CHAPTER 6

CONTROL DEWAR

6.1 General

The control dewar is the interface between the permanently installed building piping and the moveable detector. It has bayonet connections for cryogenic lines and contains the vapor-cooled current leads. It also contains a liquid helium reservoir, a LHe supply line subcooler, a LHe supply J-T valve and other required valving and instrumentation. Instrumentation required in the control dewar is detailed in Chapter 9. The control dewar is physically 0.81 m (32 in) in diameter and approximately 1.5 m (60 in) tall. It weighs about 450 kg (1000 lbs).

A schematic of the control dewar is shown in Figure 6.1. The penetrations in the control dewar are tabulated in Table 6.1. A layout of the top head of the control dewar is shown in Figure 6.2, and the configuration of key internal components is shown in Figure 6.3.

There are no penetrations through the shell portion of the vacuum vessel. This feature permits straightforward assembly of the internal components of the dewar with final closeout obtained by sliding the vacuum shell over the two torospherical heads and joining it to them with single fillet lap welds. Struts can maintain the spacing of the heads before the shell is installed. This design feature also permits access to the internal contents of the control dewar in the event a repair is required, by removal of the fillet weld which joins the heads and the shell and lifting the shell vertically off. The liquid nitrogen cooled radiation shield is constructed with joints that allow it to be removed after making cuts in the liquid nitrogen tubing.

The location for all but one of the aluminum to stainless steel material transition joints in the cryogenic lines in the service chimney is located just below the control dewar. The chimney vacuum jacket has a sleeve that will be slid up and welded once the joints are complete. Table 6.2 lists the locations of the material and shape transitions for the control dewar and chimney cryogenic lines.

6.2 Mounting and Access

The control dewar is located outside the detector, mounted on an access platform to be attached to the existing detector cryo utilities bridge at an elevation corresponding to the top access level of the muon truss. Access to the control dewar platform is made by ladder from the detector platform below it during normal operations when the CF toroid is closed. When the CF toroid is open, limited access is possible from the muon truss as well. Appropriate safety hand rails and kick plates are provided on the control dewar platform.

An additional platform will be located below the control dewar platform. This lower platform allows access to the penetrations on the bottom of the control dewar and it provides a location for the vacuum pump and other vacuum system components of the magnet system.

6.3 Vacuum Jacket

The vacuum jacket of the control dewar is common to both the chimney and solenoid. It is designed per ASME code for 0.044 MPa (6.4 psi) internal pressure and 0.207 MPa (30 psi) external pressure. The chosen wall thickness of the shell is 4.76mm (0.1875 in).

6.4 Vapor Cooled Current Leads

The vapor cooled leads must carry the full design operating current of the magnet stably at all times. In addition, they must be designed for safe operation without cooling gas flow for at least the full slow discharge time constant of the magnet (approximately 300 seconds) in the event that cooling flow is lost while the magnet is energized. Typically, extra copper beyond that needed for the normal self-sufficient operation of the leads is added to cross section of the body of the lead to achieve this specification. Often extra cooling flow is also provided beyond the minimum required by the self-sufficient condition.

For design purposes a commercial vapor cooled lead rated at 6 kA [1] is selected. Typical commercial lead pairs of this size have a manufacturer's listed helium consumption of 19.2 liters/hr. From experience with these types of leads more stable operation is achieved at an increased cold gas flow. The chosen flow rate for design is for 28.8 liters/hr (1 g/s). The leads are 38.1 mm (1.50 in) in diameter and are electrically insulated by a G-10 tube. This G-10 tube extends through the reservoir down over the connection between the lead and the superconducting bus from the magnet. A stainless steel tube seals each G-10 tube sleeved lead from the top vacuum vessel head to the top of the liquid helium reservoir. A purge box or heater can be provided to prevent the accumulation of water or water ice on the warm ends of the leads. The instrumentation required for the vapor cooled leads is described in Chapter 9.

6.5 Liquid Helium Reservoir

A stainless steel liquid helium reservoir is located in the center of the control dewar. It is constructed using 30.5 cm (12 in) schedule 10S pipe with torospherical heads. It is 32.4 cm (12.75 in) diameter and 60 cm (23.5 in) long. The maximum allowable working pressure of the reservoir is 1.03 MPa (150 psi).

During normal steady state conditions, it contains 32 liters of liquid helium and has an ullage space of 6 liters. The helium inventory of the subcooler reservoir is more than sufficient to provide cooling for the vapor cooled leads during the slow discharge of the magnet in the event of upset to the supply of helium to the control dewar. The superconducting buses for the magnet extend into the reservoir where they are cooled to superconducting temperatures just below the point where they attach to the bottoms of the vapor cooled leads. The reservoir liquid inventory is supplied by the return flow from the solenoid. The operating pressure of the control dewar is maintained as low as operationally possible relative to the refrigerator (approximately 0.132 MPa (19.1 psia)) resulting in a 4.51 Kelvin liquid bath in the reservoir.

The return flow from the solenoid enters near the bottom of the reservoir shell. The flow is diverted upward through an annulus where it flows over the coils of the subcooler. The 25.4 cm (10.0 in) diameter tube that is the inner wall of the annulus is attached to the bottom head of the reservoir and stops several centimeters below the steady state liquid helium level. Two phase return flow exits at the top of the reservoir where it returns to the refrigerator.

The subcooler is constructed of 12.7 mm (0.50 in) copper tubing with 25.4 mm (1.0 in) diameter fins. It has ten and half spirals at a 289 mm (11.375 in) centerline diameter to provide 9.5 m (31 feet) of tubing length. The liquid helium from the refrigerator to the control dewar is already subcooled due to the design of the transfer line. Any heat leak picked up through the bayonet connections is removed by the reservoir subcooler. The liquid helium supply for the solenoid enters the subcooler spiral at the bottom of the reservoir. It exits near the top of the reservoir about 2.5 cm (1.0 in) below the top of the annulus tube. The supply is then expanded through a Joule-Thompson valve and is thermally connected to the conductors at the bottom of the control dewar.

A secondary vacuum container is attached to the bottom of the reservoir. The magnet superconducting buses pass through insulating feed-throughs inside this vacuum space. The secondary vacuum container is provided to guard against potential leaks in the insulating feed-throughs.

6.6 Heat Loads

The control dewar has multilayer superinsulation in the insulating vacuum space. All the helium temperature components are surrounded by a liquid nitrogen traced radiation shield. The estimated heat loads for the control dewar are listed in Table 6.3.

6.7 Loss of Vacuum

For the helium reservoir in the control dewar, relief sizing calculations show that a heat load of 6.7 kW will be experienced for a total loss of vacuum with air condensation. The "fire condition" imposed by CGA S-1.3 [2] is not as severe as the loss of vacuum condition. For loss of vacuum a relief set at 1.03 MPa (150 psi) with a flow rate of 130 SCFM air will safely protect the helium reservoir against loss of vacuum.

References

[1] American Magnetics Inc., PO Box 2509, 112 Flint Road, Oak Ridge, Tenn 37830

[2] CGA S-1.3 Pressure Relief Device Standards, Compressed Gas Storage Containers, Compressed Gas Association, 1235 Jefferson Davis Hwy, Arlington, Va., 22202.

Table 6.1: Control Dewar Penetrations	
Top Head	
Bayonets	LHe supply He return: steady state He return: cool down/recovery LN2 supply (2) LN2 return (2)
Penetrations	Vapor Cooled Leads (2) JT valve Operator Reservoir Isolation Valve Op. Cool Down Valve Operator LHe Reservoir Relief Quench Relief (2)
Bottom Head	
Penetrations	LN2 Trapped Vol. Relief (2) JT Valve Trapped Vol. Relief Secondary Vacuum Pumpout Main Vacuum Relief Device Chimney Inlet (near center) Instrumentation Connectors Instrumentation Tubing

Table 6.2: Chimney Piping Transition Locations

Pipe Section	Material in Solenoid	Material in Chimney	Material in Dewar	Location of Transition
1Φ He Supply	6061-T6 Al	6061-T6 AL	304 SST	In Dewar
2Φ He Return	6061-T6 Al	6061-T6 AL	304 SST	Below Dewar
Shield LN2	6061-T6 Al	6061-T6 AL	304 SST	Below Dewar
Intercepts LN2	304 SST	304 SST	304 SST	None
Chimney Jacket	Aluminum	304 SST	304 SST	In Solenoid Nozzle
Pipe Section	**Shape in Solenoid**	**Shape in Chimney**	**Shape in Dewar**	**Location of Shape Transition**
1Φ He Supply	Round	Rect. or Sq.	Square	At Support Cyl.
2Φ He Return	Round	Round	Round	None
Shield LN2	Round	Round	Round	None
Intercepts LN2	Round	Round	Round	None
Chimney Jacket	Round 6 in OD at nozzle	Obround 3x7in & Round 9 in	Round	See Fig 5.1

Table 6.3: Heat Loads for the Control Dewar

Item	300 to 80 K	80 to 4 K
Bayonets	2.4 W	2.6 W
Control Valve Stem		0.5 W
Radiation	0.8 W	0.1 W
Relief Lines	negligible	0.6 W
Miscellaneous Conduction		0.1 W
Intercepts	5.0 W	
Current Leads		28.8 L/h
Total	8.2 W	3.9 W + 28.2 L.hr

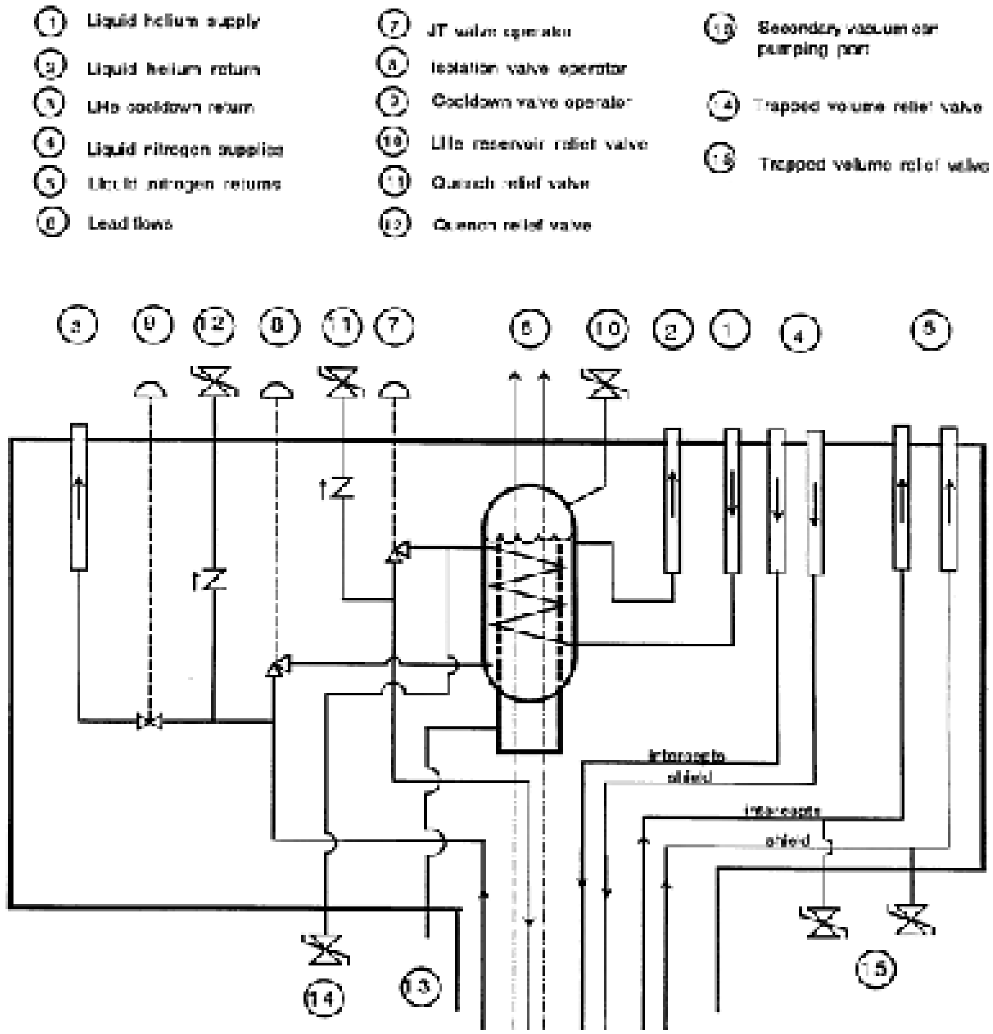

Figure 6.1 Simplified Control dewar schematic

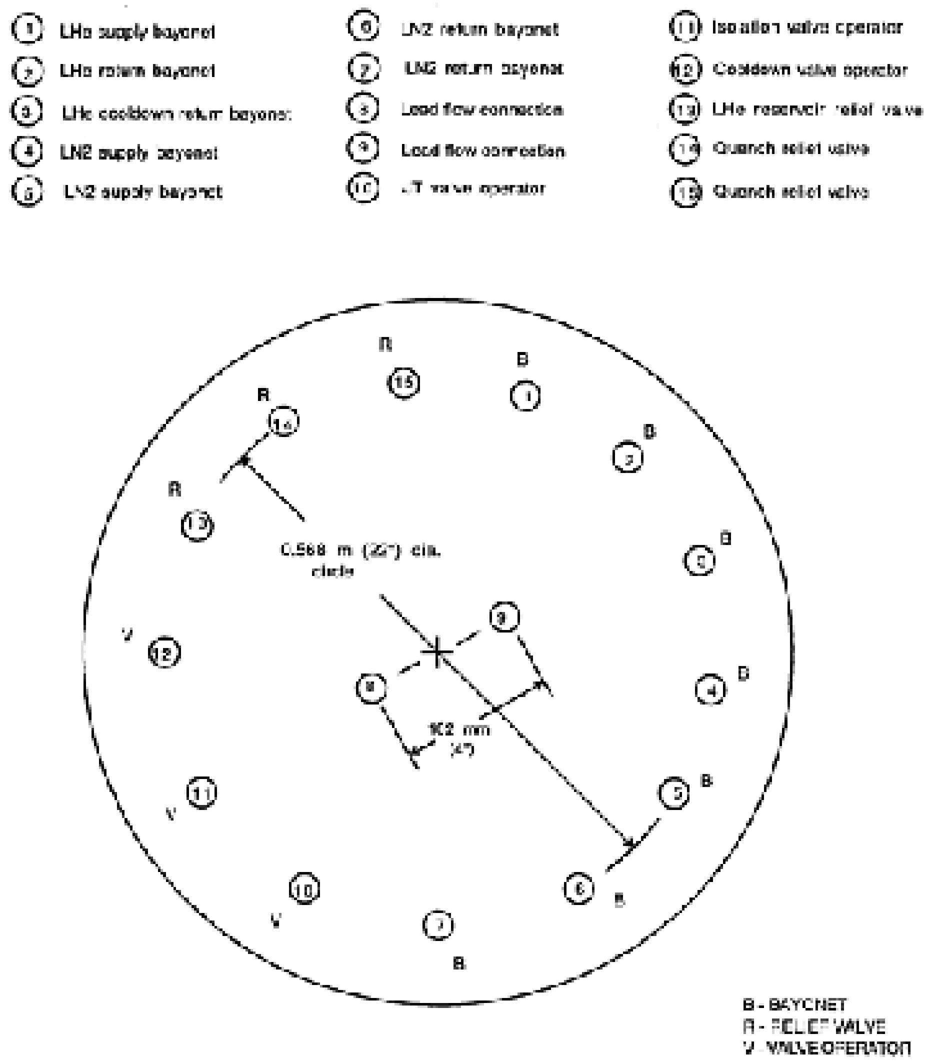

Figure 6.2 Control dewar top head layout

(not to scale)

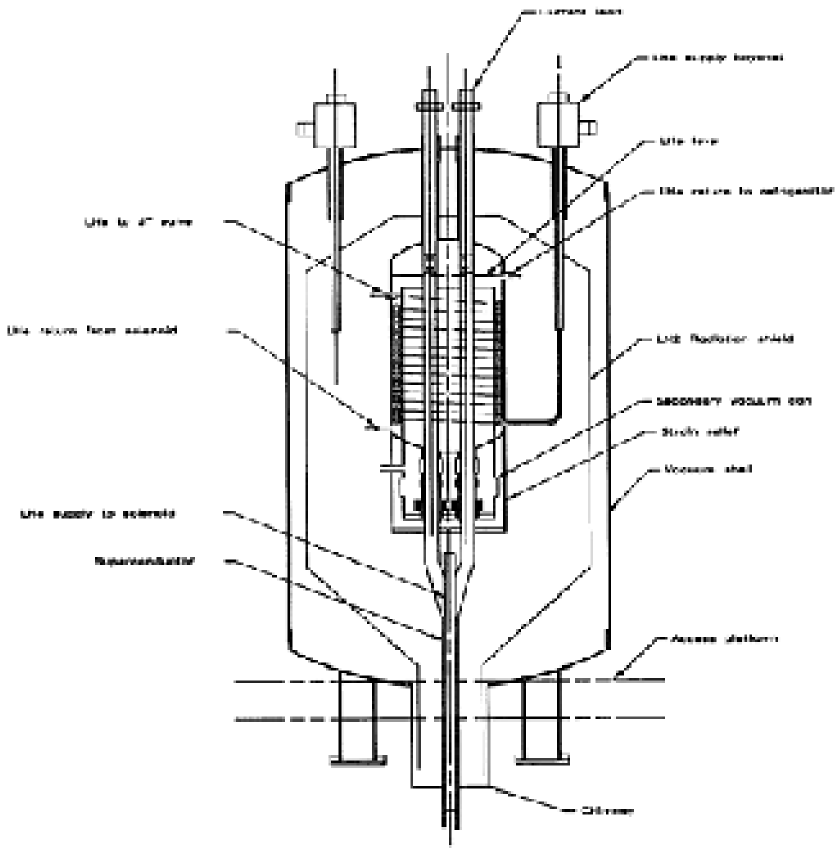

Figure 6.3 Cross section of Control dewar