Chapter – 9 Open Cycle Refrigeration System

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An open cycle refrigeration system is that the system is without a traditional evaporator. The suction gas for the refrigeration system might be from a storage tank or from a pipeline, the refrigeration system is to liquefy the gas and send the liquid to other facility or to a storage tank. The refrigerant of the system is an open flow and is not a closed recirculation circuit. The typical open cycle refrigeration system is that the system for Ammonia storage or LPG storage.

Ammonia Storage:

Refrigeration system is needed for ammonia storage for the following reasons:

(1) When the ammonia liquid coming out from the fertilizer plant, the pressure and temperature are relatively high. Usually, the working pressure for the storage tank is constructed for just slightly above the atmospheric pressure. Therefore, the pressure and the temperature of the ammonia liquid from pipe line are to be reduced before it is stored in the storage tank.

(2) The ammonia liquid inside the tank is boiled off due to heat gain through the storage tank. This boiled off gas must be re-condensed to avoid pressure build up in the tank; the re-condensed ammonia liquid is to be returned back to storage tank.

(3) To condense the flash gas from the loading system.

(4) To re-condense the flash gas from the liquid throttling to the storage tank.

An example is shown in Figure 9-1. The Ammonia liquid flow from pipeline is 98.6℉ and 242.22 Psia; the compressor suction flow is the boiled off gas and the flash gas from the storage tank and the flash gas from the loading system.

The refrigeration system shown in Figure 9-2 is designed to handle the ammonia liquid flow from the pipe line and to re-condense the gases from the storage tank and from the loading system. This refrigeration system is a compound system with a 7-stage multistage centrifugal compressor as the low stage and a 7-stage multistage centrifugal compressor as the high stage. The intermediate temperature of this compound system is 27℉.

The Figure 9-3 is the P-H diagram for this compound system. The ammonia liquid

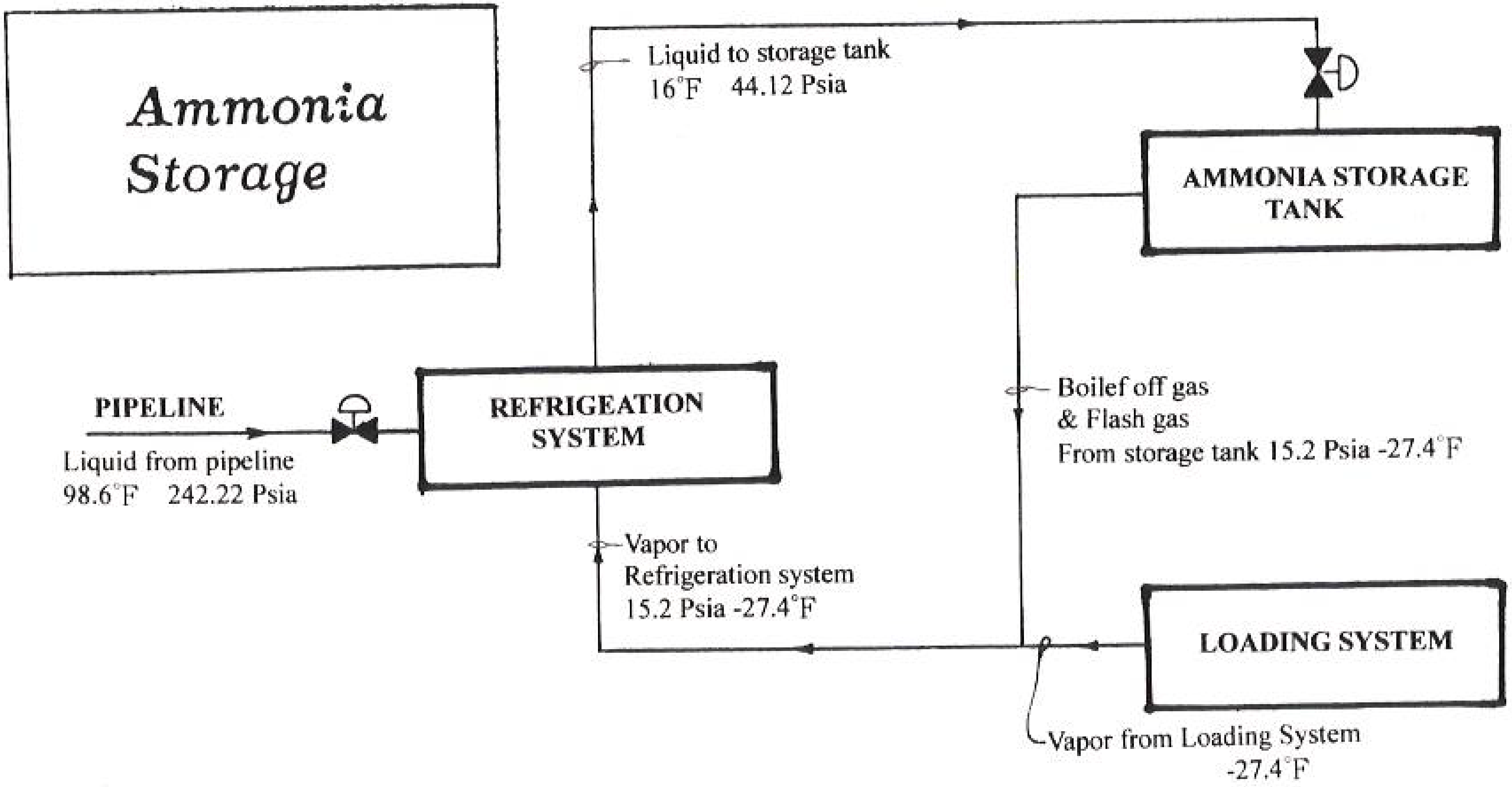

Figure 9-1 Ammonia Storage

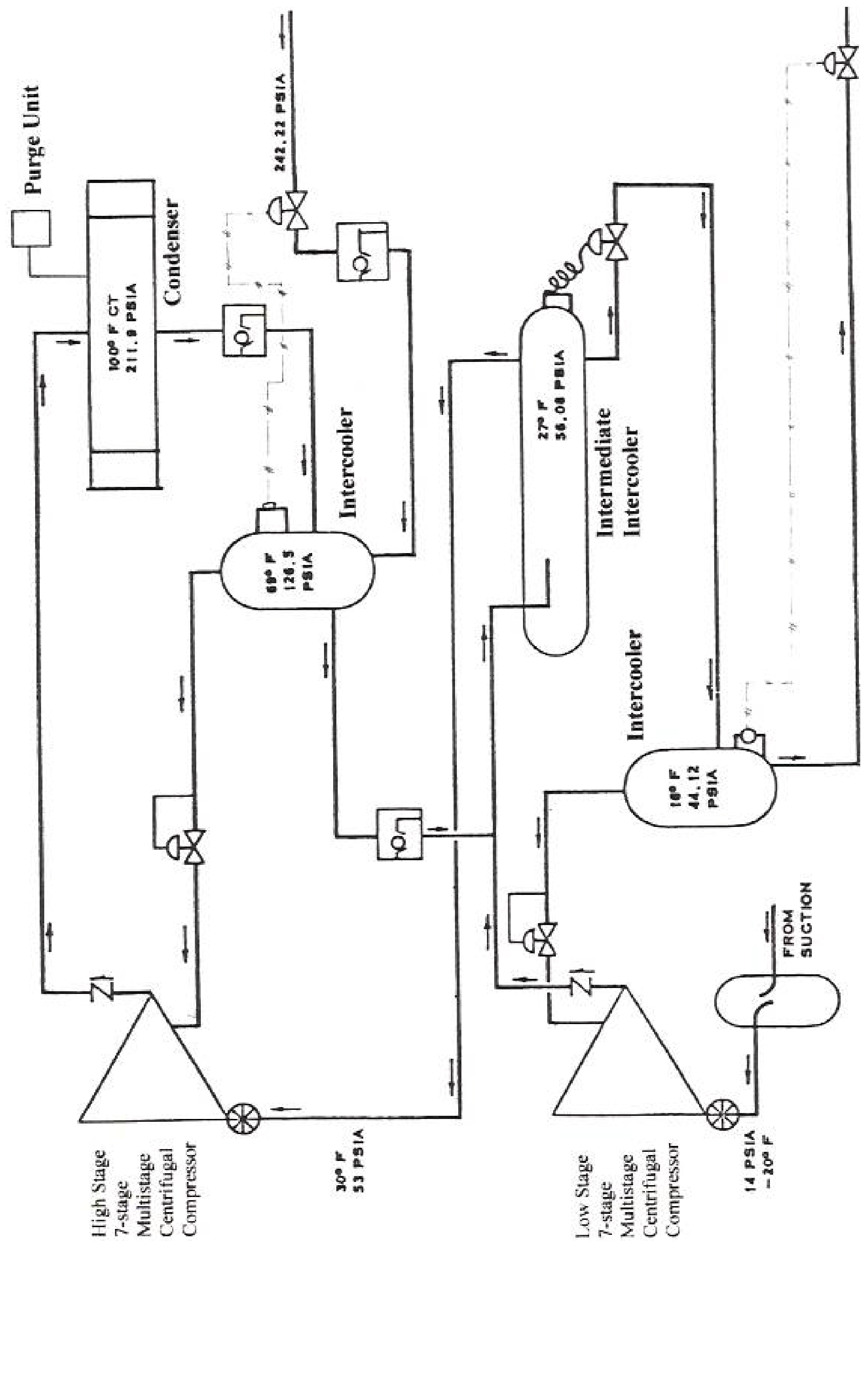

Figure 9-2 Open Cycle Refrigeration System
For Ammonia Storage

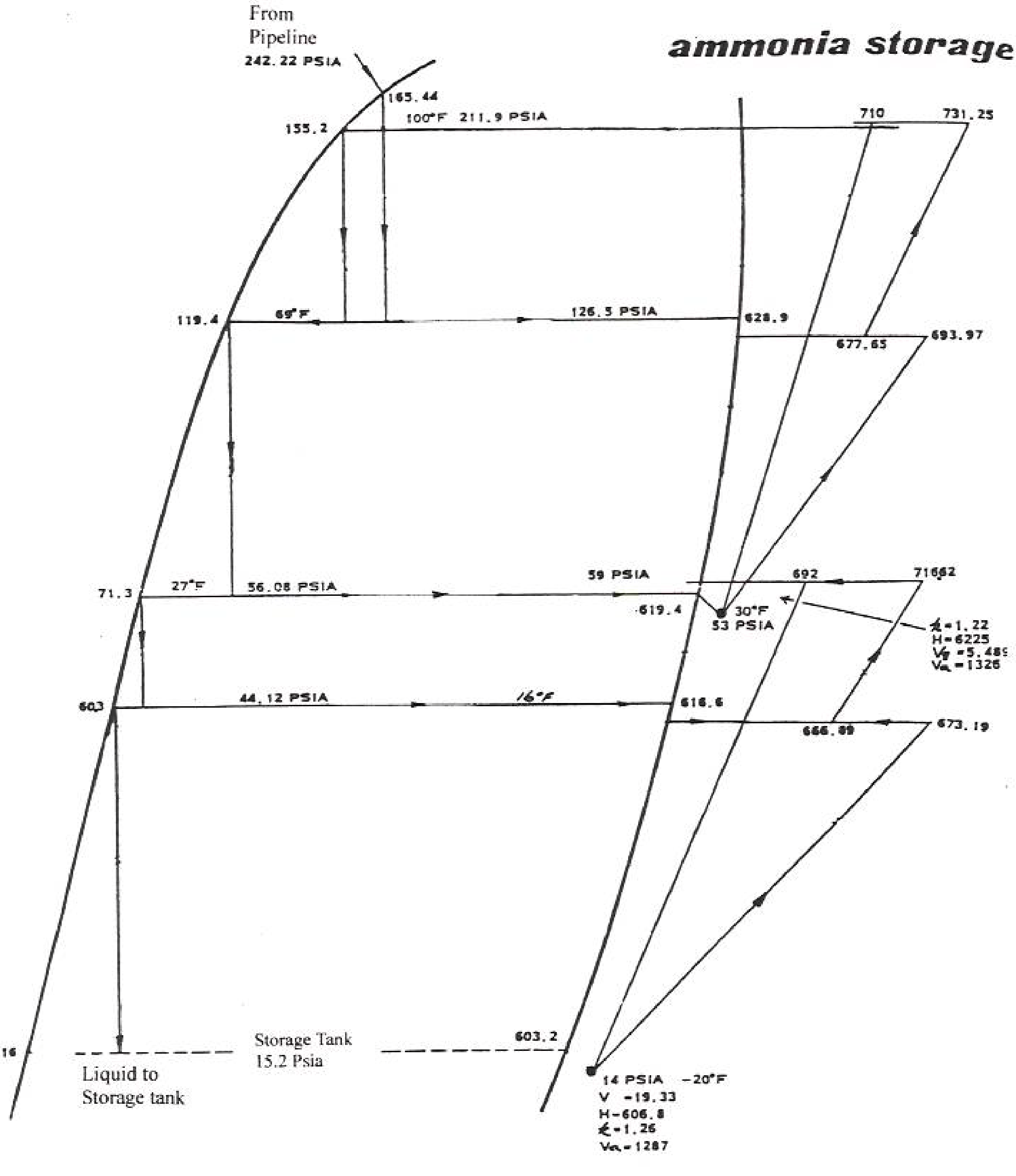

Figure 9-3 P-H Diagram for Ammonia Storage

from the pipe line is first throttling down to 126.5 Psia pressure level, then drops down to 59 Psia, then 44.12 Psia. The suction flow of the low stage compressor is from the boiled off gas and the flash gases. Side load of low stage compressor is the flash gas from the 16°F intercooler and it is connected to the inlet of the 6th stage impeller. The side load for the high stage compressor is the flash gas from 69°F intercooler; this side load is connected to the inlet of the 5th stage impeller of the high stage compressor. The liquid leaves from the low stage intercooler at 16°F 44.12 Psia is returned to the storage tank through a throttling valve.

The liquid leaves the refrigeration system in this case is saturated liquid at 44.12 Psia. The system should be modified to provide subcooled liquid instead of saturated if the pipe line is with a vertical lift.

Screw compressor instead of centrifugal should be considered if the ammonia flow rates are more suitable for the capability of screw compressors.

LPG Storage:

LPG (Liquefied Propane Gas) storage is another typical application of open cycle refrigeration. When producing LPG, it also produces Butane and Pentane in most cases. Therefore, LPG storage refrigeration system shown in Figure 9-4 also includes the Butane and Pentane storage.

All the storage tanks are designed for working pressure about atmospheric pressure. The refrigeration system is to reduce the pressure inside the storage tank by liquefying the boiled off gases and return the condensed liquid back to the storage tank.

The Figure 9-4 is a refrigeration system to liquefy the propane boiled off gas. It also uses propane as the refrigerant to condense the boiled off gases of Butane and Pentane. The Figure 9-5 is the P-H diagram for this refrigeration system.

This system was designed for a LPG terminal where the ambient temperature is high and water supply is a problem. Therefore, air cooled condenser is used. An 8-stage centrifugal multistage compressor was used to allow different evaporative temperature levels for Butane and Pentane condensing.

The description of the refrigeration system is as the following:

Condensing temperature is 135°F.

Compressor main suction gas is the boiled off gas from the Propane Storage Tank at -40°F and 14.7 Psia..

Use Propane as the refrigerant for two evaporators. One is the evaporator for Pentane condensing. ET is110°F. Suction from this evaporator is connected to the inlet of 8th stage impeller. Another evaporator is for Butane condensing. ET of 0°F. The suction from this evaporator is connected to the inlet of the 3rd stage impeller.

Three flash intercoolers are used for the compressor: (1) at 83°F 149.89 Psia, flash gas inlet to the 7th stage impeller; (2) at 37°F, 74.73 Psia, flash gas inlet to the 5th stage impeller and (3) at 0°F 38.3 Psia, flash gas inlet to the 3rd stage impeller of the compressor.

A two-stage flash intercooler is used, for the 37°F and 83°F intercooling.

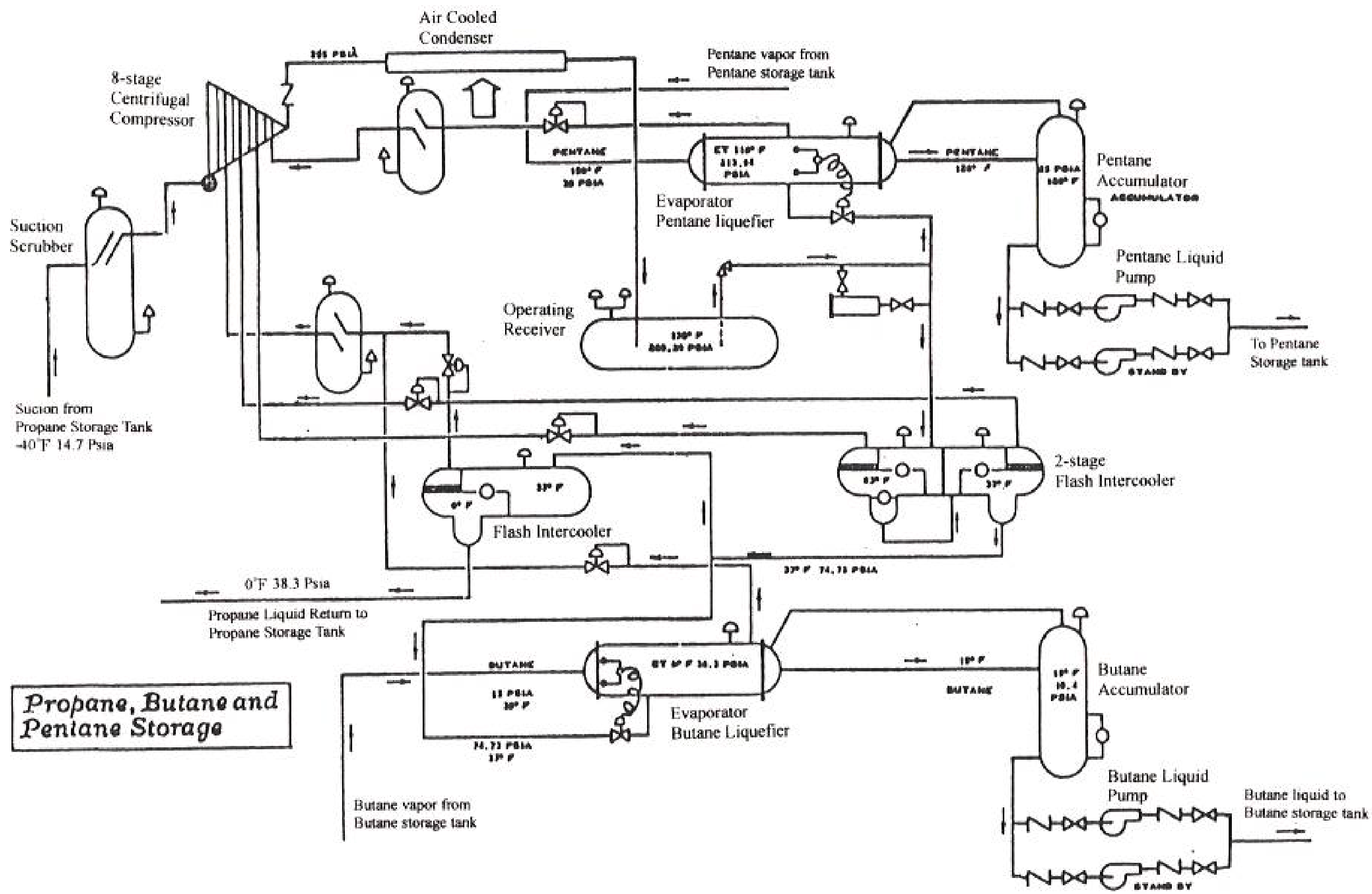

Figure 9-4 Refrigeration System for Propane, Butane and Pentane Storage

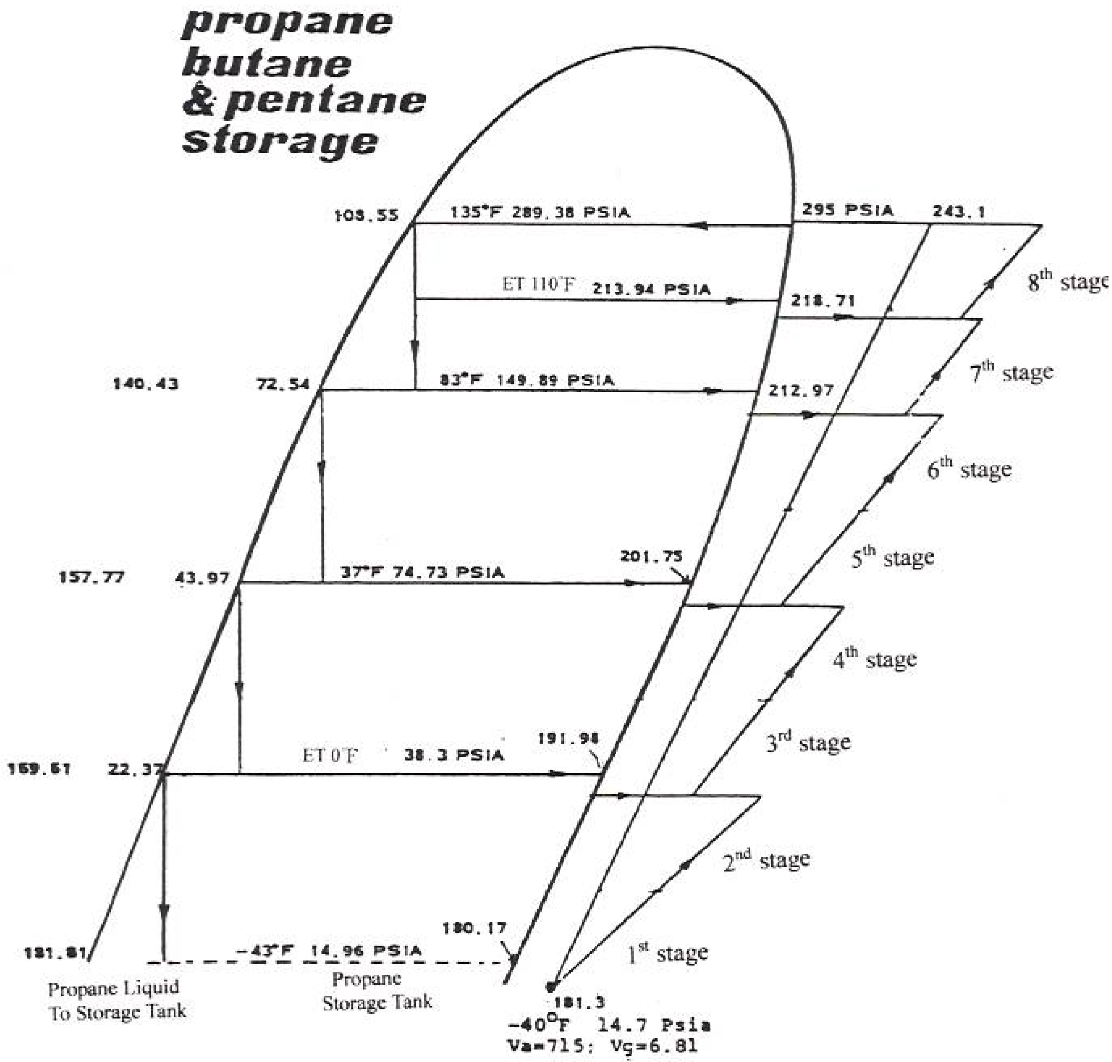

Figure 9-5 P-H Diagram for Propane, Butane and Pentane Storage

There are two streams of side loads flow from 0°F 38.3 Psia to the inlet of 3rd stage impeller of the compressor; one is the flow from the flash intercooler and the other is the vapor flow from the evaporator for the Butane condensing.

Multistage centrifugal compressor is used for this example. The refrigeration system can be designed by using screw compressor.