CHAPTER 5

SERVICE CHIMNEY

5.1 General

The service chimney is the vacuum insulated transfer line that carries the cryogenic and electrical services from the control dewar to the magnet cryostat. The insulating vacuum space of the service chimney serves as the relief line for the solenoid vacuum space, and pumpout of the magnet cryostat and control dewar vacuum spaces is done through the service chimney insulating vacuum space.

5.2 Routing

Figure 5.1 shows the path that the service chimney follows between the control dewar and the magnet cryostat. The pathway is severly constrained by existing detector elements. The chimney connects to a nozzle in the south bulkhead of the magnet cryostat at approximately the 4:00 o'clock location so that it can extend radially to the point at which it bends 90 degrees and proceeds south on a horizontal path.

The nozzle on the magnet cryostat bulkhead is a 152.4 mm (6 in) OD aluminum tube and the service chimney vacuum jacket has an aluminum to stainless transition near the bulkhead. At approximately 76 mm (3 in) south of the bulkhead, the service chimney turns east and makes a shape transition to a 76 mm (3 in) x 177.8 mm (7 in) obround shape for the span across the face of the CC cryostat. The vacuum jacket follows the curving contour of the south face of the CC on a path inclined downward approximately 27 degrees from the horizontal. The obround shape was chosen to fit in the available space between the CC and the south EC cryostats. The vacuum jacket makes a shape transition from the obround shape to a 22.9 cm (9 in) OD stainless steel tube at the outer edge of the EC where it turns and continues south once again. Along this path it runs horizontally through an area currently occupied by the south EC east cable trough. After a run of nearly 9 m (9.5 ft)it next turns eastward and upward at a 50 degree angle to the control dewar.

The chimney enters into the bottom of the control dewar and the vacuum pumping station is connected to the chimney just below the control dewar.

The chimney is supported along the face of the CC and at points along the 45 degree run. The length through the cable trough is kept clear to allow the cable trough to move south with the south EC when the detector is opened.

5.3 Vacuum Jacket

The vacuum jacket for the service chimney is designed for 0.044 MPa (6.4 psi) internal pressure and 0.207 MPa (30 psi) external pressure.

The obround length of the vacuum jacket was stress analyzed per ASME Section VIII Division 1, Appendix 13, "Vessels of Noncircular Cross Section." The wall thickness for the obround is 4.8 mm (3/16 in). The maximum allowable internal or external working pressure was calculated to be 0.36 MPa (52 psi). The allowable stress used was reduced by 20% as required by Fermilab Environment, Safety, & Health rules for special pressure vessels [1]. The obround shape was also checked for buckling stability. It was concluded that the 0.36 MPa external pressure is less than 1/10 of the critical external pressure that would cause collapse.

The 22.9 (9 in) type 304 stainless steel tube has a wall thickness of 3.18 mm (0.125 in). Per ASME code sections UG-27 and UG-28, it has an allowable internal working pressure of 2.48 MPa (360 psi) and an allowable external working pressure of 0.41 MPa (60 psi). The allowable stress used was reduced by 20% to (0.8) x (110 MPa) = 88 MPa.

5.4 Internal Contents

A layout of the internal contents of the service chimney in the obround section is shown in Figure 5.2. A layout of the chimney contents in the more traditional circular cross section for the remainder of the chimney is shown in Figure 5.3.

The first and last turns of the coil consist of doubled conductors which exit the winding and serve as the superconducting buses of the magnet. These buses are immediately attached to one side of the liquid helium supply tubing as it leaves the coil support cylinder. The arrangement of the buses and shape of the supply tubing in the obround section of the chimney was carefully chosen to minimize the thickness of the service chimney between the CC and EC calorimeters. The liquid helium supply tube is specially extruded for pressure service per ASTM-B-210 or ASTM-B-241. The tube in the obround portion is rectangular, 12.7 mm (0.50 in) x 31.8 mm (1.25 in) x 3.18 mm (0.125 in) wall. In the larger circular pipe portion of the transfer line, the tube is square, 31.8 mm (1.25 in) x 31.8 mm (1.25 in) with 19 mm (0.75 in) inside diameter. The MAWP of this tubing is estimated to be at least 11 MPa (1600 psi).

The two phase liquid helium return tubing is 19 mm (0.75 in) OD. x 1.65 mm (0.065 in) wall 6061-T6 aluminum. The MAWP for this tubing is 9.65 MPa (1400 psi). A 55 MPa (8.0 ksi) allowable stress was used in calculating the MAWP's.

There are separate liquid nitrogen circuits for the solenoid radiation shield and support intercepts. The shield circuit uses 12.7 mm (0.50 in) OD. x 1.65 mm (0.065 in) wall 6061-T6 aluminum tubing in the chimney. The support intercept circuit is of the same size but of 304 stainless steel material. These tubes have MAWP's of greater than 13.8 MPa (2000 psi).

All four nitrogen tubes are thermally connected to the radiation shield.

The chimney contains no instrumentation or voltage tap wires. The voltage tap leads from the magnet terminals exit the bulkhead on the chimney end near the chimney nozzle. The leads run along the outside of the chimney vacuum jacket back to the control dewar area. An instrumentation port is located on the solenoid bulkhead opposite the chimney end for the remaining solenoid voltage tap and instrumentation leads.

5.5 Thermal Movement and Stress

The LHe and LN2 lines in the service chimney were analyzed for combined pressure, thermal movement, and dead weight. The tubing was stress analyzed per ASME code for Pressure Piping, standard ANSI/ASME B31.3, for the thermal cases shown in Table 5.1.

The commercial pipe stress analysis and design system by Algor© [2] was used in the analysis. All stresses are well below code allowables. The locations for support of the LN2 tubing from the vacuum jacket walls are shown in Figure 5.4. Supports for the liquid helium lines are located as shown in Figure 5.5. The radial supports are of G-10 spider type guides that allow movement in the axial direction. The spider type supports are 1/8 in thick as required to support a maximum reaction force of 290 N (65 lbf) in the direction orthogonal to the piping centerline. In addition to the spiders, line stops are located at points HE7b and TR7a to anchor axial movement of the tubing. The line stops are low heat leak design stainless steel wire cables which attach the helium tubing to the radiation shield and the nitrogen tubing to the vacuum walls.

The construction of the chimney is such that the LHe and LN2 lines are built with warm offsets at various locations so that the tubing can displace to a centered position during cryogenic operation. See Table 5.2 for a listing of the magnitude and locations of the built-in warm offsets. The LHe piping and LN2 piping have built in flexibility at the control dewar to allow for 2.0 cm (0.8 inches) of movement. Clearances are selected to be large enough to preclude thermal shorts due to thermal movement.

5.6 Fabrication and Location of Field Break

Because of the greatly restricted pathway of the obround portion of the service chimney great care must be taken to ensure that this portion of the vacuum jacket of the chimney will fit against the CC vacuum vessel correctly. Detailed measurements of the shape of the end of the CC vacuum vessel have been made so that a vendor can properly conform the vacuum jacket to the desired path. A checking fixture will be made using a casting technique on the actual CC head; this item will be used to check the contour of the obround section at the vendor's.

A field break must be provided in the service chimney in the middle of the horizontal north-south section as shown in Figure 5.1, so that the control dewar and remaining attached length of chimney can be installed in the detector. Likewise, the magnet cryostat and attached portion of chimney can be installed in CC if the chimney is parted as indicated. This parting of the chimney also facilitates shipping the system to Fermilab.

The major consequence of this requirement is that provisions for cutting and then rejoining the superconducting buses in the chimney must be made. The chimney is temporarily closed out for full tests at the vendor's. Then the chimney is severed for shipping and once again rejoined after the magnet and control dewar are installed in the DØ detector. One approach might be to make the horizontal portion of the chimney overlong so that after the chimney is parted sufficient extra bus exists to make the field joint during installation.

Because alignment of the solenoid in CC is critical, some flexibility in the nozzle region of the chimney is desirable. A circumferential seam in the obround section near the nozzle may be left unwelded to permit small motions during final alignment as the magnet and chimney are installed. The inner contents of the chimney are sufficiently flexible to permit this motion. This seam can be temporarily sealed for the tests at the vendor's and the chimney splinted to permit handling, and then fully welded after installation at Fermilab. Because the location of the control dewar is not so critical it can be adjusted a few centimeters as required while the field splice is made and no flexibility is required in the chimney at the control dewar end.

5.7 Heat Loads

The estimated heat loads for the chimney are listed in Table 5.3.

5.8 Vacuum Pumping and Relief Capacity

The chimney uses low emissivity aluminum tape [3] on the inside surfaces of the vacuum jacket, the surfaces of the radiation shield, and the LHe tubing. No multilayer insulation is used in the chimney in order to maximize the pumping path to the magnet cryostat vacuum space. Calculations show that the conductance of this space along the length of the chimney exceeds 11 l/s helium at 300K at a pressure of 10^{-6} Torr. The small clearances between the radiation shield and the liquid helium tubes preclude the use of multilayer insulation in that volume.

The clear space in the chimney also serves as the magnet cryostat insulating vacuum relief venting path. With 0.122 MPa (17.7 psia) pressure at the solenoid and a 0.112 MPa (16.2 psia) vacuum lift plate at the control dewar, the relief venting path has 130 g/s helium or 300 g/s nitrogen capacity. That is well below possible failure mode flow rates for the two piping systems so rupture of either will not exceed the relieving capacity of the chimney.

5.9 Magnet Cryostat Nozzle

The routing of the cryogenic lines and superconducting buses from the chimney into the magnet cryostat through the cryostat nozzle is not expected to be trivial. The superconducting buses must be carefully anchored against motion in the magnetic field and must be everywhere thermally shorted to the helium supply tube while carefully isolated from it electrically. Custom transition pieces for the helium supply tubing are likely to be utilized in the nozzle region. A possible solution to the design problems this section of the chimney presents is indicated in Figures 5.6a, 5.6b, and 5.6c.

References

[1] It is conservative to follow Chapter 5031A of the Fermilab ES&H Manual, which permits the use of a vessel fabricated in a shop that is not a Code Shop, provided the vessel is designed according to the ASME Boiler and Pressure Vessel Code rules, but where the Code allowable values of the maximum stress S (Div 1.), or stress intensity S_m (Div. 2), are reduced by the multiplicative factor 0.8.

[2] Algor, Inc., 150 Beta Drive, Pittsburgh, PA 15238-2932.

[3] E.M.W. Leung, *et. al*, "Techniques for Reducing Radiation Heat Transfer Between 77 and 4.2 K", Advances in Cryogenic Engineering, **Vol. 25**, Plenum Press, New York (1980), p. 489.

Table 5.1: Stress Analysis Thermal Cases			
Case	LN2 Line	LHe Line	Solenoid
1	Warm	Cold	Warm
2	Warm	Cold	Cold
3	Warm	Warm	Cold
4	Cold	Cold	Cold
5	Cold	Cold	Warm
6	Cold	Warm	Cold
7	Cold	Warm	Warm
8	Warm	Warm	Warm

Table 5.2: Built-In Offsets For Thermal Movement			
Location	"X" Offset	"Y" Offset	"Z" Offset
TR6	+0.97 cm		
TR7	-0.90 cm		+0.74 cm
HE6	+0.97 cm		
HE7	-0.90 cm		+0.74 cm

Table 5.3: Heat Loads for the Chimney		
Item	300 K to 80 K	80 K to 5 K
Radiation, Obround Section	13.6 W	123 mW
Radiation, Circular Section	86.4 W	780 mW
Field Joints	-	100 mW
Conduction (Spiders)	7.6 W	440 mW
Total	108 W	1.5 W

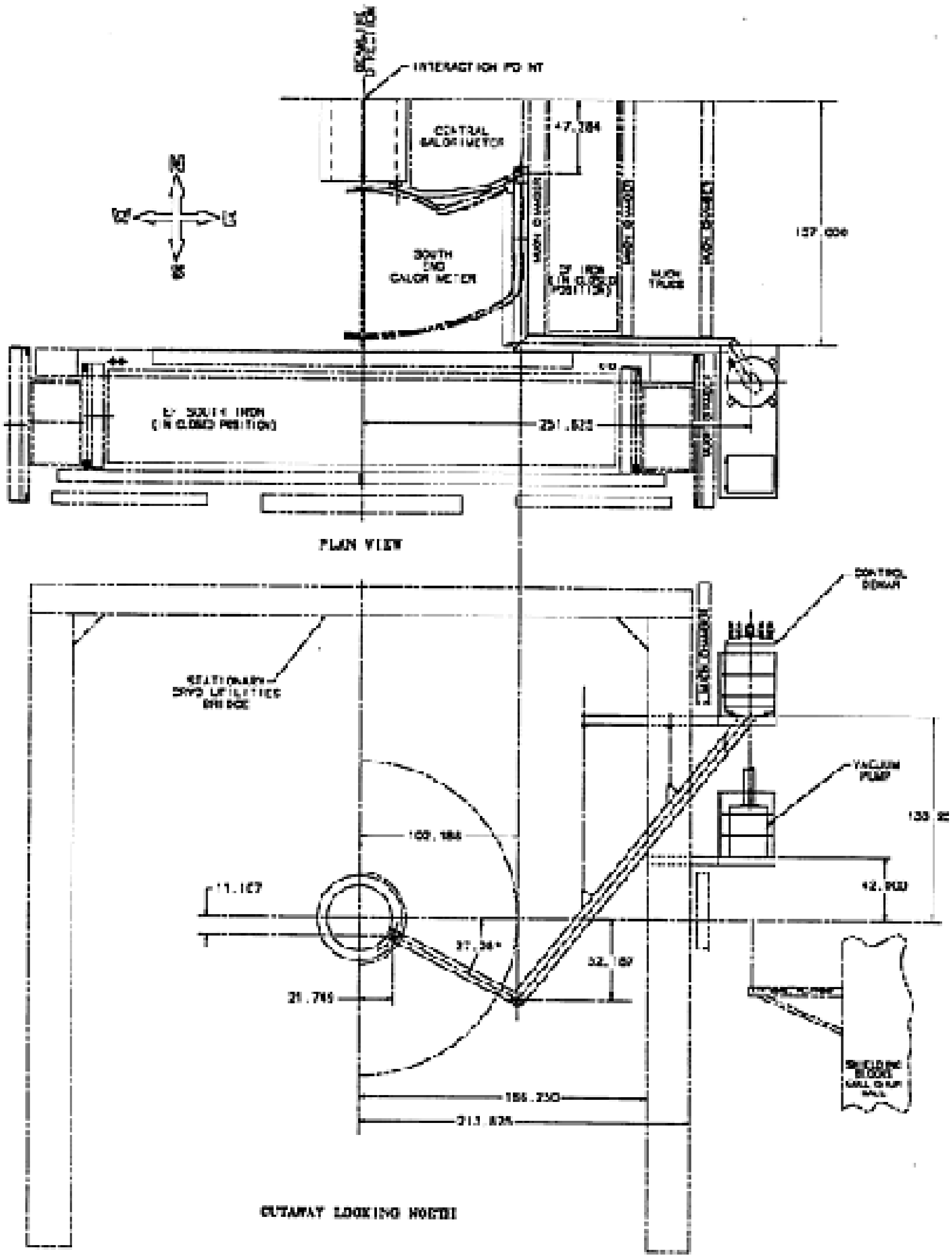

Figure 5.1 Chimney Routing

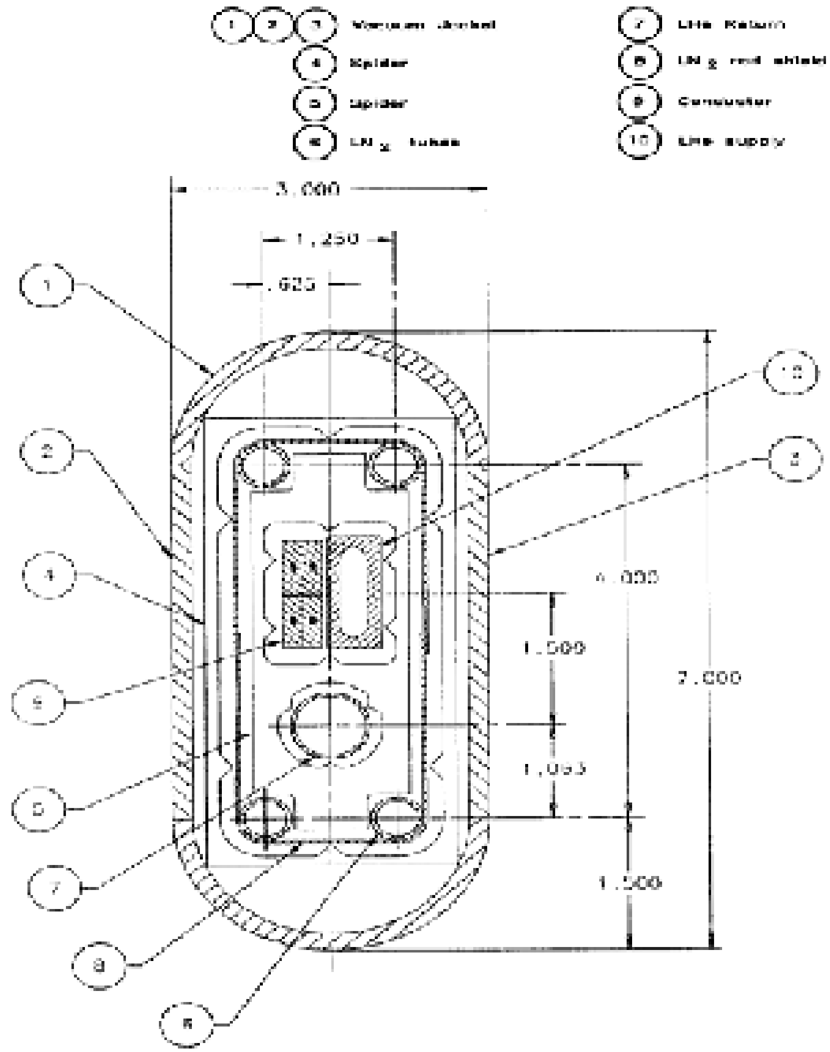

Figure 5.2 Obround chimney layout

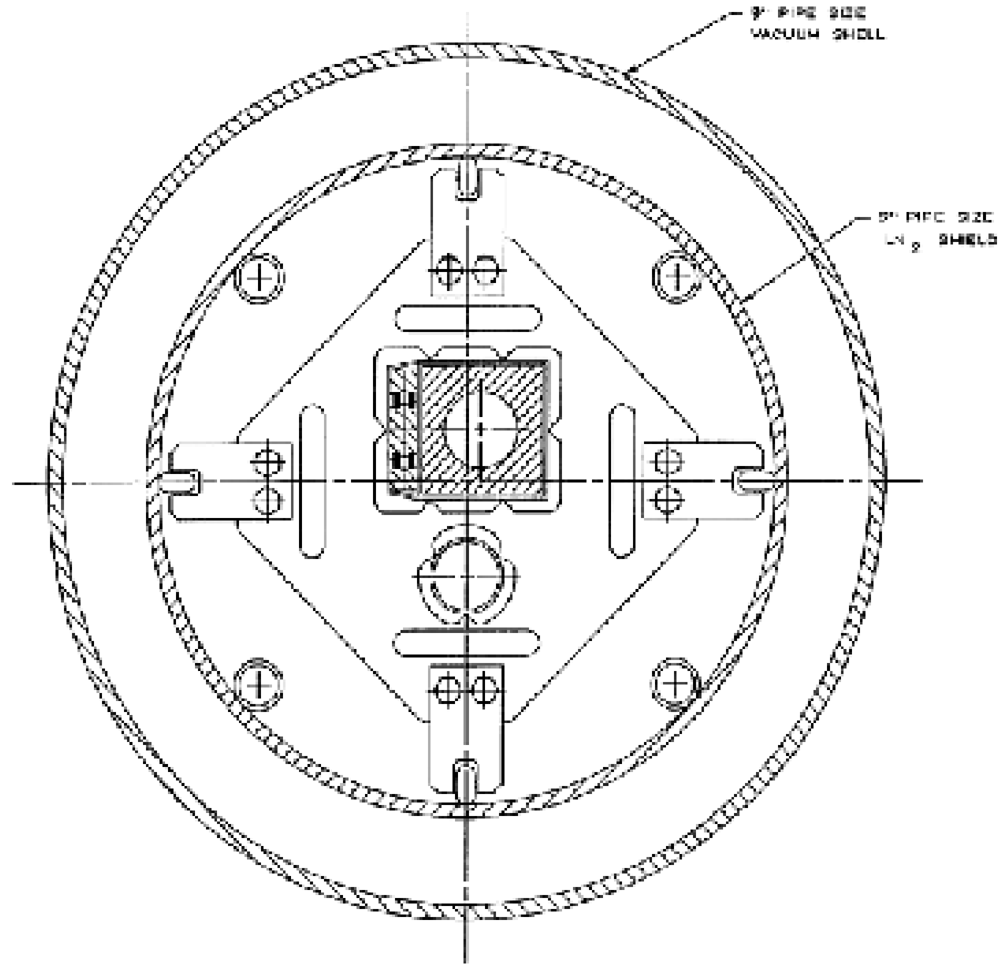

Figure 5.3 Circular chimney layout

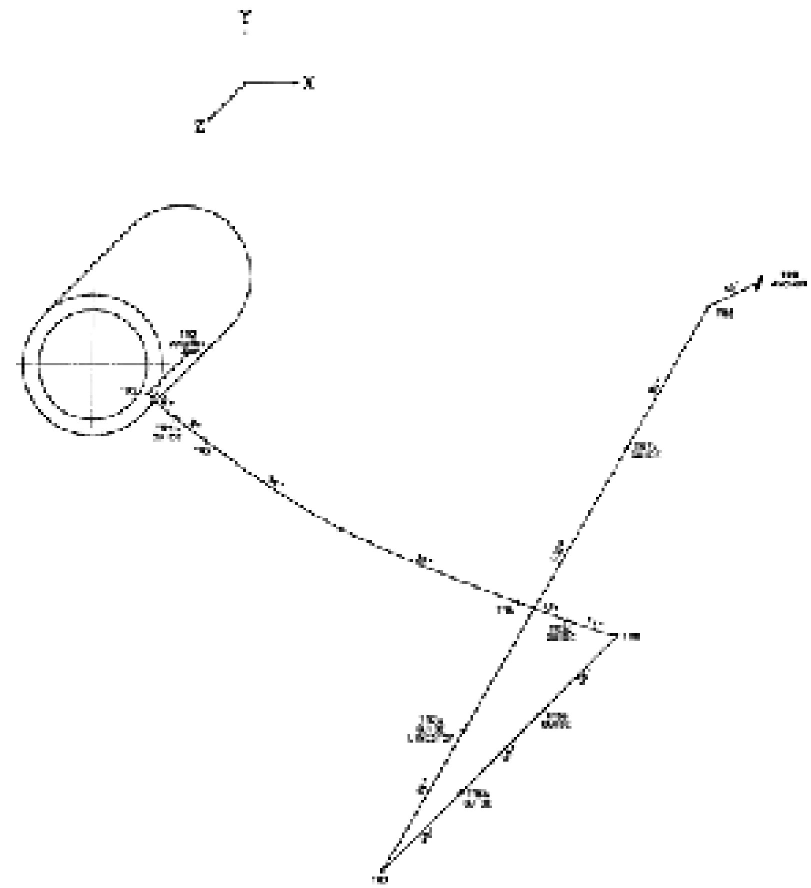

Figure 5.4
Support locations for LN2 tubing

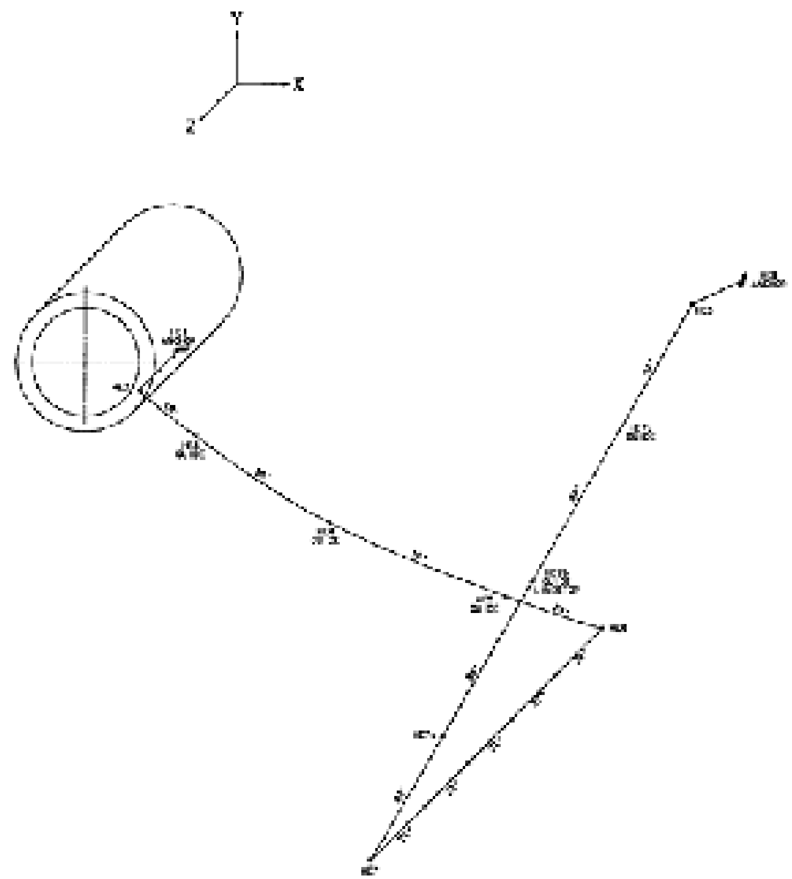

Figure 5.5
Support locations for LHe tubing

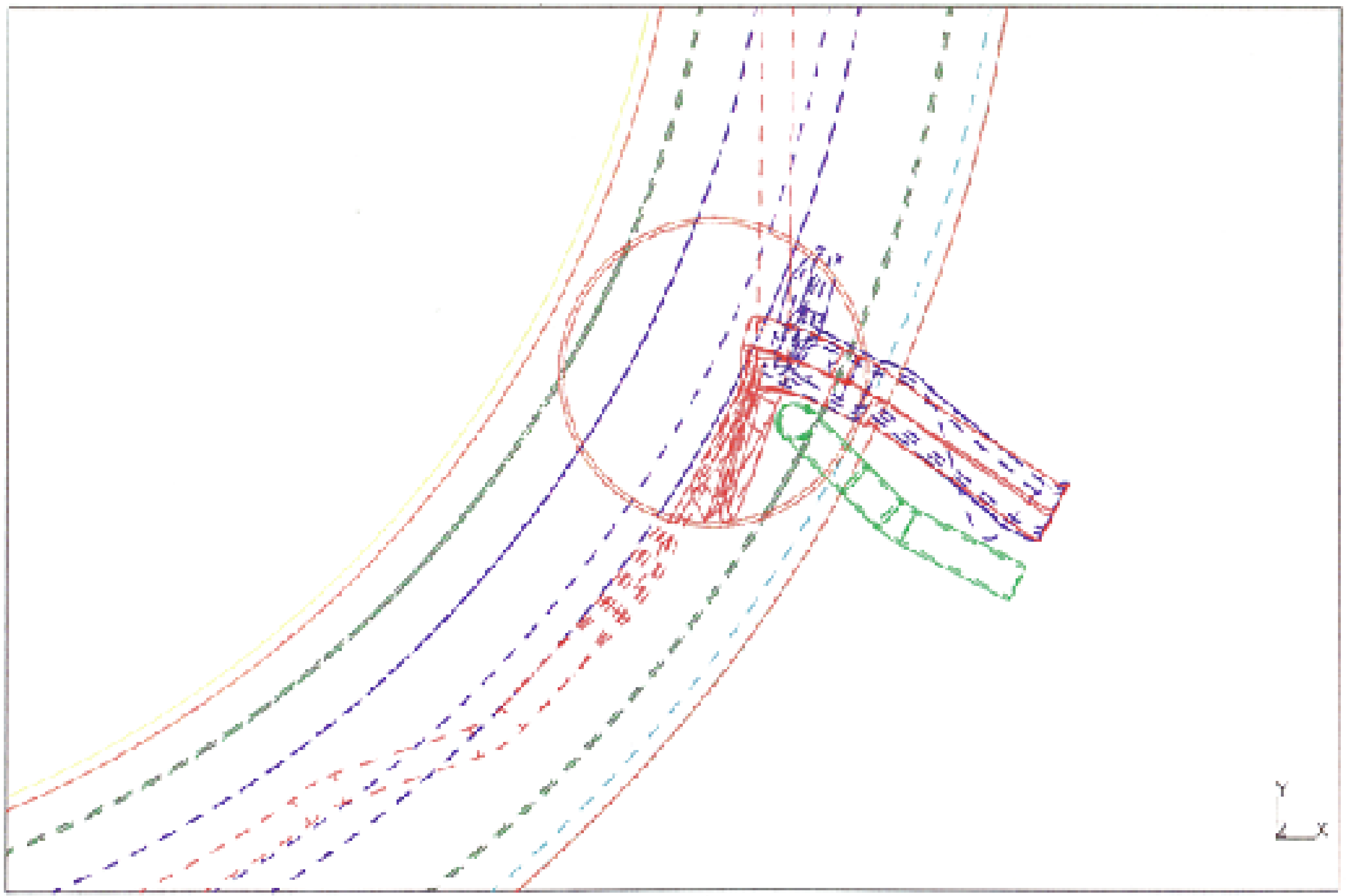

Figure 5.6a Magnet Cryostat Nozzle Detail

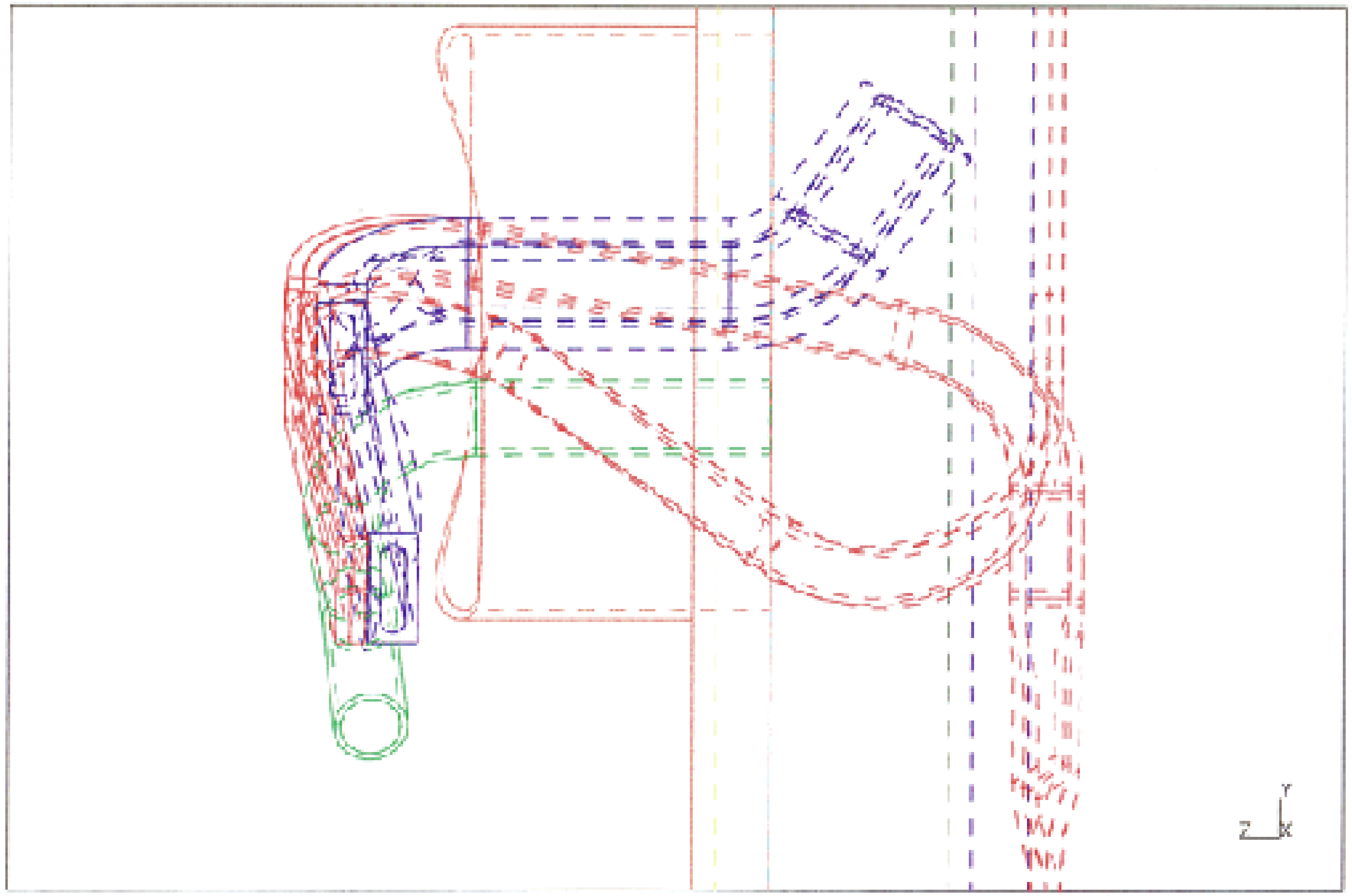

Figure 5.6b Magnet Cryostat Nozzle Detail

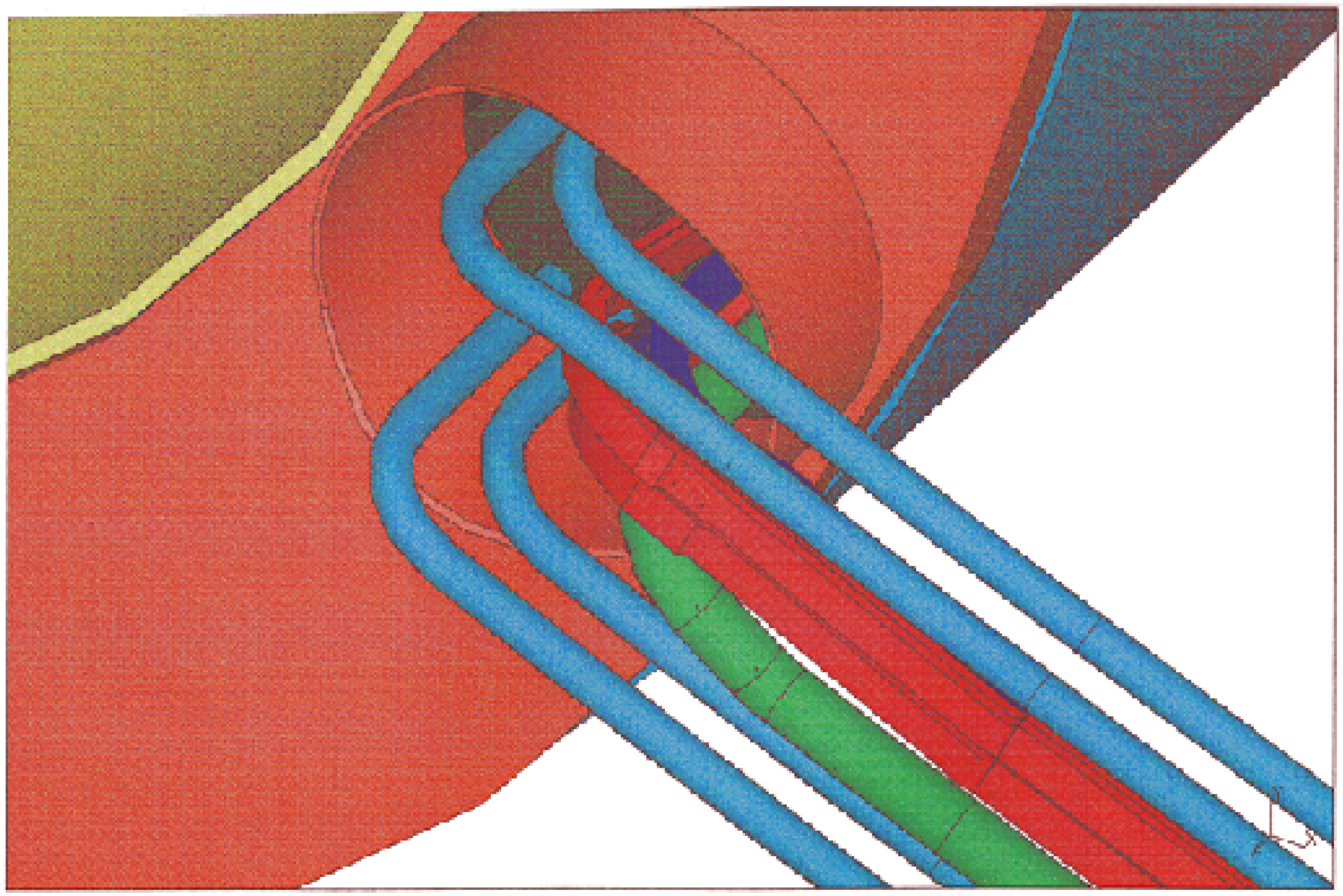

Figure 5.6c Magnet Cryostat Nozzle Detail