

NATIONAL ACCELERATOR LABORATORY  
SPECIFICATION FOR BOOSTER CHOKES

Original Issue

6 November 1969

## SPECIFICATION FOR BOOSTER CHOKES

### 1. General

The 200 GeV proton accelerator, which will be constructed near Batavia, Illinois, will include a booster accelerator. The Booster contains 96 magnets located in a circular tunnel approximately 490 feet in diameter. The magnet circuit is tuned to resonate at 15 Hz with 48 banks of capacitors connected in series with the magnets. Forty-eight (48) chokes are required to conduct the direct current around the capacitor banks. The characteristics required of these chokes are given in this specification.

The chokes have a primary and a secondary winding. The secondary winding carries a dc biased sinusoidally varying current. The frequency of the sinusoidally varying component of the current is 15 Hz.

The primary winding carries balancing currents between different resonant sections. Under normal operation, the balancing currents are zero.

### 2. Scope

The Seller shall manufacture, inspect, test, and delivery F.O.B. NAL, Batavia, Illinois, a total of fifty (50) identical chokes in accordance with these specifications.

### 3. Choke Operating Condition

3.1	DC component of secondary current	548 A
3.2	Peak secondary current	791 A
3.3	Secondary ac voltage	645 V rms, 15 Hz
3.4	Primary current (maximum)	50 V rms, 15 Hz

- 3.5 Approximate inductance at peak current 40 mH
- 3.6 Approximate resistance of secondary winding 26 mΩ

4. Technical Specification

- 4.1 Inductance uniformity Better than 1%, measured with the same instrumentation under same conditions.
- 4.2 Number of turns of primary winding 104
- 4.3 Number of turns of secondary winding 104
- 4.4 Number of monitor windings (1 turn, #14 wire). 2
- 4.5 Maximum overall dimensions 62" x 30" x 23½"
- 4.6 The coil secondary winding shall be fabricated of two parallel connected .46" square copper conductors with a .25" dia hole for water cooling. The copper conductor will be provided by NAL.
- 4.7 The primary winding shall be .843" x .032" copper conductor closely coupled with the secondary.
- 4.8 The secondary coil shall be water cooled, the cooling water manifold shall be part of the choke. The temperature rise of the cooling water under operating conditions shall not exceed 10° C with water inlet pressure = 150 psi at 32° C and water return pressure = 25 psi.
- 4.9 The cooling water circuit shall be designed for 150 psig static pressure.

- 4.10 The construction of the choke shall be of the shell type, with air gaps in the center leg surrounded by the coil in order to minimize the stray magnetic field essentially identical to the construction of the prototype choke. NAL will provide the pre-punched outer yoke laminations.
- 4.11 The coil insulation shall be a combination of glass, mica and epoxy with good radiation resistance, identical to the prototype system.
- 4.12 The choke shall be enclosed in a stainless steel skin essentially identical to the prototype choke, to minimize external stray fields.
- 4.13 The turn-to-turn and layer-to-layer insulation shall be rated for 200% of the maximum operating voltage. The coil-to-frame insulation shall be rated for 5 KV ac rms.
- 4.14 The choke secondary winding shall be divided into two equal windings with all four terminals brought out.
- 4.15 The outer terminals shall be brought out to both left and right hand side, facing the terminals. The center terminals shall be brought out to the right hand side only.
- 4.16 The water terminals shall be 3/4", brought out to the right hand side, facing the terminals.
- 4.17 The core laminations shall be grounded to the outer stainless steel skin. A terminal shall be provided for Buyer's external ground connection.
- 4.18 The contact areas for Buyer's connections to the terminals of the secondary windings shall be silver plated.
- 4.19 The completely assembled choke as well as the coil assembly shall be vacuum impregnated with epoxy resin, that is essentially identical to that of the prototype choke.

5. Factory Tests

The following factory tests shall be performed.

- 5.1 The DC resistance of all windings shall be measured with a Kelvin bridge after final impregnation of the completed choke. ✓
- 5.2 Turn ratio of the coils shall be determined by counting during winding of the coils. *record & save - pic of sec after*
- 5.3 A steel ball of 3/16" diameter shall be blown through each hollow conductor after the leads are formed, but before the connection blocks are installed. *an  
✓ shelling  
sheet  
see after  
an*
- 5.4 Hi-pot tests shall be performed as follows:
- 5.4.1 5 KV rms, 60 Hz, for 5 seconds on each winding layer during winding of the coil.
- 5.4.2 5 KV rms, 60 Hz, for 5 seconds on each winding after first bake-out, but before resin processing.
- 5.4.3 5 KV rms, 60 Hz, for 5 seconds on each winding after core-coil assembly, but before resin potting of the core-coil assembly.
- 5.4.4 5 KV rms, 60 Hz, for 1 minute on each *pr + secondary to steel* winding after final impregnation of the com-*pr - venting to* pleted choke. The leakage current reading shall be recorded for each winding at the end of 1 minute. *1000 V on sec wire*
- 5.5 The inductance shall be measured using the choke secondary winding, with the primary and both monitor windings open, after final potting of the completed choke. The repeatability of instrument readings shall be .1% or better in order to assure that the specified uniformity of inductance is achieved.
- 5.6 A *120 volt* 120 volt, 60 Hz test shall be made on the choke after final impregnation of the completed choke. First, with the choke secondary open measure input voltage and current (V1, I1). Then, resonate secondary with a suitable capacitor and measure voltage and current (V2, I2). Calculate and record: *change to  
series  
resonance*

$$XL = \frac{V1}{I1}$$

$$R = \frac{V2}{I2}$$

$$Q = \frac{XL}{R}$$

5.7 A 250 psig static water pressure shall be applied to the finalized choke. There shall be no evidence of leaks. *5 min*

5.8 The leakage inductance between primary and entire secondary shall be measured on the completed choke. *bridge, short out one*

5.9 An induced voltage test shall be performed on primary and secondary winding of at least 20 volts per turn for 1 minute. This test shall be performed after coil assembly, but before coil potting. The excitation voltage shall be raised and lowered gradually to avoid transients. Excitation voltage and current readings shall be recorded with the coils in the test core and with the coils outside the test core. *eliminate*

5.10 A test report shall be supplied to NAL, including actual test procedures, test data, and environmental data such as ambient temperature and humidity.

6. Tests After Delivery

The final acceptance tests will be conducted at NAL by NAL personnel within thirty days after delivery of the chokes. The manufacturer's representative may witness these tests. These tests will be mainly performed with the chokes operating at a dc biased, 15 Hz excitation. The tests will include measurements of inductance, leakage inductance, linearity of inductance, temperature rise and Q.

7. Drawings

The Seller shall submit within four weeks after award of contract, for approval of the design, four copies of each of the following drawings to NAL.

- 7.1 Outline drawing of the chokes, including overall dimensions, general arrangement and weights.
- 7.2 Detailed drawings of terminal arrangement with interconnections for power and water.
- 7.3 Choke coil design sheet.

On or before shipment of the choke, the Seller shall furnish the Buyer with six complete sets of prints and one reproducible of each drawing as finally approved, corrected and built.

8. Inspection

The Buyer, or his representative, shall at any time during the design, construction, assembling and testing of the chokes, be allowed to visit the Seller's shops and offices for the purpose of inspecting the progress and witnessing assembly procedures and tests. The Seller shall provide pertinent information and all reasonable facilities and assistance for the safety and convenience of the Buyer's inspectors in the performance of their duties.

9. Warranty

The equipment shall be warranted to be free of defects for the period of one year after delivery.