Thomas Jefferson National Accelerator Facility

12000 Jefferson Avenue

Newport News, VA 23606

SPECIFICATION NO:

D00000-19-00-S002-RevA

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A		Changed Title/Signature Page and completely revised format and details to match single magnet design					
REV	ECO #	DESCRIPTION	BY	CH K.	APP.	APP.	DATE

Summary of Revisions

Initial issue Date 12-11-2007

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1 STATEMENT OF WORK

1.1 General Overview

The Thomas Jefferson National Accelerator Facility (Jefferson Lab) requires one normal conducting dipole C-magnet (Tagger Magnet) with integrated vacuum vessel for the Hall-D coherent bremsstrahlung photon source to be installed within its Continuous Electron Beam Accelerator Facility (CEBAF). Upstream of the tagger magnet system the 12 GeV CEBAF electron beam will pass through a thin crystal radiator. This produces a narrow beam composed of a mixture of particles including 12 GeV electrons which did not interact in the thin target, photons generated in the target, and electrons with energy less than 12 GeV which interacted in the target and radiated the photons. The purpose of the Tagger Magnet is to separate the three classes of particles. The photon beam passes un-deviated through the magnet along the original beam axis; the 12 GeV electrons are bent by 13.4° and travel toward the electron beam dump; the energy degraded electrons produce a fan of particles which pass through a long vacuum window and are detected with scintillator counters. The energy of the photons in the photon beam is determined by measuring the momentum of the energy degraded electrons and requiring conservation of energy. For this reason the magnetic field along the path of the lower energy electrons must be accurately known. A 3-D model of the reference design of the Tagger Magnet system is shown in Figure 1. This Statement of Work covers the requirements for the Tagger Magnet, vacuum vessel, and related supports. An isometric view of the Hall-D tagger hall showing the Tagger Magnet installed along with the nearby equipment is shown in Figure 2. The requirements given within this document have been established by Jefferson Lab based upon extensive calculations and the experience gained by the successful operation of a similar tagging spectrometer in another existing experimental hall.

All references to specific manufacturers of products in this document shall have the following words appended to the requirement: "or Jefferson Lab approved equivalent".

1.2 Scope of Work

This specification covers the design, manufacture, assembly, testing, delivery, and acceptance testing of the Tagger Magnet System. Specific items to be designed and manufactured include the magnet's iron core with pole tips, the normal conducting coils for the magnet, the vacuum vessel which is to be integrated into the magnet, the stands to support and align the magnet and vacuum chamber, and all parts necessary to assemble and support the final system. The technical requirements include magnetic requirements, configuration, tolerance, and material specifications for the steel yoke/poles and assembly, configuration/performance aspects of the normal conducting coils, design specifications for the vacuum chamber, and a design for the needed stands and supports. This subcontract will feature substantial Government Furnished Material (GFM) and Government Furnished Equipment (GFE). Jefferson Lab will furnish at no cost to the subcontractor the DC Power system consistent with Section 1.4.

a. The subcontractor shall, unless otherwise noted, furnish all labor, materials, equipment and facilities to design, fabricate, test, and deliver the Hall-D tagger magnet and vacuum chamber system in accordance with this specification.

b. The Tagger Magnet System shall include the following; magnet core assembly, the Tagger Magnet stand, the adjustment cartridges for the stands, the normal conducting coils, winding fixtures and tooling, the vacuum vessel, a blank off flange for the exit window, flanges needed to vacuum test the vacuum chamber prior to assembly into the tagger magnet, vacuum chamber support brackets, the support for the vacuum chamber from the tagger magnet, all material needed for shipping transportation and assembly, and any other items required for a complete operating Tagger Magnet System not covered by this specification.

c. The vendor shall submit as part of the proposal a manufacturing plan for Jefferson Lab approval. The plan shall include descriptions of work flow and processes, including tests and "hold points" for JLAB approval. Test equipment and special fabrication tooling shall be identified and defined in detail. The Manufacturing Plan shall include the integration of the vendor's Quality Assurance Program (Section 2).

d. Any changes to the plan submitted with the proposal are not to be incorporated into the work until they have been reviewed and approval has been granted by the Jefferson Lab technical responsible or the technical responsible deputy.

e. The subcontractor shall perform the Acceptance Test before delivery to Jefferson Lab in accordance with this specification (Section 5) and subject to all local safety regulations at the subcontractor. In the event the event the magnet fails the acceptance test the subcontractor is responsible for all material, labor, and shipping needed to repair and re-test the Tagger Magnet System.

f. The subcontractor shall supply all documentation required in this specification.

g. The subcontractor shall host design and safety reviews (Section 6) at the subcontractor's facility and other design reviews as may be required.

h. The subcontractor shall prepare and present the Tagger Magnet Acceptance Test Plan to JLAB prior to the acceptance test of the Tagger Magnet (Section 5).

1.3 Information Furnished by Jefferson Lab Prior to Award

A Reference Design (RD) for the Tagger Magnet system is provided. It is based upon extensive TOSCA analysis as well as successful operation of a similar tagging spectrometer at Jefferson Lab. The Jefferson Lab RD represents one approach which Jefferson Lab considers feasible for meeting the requirements of this specification when fully developed by the subcontractor. The offeror is free to propose alternative designs, or to develop the Reference Design. The Jefferson Lab RD consists of 3D CAD models, drawings, TOSCA analysis, FEA analysis, test reports, R&D reports, engineering reports, publications, documentation of Jefferson Lab provided items and other documents.

1.4 Items Furnished by Jefferson Lab after Award

a. A DC power system complete with 3 PPM DC source, polarity switch, and current transductor.

The above items are to be furnished by Jefferson Lab at no cost to the subcontractor. The DC power supply will be delivered to the subcontractor for use on the Tagger Magnet system Acceptance Testing. The offeror shall indicate their acceptance of the offered GFM/GFE in their proposal. The offeror may propose alternatives at the offeror's expense to any of the above GFM/GFE items. The offeror shall state clearly and in sufficient detail in their proposal the design and specifications of the offered alternative item, the benefits to Jefferson Lab, and a convincing discussion of the overall Tagger Magnet schedule and the impact if any of the alternative items. All items provided by JLAB must be returned to JLAB after the successful acceptance test. The return shipping is to be at the expense of the offeror.

1.5 Responsibility

a. <u>If the Jefferson Lab Reference Design is developed</u>, steel geometry, metallurgy, handling, annealing, the clamping system for the iron yoke plates, and coil placement geometry shall be as stated in the reference design drawings and the Requirements Drawings of Section 1.9 and Section 4. Jefferson Lab will then bear responsibility for the magnetic performance requirements detailed in section 2. All other requirements shall be the responsibility of the subcontractor.

b. If the offeror proposes an alternative design, then the full responsibility (including magnetic performance requirements) for meeting all the requirements of this specification shall rest with the subcontractor. The offeror shall provide 2 months prior to the final design review documents and simulation files with sufficient detail so that Jefferson Lab may evaluate the statics and magnetostatics of the proposed design (milestone D-4). A TOSCA analysis of the subcontractor's alternate design shall accompany this documentation.

c. Jefferson Lab will appoint a technical representative authorized to interact with the subcontractor. The Jefferson Lab Technical Representative for the Tagger Magnet subcontract will be a Jefferson Lab staff engineer. Jefferson Lab reserves the right to appoint an Alternate Technical Representative to cover occasions when the Technical Representative is unavailable. Jefferson Lab reserves the right to change the individual designated as Technical Representative. Jefferson Lab reserves the right to send additional support personnel along with the Technical Representative to any function. The Jefferson Lab Technical Representative will review and approve all required documentation, make all Jefferson Lab required witness inspections, attend all design reviews, approve all milestones and other submittals and deliverables required by the Tagger Magnet subcontract.

d. Any aspects of the dipole magnet and vacuum system which are not covered explicitly by this specification, but which are obviously necessary to meet the requirements shall be furnished by the subcontractor. In the event of an oversight and/or apparent error in this specification, the subcontractor shall notify the Jefferson Lab Technical Representative for clarification/correction before proceeding with the aspect in question.

1.6 The Hall-D Tagger Magnet and Vacuum Chamber Design Documentation

The subcontractor shall provide Jefferson Lab with four sets of hard copies of all documents according to the Milestone Schedules in Section 7. Jefferson Lab requires that the magnet, vacuum chamber, and stand designs be performed on a 3D CAD system. The final design submitted (Milestone D-4) shall include 3D CAD model files in STEP format and CAD files of all subcontractor drawings in either IGES or DXF format. The subcontractor shall be responsible for providing 3D CAD models files and 2D CAD drawing files that are compatible with or can easily be converted to Jefferson Lab's 3D and 2D CAD without significant error, distortion or loss of information.

The subcontractor shall provide Jefferson Lab with input files used in all design software analysis, i.e. TOSCA, magnetic model files, and Finite Element Analysis model files that are compatible with Jefferson Lab's Siemens, UGS, SDRC, IDEAS or ANSYS FEA software (Milestone D-4).

1.7 Acceptance Testing

Acceptance testing shall be performed at the subcontractor's facility (Section 5). This testing shall demonstrate all magnetic, mechanical, thermal, electrical, and vacuum requirements are fulfilled.

In the event that the Tagger Magnet System cannot successfully meet the requirements of this specification either mechanical if the reference designed is developed or both mechanical and magnetic if a new design is proposed, the subcontractor shall be responsible for all costs associated with modification or repair or rework including shipping costs necessary to permit the assembled magnet to meet the final acceptance tests.

1.8 Shipping and Handling

Delivery shall be made to Thomas Jefferson National Accelerator Facility, Hall-D, 12000 Jefferson Avenue, Newport News, Virginia USA. The subcontractor shall be responsible for all delivery arrangements from the subcontractors Tagger Magnet System fabrication facility to Jefferson Lab Hall-D including shipping fixtures, special custom fabricated lifting devices, lifting points on the Tagger Magnet, lifting fixtures for the vacuum chamber, crating, packing, weather proofing, sea proofing and protection, customs clearance, customs duties if any, paid in full and local transportation costs into Jefferson Lab Hall-D. Jefferson Lab will apply for duty free entry.

The subcontractor's representative shall be present for the delivery, unloading and uncrating of the Tagger Magnet system. Jefferson Lab will provide unloading and uncrating services for the Tagger Magnet system at no cost to the subcontractor. The subcontractor shall be responsible for the delivery of the complete Tagger Magnet system into Jefferson Lab Hall-D including full responsibility for coordination of the delivery date and time. The subcontractor shall provide Jefferson Lab with a handling and safe lifting plan for the Tagger Magnet System not less than 6 months prior to delivery which must include a complete description including drawings and calculations if necessary of any special lifting devices that must be custom fabricated by the subcontractor to safely lift the Tagger Magnet System. Any custom lifting fixtures or shipping fixtures shall become the property of Jefferson Lab after delivery and contract close out.

1.9 Requirements Drawings

Table 1: Tagger Magnet System requirements drawings.

Drawing Number	Sheets	Drawing Title
D00000-19-00-3001	3	TAGGER INTERFACE
D00000-19-00-1006	2	Coil sub-assy
D00000-19-00-1001	2	Tagger Magnet Vacuum Chamber sub-assy
D00000-19-00-3002	1	Tagger Magnet Feature Requirements

1.10 Applicable Documents - The following documents are part of this specification. If any apparent conflict between the requirements of the reference documents and the specification is found, it shall be brought to the attention of the Jefferson Lab Technical Representative for resolution.

- ASME Code for Pressure Piping
  - B31.3 Process Piping
- ASME Boiler and Pressure Vessel Code (see paragraph 6.4.2)
  - Section II: Materials, Parts A, B, C, and D
  - Section V: Nondestructive Examination
  - Section VIII: Rules for Construction of Pressure Vessels (Divs. I and II)
  - Section IX: Welding and Brazing Qualifications
- Miscellaneous ASME Codes
  - Y14.5 Dimensioning and Tolerancing
- NEMA
  - NEMA Standards for Electrical Control 1C1-1954, latest revision, 155 East 44th St., N.Y., N.Y., which shall constitute the minimum acceptable standards.
- Institute of Electrical and Electronics Engineers (IEEE)
  - All electrical equipment shall conform to the latest standards of the Institute of Electrical and Electronics Engineers (IEEE).
- American Welding Society
  - AWS A 2.4 Standard Symbols for Welding, Brazing and Nondestructive Testing
  - AWS D1.6 Structural Welding code - Stainless Steel
  - AWS D1.1 Structural Welding code - Steel
- American Society for Testing and Materials

        - E493 Standard Test Method for Leaks using Mass Spectrometer Leak Detector in the Inside-out Testing Mode
        - E498 Testing for Leaks Using the Mass Spectrometer Leak Detector in the Tracer Probe Mode
        - E499 Testing for Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode
        - A380 Standard Practices for Cleaning and De-scaling Stainless Steel Parts
        - A578 Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
    - American Conference of Governmental Industrial Hygienists
        - Pamphlet ISBN: 1882417585 “Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposures Indices (2005)
- Miscellaneous
    - QQ-B-654A Fedaeral Specification Brazing Alloys, Silver

2 QUALITY ASSURANCE PROGRAM

The offeror shall prepare a quality assurance program for JLAB approval and shall furnish such documentation that JLAB may require. The offeror shall conduct quality control procedures and tests, which will guarantee that the product to be furnished by the offeror hereunder is in full conformance with these specifications. This program shall contain (when applicable) the mechanism for:

a. Inspection of all materials received from the offeror’s suppliers and subcontractors and the recording of this information.
b. Obtaining and recording of all material certifications and analyses.
c. The calibration and identification of standards and instrumentation used; the intervals between calibrations are also to be defined.
d. Establishment of inspection points during the production process, which will measure critical parameters.
e. The recording of all inspection data in such a manner so that the history of an item can be readily traced.
f. The submittal to the JLAB technical representative of all data related to the above.

The delivery of the QA/QC plan is Milestone D-5 (Section 7) and must be submitted with the proposal.

N.B. The Jefferson Laboratory technical representative shall have unannounced access to the offeror's plant, during regular business hours, for the purpose of conducting Quality Assurance Audits.

3 TECHNICAL REQUIREMENTS

3.1 MAGNETIC REQUIREMENTS

The following requirements are provided for offerors. The Tagger Magnet shall meet or exceed the magnetic requirements in Table 2. In addition to these requirements the steel alloys used and annealing procedures must insure that the coercive force shall not exceed 100 Ampere-Turns/Meter following saturation (ramp to 1.8 T then to zero) for the finally assembled magnet (Milestone AT&D-1).

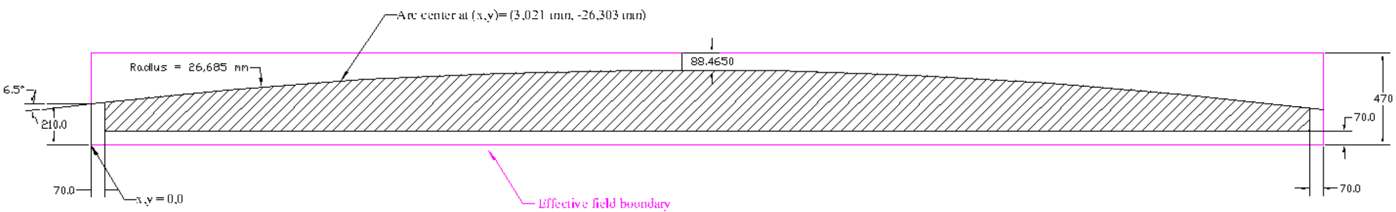
Table 2: Magnetic Requirements for the Tagger C-magnet

Requirement	Units	Value
Magnet Type		Normal conducting C-Magnet
Nominal magnetic field	T	1.500
Maximum magnetic field	T	1.80
Effective Length @1.5T	mm	6,300 $\pm$ 2
Distance to -x effective field boundary @1.5T	mm	235$\pm$ 2 Defined in drawing D00000-19-00-3002

Local uniformity volume		Defined in drawing D00000-19-00-3002
Global uniformity volume		Defined in drawing xD00000-19-00-3002

The offeror shall address these requirements in the proposal.

Fringe field uniformity



3.2 MECHANICAL REQUIREMENTS FOR THE MAGNET CORES

3.2.1 Geometrical Constraints

The maximum allowable space for the magnet is shown in the interface drawing D00000-19-00-3001. The magnet must be designed such that it can be assembled in place on the photon beam axis in the tagger hall using the lifting equipment foreseen for the hall. Due to this requirement, the maximum weight of any single assembly to be lifted in the hall is 25t which is the rating of the gantry crane over the tagger area.

The pole surfaces must be planar and parallel to $\pm$0.1 mm over the full surface after the magnet is assembled and powered to full field. Calculations and FEM analysis of the magnet and support structure must be presented with the final design to support this requirement (milestone D-8). The sealing surface between the magnet top and bottom pole and the vacuum chamber must also be parallel to within $\pm$0.2 mm. The maximum change in the gap between the pole sealing surface and the vacuum chamber sealing surface upon energizing the magnet to 1.5T and evacuating the vacuum chamber is 0.5mm. That the design meets these requirements must be demonstrated for the final design (milestone D-4).

The Tagger Magnet must be designed such that the magnet and the vacuum chamber are compatible. The top and bottom poles of the magnet form part of the top and bottom of the vacuum chamber. The vacuum forces on the poles and any forces from support brackets to the chamber from the magnet yoke must be included in the finite element analysis of the magnet. The requirements for the vacuum chamber are given in Sub-sections 3.5 and 4.4.

3.2.2 Material Requirements

The material which is planned to be used for the magnet cores must be specified at the time of the proposal. A plan must be submitted at the time of the proposal for how the chemistry of the core steel will be verified before the start of fabrication. The pole tip region of the Tagger Magnet must be free of voids, inclusions and internal defects which are larger than 0.3 inches; no evidence of defects within 0.9 inches of the finished pole surface is permitted. The proposal must include a plan describing the measures or procedures which will be taken to insure this.

Should a defect or defects in the magnet core be discovered that exceeds the criteria given above, it shall be reported in writing including any proposed repair technique or other remedy, to the Jefferson Lab Technical Representative within ten calendar days of discovery of the defects. Jefferson Lab will determine within ten calendar days after receipt of documents (including any proposed repair technique) if the piece is acceptable, repairable, or is to be rejected. If the piece is deemed “rejected” by Jefferson Lab it shall be replaced at the manufacturer’s expense.

The offeror shall address in the proposal how the requirements of this section will be achieved and present evidence of capability to conduct any required tests.

3.2.3 Material Handling and Heat Treatment

The proposal must contain a description for how the steel will be machined and how the annealing will be performed. The manufacturer must include in the proposal the type of machine on which the steel will be milled and what tolerances are possible.

The means to lift and transport all components must be foreseen and all necessary lifting fixtures must be provided. No magnetic lifting equipment may be used for the magnet cores. A preliminary lifting and assembly plan must be presented with the design of the magnet. A detailed lifting and assembly plan must be presented to JLAB 6 months before the delivery of the magnet. The detailed lifting plan must include all steps from the unloading of the delivery truck to the completion of the mechanical installation. This is deliverable D-9. The available lifting equipment is summarized in drawing D00000-19-00-3001. The truck ramp to the tagger hall at JLAB was designed so that a 73.5' long semi-truck (Classification WB-65) can back to the door. The door is 14 ft 9 in high and 14 ft wide.

3.2.4 Fiducial Features

Jefferson Lab has the responsibility of installing and aligning the Tagger Magnet System at Jefferson Lab. Jefferson Lab will perform a preliminary alignment of the Tagger Magnet using the lower pole as a reference during assembly. During assembly the lower pole will be optically surveyed and its position information transferred to fiducials on the outer surface of the iron yoke. Drawings of the fiducial monuments and the proposed placement and dimensions of the fiducial features are specified on the interface drawing D00000-19-00-3001. Placement of the final fiducial features on the final magnet must be agreed upon with the Jefferson Lab technical representative and drawings detailing the positioning are required as milestone D-10 for the design.

3.2.5 Protection

Interface surfaces between magnet core parts shall be lightly coated with the rust preventative LPS-3 or a Jefferson Lab approved equivalent. The completed core assembly (not including the vacuum wetted surfaces or o-ring sealing surfaces) shall be cleaned, masked, primed and painted as noted on the details and Core Assembly Drawing. In addition, all assembly hardware (i.e. nuts, threaded rod, and dowel pins) and all threaded holes shall be masked during painting. Prior to painting, the core shall be cleaned of dusts, oils, rust, and other contaminants to assure a smooth and durable bond. All unpainted and not vacuum wetted or sealing surfaces shall be covered with LPS-3 Rust Inhibitor. The vacuum wetted surfaces and the o-ring surfaces should be nickel plated. The protectants to be used should be specified at the time of the proposal. Any change to this protection plan must be approved by the JLAB technical representative.

3.2.6 Inspection

All finished yoke assemblies shall be inspected and shall demonstrate compliance with the dimensional tolerances given in the manufacturing drawings. In the offeror's proposal, the offeror shall indicate how the yoke assemblies will be inspected. The Jefferson Lab Technical Representative shall have the option of witnessing the dimensional inspection. To this end, the subcontractor shall notify the Jefferson Lab Technical Representative at least ten calendar days in advance of the inspection.

3.2.7 Test Results

The subcontractor shall provide copies of all tests results, ladle analysis, product analysis, material certification, and dimensional measurements to the Jefferson Lab Technical Representative within ten calendar days after obtaining such information, and not later than required by the Fabrication Milestones F-11 of Section 7.

3.2.8 Marking

Each steel assembly shall be marked on one side and on one end with its part number and weight. These markings must be easily visible after painting.

3.2.9 Assembly at the Subcontractor's Facility

Assembly of core pieces shall be performed in a clean environment to assure no foreign particulates are trapped between mating surfaces. The presence of any such particulates that lead to a compromise in the geometric reproducibility of the assembly is cause for rejection. The Jefferson Lab Technical Representative shall witness the inspection and measurement of the assembly of the magnet core at the subcontractors facility. The subcontractor shall notify the Jefferson Lab Technical Representative at least ten calendar days in advance of inspection. (Milestone F-8)

The offeror shall address these requirements in the proposal and detail how they shall be met.

3.3 MECHANICAL REQUIREMENTS FOR THE STANDS AND SUPPORTS

The magnet support must designed so that the magnet can be adjusted in position in x-z

(horizontal plane) by ± 10 mm and in y (vertical) by ±9 mm. The support must be

designed so that the photon beam line defined by the respective flanges on the interface drawing D00000-19-00-3001 lies on the nominal beam axis when the adjustment wedges and x-y table are in the middle of their motion range. The tagger spectrometer detector package will mount to the magnet support structure on the features specified for this. Any necessary mechanical support for the vacuum chamber must also be attached above the adjustment cartridges only. A minimum safety factor to yield of 3 must be used in the design of all stands. Documents detailing the mechanical safety analysis must be included in the design documentation (Milestone D-6)

The welding of the stands must be done in accordance with AWS D1.1. All welders certification must be included as part of the safety review of milestone AT&D-3.

The offeror shall address these requirements in the proposal and detail how they shall be met.

3.4 COIL REQUIREMENTS INCLUDING WATER AND POWER

The Tagger magnet normal conducting coils will be constructed from water cooled, hollow copper conductor windings, insulated with Mylar tape and with epoxy impregnated fiberglass. The coils must be mechanically compatible with the iron yoke and vacuum chamber design. The coils must meet the requirements given in Table 3. The Tagger Dipole Magnet Coils are to be wound, without conductor to conductor joints, in a fashion which minimizes the heat transfer between cooling loops as demonstrated in drawings

D00000-19-00-2010 and D00000-19-00-2011. The specification for the water fittings, temperature switches, and current connections are also specified on these drawings. The coil assembly is to be insulated from the ground potential using fiberglass supported epoxy (vacuum-pressure-impregnated fiberglass tapes and cloth).

Table 3: Partial list of coil requirements

Requirements	**Units**	**Value**
Coil Mechanical Requirements		Drawings D00000-19-00-2010 and D00000-19-00-2010 winding scheme, fittings, brazing, material. Flags, fittings and klixon should be on drawing.
Maximum Design Temperature	°C	95
Maximum operating temperature	°C	80
Maximum water pressure	PSI	120
Maximum water supply pressure drop	PSI	100
Maximum flow rate	GPM	20
Maximum water flow velocity	ft/sec	8
Maximum voltage drop across all coils connected in series for 1.8 T	V	170
Maximum Current	I	400

3.4.1 Materials

Conductor Development Association Alloy # C10200 or Alloy # C10300 annealed (or JLAB approved equivalent) hollow copper conductor shall be used. Coil assemblies shall be fabricated without any conductor joints or splices.

3.4.2 Insulation

The conductor turns are to be insulated from each other with a primary insulation of Mylar tape and a secondary insulation of fiberglass tape. The coil assembly is to be insulated from electrical ground and bound in a stable configuration using a ground wrap of fiberglass tape. The entire assembly is vacuum impregnated with epoxy. Materials shall be rejected in the event that they have been shipped or stored improperly such that contamination or degradation has taken place. No material shall be used that is beyond its published shelf life.

a. Primary conductor insulation
The primary turn-to-turn insulation material shall be 3M #56 Mylar tape or a Jefferson Lab approved equivalent, 0.0022" thick by widths suited to half lap application by manual or machine methods.

b. Secondary conductor insulation
Dry fiberglass tape, between 1/2" and 2" wide x .005" thick, in a medium or dense weave shall be used for the reinforcement of the epoxy around the individual conductors. Dry fiberglass tapes 0.007" thick, in a medium or dense weave shall be used for the reinforcement of the epoxy that forms the ground wrap. The fiberglass materials shall be "E" grade, treated with an epoxy compatible coupling agent.

c. Epoxy Formula

The following formula is required for the vacuum impregnation of the coils.
Formulation of Encapsulant (all in parts, per weight)

Shell EPON826 Resin	70
Shell EPON871 Resin (aliphatic polyepoxide) flexibilizer	<u>30</u>
	100 parts of resin

Where

Total (EEW) Epoxide Equivalent Weight is:	826 is .7(182)=127
	871 is .<u>3(430)=129</u>
	EEW = 256 (+/- 6%)

Plus
Uniroyal Chemical Co. TONOX (aromatic diamine curative)
Shell Agent-W or Agent-Y may be substituted for TONOX.
Total (HEW) Hydrogen Equivalent Weight is: 48(+/-4%)

$$\frac{HEW}{EEW} \quad \frac{48}{256} = \frac{20}{100} \quad \frac{\text{parts of C/A}}{\text{parts of resin blend}}$$

plus at the vendor's option:

Anchor Pacific K.54 Accelerator (Tris[Dimethyl Aminomethyl] Phenol)

$$= \frac{1/2}{100} \quad \frac{\text{parts of accelerator}}{\text{parts of resin blend}}$$

Cure Cycle:
2 hours at 80C, 3 hours at 150C, slow cool to 50C at 20C/hour

Other formulations will be considered if submitted with the proposal. Details of the alternate formulation; viscosity, pot life impregnation cycle, cure cycle and technical performance data such as mechanical strengths, hygroscopic behavior, and radiation resistance must be included. The vendor shall include a statement explaining the reasons for preference of the alternate formulation. Any alternate epoxy formulations proposed must, at minimum, meet the following specifications:

Operating Temperature: 95 C
Thermal Cycle Life: 100 cycles/year for 20 years
Radiation Resistance: 1.3 x 10^5 rad
Color: clear, clarity to allow visual inspection of conductors
Hardness: 90 (Rockwell D)
Flexural Strength: 16,400 psi
Heat Deflection Temperature: 116 C
Viscosity: 25 cps at 80 C
Volume Resistivity: 1.24 x 10^{15} ohm-cm.

Cured samples of any alternate epoxy formulations are to be submitted with the proposal. Acceptance of the alternative formula will be at the discretion of the Jefferson Lab Technical Representative.

d. Insulation Clarity and Finish

Insulation shall be left as clear to allow for visual inspection of individual conductors. There shall be no powder fillers, no coloring or pigmentation used in the insulation system. There shall be no painting or refinishing of coil surfaces. Excess epoxy shall be removed/cleaned so dimensional tolerances are maintained.

3.4.3 Filler Blocks

Filler blocks shall be made from NEMA Grade G-10 or G-11.

3.4.4 Braze Filler Material

Joints between copper conductors and copper electrical terminals may be brazed with silver-copper-phosphorous braze alloy per Federal Specification QQ-B-654A,Grade BcuP-5 without flux (Handy and Harmon Silfos) or the system below. Joints between copper conductors and brass fittings shall be brazed with flux using preforms or filler materials that conform to Federal Specification QQ-B-654A,Grade Vii (Handy and Harmon Easy Flow 45). All traces of flux shall be removed before potting.

3.4.5 Coil Fabrication

No deviation from procedures proposed by the vendor (detailed in the Manufacturing Plan) will be allowed without prior written approval from the Jefferson Lab technical representative.

a. Conductor Inspection
The vendor shall inspect the conductor upon receipt. The inspection shall verify cross-section dimensions; freedom from excessive warp, twist and camber; freedom from slivers, burrs or other defects on the surface; freedom from bore obstructions such that the flow requirements , as specified in Section 3.8.2, are not compromised.

b. Conductor Cleaning
The conductor shall be clean and free of slivers, burrs, and other injurious defects. The conductor shall be cleaned before application of insulating materials using a Jefferson Lab approved solvent and solvent cleaning method. Drying shall be performed with dry nitrogen or clean filtered air to avoid oil or water deposition on the cleaned surfaces.

Insulation materials and clean conductor surfaces shall be protected from skin oil, etc., by requiring shop personnel to wear clean, lint free gloves while handling conductors and insulation. Cleaned conductors, whether bare or insulated, shall be stored and processed in an area free from metallic dust and other coil contaminants. Insulation and in-process subassemblies shall be stored and/or processed in controlled clean areas.

c. Coil Winding

The vendor shall include details of the coil winding procedure in his proposal as part of the manufacturing plan. The sequence of all activities shall be clearly indicated. No joints are allowed in the windings.

d. Turn-to-Turn Insulation
A single winding of Mylar tape primary insulation shall be applied to the conductor half-lapped.

For the turn-to-turn fiberglass epoxy insulation system a single winding of half-lapped, 0.005” thick fiberglass tape shall be applied directly over the Mylar tape. The distance between edges of the fiberglass tape may range from zero to 1/8 inch. Care shall be taken to avoid damage to the insulation in subsequent handling. Damaged insulation shall be reapplied in a manner that will maintain insulation continuity.

e. Ground Wrap Insulation
One half-lapped layer of 0.007” fiberglass shall be wrapped around the straight lengths of the coil that form the body and around the straight ends of the coil that forms the cross-over.

More sparsely wound tape or cloth, suitably restrained, may be substituted in the 90 degree bend zones where excessive build-up on the small radius is expected.
Care shall be taken to prevent damage to the insulation in subsequent handling. Damaged insulation shall be replaced in a manner that will maintain insulation continuity.

f. Braze Joints
No joints are allowed conductor-to-conductor in the body of the windings.
    a. Braze Joint Sample for the Proposal
    A braze joint is specified in the enclosed drawings at the pipe fittings to the coils and from the conductor to flags. All brazes must adhere to ASME B31.9 Building Services Piping requirements. The subcontractor shall submit a representative sample of this joint with the proposal using a sample copper conductor that is within 0.15 inches of the specified copper in width and breadth and within 1/16 inch of the hole diameter. The subcontractor is required to submit a Brazing Procedure Specification with the sample braze. The sample will be sectioned and judged by the Jefferson Lab Proposal Review Board on the basis of leak tightness and freedom from flow restrictions. Disqualification of the sample braze joint is a basis for disqualification of the subcontractor's proposal for brazing.

b. Production Coil Braze Sample (as per ASME B31.9 Building Services Piping requirements)
   Before brazing the conductor-to-water fitting joints of production coils, the subcontractor shall submit to the Jefferson Lab technical representative, a sample of the braze joint using the actual copper used in the coil along with identification of the braze maker. All production personnel utilized as braze makers for the production coils must submit a sample of the braze joint. Jefferson Lab must approve the braze joint as acceptable prior to continuation of coil production work by the braze maker.

g. Fixtures for Potting and Curing
   Each magnet coil shall be vacuum impregnated with epoxy and heat cured. It is the responsibility of the vendor to design and fabricate a mold that forms the coil to the required tolerances.

h. Impregnation and Curing Processes
   a. Process Verification
      The subcontractor shall verify in his manufacturing plan that impregnation and cure of the insulation system will use the materials and handling process parameters specified in this document and shall record all cure process times and temperatures and mm of vacuum associated with the following procedures:

   b. Coil Preparation
      The subcontractor shall dry the assembled coil in an oven prior to the vacuum impregnation process and shall certify the oven drying time and temperature in a preheated oven is 135°C. Following completion of the oven drying cycle, the assembled coil shall be allowed to cool down to 25°C prior to insertion in the mold. Once installed in the mold above, a dry vacuum shall be pulled for ~ 10 minutes at 2 to 5 mm of mercury. The coil lead fittings and flags shall be protected from contact with the epoxy during impregnation and curing.

   c. De-aeration of Epoxy Resin Mixture
      The epoxy system shall be placed in its holding tank at 25°C and de-aerated in accordance with the manufacturer's recommendation. The subcontractor shall note the time and mm of mercury required to de-air the epoxy and shall set aside a one pint sample of the de-aired epoxy system prior to vacuum impregnation and record the viscosity at 25°C using a viscometer and methodology recommended by the epoxy manufacturer. The subcontractor shall retain the sample; marked "Pre-impregnation" and identified by coil number, date and viscosity reading, for

review by the Jefferson Lab technical representative and transported with the finished coil's documentation .

d. Impregnation and Cure
The coils shall be vacuum impregnated and cured in accordance with the manufacturer's recommendation. When the dry vacuum pulled on the mold is complete; flood the mold with de-aired epoxy from the holding tank and hold the vacuum until the coil impregnation is complete. Break vacuum and cure using a time and temperature sequence recommended by the resin manufacturer. The subcontractor shall record all times to, from and at temperature during the post impregnation cure cycle and cool down following cure. The subcontractor shall ensure that the coil has cooled to 25°C prior to removal from the mold. The subcontractor shall note the time and mm of mercury required to vacuum impregnate the coil and shall set aside an additional liquid sample of the epoxy system following vacuum impregnation and record the viscosity at 25°C using a viscometer and methodology recommended by the epoxy manufacturer. The subcontractor shall retain the sample; marked "post impregnation" and identify by coil number, date and viscosity reading, for review by the Jefferson Lab SOTR and transport with the finished coil's Traveler. The subcontractor shall set aside a sample of "Post-impregnation" epoxy ~ 50 gms for cure along side of vacuum impregnated coil. The cured sample shall be marked with coil number and time and temperature; for review by the Jefferson Lab technical representative and transported with the finished coil's Traveler.

e. Removal from the mold
Flash shall be removed in such a way that no sharp edges remain on the coils. Removal of flash shall not puncture the insulation or damage the flags or water fittings.

i. Impregnation Evaluation and Repair
After the removal of flash, the subcontractor shall inspect the cured coil. The following conditions are not acceptable and the coil shall be rejected if these features are evident:

a. Dry fiberglass or incomplete saturation of the fiberglass on the surface or within the coil
b. Cracks on the surface or within the coil
c. Areas of uncured resin.

The Jefferson Lab technical representative may consider repair of the above defects. Prior to repair the Vendor must submit to the Jefferson Lab's technical representative a non-conformance report with a specific, written, repair procedure, including specific electrical tests that match or exceed the requirements of this specification, Section 3.4.6. The request for permission to repair may be denied at the discretion of the Jefferson Lab's technical representative.

3.4.6 Testing

Mechanical and electrical inspections and tests shall be performed on each coil prior to assembly and after full assembly. Copies of all satisfactory and signed-off test reports shall be provided. The Vendor shall submit their Test Plan, to include equipment, procedures and report format, with their proposal. The vendor shall provide Jefferson Lab with sufficient advance notice to allow the witnessing of in-process and final acceptance inspections and tests by the Jefferson Lab technical representative or a designee.

a. Water Circuit Test
   The water passage shall be flushed with a solution of trisodium phosphate to clean the conductor bore of emulsions and other processing contaminants. After cleaning, potable water at a minimum of 30 psi shall be pumped through the coil, with a 50 to 150 micron size filter at the inlet. Flushing may end when no dirt or grease is deposited in an identical filter placed in the outlet stream for one minute.

b. Flow/Pressure Tests
   The coolant circuits shall be tested for flow and pressure drop and shall be subjected to a hydrostatic pressure test. These tests shall be performed using potable water. Flow Test inlet water temperature shall be 45 +/- 2 degrees Celsius. Flow test inlet pressure shall be 50 psi with a 30 psi minimum. Record flow (gpm) and pressure drop (psi) through each circuit. Coil-to-coil variations for identical circuits shall not exceed 5% and shall be within 10% of the expected flow when corrected for line pressure. Hydrostatic test pressure shall be 250 psi. There shall be no pressure drop, within the resolution of the pressure gage, during a 30 minute test of each water circuit. The pressure gage shall be accurate to better than 1 % over the range of 0-300 psi, and shall be graduated in not greater than 2 psi increments.

c. DC Resistance
   The DC resistance of each coil at a known temperature shall be measured and recorded, with +/- accuracy of 1 %, following the application of the fiberglass ground wall insulation. When repeated after the coil has been heat-cured, values, adjusted for temperature differential, shall agree within 2.5 %.

d. Induced Voltage Test
A vendor proposed (and Jefferson Lab technical representative approved) induced voltage test for locating shorted turns, shall be employed to test each circuit both before and after the pressure/heat curing process. The induced voltage stress shall be at least 10 Volts/turn. An Impulse test of greater voltage per turn may be substituted for this test in each part of the process. There shall be no deviation in wave shape between any of the test oscillographs.

e. DC Hipot Tests
Following the induced voltage/impulse tests (3.4.6.d), establish an intimate Ground Plane and DC hipot each circuit at 4.8kV for one minute. Record the DC leakage current at the beginning of the test, at 30 and at 60 seconds. Breakdown shall be cause for rejection of the unit under test. Coils of the same style shall display leakage currents (at the 60 second interval) of similar magnitudes.

3.4.7 Acceptance Tests

Coils will be subjected to acceptance testing at the location of manufacture. Copies of the coil factory inspection and test records shall have been shipped with the coils for purposes of identification and comparison. Failure to meet drawing and specification requirements will be considered sufficient cause for rejection. Fabrication acceptance tests shall include:

a. Dimensional Inspection
A careful visual and quantitative dimensional inspection shall be made to verify conformance to drawing and specification requirements.

b. Testing
The magnet coils will be subjected to replication of all tests described in Section 3.4.6 at the assembly facility after assembly into the magnet cores. After normalization to null out test condition differences, identical values are expected.

3.4.8 Preparation for Shipment

The following procedure must be followed when the coils are shipped.

a. Coil Identification
A removable nameplate shall be attached to the coil lead. Nameplate data shall include the vendor's name, coil weight, epoxy name, maximum test current, a unique unit serial number and the contract number. (After final magnet assembly the

nameplates will be removed from the coil leads and permanently affixed to the magnet core.)
In addition, the lead end of each coil shall be permanently marked with the same unique serial number as is on the nameplate. That marking shall be done with non-magnetic materials.

b. Coil Packaging
The coolant passages shall be drained of all water, flushed with isopropyl alcohol to provide freeze protection for residual water, drained by being blown out with compressed air, and sealed for storage and subsequent shipment. Commercial plastic protectors made for this purpose shall protect fittings. Coils shall be crated for shipment to the "magnet assembly site". The crates shall be built for handling with slings from overhead cranes and for forklift transport. Gross weight per crate shall not exceed 5 t. The crates shall protect the coils from damage in transit and from weather during transit and outdoor storage.

Each crate shall be marked with the addressee, shipper, contract number, contents and shipping weight. The subcontractor shall arrange shipping.

c. Coil Documentation
Documentation to be provided with each coil include:
Manufacturing records.
a. Obstruction Test for cleanliness of conductor
b. Flow and Pressure Tests
c. D.C. Resistance test
d. Induced Voltage Test per 3.6.4
e. Impulse Test
f. D.C Hipot Test
g. Visual Inspection
Certifications of materials by their manufacturers.

The offeror shall address these requirements in the proposal and detail how they shall be met.

3.5 VACUUM CHAMBER REQUIREMENTS

The Tagger Magnet vacuum chamber is integrated into the Tagger Magnet construction. Because the bremsstrahlung photons are emitted in a very narrow cone the magnet gap can be 30 mm over the full 6.3 m length. Because the magnet is relatively wide (470mm) and very long (6.3 m), any design which is based on inserting a separate vacuum chamber into the gap of the magnet requires greatly increasing the pole tip gap and therefore the magnet's cost and power consumption. Therefore, it was decided to require that the top and bottom poles of the magnet form part of the vacuum vessel. In order to be able to disassemble the magnet and vacuum chamber the seal between vacuum chamber and the pole tip must be an o-ring seal. The o-ring to be used should be made of the material EPDM. The large magnetic and vacuum forces between the poles could produce significant deformations of the sealing surface and result in vacuum leaks either when the magnet is off or at full current. To mitigate this risk the magnet and vacuum chamber must be designed such that the gap between sealing surfaces on the poles and the vacuum chamber o-ring seal surface may not change by more than 0.5 mm between when the magnet and the chamber is vented and when the magnet is on and the chamber is under vacuum. In addition to facilitate mechanical alignment, the support for the vacuum chamber including any mechanical reinforcement for the long exit window must be connected to the magnet yoke or magnet support structure above the alignment cartridges. The mechanical interfaces for the vacuum chamber are summarized in drawing D00000-19-00-1001. The lower energy electrons will produce a continuous fan of particles near the horizontal plane of the magnet. It is necessary to avoid any material in the gap of the vacuum chamber in order to avoid the generation of background produced if the fan of particles were to interact in the chamber.

3.5.1 Simulation

Finite element analysis of the vacuum chamber must be performed and a report submitted prior to the acceptance of the design. The maximum deflection of the chamber wall under vacuum load must be less than 2 mm. The deformation along the pole tip sealing surfaces and the exit window flange must be simulated and mechanically acceptable. Simulations must be performed to demonstrate the selections of materials and thickness for the vacuum chamber shell and reinforcing are mechanically safe. Allowables from ASME B&PV code section II are to be used. All simulation reports and documents of mechanical calculations must be submitted to Jefferson Lab 1 month before design is to be approved. The Jefferson Lab technical representative is responsible for approving the design proposal.

The stress analysis simulations must also include simulations including the vacuum pumping ports or analysis using ASME B&PV code section VIII may be used as an alternative. Analysis of the forces on the vacuum chamber during the lifting and installation procedure must also be simulated.

3.5.2 Material

The vacuum chamber is to be constructed out of Din 1.4429 (SAE 316LN) stainless steel or equivalent. Certificates of the chemical composition for all materials used in the vacuum chamber must be delivered with the chamber.

3.5.3 Welding

The welding shall be done in accordance to the specifications given in Section 1.10. All welders must be qualified to ASME B&PV code section IX or JLAB approved equivalent. Copies of welder's current certificates must be supplied at the time of the proposal.

3.5.4 Inspection of Welds

Visual inspection shall show that the Vacuum Vessel is structurally sound and free of scale, cracks, splits, caps, inclusion porosity or any defect which could be considered a source of structural failure. All welding shall be in accordance with the above specifications.

3.5.5 Cleaning

The cleaning of the vacuum chamber shall be performed as specified in ASTM A380 or JLAB approved method that is compatible with vacuum usage.

3.5.6 Mechanical and Vacuum Testing

A plan for the mechanical testing of the vacuum chamber must be submitted to JLAB 1 month before the design safety review. The mechanical testing of the vacuum chamber must be included in the acceptance tests of the Tagger Magnet System. The vacuum chamber must be installed in the magnet and evacuated. The mechanical deformations must be less than the specified maximum values. A means must be developed and used during the vacuum chamber acceptance tests which seals the exit window without significantly changing the mechanical support along the window opening. As part of the acceptance test, the deformation of the exit window gap must be measured with and without vacuum both with the magnet off and at maximum field. The vacuum chamber must be leak tested and found to be leak tight both with the magnet off and with the magnet running at the maximum field setting.

3.5.7 Lifting Plan

A plan for lifting and assembling the vacuum chamber must be developed and presented with the design. Lifting fixtures must be attached to the vacuum chamber as required by the lifting plan. Mechanical supports needed to protect the fragile parts of the vacuum chamber (photon beampipe) must be included with the chamber. Calculations showing the deflections of the chamber while supported by the proposed lifting tooling must be documented.

3.5.8 Shipping

The vacuum chamber shall be shipped in a suitable crate. The crate must be designed such that the chamber can be safely moved with standard lifting equipment (forklift dollies). When shipped all vacuum flanges must be blanked off. The chamber must be wrapped in plastic to protect it during shipping. The crate must fit in a standard 53' long semi-truck trailer (the vacuum chamber is about 36 feet long).

The offeror shall address these requirements in the proposal and detail how they shall be met.

4 THE TAGGER MAGNET SYSTEM REFERENCE DESIGN

The Jefferson Lab-provided reference design constitutes documents and drawings which describe an iron dipole C-magnet with normal conducting copper coils that, based on a TOSCA analysis, meets the Jefferson Lab magnetic requirements and dimensional requirements. The TOSCA designed iron yoke and coil packages fit within the constraints imposed by the building, available water cooling, and the equipment foreseen to be used to install the magnet. The vacuum chamber is designed such that the top and bottom poles of the iron magnet form part of the vacuum chamber. The design described in the supporting documents and with the reference drawings is a consistent design with no geometrical conflicts which integrates the vacuum chamber into the magnet design.

The Tagger Magnet Reference design consists of the following drawings shown in table 6-1, the simulation results and reports listed in table 4, and the written specifications in this sections of this document. The drawings supplied with this specification are in US and Metric Units. If needed CAD drawing files can be supplied upon request to the subcontractor in one of the following formats, DXF or IGES. 3D CAD files can be supplied in STEP or IGES format. Also, TOSCA, and IDEAS input files can be supplied. Jefferson Lab cannot supply copies of proprietary software.

Table 4: The Tagger Magnet System Reference Design Drawing List

Drawing number	Sheets	Drawing Title
D00000-19-00-0001		Tagger Assembly Drawing

D00000-19-00-1001		Tagger Magnet Vacuum Chamber sub-assy
D00000-19-00-1002		Upstream Stand sub-assy
D00000-19-00-1003		Downstream Stand sub-assy
D00000-19-00-1004		Base frame sub-assy
D00000-19-00-1005		Adjustment cartridge sub-assy
D00000-19-00-1006		Coil sub-assy
D00000-19-00-2001		Lower Yoke detail
D00000-19-00-2002		Lower Pole detail
D00000-19-00-2003		Upper Yoke detail
D00000-19-00-2004		Upper Pole detail
D00000-19-00-2005		Vacuum Chamber Clamp Detail
D00000-19-00-2006		Vacuum Chamber support Arm Detail
D00000-19-00-2010		Coil 1 Winding Detail
D00000-19-00-2011		Coil 2 Winding Detail
D00000-19-00-3001		TAGGER INTERFACE

Table 5 Documents and reports

Document number	Document name	Filename/html address
	FEM analysis of the vacuum chamber	
	FEM analysis of the magnet core	
	TOSCA Analysis	

4.1 Tagger Magnet Steel Core Assembly

This specification covers the reference design of the Tagger magnet core assemblies. Detailed specifications for the fabrication, machining and assembly of the steel yoke/poles are given in the drawings D00000-19-00-2001 through D00000-19-00-2004 and in the following subsections. The magnet core in the reference design is constructed from 4 large iron plates. These plates are held together with a combination of high tension rods and bolts. Fixtures for lifting the steel plates and monuments for surveying the pole locations are specified in the reference drawings.

4.1.1 Tagger Magnet Core Material

The core of the Tagger Magnet is to be constructed of SAE 1006 steel as specified in Table 6-3. Steel that is ingot cast shall have a rolling reduction of at least three to one to reduce the probability of voids. Continuous cast material or steel produced by other processes that minimize voids, needs no reduction. All core material used in this contract must be from the same heat. Substitution with material from another heat is prohibited. Certification of the steel chemistry is required and shall be reported in Milestones F-1.

Table 6: Chemical composition limits for SAE 1006 steel.

Impurity	**Wt.%**
Carbon	0.04 – 0.08
Manganese	0.25 – 0.45
Phosphorus	≤ 0.04
Silicon	≤ 0.4
Aluminum	≤ 0.03
Nitrogen	≤ 0.012
Oxygen	≤ 0.035
Sulfur	≤ 0.025
Copper	≤ 0.15
Nickel	≤ 0.15
Chromium	≤ 0.09
Molybdenum	≤ 0.07

4.1.2 Annealing of the magnet cores

All magnet core pieces shall be fully annealed after any cold work and/or prior to final machining. Steel shall not be handled or stored by lifting magnets or other magnetizing material at any time following the annealing process. In order to assure optimum magnetic performance, Jefferson Lab prescribes the following annealing cycle for a material similar to AISI-1006:

a. Choice of a suitable atmosphere is left to the offeror and shall be addressed in the proposal.
b. Heat piece to 1650 °F at a rate of 100 °F per hour.
c. Hold piece at 1650 °F ±50 °F for one hour per inch of thickness.
d. Furnace-cool piece to 600 °F at a rate not to exceed 50 °F/hour, then air cool.

The offeror may propose a different annealing cycle if such a cycle would achieve equivalent or better magnetic performance for the material, but Jefferson Lab approval is required for any proposed annealing cycle. The offeror shall address the annealing cycle in the proposal.

After contract award any proposed change by the subcontractor in the annealing cycle shall require written approval from the Jefferson Lab Technical Representative. Jefferson Lab shall require ten calendar days after receipt of any proposed change to approve or disapprove it.

A sample piece of the 1006 steel from the heat shall be annealed along with every annealing. The sample pieces of 1006 steel, 0.75 x 3 x 3 inches shall be extracted from excess volumes of the slabs. They shall be identified with the drawing number of the part they represent.

The Jefferson Lab Technical Representative shall be provided with heat treatment records (Milestone F-7) for approval prior to final machining. Jefferson Lab will respond within ten calendar days after receipt of documents.

4.1.3 Internal Defects & Sonic Tests for Voids and Inclusions

The subcontractor shall be responsible for the ultrasonic inspection of all pole pieces to assure delivery of steel free from discontinuities, bursts, pipes porosity, flakes, laps and seams. In order to determine the size, quantity, and location of any significant voids, non-metallic inclusions or discontinuities (lamina), the subcontractor shall ultrasonically inspect the entire volume of each pole piece in accordance with ASTM-A-578 with supplementary requirements of S1, S2, S3, S4, S5, and S9m, and provide the Jefferson Lab Technical Representative with a complete inspection record (Milestone F-9). No calibration holes shall be drilled into the pole pieces.

In order to be “unconditionally acceptable”, the ultrasonic inspection shall reveal no voids (or equivalent defects) with a characteristic diameter greater than 0.3 inches throughout the steel core volume; no evidence of defects within 0.9 inches of the finished pole surface are permitted.

Should a defect or defects in a pole piece be discovered that exceeds the “unconditionally acceptable” criteria given above, it shall be reported in writing including any proposed repair technique or other remedy, to the Jefferson Lab Technical Representative within ten calendar days. Jefferson Lab will determine within ten calendar days after receipt of documents (including any proposed repair technique) if the piece is acceptable, repairable, or is to be rejected. If the piece is deemed “rejected” by Jefferson Lab it shall be replaced at the manufacturer’s expense.

The offeror shall address in the proposal how the requirements of this section will be achieved and present evidence of capability to conduct the required ultrasonic tests.

4.1.4 Witnessing and Certification of Ultrasonic Tests

The Jefferson Lab Technical Representative shall have the option to witness all the ultrasonic inspections, and the subcontractor shall give the Jefferson Lab Technical Representative a minimum of ten calendar days notice as to the time and place of the inspections. The subcontractor shall demonstrate to the Jefferson Lab Technical Representative at the time of testing the ability of his equipment to detect deviations from the specifications of Section 4.1.3. The subcontractor shall also provide the Jefferson Lab Technical Representative with certifications of compliance with specifications (Section 4.1.3), and acceptance of the magnet shall be conditional upon compliance.

4.1.5 Work Hardening

In order to prevent deterioration of magnetic performance, the machining and drilling schedules to be followed after the pole material has been annealed shall be such as to avoid work hardening the pole material to a depth greater than 0.02 in. beneath the finished pole face surfaces and 0.05 in. beneath all other finished surfaces. For purposes of preparing these schedules the subcontractor may assume that work hardening for a properly ground sharp tool will extend to a depth equal to the thickness of the chip removed. (The thickness of the chip is defined as the dimension of the chip in the direction mutually perpendicular to the line of the cutting edge and the direction of motion of the cutting edge.) The tooth-chip load shall be adjusted to conform to the above requirements. In order to achieve this requirement, the following example procedure could be employed: For a series of cuts, each successive cut would remove ½ or less the thickness of the previous cut until the final tolerance (as indicated on the design drawings) is achieved. The offeror shall indicate in the proposal how these results will be achieved.

4.1.6 *Pole Steel Magnetic Specifications*

The offeror may propose according to magnetic specifications. The following minimum specifications for magnetic product analysis of specimen samples are given for performance according to magnetic specifications. The offeror shall state expected magnetic performance in the proposal and the method that will be used for magnetic/material certification.

Table 7-1. Magnetic Performance (each specimen as machined)

Magnetizing Force (H) Amperes-Turns/Meter	Magnetic Flux Density TESLA
80	≥ 0.20
240	≥ 0.85
500	≥ 1.25
2000	≥ 1.6
10000	≥ 1.82
25000	≥ 2.00

Coercive Force: Not to exceed 100 Ampere-Turns/Meter following saturation.

4.1.7 *Machining & Assembly Tolerances*

All machining tolerances, pole profiles, and surface finishes and assembly tolerances are indicated on the Jefferson Lab Reference Design Drawings. No relaxation of these tolerances will be permitted without written permission of Jefferson Lab. All machining operations shall be carried out either with the work stabilized at a temperature of 70 °F ±5 °F or corrected to 70 °F.

4.1.8 *Welding*

Welds are permitted on the core assembly only as indicated in the RD drawings. All welding to be performed per AWS D1.1.

4.2 Magnet Coil Reference Design

The reference design for the normal conducting coils is detailed in drawings D00000-19-00-2010 and D00000-19-00-2011. The coil is manufactured as an array with 7 turns in the horizontal and 12 in vertical. The details of the winding scheme are shown in the above drawings. Alternate winding schemes are possible but they must also insure a minimum of heat exchange between the incoming and outgoing water paths. An alternate winding scheme must be approved by the Jefferson Lab technical representative. The conductor is

an 11 mm square hollow copper conductor with a Ø7 mm conducting path. The edges of

the conductor have a 1mm radius. One example of this conductor is the LUVATA model 8143 hollow copper conductor. As shown on the drawings the outer dimension of the coil packages are 147 mm high, 697 mm wide, and xxxx mm long. Jefferson Lab requires that the water fittings specified in the above drawings be used. The placement of the water fittings, thermal switches, and flags on the reference drawings is preliminary and the offeror must propose a final design. This design must include all necessary supports for the power and water connections. The flags must have dimensions shown. There should be no exposed conductors on the final assembled magnet.

4.3 Reference Design for the Magnet Stands and Supports

The reference design for the magnet stands and the vacuum chamber support are detailed in drawings D00000-19-00-1002 to D00000-19-00-1005. Analysis of the safety factor for the stands and the deflection of the magnet iron under the gravitational load are given in the technical note "FEM analysis of the Magnet Core". The proposed selection for the vertical adjustment wedges and horizontal x-y plates are given in the reference drawings. The offeror may choose to select other adjustment systems but these must be approved by the JLAB technical representative.

4.4 Tagger Vacuum Chamber

The reference design for the vacuum chamber is detailed in the drawings D00000-19-00-1001, D00000-19-00-2005 and D00000-19-00-2006 and the technical note "FEM analysis of the vacuum chamber". The offeror must complete the design of the vacuum chamber including a complete drawing set and updated finite element analysis of the mechanical stresses.

5 TAGGER MAGNET SYSTEM ACCEPTANCE TESTING

5.1 Location

The Tagger Magnet system acceptance test shall be performed at the subcontractor's facility prior to shipping.

5.2 Acceptance Test Scope for the Reference Design Magnet

The scope and test plan for final acceptance testing shall be established at Milestone D&AT-7. The acceptance test shall demonstrate compliance with all of the requirements of this specification. The acceptance test shall include but is not limited to:

a. Verification of mechanical dimensions and tolerances
b. Verification of the assembly and disassembly procedure
c. Final magnet coil testing after assembly as described in Section 3.4.7.
d. Current ramp to full field (1.8 T) and ramp down, ramp up and hold at full field for one hour
e. Verification of the pole tip deflection when magnet is ramped to 1.5 T
f. Vacuum leak test of the vacuum chamber assembled in the magnet both at zero and full field

5.3 Acceptance Test Scope for Magnetic Performance

If the contract is awarded under magnetic performance specification (Section 3.1), the acceptance test shall also confirm that the Tagger Magnet meets the magnetic requirements. A plan for the necessary measurements must be submitted at the time of the proposal. This is not necessary if the reference design is developed.

5.4 Additional Tests Performed During Acceptance Testing

The subcontractor may perform other tests outside of the scope of the acceptance test plan at Jefferson Lab during the acceptance test period. The scope, nature and timing of such additional tests shall be mutually agreed to by the subcontractor and Jefferson Lab prior to the start of each acceptance test. Additional equipment required for tests outside of the acceptance scope shall be provided by the subcontractor. The offeror shall address this issue in the proposal.

The offeror shall address these issues in the proposal.

6 DESIGN REVIEWS

The subcontractor shall host and conduct design and program reviews for the Jefferson Lab Technical Representative and any additional personnel Jefferson Lab wishes to have in attendance. These reviews shall be held at the major milestones described in this section. The actual dates and times of these meetings shall be mutually agreed to by the subcontractor and Jefferson Lab. There shall be the following reviews:

6.1 Program Review and Preliminary Design Reviews (Milestone D-2)

This review shall take place within 45 days of the contract award and will concentrate primarily on the specification, project organization, schedule and the preliminary engineering design. Required documentation shall be submitted to Jefferson Lab prior to this review.

6.2 60% Design Package (Milestone D-3)

If the reference design is not developed further to the final design then an intermediate design package must be submitted. This design shall consist of a 60% design package.

6.3 Final Design Review (Milestone D-4)

A final design review shall be conducted to review the 100% design at the time of submission of the 100% package.

6.4 Magnet and Vacuum Chamber Safety and Acceptance Test Plan Review (Milestones AT&-3&4)

The Tagger Magnet System Safety and Acceptance Test Plan shall be prepared and presented by the subcontractor at a Review to be held at Jefferson Lab prior to the start of Acceptance Testing (Milestone AT&D-3&4). The subcontractor shall have primary responsibility for presenting and defending the Tagger Magnet System design safety and Acceptance Test Plan. The Review Committee will be appointed by JLAB. This Review will review all relevant tagger magnet, vacuum chamber, and support stand design and safety calculations, design data, and the magnet acceptance test plan. Successful conclusion of this Review and resolution of issues resulting from this Review are required before Tagger Magnet System acceptance test may begin (Milestones AT&D-5).

7 SUMMARY OF MILESTONES

7.1 TAGGER MAGNET SYSTEM DESIGN MILESTONES

The following table lists the required milestones and deliverables relating to the design of the Tagger Magnet system.

Table 11-1 Milestones for the design of the Tagger Magnet system.

Milestone Number	Milestone	Months ARO	Deliverable
D-1	Notice to Proceed	0	Contract Signed
D-2	Preliminary Design Review	1.5	PDR Document
D-3	60% Drawing package	4	documents/drawings (necessary if reference design is not pursued)
D-4	Final Design Review	6	FDR Documents
D-5	Magnetic Analysis complete	6	Document (necessary if reference design is not pursued)
D-6	Stress Analysis complete	6	Document
D-7	Lifting and assembly plan	6	Document
D-8	Fiducial Monument placement fixed	6	Drawing
D-9	Magnet Traveler complete (Manufacturing Plan)	12	Document
D-10	100% Drawing package	12	FDR drawings/documents
D-11	Final Drawing package	15	Accepted

			drawings/documents Before contract close out

7.2 FABRICATION MILESTONES

Milestone Number	Milestone	Months ARO	Deliverables
F-1	Receipt of steel for magnet core	18	Inspection & Acceptance Report including material certification
F-2	Test results for magnet properties of steel	24	Test Report
F-3	Receipt of Copper conductor	12	Inspection & Acceptance Report including material certification
F-4	Winding Tooling Complete	18	Report
F-5	Coil winding and potting complete	24	Report
F-6	Coil acceptance test	24	Report-Witness Inspection
F-7	Heat Treatment Records	24	Report-Witness inspection
F-8	Magnet assembly inspection	26	Report–Witness inspection
F-9	Magnet Steel Ultrasound Inspection	20	Report –Witness inspection
F-10	Magnet Steel Complete	26	Report

F-11	Magnet System Complete	28	Report
F-12	Factory Tests complete	28	Report-Witness Inspection

7.3 ACCEPTANCE TESTING AND DELIVERY MILESTONES

Milestone Number	Milestone	Months ARO	Deliverables
AT&D-1	Coercive force measurement	28	Acceptance test report
AT&D-2	Safety& Failure Effects Analysis	28	Document
AT&D-3	Safety Review at JLAB	28	Reviewers Report from JLAB
AT&D-4	Acceptance Test Readiness Review at JLAB	28	Acceptance Test Plan Reviewers Report from JLAB
AT&D-5	Magnet Acceptance	31	Certificate from JLAB

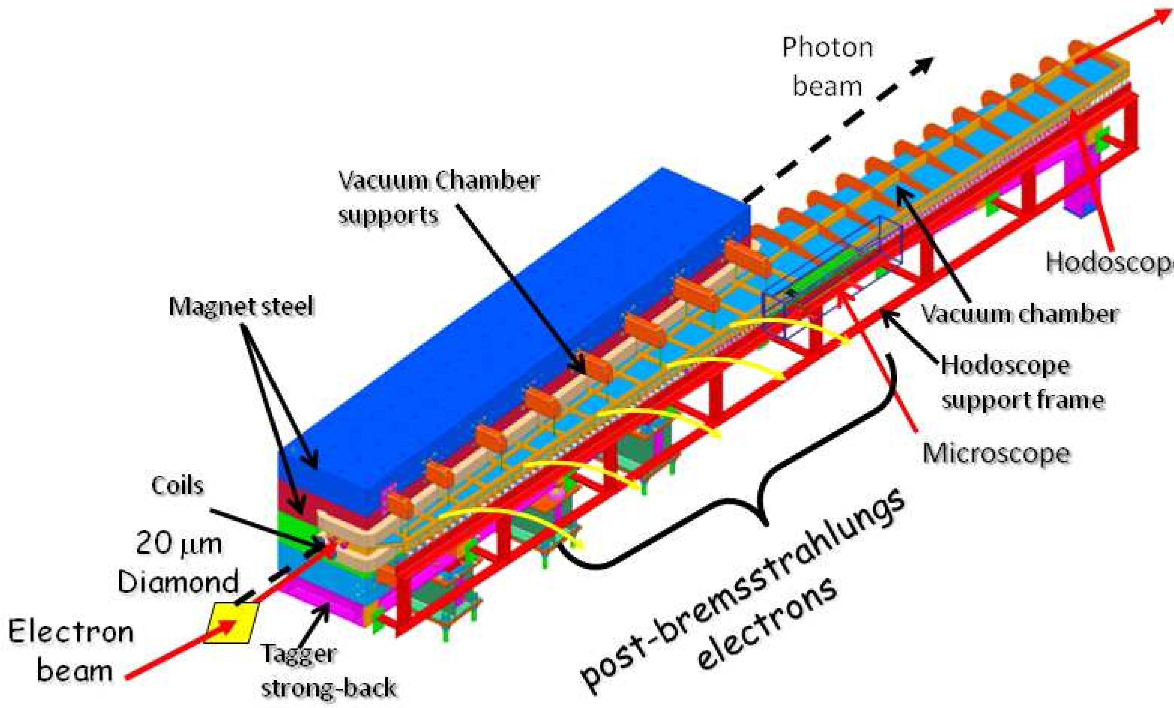


Figure 1. Hall-D electron tagging spectrometer. Shown are the Tagger Magnet, vacuum chamber, supports, and the detector packages. The detector packages are the hodoscope and the microscope and are not part of this order.

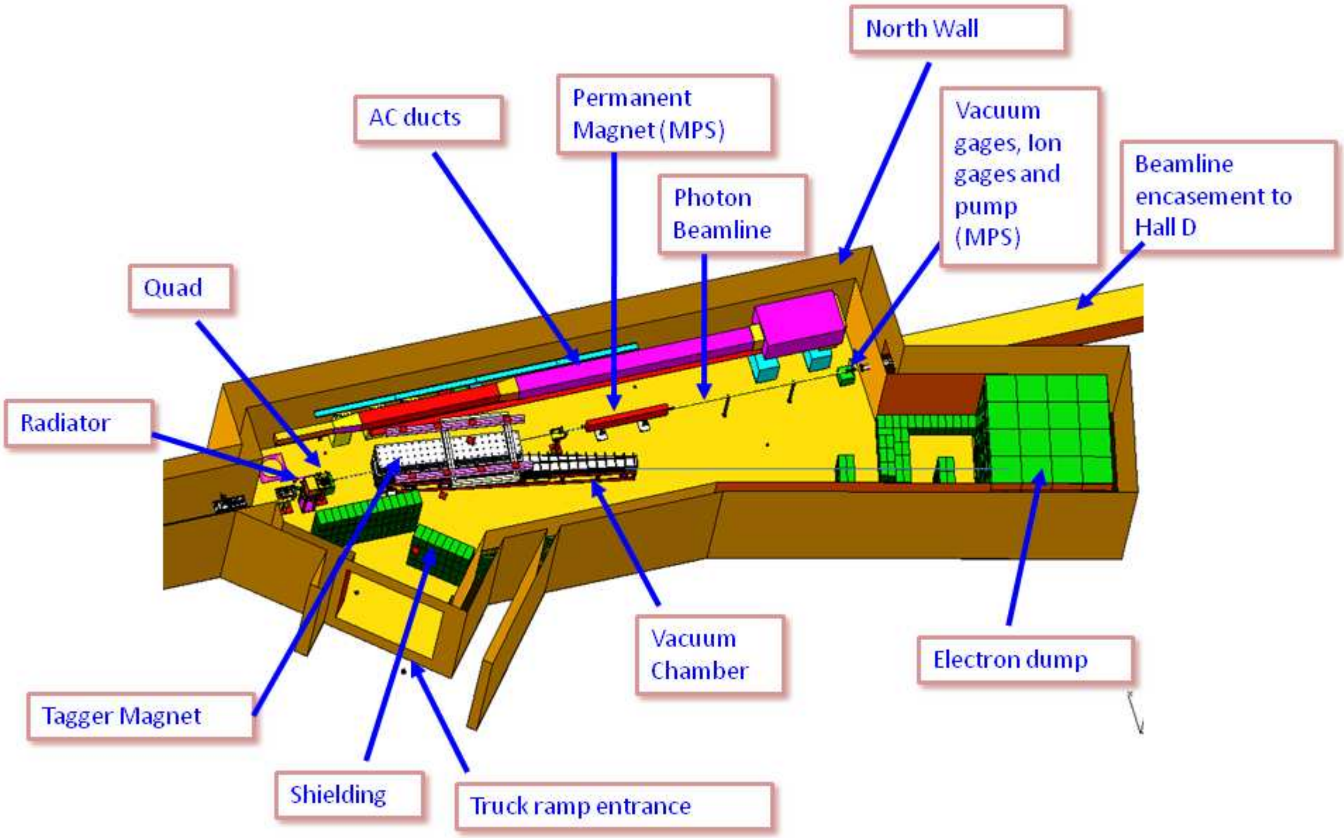


Figure 2 Layout of the major equipment in tagger hall showing the location of the tagger magnet and vacuum chamber.