
9f	Collared Coils	1.1.1.1.1	Electrical Test after collaring - HV leakage current: poles to ground.	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									

9g	Collared Coils	1.1.1.1.1	Electrical Test after collaring - HV leakage current: upper to lower pole	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
9h	Collared Coils	1.1.1.1.1	Electrical Test after collaring - HV leakage current: Q.H. to coils.	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
9I	Collared Coils (Poles)	1.1.1.1.1	Electrical Test after collaring - Discharge (interturn) voltage test.	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
9l	Collared Coils (Dipole)	1.1.1.1.1	Electrical Test after collaring - Discharge (interturn) voltage test.	LHC-MMS/98-198 Rev.2.0 Annex B10: Electrical Tests of the layers, poles, and collared coils									
10	Collared Coils	1.1.1.1.1	Measurement of sizes of the collared coil	LHC-MMS/98-198 Rev.2.0 Annex B9: Mechanical tests and tolerances of the layers, poles and collared coils.									
11	Collared Coils	1.1.1.1.1	Warm magnetic measurement	LHC-MMS/98-198 Rev.2.0 Annex B18									
12a	Active Part / Cold Mass components	1.1.1.1	Electrical (Reception) Tests on cold mass components: collared coils	LHC-MMS/98-198 Rev.2.0 Annex B22 (Table A)									
12b	Active Part / Cold Mass components	1.1.1.1	Electrical (Reception) Tests on cold mass components: Spool pieces	LHC-MMS/98-198 Rev.2.0 Annex B22 (Table A)									
12c	Active Part / Cold Mass components	1.1.1.1	Electrical (Reception) Tests on cold mass components: Busbars (MB,QF, QD, AUX)	LHC-MMS/98-198 Rev.2.0 Annex B22 (Table A)									
13	Active Part Assembly	1.1.1.1	Yoke Closing Gap check & visual inspection	LHC-MMS/98-198 Rev.2.0 Annex B27									
14	Completed Cold Mass	1.1.1.1	Inspection of longitudinal welds	Safety Test LHC-MMS/98-198 Rev.2.0 Annex B33									
15	Active Part Assembly	1.1.1.1	Geometry : determination of the Theoretical Reference plane of the c.m., after the cylinder longitudinal welding	LHC-MMS/98-198 Rev.2.0 Annex B27									

16a	Active Part Assembly	1.1.1.1	Geometry : Alignment of the c.m. support bases	LHC-MMS/98-198 Rev.2.0 Annex B27									
16b	Active Part Assembly	1.1.1.1	Geometry : determination of the Theoretical Reference plane of the c.m., after the welding of the c.m. support bases	LHC-MMS/98-198 Rev.2.0 Annex B27									
17a	Cold Mass Assembly	1.1.1.1	Geometry : Sextupole correctors magnets alignment	LHC-MMS/98-198 Rev.2.0 Annex B28									
17b	Cold Mass Assembly	1.1.1.1	Geometry : Octupole/Decapole correctors magnets alignment	LHC-MMS/98-198 Rev.2.0 Annex B28									
18a	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: DC resistance of windings	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18b	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: DC resistance of Q.H.	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18c	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: check of localisation of spools voltage taps	LHC-MMS/98-198 Rev.2.0 Annex B22, Section 3									
18d	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: DC resistance of Spools	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18e	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: DC resistance of instrumentation	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18f	Cold Mass Assembly	1.1.1.1	Electrical – Test before end caps positioning: Complex impedance of Spools	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18g	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: Complex impedance	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									

18h	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: Capacitance to ground	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18i	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: Q.H. Capacitance to dipole	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18l	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: H.V. leakage current, magnet to ground	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18m	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: H.V. leakage current, Q.H. to coils	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18n	Cold Mass Assembly	1.1.1.1	Electrical – Test before end caps positioning: Poles (interturn voltage) test	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18o	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: Dipole Discharge (interturn voltage) test	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18p	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: external voltage taps	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18q	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: H.V. leakage current MB busbar to busbar	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18r	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: H.V. leakage current QF and QD busbar to ground	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18s	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: H.V. leakage current QF and QD busbar to busbar	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									

18t	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: Isolation Resistance Spool busbar to busbar	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18u	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: Isolation Resistance (QF and QD)	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
18v	Cold Mass Assembly	1.1.1.1	Electrical - Test before end caps positioning: Isolation Resistance Spool Busbar to ground	LHC-MMS/98-198 Rev.2.0 Annex B22, Table B									
19	Cold Mass Assembly	1.1.1.1	Geometry : Alignment of the end covers	LHC-MMS/98-198 Rev.2.0 Annex B29									
20	Completed Cold Mass	1.1.1.1	Final Measurement of the Cold Mass Geometry after the adjustment of : cold bore tubes extremities, heat exch. Tube, M1, M2, M3 flanges. (NOTE: the measurements will be performed with the“geometric/magnetic” mole).	LHC-MMS/98-198 Rev.2.0 Annex B27									
21	Completed Cold Mass	1.1.1.1	Final warm magnetic measurements	LHC-MMS/98-198 Rev.2.0 Annex B18									
22	Completed Cold Mass	1.1.1.1	Inspection of welds (end covers, c.m. bases, auxiliary busbar line, bellows and connections)	Safety Test LHC-MMS/98-198 Rev.2.0 Annex B33									
23	Completed Cold Mass	1.1.1.1	Leak Test	LHC-MMS/98-198 Rev.2.0 Annex B32									
24	Completed Cold Mass	1.1.1.1	Pressure Test	Safety Test LHC-MMS/98-198 Rev.2.0 Annex B33									
25a	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: DC resistance of windings	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25b	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: DC resistance of Q.H.	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									

25c	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: DC resistance of Spools	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25d	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: DC resistance of instrumentation	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25e	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: External Dipole voltage taps test	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25f	Completed Cold Mass (Note: c.m. with Diode stack, ONLY for FULL TEST configuration)	1.1.1.1	Final electrical Test: Complex impedance of spools	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25g	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: Complex impedance	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25h	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: Capacitance to ground	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25I	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: H.V. leakage current, magnet to ground	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25l	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: H.V. leakage current, Q.H. to coils	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25m	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: Discharge (interturn) voltage test	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25n	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: H.V. leakage current, QF and QD busbar to ground	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25o	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: Isolation Resistance Spool busbar to ground	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									
25p	Completed Cold Mass (Note: c.m. with Diode stack)	1.1.1.1	Final electrical Test: Ground electrical continuity	LHC-MMS/98-198 Rev.2.0 Annex B22, Table C									

ANNEX B3: REQUIREMENTS FOR THE CLEAN AREA

1. SCOPE

This Annex outlines the requirements for the area where winding, curing and pole assembly will take place.

Any work at the Contractor's premises, done on coils, coil components in their final (ready to assemble) conditions or on coil insulation materials, shall be performed in a clean area.

2. DEFINITION OF CLEAN CONDITIONS

The term CLEAN CONDITIONS refers to the working conditions and special measures which shall be applied to avoid contamination by conventional workshop contaminants such as oil, machine or finger grease, swarf, dirt, atmospheric dust, paint, etc.

3. DESCRIPTION OF A CLEAN AREA

A CLEAN AREA is a separate building or Annex A suitable area of the normal workshop space may be adapted, provided it is completely isolated from the rest of the workshop.

The CLEAN AREA is a controlled area with:

- Environmental control of particulate contamination, temperature 20 °C ± 5 °C, humidity (55 % ± 15 %), air change and filtering of the inlet air,
- A floor of fine screed concrete or equivalent, which shall be adequately painted or sealed,
- Adequate lighting for the type of process being carried out,
- Adequate heating, well guarded to reduce the risk of fire. NB: Naked-flame heating is not acceptable,
- Specific controls for entrance and exit.

4. WORKSHOP CONDITIONS

4.1. General

Initial work on coil components -e.g. storage and preparation for machining, forming, assembly, etc. may be done under normal workshop conditions, unless the Technical Specification states otherwise.

Once the initial work is complete, the materials shall be cleaned according to the specifications and moved to the CLEAN AREA.

4.2. In the CLEAN AREA

The following conditions shall apply in the CLEAN AREA.

a) Environmental

Smoking is strictly forbidden. Panels indicating that the CLEAN AREA is a NON SMOKING AREA shall be placed at the entrance and in visible places. The storage, preparation and consumption of food and drinks shall not be permitted.

Machining and forming of metallic parts and welding are not allowed.

b) Working Dress

Normal working dress shall be clean laboratory-type coat, suitable clean gloves and clean disposable overshoes (unless operator wears shoes stored in locker-room annexed to the clean area).

c) Tools and Equipment

A minimum quantity of degreased and cleaned hand-tools and equipment shall be retained in the CLEAN AREA as part of its permanent equipment.

Overhead cranes shall have drip trays to prevent oil drips contaminating material being worked in the CLEAN AREA.

ANNEX B4: REQUIREMENTS FOR THE SUPERCONDUCTING CABLE DURING ELECTRICAL INSULATION

1. CLEANING OF THE SUPERCONDUCTING CABLE

The main purpose of cleaning prior to insulation is to remove any particles which could damage the insulation and to eliminate contaminants on the external surface of the cable. The cleaning must not damage the coating of the strands. The integrity of the coating will be established at CERN by measuring the interstrand contact resistance of the cable after cleaning (1 m long sample).

The cleaning shall meet the following special requirements:

- the detergent shall not alter the composition of the tin oxide layer of the wire coating nor the copper oxide present in the tin-silver layer,
- the detergent shall be compatible with the polyimide insulation to exclude any long-term deterioration,
- no stains, blots or dirty marks shall remain after drying,
- the drying process, if any, shall guarantee that no trace of moisture and detergent remains inside the cable and that the oxides mentioned above are not modified. This is of special importance if a semi-aqueous solution is to be used as a cleaning agent. The use of a fluorescein in a minute quantity (e.g. 1 g diluted in 40 m^3 of water) and test under ultraviolet light shall be considered as one possible method to check the efficiency of the drying method. No temperature higher than 50 °C is permitted during the drying operation.

The Contractor shall propose a cleaning procedure meeting the above requirements and provide CERN with samples of cables cleaned by that procedure. CERN’s approval shall be obtained before cable insulation begins.

2. INTEGRITY OF THE CABLE

The insulation line will be equipped with a control and instrumentation system which will assure that the individual strands have not been displaced from their as-formed position before the wrapping of the insulation. In particular, detectors able to detect a momentary increase in cable thickness as a displaced strand passes through shall be installed at the two extremities of the insulation line.

3. SPOOLING

If transport of (insulated) cable is unavoidable, the utmost attention shall be paid to providing adequate external protection and dustproof / litterfree packing. Great care shall also be taken in storage and handling. On all cable storage spools, the cable layers shall be separated by an antistatic protection sheet to prevent damage of one layer by another. These protection sheets shall be renewed at each spooling. On the spools, both cable ends shall be accessible for electrical resistance measurements.

The spools shall be designed and constructed to prevent damage to the cable and its insulation during spooling and unspooling. There shall be a distance of about 2 mm between the wound cable and the rims of the spool, as sketched in Figure B4.1.

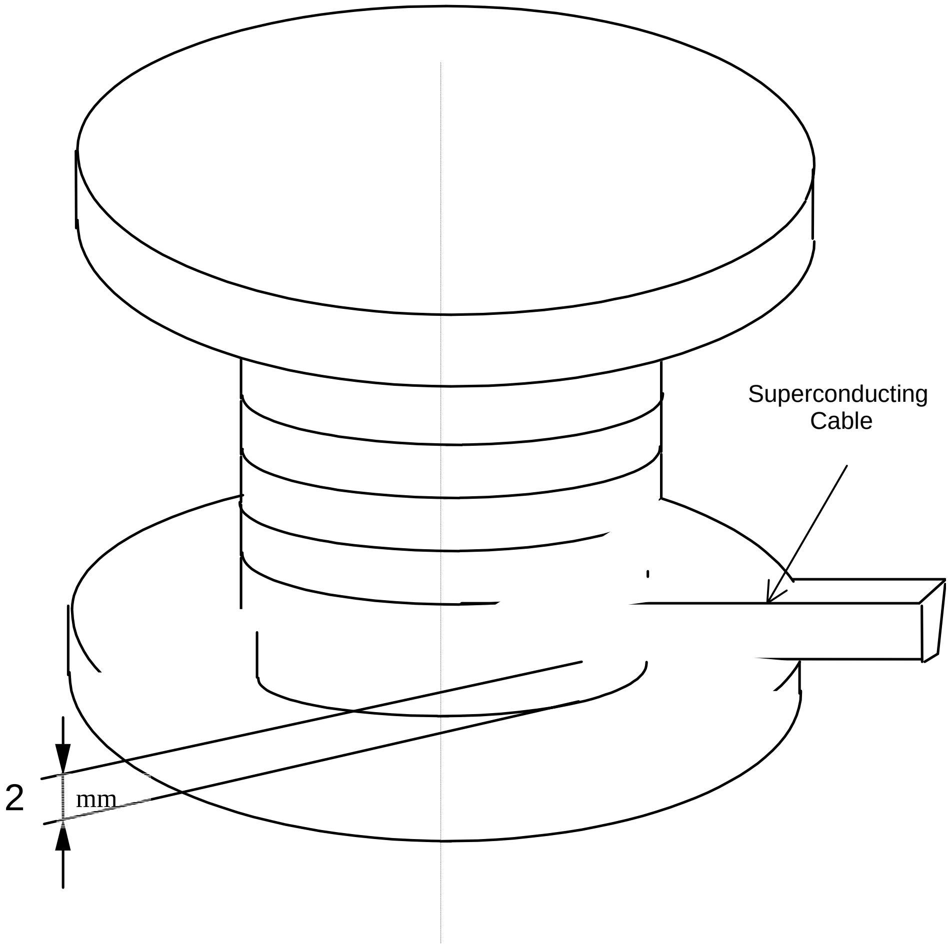

Figure B4.1: Spool design

ANNEX B5: INSULATION OF COPPER WEDGES

1. INSULATION

The insulated copper wedges are described in drawings:

– LHCMB__A0051	Coil - Cu-wedge insulated inner layer III-IV
– LHCMB__A0053	Coil - Cu-wedge insulated inner layer-IV-V
– LHCMB__A0055	Coil - Cu-wedge insulated inner layer-V/VI
– LHCMB__A0057	Coil - Cu-wedge insulated outer layer-I/II

The copper wedges shall be cleaned and lightly brushed before being insulated.

The main purpose of cleaning before insulation is to remove any particles which could damage the insulation and to eliminate contaminants on the external surface of the copper wedges

The cleaning shall meet the following special requirements:

- the brushing shall not damage or spoil the surface state and the size of the copper wedges,
- the detergent shall be compatible with the polyimide insulation to exclude any long-term deterioration,
- no stains, blots or dirty marks shall remain after drying,
- the drying process, if any, shall ensure that no trace of moisture and detergent remains on the copper wedge surface. This is of special importance if a semi-aqueous solution is to be used as a cleaning agent. The use a fluorescein in a minute quantity (e.g. 1 g diluted in 40 m^3 of water) and test in ultraviolet light shall be considered as one possible method of checking the efficiency of the drying method. No temperature higher than 120 °C is permitted during the drying operation.

The Contractor shall propose a brushing and cleaning procedure meeting the above requirements. CERN's approval shall be obtained before copper wedge insulation begins.

The insulation material and the procedure are the same as used for the cable, but the wrapping is different.

The following table gives details about the characteristics of the insulation.

Table B5.1– Characteristics and parameters of insulation.

	Tape type	Tape Thickness	Average tape Width	Configuration
Insulating layer 1	Polyimide Film	50.8 µm ± 3%	11.0 ± 0.10mm	gap $0.5\,^{+0.0}_{-0.4}$ mm pitch 11.3 mm
Insulating layer 2	Polyimide Film	50.8 µm ± 3%	11.0 ± 0.10mm	gap $0.5\,^{+0.0}_{-0.4}$ mm pitch 11.3 mm. (shifted by 5.5 mm with respect to layer 1)
Insulating layer 3	Adhesive Polyimide Film	68.6 µm ± 3%	9.0 ± 0.10 mm	Gap 2 mm ± 0.2 mm, pitch 11 mm

Special care shall be paid to the insulation of the extremities. The tapes continue until the end, then they are cut and spot glued. The glue shall be approved by CERN and will be the minimum quantity necessary to keep the tapes in place during the handling and assembly of the pieces. Extra thickness larger than 0.01 mm owing to the glue is not acceptable. The glue shall be put on the inner side of the tapes (the one facing the copper wedge).

Finally a “cap” made is made at each extremity using adhesive polyimide strip. Particular care shall be paid to limit the overlapping of the strip (maximum one layer).

The insulated copper wedges shall stay clean during storage and handling. Swarf, dust and any other contaminants are not permitted.

A suitable time (a week) prior to their use, the films shall be stored in a clean area, which is temperature and humidity controlled, such that their moisture content is below 2 % at the time of use.

2. ELECTRICAL CHECKS

The on-line electrical check of the copper wedges during the insulation procedure is the same as the one for the cable (see Annex B7). In case of detected electrical failure the insulation of the copper wedge shall be removed and remade. No joining of the tape is acceptable on any insulated copper wedge.

ANNEX B6: PROCUREMENT AND PREPARATION OF END SPACERS, CHIPS AND WEDGE-TIPS

1. INTRODUCTION

One set of spacers and wedge-tips is necessary for each pole and contains 24 pieces.

- 17 different end spacers (10 for the inner layer and 7 for the outer layer).
- 7 different chips and wedge-tips (5 in the inner layer and 2 in the outer layer).

Four sets (96 pieces) are necessary for a twin aperture dipole.

All the end spacers and the chips described in drawings N. LHCMB__A0076 and 88, are produced by machining a glass fibre reinforced epoxy material. All the surfaces defining each end spacer have been computed with dedicated software at CERN.

All the other chips and wedge-tips are produced by injection moulding.

The end spacers, chips and wedge-tips define the position of the cable in the ends of the dipole layers.

The end spacers, chips and the wedge-tips will be procured by the cold mass Contractor following the indication of the CERN Technical Specification annexed in Annex G19 (for the end spacers) and the indication given in this Annex (for the chips and the wedge-tips).

2. TECHNICAL ASPECTS

2.1. End spacers

2.1.1. Supply

The procurement of the end spacer sets is the responsibility of the Contractor and shall follow the CERN Technical Specification attached as Annex G19. CERN will make available to the Contractor all the programs and files utilised for the end spacer design. Any modification of the end spacers design shall be proposed, discussed and agreed with CERN.

2.1.2. Incoming inspection procedures

A standard incoming inspection of the components is the responsibility of the cold mass Contractor.

2.1.3. Manipulation and storage

The Contractor must store the end spacers and wedge-tips in the same area were the winding takes place. Swarf, dust and any other contaminants on the end spacers and wedge-tips are not permitted.

2.1.4. Preparation of end spacers by adhesive coating

A layer of B-stage epoxy shall be deposited on the surfaces in contact with the cable. The epoxy layer thickness shall be between 0.05 and 0.15 mm to limit penetration of the resin between the cable and its insulation. The required thickness can be achieved by depositing the resin with a paintbrush and letting the resin flow vertically under its own weight. Once coated, the spacers shall be used within one month if stocked at ambient temperature. The following procedure has been successfully applied at CERN:

- *resin system* *:* CYBA XD4447™ (100 parts in volume)+ XD4448™ [1] (35 parts in volume),
- *procedure* *:* paint a thin layer of mixture with a brush, thereafter either leave at least 12 h at ambient temperature or heat for 1h at 100 °C.

The selected resin and the coating procedures (if different from the above mentioned one) shall be submitted to CERN for approval.

2.2. Chips and wedge tips

2.2.1. Procurement

The procurement of the sets of chips and wedge tips is the responsibility of the Contractor. These components give the shape to the cable in the coils ends. They are produced by injection moulding and the chosen material is ULTEM™ 2300. All the surfaces defining each end spacer have been computed with dedicated software at CERN. CNC and IGES files for the desired geometries are available.

The references of the “Mandatory Supplier” qualified by CERN for the procurement of these components are indicated in the contractual documents.

The chips and wedge-tips for one pole consist of 7 pieces:

- 5 chips and wedge-tips for the inner layer (positions 11 to 15 in drawing LHCMB__A0011),
- 2 chips and wedge-tips for the outer layer (positions 8 and 11 in drawing LHCMB__A0012).

2.2.2. Materials

The material to be used is ULTEM™ 2300. ULTEM™ 2300 is a 30 % glass fibre reinforced base resin offering higher modulus, mechanical strength and heat deflection temperature under load compared to non-reinforced resin. The ULTEM™ resin is a polyetherimide. The main characteristics of the resin are good heat resistance, inherent flame retardancy with low smoke evolution and good mechanical properties.

2.2.3. Geometry and surface state and density.

CERN has optimised the geometry of the curved surfaces of the pieces which define the position of the conductor in the ends. On request, CERN can supply to the cold mass Contractor the numerical outputs defining the surface of the spacers in IGES format files.

The dimensional tolerances are reported in the drawings. The elliptical surfaces are set at ± 0.2 mm with respect to the theoretical surfaces.

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[1] XD4447, XD4448 are trademarks of CIBA-GEIGI

No evident marks of the injection points are admissible on the elliptic surfaces. On the cylindrical surfaces small traces of the injection points are acceptable if they are included inside the piece or if they are removed before mounting the piece. Marks of the extractors are acceptable on cylindrical surfaces and on the inner elliptic surfaces, but only if their depth is less than 0.2 mm.

No vacuum, bubbles or porosity, which could reduce the mechanical strength of the spacers, are acceptable. CERN will check the first prototypes by means of ultrasonic sensors and mechanical tests and reserves the right to check other pieces during the production.

2.2.4. Quality

The Contractor shall provide a certificate of conformity to the Technical Specification for each production batch. The certificate shall be report the results of the dimensional measurements performed on a representative sample of each production batch.

2.2.5. Transport

Particular attention shall be given to keeping the surface clean, undamaged, and avoiding breaks in the extremities of the chips and wedge tips.

2.2.6. Preparation of the chips and wedge tips by adhesive coating

A layer of B-stage epoxy (see Section 2.1.4) shall be deposited on the surfaces in contact with the cable. The epoxy layer thickness shall be between 0.05 and 0.15 mm to limit penetration of the resin between the cable and its insulation. The required thickness can be achieved by depositing the resin with a paintbrush and letting the resin flow vertically under its own weight. In order to ensure a good bond, the surface of the end spacers shall be of an adequate roughness (class N10, see the relevant drawings) which can be obtained by sandblasting.

ANNEX B7: ELECTRICAL TEST DURING CABLE INSULATION, POLYIMIDE SPLICING AND REPAIR

1. ELECTRICAL TEST

The integrity of the cable insulation shall be tested on-line during the wrapping of the two inner 50 µm-thick polyimide tapes using a test voltage of 1 kV r.m.s. at a frequency of 50-500 Hz. The reference test apparatus is a bed of chrome-plated-steel balls (1 mm diameter) through which the insulated cable passes. Systems using a set of rollers may also be used provided that they can demonstrate at least an equal fault detection capability. On the other hand the use of brushes or whiskers is excluded due to the danger of depositing conducting particles. Alternative methods can be agreed upon and must be at least as performing as the above aforementioned one.

If an electrical failure is detected the insulating machine shall automatically stop and the repair procedure is carried out.

2. POLYIMIDE SPLICING AND REPAIR

The polyimide splicing and repair procedure shall be applied if either a short circuit to ground is detected during cable insulation or if the tape supply from a spool is exhausted / interrupted.

The insulating tape on the cable shall be held in place by a non-invasive, clean clamp to avoid loss of the wrapping tension. Joining of the tape ends shall be performed by a short piece of self-adhesive connecting tape, of the same width, 16.5 ± 1 mm long. The material is 20 µm thick MYLAR™[2] for cryogenic applications (yellow in colour). The connecting tape shall equally overlap the two ends under repair, and be attached so that it will later be located at the outside of the regular insulating tapes (see Figure B7.1).

In case of a detected short circuit, *both* insulating tapes shall be replaced over a region extending at least 500 mm from the failure spot on both sides. The two resulting splices shall in no case overlap but be located at least 3 turns apart (see sketch below, left side).

Every spliced or repaired zone shall be clearly visible. The operation shall also be recorded in the accompanying traveller, defining the spool number as well as the location and kind of the repair.

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[2] MYLAR is a trademark of Dupont de Nemours, USA

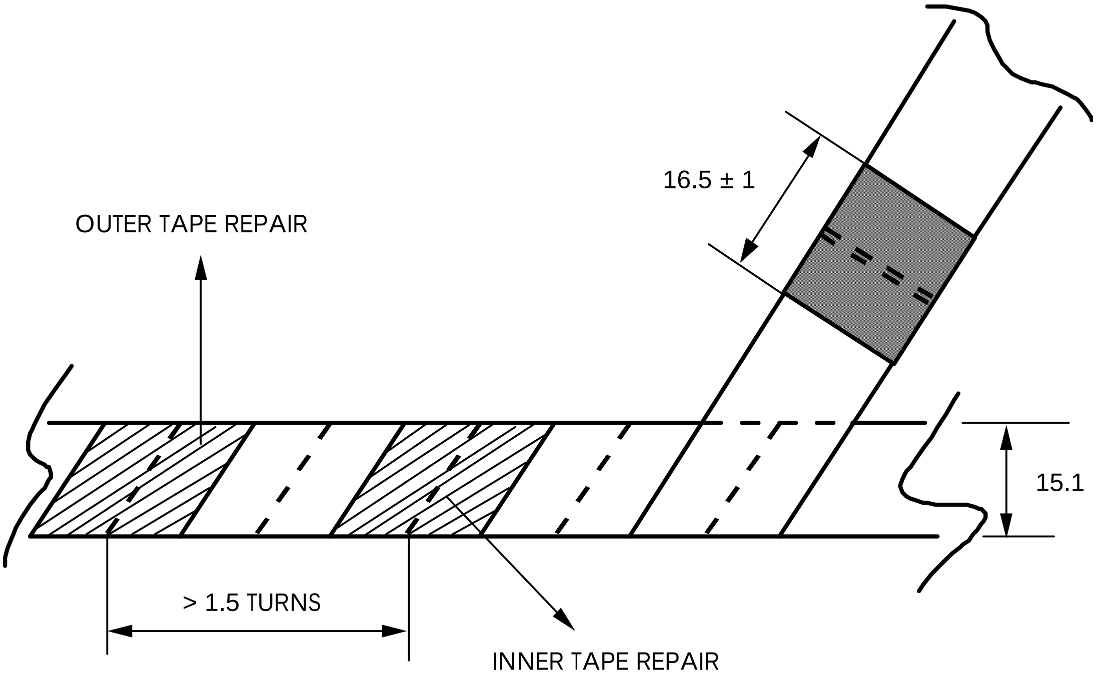

Figure B7.1: Tape repair

ANNEX B8: SURFACING THE LAYER ENDS

1. INTRODUCTION

The conductors in the layer ends are aligned on the inner radius and held in place by the end spacers. Because of the inclination of the conductor, a free space remains between the conductors and the theoretical external layer radius. After the winding of a layer these spaces must be filled with resin to hold the cable firmly in place and to restore the nominal cylindrical shape of the layer ends. This operation, also referred to as "impregnation", requires perfect adherence of the cable to the end spacers. This operation is described below.

2. SURFACING OF THE LAYER ENDS

2.1. Tooling

Special moulds are needed for the impregnation of the layer ends. They shall be designed so that the layer ends are confined in their nominal volume during impregnation.

With the standard method, the resin shall be injected under pressure (about 10 bar) when warm. An outlet shall be placed on the opposite side to the inlet to allow the air to leave the mould. During the preparation of the end spacers, small grooves shall be machined in the end spacers to provide channels for distributing the resin in all the layer blocks. The groove size must not affect the mechanical performance of the end spacers. The grooves must not be deeper than one millimetre, nor wider than two millimetres.

Alternative methods may be agreed upon.

2.2. Resin

The resin shall not flow into the layer straight section and shall not penetrate between the polyimide tape insulation and the cable: this excludes the use of very low viscosity systems. Too high a viscosity would lead to the opposite effect, leaving the coil ends too “spongy” and structurally unstable because the resin would not fill all the voids.

The ability of the resin to sustain thermal shocks under pressure without breaking depends not only on the base resin but also on the presence of additives and on the type and relative amount of the hardener. The penetration of the resin inside the layer ends is determined by viscosity, injection pressure and layout of the moulds. Therefore, the composition and procedures below shall be carefully followed to obtain impregnation of the required quality.

– system:	STYCAST™[3] 2850FT (100 parts in weight) + Catalyst 11 (4 ± 0.2 parts in weight)
– supplier :	Emerson & Cuming, Inc.
– description:	epoxy resin, heavily charged (about 70 % in weight)
– viscosity:	3000 centipoise at 65 °C
– elastic modulus:	25 000 MPa at 20 °C

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[3] STYCAST is a trademark of Emerson & Cuming

2.3. Outline impregnation procedure

- Preparation of the mould:
  - clean the filling holes
  - insert the required joints to avoid that the resin flows into the straight layer section
  - paint with a releasing agent
- Pre-heating:
  - place the layer inside the mould
  - verify the correct closing, adjust the shims if necessary (depends on the coil size)
  - preheat at 70 °C
- Preparation of the resin:
  - outgas under vacuum the STYCAST™ 2850FT + Catalyst 11 for 20 minutes at 70 °C
- Impregnation:
  - inject under pressure (about 10 bar) and maintain the pressure for 30 minutes at 70 °C (higher temperatures make the system less resistant to thermal shocks and more brittle);
  - warm-up to 100 °C and maintain the pressure for 2 hours
  - natural cool-down
  - open mould but not before temperature has fallen below 40 °C

ANNEX B9: GEOMETRICAL AND MECHANICAL MEASUREMENTS AND TOLERANCES OF THE LAYERS, POLES AND COLLARED COILS

1. INTRODUCTION

After the coil winding and pole assembly azimuthal size of the layer and the equivalent modulus of elasticity are measured. These measurements will be the basis for the evaluation of the reproducibility of the coils during the production and for the shim definition in view of the collaring operation.

Separate layers and then assembled poles have been extensively measured during the pre-series production to control and settle the tooling and the procedures.

For series production, in principle only assembled poles will be measured. The measuring procedure will be agreed between the Contractor and CERN according to the results obtained for the pre-series coils. The final goal is to measure only the layer jump, the ends and only few points in the straight section.

Sections 2 and 3 report on the measurements of the separate layers (should they be needed) and assembled pole respectively. Section 4 summarises the design tolerances to be achieved for the acceptance of the coils. Finally, Section 5 describes the mechanical measurements to be taken on the collared coils.

The dimensions and relative tolerances are quoted at 20 °C. The temperature during the measurements shall be stated in the document mentioned in Section 6.

1.1. Software and database for the measurements

During each measurement on the layers and poles, the measured values shall be recorded using the CERN supplied hardware and software, which produces sets of files containing the detailed measurement raw data.

For monitoring the layers and the pole azimuthal length, the raw data needs to be treated and normalised in standard format. CERN will supply the Contractor with software that will treat the raw data files and do an automatic upload of converted data into the "*Collared coil database*". This "*Collared coil database*" is part of the Traveller and will be used as a first step in the process of storing the information in the CERN EDMS system. The "*Collared coil database*" was designed using MS Access® and the data entry is executed via a user-friendly PC interface also provided by CERN. The architecture of the database was designed assuming that the measurement steps follow the sequence given in the Cold Mass Assembly Workflow Diagram (part of Annex B34). The operation, which generates each data item in the database, is identified in parentheses in the data entry form.

For traceability, the names of the original raw data files shall be saved in the database and copies will be attached to the Traveller. The summary results on some of the measurements steps shall be reported to CERN before proceeding with the assembly. For these reasons, the database is supplied to the Contractor including a facility to e-mail the data to CERN and to mark the accepted data as checked.

The database includes the retrieve forms and the main parameters summary reports, which will be used as Traveller pages.

2. INNER LAYER AND OUTER LAYER MEASURING PROCEDURE

Measurements of the single layers may be required following changes of coil components, qualification of new or modified tooling, or to understand non-conformities. In this case the layers will be measured after curing, electrical tests and surfacing, as described below.

The straight part shall be measured every metre and the measured section must be longer than a cable twist pitch (≥ 130 mm).

The measuring points shall be always at the same position (tolerance ± 20 mm) for all the measured layers.

The non-connection side and connection side ends are also measured. The measured section shall start at the beginning of the cable bends and shall cover at least 100 mm.

At each measured point, at least three pressure pre-cycles shall be applied before the real measurement cycle is performed. The coil compression must be varied between zero and the maximum values reported in the following table. The deformations shall be recorded during the loading and unloading of the coil. Continuous monitoring of the coil inductance at the test frequency of 10 kHz is recommended for early detection of faults during the pressure cycles (see Annex B10).

Measured section	Maximum compression of the cycle [MPa]
Straight part	120
Transition regions	60
Coil ends	30

The length of the layer shall be measured, with the unloaded layer lying on a flat plane (flatness ± 0.5 mm over one metre), using supports that maintain the transverse shape of the layer under test.

3. ASSEMBLED POLE MEASURING PROCEDURE

After the assembly of the poles, the final mechanical measurements shall be made.

The straight part shall be measured in three points. For each measured point, the measured section shall be longer than a cable twist pitch (≥ 130).

The measuring points shall be always at the same position (tolerance ± 20 mm) for all the measured layers.

The non-connection side and connection side ends are also measured. The measured section shall start at the beginning of the cable bends and shall cover at least 100 mm.

The layer jump and splice region shall be measured in two sections:

- one section corresponds to the layer jump,
- the second section corresponds to the splice.

At each measured point, at least three pressure pre-cycles shall be applied before the real measurement cycle is performed. The coil compression shall be varied between zero and the maximum values reported in the following table. The deformations shall be recorded during the loading and unloading of the coil. Continuous monitoring of the coil inductance at the test frequency of 10 kHz is recommended for early detection of faults during the pressure cycles (see Annex B10).

The extremities of the assembled pole shall be measured with a special press for the coil ends. The press shall work as a “closed cavity ” tool. By virtue of the small axial dimension of this special press, it will be possible to perform 3 measurements on the end region (180 mm).

Measured section	Maximum compression of the cycle [MPa]
Straight part	120
Layer jump section(s)	120
Coil ends	70

The coil and pole longitudinal lengths shall also be measured. This shall be done with the unloaded coils and poles lying on a flat plane (flatness ± 0.5 mm over one metre).

4. TOLERANCES

All the dimensions and their tolerances are shown in the drawings :

LHCMB__A0002	Coil, conductor distribution
LHCMB__A0022	Coil assembly - Ground insulation layer jump up
LHCMB__A0023	Coil assembly - Ground insulation layer jump down
LHCMB__A0020	Coil assembly - Ground insulation for coil heads

The dimensions are considered at room temperature under nominal compression.

For the straight part, the tolerance specified in the above drawings refers to the *average value* over the measured points.

For each layer and pole the difference between the *average* azimuthal size and the *minimum* and *maximum* size shall stay within ± 50 µm. The average values shall be consistent with the drawings of Annex A (tolerance ± 0.03 mm). The layers size is defined by the closed curing mould, the winding poles and mandrels and the sizing bars. The design of the tooling to reach the above mentioned tolerances is the responsibility of the Contractor. If during the series one or more pole (or layers if measured) are out of the tolerance range, extensive measurements shall be scheduled in order to collect enough data to localise and solve the problem. The measurements and the corrective actions will be at the Contractor’s charge.

All the poles assembled in a twin aperture dipole shall have a similar modulus of elasticity, measured at 60 MPa on the unloading curve. The maximum permissible difference is ± 15 % with respect to the average computed over the layers belonging to the same twin aperture dipole.

5. MEASUREMENTS OF THE SIZE OF THE COLLARED COILS

The measured dimensions of the collared coils after collaring are functions of the coil pre-stress and allow assessment of the collaring procedure. After collaring, the collared coils are put on a flat surface or rails (flatness or straightness ± 0.3 mm over one metre) and the dimensions are measured at several points. The contact between the measuring gauge and the collared coils will be assured by Johansson blocks.

The collared coils will measured at:

1. three sections on the connection side end. The first after 40 mm from the edge of the collared coils, the others every 70 mm,
2. two sections in the layer jump region or close to it (one section every 100 mm),
3. one section every 4500 mm along the straight part,
4. three sections on the non connection side, the first at 180 mm from the edge of the collared coils, the others every 70 mm.

In every section the vertical dimension is measured at 2 points corresponding to the vertical axis of symmetry of the apertures (points 3,7 in Figure B9.1). The horizontal size shall be measured at one point along the horizontal axis of symmetry of the collars (point 10 in Figure B9.1).

6. DOCUMENTS

All the files containing the measured values at the different points shall be attached to the Traveller. The format and the preparation sequence of these files will be defined in agreement with the Contractor.

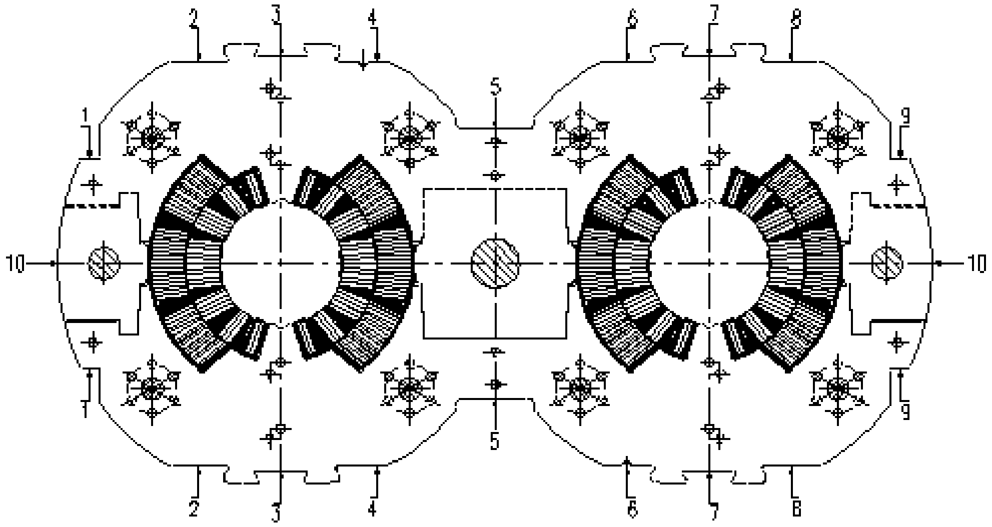

Figure B9.1: Measuring points in the cross section of the collared coils

ANNEX B10: ELECTRICAL TESTS ON THE LAYERS, POLES AND COLLARED COILS

1. INTRODUCTION

Three steps are scheduled in the electrical acceptance tests during the manufacture of the collared coils:

A. after curing (polymerisation) of the layers,

B. after assembly of the layers (poles),

C. after collaring.

It is good practice to make *intermediate* electrical tests after critical phases of the construction to permit early fault detection. While CERN recommends such tests, it is up to the Contractor to decide upon their extent and sequence.

The test conditions together with their preparatory steps are detailed in Tables B10.A, B, and C of this Annex.

2. GENERAL REMARKS (REFERRED TO IN TABLES B10.A, B, C)

- All warm electrical tests shall be carried out with the coil resting on an insulating support (e.g. the test bench used for the magnetic measurements)
- Measurement of DC resistance:
  - the resistance measurement of the quench heaters shall be made with a 4-wire ohmmeter.
  - the resistance measurement of the layers and poles shall be made with a stabilised test current of 1.000 A with resolution better than ± 0.01 A and reading of the voltage drop by a digital voltmeter.
  - the resistance measurement of the layer jump shall be made by the same procedure as for the layers and poles, but with a stabilised test current of up to 30A to achieve sufficient precision for the voltage reading. This measurement shall be made at ambient temperature, (temperature control: 20 ± 0.5 °C, or ambient temperature corrected to 20 °C), before insulation, with the voltage pickups attached at a distance of 5 mm from the soldering as shown in Figure B10.1.

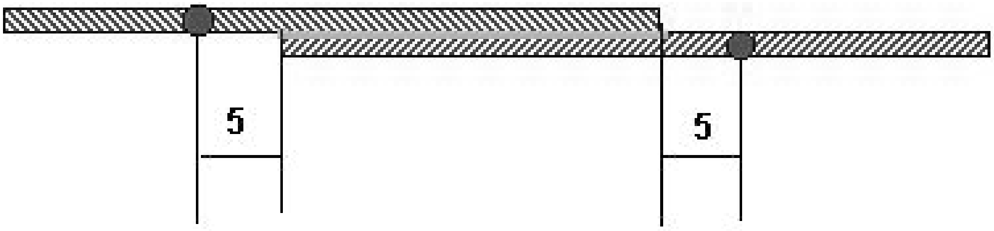

Figure B10.1 Measurement of the layer jump resistance: position of the voltage pickups (dim. in mm)

- HV leakage current tests
  - for the HV leakage current test of the dipole to ground, the quench heaters shall be connected to the dipole,
  - before and after the HV leakage current test, the insulation resistance shall be checked using a test voltage of 1 kV.
- Pulse discharge (interturn voltage) test
  - the discharge test shall comprise 10 pulses at intervals of 1 second.
  - the positive pole of the test generator (+ HT) shall be attached to the *external* connection of a layer or a pole.
  - the first test results for each layer will serve as reference data for all subsequent tests. Special attention shall therefore be paid to recording the measurement conditions and the test results, in particular for those made under load.
  - to validate the resolution of the set-up an interturn short circuit shall be simulated for all test steps, access to the layers permitting.
- Insulation test of the copper wedges

The test voltage is applied to the wedge by a needle piercing the insulation in the middle of the outer (thick) edge. The other terminal of the measurement apparatus is connected to the non-insulated part of a cable end.

The number of wedges to be tested individually is 24 for each inner layer and 8 for each outer layer.

3. DOCUMENTS

All the files containing the measured values shall be available on a diskette attached to the Traveller. The format and the preparation sequence of these files will be defined in agreement with the Contractor.

MANDATORY Acceptance tests after curing of the layers

- Recommended intermediate tests
  - after demoulding: Visual inspection of insulation, in particular at the inner side of the curved coil ends
  - before discharge test under load: Measurement of insulation resistance (V = 2500 V, I < 8 μA, t = 30 s)

Table B10.A – MANDATORY Acceptance tests after curing of the layers

TEST	OBJECT	CONDITIONS	LIMITS
DC resistance	Inner and outer layers	I=1A	comparison with reference coil
Complex impedance	Idem	*f=1.0Hz to 10.0kHz* *(Soft: Promit)*	comparison with reference coil
Insulation resistance of copper wedges	Idem	V=500V, I < 0.5μA, t = 30 s *(Megger : BM21)*	R>1000 MΩ
Discharge (interturn voltage) test,	Idem	V=120V/turn Inner layer 1.8kV, outer layer 3.0kV *(Soft: EDMA)*	comparison with reference coil

MANDATORY Acceptance tests after assembly of a pole

Table B10.B – MANDATORY Acceptance tests after assembly of a pole

TEST	OBJECT	CONDITIONS	LIMITS
Insulation between layers (to be done BEFORE soldering of the layer jump)	Pole	V=1kV, t=30 s	R> 1000 MΩ
DC resistance (conductors)	Pole	I=1.00A	comparison with reference coil
DC resistance (brazed joint)	Layer jump	I=10-30A	comparison with reference coil
Complex impedance	Pole	*f=1.0Hz to 10.0kHz*	comparison with reference coil
Discharge (interturn voltage) test	Pole	100V/turn, i.e. 4.0 kV/pole *(Soft:EDMA)*	comparison with reference coil

MANDATORY Acceptance tests after collaring

- Recommended intermediate tests
  - Measurement of insulation resistance during collaring
  - Continuos recording of DC resistance of poles during collaring
  - Measurement of insulation resistance after collaring, press open (R > 1000 MΩ: Coils + Q.Hs to ground: 5 kV, 30 s QHs to coils: 3 kV, 30 s)

Table B10.C – MANDATORY Acceptance tests after collaring

TEST	OBJECT	CONDITION	LIMITS
DC resistance of windings	Poles, dipoles and full magnet	I=1.00A {HP Data Logger)	comparison with reference coil
DC resistance of quench heaters	All magnet quench heaters	4-wire Ohmmeter {HP Data Logger)	comparison with reference coil
Complex impedance	Poles Dipoles and full magnet	*f=1.0Hz to 10.0kHz* *(Soft:Promit 2001)*	comparison with reference coil
Capacitance to ground	Dipoles + quench heaters (Per aperture) Magnet + quench heaters	Megaohmmeter, t = 60 s Vmin. : 500V	comparison with reference coil
Capacitance to dipole	All quench heaters (Per aperture)	Megaohmmeter, t = 60 s Vmin. : 500V	comparison with reference coil
HV leakage current, Poles to ground	Dipoles	V=6 kV, t = 300 s Quench heaters connected to layers	I< 15 μA
HV leakage current, upper to lower pole	Dipoles	V = 3 kV, t = 300 s	I< 10 μA
HV leakage current, quench heaters to coils	Dipoles	V = 3 kV, t = 300 s, (quench heaters per aperture grouped), (*)	I< 10 μA
Discharge (interturn voltage) test	Poles	100 V/turn, i.e. 4 kV per pole (10 pulses). *(Soft:EDMA)*	comparison with reference pole
Discharge (interturn voltage) test	Dipoles (full magnet)	50 (25)V/turn, i.e. 4 kV total (10 pulses) *(Soft:EDMA)*	comparison with reference magnet
Discharge (Q.H. connections integrity) test	Q.H. 1 circuits (2 strips) is series	V= 0.8kV (400V/strip), c =2 μF (5 pulses), (**).*(Soft:EDMA),*	comparison with reference

(*) and (**): Value to be confirmed

ANNEX B11: COIL INTER-LAYERS PROCUREMENT AND ASSEMBLY

1. PROCUREMENT

The procurement of the so-called “Coil Inter-layers” is the responsibility of the Contractor. Each cold mass contains 120 m of standard Coil Inter-layers and eight End Inter-layers. All the details on the production of these components are contained in the CERN Technical Specification attached in the Annex G13.

References to suppliers qualified by CERN for the procurement of this component are given in the contractual documents.

2. ASSEMBLY PROCEDURE

The formed inter-layers are applied on the inner layer starting from the layer jump region. The last piece before the beginning of the non-connection ends will be adapted in order to match with the inner layer length. The last parts to be positioned correspond to the ends.

No glue is necessary since the “L” shape of the inter-layers keeps them in place. If necessary for the assembly, some spot gluing can be done at a few points at the location of the Cu-wedges. The glue, the procedure and the number of points must be approved by CERN.

The outer layer can then be positioned on the inner one.

ANNEX B12: PROCUREMENT OF STABILISERS, LAYER–JUMP BOX, LAYER–JUMP FILLING PIECES. SOLDERING OF THE LAYER-JUMP, COIL INTERCONNECTION AND END STABILISERS

1. PROCUREMENT OF COMPONENTS:

The interconnection of the two coil layers in the "layer jump" and "splice" regions is presented in the general assembly drawing LHCMB__A0001, in more detail in drawings LHCMB__A0022, LHCMB__A0023.

The following components :

1. Layer-jump and ends copper stabilisers (three types),
2. Layer-jump box,
3. Layer-jump filling pieces,

will be procured by the Contractor following the indications listed below.

1.1. Layer-jump and ends copper stabilisers

The copper stabilisers geometries are detailed presented in drawing LHCMB__A0048, LHCMB__A0049 and LHCMB__A0050.

The copper profiles shall be cold drawn.

The material shall be either ETP copper or OF copper.

The hardness of the layer-jump stabiliser shall be greater than HV 70 (at room temperature).

The ends stabilisers shall be annealed.

1.2. Layer-jump box

The layer-jump box geometry is presented in drawing LHCMB__A0013. Its assembly in the pole is described in the Annex B12. The material utilised for the production (by injection) of the box shall be ULTEM™or IXEF™[4] (Polyarylamide).

After injection, the box shall be machined to its final thickness. The "S" shaped slot to house the cable shall be machined.

1.3. Layer-jump filling pieces

The layer-jump filling pieces geometry are detailed presented in drawings LHCMB__A0089, LHCMB__A0090 and LHCMB__A0091. The assembly of the pieces in the pole is described in the Annex B12. The material utilised for the manufacturing of the filling pieces shall be glass fibre reinforced epoxy material (G11 or similar).

The references of the "Mandatory Supplier" qualified by CERN for the procurement of these components are indicated in the contractual documents.

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[4] IXEF is a trademark of Solvay

2. FORMING AND SOLDERING OF THE COPPER STABILISERS

2.1. Introduction

This Annex combines the descriptions of several soldering/insulation procedures which are performed at different spots and at different phases during the manufacture of a pole. The Contractor shall be responsible for the quality and performance of the soldered joints and for all manufacturing faults, including hidden ones which may be discovered during tests or the operation of the magnets. Should any of the soldered joints specified herein reveal any defects due to manufacturing or other faults, CERN will be entitled to the urgent repair or replacement of the faulty part(s) free of charge.

The descriptions reflect the general approach and mention the key points to be observed. In particular, all tooling shall be designed to minimise the strain in the cables and to avoid local overpressures or over-temperatures. Details of the execution may vary slightly according to the Contractor’s specific conditions.

Notwithstanding the descriptions given below, the Contractor shall submit, for CERN’s approval, the design of all special tooling, moulds etc., as well as complete details of all steps of the manufacturing procedure.

As a general rule, the superconducting cable shall be carefully brushed and cleaned to remove the thin oxide layers before any soldering operation. Full penetration of the solder shall be demonstrated by metallography tests.

The procedures described are interleaved with other manufacturing steps that are mentioned for reference. They are enclosed in brackets and written in *Italics*.

2.2. Forming and soldering of the copper stabiliser of the layer jump

The term “layer jump” designates the area where the two (coil) layers are joined to form a pole. It comprises the ramp region (where the cable of the inner layer is raised on a copper stabiliser to the level of the outer layer) and the splice (where the two cables are connected).

Before winding, the inner layer cable shall be soldered to a copper strip and formed to a precise shape linking the lower and upper levels. Care shall be taken to limit internal stress and possible damages to the superconducting filaments.

Forming and soldering shall be performed inside a mould under pressure.

The inner layer cable shall be pre-tinned under a moderate tension (about 100 N) with silver-tin 96-4 alloy. The copper stabiliser to be soldered to the inner layer cable shall be silver-tin coated.

Before soldering, the cable and the copper stabiliser shall be cleaned with an acid-free pickling solution. A silver-tin 96-4 sheet (0.15 x 5 x 300 mm^3) is thereafter placed between the cable and the copper stabiliser, and the whole closed in the mould. The inner layer cable shall be guided not only along the length of the solder, but also at least 50 mm outside this region to limit incorrect positioning of the strands. Special care shall be paid to prevent silver-tin from flowing outside the portion of cable which is soldered to the stabiliser.

Thermal insulation shall be fitted between the main mould where soldering occurs and the additional guide which limits the deformation of the cable outside the soldering region.

Thereafter the mould shall be heated to 200 °C. Only when this temperature is reached shall the forming blade of the tooling be displaced to form the ramp to the right geometry. The shape of the forming blade shall take into due account the spring-back of the cable.

Once the cable and copper stabiliser are formed and firmly held in place the mould shall be heated from 200 °C to 220 °C to make the silver-tin alloy flow and to braze the cable to the copper stabiliser. The total time needed for the thermal cycle shall not exceed 20 minutes. The mould shall be heated by resistive heaters, the temperature be controlled within ±2 °C.

After cooling down, the solder shall be carefully rinsed with alcohol. The overall thickness of cable plus stabiliser shall be checked every 40 mm at the middle of the cable, starting 10 mm from the beginning of the ramp. The maximum deviation from nominal shall not exceed ± 0.05 mm.

The results of the measurements shall be recorded in the Traveller.

(Winding of the inner layer follows).

2.3. Soldering the copper stabiliser to the cable ends

After the winding of a layer but before curing, a copper stabiliser shall be soldered to the outer cable end. The stabiliser is located partially within the last end spacer and extends outwards by 1000 mm (see drawings LHCMB__A0049, LHCMB__A0050). The solder shall be supplied only on the first 90 mm after the coil end. The operation comprises the soldering of a copper slab followed by partial insulation of the joint.

The soldering shall be executed in a mould under pressure. Before soldering, the cable must be cleaned with acid-free pickling solution. A silver-tin 96-4 sheet (cross section 0.4 x 10 mm) is thereafter placed between the cable and the copper slab, and the sandwich closed in the mould which confines it to the nominal geometry defined in the drawings mentioned above. The closing pressure of the mould shall be kept controlled around 5 MPa. Soldering is obtained by heating the mould to 220 °C for 5 minutes. The mould shall be heated by resistive heaters, the temperature controlled within ± 2 °C. Special care shall be devoted to protect all the parts which are not brazed against an undue temperature rise.

After soldering the joint shall be carefully rinsed with alcohol, thereafter insulated according to the same standards as for the rest of the layer.

The insulated end stabiliser shall then be undergo curing (polymerisation) together with the inner layer. Electric test and filling of the layer ends follow.

Essentially the same procedure applies for the outer layer, with the exception that no copper stabiliser for the layer jump is provided.

2.4. Soldering of inner to outer layer

The connection between the inner and outer layers requires careful initial alignment of the two parts. The operation itself consist of three main sequential steps: bending the outer layer cable to the position of the joint with the inner layer, cutting the outer layer cable to the right length, finally soldering the inner layer cable with the outer layer.

The soldering shall be performed in a dedicated mould, which during soldering closes with a pressure of 15 ± 5 MPa over a length of at least 120 mm. The outer layer cable shall be pre-tinned with a tin-silver 96-4 alloy over the length of the joint.

Before soldering, the cables shall be brushed and cleaned with acid-free pickling. A tin-silver 96-4 sheet (0.15 x 5 x 120 mm) is thereafter placed between the two cables, and the whole closed in the mould under the required pressure. Soldering is obtained by heating the mould at 220 °C for 5 minutes.

The total time needed for the thermal cycle shall not exceed 15 minutes. The mould shall be heated by resistive heaters, and temperature controlled within ± 5 °C looking at the melting of the tin-silver alloy.

Special care shall be devoted to protect all the parts which are not soldered against an undue temperature rise.

After cooling down, the joint shall be carefully rinsed with alcohol, thereafter its thickness shall be measured at the middle of the cable in three points: at 10, 60 and 110 mm from its extremity.

The thickness of the joint (copper strip + inner layer cable + outer layer cable) shall not exceed the nominal thickness by more than ± 0.05 mm at any of the three measuring points above.

The results of the measurements shall be recorded in the Traveller.

3. INSULATION AND RECONDITIONING OF THE LAYER JUMP REGION

After the soldering of the joint, the layer jump region shall be re-insulated by wrapping it with the same insulation tapes as specified for the regular cable. Once the wrapping is completed, the end spacers of the outer (coil) layer shall be put in position together with the inner and outer layer conductors. Resin type CYBA XD4447™ + XD4448™[5] shall be applied only on the ***external*** side of the wrapping, where adhesion to the other cable turns and the end spacers is required. In order to avoid any risk of resin flowing into the cable, the amount of resin shall be the minimum needed for giving the required bonding and shall not exceed 2.5 g per linear metre of cable.

For reconditioning, the region concerned shall be placed inside a precise dedicated mould confining the layers to their nominal geometry. The mould shall cover the end spacers, the layer jump and at least 500 mm of the straight part, and be designed to provide a moderate longitudinal compressive force (between 2000 and 5000 N) against the outer layer end spacers.

Individual shims shall be put in the mid-plane such that a compressive azimuthal pressure between 20 and 30 MPa is applied on the layers when the mould is fully closed. Under these conditions the mould shall be heated up to 105 ± 5 °C for 30 minutes.

Another acceptable solution is the replacement of third insulating layer (Table 6.1.3) by a pre- impregnated “prepreg” insulating glass-fibre tape of a thickness of 110 µm. No resin coating is required in this case and the curing time is 90 minutes at 130 °C.

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[5] XD4447, XD4448 are trademarks of CIBA-GEIGI

ANNEX B13: SORTING OF POLES AND COLLARED COILS

1. INTRODUCTION

The systematic errors in the position of the superconductors due to the size of the mechanical components or to the tooling represent a risk for the dipole field quality.

For this reason, it is important to sort the components in order to average the systematic errors to zero.

This Annex describes the sorting of the coils in the dipole aperture and the orientation of the collar packs (or couples) and the collared coils inside the cold mass.

The Contractor shall design his tooling and define his manufacturing procedures in order to satisfy the needs of sorting.

2. COILS

Only layers wound with cables from the same supplier shall be paired into poles and apertures. Exceptions to this rule shall be approved in writing by CERN.

Layers wound and cured in the same production line (same winding mandrel, winding machine, curing mould and sizing tooling, curing press) shall be assembled in the same collared coils. There must therefore be a buffer stock of coils between the winding and curing operations and the collaring operation. For each layer, the identification of the production tooling used shall be reported in the Traveller.

3. COLLARS AND COLLARED COILS

All the type 1 collars of a given collared coils have the witness R2 cavity on the same side.

Two combinations are possible (looking at the collared coils from the connection side):

- witness on the diagonal + 45 °, 225 ° (positive diagonal)
- witness on the diagonal – 45 °, - 225 ° (negative diagonal)

Each collared coil shall be marked with its “up” orientation (see drawing LHCMB__A0009).

When the collared coils are assembled into the iron yoke the orientation “up” can be maintained or reversed.

The Contractor using pre-assembled collar couples shall divide his total production into four groups corresponding to the four possible combinations of the orientation of collar embosses and collared coils:

Group 1	witness on positive diagonal	orientation “up” maintained
Group 2	witness on negative diagonal	orientation “up” maintained
Group 3	witness on positive diagonal	orientation “up” reversed
Group 4	witness on negative diagonal	orientation “up” reversed

The Contractor using pre-assembled collar packs shall shuffle the collar packs (i.e. the ridges of two adjacent collar packs are facing once the non connection side and once the connection side).

Furthermore, he shall divide his total production of collared coils into two groups corresponding to the possible orientation of the collared coils.

Group 1 orientation “up” maintained

Group 2 orientation “up” reversed

For each dipole the Group type shall be reported in the Traveller.

ANNEX B14: QUENCH HEATERS, COIL PROTECTION SHEETS AND SHIM RETAINERS

1. QUENCH HEATERS

1.1. Generalities and procurement

The quench heaters consist of partially copper plated stainless steel strips sandwiched between electric insulating foils with suitable electrical and mechanical properties to withstand high voltages, low temperatures, pressures and ionizing radiation. In the case of a quench in these magnets, heaters are required to suppress superconductivity in the outer layer coils very rapidly.

The energy stored in a capacitor bank is discharged into the heater strips (± 450 V with a mid connection to ground), providing a peak current of around 75 A. The time constant of the heater circuit is between 50 and 100 ms.

The resistance developing throughout the coils provokes a resistive voltage drop that switches the magnet current towards the cold by-pass diode stack connected across the magnet within a short lapse of time (typically no further current passes through the magnet after one second). This fast current commutation process reduces the peak temperature as well as the maximum voltages developed inside the magnet and to ground.

Please note that the quench heaters procurement is in responsibility of the Contractor. The Technical Specification attached in Section G2 describes all the technical aspects of the quench heaters procured by CERN for the pre-series production.

1.2. Description

(See drawings from LHCMB__A00124 to LHCMB__A00127)

The quench heaters are pairs of 25 μm thick and 15 mm wide stainless steel (AISI 304 or AISI 316L) strips, which are sandwiched and bonded to two layers of polyimide electrical insulation foil. The latter acts as support and insulation of the strips against the coils and the collar structure, which is at ground potential and mechanically compresses the complete coil structure. The thickness of both insulation foils is 75 μm. A 25 μm thick layer of epoxy glue is added on one side of the foils to provide bonding during the manufacture process (typically, warm rolling).

The quench heaters cover the entire length of each outer coil (about 15 m). For redundancy there are two strips per coil quadrant placed such that they cover several (13) cable turns.

The stainless steel strips are partially copper-plated (see drawing LHCMB__A00127). The total cycle is 520 mm long, alternating 400 mm plated and 120 mm non-plated periods. This makes the overall resistance of the strips drop from 1.5 Ω/m to about 0.35 Ω/m at 1.9 K.

Once installed, the quench heaters are compressed between coil and collars up to levels around 50 MPa; therefore, the stainless steel strips must have smooth burr-free edges to avoid punching through the electrical insulation foils. Electric wires are to the ends of the copper plated strips for current feeding.

The quench heaters have a rectangular shape fitting the geometry of the straight part of the outer layer coil. Along the straight part of the coil, the quench heaters shall be creased with about a 90 ° bend. In the coil extremities (over the coil ends), additional pieces of polyimide foils of adequate geometry shall be adapted by the assembler to fit the geometry of the magnet pole extremities.

Information about quench heaters wiring are given in Annex B23 and C16.

2. COIL PROTECTION SHEETS AND SHIM RETAINERS

2.1. Generalities and procurement

The coil protection sheets surround the insulated poles of each aperture. The lower protection sheet is the one closer to the coil and outer protection sheet the one closer to the collars. These 0.5 mm thick austenitic steel sheets protect the ground insulation and allow relative displacements between the collars and the insulated poles.

The shim retainers house the inner layer shims and prevent their displacement inside the bore cavity during collaring.

The procurement of the coil protection sheets and shim retainers is the responsibility of the Contractor.

This Annex describes the main characteristics of the above mentioned items.

2.2. Features of the coil protection sheets

The shape of the coil protection sheets and shim retainers is defined in the drawing LHCMB__A0021 - Collared coil assembly - Ground insulation straight part.

The material is austenitic steel with the following mechanical and physical characteristics:

Yield strength at room temperature	≥ 250 MPa
Tensile strength at room temperature	≥ 450 MPa
Elongation at room temperature	≥ 30 %
Brinnell Hardness at room temperature	≥ 180
Relative magnetic permeability at room temperature *	≤ 1.005
Spread of the magnetic permeability *	± 0.001

** measured after 5 thermal cycles from room temperature to 4.2 K on cold formed samples*

CERN has qualified the three following grades:

Sandvik	13RM19™
Kawasaki	KHMN™
Nippon Steel	YUS 130 S™

The Contractor shall send to CERN for approval the measured properties of the material he intends to use (if different from the above mentioned grades).

After CERN approval the sheets are cut into the right dimensions and cold formed.

Before the assembly, the coil protection sheets and shim retainers must be cleaned. Swarf, dust and any other contaminants are not permitted.

2.3. Assembly procedure

The upper and lower formed coil protection sheets are assembled on the outer layer coil starting from the layer jump region. To avoid a weakness of the section radial, the outer protection sheet shall be placed so as to overlap the inner one close to its mid length. The last piece before the beginning of the non-connection ends shall be adapted to match the outer layer length. The last parts to be positioned correspond to the ends.

The shim retainers containing the inner layer shims are placed in the straight part of the inner layer starting from the connection side.

The last piece before the beginning of the non-connection ends will be adapted to match the inner layer length.

ANNEX B15: MAGNETIC CHARACTERISTICS AND TOLERANCES FOR THE RODS AND SHIMS UNDER THE RESPONSIBILITY OF THE CONTRACTOR

1. MAGNETIC CHARACTERISTICS FOR THE COMPONENTS OF THE LHC DIPOLE COLD MASS UNDER THE RESPONSIBILITY OF THE CONTRACTOR

In the following Table B15.1 are resumed the requirements for the magnetic characteristics for all the components that are not a CERN supply and that are in responsibility of the Contractor.

Were the choice between different materials is possible, CERN is available to discuss with the Contractor the proposed solution in term of chosen material. The official agreement of CERN is mandatory for all the selected materials. CERN could ask for μ_r measurement at 4.2 K for the proposed material.

Table B15.1: Magnetic characteristics of components under responsibility of the Contractor

Items	**Reference Drawing**	**“μ_r” value**	**Material**	Note
Coil protection sheets & Shim retainers	LHCMB__A0020, 21, 22	≤ 1.005	Austenitic Steel as specified in this Annex	
Collaring rods	LHCMB__A0044, 45	≤ 1.005	316LN,316L	
Collar pack rods	LHCMB__A0101	≤ 1.005	316LN, 316L, 304L	
Tie rod yoke	LHCMB__A0132	Not spec.	304L	
Bearing pipes	LHCMB__A0135, 137, 143, 147	Not spec.	304L	
Tap rod	LHCMB__A0144	Not spec.	304L	
Insert pack rods	LHCMB__A0150, 153	Not spec.	304L,316L, 316LN	
Iron insert slide-sheet	Tender drawing: LHCMBB_A0001, Pos. 13	Not spec.	Low carbon steel (soft iron)	*
Iron insert shim	Tender drawing: LHCMBB_A0001, Pos. 14	≤ 1.005	**	

* The permeability should be close to the one of the iron laminations (Annex C8)

** Austenitic steel or non-ferrous metal (copper, brass, Cu/Be) could be proposed.

2. TOLERANCES

The thickness off all the shims (polymerisation shims, collaring shims, iron insert slide-sheet, iron insert shims, etc.) shall have the tolerance of ± 0.01 mm. The thickness shall be measured each every metre. These measurements shall be added to the Traveller.

The tolerances of the rods are indicated in the reference drawings.

3. DOCUMENTATION

The Certificates of Conformity, results from inspection tests, etc. for the above mentioned cold mass components shall be added to the Traveller.

ANNEX B16: COLLARING PROCEDURE

The procedures and the sequence of the collaring operations will be fine-tuned during the production of the first units. The starting procedure includes the following main steps:

- approaching phase,
- cycling and insertion of the small rods,
- full load and insertion of the locking rods,
- release of the load.

The cycling procedure reported below is a suggestion. The Contractor is invited to discuss with CERN the cycling procedure that he prefers according to his expertise and tooling. The cycling procedure shall be approved by CERN.

Step 1 Approaching phase

In the approaching phase the collar and coil assembly, placed in its collaring tooling and resting on the intermediate beam of the press is moved upward to be put into contact with the upper beam of the press.

Step 2 Cycling and insertion of the small rods

During the cycling phase the press loads and unloads the collar and coil assembly in a controlled manner in order to settle the coils in the collar cavity.

At the end of the cycling phase the thin locking rods (Φ=12.5 mm, Φ=20.5 mm) are inserted. The press force is gradually released.

The force cycles of this phase are:

- 0 - 100 tonne-force/m,
- 50 - 200 tonne-force/m,
- 100 - 300 tonne-force/m,
- 200 - 400 tonne-force/m,
- 250 - insertion force.

The press force is then released in order to align all the components.

Step 3 Full load and insertion of the locking rods

In this phase the press loads the collars until the pressure permits the extraction of the thin rods. The pressure is then raised cyclically until the press applies the full load and the locking rods are inserted. The insertion force is about 1300-1500 t/m. The cycling procedure is:

- 0 – pressure necessary to extract the rods Φ=12.5 mm, Φ=20.5 mm,
- 350 – 500 tonne-force /m,
- 400 – 600 tonne-force /m,
- 500 – 800 tonne-force /m,
- 600 – 1000 tonne-force /m,
- 800 – 1200 tonne-force /m,
- 1000 – pressure necessary to insert the nominal locking rods.

CERN encourages the Contractor to foresee appropriate tooling (i.e. a diamond shape) to be fixed at the rod extremities in order to clean the rod path during the insertion.

Step 4 Releasing of the load

When the rods are inserted, the collaring force is gradually released and the locking rods, housed in the collars, lock the collared coil assembly. This phase is completed when the collaring force of the press is totally removed.

The points where the press force is applied during the different phases of the collaring are reported in Figure B16.1.

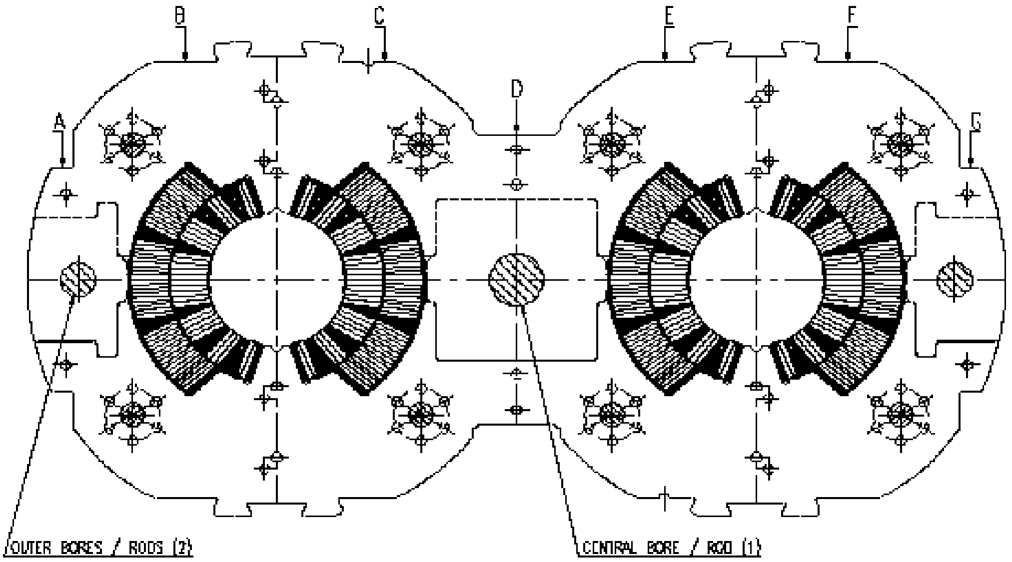

Figure B16.1: Points of pressure applied during collaring

ANNEX B17: COIL PRE-STRESSES AFTER COLLARING AND COLLARING SHIMS

1. NOMINAL COIL PRE-STRESS AFTER COLLARING

The values for the compressive pre-stresses in the coils after collaring and at room temperature shall be chosen within the ranges indicated in the following table:

Table B17.1: Coil pre-stress after collaring

	Straight part (including layer jump and splice)	End part (last 50 mm section)
Inner layer	70 ± 15 MPa	From 30 MPa to the straight part value
Outer layer	75 ± 15 MPa	From 30 MPa to the straight part value

Experience from LHC short dipole models and full length prototypes, shows that satisfactory results are obtained with a pre-stress in the outer layers slightly higher than that of the inner layers. The Contractor shall respect this configuration of pre-stress level between the two layers.

A smooth transition of pre-stress between straight part and end regions shall be provided in the transition region (from ~ 20 mm outside to ~ 50 mm inside the end spacer zone).

The Contractor's responsibility for manufacturing/assembling apply to the full, above indicated, ranges of pre-stress.

2. COLLARING SHIMS

2.1. Procurement

The collaring shims shall be made out of glass-fibre/epoxy composite. In case the Contractor would like to propose a different material, the alternative solution shall be discussed and approved by CERN.

The shims could be made of a sandwich of different thicknesses (max. 3 pieces). The shim thickness (for single or assembled shims) will be measured at each metre. The tolerance of the shim thickness shall be ± 0.01 mm. These measurements shall be added to the Traveller.

2.2. Shim thickness calculation

The design assumes that with the nominal collaring shims thickness (0.8 mm for the outer layer and 0.2 mm for the inner layer) the required field quality shall be achieved and the layer pre-stress should be in the centre of the admissible pre-stress ranges given above. For each layer, the Contractor shall calculate the thickness of the "theoretical collaring shims" necessary to obtain the nominal pre-stress values. If the calculated values do not differ from the nominal ones by more than ± 0.1 mm, the nominal shims shall be used. If not, the Contractor shall ask CERN for instruction on the choice of the shim thickness to be used. In addition the Contractor shall investigate the reason of the out-of-tolerance and take the necessary corrective actions in agreement with CERN.

ANNEX B18: WARM MAGNETIC MEASUREMENTS

Exciting the coils by a small DC current makes it possible to determine their quality by measuring the magnetic field they produce. Two magnetic measurements shall be performed:

- on the collared coils, before mounting in the yoke,
- on the finished cold mass.

Out of tolerance components and incorrect assembly will be revealed by these measurements which will facilitate a rapid diagnosis of problems.

The first measurement permits to check the quality of the collared coils. This measurement will also give the magnetic length of the coils, which shall be used to control the magnetic length of the yoke as explained in Annex B19.

The second measurement shall be done on the cold mass after the positioning of the spool pieces. The acceptance criteria for these measurements are given in Annex B1.

1. EQUIPMENT

Two different benches shall be built by the Contractor to perform the two measurement.

1.1. Collared coil bench

The magnetic field direction shall be measured with an accuracy better than 0.1 mrad (0.1 mm over 1 m) with respect to reference surfaces of the collars. The Contractor shall provide a bench supporting the complete collared coil assembly that is consistent with this accuracy on the transverse levelling along the whole length of the assembly. The collared coil shall be placed on adjustable supports and clamped to meet the levelling accuracy defined above. The free space between two consecutive supports shall not be greater than 500 mm**.** A jig with a tilt sensor (accuracy: 0.05 mrad, resolution: 0.01 mrad), sliding on the reference surface of the collared coil assembly shall be provided to check that its orientation is within ± 0.1 mrad along the whole length. A periodic check shall be made to control the stability of the bench. The periodicity of these checks shall be agreed with CERN, a periodicity of one month is considered as appropriate.

Moreover, the bench and its environment shall cope with the following requirements to minimise the perturbations in the quality of the field measurement:

- “large” magnetic objects (more than 10 dm^3 per linear metre) must be kept at a distance of more than 3 m from coil axis,
- “small” magnetic objects (non concentrated, up to 0.5 dm^3 per linear metre, such as screws, nails, concrete reinforcement …) must be kept at a distance of more than 0.4 m from coil axis,
- no magnetic object may be allowed at a distance closer than 0.4 m from the axis.

1.2. Cold mass bench

The same measurement shall be performed on the finished cold mass assembly. The cold mass shall be placed on three supports reproducing the same supporting as the three feet of the cryostat. The levelling of these supports shall be within ± 0.1 mrad and the central support shall be aligned with the two others to within ± 0.1 mm.

The presence of magnetic objects around the cold mass during measurement, is less important than for the collared coils. The acceptable limits will be assessed empirically at the Contractor’s premises.

2. SPACE AND ENVIRONMENT

The necessary space around the bench supporting the collared coils is described in drawing LHCMMWED0008. The same space is required for the cold mass bench. Both benches may be located in the same room provided that they are at a distance of over 4 m apart between axes. This space shall be an enclosed area, clean, free from dust and noise. As electrical noise can greatly reduce the quality of the measurements, heavy machinery, arc welding equipment, cranes, etc, shall be banned from the measurement site or shall be shut down during the measurements.

An extension at each end of the cold bore tubes (1 m long max.) shall be necessary to cope with the length of the probe. These extension tubes can be supplied by CERN, and shall be supported at the ends of the benches. The exact dimensions will be given before the Contract signature.

Both ends of the benches shall be able to accommodate the probe driving system. This system positions the probe at each measurement step (about 20). The reproducibility for the position of the first step with respect to collared coils or the cold mass shall be within 0.5 mm and the accuracy of the distance between the first and last step shall be better than ± 0.3 mm. The adaptation of this system on the benches will be defined in collaboration between the Contractor and CERN.

3. PROCEDURE, MANPOWER AND OPERATION TIME

Probes and their associated electronics, a probe driving system and calibration equipment will be supplied by CERN (Annex E3).

The first step of the magnetic measurements shall consist in passing through all along the cold bore tubes a gauge of 500 mm length and 49.4 mm diameter (provided by CERN). This operation will exclude the risk of blocking the measuring mole during the measurements.

The probe, or “magnetic mole”, is introduced inside the cold bore tube and measures the magnetic field produced by a small DC current in the coils. The search coils inside the probe are 750 mm long and about 20 measurement positions are necessary to cover the whole length of the collared coils or of the cold mass. A measurement is made by a rotation of one turn of the search coil assembly. At each position, four measurements are made, in order to improve the quality of the results: clockwise and counter-clockwise rotations, both with a positive and a negative DC excitation current. All the measurement operations are automatic, only introducing and removing the mole from the cold bore tube is manual.

The Contractor’s team is supposed to have been trained to use this equipment, by CERN’s specialists, during the pre-series production. The Contractor shall perform these measurements without the assistance of CERN. A complete magnetic measurement of the two apertures should take less than 4 hours.

A calibration of the measuring system shall be carried out periodically to control its stability. A calibration periodicity of one month is considered appropriate.

ANNEX B19: FINE TUNING OF THE MAGNETIC LENGTH

1. INTRODUCTION

CERN requires that magnetic length of all the dipoles to be equal. This parameter will be derived from the warm magnetic measurements. Variation in the magnetic length shall be compensated when necessary by the procedure described below.

2. ADJUSTMENT OF THE NON-MAGNETIC LAMINATION PACKS IN THE NON-CONNECTION SIDE

The connection side and non-connection side non-magnetic laminations packs are assembled with a nominal length of 522 mm.

These packs shall be adjusted in order to compensate for possible differences of the magnetic length of the collared coils.

In any case, the minimum length of the extremity packs shall not be less than 472 mm in order to limit the magnetic field in the layer jump region.

The non-magnetic part of the extremities packs shall be equal on both sides for symmetry reasons.

One pack of the magnetic laminations shall be consequently adjusted in length (utilising, if necessary, special laminations provided by CERN with a reduced thickness of 1.5 mm) in order to maintain constant the total mechanical length of the half-yoke.

ANNEX B20: HALF-YOKE ASSEMBLY

1. INTRODUCTION

The magnetic circuit of the LHC dipole magnets is made of a yoke split in the vertical symmetry plane and a pair of smaller inserts. The smaller inserts are separate from the main part in order to facilitate the assembly of the yoke around the collared coils.

This Annex describes the specification concerning the half-yoke assembly. The specification for the inserts packs is given in Annex B21.

2. TECHNICAL REQUIREMENTS

The half-yoke assembly shall be fabricated in accordance with the reference drawings LHCMB__A0003 and LHCMB__A0004.

The central section of the half-yoke is composed of a stack of 5.80 mm thick low carbon steel laminations. It is 13554 mm in length. The end sections, which end the yoke around the coil heads, are composed of a stack of 3.0 mm thick non-magnetic steel laminations. They are 522 mm in length on both sides. These lengths shall be adjusted as described in Annex B19 for fine tuning the magnetic length.

The central section of the half-yoke shall be fabricated as a series of short packs of a convenient length (maximum 1.5 m) in order, for instance, to optimise the stacking procedure or to limit the weight to be handled. In this case, the yoke laminations shall be fixed by locking pipes as illustrated in the reference drawing.

In order to obtain stiff and solid packs around the magnet heads, the non-magnetic steel laminations shall be welded together as illustrated in the reference drawing. The rigidity of these ending packs is required for providing firstly, a sound support for the 50 mm thick end plates, which are bolted to them and secondly, a robust fixed point[6] of the busbars.

The end laminations of the half-yoke shall be perpendicular to the reference planes “A” and “B” within 1 mm as indicated in the reference drawing. For this purpose, a special slot (referred to in the drawing as “witness mark”) on the external circumference of the yoke-lamination indicates the side where the wall thickness is expected to be greater, i.e. at the upper limit of the tolerance range. The aim of the witness mark is to allow stacking of the laminations in a controlled way in order to obtain an optimal and uniform length of the packs and average out systematic geometric imperfections. The suggested procedure consists of a 100 % shuffle of the lamination faces (left/right-side change for each adjacent lamination during stacking).

The laminations shall be stacked on an adequate bench having sufficient rigidity and the correct flatness to guarantee the required evenness of the mating surfaces.

The Contractor shall be responsible for all the additional machining operations that are required on the standard laminations. In the central section of the half-yoke, radial slots must be machined according to views “X” and “Y” of the reference drawing in order to provide for sufficient cooling and venting during quench for the collared-coils. One such lamination shall be inserted every 1 - 1.5 m along the half-yoke.

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[6] The fixed point denotes the longitudinal fixing of the busbars with respect to the half-yoke

In the non-magnetic steel laminations, the busbar slots must be enlarged in order to provide sufficient room for the fixed point of the busbars. Details concerning the related laminations, types B1, B2 and B3, are given respectively in view “X”, section C-C and view “Y” of the reference drawing.

The stacking factor[7] shall be controlled within a tolerance range of ± 0.25 % about the nominal value of 98.5 %. The stacking factor shall be measured on every pack, to demonstrate its uniformity among the full half-yoke assembly.

Whenever necessary, 0.2 mm thick non-magnetic steel washers can be inserted in between adjacent laminations around the locking pipes to adjust the stacking factor or to improve control of the perpendicularity of the end laminations with respect to the reference planes “A” and “B”. The utilisation of washers of large diameter is strongly suggested. In place of washers, foils of non magnetic metal sheets or material qualified for radiation doses higher than 10^7 Gy without any damage (polyimide, Peek™, etc) are also suggested. In this case, the proposed material shall be approved by CERN.

The low carbon steel laminations are produced by fine blanking from 5.8 mm ± 0.15 thick low carbon steel sheets. The non-magnetic steel laminations are produced by fine blanking from 3.0 mm ± 0.05 thick non-magnetic steel sheets. More details about the raw material itself and the manufacturing process of these laminations are given in Annexes C8 and C9.

3. CONTRACTOR‘S RESPONSIBILITIES

The Contractor shall be responsible for preparing his own (including design, procurement and installation) stacking bench(es) and lifting devices.

The Contractor shall provide CERN with a detailed assembly and control procedure, which precisely describes the sequence of manufacture and inspection of the half-yokes as required in Section 8.2.5.

The Contractor shall record in the Traveller the following information:

- Length of non-magnetic steel packs,
- Length of low-carbon steel packs,
- Stacking factor of each pack, non-magnetic steel and low-carbon steel,
- Average stacking factor.

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[7] The “stacking factor” denotes the ratio between the mass of the half yoke as fabricated and the mass of a solid yoke made with the same external dimensions and material.

ANNEX B21: PACKING OF THE INSERT LAMINATION

The iron insert is also part of the dipole's magnetic circuit. Like the yoke laminations, the insert laminations are produced by fine blanking from 5.8 ± 0.15 mm thick low-carbon steel sheets.

There are two type of insert lamination type (see Drawing: LHCMB__A0148 "Iron Yoke Insert", LHCMB__A0152 "Austenitic Insert",) to be assembled. More details about the raw material and the manufacturing process of the laminations are given in Annex C8.

The insert elements shall be assembled in packs of an appropriate length (i.e. easy handling of the packs) according to the following procedure.

A special slot ("Witness mark" in the drawing) on one vertex of each insert lamination will indicate the side where the thickness of the lamination is expected to be higher (upper tolerance limit: + 0.15 mm). The aim of this witness mark is to permit a controlled stacking of the laminations in order to obtain an optimum and constant length of the lamination packs and to average out systematic geometric imperfections. The suggested procedure consists in a 100 % shuffle of the lamination sides (left/right-side change for each adjacent lamination during stacking).

The stacking factor shall be controlled within a tolerance range of ± 0.25 % about the nominal value, which shall equal 98.5 %. The stacking factor shall be measured on every pack, so as to demonstrate its uniformity among the full half-yoke assembly.

The same procedure should apply for non-magnetic steel inserts, which shall be installed at the magnet extremities.

The Contractor shall provide CERN with a detailed assembly and control procedure, which precisely describes the sequence of manufacturing and inspection as required in Section 8.2.5.

The Contractor shall record in the Traveller the following information:

- Length of non-magnetic steel packs,
- Length of low-carbon steel packs,
- Stacking factor of each pack, non-magnetic steel and low-carbon steel,
- Average stacking factor.

ANNEX B22: ELECTRICAL TESTS DURING AND AFTER THE COLD MASS ASSEMBLY

The collared coils, the busbars, the spool pieces, etc. are systematically tested electrically during and at the end of their manufacture. The last tests are made during their provisional acceptance at CERN.

Nevertheless, electrical tests are mandatory before welding of end covers (see Table B) and before shipment of the cold mass (see Table C).

Tests before and during the cold mass assembly are recommended (see Section 2, 3 and 5) to check the integrity of the components before their installation in the cold mass. In general, the components will arrive at the cold mass assembly after a storage period and after having several major displacements.

1. ELECTRICAL TEST PROCEDURES

1.1. General comments about the Mandatory test

- *Measurement of the DC resistance*: The resistance measurements of the quench heaters shall be made with a 4-wire ohmmeter.
- *High voltage (HV) leakage current tests*: For the HV leakage current test of the dipole to ground, the quench heaters shall be connected to the dipole.
- *High voltage (HV) leakage current tests*: Before and after the HV leakage test, the insulation resistance shall be checked using a test voltage of 1 kV, $I \leq 1$ µA, $t = 60$ s.
- *Pulse discharge (interturn voltage) test*: The discharge test shall comprise 10 pulses at intervals of 1 second.
- *Pulse discharge (interturn voltage) test*: The positive pole of the test generator (+ HT) shall be attached to the *external* connection of a layer or a pole.
- *Pulse discharge (interturn voltage) test*: The first test results for each layer will serve as reference data for all subsequent tests. Special attention shall therefore be paid to the documentation of the measurement condition and the test results, in particular for those carried out under load.

1.2. Recommended tests

For the tests classified as “Recommended Tests” the Contractor shall propose test plan conditions and limits taking into account the conditions and limits specified for the mandatory tests.

2. ELECTRICAL (RECEPTION) TESTS PREREQUISITE TO THE COLD MASS ASSEMBLY

Table B22.A: Mandatory Reception tests of the cold mass components

Components	**R (DC) [mΩ]**	**R (Insul.) [MΩ]**	**Complex Imped.**
Collared Coils (dipoles 1 & 2)	X	X	
Spool Pieces (Correctors)	X (*)	X	X
Busbars (MB, QF, QD, Aux.)		X	

(*) Reference values will be provided for each type of spool piece.

3. RECOMMENDED INTERMEDIATE TESTS DURING THE COLD MASS ASSEMBLY

- Busbar Resistance (isolation) after the assembly of the first half-cylinder
- Magnet Resistance (isolation) + busbars +quench heaters before entering the welding press
- Magnet Resistance (isolation) + busbars + quench heaters after welding (in the unloaded press)
  - DVM Measurements with resolution better than 0.1 mV
- Visual check that auxiliary busbar of each spool piece is attached in the correct order
- Visual checks that each spool piece voltage tap is connected on the “A” terminal of the corresponding spool.

4. MANDATORY ELECTRICAL TESTS: AFTER THE WELDING OF THE SHRINKING CYLINDER, THE POLES INTERCONNECTION AND THE BUSBAR CONNECTION (WITHOUT ENDCAPS)

TableB22.B: **Mandatory Tests without ENDCAPS and without DIODE STACK**

TEST	OBJECT	CONDITION	LIMITS
DC resistance of windings	Poles, dipoles and full magnet	I=1.00A {HP Data Logger)	comparison with reference coil
DC resistance of quench heaters	All magnet quench heaters	4-wire Ohmmeter {HP Data Logger)	comparison with reference coil
DC resistance of spools	For each type	I=1.00A (HP Data Logger)	comparison with reference coil
DC resistance of instrumentation	Cryo-heater Temperature sensor	Ohmmeter 4 wire (HP Data Logger)	comparison with reference Components
Complex impedance of spools	For each type	*f=1.0Hz to 10.0kHz* *(Soft:Promit 2001)*	comparison with reference coil
Complex impedance	Poles ; Dipoles and full magnet	*f=1.0Hz to 10.0kHz* *(Soft:Promit 2001)*	comparison with reference coil
Capacitance to ground	Magnet +All quench heaters	Megaohmmeter, t = 60 s Vmin : 500V	comparison with reference coil
Capacitance to dipole	All quench heaters	Megaohmmeter, t = 60 s Vmin : 500V	comparison with reference coil
HV leakage current, Magnet to ground	Magnet + All quench heaters and dipoles busbars.	V=5 kV, t = 300 s Q.H. connected to magnet	I< 25 µA
HV leakage current, quench heaters to coils	All quench heaters	V = **3** kV*, t = 180 s, (quench heaters grouped)	I< 20 µA
Discharge (interturn voltage) test	Poles	70 V/turn, i.e. 2.8 kV per pole (10 puls) *(Soft:EDMA)*	comparison with reference pole
Discharge (interturn voltage) test	Dipoles (full magnet)	50 (25)V/turn, i.e. 4 kV total (10 puls) *(Soft:EDMA)*	comparison with reference magnet

External voltage taps	All taps	I=1.00A (HP Data Logger)	comparison with the resistance of poles and layers
HV leakage current MB bus bars	External Bus to Internal Bus	V = 5kV t = 180s	I< 10 µA
HV leakage current QF;QD bus bars to ground	All Q Bus to ground	V = 5kV t = 180s	I< 10 µA
HV leakage current QF;QD bus Bus to Bus	Bus QF and QD ext. To Bus QF and QD int.	V = 5kV t = 180s	I< 10 µA
Isolation Resistance spool Bus Bus to Bus	Bus 1,3,5,7,9,11,13,15,17,19 To Bus 2,4,6,8,10,12,14,16,18,20	V = 1.5kV t = 60s	R > 500MΩ
Isolation Resistance spool Bus to Bus QF & QD	Spool Bus Slot ext. To Bus QF Spool Bus Slot int. To Bus QD	V = 1.5kV t = 60s	R > 500MΩ
Isolation Resistance spool Bus to Ground	All spool Bus	V = 1.5kV t = 60s	R > 500MΩ
Continuity tests of spool and connected busbar	All spool Bus	I=1 A	This test may be suppressed if DC resistance of spools includes the busbar also
Localisation of spool voltage taps (to be on terminal “A”	All voltage taps of each spool	I=1 A	Check that voltage tap is on correct side of spool

5. RECOMMENDED INTERMEDIATE TESTS AFTER THE TACK WELDING OF EACH END COVERS :

- Insulation to ground of all (dipoles, quadrupoles, auxiliaries) busbars circuits, including the diode stack bypass
- Insulation to ground of instrumentation wiring

Insulation tests after forming and installation of the Instrumentation Feedthrough System tube:

- Dipoles wiring applicable voltage: V = 1 kV,
- Spool pieces wiring applicable voltage: V = 1 kV,
- Instrumentation wiring applicable voltage: V = 4.5 V.

6. MANDATORY TESTS AND PROCEDURE BEFORE AND AFTER THE MOUNTING OF THE PROTECTION DIODE STACK

- Diode stack polarity shall be checked before the mounting of the diode stack and then proceed with the installation.
- At any insulation tests, it is imperative to connect together (short circuit) the two taps wires 012 and 013.
- Any testing after the mounting of the diode shall be done AC (~ 10 kHz) with Zener diode stack protection circuit connected in parallel to the diode stack as described in the Diode Handling Engineering Specification (attached in Annex B31). The same precaution must be taken for resistance and continuity tests with the diode stack already in place.

7. MANDATORY TESTS AFTER THE ASSEMBLING OF THE IFS AND BEFORE THE ASSEMBLING OF THE "LINE N" JUMPER

Table B22.C: Mandatory Tests AFTER the assembling of the IFS and BEFORE the assembling of the "line N" jumper

TEST	OBJECT	CONDITION	LIMITS
HV leakage current QF;QD bus Bus to Ground	All Q Bus	V = 5kV t = 120s (Diode short circuited)	I< 10 μA
DC resistance of spools *	For each type	I=1.00A (HP Data Logger)	comparison with reference coil
Complex impedance of spools *	For each type	*f=1.0Hz to 10.0kHz* *(Soft:Promit 2001)*	comparison with reference coil
Isolation Resistance spool Bus * to Ground	All spool Bus	V = 1.5kV t = 60s	R > 500MΩ

* ONLY in case of STANDARD TEST configuration of the cold mass

NOTE: The measurements will be done through the IFS exit connector

8. MANDATORY FINAL TESTS BEFORE THE COLD MASS SHIPPING

Table D: Mandatory Final Tests before the cold mass shipping

TEST	OBJECT	CONDITION	LIMITS
DC resistance of windings	Dipoles and full magnet (Apply Zener diode protection on diode)	I=1.00A {HP Data Logger)	comparison with reference coil
DC resistance of quench heaters	All magnet quench heaters	4-wire Ohmmeter {HP Data Logger)	comparison with reference coil
DC resistance of spools *	For each type	I=1.00A (HP Data Logger)	comparison with reference coil
DC resistance of instrumentation	Cryo-heater Temperature sensor	Ohmmeter 4 wire (HP Data Logger)	comparison with reference Components
External Dipoles voltage taps	All taps	I=1.00A (HP Data Logger)	comparison with the resistance of poles and layers
Complex impedance of spools *	For each type	*f=1.0Hz to 10.0kHz* *(Soft:Promit 2001)*	comparison with reference coil
Complex impedance	Full magnet (Special procedure)	*f=1.0Hz to 10.0kHz* *(Soft:Promit 2001)*	comparison with reference coil
Capacitance to ground	Magnet +All quench heaters	Megaohmmeter, t = 60 s Vmin : 500V	comparison with reference coil
HV leakage current, Magnet to ground	Magnet + All quench heaters and dipoles busbars. (Diode short circuited)	V=5 kV, t = 120 s Quench heaters connected to layers	I< 25 µA
HV leakage current, quench heaters to coils	All quench heaters	V = 3 kV*, t = 120 s, (four quench heaters grouped)	I< 10 µA
Discharge (interturn voltage) test	Full magnet (Special procedure)	25 V/turn, i.e. 2 kV/ Dipole (10 puls) *(Soft:EDMA)*	comparison with reference pole

Isolation Resistance spool Bus to ground *	All spool Bus	V = 1.5kV t = 60s	R > 500MΩ
Ground Electrical continuity	Cold mass	I = 25 to 40A	V = < 2.5 to 4.0V R< 100mΩ

* ONLY in case of FULL TEST configuration

NOTE: A SPECIAL PROCEDURE will be communicated in due time for the IMPEDANCE and DISCARGE tests.

ANNEX B23: IMPLEMENTATION OF THE COLD MASS INSTRUMENTATION

The instrumentation to be mounted on the cold mass (see Section 7.3 and Annex C16) consists of:

- Voltage taps, to detect quenches of dipole windings and permit diagnostics on the spool pieces:
  - 50 % of the cold masses (type A), equipped with sextupole and decapole/octupole spool pieces, will have 14 voltage taps,
  - 50 % of the cold masses (type B), equipped only with sextupole spool piece, will have 10 voltage taps,
- 2 diode stack voltage tap wires, which will be provisionally short-circuited and insulated from ground. These two wires shall be pre-installed inside the cold mass,
- 2 current taps to power the protection diode stack and which shall be installed on the bus-bar interconnections,
- 2 current taps to allow magnetic axis measurement shall be installed between the two poles of each aperture,
- 1 temperature sensor at the centre of each cold mass,
- 1 cryo-heater.

1. VOLTAGE AND CURRENT TAP INSTALLATION

The voltage taps are fitted during the assembly of the magnet and before the mounting of the end covers. These taps are located on the superconducting cables interconnecting the poles, the two dipoles, the dipoles to the busbars and the spool piece magnet connections.

The location of these voltage taps is shown in drawings LHCMBA_E0005, LHCMBB_E0005, LHCMBA_A0003 and LHCMBB_A0003. Current taps are also mentioned on these drawings.

Two types of voltage taps are utilised:

1. The first type consist of tin-plated copper lugs, to be bent around and then soldered on the bare SC cable extremity and subsequently carefully insulated. The ends of the lugs are formed as a solder lug to accept a connecting insulated wire. The voltage tap dimensions are shown in drawing LHCMB__E0046.

After having made all the connections, the various voltage tap copper strips are placed on the bare cable and soldered with a soldering iron. The soldering iron touches the strip surface opposite to that in contact with the cable. By thermal conduction the heat passes through the copper strip and melts the solder.

The connections are now insulated. Particular care shall be taken to leave the lug completely free.

2. The second type consists of a standard lug fixed with a screw in a dedicated position on the busbars copper stabiliser.

The minimum length of the voltage tap wires shall be longer than 6000 mm.

During high voltage tests on the coils, the wires are at the same potential of the coils and their ends shall be insulated from ground.

A label with the name indicated in the column “number” of the Instrumentation List shall be attached to each wire. A check on the correct labelling of the wires shall be performed by injecting 1A DC current in the coils and measuring, with a DVM, the voltage of each tap as mentioned in Annex B22.

In the case of the protection diode stack, the two voltage tap wires are soldered directly to the diode stack lugs before it is installed. EE014 to the anode and EE015 to the cathode.

After installing the diode stack, the above wires are connected to those coming from the cold mass through the connector block. See drawings LHCMB__E0069, LHCMB__E0073 and LHCMB__E0074.

2. TEMPERATURE SENSOR

One temperature sensor per cold mass will be supplied by CERN (see also Annex C16). Each temperature sensor will be equipped with a sufficient length of wire. The final type of sensor is selected by CERN. The size of its housing and its mounting by two M3 screws is shown in drawing LHCMB__A0156.

The contractor shall test the temperature sensor comparing the measured electrical resistance with the value (range) indicated in the certificate of conformity of the delivered sensor. The resistance of the sensor shall be measured with an instrument using a 4-wire method, before mounting. This measurement and a low voltage ground insulation test shall be performed after mounting in the centre of the cold mass and the installation of its wires. These two tests shall be repeated several times during the cold mass mounting and as acceptance tests at the end of the cold mass fabrication

The type, serial number and the values of the functionality tests values shall be attached in the Traveller.

3. CRYO-HEATER

One cryo-heater per cold mass will be supplied by CERN.

It consists of a 100 Ω, 40 W power resistor. Its mounting by two M3 screws is shown in drawings LHCMB__A0156.

4. QUENCH HEATER WIRING

Annex B14 describes the quench heaters. Each quench heater consists of two strips which shall be connected in series on the non connection side as shown in drawings LHCMB__A0025 and LHCMB__A0026. Tests shall be performed to measure the resistance, the insulation to ground and to coils (see Annex B22) and the correct labelling of wires with respect to the corresponding quench heaters. The total number of wires for the connection of the quench heaters of a cold mass is 16. The wires will be provided in two colours. The Contractor is responsible for a convenient and correct labelling procedure for the identification of the wire throughout the assembly. CERN will provide a procedure in order to check the wire position (after the completion of the cold mass assembly) through electrical measurements.

5. INSTALLATION PROCEDURE AND DETAILS

For all the above operations, more details are given in the revision (now in preparation) of the document called “Installation Procedure”, similar to the document already provided for the “pre-series” contract (Ref.: LHC-MMS-GB/5837).

Concerning general wiring at the ends of the cold mass, see also drawings LHCMBA_E0004, LHCMBB_E0004 and LHCMB__E0005.

ANNEX B24: DEFINITION OF THE LONGITUDINAL BEVELLING OF THE HALF-CYLINDERS

1. INTRODUCTION

Two half-cylinders constitute the “shrinking cylinder”, which fit very tightly around the yoke of the magnet.

The shrinking cylinder has first a structural function. It shrinks around the yoke during the welding operation so as to close the yoke-gap, providing a minimum mating force at the half-yokes interface and the nominal pre-stress as specified in Sections 7.2.1.1 and 7.2.1.2. It is the part of the cold mass that provides flexural rigidity to minimise the vertical deflection induced by the magnet dead load. It is also the part of the cold mass that maintains the required horizontal sagitta. All other magnet parts are straight “as built”.

Secondly, the shrinking cylinder with the end covers, cold bore tubes, heater exchanger and various nozzle fitting, form the containment vessel of the super fluid helium.

2. TECHNICAL REQUIREMENTS

The half-cylinders will be bevelled lengthways on both straight edges in preparation for welding.

CERN will provide the Contractor with the necessary half-cylinders already bevelled.

The Contractor shall be responsible for the definition of the bevel detail as well as for the determination of the half-circumference of the half-cylinders. CERN will procure the half-cylinders bevelled accordingly.

ANNEX B25: ACTIVE PART ASSEMBLY

1. INTRODUCTION

The active part includes the magnet components that contribute towards generating the magnetic field, to ensure the field quality and to take up the Lorentz' forces which are produced during operation.

This Annex describes the specification relative to the assembly of the active part. It therefore includes a sequence of assembly operations to be performed in sequence in preparation for the longitudinal welding of the shrinking cylinder.

The main components of the active part are the collared coils, the end plates, the half-yokes, the yoke inserts, the busbars and the half-cylinders.

2. TECHNICAL REQUIREMENTS

The active part assembly shall be made in accordance with the reference drawing LHCMBB_A0002 (as regarding the "type B" cold mass).

This part of the cold mass assembly is of great importance with regard to the requirements of the cold mass geometry as specified in Section 7.2.2.

The active part shall be assembled directly on the intermediate beam of the welding press to avoid unnecessary rotation and transport before the longitudinal welding of the half-cylinders. Indeed, any rotation and/or transport of the active part "as assembled" but not welded could lead to undesirable additional twist in the laminated structure.

The active part assembly is the sequence of operations, listed below.

1. Install the lower half-yoke on the special bench designed to rotate it.
2. Install the defocusing (QD) quadrupole busbars in the lower half-yoke slot. The fixed point must be made at this stage.
3. Fit the lower half-cylinder.
4. Fasten the parts mentioned in 1, 2 and 3 together with the turning jig and turn the assembly through 180°.
5. Remove the turning jig, move the half-yoke/bus-bars/half-cylinder assembly to the press area and put it in the press cradles, which are pre-installed on the intermediate beam.
6. Level and clamp the half-yoke so that its mating surface is flat and straight.
7. Fit the collared-coils/0.3 mm thick shims yoke inserts/end plates assembly in the lower half-yoke/busbars/half-cylinder assembly. As explained in Section 1.3.1, there are two dipole types which differ in the internal connection of busbars and the layout of the spool piece correctors. The collared coil assembly shall be offered up to the lower half-yoke so that dipole 1 is in the uppermost position for "type A" dipoles and in the lower position for "type B" dipoles. Install the 0.5 thick shim (between the yoke lamination and the inserts). The collared coil assembly shall be (previous the lowering down in the lower half-yoke) provided with the rectangular filling pieces (blocked by clamps). The other rectangular filling pieces shall be mounted on the collared coils after its positioning inside the lower half-yoke (see drawing LHCMBB_A0001).

8. Lower the upper half-yoke on the collared-coils/yoke inserts assembly and level it.
9. Install the focusing (QF) quadrupole busbars and dipole busbars in the upper half-yoke slots. The longitudinal position of the fixed point has to be adjusted with respect to that of QD bus bar in the lower half-yoke.
10. Lower the upper half-cylinder on the upper half-yoke.

Before operation N° 7, the end plates shall be attached to the collared coils' ends so that the coils' cables and instrumentation wiring pass through them. At this stage of the active part assembly, the cables' ends could be already shaped in preparation for soldering, which is to be done in the following steps of the cold mass assembly (see Annex B28). If the cable ends are shaped at this stage, the Contractor shall do so according to the orientation of the collared coil with respect to the yoke, as described in point 7 above. During the shaping operations, the end plates shall be temporarily fixed to a special support resting on the collar perimeter in order to guarantee a correct final geometry and positioning of the electrical connections. The 0.3 mm thick shims (between the collared coil and the yoke inserts) and the 0.5 thick shim (between the yoke lamination and the inserts) are defined as nominal shims to be assembled if all the components are nominal and assembled under nominal stress. The definition of the real shims will depend by the measure and comparison of the three components: collared coils, insert packs and half-yoke opening).

The active part assembly is then ready for longitudinal welding of the half-cylinders.

3. CONTRACTOR'S RESPONSIBILITIES

The Contractor shall be responsible for preparing (including design, procurement and installation) the necessary lifting devices for the collared coils/yoke inserts/end plates assembly as well as for the half-yoke assembly. The levelling and clamping tools, turn over bench(es), turning jigs and other tooling are also under the Contractor's responsibility.

ANNEX B26: CURVING AND LONGITUDINAL WELDING OF THE SHRINKING CYLINDER

1. INTRODUCTION

The requirements concerning the curving process of the active part and the longitudinal welding of the half-cylinders are specified in this Annex.

The longitudinal welding of the half-cylinders is a very important operation. Indeed, structural parameters, which govern the magnet behaviour during operation at 1.9 K, are resulting from this critical phase. These parameters are a closed gap between the yoke-halves, a minimum mating force at their interface and a nominal pre-stress in the shrinking cylinder. The desired horizontal curvature is also built in at this stage of the cold mass assembly.

2. TECHNICAL REQUIREMENTS

2.1. Curving process

The required geometry for the active part assembly is illustrated in the reference drawing LHCMB__S0001.

The curving process, performed simultaneously with the longitudinal welding, applies to the active part assembly in its status as illustrated, except for the welds, in the reference drawing LHCMBB_A0002. It consists of pushing the active part assembly, which is sitting in the lower press cradles[8] supported by the intermediate beam[9], upwards against the upper press cradles. The upper press cradles are equipped with adjustable wedges providing the required curvature in the active part assembly.

The half-cylinders will be provided “pre-curved”, so that there should be only a rather limited spring-back after longitudinal welding and release of the press loading.

The measurements of the active part geometry shall be made by the procedure described in Annex B27. CERN will provide the Contractor with a 3D measuring machine (Laser Tracking System) allowing the requested measurements to be made (see Annex E5).

The curving process shall be reproducible so that the horizontal curvature of the active part is controlled within the global tolerance range as defined in Section 7.2.2 throughout the entire cold masses production.

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[8] The press cradles denote the saddle-shaped modules which are aligned on the intermediate beam of the press, in which the active part assembly resting during this phase of the cold mass assembly until completion of the longitudinal welding.

[9] The intermediate beam is a 230-mm thick beam on which the active part components are assembled in preparation for the longitudinal welding of the shrinking cylinder.

2.2. Longitudinal welding

The welding operation shall be performed in the welding-press provided by CERN for this purpose. A short description of the welding-press including its main functions and characteristics is given in Annex E4 (see also drawing LHCMB_TW0003 entitled “LHC Welding Press Assembly”).

The active part assembly, as delivered from the preceding assembly phases, is placed in the press cradles so that the two apertures are positioned vertically one above the other (dipole I in upper position and dipole II in lower position for the dipoles of type A).

The required pre-stress, which is specified in Section 7.2.1.2., is mainly built up by a compressive loading developed by the press and applied vertically to the active part assembly via the press cradles. Owing to the weld-shrinkage, the pre-stress in the shrinking cylinder is increased so that it finally reaches the required value, i.e. at least 150 MPa, after complete release of the press loading.

The induced pre-stress depends mainly on three leading parameters: the half-circumference of the half-cylinders, the stiffness of the collared coils and the weld-shrinkage. The Contractor shall be responsible for controlling these three parameters so that the required pre-stress is achieved uniformly throughout the entire production.

A minimum pressing load, which is to be determined by the Contractor in conjunction with the above-mentioned leading parameters, will guarantee a successful assembly. The Contractor may include, specific measurements (gap measurements during the pressing and welding process for instance), which he deems necessary to achieve the requirements. This should include, whenever necessary, the manufacture of instrumented welding models (for example with strain-gauges for monitoring the induced pre-stress, displacement transducers for monitoring the gap closure and possibly with capacitive-gauges for monitoring the induced mating force) of representative sizes (full scale in cross section and minimum 1.5 m length).

Although CERN will provide the welding-press and the welding equipment, the Contractor remains responsible for the welding operations and for the final quality of the weld.

The longitudinal welds shall be checked as specified in Annex B33.

In addition, a number of run-off test plates shall be provided throughout the entire production. The number of these production test plates and the checks required on them are defined in Annex B33. The extra-length, which has been provided in the half-cylinders (half-cylinder length “as built” is 15350 mm whereas the net length is 14792 mm), can be used as a production test plate.

The welded joint shall be fully austenitic, i.e. free from any δ-ferrite. To this end, the filler material WNr. 1.4455, which is an austenitic steel, is mandatory for this application. The Contractor shall be responsible for the procurement of the filler material, which shall be documented with a material certificate according to EN 10204/3.1.B. Should the Contractor wish to use another filler material, formal approval from CERN shall be requested prior to its utilisation.

From the experience gained at CERN during the R & D programme, it is known that some batches of filler metal may be unacceptable although the chemical analysis of the wire shows acceptable figures with respect to the standard. The only way to detect bad wires is by X-ray examination of a test plate. Indeed, systematic checks on several batches have shown that there were no significant differences in the chemical analysis, except in the sulphur content. Filler metals with a higher sulphur content (of the order of 100 ppm) have shown a better behaviour and have given better welds than others with a lower sulphur content (of the order of 10 ppm).

Therefore, CERN strongly recommends the Contractor to check systematically some spools of each new batch by producing a test plate and X-ray testing it. This check shall be part of the inspection and test plan presented in Annex B2.

2.3. Welding process

Following CERN experience, the welding process that gave the best results in terms of weld quality whilst maintaining a reasonable production rate is a combination of the GMAW and STT[10] welding process. In this case there are four weld beads in total, one root pass performed in STT and three filling passes performed in GMAW.

Although CERN will provide the Contractor with a set of welding parameters for both root and filling passes, the welding operation and the results obtained will be under the Contractor's responsibility. The Contractor shall qualify the welders and the welding procedure itself according to the relevant requirements defined in Annex B33 entitled "Safety Tests".

3. CONTRACTOR'S REPONSIBILITIES

The Contractor shall provide a detailed assembly and control procedure, which precisely describes the sequence of curving, longitudinal welding and inspection of the active part assembly.

In particular, all the checks and measurements requested in this Annex shall be recorded in the Traveller.

At the completion of the longitudinal welding activities, at the same time as the "Yoke Closing Gap" check, a mandatory Visual Inspection of the welded assembly is required. The Contractor shall visually check the integrity of all the sub-assemblies and components, that no obstructions or objects are present in the half-yoke openings.

The Contractor shall remove from the active part assembly all possibly remaining projections or various debris produced during the welding operation.

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[10] STT stands for Surface Tension Transfer. This is basically an advanced MIG/MAG welding with a closed-loop regulation that optimises the welding energy on the basis of the actual welding conditions (thanks to relevant information provided by the arc itself).

ANNEX B27: INSPECTION OF THE ACTIVE PART GEOMETRY

1. INTRODUCTION

In this Annex, the procedure for inspecting the active part geometry is described. The Contractor shall be responsible for making of the complete inspection as described hereafter.

CERN will provide the Contractor with an adequate 3D-measuring instrument, which is a LTD500 Laser Tracking System[11], making it possible to determine the Cartesian co-ordinates, X-Y-Z of points distributed in space. More details about this measuring device are given in Annex E5.

As specified in previous sections, some of the cold mass components shall be precisely positioned with respect to the active part assembly, i.e. with respect to the theoretical geometric axes, V1 and V2. Therefore, the active part geometry shall be inspected at specific stages of the cold mass assembly. This inspection is one of the most important checks that shall be performed several times during the final assembly stages. It makes it possible to determine the theoretical geometric axes of the cold bore tubes, V1 and V2, which constitute the basis of all the positioning performed during the completion of the cold mass. The phases during or after which the geometry shall be checked or the positioning shall be done are defined hereafter.

CERN reserves the right to ask for the measurement of the active part geometry in the welding press under load before welding the shrinking cylinder, should these measurements be proven necessary.

2. DESCRIPTION OF THE PROCEDURE

The inspection of the active part geometry includes the measurement of the geometrical axes of each cold bore tubes in a common Cartesian co-ordinate system. From these measurements, the vertical straightness and the horizontal curvature of the cold mass are verified.

During these measurements, the active part assembly shall be resting on 3 temporary support bases, which shall be positioned at the final locations of the cold mass support bases, which are 5400 mm apart. The temporary support bases shall be pre-aligned before starting the inspection. The active part assembly shall be turned so that it stands in operating position with the two apertures in the horizontal plane. An external reference system, composed of approximately 10 points distributed homogeneously around the cold mass, shall be created and measured in order to make possible the link between the different sets of measurements taken in the two cold bore tubes.

Inside and along each cold bore tubes, every 250-300 mm has to be taken measurements. The measurement co-ordinate system has to be positioned with its origin on the connection end at the end plate or at the end covers, depending on the stage of the cold mass assembly. A semi-automated process guides the operation.

By a least squares method, the actual measured co-ordinates of the cold bore tube are positioned so that they best fit the theoretical geometric axes of the cold bore tubes V1 and V2 (the “arc” together with the “straight ends”), which are 194.52 mm apart.

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[11] Made by Leica

The solution is such that the sum of the squares of the differences between the measured co-ordinates and the theoretical co-ordinates is minimum.

From the above-mentioned fitting operation, the orientation of the actual measured plane V1-V2 and more specifically that of the lines V1 and V2 is known in the nominal, theoretical co-ordinate system. These lines V1 and V2 will be referred to hereafter as the datum axes of the active part. These lines lie in a perfect plane, the plane V1-V2, which will be referred to hereafter as the datum plane of the active part.

From the above-mentioned measurements, the Contractor shall check that the active part geometry fulfils the requirements of Section 7.2.2, i.e. the active part geometry shall be included in the global tolerance range which has been defined in Section 7.2.2.2 (at this stage, the ends of the cold bore tubes, as they are only fixed once the end covers are welded, can be out of the tolerance range of 0.3 mm radius with respect to the V1 and V2). During these measurements, the longitudinal position of the end plates has to be determined one respect to the other.

CERN reserves the right to change, improve and optimise the procedures for the cold mass geometry and alignment measurement and inspection.

3. RELATIONSHIP WITH MAGNETIC PARAMETERS

Ideally, the active part geometry should correspond exactly to the curved trajectory, which is imposed by the dipole field. Therefore, the final inspection of the geometry shall include the measurement of the magnetic axes. To this end, CERN will provide the Contractor with the a special probe or “geometric/magnetic mole”, together with its associated electronics as described in Annex E5. This probe will be used together with the LTD500 system.

The measurement of the magnetic axes is possible by connecting the poles in opposition so that the dipole actually works as a skew-quadrupole (QCD measurement). During these measurements, the poles shall be excited with a small AC-current of about 1 A.

The geometric measurements and the magnetic measurements shall be performed simultaneously.

4. CONTRACTOR’S RESPONSIBILITIES

The Contractor shall provide CERN with a detailed inspection procedure. All the results of the measurements shall be recorded in the Traveller.

ANNEX B28: PREPARATION OF THE MAGNET EXTREMITIES

1. INTRODUCTION

This Annex describes the various operations which are to be done before the active part is closed with the end covers to become the so called “cold mass assembly”. These operations are:

1. welding the end plates (the welding of the end plate to the shrinking cylinder shall be performed before the first geometric measurement is performed. The reason is that at this stage the origin of the measuring co-ordinate system is fixed on the end plate which can move during the welding operation),
2. making and finishing the electrical connections,
3. installing the cylindrical filling pieces,
4. installing of the corrector magnets.

The corrector magnets (without supports) are the only components delivered by CERN for the activities covered by this annex. All the ancillary components necessary for the preparation of the magnet extremities are the responsibility of the Contractor and are shown in the following drawings:

For the Connection side:

LHCMBA_E0002 (“type A” dipole),
LHCMBB_E0002 (“type B” dipole).

For the Lyre side:

LHCMB__E0005 (“type A” and “type B” dipole).

2. END PLATES

The end plates shall be fixed to the shrinking cylinder by a discontinuous circumferential weld as illustrated in section E-E and inside the view “B” of the reference drawings LHCMBA_A0002 and LHCMBB_A0002.

The total area of the weld cross-section shall be sized to take up the axial component of the Lorentz’ forces which occur during operation. Calculations have shown total forces of the order of 50 t to 70 t. About 50% of this force is transferred to the end plates via special screws (2 per aperture), which shall be tightened with a torque of 150 Nm (with the thread lubricated with MoS2). These figures will be checked on the prototypes now being manufactured. Therefore, the cross-sectional area of the weld shall be designed to withstand 70 t.

The weld shrinkage, which is known to occur inwards, is very likely to hamper an easy fitting and correct positioning of the end covers. Therefore, the Contractor shall select an appropriate welding process in order to minimise the induced deflections.

The filler metal WNr. 1.4455, which is an austenitic steel, is mandatory for this application. The Contractor shall be responsible for the procurement of the filler material, which shall be documented with material certificate according to EN 10204/3.1.B.

Recommendations on the above-mentioned operations will be given by CERN in the form of assembly and control procedures (“shop-floor” documents), which are applied at CERN in the Magnet Assembly Facility (See Annex F).

3. CYLINDRICAL FILLING PIECES

The cylindrical filling pieces will be inserted and blocked by the dedicated stoppers and screws (see drawing LHCMBB_A0001 and 2).

4. ELECTRICAL CONNECTIONS

In this section the requirements concerning the electrical connections to be made between the upper pole and lower pole of each aperture, dipole "type A" and dipole "type B" and the connections with the powering busbars and the diode stack by-pass are specified. There are 5 connections to be made.

The Engineering Specification LHC-DCB-ES-0001 (attached to this Annex) describes the connection layout for the busbars of the LHC dipole cold masses.

Half of the requested cold masses, shall be fabricated with electrical connections of "type A" according to drawing LHCMBA_E0005 and the other half with electrical connections of "type B" according to drawing LHCMBB_E0005.

The electrical connections shall be made in the following sequence:

a) Forming the coil-terminals[12] together with their stabilising copper sections.

b) Soldering of connections.

c) Inspections and measurements of all the junctions (according to the procedure agreed upon between CERN and the Contractor during the manufacturing of the pre-series cold masses).

d) Insulation of all connections including the diode stack connections according to drawing LHCMB__S0006 for "type A" and "type B" dipole.

e) Electrical test of the coils and busbars according to Annex B22.

f) High voltage test of the insulation to ground according to Annex B22, Section 6.

Steps a) and b) could be completed before yoking the collared coils, just after having fitted the end plates at the collared coil ends. This would considerably ease the installation of the forming and soldering tools. The following steps shall be executed after having welded the end plates to the shrinking cylinder.

In case of a "Full Tests Configuration" of the cold mass, special connections and equipment are requested as defined in the drawings:

- for "type A" cold mass: LHCMBA_S0008
  LHCMBA_S0009
  LHCMBA_S0010
  LHCMBA_S0011

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[12] The coil terminals denote the straight part of the cable, i.e. its extremity, coming from the poles (upper and lower poles) and passing through the end plates

- for “type B” cold mass: LHCMBB_S0008
  LHCMBB_S0009
  LHCMBB_S0010
  LHCMBB_S0011

The inspection of the active part geometry shall be made at this stage.

5. POSITIONING OF THE COLD MASS SUPPORT BASES

The three support bases have to be positioned on the pre-aligned and pre-tilted temporary supports (those of the finishing station). Once the datum plane of the cold mass is known and the distance between the end plates determined, the longitudinal positioning of the support bases can be made. This operation is also assisted by the measurements realised with the LTD500, placed in an appropriate place, from which the three supports are “visible”. The link between the nominal, theoretical co-ordinate system is the above-mentioned external reference system. The requirements on the position of the cold mass support bases are given in the drawings LHCMBA_S0001 and LHCMBB_S0001. Once positioned correctly, the support bases shall be welded to the shrinking cylinder. The key point of this operation is that the cold mass assembly shall resting on its support bases (with the weight of the cold mass acting on them) during the welding operation.

6. PREPARATION OF THE EXTREMITIES OF THE SHRINKING CYLINDER

The shrinking cylinder, which is longer than required, shall be cut to its final length compensating the possible errors of the active part length. Its ends shall be machined internally to a correct bore diameter thus ensuring correct alignment and jointing with the bevel-edge of the end cover. This latter operation eliminates local circularity defects and the reduction in diameter as well, which are caused by the inward deflection of the shrinking cylinder end when the end plate is welded to it.

The straight cutting of the shrinking cylinder at both ends shall be perpendicular to the straight ends of the theoretical geometric axes of the cold bore tubes, V1 and V2. The cutting plane shall be localised at 42.5 mm (± half of the error of the active part length) with respect to the external surface of the end plate. These geometric requirements are illustrated in the drawing LHCMBB__S0001. The total developed length of the shrinking cylinder shall be controlled at the level of the central line “W”, which can be considered as the mechanical axis of the active part.

The internal machining operation shall be performed so that the boring centre is concentric with the datum axis W within 0.2 mm. In practice if the horizontal curvature of the active part deviate from the nominal curvature, this requirement leads to a significant variation of the wall thickness of the shrinking cylinder (error of concentricity between the inside and outside diameters). In this case, the internal machining operation shall be performed so that the boring centre is concentric with the internal bore of the shrinking cylinder, which shall be measured at 10 mm from the outer surface of the end plate to within 0.7 mm trying to minimise the off-centring with respect to the datum axis W. The boring operation shall be limited to a depth of 12 mm with respect to the straight cut of the shrinking cylinder as illustrated in view “P1” of the drawing LHCMBB_S0002. In order to achieve a correct positioning of the end covers the alignment of the cutting machine has to be made utilising the LTD500 measuring system. A semi-automated process, based on systematic routines, guides the operation. The link between the nominal, theoretical geometry is the external reference system.

7. CORRECTOR MAGNETS

In this section, the requirements concerning the mounting, the alignment and the electrical connection of the corrector magnets are specified.

In order to compensate for the systematic sextupolar and decapolar field errors induced by persistent currents of the main dipole, the active part must be equipped with small sextupole and decapole corrector magnets. These corrector magnets shall be installed around the cold bore tube ends on the lyre and the connection sides.

In order to be efficient, these corrector magnets shall be aligned to within ± 0.3 mm with respect to the straight ends of the datum axes V1 and V2. In order to satisfy these requirements, the spool piece supports on which the correctors shall be pinned are localised with respect to the datum axes V1 and V2 within 0.3 mm.

The positioning operation requires the use of the LTD500 measuring system and of a positioning jig, which is centred with respect to the shrinking cylinder extremity. The operation is performed by means of Y-Z slides and of a rotation unit. A semi-automated process based on systematic routines guides the operation. The link between the nominal, theoretical geometry is the external reference system.

The assembly drawings, LHCMB__E0003 and LHCMB__E0015, show the positioning jigs for the sextuple corrector magnets and for the decapole/octupole corrector magnets respectively.

The relevant operations shall be performed in the following sequence for the sextupole corrector magnets:

a) Fix the spool piece support to the positioning jig,

b) Install the positioning jig by centring it in the internal bore of the shrinking cylinder extremity. Fix it firmly onto the shrinking cylinder outside.

c) Align the spool piece support with the datum axes V1 and V2 by making Y and Z translations and rotation about the main axis as needed until a perfect match is obtained. Use the reflectors and the LTD500 measuring system for this operation. Screw and secure by tack welding the spool piece support.

d) Remove the positioning jig and pin the sextupole corrector magnet to its support.

Repeat the above mentioned operations (a), b), c) and d)) for the decapole/octupole corrector magnets on the connection side.

Then, continue according to the following steps:

e) Forming of the corrector magnets’ terminals and of the auxiliary busbars in preparation for their electrical connection.

f) Soldering of all the electric connections, including instrumentation wires:

- for cold mass “type A”
  Connection side, see drawing: LHCMBA_E0001
  Lyre side see drawing: LHCMBA_E0003
- for cold mass “type B”
  Connection side : N/A (no correctors are present)
  Lyre side, see drawing: LHCMBB_E0003

g) Inspection of the electric connections (to be defined later)

h) Insulation to earth

i) Electrical tests and insulation tests according to Annex B22

j) Only half of the requested cold masses shall be equipped with both the sextupole and decapole/octupole corrector magnets (“type A” cold mass). The other half shall be equipped with the sextupole corrector magnets only (“type B” cold mass).

8. DIPOLE BUSBARS SHORT-CIRCUIT CONNECTION

The dipole busbars, interior and exterior, shall be short-circuited on the connection side. These short circuits shall be obtained by mechanical clamping as shown on drawing LHCMB_SA0003. An indium foil shall be inserted between the two cables to lower the electrical resistance of the junction.

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the
Large
Hadron
Collider
project

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249359

Date:2001-04-27

Engineering Specification

ELECTRICAL CONNECTIONS OF THE LHC MAIN DIPOLES

Abstract

This engineering specification concerns the connections of the LHC main dipoles. It defines the interconnections of the internal and external apertures of each cold mass, the two types of bus-bar for the series connections of the main dipoles and the connection of the protection diode stacks.

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History of Changes

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0.1	2000-12-07	11	First submission for check
0.2	2001-04-27	all	New submission for engineering check

Table of contents

1. REFERENCE DOCUMENTS

- LHC Magnet Polarities: LHC-DC-ES-0001.00 rev. 1.1
- Minutes of the P & LC meeting of 19 May 1999
- Minutes of MARIC meeting of 23 August 2000

2. CONVENTIONS

There are two beams circulating in LHC: Beam 1 and Beam 2.

The protons in Beam 1 circulate in clockwise direction when looking from above. The main dipole field is always directed upwards for Beam 1 and downwards for Beam 2.

An MBA dipole cold mass is equipped with MCS sextupole spool pieces at the lyra end and MCDO decapole and octupole spools pieces at the connection end.

An MBB dipole cold mass is equipped with MCS sextupole spool pieces at the lyra end.

The positions "right" and "left" in the transversal plane are to be understood from the point of view of an observer looking along the longitudinal axis of the magnet and facing the electrical connection ends (i.e. looking from the Beam 1 upstream end of the magnet).

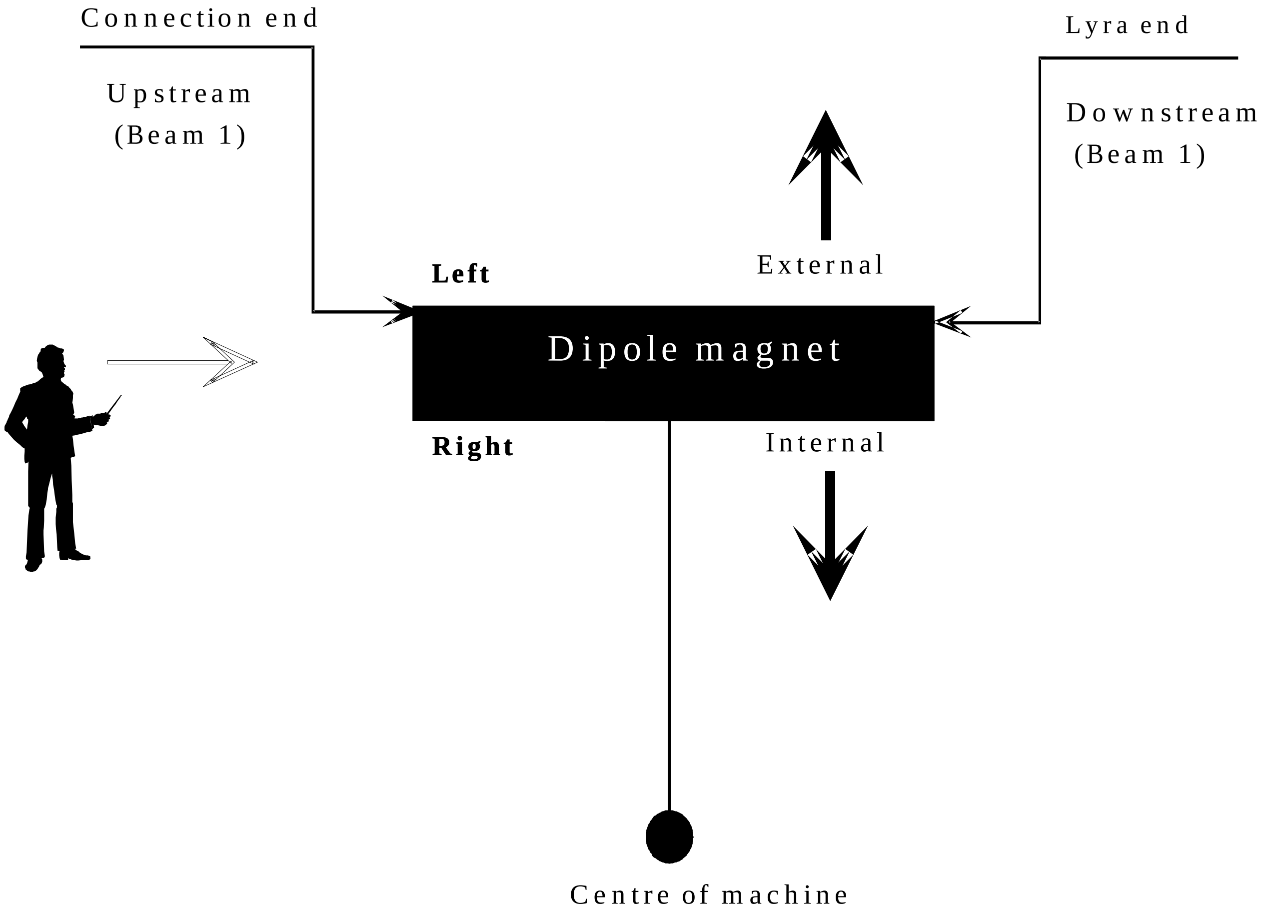


Fig. 1: Conventions

3. COILS AND INTERNAL CONNECTIONS

The two windings of each dipole are identical and connected in series so that the magnetic fields of each aperture are parallel and in opposite directions.

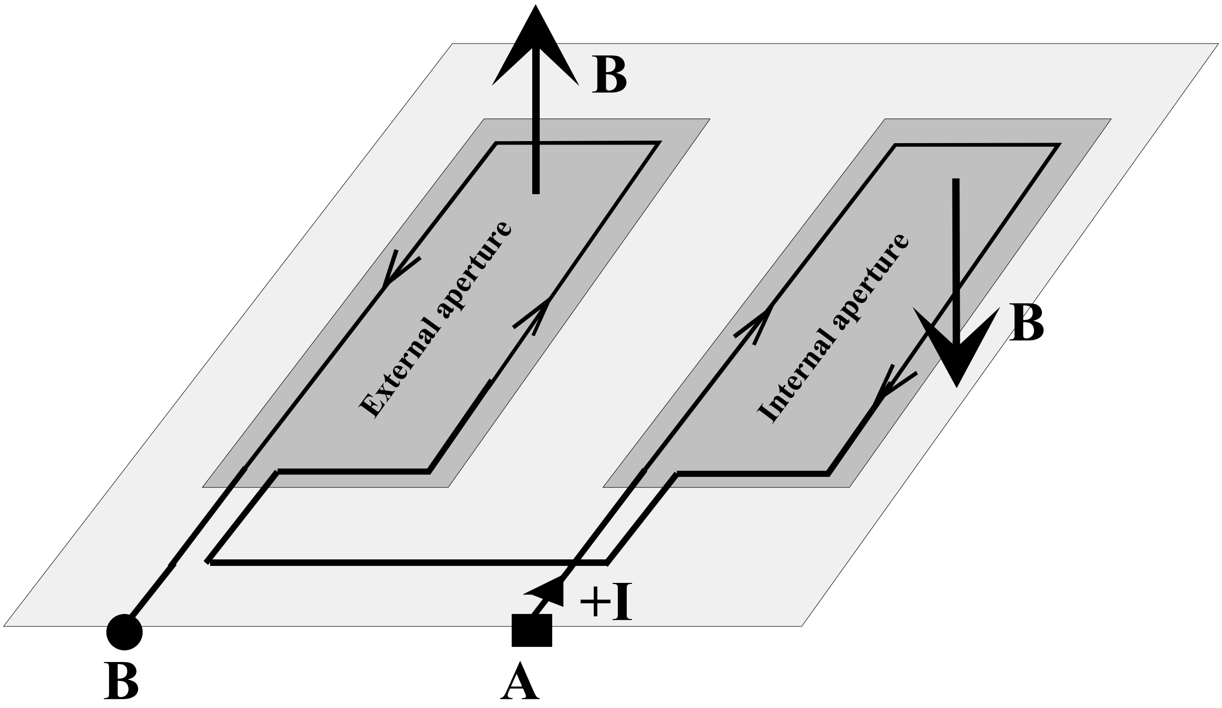


Fig. 2: Apertures and Electrical Connections

3.1 CURRENT ORIENTATION

The windings of the dipole apertures are connected so that the current that generates an upwards pointing vertical magnetic field in the external aperture and a downwards pointing vertical magnetic field in the internal aperture is said to be positive. Because of both this convention and the magnet design:

- Letter A indicates the positive current input terminal.
- Letter B indicates the positive current output terminal.

This configuration is invariable for all the magnet assemblies of the main dipole magnets.

4. BUS-BARS AND COIL CONNECTIONS

Each dipole magnet has its full set of bus-bars comprising two quadrupole bus-bars sets (a focussing and a defocussing one) and a dipole bus-bar set.

Each dipole bus-bar set consists of two bus-bars running along the dipole in a slot in the lower left-hand side of the transverse cross-section of the dipole.

A right bus-bar and a left bus-bar are therefore defined in terms of their position inside this slot.

One of these bus-bars is continuous whereas the other consists of two sections connecting the terminals A and B of the twin-aperture magnet.

There are two types of bus-bar sets associated with the two different types of dipoles.

- The DCBA bus-bar full set is part of the MBA dipole assembly. It comprises the DCBA dipole bus-bar set that consists of a continuous bus-bar on the right hand side and of a two-section bus-bar connected to the winding terminals on the left hand side.

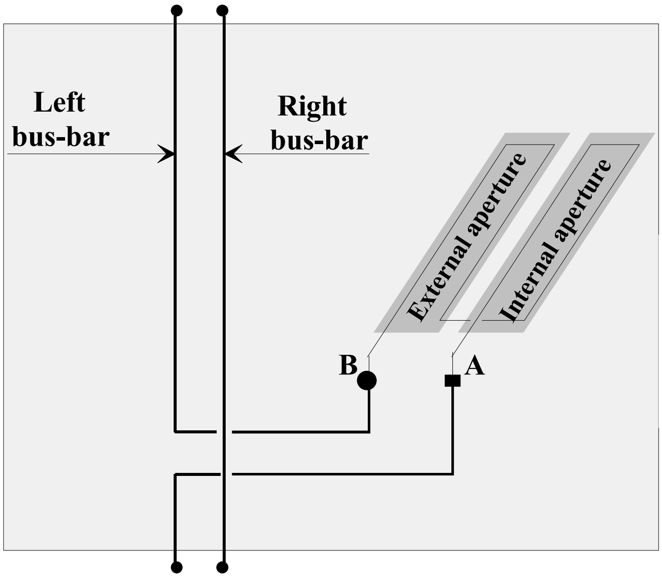


Fig. 3: DCBA dipole bus-bar set, part of the MBA dipole assembly.

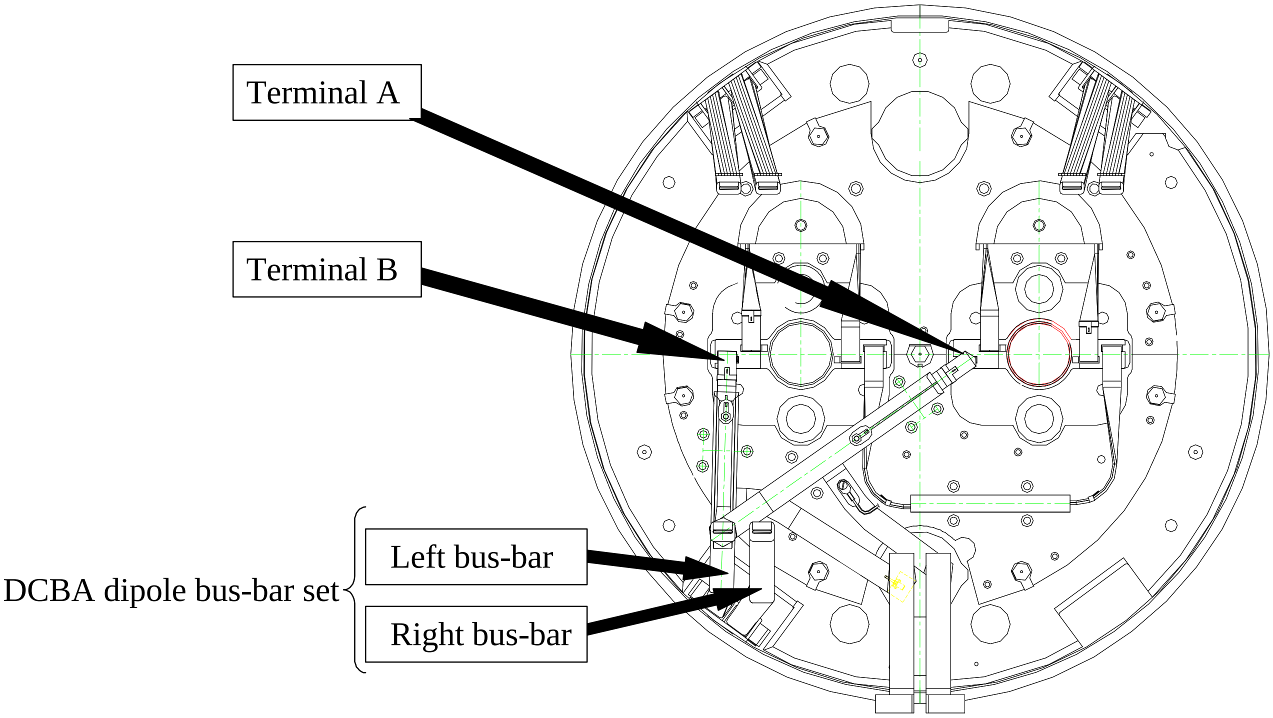


Fig. 4: Connection end of MBA dipole

See drawing LHCMBA-E0005

The DCBB bus-bar full set is part of the MBB dipole assembly. It comprises the DCBB dipole bus-bar set that consists of a continuous bus-bar on the left hand side and of a two-section bus-bar connected to the winding terminals on the right hand side.

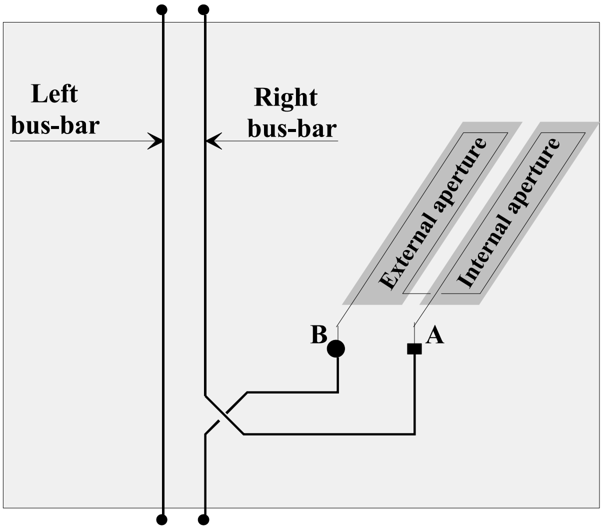


Fig. 5: DCBB dipole bus-bar set, part of the MBB dipole assembly

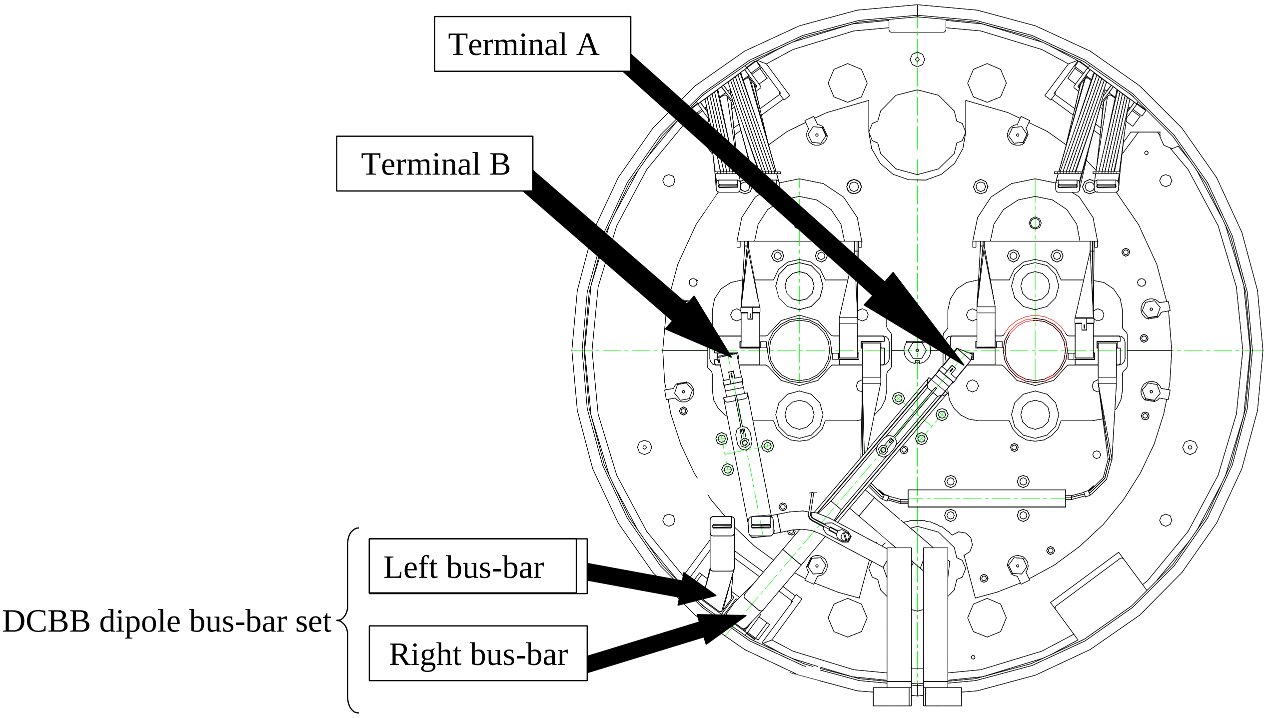


Fig. 6: Connection end of MBB dipole

See drawing LHCMBB_0005

5. DIODE STACK CONNECTIONS

The protection diode stacks shall be connected between terminals A and B according to two different types of diode stack: types AR and AL. Each type of diode stack can be associated with either the MBA-type or MBB-type dipoles, thus entailing four combinations detailed below.

The diode stack types are arranged so that all the dipoles in the same LHC sector have diode stacks of identical type, whatever dipole type is installed.

5.1 DIODE STACK TYPE AR

The anode of the diode stack is connected to terminal A (or to the right-hand terminal as viewed from the location as defined in paragraph 2), whereas the cathode is connected to the left-hand terminal B.

This diode stack is called: "AR" for "Anode on the Right".

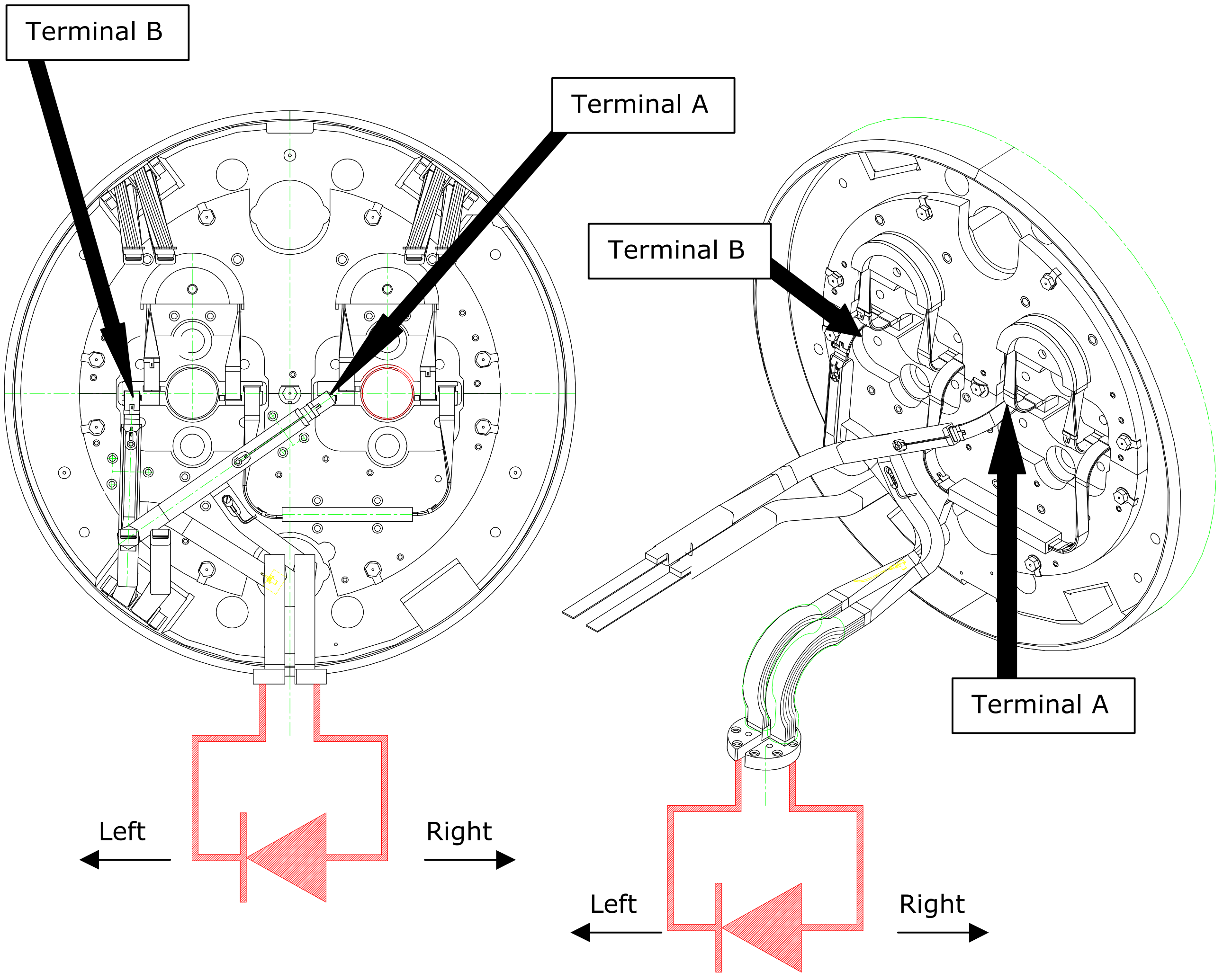


Fig. 7: Case 1 - Dipole MBA with diode stack AR

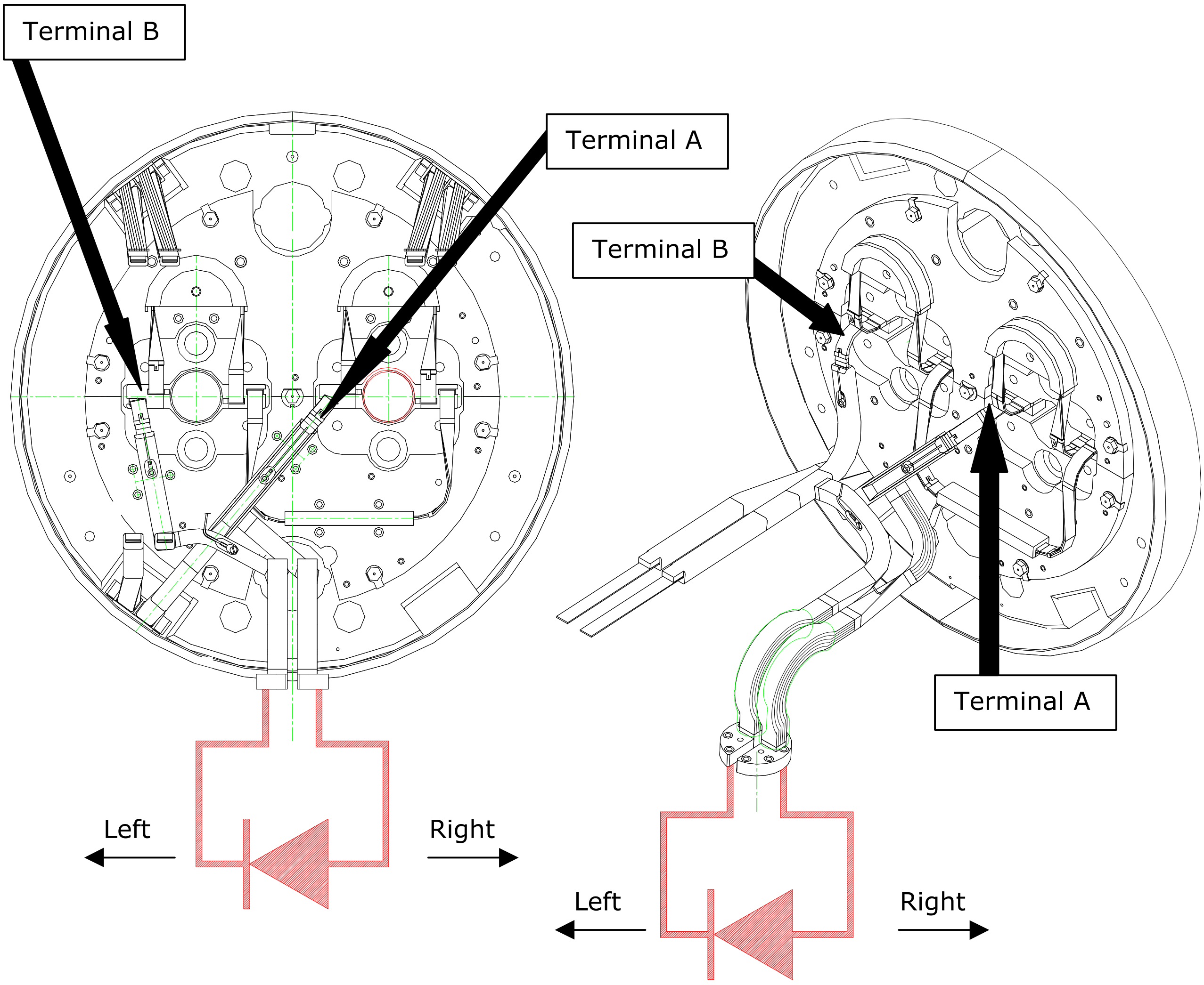


Fig. 8: Case 2 - Dipole MBB with diode stack AR

5.2 DIODE STACK TYPE AL

The anode of the diode stack is connected to terminal B (or to the left-hand terminal as viewed from the location as defined in paragraph 2), whereas the cathode is connected to the right hand terminal A.

This diode stack is called: "AL" for "Anode on the Left".

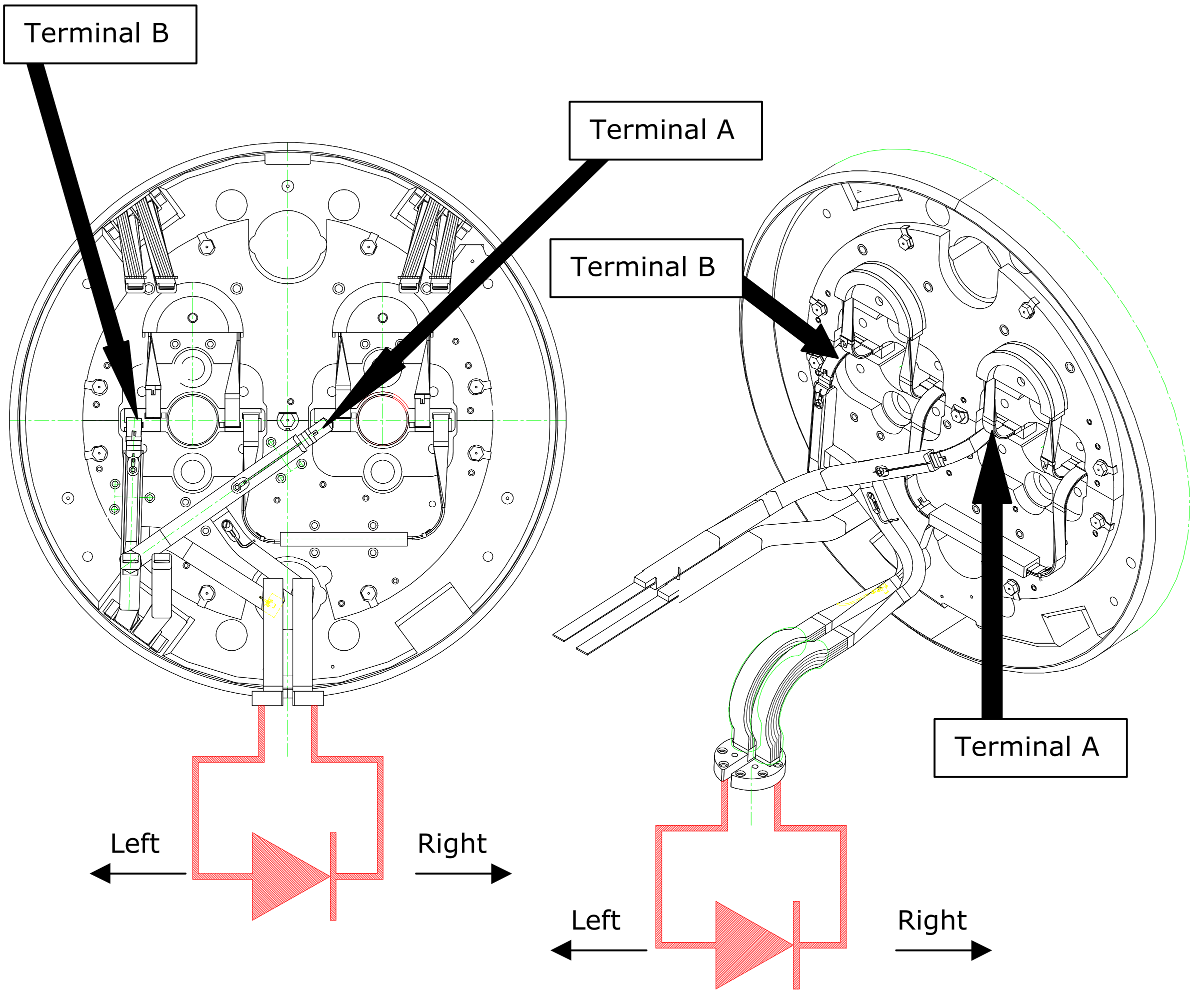


Fig. 9: Case 3 - Dipole MBA with diode stack AL

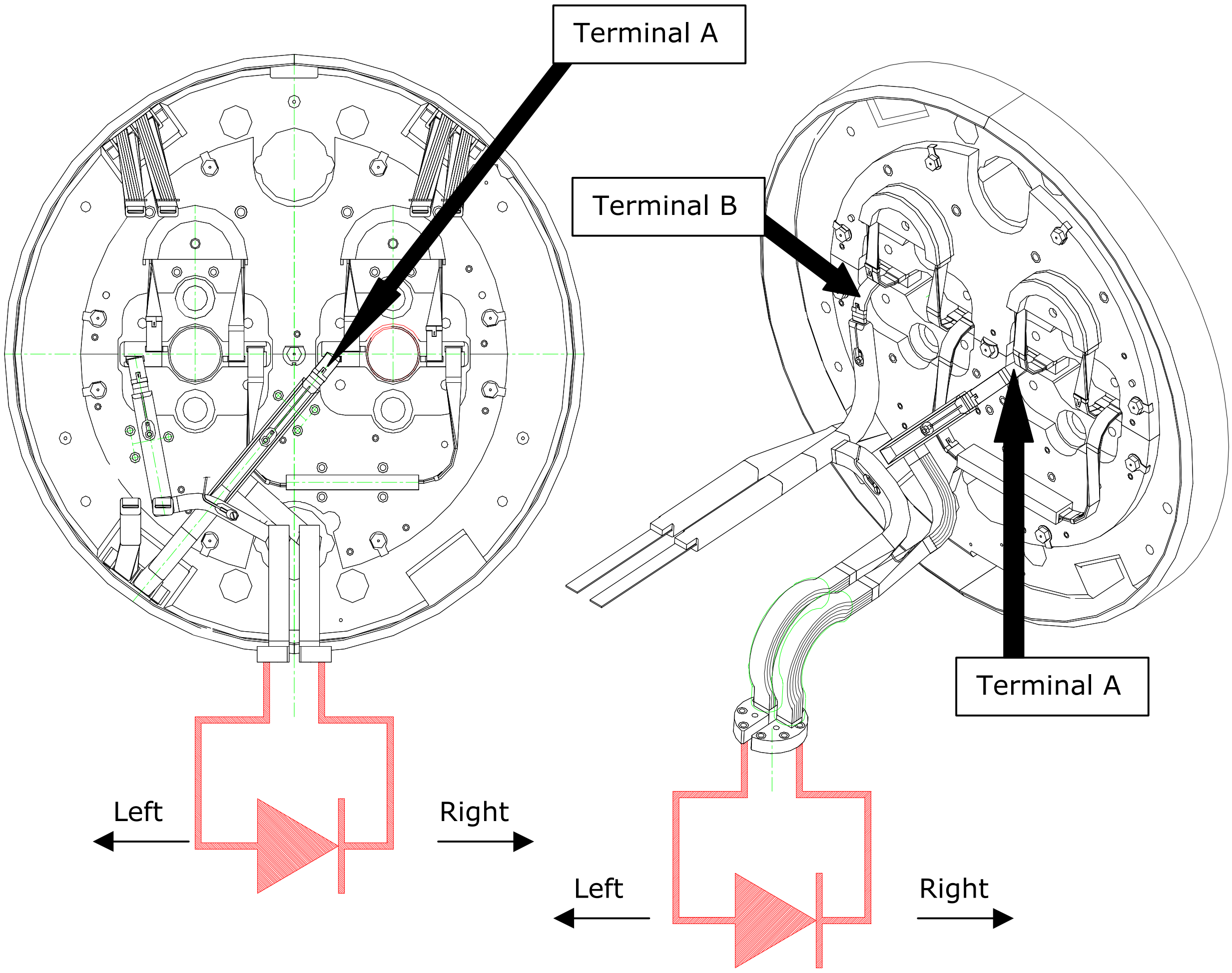


Fig. 10: Case 4 - Dipole MBB with diode stack AL

5.3 TABLE SUMMARISING THE REQUIREMENTS

SECTOR 1 – 2	DIODE STACK TYPE AR
SECTOR 2 – 3	DIODE STACK TYPE AL
SECTOR 3 – 4	DIODE STACK TYPE AL
SECTOR 4 - 5	DIODE STACK TYPE AL
SECTOR 5 – 6	DIODE STACK TYPE AR
SECTOR 6 - 7	DIODE STACK TYPE AR
SECTOR 7 - 8	DIODE STACK TYPE AR
SECTOR 8 - 1	DIODE STACK TYPE AL

Table 1: Diode stack distribution

5.4 WIRING AND EQUIPMENTS OF THE ARC CELLS

5.4.1 BEAM 1 IN EXTERNAL APERTURE

All diode stacks are type AR

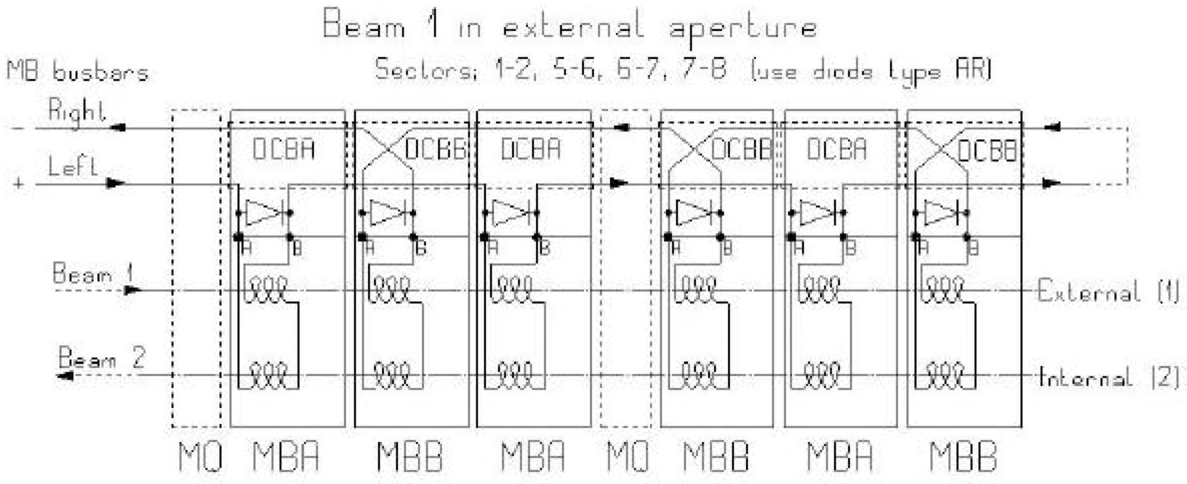


Fig. 11: Beam 1 in external aperture

5.4.2 BEAM 2 IN EXTERNAL APERTURE

All diode stacks are type AL

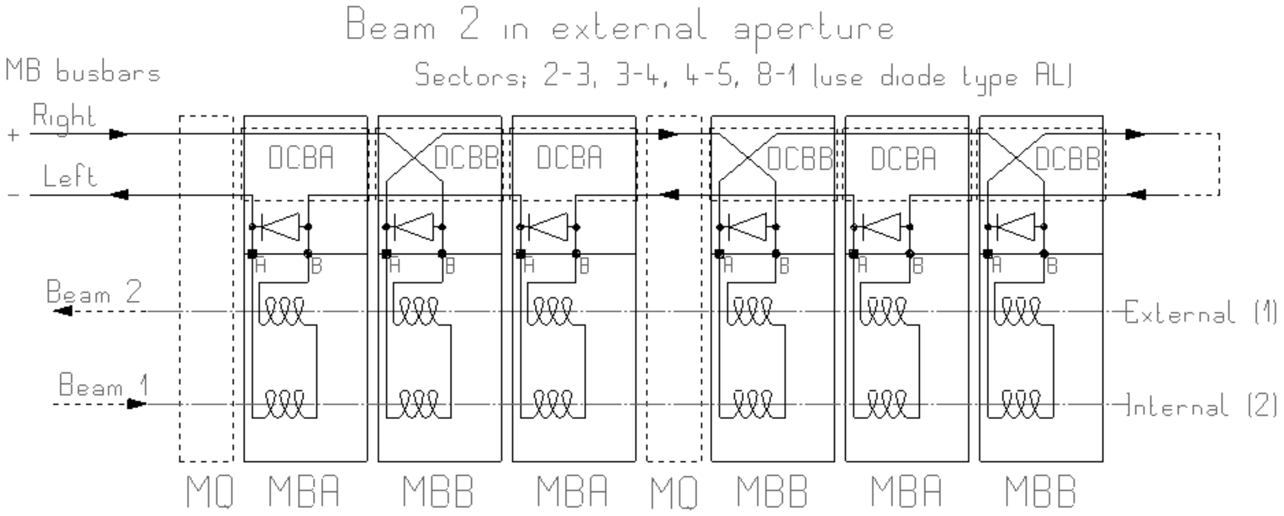
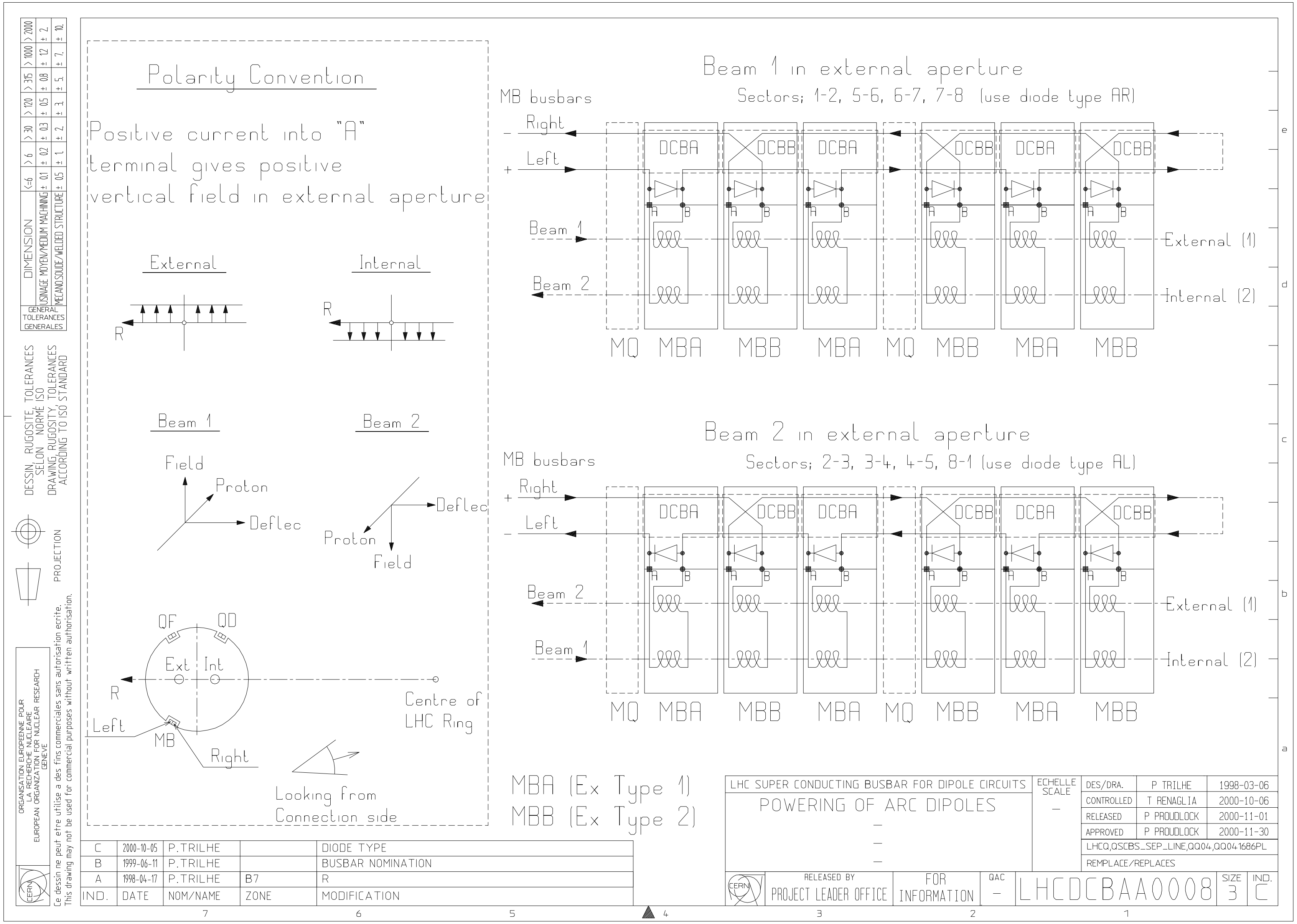


Fig. 12: Beam 2 in external aperture

6. DRAWING

All the details of this engineering specification are also presented in drawing LHCDCBAA0008 page 13.


Polarity Convention
Positive current into "A" terminal gives positive vertical field in external aperture
External
Internal
R
R
Beam 1
Field
Proton
Deflec
Beam 2
Deflec
Proton
Field
QF
QD
Ext
Int
R
Left
MB
Right
Centre of LHC Ring
Looking from Connection side
Beam 1 in external aperture
Sectors; 1-2, 5-6, 6-7, 7-8 (use diode type AR)
MB busbars
Right
Left
Beam 1
Beam 2
External (1)
Internal (2)
DCBA
DCBB
A
B
MQ
MBA
MBB
Beam 2 in external aperture
Sectors; 2-3, 3-4, 4-5, 8-1 (use diode type AL)
MBA (Ex Type 1)
MBB (Ex Type 2)
LHC SUPER CONDUCTING BUSBAR FOR DIPOLE CIRCUITS
POWERING OF ARC DIPOLES
ECHELLE SCALE
DES/DRA. P TRILHE 1998-03-06
CONTROLLED T RENAGLIA 2000-10-06
RELEASED P PROUDLOCK 2000-11-01
APPROVED P PROUDLOCK 2000-11-30
LHCQ,QSCBS_SEP_LINE,QQ04,QQ041686PL
REMPLACE/REPLACES
RELEASED BY PROJECT LEADER OFFICE
FOR INFORMATION
QAC
LHCDCBAA0008
SIZE 3
IND. C
C 2000-10-05 P.TRILHE DIODE TYPE
B 1999-06-11 P.TRILHE BUSBAR NOMINATION
A 1998-04-17 P.TRILHE B7 R
IND. DATE NOM/NAME ZONE MODIFICATION
GENERAL TOLERANCES GENERALES
DIMENSION
USINAGE MOYEN/MEDIUM MACHINING
MECANOSOUDE/WELDED STRUCTURE
<=6 ± 0.1 ± 0.5
> 6 ± 0.2 ± 1.
> 30 ± 0.3 ± 2.
> 120 ± 0.5 ± 3.
> 315 ± 0.8 ± 5.
> 1000 ± 1.2 ± 7.
> 2000 ± 2. ± 10.
DESSIN, RUGOSITE, TOLERANCES SELON NORME ISO
DRAWING, RUGOSITY, TOLERANCES ACCORDING TO ISO STANDARD
PROJECTION
ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
GENEVE
Ce dessin ne peut etre utilise a des fins commerciales sans autorisation ecrite.
This drawing may not be used for commercial purposes without written authorisation.
a
b
c
d
e
1
2
3
4
5
6
7

ANNEX B29: POSITIONING AND WELDING OF THE END COVERS, AND OF THE AUXILIARY BUSBARS TUBE

1. INTRODUCTION

In this Annex, the requirements concerning the positioning and the welding of the end covers to the shrinking cylinder ends are specified. An appropriate control of the positioning operation is required in order to allow the correct alignment and connection to the adjacent magnets in the LHC machine. Indeed, the adjacent magnets will first be mutually aligned in order to maximise the mechanical aperture of the machine. Secondly, they will be connected electrically in series and mechanically via the interconnection bellows.

2. TECHNICAL REQUIREMENTS

2.1. Mandatory visual check

Before starting positioning, a mandatory visual inspection of the assembly is required. The Contractor shall visually check the integrity of all the sub-assemblies and components, that no obstructions or object are present in the cold mass extremities. A vacuum cleaning procedure is also mandatory in order to avoid the presence inside the cold mass extremities of any chips and burrs.

2.2. Positioning

The end covers shall be aligned with respect to the active part geometry, i.e. with respect to the theoretical geometric axes of the cold bore tubes, V1 and V2, within the requested tolerances as specified in the reference drawing LHCMBB_S0001 in views “C” and “D”. Please also refer to Section 7.2.3.2.

The final positioning of the end covers is mainly obtained by the weld-preparation of the shrinking cylinder ends.

The radial positioning of the end cover is then achieved by using a centring ring, which shall be tightly fitted, first in the cylindrical edge of the end cover and secondly in the shrinking cylinder bore as shown in view “P2” of the drawing LHCMBB_S0002.

Finally, the end cover shall be rotated so that its symmetry plane “A” is localised and parallel within 1 mm with respect to the plane V1-V2. This operation requires also the use of the LTD500 measuring instruments and of the associated routines.

2.3. Welding

Before welding, the end cover shall be firmly tack-welded on the shrinking cylinder end in order to avoid any relative rotation during the welding operation.

The Contractor shall be responsible for selecting an adequate welding process, which shall ensure the required compactness, leak-tightness and a low weld-shrinkage.

As for the longitudinal welding of the shrinking cylinder, the welding procedure specification applied to the circular welding of the end covers and the welders shall be qualified according to the requirements of Annex B33 entitled “Safety Tests”.

The welded joint shall be fully austenitic, i.e. without any δ-ferrite. To this end, the filler metal W.Nr.1.4455, which is an austenitic steel grade, is mandatory for this application. The Contractor shall be responsible for the procurement of the filler material, which shall be documented with a material certificate according to EN 10204 / 3.1.B. Should the Contractor wish to use another filler material, formal approval from CERN shall be requested prior to its utilisation.

These circumferential welds shall be inspected according to the requirements of Annex B33.

2.4. Welding of the ancillary components to the shrinking cylinder

After the welding of the end covers, the welding of the auxiliary busbars tube with its six auxiliary supports shall be made.

The welds are discontinuous in order to minimise the heat input and the weld shrinkage.

After the welding of the cold bore tubes extremities to the end covers a “go” gauge test on the inner diameter of the tubes shall be carried out in order to check that the inner diameter is $\geq$ 49.65 mm.

3. CONTRACTOR’S RESPONSIBILITIES

The Contractor shall provide CERN with a detailed assembly and control procedure, which precisely describes the sequence of positioning, circular welding and inspection as specified in Section 8.2.5. In particular, all the various checks, measurements and welding qualification records as requested in the present Annex shall be recorded in the Traveller.

Recommendations for the above-mentioned operations will be given by CERN in the form of assembly and control procedures (“shop-floor” documents), which are applied at CERN in the Magnet Assembly Facility (see Annex F). The eventual use of the CERN procedure(s) does not relieve the Contractor of his responsibilities.

ANNEX B30: INSTRUMENTATION FEEDTHROUGH SYSTEM ASSEMBLY

1. INTRODUCTION

The complete Instrumentation Feedthrough System (IFS) for the LHC arc cryo-magnets is essentially an electrical communication path from inside the dipole magnet liquid helium bath to the outside of the cryostat. The electrical path is required for continuous and independent on-line monitoring of various diagnostics and control signals.

The complete IFS consists of an extension to the cold mass, an interface-flange on the cryostat and a cover-flange with leak tight electrical feedthroughs.

The extension to the cold mass, termed the IFS Tube consists of a stainless steel tube with specific end flanges through which run the 40 (dipole type A) or 36 (dipole type B) cold mass instrumentation wires. The installation of the IFS Tube has to be done during the cold mass manufacture.

The installation of the wires in the tube, the welding to the cold mass and the tube forming process shall be performed with specific tooling fixed to the cold mass.

The IFS Tube being an integral part of the cold mass is a cryogenic pressure vessel and shall therefore fulfil the design requirements and undergo the same pressure and leak test conditions as described in Annexes B32 and B33.

Electrical circuits and instrumentation wires shall be electrically tested after the IFS Tube assembly in accordance with the test conditions described in Annex B22.

After the assembly and during transport, the IFS Tube shall be protected against damage using specific transport restraints as shown in drawing LHCMB__S006.

An overview of the IFS tube after assembly can be found on drawing LHCMB__S0005.

2. MAIN PARAMETERS

The complete IFS needs to fulfil a number of specific requirements, some of which are common with the cold mass specification. The main parameters are:

- Number of wires to feed-through: 40 (MBA) or 36 (MBB),
- Maximum test voltage: see Annex B22,
- Component leak: see Annex B32,
- Test pressure: see Annex B33,
- Temperature range: 1.9 to 293 K,
- Heat load budget to 1.9K: 0.3 Watt,
- Movement essentially due to thermal contraction between cold mass (cold end) and cryostat interface (warm end): 20 mm.

3. COMPONENTS

3.1. Tube

The IFS Tube found on drawing LHCMB__S00015 consists of a single smooth seamless 8/10mm AISI316L tube welded to a cold end flange on one side and to a warm end flange on the other side.

All rough edges are removed from the assembly in order not to damage the wire insulation during installation of the instrumentation wires in the tube.

The forming / bending of the IFS Tube shall take place after installation of the wires and start at the cold mass end, as specified below.

The maximum allowed ovalization of the tube after bending shall be less than 10%.

3.2. Insulating wire guide

The insulating wire guide as shown on drawing LHCMB__S00017 serves to guide the wires from the cold mass into the tube and to locate and identify the wires in case of dismounting. It protects the wires during welding of the IFS Tube cold end flange to the cold mass end cover. The choice of the material of the insulating wire guide was made in order to fulfil the cryogenic, electrical and radiation conditions. CERN has selected the following material: polyethylene D80 or equivalent (CERN SCEM 44.86.60.280.8). Other materials selected by the Contractor must be approved by CERN.

3.3. Protecting sleeve

A protecting sleeve shall protect the bundle of wires during assembly and normal operation. It shall be installed before the installation of the wires in the IFS Tube. The choice of the material of the protecting sleeve is done in order to fulfil the cryogenic, electrical and radiation conditions. The sleeve shall be flexible to allow the bending / forming of the IFS Tube, the dimension shall not affect the filling ratio of the IFS Tube. CERN has selected the following material: Fiber Glass sleeve D10 (CERN SCEM 04.86.51.110.2). Other materials selected by the Contractor shall be approved by CERN.

3.4. Test connectors

All 40 or 36 wires coming out of the tube at the warm end shall be connected to temporary testing connectors. The connections shall be numbered (numbers 1 to 40) in order to have an additional positive identification of all wires. The connectors will be used to perform the electrical acceptance test upon arrival of the cold masses at CERN. The connectors will be dismounted after the CERN reception tests of the cold mass and re-cycled (send back to the Contractor). CERN will supply a sufficient number of connectors to be utilised all along the cold mass production.

4. ASSEMBLY OF THE IFS TUBE

The instrumentation wires of each cold mass shall exit through the instrumentation outlet of the connection end cover, shall be continuous and unbroken and shall present an unravelled length of 4m measured from the cold mass interface reference plane (see drawing LHCMB__S0006, Ref. Plane A).

During handling of the cold mass before assembly of the IFS Tube the wires shall be protected with appropriate equipment.

The CERN proposed assembly procedure is as follows:

- Pull the 36 or 40 wires through the specified holes in the insulating wire guide sleeve using the protection sleeve.
- Identify all the wires before their installation in the IFS Tube.
- Install the wires in the IFS Tube.
- Identify and strip the wires, connect them to the test connectors.
- Perform (if necessary) an intermediate electrical test as specified in Annex B22.
- Weld the IFS Tube cold end flange to the cold mass.
- Install the bending tooling on the cold mass.
- Start bending at the cold mass end, gently pull at the wires after each bend.
- Check the dimensions and adjust them (within the specified limits). If necessary, adjustments to specific dimensions concerning the shape of the formed assembly may be carried out to achieve compliance with the overall specified dimensional tolerances. This concerns the bending of the tube, which at any time shall not exceed more than 20% of the required bending angles.
- Mount the transport restraints.
- Perform (if necessary) an intermediate electrical tests as specified in Annex B22.
- Introduce the wires and the test connectors inside the warm end box, close the warm box for pressure and leak test.
- Perform the pressure and leak tests as specified in Annexes B32 and B33.
- Perform an electrical tests as specified in Annex B22 and B23.

The Contractor can propose variations on the details of this CERN proposed assembly procedure.

Toolings suiting the assembly procedure are under responsibility of the Contractor. Procedures and tooling shall be submitted to CERN for approval.

CERN will transmit to the Contractor, when available, all the information and the experience gained on the IFS Tube installation on the pre-series dipole cold masses.

The major manufacturing steps, quality control, checks and any dimensional adjustments concerning the IFS assembly shall be indicated, in the Traveller.

5. CLEANING

All surfaces of the components (both inside and outside) are interfaces either to cryogenic fluids or to the insulation vacuum. They shall be cleaned and rendered free from contamination, dust, welding flux, scale, grease, hydrocarbons and any other substance that may impair the ability to establish or maintain the required vacuum, the purity of the cryogenic fluids or the dielectric breakdown properties between the wires.

6. TESTING

All IFS component parts of this specification are subjected to the following tests, to be carried out by the Contractor before delivery.

- Leak test: see Annex B32.
- Pressure test: see Annex B33.

- Electrical test: see Annex B23.

Procedures, test reports and inspection files defined by the Contractor must be approved by CERN before application. The procedures and test reports are included as a formal part of the acceptance of the supply.

7. TRANSPORT RESTRAINTS

The transport restraint(s) as shown on drawing LHCMB__S0021 are required to fix and protect the IFS Tube during transporting and handling of the cold mass. As indicated on the drawing it shall be possible, with the transport restraint in place, to cut the warm end box to a length of 20 mm (with automatic cutting equipment) and to leave a gap of 10 mm around the cold mass to mount the Multi Layer Insulation (MLI).

ANNEX B31: INSTALLING THE PROTECTION DIODE STACK

1. INTRODUCTION

The Engineering Specification LHC-DCB-ES-0001 (attached to the Annex B28) describes the different layout (polarity and connection scheme) of the diode stack to be installed in the LHC dipole cold masses.

The diode stack assembly is made according to drawing LHCDQDDP0002 and shall be mounted according to the Engineering Specification LHC-DQD-ES-001 attached to this Annex.

2. ASSEMBLY OF THE DIODE STACK ON THE COLD MASS

The following are the main steps of the assembly procedure for the mounting of the diode stack on the cold mass.

- The insulation tubes (see drawings LHCMB__E0069) shall be slid to the diode stack high current leads.
- The diode stack current leads shall be push upward in order to clear the way for the diode stack insertion in the diode stack box.
- The diode stack shall be installed in the diode stack box by the utilisation of a dedicated tooling (see drawing LHCMB__E0081).
- The high current leads shall be screwed to the diode stack connections following the instructions in the annexed Engineering Specification LHC-DQD-ES-001 (paragraph 3.2).
- The insulation piece (see drawing LHCMB__E0069) shall be mounted.
- The instrumentation wiring shall be installed and fixed following the instructions in Annex B23.
- The electrical continuity and insulation shall be checked following the general instructions and recommendations of the Annex B22 and of the Engineering Specification LHC-DQD-ES-001.
- Install the insulation cover on the diode stack instrumentation wiring.
- Install and weld the diode stack box cover.

Pressure and leak tests will follow as describe in the Annexes B32 and B33.

3. DIODE STACK ASSEMBLING PRECAUTIONS

The following Engineering Specification LHC-DQD-ES-001 describes all the mandatory precautions to be taken during the manipulation and mounting of the diode stack, its current leads and instrumentation wiring.

CERN
CH-1211 Geneva 23
Switzerland

the
Large
Hadron
Collider
project

LHC Project Document No.
LHC-DQD-ES-0001

CERN Div./Group or Supplier/Contractor Document No.
LHC / ICP

EDMS Document No.
250263

Date:2001-01-16

Engineering Specification

HANDLING OF BY-PASS DIODES AND PRECAUTIONS DURING ELECTRICAL TESTS ON MAGNETS

Abstract

This document gives instructions for the mounting of the high current connections and instrumentation wires of the diode stacks for the lattice dipoles and quadrupoles in the LHC. It also includes instructions for the venting of the diodes as well as precautions to be respected during electrical tests after installation of the diode stack in the cold mass. This document is not a technical specification for the mounting (mechanical part) of the diode stack into the cold mass.

Prepared by :	***Checked by :***	***Approved by:***
Dietrich HAGEDORN LHC-ICP Dietrich.Hagedorn@Cern.Ch	**Alain GHARIB** **Jean-Michel FRAIGNE** **Reiner DENZ** **Felix RODRIGUEZ-MATEOS** **Norbert SIEGEL**	**Carlo WYSS** **Philippe LEBRUN** **Thomas TAYLOR** **Paul PROUDLOCK**

History of Changes

Rev. No.	*Date*	*Pages*	*Description of Changes*
0.1 – draft	20-10-2000	8	1st draft prepared by the author
1	16-01-2001	8	First version released.

Table of Contents

1. INTRODUCTION

In the LHC each twin aperture dipole and each one of the two apertures of the quadrupole magnet is bypassed by one diode.

The diodes are mounted under high pressure in clamping systems to ensure the required quality of thermal and electrical contacts between heat sinks and the diode electrodes. The clamping system, serving also as heat sink, for the dipole diodes will house one diode and the clamping system for the quadrupole diode will house two diodes electrically insulated from each other.

The diodes shall operate safely and reliably within a temperature range of 1.9 K to about 430 K during 20 years.

In case of a superconducting magnet quench the dipole diodes conduct a current pulse rising to 13 kA within less than 0.5s and then decaying exponentially with a time constant of about 105 s giving a temperature rise inside the diode of up to 430 K (after ageing due to radiation). The current in the quadrupole diodes will decay exponentially from about 13 kA with a time constant of about 45 s.

After assembly of the diode stacks they will be tested in liquid helium at 4.2K. During the testing the hermetically sealed diode capsules are tight and normally no helium will penetrate into capsule. It has been decided not to vent the diode capsules during these tests in order to avoid any penetration of moisture and dust during these tests and during the transport and storage of the tested diode stacks thereafter.

During long-term operation of the LHC superfluid helium may be trapped in a non-vented diode capsule and excessive overpressure inside the capsule may occur during a magnet quench. Internal pressure tests on the diode capsules have shown that the ceramic housing cracks at about 6 Mpa. This internal pressure reduces significantly the contact pressure on the diode wafer and in the worst case it may lead to an open circuit situation apart from the insufficient thermal and electrical contact quality.

It has therefore been decided to vent all diodes just before the final installation of the diode into the cold mass of the magnet. As vented diodes are very sensitive to moisture and dust pollution - condensing water will seriously deteriorate the internal contact surfaces - some precautions must be respected during venting and afterwards in order to reduce the risk of pollution to a minimum.

Furthermore, the electrical contact quality of the high current connections between the diode connection bars and the magnet bus bars are essential for the reliable performance of the interconnections.

This Engineering Specification is not a detailed technical specification of the mounting (mechanical part) of the diode stacks but mainly a guide for handling of the diode stacks and necessary precautions to be respected during electrical tests. For detailed information on the mechanical part of the diode installation (positioning, welding of the cap, etc.) the Enegineering Specification for the mounting of the cold mass - written by the MMS-Group in the LHC-Division - shall be consulted.

Important: By no means the diode package shall be dismounted or the clamping force of the stack changed. In case of damage, the diode stack as a whole must be replaced by a new one.

2. PURPOSE

During the review of series tests of LHC lattice magnets on 5-7 July 2000 the board has recommended that the protection diodes in both MB and MQ cold masses should be mounted at the magnet manufactures premises.

The main objective of this specification is to provide the necessary information for:

- the mounting of the electrical high current contacts.
- the venting of the diode capsules and provisional sealing.
- the storage of the diode stacks after venting of the diodes.
- the connection of instrumentation wires.
- the precautions to be respected during electrical tests on the magnets after diode installation.

3. ELECTRICAL HIGH CURRENT CONTACTS

3.1 PREPARING THE CONTACT SURFACES AND POLARITY CHECK

The high current contact surfaces of the diode bus bars are Ni-plated and need to be cleaned with alcohol only. The counterparts on the magnet side are tin plated (half moons for the dipole stacks and rectangular connection plates for the quadrupole stacks) and must be clean and free of oxides.

Before mounting of the diode stacks the correct polarity type must be checked either by looking at the diode symbol on the diode housing or by means of a diode checker of a usual multimeter.

3.2 CONTACT PRESSURE (TORQUE)

In order to ensure the required contact pressure the following torque on the socket head screws must be applied:

Dipole diode stack half moon connection plates:	M6 with 5.5 Nm
Quadrupole diode stack rectangular connection plates:	M5 with 4.0 Nm

3.3 VERIFICATION OF CONTACT PRESSURE (TORQUE) ON CONNECTION BUS BARS

The torque of the socket head screws (M6) for the dipole diode stack (Pos. 27 on Drawing No. LHCDQDDP0002) shall be verified and must be 5.5 Nm.

The torque of the socket head screws (M5) for the quadrupole diode stack (Pos. 34 on Drawing No. LHCDQDQP0051) shall be verified and must be 4.0 Nm.

4. VENTING OF THE DIODE CAPSULE

Important: The time interval between the venting of the diode and final installation shall be reduced to a minimum in order to minimise the risk of pollution.

4.1 PREPARATIONS FOR VENTING

- Cleaning with alcohol of the rim part to be cut.
- Control of temperature of the diode stack and ambient (must be equal within ±1ºC.).
- Control of humidity (must be less than 50%).
- Preparing of a plastic bag with moisture absorber and sealing apparatus.

4.2 CUTTING THE RIM

On two opposite positions, which are accessible on the diode, the rim shall be cut along the circumference on a length of least 6 mm each (maximum 12 mm). For cutting the special tool only shall be used, which will be supplied by CERN. A first demonstration will be given by one of our specialists.

4.3 PROVISIONAL SEALING BY VARNISHING

The varnish is a temporary measure only, in case of vacuum or pressure test, the sealing will no longer be tight. The special varnish for low temperature applications IMI-7013 Varnish (formerly GE 7031 varnish) will be supplied by CERN. A thin layer of varnish only shall be applied. Drying time is about 10-15 minutes (25µm film, tack free) and complete curing after about 12 -24 hours at room temperature.

4.4 STORAGE OF THE DIODE STACKS WITH VENTED DIODES

In case the diode stack is not immediately mounted into the cold mass or removed after first mounting, it must be stored in a plastic bag with moisture absorber and hermetically sealed. This is mandatory in order to avoid problems in case of temperature variations or pollution by dust.

5. VOLTAGE TAPS

All voltage taps (wires) must be finally soldered to the tags of the diode capsule according to the following table:

Magnet type	**Wire name**	**Diode electrode**
Dipole	EE014	Anode
Dipole	EE015	Cathode
Ext. Quadrupole(SSS)	EE014	Anode of ext. diode
Ext. Quadrupole (SSS)	EE015	Cathode of ext. diode
Int. Quadrupole(SSS)	EE024	Anode of int. diode
Int. Quadrupole (SSS)	EE025	Cathode of int. diode

The multipurpose wires are already connected to the internal diode bus bars inside the cold mass.

6. PRECAUTION DURING ELECTRICAL TESTS AFTER DIODE STACK INSTALLATION

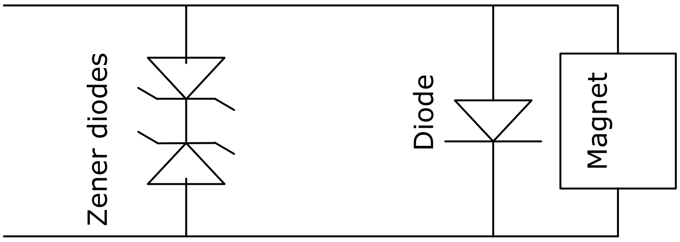
6.1 DURING INSULATION TESTS TO GROUND

During insulation tests on the dipole coils to ground, it is mandatory that the diodes are short circuited preferably via the multipurpose wires (EE012 and EE013).

During insulation tests to ground on the quadrupole coils in the short straight section, it is mandatory to short circuit the diodes preferably via the multipurpose wires (EE012 and EE013, EE022 and EE023).

6.2 DURING POLARITY - AND ELECTRICAL CONTINUITY TESTS

In order to avoid that a current can pass through the diode in forward direction and alter the measurements during continuity tests or in order to avoid high transient voltages in reverse direction during polarity checks, a bi-directional transient suppresser diode or a series connection of Zener diodes (back to back), as shown below, must be connected to the multipurpose wires given in section 6.1. The transient suppresser diode or the Zener diodes must be dimensioned according to the applied test current and the expected voltage across the magnet during continuity tests.



6.3 VOLTAGE LIMITS FOR DIODES.

Important: The diodes may be destroyed if the following limits are not respected:

- - Maximum reverse voltage: $U_{rmax} < 200$ V
- - Maximum reverse current: $I_{rmax} < 1$mA

These values are valid for diffusion type diodes from DYNEX only. In case of epitaxial diodes these values are different and will be communicated separately.

7. RISKS OF DIODE POLLUTION DURING TRANSPORT AND STORAGE

After final installation of the diode and closure (welding) of the can, the cold mass should be filled with clean and dry nitrogen or helium slightly above atmospheric and closed. For pressure tests clean and dry nitrogen or helium only shall be used in order to avoid the penetration of humidity.

After pressure and vacuum tests the provisional varnish sealing will be destroyed and care must be taken that no humid and/or polluted air or even dust penetrates into the vented diode. Especially after transports sufficient time must be given for temperature compensation. The time interval necessary depends on the temperature differences and heat exchange.

8. REFERENCES

Technical Specification for the Supply of High Current Bypass Diodes for the LHC Superconducting Magnets: IT-2723/LHC/LHC (LHC project document number: LHC-DQD-CI-0002)

Technical Specification for the Manufacture, Assembly and Liquid Helium Testing of Bypass Diode Stacks: IT-2648/LHC/LHC (LHC project document number: LHC-DQD-CI-0001).

ANNEX B32: ROOM TEMPERATURE VACUUM LEAK TESTING

1. INTRODUCTION

During operation, the cold mass contains superfluid helium at 1.9 K and is bounded by evacuated enclosures. These enclosures include the so-called **insulation vacuum**, **beam vacuum cold bores** and **heat exchanger tube**.

Before its entry into service, each dipole cold mass shall undergo extensive testing. Included in the test program, is verification of the leak tightness of the cold mass enclosures under operational conditions. As a **provisional acceptance test**, the cold mass shall undergo **room temperature leak testing**.

2. GENERAL DESCRIPTION OF THE TESTS

The objective of the room temperature leak test is to measure the helium leak rates of the cold mass, cold bores and heat exchanger. The leak test shall be made by measuring the helium concentration in each of the evacuated enclosures upon pressurisation of the cold mass or heat exchanger. The helium concentration shall be measured using a **mass spectrometer leak detector**. The test shall be performed in accordance with international (or national equivalent) leak testing standards. The leak tightness measurements shall be made during the safety pressure tests. For information, the test pressures are as follows:

Cold mass	2.6 MPa
Heat exchanger	0.5 MPa (internal pressure)

3. SCOPE

This specification is for **final room temperature leak testing** of dipole cold masses before their cold operation. It describes the item to be tested and defines the equipment, the preparations, the procedure and the quality assurance documentation. Acceptance will be declared under the following conditions:

Cold mass to insulation vacuum	$\leq 1\cdot10^{-10}$ Pa·m^3/s
Cold mass to beam vacuum cold bores	$\leq 1\cdot10^{-11}$ Pa·m^3/s
Cold mass to heat exchanger	$\leq 1\cdot10^{-6}$ Pa·m^3/s
Heat exchanger to insulation vacuum	$\leq 1\cdot10^{-10}$ Pa·m^3/s

Note: all leak rates are given at 20 °C with enclosure at test pressure (helium at 100%)

4. EQUIPEMENT REQUIRED FOR THE TEST (SEE FIGURE B32.1)

4.1. General

The equipment used for leak testing of the cold mass enclosures shall be compatible with clean vacuum systems. No internal or external contamination of the cold mass, cold bores or heat exchanger shall result from the tests.

4.2. Vacuum vessel

The vacuum vessel shall be clean to high vacuum standards. Sealing of the end flanges may be achieved using elastomer o-rings. The free volume inside the vacuum vessel together with the pumping speed of the principal pumping group will strongly influence the leak testing time constant. The vacuum vessel design shall be compatible with the requirements of the pressure test

4.3. Turbomolecular pumping group 1 & 2

The pumping groups shall consist of a turbomolecular pump in series with an oil sealed rotary backing pump. To avoid oil back streaming via the turbo in the event of electrical failure, the connecting manifold between the two pumps shall have a normally closed electromechanical valve. In addition, the backing side of the turbomolecular pump should be equipped with a valve system to enable a helium leak detector to be connected. The input manifold on the turbomolecular pump shall be equipped with suitable vacuum gauges.

4.4. Rough pumping group

The rough pumping group shall be suitable for the repeated pumping of the vacuum vessel enclosure in the pressure range of 0.1 MPa to 10 Pa. A suitable pump would be a oil-sealed rotary pump. To avoid oil back streaming in the event of electrical failure, the connecting manifold between the pump and the vacuum vessel shall have a normally closed electromechanical valve.

4.5. Auxiliary pumping group 1 & 2

The auxiliary pumping group shall be suitable for repeated pumping of large enclosures containing helium gas. The pump will be required to operate in the range 0.1 MPa to 10 Pa. A suitable pump system would be an oil sealed rotary pump dedicated for this use. To avoid parasitic helium signals, the pump shall not exhaust into the ambient air of the test area.

4.6. Vacuum pressure gauges

The vacuum gauges on the vacuum enclosure shall cover the range 0.1 MPa to 10^{-3} Pa nitrogen equivalent. Suitable gauges would be the thermal conductivity (Pirani) gauge and cold cathode ionisation (Penning) gauge combination.

4.7. Helium Leak detector 1, 2 & 3

The leak detectors shall have a sufficient sensitivity to enable the leak tightness values mentioned in Section 2 to be measured.

4.8. Calibrated helium leak

The calibrated helium leak shall be in the range 10^{-8} to 10^{-10} Pa·m^3/s and have a clearly marked test date.

4.9. Chart recorder

Chart recorders (or an on-line data acquisition system) shall be used to record the leak detector and pressure measurement signal for the complete duration of the test. Each step of the leak test shall be clearly identified.

4.10. Pressurised helium circuits

The equipment required for the pressurisation of the cold mass and heat exchanger helium circuits shall conform to international (or national equivalent) safety requirements. To avoid contamination of the test area with helium, the circuits shall be of all metal construction.

5. PREPARATIONS

All components used for closing the vacuum envelope shall have been cleaned and individually leak tested to a sensitivity compatible for the subsequent leak test.

The assembly may take place only in a clean dust-free closed area. No machining operations may take place in or close to this assembly area. Areas used for cryogenic operations with abnormal helium concentrations in the ambient air shall be avoided.

Before assembly, all vacuum sealing surfaces should be visually inspected for damage and contamination.

The seals of the test vacuum vessel and all connections to the principal pumping group and leak detectors shall be elastomer O-rings. If the required leak testing sensitivity cannot be achieved, it may be necessary to use metal seals.

The cold mass, cold bores and heat exchanger envelopes within the vacuum vessel envelope shall be of an all-metal construction, including the seals at all de-mountable flanges. Oil or grease shall not be used on any of these seals. Pre-testing of metal sealed joints on the cold mass is advised before final assembly of the vacuum vessel end flanges.

6. LEAK TEST PROCEDURE

The leak tests shall be performed in accordance with international (or national equivalent) leak testing standards (e.g. EN, DIN, AFNOR, etc.) by accredited personnel. If the former and the latter conditions are not satisfied, a detailed leak test procedure shall be submitted for CERN approval before the commencement of leak testing activities.

A typical leak test sequence could be as follows (see Figure 1):

- Install cold mass in vacuum vessel,
- Evacuate vacuum vessel, cold mass, heat exchanger and cold bores,
- Pressurise cold mass (measure leak rate to insulation vacuum, heat exchanger and cold bores),
- Depressurise and evacuate cold mass,
- Pressurise heat exchanger (measure leak rate to insulation vacuum),
- Depressurise and evacuate heat exchanger,
- Vent all volumes to dry nitrogen gas,
- Remove cold mass from vacuum vessel,
- Install protection covers on cold bores, heat exchanger and cold mass flanges.

7. RESULTS AND DOCUMENTATION

A detailed leak test report for each dipole cold mass shall be submitted before provisional acceptance can be declared. The following documentation shall be supplied with each report:

a) A copy of the chart recorder output(s), with all steps of the leak test identified, *b)* A data sheet/computer readable file with the following information:

- Cold mass supplier name,
- Contract number,
- Cold mass serial number,
- CERN leak test technical specification employed,
- Name and qualification of personnel performing the tests,
- Place of the test,
- Date of the test.

And for each enclosure:

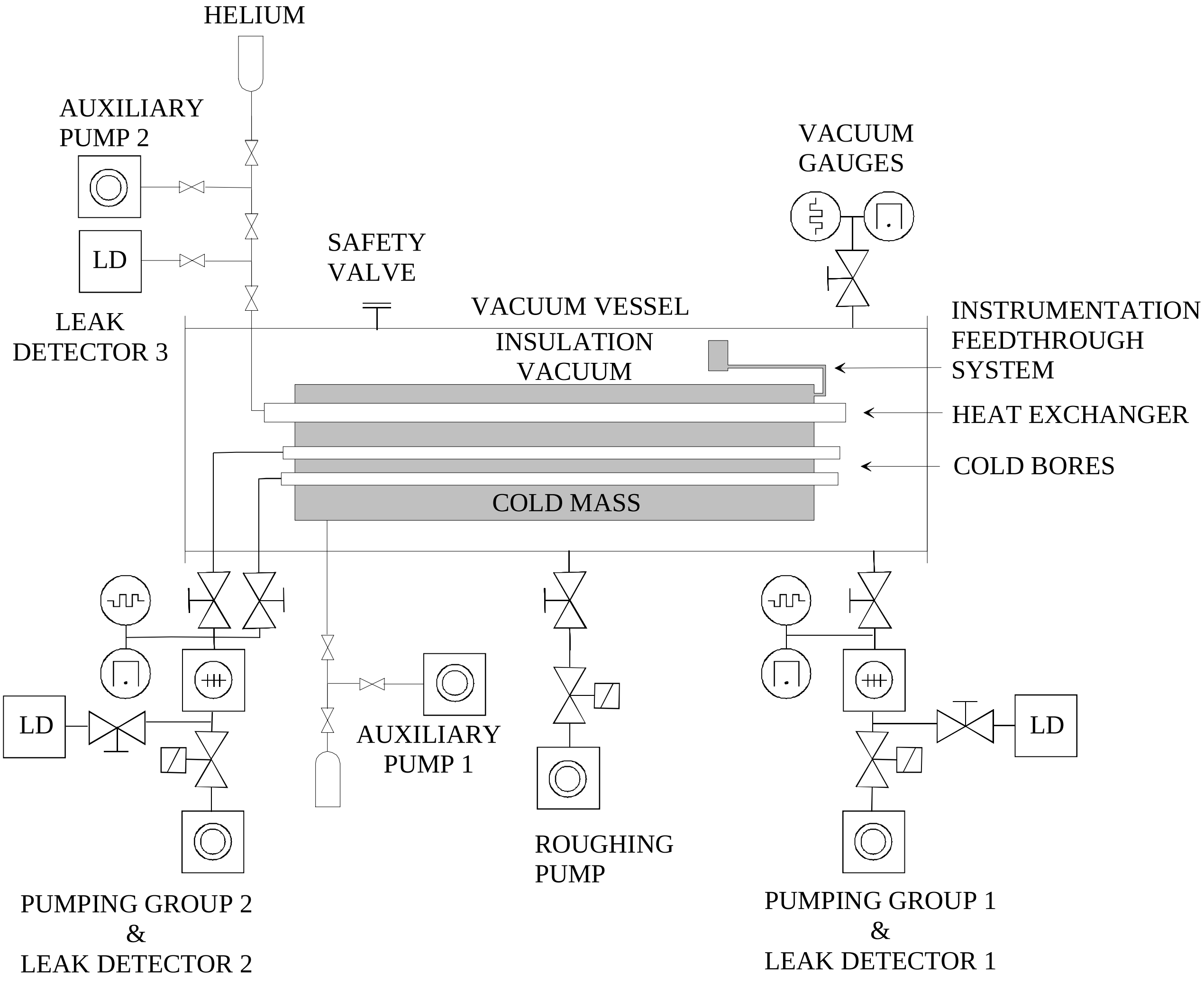
- Name of enclosure under test,
- Leak tightness requirement,
- Leak test method,
- Description of leak test equipment,
- Size of calibrated leak,
- Measured signal of the calibrated leak,
- Measured residual signal of the evacuated enclosure,
- Smallest readable signal,
- Estimated volume of the evacuated enclosure,
- Measured time constant of evacuated enclosure,
- Helium pressure employed,
- Measured signal during the test,
- Calculated smallest detectable signal,
- Conformity/Non-conformity.

The leak test report shall also include all anomalies, corrective actions, repetitions of tests, and correspondence with CERN.

In the event of leak, a non-compliance procedure shall be opened as described in Section 8.2.6. CERN will be contacted for approval on the proposed corrective action.

Fig. B32.1: Dipole cold mass leak testing typical test setup

LEAK TEST SEQUENCE: COLD MASS TO INSULATION VACUUM
COLD MASS TO HEAT EXCHANGER
COLD MASS TO COLD BORES
HEAT EXCHANGER TO INSULATION VACUUM



IMPORTANT:
THE CIRCUITS TO PRESSURE THE COLD MASS AND HEAT EXCHANGER SHOW ONLY THE COMPONENTS THAT ARE REQUIRED TO EXECUTE THE LEAK TESTING. THE RELEVANT SAFETY STANDARDS FOR PRESSURISED CIRCUITS MUST BE APPLIED.

ANNEX B33: SAFETY TESTS

1. INTRODUCTION

The inspection and test plan for the welded joints of the cold mass shall be the one defined following the experience gained on the pre-series production. At the time of writing the inspection and tests expected to be necessary for the series production and to be quoted in the Tender Form are indicated in the tables of this Annex.

1.1. Raw materials

The raw materials used for manufacturing the cold mass components, that constitute its envelope (i.e. the He II containment vessel), shall be accompanied by inspection certificates according to EN 10204-3.1.B. The cold mass components concerned are:

- The shrinking cylinder
- The end covers
- The cold bore tubes
- The He heat exchanger tube
- The interconnections bellows
- The diode stack container, including its T-shaped connection to the cold mass.

More details about the above mentioned items and about the corresponding raw materials are given in the relevant technical specifications included in this Technical Specification (see Annex G).

CERN reserves the right to check the raw materials certificates before the actual assembly is started and to ask for additional production test plates for any further investigations, which it deems necessary.

All the above mentioned items shall be identified by a serial number in a permanent and visible marking.

1.2. Welding operations

All the welders involved in the cold mass assembly shall be qualified for the work they are assigned to under the EN 287.1 standard, including for automatic welding operations.

Welding Procedure Specifications (W.P.S.s) shall be issued and certified by Procedure Qualification Records (P.Q.R.s) both in line with the EN 288.3 standard. The P.Q.R.s shall be issued before the manufacture can take place.

2. INVENTORY OF WELDED JOINTS

There are four types of welded joints which shall be submitted to a Procedure Qualification Record:

- the longitudinal joints of the shrinking cylinder,
- the circumferential joints of the end covers,
- the cold mass support base joints,
- the circular butt joints on the interconnection bellows, the interconnection pipes and the diode stack container.

Depending on their nature and their accessibility, these joints shall be submitted to the following inspection and test plan. The requirements concerning both the welding procedures qualification and the production welds are specified.

2.1. Longitudinal weld of the shrinking cylinder

The longitudinal welding of the shrinking cylinder shall be carried out with the welding equipment supplied by CERN. This equipment allows the recording of the major welding parameters. For each longitudinal weld these parameters shall be recorded and checked for possible deviations. The outcome of these checks shall be noted in the Traveller, while the complete data set shall be stored together with the corresponding test plates. In case of any non conformity observed in the recorded welding parameters or in the analysis of the X-ray tests performed on the test plates or on the longitudinal welds, the Contractor shall undertake all the corrective actions as required by the Quality Assurance Plan. In particular, if a longitudinal joint turns out to be out of conformity, an X-ray inspection of a small sample of cold masses shall be carried out at the Contractor’s expense. The sample shall contain cold masses welded before and after the cold mass found to be out of conformity. The size of the sample will be defined in agreement with CERN depending on the type of non conformity.

Table B33.1 : Longitudinal weld of the shrinking cylinder

Tests	Standards	Welding Qualification (if necessary)	Production		Acceptance
			Weld joint	Test plates	
Non destructive tests					
Visual inspection	EN 970	100%	100%	100%	EN 25817
Inspection X-ray	EN 1435	100%	5% (*)	100%	[1] EN 25817 class B
Destructive Tests (**)					
Transverse tensile test, *1 required*	EN 895 EN 10002-1	X			[3]
Longitudinal tensile test within the weld bead *1 required*	EN 876	X			[4]
Charpy V-Notch test (4.2 K) *3 required in heat affected zone* *3 required in welded metal*	EN 875 ISO 148 EN 10045-1	X			[5] Energy > 60 J
Bending test *1 required normal* *1 required root*	EN 910 ISO 7438	X			[6]
Macrography *1 required*	EN 1321	X			[7] EN 25817
Micrograph *1 required*	EN 1321	X			[8] EN 25817
Magnetic permeability *1 required*		X			[9]

X: required test

All the tests shall be performed at room temperature unless otherwise stated.

(*): 5 % means the two longitudinal welds of one cold mass in twenty fully inspected.

(**) : These tests have to be performed after 5 thermal cycles in liquid nitrogen.

2.2. Circumferential weld of the end covers

Table B33.2 : Circumferential weld of the end covers

Tests	Standards	Welding Qualification (if necessary)	Production		Acceptance
			Weld joint		
Non destructive tests					
Visual inspection	EN 970	100%	100%		EN 25817
Inspection X-ray	EN 1435	100%			[1] EN 25817 class B
Inspection γ-ray	EN 444		5% (*)		[1] EN 25817 class B
Destructive Tests *(**)*					
Transverse tensile test, *1 required*	EN 895 EN 10002-1	X			[3]
Longitudinal tensile test within the weld bead *1 required*	EN 876	X			[4]
Charpy V-Notch test (4.2 K) *3 required in heat affected zone* *3 required in welded metal*	EN 875 ISO 148 EN 10045-1	X			[5] Energy > 60 J
Bending test *1 required normal* *1 required root*	EN 910 ISO 7438	X			[6]
Macrography *1 required*	EN 1321	X			[7] EN 25817
Micrograph *1 required*	EN 1321	X			[8] EN 25817
Magnetic permeability *1 required*		X			[9]

X: required test

All the tests shall be performed at room temperature unless otherwise stated.

(*): 5 % means the two circonferential welds of one cold mass in twenty inspected as possible (~20 % of the circumference).

(**): These tests shall be performed after 5 thermal cycles in liquid nitrogen.

2.3. Weld of the cold mass support bases and the auxiliary busbars line ("tube N") supports

Table B33.3 : Welds of the cold mass bases and auxiliary busbar line

Tests	Standards	Welding Qualification (if necessary)	Production		Acceptance
			Weld joint		
Non destructive tests					
Visual inspection	EN 970	100%	100%		EN 25817
Inspection X-ray	EN 1435 EN 444	100%			[1] EN 25817 class D
Destructive Tests(*)					
Transverse tensile test, *1 required*	EN 895 EN 10002-1				[3]
Longitudinal tensile test within the weld bead *1 required*	EN 876				[4]
Charpy V-Notch test (4.2 K) *3 required in heat affected zone* *3 required in welded metal*	EN 875 ISO 148 EN 10045-1				[5] Energy > 60 J
Bending test *1 required normal* *1 required root*	EN 910 ISO 7438				[6]
Macrography *1 required*	EN 1321	X			[7] EN 25817
Micrograph *1 required*	EN 1321				[8] EN 25817
Magnetic permeability *1 required*					[9]

X: required test

All the tests shall be performed at room temperature unless otherwise stated.

(*): These tests shall be performed after 5 thermal cycles in liquid nitrogen.

2.4. Weld of interconnection bellows, connection pipes and diode stack container

Table B33.4 : Weld of interconnection bellow, connection pipes, and diode container

Tests	Standards	Welding Qualification (if necessary)	Production		Acceptance
			Weld joint		
Non destructive tests					
Visual inspection	EN 970	100%	100%		EN 25817
Inspection by X-ray **or** by dye penetrant where X-ray tests are not feasible (*)	EN 1435 EN 571-1	100%	5% (**)		[1] EN 25817 class B
Destructive Tests(***)					
Transverse tensile test, *1 required*	EN 895 EN 10002-1				[3]
Longitudinal tensile test within the weld bead *1 required*	EN 876				[4]
Charpy V-Notch test (4.2 K) *3 required in heat affected zone* *3 required in welded metal*	EN 875 ISO 148 EN 10045-1				[5] Energy > 60 J
Bending test *1 required normal* *1 required root*	EN 910 ISO 7438				[6]
Macrography *1 required*	EN 1321	X			[7] EN 25817
Micrograph *1 required*	EN 1321	X			[8] EN 25817
Magnetic permeability *1 required*		X			[9]

X: required test

All tests have shall be performed at room temperature unless otherwise stated.

(*): List of welds with the applicable test inspection type (X-ray or dye penetrant) will be communicated to the Bidders in due time.

(**): 5 % means all the welds of one cold mass in twenty fully inspected.

(***):These tests must be performed after 5 thermal cycles in liquid nitrogen.

Notes:

[1]: Each inspected part shall be marked to be easily located. During manufacture, any weld which has unacceptable defects revealed by X-ray or γ-ray inspection shall be repaired and re-inspected. In this case, the films showing the original defects shall be kept available for traceability. Inspection reports shall contain all the relevant information on the quality and types of films used, the type of illumination, distances, exposure times.

[2]: -

[3]: Ultimate Tensile Strength (U.T.S.) shall be at least equal to the minimum value which is specified for the base metal.

[4]: The value obtained for Ultimate Tensile Strength shall be at least equal to the minimum guaranteed values for the base metal. The following inequality should also be verified : $R \times A > 10\,500$ and $A > 14$. Where R represents the U.T.S. in MPa and A the elongation in %.

[5]: To determine impact energy, three test pieces shall be taken from the welded metal and three from the Heat Affected Zone. The test temperature shall be 4.2 K. The test procedure shall be approved by CERN.

[6]: The bending test shall be performed until parallel branches are obtained for face and root bending. If cracks appear in the welded metal or the junction area, the maximum allowable length of the defect is 3 mm.

[7]: Macro-examination either with the naked eye or at magnification up to ×50, shall reveal no defects according to the acceptance criteria which are defined in EN 25817. Furthermore, the macrography is a reference control for the number and distribution of passes for judging the compliance with the validity limits set by the procedure qualification.

[8]: The results of these examinations shall be accompanied by appropriate photographs (magnification up to × 500). The test should confirm a fully austenitic structure, i.e. no presence of residual δ-ferrite or sigma phase, completeness of penetration, compactness and geometrical shape of the passes.

[9]: The relative magnetic permeability within the welded joint shall be lower than 1.01 for a field of 80 000 A/m (=1 000 Oe) at room temperature.

3. PRESSURE TEST

After completion of the cold mass the Contractor shall, before delivery, conduct a final pressure test according to the following procedure.

The cold mass shall be pressurised (in the case of a test made without any vacuum cryostat) at 26 bar absolute with clean Helium gas. CERN accepts some mix of helium and nitrogen gas for the pressure/leak test, providing that the necessary correction is made for the leak test sensitivity. The pressure and leak tests could be performed together with the cold mass inserted into the vacuum cryostat (the test pressure becomes 25 bar absolute). The test procedures shall, in this case, be subject to previous agreement with CERN. The mandatory visual inspection of the cold mass welds will be done after extraction of the cold mass from the testing cryostat.

The leak test is covered in the Annex B32 “Room temperature vacuum leak testing”.

The test procedure consists of a steady build-up at approximately one-tenth of the test pressures per minute until half the pressure level is reached. Thereafter, pressure is increased by steps of one tenth of the test pressure with intervening pauses until the test pressure is attained, where it is kept for half an hour. It is then lowered to four fifths of the test pressure for a visual inspection of the cold mass.

The pressure and the leak tests could be performed together, subject to the previous agreement of the procedure by CERN. In this case, the mandatory visual inspection of the cold mass welds will be made after the extraction of the cold mass from the testing device.

ANNEX B34: TRACEABILITY, TRAVELLER, QA DOCUMENTS

1. WORK FLOW PROCESS DIAGRAM

The Workflow Process Diagram is the graphical representation of the manufacturing process. It indicates all procedures and tests to be performed at each manufacturing step in accordance with the ITP (Inspection and Test Plan) (see Annex B2).

The tests marked with T are mandatory and their results shall be recorded and transmitted to CERN.

The files of tests results in the EXCEL™ format imposed by CERN shall be sent to CERN via electronic (EMAIL) or File transfer (FTP) to the responsible Engineer for approval and storage.

The tests data format will be transmitted to the Contractor in due time.

WorkFlow Process Diagrams (Flow Charts N° 1 and 2) are attached below.

2. COMPONENTS TRACEABILITY

To keep full traceability, the Contractor shall identify all components entering in the Cold Mass. The components identified in the Assembly Breakdown Structure shall be registered and shall be identified obligatorily either by a serial number or by a batch number.

An electronic "Traveller" designed at CERN and based on the Assembly Breakdown Structure will allow the storage of identification and characteristics parameters of each component.

The Traveller structure is following the structure of the Assembly Breakdown Structure. (see Tables B34.1 and B34.2 attached below)

All the "CERN delivered components" identified in the Traveller shall be registered and all their main parameters and characteristics, as defined by CERN, will be recorded.

All the components under the Contractor responsibility and defined in the Traveller will be record in the appropriate form as defined by CERN.

At the delivered to CERN, each cold mass shall be accompanied with an identification summary (electronic and paper format) listing the components used for its assembly.

(See following Section 6: "Delivery to CERN")

3. NON-CONFORMITY

In case of non-conformance discovered during the manufacture either on component, on assembling procedure, or on test, the Contractor must open a Non-Conformity and send to CERN the Non-Conformity report document (in CERN format, see Non Conformance report example attached below).

This document in electronic format shall be sent via Email to CERN responsible Engineer for appropriate action.

4. CHANGE NOTICE

If case of any deviation from the manufacturing procedure (design, components, tooling, manufacture or test procedure), a Change Notice report form must be prepared and sent to CERN via Email to the responsible Engineer for appropriate action (See Change Notice report example attached below).

5. TEST LEVEL

Test results shall be recorded in the EXCEL™ format imposed by CERN. These test results shall be sent to CERN via electronic mail (EMAIL) or File transfer (FTP).

These files will be sent to CERN in due time (for example: after winding, after curing, after collaring, after the longitudinal welding of the Cold Mass or after completion of the cold mass assembly).

Sending sequence will be agreed in due time between CERN and the Contractor.

All Non-Conformities concerning test procedures and test results shall be recorder and transmitted to CERN for appropriate actions. The Non-conformities discovered shall be closed before execution of the next step as described in the I.T.P.

6. DELIVERY TO CERN

Before shipment of a cold mass to CERN, the Contractor shall send to CERN the copy (electronic and paper) of the full Traveller of the cold mass.

An identity document (see examples attached to this annex) shall be produced and shall contain the cold mass components identification, all tests reference, all non-conformities discovered and closed, and all relevant change notices.

7. ROLE OF QUALITY INSPECTOR AT CONTRACTOR SITE

The role of the Quality Inspector at firm is to verify the correct execution of the Technical Specification.

He will ensure that manufacturing procedures, the tooling used are conforming to the specifications and that all tests are done with correct procedures and calibrated equipment.

He will also ensure that all procedures, all test are supervised and signed according the organisation chart diagram in place at Contractor.

The Inspectors will act as observers. They will not be authorised to accept or to negotiate any changes within the frameworks of the contracts between CERN and the different Contractors.

They will be the CERN witnesses for the correct execution of the manufacturing sequences, manufacturing procedures, test methods, test performance and test reports during the series production of the above items.

Inspectors shall report and be in continuous and direct contact with the CERN engineers (or their delegates) directly responsible for the various manufacturing contracts, via telephone, fax and e-mail and will keep them informed about the Contractor’s progress.

Inspectors shall be under the administrative responsibility of their direct employer. Concerning the technical inspection duties, they shall report directly to the responsible CERN engineer. They shall be present at the Contractor’s premises during normal working hours and when required outside of these hours during critical manufacturing phases.

The responsible CERN engineers (or their delegates) may come during normal working time without any notice, to visit, inspect and discuss technical issues with the Inspectors and the Contractor.

In case of technical disagreement between Contractor and Inspector, the case will be discussed and clarified between the responsible CERN engineer, assisted by the Inspector, and the Contractor and a written report will be established stating the problem and its solution.

It is the duty of Inspectors to report to CERN any non-conformity discovered at any time during the manufacture and test procedures. He shall make sure that the non-conformity form shall be filled and sent by E-mail to the responsible CERN engineer.

In case of a disagreement between the Inspectors and the Contractor concerning the execution of the CERN Technical Specification, the Inspectors will inform the responsible CERN engineer immediately, who will take the appropriate action.

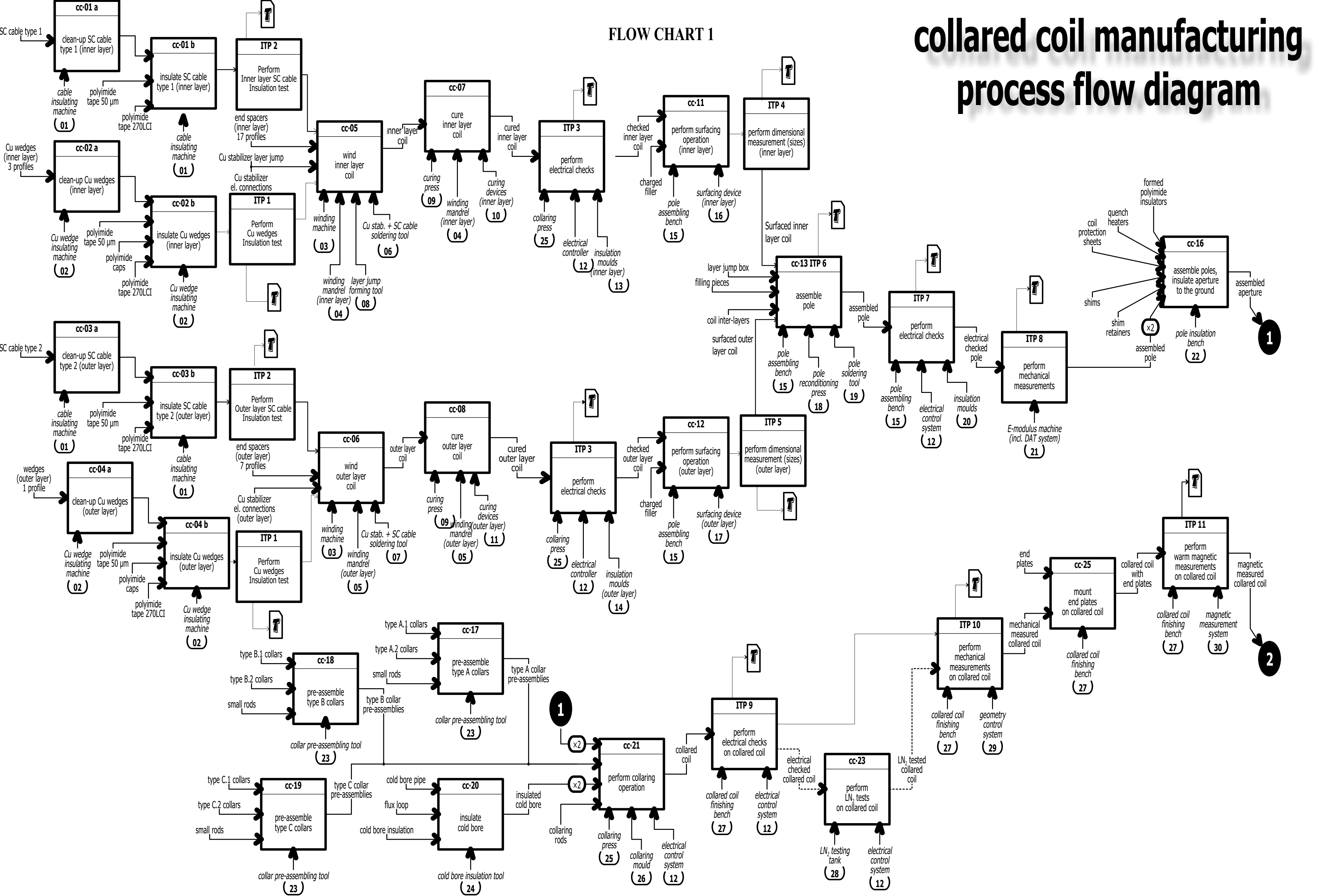
At the end of each working week the Inspectors shall send to the responsible CERN engineer a short written status report stating the situation of activities, tests performed and possible problems encountered or foreseen.

8. REMARKS

More practical and technical details concerning the traceability, Traveller, and test recording will be given in detailed technical meetings with the Contractor and with the delivery of the application software.

collared coil manufacturing process flow diagram

FLOW CHART 1



cold mass manufacturing process flow diagram

FLOW CHART 2

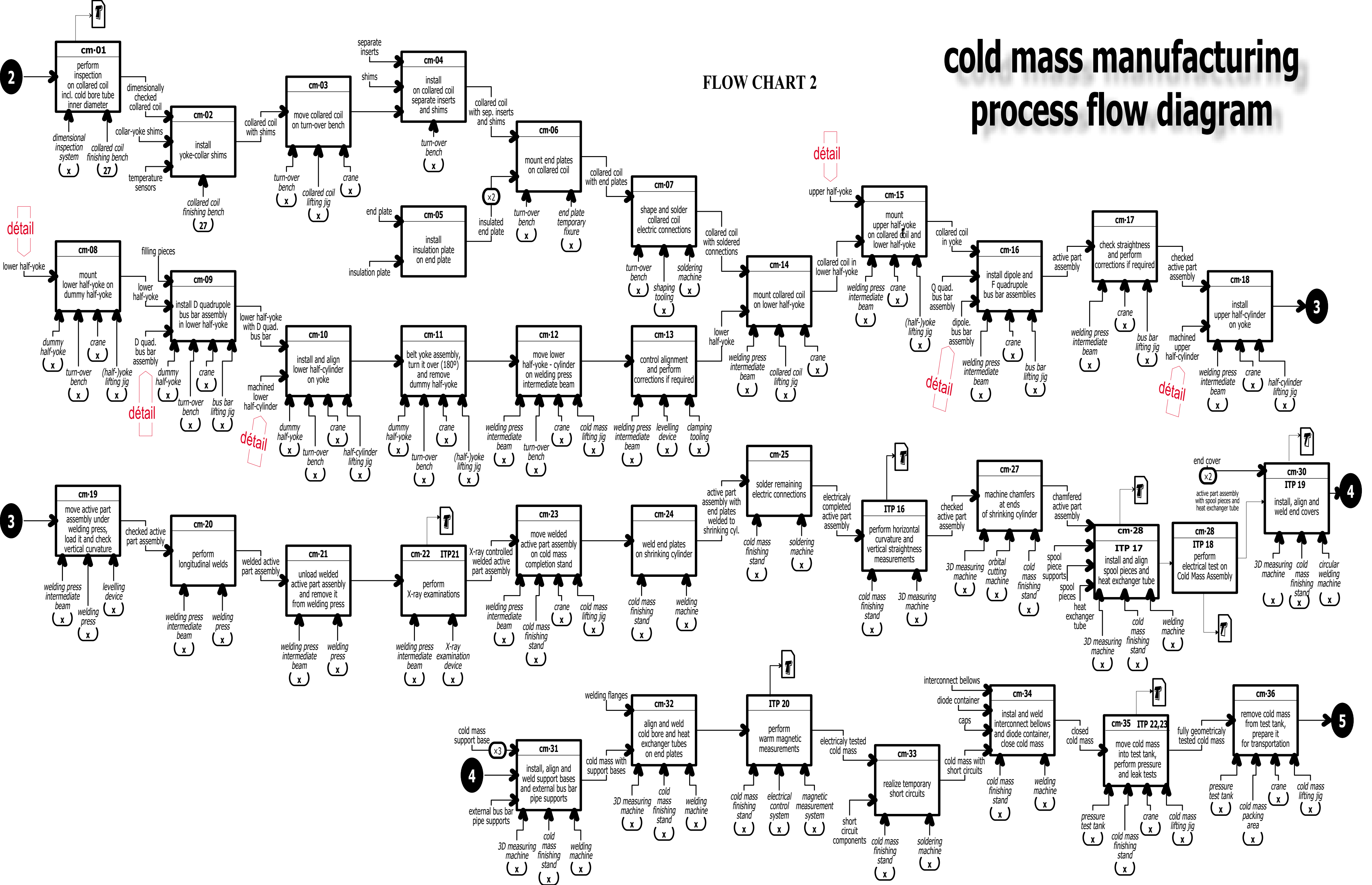


Table B34.1: Structure of Collared Coil

Collared Coil					HCMB__A001	Serial Number
1.1.	Collaring Rods (3)				HCMB__A101	Serial Number
1.2.	Shims				HCMB__A119	Serial Number
1.3.	Shim Retainers				HCMB__A120	Serial Number
1.4.	Cold Bore Tubes (2)				HCVCC_001	Serial Number
1.5.	Quench Heater				HCMB__A025	Serial Number
1.6.	Collars A Type 1				HCMB__A099	Batch Number
	1.6.1.	Raw Material				Batch Number
1.7.	Collars A Type 2				HCMB__A100	Batch Number
	1.7.1.	Raw Material				Batch Number
1.8.	Collars B Type 1				HCMB__A102	Batch Number
	1.8.1.	Raw Material				Batch Number
1.9.	Collars B Type 2				HCMB__A103	Batch Number
	1.9.1.	Raw Material				Batch Number
1.10.	Collars C Type 1				HCMB__A105	Batch Number
	1.10.1	Raw Material				Batch Number
1.11.	Collars C Type 2				HCMB__A106	Batch Number
	1.11.1	Raw Material				Batch Number
1.12.	Poles (4)				HCMB__A010	Serial Number
	1.12.1.	Coil Layer Inner (2)			HCMB__A011	Serial Number
		1.12.1.1.	Copper Stabilizer		HCMB__A050	Serial Number
		1.12.1.2.	Cable Supra Isolated		HCMB__AI46	Serial Number
			1.12.1.2.1.	Polymide Tape P1	HCMB__A109	Batch Number
			1.12.1.2.2.	Cable Supra Type 1	HCMB__A046	Serial Number
			1.12.1.2.3	Polymide Tape A1	HCMB__A110	Batch Number
		1.12.1.3.	End Spacers		HCMB__A059	Serial Number
		1.12.1.4.	Isolated Cu Wedges		HCMB__A051	Batch Number
			1.12.1.4.1.	Polymide Tape P1	HCMB__A109	Batch Number
			1.12.1.4.2.	Cu Wedges (4 type)	HCMB__A052	Batch Number
			1.12.1.4.3	Polymide Tape A1	HCMB__A110	Batch Number
	1.12.2.	Coil Layer Outer (2)			HCMB__A012	Serial Number
		1.12.2.1.	Copper Stabilizer		HCMB__A050	Serial Number
		1.12.2.2.	Cable Supra Isolated		HCMB__AI47	Serial Number
			1.12.2.2.1.	Polymide Tape P1	HCMB__A109	Batch Number
			1.12.2.2.2.	Cable Supra Type 2	HCMB__A047	Serial Number
			1.12.2.2.3	Polymide Tape A1	HCMB__A110	Batch Number
		1.12.2.3.	End Spacers		HCMB__A080	Batch Number
	1.12.3.	Coil Interlayer Spacer			HCMB__A093	Serial Number
	1.12.4.	Coil Interlayer Ends			HCMB__A094	Serial Number
	1.12.5.	Layer Jump box			HCMB__A089	Serial Number
	1.12.6.	Layer filling Pieces(2)			HCMB__A090	Serial Number
1.13.	Grd Insulation				HCMB__A020	Serial Number
1.14.	Coil Protection Sheet				HCMB__A108	Serial Number

Table B34.2: Cold Mass Assembly Traveller Structure

Cold Mass Assembly		HCMBX__A001	Serial Number	Remark X = A or B
1.1 Busbars set (Type A or Type B)		HCDCBHA-055/056	Serial Number	
1.2 Shrinking Cylinder(Concave)		HCMB__S142	Serial Number	
1.3 Shrinking Cylinde (Convex)		HCMB__S143	Serial Number	
1.4 End Cover Connection Side		HCMB_S008	Serial Number	
1.5 End Cover Lyre Side		HCMB_S007	Serial Number	
1.6 Collared Coil		HCMB__A001	Serial Number	
1.7 Half Upper Yoke			Serial Number	
1.7.1	Low Carbon Lamination Type A	HCMB__A133	Batch Number	
1.7.2	Low Carbon Lamination Type AA	HCMB__A134	Batch Number	
1.7.3	Low Carbon Steel Insert	HCMB__A148/149	Batch Number	
1.7.4	Lamination Pack Type B	HCMB__A139/141	Batch Number	
1.7.5	Lamination Pack Type D	HCMB__A140	Batch Number	
1.7.6	Lamination Pack Type D1	HCMB__A141	Batch Number	
1.8 Half Lower Yoke			Serial Number	
1.8.1	Low Carbon Lamination Type A	HCMB__A133	Batch Number	
1.8.2	Low Carbon Lamination Type AA	HCMB__A134	Batch Number	
1.8.3	Low Carbon Steel Insert	HCMB__A148/149	Batch Number	
1.8.4	Lamination Pack Type B	HCMB__A139/141	Batch Number	
1.8.5	Lamination Pack Type D	HCMB__A140	Batch Number	
1.8.6	Lamination Pack Type D1	HCMB__A141	Batch Number	
1.9 Heat Exchanger tube		HCQBX_P004	Serial Number	
1.10 Sextupole (2)		HCMCFMG001	Serial Number	
1.11 Octupole/Decapole (Type A)		HCMCDOA001	Serial Number	
1.12 Wiring Kit			Serial Number	
1.13 Diode Stack Type B or type A)			Serial Number	
1.14 Temperature Sensor			Serial Number	
1.15 Interconnection Bellows set			Serial Number	

Table B34.3: Coils components identification summary

Internal coil 1					
Component Type	**Part ID**	**Serial Number or Batch Number**	**Conponent Type**	**Part ID**	**Serial Number or Batch Number**
Inner Layer Superconducting Type 1	HCMB__A046		Inner Layer Spacer set	HCMB__A059	
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 1	HCMB__A052				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 2	HCMB__A054				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 3	HCMB__A056				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 4	HCMB__A058				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				

Internal coil 2					
Component Type	**Part ID**	**Serial Number or Batch Number**	**Conponent Type**	**Part ID**	**Serial Number or Batch Number**
Inner Layer Superconducting Type 1	HCMB__A046		Inner Layer Spacer set	HCMB__A059	
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 1	HCMB__A052				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 2	HCMB__A054				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 3	HCMB__A056				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 4	HCMB__A058				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				

Internal coil 3					
Component Type	**Part ID**	**Serial Number or Batch Number**	**Conponent Type**	**Part ID**	**Serial Number or Batch Number**
Inner Layer Superconducting Type 1	HCMB__A046		Inner Layer Spacer set	HCMB__A059	
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 1	HCMB__A052				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 2	HCMB__A054				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 3	HCMB__A056				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 4	HCMB__A058				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				

Internal coil 4					
Component Type	**Part ID**	**Serial Number or Batch Number**	**Conponent Type**	**Part ID**	**Serial Number or Batch Number**
Inner Layer Superconducting Type 1	HCMB__A046		Inner Layer Spacer set	HCMB__A059	
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 1	HCMB__A052				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 2	HCMB__A054				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 3	HCMB__A056				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 4	HCMB__A058				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				

External coil 1					
Component Type	**Part ID**	**Serial Number or Batch Number**	**Conponent Type**	**Part ID**	**Serial Number or Batch Number**
Outer Layer Superconducting Type 2	HCMB__A047		Outer Layer Spacer set	HCMB__A080	
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 1	HCMB__A052				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 2	HCMB__A054				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 3	HCMB__A056				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 4	HCMB__A058				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				

External coil 2					
Component Type	**Part ID**	**Serial Number or Batch Number**	**Conponent Type**	**Part ID**	**Serial Number or Batch Number**
Outer Layer Superconducting Type 2	HCMB__A047		Outer Layer Spacer set	HCMB__A080	
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 1	HCMB__A052				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 2	HCMB__A054				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 3	HCMB__A056				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 4	HCMB__A058				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				

External coil 3					
Component Type	**Part ID**	**Serial Number or Batch Number**	**Conponent Type**	**Part ID**	**Serial Number or Batch Number**
Outer Layer Superconducting Type 2	HCMB__A047		Outer Layer Spacer set	HCMB__A080	
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 1	HCMB__A052				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 2	HCMB__A054				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 3	HCMB__A056				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 4	HCMB__A058				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				

External coil 4					
Component Type	**Part ID**	**Serial Number or Batch Number**	**Conponent Type**	**Part ID**	**Serial Number or Batch Number**
Outer Layer Superconducting Type 2	HCMB__A047		OuterLayer Spacer set	HCMB__A080	
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Inner Layer Superconducting Type 1	HCMB__A046				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 1	HCMB__A052				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 2	HCMB__A054				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 3	HCMB__A056				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				
Copper wedge Type 4	HCMB__A058				
Polyimide Tape Type A1	HCMB__A110				
Polyimide Tape Type P1	HCMB__A109				

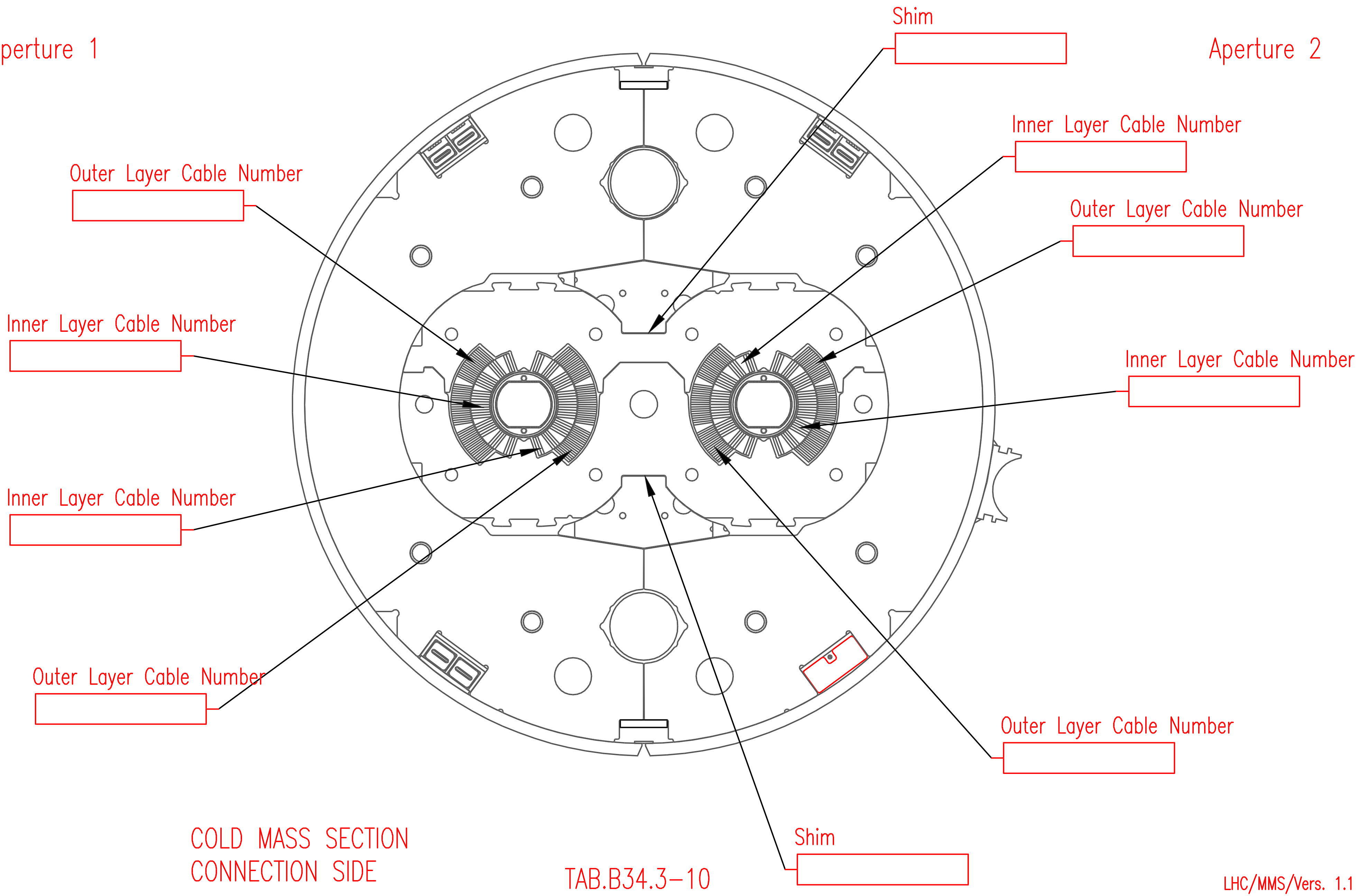
Table B34.4: Collared Coil Components identification summary

Component Type	**Part ID**	**Serial Number or Batch Number**
Aperture 1		
Inner Layer Superconducting Type 1	HCMB__A046	
Outer Layer Superconducting Type 2	HCMB__A047	
Inner Layer Superconducting Type 1	HCMB__A046	
Outer Layer Superconducting Type 2	HCMB__A047	
Quench Heater	HCMB__A025	
Quench Heater	HCMB__A025	
Quench Heater	HCMB__A025	
Quench Heater	HCMB__A025	
Quench Heater	HCMB__A025	
Cold Bore Tube	HCVCC_001	
Aperture 2		
Inner Layer Superconducting Type 1	HCMB__A046	
Outer Layer Superconducting Type 2	HCMB__A047	
Inner Layer Superconducting Type 1	HCMB__A046	
Outer Layer Superconducting Type 2	HCMB__A047	
Quench Heater	HCMB__A025	
Quench Heater	HCMB__A025	
Quench Heater	HCMB__A025	
Quench Heater	HCMB__A025	
Cold Bore Tube	HCVCC_001	
Coil Interlayer Spacer	HCMB__A093	
Coil Interlayer Ends	HCMB__A094	
Layer Jump box	HCMB__A089	
Layer filling Pieces(2)	HCMB__A090	
Collared Coil	HCMB__A001	
Collars A Type 1	HCMB__A099	
Collars A Type 2	HCMB__A100	
Collars B Type 1	HCMB__A102	
Collars B Type 2	HCMB__A103	
Collars C Type 1	HCMB__A105	
Collars C Type 2	HCMB__A106	
Grd Insulation	HCMB__A020	
Coil Protection Sheet	HCMB__A108	
Central Collaring Rods	HCMB__A148	Diameter:
Side Collaring Rods	HCMB__A149	Diameter:
Shims	HCMB__A119	Val: Val:
Shim Retainers	HCMB__A120	Val: Val:

COLD MASS NUMBER HCMBX_A001

X=A or B
☐ ☐

Serial Number ☐ Company ☐



COLD MASS SECTION
CONNECTION SIDE

TAB.B34.3-10

LHC/MMS/Vers. 1.1

Table B34.6: Cold Mass components identification summary

Cold Mass Assembly		
Component Type	**Part ID**	**Serial Number or Batch Number**
Low Carbon Laminations (A,AA)	HCMB__A133	
Low Carbon Steel Insert	HCMB__A148/149	
Lamination Pack (B,D,D1)	HCMB__A139/141	
Collared coil	HCMB__A001	
Temperature Sensor	HCQITEFCXT	
Bus Bars set Type A	HCDCBHA-055	
Bus Bars set Type B	HCDCBHA-056	
Heat Exchanger tube	HCQBX_P004	
Shrinking Cylinder (Concave)	HCMB__S142	
Shrinking Cylinder (Convex)	HCMB__S143	
Wiring Kit		
End cover (Connection side)	HCMB_S008	
End cover (Lyre side)	HCMB_S007	
Diode Stack		
Interconnection Bellows set	HCMB_S011	
Aperture 1		
Sextupole	HCMCFMG001	
Octupole/Decapole	HCMCDOA001	
Aperture 2		
Sextupole	HCMCFMG001	
Octupole/Decapole	HCMCDOA001	

CERN
CH-1211 Geneva 23
Switzerland

the
Large
Hadron
Collider
project

LHC Project Document No.
LHC-

EDMS Document No.

Nonconformance Number

Nonconformance Report

IDENTIFICATION

1. Originator Name:	3. Date:
2. Contractor/Supplier:	4. NC No:
5. Contract No:	
6. Part description:	8. Qty:
7. Part ID:	9 Dwg No:

10. Found during what activity:

☐ Incoming inspection ☐ In-process inspection ☐ Final inspection	☐ Other:

11. Description of nonconformance (use continuation page if necessary)

12. Action taken to prevent misuse (use continuation page if necessary)

DISPOSITION

13	☐ Use-as-is ☐ Repair ☐ Rework	☐ Return to supplier ☐ Reject	Responsible Manager Name: Date:

14. Approval of USE-AS-IS disposition	Project Engineer	Project Management
☐ Non-critical NC	Name:	Name:
☐ Critical NC	Date:	Date:

15. Approval of repair, rework, return to supplier, rejection disposition

Project Engineer	Name:	Date:

CORRECTIVE/PREVENTIVE ACTION

16. Description of proposed action (use continuation page if necessary)

17. Approval of corrective/preventive action

Project Engineer	Name:	Date:

CLOSING THE NONCONFORMANCE

18. Planned disposition has been completed and corrective/preventive action has been initiated

Project Engineer	Name:	Date:

CERN
CH-1211 Geneva 23
Switzerland

the
Large
Hadron
Collider
project

LHC Project Document No.
LHC-

EDMS Document No.

Nonconformance Number

Change Notice Report

IDENTIFICATION	
1. Originator Name:	3. Date:
2. Contractor/Supplier:	
5. Contract No:	4. Technical Specification concerned :
6. Part or set involved :	
7. Part ID:	8 : Application to :

9. Derogation requested:

10. Solution Proposed :

11. Information or related drawings number

DECISION	
12. ☐ Procedure approuved ☐ Extra Cost ☐ CERN approuval ☐ Impact on schedule	Responsible Manager at firm Name: Date:

13. In case of extra cost or Impact on Planning please specify:

Cost : Expected Effort Date:

Impact on Planning (week):

14. CERN Approval

Project Engineer Name: Date:

ANNEX B35: PLANNING AND SCHEDULING REQUIREMENTS

Please refer to the Annex D document:
"Planning & Scheduling Requirements for Institutes, Contractors and Suppliers".
(Doc. Number:LHC-PM-QA-301.01 rev. 1.1)

ANNEX C: DESCRIPTION OF THE CERN SUPPLIED COMPONENTS FOR THE “SERIES” COLD MASSES

C1	Superconducting cables (for inner & outer layers)
C2	Polyimide tapes for cable and copper wedges insulation (two types)
C3	Copper wedges (4 types)
C4	*Void*
C5	Polyimide (in rolls) for the coils ground insulation
C6	Collars
C7	Insulated Cod Bore tubes
C8	Low carbon steel half-yoke & insert laminations
C9	Non-magnetic steel half-yoke & insert laminations
C10	Busbar subassemblies
C11	Shrinking half-cylinders
C12	Spool pieces
C13	End covers
C14	Helium heat exchanger tube
C15	Interconnection bellows
C16	Instrumentation for the cold mass
C17	Protection Diode stack
C18	Tube for the Auxiliary Busbars line (“N-line”)

ANNEX C1: Superconducting cable (for inner and outer layers)

The superconducting cable will be delivered DDU to the Contractor’s premises. Each unit length will be on a dedicated spool (bore diameter 127 mm). For each unit length, a certificate of conformity will be provided, listing the following measured values of the main cable characteristics important for the cold mass assembler.

Name of the product

Cable identification code

Cable length (m)

CMM (Cable Measuring Machine) results:

- Average width (mm)
- Average mid thickness (mm) at 20 MPa
- Average keystone angle (°)

Ten stack results:

- Mid thickness at 50 MPa

Cable transposition direction

Cable transposition pitch

Result of bend test

Cable visual examination

Critical current

Heat treatment number

Data on the dimensions of the cable over the length are available upon request.

ANNEX C2: Polyimide tapes for superconducting cables and copper wedges insulation

1. INTRODUCTION

The insulating films for the dipole cable insulation as described in Section 6.1.3 of the main dipole specification will be supplied by CERN as free issue material. The insulation system is a so-called "all polyimide system".

2. FILM TYPES

Two types of films are used :

a) The first, "plain film", is used for the inner insulation wraps applied around the cable and is made solely of polyimide material.

b) The second is an all-polyimide adhesive film, applied as a covering wrap in a barber's pole fashion, i.e. leaving a gap between successive turns, with the adhesive directed outwards. It is made of a layer of plain film coated on one side with a layer of polyimide based adhesive. The adhesive coating as delivered has a nominal thickness of 5 μm. It is non-sticky at room temperature and bonds to itself at a temperature of 185°C at already a moderate contact pressure.

3. DIMENSIONS AND PROPERTIES OF FILMS

All films are supplied in pad roll form. Film types and dimensions are shown in Table C2.1.

Table C2.1: Dimensions of the polyimide films

Type of film	Thickness [μm]	Average width [mm]	Pad roll diameter ID / OD (mm)
Plain tape P1	50.8 ± 3%	11.0 ± 0.1	all rolls 76±1 / 299±6
Adhesive tape A1	68.6 ± 3%	9.0 ± 0.1	> 90% of rolls 76±1 / 242±14 < 10% of rolls 76±1 / 214±14

The rolls of adhesive film are exempt of splices, in most of rolls the coating faces outwards. However, before wrapping the cable, the coating side of each roll of adhesive film shall be checked by the Contractor. The typical “peel strength” of the adhesive is 0.05 N per mm of tape width.

4. STORAGE CONDITIONS AT THE CONTRACTOR PREMISES

Safe storage conditions shall be ensured. A suitable time prior their use, the films shall be stored in a clean area which is temperature and humidity controlled, such that the moisture content of the films is below 2% at the time of use.

5. GENERAL GUARANTEED PROPERTIES OF POLYIMIDE FILMS

The properties of the film comply with the values given in the Table C2.2. ASTM and MIL standards are given for information.

Table C2.2: Properties of the polyimide films

Guaranteed values of selected properties		
Property	Value	Test Method
Tensile strength, minimum (25 °C)	150 MPa	ASTM D-882
Elongation to rupture, minimum (25 °C)	60%	ASTM D-882
Shrinkage, maximum (120 min at 23 °C)	0.2%	MIL-P-46112B(MR-2) or equivalent
Moisture absorption, maximum	4%	ASTM D-570 or equivalent
Dielectric strength, minimum	90 V/µm	ASTM D-149

6. MARKING

Each box is marked with a CERN serial number, which corresponds to the CERN certification of conformity. This is the reference number which must be indicated by the cold mass Contractor on the quality control documents.

Each roll of film is provided with at least the following marking :

- film thickness,
- lot number,
- film width,
- film length.

ANNEX C3: Copper wedges

1. INTRODUCTION

The magnetic field quality of the dipole depends on the correct geometrical position of the cables and on their distribution in the coils. In fact, the desired field quality is obtained by spacing the different blocks of cables of the superconducting coil. For this purpose insulated copper wedges are inserted during the winding. The required high quality of the field calls for high precision and tight tolerances of the copper wedges.

2. TECHNICAL ASPECTS

2.1. Material

Material: ETP or oxygen free copper to standard DIN1787.

Hardness: HV>85 at room temperature and HV>55 at 190°C ± 10°C.

2.2. Dimensions and tolerances

All the dimensions and their tolerances are shown in the drawings:

LHCMB__A0052	Coil-Cu wedge bare,	inner layer	III/IV
LHCMB__A0054	Coil-Cu wedge bare,	inner layer	IV/V
LHCMB__A0056	Coil-Cu wedge bare,	inner layer	V/VI
LHCMB__A0058	Coil-Cu wedge bare,	outer layer	I/II

2.3. Manipulation and shipping to possible subcontractors

It is responsibility of the dipole Contractor to arrange for a safe and efficient packing, transport and delivery of the copper wedges to their possible subcontractors for the insulation. Particular attention shall be paid to avoid relative movements between copper wedges which may lead to surface damage: marks, scores, scratches, etc. This type of damages is not permitted.

The same attention shall be paid during the manipulation and storage of the copper wedges at the dipole Contractor’s premises.

ANNEX C4:

Void

ANNEX C5: Polyimide film (in rolls) for the coil ground insulation

1. INTRODUCTION

The insulating films used for making the ground insulation placed around the dipole magnet coils (see Section 6.4.1 of technical specification) will be supplied by CERN. These films are made solely of polyimide material.

2. FILM DIMENSIONS AND PROPERTIES

The film is suitable for hot forming with small bending radii without the formation of cracks.

All films are supplied in roll form without splices, the dimensions are shown in Table C5.1.

Table C5.1: Dimensions of the polyimide films

Type of film	Average thickness [μm]	Average width [mm]	ID (mm) / minimum film length per roll (m)
Plain film	125 ± 3%	250 ± 1.5	> 70% of rolls : 76.5±1 / > 300 < 30% of rolls : 76.5±1 / > 50

The physical properties of this film are shown in Table 2 of the Annex C2.

3. STORAGE

Safe storage conditions shall be ensured. A suitable time before use, the films shall be stored in a clean area, which is temperature and humidity controlled, so that their moisture content is below 2% at the time of use.

4. MARKING

Each box is marked with a CERN serial number, which corresponds to the CERN certification of conformity. This is the reference number which shall be indicated by the cold mass Contractor on the quality control documents.

Each roll of film is provided with at least the following marking :

- film thickness,
- lot number,
- film width,
- film length.

ANNEX C6: Collars

1. INTRODUCTION

The collars retain the coils of the dipoles and transmit the compressive pre-stress. The size and shape of the poles are linked to their containment system. The required high quality of the field calls for high precision and tight tolerances on the collars. The collars are precision-fine-blanked from high-strength austenitic steel sheets 3 mm thick.

Six different collar shapes are specified: two (type 1 and type 2) for the straight section coil region, two for the coil layer jump and splice region, two for the coil ends.

2. TECHNICAL ASPECTS

2.1. Material

The collar raw material is an austenitic steel grade (Nippon Steel YUS 130 S) with the following mechanical properties measured at room temperature:

Yield strength (offset=0.2%)	400-500 MPa
Tensile strength	700-800 MPa
Elongation A_5	$\geq$ 40 %
Brinell hardness	$\geq$ 100
Magnetic permeability (@ 4.2 K)	1.0021± 0.0005

2.2. Dimensions and tolerances

The geometry of the collars is described in the drawings:

LHCMB__A0099	Collared coils assembly-austenitic steel collar A,	type 1
LHCMB__A0100	Collared coils assembly-austenitic steel collar A,	type 2
LHCMB__A0102	Collared coils assembly-austenitic steel collar B,	type 1
LHCMB__A0103	Collared coils assembly-austenitic steel collar B,	type 2
LHCMB__A0105	Collared coils assembly-austenitic steel collar C,	type 1
LHCMB__A0106	Collared coils assembly-austenitic steel collar C,	type 2

2.3. Criteria for the acceptance of the batches

- Example measurements repeated 19 times on the same collar show a maximal deviation (Max value – Min value) of 5 μm and a standard deviation σ = 1.8 μm.
  Assuming a gaussian distribution this gives in an interval of $\pm 3\sigma$, 99.73% of the measurements. Thus an interval of $6\sigma = 10.8$ μm is due only to the measuring tool (in this case a 3D machine).

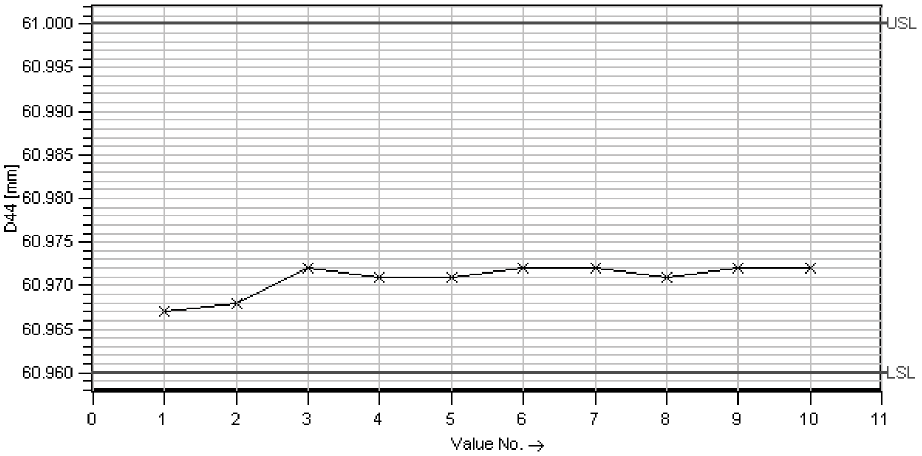


Figure C6.1: 10 measurements of the same collar.

- Example measurements repeated on ten consecutive collars show a maximal deviation of 16 µm and a standard deviation of σ = 5.2 µm.

  In this case the interval of ±3σ = ±15.7 µm, is due to a series of causes:

  – measuring tool,
  – positioning of the collar,
  – operator,
  – residual internal stresses in the steel,
  – natural variability of the process.

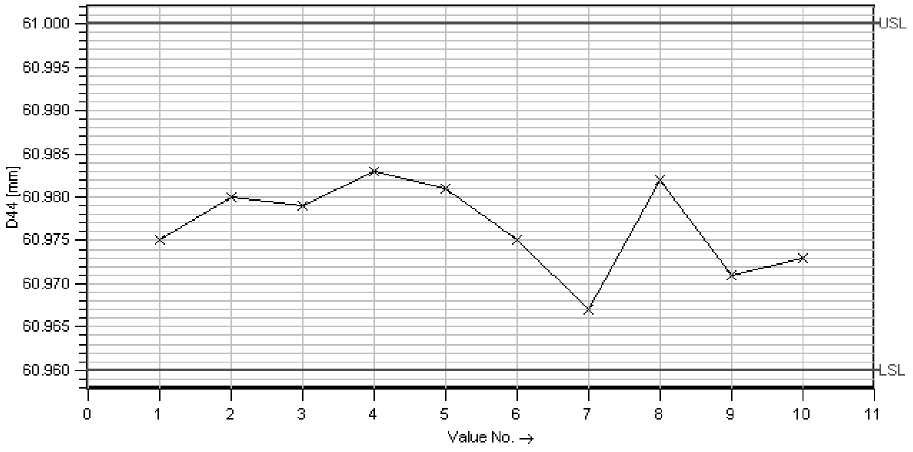


Figure C6.2: measurements of 10 consecutive collars

For all these reasons, for the acceptance of the collar batches at the beginning of the collar production, CERN will consider the mean of the three values given from control level A (see Annex G4 page 16). Details on the acceptance procedure for the beginning of the collar production are given in Annex G4.

For the collar series production, one collar per batch (one cold mass) will me measured, as indicated in drawing LHCMB_A0158, using a 3D computer controlled scanner. The following procedure will apply:

- Floating means of the measurements of the current batch and of the previous two batches are evaluated,
- If the mean values (for each measured point) are in tolerance the current batch is accepted,
- If the mean values are out of tolerance, the following procedure shall apply:

a) five collars for each of the three batches shall be checked,

b) For each measured point, the mean of the values for the six collars of the same batch will be evaluated,

c) if one or more of the mean values is out of tolerance the batch shall be rejected.

CERN is evaluating the possibility of using the procedure “gage R&R” from the MSA (Measurement Systems Analysis) from QS9000 to qualify the measurement system for the series production.

2.4. Manipulation and shipping to possible subcontractors

It is responsibility of the dipole Contractor to arrange for safe and efficient packing transport and delivery of the collars to their possible subcontractors for the preparation of the collar packs or of the collar couples.

The collars and the collar packs or couples must stay clean during storage and handling. Swarf, dust and any other contaminant are not permitted.

ANNEX C7: Insulated cold bore tubes

1. INTRODUCTION

The cold bore tubes of the LHC superconducting magnets are seamless non-magnetic austenitic steel tubes to be used as part of the cold mass of the LHC superconducting dipole magnets. The tubes are of about 16 m long.

The insulated cold bore tubes will be placed in the aperture of the coils and will form part of the inner wall of the helium vessel that contains the active part of the magnet. In addition, the cold bore tube is the passage for the circulating particle beams. As such, the tube wall separates the helium volume from the beam vacuum.

The operational conditions of the tubes are summarised in the following Table C7.1

Table C7.1: Operation condition for the cold bore tubes

Condition	**Temp.**	**Internal pressure**	**External pressure**
Normal operation	1.9 K	$< 1.10^{-9}$ Pa ($\equiv 1.10^{-11}$ mbar)	0.13 MPa (≡ 1.1 bar abs)
Test	300 K	$< 1.10^{-7}$ Pa ($\equiv 1.10^{-9}$ mbar)	2.6 MPa (≡ 26 bar abs)
Cool down- Warm up (~ 25 cycles)	300 – 1.9	$< 1.10^{-9}$ Pa ($\equiv 1.10^{-11}$ mbar)	2 MPa (≡ 20 bar abs)

2. DELIVERY STATE OF THE COLD BORE TUBES

- The tubes will be delivered according to the following considerations.
- The tubes are seamless in view of leak tightness and homogeneity of magnetic permeability.
- The tubes are made from austenitic steel grade AISI 316 LN.
- The main dimensions and tolerances for the bare tubes are as follows:

Length	15.5 m	(- 0, + 15) mm
External diameter	53 mm	(- 0.15, + 0.15) mm
Wall thickness	1.5 mm	(- 0.10, + 0.10) mm
Straightness		0 ± 0.5 mm/m

- The roughness, Ra, does not exceed 1.6 µm (equivalent to N7) for inner and outer surfaces.
- The tubes are cleaned internally and externally to ensure that they are free from dirt, dust, grease, burrs and metal chips. In addition, the tubes are subjected to a 24-hour vacuum bakeout at 150°C.
- The tubes are leak-tested and the total leak rate per tube is guaranteed not to exceed $1 \cdot 10^{-11}$ Pa m^3 s^{-1} with an external helium pressure of 26 bar (absolute).
- The tubes will be supplied sealed with end plugs and packed.

3. INSULATION

3.1. Introduction

The insulation of the cold bore tubes is composed by three different types of tapes arranged in four layers, the last one half overlapped. The tapes are wrapped around the tube following the layout of drawing LHCMB__S0004. Curing is performed after wrapping around the four layers of insulation a 50% overlapped layer of a suitable release tape. Curing temperature/time are 185°C for 30 minutes.

3.2. Characteristics of the insulation tapes

The first and the second insulation layers are made by an one-side epoxy-coated polyimide tape wrapped with the glue towards the tube. The epoxy resin is of a B-stage fast curing type, based on a modified Bisphenol-A

The third insulation layer is made by a "prepreg" tape using a similar type of resin as the first two layers. The fourth insulation layer is made by a polyimide tape coated on both sides by a polyimide glue.

The main characteristics of the tapes are summarised in Table C7.2

Table C7.2: Characteristics of the insulation

Layer	Denomination	Width (mm)	Thickness (µm)	Composition
1st layer	Tape 1	20	70	epoxy/polyimide
2nd layer	Tape 1	20	70	epoxy/polyimide
3rd layer	Tape 2	20	200	E-glass prepreg
4th layer	Tape 3	20	60	PI with PI glue on both sides

3.3. Certification

Each insulated tube will be delivered to the Contractor with a certification of conformity of the insulation which is a complement of the certification issued for the bare tube. The checks done after insulation are:

- visual inspection, to verify the absence of macroscopic defects,
- go-no-go check on the whole tube length to verify that the outer diameter of the insulated does not exceed (in any point) 54.3 mm, and the inner diameter is ≥ 49.65 mm,
- dielectric check at a DC testing voltage of 5 kV.

4. OBLIGATION OF THE CONTRACTOR

The Contractor shall be responsible of the buffer storage of the insulated cold bore tubes whenever it is necessary.

The end plugs shall not be removed without CERN's approval.

The Contractor shall take every precaution during the handling operations and/or during the storing periods in order not to damage the tubes (i.e., with respect to their shape, straightness and surface quality), their insulation and in order not to spoil their cleanliness. The relatively low inertia of the tube cross section is given here to emphasize the importance of the first remark, $I = 80527\ \mathrm{mm}^4$. The cold bore, internal and external surfaces, should not be exposed to materials, such as halogen containing materials, which may decompose into corrosive products. Similarly, products containing silicon are known to be difficult to remove.

Before and after completion of the collaring operation, the Contractor shall check the inside diameter of the cold bore tube along its entire length with a “go” plug gauge (Ø ≥ 49.65 mm) in order to determine the minimum diameter of the bore. The results of this measurement shall be reported in the Traveller. The material proposed for the plug gauge must be approved by CERN. Lubricants of the gauge are not permitted. A measurement of the minimum inner diameter of the cold bore after its integration is required to confirm the expected machine mechanical aperture. In case the “go” gauge does not pass the entire length of the cold bore tubes, a non-compliance procedure shall be opened as described in Section 8.2.6. CERN will be contacted for approval on the proposed corrective actions. The Contractor shall then perform the warm magnetic measurements as well.

After completion of these checks, the end plugs shall be re-installed and the collared coil assembly prepared for the following phases of the dipole assembly. The “go” gauge check shall be repeated after completion of the cold mass using the above mentioned procedure.

ANNEX C8: Low carbon steel half-yoke and insert lamination

1. LOW CARBON STEEL LAMINATION MATERIAL CHARACTERISTICS

- Low carbon mild steel, hot rolled, and annealed
- Yield Strength : $\sigma_{0.2}$ ≥ 140 MPa
- Tensile Strength: σ_R ~ 280 MPa
- Elongation: ≥ 50%
- Thermal Contraction Coefficient
- (integrated between 300 K and 1.9 K) $\alpha = 2.0\ 10^{-3}$
- Max. Coercitivity after Hmax > 5000 A/m: 75 A/m ± 10 %
- Permeability at H = 40 A/m: B ≥ 0.04 T
- Permeability at H = 1200 A/m: B ≥ 1.5 T
- Permeability at H = 24000 A/m: B ≥ 2.0 T

The low-carbon steel sheets will be delivered to the firms in charge of the fine blanking protected by a layer (3-5 µm of thickness) of mill scale. This type of protection layer has shown very good characteristics in terms of adherence, uniform thickness and resistance.

The yoke and insert laminations are obtained from the fine-blanking procedure. The final geometry of the laminations and inserts fulfil two major requirements, namely compliance with the dimensional tolerances, typically ±0.02 mm (see drawings), and the high quality of the cut edges.

After fine-blanking, the laminations will be deburred, degreased and finally delivered to the Contractor’s premises protected by a very thin layer of anticorrosive agent (Anticorit DW Bio Super™ or similar).

The geometry of the half-yoke lamination and insert lamination is presented in the drawings: LHCMB__A0133“Iron-Yoke Lamination, type A” and LHCMB__A0148 “Iron-Yoke Insert”.

2. CRITERIA FOR THE ACCEPTANCE OF THE BATCHES

The batch of laminations will be accepted utilising a procedure very similar to the one presented for the collars acceptance. Please refer to the Section “Annex C6: Collars , 1.3 Criteria for the acceptance of the batch” for more details.

3. HANDLING AND SHIPPING TO POSSIBLE SUBCONTRACTORS

It is the responsibility of the dipole Contractor to arrange for safe and efficient packing, transport and delivery of the yoke and insert laminations to their possible subcontractors for the preparation of the lamination packs.

The laminations and the lamination packs shall stay clean during the storage and handling. Swarf, dust and any other contaminants are not permitted.

ANNEX C9: Non-magnetic steel half-yoke and insert lamination

1. NON-MAGNETIC STEEL LAMINATION MATERIAL CHARACTERISTICS

Cold-rolled Austenitic Steel

– Yield Strength :	$\sigma_{0.2}$ ~ 350 MPa
– Tensile Strength:	σ_R ~ 600 MPa
– Elongation:	≥ 40%
– Thermal Contraction Coefficient	
– (integrated between 300 K and 1.9 K)	$1.6\ 10^{-3} \leq \alpha \leq 2.2\ 10^{-3}$
– Permeability at H > 80000 A/m, (@ 1.9 K):	$\mu \leq 1.002$

The yoke and insert laminations are obtained from the fine-blanking procedure. The final geometry of the laminations and insert fulfil two major requirements, namely compliance with the dimensional tolerances, typically ±0.02 mm (see drawings), and the high quality of the cut edges.

The geometry of the half-yoke lamination and insert lamination is presented in the drawings: LHCMB__A0139 “Iron-Yoke Lamination, type A” and LHCMB__A0152 “Iron-Yoke Insert”.

After the fine blanking, the yoke and insert laminations are deburred and degreased.

2. CRITERIA FOR THE ACCEPTANCE OF THE BATCHES

The batch of laminations will be accepted utilising a procedure very similar to the one presented for the collars acceptance. Please refer to the Section “Annex C6: Collars, 1.3 Criteria for the acceptance of the batch” for more details.

3. MANIPULATION AND SHIPPING TO POSSIBLE SUBCONTRACTORS

It is the responsibility of the dipole Contractor to arrange for safe and efficient packing, transport and delivery of the yoke and insert laminations to their possible subcontractors for the preparation of the lamination packs.

The laminations and the lamination packs shall stay clean during the storage and handling. Swarf, dust and any other contaminants are not permitted.

ANNEX C10: Busbar subassemblies

1. INTRODUCTION

Each dipole cold mass contains three sets of compact busbars sub-assemblies. These busbar sub-assemblies will be provided by CERN in suitable configurations so that they are ready for fitting in the yoke slots.

Observing the cold mass assembly from the “Connection Side”, the three sets (focusing quadrupole busbars, defocusing quadrupole busbars, “type A” or “type B” dipole busbars) shall be respectively installed in the upper left, upper right and lower left recesses and positioned longitudinally by fixed point:

- For cold mass “type A”, see drawing LHCDCBHA0055
- For cold mass “type B”, see drawing LHCDCBHA0056.

2. TECHNICAL DESCRIPTION

2.1. Focusing quadrupole busbar set

A focusing quadrupole busbar set is enveloped in an insulating casing which is made of a full-length double cavity jacket. This set contains:

- 2 busbars with a cross-section measuring 20 mm x 10 mm,
- 10 superconducting wires.

Refer to drawing LHCDCQHA0002.

2.2. Defocusing quadrupole busbar set

A defocusing quadrupole busbar set is enveloped in an insulating casing which is made of a full-length double cavity jacket. This set contains:

- 2 busbars with a cross-section measuring 16 mm x 10 mm,
- 10 superconducting wires.

Refer to drawing LHCDCQHA0010.

2.3. Dipole busbar set

Please refer to Engineering Specification LHC-DCB-ES-0001 attached at Annex B28.

There are two types of dipole busbar sets. The dipole cold mass shall be equipped either with a set of Type A or with a set of Type B. Half of the total dipole cold masses requested for the LHC machine shall be equipped with a set of Type A dipole busbars and the other half with a set of Type B dipole busbars.

Each set will contain an interior and an exterior dipole busbar with a cross-section of 20 mm x 16 mm.

- Refer to drawing LHCDCBHA0010`for “type A” dipole,
- Refer to drawing LHCDCBHA0002`for “type B” dipole.

ANNEX C11: Shrinking cylinder

1. INTRODUCTION

The outermost cold mass component is a shrinking cylinder (see drawing LHCMBPSA0006 “Shell–rough shape without bevel edge”).

Its structural function is to contain all the magnet parts, to apply the requested additional pre-stress (at 293 K and at 1.9 K) to the half-yokes, and withstand the magnetic forces arising during the energisation of the coils. The other function is to act as a helium vessel for cryogenic operation.

The cylinder, 10 mm thick, is composed of two half-cylinders which will be welded together along two axial edges. The nominal inner radius is of 275 mm.

The two half-cylinders are bent in opposite directions so that one is concave and the other is convex in order to achieve the specified horizontal curvature of the dipole cold mass.

2. MATERIAL SPECIFICATION

The steel sheets utilised for the manufacturing of the half-cylinders are made of austenitic steel grade 316 LN. The steel grade shall be stable from the metallurgical point of view (i.e. no deterioration of the austenitic structure should occur during the lifetime of the shrinking cylinder). It is expected that the cylinder will have to withstand approximately 25 thermal cycles from room temperature down to 1.9 K, the cold mass operating temperature. The steel grade shall be easily weldable.

3. PHYSICAL AND MECHANICAL PROPERTIES

– Permeability at H > 80 10^3 A/m, @ 293 K:	$\mu \leq 1.005$
– Yield Strength :	$\sigma_{0.2} \sim 300$ MPa
– Tensile Strength:	$\sigma_R \sim 600$ MPa
– Elongation:	A5 ≥ 40%
– Thermal Contraction Coefficient (integrated)	$\alpha \sim 3\ 10^{-3}$
– Charpy V notch resilience @ 4.2 K (ISO-V notched samples)	> 120 J cm^{-2}

4. DIMENSIONS AND TOLERANCES

The rough half-cylinders will be inspected and prepared by bevelling the longitudinal edges and the extremity edges following the specifications of the Annex B24.

The dimensions of the half-cylinder and the required tolerances are given in the drawings of Annex A.

The most important features of the half-cylinders are the quality of the inside, i.e. the circularity of the inner surface, the overall horizontal straightness and the vertical curvature.

The inside of the half-cylinder is of prime importance as it is in close contact with the yoke laminations of the magnet. The assembly procedure and the final welding of the full-length half-cylinders around the magnet parts require perfect contact between the inner surface of the shrinking cylinder and the yoke laminations. The circularity, i.e. the shape tolerance, of the inside surface shall be within 0.5 mm at maximum.

Although the tolerance range related to the wall thickness may extend to 1 mm for the total production, the variation of the wall thickness of a pair of half-cylinders shall be controlled within 0.5 mm. This means that only the following cases are accepted for every pair of half-cylinders to be assembled:

- 10.0 ≤ wall thickness (w.t.) ≤ 10.5
- 10.1 ≤ w.t. ≤ 10.6
- 10.2 ≤ w.t. ≤ 10.7
- 10.3 ≤ w.t. ≤ 10.8
- 10.4 ≤ w.t. ≤ 10.9
- 10.5 ≤ w.t. ≤ 11.0

The concave half-cylinders will be marked with a sequential number “U-000x” that means also that it is the upper half-cylinder. The convex half-cylinders will be marked with a sequential number “L-000x” that means also that it is the lower half-cylinder.

The two half-cylinders of a pair, which shall be put around the same magnet will be provided with the same sequential number.

ANNEX C12: Spool pieces

The main dipole magnets will be equipped with small sextupole and decapole/octupole corrector magnets to compensate for the systematic sextupolar and decapolar field errors of the dipoles. The sextupoles will be connected in series to form two families per octant. The same will apply for the decapoles and octupoles.

The required electrical tests (for acceptance and control after the installation) are described in the Annex B22: “Electrical tests before and after the cold mass assembly”.

The description of the mounting procedure is given in the Annex B28: “Preparation of the Magnet Extremities”.

The main design parameters are given in the following tables.

Table C12.1: Main parameters for the SEXTUPOLE corrector (MCS)

Nominal field at 17 mm	0.471 T
Magnetic length (1.9K)	0.11 m
Peak field in coil	1.9 T
Nominal Current	550 A
Turns/coil	26
Overall length (including shield)	~ 160 mm
Inner diameter, aperture	58 mm
Overall Outer diameter	~ 120 mm
Weight	4 kg

Table C12.2: Main parameters for the DECAPOLE corrector (MCD part of MCDO)

Nominal field at 17 mm	0.1 T
Magnetic length (1.9K)	0.066 m
Peak field in coil	2.4 T
Nominal Current	550 A
Turns/coil	40
Overall length (including shield)	~ 110 mm
Inner diameter, aperture	64 mm
Outer diameter (inc. ground insulation)	~ 115 mm
Weight (of MCDO)	4 kg

Table C12.3: Main parameters for the OCTUPOLE corrector

(MCO part of MCDO, nested inside the MCD)

Nominal field at 17 mm	0.04 T
Magnetic length (1.9K)	0.066 m
Nominal Current	100 A
Overall length (including shield)	~ 110 mm
Inner diameter, aperture	58 mm

ANNEX C13: End covers

1. INTRODUCTION

The end covers of the LHC superconducting magnets are dished heads equipped with a number of tubular nozzles, which provide the cold mass assembly with free passages for the cold bore tubes and for the interconnection busbars. They are part of the outside envelope of the cold mass and therefore must be leak tight with respect to the superfluid helium at 1.9K, which is used as cooling medium.

The end covers shall be made of an austenitic steel, grade 316LN, in order to be fully compatible with the shrinking cylinder and to providing for the requested toughness at low temperature.

2. TECHNICAL DESCRIPTION

The main dimensions of the end covers and the requested tolerances are:

• Depth$_{\text{inside}}$	184	mm	± 0.1	mm
• Large radius$_{\text{inside}}$	570	mm	± 1	mm
• Knuckle radius	110	mm	± 0.5	mm
• Wall thickness	12	mm	(-0;+1)	mm

The reference drawings are LHCMB__S0007 and LHCMB__S0008.

Several alternative techniques for the end covers manufacturing, including welding, casting, forging, punching or powder metallurgy, are possible. The relevant inspection and test plan to be implemented will have to be adapted accordingly. More details about it are given in the above-mentioned specification.

Whatever the manufacturing technique, the metallurgical structure of the end covers after solution annealing shall be fully austenitic and homogeneous. Good weldability is of course required as the end covers must be welded to the shrinking cylinder.

ANNEX C14: Helium heat exchanger tube

1. INTRODUCTION

The helium heat exchangers tubes (see drawing LHCQBX_P0004) are part of the cooling loop of the LHC superconducting dipole magnets and are placed through the dipole cold masses. The vaporisation of liquid helium flowing in the exchanger tubes allows the pressurised helium bath in which the superconducting magnet is immersed to be cooled down to 1.9 K.

The helium heat exchanger tube is a seamless tube made of oxygen-free copper (OFC) and equipped with austenitic steel end pieces. These austenitic steel end pieces are necessary for the easy welding of the heat exchanger tube to the austenitic steel end covers that close the cold mass extremities.

During their lifetime, the helium heat exchanger tubes will have to withstand some 25 complete thermal cycles from room temperature down to 1.9 K and back.

Before delivery, each helium heat exchanger tube will undergo the following tests:

- Hydraulic pressure test at 3 MPa of external pressure at 293 K,
- Global Helium leak test at 293 K. Max. allowable leak rate is 1.10^{-10} Pa m^3/s.

2. TECHNICAL DESCRIPTION

The following Table C14.1 shows the main parameters and characteristics for the helium heat exchanger tubes. All the pressures given are absolute.

Table C14.1 : Main parameters for the helium heat exchanger tube

Overall length	15338.5 (± 2)	mm
Outside diameter	58.0 (–0,+0.3)	mm
Inside diameter	54.0 (-0.3,+0)	mm
Wall thickness	2.15 (±0.15)	mm
Material yeld point ($R_{\rho 0.2}$)	250	MPa
Material ultimate tensile strength(R_m)	275	MPa
Elongation at rupture (A)	15 %	
Normal operation Condition	1.9 K; 16 mbar (inner pressure); 1.3 bar (outer pressure)	
Test operation condition	300 K; 1 bar (i.p.); 26 bar (o.p.)	
Cool down & warm up cycle	300-1.9 K;4.5 bar (i.p.);10 bar (o.p.)	

ANNEX C15: Interconnection bellows

1. INTRODUCTION

During cool down to the operating temperature of the LHC, the magnets shrink longitudinally by about 3 mm per metre length, i.e. about 45 mm in total. In order to cope with this thermal contraction, the cold mass is equipped with bellows providing for the necessary longitudinal flexibility in the interconnection region between two adjacent magnets in the LHC machine.

CERN will provide the Contractor with the bellows of the types listed hereafter.

2. TECHNICAL DESCRIPTION

There are 3 types of bellows to be installed on the “lyre side” or “downstream” side of the cold mass assembly.

The lines M1, M2 and M3, which correspond respectively to the defocusing quadrupole busbars, the focusing quadrupole busbars and the dipole busbars, shall be equipped with bellows of “TYPE M”. These bellows are made of “U-shaped” convolutions. They are illustrated on the drawing LHCMB__S0084 and LHCMB__S0085. Their main characteristics are:

• Inside diameter	80	mm
• Outside diameter	101	mm
• Number of convolutions	10	
• Free length of convolutions	95.5	mm
• Total free length	209.5	mm

The line X, which corresponds to the helium heat exchanger tube, is equipped with 2 types of bellows. One type, called “type X external bellow” has the same function as the type M bellows and it is shown on the drawing LHCMB__S0090. Its main characteristics are:

• Inside diameter	54.4	mm
• Outside diameter	73.4	mm
• Number of convolutions	16	
• Free length of convolutions	73.8	mm
• Total free length	136.5	mm

The other type, called “type X internal bellow” is placed inside the end cover nozzle, through which the helium heat exchanger tube passes. The function of this bellows is to compensate for the differential thermal contraction which occurs between the helium heat exchanger tube and the cold mass envelope. This bellows is also made of “U-shaped” convolutions. It is illustrated on the LHCMB__S0087. Its main characteristics are:

• Inside diameter	66	mm
• Outside diameter	79	mm
• Number of convolutions	8	
• Free length of convolutions	47	mm
• Total free length	69	mm

All these bellows are made of austenitic steel, grade 316 L. More details about the technical requirements, which are applicable to these items, are given in the Technical Specification annex in the Section G11.

ANNEX C16: Instrumentation for the cold mass

1. INTRODUCTION

As already mentioned (see Section 7.3 and Annex B23), the instrumentation to be mounted on the cold mass will consists of:

- Voltage taps, to detect quenches of dipole windings and permit diagnostics on the spool pieces and diode stack:
  - 14 voltage taps in “type A” cold mass,
  - 10 voltage taps in “type B” cold mass,
- 2 current taps to power the protection diode stack and which shall be installed on the bus-bar interconnections,
- 2 current taps to allow the magnetic axis (QCD) measurement,
- 1 temperature sensor at the centre of each cold mass,
- 1 cryo-heater.

2. VOLTAGE TAPS AND THEIR WIRING

Voltage taps are installed at several locations on the coils and busbars of the cold mass. They consist of tin-plated copper lugs, fixed on the bare SC cable or on the busbars copper stabiliser and insulated. The top of the lugs is formed as a solder lug to accept a connecting insulated wire.

Two type of voltage tap are used.

The first type consists of tin-plated copper lugs, bent around and then soldered on the bare SC cable extremity and subsequently insulated. The ends of the lugs are formed as a solder lug to accept the connecting insulated wire. The voltage tap dimensions are shown in drawing LHCMB__E0046

The second type consists of a standard lug fixed with a screw in a dedicated position on the busbars copper stabiliser.

The voltage tap connection wires shall be made of copper wire (section: 0.15 mm^2; 19 wires of ∅ 0.102 mm), with a polyimide film insulation selected by CERN to withstand a service voltage of 1kV (5kV max. test voltage at room temperature), the superfluid helium temperature and the foreseen level of radiation.

3. WIRING FOR THE PROTECTION DIODE STACK CURRENT FEEDINGS

Two wires connected to the interconnecting busbars shall be installed inside the cold mass. These two wires shall be made of copper (0.6 mm^2, 19 x 0.203 mm), with a polyimide film insulation selected by CERN to withstand a service voltage of 1kV (5 kV max. test voltage at room temperature), the superfluid helium temperature and the predicted level of radiation.

4. TEMPERATURE SENSORS

CERN will supply one temperature sensor per cold mass that shall be installed by the Contractor in the middle of the cold mass according to drawing LHCMB__A0156. Each temperature sensor will be already equipped with four connection wires arranged in a cable and long enough to reach the outlet of the cold mass. The four wires will be made of copper wires (0.057 mm^2, 7 x 0.102 mm), insulated with polyimide film selected to withstand a service voltage of 250 volts, the superfluid helium temperature and a level of radiation determined by CERN.

5. CRYO-HEATER AND ITS WIRING

A cryo-heater will be installed in the bottom of the connection side cold mass end on the end plate. It is connected by two wires. These two wires shall be made of copper (0.155 mm^2, 19 x 0.102 mm), with a polyimide film insulation selected by CERN to withstand a service voltage of 250V, the superfluid helium temperature and the foreseen level of radiation.

6. QUENCH HEATERS WIRING

The quench heaters are described in Annex B14. The 16 wires of the 8 quench heaters shall be made of copper wire (0.155 mm^2, 19 x 0.102 mm), with a polyimide film insulation selected by CERN to withstand a service voltage of 1kV, the superfluid helium temperature and the foreseen level of radiation.

7. ANCILLARY COMPONENTS

The procurement of all the ancillary components such as: protection sleeves, standard clamp, screws, etc. are the responsibility of the Contractor. These components will be of the same types already selected and approved by CERN for the pre-series production.

ANNEX C17: Protection diode stack

1. INTRODUCTION

The LHC involves the operation of about 1250 twin aperture superconducting dipole magnets each at currents up to 13 kA. Essential elements for the protection of these dipoles are high current by-pass diodes mounted inside the liquid helium vessel and operating at a temperature of 1.9 K. The diodes shall operate safely and reliably within a temperature range of 1.9 K to about 430 K during all the life of the LHC accelerator.

Each twin aperture dipole is by-passed by one dipole diode stack.

2. TECHNICAL DESCRIPTION

The diodes are mounted under high pressure in clamping systems to ensure the required quality of thermal and electrical contacts between heat sinks and the diode electrodes. The clamping system for the dipole diodes will house one diode. In case of a magnet quench the dipole diodes conduct a current pulse up to 13 kA decaying exponentially with a time constant of about 105s giving a temperature rise inside the diode of up to 300 K.

To avoid overheating, the diodes are mounted between cylindrical copper blocks acting both as heat sinks and high current connections. Three insulated stainless steel rods and eight Cu-Be spring washers are used to press the heat sinks against the diode contact surfaces under a force of about 40 kN.

The centring of the compression force is ensured by centring pins between the diode electrodes and the heat sinks and centring pins of fibreglass reinforced epoxy at the end plates. Insulation plates made of fibreglass-reinforced epoxy insulate the stainless steel end plates from the electrical connections (heat sinks).

After assembly of the diode stacks, they have been tested in liquid helium at 4.2K. During these tests, the hermetically sealed diode capsules are tight and normally no helium will penetrate into capsule.

To avoid, during long-term operation of the LHC, that superfluid helium is trapped in a non-vented diode capsule and excessive overpressure inside the capsule may occur during a magnet quench, all diode capsules will be vented just before the final installation of the diode into the cold mass of the magnet. As vented diodes are very sensitive to moisture and dust pollution (e.g. condensing humidity) will seriously deteriorate the internal contact surfaces - strict precautions must be respected during venting and afterwards in order to reduce the risk of pollution to a minimum as described in Annex B31.

Important Note: By no means the diode stack shall be dismounted or the clamping force of the stack changed.

In case of damage, the diode stack as a whole shall be replaced by a new one.

ANNEX C18: Auxiliary line for busbars (line “N”)

1. INTRODUCTION

The “N-lines” tubes of the LHC superconducting magnets are seamless non-magnetic austenitic steel tubes to be used as part of the cold mass of the LHC superconducting dipole magnets. The tubes are of about 16 m long.

The operational conditions of the tubes are summarised in the following Table C18.1

Table C18.1: Operation condition for the «N-line » tube

Condition	**Temp.**	**External pressure**	**Internal pressure**
Normal operation	1.9 K	< 1.10^{-4} Pa (≡ 1.10^{-6} mbar)	0.13 MPa (≡ 1.1 bar abs)
Test	300 K	< 1.10^{-7} Pa (≡ 1.10^{-9} mbar)	2.6 MPa (≡ 26 bar abs)
Cool down-Warm up (~ 25 cycles)	300 – 1.9	< 1.10^{-4} Pa (≡ 1.10^{-6} mbar)	2 MPa (≡ 20 bar abs)

2. DELIVERY STATE OF THE “N-LINE” TUBES

- The tubes will be delivered according to the following considerations
- The tubes are seamless in view of leak tightness
- The tubes are made from austenitic steel grade AISI 304 L
- The main dimensions and tolerances for the tubes are as follows:

Length	15.0 m	(- 0, + 50) mm
External diameter	53 mm	(- 0.40, + 0.40) mm
Wall thickness	1.5 mm	(- 0.20, + 0.20) mm
Straightness		0 ± 1.0 mm/m

- The roughness, Ra, does not exceed 3.2 µm for inner and outer surfaces
- The tubes are cleaned internally and externally to ensure that they are free from dirt, dust, grease, burrs and metal chips
- The tubes will be supplied sealed with end plugs and packed.

ANNEX D: AVAILABLE DOCUMENTS OF QUALITY ASSURANCE PLAN (QAP) FOR THE LHC PROJECT

Please refers to the attached CD-ROM (CERNDOCS Version 2.0): “CERN Official Documents: quality assurance, safety, purchasing, etc…”

ANNEX E: CERN SUPPLIED TOOLING AND MEASURING EQUIPMENT

(Tooling delivered for the “pre-series” production and applicable to the “series” production).

E1	Presses for E-modulus measurements
E2	Instruments for electrical measurements
E3	Equipment for magnetic measurements
E4	Welding press
E5	Equipment for geometrical measurement and alignment

ANNEX E1: Presses for E-modulus measurements

1. INTRODUCTION

The field quality of the dipole is defined by the position of the cable in the superconducting coils. The size and the modulus of elasticity of the superconducting layers and poles must be measured to verify their precision. Each item is measured in several points along its length. Each measured point is approximately 150 mm long in the straight part and approximately 60 mm long in the end parts. In order to perform the above mentioned measurements, CERN will delivery to the Contractor two different presses: one press (so called “E-modulus press”) dedicated to the measurements on the straight part, another small press (so called “Press for the pole ends”) working as a closed cavity tool, dedicated to the measurements of the end regions (heads) of the assembled poles.

2. TECHNICAL DESCRIPTION OF THE SUPPLY

2.1. “E modulus press”

The press consists of:

- mechanical frame, pressing bars and measuring poles,
- hydraulic and/or mechanic system for the application of the load,
- displacement and pressure measuring system,
- coil supports,
- data acquisition system,
- automatic control of the superconducting layer and pole displacements, of the loading and measuring systems.

Mechanical frame, pressing bars and measuring poles

The separate layers or the superconducting poles are compressed inside a cavity defined by the mechanical frame and the measuring poles. The compressive forces are applied through pressing bars. These components define the measurement precision and are machined within tolerances of + 0.01 mm.

Hydraulic and/or mechanical system for the application of the load

The load is applied to the assembled superconducting poles, on the inner layer, on the outer layer and on the right and left-hand side respectively. Therefore four forces are applied and measured simultaneously. Each force is controlled independently from the others during the loading and the unloading.

Displacement and pressure measuring system

The coil deformation is measured by transducers positioned as close as possible to the coil base. The force applied on each pressing bar is measured by strain gauges and/or pressure transducers.

Coil supporting frame

The superconducting poles and the layers move relatively to the measuring device during the measurement of each Section. There are to be two supporting frames for the layers and poles, one at each end of the measuring machine. Each supporting frame has the following dimensions:

- length: 17 m
- width: 600 mm

Data acquisition system

The deformation of each layer and of the poles and the compressive force is recorded during the loading and unloading cycle using the program LabVIEW™ from National Instruments.

Automatic control of the displacements loading and measuring system

The coil displacement on the coil supports, the loading and unloading cycle and the data acquisition, are automatically actuated and recorded.

2.2. "Press for the pole ends"

CERN will delivery to the Contractor a special small press dedicated to the measurements of the end region of the assembled poles. This press will be an evolution of the press prototype already built at CERN and utilised for the measurements of the last collared coils prototypes in the industry. The functioning of this press is simple due to the fact that it is working as a "closed cavity" tool.

By means of mechanical adjustable stoppers the press will close at a well defined geometry (the nominal geometry) the installed pressure gauges will then read the pre-stress on the inner and outer layer of the pole. The axial dimension of the press (~200 mm) will permit to perform the measurement of the whole pole end region in one stroke. The main aim of this tool is to help in the appropriate definition of the shims in the heads region and in the transition region between the heads and the straight part.

Mechanical frame

The active part of the mechanical frame will consist of two components: the upper element will define the circular part of the nominal closed cavity. The lower element will define the mid-plane of the magnet and it will be instrumented with pressure gauges. These components define the measurement precision and they will be machined within tolerances of ± 0.025 mm.

A smaller hydraulic jack will allow moving vertically the press in order to ease the insertion of the pole in the measuring cavity.

Hydraulic and/or mechanical system for the application of the load

The load is applied to the assembled superconducting pole heads on both inner and outer layer at the same time. The compressive forces are applied thanks to a hydraulic cylinder pushing on the upper element.

Displacement and pressure measuring system

No displacement is measured because the pressing force will act until the press as reached the stable position of "closed cavity". Adjustable mechanical stoppers define this position.

At this point, the pre-stresses on each layer (four measurements) have to be recorded by the data acquisition system.

Pole supporting frame

The contractor is fully responsible to equip him with a suitable frame where the pole has to rest during the measurements. The machine can be moved from one side of the frame to the other side to measure both the extremities of the poles. The frame shall allow to

a) *Position the coil into the measuring press*

b) *Guarantee the correct alignment between the pole and the press cavity*

Data acquisition system

CERN is now qualifying the pressure gauges and data acquisition system for the press. As soon a decision will be taken, more information will be communicated to the Contractor.

3. DELIVERY CONDITIONS

CERN will provide the delivery and assembly of the “E-modulus press” and “Press for the pole ends” at the dipole Contractor premises. CERN or the subcontracting company personnel must have free access during normal working time to the above mentioned premises. The contractor will be informed of the infrastructure requirements in due time. Adequate documentation for the use of the machine will be provided.

3.1. “Press for the pole ends”

CERN will delivery to the Contractor a special small press dedicated to the measurements of the end region of the assembled poles. This press will be an evolution of the press prototype already built at CERN and utilised for the measurements of the last collared coils prototypes in the industry. The functioning of this press is simple due to the fact that it is working as a “closed cavity” tool.

By means of mechanical adjustable stoppers the press will close at a well defined geometry (the nominal geometry) the installed pressure gauges will then read the pre-stress on the inner and outer layer of the pole. The axial dimension of the press (~60 mm) will permit to perform three measurements on each pole end region. The main aim of this tool is to help in the appropriate definition of the shims in the heads region and in the transition region between the heads and the straight part.

Mechanical frame, pressing bars and measuring poles

The mechanical frame will consist of two components: the upper element will define the circular part of the nominal closed cavity. The lower element will define the mid-plane of the magnet and it will be instrumented with pressure gauges. These components define the measurement precision and will be machined within tolerances of + 0.01 mm.

Hydraulic and/or mechanical system for the application of the load

The load is applied to the assembled superconducting pole heads on both inner and outer layer at the same time. The compressive forces are applied through pressing bars.

Displacement and pressure measuring system

No displacement is measured because the pressing force will act until the press as reached the stable position of “closed cavity”. Adjustable mechanical stoppers define this position.

At this point, the pre-stress on each layers (four measurements) have to be recorded by the data acquisition system.

Press supporting frame

The support frame for the press, remains full responsibility of the Contractor. CERN will communicate in due time all the geometric and technical parameters in order to define a support frame compatible with the Contractor’s production site.

Data acquisition system

CERN is now qualifying the pressure gauges and data acquisition system for the press. As soon a decision will be taken, more information will be communicate to the Contractor.

4. DELIVERY CONDITIONS

CERN will provide the delivery and assembly of the “E-modulus press” and “Press for the pole ends” at the dipole Contractor premises. CERN or the subcontracting company personnel must have free access during normal working time to the above mentioned premises. The contractor will be informed of the infrastructure requirements in due time. Adequate documentation for the use of the machine will be provided.

ANNEX E2: Instruments for electrical measurements

The full list of the instruments and apparatus part of the CERN’s supply for the Scope of the Supply is reported here. These apparatus are available for the electrical checks and tests during and after the collared coils manufacturing and during and after the cold mass assembly.

Two identical sets of electronic instruments (in two racks) associated with these measurements will be supplied by CERN. The first set was already delivered to the Contractor.

- Low voltage tests
  - Digital multimeter (6 1/2 digits)
  - Network analyser 10 mHz to 20 kHz
  - DC Bipolar Power Supply, regulated in current and voltage, stability 5.10^{-4}, ± 6 A, ± 36V
  - DC Unipolar Power Supply, regulated in current and voltage, stability 5.10^{-4}, from 30 A to 40 A included, from 60 V to 65 V included
  - Data acquisition station (60 channels)
- High voltage tests
  - Megohmmeter 0 to 5000 V in 25 V steps (AVO BM 21)
  - Reading of either R [MΩ] or leakage current I [100 nA]; Capacitance [µF]
  - Dielectric strength meter DC 0 to 12 kV (I_{max} output 1 mA)
  - Current limiter:100 µA to 500 µA
  - Reading of leakage current - better than 100 nA
  - Voltage ramping slope:100 V/s
- Impulse tests
  - Ringer (Seits Instruments WP6)
  - Voltage: 50 V to 6 kV Capacitors: 500 nF to 2.0 µF
  - Transient response analyser
  - Card PC scope (IMTEC T12840) + software (CERN)
  - PC 486 66 MHz or similar
  - Software for all instrumentation equipment
  - Color printer
  - 19" rack (standard CERN)

ANNEX E3: Equipment for magnetic measurements

1. INTRODUCTION

Two magnetic measurements shall be performed during the fabrication process,

1. on the finished collared coils,
2. on the finished cold mass.

This Annex E3 describes the equipment which will be used by CERN for this operation, the procedure which will be followed and the required space and environment.

An acceptance test shall be performed on the collared coils based on the magnetic field quality delivered by the coils excited by 10 to 20A DC current. Contractor's staff will carry out the measurements, after training by CERN's staff.

The analysis will be carried out jointly by CERN and the Contractor using Statistical Process Control methods, so as to separate random from deterministic effects, identify the sources of systematic errors and control them.

2. EQUIPMENT

A precise measurement of the 0.01 T magnetic field induced by a 20 A DC current in the collared coils is made using the technique of rotating search coils and harmonic analysis. These rotating coils are mounted in a so-called "magnetic mole" which is inserted in the cold bore tube. Measurements are taken on 20 (or 21) fixed positions in order to cover the whole coil length. The induced field should not be perturbed by external fields or by the presence of magnetic materials. For that reason, the collared coils shall be supported by non-magnetic elements as suggested on drawing LHCMMWED0009. The supplier shall provide the necessary supports.

On each end of the collared coils, extension tubes and driving system will have to be installed to the bench. All the electronic equipment is contained in two standard racks.

Once the equipment is installed and ready to be used, four working hours are sufficient to perform the complete measurement.

2.1. The probe

CERN developed a dedicated device to measure with a high accuracy the magnetic field produced by a small DC excitation current (between 10 and 20 A), in the coils. This device, hereafter called ”magnetic mole”, is introduced inside the cold bore tube and in 20 (or 21) steps covers the entire length of the coils. The main components are a 750 mm long rotating search coil assembly, an encoder and a precise tilt sensor. The probe assembly is shown in drawing LHCMMWED0020. At one end of the mole, a special connector gathers all the electric wiring plus one small tube carrying 6 bar compressed air to actuate a pneumatic brake. The utilisation of a dry nitrogen line is strongly suggested, anyway CERN will specified in due time the level of purity required if standard compressed air is utilised. The special cable is supplied by CERN. At the other end, is attached another device, hereafter called “the motorization”.

2.2. The motorization

Rotation of the search coil assembly and a precise levelling of the “magnetic mole” are driven by two different electric motors included in another device mechanically linked to the magnetic mole. At the other end a connector gathers all the electric wiring. The cable will be supplied by CERN. The length of this device is about 500mm.

2.3. The driving system

The 20 (or 21) measurement steps are controlled by a driving system placed at both ends of the cold bore tubes. The displacement of the magnetic mole and its motorization is done by a stainless steel cable. This system and the cables are supplied by CERN. The final version is still under development.

2.4. The electronic equipment

Two electronic racks associated with these measurements will be supplied by CERN.

Calibration system

The calibration system supplied by CERN consists of a U-shaped dipole magnet (1000 x 400 x 400 mm approx.), a 1500 mm long tube, similar to the cold bore tube, mounted in the centre of the magnet and in which the probe will be introduced to be calibrated, an NMR probe to control the magnetic field and a tilt sensor to control the field direction. This assembly must be fixed on a stable base, near the benches described in Annex B18.

3. SPACE AND ENVIRONMENT

The necessary space around the bench supporting the collared coils is described in drawing LHCMMWED0008.

To minimise magnetic perturbations the following limits shall apply:

- “large” magnetic objects (~ 10 dm^3 per linear meter) to be kept at a distance of more than 3 m from coil axis,
- “small” magnetic objects (non concentrated, up to ~ 0.5 dm^3 per linear meter such as screws, nails, reinforcement irons in concrete) to be kept at a distance of more than 0.4 m from coil axis,
- no magnetic objects admitted closer than 0.4 m to axis.

Electrically noisy environment can greatly degrade the quality of the measurements. Heavy machinery, arc welding equipment, cranes etc shall be banned from the test site or shall be shut down during the measurements.

ANNEX E4: Welding press

A hydraulic press is required to impart the required geometry and pre-stress to the cold-mass structure whilst welding together the two austenitic-steel half-cylinders. This press is constructed of three full length horizontal beams called bottom, intermediate and top beam (see Drawing: LHCMB_TW0003 “ LHC welding press–assembly”in Annex A). The bottom and top beams are fixed to structural connecting components to form a rigid cage structure. The intermediate and top beams are equipped with “lower and upper modules”, matching the shape of the cold mass.

The intermediate beam is used as the cold mass assembly platform and must be able to roll in and out of the press. In its working position inside the press, this beam is moved vertically by simultaneous activation of all the hydraulic jacks fitted on the bottom beam. When the jacks move upwards, the cold mass (diameter 570 mm, length 15200 mm, weight 250 kN) is pushed against the upper modules mounted on the upper beam and is hence forced to take up the required shape.

The structural connecting components joining and supporting the top and the bottom beams accurately, guide the intermediate beam during its movements and take up the forces of the jacks. The supporting structure also serves as a stable support for the other parts of the press and must permit the precise alignment of the whole structure.

The press must be able to accommodate either two welding heads or two milling machines inside its working window as well as the complete cold mass. All components of the press (welding and milling units included) must be easily accessible for maintenance and repair.

The press working range is between 500 kN/m and 12 MN/m with a maximum stroke of 100 mm. The maximum working pressure in the jacks is 650 bar. The available working window has a maximum width of 2200 mm and height of 1600 mm.

The press must be equipped with two fully automatic welding units and with two multi-pass laser tracking systems that control and, if necessary, correct the welding parameters in real time.

The press equipment is completed by two milling units to remove faulty weld seams whilst maintaining the cold mass under pressure.

ANNEX E5: Equipment for geometrical measurements and alignment

1. INTRODUCTION

An optical measuring system, based on laser tracking technology will be supplied by CERN to the Contractor in order to make the mechanical measurements and to assist the different alignment operation during the cold mass assembly. Section 7.2.3 and Annex B27 present the permitted ranges and the procedures for such measurements. The aim of the optical measurements is to identify, to qualify and to align the position of the cold bore tubes (mechanical axes) with respect to the nominal axes of the cold mass.

2. THE LASER TRACKING SYSTEM

The laser tracking measuring system makes the positioning and alignment measurements possible with a very precise and reliable procedure. The system takes advantage of the 3D laser tracking using interferometer and absolute distance meter techniques. The equipment is mainly composed of a measuring head, a mirror target and a control unit.

Simply speaking, as a first step, the measuring head will be set at a controlled referenced position with respect to the cold mass. The measuring heads will emit a laser beam in the direction of the mirrored target that will be placed inside one cold bore tube of the cold mass. The target will be oriented in order to reflect the laser beam back along the same path of the tracker. From this moment, through the high rate of the laser beam measurement (several thousands of measurements per second) and utilising the control motors of the measuring heads, the system is able to follow and to measure any movements of the mirrored target for a wide range of displacements and speeds. However, the measurements are taken in fixed non moving target in order to gain accuracy of the measurements.

The absolute accuracy in such conditions is 10 ppm while the reproducibility is 5 ppm. These values guarantee the required precision for the qualification and control of the beam tube position inside the cold mass.

CERN has selected the following laser tracking system:

- LEICA LTD 500™

3. THE “GEOMETRIC” AND “GEOMETRIC/MAGNETIC” MOLES

CERN will provide a dedicated device that can be introduced inside the cold bore tubes to perform the geometric measurement of these tubes. This mole is equipped with a reflector, which associated with the Laser Tracking System measures the position of the centre of the tube. This corner cube is by construction centred on two orthogonal diameters of the tube. Driving of the mole will be similar to that of the “geometric/magnetic mole” and as well supplied by CERN.

This mole will be equipped with four precise search coils which will make it capable to measure the centre and the direction of the magnetic field. This function will be mostly used to check the good positioning of the spool pieces corrector magnets but also to control the centre of the coils by powering their poles in opposition creating thus a skew quadrupole with a well defined axis.

ANNEX F: GENERAL DOCUMENTS AVAILABLE ON PERFORMANCES AND FIELD QUALITY FOR THE LHC MAIN DIPOLE PROTOTYPES AND "PRE-SERIES" COLD MASSES.

ANNEX F1: Field error naming conventions

Please refers to the attached Engineering Specification (LHC-M-ES-0001.00 rev. 1.1.): “Field error naming conventions for LHC magnets”.

CERN
CH-1211 Geneva 23
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the
Large
Hadron
Collider
project

LHC Project Document No.
LHC-M-ES-0001.00 rev. 1.1

CERN Div./Group or Supplier/Contractor Document No.
LHC-MMS/ES/01

EDMS Document No.

Date: 1998-08-24

Engineering Specification

FIELD ERROR NAMING CONVENTIONS FOR LHC MAGNETS

Abstract

This note defines the naming conventions used for multipole expansion of field errors in the aperture of LHC accelerator magnets. We limit ourselves here to magnet measurement and calculation. Coordinate systems are described. An appendix clarifies the conventions. See the 'Table of Contents' on page 3.

Prepared by :	***Rev. 1.0 Checked by :***	***Rev. 1.0 Approved by:*** the 40th Parameter and Layout Committee Meeting held on 1998-06-10.
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History of Changes

Rev. No.	***Date***	***Pages***	***Description of Changes***
1.0	1998-06-15	10	First Version
1.1	1998-08-24		Addition and small changes in Par. 5.2 and 5.6. Clearer definition of magnetic length, par 2.3.

Table of Contents

1. INTRODUCTION

The aim of this note is to define the naming conventions used for multipole expansion of field errors in LHC accelerator magnets. The naming is based on those found in [1] and [2].We limit ourself here to magnet measurement and calculation.

2. DEFINITION OF FIELD ERRORS.

We express the magnetic field $\boldsymbol{B} = B_y + iB_x$ in the 2-D imaginary plane (x,y) using the harmonic expansion in terms of the complex variable $\boldsymbol{z} = x+iy$. Often, instead of the field, the field integral parallel to the magnet axis (s-axis) is used. In this case $B_y + iB_x$ stands for $\int_{magnet} (B_y + iB_x)ds$. The coefficients of the field expansion then also represent integral values, and this should be made clear when presenting them.

2.1 FIELD MULTIPOLE EXPANSION.

A 2-dimensional field with components in x and y direction can be expanded like:

$$B_y + iB_x = \sum_{n=1}^{\infty} \boldsymbol{C}_n z^{n\text{-}1} = \sum_{n=1}^{\infty} (B_n + iA_n) z^{n-1} \qquad (1)$$

This definition defines the multipole coefficients independent of a reference radius. $\boldsymbol{C}_n$ is given in Tm^{1-n} (or Tm^{2-n} for a field integral). B_n is called a normal, A_n a skew coefficient. A multipole coefficient with n=1 is called a dipole coefficient, n=2 a quadrupole coefficient etc.

2.2 THE MAIN FIELD AND THE MAIN FIELD INTEGRAL.

The *main field strength* of a magnet is defined by the multipole coefficient B_N (note capital letter N) for a normal magnet and A_N for a skew magnet.
N=1 for a dipole, N=2 for a quadrupole etc. The main field of a 2N-pole magnet is:

$$B_y + iB_x = B_N z^{N\text{-}1} \text{ (normal magnet)} \qquad (2)$$

$$B_y + iB_x = iA_N z^{N\text{-}1} \text{ (skew magnet)} \qquad (3)$$

The *main field strength integral* of the whole magnet is defined by $\int_{-\infty}^{+\infty} B_N ds$. We call it the '$B_N$ integral '.

2.3 THE MAGNETIC LENGTH

The magnetic length $L_n^{(m)}$ of a field produced by a multipole of order n is determined by dividing the field integral of this multipole by the field of the multipole in the center of the magnet. For multipoles $B_{n,center}$ and $A_{n,center}$ in the center of the magnet we have:

$$L_n^{(m)} = \frac{\int_{-\infty}^{+\infty} B_n ds}{B_{n,center}} \text{ or } L_n^{(m)} = \frac{\int_{-\infty}^{+\infty} A_n ds}{A_{n,center}}.$$

The magnetic length $L_N^{(m)}$ of the main field is often used and is also simply written as $L^{(m)}$.

2.4 MULTIPOLE COEFFICIENTS AT A REFERENCE RADIUS.

In respect to a reference radius R_r the field expansion takes the form:

$$B_y + iB_x = \sum_{n=1}^{\infty} C_n^{(r)} \left(\frac{z}{R_r} \right)^{n-1} = \sum_{n=1}^{\infty} (B_n^{(r)} + iA_n^{(r)}) \left(\frac{z}{R_r} \right)^{n-1} \qquad (4)$$

Here $C_n^{(r)} = C_n R_r^{n-1}$. The field due to a multipole of order *n* at position x = R_r, y = 0 is just given by $B_y = B_n^{(r)}$ and $B_x = A_n^{(r)}$. $B_n^{(r)}$ and $A_n^{(r)}$ are given in [T] (or in Tm for a field integral).

2.5 MULTIPOLE COEFFICIENTS AT A REFERENCE RADIUS, RELATIVE TO THE MAIN FIELD.

The field is expanded relative to the main field component $B_N^{(r)}$ of a normal magnet or $A_N^{(r)}$ of a skew magnet.

$$B_y + iB_x = B_N^{(r)} \sum_{n=1}^{\infty} c_n \left(\frac{z}{R_r} \right)^{n-1} = B_N^{(r)} \sum_{n=1}^{\infty} (b_n + ia_n) \left(\frac{z}{R_r} \right)^{n-1} = B_N R_r^{N-1} \sum_{n=1}^{\infty} (b_n + ia_n) \left(\frac{z}{R_r} \right)^{n-1}$$

$$B_y + iB_x = A_N^{(r)} \sum_{n=1}^{\infty} c_n \left(\frac{z}{R_r} \right)^{n-1} = A_N^{(r)} \sum_{n=1}^{\infty} (b_n + ia_n) \left(\frac{z}{R_r} \right)^{n-1} = A_N R_r^{N-1} \sum_{n=1}^{\infty} (b_n + ia_n) \left(\frac{z}{R_r} \right)^{n-1} \qquad (5)$$

For a normal magnet $c_n = \frac{C_n^{(r)}}{B_N^{(r)}} = \frac{C_n}{B_N} R_r^{n-N}$, for a skew magnet $c_n = \frac{C_n^{(r)}}{A_N^{(r)}} = \frac{C_n}{A_N} R_r^{n-N}$.

The coefficients b_n and a_n represent the normal and skew relative field errors at the reference radius. They are dimensionless. For practical purposes they are often given in *units* of 10^{-4}.

2.6 SIZE OF THE REFERENCE RADIUS.

Until now R_r was always chosen equal to 1 cm. Recently however [3] the Parameter and Layout Commitee approved a change to: **R_r = 0.017m**.

3. COORDINATE SYSTEMS FOR MAGNET MEASUREMENT AND DESIGN.

The multipole coefficients will depend on the coordinate system in which they are expressed. We will not go into any details (see [2]), but will describe coordinate systems used as far as necessary to correctly interpret the results of field measurement or calculation.

3.1 NAMING CONVENTIONS FOR THE MAGNET GEOMETRY.

Top of the magnet. This is the top of the magnet as delivered in its cryostat, and as it would be when placed in LHC.
Connection End. This is the end of the magnet where the current enters and exits the coils. This is not necessarily the side of the magnets where the current leads come in the cryostat.
Apertures of two-in one magnets. The left aperture of a two-in-one magnet as seen from the connection side, is called Aperture 1, the one on the right is called Aperture 2, see Fig.1.

3.2 COORDINATE SYSTEM FOR MAGNETIC MEASUREMENT.

This is the system (see Fig.1) in which the final results of field error measurements are expressed. The coordinate system (x,y,s) is orthogonal and right-handed.
The *s-axis* goes through the ‘center' of the magnetic field in the aperture(s). The positive s-axis comes out of the magnet at the connection side ('out of the paper' in Fig. 1), in both apertures. In general, the s-axis is a straight line and is the mean magnetic axis of an

aperture. There is no universal definition where s=0 is located. In practice (see [2])the s-axis is often found from adjusting the measurement coils to a position where $c_{N-1} = 0$ at several places along the axis. In the case of a dipole however the axis is often determined by finding the zero's of selected higher order multipoles .
The *x-axis and y-axis* form the 'horizontal' and 'vertical' axes, as determined from field measurements. For instance, for a normal magnet the field on the x-axis will be perpendicular to the x-axis. In a dipole the main field is parallel to the y-axis The x-axis goes to the right seen from the connection side. A method used in practice to determine the axes [2] is to rotate the coordinate system around the s-axis until $a_N = 0$ for a normal magnet, or $b_N = 0$ for a skew magnet.
A *positive rotation* in this system around the s-axis goes in counter-clockwise direction seen from the connection side.
In a two-in-one magnet the two coordinate systems are not necessarily parallel to each other. In practice the angle which the y-axis ('the field') makes with the gravitional normal can be defined as a rotation in the x-y plane. Fig. 1 shows an example of a negative angle.

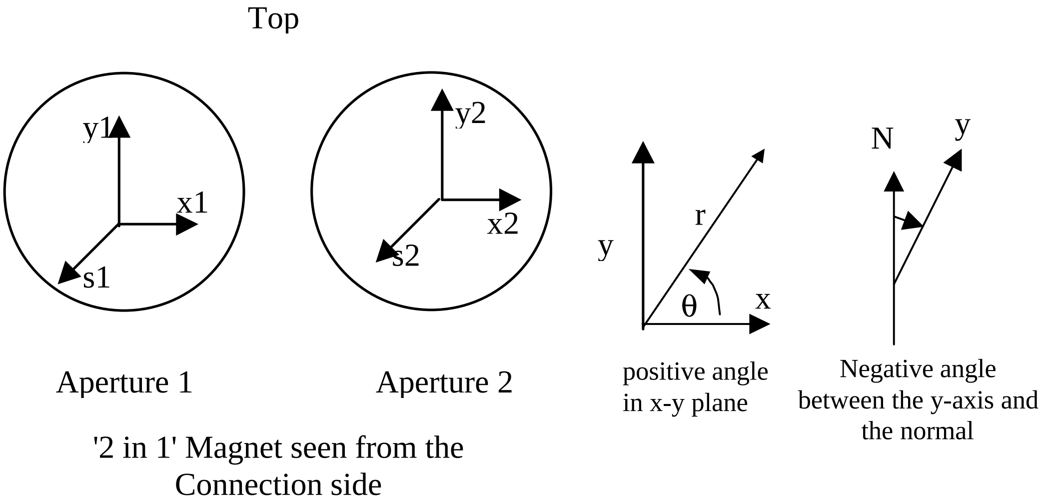

Fig. 1. Coordinate system of magnetic measurement. It is 'fixed to the field of the magnet'.

3.3 COORDINATE SYSTEM FOR MAGNETIC CALCULATION.

This system is used for field calculation. It is essentially the same as the one for magnetic measurement, however the coordinate systems in the two apertures are strictly parallel by definition. The s-axis goes through the geometric center of the magnet. The x-axes lie on a straight line connecting the coil centers. Results for two-in-one magnets are usually given for aperture 2.

4. REFERENCES.

[1] R. Wolf, *Field Error Definitions for LHC. Version 1*, AT-MA Internal Note 94-102, CERN, 1994.
[2] L. Bottura *Standard Analysis Procedures for Field Quality Measurement of the LHC Magnets Part I: Harmonics,*LHC/MTA MTA-IN-97-007, July 21, 1997, revised March 27, 1998
[3] *Parameter & Layout Committee, Minutes of the 36th Meeting*, 18 March, 1998.
[4] H.Grote, F.C. Iselin. *The MAD program, version 8.21, User's Reference manual* on http://wwwslap.cern.ch/~fci/mad/mad8/mad.html, 1998.

5. APPENDIX.

5.1 DEPENDENCE OF THE MULTIPOLE COEFFICIENTS ON THE REFERENCE RADIUS.

From the definitions above it follows that B_n and A_n are independent of the reference radius and that $C_n^{(r)} = C_n R_r^{n-1}$ and $c_n = \frac{C_n}{B_N} R_r^{n-N}$ (or $c_n = \frac{C_n}{A_N} R_r^{n-N}$).

Therefore $B_n^{(r)}$ and $A_n^{(r)}$ are proportional to R_r^{n-1} while b_n and a_n are proportional to R_r^{n-N} . The dependence on R_r is therefore different for these two types of coefficients, except for a dipole where both are proportional to R_r^{n-1}.

5.2 REFERENCE FRAME TRANSLATION AND ROTATION.

The multipole coefficients depend on the position of the reference frame.
If the reference frame is *translated by* $\Delta\mathbf{z}$ (see Fig. 2), the harmonic coefficients in the original system *x*,*y* transform [2] in the translated system *x'*,*y'* according to:

$$\mathbf{C}'_n = B'_n + iA'_n = \sum_{k=n}^{\infty} \left(\frac{(k-1)!}{(n-1)!(k-n)!} \right) \mathbf{C}_k \Delta\mathbf{z}^{k-n} \quad \text{and} \quad C_n^{(r)'} = \sum_{k=n}^{\infty} \left(\frac{(k-1)!}{(n-1)!(k-n)!} \right) C_k^{(r)} \left(\frac{\Delta\mathbf{z}}{R_r} \right)^{k-n}$$

The coefficient c_n transforms in the same way as $C_n^{(r)}$.

If the reference frame is *rotated by an angle* θ *(*see Fig. 3), the harmonic coefficients in the original system *x*,*y* transform in the translated system *x'*,*y'* according to:

$$\mathbf{C}'_n = B'_n + iA'_n = \mathbf{C}_n e^{in\theta} .$$

Here we have used the fact that $B'_y + iB'_x = e^{i\theta}(B_y + iB_x)$ and $z' = e^{-i\theta} z$.

$C_n^{(r)}$ and c_n transform in the same way. Note that their *modulus* is unchanged.

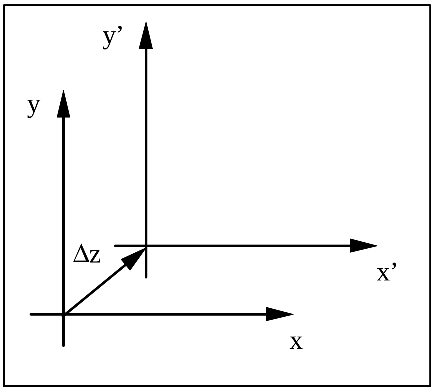

Fig. 2. Translation of the reference frame.

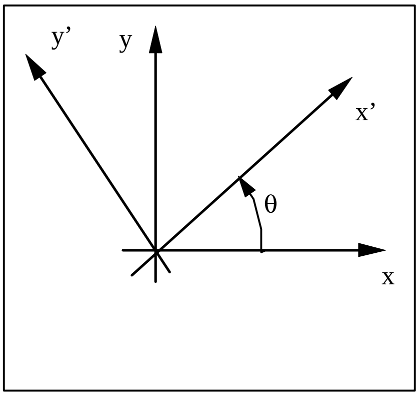

Fig. 3. Rotation of the reference frame

5.3 FIELD MULTIPOLE EXPANSION IN FOURIER SERIES.

Above we have used the complex variable z for the multipole expansion. The field components also be expressed in polar coordinates *r*, θ in a Fourier type expansion:

$$B_x = \sum_{n=1}^{\infty} r^{n-1} \left(B_n \sin(n-1)\theta + A_n \cos(n-1)\theta \right) \qquad B_y = \sum_{n=1}^{\infty} r^{n-1} \left(B_n \cos(n-1)\theta - A_n \sin(n-1)\theta \right)$$

$$B_r = \sum_{n=1}^{\infty} r^{n-1}\left(B_n \sin(nq) + A_n \cos(nq)\right) \qquad B_q = \sum_{n=1}^{\infty} r^{n-1}\left(B_n \cos(nq) - A_n \sin(nq)\right).$$

5.4 MULTIPOLE EXPANSION OF A POTENTIAL.

We present here the multipole expansion of several different potentials, compatible with the multipole expansion of the field as defined above.

A *complex potential* F can be defined as:

$$B_y + iB_x = -\frac{\mathrm{d}\Phi}{\mathrm{dz}} \text{ with } \Phi = -\sum_{n=1}^{\infty} \frac{1}{n} C_n z^n$$

A *scalar potential V* can be defined such that the field ***B*** is found from $\boldsymbol{B} = -\nabla V$:

$$B_x = -\frac{\partial V}{\partial x}, B_y = -\frac{\partial V}{\partial y} \quad \text{or} \quad B_r = -\frac{\partial V}{\partial r}, B_\theta = -\frac{1}{r}\frac{\partial V}{\partial \theta}.$$

This potential can be identified with the imaginary part of the complex potential.

$$V = -\mathrm{Im}\left(\sum_{n=1}^{\infty} \frac{1}{n} C_n z^n\right) = -\sum_{n=1}^{\infty} \frac{r^n}{n}\left(B_n \sin(nq) + A_n \cos(nq)\right).$$

A *vector potential* ***A*** can be defined such that $\boldsymbol{B} = \nabla \times \boldsymbol{A}$. The x and y components of this potential are equal to zero. The field can be found from the s-component *A*$_s$:

$$B_x = \frac{\P A_s}{\P y}, B_y = -\frac{\P A_s}{\P x} \quad \text{or} \quad B_r = \frac{1}{r}\frac{\P A_s}{\P q}, B_q = -\frac{\P A_s}{\P r}.$$

A_s can be identified with the real part of the complex potential:

$$A_s = -\mathrm{Re}\left(\sum_{n=1}^{\infty} \frac{1}{n} C_n z^n\right) = -\sum_{n=1}^{\infty} \frac{r^n}{n}\left(B_n \cos(nq) - A_n \sin(nq)\right).$$

5.5 THE MAGNETIC FLUX THROUGH A RECTANGULAR COIL.

The magnetic flux per meter through a rectangular coil with sides at at z=0 and $z = z_0$ parallel to the s-axis is just $-A_s(z_0)$. Therefore the flux Ψ through a rectangular coil (Fig. 4) with sides of length L parallel to the s-axis at z=z$_1$ and $z = z_2$ is:

$$\Psi = L\,\mathrm{Re}\left(\sum_{n=1}^{\infty} \frac{1}{n} C_n (z_2^n - z_1^n)\right).$$

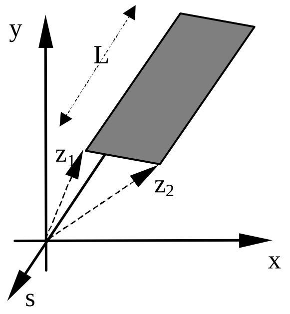

Fig. 4. Rectangular coil with sides parallel to the s-axis.

5.6 THE MULTIPOLE COEFFICENTS EXPRESSED IN THE LHC MACHINE COORDINATE SYSTEM OF BEAM 1.

There are two beams circulating in LHC, Beam 1 and Beam 2. *The protons in Beam 1 circulate in clockwise direction* when looking from above. The main dipole field is always directed upwards in Beam 1 and downwards in Beam 2.
It is foreseen (April 1998) that the Main Dipoles and almost all Quadrupoles in the machine are orientated such that the protons of Ring1 enter at the connection side.
For two-in-one magnets Aperture 1 then corresponds to the 'outer aperture' and Aperture 2 to the 'inner aperture' in respect to the machine center. The two beams cross at several points and so alternate between the inner and outer aperture of the two-in-one magnets.
The coordinate system in LHC for Beam1 is defined, however the one for Beam 2 is still under discussion.
The coordinate system of Beam 1, centered on the central orbit is illustrated in Fig. 5.

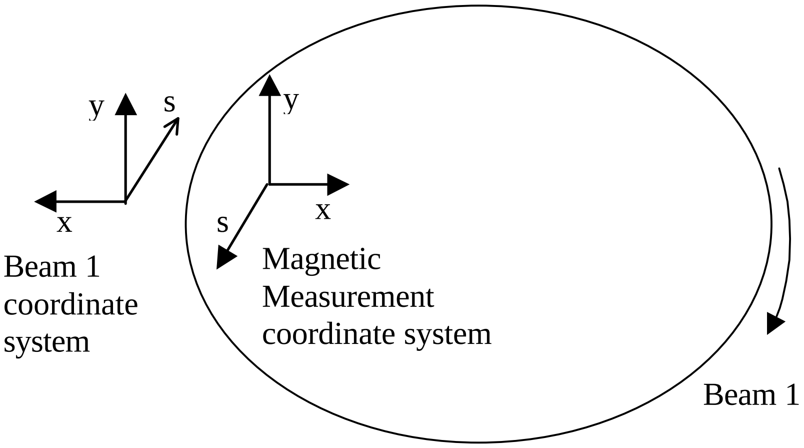

Fig. 5 Machine coordinate system of Beam1 compared with magnetic measurement coordinate system.

Aside from small effects due to magnet alignment in LHC, the multipoles C_n and c_n in the magnetic measurement reference frame then transform[1] as follows when expressed in the coordinate system of Beam1:

$C_{n,Beam1} = (-1)^{n-1} C_n^*$, which gives $B_{n,Beam1} = (-1)^{n-1} B_n$ and $A_{n,Beam1} = (-1)^{n} A_n$

$c_{n,Beam1} = (-1)^{n-N} c_n^*$, which gives $b_{n,Beam1} = (-1)^{n-N} b_n$ and $a_{n,Beam1} = (-1)^{n-N+1} a_n$.

5.7 FIELD ERRORS IN ACCELERATOR DESIGN PROGRAM MAD.

The n values used in MAD[4] for indicating the multipoles are 1 lower than we have used above (so in MAD $n = 0$ is a dipole, $n = 1$ is a quadrupole, etc). In this paragraph we use the usual definition of n. We assume that the measured multipole errors are expressed in the coordinate system of Beam 1 (see Par. 5.6), which is also used by MAD.
A normal field component in MAD is defined similar to:

$B_y + iB_x = \frac{1}{(n-1)!} B_{n-1}^{MAD} z^{n-1}$, where B_{n-1}^{MAD} is real. Note that $B_{n-1}^{MAD} = \frac{\partial^{n-1} B_y}{\partial x^{n-1}}$.

The input to MAD has to be given as a (possibly integrated) normalized strength $K_n = \frac{q}{P} B_n^{MAD}$ where q is the particle charge and P is the beam momentum.

A skew multipole is defined by rotating a normal multipole by an angle $y_m = +\frac{p}{2n}$.

The field changes to: $B_y + iB_x = \frac{1}{(n-1)!} B_{n-1}^{MAD} e^{-iny_m} z^{n-1} = -i \frac{1}{(n-1)!} B_{n-1}^{MAD} z^{n-1}$.

The earlier definition **(1)** of the field of a multipole was:
$B_y + iB_x = (B_n + iA_n) z^{n\text{-}1}$.

Therefore normal multipoles have $K_{n-1} = \frac{q}{P}(n-1)!B_n$

and skew multipoles have $K_{n-1} = -\frac{q}{P}(n-1)!A_n$.

Note that a normal magnet with main component K > 0 has $B_y > 0$ on the positive x-axis, while a skew magnet with main component K > 0 has $B_x < 0$ on the positive x-axis.

MAD also excepts *relative field errors* in the form of relative strengths errors k_normal_n and k_skew_n. The relation between these relative strength errors and the relative field errors is simply: $k\_\mathrm{normal}_{n-1} = b_n$ and $k\_\mathrm{skew}_{n-1} = a_n$.

5.8 MAIN PARAMETER LIST.

Parameter	Description	Unit
*	complex conjugate	
B_x	magnetic field in x-direction (or integral of)	T, (Tm)
B_y	magnetic field in y-direction (or integral of)	T, (Tm)
B_r	magnetic field in r-direction (or integral of)	T, (Tm)
B_θ	magnetic field in θ-direction (or integral of)	T, (Tm)
C_n	multipole coefficient = $B_n + i\,A_n$	Tm^{1-n}, (Tm^{2-n})
B_n	normal multipole coefficient	Tm^{1-n}, (Tm^{2-n})
A_n	skew multipole coefficient	Tm^{1-n}, (Tm^{2-n})
$C_n^{(r)}$	multipole coefficient = $B_n^{(r)} + i\,A_n^{(r)}$ at R_r	T, (Tm)
$B_n^{(r)}$	normal multipole coefficient at R_r	T, (Tm)
$A_n^{(r)}$	skew multipole coefficient at R_r	T, (Tm)
c_n	multipole coefficient = $b_n + i\,a_n$, relative to main field at R_r	
b_n	normal multipole coefficient at R_r, relative to main field at R_r	
a_n	skew multipole coefficient at R_r, relative to main field at R_r	
$L_n^{(m)}$	The magnetic length of a multipole of order n.	m
i	complex unit vector	
n	multipole number (n = 1 is a dipole, etc)	
N	multipole number of the main field (N = 1 is a dipole magnet, etc)	
R_r	reference radius R_r = 0.017 m	m
x, y, z, r, θ	$z = x + i\,y = re^{i\theta}$,complex position vector	
s	axial coordinate	m

ANNEX F2: Quench levels in 15-m long dipole prototypes and first pre-series cold masses.

Magnet Name	Field level at 1st quench	Number of quenches before reaching(1) 8.33 T	Number of quenches before reaching(1) 9.0 T	1stquench level [T] after the 1st thermal cycle	Quenches Starts(2) in C. Ends	Quenches Starts(2) in Straight Part	Quenches Starts(2) in N.C. Ends
MBP2N1	7.35 T	3	20	8.39	10/86	23/86	47/86
MBP2N2	7.46 T	2	8	Not performed(4)	7/16	1/16	7/16
MBP2O1	8.23 T	1	5	8.76	6/22	0/22	14/22
MBP2A2	7.24 T	3	Not reached(3)	7.98	7/45	0/45	35/45
MBP2O2	8.64 T	0	1	8.85	3/11	2/11	6/11
HCMBB_A0001-01000001	8.31 T	1	1	No quench up to 9	1/5	2/5	1/5

(1) The given numbers include the cases where quenches occurred at the field level of 8.33 T or 9 T. These numbers comes from the first run of the cold tests at 1.9 K.

(2) These proportions are given with respect the total number of training quenches performed at 1.9 K. The sums can be less than 100 % because some impredictable quenches appeared during magnetic measurements and cannot be then localised longitudinally. Concerning the Quench Antennas used for the longitudinal quench localisation inside each aperture, they are made of 13 sections each having a length of 1.292 m. The straight part of the coil is covered with 11 sections and the both ends are covered with the 2 remaining sections. In the table, the distinction was made between ends located in the connection side and in the non connection side and both types were defined with a length equal to 0.186 m.

(3) As evidenced in the quench distribution (35/45) quenches at the non connection side all at the same point, this prototype has evidenced a weak point due to manufacture that has prevented the magnet to reach the provisional ultimate field.

(4) Due to a short circuit between the coil and the cold bore tubes appeared after the 16th quench, this prototype could not be tested any more.

ANNEX F3: Field Quality in 15 m long prototypes and "pre-series" cold masses

Please refers to the attached document LHC Project Report 467: "Control of field quality for the production of the main LHC dipoles".

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
European Laboratory for Particle Physics

Large Hadron Collider Project

LHC Project Report 467

Control of field quality for the production of the main LHC dipoles

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Abstract

We review the warm magnetic measurements of the first four main dipole prototypes (8 apertures) and their agreement with nominal design. We then estimate the order of magnitude of the corrections that may be needed to re-center the low-order normal harmonics around the nominal values for the forthcoming series production. Correction strategies that provide the minumum impact on production schedule and costs are analysed. For the case of b_3 and b_5 two possibilities are considered: a variation of the shims to optimize the azimuthal length of the two coil layers, and a variation of the copper wedges of the inner layer, leaving unchanged the azimuthal coil size. For optimizing b_2 and b_4, we consider modifications of the shape of the ferromagnetic insert, that is placed between the collars and the yoke. Comparison between measurements and simulations of the implemented insert modifications are given and a final design is proposed. Intrinsic limits to the control of field quality during the production are discussed.

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Geneva, 28 March 2001

1 Introduction

The pre-series production of the main LHC dipoles has been recently started [1]. In this paper we analyse the magnetic measurements at room temperature relative to four dipole prototypes. Checks againsts nominal values and targets for the beam dynamics are given.

We first analyse the data relative to the collared coils; these values are relevant for studying the odd normal multipoles, since the effect of the iron yoke is rather reproducible and in agreement with simulations [2]. We trace back the origin of an offset between the nominal values and the measured ones, and we propose two correction strategies to re-center and control the production.

We then analyse the assembled cold mass data to study the even normal multipoles. In order to correct the b_2 and b_4 observed in the prototypes, we propose a corrective action based on the modification of the ferromagnetic insert placed between the collars and the iron yoke. A special prototype has been built to test the proposed solutions: we discuss the agreement of simulations with experimental measurements and an insert design for the series production.

All the analysed correction strategies are aimed at minimizing the impact on the time schedule and costs. The approach is based on evaluating sensitivity tables that provide the effect of these corrective actions on field quality. Optimization of even multipoles through insert shaping has been already implemented.

2 Fine tuning of odd multipoles

2.1 Warm measurements of collared coils

In Table 1 we give the warm magnetic measurements carried out on the collared coils of the first four prototypes made with stainless steel collars: MBP2N2, MBP2O1, MBP2O2 and MBP2A2. Data of the first prototype with aluminium collars MBP2N1 are not considered, due to the different structure and materials. Averages along the straight part (first and last measurements are discarded because of end effects, 18 positions along the axis are kept) are given in the usual units of 10^{-4} at a reference radius of 17 mm. Conventions for aperture numbering and reference systems are given in [3]. Magnetic measurements are taken at low current (12 A) and at 300 K.

Table 1: Field-shape harmonics measured at room temperature of the first four prototypes, collared coils, straight part, in units 10^{-4} of dipole field at 17 mm

	MBP2N2		MBP2O1		MBP2O2		MBP2A2	
	Ap. 1	Ap. 2	Ap. 1	Ap. 2	Ap. 1	Ap. 2	Ap. 1	Ap. 2
b_3	3.8	2.3	-1.1	-3.0	6.3	5.3	-1.9	-1.7
b_5	-0.16	0.01	0.37	0.27	0.85	0.45	1.52	1.10
b_7	0.79	0.85	0.70	0.66	1.01	0.99	0.61	0.52
b_9	0.27	0.27	0.30	0.31	0.34	0.30	0.45	0.44
b_{11}	0.75	0.75	0.76	0.76	0.78	0.78	0.76	0.77

2.1.1 Systematic part

Experimental results for the averages are given in Table 2, second column. The harmonics expected in the collared coils with the nominal geometry are given in the

Table 2: Averages odd multipoles in the collared coils of the first four prototypes: measurements at 300 K, successive post-processing of measurements (A, B and C), and nominal values. A: measurements minus the effect of non-nominal shims. B: A minus the effect of coil deformations. C: B minus the effect of the magnetic permeability of the collars.

	Measur.	A	B	C	Nominal
b_3	1.2	1.5	4.7	5.9	3.9
b_5	0.55	0.41	-0.46	-0.80	-1.02
b_7	0.76	0.83	0.81	1.03	0.73
b_9	0.34	0.31	0.31	0.31	0.12
b_{11}	0.76	0.76	0.76	0.76	0.70

last column of the same table. A non-zero value of the sextupole and decapole components (around +4 and -1 units respectively) was originally put in the nominal design to partially compensate at injection the contribution of the persistent currents [4]. These nominal values take into account the geometry of the current distribution, but neglect the collar deformation due to prestress and the magnetic permeability of the collar. Moreover, the collared coil components are obviously assumed with nominal dimensions. The four prototypes feature in average a discrepancy of -2.7 units for the sextupole and +1.5 units of decapole with respect to the nominal design (difference between the second column and the last column of Table 2). In the following, we try to trace back the origin of this discrepancy. On the other hand, higher order multipoles show a better agreement with the design: the discrepancy is much less than half a unit from b_7 onward. This is an expected feature, since any displacement of the current lines affects less the higher orders than the low ones, according to a power series decrease given by the Biot-Savart law (see Ref. [5]). Therefore, high order multipoles are much easier to control than the low order ones.

The four prototypes have been built with shims (see Figure 1) different from the nominal ones, in order to optimize the azimuthal prestress that is imposed to the coil during manufacturing. Different shim thicknesses (see Table 3) have therefore given rise to different azimuthal coil lengths, and to a variation of the odd multipoles. The sensitivity of the multipoles on the azimuthal coil length is given in Appendix A, where a model without coil deformations is considered. In Table 2, third column (A), we subtract from the measured data the multipole variation due to shims different from the nominal ones according to our sensitivity estimate.

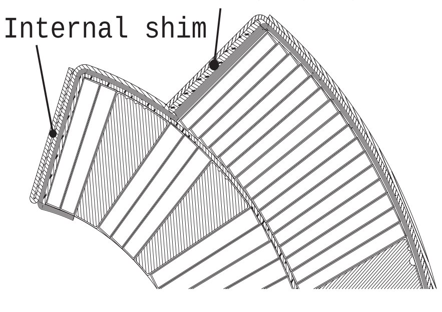

Figure 1: Cross-section of the LHC dipole coil, magnified view of the coil poles and shims

Table 3: Shim dimensions and azimuthal prestress measured in the collared coils at 300 K for the first four prototypes

	N2	O1	O2	A2	Nominal
Shims (mm)					
Internal	0.43	0.32	0.47	0.20	0.40
External	1.12	0.98	1.09	1.00	1.00
Prestress (MPa)					
Internal	62	51	55	50	60-90
External	77	55	64	52	60-90

Another contribution is given by the deformation of the coils. The azimuthal prestress imposed on the coil deforms the cavity of the collars and therefore modifies the coil shape and its multipolar content. The deformation is relevant at room temperature, where the azimuthal prestress in the collared coils is of the order of 50-75 MPa (see the data for the four prototypes in Table 3) 1). Due to the different thermal contraction coefficients of the coil and of the collars, one has a very strong prestress loss at 1.9 K, i.e. from 50-75 MPa to 20-30 MPa [6]. The impact of a given azimuthal prestress on the multipolar content is estimated in Appendix B through a finite element code [7] and a magnetostatic code [8]. In Table 2, fourth column (B), we subtract from experimental data both the contribution due to non-nominal shims, and to the collar deformation according to our estimates.

Another effect is due to the magnetic permeability of the stainless steel collars. An estimate of the influence of this parameter on field quality is given in Appendix C. The magnetic permeability at 1.9 K in the stainless steel used for the prototypes ranges from 1.0020 to 1.0035 [9]. At room temperature, we assume that all the prototypes were built with collars featuring the same magnetic permeability of 1.0020. In Table 2, fifth column (C), we subtract from experimental data the contribution of different shims, of the coil deformation, and of the magnetic permeability. The estimate (C) agrees with the nominal design, within two sigma of the distribution (see next paragraph).

Data from Table 2 show that the discrepancy between nominal design and measured values is mainly due to the collar deformation (-3.2 units of b_3 and +0.9 of b_5) and to the magnetic permeability of the collars (-1.2 units of b_3 and +0.35 of b_5). The shims do not give a relevant contribution since, in average, they have been chosen close to the nominal ones.

2.1.2 Random part

In Table 4 we carry out the analysis of the sigmas of the multipoles. Experimental data relative to the four analysed prototypes are analysed in the following way. We first consider the variation of multipoles from aperture to aperture of the same magnet. Experimental data (converted in the corresponding sigmas) are given in Table 4, second column. We then evaluate the sigma of the apertures of all magnets (Table 4, third column). The

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1) One observes an additional increase in the prestress of the order of 5 MPa in the assembled cold mass, due to interference between the collars and the yoke; this effect disappears at 1.9 K, where the yoke is not affecting any more the azimuthal prestress.

Table 4: Standard deviations of the odd multipoles (collared coils, room temperature): measured values of the sigma between apertures of the same magnet, of the sigma between apertures of different magnets and its post-processing (A and B), and target values. A: experimental sigma between apertures of different magnets, assuming nominal shims. B: experimental sigma between apertures of different magnets, assuming nominal shims and nominal prestress.

	Same magnets	Diff. magnets	A	B	Target
b_3	1.0	3.8	1.5	1.5	1.4
b_5	0.23	0.58	0.43	0.45	0.42
b_7	0.04	0.19	0.07	0.07	0.22
b_9	0.02	0.08	0.04	0.04	0.07
b_{11}	0.01	0.01	0.01	0.01	0.00

target values for the sigmas specified by the beam dynamics (Table 9901, see Ref. [10]) are given in the last column of Table 4. One observes that the variation between apertures of the same magnet is well below the target values (last column in Table 4). This means that apertures of the same magnets are extremely reproducible, beyond what is required by beam dynamics.

On the other hand, the variation of the multipoles among different magnets is higher than the targets. Indeed, one has more than a factor two for b_3 and nearly a factor 1.5 for b_5. This means that at this early stage of the production the variability from magnet to magnet is still not under control. We try to trace back the origin of this variability, and we find that a relevant part is due to shims whose thicknesses is different from the nominal one. If we extract from the experimental data the part relative to the non-nominal shims (see Table 3) according to our sensitivity estimates (see Appendix A), the resulting sigma is in agreement with the target values (Table 4, column A). In column B we extracted both the contribution due to non-nominal shims and the different deformations due to variations in the prestress: the result is very similar to column A. One concludes that the sigma of the multipoles is mainly due to the different shim size, and not to differences in prestress.

2.1.3 Summarizing

In the four analysed prototypes, average b_3 and b_5 feature discrepancies with respect to the nominal design (more than 0.5 units), and the random part of b_3 and b_5 is larger than target values (up to a factor three). Indeed, if the contributions of non-nominal shims, collar deformation, and collar magnetic permeability are taken into account, the agreement of the average multipoles is recovered. We also found that the out-of-target random part of the low-order odd multipoles is due to non-nominal shims used for optimizing the prestress, in view of trying to achieve a better training performance. The discrepancies in the systematic component with respect to the nominal design of b_3 and b_5 are of -2.7 units and +1.5 units respectively.

The coil cross-section was optimized for the previous collar design, and aimed at a correction of persistent currents of 50% for the b_3 and 80% for the b_5 [1]. This is not consistent with the beam dynamics requirements [11, 12], that aim at a b_3 as low as possible

Table 5: Effect of an additional shim of 0.1 mm on odd multipoles at 300 and 1.9 K

	Inner		Outer	
	300 K	1.9 K	300 K	1.9 K
b_3	1.7	1.8	1.2	1.3
b_5	-0.25	-0.28	0.01	-0.02
b_7	0.12	0.12	-0.03	-0.03
b_9	0.05	0.05	0.00	0.00
b_{11}	0.00	0.00	0.00	0.00

at high energy, and therefore a geometric b_3 of zero. Therefore, the discrepancies in the systematic component of b_3 with respect to the optimal design is around +4 units. For b_5, a lower correction could be envisaged (50% only [12]), thus reducing the discrepancy to one positive unit.

This estimate provides the order of magnitude needed for re-tuning b_3 and b_5. More refined estimates of the needed correction should be worked out, taking into account the iron yoke effect, warm-to-cold correlations, a design change of the internal shape of the collars used in the preseries to partially compensate collar deformation [13], and the revised estimates of the persistent current contributions [14].

In the following we analyse the possibility of performing a re-tuning of these low-order multipoles by means of small variations of the nominal design.

2.2 Fine tuning of sextupole and decapole

2.2.1 Variation of shims

A variation of the allowed multipoles (mainly b_3 and b_5) can be obtained by varying the azimuthal coil length. This can be easily tuned during the production by changing the shim thickness (two free parameters: inner and outer layer). Indeed, if the coil and the collar dimensions are within the specifications, a shim variation also produces a change of prestress, and therefore of deformation. At room temperature, a 0.1 mm change in the shim size produces an additional prestress of around 12 MPa [15]. At 1.9 K this variation becomes 7 MPa (see Ref. [6]). The admissible window for the prestress is now fixed at 75 ± 15 MPa at room temperature; therefore the range of the allowed variation of the shim size is 0.12 mm. The impact on the multipoles is given in Table 5, where the contribution of a 0.1 mm variation of coil length (Appendix A) is added to the effect of an additional deformation (Appendix B) of 6 MPa at 300 K (first column) or of 3 MPa at 1.9 K (second column). Numerical data show that the maximum range of variation of the odd multipoles is 3.5 units of b_3, 0.4 units of b_5, and 0.17 of b_7. This is not sufficient for re-tuning b_3 and b_5 on the target values, the case of b_5 being more difficult.

2.2.2 Variations of coil cross section

For obtaining a wider possibility of changing the multipolar content, one should vary the lay-out of the blocks and of the copper wedges. We restrict ourselves to analyse copper wedge variations that preserve the shape of the coil, thus avoiding a change of the collars and of the tooling relative to the coil production. However, modification of the copper wedges implies also a change of the spacers at the head of the coil. Such a change can be managed with the existing design and manufacturing procedures within a 3 months time span [16].

In the present design, the inner layer is composed of four blocks separated by three copper wedges (see Figure 2), parametrized by the four azimuthal angles φ_3, φ_4, φ_5, φ_6, and by the four inclination angles α_3, α_4, α_5, α_6. Blocks 3 and block 6 are fixed by the midplane and by the collar pole respectively, and one is left with four degrees of freedom: φ_4, φ_5, and α_4, α_5. The outer layer features two blocks and one copper wedge and therefore a change of the copper wedge without affecting the coil shape is not possible. In the previous 5 block design two degrees of freedom only would have been available.

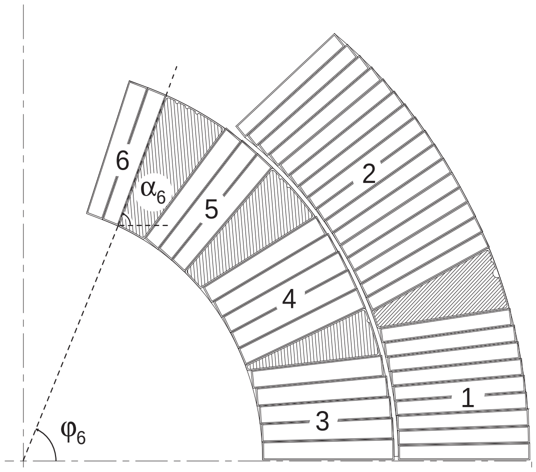

Figure 2: Cross-section of the LHC dipole coil, magnified view of the blocks

The mechanical constraints on the allowed variations of the angles φ_4 and φ_5 are rather loose: one only has to avoid that the copper wedge minimum thickness is smaller than 0.5 mm, because of the manufacturing process [13]. This limits the negative variations of φ_4 to 7 mrad. Positive variations of φ_4 and both negative and positive variations of φ_5 are allowed up to more than 35 mrad (i.e., 1 mm on the internal edge), that is far beyond what is needed to tune field quality. The inclination angles α_4 and α_5 should not differ too much from the corresponding positioning angles φ_4 and φ_5, to avoid a large tilt of the conductor with respect to the radial direction. This difference should not exceed 100-200 mrad (i.e., 5 to 10 degrees), also in this case enough for our purposes.

The effect of a slight change in the positioning of blocks 4 and 5 was analysed using a magnetic model where the geometric part only is considered. We assume that other effects like iron saturation and persistent currents can be added independently. In Table 6 we summarize the results: we considered a variation of φ_i that produces a shift in the block of $\Delta l = r\Delta\varphi_i = 0.1$ mm, where $r = 28$ mm is the inner coil radius. We also considered a variation of the tilt angles α_i that produces a shift in the middle of the block of $\Delta l = r_c\Delta\alpha_i/2 = 0.1$ mm, where $r_c = 15.4$ mm is the conductor width.

One can observe that the effect of a change in α_4 or φ_4 on b_3 and b_5 is rather similar; the same happens for α_5 or φ_5. Indeed, a variation of α has a smaller impact on b_7. This sensitivity table shows that changes of the order of a few tenths of mm in the positions of blocks 4 and 5 (without any collar modification) allow to re-center b_3 and b_5 on the optimal values for beam dynamics.

Table 6: Effect of a variation of 0.1 mm in the position of blocks 4 and 5 on multipolar errors

	Δb_3	Δb_5	Δb_7
$\delta\varphi_4$	-3.3	-0.50	+0.32
$\delta\alpha_4$	-2.5	-0.43	+0.14
$\delta\varphi_5$	-0.7	+0.88	-0.09
$\delta\alpha_5$	-0.7	+0.54	-0.01

3 Fine tuning of even multipoles

The two-in-one design of the LHC collars significantly breaks the left-right symmetry in each of the apertures, and leads to non-zero even multipoles. A relevant multipolar content of b_2 and b_4 naturally arises in a non-optimized design, and must be corrected to recover the nominal field quality. Higher order even multipoles are negligible due to the relatively high distance between the centre of the aperture and the outer radius of the collar (around 100 mm). The correction has to be carried out through a careful shaping of the iron yoke and of the ferromagnetic insert that transmits the forces between the yoke and the collars [4].

3.1 Warm measurements of assembled cold masses

In Table 7 we give the warm magnetic measurements carried out on the assembled cold masses of the first three final prototypes: MBP2N2, MBP2O1 and MBP2A2. Averages along the straight part are given in the usual units of 10^{-4} at a reference radius of 17 mm. Magnetic measurements are taken at low current (12 A) and 300 K averaging for positive and negative current flow. In the case of MBP2A2, that features sections different from the nominal one, the average is carried out along the nominal part only.

Table 7: Even field-shape harmonics measured at room temperature of the first three prototypes, assembled cold masses

	MBP2N2		MBP2O1		MBP2A2	
	Ap. 1	Ap. 2	Ap. 1	Ap. 2	Ap. 1	Ap. 2
b_2	4.04	-3.73	3.83	-4.78	4.78	-5.15
b_4	-0.40	0.40	-0.26	0.14	-0.21	0.53
b_6	-0.07	0.02	-0.02	-0.01	-0.02	-0.01

In this case, the average of apertures 1 and 2 is taken changing the sign of aperture 2. Averages and sigmas of the average multipoles in the three prototypes are given in Table 8, together with the nominal values and the targets for the sigma. One observes a relevant average b_2 (around 5 units), and a non negligible average b_4. On the other hand, the sigmas are below the target values. Therefore, solutions to optimize the average b_2 and b_4 have been analysed.

Table 8: Averages and sigma of even multipoles in the first three prototypes (assembled cold mass, room temperature) versus nominal and target values

	Average		Sigma	
	Measur.	Nomin.	Measur.	Target
b_2	4.39	0	0.54	0.68
b_4	-0.32	0	0.11	0.49
b_6	-0.02	0	0.02	0.09

3.2 Insert modifications to optimize even multipoles

The ferromagnetic insert (see Figure 3) has a relevant influence on the low-order even multipoles, and small modifications of its design can optimize them. At injection the magnetic field in the insert is of the order of some tenths of Tesla and therefore the iron is not saturated: field lines are perpendicular to the insert contours B-C-D and B'-C'-D' (see Figure 3) that face the collars. For this reason neither the dimension of holes H and H' inside the insert nor the shape of the upper part E-F and E'-F', in contact with the iron yoke, have relevant influence on field quality at injection.

3.2.1 Constraints to insert optimization

The insert is used to make it possible to assemble the iron yoke around the collars and to transmit via the yoke to the collars the forces generated by the shrinking cylinder so as to stiffen the dipole structure and minimize displacements. The force is transmitted from the yoke on the insert through the contact E'-F'-F-E and from the insert to the collars through the contact B'-A'-A-B. The elliptic parts of the collars C-D and C'-D' receive negligible forces and therefore are free for magnetic field optimization. The length of the contact E'-F'-F-E is not critical, and can be safely reduced around the ends E' and E up to at least 20 mm without affecting the mechanical role of the insert. A severe constraint is the length of the contacts B-C and B'-C': at least 4 mm are required to ensure a good positioning of the insert inside the collars during the assembly [13]. In the present design this length is 8.2 mm.

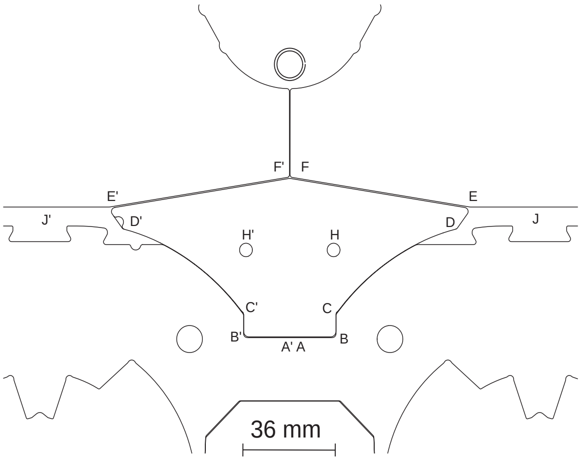

Figure 3: Insert geometry with collars and yoke

Modification of the insert geometry to optimize field quality mainly involves material removal. The additional empty volume created by these modifications will be filled with liquid helium, and if these volumes are relevant one could use fillers to reduce its quantity. Fillers between the upper part of the collar and the yoke (points J and J' in Figure 3) are already foreseen: relevant cuts in points D-E and D'-E' could be filled by simply modifying the existing fillers.

The 5.8 mm thick inserts are manufactured by fine blanking. Sharp edges have to be rounded with curvature radii of the order of 2 mm, due to fine blanking constraints.

3.3 Analysed modifications of the insert

We selected three regions of the insert contour in contact with the collars to act on the lower order normal multipoles (see Figure 4).

- A triangular cut at 45 degrees on the lower corner of the insert.
- A semihole of 8 mm radius in the mid part of the elliptic contour of the insert.
- An 18 mm cut of the toe of the insert.

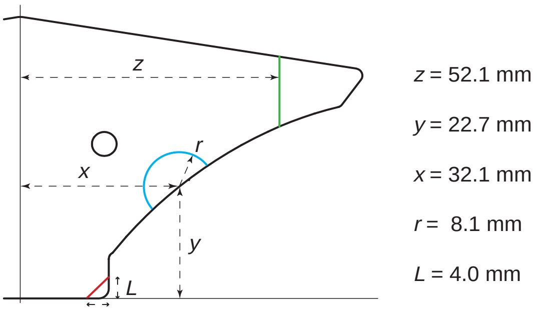

Figure 4: Insert geometry modifications tested on prototypes

These solutions have been worked out using a numerical code [8], to find ways of acting independently on b_2 and b_4 without affecting too much b_3. Results (see Table 9) show that the triangular and the circular cut have similar effects (1.5 units in b_2 and no impact on higher orders). On the other hand, the cut of the insert toe is the only way of acting also on b_4. Three sections with inserts featuring the above modifications have been built and assembled in the prototype MBP2A2 to test the validity of our magnetostatic code. Results are given in Table 9 , where a confidence level of 95 % (two sigma) has been considered for the experimental measurements. The agreement between simulations and experiments is excellent.

The impact of these modifications on the multipoles at higher fields has been checked. Iron saturation starts to be relevant at a current of 5000 A. In all cases the variation in the quadrupole is below two units, i.e. the same order of magnitude as in the nominal design [17, 18].

3.4 Proposed modifications of the insert

The version of the insert used for the first pre-series magnets has been chosen to reduce the even multipoles as much as possible. One has to correct four units of b_2 and -0.3 units of b_4. Among the different possibilities offered by the tested insert modifications, it has been decided not to modify the lower part (triangular cut). Therefore, both the semicircular hole and removing of part of the insert toe has been used. A smaller cut of the toe (14 mm instead of 18 mm, see Fig. 5) has been implemented to avoid an overcorrection of both multipoles. According to the experimental measurements, this insert modification

Table 9: Sensitivity on insert modifications, computed versus measured values

	Δb_2	Δb_3	Δb_4
Triangle Comp.	1.22	-0.33	0.04
Triangle Meas.	1.15 ± 0.30	-0.25 ± 0.16	0.00 ± 0.06
Circle Comp.	1.56	-0.16	-0.04
Circle Meas.	1.84 ± 0.24	-0.23 ± 0.14	-0.06 ± 0.14
Cut Comp.	3.43	0.83	-0.29
Cut Meas.	3.09 ± 0.26	0.66 ± 0.14	-0.29 ± 0.06

should provide a correction of 3.9 units of b_2 and -0.26 units of b_4. A test of this solution on the last prototype is in progress.

Some concern has been expressed about the impact of these modifications on b_3; the proposed new design increases b_3 by less than 0.5 units, according both to the measurements and to the simulations shown in Table 9. This effect is small when compared to the reproducibility of this multipole (one observes variations of 1 to 2 units between apertures of the same magnet, see Table 1). Moreover, the target for the sigma of b_3 is 1.5 units, i.e. three times larger then the variation induced by insert modifications. This additional effect of less than 0.5 units is also much smaller than the observed discrepancies with respect the nominal design (around 3 units).

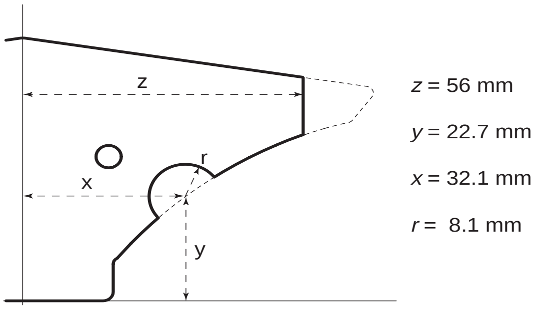

Figure 5: Insert geometry chosen for the series

4 First estimates of uncertainty

Beam dynamics simulations are based on the assumption that one has eight production lines; each line produces magnets whose multipoles have a Gaussian distribution with the same sigma, and different averages. The standard deviation of these averages is called the uncertainty. At this very early stage of the production, variations in magnet field quality between the producers lie in the different shim thicknesses used in the collared coil. This may be due to variation in the azimuthal coil length of the cured coils, depending on the tooling. The shims thickness that has been used in the last collared coils built in the three firms (the first magnet of the pre-series for Ansaldo and Noell, and the third one for Alstom) are given in Table 10.

To work out the impact of these variations on field quality, we have to use the sensitivity estimates shown in Appendix A, since different shims are used to aim at the

Table 10: Shim sizes used for the first Ansaldo and Noell pre-series magnet, and for the third Alstom, and impact on low-order odd multipoles

	Shims [mm] Inner	Shims [mm] Outer	Δb_3	Δb_5	Δb_7
Alstom	0.35	0.95	5.0	-0.60	0.17
Ansaldo	0.25	0.90	2.3	-0.23	0.05
Noell	0.15	0.97	1.4	0.09	-0.10
Estimated uncertainty (sigma)			1.9	0.35	0.13
Target uncertainty (sigma)			0.9	0.42	0.00

same nominal prestress. We therefore obtain the expected variations in the odd normal multipoles of the collared coils between the three producers. A comparison with the target value (last two rows of Table 10) shows that if these shims thicknesses were kept along the production, the uncertainty for b_3 would be two times larger than the target. This is an optimistic estimate, since all the other effects are neglected.

To reduce the uncertainty due to shim size below the target values, the shims thickness variation among different firms should not exceed 0.03 mm. A uniformization of the shim thicknesses to the same average value would allow to reduce the uncertainty below the target value, within the prestress constraints.

5 Intrinsic limits to the production control

In this last section we give an estimate of the intrinsic limits to the control of the normal multipoles during the manufacturing. These limits are due to a variability of the field quality in the dipoles that we do not manage to modelize in a deterministic way, and that therefore we cannot control. An estimate of these limits is a relevant topic for understanding up to which precision the cross-section design and optimization should be carried out. Moreover, they provide the most optimistic estimate of what we can expect from the production control. A check of the consistency of these limits with the target values for the beam dynamics is also necessary to verify the feasability of the machine.

A first estimate of these intrinsic limits in the field quality control is based on the approach described in Ref. [19, 5]. Due to mechanical tolerances, conductors will never be exactly in the nominal design positions. The effect of these imperfections on the multipole components can be estimated: assuming that conductors are randomly placed around their nominal positions with an r.m.s. displacement of 0.025 mm, we obtain the corresponding distribution of random multipolar components whose sigma is given in Table 11, second column. These values agree to the measured variations of the multipoles along the longitudinal axis of the magnet (see Ref. [5]).

A second estimate of the lower bound to the control of field harmonics can be given by the variation of the multipoles from aperture to aperture of the same magnet. This is an experimental measurement of our capability of reproducing the same field harmonics in optimal conditions (same tooling, same manufacturer, same collaring). The sigma of the multipole distribution corresponding to the measured variations from aperture to aperture are given in Table 11, third column.

These two estimates are not very different, the first one being somewhat more

Table 11: Estimate of the intrinsic limits to multipole control during production and target values, in sigma of the corresponding Gaussian distribution

	Limits		Target	
	Simulations	Exp. Data	Sigma	Uncertainty
b_2	0.71	0.5	0.68	0.85
b_3	0.43	1.0	1.45	0.87
b_4	0.26	0.06	0.49	0.34
b_5	0.15	0.23	0.42	0.42
b_7	0.05	0.05	0.22	0.00
b_9	0.02	0.02	0.07	0.00
b_{11}	0.01	0.01	0.00	0.00

optimistic for the odd multipoles and pessimistic for the even ones. One can conclude that in a single magnet, the intrinsic limit in the control of the multipoles is around 0.5 units of b_2, up to 1 unit of b_3, 0.1 units of b_4 and 0.2 units of b_5 (one sigma). This is also the best agreement that we can expect between our model and measurements of a single magnet. In principle, the control over the average of a set of N magnets can be carried out with a higher precision, since one gains a factor $\sqrt{N}$.

The target values for beam dynamics are also given in Table 11: in column 4 we give the target sigma for a single production line, and in column 5 we give the sigma of the averages between different production lines (i.e, the uncertainty). A comparison with column 2 and 3 of the same Table shows that the estimated intrinsic limits to production control (both from simulations and experimental data) are not in conflict with the beam dynamics requirements.

6 Conclusions

We have analysed the field quality at room temperature of the first four final LHC dipole prototypes. The aim of this work is to give a preliminary assessement of the agreement of the field shape with the nominal design and with the target values, and to outline possible correction strategies that minimize the impact on the time schedule and costs.

The collared coil data of four prototypes have been analysed. The average odd multipoles feature a discrepancy of -3 units of b_3 and of +1.5 units in b_5. This is mainly due to two effects: the deformation of the collars due to the azimuthal prestress, and the magnetic permeability of the collars. When these effects are taken into account, one recovers a good agreement between design and measurements.

We point out that the nominal design is not consistent with the beam dynamics requirements: the coil cross-section aims at a relevant correction of b_3 persistent currents at injection, whilst beam dynamics considerations require no correction at all. This decreases the optimal value of b_3 by around 7 units, bringing the discrepancy from -3 units to +4 units.

The standard deviation of the odd multipoles is larger than the targets. This is mainly due to the use of different shim sizes to optimize the prestress in the coil. If this effect is taken out using the current estimates, the standard deviation of odd multipoles agrees with the targets.

We explore two possibile strategies to perform a tuning of b_3 and b_5 during the production. A change in the shim size allows to act in a very simple way on b_3 up to ±3 units and on b_5 up to ±0.3 units. A larger re-tuning of b_5, as it is suggested by experimental data, would require a change in the coil cross-section. We outline a strategy that allows to change two copper wedges in the internal layer without changing the collar shape, thus minimizing the impact on production.

The assembled cold mass data of three prototypes have been analysed to work out estimates on even normal multipoles. A relevant value of b_2 (5 units) has been found. On the other hand, the standard deviations of even multipoles are well below the targets. We have worked out three modifications of the ferromagnetic insert between the collars and the iron yoke to optimize b_2 and b_4. These solutions have been tested on a prototype, finding a good agreement with simulations. We then have proposed a new design of the insert to minimize both b_2 and b_4, that will be used for the pre-series production.

We have given a first estimate of the uncertainty, based on the assumption that it is due to different shim thicknesses used by the three producers. If the foreseen values will be used for all the production, the uncertainty in b_3 will be three times larger than the target. This could have a relevant impact on the recently foreseen installation scenarios [20].

We have worked out an estimate of the intrinsic limits that one has on the control of field harmonics on a single magnet, both for the design and optimization phase, and during the production. These limits are consistent with the target values of the random components.

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A Sensitivity on azimuthal cavity size

We consider a coil compression that leads to a larger cavity azimuthal size of $\Delta l = 0.1$ mm (measured from the midplane to the pole). The effect of this change on the multipoles can be first modelled by assuming that the coil uniformly shrinks in the azimuthal coordinate [model 1, see Table 12]. However, copper wedges are much harder than the coil: their Young modulus is around 100 GPa, whilst the coil features a pressure-dependent Young modulus of the order of 10 GPa at 60 MPa. Therefore, we considered a second approximation where copper wedges are incompressible and all the shrinkage in the azimuthal size is due to a compression of the blocks [model 2, Table 12]. Moreover, we considered a finite element model of the magnet cross section and we simulated the effect of a shim whose size is 0.1 mm larger, *but keeping the same prestress* (i.e., the same collar deformation) by reducing the unloaded coil length of 0.1 mm [model 3, Table 12]. The results of the model 2 and 3 are very similar, and agree with previous estimates given in Ref. [21].

Table 12: Effect of a 0.1 mm larger azimuthal cavity size on odd multipolar errors, estimates through numerical models

	Inner coil		
	Δb_3	Δb_5	Δb_7
Model 1	+1.3	-0.41	+0.15
Model 2	+1.8	-0.33	+0.13
Model 3	+1.9	-0.32	+0.13
	Outer coil		
	Δb_3	Δb_5	Δb_7
Model 1	+1.4	-0.06	-0.02
Model 2	+1.5	-0.07	-0.02
Model 3	+1.4	-0.06	-0.02

B Sensitivity on deformations

The effect of collar deformations on field quality has been evaluated using a finite element code [7] for the structural analysis, and a magnetostatic code [8] for the multipole evaluation. The finite element model and its properties are described in Ref. [6]. Here, we use the model to work out the effect of a given azimuthal prestress on the multipoles, *keeping constant the geometry of the unloaded cavity.* Prestress at 300 K is around 75 MPa, and at 1.9 K is around 30 MPa. Therefore the effect of collar deformation is expected to be much more visible at room temperature. In Table 13 we give the impact on odd multipoles of the collar deformation as a function of the azimuthal prestress of the coils. One can see that the effect of deformations is non-negligible mainly for b_3 and b_5. From b_9 onard the effect is less than 0.1 units. Explicit dependence around the working point of 70 MPa can be worked out through linearization:

$$\Delta b_3 = -0.98 - 0.0363\,\sigma \qquad (1)$$

$$\Delta b_5 = 0.38 + 0.0112\,\sigma \tag{2}$$

$$\Delta b_7 = -0.07 - 0.0017\,\sigma \tag{3}$$

Table 13: Effect of a collar deformation due to an azimuthal prestress σ on odd multipoles

σ (MPa)	Δb_3	Δb_5	Δb_7
10	-1.0	0.37	-0.06
20	-1.6	0.56	-0.09
30	-2.0	0.70	-0.11
40	-2.4	0.83	-0.13
50	-2.8	0.95	-0.15
60	-3.2	1.07	-0.17
70	-3.5	1.17	-0.18
80	-3.9	1.28	-0.20
90	-4.2	1.37	-0.21

The sensitivity on the prestress is similar at 300 K and at 1.9 K, but at 1.9 K one has an additional offset in the multipoles due to the different thermal contraction coefficients of the collar and of the coil. Further analysis should be carried out, based both on finite element models and warm-to-cold correlations worked out by magnetic measurements.

C Sensitivity on collar permeability

The stainless steel used for the collars has a magnetic permeability that differs from one by a few units in 10^{-3}. Typically, μ is 1.002 to 1.003, and its value has small variations (of the order of 10^{-4}) when the external magnetic field ramps from 0.1 T to 8 T. The dependence of the shift induced in the multipoles on the magnetic permeability is linear; values are given in Table 14. Also in this case, the effect is non-negligible on b_3 and b_5.

Table 14: Effect of a non-zero collar permeability on odd multipoles

μ_c	Δb_3	Δb_5	Δb_7
1.0010	-0.6	0.17	-0.04
1.0015	-0.9	0.25	-0.06
1.0020	-1.3	0.34	-0.08
1.0025	-1.6	0.42	-0.10
1.0030	-2.0	0.51	-0.12
1.0035	-2.3	0.59	-0.14

D Examples of copper wedge modifications

We consider a modification of the coil cross-section in the position of the block 4, azimuthal position (variable ϕ) by 0.1 mm. This implies a change in the angle of $0.1/28/\pi * 180 = 0.204$ degrees, i.e. 3.57 mrad. In the AUTOCAD^{TM} input file, this change in the variable ϕ corresponds to add a slice of 0.1 mm to the copper wedge between the third and the fourth block, and to remove the same slice from the copper wedge between the fourth and the fifth block. According to our sensitivity tables, the impact of this modifications on b_3, b_5 and b_7 is of -3.3, -0.50 and +0.32 units respectively.

As a second example, we consider a modification of the tilt angle α_4 by 0.15 mm. This implies a change in the angle of $0.15/7.7/\pi * 180 = 2.232$ degrees, i.e. 19.48 mrad. In the AUTOCAD^{TM} input file, one has to increase by 2.232 degrees the angle of the copper wedges between the third and the fourth block, and has to reduce the angle of the copper wedge between the fourth and the fifth block by the same amount. This modification should change b_3, b_5 and b_7 by -3.8, -0.63 and +0.20 units respectively.

ANNEX G: TECHNICAL SPECIFICATIONS RELEASED BY CERN FOR THE PROCUREMENT OF THE COLD MASS COMPONENTS AND TOOLING

G1: LHC-MMS/98-198/G01 - (EDMS No. 102689)

Technical Specification for the Supply of Copper Wedges for the Cold Masses of the LHC Superconducting Dipole Magnets. *(For the series production).*

G2: LHC-ICP/01-242/FRM - (EDMS No. -)

Technical Specification for the Supply of Quench Heaters for the series LHC Superconducting Main Dipole Magnets. *(For the series production). (NOT YET AVAILABLE).*

G3: LHC-MMS/98-198/G03 - (EDMS No. 102690)

Technical Specification for the Supply of Austenitic Steel Strips for the Collars for the Cold-Masses of the LHC Superconducting Dipole Magnets. *(For the series production).*

G4: LHC-MMS/98-198/G04 - (EDMS No. 102691)

Technical Specification for the Supply of Fine-Blanked Austenitic Steel Collars for the Cold-Masses of the LHC Superconducting Dipole Magnets. *(For the series production).*

G5: LHC-MMS/98-198/G05 - (EDMS No. 109770)

Technical Specification for the Supply of Seamless Austenitic Stainless Steel Tubes for the LHC Main Dipole and Quadrupole Superconducting Magnets *(For the series production).*

G6: LHC-MMS/98-198/G06 - (EDMS No. 102761)

Technical Specification for the Supply of Fine-Blanked Austenitic Steel Yoke Laminations for the Cold Masses of the LHC Superconducting Dipole Magnets. *(For the series production).*

G7: LHC-MMS/98-198/G07 - (EDMS No. 102760)

Technical Specification for the Supply of Fine-Blanked Low-Carbon Steel Yoke Laminations for the Cold Masses of the LHC Superconducting Dipole Magnets. *(For the series production).*

G8: LHC-MMS/98-198/G08 - (EDMS No. 103374)

Technical Specification for the Supply of Austenitic Stainless Steel Shells for the Cold-Masses of the LHC Superconducting Dipole Magnets. *(For the series production).*

G9: LHC-MMS/98-198/G09 - (EDMS No. 114576)

Technical Specification for the Supply of Austenitic Steel End Covers for the Cold-Masses of the LHC Superconducting Dipole Magnets. *(For the series production).*

G10: LHC-MMS/98-198/G10 - (EDMS No. -)

Technical Specification for the Supply of Oxygen-Free Copper Helium Heat Exchanger Tubes for the LHC Main Dipole and Quadrupole Magnets. *(For the series production). (NOT YET AVAILABLE).*

G11: LHC-CRI/BS/cl - (EDMS No. 108633)

Technical Specification for the Supply of LHC Belows Expansion joints. *(For the series production).*

G12: LHC-MMS/98-198/G12 - (EDMS No. 102817)

Technical Specification for the Supply of Austenitic Steel Strips for the non-magnetic Laminations of the Cold Masses of the LHC Superconducting Dipole Magnets. *(For the series production).*

G13: LHC-MMS/98-198/G13 - (EDMS No. 103981)

Technical Specification for the Supply of Coil Inter-Layers for the Cold-Masses of the LHC Superconducting Dipole Magnets (first 100 dipoles). *(For the pre-series production).*

G14: LHC-MMS/99-202 - (EDMS No. 104306)

Technical Specification for the Supply of Polyimide Film for the Cable and Ground Insulation of the LHC Superconducting Magnets. *(For the series production).*

G15: LHC-MMS/98-180 - (EDMS No. 102194)

Technical Specification for the Supply of Three Hydraulic Presses for Assembling and Welding the LHC Superconducting Dipole Magnets

G16: LHC-MMS/98-184 - (EDMS No. 102199)

Technical Specification for the Supply of Pole Measuring Machines for the LHC Superconducting Dipole Magnets.

G17: LHC-MMS/99-199 - (EDMS No. 102523)

Technical Specification for the Supply of Portable 3-D Measuring Systems allowing the on-site Dimensional Inspection of the Cold Masses of the LHC Dipole Magnets.

G18: LHC-MMS/99-209 - (EDMS No. 108110)

Technical Specification for the Supply of Machined End-Spacers for 90 LHC Main Dipole Magnets.

G19: LHC-MMS/2001-229 - (EDMS No. -)

Technical Specification for the Supply of Helium filling pieces for the Cold-Masses of the LHC Dipole Magnets. *(For the series production). (NOT YET AVAILABLE).*