CHAPTER 7

REFRIGERATION SYSTEM

7.1 General Requirements

The DØ solenoid system will require a cryogenic refrigeration system to supply LN2 and LHe to the magnet. In addition to the magnet, a Visible Light Photon Counter (VLPC) system with liquid helium cryostats will also be added to the upgraded detector. The two new systems will operate simultaneously and are thus considered together in designing the required refrigeration system needed for the upgraded detector.

An existing cryogenic system at DØ supplies LN2 refrigeration to the three existing liquid argon calorimeter cryostats of the detector and provides for storage of pure liquid argon required by the calorimeters. An existing control system enables the automatic operation of the calorimeter cryostats at fixed pressure and liquid argon level.

Economic and operational considerations indicate that and upgrade/modification of the existing DØ cryogenic system is most appropriate. An existing LN2 dewar storing 75.7 kl LN2 has adequate capacity for the liquid nitrogen needs of the magnet cryostat, the VLPC cryostats, and a helium refrigerator/liquifier of adequate capacity.

A standard Fermilab satellite **ST**and **A**lone **R**efrigerator (STAR) will be installed to provide the helium refrigeration required. The capacity of the STAR is sufficient for nonsimultaneous cooldown and simultaneous operation of both the solenoid and VLPC systems. The STAR refrigerator will make LHe into a 2000 L storage dewar. This dewar will supply liquid via separate transfer lines to the magnet control dewar and the VLPC cryostats.

7.2 Building Requirements

There is adequate space in the DØ Assembly Building (DAB) to house the STAR expansion engines, heat exchanger, helium storage dewar, and valve box.

An annex will be added to the existing DØ Tevatron compressor building to house two additional Mycom compressors; the mass flow from one compressor will be allocated to the DØ STAR and the other compressor will serve as an on-line spare for either DØ or the Tevatron. Additional helium purifier equipment will be installed at the compressor building annex for the added Mycom compressors.

7.3 Flow Diagram

A simple box diagram of the refrigerator system is shown in Figure 7.1 and the corresponding simplified flow diagram is shown in Figure 7.2.

7.4 Hardware Components

The hardware components that make up the new LHe refrigerator system are the compressors, a heat exchanger, expansion engines, a valve box, a LHe storage dewar, transfer lines, and a solenoid (including the service chimney and control dewar).

7.4.1 Compressor

The two 400 HP two-stage Mycom compressor to be installed for the DØ refrigeration system are identical to those used in the Tevatron. They are specified to provide 50 g/s helium at a discharge pressure of 20 atms, but measurements show they typically provide 57 g/s mass flow. Two standard full-flow three stage purifiers will also be installed with the compressors to remove oil and water from the discharge helium. Piping in the DØ compressor building annex will permit the eventual connection of the compressors into the Tevatron helium system. The discharge and suction lines of the DØ compressors run across the Tevatron berm to DAB; a dirty gas return line and inventory management line are provided to a helium buffer tank near DAB. The system is very similar to the system presently used at the Tevatron, and in particular to the STAR used at the collider detector facility at BØ.

7.4.2 Heat Exchanger

The STAR heat exchanger is a horizontal vacuum vessel containing the LN2/He and He/He heat exchangers. It will be located in the DAB assembly hall.

7.4.3 Expansion Engines

The STAR uses a dry reciprocal expansion engine across the process stream and a wet reciprocal expansion engine in the process stream. These engines are provided in individual vacuum vessels and connect to the heat exchanger with U-tubes. They will be located near the heat exchanger in the DAB assembly hall. These expansion engines are used throughout Fermilab and there are available spare engines in case of failure or other severe problems.

7.4.4 Valve Box

A valve box serves as a junction between the heat exchanger, wet engine, storage dewar and transfer line with interconnections made with U-tubes. It is a vacuum box with external bayonet fittings and valve operators and internal cold piping and valves. The box contains two control valves: the high to low pressure bypass valve and a J-T valve in parallel with the wet engine. The valve box will be located near the expansion engines and heat exchanger in DAB.

7.4.5 Storage Dewar

The STAR refrigerator will make LHe into a 2000 L storage dewar. This dewar will be a commercially procured ASME Boiler and Pressure Vessel Coded dewar with an MAWP of 7 atmospheres. The pressure rating is appropriate for pressures encountered during quenches and cooldowns. In the steady-state condition the dewar will operate at 1.8 atm, 4.9K which will be the driving pressure of the flow through the magnet. The storage dewar will be located in DAB near the expansion engines.

7.4.6 Transfer Line

U-tubes will connect the storage dewar, heat exchanger and LN2 header to the LN2/LHe/GHe transfer lines. One transfer line will deliver cryogens to the detector standby position in the Assembly Hall and another will deliver cryogens to the Collision Hall. U-tubes connect the transfer line to the magnet system control dewar.

7.4.7 Control Dewar and Solenoid

The control dewar is described in Chapter 6. It is the interface between the permanently installed cryogenic building piping and the service chimney and solenoid mounted on the moveable detector.

7.5 System Heat Loads and Capacity

A detailed description of the low temperature components and the identified heat loads to the LN2 and LHe systems are given in Table 7.2. The total identified steady state helium heat load is approximately 40 W plus 28.8 L/hr with an additional 20 W during charging. The nitrogen heat load is approximately 241 W equivalent to approximately 5.4 L/hr.

Figure 7.3 shows the nominal capacity of the STAR refrigerator with the identified and expected heat loads. It can be seen that there is adequate refrigeration to handle the heat load from both the magnet system and the VLPC system.

7.6 Refrigerator Control System

The refrigerator/compressor control system will be supported by the existing DØ cryogenic control system. The control system is described in chapter 9.

Table 7.1: DØ STAR Refrigerator Loads		
System	Refrigeration	Liquefaction
Solenoid System	38.4 W	1 g/s
VLPC System	270 W	—
Total	308.4 W	1 g/s

Table 7.2: Heat Loads for the Solenoid System		
Item	300 to 80 K	80 to 4 K
5' U-Tube (Valve Box to Dewar)	—	3.1 W
2000 L He Dewar	7.6 W	1.5 W
5' U-Tube (LHe Dewar to Transfer Line)	—	3.1 W
270' Transfer Line	38.5 W	2.5 W
15' U-Tube (Transfer line to Control Dewar	—	4.1 W
Control Dewar	8.2 W	3.9 W + 1 g/s
Solenoid	165.3 W	12.5 W
15' U-Tube (Control Dewar to Transfer LIne	—	4.1 W
10' U-Tube (Transfer Line to Valve Box)	—	3.6 W
5' U-Tube (LN2 Tank to LN2 Transfer LIne)	2.8 W	—
100' LN2 Transfer Line	15.5 W	—
5' U-Tube (LN2 Transfer LIne to LHe Line)	2.8 W	—
LHe Refrigerator	10 L/hr	—
Totals	240.7 W + 10 L/hr	38.4 W + 1 g/s

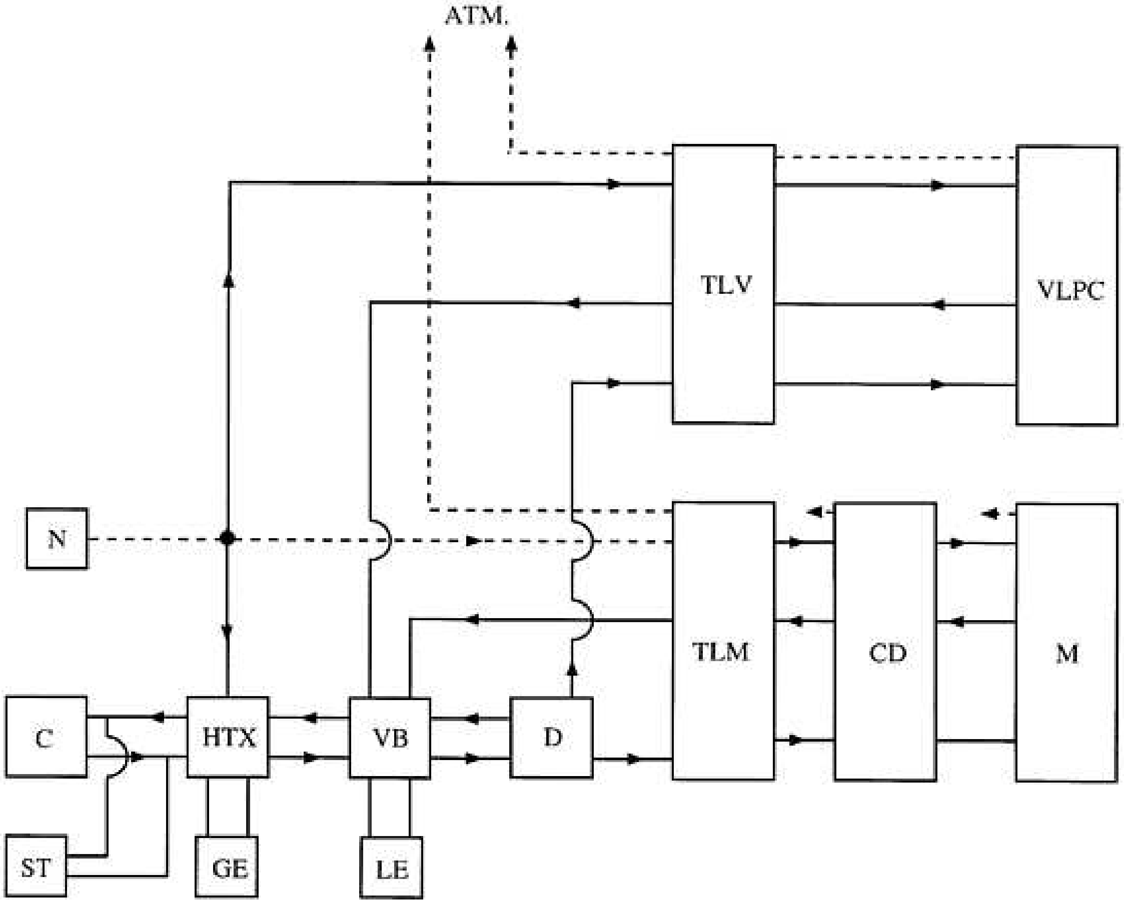

FIGURE 7.1: **Refrigeration System - Box Diagram**

Symbols: N=liquid nitrogen tank; C=compressor; ST=storage / buffer tank; HTX=heat exchanger; GE=gas expansion engine; LE=liquid expansion engine; VB=value box; D=LHe dewar; TLM=transfer line for magnet; CD=control dewar; M=magnet; TLV=transfer line line for VLPC cryostat; VLPC=VLPC cryostat

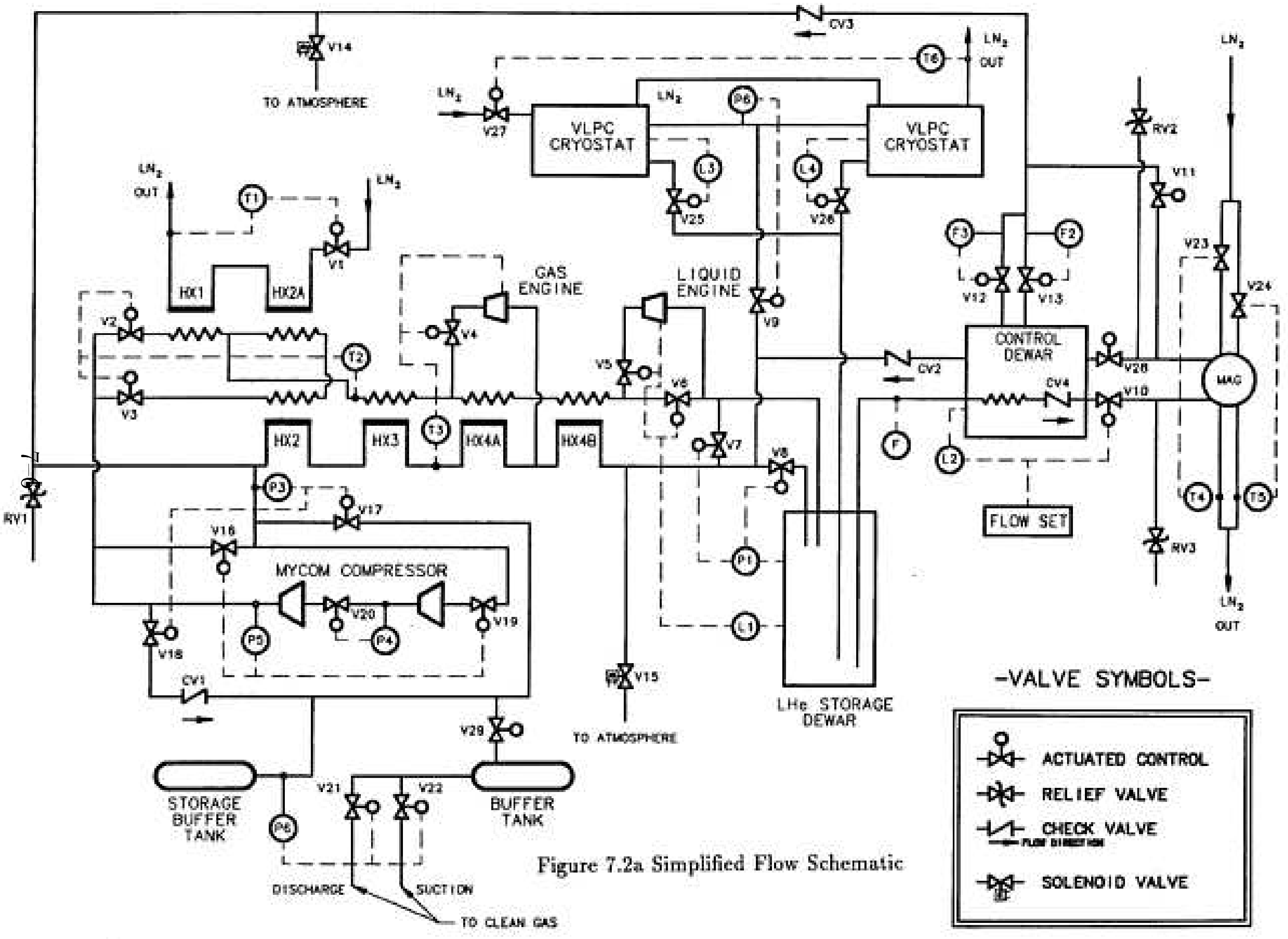

Figure 7.2a Simplified Flow Schematic

Valve Legend

V1	Heat Exchanger LN2 Control Valve
V2	HX1 Flow Control Valve
V3	HX2 Flow Control Valve
V4	Dry Engine Flow Control Valve
V5	Wet Engine Flow Control Valve
V6	J-T Valve
V7	Bypass Valve
V8	Storage Dewar Pressurizing Valve
V9	Control Dewar Pressurizing Valve
V10	Magnet Flow Control Valve (J-T Valve)
V11	Cool-down Valve
V12,13	Vapor Cooled Lead Flow Control Valve
V14,15	Solenoid Valves for Open Cycle Operation
V16	Suction Side Inventory Control Valve
V17	Discharge Side Inventory Control Valve
V18	1st Stage Slide Valve
V19	Compressor Bypass Valve
V20	Interstage Slide Valve
V21	Clean Gas Supply Valve
V22	Dirty Gas Discharge Valve
V23,24	Magnet LN2 Control Valves
V25,26	VLPC Cryostat Control Valves
V27	VLPC Nitrogen Control Valve

Figure 7.2b

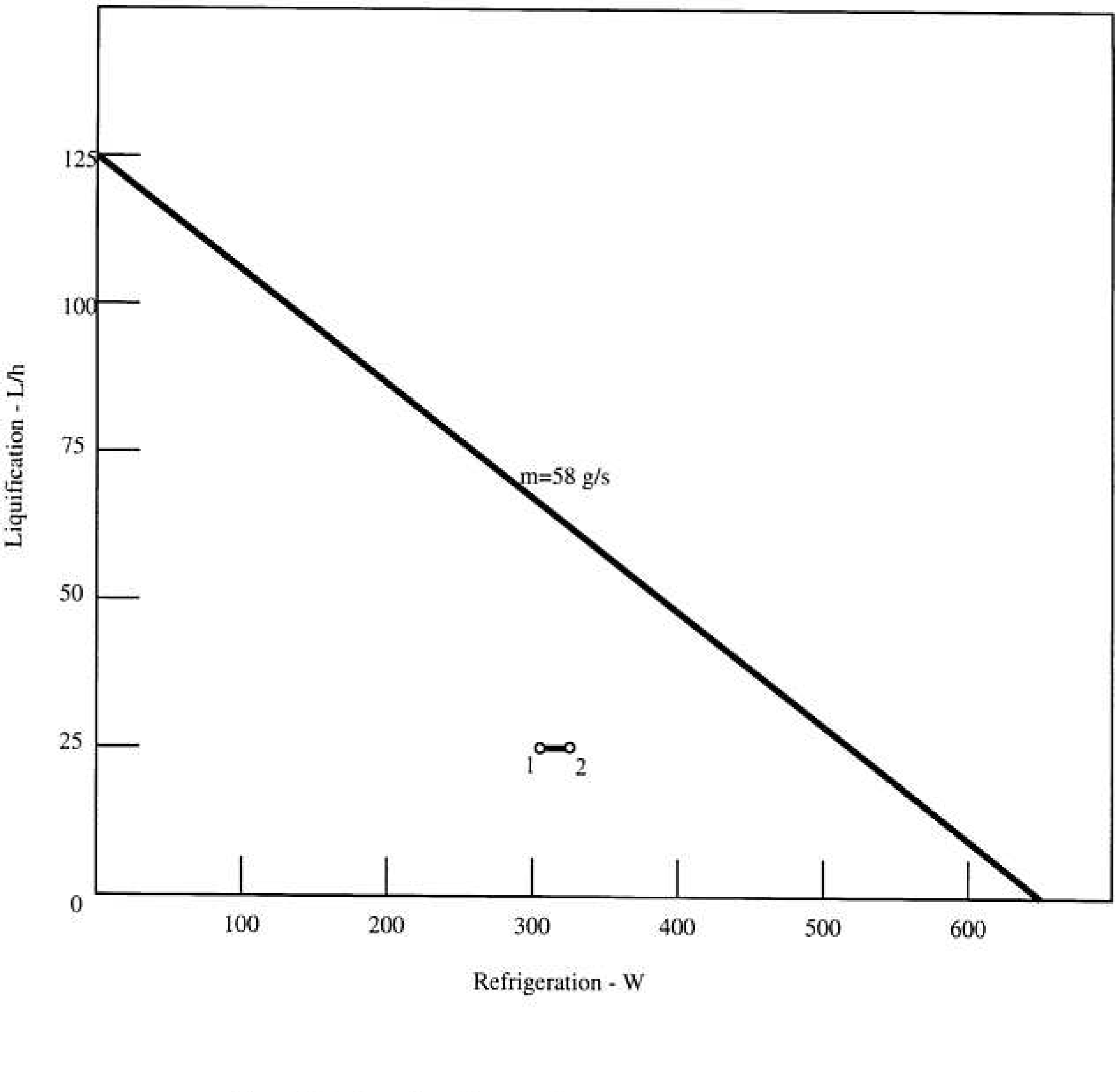

Figure 7.3: **Capacity of star refrigerator and (1) identified steady state heat load, (2) max. expected charging heat load**