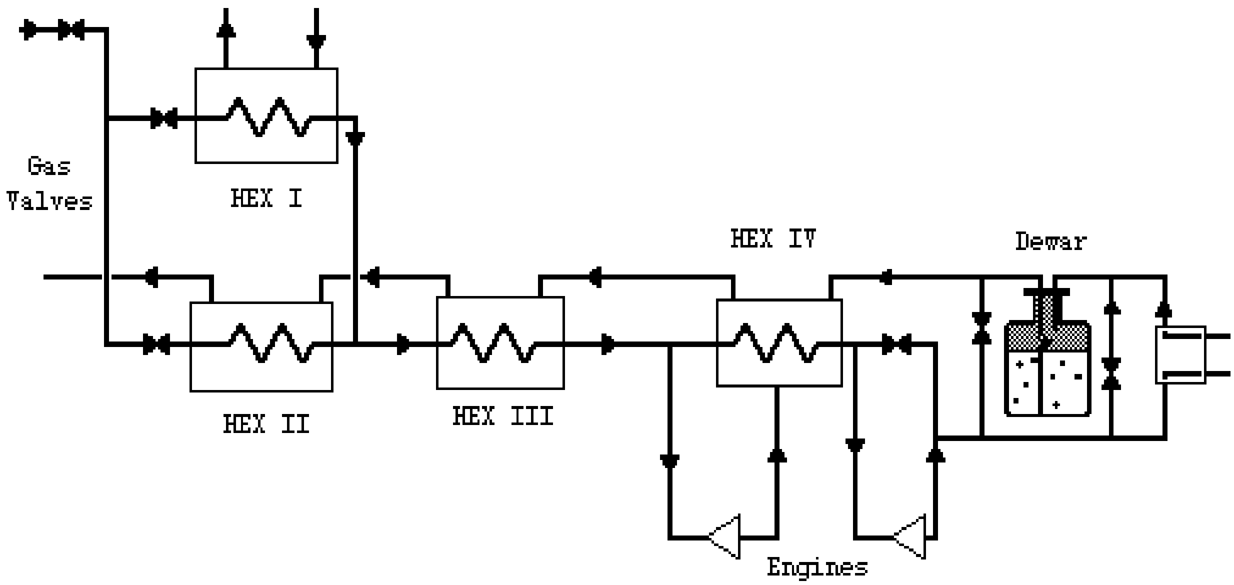
FLOW DIAGRAM FOR A SATELLITE REFRIGERATOR

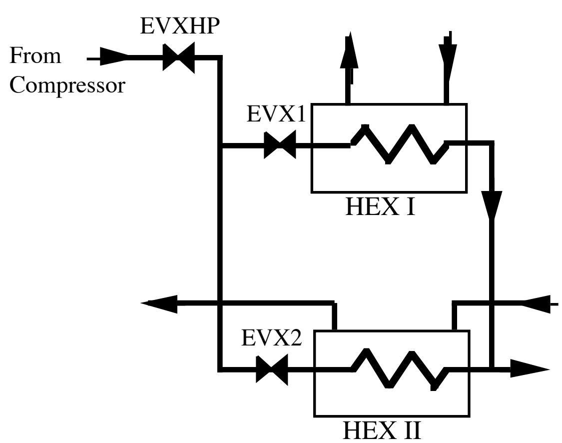
This is a simplified flow schematic for a satellite refrigerator. It builds on the basic system you saw back in the chapter on Refrigeration.



The following diagrams and descriptions explain specific parts of a satellite refrigerator system.

THE HEAT EXCHANGER VALVES

These three valves EVXHP, EVX1, and EVX2 control the helium coming from the compressor and going to the heat exchangers.

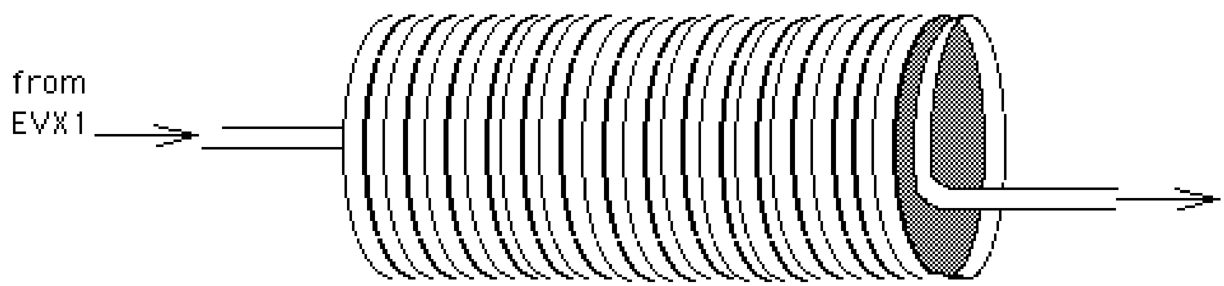


EVXHP: This valve can be found on the PS1, PS4, and MCC refrigerators. It is the main shut off of helium flow to the system. Typically, a ball valve is electrically operated from the local cryo control room. When operating, this valve is used as an emergency shut off to secure high-pressure (300 psia) helium in the event of a rupture. The valve is also used to give double valve protection for some maintenance procedures.

EVX1: This valve controls the flow of helium gas through the tube side of HEX 1. This is a "Valtek" globe valve with an "Industrial Device" electric actuator. This actuator is modulated by the controls system using a PID Loop. It varies based on the helium temperature leaving HEX I. This heat exchanger is also called the nitrogen pre-cooler, which is the starting point in your Cool Down Procedure.

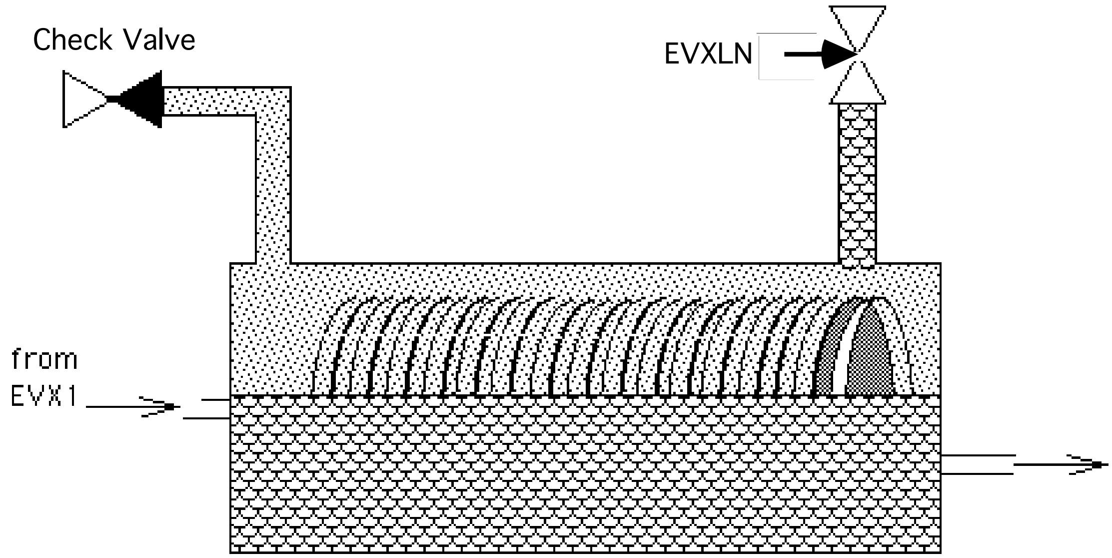
EVX2: This valve is similar to EVX1, but the difference involves its capability of handling much more flow. EVX2 can be opened during the cool down procedure, but only after the dry engine is running and the temperature on the shell side of HEX II is below 90°K. During normal operation, this valve varies between 75% and 100% open.

THE HEAT EXCHANGER - HEX I



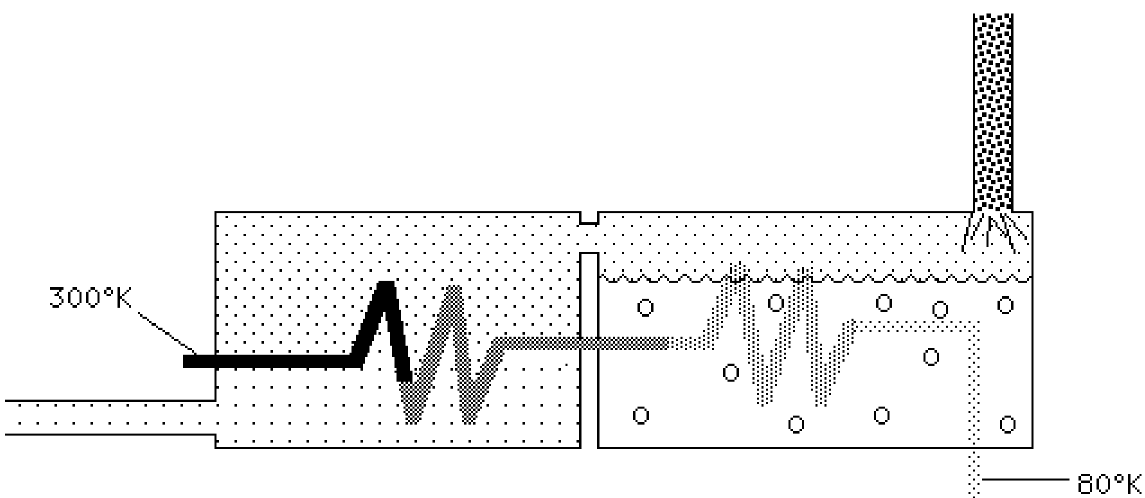
The tube side of the heat exchanger is spiral wound copper tubing and may be more than one layer deep. In HEX I, the tube side is submerged in a liquid nitrogen bath. This is very likely the most efficient style of heat exchanger.

EVXLN and the LN2 POT



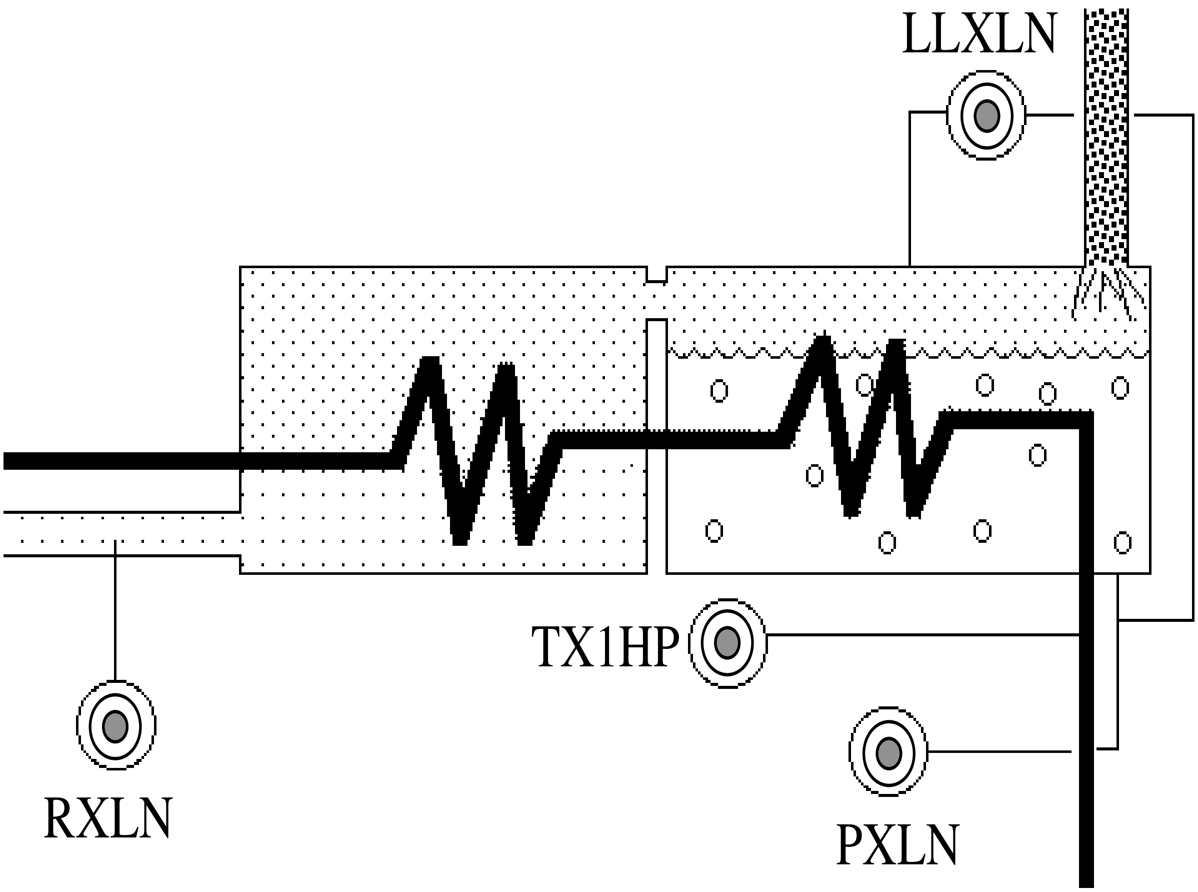
EVXLN: This valve controls the amount of liquid nitrogen flow to HEX I based on the level in the "POT." The LN_2 pot is simply a six-inch pipe mounted horizontally so it can serve as a liquid vessel for the tub side to be immersed in. The other valve is a simple check valve that vents to atmosphere.

REALITY



In reality, the liquid nitrogen enters and fills the pot, which covers only the last half of the tube bundle. The cold gas leaving the pot cools the first half of the tube bundle before it exits to atmosphere. This is the way the helium stream initially reaches the 80°K temperature range during cool down.

INSTRUMENTATION for HEX I



LLXN: This is a Barton ΔP transducer, which is calibrated to read the level of liquid nitrogen in the pot. Typically, this level should be 50% or greater.

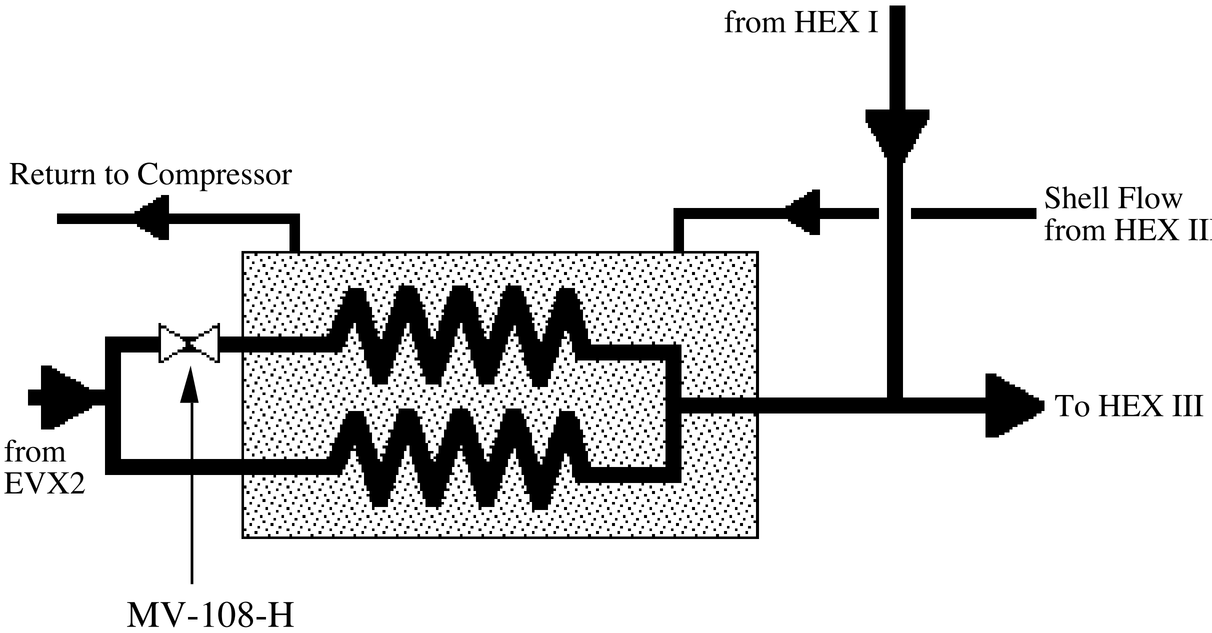
RXLN: This is a carbon resistor that reads the temperature of the nitrogen leaving HEX I. Typically, this temperature should be around 265°K.

TX1HP: This is a VPT, calibrated with N_2, which reads the temperature of the helium stream leaving HEX I. Typically, this temperature is 80°K.

PXLN: This is a "Setra" pressure transducer. It reads the pressure in the nitrogen side of HEX I. This pressure is around one psig.

THE HEAT EXCHANGER - HEX II

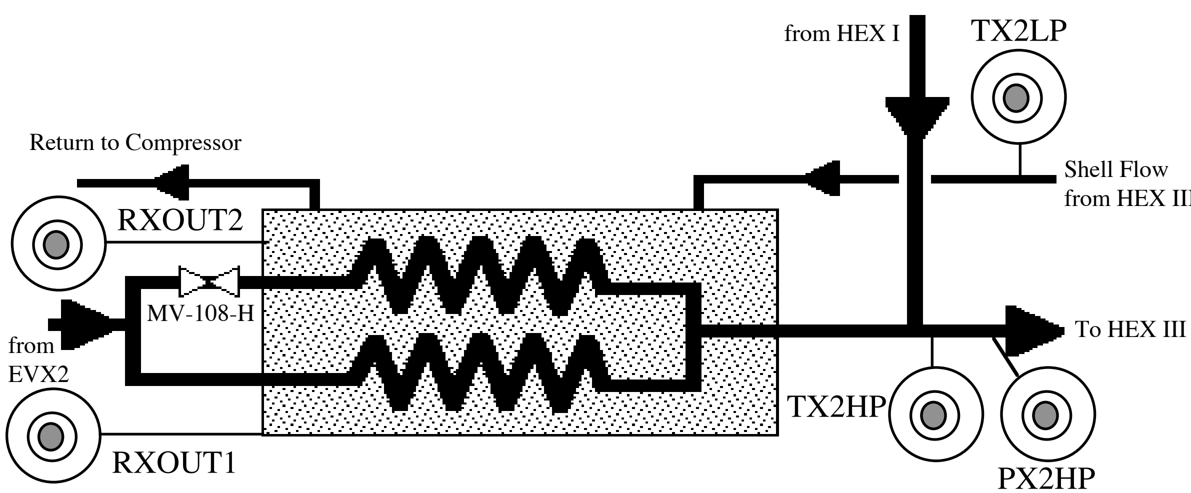
Heat exchanger two is a tube and shell type. The return flow on the shell side consists of cold gas that cools the entering high-pressure helium in the tubes.



MV-108-H: This manual valve is used to adjust flow through the two halves of HEX II. Proper adjustment is achieved when the outlet resistors (RXOUT 1 & 2) of the shell side are equal.

Helium Flow: As you can see, the flow path through this heat exchanger is straightforward. Remember - HEX II is used only after the dry engine is running and producing sufficiently cold gas to act as a coolant for the entering high-pressure helium stream.

INSTRUMENTATION for HEX II



RXOUT1: This is a shell side resistor, which reads the shell side helium as it exits HEX II. Usually, this resistor reads >280°K. (Compare this reading with that of RXout2.)

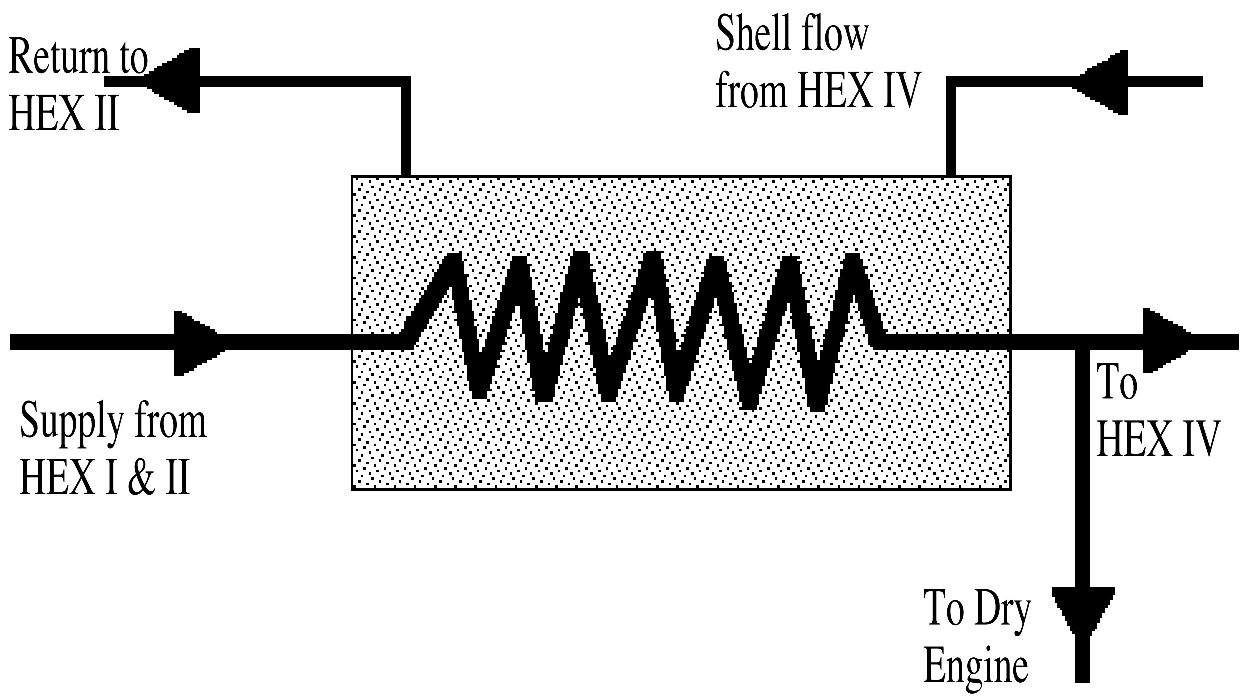
RXOUT2: This is a shell side resistor, which reads the shell side helium as it exits HEX II. Usually, this resistor reads >280°K. (Compare this reading with that of RXout1.)

TX2LP:This is a VPT charged with nitrogen gas. It reads the temperature of the shell side flow between HEX II and HEX III. Typically, this reads around 80°K.

TX2HP: This is a VPT charged with nitrogen gas. It reads the temperature of the tube side flow between HEX II and HEX III. Typically, this reads around 80°K.

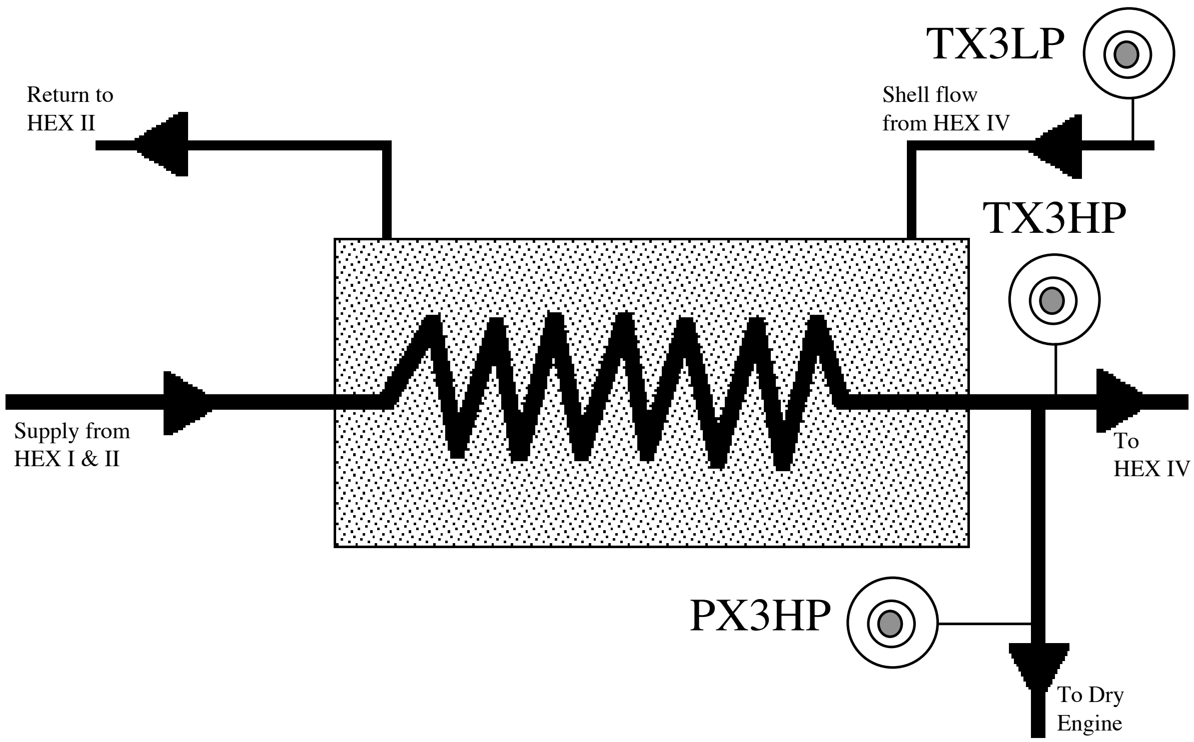
PX2HP: This is a 0-500 psig "Setra" transducer. It reads the pressure in the high-pressure helium supply stream as it exits HEX I and HEX II.

THE HEAT EXCHANGER, HEX III



This heat exchanger is also of the tube and shell counter flow design. It continues the refrigeration process by cooling the high-pressure helium stream with cold gas returning from the dry engine through the shell side of the heat exchanger. It's also possible that two phase from the rest of the refrigerator may be in this mixture.

INSTRUMENTATION for HEX III

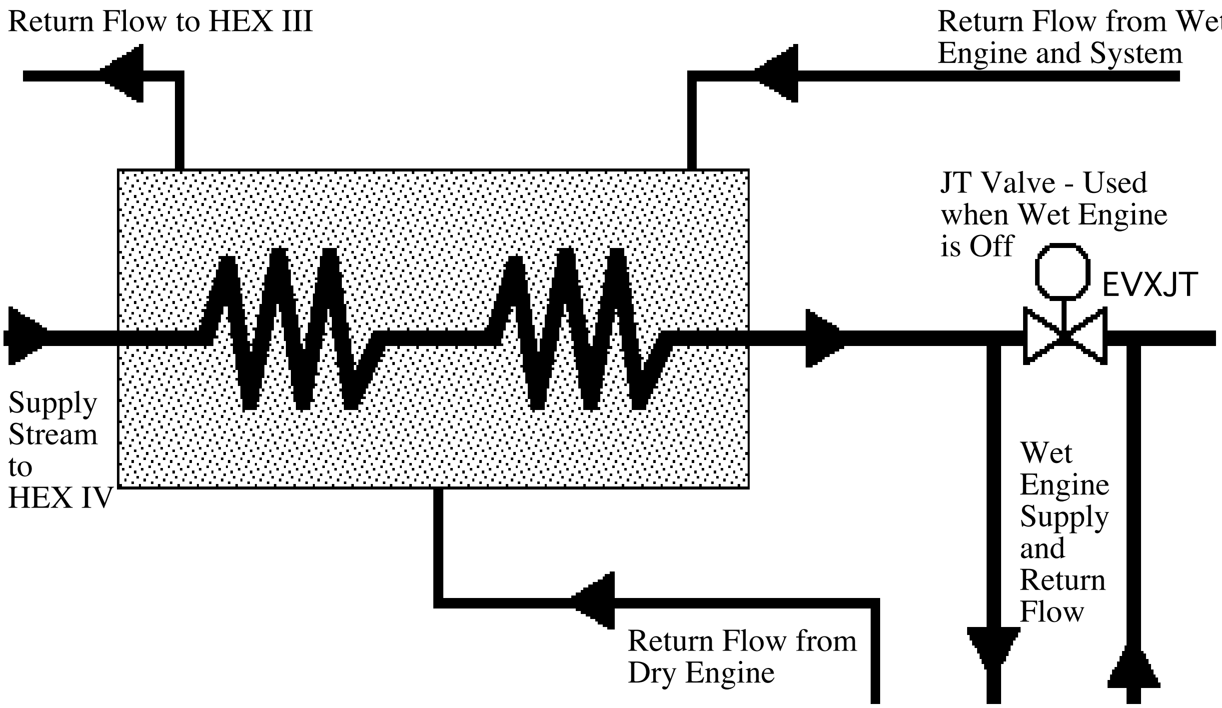


TX3LP: This is a VPT charged with neon gas. It reads the temperature of the return flow from HEX IV before it enters HEX III.

TX3HP: This is a VPT charged with neon gas. It reads the exit gas temperature of the high-pressure helium stream before it enters the dry engine and HEX IV.

PX3HP: This is a "Setra" transducer with a 0-500 psig range. It reads the pressure of the helium supply stream as it exits HEX III and heads for the dry engine.

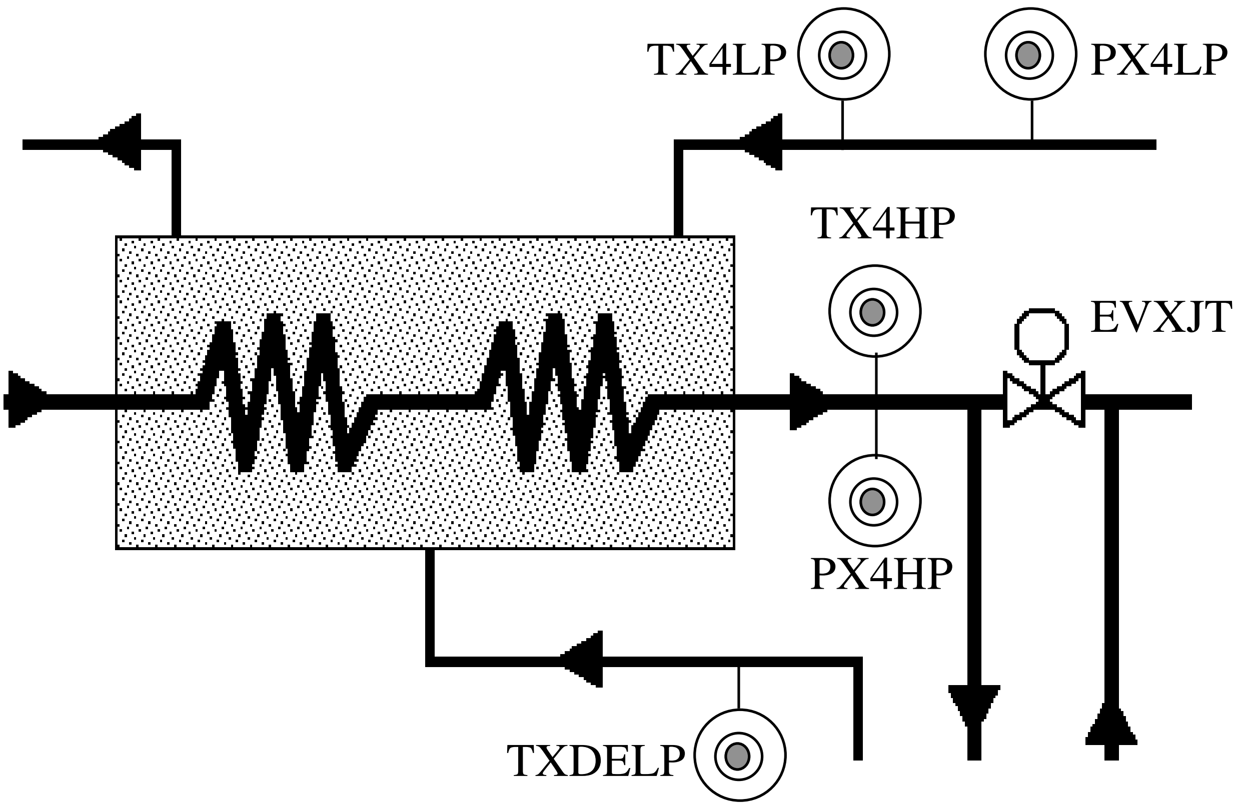
THE HEAT EXCHANGER, HEX IV



This heat exchanger is also of the tube and shell counter flow design, but its operation is a bit more complicated than the other heat exchangers. Cold gas from the dry engine directly enters the shell side of this exchanger. You may also find liquid helium entering the shell side of this exchanger from the wet engine, the system, or both.

EVXJT: This is a Joule-Thomson valve. It is specifically a one half-inch Cryolab globe style valve with a Cv of .32. Typically, this valve is closed during normal operation.

INSTRUMENTATION for HEX IV



TX4LP: This is a VPT charged with helium gas. It reads the return flow gas temperature entering the shell side of HEX IV.

PX4LP: This is a pressure transducer, which reads the shell side pressure of HEX IV.

TX4HP: This is a VPT charged with helium gas. It reads the temperature of the gas leaving HEX IV before it goes to the wet engine.

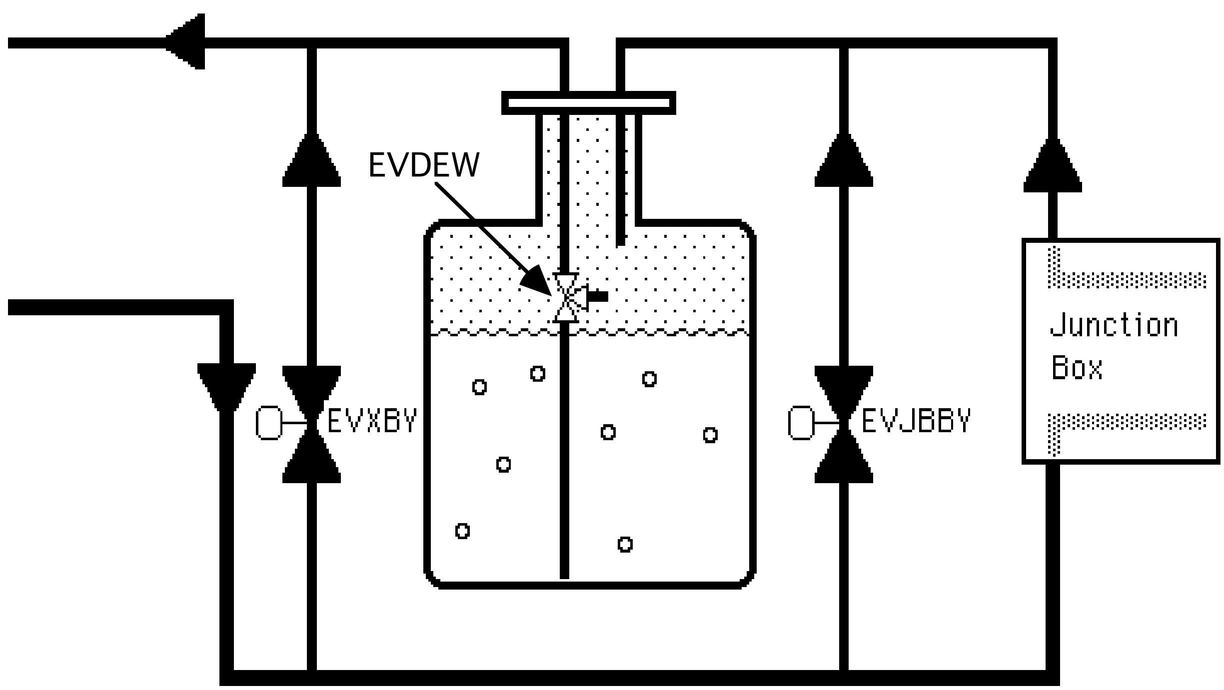
PX4HP: This is a 0-500 psig pressure transducer, which reads the pressure of the gas leaving HEX IV before it goes to the wet engine.

TXDELP: This is a VPT charged with hydrogen gas. It reads the temperature of the gas flow coming from the dry engine.

DEWAR, VALVES, and JUNCTION BOX

A Dewar is a vacuum-jacketed vessel used as a reservoir for any cryogenic liquid. The External Beamline's refrigerators use its helium Dewars as a phase separator as well as a reservoir. The return flow of helium, from either the magnets or the bypass valve EVJBBY, enters the Dewar and separates into liquid and gas.

The junction box is the point where the magnet string is attached to the refrigerator. Single phase helium flows from the junction box, through the transfer line to the magnet string, and then returns, as two-phase, to the junction box. (Cold gas can and does pass through the magnet strings, but generally this is only during cool down. Magnet operation requires liquid helium to obtain superconductivity.) The junction box accommodates the two-phase return from the magnet string to the refrigerator. It also houses the valve EVJBBY and a sub-cooler.

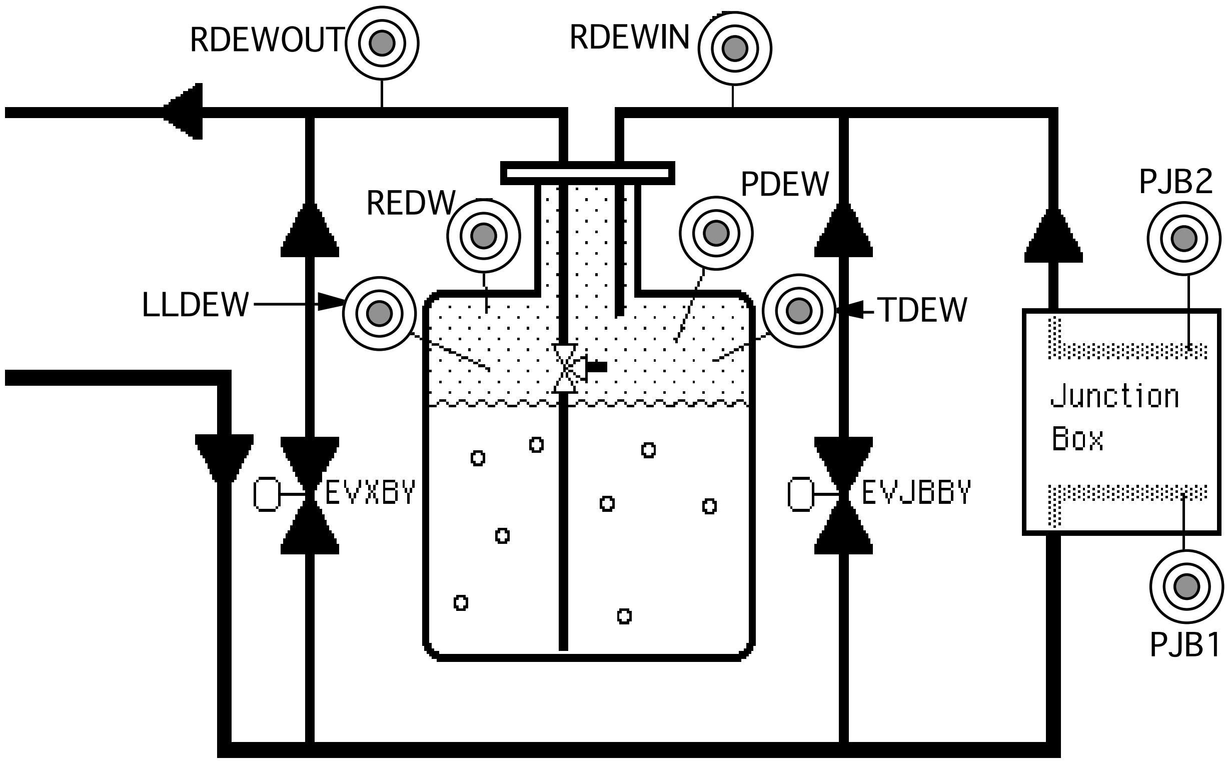


EVXBY: This valve has a Cv of 1.8 and is used as a transfer line pressure control valve. During cool down, it can be used shorten the loop by eliminating the Dewar.

EVDEW: This is a full three-way valve. With the valve in the open position, liquid is drawn from the bottom of the Dewar. In the closed position, it draws gas from the upper part of the Dewar. During normal operation, the valve allows the Dewar to fill to about 78%.

EVJBBY: This is the bypass valve used to control the inlet temperature of the wet engine. It can also be used to fill the Dewar or complete a loop for a test run of the refrigerator while isolating the magnet strings. It has a Cv of 3.3.

DEWAR INSTRUMENTATION



RDEWOUT: This is a carbon resistor mounted on a u-tube. It reads the temperature of the helium leaving the Dewar.

RDEW: This is a carbon resistor located inside the Dewar. It reads the Dewar temperature.

LLDEW: This is an AMI probe, used to measure the liquid level in the Dewar.

RDEWIN: This is a carbon resistor mounted on a u-tube. It reads the temperature of the helium entering the Dewar.

PDEW: This is a Setra transducer. It reads the internal pressure of the Dewar.

TDEW: This is a VPT charged with helium. It reads the temperature of the helium inside the Dewar.

PJB1: This is a Setra transducer. It reads the supply pressure of the helium in the junction box.

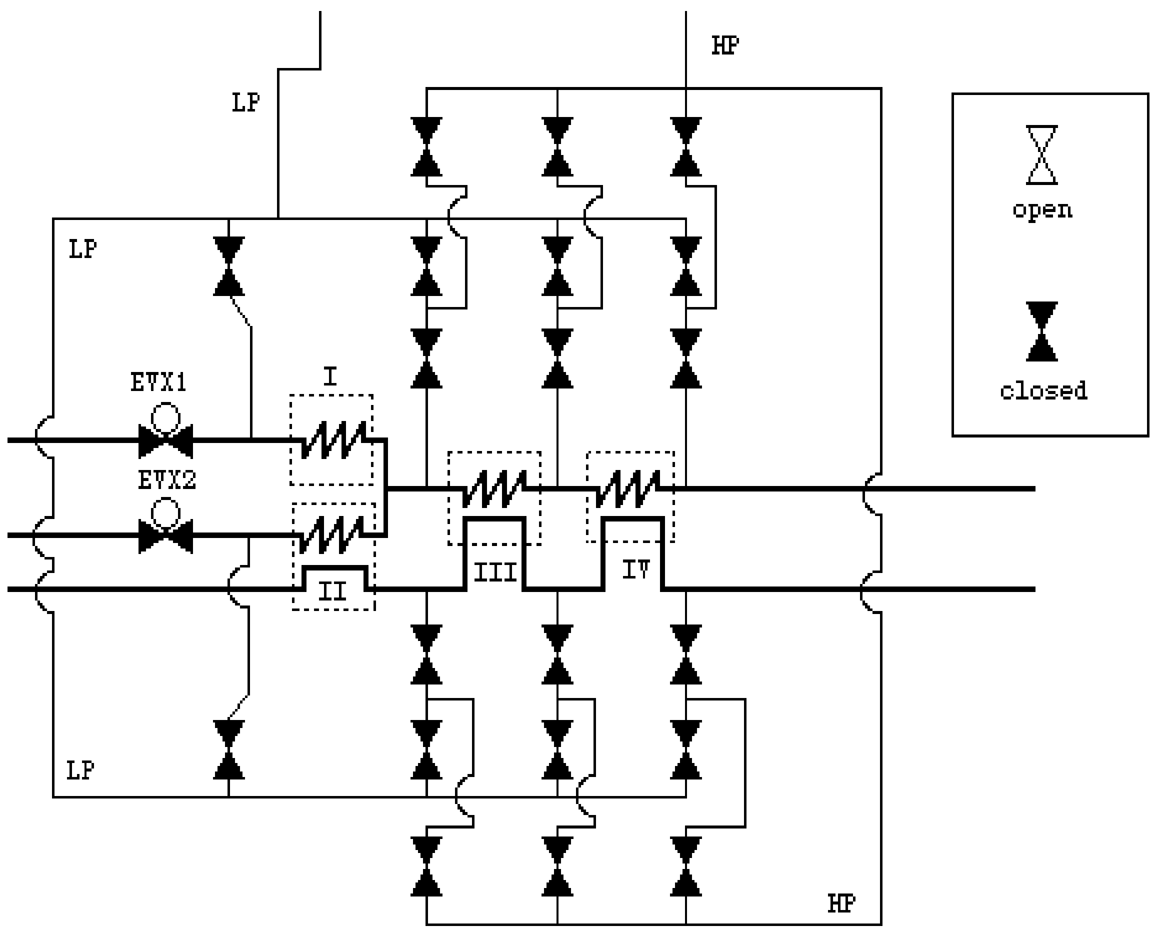
TJB1: This is a helium VPT, which measure the temperature of the supply helium.

PJB2: This is a Setra transducer. It reads the return pressure of the helium in the junction box.

TJB2: This is a helium VPT, which measure the temperature of the return helium.

BLOCK & BLEED

The block and bleed panel is a manifold system of valves used to connect various parts of the refrigerator together. During cool down of the refrigerator, this panel is always used to help speed up the process.

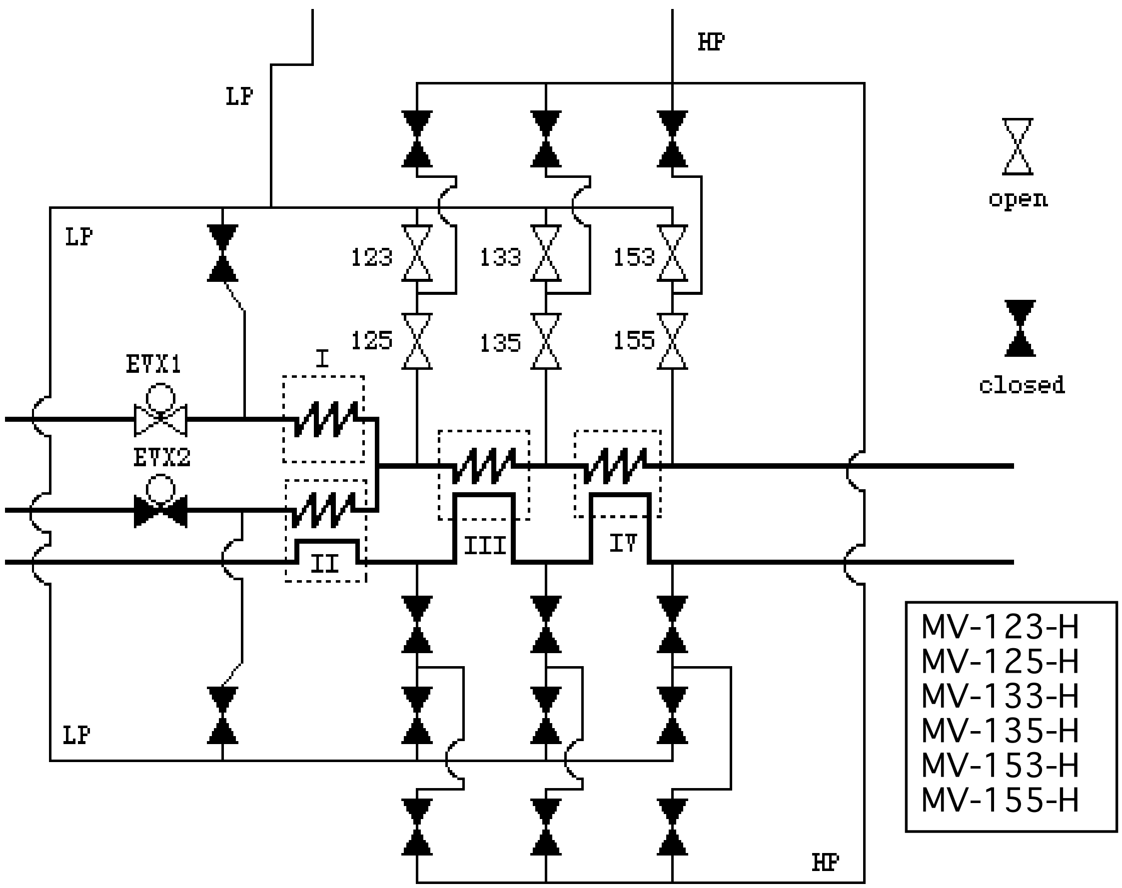


CLEANING THE SYSTEM

Before the following cool down process can begin, the system must be cleaned. Cleaning consists of flowing warm helium gas through each part of the system (compressor, heat exchanger, storage Dewar, magnet strings) and also through an adsorber. This cleaning must lower the contamination level to below 5 ppm on an ARC cell.

COOL DOWN

Please note which of the following block and bleed valves are open and which are closed.



The cool down procedure states that these valves (listed in the bottom corner of the diagram) should be open and possibly throttled.

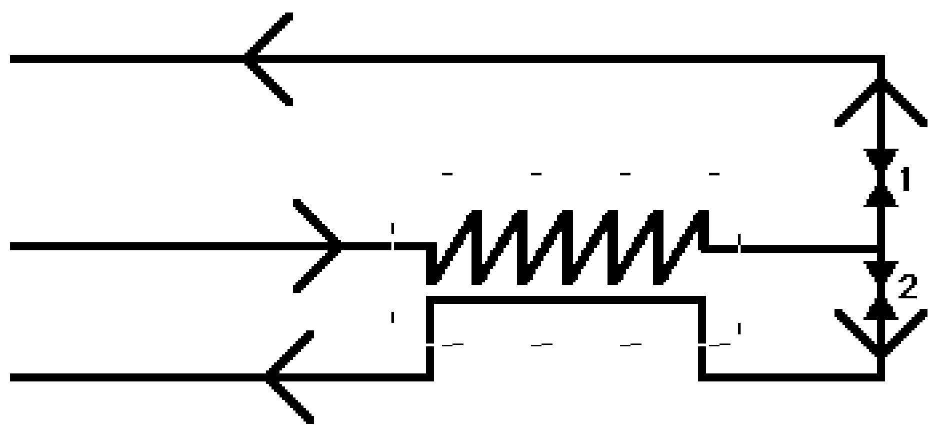
Valves **123** and **125** provide a single pass flow through HEX I, which aids in cooling the exchanger quickly. Throttling may be necessary to maintain stable suction pressure and to prevent relief valves from lifting. This portion of the procedure is the 300°K to 80°K transition. **IMPORTANT** - Once a heavy frost develops on these valves, they should be closed. This will direct more flow through HEX III.

Valves **133** and **135** provide a cool down path for HEX III. A heavy frost and proper instrument reading will dictate when to close these valves and direct more flow to HEX IV. The dry engine will be started when these valves are cold and are ready to be closed. This will establish a refrigerator flow path as well as begin the cool down of the shell sides of heat exchangers II and III.

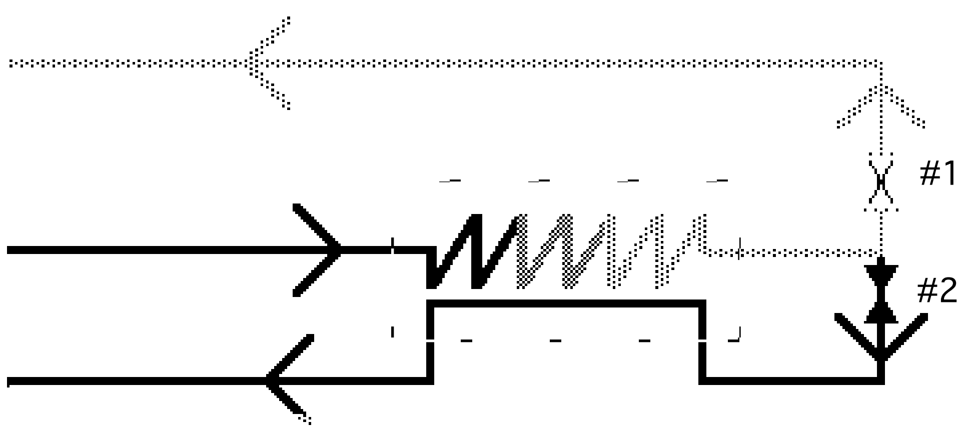
FLOW PATTERN

Why is single pass flow used?

Please look at the following diagrams and decide which of the two valves you would open to cool down this heat exchanger? Then think about why it might matter.

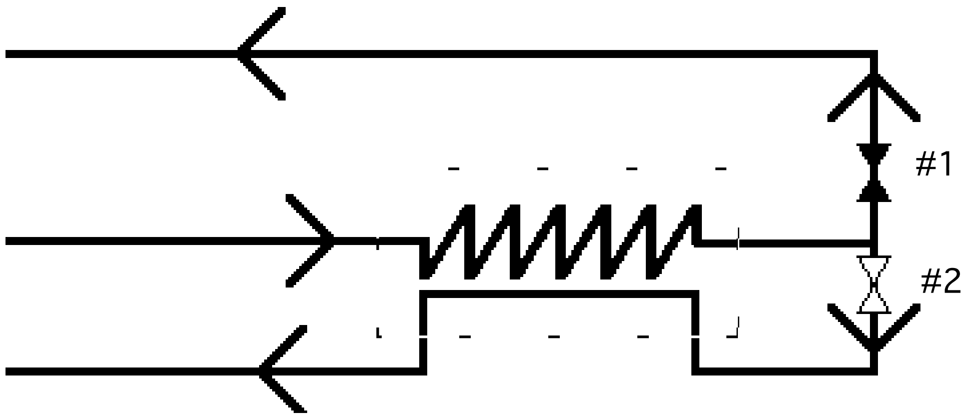


VALVE #1



Valve #1: Single pass flow is the proper method of cooling down the heat exchangers. When the tube side is cold, the heat exchanger can be "turned." (This method of single pass flow can also turn a Dewar.) The term "turned" means that the supply flow of gas can give up its heat to the return flow — you don't have a heat exchanger until this is possible.

VALVE #2



Valve #2: Do you remember this formula, T° in = S° out and T° out = S° in? If you bring a warm gas through the return side, you will simply warm the supply side and the heat exchanger will stay one temperature throughout. In order for a heat exchanger to function properly there must be a differential in temperature — there must be a cold end as well as a warm end.