BROOKHAVEN NATIONAL LABORATORY **Spec. No.: CSN 0219**

RELATIVISTIC HEAVY ION COLLIDER Issue Date: August 20, 1996

STAR Detector Division Specification Rev. No. : A

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Title: 2500 KVA Rectifier Transformer for STAR Solenoid Magnet.

QA Category: A2

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REVISION RECORD

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This specification consists of 19 pages and 1 Figure

1.0 Scope

1.1 This specification, in conjunction with other documents, defines the performance, design requirements, configuration, construction, materials, quality assurance, inspection, testing, workmanship, and packaging of rectifier type transformers. The transformers will be part of a Thyristor controlled, 12 pulse, 4372.5KW continuous duty Rectifier system. The system shall be used to convert three phase, 13.8KV, 60 Hz power to 825VDC, 5300Amp power for the STAR solenoid magnet main winding.

1.2 The transformers shall be of the liquid immersed, inert gas sealed, oil air/future forced air (OA/FFA) cooled type. The transformers shall be suitable for outdoor operation. The transformers shall be built and braced for rectifier service with ratings and configurations as shown on the attached Data Sheet, which shall be considered part of this specification.

1.3 Seller Responsibility

1.3.1 The seller shall furnish all equipment, materials, tools, facilities and labor to perform all the work necessary to design, manufacture and test the transformer as per this specification. The seller shall also provide all labor and resources to produce detailed up-to-date documentation of the transformers. The transformers shall be designed to have an expected service life in excess of twenty years.

1.3.2 The seller will be responsible for the design, construction and testing of the specified transformers. The seller will not be responsible for the installation and system testing at Brookhaven National Laboratory (BNL).

1.3.3 The seller shall be responsible for the on-time delivery of the transformers.

2.0 Applicable Documents

2.1 The following documents form a part of this specification and are to be used as standards in the design and manufacture of rectifier transformers. Unless otherwise specified, the issue date or revision level shall be that in effect on the date of the Invitation to Quote. Exceptions to these standards shall be approved in writing by BNL.

Number	Title
ANSI/IEEE Standard C57	Distribution, Power and Regulating Transformers
ANSI/IEEE Standard 519	IEEE Guide for Harmonic Control and Reactive Compensation of Static Power Converters
BNL - QA -101	Supplier Quality Assurance Requirements
Code of Federal Regulations Title 29, Section 1910	OSHA General Industry Safety and Health Regulation and Standards

Federal Standard No. 595A	Matching Paint Colors
NEMA	SG-5, Indoor Power Switch Gear
NFPA 70	National Electric Code
RHIC DS-1	RHIC Design Standard

2.2 All transformers supplied under this specification shall be in strict accordance with the latest standards, publications and definitions of the IEEE, ANSI, NEMA and NEC where applicable. The transformers shall be manufactured in accordance with the best of existing techniques and recognized engineering practices. In all cases reference shall be made to recommended procedures or standards of the above organizations. Where this specification differs from the above standards and procedures, this specification shall apply, (see 3.1.3).

3.0 Requirements

3.1 Parts, Materials and Processes

3.1.1 Materials which may be defined as hazardous in accordance with Title 29, Code of Federal Regulations, Section 1910.1200 shall not be used. More specifically, asbestos or asbestos-type insulation, insulating or dielectric fluids containing PCB's, etc., **shall not** be used. Where a choice of materials is available, e.g. cables, support hardware, etc., preference shall be given to material or equipment exhibiting a higher level of fire retardancy, low oxygen content, etc.

3.1.2 The specifications for the various portions of the work describe certain special materials, processes and products of manufacture which will be required unless equal construction is specifically approved in writing by BNL Divisions of Contracts and Procurements. Should the seller propose to furnish other "equal" materials, processes, or products either in substitution for, or as an alternate to the specifications, such substitution can be approved by BNL only if described in full detail. The Cognizant BNL Engineers' decision as to the equality of any materials, processes and products to those specified shall be final, but the approval of BNL shall not relieve the seller from his responsibility concerning such work or affect the guarantee covering all parts of the work.

3.1.3 The BNL Cognizant Engineer shall have final approval on design considerations, specification interpretation, control, protection and testing. No deviation from this specification shall be allowed unless specifically authorized by BNL in writing.

3.1.4 The seller will be held responsible for the design, construction and testing of the transformer. However, the seller will not be held responsible for the installation and system testing at Brookhaven.

3.2 Submittals by Seller

3.2.1 The seller shall submit a proposal that gives a **PARAGRAPH by PARAGRAPH** response as to how he intends to comply with this specification. Any exceptions which the seller may take to the specification shall be clearly noted in the proposal. The seller shall state in the proposal that he is in full compliance with all aspects of this specifications which are not noted as exceptions.

3.2.2 The seller shall fill out the attached form entitled "Seller Data Sheet" and return it with his proposal. All exceptions on this form shall also appear in the exceptions section as per section 3.2.1.

3.2.3 The proposal shall include a list of transformers that the seller has produced and shipped that have similar ratings and construction to those offered in his proposal. The list shall include the performance data for these transformers, the purchaser's name and shipping date.

3.2.4 The seller shall describe in his proposal the testing capabilities of his facility and the electrical capacity of the test site.

3.2.5 Three sets of preliminary outline drawings showing the tank overall dimensions, all component placements, preliminary schematics and a preliminary manufacturing schedule shall accompany the proposal.

3.2.6 Three (3) weeks prior to first article testing, the seller shall submit for BNL's review and approval, a copy of the final test procedure.

3.2.7 The seller shall specify in detail the guarantee period and its provisions in his proposal.

3.3 Design Reviews

3.3.1 Prior to awarding a contract under this specification a pre-award meeting shall be held at the seller's facility. At this time a preliminary review of the submitted design will be held and the capability of the seller to produce these transformers in a timely manner will be evaluated.

3.3.2 The final design review (FDR) shall be held ten (10) weeks after receipt of order and prior to the start of fabrication. Three (3) sets of all electrical schematic drawings, mechanical assembly drawings, a manufacturing schedule, a preliminary acceptance test procedure, and a complete parts list shall be submitted to BNL at least two (2) weeks prior to the FDR date. Agreement shall be reached during the FDR not only on the drawings and material submitted, but also on the seller's manufacturing plan, preliminary test procedure and schedule. The results of the FDR shall be documented by the seller and submitted to BNL for approval. After written approval of the FDR by BNL the seller shall promptly begin the assembly of the transformer.

3.4 Transformer Performance and Design Characteristics

This section of the specification describes the performance and physical characteristics of the units required. Alternate products or schemes offered by the seller that may provide equal or better performance and reliability will be subject to approval by the BNL Cognizant Engineer.

Specific ratings and information for these transformers are given in the data sheets which are found at the end of this document. This section describes the data sheets and all additional requirements.

3.4.1 These transformers shall be of the liquid immersed, (silicone insulating fluid or mineral oil), inert gas sealed, oil air/future forced air (OA/FFA) type, suitable for outdoor operation. They shall conform to ANSI standard C57 and applicable subdivisions.

3.4.2 The transformer shall give full rated performance with an input voltage of 13.8 kV, +10% , -5%, without exceeding the specified temperature rise. The OA and FA ratings are given in the Transformer Data Sheet.

3.4.3 The transformer impedance, based on the nominal convection cooled (OA) KVA rating, shall not differ from the value as specified on the transformer data sheet by more than +/- 5%.

3.4.4 The voltage ratio, phase shift and phase balance in each transformer shall be maintained from no load to full load conditions within close limits, as specified in the data sheets.

3.4.5 The transformers shall be designed to avoid all mechanical resonances at frequencies less than 150 Hz.

3.4.6 The transformers shall have an extended delta primary and a wye secondary. The transformers shall have secondary taps as defined in the data sheet. The taps shall be changed by means of internal link boards accessible from the outside of the tank through service ports. As option “A” the seller shall include the cost of an external manual tap changing switch in his proposal. All taps shall be rated for full rated secondary current. Alternate schemes such as Delta primary and Zig-Zag secondary or configurations with primary taps may be proposed and will be evaluated by BNL.

3.4.7 Transformers which differ only in the direction of their phase rotation shall be of identical construction. The phase rotation shall be selectable by connection of the winding terminals accessible from the service ports or top cover, both lead and lag configuration shall be possible within the same units.

3.4.8 The observed average winding temperature rise, by resistance measurements, shall not exceed 55 degrees C at full rated KVA. The hot spot winding temperature rise shall not exceed 80 degrees C for a 30 degree C average ambient temperature (40 degree C peak) over a 24 hour period without fans. The temperature rise of the insulating liquid shall not exceed 55 degrees C when measured near the top of the main tank.

3.4.9 The seller shall take into account the additional load due to the harmonic load currents. The harmonic content of the line current for each transformer, in percent of the fundamental, is as defined in the ANSI/IEEE Standard 519.

3.5 Detailed Requirements

3.5.1 Transformer Load

3.5.1.1 Two transformers, phase shifted +/-15 degrees apart, will supply power to two SCR controlled rectifier bridges (see Fig. 1). The DC output of each bridge shall be series connected to a balanced RLC filter system to provide 12 pulse output to a large inductive load. The output ratings are defined as continuous duty, steady state DC and the transformers shall be designed for this type of application.

3.5.1.2 The transformers shall be designed and braced to withstand the available short circuit currents as specified in the transformer data sheets.

3.5.1.3 The transformer shall be rated to withstand the maximum rated load without over heating. The seller shall take into account the additional load due to harmonic load currents.

3.5.2 Transformer Core

3.5.2.1 The core shall be of non-aging high permeability silicon steel in thin laminations, properly annealed after cutting and with smooth edges. Both sides of each sheet shall have a baked on heat resistant insulation. All materials used shall be chemically non-interactive with the selected transformer insulating fluid. The core shall be carefully assembled and rigidly clamped in all directions to insure adequate mechanical strength and to reduce vibration to a minimum under all operating conditions.

3.5.2.2 The core shall be solidly grounded at one location only. The core ground strap shall be conveniently located for ease of inspection and testing through an inspection port.

3.5.2.3 The seller shall state the maximum operating core losses, both hysteresis and eddy current, as well as the weight of the core in his proposal. The losses shall be stated at rated voltage and at 110% of rated voltage.

3.5.2.4 The seller shall include in his proposal the maximum operating core flux density.

3.5.3 Windings

3.5.3.1 All windings shall be made of high grade electrical copper with a conductivity of 101% IACS as per ASTM standards. There shall be no bolted, soldered, or welded connections or splices in any of the windings except tap connections. The primary and secondary windings shall be cylindrical and concentric with anchoring clamps suitable for rectifier duty. They shall be sized and clamped to handle the rms operating, inrush and peak let-through currents.

3.5.3.2 The windings shall have high dielectric and mechanical strength and shall be arranged to permit free circulation of the insulating fluid. They shall be adequately braced to prevent distortion due to any operating or fault condition. The coils shall be constructed, shaped and braced to allow for expansion and contraction due to temperature changes while avoiding abrasion of the insulating materials. Proper internal barriers shall be provided and the end coil insulation shall have additional protection against high voltage stress breakdown.

3.5.3.3 The transformer shall be constructed with electrostatic shields properly isolated and grounded via a visible ground strap.

3.5.3.4 All taps shall be rated for the maximum operating current capacity of the transformer.

3.5.3.5 The windings shall withstand induced and dielectric test voltages in accordance with ANSI C57 and as required in this specification.

3.5.3.6 The seller shall specify the copper losses, the maximum current density and the weight of each coil in his proposal.

3.5.3.7 The transformer shall have an efficiency at full rated KVA load greater than that given in the Transformer Data Sheet. The vendor shall state the expected efficiency of the transformers in his proposal.

3.5.4 Bushings

3.5.4.1 The transformers shall have the primary, secondary and neutral leads brought out from the tank through bushings rated for full current and the appropriate voltages. The high voltage bushings shall have a BIL rating of 110 KV and the low voltage bushings shall have a BIL rating of 60kv. The high voltage bushings shall be tested at 34 kV rms as per ANSI C57. All bushings shall be ceramic, homogeneous and free from cavities or other flaws affecting their mechanical strength or dielectric qualities. All bushings shall be impervious to moisture and shall be oil tight.

3.5.4.2 The secondary and neutral bushings shall be located at the top of the transformer. The primary bushings shall be separately enclosed in suitable outdoor enclosures. The primary cable entry shall be either through the top or the bottom of the bushing enclosure via metal conduit. The doors of the enclosure shall be interlocked with micro-switches; the contacts of which shall be wired to the Main Terminal Box in a suitable conduit. Two sets of form C contacts shall be provided per door suitable for operation on a 24 volt DC system. The enclosure doors shall be electrically bonded to the tank.

3.5.5 Transformer Tank

3.5.5.1 All tanks shall be designed for outdoor service. All exterior surfaces shall be free of scale, rust and grease. The tank shall be painted with two coats of rust proof primer and

two coats of an exterior semi-gloss enamel, color "Light Gray" as per Federal standard No.595A, color No.26440.

3.5.5.2 The tank shall have adequate radiators mounted on it to maintain the proper cooling for the transformer. The seller shall specify the type and number of forced air cooling fans that can be mounted on the radiators (FFA). These will not be part of the order, however the seller shall make provisions for their mounting.

3.5.5.3 All tanks shall be made of steel and shall be oil tight and shall be constructed for **Inert Gas Pressure Operation with a removable top cover**. All gaskets shall be made of material which will not deteriorate under normal service conditions. All hardware shall be stainless steel, including but not limited to bolts, nuts, washers, etc.

3.5.5.4 Suitable hatches shall be provided to facilitate servicing.

3.5.5.5 The tank shall be provided with a pressure relief diaphragm or valve of adequate size to protect the tank against an explosion due to arcing below the surface of the oil. The relief device shall be designed to minimize the discharge of oil and the entrance of air and water after it has opened. It shall be equipped with alarm contacts suitable for operation on 24 volt DC circuits. The alarm contact leads shall be run via a suitable conduit to the main water tight terminal box mounted on the tank.

3.5.5.6 The tank shall be able to withstand an internal vacuum of 1 torr without deforming. The transformer shall operate pressurized with an inert gas (N2) to a pressure of several pounds per square inch. The pressurized transformer shall not exhibit any leaks, especially around the sealed top of the unit, fittings, valves, and other tank penetrations.

3.5.5.7 The vendor shall state the external dimensions of the tank in his proposal. These dimensions shall include the size of the radiators and terminal boxes.

3.5.5.8 The vendor shall provide the following valves especially designed for use with the selected insulating fluid and which shall hold hot fluids without leaking.

3.5.5.8.1 Valve for draining and sampling the liquid in the extreme bottom of the tank.
3.5.5.8.2 Lower filter press connection and complete drain.
3.5.5.8.3 Upper filter press connection.
3.5.5.8.4 Liquid inlet and outlet shutoff valve.
3.5.5.8.5 Valve for draining the radiators.
3.5.5.8.6 Gas pressurization regulator valve, regulator range of 1 to 10 psi.

3.5.5.9 The transformers shall be provided with a magnetic type fluid level gauge equipped with adjustable low level alarm contacts (form C) suitable for operation on a 24 volt DC system. The alarm contact leads shall be run to the main terminal box in a suitable conduit. The gauge shall have a dark face dial with light markings and a light colored indicating hand. The diameter of the dial (inside bezel) shall be 3-1/4 inch, +/-1/4 inch. The dial markings shall show the 25 degrees C level and the minimum and maximum levels. The words "liquid

Level" shall be on the dial or on a easily visible nameplate adjacent thereto. The 25 degrees C liquid level shall be shown on the tank by suitable permanent markings.

3.5.5.10 The transformer shall be provided with an indicating dial thermometer to indicate the oil temperature. It shall be equipped with adjustable alarm contacts (form C) suitable for operation on a 24 volt DC system. The alarm contact leads shall be run to the main terminal box in a suitable conduit. The thermometer shall have a dark face dial with light markings, a light colored indicating hand, and an orange-red maximum indicating hand, with provision for resetting. The diameter of the dial (inside bezel) shall be 4-1/2 inches +/-1 inch. The dial markings shall cover a range of 0 to 120 degrees C. The words "liquid Temperature" shall be on the dial or on a suitable nameplate mounted adjacent to the indicator.

3.5.5.11 A winding temperature simulator device with a thermal element mounted in a well and responsive to the simulated winding hottest spot temperature of the transformer shall be provided. It shall be equipped with adjustable alarm contacts (form C) suitable for operation on a 24 volt DC system. The leads shall be run to the main terminal box in a suitable conduit. The instrument shall have a dark face dial with light markings, a light colored indicating hand, and an orange-red maximum indicating hand with provisions for resetting. The diameter of the dial (inside bezel) shall be 4-1/2 inches, +/-1 inch. The dial markings shall cover a range of 0 to 180 degrees C. The words "Winding Temperature" shall be on the dial or on a suitable nameplate mounted adjacent to the indicator.

3.5.5.12 The transformer shall be provided with a pressure-vacuum gauge. The scale range for the pressure-vacuum gauge shall be between 10 psi positive and negative. The diameter of the dial (inside bezel) shall be 3-1/2 inches, +/-1/4 inch. The gauge shall have a dark-face dial with light-colored markings and a light-colored pointer.

3.5.5.13 The tank shall be provided with two (2) NEMA standard stainless steel ground pads located diagonally opposite each other at the base of the tank for BNL's use. These pads shall be drilled and tapped to accept NEMA 2 lugs.

3.5.5.14 All tanks shall be equipped with lifting eyes and skid rails suitable for frequent lifting and handling of the transformers by overhead crane and forklift.

3.5.5.15 Data sheets describing all gauges, meters and protective devices shall be submitted to BNL for approval and shall be included in the design manual, see section 3.8.3.

3.5.6 Insulating Fluid

3.5.6.1 The vendor shall include as part of his proposal the options of building the transformers for use with: (1) silicone insulating fluid or (2) mineral oil.

3.5.6.2 A data sheet describing the insulating fluid used for the power transformer shall be furnished by the seller in his proposal. If a petroleum oil is used it shall be a pure mineral oil obtained by fractional distillation of petroleum unmixed with any other substance. It shall be prepared and refined especially for use in power transformers, and shall be free from

moisture, acid, alkali and sulfur compounds. It shall be certified free of PCB's. It shall not form a deposit under normal operating temperatures. The oil shall have the following physical characteristics:

3.5.6.2.1 Dielectric strength, not less than 26KVac between one inch discs spaced 1/10 inch apart.
3.5.6.2.2 Viscosity, not to exceed 57 Saybolt at 40 degrees C.
3.5.6.2.3 Freezing point, not higher than -40 degrees C.
3.5.6.2.4 Flash point, not under 132 degrees C (open cup).
3.5.6.2.5 Burning point, not less than 140 degrees C (open cup).
3.5.6.2.6 Color, very pale amber to water white clear.
3.5.6.2.7 It shall be an uninhibited oil.

3.5.6.3 A data sheet for the fluid selected shall be sent to BNL for approval before the final design review.

3.6 MAIN TERMINAL BOX

3.6.1 All accessories which require wiring shall be provided with a suitable galvanized steel conduit run to a water tight hinged terminal box. This box shall be mounted on the tank and shall house a terminal board to provide connections to controls, alarms and auxiliary power cables. The terminal box shall be watertight for outdoor use and provided with conduit entrance fittings for use by BNL. There shall be 10 spare terminals provided for later use by BNL. An electrical drawing shall be supplied showing how all the components are wired and how they can be interconnected to BNL's circuitry.

3.7 NAMEPLATE

3.7.1 The vendor shall supply a stainless steel type "C" nameplate for each transformer giving all standard information, including the following:

3.7.1.1 Manufacturer's name and address.
3.7.1.2 Manufacturer's part number.
3.7.1.3 BNL’s part number.
3.7.1.4 Type, serial number and date of manufacture.
3.7.1.5 Input voltage and current rating (OA).
3.7.1.6 Output voltage and current rating for each tap (OA).
3.7.1.7 KVA ratings.
3.7.1.8 Percent Impedance.
3.7.1.9 Total weight with and without oil, tank weight.
3.7.1.10 A phase shift diagram.
3.7.1.11 Outline diagram including wiring and terminal designation in their relative location.
3.7.1.12 Allowable temperature rise.
3.7.1.13 x/r ratio at rated load and 40 degrees C ambient.
3.7.1.14 Insulating fluid volume and type.

3.7.1.15 Maximum tank pressure.
3.7.1.16 The change in liquid level per 10 degrees C change in temperature.

3.8 Documentation

3.8.1 Before delivery of the final transformer two (2) copies of the final parts list shall be supplied by the seller. This shall list all components used in the fabrication of the transformers, identifying those parts recommended by the vendor as required spare parts to insure efficient, reliable operation. The data shall include current unit price and supplier of all component parts.

3.8.2 Upon delivery of the first transformer two (2) sets of "as built" mechanical assembly and electrical schematics, signed, final prints shall be supplied by the seller. One high quality reproducible copy of the final "as built" drawings shall be furnished. These prints shall be made to the highest professional drafting standards. Computer CAD system drawing plots shall be provided on 3 1/2 inch floppy disk or CD-ROM in the format of "AutoCAD" drawing plot files. Drawings shall conform to the guidelines set forth in RHIC Design Standard DS-1 revision 5.

3.8.3 The information required under paragraphs 3.8.1 and 3.8.2 as well as all test results, technical descriptions, data sheets on gauges, meters, valves and other pertinent components shall be supplied in bound design and operations manuals. Two copies of this manual shall be supplied for each series of transformer at the time of delivery of the last transformer.

3.8.4 A transformer / winding data sheet shall be provided.

4.0 TESTING

4.1 The BNL cognizant engineer and/or his representatives shall have access to the sellers facility during fabrication and testing. BNL reserves the right to witness any and all tests. The seller shall formulate an acceptance test procedure (ATP) and shall provide the facilities and instrumentation at his plant to perform all necessary tests to ensure compliance with all parts of this specification. The ATP shall include, but not be limited to, the specific tests outlined below. This ATP shall be agreed upon prior to commencement of fabrication of the transformers. BNL reserves the right to require additional or more extensive tests to be conducted in case of marginal design and performance. The seller shall provide fifteen (15) working days notice in advance of the test date(s) so that BNL can make the necessary travel arrangements.

4.2 First Article Test.

4.2.1 A heat run as defined in section 4.2.2 shall include the transformer base load plus the harmonic load current effect. The heat run test shall be performed on the first article transformer and shall be witnessed by BNL to insure compliance with the specification and the bid document. Upon successful completion of the first article acceptance test, BNL shall provide a written approval and a release for the remaining units. The remaining units shall then be tested in accordance with the tests in section 4.3. The seller shall provide a copy of the heat run test results to BNL.

4.2.2 The factory heat run shall be performed to determine that the transformer meets the specified temperature rise for both OA and FA loading conditions. Fans shall be temporarily mounted for the FA portion of the test. Based on the test results of the first article transformer BNL reserves the right to require that a heat run be performed on any or all of the subsequent units manufactured.

4.2.3 An impulse test on the line side terminals shall be conducted at the BIL crest value of 110kv.

4.3 Acceptance Tests For All Transformers.

4.3.1 The following tests shall be performed on the first article transformer and all production units.

4.3.2 Each transformer shall be tested by the standard ANSI open circuit test to determine core losses and the standard ANSI short circuit test to determine copper losses.

4.3.3 Winding resistance shall be measured for all windings on the rated voltage tap position and recorded. The measurement accuracy shall be < 0.1%.

4.3.4 The impedance at rated current and frequency for each tap position shall be measured and recorded.

4.3.5 No load turns ratio test shall be performed on each phase and for all taps of each transformer and shall be recorded.

4.3.6 A phase relation test shall be performed to verify the phase shift (0.1%), voltage balance (0.1%) and phase angle balance (+/- 0.1%).

4.3.7 A high potential test shall be performed on each transformer. For those transformers subjected to a heat run, this test shall be performed immediately after the heat run. The test shall be performed at 60 Hz and the winding shall be subjected to the specified test voltage for one minute. The test voltage of **34 kv RMS** shall be applied between the primary winding and the secondary winding and the primary winding and the tank. The secondary winding to tank shall be tested at **2.5kv RMS**. All actual leakage currents shall be recorded at the end of one minute while the specified voltage is applied to the winding.

4.3.8 A turn to turn insulation test shall be performed at 400 Hz or higher frequency. This test shall directly apply or induce a voltage on the primary winding whose value is equal to twice rated value for the duration of 7200 cycles of the applied frequency.

4.3.9 Tank pressure withstand test shall be performed on each completed transformer. The test shall consist of pressurizing the tank to a pressure of +8 PSIG for eight (8) hours and recording the pressure loss readings. All seals and weld joints shall be tested using a soap water mixture during the pressure test.

4.3.10 All interlock protection and alarm indication circuits shall be checked for proper operation. Actual fault conditions shall be induced where possible.

4.4 The cognizant BNL engineer and/or his representative shall witness all of the above tests. Certified copies of all test data, for each unit, shall be supplied to the cognizant BNL engineer and shall also be included in each copy of the instruction manual.

5.0 Quality Assurance Provisions

5.1 General

Articles furnished in compliance with this specification shall be produced under the controls established herein and as required by the applicable contract. Additional Quality Assurance requirements are in accordance with this specification and BNL-QA-101; Sections 3.1.2, 4.1, 4.3, 4.4 (except 6 weeks ARO) including 4.4.2 and 4.4.4, 4.5 (except 7 working days), 4.6 (except 6 weeks ARO), 4.7, 4.7.1, 4.10 including 4.10.1, 4.10.2, 4.10.3 and 4.10.5, 4.13, 4.16, 4.18 including 4.18.3, 4.18.4, 4.19, and 4.21.

5.2 Responsibility for Inspection and Tests

5.2.1 Approval by BNL shall not release the seller from his responsibility to correct conceptual design, manufacturing, or any mistakes.

5.2.2 The seller shall cooperate with and aid representatives of BNL when they desire to witness construction, progress and the various required inspections and tests.

5.2.3 All purchased articles from subcontractors or manufacturers released for inclusion in this transformer shall be clearly identified to indicate conformance to seller's receiving inspection.

5.2.4 All elements of this transformer shall be covered by a guarantee against material and manufacturing faults. The seller shall specify in detail the guarantee period and its provisions. The guarantee period shall be for a period of at least two (2) years from the final acceptance test date.

5.3 Final Acceptance

For purpose of warranty under an order for these transformers, final inspection (acceptance) is defined as the successful completion of acceptance tests at BNL to substantiate the compliance of the modules with this specification. Final Acceptance will be completed within twelve (12) months after receipt of the units at BNL. The seller will be notified of the test dates and may have a representative present to witness the tests. The seller shall be held responsible for the contracted performance of the transformers produced and delivered to BNL.

Final Acceptance testing at BNL shall include any or all of the following tests:

a. Hi-pot testing
b. Full power heat run
c. Interlock and protection circuits
d. Any other standard tests deemed necessary by the BNL cognizant engineer to confirm conformance to the specification.

6.0 Preparation for Delivery

All units and parts of the equipment shall be properly packaged and delivered in an undamaged condition to BNL. All transformers shall be shipped with insulating fluid and shall be pressurized with an inert gas. The seller shall ship all transformers via air ride trucks. Devices shall be installed on the transformers during shipment which will record any unusual mechanical shocks or tipping.

7.0 Notes

7.1 Definitions

7.1.1 BNL - BNL shall mean the Associated Universities, Inc., Upton, NY 11973-5000, operating Brookhaven National Laboratory, acting by and through its Division of Contracts & Procurement. BNL is responsible to the Department of Energy for the article described by this specification.

7.1.2 Seller - Seller is the agency responsible to BNL for supplying the article described in this specification. The seller shall be directly responsible to BNL for all approvals, submittals, proposed changes or deviations to this specification.

7.1.3 Failure - A failure shall be defined as any occurrence, including one time non-repeatable anomalies either sudden or gradual in nature which causes the transformer performance to deviate from specified limits without adjustment of controls other than normal operating controls.

7.1.4 ANSI - American National Standards Institute.

7.1.5 ASTM - American Society for Testing Materials.

7.1.6 IACS - International Annealed Copper Standard.

7.1.7 IEEE - Institute of Electrical and Electronics Engineers.

7.1.8 NEMA - National Electrical Manufacturers Association.

7.1.9 NEC - National Electrical Code.

7.1.10 FFA - Future Forced Air.

7.1.11 OA - Oil to Air.

7.1.12 FA - Forced Air.

8.0 Specification Data Sheets

The following sections contain data sheet sections which are part of this specification. These include the transformer specification data sheet, specifying performance requirements and the Seller Data Sheet characterizing the configuration of the transformer to be supplied by the seller. It is intended that upon the review of detailed designs and any modified Seller Data Sheet entries, the Seller Data Sheets shall become part of this specification.

8.1 Specification Data Sheet

8.1.1 2500 KVA Transformer (**T1**).

a.	Rating, KVA. (OA / FFA)	2500 / 3000 KVA
b.	Winding configuration with electrostatic shield	Extended Delta-Wye
c.	Relative Phase Shift	+15 Elec. Deg.+/- 0.1%
d.	Primary voltage, Volts (+10% max, -5% min)	13.8KVrms, 60HZ, 3 Phase.
e.	Secondary voltage, Volts	
	Secondary tap voltages defined at 13.8KV primary.	
	Secondary Tap 1 (100%), volts	333 Vrms
	Secondary Tap 2 (90%), volts	300 Vrms
	Secondary Tap 3 (80%), volts	266 Vrms
	Secondary Tap 4 (45%), volts	150 Vrms
f.	Secondary current, max, line amperes	4330 Amp
g.	Transformer Impedance 90% tap	5.0%.+/- 5.0%
	Max difference between matching transformers	mean +/- 5.0%
h.	Voltage Balance, no load (phase to phase)	0.1%
	Max difference between matching transformers	0.1%
i.	Efficiency	> 98%
j.	Load Duty Factor	Continuous
k.	Available short circuit current (to primary terminals)	15 kAmp
l.	Material, windings, bus bar, leads	copper
m.	Cooling	OA/FFA
n.	Insulating fluid (see 3.5.6)	Silicone/Mineral oil
o.	Ambient Air Temperature	-30 to +40 Degrees C.
p.	Average Temperature Rise, Deg. C	55 Degrees C
q.	Humidity	100%
r.	Altitude	< 100 meters

s.	High potential test voltage (hv terminal)	34 kV rms.
t.	B.I.L. test voltage (hv terminal)	110 kV
u.	High potential test voltage (lv terminal)	2.5 kV

8.1.2 2500 KVA Transformer (**T2**).

a.	Rating, KVA. (OA / FFA)	2500 / 3000 KVA
b.	Winding configuration with electrostatic shield	Extended Delta-Wye
c.	Relative Phase Shift	-15 Elect. Deg. +/- 0.1%
d.	Primary voltage, Volts (+10% max, -5% min)	13.8KVrms, 60HZ, 3 Phase.
e.	Secondary voltage, Volts Secondary tap voltages defined at full load current and at 13.8KV primary.	
	Secondary Tap 1 (100%), volts	333 Vrms
	Secondary Tap 2 (90%), volts	300 Vrms
	Secondary Tap 3 (80%), volts	266 Vrms
	Secondary Tap 4 (45%), volts	150 Vrms
f.	Secondary current, max, line amperes	4330 Amp
g.	Transformer Impedance 90% tap	5.0%.+/- 5.0%
	Max difference between matching transformers	mean +/- 5.0%
h.	Voltage Balance, no load (phase to phase)	0.1%
	Max difference between matching transformers	0.1%
i.	Efficiency	> 98%
j.	Load Duty Factor	Continuous
k.	Available short circuit current (to primary terminals)	15 kAmp
l.	Material, windings, bus bar, leads	copper
m.	Cooling	OA/FFA
n.	Insulating fluid (see 3.5.6)	Silicone/Mineral oil
o.	Ambient Air Temperature	-30 to +40 Degrees C.
p.	Average Temperature Rise, Deg. C	55 Degrees C
q.	Humidity	100%
r.	Altitude	< 100 meters
s.	High potential test voltage (hv terminal)	34 kV rms.
t.	B.I.L. test voltage (hv terminal)	110 kV
u.	High potential test voltage (lv terminal)	2.5 kV

8.2 Seller Data Sheet, (T1)

8.2.1 Primary Voltage _____

8.2.2 Secondary Voltage _____

8.2.3 Core Losses (110% /100% of rated V) _____/_____

8.2.4 Copper Losses (OA/FFA KVA rating) _____/_____

8.2.5 Total Losses _____

8.2.6 Transformer Efficiency _____

8.2.7 Impedance (100% /90% /80 %/ 45 % tap) _____/_____/_____/_____

8.2.8 X/R ratio _____

8.2.9 Operating flux (110%/100% voltage) _____/_____

8.2.10 Dimensions Tank (HWL) _____

8.2.11 Weight of core _____

8.2.12 Weight of copper _____

8.2.13 Total weight of tanked unit-dry _____

8.2.14 Total weight of tanked unit wet(silicone/mineral oil) _____/_____

8.2.15 Minimum allowable spacing between transformers with silicone fluid (determined by cooling requirement) _____

8.2.16 Minimum allowable spacing between transformers with mineral oil (determined by cooling requirement) _____

8.2.17 Gallons of fluid required (silicone/mineral oil) _____/_____

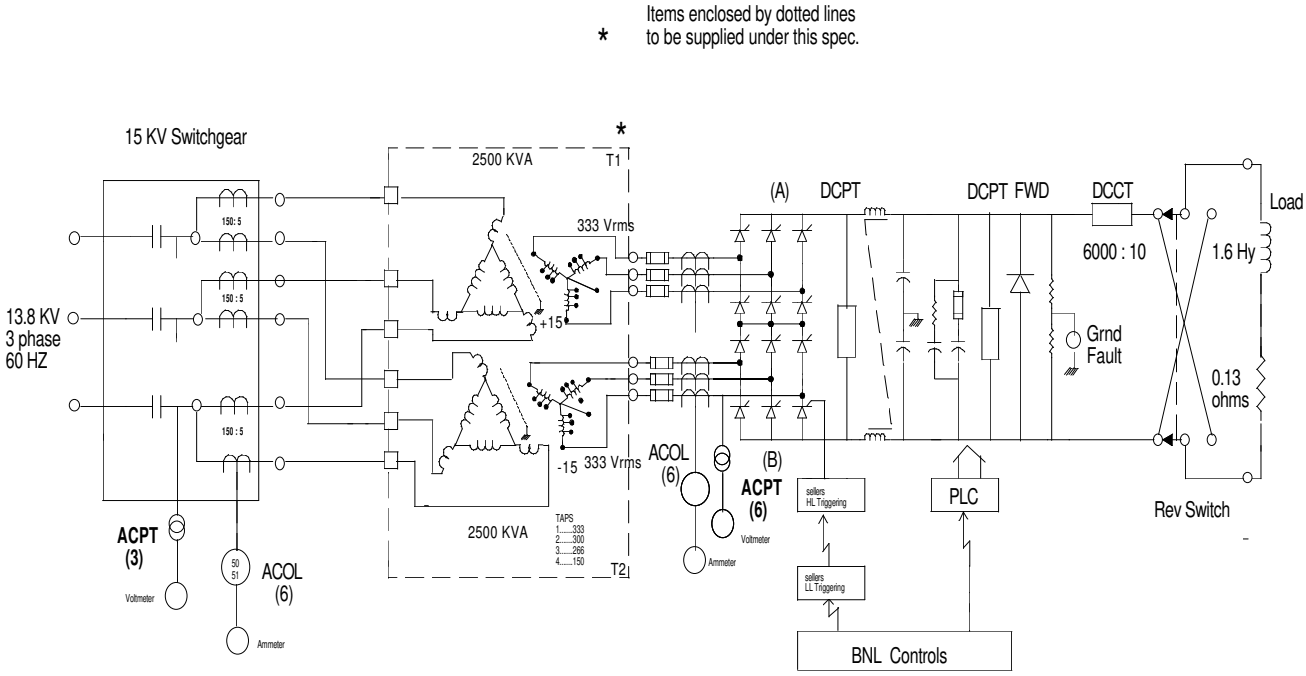
8.2.18 Winding Configuration _____

8.2.19 Tap Configuration _____

8.2.20 Submit a B-H Curve of the Transformer Steel

8.3 Seller Data Sheet, (T2)

8.3.1	Primary Voltage	_____
8.3.2	Secondary Voltage	_____
8.3.3	Core Losses(110% /100% of rated V)	_____/_____
8.3.4	Copper Losses(OA/FFA KVA rating)	_____/_____
8.3.5	Total Losses	_____
8.3.6	Transformer Efficiency	_____
8.3.7	Impedance (100% /90% /45.5 % taps)	_____/_____/____
8.3.8	X/R ratio	_____
8.3.9	Operating flux (110% / 100% voltage)	_____
8.3.10	Dimensions Tank (HWL)	_____
8.3.11	Weight of core	_____
8.3.12	Weight of copper	_____
8.3.13	Total weight of tanked unit-dry	_____
8.3.14	Total weight of tanked unit wet (silicone/mineral oil)	_____/_____
8.3.15	Minimum allowable spacing between transformers with silicone fluid (determined by cooling requirement)	_____
8.3.16	Minimum allowable spacing between transformers with mineral oil (determined by cooling requirement)	_____
8.3.17	Gallons of fluid required (silicone/mineral oil)	_____/_____
8.3.18	Winding Configuration	_____
8.3.19	Tap Configurations	_____
8.3.20	Submit a B-H Curve of the Transformer Steel	



One line diagram of the STAR Detector
Magnet Main Winding Power Supply

FIG. 1