TECHNICAL SPECIFICATION

SPECIFICATION FOR PULSED BENDING MAGNETS

FOR THE INJECTION LINES TO THE CERN 28 GeV PROTON SYNCHROTRON

AND THE BOOSTER INJECTOR

P. Bossard
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</table>
1. INTRODUCTION

(see drawing SI 1.13.1002.0)

1.1 General

In order to extend the facilities of the 28 GeV CERN Proton Synchrotron, i.e. to inject the beam from the linear accelerator alternately into the future Booster accelerator or the main Proton Synchrotron, one or two pulsed switching magnets are required, referred to as IB 1 and IB 2.

The switching magnets as described in this specification shall produce uniform magnetic fields for the deflexion of beams of charged particles. Since the magnets will also be supplied with pulsed direct current, their cores must be made of insulated steel laminations.

1.2 Types of magnets - Main parameters

The two switching magnets IB 1 and IB 2 have different gap heights, but are identical for all other dimensions.

The magnets are water cooled by means of an electrically independent cooling layer, supplied with town water or demineralized water.

Both magnets are provided with dismountable end blocks to allow for future individual trim of the magnet end fields.
<table>
<thead>
<tr>
<th>MAIN PARAMETERS</th>
<th>IB 1</th>
<th>IB 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Steel</strong></td>
<td></td>
<td></td>
<td>cm</td>
</tr>
<tr>
<td>Pole gap</td>
<td>10.0</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>Pole width</td>
<td>40</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Core length</td>
<td>0.9</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Equivalent length</td>
<td>1.0</td>
<td>1.0</td>
<td>m</td>
</tr>
<tr>
<td>Gap field density</td>
<td>3.0</td>
<td>1.0</td>
<td>kG</td>
</tr>
<tr>
<td>Core field density (max)</td>
<td>10</td>
<td>4</td>
<td>kG</td>
</tr>
<tr>
<td><strong>Coil</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of turns</td>
<td>120</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Resistance (max. at 20°C)</td>
<td>50</td>
<td>50</td>
<td>mΩ</td>
</tr>
<tr>
<td>Inductance</td>
<td>100</td>
<td>80</td>
<td>mH</td>
</tr>
<tr>
<td>Current pulsed or continuous d.c.</td>
<td>210</td>
<td>88</td>
<td>A</td>
</tr>
<tr>
<td><strong>Pulsed operation, d.c.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rise time voltage (max.)</td>
<td>200</td>
<td>200</td>
<td>V</td>
</tr>
<tr>
<td>Flat top current</td>
<td>210</td>
<td>88</td>
<td>A</td>
</tr>
<tr>
<td>Flat top length (min.)</td>
<td>100</td>
<td>100</td>
<td>ms</td>
</tr>
<tr>
<td>Repetition rate (max.)</td>
<td>1</td>
<td>1</td>
<td>cps</td>
</tr>
<tr>
<td><strong>Continuous operation, d.c.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>210</td>
<td>88</td>
<td>A</td>
</tr>
<tr>
<td>Power consumption</td>
<td>2.4</td>
<td>0.5</td>
<td>kW</td>
</tr>
<tr>
<td>Water flow rate (min.)</td>
<td>4</td>
<td>4</td>
<td>L/min</td>
</tr>
<tr>
<td>Pressure drop (max.)</td>
<td>2</td>
<td>2</td>
<td>atm.</td>
</tr>
<tr>
<td>Temp. rise of water (max.)</td>
<td>10</td>
<td>--</td>
<td>°C</td>
</tr>
<tr>
<td>Temp. rise, copper/water</td>
<td>20</td>
<td>--</td>
<td>°C</td>
</tr>
<tr>
<td><strong>Weight (total, excl. base)</strong></td>
<td>4.2</td>
<td>4.2</td>
<td>tons</td>
</tr>
</tbody>
</table>
1.3 Scope of the tender

Tenders are asked for two different cases, A or B, as follows:

A) 1 magnet type IB 1, with the option of ordering later
   1 additional item type IB 2,

B) 1 magnet type IB 1 and
   1 magnet type IB 2, ordered at the same time.

It is understood that all items shall be manufactured,
tested and delivered to CERN, at Meyrin, according to the present
specifications. All ancillary equipment must be supplied and
mounted by the manufacturer, so that after delivery the magnets
are ready for immediate service.

Tenders must not include the manufacture of any part
of the supporting base, which will be ordered separately by CERN.

1.4 Access to information and tests

It is demanded that CERN be informed about all technical
details of the construction and of any subcontracting. The
contractor must supply three complete sets of fabrication drawings,
for internal use at CERN.

CERN also demands the rights of access to the factory during
manufacture and to have a representative present at all tests described
in this specification.

1.5 Guarantee

The attached drawings are the result of an initial study.
The manufacturer is entirely responsible for his design and must
guarantee for a faultless construction of the magnet.
One year after acceptance, all characteristics must still meet the present specification.

The formal acceptance of the magnets will be postponed until they have been excited to full magnetic field and their parameters measured at CERN. This testing shall take place within three months after delivery.

1.6 Delivery

CERN is interested in a short term for delivery of the magnets, possibly 8 (eight) months after the date of the order for magnet IB 1, and 12 (twelve) months for IB 2.

2. MAGNETIC CIRCUIT

(see drawing SI 1.13.1002.0)

2.1 Mechanical construction of the core

The core consists of phosphate insulated laminations of silicon steel transformer sheets which are held together by insulated bolts between end plates of magnetic material (low carbon magnet steel).

The core must form a consistent block, in order to assure absolute mechanical stability, within the tolerances as given below.

The ancillary equipment (instruments, connections, coil supports etc.) must be mounted on the end plates, or fixed to the core by means of dovetail slots or welded on strips. It is not permitted to drill and tap directly into the laminations.
It is understood that the manufacturer may propose a core construction different from that shown on the drawing. For example, in the case of a welded core with strips on the outside, the tool costs for the laminations may be considerably smaller, as no holes or dovetail slots would be required at all.

**Tolerances:**

To obtain the required uniformity of the magnetic field the following tolerances must be adhered to, in addition to those given on the drawings:

a) The gap height must be within $\pm 0.1$ mm (at magnet centre).

b) Transversally the pole faces must be flat and parallel within 0.02 mm (determines tolerance of laminations)

c) Longitudinally the pole faces must be flat and parallel within $\pm 0.1$ mm (determines tolerance of stacking and rigidity of the finished core).

d) The reference surface situated on top of the magnet must be parallel to the horizontal centre plane within 0.01 mm and at the nominal distance within $\pm 0.1$ mm

**Inspection:**

Before assemblage, the single laminations will be inspected by a representative of CERN. The core dimensions will be checked before and after the assemblage of the complete magnets. About suitable methods and measuring equipment shall be discussed later but in principle the manufacturer must supply the instruments as templates, micrometers, optical devices, etc. required for this examination.

Moreover, it must be proved that the rigidity of the core is sufficient to guarantee for mechanical stability with time.
Normal handling, transport etc. must not affect the dimensions specified above.

Finish:

Except for the gap surfaces which must be protected by an agreed rust preventive only, the whole magnet core must be painted with at least one coat of priming and two finishing coats of an enamel to be selected in agreement with CERN.

2.2 Magnetic properties of the core material

The coercive force must be rather small, in order to obtain a low remanent field. Therefore, the use of high grade silicon steel transformer sheets is proposed. It is strongly preferred that a standard quality, 0.5 mm or 1.00 mm thick is used, although from the point of view of eddy current a higher lamination thickness may be acceptable. The following magnetic characteristics must be guaranteed for the silicon steel laminations and the low carbon solid steel end plates:

- coercive force smaller than 0.5 and 1.0 A/cm respectively
- flux density for 10 A/cm larger than 13000 Gauss.

The manufacturer must supply at least one sample of each roll of steel of which the magnets will be made. To conform to our existing apparatus the samples must be rings of stacked laminations having an inner diameter of 76 ± 0.1 mm, outer diameter 114 ± 0.1 mm and a height of 15 ± 0.1 mm. Square sheets, approximately 130 x 130 mm² large, are also acceptable, to be stamped at CERN with existing tools.

The samples will be measured at CERN and must satisfy the specification as detailed above. CERN reserves the right to reject magnets presenting irregularities of the magnetic field caused by defects in the iron body (reference is made to section 1.5 about the formal acceptance).

In the event of irresolvable disputes concerning the results of magnetic measurements a neutral institution will be asked to arbitrate.

PS/7265
3. EXCITING COILS

(see drawing 1.13.1003.0)

3.1 Conductor material and dimensions

The conductors must be made of electrolytic copper having a resistivity inferior to $1.76 \times 10^{-8}$ ohm.m at 20° C. Preference should be given to a OFHC or a similar type of copper, free from gas, which can be brazed without difficulties.

The profile of the conductor is a rectangle of 4 x 40 mm² with slightly rounded-off corners, and a minimum cross-sectional area of 150 mm².

The manufacturer must guarantee that the resistance measured between the main terminals shall not exceed the maximum values given on page 5 (table).

The profile of the conductor used for the cooling layer is a rectangle of 10 x 10 mm², with a central cooling duct with a 8 mm Ø circular or a 7 x 7 mm² square shape.

3.2 Construction and insulation of the coils

Temperature gradients due to water cooling and magnetic forces subject the coils to heavy mechanical stresses. The manufacturer must assume complete responsibility that the coils will satisfy all requirements for the tests described hereafter and assure undisturbed safe operation lasting for years.

The coils consist of two layers, with an intermediate layer for indirect water cooling, in other words of double pancakes water-cooled from the inside.
Although the cooling conductors are not electrically powered, they must be insulated between turns, in order to avoid field distortions due to eddy currents. In order to have both water connections situated on the outside of the coils, the cooling layer is wound from two parallel conductors, with a joint at the inside of the coil for water reversal.

Since the inlet temperature of the cooling water may be as low as 10°C, i.e. below the dewpoint of the surrounding atmosphere, the coils may be completely wet with condensing water. It is therefore important that the insulation be guaranteed watertight to avoid short circuits under these circumstances.

The maximum temperature rise of the coils being as high as 40°C, the difference of thermal expansion between the conductors would amount to 1...2 mm if they could move freely. The coils must be constructed in such a way and the insulation must be sufficiently strong and elastic that even a large number of thermal cycles will not deteriorate the state of the insulation.

The insulation for the individual conductors and the mass-insulation of the coils must be built up with tapes consisting of glass and integrated mica. No other materials (i.e. cotton, mica foils etc.) are admitted. The tapes must be of the type specially treated in order to obtain a good adhesion to epoxy resins. For the same reason the conductors must be carefully cleaned with acetone or a similar solvent immediately before the insulating process.

All parts of the coils must be impregnated under vacuum. The choice of the epoxy resin and details of the impregnation procedure are the responsibility of the manufacturer. In principle, it is also permitted to employ epoxy pre-impregnated tapes which do not necessarily imply a further vacuum treatment, but adequate measures must be taken to obtain a quality as high as by proper vacuum impregnation.
Before the construction of the coils can be started, the manufacturer must submit a few samples consisting of the insulation to be employed, applied to conductors of comparable dimensions.

3.3 Cooling and thermal protection

The hydraulic connections between the coils and the main water manifolds must be made by means of radiation resistant rubber hoses which are fitted with usual hose-clips.

All brazings must be carried out with great care. The manufacturer is entirely responsible that no obstruction nor leakage may occur even after prolonged magnet operation. Possibly solder without demand for additional brazing flux should be employed.

The whole cooling system must be electrically insulated from the iron yoke. Therefore it is indicated to mount all ancillary equipment, as the instruments, the main couplings etc. on insulating panels.

Since demineralized water may be used, all metallic parts inside the cooling system must be made of copper, stainless steel or bronze. However, certain standard parts made of brass may exceptionally be tolerated.

The maximum pressure of the cooling water may be as high as 16 atm, and the maximum outlet temperature 50°C. The cooling system must be suitable for continuous operation under these conditions.

A list of CERN standard parts is given in section 4.5. All instruments as described in the following must be purchased accordingly.

The main inlet and outlet water couplings are standard. Before entering the manifolds, the water passes through a standard filter with apertures smaller than 0.5 mm.
To monitor the inlet pressure a manometer having a range of 1...16 atm must be used with a pair of insulated auxiliary contacts which open whenever the pressure is out of a certain adjustable range (minimum and maximum settings).

Near each water outlet (the thermometer shown on the standard drawing is not used for this particular case and replaced by "MICROTHERM" temperature switches) and on the outside surface of each pancake small temperature sensitive switches must be mounted, provided with auxiliary contacts which open whenever the temperature reaches 90°C. To improve the heat transmission it is desirable to make the insulation between the sensors and the conductor as thin as possible. However, it must still withstand the high voltage tests described hereafter. All temperature sensors must be wired to a central terminal strip where they are connected in series.

It is suggested to use the standard "MICROTHERM" elements, but other makes of comparable characteristics are acceptable as well.

All above interlock-contacts and some other devices (emergency stop button, signal lamp relay etc.) must be connected to a standard multiple plug, part of a central control box mounted near the electric main terminals.

3.4 Electric terminals

The connections to the coils are made with insulated copper bars or cables, adequately fixed to the yoke of the magnet. To conform to our existing supply cables, the terminals have to be made as indicated on the drawings.

3.5 Mounting of the coils - Protective covers

The coils must be carefully fixed to the steelwork by means of supporting jacks and clamps, so that the pulsed mechanical forces caused by the magnetic field cannot damage any part. Rubber pads
must be inserted between the coils and all supports.

Near the connection end of the magnet a removable protective cap must be mounted, covering at least the main terminals and all other electric connections of the coils. It must be made from non-magnetic material, insulating or insulated on the inside (moulded fibreglass, welded PVC, inside coated metal etc. are suitable) and of a colour to be selected in agreement with CERN.

3.6 Leak and flow tests

a) Leak tests of the conductor bars

Before the construction of the coils can be started, the watertightness of the cooling conductor, as delivered by the manufacturer, must be proven. Therefore the conductor must be pressurized to 60 atm (with air under water or water only). Conductors which show any evidence of a leak must be rejected.

b) Leak test of the joints

It is essential to verify that the brazings inside the coils and at the end connections are absolutely watertight before they are insulated. Therefore the assembled coils must be pressurized to 60 atm (with air under water or water only) before such connections are insulated.

c) Leak and flow tests of the finished coils

The finished coils (unpainted) will be inspected by a representative of CERN. The water flow in each circuit for nominal pressure drop must be measured. It should be essentially equal for equivalent circuits and correspond to the minimum values given on page 5 (table). The finished coils must be pressurized to 40 atm (with air under water, or water only). No evidence of a leak must appear.
d) **Leak test of the finished magnet**

The whole cooling system of the finished magnet must be pressurized with water to 30 atm. It must be absolutely watertight.

The manometer must be disconnected during this test.

### 3.7 Electric tests

After the hydraulic test specified above, the finished coils must be prepared for the succeeding electric tests.

In principle, each high voltage test as specified hereafter, must be performed in the following way:

Before and after the high voltage test, the insulation resistance must be measured with at least 1 kV d.c. It must not be smaller after the test (10 % tolerance). However, if it appears to have dropped by more, succeeding tests of half duration must be applied until the insulation resistance stabilizes or breaks down.

a) **Thermal cycling (sample test)**

CERN reserves the right to select whatever coils to be cycled as follows:

The coil must be energized at nominal current until a temperature rise of 45 ... 50°C is reached. After the coil has completely cooled off it must be energized again and so on. Thermal cycling must be made not before one week after the impregnation.

After 50 complete cycles the insulation must not show any sign of degradation and furthermore satisfy the following
high voltage tests.

b) Conductor-to-ground insulation high voltage test

After 6 ... 12 hours of complete submersion under water at ambient temperature the coils must be lifted out and wrapped into wet cloths, used as artificial ground. A test voltage of 5 kV rms at 50 cps must be applied between the coils and ground for one minute.

c) Inter-turn insulation induced voltage test

Immediately after the high voltage test a voltage of 20 V rms per turn must be induced to the coils for one minute. For this test the coils should be used as the secondary of a transformer at a frequency of some hundred cps. The primary current and the induced voltage must not vary during the whole test period. The manufacturer may propose a different method to detect inter-turn short circuits.

d) Electric tests of the finished magnets

The completely assembled magnets will be inspected as follows:

- 5 kV high voltage test:

  5 kV rms at 50 cps must be applied between the coil and the iron body for one minute.

- 2 kV high voltage test:

  The circuit of the temperature sensors must be tested with a voltage of 2 kV rms, for one minute against the coil and for one minute against the iron body. The same applies to the interlock circuits.

- The wiring of the interlock system must be checked.

- The resistance of the coil must be verified. It must not exceed the maximum values given on page 5 (table).
- The d.c. parameters and the cooling performance must be checked with a test run at nominal direct current.

- The a.c. parameters, in particular the insulation of the core structure, must be checked with a test run, possibly at 50 cps alternative current.

- The above tests, performed during the final inspection at the factory, will be repeated after delivery at CERN. The high voltage tests will be performed with 20 °/o lower voltages.

4. MISCELLANEOUS

4.1 Marking plate

In a suitable position the magnets must be marked with the following:

1. Max. voltage                   6. Permissible temperature rise
2. Flat top current                7. Water flow (i/min), nom.
4. Inductance                     9. Iron length
5. Flat top field                 10. Magnet weight

4.2 Technical information to be furnished by the manufacturer

a) Details of the mechanical, magnetical and chemical properties of the steel: address of supplier(s).

b) Mechanical and electrical properties of the copper and insulating material: address of supplier(s); detailed description of the insulating and impregnation procedure.

c) Name and address of any subcontractors.

d) Any important technical modification with respect to the present specification.

e) The essential time schedule of manufacture followed by monthly progress reports.
4.3 List of samples to be furnished by the manufacturer

<table>
<thead>
<tr>
<th>Subject</th>
<th>Quantity</th>
<th>Ref. (para.)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>1 per magnet</td>
<td>2.2</td>
<td>1 item to be taken from each roll of steel sheet</td>
</tr>
<tr>
<td>Copper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric conductor</td>
<td>0.5 m</td>
<td>3.1</td>
<td>bare copper</td>
</tr>
<tr>
<td>Cooling conductor</td>
<td>0.5 m</td>
<td>3.1</td>
<td>bare copper</td>
</tr>
<tr>
<td>Brazings</td>
<td>2 ... 3 items</td>
<td>3.2/3.3</td>
<td>electrical and water connections of the coil</td>
</tr>
<tr>
<td>Insulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coil structure</td>
<td>1 item</td>
<td>3.2</td>
<td>conductor + mass insulation</td>
</tr>
<tr>
<td>Paint</td>
<td>sample card</td>
<td>2.1/3.5</td>
<td>for selection at CERN; iron body, protective covers</td>
</tr>
</tbody>
</table>

Other samples:

It is indicated to supply some more samples as from materials used for general purposes (wires, terminal strips, insulating plates etc.)
4.4 Transport

The transportation of the magnets from the place of manufacture to CERN is the responsibility of the contractor.

CERN must be notified of the dispatch of each magnet, the transporter and the estimated time of arrival at CERN.

4.5 List of CERN standard accessories

The following items will be delivered by CERN, free of charge:

- 1 water filter, 1/2" G, bronze
- 1 pair of water couplings, 1/2" G (main water connections)
- 1 manometer 0 ... 16 atm, with interlock contact (on water inlet)
- thermometer is NOT used. Replaced by "MICROTHERM" temperature switches on water outlet
- 6 "MICROTHERM" temperature switches, 90° C (2 on water outlets, 4 on coil surfaces)
- radiation resistant rubber hoses, incl. hose clips
- the components of the control box:
  1 relay, 1 multiple connector (Burndy, 12 pins),
  1 emergency stop button switch.
Coupe AA

Coupe BB, 6e ch. 7

Coupe CC, 6e ch. 7

Poids culasse : 37 T
II bobine 0,5 T
II total 42,5 T.
Tous les pilotherms en série sur bornes extérieures

Manomètre d'entrée 16 atm
double contact min-max.

Thermomètre de sortie 0-100°C
double contact min-max.

Arrêt d'urgence

Barette de connexion intermédiaire (a vis)

Cable ligne 10 fois 0,5 mm² blindé

Prise BURNDY 12 broches

ref : UT 02-14.12P.5T.

1 Commun
2 Pression eau
3 Temp. eau
4 Temp. enroulement
5 Arrêt d'urgence
6.7.8. Réserve
9 0 V
10 +48 V
12 Blindage cable

Alimentation auxiliaire

DESCRIPTION

POS.

MAT.

OBSERVATIONS

CIRCUITS SECURITE

POUR AIMANTS

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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