16. Near Detector Siting and Assembly

16.1 Introduction

The NOνA Near Detector will be located underground on the Fermilab site, in a new cavern adjacent to the MINOS access tunnel, downstream of the MINOS shaft. Chapter 4 discusses the rationale and requirements of the Near Detector. The purpose of this chapter is to show where it will be placed, tell how its location was chosen and indicate the details involved in assembling this detector there. Most aspects of the design of the Near Detector – PVC extrusions, modules, planes, blocks, fiber readout – were developed for the Far Detector. They are used for the Near Detector so that it will be as similar as possible to the Far Detector. Other chapters of this TDR go into considerable detail as to the particulars of this design.

Figure 16.1 is a schematic view of the planned detector. There is an active detector part, similar to the Far Detector and broken logically into veto, fiducial and shower containment regions, followed by a steel and liquid scintillator muon catcher. The upstream end, without steel, is held firmly in place by a "bookend."

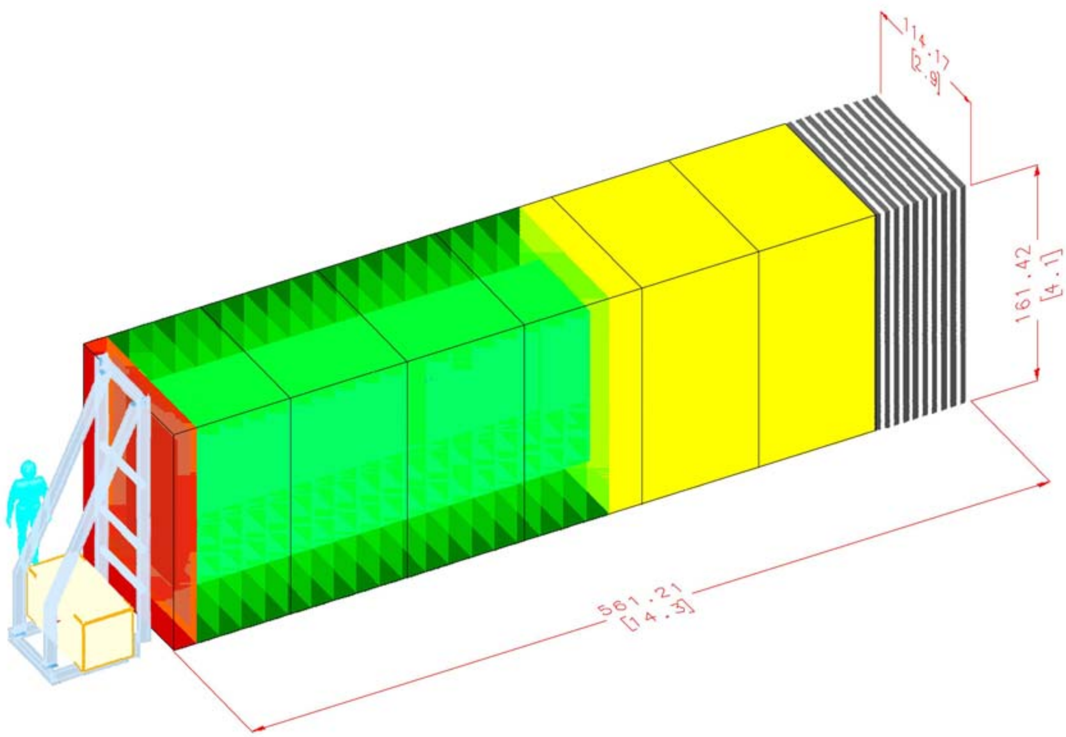


Fig. 16.1: View of the Near Detector indicating its various sections. The veto (red), fiducial (green, with actual fiducial volume highlighted) and shower containment (yellow) regions represent only a logical breakdown; all are constructed in the same manner, with six physical blocks indicated. The muon catcher region is ten planes of 0.1 m thick steel each with a plane of liquid scintillator attached (four planes in the most downstream case). The upstream bookend provides support and holds the detector in place.

16.2 The Near Detector Site

16.2.1 Technical Siting Criteria

The plan view shown in Figure 16.2, upper pane, indicates the path of the NuMI access tunnel from the MINOS shaft downstream to the MINOS near detector. It is seen that this location is appropriate for the placement of an off-axis detector, and calculations show that the off-axis angle of the Far Detector can be matched by that of a Near Detector in this region. However, seen from an off-axis position so close longitudinally to the decay region, the neutrinos come from a line source, unlike the effective point source of the Far Detector. The decision has been made to have the correct off-axis angle for the part of the decay region from which comes the highest flux of muon neutrinos. Note that this decision is not a trivial one. In particular the electron neutrinos come from a different part of the decay region and thus have an effectively different off-axis angle. The detector axis is similarly aligned so that the neutrinos at the appropriate off axis angle enter perpendicular to the face. Given the angle of the tunnel, it is not possible to achieve this condition without some excavation. Earlier attempts to design a smaller excavation, with most of the detector angled across the tunnel, met with serious logistical problems and were supplanted.

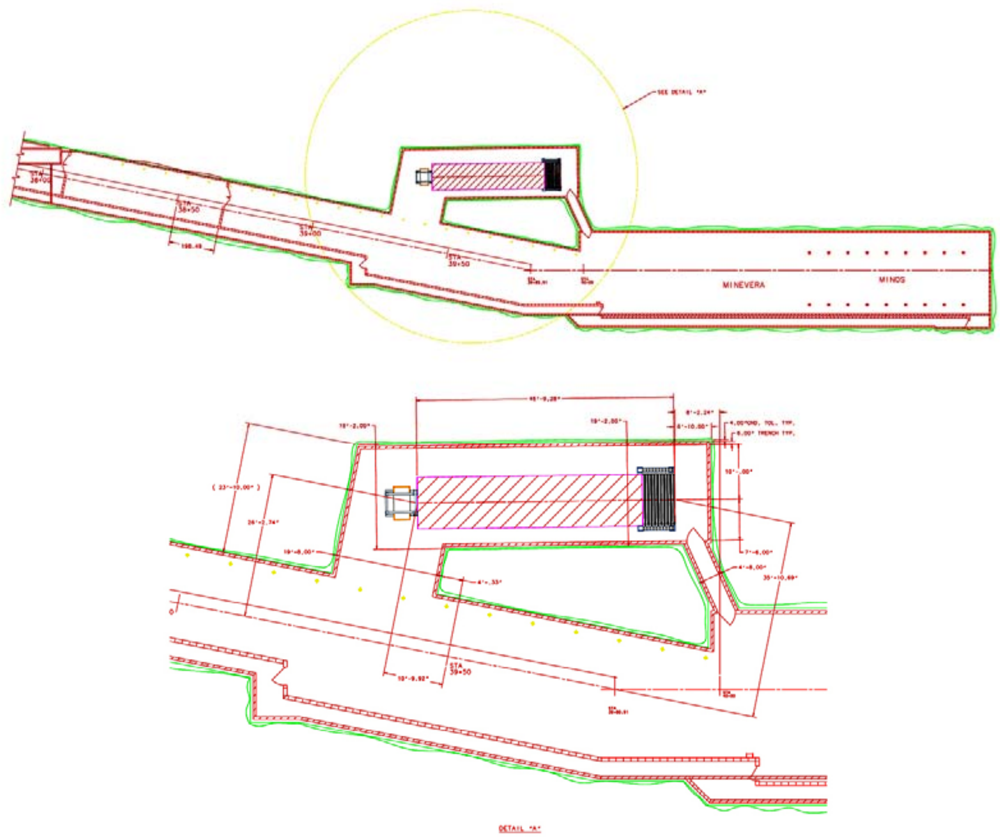


Fig. 16.2: Plan view of the downstream MINOS access tunnel with the NOνA Near Detector indicated. The top pane shows the tunnel from the shaft area at the left to the MINOS near detector at the right. The lower pane is an expanded view of the new cavern to be excavated. The green highlighting indicates the rock surfaces after the excavation is complete. The passageway below and to the right of the detector is a required safety egress from the cavern. North is to the right in this figure.

As is noted in Figure 16.2, the cavern is constructed so that the lower (east) wall is quite close to the detector. All horizontal modules of the detector will have readouts on the opposite (west) side, and sufficient clearance is provided there for installation and maintenance. Similarly all vertical planes will have their module snouts facing west. This orientation, as opposed to the opposite, is chosen so that the detector can be placed as required by the physics while maximizing the size of the rock pillar between the existing tunnel and the new cavern. A preliminary opinion of Fermilab's underground construction expert is that this excavation is safe and constructible for the cost quoted. A more detailed discussion of the excavation process is given in [1].

The detector requires a certain amount of infrastructure. In particular the readout electronics will require two standard relay racks and the cooling system will require a water facility 8 feet long by 4 feet wide by 8 feet high. These fit easily in the access tunnel upstream and downstream of the new cavern. If more power is required it can easily be supplied through the shaft area. If water is required it can be taken from the nearby sump, as is done for MINOS.

16.2.2 MINOS Shaft Area

Shown in Figure 16.3 is one view of the MINOS access shaft indicating how the MINOS near detector segments were brought underground. Figure 16.4 is a plan view of the shaft cross section showing a NOvA Near Detector block similarly being lowered. A 31 plane block in its transport cradle (see below) is seen to fit in the open shaft area even when the space occupied by tunnel infrastructure is taken into account. The steel for the muon catcher will be lowered in a manner similar to the MINOS planes, in particular one plane at a time.

Fig. 16.3: View from the bottom of the vertical D-shaped MINOS shaft as a MINOS near detector plane comes down the shaft. The MINOS module shown is ~4.5 m wide by ~3.5 m high by ~0.2 m thick (including the red strong-back frame).

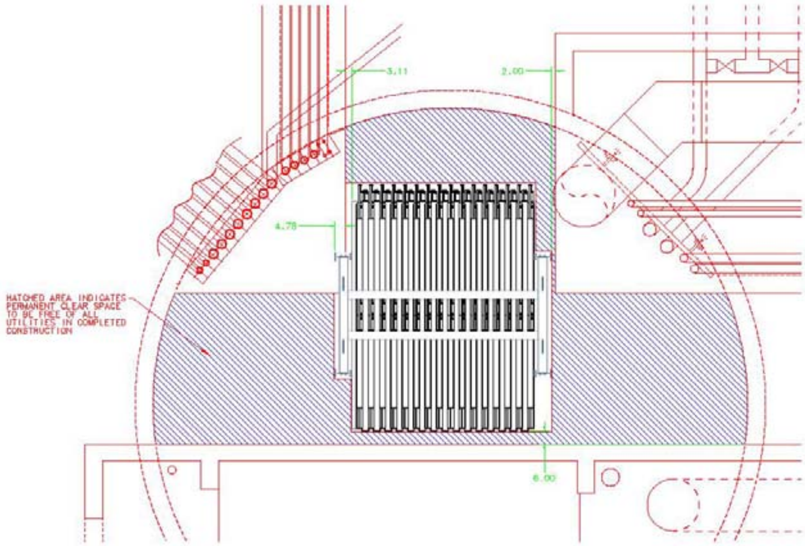


Fig. 16.4: Plan view of the MINOS shaft indicating the space occupied by a 31 plane NOνA Near Detector block.

16.2.3 Design Changes in the Near Detector Site since the CDR

In the CDR a large region of the tunnel was considered appropriate for the detector. It was also being actively considered that the Near Detector would be moved to different areas to see neutrinos of different energies. There was no excavation. It is now considered that since the decay region of NuMI is a line source as seen from the Near Detector, neutrinos of a range of energies and angles are all seen at any single location. Also, in the CDR the neutrinos did not enter the detector normal to its face, leading to a serious difference between Near and Far Detectors.

16.2.4 Work Remaining to Complete the Near Detector Site Design

A consulting engineer will be employed to study the rock properties in and near the proposed cavern location. Minor location changes which do not compromise the ND physics potential can still be considered.

16.3 Near Detector Design

16.3.1 Technical Design Criteria for the Near Detector

The physical design of the Near Detector is constrained by three requirements. The first is that it should be as similar as possible to the Far Detector in material and segmentation. This requirement ensures that the Near and Far efficiencies for signal and background events are essentially the same. Ideally, this will allow us to understand both the ν_e charged current and the ν neutral current beam spectra seen in the Near Detector as a measure of the expected backgrounds to $\nu_\mu \rightarrow \nu_e$ oscillation signals in the Far Detector. In practice there are three unavoidable differences. The first is that the Near Detector sees the decay region as a line source as was noted above. The second is that the Near Detector is smaller and thus has wavelength shifting fibers much shorter than those in the Far Detector. The third is that there are multiple events per NuMI spill so that the electronics must be different (this is discussed in Chapter 14, Section 13.8).

The second requirement is that there must be a fiducial volume of order 20 tons, which sets a minimum size, while the third is that the pieces from which the detector is constructed must fit down the MINOS access shaft. This last sets a practical maximum size for the detector transverse dimension and is shown to be satisfied as is seen above.

16.3.2 Near Detector Overview

The Near Detector uses the same technology as the NOνA Far Detector and satisfies the space constraints described above. It is 2.8 m wide, 4.1 m high and 14.5 m long. The first 12.5 meters is composed of similar extrusion cells to those in the Far Detector. The transverse size is of course scaled down from that of the Far Detector, but the longitudinal and transverse segmentations are the same as in that case. As noted, the detector is split into four logical parts: an upstream veto region, a fiducial event region, a shower containment region and the steel/scintillator muon catcher as is shown in Figure 16.1. The 4.85 m long shower containment length is chosen to fully contain electron showers from charged current ν_e interactions of a few GeV. The active detector sections are followed by a muon catcher composed of 1.0 meters of steel interspersed with ten planes of liquid scintillator cells (with three extra planes at the downstream end). There are ten steel plates each 4.1 x 2.9 x 0.1 m^3 with a mass of 8.2 metric tons. The length of the muon catcher is chosen so that it plus the shower containment region will stop muons from few GeV charged current ν_μ interactions. The parameters of the detector are summarized in Table 16.1 and presented in more detail in [2].

Parameter	ParameterValue
Total mass	215 metric tons
Active detector mass	125 metric tons
Extrusion cells, liquid scintillator, waveshifting fiber, APD readout	Identical to the NOνA Far Detector except for size
Number of channels	15,904
Total Liquid Scintillator	29,616 gallons
Detector PVC width Full width PVC height Full height Length	(3 upstream blocks differ slightly from 3 downstream) 2.553 m, 64 cells and 2.633 m, 64 cells 2.83 m, 2.91 m 3.829 m, 96 cells and 3.949 m, 96 cells 4.11 m, 4.23 m 14.5 m
Total active planes	199 planes, 99 horizontal & 100 vertical
Basic block in the active section # planes, Thickness 31 plane block Empty mass of block Full mass of block	 31 planes 2.09 m A blocks (ups 5.83, dns 6.08) B blocks (ups 5.77, dns 6.02) metric tons ~19.51 metric tons
Veto region, # of active planes	6 planes
Fiducial region, # of active planes Width (m) Height (m)	108 planes 1.17 m (approx 70 cm wide picture frame 2.45 m around fidvol)
Fiducial mass	~20 metric tons
Shower containment region, # of active planes	 72 planes
Muon catcher Steel (m/section, # of sections) # of active planes	 0.1 m, 10 sections 13 planes, 6 vert & 7 hor
Muon catcher mass Steel Scintillator planes	 81.6 metric tons 8.5 metric tons

Table 16.1: Near Detector Parameters

16.3.3 Assembly Process for the Near Detector

Altogether there will be 199 planes of PVC with liquid scintillator, 99 planes with horizontal cells and 100 with vertical cells. The total mass of the detector is 215 tons with 125 tons active. The fiducial mass is ~ 20 tons.

The detector will be constructed in 31 plane blocks for uniformity with the Far Detector. With an odd number of planes per block, there are two possible configurations, called A when the first and last planes are vertical and B when they are horizontal. The block configuration starting from the upstream end is to be ABABAA, mimicking the Far Detector superblock arrangement. The blocks will be constructed at Argonne National Laboratory using a considerably scaled down version of the procedure envisioned for the Far Detector. There will be an assembly table as is seen in Figure 16.5. Blocks are constructed in a horizontal orientation, with successive planes stacked upon each other as is shown in parts (b) and (c) of the figure. The modules are stacked against a steel plate which will become part of the block transporting cradle and eventually the baseplate in the tunnel. The table will have “module stops” attached to one side to assure alignment. The first step for each module is that Devcon adhesive is applied to the top by an appropriate dispenser. Next the module is flipped about its long axis by hand so that the glue side is on the bottom. It is then moved by a vacuum lifting fixture to its designated location in the currently active plane. When a block is completed it is rotated to its final upright position. This

process is much simpler than the corresponding one for the Far Detector. The assembly table is hinged on one end, as seen in Figure 16.5b, and with an empty (of scintillator) weight of only ~5.5 metric tons, the block is easily rotated by a crane.

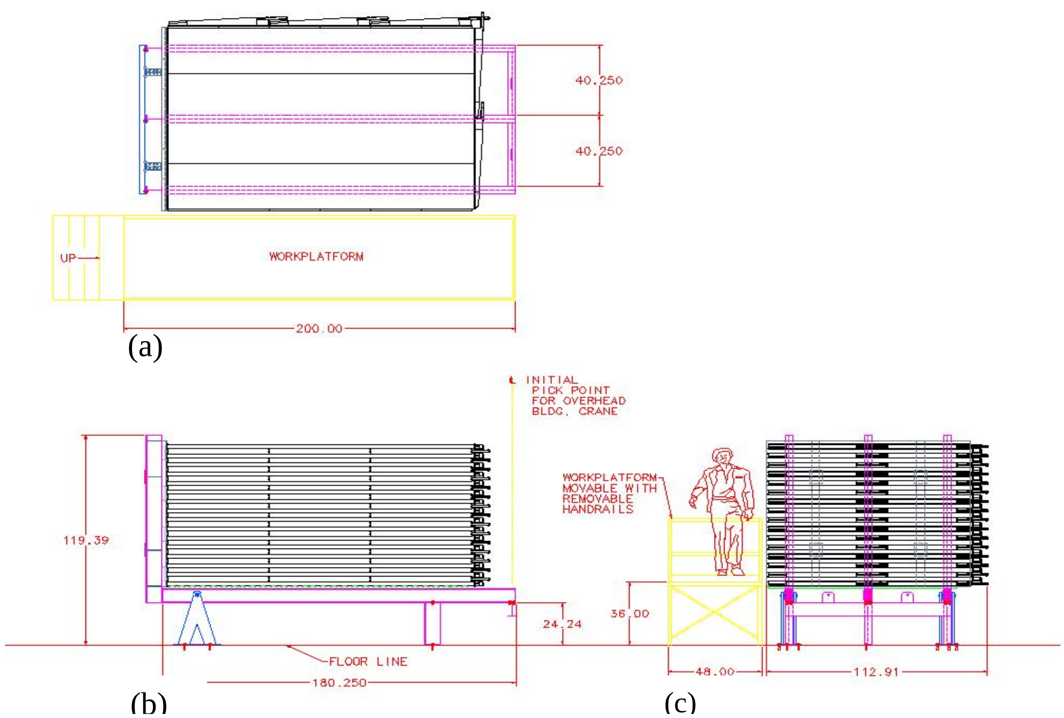
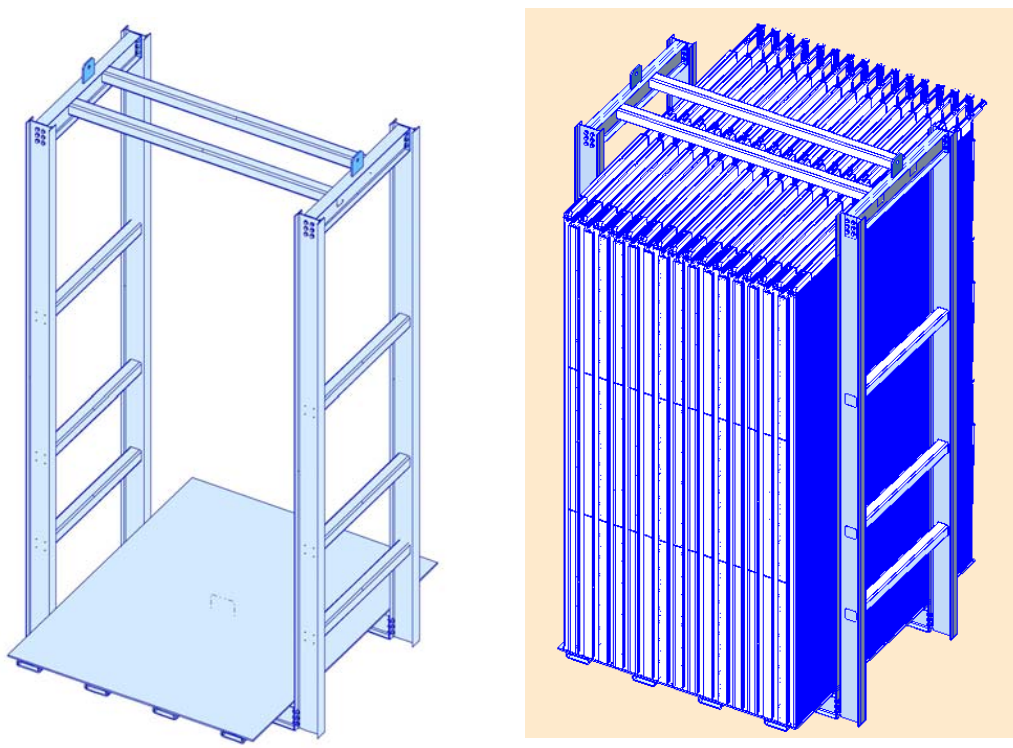


Fig. 16.5. The Near Detector assembly table. Part (a) is a plan view of the table itself. Part (b) is an elevation view of the table holding a completed block. The hinge for rotating the block to upright is seen on the left. Part (c) is a transverse cut of the completed block on the table. The work platform height is adjustable so that the workers move higher as planes are added.

When a block is completed, the remainder of the cradle is constructed around it. Figure 16.6a shows an empty cradle including the baseplate while 16.6b shows a loaded one transporting a block. The cradle is used to transport the block to the Fermilab MINOS Service Building and then to lower it down the MINOS shaft, as was indicated in Figure 16.4. The detector blocks will be on wheels which are part of the cradle assemblies, and will easily be positioned in the ND cavern. As the detector is constructed, the sides and top of the cradle are removed while the bottom, lifted off the wheels, remains. In practice, three of the ND blocks will first be used as part of the IPND in the MINOS service building, and will be drained of scintillator and lowered to the ND cavern when the IPND is decommissioned.

The muon catcher part of the detector resembles MINOS and is assembled similarly. Each active detector plane (4 planes in the most downstream case) will be attached to its corresponding steel plate by several strong clips welded to the plate. The steel planes will in turn be supported "hanging file folder style" from a steel support. The steel will have protrusions on the sides ("ears") by which each is hung from the support structure. A conceptual diagram showing the plates and support structure is shown in Figure 16.7.



(a) (b)

Fig. 16.6: The block moving cradle. In (a) the cradle is empty to show its construction. In (b) it is loaded with a Near Detector block.

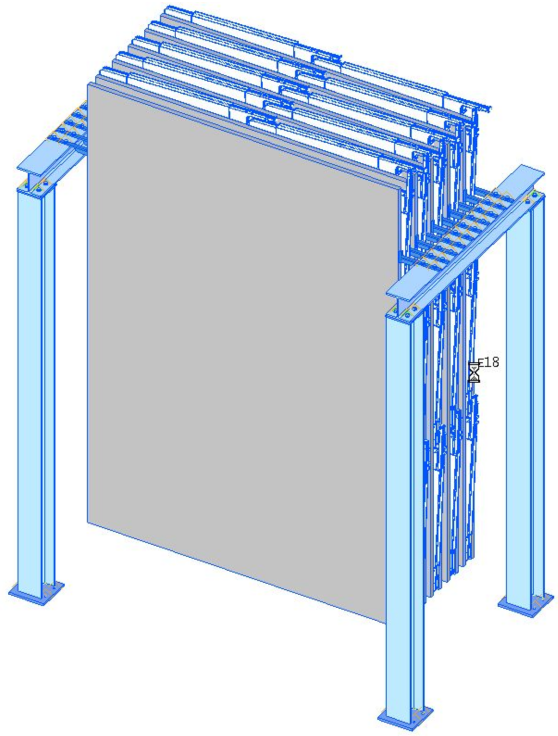


Figure 16.7. Conceptual design of the muon catcher section and its support structure.

16.3.4 Filling the Near Detector with Scintillator

The active detector planes will be filled with scintillator after they are assembled into a detector, i.e. they are empty while being moved. The plan is to fill the planes from a tanker on the surface and fitted with a shrouded pipe the length of the shaft, with a Far Detector like filling system (see Chapter 17) extending to the detector location. A pressure reducing valve will be used to reduce the liquid pressure from the 300' high vertical pipe. An approximately 50 gallon relaxation tank to allow static charge to neutralize will be placed at the bottom. The buildup of static charge in oil pumped through pipes has been determined to be a real problem in NOvA and is discussed in [3]; this relaxation tank provides an extra level of safety in the case of the long vertical drop. A separate pipe will vent pseudocumine vapor to the tanker. Details of the piping are given in [4].

Three precautions will be taken to prevent spilling of liquid scintillator as it travels down the shaft. The first is to protect the vertical pipe with a shroud. The second is to assert that there be no other activity in the shaft while filling is taking place. The purpose is to be sure that the filling pipe is not struck and ruptured. The final precaution is to place a secondary containment device at the bottom of the shaft. This commercial device is called a spill berm and one will similarly be placed under and around the filled detector. This device is similar to a plastic "kiddie pool." The sides form essentially a fence which is made high enough to contain a potential spill of the entire liquid scintillator volume. Beneath the shaft this is the volume of the pipe plus that of one tanker while in the ND cavern this is the entire volume of the detector.

16.3.5 Fire Protection

The liquid scintillator is mildly flammable, and thus the detector in the cavern will need fire suppressant. Flooding the cavern with an oxygen depleted atmosphere is straightforward. The cavern entrance and emergency escape way will have fire doors which will automatically close in case of a blaze.

16.3.6 Changes in the Near Detector Design and Assembly Since the CDR

The CDR contained few details about how the detector would be assembled. However at the time the CDR was prepared it was planned to construct the detector out of seven- and eight-plane segments, rather than 31-plane blocks. The entire detector can now be lowered down the shaft in 16 trips, six for the active blocks and ten for the steel/scintillator planes.

16.3.7 Work Remaining to Complete the Near Detector Design and Assembly Plan

Detailed configuration of the steel planes still needs to be established. The design will be based on the successful MINOS one.

The safeguards in and below the shaft during detector filling need to be worked out.

References

[1] Discussion of the NOvA Near Detector Location and an Alternate Location, V.D. Bogert, NOvA DocDB #1922, May 2007. This is a PowerPoint document; the decision to construct the ND cavern was made as a result of this presentation.
[2] Near Detector Parameters, K. Kephart, NOvA DocDB #1136, May 2007
[3] Liquid Scintillator Handling – Safety, M. Gebhard and J. Musser, NOvA DocDB #1118, November 2006
[4] Near Detector Scintillator Supply Pipe, D. Pushka, NOvA DocDB #2064, May 2007