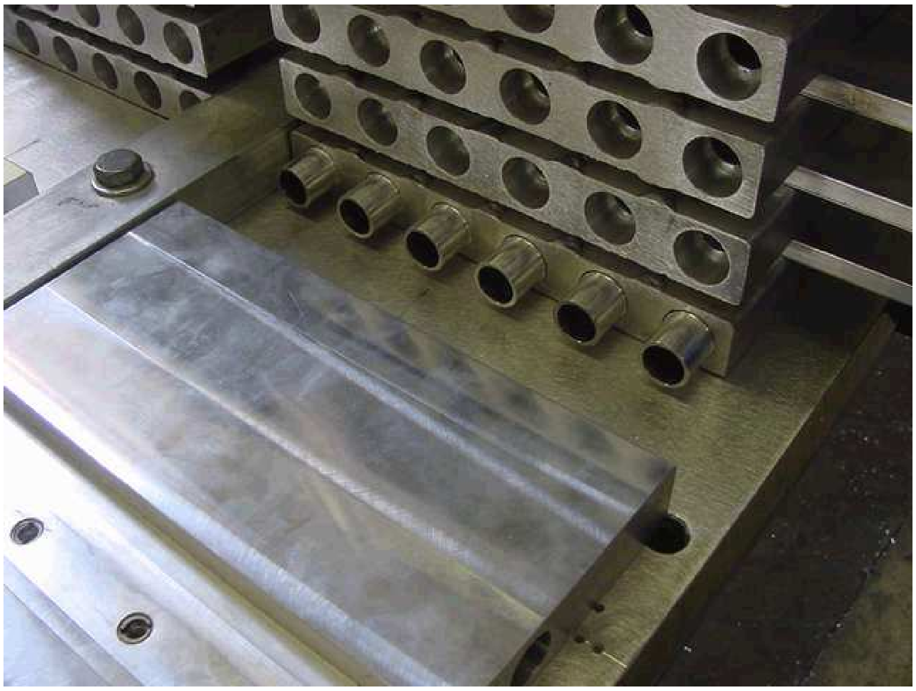

Figure 1: Cross section of MINOS near detector coil

1 Coil

This chapter describes the requirements of the MINERνA coil, and what these requirements imply for the coil design. Estimates are given for the coil design, fabrication, and installation costs. Much of the design of the coil is borrowed from that of the MINOS near detector coil.

In order to get a high magnetic field and therefore best momentum resolution, the current will be high enough to saturate the low carbon steel. To do this the detector coil must carry 28,000 A-turns and as a result the detector will have a magnetic field of 1.6T in the beam region. This high current on the coil turn (which is about xxx m long) will require substantial cooling. A low-conductivity water (LCW) closed loop provides the coil-cooling water.

The coil consists of two approximately xx m long legs (bore and return) and two approximately xxx m long sections to connect the bore and return legs (upstream and downstream).

Each conductor is formed by a 1.1 in$\times$1.5 in rectangular cross section aluminum bar with a 0.65in diameter channel through its center. The conductor is cooled by flowing LCW through the center channel. The cross section of the one of these conductors is shown in Figure 3. The coil has 48 turns where the conductors are arranged in a layer as shown in Figure 3.

The electrical connections are made using welded lap joints. An example of one of these joints is shown in Figure 1. Groups of 6 conductors are formed into planks. The current flows in parallel through the conductors within a plank. The lap joints require less installation labor than designs requiring in situ welding.

Input and output water manifolds will be located at all four corners of the device. Water passes through one plank before returning to the chiller, giving 8$\times$4 separate water circuits. The water flows in parallel within a plank. Flow calculations show that the flow rates in the different conductors within

Figure 2: Figure showing a completed plank complete with welded lap joints.

a plank are fairly well balanced [6].

There is only one electrical circuit. Each conductor carries 833A and the coil is powered by a 5000A supply.

1.1 Coil Manufacture and Installation

The pre-tested aluminum conductor is delivered directly to the fabricator on spools where it is uncoiled, straightened, and cut to length. The ends of the conductor are prepared for welding in two ways: the hole is countersunk for a stainless-steel ferrel and the edges are beveled to allow for full penetration welds. The 8 conductors in a plank are welded together. Ferrels are inserted into the lap-joint pieces and mated with the conductors and then welded. The planks are wrapped in two layers of B-stage epoxy and painted with epoxy paint. The finished planks are then pressure and flow tested prior to delivery to Fermilab.

After delivery the completed components are lowered into the NuMI near detector hall though a drop shaft using a special lifting fixture. Because the MINERνA coil will be significantly shorter than the MINOS near detector coil (xxx m compared to yyy m), the installation is not expected to be nearly as challenging.

The coil is installed after the detector has been mounted. The planks are rigged into position using a special “spreader bar” lifting fixture to support the free end of the plank as it enters the bore. Note that the center segment of the coil assembly (8 full-length planks) weighs about 500 kg. The planks are flexible, and could be easily damaged if overstressed. After a new plank is put in place, the lap-joint connection is completed. Before the lap connections are made the surfaces will be chemically cleaned and a surface coating will be applied. There is a relatively short time (minutes) between the preparation of the surface and the mating of the splice.

Before the installation can proceed, brackets are mounted on the steel support structure to support the return coil. The coil's components include 16 long planks and 16 short planks. Installation of the first 4 planks is somewhat different than the remainder of the planks. Rollers on the lifting fixture enable the planks to slide smoothly into the bore of the detector, where it rests on insulation in the central collar tube. The long return plank is then rigged into position on the support brackets under the detector. A short plank is rigging into position on the downstream end of the detector and connected to the first two planks. Each connection will be checked for electrical integrity. The water connections to each end of the planks will also be made. A second short plank is installed on the upstream side of the detector and is only connected to the return plank. This completes the first circuit of planks. After this point, the installed coil sections are self-supporting. The planes will then be checked for water integrity.

The remaining planks are installed in a helical pattern. First a bore plank is installed, then a downstream plank, then a return plank, and finally an upstream plane. As each plank is installed it is electrically connected to the previous plank. Final installation of the coil includes making connections to the power supply and tests of the entire LCW system.

1.2 Coil cooling systems

The coil cooling system will connect to a LCW cooling system. The coil cooling system will run at about $100 \times 28/48$ gpm and must carry off the $80 \times 28/48$ kW of heat generated by the coil power supply, coil, and power bus. Note that only the coil itself is connected to the chiller. The supply and bus are cooled using non-chilled water. By comparison, the MINOS near detector cooling system runs at about $100 \times 28/48$ gpm and must carry off the $80 \times 28/48$ kW. Additional cooling must certainly be added to the detector hall accomodate this load.

1.3 Power System

The near detector coil a PEI 150-5 running at 5KA to deliver 5000A or 833A per conductor. The supplies are equipped with input and output filters to reduce electronic noise pickup. The power supply has remote readout and remote control capabilities. The supply, cooling system, and interlocks will be provided by the FNAL Accelerator Division. The supply's control and monitoring systems will be interfaced to the MINERνA slow control systems.

The coil power supply will have a current regulator and precision readout to continuously monitor its current. In addition a resistance bridge will be installed to monitor for small changes in the resistance of the coil. Thermal interlocks will also be provided in the event of excessive heating.

The power supply is also water-cooled and needs 5gpm and a maximum pressure drop of 100psi with a differential pressure of 60 PSI.

1.4 Magnetic calibration

The calibration of the magnetic field in the detector will be done by the installation of Induction Coils at a few radii per plane. These coils will be read out by a PC with Labview. This program can waveform digitize the Induction Coil signals. The current control can be automated, or manual. But by monitoring the current we expect to achieve an accuracy on the magnetic field of xxx %, as is required by the physics specifications. Although the coils themselves (called Bdot cables) will have to be purchased new, the other hardware can all come from recycled MINOS hardware.

Bdot system	$13,383.55	130%	$17,398.62

Table 1: Estimated Costs for the magnetic calibration system

Item	FY01 costs	Units	FY06 costs	needed	total
Bdot loop	$0.70	$/ft wire	$0.81	630.00	$511.24
Twisted Pair	$1.00	$/ft wire	$1.16	2,700.00	$3,130.04
Bdot connectors	$6.26	$/half loop	$7.26	1,126.80	$8,177.25
Bdot boards	$15	$/board	$17.39	90.00	$1,565.02

Table 2: Estimated costs for the magnetic calibration system broken down by components

1.5 Costs

The costs for the MINERνA coil are based on the MINOS near detector design in most details.

Coil	$95,902.59	130%	$124,673.36

Table 3: Estimated Costs for the coil

No installation estimates.

No figure of the detailed layout. Need something...

Item	FY01 costs	Units	FY06 costs	needed	total
Conductor	\$11.95	$/ft$	\$13.85	1,665.00	\$23,065.18
Fabrication	\$37.74	$/ft$	\$43.75	1,665.00	\$72,837.41

Table 4: Estimated costs for the MINERνA coil and its fabrication