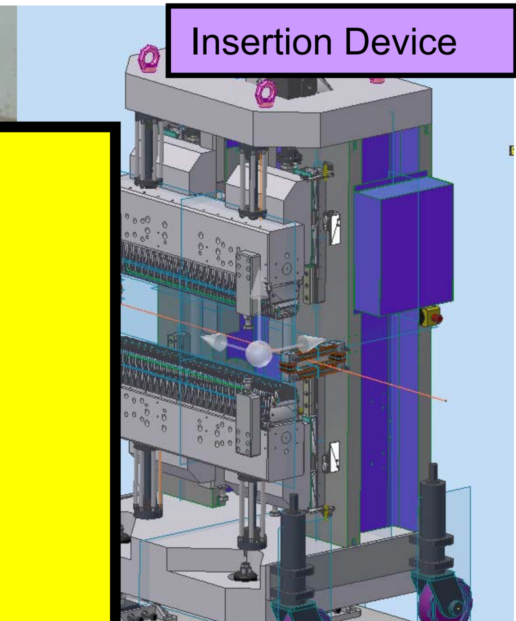

Specifications
Quality Control
Manufacturing
Testing
(Part II)

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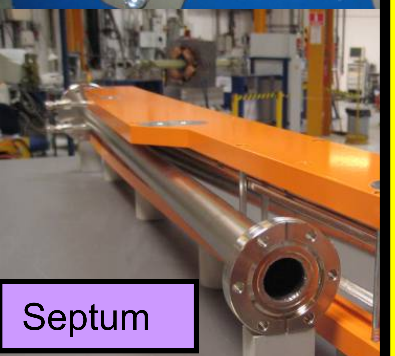
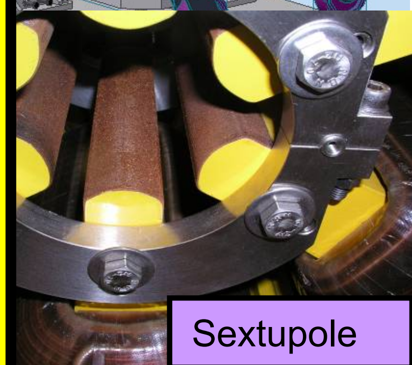
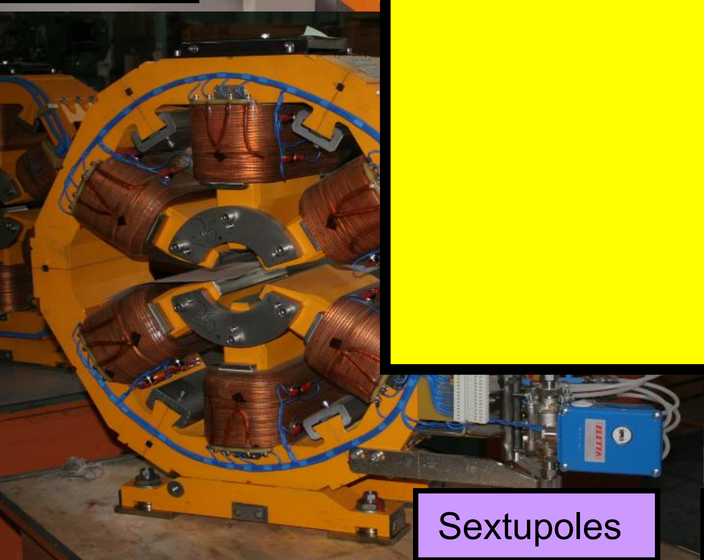
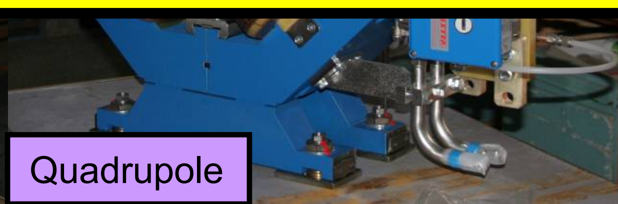
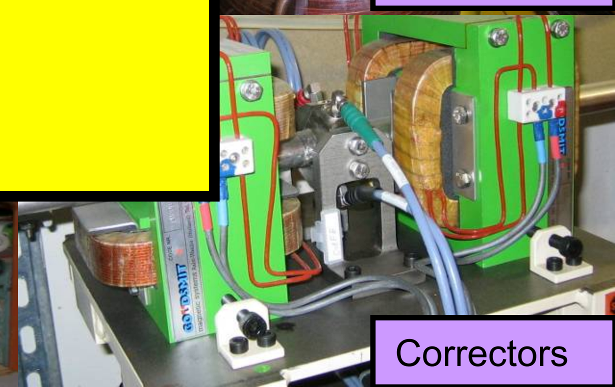










7.) Technical Specifications: Magnetic Steel

7.1)Steel characteristics for the magnet

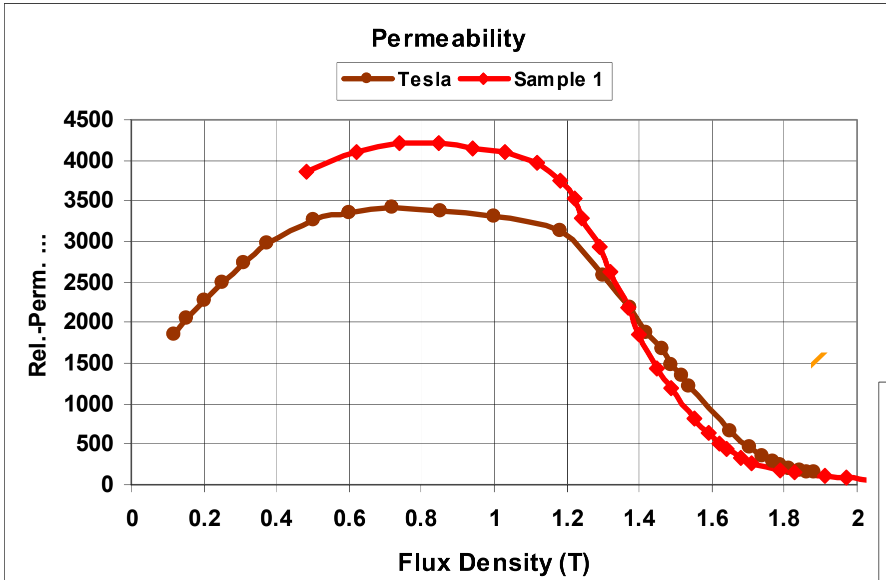
7.1.1) It is envisaged that this specification will be met by cold rolled, fully annealed, non-oriented, laminated steel.

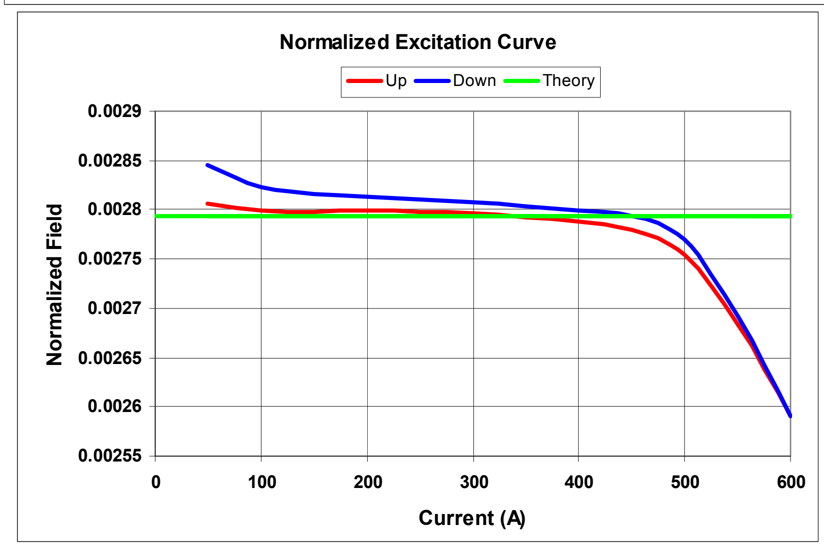
7.1.2)The table below gives the minimum values of induction under d.c. excitation acceptable at the stated values of field parallel to the rolling direction; values of relative permeability are shown for convenience. Tests are assumed to be made on strips, so that properties parallel and perpendicular to the rolling direction can be separately assessed. Induction measured perpendicular to the rolling direction shall be not less than 20% lower than the values given in the table below

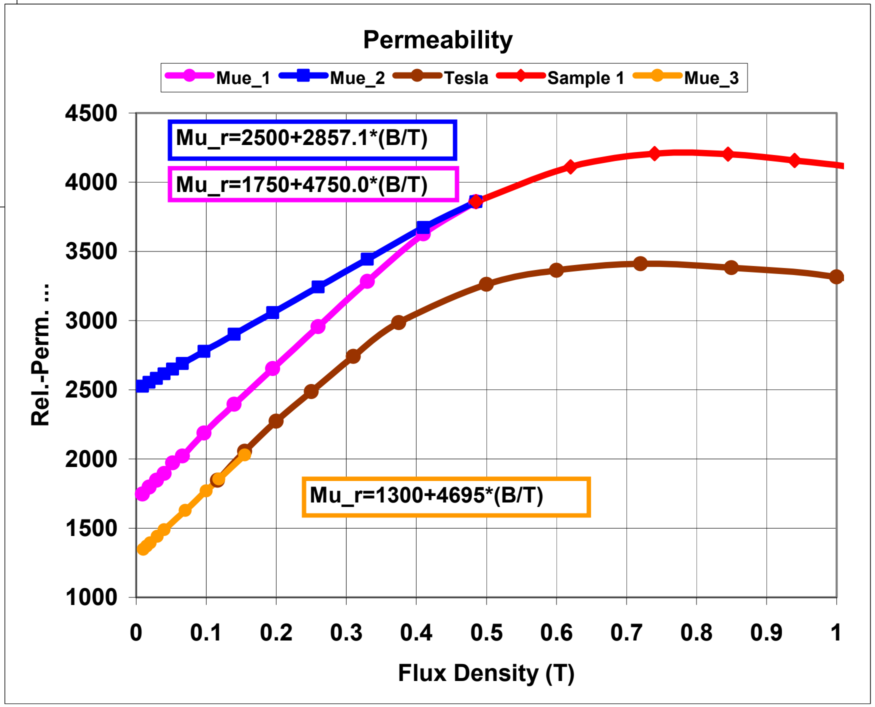
7.) Technical Specifications: Magnetic Steel

Magnetic field [A/m]	Minimum induction parallel to rolling direction [T]	Relative d.c. permeability
116	0.50	3430
208	1.00	3826
300	1.30	3448
597	1.50	1999
1343	1.60	948
3236	1.70	418
6855	1.81	210
12490	1.91	122

7.) Technical Specifications: Magnetic Steel







7.) Technical Specifications: Magnetic Steel

7.1.3)The coercitivity is defined as the field required to produce zero induction in a mixed sample of the steel after repeated cyclical excursions to high induction with a field of ≥ 10000.0 A/m.

Maximum allowed coercitivity in a single sample 80 A/m;
Maximum variation from the mean ± 15 %

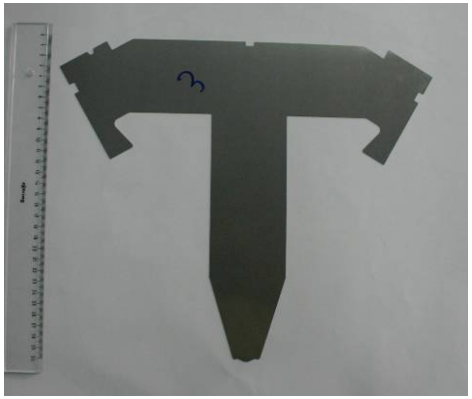
7.1.4)The steel magnetic properties shall be guaranteed on bulk samples after stamping without any further heat treatment or annealing.

7.1.5)The steel is required to be coated, at least, on one side with an inorganic insulating coating with a maximum thickness of 5 μm

7.2)Laminations

7.2.1)Nominal thickness of the lamination is 1 mm.

7.) Technical Specifications: Magnetic Steel



7.) Technical Specifications: Magnetic Steel

7.3) Testing of Steel

7.3.1)Steel is normally produced in 'batches'. All batches of steel produced by the steel suppliers shall have test samples taken from the beginning and end of the batch, together with a further sample from the middle of the batch. In exceptional circumstances, where tests on these samples indicate that a large variation of magnetic properties, greater than 15% peak-to-peak, is present within a single batch, CELLS shall be entitled to call for further samples to be taken at one quarter and three quarters through the batch.

7.3.2)All three samples of each batch shall have the following measurements carried out with a strip sample technique for properties parallel and normal to the rolling direction

i) Permeability at all values of induction specified in section 7.1.2;

ii) Coercivity as defined in section 7.1.3.

7.3.3)The surface insulation shall be checked on three samples taken at locations indicated above, using the standard insulation measuring technique of the steel manufacturer

7.) Technical Specifications: Magnetic Steel

7.3) Testing of Steel

7.3.4)The thickness of the steel shall be checked on samples, taken at locations indicated above.

7.3.5)The tenderers shall provide information at tender on the proposed methods for magnetic, electrical and physical measurements of the magnet steel.

7.4)Steel supplier

7.4.1)Steel of the described quality is available from a number of suppliers and the manufacturer has full liberty to choose any source of suitable material. CELLS believes that e.g. steel type 1200-100A coated on both sides with Stabolit 70 will comply with this specification. CELLS has identified the supplier for this steel:

ThyssenKrupp Electrical Steel GmbH (EBG)
Altendorfer Str. 120
D-45143 Essen
Germany

8.) Techn. Specs.: Laminations and Yokes

8.1)Laminations stamping

8.1.1)The manufacturer is responsible for achieving the required dimensional tolerances for all laminations to meet the mechanical specifications.

8.2)Lamination stamping tests

8.2.1)Prior to start production stamping and after each re-grinding of the stamping tools, a certain number of lamination will be punched and <u>three</u> of them shall be measured. In addition, after every 5000 laminations during the stamping operation, a lamination will be taken at random from the production line, and measured. The suitability of the lamination will be judged with respect to the lamination drawing that will have been approved by CELLS. The measurements shall be submitted to CELLS for approval.

8.2.2)CELLS reserves the right to be present during all such measurements.

8.) Techn. Specs.: Laminations and Yokes

8.2)Lamination stamping tests

8.2.3)The tested laminations, duly marked with an identifying label, shall then be made available to CELLS for independent verification of dimensional tolerances.

8.2.4)CELLS is entitled to reject any lamination which is not within tolerances, as specified in the appropriate drawing.

8.2.5)The maximum burr at any location on the lamination must not exceed 0.025 mm; no subsequent deburring operation will be permitted.

8.2.6)Re-grinding of the tooling must be carried out at such intervals as are necessary to maintain the required dimensional tolerances of all laminations.

8.2.7)After stamping, the laminations produced from each batch of steel shall be stored separately to allow the shuffling operation as described below to be undertaken. The batch of origin of all laminations shall continue to be identifiable.

8.) Techn. Specs.: Laminations and Yokes

8.2)Lamination stamping tests

8.2.8)In order to successfully carry out the shuffling operation, all steel delivered for use in Phase 2 of the contracts must be stamped and stored before commencing any further handling and processing operations on the laminations. The steel shall be protected against corrosion.

8.3)Laminations shuffling

8.3.1)This section applies only to laminations produced for use in the second phase.

8.3.2)The required magnetic identity between the magnets requires appropriate shuffling of the laminations in such a way that each magnet contains steel representative of each steel production batch, in roughly equal proportions. Manufacturers shall therefore plan a strategy to achieve this, taking into account the number of steel batches required for the magnet production, and the expected variation of magnetic properties within each batch.

8.) Techn. Specs.: Laminations and Yokes

8.) Techn. Specs.: Laminations and Yokes

8.3) Laminations shuffling

8.3.3)Final details of the shuffling process shall be agreed with CELLS; these will depend on the results obtained during the magnetic testing of the steel and the periodic measurement of the laminations defined in section 8.2.1.

8.4) Yoke

8.4.1)Tenderers shall indicate whether it is their intention to stack and glue laminations to produce yokes in a final state or whether it is their intention to stack and weld the laminations to produce a yoke

8.) Techn. Specs.: Laminations and Yokes

8.4) Yoke

8.4.2)Tenderers shall indicate whether it is their intention to perform further machining on one or more faces of the block after yoke assembly. Where such machining is proposed, tenderers shall give a clear explanation of how they intend to ensure that the specified dimensions required on the yoke will be achieved. In any case machining of the any part of the yoke is restricted to:

a.) Machining of the pole profile

b.) Machining of the reference planes for the alignment features, as set in section 3.5.

c.) Machining of the reference for the support feet

The pole has one machined end chamfer to correct the end field in order to provide the correct harmonic analysis. After magnetic measurements of the pre-series magnet the final shape of the end chamfer will be confirmed.

8.) Techn. Specs.: Laminations and Yokes

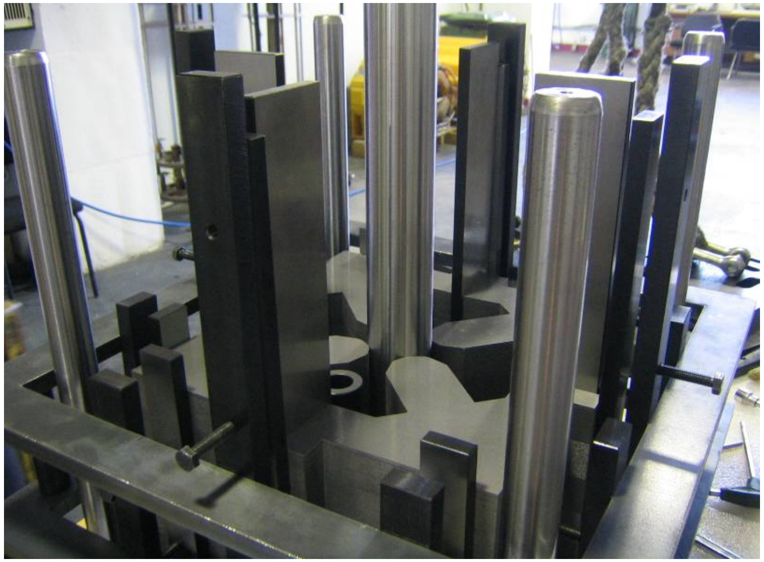
8.4) Yoke

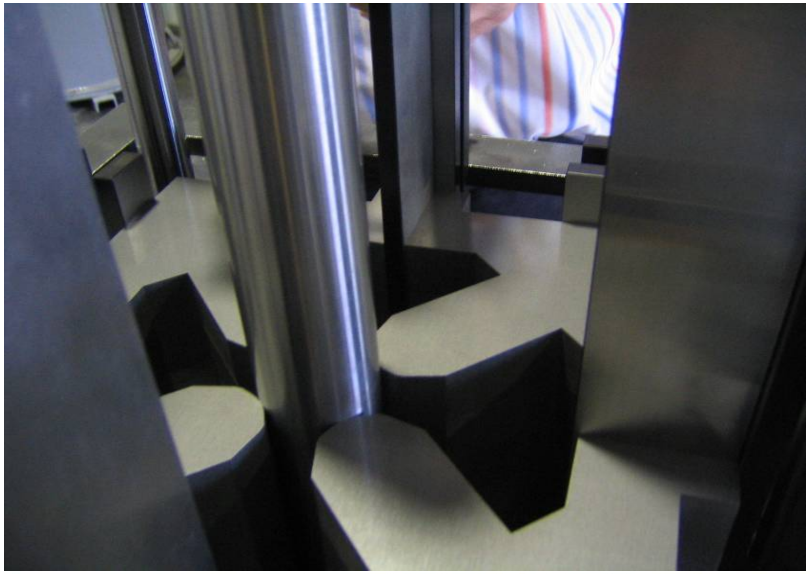
8.4.3)During the stacking of the initial pre-series, a record shall be kept of the weight of laminations used for the yoke. After acceptance of the pre-series, these weight will be defined as the standard weight of laminations in a given yoke.

8.4.4)During stacking of the production magnet yokes, the number of laminations to be included in the yoke will be determined by weight, and shall be within plus or minus half the weight of a single lamination of the standard weight of laminations in a yoke block.

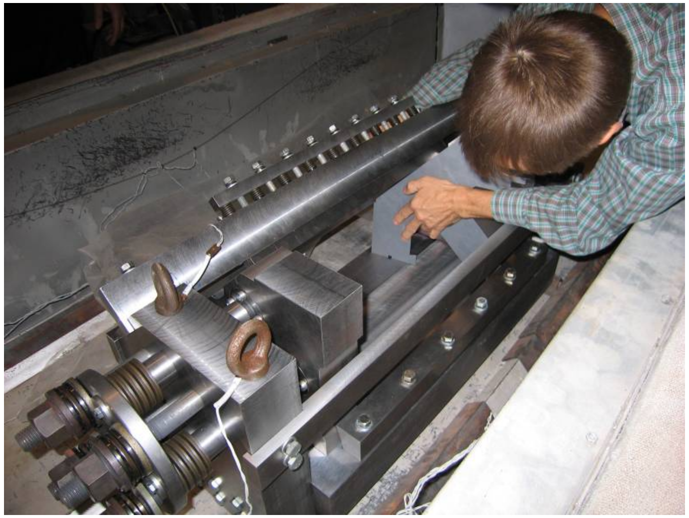
8.4.5)The packing factor has to be at least 98 % and has to be within ±0.5 % for all of them.

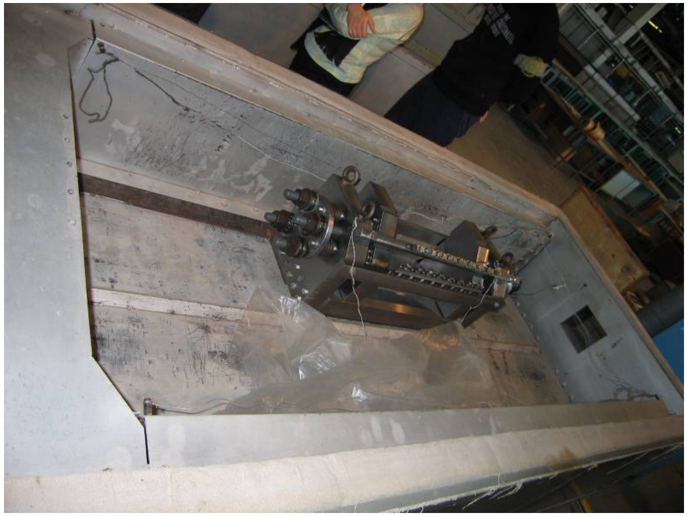
Stacking fixture



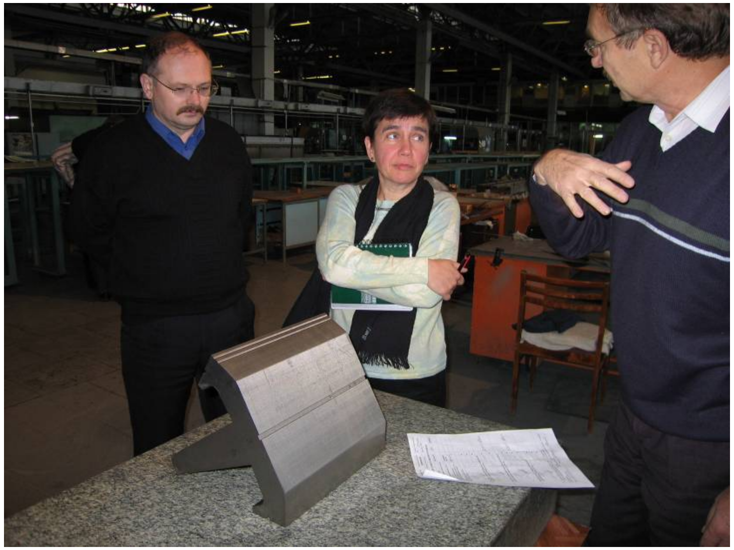


Fixture for the gluing Process





Mechanical Test of Yoke



8.) Techn. Specs.: Laminations and Yokes

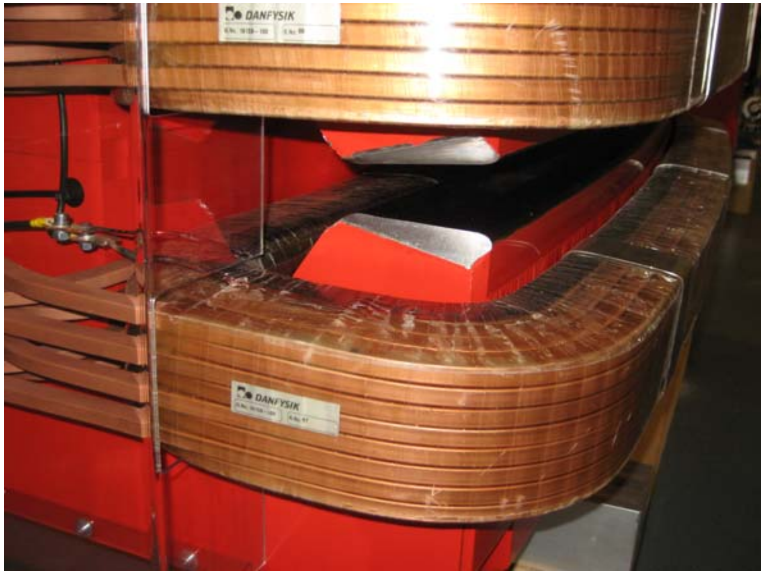
8.5)Bending magnet ends

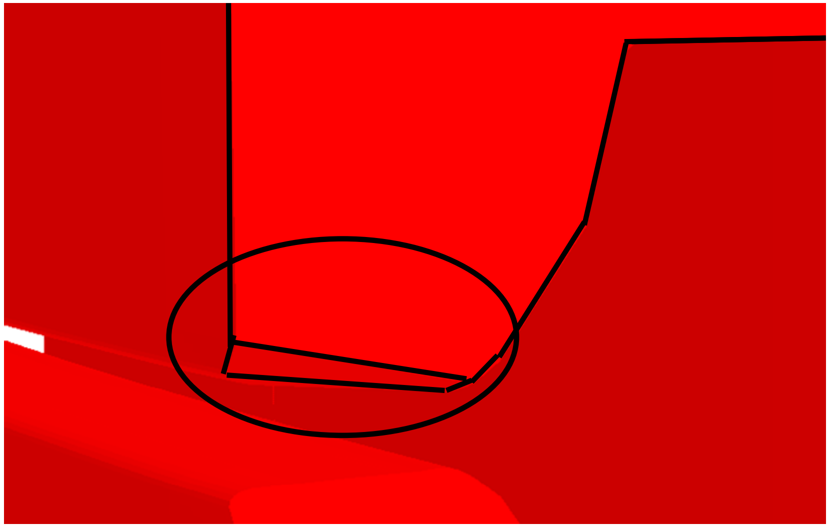
8.5.1)To control both the effective length and the integrated field quality of the bending magnet, the ends of the poles of each magnet will be chamfered, as specified on the appropriate drawing.

8.5.2)To decide the length and the angle of the end chamfer a set of different chamfers, as specified on the appropriate drawing, will be produced during the first phase and a set of magnetic measurements will be taken for the pre-series magnet equipped with all different chamfers. After evaluation of the magnetic measurements done by CELLS the length and angle of the end chamfer to be machined on the production magnets will be communicated to the manufacturer before the second phase starts.

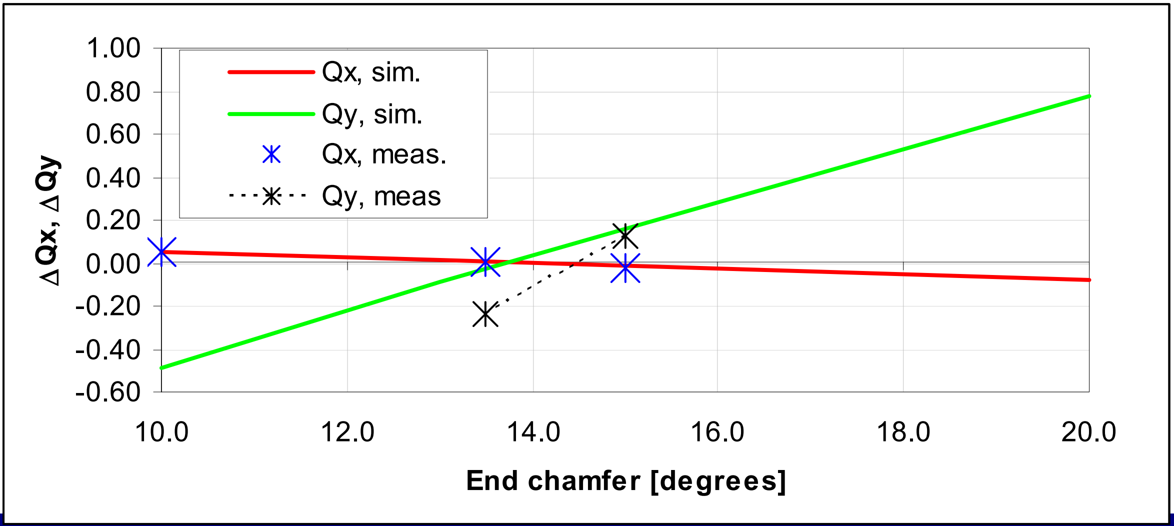
8.5.3)Irrespective of the technique used for producing the end modification, the laminations that are to be included in the end region of the poles will be taken from the same stock of shuffled laminations as the unmodified pole region.

8.) Techn. Specs.: Laminations and Yokes





chamfer	OPERA-3D	Measured
10.0º	8.2	8.1
13.5º	9.2	9.2
20º/15º	11.6	10.0



8.) Techn. Specs.: Laminations and Yokes

8.6)Mechanical yoke testing

8.6.1) After the laminations have been assembled and machined into a yoke the main geometrical dimensions will be carefully checked according to the tolerances of the relevant drawings. Features that shall be controlled are:

a.) Length measured at three different locations along the yoke.

b.) Flatness of the whole assembly

c.) Squareness of the sides and of the end faces

d.) Longitudinal shape of the yoke will be checked with a jig, the construction of which is part of this contract.

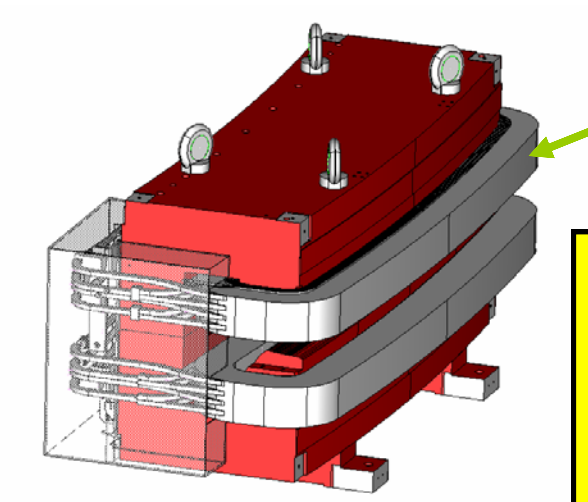
8.6.2)After assembling of the complete yoke the functional tolerances among which the distance between the reference surfaces on the top and bottom of the bending magnets and the median plane will be checked with the magnet both powered and unpowered. The dimensional controls are specified on the appropriate drawings.

8.) Techn. Specs.: Laminations and Yokes

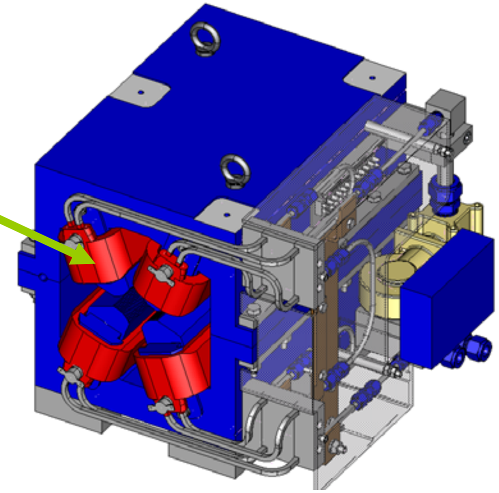
8.7)Protection and painting

8.7.1)After assembly and control, the yokes will be protected against rust by painting. Two-component epoxy paint shall be used, which the manufacturer shall ensure is hard and mechanically resistant. The unpainted areas, as indicated in the appropriate drawings shall be protected by a light oil or other rust preventative measures. The colour will be RAL 3026.

Size of Coils.



Coils



The currents and the windings of the coil have to make the excitation

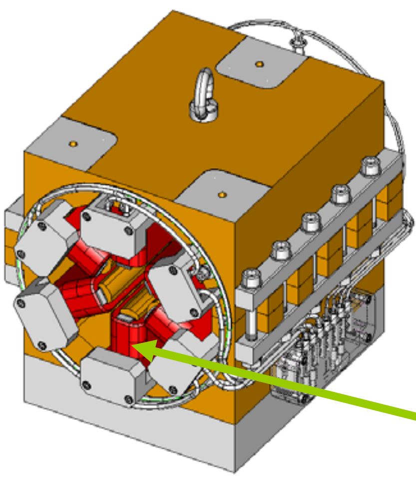
$$N*I = B_0(g+l_{Fe}/\mu_r)/\mu_0$$

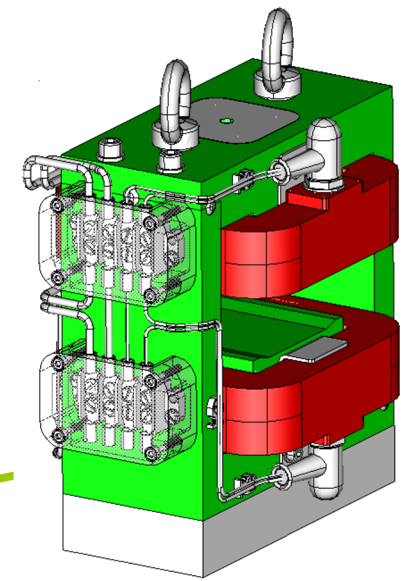
$$N*I \approx B_0 g/\mu_0$$

For the ALBA bending with a gap of 36 mm and a flux density of 1.42 T the excitation is:

$$N*I = 40680 \text{ A*Wdgs}$$

This can be done by a larger number of windings or a high current.

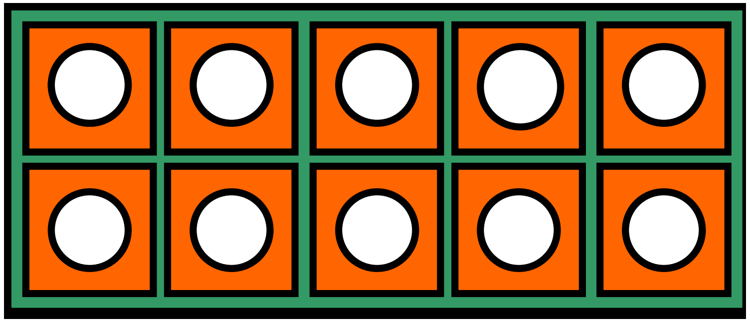




Coils

Coil Geometry

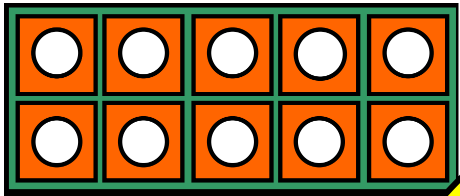
Standard design is rectangular copper (or aluminium) conductor, with cooling water tube. Insulation is glass cloth and epoxy resin.



Amp-turns (NI) are determined, but total copper area (A_{copper}) and number of turns (N) are two degrees of freedom and need to be decided.

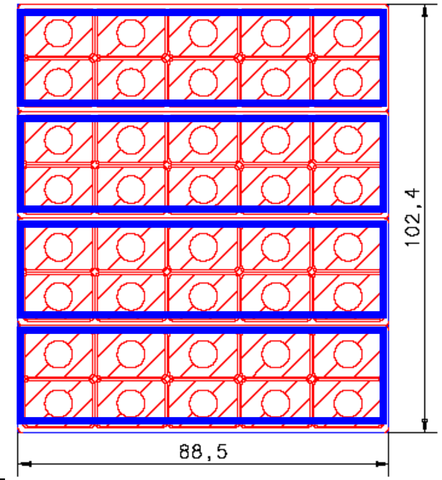
Current density:
$j = NI/A_{copper}$
Optimum j determined from **economic** criteria.

Size of the Coil

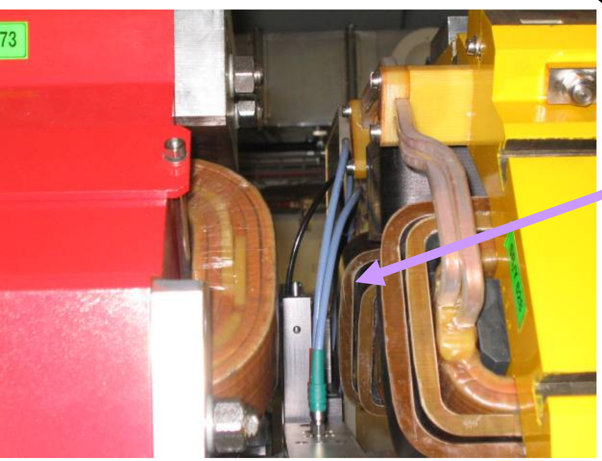


2 layers

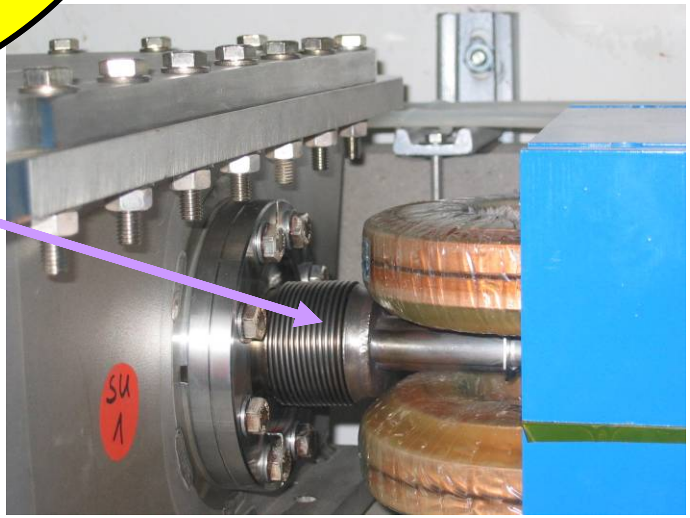
A small number of layers needs more space in the longitudinal directions. A high number of layers needs more space for the magnets in the vertical direction. For the number of layers one has to make a compromise and it depend upon the machine



8 layers / 4 pancakes



Space within the machine for the components should be as small as possible.



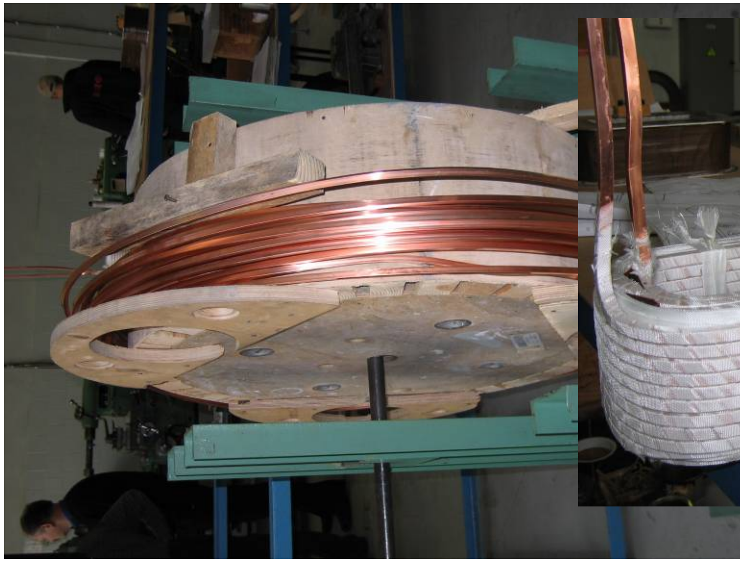
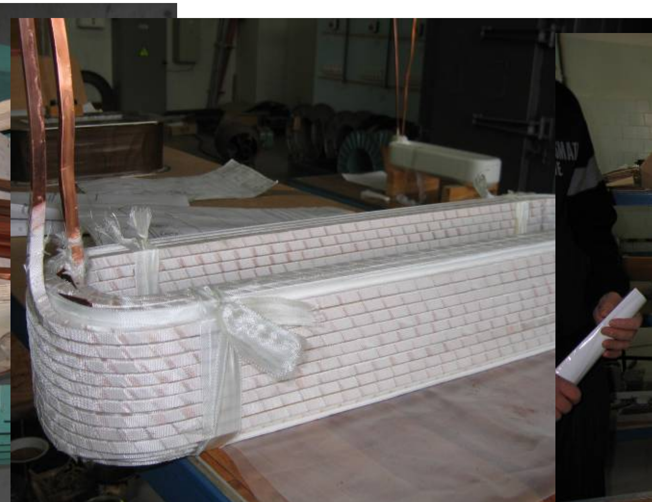
9.) Technical Specifications: Coils

9.1)Coils manufacturing

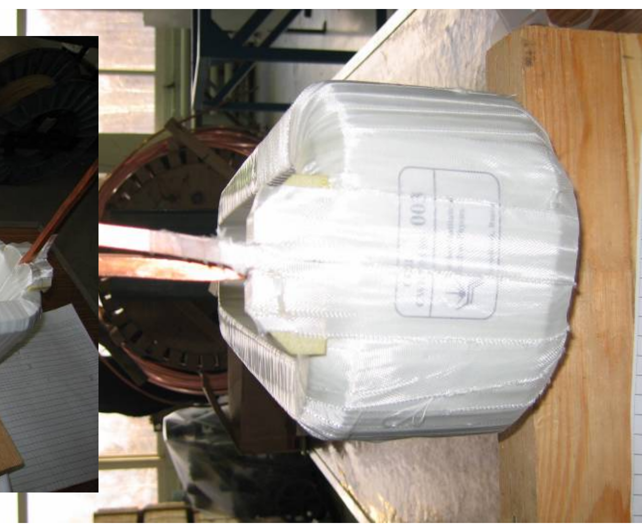
9.1.1) Bending magnets have two (2) coils. Each coil is made of four (4) individual pancakes. Each pancake is composed of 10 turns; therefore, each coil has 40 turns. The coils shall be manufactured using a solid copper conductor with a central hole for the passage of cooling water, according to the CELLS design.

9.1.2)The coil is designed to have a maximum temperature rise in the cooling water of 10°C with a differential pressure of 7 bar. Under these conditions the maximum coil temperature will be ≤35°C. It is essential that the insulation system withstands repeated thermal cycling without mechanical or electrical failure.

9.1.3)The coils will operate in a radiation environment, and must therefore be built using glass and epoxy resin insulation system. No materials other than those specified in this section of the specification will be permitted. The materials that will be used for insulation will be subject to written authorization from CELLS.








9.) Technical Specifications: Coils

9.1.4) Inter-turn resistance shall be provided by wrapping the copper conductor with a borosilicate glass cloth, half-lapped to produce a minimum insulation thickness of 0.5 mm turn-to-turn. After completion of winding, an outer ground insulation shall be provided by further layers of half-lapped glass cloth of minimum thickness 1.0 mm.

9.1.5) On completion of the coil winding, electrical and water terminations shall be attached to the leads.

9.1.6) Each pancake shall have one (normally closed) over-temperature switch, set to open an electrical circuit at 60˚±5˚C. These switches shall be fitted each with two external leads or connections, and shall either be fitted before the impregnation process, or glued to the surface of the coil after impregnation. Whichever technique is used, the manufacturer will ensure that good thermal and mechanical contact is obtained using materials that meet the requirements of this specification.

9.1.7) All voids arising within the pancakes shall be packed with glass roving in order to avoid the occurrence of resin-rich areas and delamination. The material used shall conform to the glass requirements described below.

9.) Technical Specifications: Coils

9.1)Coils manufacturing

9.1.8)The insulation in the vicinity of the pancakes leads and terminations will require special attention, in order to provide adequate strength and to avoid the presence of excessive resin in that area. Glass roving or pre-formed glass epoxy inserts must be utilised in these areas, and all materials used must conform to the requirements described below.

9.1.9) The manufacturer shall estimate the degree of conductor keystoning that will occur in certain areas of the coil. Resulting voids consequently introduced into the coil must therefore be filled, using the methods indicated above in 9.1.8.

9.1.10) No joints within the pancakes will be permitted.

9.) Technical Specifications: Coils

9.2)Conductor

9.2.1)The copper shall be Cu-OF Oxygen free (ISO designation) annealed after cold work (dead soft fully annealed temper).

9.2.2)The copper shall be free of cracks, porosity and voids. It shall not have any tendency for hydrogen embrittlement. Very good characteristics for brazing are required as well as a ductibility which permits the winding of the conductor into magnet coils with tight bends.

9.2.3)The composition shall be at minimum 99.99 % Cu (+Ag).The oxygen content shall be kept below 10 ppm.

9.2.4)The electrical resistivity shall be less than $17.1 \times 10\text{-}9\ \Omega\text{m}$ at 20°C.

9.2.5)The uniformity of the conductor shall be such that the resistance of all coils constructed from it shall be equal to within +/-1%.

9.) Technical Specifications: Coils

9.3)Conductor supplier

9.3.1)Copper conductor of the described quality is available from a number of suppliers and the manufacturer has full liberty to choose any source of suitable material. CELLS has identified a supplier for a conductor that will comply with this specification:

Luvata
Kuparitie, P.O.Box 60
FIN-28101 Pori, Finland
www.luvata.com

9.) Technical Specifications: Coils

9.4)Conductor tests before winding

9.4.1)Test certificates shall be available relating to tests undertaken by the copper manufacturer, to include dimensions, resistivity and Brinell hardness.

9.4.2)The cooling channel must permit the free passage of a 5.3 mm diameter ball.

9.4.4)Before construction commences, the conductor shall be hydraulically tested at a pressure of 100 bar for five minutes. Conductors revealing any evidence of leakage shall be rejected.

9.4.5)Before the winding of the coil, the conductor shall be cleaned and sandblasted.

9.) Technical Specifications: Coils

9.5)Pancake winding

9.5.1) Scrupulous care shall be exercised at all stages of the coil construction in the handling of all the components, which shall be undertaken in a clean environment. All working surfaces shall be cleaned immediately prior to be used, and protective gloves shall be worn by all the staff involved. Quality control of this design will have to guarantee the lack of any conductive occlusion between wires (cutting, dust, …). Moreover, excessive hammering (hardening) of the conductor which could destroy the fibreglass tape, shall be avoided.

9.5.2) After completion of pancake winding, the pancakes shall be tested with a gas (helium or halogen) at a pressure of 15 bar for thirty minutes. The soundness of the pancake shall be checked at the end of the thirty minutes by passing the probe of a leak detector over the full outer surface of the pancake. This detector will be a mass spectrographic device tuned to the test gas, or similar system. Impregnation shall not be undertaken on any pancake exhibiting evidence of leakage.

9.) Technical Specifications: Coils

9.6)Pancake insulation and impregnation

9.6.1)The pancakes shall be vacuum impregnated. The use of a mould is considered to be essential, and such a mould must apply direct contact pressure to as great a surface area of the pancake as can be achieved.

9.6.2) Impregnation and curing shall be preceded by oven drying of a pancake and degassing of the resin, pancake and mould. Use of an open mould for the impregnation operation is preferred.

9.6.3)The thickness of unreinforced resin on the surface of a finished pancake must not exceed 0.5 mm.

9.6.4) After completion, the resin on the pancakes must be fully transparent, with no colouriser or additive that would limit observation of the copper turns used within the resin system. No paint or other external coating will be allowed.

9.6.5) No pancake shall be repaired after its initial impregnation without the written approval of CELLS.

9.) Technical Specifications: Coils

9.7)Terminations of the coil

9.7.1)The magnets shall be designed with all mechanical services (i.e. cooling water manifolds) and all electrical connections (including power terminals) on the inside of the ring at the downstream end of the bending magnet.

9.7.2) Magnets shall be supplied with an inlet manifold and outlet manifold mounted on the mechanical services panel. The manifold shall be manufactured from metric stainless steel tube, grade 316, suitable for connection to the supply and return water system via a single Swagelok compression fitting onto each manifold. The manifold pipe will be mounted vertically on the mechanical services panel and the connection point will be at the bottom end of the tube.

9.7.3) Magnets shall be equipped with a water flow controller Eletta type at the outlet manifold. All part of this controller in contact with water will be in brass with Canigen coating. The Eletta switch will include a witness window for visual flow indication.

9.7)Terminations of the coil

9.7.4)The water connections on the coils shall be manufactured from phosphor bronze, and shall be attached to the coil by a silver brazing technique to give a system which is unaffected by demineralised water.

9.7.5)The electrical connections for power terminals shall be mounted on the electrical and mechanical services panel which shall be rigidly supported on the magnet. These terminals shall be suitable to receive the incoming supply cable connectors, and will be designed to withstand a maximum force of 50 kg exerted by the incoming cables on the terminals. The connection between the coil terminals and the services panel shall be the responsibility of the manufacturer.

9.7.6)The manufacturer shall, during initial design, avoid locating any organic based material in the median plane of the magnet centre where it would be subject to long-term radiation damage from the beam. Coil water connections to the manifolds shall be well above and below the beam-line. Where water conduits cross the beam-line horizontal plane, pipe work shall be metallic.

9.) Technical Specifications: Coils

9.7)Terminations of the coil

9.7.7)The coil terminals, the connection posts and all metallic parts connected to them will be protected against accidental contact by an insulating, transparent cover, which can only be removed by the use of tools; tenderers' proposals for this cover shall be described in the offer.

9.7.8)The water connection between the coil terminals and the manifold shall be of non-conducting tube, having suitable mechanical properties, and suitable for use in a high radiation environment. Tenderers shall indicate in their quotation, the type of material that they propose for these tubes.

9.7.9)The cabling of the over-temperature interlock switches shall be part of the contract. The two terminals of each switch shall be mounted on the electrical services board as specified.

9.7.10) A single terminal connection post able to receive a 10 mm^2 cable shall be provided for earthing the yoke. The manufacturer shall ensure that there is adequate electrical connection between the yoke, manifolds and other components so that all the exposed metallic parts of the magnet are safely earthed by this terminal post.

9.) Technical Specifications: Coils

9.8) Coils testing

9.8.1)The brazed termination shall be tested at a pressure of 60 bars for 10 minutes.

9.8.2) During the total immersion of each coil in water the conductor shall be pressurised at 30 bar with water and sealed. The pressure shall be recorded, and any drop of pressure larger than 2 % during the 24 hours period shall result in rejection of the coil.

9.8.3) The water flow for each of the water channels in a coil shall be separately measured with a pressure differential across the channel of 7 bar. The flow rate shall not be less than the flow rate, as calculated by the manufacturer and communicated to CELLS during the design phase, on which the coil thermal calculations are based. The flow in any coil shall also be in the range of ±10% of the mean for all coil flow measurements.

9.8.4)The electrical resistance of all coils shall be measured with a DC bridge. The values shall be corrected to 23˚C, and must be within ±1% of the mean value for all coils.

9.) Technical Specifications: Coils

9.8)Coils testing

9.8.5) Each coil shall be immersed in tap water at ambient temperature, but with the terminals exposed above the water level. Any other part of the coil body not then completely immersed shall be covered with wet cloths the ends of which are in contact with the water. The following test sequence shall then be carried out:

(a) Record insulation resistance between coil terminals and water bath, using minimum voltage of kV. Insulation resistance shall above 50 MOhm.

(b) Apply direct voltage of 5 kV between coil terminals and water bath for one minute, and record the leakage current;

(c) Repeat measurement as in (a).

Any coil exhibiting evidence of breakdown or significant changes of insulation resistance during these tests shall be rejected.

9.) Technical Specifications: Coils

9.8)Coils testing

9.8.6) After completion of the tests in 9.8.6 each coil shall be energised until the coil temperature increases to 60˚C, as measured by the change in electrical resistance. During this period water shall be sealed within the conductor by means of a valve. On attaining the required temperature the current shall be interrupted and water at room temperature allowed to flow through the coil until the conductor again assumes the ambient temperature, as measured by the conductor resistance. The valve shall then again be closed and the foregoing cycle repeated fifty (50) times. The manufacturer may wish to undertake this procedure on a number of coils simultaneously. This test shall be performed in each one of the coils for the pre-series bending magnet and for one in each 5 coils for the series production.

9.8.7) On completion of the thermal cycling the insulation tests described in shall be repeated, and significant changes of insulation resistance or breakdown characteristics shall again be sufficient reason for rejection of a coil. Any coil exhibiting evidence of cracking or delamination shall also be rejected.

9.) Technical Specifications: Coils

9.8)Coils testing

9.8.8) Immediately after the test described in 9.8.7 the coil shall be tested by using it as the secondary winding of a transformer. A maximum voltage of 2 kV RMS shall be induced across the coil terminations for a period of one minute, and the corresponding primary current recorded. Any indication of short-circuiting between turns shall result in rejection of the coil.

10.) MECHANICAL AND ELECTRICAL TESTS ON COMPLETE MAGNETS

10.1)Mechanical and electrical tests on complete pre-series magnet

10.1.1) After the magnets have been assembled with coils and cooling hoses, the complete assembly will be measured to ensure that it complies with the dimensional tolerances as specified.

10.1.2) All the dimensions will be checked according to the appropriate magnet assembly drawing.

10.1.3)The measuring techniques will be specifically designed to check each and all of the dimensions and dimensional tolerances defined in the appropriate assembly drawing and in this specification. These will be subject to CELLS approval. Manufacturers are requested to give details of their proposed assembly measurement techniques in their tenders.

10.) MECHANICAL AND ELECTRICAL TESTS ON COMPLETE MAGNETS

10.1)Mechanical and electrical tests on complete pre-series magnet

10.1.4) As an essential part of these tests and the subsequent production checks, the manufacturer shall develop and manufacture an instrument that is capable of making precision measurements of the gap region. This instrumentation is required to have the following features:

a.) a measurement sensitivity and reproducibility equal to or better than ±10 μm;

b.) a monitorable electrical output, allowing gap dimensions to be continuously measured as the gauge traverses through the magnet;

c.) accuracy and sensitivity unaffected by magnetic fields, i.e. to be capable of performing the required measurements with the bending magnet powered.

10.) MECHANICAL AND ELECTRICAL TESTS ON COMPLETE MAGNETS

10.1)Mechanical and electrical tests on complete pre-series magnet

10.1.5) A direct voltage of 5 kV shall be applied between the terminals of each coil and its magnet yoke for one minute. Any coil showing evidence of breakdown, indicated by a leakage resistance of less than 50 MΩ, shall be rejected.

10.1.6) A maximum d.c. operating current test with a coil excitation of 530 A shall be carried out for a period of at least two hours, with cooling water circuits set to provide a differential pressure not greater than 7 bar. During this test, the water inlet and outlet temperature shall be monitored, and the temperature of coil surfaces and all coil interconnections and terminals checked with contact thermometers. Results shall be judged with respect to the appropriate magnet thermal specifications. Any coil showing evidence of overheating, local hot spots or other faults during this period shall be rejected. This test can be performed at the commencement of the magnet measuring sequence, with the magnet connected to a power supply and cooling water.

10.) MECHANICAL AND ELECTRICAL TESTS ON COMPLETE MAGNETS

10.1)Mechanical and electrical tests on complete pre-series magnet

10.1.7)The manufacturer shall demonstrate the operating efficiency of the over-temperature switches by raising the temperature of each coil to the value (60˚C) at which the switches are guaranteed to operate. The technique that is to be used for the necessary overheating shall be agreed with CELLS. Because of the danger of damage to the coil, CELLS strongly prefers a method involving the external heating of the circulating water. Details of the proposed method shall be included in the tender.

10.1.8)The manufacturer shall demonstrate the operating efficiency of the water flow switch by restricting slowly the supply of water with the magnet unpowered.

10.) MECHANICAL AND ELECTRICAL TESTS ON COMPLETE MAGNETS

10.2) Mechanical and electrical tests on complete production magnets

10.2.1) After the magnets have been assembled with coils, cooling hoses and mounting brackets fitted, the complete assembly will be measured to ensure that it complies with the dimensional tolerances as specified.

10.2.2) All the dimensions will be checked according to the appropriate magnet assembly drawing.

10.2.3) A direct voltage of 5 kV shall be applied between the terminals of each coil and its magnet yoke for one minute. Any coil showing evidence of breakdown, indicated by a leakage resistance of less than 50 MΩ, shall be rejected.

10.) MECHANICAL AND ELECTRICAL TESTS ON COMPLETE MAGNETS

10.2) Mechanical and electrical tests on complete production magnets

10.2.4) A maximum d.c. operating current test with a coil excitation of 530 A shall be carried out for a period of at least two hours, with cooling water circuits set to provide a differential pressure not greater than 7 bar. During this test, the water inlet and outlet temperature shall be monitored, and the temperature of coil surfaces and all coil interconnections and terminals checked with contact thermometers. Results shall be judged with respect to the appropriate magnet thermal specifications. Any coil showing evidence of overheating, local hot spots or other faults during this period shall be rejected. This test can be performed at the commencement of the magnet measuring sequence, with the magnet connected to a power supply and cooling water.

10.) MECHANICAL AND ELECTRICAL TESTS ON COMPLETE MAGNETS

10.3)Acceptance tests after delivery

10.3.1) After delivery, the bending magnets shall be visually inspected for mechanical damage suffered in transit. Any such damage shall be reported to the manufacturer. Possible repair shall be subject to agreement with CELLS. Where the damage has resulted in alteration to the magnet iron geometry or to the soundness or shape of coil conductor, insulation or terminals, the magnet shall be rejected.

10.3.4) Electrical tests shall be carried out by staff of CELLS after delivery. The manufacturer has the right to be represented during these tests but shall notify CELLS in writing if this right is to be exercised.

10.3.5) A direct voltage of 5 kV will be applied between the terminals of each coil and its magnet yoke for one minute. Any coil showing evidence of breakdown, indicated by a leakage resistance of less than 50 MΩ, shall be rejected.

10.3.6)The magnet will be energised at the maximum current of 530 A for a period of at least two hours. Any coil showing evidence of breakdown, local hot spots or other faults during this period shall be rejected.

Travellers

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INSPECTION REPORT

ALBA QUADRUPOLE MAGNET

No Q260CX-034

Travellers

INSPECTION REPORT

ALBA QUADRUPOLE MAGNET Q260CX-034

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Travellers

1. MAIN DESIGNED PARAMETERS

No	PARAMETERS		UNITS
1	Bore diameter	61.0 ± 0.04	mm
2	Yoke length	260	mm
3	Total magnet weight	550	kg
4	Maximum current	200	A
5	Gradient at 200 A	22.4	T/m
6	Integrated gradient at 200A	6.4	T
7	Magnetic effective length	288	mm
8	Maximum DC resistance (for T=20°C)	59	mΩ
9	Maximum voltage drop (for T=20°C)	11.8	V
10	Maximum pressure drop	7	bar
11	Water flow at ΔP=7 bar	12.4	l/min
12	Water temperature rise at ΔP= 7 bar, and I_{max} = 200 A (DC)	2.5	°C

Travellers

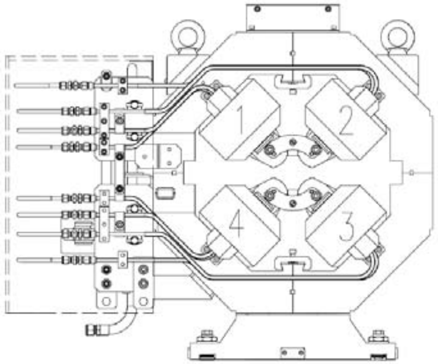
2. ASSEMBLING

The quadrupole magnet Q260CX-034 comprises the following quadrants and coils:

	Quadrants		Coils	
	Drawing	Number	Drawing	Number
1	CWK5 02 02	133	CWK5 07 00	139
2	CWK5 02 01	134	CWK5 06 00	186
3	CWK5 03 02	135	CWK5 09 00	164
4	CWK5 03 01	136	CWK5 08 00	187

Yoke spacer left	no
Yoke spacer right	no
Legs from coils terminations	169
Legs from back side	170
Flowmeter "Eletta" on the flow	3.2-6.4 l/min

	Side of coils terminations	Back side
Upper clamp	133	133.
Lower clamp	136	136.

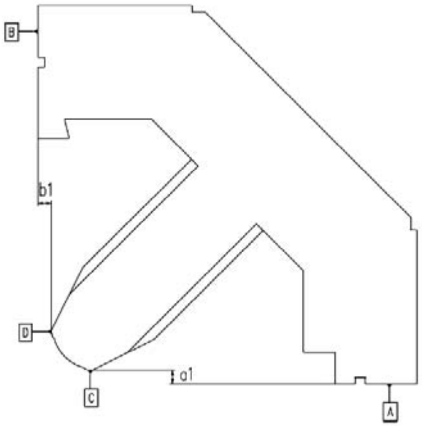


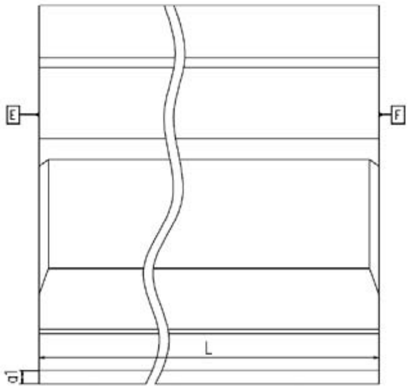
Travellers

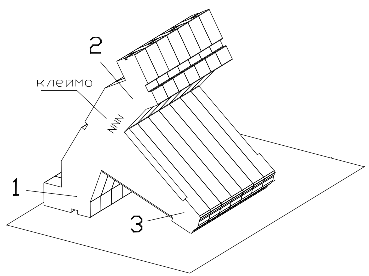
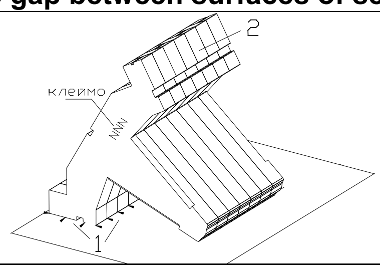
3. YOKE PARAMETERS

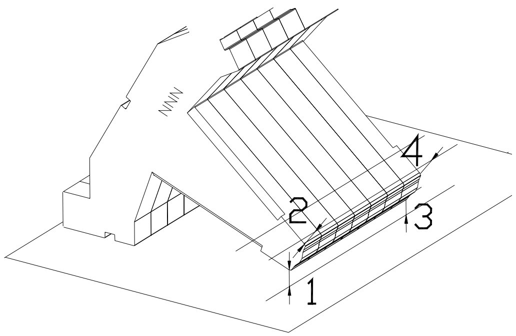
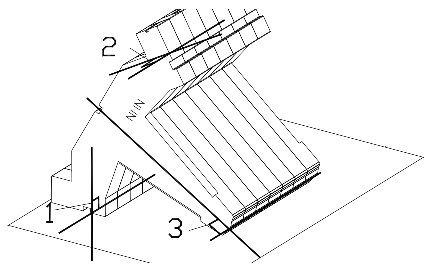
3.1. MAIN QUADRANTS PARAMETERS

Parameter	Reference, mm	Segment number			
		133	134	135	136
Yoke length **L**	260 ± 0.1	0.0	0.0	0.0	0.0
Stacking factor	0.97	>0.97	>0.97	>0.97	>0.97
Nonflatness of surface **A**	0.02	0.02	0.02	0.02	0.02
Nonflatness of surface **B**	0.02	0.02	0.02	0.02	0.02
Nonflatness of shim **C**	0.02	0.00	0.01	0.00	0.00
Nonflatness of shim **D**	0.02	0.00	0.01	0.00	0.01
Perpendicularity **E** to pole	0.1	0.0	0.0	0.0	0.0
Perpendicularity **F** to pole	0.1	0.0	0.0	0.0	0.0
a1	11.0 ± 0.02	0.00	-0.01	0.00	0.00
b1	11.0 ± 0.02	0.00	-0.01	-0.01	0.00





<table>
<tr><td colspan="4">1.1. PARAMETERS of THE SEGMENT No. 012</td></tr>
<tr><th colspan="2">PARAMETERS</th><th colspan="2">MEASURED</th></tr>
<tr><td>1</td><td>Drawing of the segment</td><td colspan="2">CWLF</td></tr>
<tr><td>2</td><td>Temperature conditions in the oven</td><td colspan="2">Normal</td></tr>
<tr><td>3</td><td>Visual checking for quality of segment (cracks, glue, color and etc)</td><td colspan="2">OK</td></tr>
<tr><td rowspan="4">4</td><td colspan="3">Length of segment in 3 checkpoints. Nominal value is 150± 0.1mm</td></tr>
<tr><td rowspan="3">
</td><td>1</td><td>0.0 mm</td></tr>
<tr><td>2</td><td>0.0 mm</td></tr>
<tr><td>3</td><td>0.0 mm</td></tr>
<tr><td rowspan="3">5</td><td colspan="3">The gap between surfaces of segment and base plate (2 measures). Nominal : 0.02 mm.</td></tr>
<tr><td rowspan="2">
</td><td>1</td><td>0.02 mm</td></tr>
<tr><td>2</td><td>0.02 mm</td></tr>
</table>

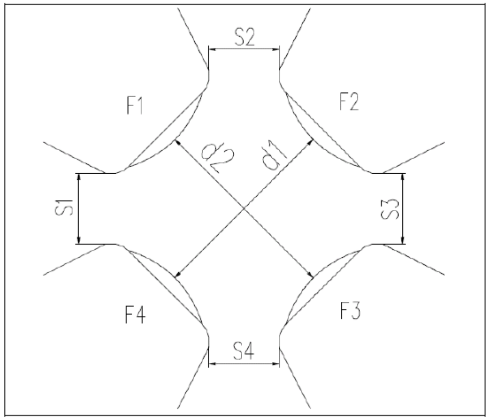
<table>
<tr><td rowspan="5">6</td><td colspan="3">The gap between shims and base plate (4 measures). Nominal : 10 ± 0.025 mm.</td></tr>
<tr><td rowspan="4">
</td><td>1</td><td>-0.005 mm</td></tr>
<tr><td>2</td><td>0.000 mm</td></tr>
<tr><td>3</td><td>-0.005 mm</td></tr>
<tr><td>4</td><td>+0.005 mm</td></tr>
<tr><td rowspan="4">7</td><td colspan="3">Non-perpendicularity of surfaces of the segment (3 measures). Nominal: 0.1 mm</td></tr>
<tr><td rowspan="3">
</td><td>1</td><td>0.1 mm</td></tr>
<tr><td>2</td><td>0.1 mm</td></tr>
<tr><td>3</td><td>0.1 mm</td></tr>
</table>

Travellers

3.2. INTERPOLE GAPS inaccuracy

Reference: d = 61.0 ± 0.04 mm

s = 22.0 ± 0.03 mm



	Commutation side		Back side
d1	0.00	**d2**	-0.01
d2	0.00	**d1**	0.00
S1	-0.01	**S3**	0.00
S2	0.00	**S2**	0.00
S3	-0.01	**S1**	-0.01
S4	-0.01	**S4**	-0.01
F1	4.75	**F2**	4.8
F2	4.8	**F1**	4.8
F3	4.75	**F4**	4.8
F4	4.8	**F3**	4.8

Travellers

4. TESTING OF COILS

4.1. TESTING OF COIL No 139 CWK5

No	PARAMETERS	MEASURED	REFERENCE
1	Dimensional control before impregnation	Ok	Ok
2	Dimensional control after impregnation	Ok	Ok
3	Visual inspection for cracks and insulation damage	Ok	Ok
4	Hydraulic leak test: 30 bar - 24 minute	Ok	Ok
5	Water flow measurement (ΔP = 7 bar)	2.8	l/min
6	Electrical resistance at temperature	14.37 Ω At 21 °C	
7	Electrical resistance recalculated at 23° C	14.48 mΩ	
8	Leakage current between coil termination and water bath at 5000 DC V at start	<10 µA	<100 µA
	Leakage current between coil termination and water bath at 5000 DC V after 24 hours	<10 µA	<100 µA
9*	Thermal cycling test 30 cycles T_{min} = 20° C, T_{max} = 60° C		
	Leakage current between coil termination and water bath at 5000 DC V at start		
	Leakage current between coil termination and water bath at 5000 DC V after 24 hours		
10	Inter turn insulation test for coil	Ok	Ok

* - tests 9 to carry out for each coil of pre-serial magnet and for each 20 coil of serial magnets

This has to be done for all 4 coils

Travellers

5. COMPLETE MAGNET TEST

No	TEST	MEASURED
1	Visual inspection	Ok
2	Dimensional control, main dimensions	Ok
3	Water flow at pressure drop	10.5 l/min at 7.0 bar
5	Electrical resistance recalculated at 23° C	58.0 mΩ
6	Leakage current between coils circuit and the magnet yoke at U = 5 kV DC during 1 minute.	<10 μA
7	Full power test: Duration: 2 hour Current: 200 A ΔP = 5 bar	Ok
8	Thermal switch test	Ok
9	Water flow switch test	5.4 l/min

Travellers

6. MAGNETIC MEASUREMENTS

In the beginning the magnet has been cycled 3 times from 0 A to 200 A and back to 0 A.
Then the magnet has been aligned at current 150 A.
The measurements have been done at decreasing current from 200 A.

List of files with results of magnetic measurements:

Q260CX_034_200A_01.pdf The current is 200 Amperes at the decreasing.

Q260CX_034_180A_01.pdf The current is 180 Amperes at the decreasing.

Q260CX_034_150A_01.pdf The current is 150 Amperes at the decreasing.

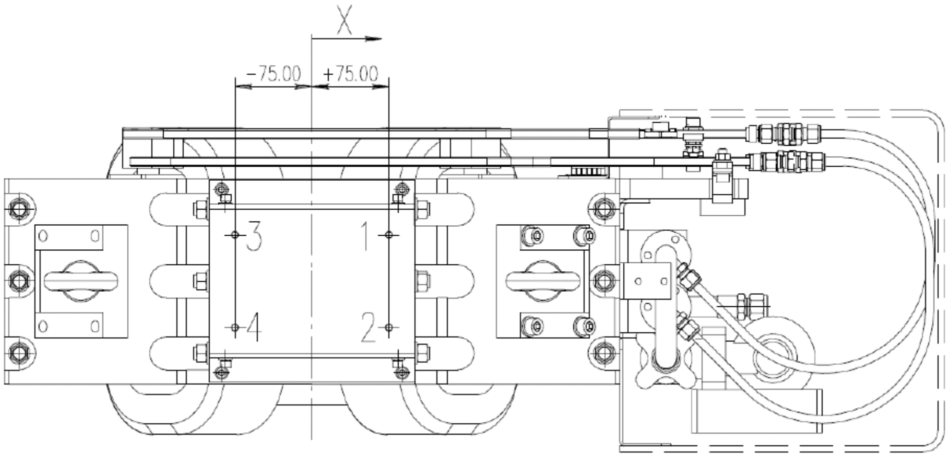
Q260CX_034_100A_01.pdf The current is 100 Amperes at the decreasing.

Q260CX_034_050A_02.pdf The current is 50 Amperes at the decreasing.

Travellers

7. ALIGNMENT PLATE

Positions of holes in the alignment plate from the girder.
Accuracy of the position measurements is ± 0.03mm.



	Reference		Measured	
	X	Z	X	Z
Point 1	75.00	760.00	75.01	759.97
Point 2	75.00	760.00	75.01	759.94
Point 3	-75.00	760.00	-74.98	759.95
Point 4	-75.00	760.00	-74.99	759.92

11.) PACKING AND TRANSPORTATION

11.1) Packing

11.1.1)The contractor will submit to CELLS a solution for the packing. This packing will have to use the classical handling tools. The magnet packed shall be protected against the elements, the projections and the breaks during transportation and storage.

11.1.2)The packing of each magnet shall be dust proof, water proof and will have to protect the steel parts against the oxidation. Moreover, the pieces shall be protected against the strain, impacts and rubbing which can damage their surfaces.

11.1.3) A particular protection shall be required for brittle parts (reference surfaces, electrical connections and coils).

11.1.4)The coils shall be rinsed, dried and sealed before expedition in order to avoid any frost.

11.) PACKING AND TRANSPORTATION

11.2) Transportation

11.2.1) The contractor will include in his tender the transport from the factory :

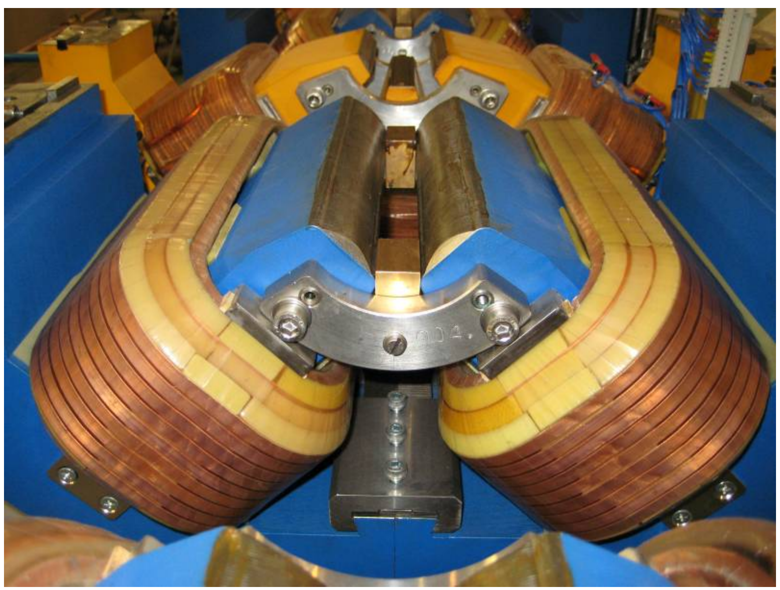
a.) to the site where CELLS will control and measure the magnets. This place will not be necessarily in the CELLS site.

b.) or to the storage area that CELLS will indicate. This storage area will be at CELLS site or nearby.

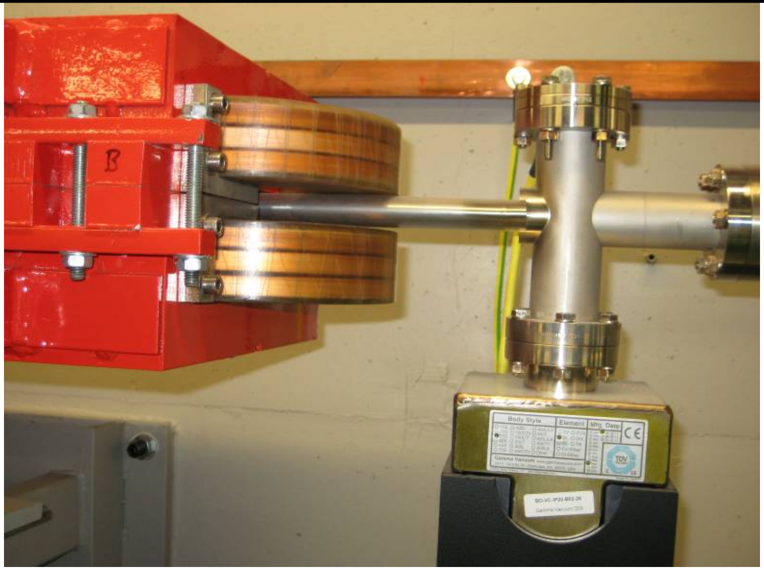
11.2.2)The contractor keeps the responsibility of the bending magnets until the delivery to one of the sites listed above. CELLS will supply the local handling tools.

11.2.3)The transfer of risks shall take place when the load is laid down on the ground.

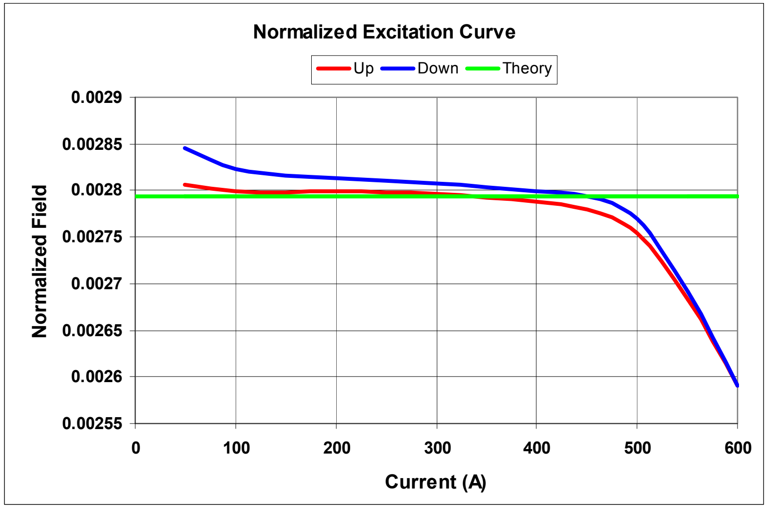
Assembling of Yokes

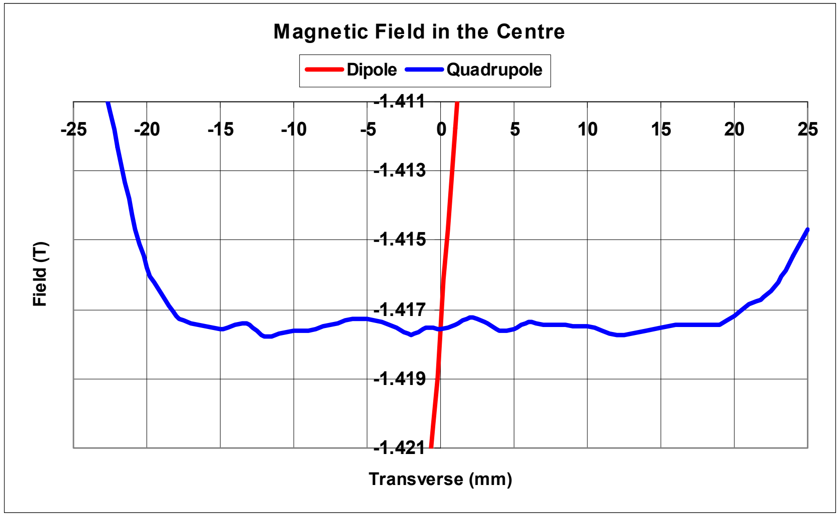


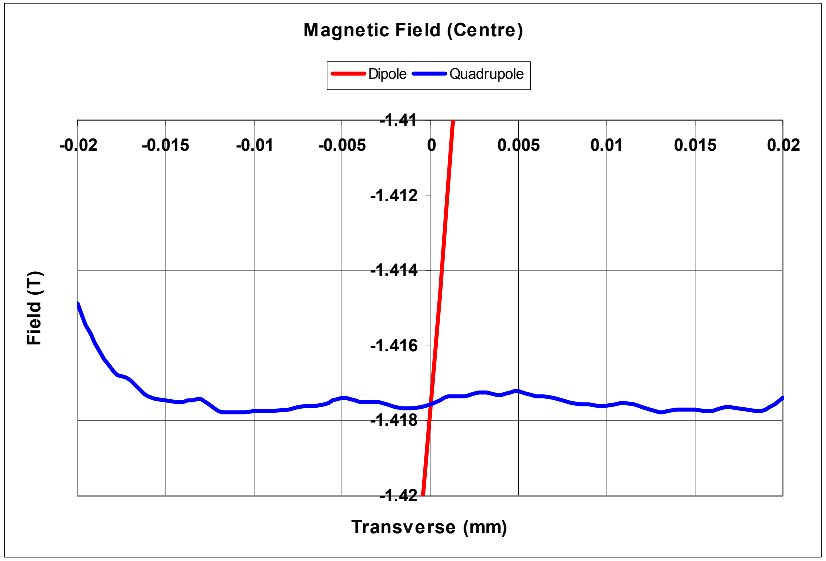
Space between Magnets

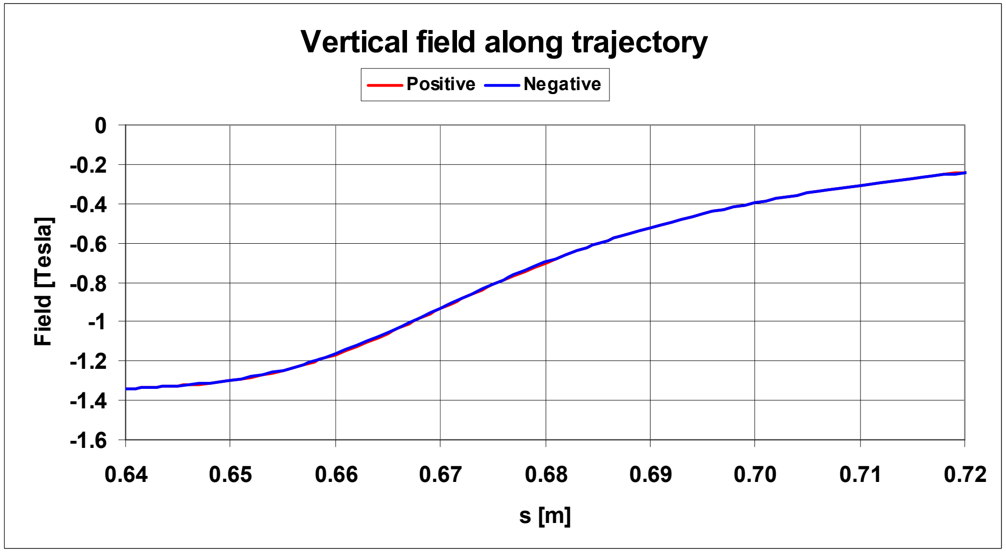


Results of magnetic Measurements

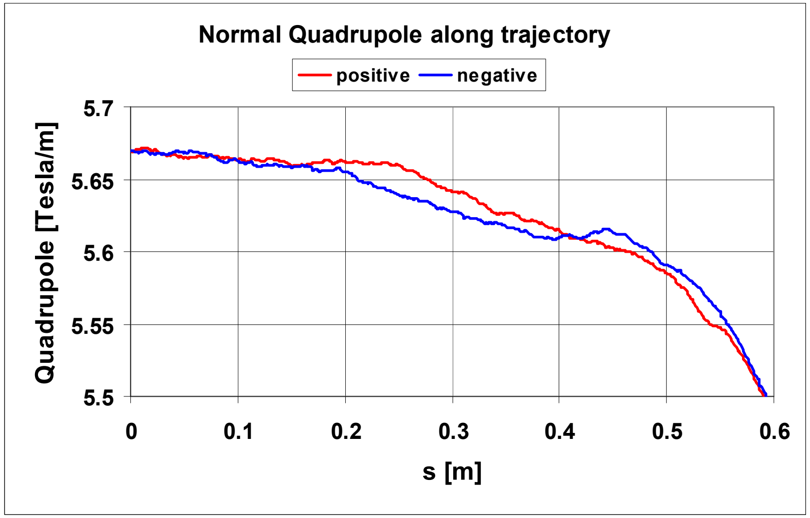


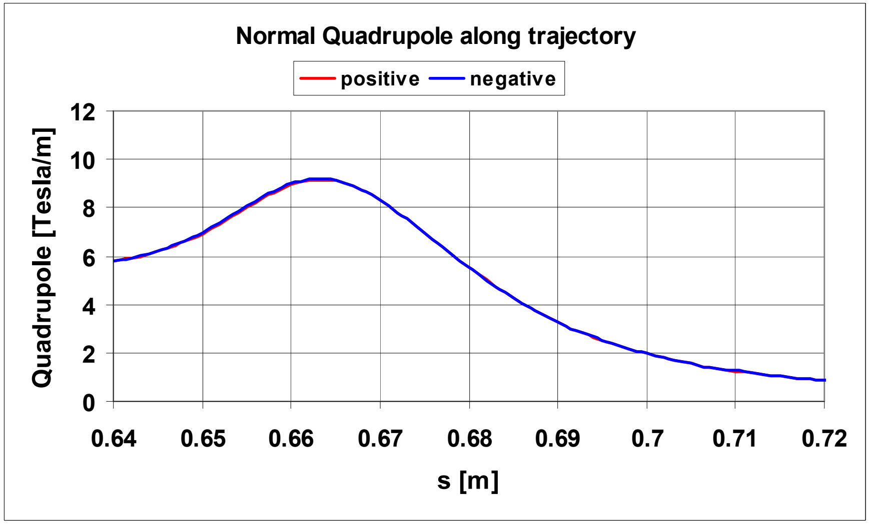




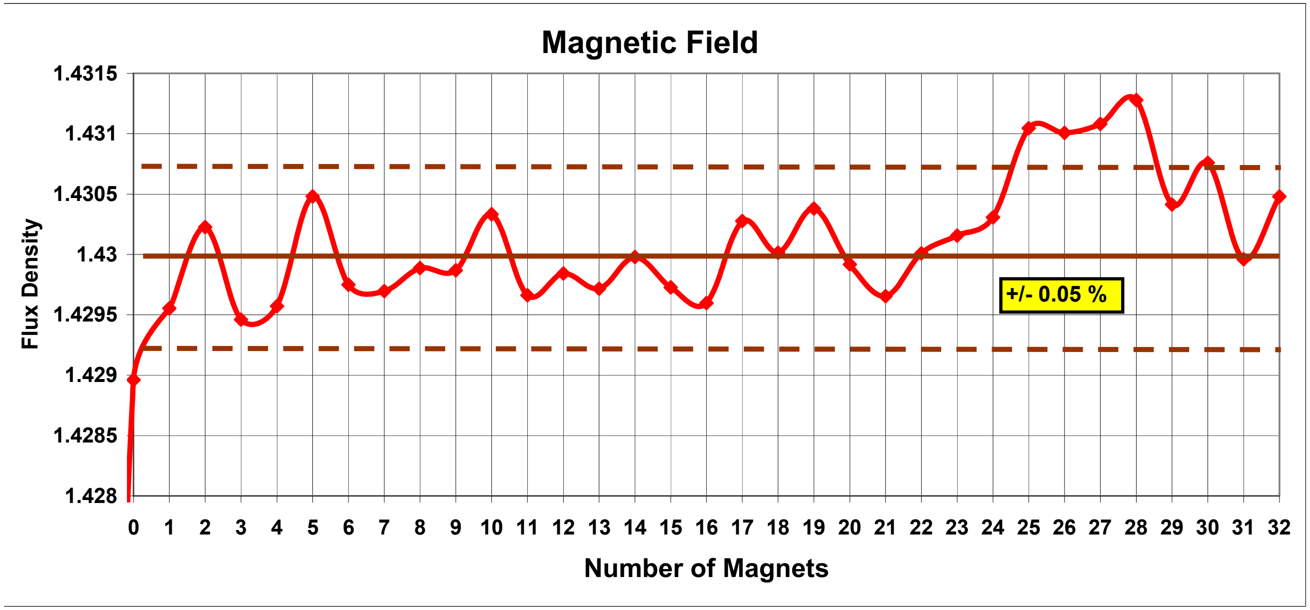


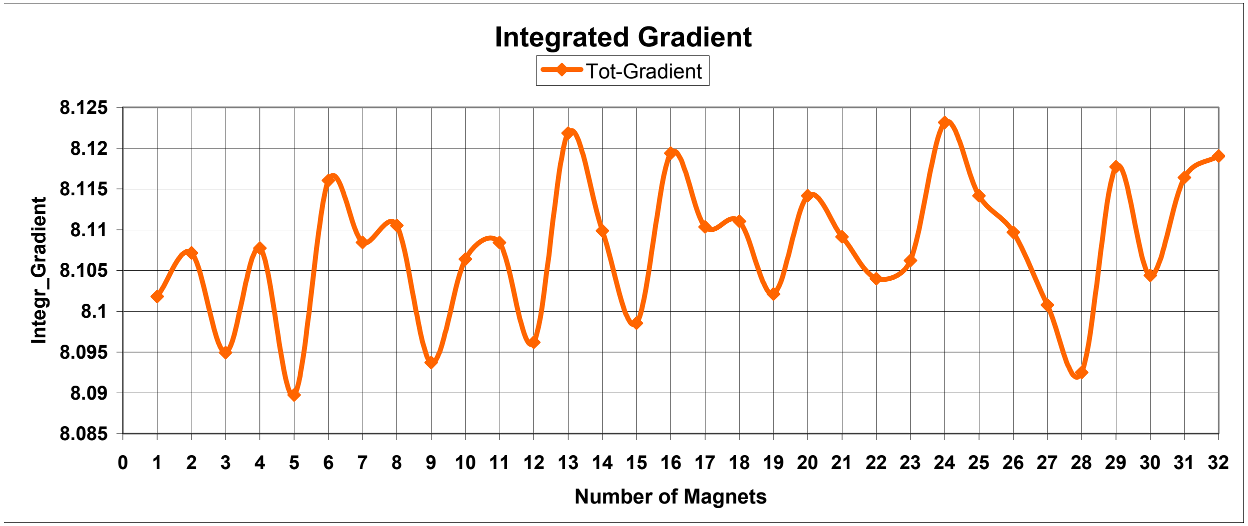
Results of magnetic Measurements



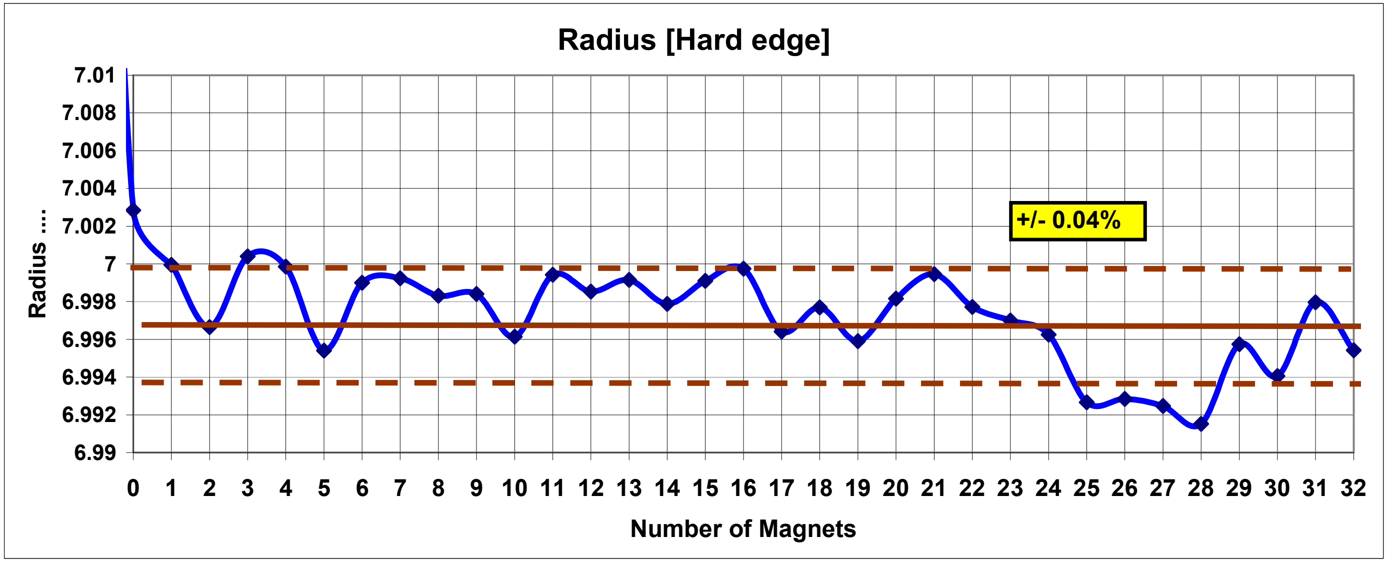


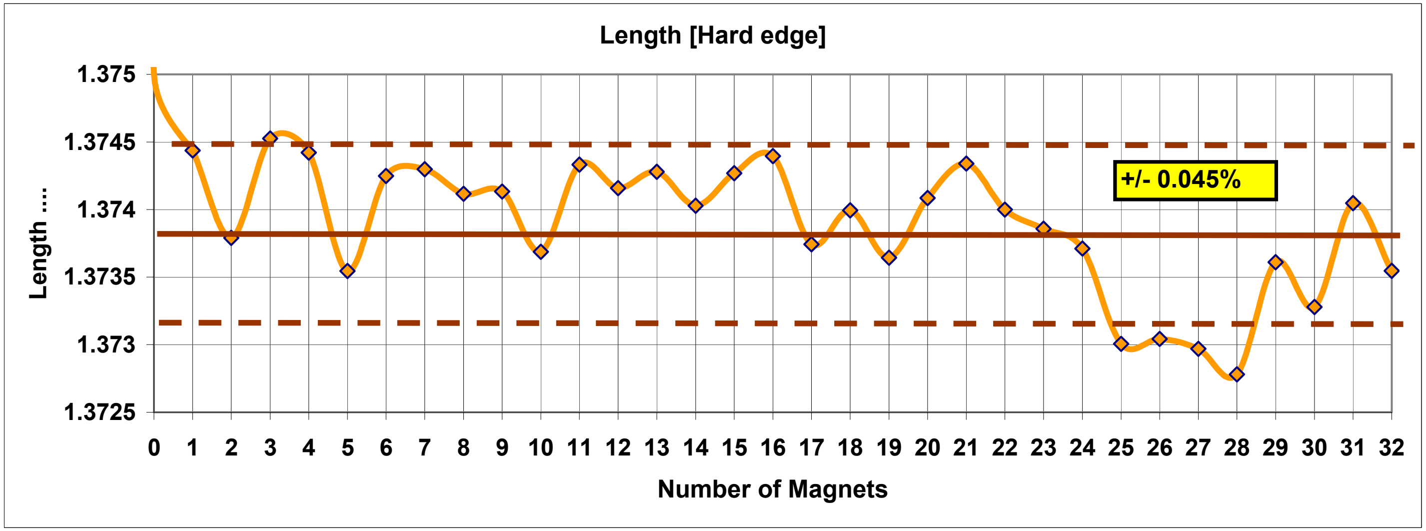
Results of magnetic Measurements



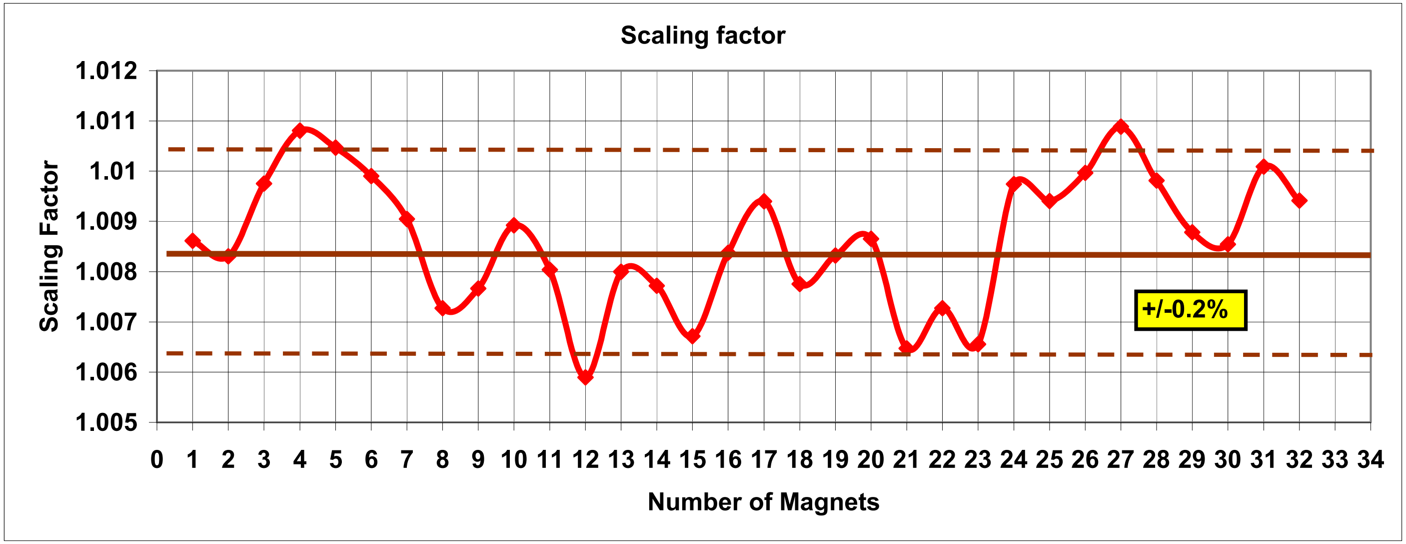


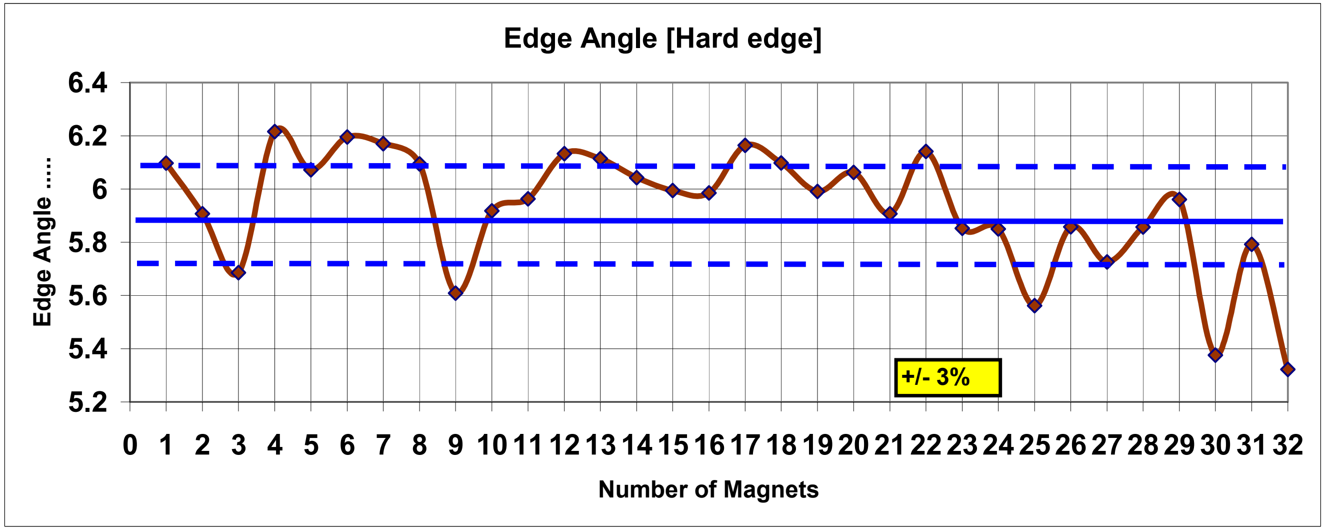
Results of magnetic Measurements





Results of magnetic Measurements





Higher Multipoles in a Quadrupole

Typical results from a quadrupole

QUADROPOLE REGISTRATION CERTIFICATE OF Q500CX_021_180A_02

Date: 10:08:00 12.05.2008
Quadropole effective length (L): 50.00 cm. Coil radius (R): 2.65 cm. Horizontal shift:0.0094 mm.
Main current (I_M): 0.0000 A Vertical shift: 0.0131 mm.
Correction current: I = 0.0000 A Angle of slope:0.00001 rad.
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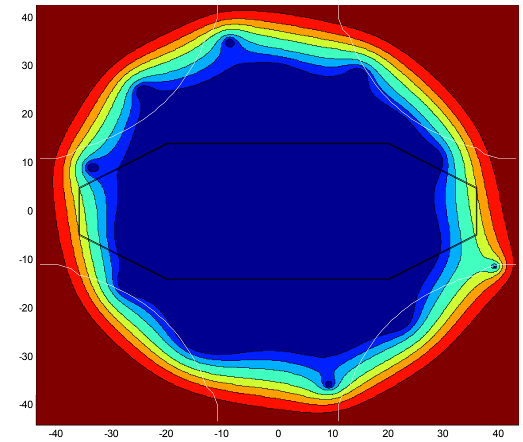
Harmonic (n)	Magnetic field amplitude at radius 1.00 cm.		Magnetic field amplitude at reference radius 2.500 cm.				Phase (rad.)
	$\sqrt{A_n^2+B_n^2}$ (Gs)	relative	B_n (Gs)	A_n (Gs)	$\sqrt{A_n^2+B_r^2}$ (Gs)	relative	
1	3.686146	0.001616	-2.15540	-2.99030	3.686146	0.000646	0.94624
2	2281.200	1.000000	-5703.00	-0.15592	5703.001	1.000000	0.00002
3	0.536546	0.000235	1.404338	3.045198	3.353416	0.000588	1.13869
4	0.084272	0.000037	1.312289	0.108339	1.316754	0.000231	0.08237
5	0.015485	0.000007	0.552235	0.246860	0.604900	0.000106	0.42037
6	0.009163	0.000004	0.890467	0.087789	0.894784	0.000157	0.09827
7	0.001125	0.000000	0.235104	-0.14181	0.274563	0.000048	-0.5427
8	0.001022	0.000000	-0.53130	0.326749	0.623742	0.000109	-0.5513
9	0.000060	0.000000	-0.07418	0.054630	0.092131	0.000016	-0.6347
10	0.000326	0.000000	1.230373	0.189723	1.244915	0.000218	0.15299
11	0.000038	0.000000	0.080772	0.351094	0.360266	0.000063	1.34467
12	0.000010	0.000000	0.066473	0.228560	0.238030	0.000042	1.28777
13	0.000006	0.000000	0.021216	0.380901	0.381491	0.000067	1.51515
14	0.000003	0.000000	0.390377	0.071631	0.396894	0.000070	0.18147
15	0.000001	0.000000	0.201315	0.075037	0.214845	0.000038	0.35678
16	0.000000	0.000000	-0.03192	0.144512	0.147997	0.000026	-1.3533
17	0.000000	0.000000	0.066092	0.200132	0.210763	0.000037	1.25183
18	0.000000	0.000000	0.186873	0.076697	0.202000	0.000035	0.38945
19	0.000000	0.000000	0.091177	0.083107	0.123369	0.000022	0.73913
20	0.000000	0.000000	0.063095	0.019988	0.066185	0.000012	0.30679

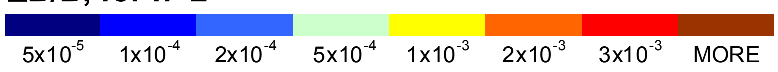
Operator: Blinov Semenov

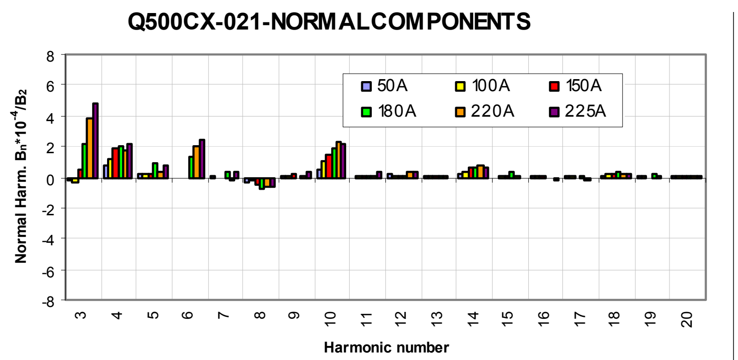
$\frac{\int \vec{H}\,dl}{L} = \frac{\int \vec{H}_y\,dl}{L} + \frac{\int \vec{H}_x\,dl}{L}$; where $\frac{\int H_y\,dl}{L} = \sum_n \left(\frac{r}{r_0}\right)^{n-1} \cdot (A_n \cos(n\varphi) - B_n \sin(n\varphi))$ $\frac{\int H_x\,dl}{L} = \sum_n \left(\frac{r}{r_0}\right)^{n-1} \cdot (A_n \sin(n\varphi) + B_n \cos(n\varphi))$

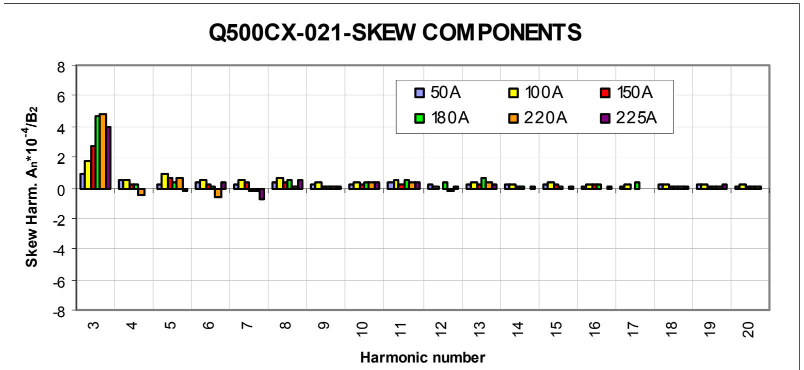
Signature:



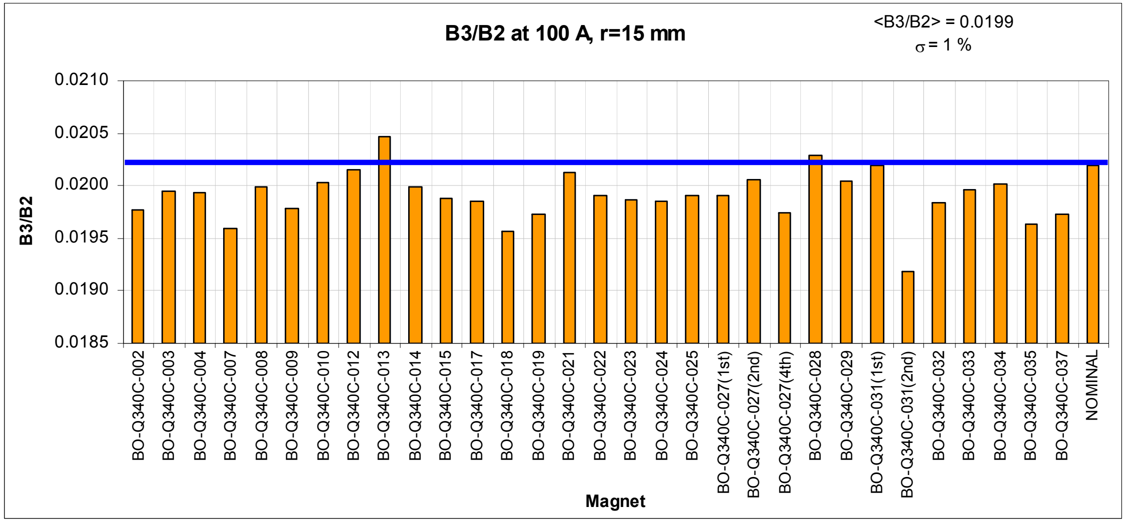
ΔB/B, for n>2



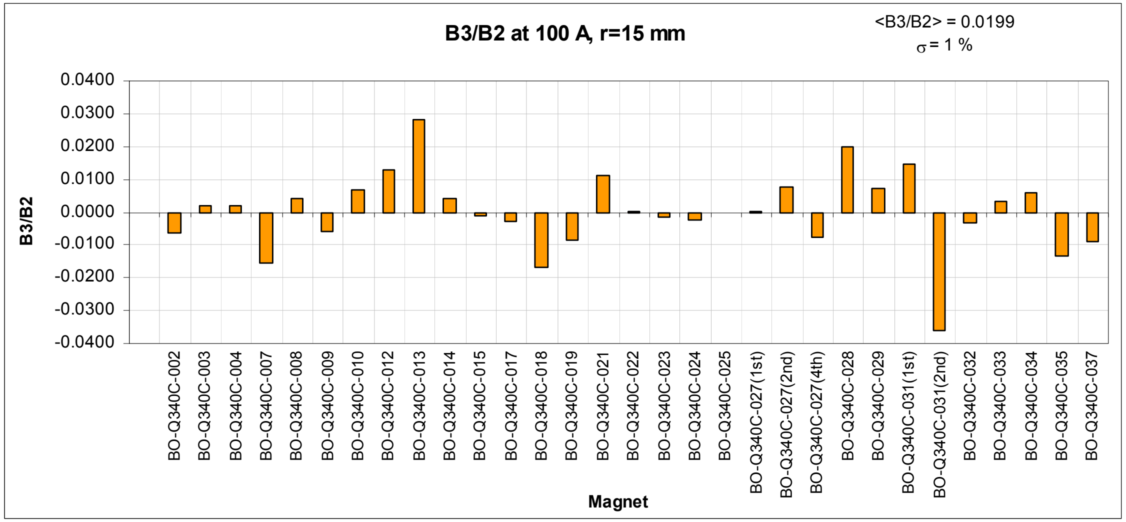




Sextupole Component in a Quadrupole



Ratio B3/B2 at 100 A and 15 mm
Nominal should be 0.0202
Average is 0.0199



Dispersion of the B3/B2 value with respect to the average.There are a couple of measurements (#13 and #31-2nd) that need to be re-evaluated

Higher Multipoles in a Sextupole

Typical results from a sextupole

SEXTUPOLE REGISTRATION CERTIFICATE OF S220_053_200A_01

Date: 17:22:04 26.05.2008
Sextupole effective length (L): 22.00 cm. Coil radius (R): 2.65 cm.
Main current (I_M): 0.0000 A
Correction current: I = 0.0000 A
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Horizontal shift: 0.0102 mm.
Vertical shift: -0.0060 mm.
Angle of slope: 0.00006 rad.

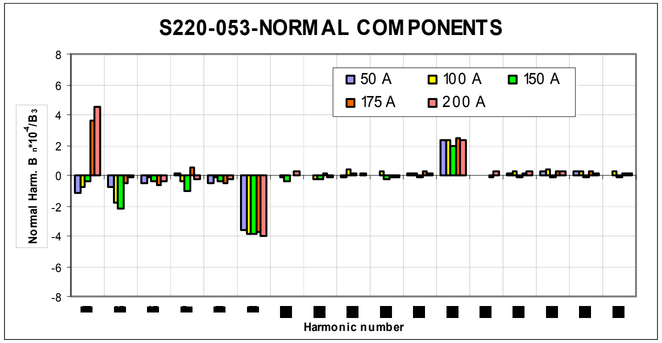
Harmonic (n)	Magnetic field amplitude at radius 1.00 cm.		Magnetic field amplitude at reference radius 2.500 cm.				Phase (rad.)
	$\sqrt{A_n^2+B_n^2}$ (Gs)	relative	B_n (Gs)	A_n (Gs)	$\sqrt{A_n^2+B_n^2}$ (Gs)	relative	
1	3.680949	0.009914	1.783028	-3.22027	3.680949	0.001586	-1.0651
2	0.876485	0.002361	-1.88862	1.111091	2.191213	0.000944	-0.5317
3	371.3055	1.000000	-2320.65	-0.39683	2320.659	1.000000	0.00017
4	0.083956	0.000226	-1.04249	-0.79628	1.311818	0.000565	0.65228
5	0.005384	0.000014	0.032469	0.207771	0.210293	0.000091	1.41577
6	0.000999	0.000003	0.095527	0.019949	0.097587	0.000042	0.20587
7	0.000637	0.000002	0.071369	-0.13824	0.155583	0.000067	-1.0942
8	0.000339	0.000001	0.072383	-0.19358	0.206676	0.000089	-1.2129
9	0.000623	0.000002	0.914409	-0.26187	0.951169	0.000410	-0.2789
10	0.000043	0.000000	-0.06451	-0.15236	0.165462	0.000071	1.17023
11	0.000013	0.000000	0.029572	-0.11572	0.119444	0.000051	-1.3206
12	0.000003	0.000000	-0.03047	-0.06379	0.070694	0.000030	1.12516
13	0.000002	0.000000	0.026661	-0.12589	0.128684	0.000055	-1.3621
14	0.000001	0.000000	-0.03784	-0.09055	0.098143	0.000042	1.17494
15	0.000001	0.000000	-0.54882	-0.09192	0.556468	0.000240	0.16594
16	0.000000	0.000000	-0.06583	-0.04612	0.080384	0.000035	0.61119
17	0.000000	0.000000	-0.04845	-0.07731	0.091246	0.000039	1.01095
18	0.000000	0.000000	-0.06500	-0.10367	0.122362	0.000053	1.01075
19	0.000000	0.000000	-0.03714	-0.09575	0.102704	0.000044	1.20076
20	0.000000	0.000000	-0.03286	-0.08980	0.095629	0.000041	1.21997

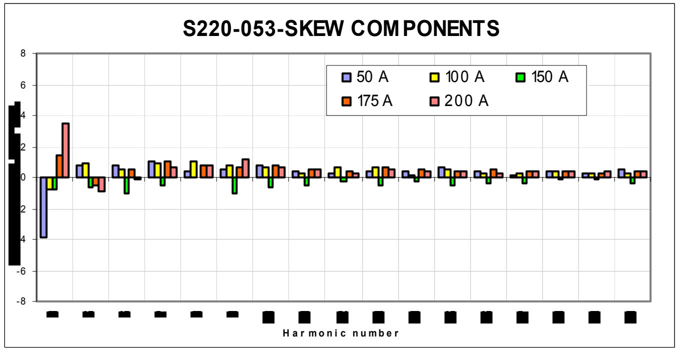
$$\frac{\int H \cdot dl}{L} = \frac{\int H_r \cdot dl}{L} + \frac{\int H_\varphi \cdot dl}{L}; \text{ where } \frac{\int H_r \cdot dl}{L} = \sum_n \left(\frac{r}{r_0}\right)^{n-1} \cdot (A_n \cos(n\varphi) - B_n \sin(n\varphi)) \quad \frac{\int H_\varphi \cdot dl}{L} = \sum_n \left(\frac{r}{r_0}\right)^{n-1} \cdot (A_n \sin(n\varphi) + B_n \cos(n\varphi))$$

Operator: Levichev Okunev

Signature:

The magnets are looking pretty good. All the higher harmonics from the quadrupole and sextupole don't have any influence upon the dynamic aperture





Acknowledgment

Many thanks to

Niels Mark

Jack Tanabe

Thank you very much

And I wish you a lot of luck in

your carrier

(einfeld@cells.es)