TECHNICAL SPECIFICATION FOR CLARA VBC DIPOLE MAGNETS

Accelerator Science and Technology Centre
STFC Daresbury Laboratory
Warrington WA4 4AD
United Kingdom

ABSTRACT

The Compact Linear Accelerator for Research and Applications (CLARA), a dedicated facility for research into free-electron lasers (FELs) is planned at STFC's Daresbury Laboratory. This document lays out the specification for the four dipole magnets for the variable bunch compressor (VBC) in the second phase of CLARA.

Author: *Ben Shepherd*

Checked By: *Jim Clarke*

Version: *0.2*

Date: *11 November 2015*

Document Change Record

Version	Date	Section/Sheet	Comment
0.1	22 April 2015	All	First draft
0.2	11 May 2015	All	Comments from JAC

CONTENTS

INTRODUCTION

1 CLARA

1.1 The Accelerator Science and Technology Centre (ASTeC) at STFC Daresbury Laboratory is currently building a new FEL test facility, CLARA – the Compact Linear Accelerator for Research and Applications. The facility will be used for research into efficient FEL schemes to produce ultra-short pulses of high-brightness coherent light.

1.2 The CLARA Conceptual Design Report (CDR) was published in July 2013, and can be found on the ASTeC website: http://www.stfc.ac.uk/ASTeC/resources/PDF/CLARA_CDRv2.pdf.

1.3 The electron beamline will transport an electron beam from the 5 MeV gun, through a series of linacs which accelerate the beam to a final energy of 250 MeV.

1.4 A schematic layout of the Phase 2 beamline is shown in Figure 1. The dipoles in this specification will be used in the CLARA variable bunch compressor (VBC), as shown on the right.

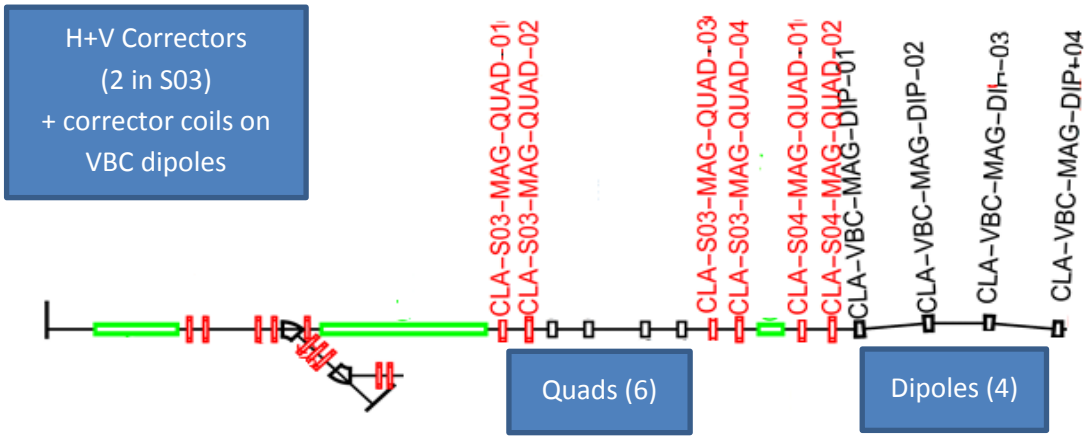

Figure 1. Layout of the CLARA Phase 2 beamline.

2 The Specification and Contracts

2.1 This specification covers the magnetic, electrical, mechanical and thermal design and the construction of the 4 dipoles and one spare coil, together with necessary testing and the detailed measurement of their magnetic performance by the manufacturer. Subsequently, the magnets will be delivered to STFC's Daresbury Laboratory.

2.2 To ensure compatibility with the overall beamline design, various parameters have been fixed (these are **mandatory**). Other parameters are undefined or **nominal** to provide the manufacturer with scope to optimise these features to suit the manufacturer's preferred construction techniques and to minimise cost.

3 Evaluation of Bids

3.1 Please see ITQ RE150101 Section 5 for details of our evaluation criteria, weighting and process.

SECTION A - GENERAL

A1 Scope of Contract

A1.1 This specification covers the:

- engineering design;
- manufacture and assembly;
- magnetic measurement;
- electrical and mechanical testing;
- delivery to Daresbury Laboratory, Warrington, WA4 4AD, UK;

of:

- 4 dipole magnets with trim coils, and
- one spare dipole coil.

A1.2 The specification also covers the supply of all materials and the construction of all tools, jigs and fixtures required to complete the contract.

A1.3 The magnets, as manufactured, will comprise yokes, coils, water cooling circuits, electrical termination blocks, coil interconnections, insulated protective covers, support feet and all other mechanical brackets and fittings required for their full assembly.

A1.4 The contract will be complete when all magnets have been delivered to STFC's Daresbury Laboratory, Warrington, UK, when acceptance tests have been completed and all specified documentation, including magnetic measurement data has been received by STFC.

A1.5 The manufacturer shall guarantee the delivered equipment against defects due to either faulty components or faulty manufacture for a period of 18 months after delivery of the equipment.

A2 Contract Management and Quality Assurance

A2.1 At the start of the contract the manufacturer shall nominate a Contract Engineer who will be responsible for all reporting and contact with the nominated STFC point of contact.

A2.2 Within two weeks of the commencement of the contract, the manufacturer shall issue a detailed programme covering the design, procurement, manufacturing, testing and assembly phases in sufficient detail to allow regular progress monitoring. Thereafter, and throughout the contract, the Contract Engineer shall supply a written report to STFC every month, detailing progress with respect to this programme.

A2.3 The manufacturer shall maintain and apply a Quality Assurance (QA) system compliant with ISO9001:2000 for the design, manufacture and testing of all systems and equipment provided by them.

A2.4 The manufacturer shall ensure that all subcontractors have a similar QA system and shall take all the necessary actions to guarantee the quality of the subcontractor's delivery.

A2.5 Within two weeks of the start of the contract, the Supplier shall provide a QA plan for STFC's approval, listing all certification, supporting documentation and procedures that will be implemented within the contract, and which will form the basis of the final QA dossier.

A2.6 Before completion of the contract the Supplier will provide a PDF format copy of the QA dossier, certifying that the equipment conforms to the specification and the supplied engineering drawings, and containing all certificates, relevant documents and results of test procedures.

A2.7 The QA dossier will include full support documentation including operation and maintenance manuals and all relevant safety issues, as appropriate.

A2.8 All documentation will be in English.

A2.9 No acceptance or approval by STFC of quality assurance document, procedure or test result shall release the Supplier from his responsibilities in fulfilling the terms of this contract.

A3 General Description of the Magnets

A3.1 The magnets will all be excited by direct current (D.C.).

A3.2 The 4 identical dipoles will be rectangular parallel-ended magnets, with the beamline entering and exiting the magnets at an angle to the pole faces. It is planned to operate the dipoles with a single power supply, and each dipole needs to have independently-adjustable trim coils to provide additional steering.

A3.3 The magnet yokes shall be assembled from solid or laminated steel, as specified in Section C. All types of magnet should be able to be split to allow the vacuum chamber to be introduced from above.

A3.4 Provision for mounting survey monuments is required on the top surface of the magnets. These are detailed in the appropriate drawings.

A4 Quantities of the Contract

A4.1 The following items are required:

- 4 dipoles, and
- one spare dipole coil.

A4.2 The contract will include:

- the magnetic design of magnets to meet the performance specification;
- mechanical, thermal, and electrical designs, carried out in collaboration with STFC;
- the provision of all tools, jigs and fixtures;
- the procurement of all materials for the production of the magnets;
- manufacture, testing, magnetic measurement and delivery of the items.

A4.3 All designs, tools and materials obtained during the contract shall remain the property of STFC, and shall be surrendered to STFC at any time during the contract, within one month of the receipt of written notification. The manufacturer will be required to hold the tooling in a satisfactory storage area for a period of 5 years from the completion of the contract.

A4.4 The design and all measurements shall become the property of STFC with the exception of any clearly defined prior-art which is and shall remain the property of the manufacturer.

A5 Programme and Delivery

A5.1 The following programme is required for these magnets:

- Contract placed beginning week 1;
- Detailed programme and QA plan issued to STFC end week 2;
- Completion of designs (including tooling design): end week 5;
- Final Design Review and STFC approval beginning week 6;
- Completion of manufacture and measurement of dipoles end week 20;
- Completion of delivery of all magnets end week 21.

A5.2 The delivery of all magnets shall be to the Daresbury Laboratory, Warrington, WA4 4AD, U.K., carriage paid by the manufacturer. Package weights should be clearly indicated on the outer cover.

A5.3 During the contract, and particularly during the design phase, Design Review Meetings shall be held between STFC and the manufacturer. These shall alternate between STFC's Daresbury Laboratory and the manufacturer's premises.

A5.4 All magnets shall be protected during transport from damage due to dirt, weather and rough handling. Tenderers should state, in their offer, their proposed package and delivery arrangements.

A6 Magnetic Design

A6.1 The design of the pole profiles and pole ends to achieve the required field configuration of the magnets will be the responsibility of the manufacturer.

A6.2 The control of quality for the magnets will be by magnetic measurements, mechanical, electrical and thermal tests.

A7 Engineering Design

A7.1 Whilst the magnetic, electrical, mechanical and thermal design of the magnets, including the yokes and coils attachments, shall be the responsibility of the manufacturer, STFC has carried out preliminary work to enable the design of power supplies and other associated engineering systems to proceed.

To maintain compatibility with this work, the specification of the magnets and the attached drawings define limits for some of the engineering parameters, or will indicate fixed values for certain parameters; these are **mandatory**, and will be contractually binding.

A7.2 The engineering design of the magnets will include the following details:

- Features for the mounting of survey monuments;
- a footplate to interface with STFC's girder arrangement;
- the position of power and water connections.

These details need to comply with STFC's layout and planning and arrangements will be jointly agreed early during the design phase of the contract.

A7.3 Before the manufacture of any tools or dies commences, the manufacturer shall communicate the final conclusions of the magnetic modelling, mechanical, electrical, and thermal designs to STFC. This will take the form of computer generated graphics, summary papers giving numerical data and drawings of the resulting design.

A7.4 Each individual coil, yoke and each complete magnet will be identified and numbered. The identification number will be stencilled onto the component at an agreed position, as shown on manufacturer's drawings approved by STFC. The manufacturer shall utilise a numbering system with the following identifying format for both quality control records and the item identification:

- Characters 1 to 5: 'CLARA' (Compact Linear Accelerator for Research and Applications);
- Character 6: 'D' (Dipole);
- Character 7: 'C' (Coil);
  or 'Y' (Yoke);
  or 'M' (Complete Magnet)
- Characters 8 and 9: 'nn' (integer number starting at 03).

These number sequences will be used for all manufacturing and test records and in all communications when reference is made to specific components or magnets.

A7.5 The magnets shall be designed with lifting brackets that are adequate for the support of the complete magnet.

A7.6 The design shall ensure that the upper and lower halves of magnets correctly mate and align on reassembly after separation to insert the vacuum vessel.

A7.7 Preliminary designs for the structures needed to support and align the bases of the magnets have been carried out by STFC and these are shown in the attached drawings. These are to be included in the manufacture of the magnets.

A8 Drawings

A8.1 The drawings listed in Appendix A are supplied as part of this request to tender and are an integral part of the specification.

A9 Information and Approval

A9.1 Before commencing construction of magnets or any necessary tools or dies, the manufacturer shall submit to STFC, for approval, copies of all drawings that will be used in the manufacture. Details of the required drawing format are given in section A12 below. After approval, one copy, signed by an authorised representative of STFC, will be returned to the manufacturer not later than two weeks from the receipt of the drawings. No manufacture of any item will commence without approval of the relevant drawings. This approval will not relieve the manufacturer of any of their responsibilities under the contract.

A9.2 Manufacture of the magnets, or any tools or dies that will be needed for that manufacture, will not commence until STFC has fully approved, in writing, the magnetic, electrical and thermal design figures submitted according to this specification. In the exceptional case, where the manufacturer can demonstrate that an item is not dependent on the completion and approval of the engineering designs, and where a delay in commencing the manufacture of that item can be shown to lead to a delay in the delivery of the magnets, STFC will approve, in writing, an early commencement of that manufacturing process.

A9.3 The manufacturer shall not make use of any major sub-contractor unless full details of the type and location of the sub-contractors' factory, the nature of the work that is to be subcontracted, and the contractual timescale for that work have been submitted to STFC. The sub-contract shall not be placed until written approval has been given by STFC. Copies of all technical documents passed between the manufacturer and sub-contractors will be provided to STFC.

A10 Testing and Magnetic Measurement of the Magnets

A10.1 The manufacturer shall be responsible for the electrical, thermal, and mechanical testing of the magnets as specified in the appropriate sections. This shall include the provision of all test gear and measuring apparatus needed to carry out the tests as detailed.

A10.2 All tests will be carried out at the premises used for the manufacture and assembly of the magnets, and sub-contractors shall not be used for any tests or measurements, unless specifically approved by STFC in writing.

A10.3 Magnetic measurement of all magnets will be carried out at the manufacturer's premises after the conclusion of all electrical and mechanical tests that are specified at works. The magnetic tests will be the responsibility of the manufacturer, and will be made on equipment supplied by the manufacturer, as described in the appropriate sections. STFC reserves the right to be represented at all such tests and measurements.

A10.4 The manufacturer shall provide all necessary facilities for these tests, measurements and adjustments, in particular:

- a suitable test area, of adequate size, clean and illuminated, and temperature stabilised to ±2˚C;

- a 'point-by-point' magnetic measuring system capable of producing a field map of the magnets in three dimensions; this to be capable of measuring magnetic flux-density to an accuracy of ±0.01 % of reading plus ±0.006% of full scale, at excitation levels as defined elsewhere;
- one or more controllable DC power supplies capable of delivering the rated current of the magnets, as specified; the power supply to be monitored and stabilised to $\pm 1.0 \times 10^{-5}$ or better at the rated magnet current.

A10.5 The nature and technical capabilities of the magnet measuring equipment to be made available by the manufacturer for these tests and measurements should be fully described in the quotation.

A11 Inspection During Manufacture and Testing

A11.1 STFC and its authorised representatives shall have reasonable access to the premises of the manufacturer for the purposes of inspection during all stages of manufacture and tests under the contract.

A11.2 STFC and its authorised representatives shall have reasonable access to the premises of all sub-contractors for the purposes of inspection during all stages of manufacture and tests under the contract. This shall be ensured by a suitable clause written into any contract covering any manufacturing process that is to be carried out by a sub-contractor.

A11.3 STFC or its authorised representative will inspect and approve all tooling, fixtures, materials and test equipment prior to their use in fulfilment of the terms of the contract.

A11.4 Inspection and approval under the terms of this specification shall not release the manufacturer from any responsibilities under the terms of the contract.

A11.5 STFC or its authorised representatives shall be entitled to witness all tests that may be necessary under the terms of this specification. The dates of the tests will be notified ten working days in advance to STFC by the manufacturer.

A11.6 The results of all tests shall be recorded on test certificates which shall be kept for this purpose. An electronic copy of all such certificates shall be provided to STFC within ten working days of the test in question.

A12 Manufacturer's Design Drawings

A12.1 The manufacturer shall supply completed manufacturing drawings in PDF format. During the design phase, 3D model information should be supplied in Pro/E or STEP files.

A12.2 The manufacturer will be required to provide full details of the design of the finished magnets, including yoke, coils, sub-assemblies, cooling circuits, terminals, brackets, fittings and all other attachments including survey requirements. This will comprise a full set of engineering drawings showing all components and sufficient assembly details to allow complete and satisfactory construction of the magnets. A complete set, as per A9.1 above, shall be delivered to STFC, according to the timescale defined in A5.1 above.

A12.3 The total number of drawings will be agreed with STFC during the design exercise. It will include a general arrangement that incorporates a complete component list with material details and suitable cross-references to other drawings. It will also include drawings of the yoke assembly and sub-assemblies and of the coils.

A12.4 STFC will provide a batch of drawing numbers for all design and manufacturing drawings, so that these drawings can be incorporated into the STFC registry.

A13 Engineering Standards

A13.1 All labelling, manuals, drawings and other documentation shall be in English.

A13.2 The equipment and drawings must in all respects comply with the relevant BS/IEC standards, recommendations and reports including the latest revisions including but not limited to:

- The Health and Safety at Work etc. Act, 1974;
- BS-7671 "Requirements for electrical installations";
- The Control of Substances Hazardous to Health Regulations, 1994;
- The Chemicals (Hazard Information and Packaging) Regulations, 1993
- Classification of degrees of protection provided by enclosures BS-5490/IEC-529;
- Safety of machinery – Electrical equipment of machines Part 1 BS EN 60204-1:1993;
- Graphic symbols for diagrams BS-3939/IEC-617;
- All other applicable standards.

A13.3 All exposed conductors shall be shielded against contact to IP2X.

A13.4 The magnets shall be built using Metric fittings and fasteners.

A13.5 Asbestos or asbestos-type insulation, and insulation containing PCBs shall not be used. Where a choice of materials is available (e.g. cables, support hardware), preference shall be given to materials or equipment exhibiting a higher level of fire resistance.

SECTION B - DIPOLE MAGNET DETAILS

B1 Description of the Dipole Magnets

B1.1 The four dipoles will all be rectangular parallel-ended ‘H-core’ magnets, with the deflected beam path at an angle to the pole face.

B1.2 The magnets will be excited by two coils mounted on the poles, clear of beam and vacuum components in the median plane. STFC require that all the magnets be water cooled (via external or internal cooling channels). The thermal and cooling parameters given in D1.3 are **mandatory**.

B1.3 The dipoles should have additional independently-powered trim coils mounted on the poles. These are intended to provide extra correction in the horizontal plane.

B1.4 The trim coils should be able to generate the required additional field (shown in B2.1) irrespective of the current in the main coils.

B1.5 To generate the pure dipole field required in the magnets, it is anticipated that the pole faces will, in the transverse plane, have flat, parallel central regions and be terminated with shims at the inner and outer edges of the poles.

B1.6 Holes will be provided for survey mounts. Further details are given in the supplied drawing.

B2 Parameters for Dipoles

B2.1 The following dipole magnet parameters are **mandatory**:

	Main coils	**Trim coils**	**Units**
Number of magnets required	4		
Number of spare coils required	1		

Minimum magnetic strength $\int B.dl$ at nominal current, evaluated along the beam path	100	1.5	T.mm
Minimum vertical magnetic field at nominal current	500	7.5	mT
Bend radius of electron beam	1000		mm
Magnetic length	200		mm
Local horizontal good field region (available to the electron beam along the complete arc within the dipole)	±34		mm
Vertical good field region (available to the electron beam along the complete arc within the dipole)	±17		mm
Minimum magnet pole gap (at centre)	44		mm
Maximum integrated field variation in good field region $\int \Delta By/B(0).ds$ (measured along arc, relative to expected linear variation)	$\pm 1 \times 10^{-4}$		
Linearity of field amplitude vs. current over full range	98%		
Maximum residual field at zero current	0.2		mT
Clear vertical aperture for vacuum chamber	42		mm
Clear horizontal aperture for vacuum chamber	180		mm
Bend angle	200	3	mrad
Angle between magnet end faces	0		°
Tolerance on angle between magnet end faces	±0.1		°
Maximum overall width of magnet	500		mm
Maximum overall height of magnet (excluding baseplate)	440		mm
Maximum overall length of magnet	316		mm

Drawings of the dipole magnet, with the above dimensions clarified and the vacuum vessel position identified, have been included with the specification – see Appendix A.

B3 Magnetic Measurements of Dipoles

B3.1 After all electrical and mechanical tests have been completed, each dipole will be magnetically measured. The measurements will characterise the magnet by measuring the vertical magnetic flux density (B_y) on a 3-dimensional grid having the following parameters at the nominal current under DC excitation:

- horizontal range: on the beam centre line, and in steps of 5 mm out to the edge of the horizontal good field region as defined in the appropriate section;
- longitudinal range: in a curved arc following the beam path in 5 mm steps, extending in a straight line at either end 200mm beyond the edges of the poles;
- vertical range: in the midplane, and in 5 mm steps extending to the edge of the vertical good field region as defined in the appropriate section.

In addition, measurements at the horizontal and longitudinal positions specified above will be carried out, but in the median plane only, at DC excitation currents of 50% and 110% of the nominal current.

B3.2 The linearity of each dipole shall be tested as follows. The magnet shall be degaussed by powering to the nominal current in each polarity twice and then reducing the excitation to zero. The field at a single point in the centre of the magnet shall then be measured at 5% intervals from 0 to 110% of the nominal current.

B3.3 The above measurements should be repeated for the trim coils, after degaussing the magnet using the main coils and powering the main coils to 100% of the nominal current. One field map at 100% trim coil excitation should be sufficient.

B3.4 The residual field in each dipole shall be tested as follows: the magnet shall be ramped from zero to nominal current and back to zero, three times. The field at the horizontal, vertical and azimuthal centre of the magnet shall then be measured.

B3.5 The magnet shall be rejected if **any** of the following conditions are met:

- the integrated transverse variation at nominal current of vertical field within the good field region is greater than the specified value;
- the integrated magnetic strength at nominal current is less than that specified;
- the linearity is less than 98%;
- the residual field is greater than 0.2 mT.

B3.6 The manufacturer shall assemble comprehensive documentation in PDF format relating to the tests, measurements and adjustments carried out on each dipole. This will record the number of the dipole together with details of all test results and measurement data obtained for that magnet. This will provide a long-term record of the dipole's magnetic performance which is of major operational significance to STFC.

B3.7 The manufacturer shall provide measurement data for each magnet in spreadsheet format.

SECTION C - MAGNET YOKES

C1 Yoke Assembly – General

C1.1 It must be possible to split the dipole magnets, to introduce the vacuum vessels from above.

C1.2 Taking due account of the coil dimensions and the space required to introduce the coils onto the magnet, the manufacturer shall propose the number and nature of individual yoke sub-assemblies (blocks) from which the completed magnets will be assembled. This will be part of the engineering design, and subject to agreement by STFC. Tenderers should indicate, in their quotation, the recommended division of the yoke for the magnets.

C1.3 Tenderers are free to propose the use of either solid or laminated yokes.

C1.4 If laminated yokes are proposed, the tenderers should determine and indicate in their tender document the method of stacking and securing the laminations they intend to use. These methods shall be proposed as part of the engineering design, and subject to STFC's approval.

C1.5 Where laminated yokes are proposed, tenderers should give a clear explanation of how, by machining, they intend to ensure that the specified dimensions and angles required on the completed block will be achieved.

C2 Steel

C2.1 This section defines the steel quality that is to be used for the magnet yokes.

C2.2 The magnetic performance of the magnets is the responsibility of the manufacturer, who must choose steel of the correct grade to meet the required performance. However, the material used in the magnet yokes shall comply with the following magnetic properties:

Field *H* (A/m)	**Minimum Induction *B* (T)**	**Minimum relative permeability μ_r**
150	0.5	2650
320	1.0	2480
1000	1.5	1190

The material's coercivity should not exceed 100 A/m.

C3 Dimensional Control

C3.1 The acceptance of the yokes will be determined by measuring all dimensions shown on the specification drawings or within this specification as mandatory. No further dimensional measurements are required, as acceptance is based on magnetic performance.

C4 Painting the Yokes

C4.1 After assembly and control, the yokes will be protected against rusting by coating the appropriate surfaces by means of a powder coating system of minimum thickness 0.2mm. The following faces will not be painted:

- reference and mating faces;
- the survey monument supports.

C4.2 The unpainted areas shall be protected by a light oil or other rust preventative measures. The colours to be used for the magnets will be specified by STFC at an early stage of the contract.

SECTION D - COILS

D1 Construction Method

D1.1 The coils shall be constructed using solid copper conductor, or hollow conductor with a water cooling channel where necessary.

D1.2 The coil conductors shall be insulated by an enamelled surface layer which provides adequate inter-turn insulation. This enamel insulation shall comply with IEC standard 60317-8 and satisfy the requirements of Thermal Class H specifications. Additional outer-ground insulation shall be added to ensure that the coils meet the IP2X specification.

D1.3 The coils of the magnets shall be designed to have the following thermal parameters when operated with nominal flow in the water cooling circuit (the inlet water temperature should be assumed to be 25˚C):

Maximum allowed coil temperature rise at nominal DC current (measured at coil surface inside magnet gap)	10	˚C
Maximum allowed coil temperature rise at nominal DC current (measured by coil resistance)	15	˚C
Maximum allowed coil temperature rise at 110% of nominal DC current (measured at coil surface inside magnet gap)	15	˚C
Maximum allowed coil temperature rise at 110% of nominal DC current (measured by coil resistance)	20	˚C

D1.4 The wound coils will be mechanically consolidated by the use of an epoxy resin system applied either during the winding of the coils or present as a 'B stage' coating on the coil material. The manufacturer shall ensure that the bonding process is adequate for the long-term mechanical stability and soundness of the coil and that the design used provides an adequate outer electrical insulation.

D1.5 The coils shall be terminated on suitably mounted, insulated, connection panels.

D1.6 After completion of winding and the curing of the resin bonding system, the resin on the coils must be fully transparent, with no colouriser or additive that would limit observation of the enamelled turns within the coil. No paint or other external coating will be allowed.

D2 Conductor

D2.1 The conductor shall use oxygen-free high conductivity (OFHC) copper with a maximum volume resistivity of 17.3 nΩm at 20˚C, and its properties shall be as specified in DIN 1787 OF-Cu (DE), or BS 6017:1981 Cu-OF (UK), or A 53-100 Cu-c1 (France).

D2.2 The material shall be in the fully-annealed condition prior to winding, and the coil fabrication method must be such as to minimise work hardening during the winding operation.

D2.3 The dimensions of the conductor shall be as determined by the manufacturer’s design, as approved by STFC.

D2.4 The uniformity of the conductor shall be such that the resistance of all coils constructed from it shall be equal to within ±5%.

D2.5 The use of joints within the coils will not be permitted.

D3 Bonding and Outer-insulation System

D3.1 No material, other than those detailed in this section shall be included in the coil without the written permission of STFC or its authorised representative. All materials must be suitable for use in a high radiation environment.

D3.2 The resin bonding system shall comprise a radiation-resistant epoxy resin with an anhydride curing agent, with optional inclusion of an accelerator. The choice of the resin supplier, the resin type and the curing agent are left to the manufacturer. However this choice is part of the offer and must be indicated within the offer, with corresponding technical documents appended.

D3.3 Any addition of additives or wetting agents will be subject to written authorisation from STFC.

D3.4 The use of additives with resin systems is known in many cases to prejudice the required mechanical and electrical properties, in particular the irradiation stability. Dilutants, fillers, plasticisers and flexibilisers are therefore specifically prohibited.

D3.5 Details of bonding and curing operations for the resin system must be submitted at the tendering stage. STFC will approve all materials and processes prior to use in coil manufacture, but such approval shall in no way release the manufacturing company from any of its responsibilities under the contract.

D3.6 The coil terminals, the connection posts and all metallic parts connected to them will be insulated from the yoke and able to sustain 5 kV DC without any electrical breakdown and with an insulation resistance greater than 10 MΩ.

D3.7 The coil terminals, the connection posts and all metallic parts connected to them will be protected against accidental contact by an insulating, transparent cover, shielded against contact to IP2X, which can only be removed by the use of tools; the tenderer's proposals for this cover shall be described in the offer.

D3.8 A single terminal connection post able to receive a 10 mm^2 cable shall be provided for earthing the yoke and other components. This shall be connected to all laminations (if used) in each block comprising the yoke by means of a single, resistive, conducting strip painted along the yoke block. This shall be designed so as not to create a shorted turn around the yoke laminations.

D4 Water Connections

D4.1 Magnets should be supplied with an inlet manifold and outlet manifold mounted on the magnet. The manifold should be manufactured from metric stainless steel tube, grade 304/316 and conform to ASTM A269, suitable for connection to the supply and return water system via a single Swagelok metric 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.

D4.2 All hoses and pipes located on the magnet should be metric Swagelok. Swagelok American Standard Pipe Thread (NPT) is NOT to be used.

D4.3 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 electron beam. Water connections to the manifolds should be well above and below the beam-line. Where water conduits cross the beam-line horizontal plane, pipe work should be metallic.

D4.4 The manufacturer shall ensure that there is adequate electrical connection between the earthing post, the manifolds and other components so that all the exposed metallic parts of the magnet are safely earthed by this terminal post.

D5 Inspection and Tests of Coils at Works

D5.1 STFC or its authorised representative shall inspect and approve all tooling, fixtures, materials and processes prior to their use in fulfilment of the contract.

D5.2 Inspection and approval shall not release the manufacturer from any responsibilities under the terms of the contract.

D5.3 All coils shall bear an identification number stencilled in a position as shown on manufacturer's drawings approved by STFC, as described in A7.4 above.

D5.4 The programme of tests to be carried out shall be as specified in Section D6 below.

D5.5 All tests shall be undertaken using equipment and procedures which have been agreed by STFC. The tenderer must specify the methods which it is proposed to use to carry out the test programme.

D5.6 STFC reserves the right to reject any material or coil not fulfilling the conditions laid down in this specification.

D5.7 No conductor or coil failing any test shall be used or repaired without the written permission of STFC or its authorised representative.

D6 Test Schedule for Coils at Works

D6.1 Test certificates shall be available relating to tests undertaken by the copper manufacturer, to include dimensions, resistivity and Brinell hardness.

D6.2 All coils shall be visually inspected, and must be free from cracking, voids and other flaws or defects. The bonding insulation must not exhibit resin-rich areas, and the thickness of resin on the coil surface must not exceed 0.5 mm. Coils failing to satisfy any of these criteria shall not normally be accepted.

D6.3 The electrical resistance of all coils shall be measured with a DC bridge. The values shall be corrected to 20˚C, and must be within ±5% of the mean value for all coils.

D6.4 Each coil shall be energised until the coil temperature increases to 55˚C, as measured by the change in electrical resistance. On attaining the required temperature the current shall be interrupted and the coil allowed to cool until the conductor again assumes the ambient temperature, as measured by the conductor resistance. This cycle shall be repeated ten (10) times. Any coil exhibiting evidence of cracking or delamination shall be rejected. The manufacturer may wish to undertake this procedure on a number of coils simultaneously.

D6.5 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:

- Record insulation resistance between coil terminals and water bath, at a voltage of 500 V.
- Apply direct voltage of 5 kV between coil terminals and water bath for one minute, and record the leakage current.
- Repeat the insulation resistance measurement.

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

D6.6 Immediately after the test described in D6.5 above the coil shall be tested by using it as the secondary winding of a transformer. A maximum voltage of 2.5 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.

SECTION E - MECHANICAL AND ELECTRICAL TESTS

E1 Mechanical Test and Measurement Programme

E1.1 The manufacturer shall give details of their normal test procedure for routine mechanical tests during manufacture with the tender. Details of the specific tests which will be used in this contract shall be agreed at the Design Review.

E2 Electrical Test and Measurement Programme

E2.1 A direct voltage of 2 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 10 MΩ, shall be rejected.

E2.2 On each magnet, the coils shall be powered for a period of at least two hours at the nominal current specified and with the nominal water flow rate. During this test the temperature of coil surfaces and all coil interconnections and terminals will be checked with contact thermometers; the coil voltage and current shall be monitored with an accuracy that will allow the average coil temperature rise, measured by resistance, to be assessed. Results shall be judged with respect to the appropriate magnet thermal specifications.

During this time, the mechanical, electrical and thermal stability of the magnet will be monitored. Any magnet showing evidence of any of the following shall be rejected:

- electrical discharge in the coils, at the terminals between laminations or parts of the yoke and other fittings;
- overheating of the coils;
- a terminal voltage which is more than 5% lower than the mean for that type of magnet (evidence of low inductance due to a shorted turn around the yoke).

E2.3 The inductance of each magnet should be measured and recorded.

E3 Acceptance Tests after Delivery

E3.1 After delivery, each magnet will be visually inspected for mechanical damage suffered in transit. Any such damage will be reported to the manufacturer. Possible repair will be the subject to the agreement of STFC. 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 normally be rejected.

E3.2 Electrical tests shall be carried out by STFC staff at Daresbury Laboratory after delivery. The manufacturer has the right to be represented during these tests but shall notify STFC in writing if this right is to be exercised. Likewise, STFC will endeavour to provide the manufacturer with adequate notice concerning the timing of such test sequences.

E3.3 A direct voltage of 2 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 10 MΩ, shall be rejected.

E3.4 Each magnet will be energised with a direct current of value equal to the nominal current specified in the appropriate magnet parameters, 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.

SECTION F - FIDUCIALS FOR MAGNETS

F1.1 For the dipole magnets, four survey fiducials are required on the top face of the magnet as specified on the drawing.

F1.2 A circular area 50 mm in diameter should be left unpainted around each fiducial hole.

SECTION G - TENDER PRESENTATION

The following list of required information must be used as a basis for preparing the technical sections of the tender. The technical information so supplied shall be used for tender adjudication and shall be one of the judgment criteria for the placement of the contract.

G1 General

G1.1 The tenderer must consider each clause of the specification in turn, and comment on any with which they do not propose to comply, providing in such cases a detailed explanation of any departures from the conditions defined in this specification.

G1.2 The tenderer should indicate the proposed method of undertaking each of the required tests and measurements, including brief details of the equipment that is to be used.

G1.3 The tenderer must identify all parts of the contract which require subcontracting, together with the identity of the proposed subcontractor.

G1.4 The location of all manufacturing processes associated with the contract must be given.

G2 Compliance and Adjudication

G2.1 In order to allow STFC to judge the compliance and suitability of the quotation, the tenderer is asked to provide the following items of information;

- the design facilities available to the tenderer in-factory;
- the manufacturing facilities available to the tenderer in-factory or through a sub-contractor;
- the experience of the manufacturer in the design and construction of electro-magnets for use in particle accelerators or other precision application.

G3 Timescales and Price

G3.1 The tenderer shall provide a programme showing the following milestones for the delivery schedule requested in section A5.1:

- the placement of contract;
- the commencement of design;
- the completion of design and the submission of all drawings and design calculations;
- the approval of the design by STFC following the Design Review meeting;
- the ordering of materials;
- the delivery of materials;
- the completion of tooling and fixtures;
- the commencement of manufacture of magnets;
- the commencement of magnetic measurement of the magnets;
- the delivery of the magnets.

G3.2 The tenderer should provide information relating to the packing that would be used for delivery of the magnets.

G4 Magnet and Engineering Design

G4.1 An indication of the solutions or parameters for major design features should be given.

G4.2 The tenderer should give a brief indication of the proposed method of mounting the coils on each of the magnets.

G4.3 The tenderer should provide details of any difficulties in achieving the tolerances defined in the specification or attached drawings.

G5 Magnetic Steel and Yoke

G5.1 The tenderer shall indicate the proposed source of supply of the steel that will be used in the magnet yokes.

G5.2 Technical information required for the proposed steel should include:

- type of the proposed steel and whether solid or laminated steel is proposed;
- thickness of laminations (if proposed);
- proposed nature of bonding and insulated coating (if laminations are proposed);
- quoted permeability as a function of flux density;
- quoted coercivity.

G5.3 The tenderer should indicate the test and measurement methods that are proposed for quality control of the magnetic, electrical and physical properties of the magnet steel.

G5.4 The tenderer should indicate the method to be used to accurately measure the pole profiles.

G6 Coil Production and Testing

G6.1 The tenderer should indicate the expected source of supply for copper conductor.

G6.2 The tenderer should give details of the proposed conductor sizes and cross-section, inter-turn insulation and coil winding operation for all magnets.

G6.3 The tenderer should indicate the proposed source of supply of the epoxy resin chemical system proposed for the impregnation or bonding process, together with details of its expected mechanical, thermal and radiation properties.

G6.4 Details of the method of mechanically binding and providing an external ground insulation to the coils should be provided. Where an epoxy resin system is proposed, the tenderer should indicate the proposed source of supply of that chemical system, together with details of its expected mechanical, thermal and radiation properties.

G6.5 A brief description should be given of the equipment which is proposed for the various tests listed in the coil test schedule.

G6.6 Details of the proposed direct or indirect cooling scheme should be given. Expected coolant flow, pressure drops and resulting coil temperature should be indicated.

G6.7 The tenderer should indicate, with justification, whether coil over-temperature switches are required. Details of coil over-temperature switches should be given if they are proposed.

G7 Electrical Connections

G7.1 The tenderer should indicate what types of connections are proposed for the cables as well as the proposed layout of terminal boards and protective covers.

G7.2 The tenderer should indicate the proposed method of coil electrical interconnection.

G8 Magnetic Measurements

G8.1 The tenderer should confirm that they propose to carry out the full sequence of magnetic tests as specified.

G8.2 The tenderer should indicate the techniques that are proposed for the magnetic tests and, where these differ from those specified, should give a detailed explanation of how the proposed techniques will provide the measurement data required to the resolution and accuracy specified.

G8.3 The tenderer should give a full description of the proposed equipment for carrying out the magnet measurements, together with its location if not at the factory of the manufacturer.

APPENDIX A - DRAWING LIST

Drawing Number	**Issue**	**Title**
256-11161	A	CLARA Dipole Type 3
256-11494	A	CLARA VBC Layout