

TECHNICAL SPECIFICATION

**MANUFACTURE OF SEPTUM ELECTROMAGNET YOKES FOR THE SPS
ACCELERATOR**

This specification concerns the manufacture of 14000 mild steel laminations and their assembly into 20 septum electromagnet yokes. The manufacture of these yokes requires a mastery of various processes: die-stamping, chemical cleaning, heat treatment, mechanical assembly and mechanical and electrical inspection.

Prévessin, September 1998

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Appendix 1 : Recommendations ISO R 1101

Appendix 2 : Assembly procedure

Appendix 3 : Inspection reports - documents attached for information. Procedure to be determined with the manufacturer

1 INTRODUCTION

The European Organization for Nuclear Research (CERN) is currently operating a large circular 450 GeV proton accelerator, the Super Proton Synchrotron (SPS).

Septum electromagnets of the type described herein, fitted in stainless steel vacuum tanks connected to the SPS vacuum chamber, are used to extract the proton beam from the accelerator or inject antiprotons or electrons.

Each electromagnet essentially consists of a double septum coil and two yokes, one on the right and one on the left, weighing about 520 kg; they are required to operate in a high vacuum of 10^{-7} Pa and a highly radioactive environment.

2 INFORMATION ON THE PURPOSE OF THIS PRICE ENQUIRY

2.1 Purpose of the price enquiry

This specification concerns the manufacture and delivery of 14.000 mild steel laminations assembled into:

- 10 right-hand SM yokes (drawing 8032.6.626.1),
- 10 left-hand SM yokes (drawing 8032.6.627.1).

These yokes will subsequently be fitted with coils and accessories at CERN.

The delivery schedule is defined in the tender form.

The overall drawing is shown in Fig. 1. The detailed structural drawings listed in Table 2 of paragraph 2.3 are appended to this specification.

CERN will provide, free of charge, all the components and the material (mild steel) needed to make the yokes; the components shall have been carefully cleaned for installation in a high vacuum. The list of components supplied by CERN is given in Table 3 in Section 2.4.

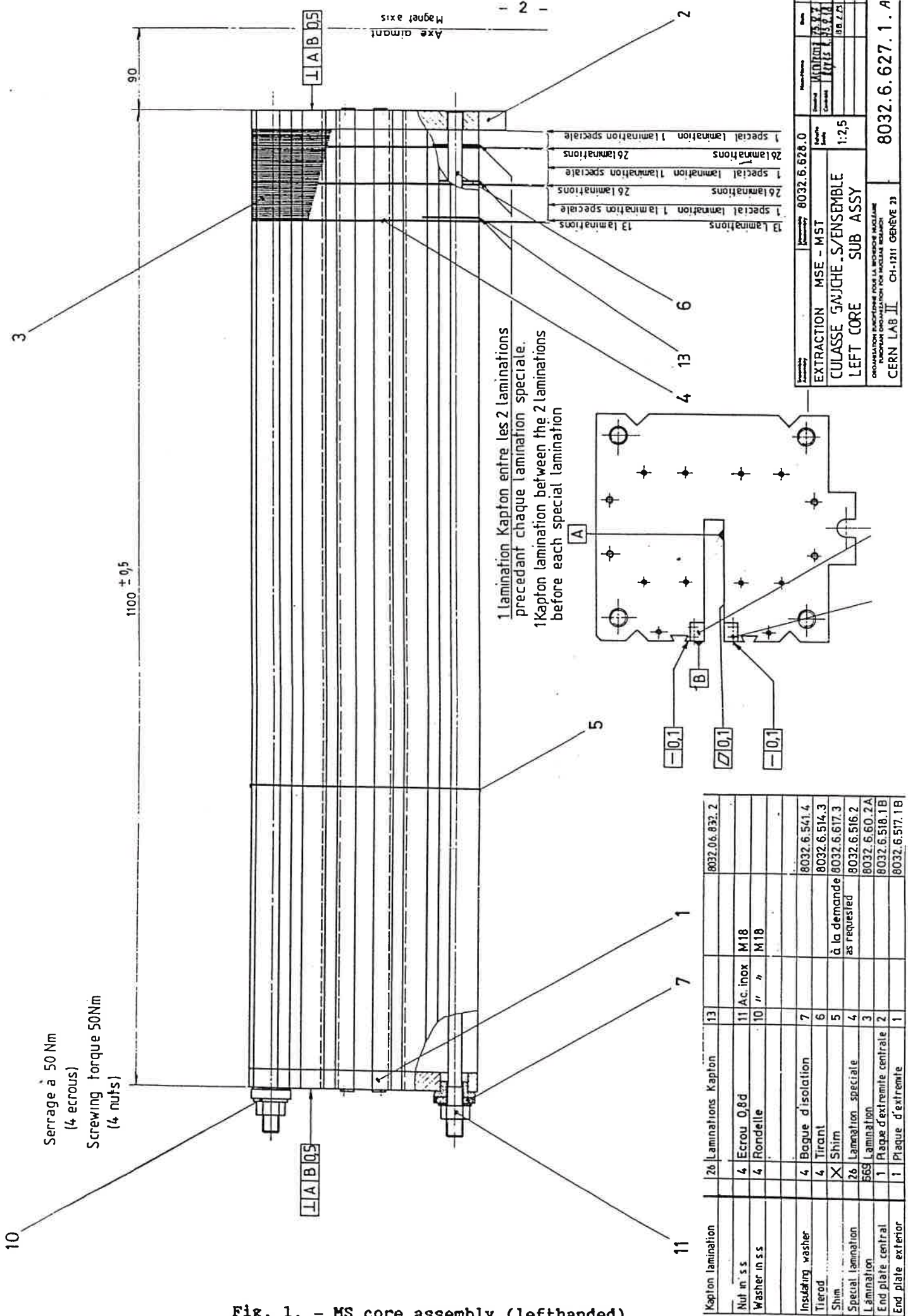
The tender shall include the operations below:

- Manufacture of about 14.000 laminations, including cleaning and surface treatment by oxidation needed for the electrical insulation between laminations.

CERN has 2 cutting tools formerly used to make 100 yokes. These tools are available for production.

The bidder shall decide whether a new cutting tools has to be made (which will become CERN's property) or to make use of the existing tool, or whether a laser cutting method is preferable and less expensive for him.

- Electrical inspections of the sets of laminations.
- Cleaning the laminations.
- Assembling the yokes.
- Mechanical and electrical inspections of the assembly.
- Installation on the transport supports.
- Packing and transport.



Serrage à 50 Nm
(4 écrous)
Screwing torque 50Nm
(4 nuts)

1100 ± 0.5

90

Axe aimant
Magnet axis

1 lamination Kapton entre les 2 laminations
precedant chaque lamination speciale.
1 Kapton lamination between the 2 laminations
before each special lamination

Kapton lamination	26	Laminations Kapton	13	8032.06.832.2
Nut in s.s	4	Ecrou 0,8d	11	Ac. inox M18
Washer in s.s	4	Rondelle	10	" " M18
Insulating washer	4	Bague d'isolation	7	8032.6.541.4
Tierod	4	Tirant	6	8032.6.514.3
Shim	X	Shim	5	à la demande as requested
Special lamination	26	Lamination speciale	4	8032.6.516.2
Lamination	568	Lamination	3	8032.6.60.2A
End plate central	1	Plaque d'extremite centrale	2	8032.6.518.1B
End plate exterior	1	Plaque d'extremite	1	8032.6.517.1B

Reference	8032.6.628.0	Date	
Project	EXTRACTION MSE - MST	Drawn	MINILOI
Client	CULASSE GAUCHE S/ENSEMBLE	Checked	ETTES
Part	LEFT CORE SUB ASSY	Scale	1:2,5
ORGANISATION RESPONSABLE POUR LA PRODUCE FACILITE		CERN LAB II	
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH		CH-1211 GENEVE 23	
8032.6.627.1.A			

Fig. 1. - MS core assembly (lefthanded).

2.2 List of main characteristics

The main characteristics are summarised in Table 1. Detailed information on the dimensions may be found in the corresponding working drawings.

Table 1
Main characteristics of the SM yokes

Characteristics	Figures
<u>Mechanical</u>	
– Mass of a right or left-hand yoke (kg)	520 (approx.)
– Nominal length (mm)	1100 ± 0.5
– Straightness, surface planeness (mm)	0.3
– Compression between laminations (daN/cm)	5
– Stacking factor, minimum	0.97
– Area of a lamination (m ²)	0.05975
– Maximum burr (mm)	0.03
<u>Electrical</u>	
– Resistance of 10 laminations (Ω /cm ²)	> 0.033
– Resistance of 1 yoke (M Ω)	> 10
<u>Vacuum</u>	
– Bake-out temperature (C°)	200
– Residual gas pressure (Pa)	10 ⁻⁷

2.3 Tendering and manufacturing drawings

The drawings listed in Table 2 form part of this specification. These structural drawings are valid for tendering purposes only. CERN reserves the right to make minor detail amendments to them before manufacture is started.

The final manufacturing drawings will be provided when the contract is signed.

CERN's drawings are made to the ISO standards. An extract from ISO recommendation R 1101 relating to positional tolerances is appended hereto (APPENDIX 1).

If the manufacturer makes his own working drawings, he shall provide CERN with 3 complete sets before starting manufacture.

Manufacture may not start until CERN's written approval of these drawings has been received.

Table 2
List of drawings for yoke manufacture

N°	Title	CERN drawing – Lab 2/N°
	<u>Yoke and components</u>	
1	Septum magnet: right-hand yoke	8032.6.626.1
2	Septum magnet: left-hand yoke	8032.6.627.1
3	Lamination	8032.6.60.2
4	Special lamination	8032.6.516.2
5	KAPTON lamination	8032.6.832.2
6	Central end plate	8032.6.517.1
7	End plate	8032.6.518.1
8	Tie rod	8032.6.514.3
9	Insulating ring	8032.60.747.4
10	Stainless steel nut and washer	M 18
11	Shim	8032.6.617.3
12	Lamination cutting diagram	8032.6.831.3
	<u>Tooling</u>	
13	Lamination cutting tool (Bloc Suisse)	
14	Special lamination withdrawal tool	No drawing
15	Assembly bench	8032.16.523.0
16	Transport support	8032.16.526.0
17	Lifting beam	8032.6.820.0

2.4 Material and components supplied by CERN

Mild steel sheets for the laminations

CERN will provide :

- 14 tonnes of MAGNETIL BC mild steel (Cockerill, Belgium) in sheets measuring 1880 X 840 X 1.5 mm, steam-blued, lightly oiled.

Tooling

- 1 lamination cutting tool (150-tonne press),
- 1 secondary cutting tool for the special laminations,
- 1 tool (2 plates and 4 columns) for measuring the insulation between laminations,
- 1 assembly bench,
- 16 transport and storage supports,
- 1 stabilised 10 A d.c. electric power supply with its connections,
- 1 precision digital voltmeter,
- 1 megohmmeter.

Finished components ready for assembling the yokes

CERN will provide the components below, cleaned for vacuum, in plastic (polythene) packaging.

Table 3
List of components provided by CERN

	Number	Designation
1	600	KAPTON laminations
2	20	Central end plates
3	20	End plates
4	80	Tie rods
5	80	Insulating rings
6	80	Stainless steel nuts
7	80	Stainless steel washers
8	400	Steel shims
9	16	Transport and storage supports

2.5 Facilities to be provided by the manufacturer

The bidder shall be perfectly familiar with the techniques needed to make cut-out components either by laser¹ or by stamping; he shall have the tooling needed for manufacture and mechanical inspections.

The yokes shall be assembled in a clean room in controlled conditions. This room shall contain the clean components and laminations, the assembly bench and the equipment for handling the assembled yokes and an insulating surface plate for inspecting them.

The oxidation process should preferably be operated by the manufacturer but may be sub-contracted (see § 4.2).

The bidder shall make a number of cases for handling the laminations without damaging them (see § 4.2).

¹ If this method is cheaper than stamping, taking account of the cutting tools provided by CERN.

2.6 List of samples

Laminations during cutting

One lamination from every batch of 500 shall be numbered and set aside for inspection; in addition, the first and last 12 shall be extracted and handed over to CERN's inspectors.

Specially cut laminations

4 special laminations, 1 from the first batch and 1 from the last, shall be extracted, numbered and set aside.

Laminations after oxidation

40 laminations shall be taken by way of samples from the various batches, not numbered but wrapped in numbered polyethylene packs, for electrical insulation checks; variations may occur from one batch to another.

2.7 Inspection certificates

The manufacturer shall complete, for each yoke, an inspection certificate to be drawn up in consultation with CERN (§ 5.2).

_This certificate shall show:

- the yoke number and the date,
- the composition of the yoke consisting of type 1, type 2, type 3, special and KAPTON laminations,
- the results of the mechanical measurements,
- the results of the electrical measurements.

Another inspection sheet shall be drawn up for the protection, cleaning and oxidation of the laminations for each case; it shall show:

- date,
- type of lamination,
- number of laminations (from 1 to 14.000),
- measured air gap parallelism,
- measured burr,
- electrical measurements.

3 OPERATING CONDITIONS

These septum electromagnets are intended for the extraction or injection of particles in high-vacuum conditions. Very precise alignment conditions are therefore necessary.

The straightness and planeness tolerances on the septum which are essential to ensure an alignment on the machine to within 1/10 mm and the tolerances needed for the perfect adjustment of the coil in the yokes on their shared support require very strict manufacturing tolerances and necessitate special assembly tooling. It must be possible to bake the yokes out at 200°C owing to the vacuum requirements.

The specified residual gas pressures are below 10^{-7} Pascal (10^{-9} torr), meaning that very strict precautions must be taken with respect to cleanliness, handling and cleaning

of the components before, during and after their assembly: in particular, gloves must always be worn.

4 TECHNICAL DESCRIPTION OF THE MS YOKES

4.1 Composition

A complete right or left-hand yoke (see drawings CERN–Lab 2/ 8032.6.626.1 et 627.1) shall consist of:

- about 670 mild steel sheets or laminations measuring 1.50 mm \pm 0.03 mm thick (drawing 8032.6.60.2),
- 26 laminations of the same steel grade (drawing 8032.6.516.2),
- 26 special KAPTON²⁾ 125 microns thick (drawing 8032.6.832.1),
- 2 ARMCO mild steel end sheets or plates 20 mm thick (drawing 8032.6.517.1 and 518.1),
- 4 special treated steel tie rods 1150 mm long (drawing 8032.6.514.3),
- 4 insulating rings consisting of 2 stainless steel components hot and cold-crimped together, with the interior coated with an alumina film (drawing 8032.60.747.4),
- 4 stainless steel M 18 nuts,
- a number of shims (drawing 8032.6.617.3) needed to make up for the accumulated unintentional differences in thickness between laminations and to meet the planeness, twist and straightness tolerances of the yoke (an average of ten per yoke)..

4.2 Description of the components to be made

Laminations

The laminations (drawing 8032.6.60.2) have 4 holes for 4 tie rods for the assembly and tightening of the yokes. Via aluminium rods, the screws secure the yokes to their supporting plate. The swallowtail notches are designed to hold the special sliding nuts for securing flanges. The 4 mm chamfer on one corner is a guide.

Special laminations

The special laminations, on which the air gap is widened to 70 mm over a length of 110 mm (drawing 8032.6.516.2), make it possible to fit the flat coil holding springs in the yoke.

Manufacture of the laminations

Cutting out

The tolerances on the air gap finally obtained once the yoke has been assembled are very close, meaning that each lamination must be cut out, boxed and handled with the greatest of care.

Moreover, the MAGNETIL BC³⁾ mild steel sheets supplied from the rolling mill in strips 840 mm wide, 1880 mm long (in the rolling direction) and with a gauge of 1.50 mm are not perfect and there is a slight thinning (-0.04 mm) on the side sections (at 15 mm from the edges, cross-sectional drawing 8032.6.831.3).

²⁾ KAPTON : Registered trade mark of Dupont de Nemours for the radiation-resistant polyimide product of high dielectric, thermal and mechanical quality.

³⁾ Cockerill (Belgium)

A distinction must therefore be made between 3 types of laminations cut from the three 270 mm strips from the initial 840 mm-wide sheet:

- type 1 "white" laminations, cut from the central strip and unbevelled,
- type 2 "yellow" laminations, bevelled and thicker on the side of the chamfered corner,
- type 3 "red" laminations, bevelled and thinner on the side of the chamfered corner.

Every precaution shall therefore be taken to avoid mixing the 3 types of lamination and observe the cutting-out direction.

Each type of lamination shall be put into boxes of the colour of their type, white, yellow and red, for types 1, 2 and 3 respectively; each box shall hold about 350 laminations; the recommended internal dimensions of the boxes are 800 x 285 and 225 mm deep..

The one-pass cutting tool proposed and supplied by CERN has already been used to cut out about 70.000 laminations with a 150 -tonne press. It must be reground once the burr exceeds 0.03 mm.

In any event, a micrometer check must be made every 500 laminations to prevent the burr from exceeding that size, which would result in a loss of electrical insulation in the basic blocks of 26 laminations.

Damaged or even slightly warped laminations must always be rejected.

After cutting out the laminations must be perfectly plane and stored in their type 1, 2 or 3 boxes as described above, chronologically numbered and marked on the outside with their colours white, yellow and red so as to be easily identifiable.

About 600 type 1 (white) laminations, or about 2 boxfuls, shall be re-used to be made by the 2nd cutting tool into special laminations and packed in two separate boxes properly marked on the outside.

Cleaning

All the laminations shall be cleaned, box by box, just before hot-air oxidation (4 hours at 340°C).

Degreasing shall be performed by means of hot perchloroethylene vapour and the laminations thus cleaned shall be placed in the furnace and oxidised on the same day. The manufacturer may propose another method, for which he shall obtain CERN's written agreement.

Oxidation

In order to ensure good primary insulation between them, the original already "steam-blued" laminations shall be oxidised, a few millimetres apart, in an air-circulation furnace at 340°C for 4 hours.

Surface insulation measurements shall be made on samples (see § 5.3).

4.3 Description of the components supplied by CERN

End plates (see drawings 8032.6.517.1 and 518.1)

These are of the same shape as the laminations but have a larger number of securing holes. The air gap and the tie rod holes are larger, the base of the air gap is rounded and there is a depression on the front of the air gap to prevent a short circuit between the coil and the plate.

The central end plate also has a bulge at the lower end to lock the yoke longitudinally on its support.

The end plates are interchangeable between right and left-hand yokes.

Insulating ring (see drawing 8032.60.747.4)

The "insulating ring actually consists of a stainless steel ring and an alumina-coated stainless steel washer crimped into a heat-expanded ring.

Tie rods (see drawing 8032.6.514.3)

The tie rods are of VCN35H steel with a chemically applied nickel coating 10 to 15 microns thick.

Shims (see drawing 8032.6.617.3)

The shims are machined in batches from 0.1 mm steel foil. They are virtually always essential for making up gauge faults on the outsides of the laminations and thus make it possible to meet the required tolerances on the twist, planeness and straightness of the yokes.

Nuts, washers

These are of stainless steel and supplied by CERN.

4.4 Yoke assembly procedure

The components needed to assemble a right or left-hand yoke are listed in Table 4.

Table 4
List of components required for a yoke

Components	Number
Central end plate	1
Laminations type 1 (white)	1 set of 13
KAPTON laminations	27 (taken 1 by 1)
Special laminations (white)	26 (taken 1 by 1)
Laminations type 2 (yellow)	9 sets of 26
Laminations type 3 (red)	9 sets of 26
Laminations type 1 (white)	7 sets of 26
Laminations type 1 (white)	1 set of 26
End plate	1
Shims	About twenty
Tie rods	4
Insulating rings	4
Washers M 18 stainless steel	4
Nuts M 18 stainless steel	4

Assembly

With the assembly bench placed as shown on the drawing, the components shall be fitted in the sequence below (the successful bidder will be given a more detailed table and instructions).

Set N°	Description of the components
1	<ul style="list-style-type: none">– Central end plate– One set of 13 laminations type 1 (white)– Insert a KAPTON lamination between the 12th and 13th laminations– One special lamination (white)
2	<ul style="list-style-type: none">– One set of 26 laminations type 2 (yellow)– Insert a KAPTON lamination between the 25th and 26th laminations– One special lamination (white)
3	<ul style="list-style-type: none">– One set of 26 laminations type 3 (red)– Insert a KAPTON lamination between the 25th and 26th laminations– One special lamination (white)
4 to 24	<ul style="list-style-type: none">– Continue with the sequence type 1, type 2, type 3, with a KAPTON lamination between the 25th and 26th laminations and a special lamination after the 26th of each set, up to and including the 24th set
25	<ul style="list-style-type: none">– The 25th set shall consist of 26 type 1 (white) laminations with, in addition, the KAPTON and the special lamination
26	<ul style="list-style-type: none">– The 26th set shall consist of 26 type 2 (yellow) laminations with, in addition, the KAPTON and the special lamination
27	<ul style="list-style-type: none">– The 27th and last set, type 1 (white), with a KAPTON lamination, shall make it possible to obtain the correct length.
	<ul style="list-style-type: none">– Outer end plate

The 27th set shall make it possible to adjust the length of the yoke to 1100 \pm 0.5 mm measured along the 4 edges after the gradual tightening of the 4 tie rods -- insulating rings -- washers and M18 nuts to a torque of 50 Nm.

It is usually necessary to insert a number of shims to be distributed among the last sets to ensure that the final end face of each yoke is properly perpendicular.

Handling, inspection, placing, preparation for transport

The tooling shall then be set to the "yoke removal" position and the yoke shall be removed from the tooling using the special lifting beam supplied by CERN; this lifting beam makes it possible at the same time to turn the yoke through 90° and, in an initial phase, to place it on an inspection plate in the inverse position to its final one.

The final inspection of adherence to tolerances and a measurement of the insulation resistance of the yoke shall be performed on this plane insulating inspection plate or bench (not supplied); any necessary finishing work, including refitting on the assembly tooling, shall be done.

The yoke shall then be raised again using the lifting beam, turned through 180° and placed and secured to the transport and storage support (drawing 8032.16.526.0).

The yoke, firmly secured to its support, shall then be placed in a waterproof box for dispatch to CERN as set out in § 6.

5 INSPECTIONS

5.1 Identification procedure

- The yokes shall be numbered in order of their assembly from 201 G (left) and 201 D (right) to 210 G and 210 D.
- The number shall be engraved on the edge and the visible surface of each end, central and outside plate.

5.2 Mechanical inspections

General

The mechanical inspections shall be made by the manufacturer at his premises before delivery to CERN. CERN's inspectors may make some inspections at the manufacturer's premises.

They shall be provided with the necessary staff and equipment for these operations as quickly as possible.

Mechanical inspections of the laminations

The first laminations shall be inspected when they are cut out, in the presence of CERN's inspectors.

Any non-plane lamination or those with burrs exceeding 0.03 mm will be rejected.

On the few special laminations, any burrs exceeding 0.03 mm may be filed off by hand.

All the dimensions of drawing 8032.6.60.2 shall be checked on the first laminations.

The size of the air gap shall be checked at the same time as the flashes.

Mechanical inspections of the assembled yokes at the manufacturer's premises

An inspection sheet, on which the results of the various inspections shall be entered, shall be drawn up in consultation with CERN for each previously numbered yoke (§ 5.1)

The form of the sheet will be determined with the manufacturer before construction work is started.

5.3 Electrical insulation

5.3.1 Sheet-steel surface insulation

The insulation of the laminations may be measured on a set of 10 using tooling provided by CERN; the 4 columns shall be tightened by means of a dynamometric spanner set to 50 Nm; the DC. potential difference measured for a 10 A current shall be at least 330 mV, corresponding to a surface insulation of 1 Ohm.cm². This surface insulation figure is the minimum to be obtained before the laminations are assembled. Each box of about 350 laminations shall be inspected, a set of 10 shall be taken and carefully measured and then returned to the same box. The results shall be recorded on the relevant inspection sheet.

5.3.2 Yoke insulation

Once the yoke has been finally assembled, its longitudinal electric resistance shall be checked by means of the megohmmeter supplied. The resistance shall not be lower than 10 MΩ.

5.4 Inspections at CERN

A full mechanical inspection will be made again after transport to CERN. The electrical resistance of each assembled yoke will be measured again, overall and set by set.

The manufacturer will be immediately informed of any faulty yoke. Where appropriate, the manufacturer may, at his own expense, send an inspector to confirm the correctness of the inspections made at CERN.

Yokes found to be faulty will be returned to the manufacturer's premises, at his expense, for repair or replacement within the shortest possible times.

6 PACKING TRANSPORT

The assembled yokes are very sensitive to shocks, which would destroy their straightness and planeness.

Damp and bad weather can also damage the electrical insulation.

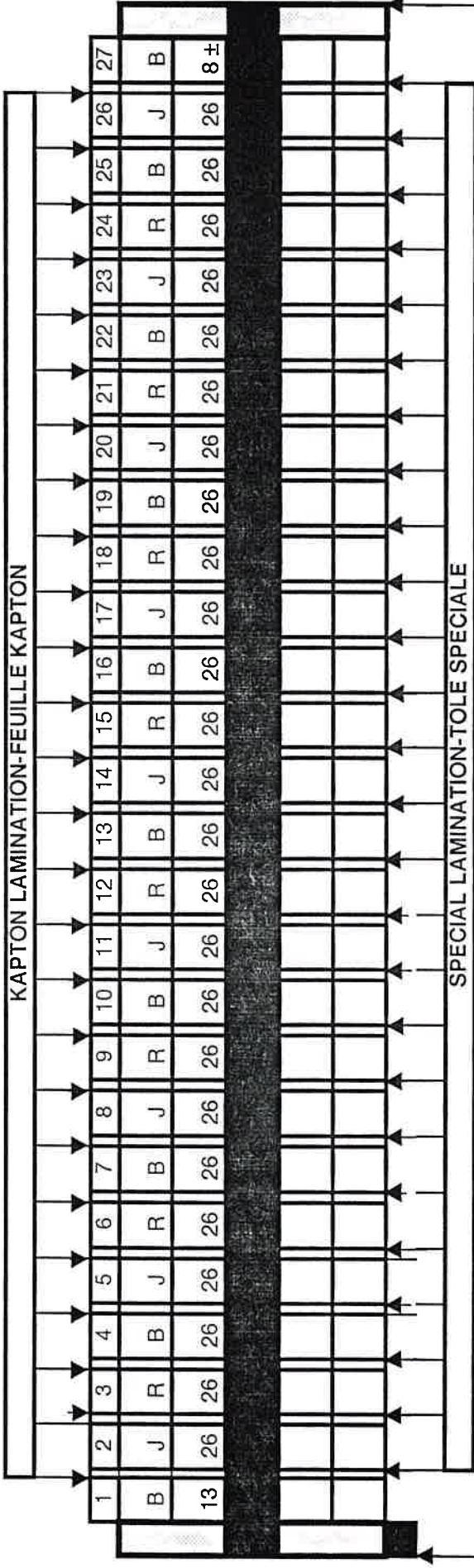
After the mechanical and electrical inspections, the yokes shall be firmly secured to their transport support and the whole shall be cleanly packed inside wooden boxes lined with a material which is proof against dust, shavings and damp, in order to prevent any deformation or damage to the yokes during transport.

For the production of the 20 yokes, CERN proposes to provide only 16 transport supports (§ 2.4) to be used for the first deliveries and to be returned in good time with the waterproof boxes to the manufacturer for the subsequent deliveries.

With the final yokes, the manufacturer shall, at his own expense and on his own responsibility, return to CERN all CERN's tooling and any which have been made for the proper completion of this order, together with the boxes of mild steel sheet not used for this order, whether full or not.

**MS CORE ASSEMBLY LEFT/ RIGHT OR MSE MST.Core number
CONSTRUCTION CULASSE GAUCHE/ DROITE MSE OU MST.Numero de culasse :**

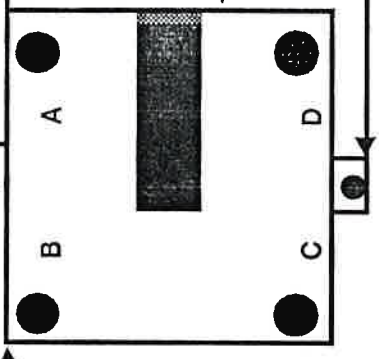
**Right-droite
Left-gauche**



PLAQUE D'EXTREMITE CENTRALE
END PLATE CENTRAL

PLAQUE D'EXTREMITE EXTERIEURE
END PLATE EXTERIOR

▼ Mesure de la rectitude +/- 0.15 mm :
R1

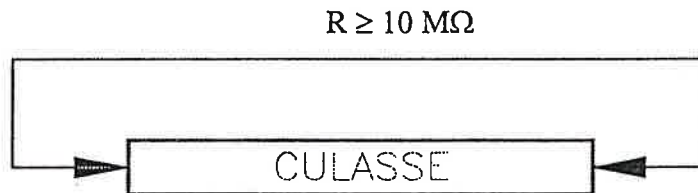


← R2
Mesure de la rectitude +/- 0.15 mm :

Nombre de tôles utilisées	
Blanches :	
Jaunes :	
Rouges :	
Total :	

Longueur culasse : 100 mm +/- 0.5	
A-A' =	
B-B' =	
C-C' =	
D-D' =	

← Suivant orientation de la découpe de la plaque. culasse droite ou gauche

Resistance measurement of cores
Mesure de résistance de culassesTools used : Megohmmeter
Appareil utilisé : MégohmmètreR = Identification of core : No
R = Identification de culasse : NoResistance of Core $\geq 10\text{M}\Omega$
Résistance de Culasse $\geq 10 \text{ M}\Omega$ Date :
Controlled by
Controlé par

