TECHNICAL MANUAL
Liquid Tube Trailer
Model: HP^2-2500

Technical Service 800-400-4683
www.chartparts.com

MANUAL # 15093342
Rev – 2

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Draft	Original Issue 07/14/2011
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Rev – 2	Issue 11/01/2011

Chapter 1

1 SAFETY AND WARRANTY STATEMENT

1.1 SAFETY STATEMENT

All operators should have full and complete understanding of the content of this manual before operating the equipment described. The manual is intended to describe the operation of the equipment and not intended to supersede any site specific standards.

1.2 WARRANTY STATEMENT

(Reference – Refer to sales order documentation)

*Vacuum integrity as measured by conformance to Chart NER (**N**ormal **E**vaporation **R**ate) specifications is warranted for 1 years from the date of invoice.*

Piping components are warranted for a period of 90 days from the date of invoice or as warranted by OEM. Authorization to replace piping components can be given by the product manager, regional sales person or customer service representative.

*All replacements under warranty with a component price less than $75.00 will be replaced at no charge. The **R**eturn **M**aterial **A**uthorization (RMA) process must be initiated prior to replacements being sent out. All components exceeding $75.00 that are replaced under warranty will be invoiced to the customer. Upon return of the components the customer will be issued a credit based on our component evaluation.*

Chart Distribution and Storage Group will not be liable for product losses, component replacement labor exceeding 2 hours for actual replacement and 2 hours travel time (4 hours @ $65.00/hour), or any other costs not related to replacement of components covered by warranty.

Chapter 2

2 SAFETY

2.1 GENERAL

Cryogenic containers, stationary or portable are from time to time subjected to assorted environmental conditions of an unforeseen nature. This safety bulletin is intended to call attention to the fact that whenever a cryogenic container is involved in any incident whereby the container or its safety devices are damaged, good safety practices must be followed. The same holds true whenever the integrity or function of a container is suspected of abnormal operation.

Good safety practices dictate the contents of a damaged or suspect container be carefully emptied as soon as possible. Under no circumstances should a damaged container be left with product in it for an extended period of time. Further, a damaged or suspect container should not be refilled unless the unit has been repaired and re-certified.

Incidents which require that such practices be followed include: highway accidents, immersion of a container in water, exposure to extreme heat or fire, and exposure to most adverse weather conditions (earthquake, tornadoes, etc.) As a rule of thumb, whenever a container is suspected of abnormal operation, or has sustained actual damage, good safety practices must be followed.

In the event of known or suspected container vacuum problems (even if an extraordinary circumstances such as those noted above has not occurred), do not continue to use the unit. Continued use of a cryogenic container that has a vacuum problem can lead to embrittlement and cracking. Further, the carbon steel jacket could possibly rupture if the unit is exposed to inordinate stress conditions caused by an internal liquid leak.

Prior to reusing a damaged container, the unit must be tested, evaluated, and repaired as necessary. It is highly recommended that any damaged container be returned to Chart for repair and re-certification.

The remainder of this safety bulletin addresses those adverse environments that may be encountered when a cryogenic container has been severely damaged. These are oxygen deficient atmospheres, oxygen enriched atmospheres, and exposure to inert gases.

2.2 OXYGEN DEFICIENT ATMOSPHERES

The normal oxygen content of air is approximately 21%. Depletion of oxygen content in air, either by combustion or by displacement with inert gas, is a potential hazard and users should exercise suitable precautions.

One aspect of this possible hazard is the response of humans when exposed to an atmosphere containing only 8 to 12% oxygen. In this environment, unconsciousness can be immediate with virtually no warning. When the oxygen content of air is reduced to about 15 to 16%, the flame of ordinary combustible materials, including those commonly used as fuel for heat or light, may be extinguished. Somewhat below this concentration, an individual breathing the air is mentally incapable of diagnosing the situation because the onset of symptoms such as sleepiness, fatigue, lassitude, loss of coordination, errors in judgment and confusion can be masked by a state of "euphoria," leaving the victim with a false sense of security and well being.

Human exposure to atmosphere containing 12% or less oxygen leads to rapid unconsciousness. Unconsciousness can occur so rapidly that the user is rendered essentially helpless. this can occur if the condition is reached by an immediate change of environment, or through the gradual depletion of oxygen.

Most individuals working in or around oxygen deficient atmospheres rely on the "buddy system" for protection-obviously, the "buddy" is equally susceptible to asphyxiation if he or she enters the area to assist the unconscious partner unless equipped with a portable air supply. Best protection is obtainable by equipping all individuals with a portable supply of respirable air. Life lines are acceptable only if the area is essentially free of obstructions and individuals can assist one another without constraint.

If an oxygen deficient atmosphere is suspected or known to exist:

1. **Use the "buddy system." Use more than one "buddy" if necessary to move a fellow worker in an emergency.**
2. **Both the worker and "buddy" should be equipped with self-contained or airline breathing equipment.**

2.3 OXYGEN ENRICHED ATMOSPHERES

An oxygen-enriched atmosphere occurs whenever the normal oxygen content of air is allowed to rise above 23%. While oxygen is nonflammable, ignition of combustible materials can occur more readily in an oxygen-rich atmosphere than in air; and combustion proceeds at a faster rate although no more heat is released.

It is important to locate an oxygen system in a well ventilated location since oxygen-rich atmospheres may collect temporarily in confined areas during the functioning of a safety relief device or leakage from the system.

Oxygen system components, including but not limited to, containers, valves, valve seats, lubricants, fittings, gaskets and interconnecting equipment including hoses, shall have adequate compatibility with oxygen under the conditions of temperature and pressure to which the components may be exposed in the containment and use of oxygen. Easily ignitable materials shall be avoided unless they are parts of equipment or systems that are approved, listed, or proved suitable by tests or by past experience.

Compatibility involves both combustibility and ease of ignition. Materials that burn in air may burn violently in pure oxygen at normal pressure, and explosively in pressurized oxygen. In addition, many materials that do not burn in air may do so in pure oxygen, particularly when under pressure. Metals for containers and piping must be carefully selected, depending on service conditions. The various steels are acceptable for many applications, but some service conditions may call for other materials (usually copper or its alloy) because of their greater resistance to ignition and lower rate of combustion.

Similarly, materials that can be ignited in air have lower ignition energies in oxygen. Many such materials may be ignited by friction at a valve seat or stem packing, or by adiabatic compression produced when oxygen at high pressure is rapidly introduced into a system initially at low pressure.

2.4 NITROGEN AND ARGON

Nitrogen and argon (inert gases) are simple asphyxiates. Neither gas will support or sustain life and can produce immediate hazardous conditions through the displacement of oxygen. Under high pressure these gases may produce narcosis even though an adequate oxygen supply sufficient for life is present.

Nitrogen and argon vapors in air dilute the concentration of oxygen necessary to support or sustain life. Inhalation of high concentrations of these gases can cause anoxia, resulting in dizziness, nausea, vomiting, or unconsciousness and possibly death. Individuals should be prohibited from entering areas where the oxygen content is below 19% unless equipped with a self-contained breathing apparatus. Unconsciousness and death may occur with virtually no warning if the oxygen concentration is below approximately 8%. Contact with cold nitrogen or argon gas or liquid can cause cryogenic (extreme low temperature) burns and freeze body tissue.

Persons suffering from lack of oxygen should be immediately moved to areas with normal atmospheres. SELF-CONTAINED BREATHING APPARATUS MAY BE REQUIRED TO PREVENT ASPHYXIATION OF RESCUE WORKERS. Assisted respiration and supplemental oxygen should be given if the victim is not breathing. If cryogenic liquid or cold boil-off gas contacts worker's skin or eyes, the affected tissue should be flooded or soaked with tepid water (105-115ºF or 41-46ºC). DO NOT USE HOT WATER. Cryogenic burns that result in blistering or deeper tissue freezing should be examined promptly by a physician.

Additional information on nitrogen and argon and liquid cylinders is available in CGA Pamphlet p-9. Write to the Compressed Gas Association, Inc., New York, NY 10110.

NOTE:

Extracted from Safety Bulletin SB-2 from Compressed Gas Association, Inc., New York, dated March 1966 and from the "Nitrogen Material Safety Data Sheet"" published by Air Products and Chemicals, Inc., Allentown, PA 18105, dated 1 June 1978.

Chapter 3

3 SYSTEM INFORMATION

3.1 RECEIVING CHECKPOINTS

1. Check braces, skids, wooden chocks, and other shipping supports. Damage or deformation would indicate the possibility of mishandling during shipment.

2. Examine welded or brazed joints on plumbing for cracks or deformation, especially near valves and fittings.

3. Check points where pipes exit the tank for cracks or breaks.

4. Check relief valves and burst discs for dirt or damage.

5. Check vessel pressure using vessel Pressure Indication Gauge (PI-01). If pressure is zero, extra precautions against contamination and impurities must be taken.

6. Check for any damage to trailer components, vessel or piping due to shipping issues. If visual damage has occurred notify your company's tank specialist and/or CHART prior to filling.

7. Check the container vacuum.

    a) If warm vacuum is above 20 microns, consult factory.

3.2 VACUUM CHECK PROCEDURE

CAUTION: UNAUTHORIZED CHANGING OF THE VACUUM PROBE WILL VOID VESSEL WARRANTY.

1. The standard CHART vacuum probe is a Teledyne-Hastings DV-6R probe. Select a compatible instrument to read the output of the vacuum probe.

2. Remove the rubber cap on probe outlet to expose contact. Note .that probe housing need not be opened to do this.

3. Plug the instrument to the probe and calibrate the instrument.

4. Open the vacuum probe isolation valve. Wait for 5 minutes and take vacuum reading. Note that valve handle protrudes through protective housing and can be turned without opening the housing.

5. Close the isolation valve and take a second reading. Monitor the rate of rise in vacuum probe with isolation valve closed. If the vacuum continues to rise at a constant rate, it is possible that the probe assembly is leaking. Consult the factory.

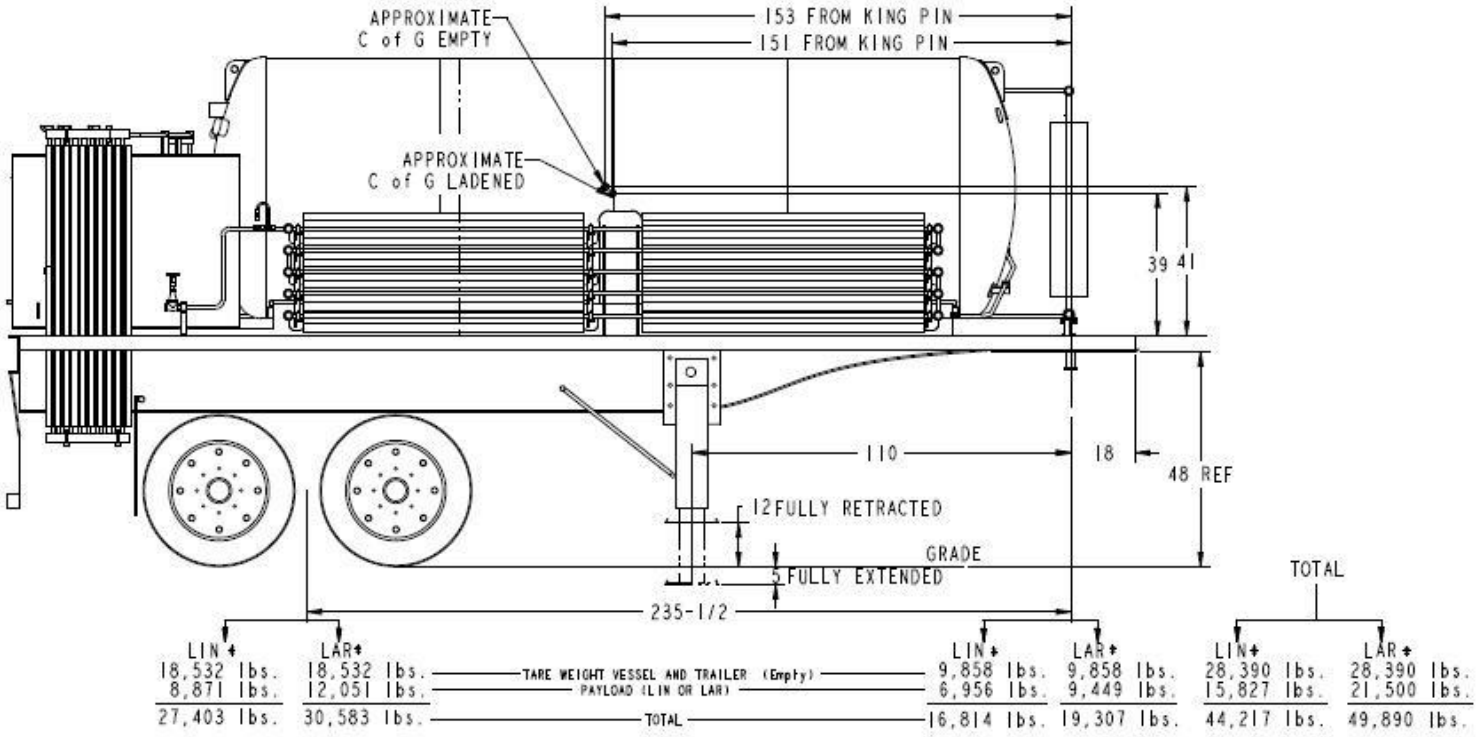
6. Verify that the isolation valve is closed.

7. Replace the rubber probe cap.

Record vacuum readings for future reference and compare current vacuum reading with reading taken prior to shipping. Vacuum levels will vary slightly as vessel temperatures change.

3.3 SYSTEM OVERVIEW

Figure 1 - Summary of Dimensions and Weights (Details from O & D drawing found in appendix)



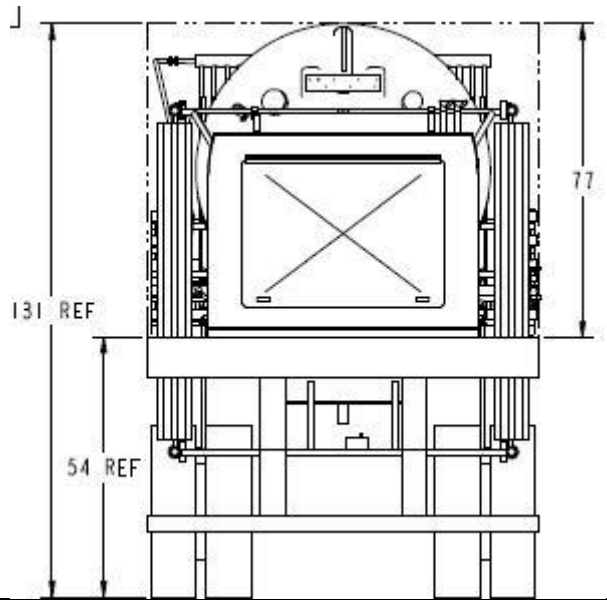
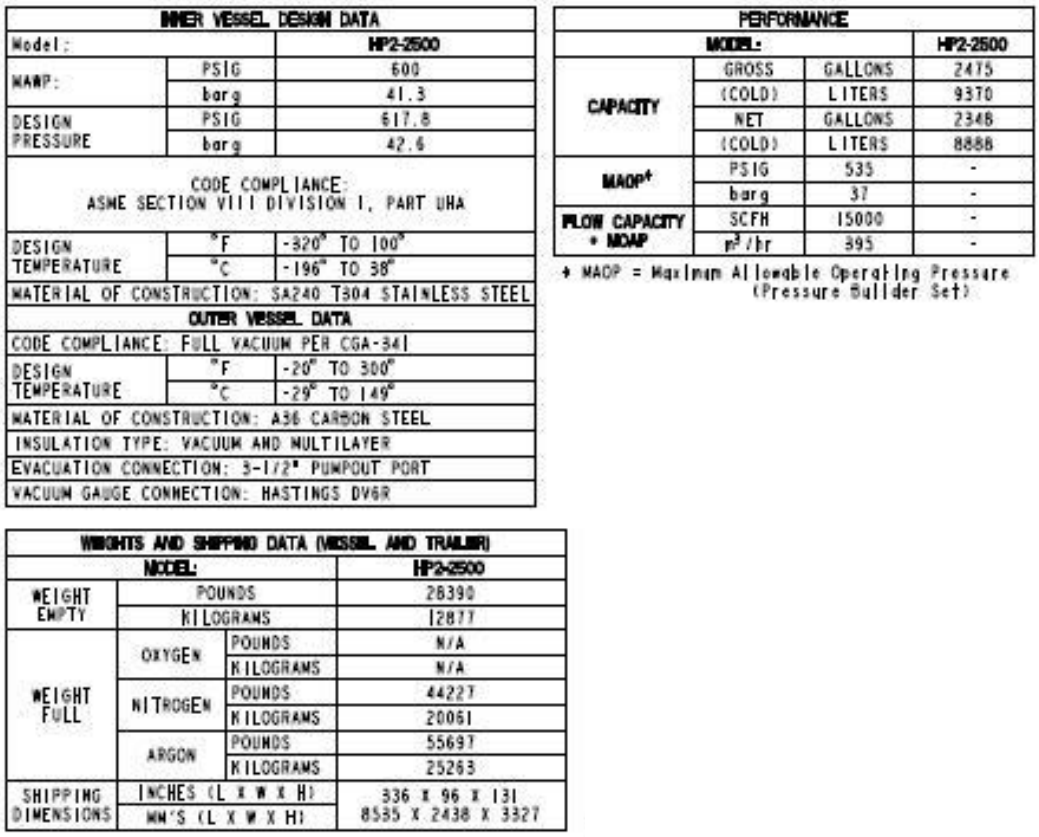


Figure 2 - General Specifications (From O&D Drawing)



INNER VESSEL DESIGN DATA		
Model:		HP2-2500
MAWP:	PSIG	600
	barg	41.3
DESIGN PRESSURE	PSIG	617.8
	barg	42.6
CODE COMPLIANCE: ASME SECTION VIII DIVISION 1, PART UHA		
DESIGN TEMPERATURE	°F	-320° TO 100°
	°C	-196° TO 38°
MATERIAL OF CONSTRUCTION: SA240 T304 STAINLESS STEEL		
OUTER VESSEL DATA		
CODE COMPLIANCE: FULL VACUUM PER CGA-341		
DESIGN TEMPERATURE	°F	-20° TO 300°
	°C	-29° TO 149°
MATERIAL OF CONSTRUCTION: A36 CARBON STEEL		
INSULATION TYPE: VACUUM AND MULTILAYER		
EVACUATION CONNECTION: 3-1/2" PUMPOUT PORT		
VACUUM GAUGE CONNECTION: HASTINGS DV6R		

PERFORMANCE			
MODEL:			HP2-2500
CAPACITY	GROSS (COLD)	GALLONS	2475
		LITERS	9370
	NET (COLD)	GALLONS	2348
		LITERS	8888
MAOP†	PSIG		535
	barg		37
FLOW CAPACITY * MOAP	SCFH		15000
	m^3/hr		395

† MAOP = Maximum Allowable Operating Pressure (Pressure Builder Set)

WEIGHTS AND SHIPPING DATA (VESSEL AND TRAILER)			
MODEL:			HP2-2500
WEIGHT EMPTY	POUNDS		28390
	KILOGRAMS		12877
WEIGHT FULL	OXYGEN	POUNDS	N/A
		KILOGRAMS	N/A
	NITROGEN	POUNDS	44227
		KILOGRAMS	20061
	ARGON	POUNDS	55697
		KILOGRAMS	25263
SHIPPING DIMENSIONS	INCHES (L X W X H)		336 X 96 X 131
	MM'S (L X W X H)		8535 X 2438 X 3327

The Liquid Tube Trailer HP^2-2500 is an innovative mobile gas supply system. It's a versatile solution for a wide range of temporary applications typically supported by gaseous high pressure tube trailers in nitrogen or argon service. With its patented on-board high pressure, high performance pressure builder and vaporizer design, the Liquid Tube Trailer precisely manages the heat for optimum gas flow while keeping the liquid cold for maximum hold time during intermittent use and reduced filling losses.

Applications can now be serviced with one dedicated asset ready to be refilled on site with an Orca® or cryogenic transport without taking the application off line (low pressure applications). This unique mobile gas supply system can be configured to a wide range of pressures and flows to supply many applications with gas *or* liquid and can easily be switched from service to service as needed. The Liquid Tube Trailer is also ideal for customer start ups, bulk supply trials, as a backup for servicing permanent cryogenic equipment, or as an Orca backup.

PRODUCT HIGHLIGHTS VS. GAS TUBE TRAILER

• Only one unit per application required • Lower gas distribution costs • Higher customer gas utilization • Zero to low gas losses (pressure dependent) • Refill without taking application off line* • 45% greater storage capacity than super jumbos • No hidden costs from DOT requalification testing • Less wear and asset tie-up on HP pump	• 16 ft. shorter trailer length (28 ft vs. 44 ft) • Transportable under full product load • Easy service change • No external power required • Works in liquid nitrogen freezing applications • Orca emergency delivery backup • Data Online® Wireless Telemetry & GPS available ** Low pressure applications only*

A Chart vessel is designed for long-term storage of cryogenic liquefied gases under pressure in the range of 5 PSI (0.4 kg/cm^2) to the MAWP (Maximum Allowable Working Pressure). Operation of the equipment is fully automatic with the unit's pressure control system set to maintain preset pressure and flow conditions into a customer's pipeline.

The vessel is comprised of a stainless steel inner tank encased in an outer carbon steel vacuum shell. The insulation system between the inner and outer containers consists of composite insulation and high vacuum to ensure long holding time. The insulation system designed for long-term vacuum retention is permanently sealed at the factory to ensure vacuum integrity. The units have a tank pressure relief device, which is set at the factory. As a secondary pressure relief device, the container is further protected from over-pressurization by a rupture disc. The bursting disc will rupture completely to relieve inner tank pressure in the event the tank relief valve fails and pressure exceeds the rupture disc setting. The vacuum space is protected from over-pressurization by use of a tank annulus rupture disc assembly. Pressure relief devices used on Chart vessels designed for the U.S. specifications meet the requirements of CGA Pamphlet S1.3, "Pressure Relief Device Standards, Part 1, for Stationary Vessels."

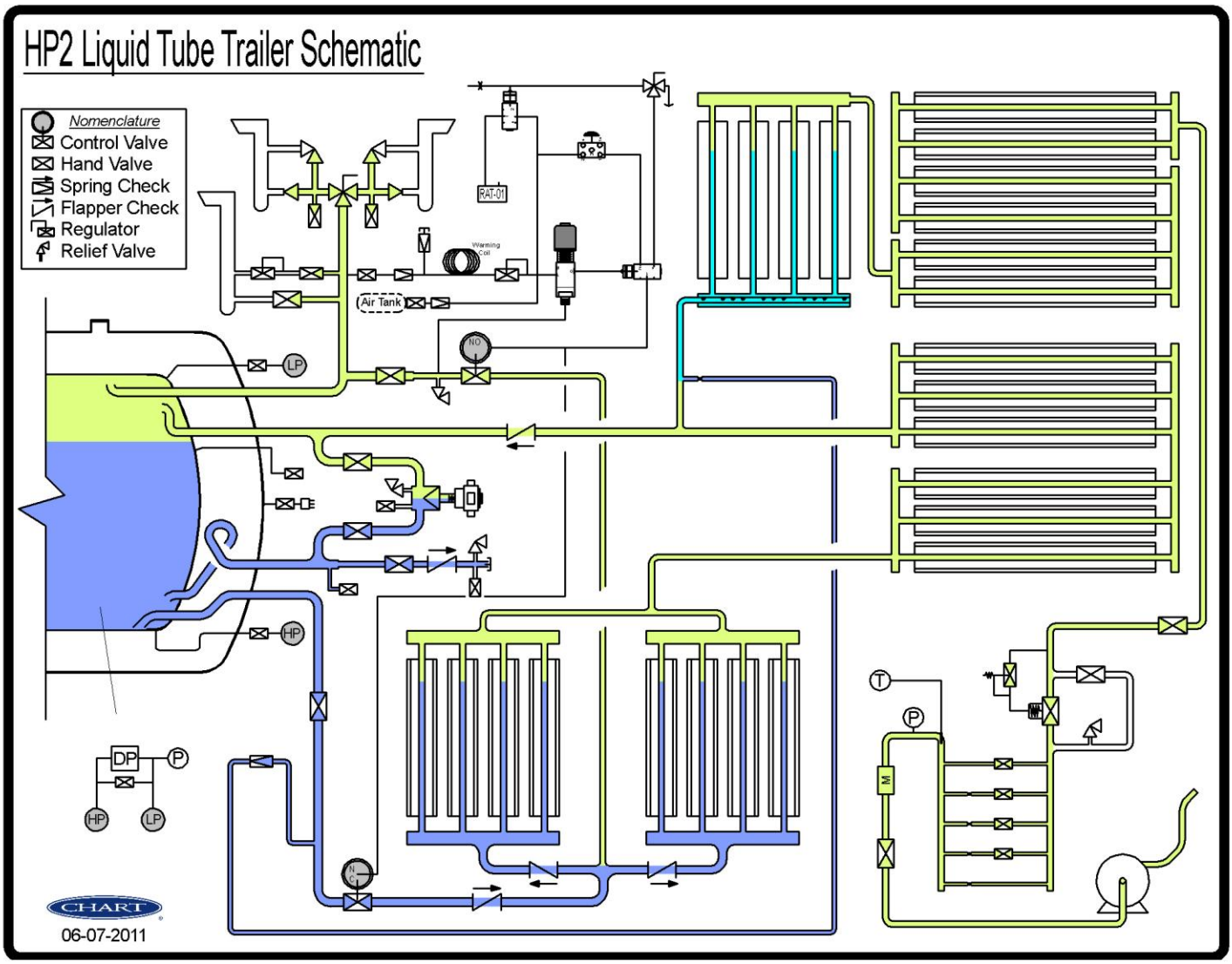
Lifting lugs are secured to the heads and are intended to be only used when the tank is empty. Moving requires the use of a crane and adherence to specific rigging instructions, which may vary from vessel to vessel. Some Chart vessels cannot be lifted with one hook only.

Controls, Pressure Gauge And Liquid Level Gauge Used To Operate The System Are located in the Piping Cabinet with the End User Controls Located on the Curbside.

3.4 OPERATING DESCRIPTION

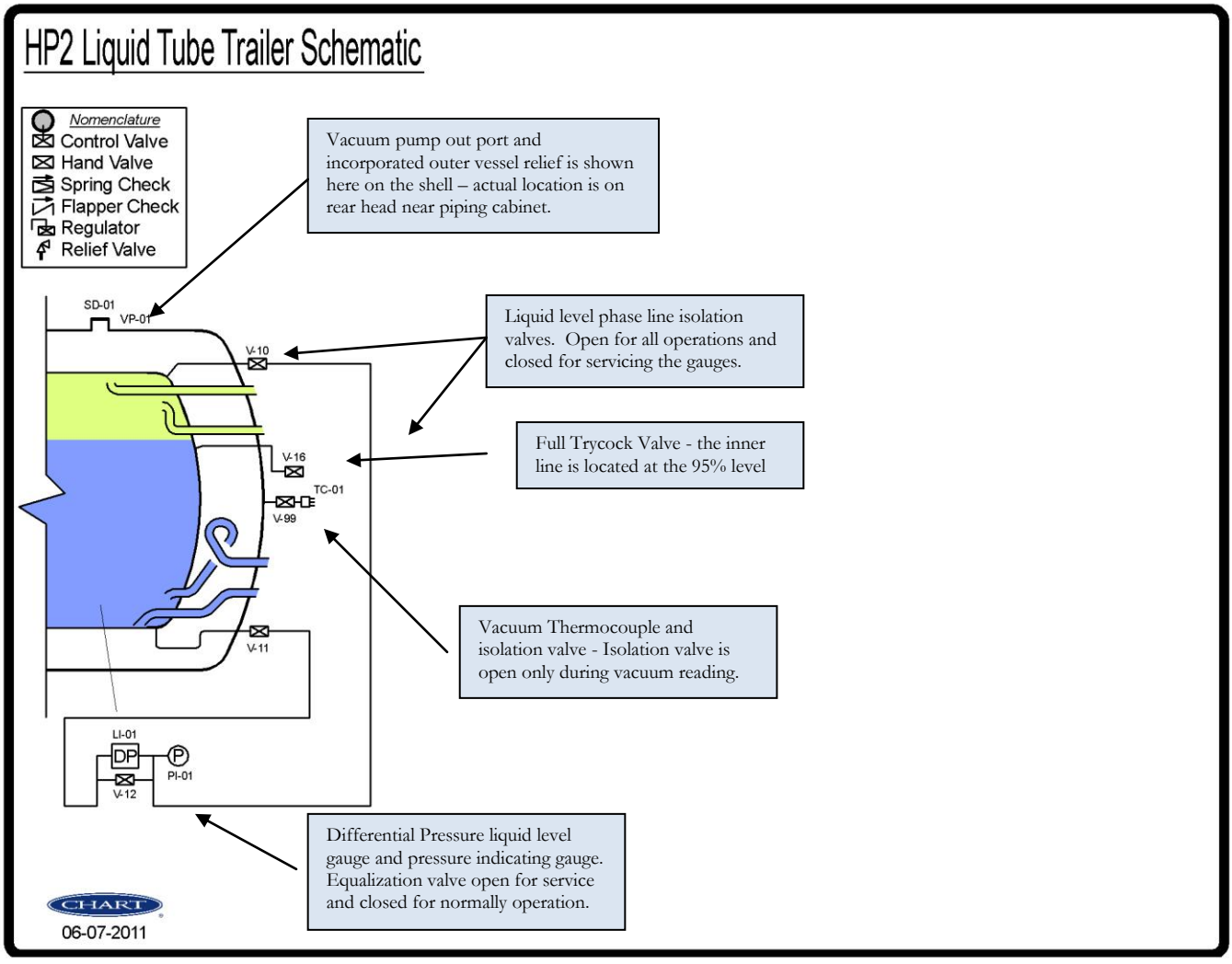
The flow scheme is based on Charts patented (US patent # 6,799,429) HP2 pressure building and gas withdrawal system. The following sections will break down the overall schematic (Figure 3) into the individual circuits.

Figure 3 - Overall Schematic



3.5 OUTER VESSEL CONNECTIONS/GAUGES ASSY

Figure 4 - Outer Vessel Connections/Gauge Assembly



The outer vessel vacuum pump connection (pump out) is located on the piping end of the vessel above the cabinet. It is Charts bulk tank standard pump-out. The vacuum port plug also acts as the outer vessel relief. Annular leaks will result in pressurization of the vacuum space and this plug will lift.

See section 3.2 for vacuum level procedure.

Liquid level indication uses differential pressure gauge to measure the level. The level measurement is in inches of water. A look up chart is used to convert the indication to a weight or volume.

Table 1 - Outer Vessel Connections/Gauge Assembly

Code	Description	Function
V-10	VALVE, GAS PHASE LOW	• Isolation valve to repair/replace liquid level gauge
V-11	VALVE, LIQUID PHASE HIGH	• Isolation valve to repair/replace liquid level gauge or pressure gauge.
V-12	VALVE, EQUALIZATION	• With the liquid phase high and low closed, this valve is opened to equalize pressure on the high and low side of the liquid level gauge to service or check the gauges zero point.
V-16	VALVE, FULL TRYCOCK	• Line feeding valve is at 95% level (per CGA 341 a safe fill level).
V-99	VALVE, TC-01 ISOLATION	• Isolates TC probe. • Only open when checking vacuum • Close immediately after checking to prevent potential vacuum leaks in through the assembly.
LI-01	LEVEL INDICATOR, INNER	• Liquid level is measured using differential pressure between a high phase tap (liquid side of tank very close to the bottom of the tank) and low phase tap (vapor side of tank).
PI-01	PRESSURE INDICATOR, INNER	• To indicate storage pressure.
TC-01	THERMOCOUPLE, OUTER Vacuum	• To check vacuum levels between the inner and outer vessels. • Isolation valve V-99 must be opened to measure vacuum.
VP-01	VACUUM PORT	• Large pump out port. Consult factory for vacuum assistance.
SD-01	PRESSURE SAFETY ELEMENT, OUTER	• To protect the outer vessel during inner vessel failure.

3.6 VENT ASSEMBLY

Dual relief vent circuit allows for "on the fly" servicing of reliefs and burst discs. The vessel is built to the DOT exception that requires the vessel pressure to be below 25.4 psig during transit. The reliefs meet or exceed the ASME and CGA requirements. Maintaining transit pressure is accomplished by the road relief circuit/regulator.

The diverter valve that selects the relief and burst disc allows full rated flow in any position and has no off position. It is recommended under normal operating conditions to keep the diverter in a mid position. This will keep full pressure on all relief components allowing the operator during relief failure to isolate the relief needing service with confidence that the active reliefs are functioning properly.

Figure 5 - Vent Circuit

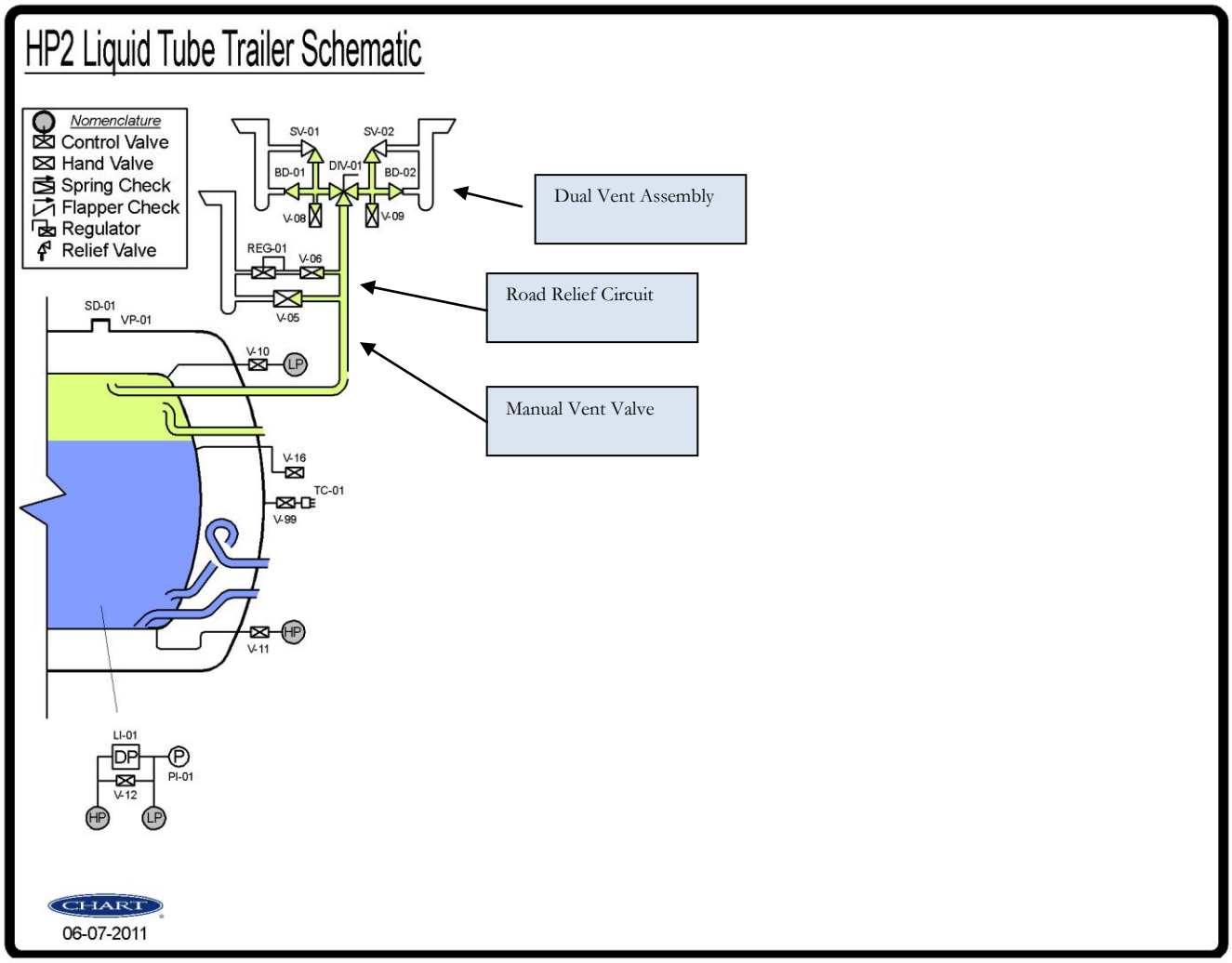


Table 2 - Vent Components

Code	Description	Function
V-05	VALVE, MANUAL VENT	• Classic manual vapor vent valve. • When open, the storage gas flows from the storage to the vent stack.
V-06	VALVE, ROAD RELIEF	• Classic road relief valve. • When open, the storage gas flows from the storage to the secondary pressure control valve. • Used to control pressure during transit. (To meet DOT/CGA rules the storage pressure must be below 25.4 psig for transit)
V-08	VALVE, DUAL RELIEF DRAIN	• To replace a safety relief valve : - Isolate using the diverter valve - Open the dual relief drain to vent piping between the diverter and the safety.
V-09	VALVE, DUAL RELIEF DRAIN	• To replace a safety relief valve : - Isolate using the diverter valve - Open the dual relief drain to vent piping between the diverter and the safety.
REG-01	REGULATOR, ROAD RELIEF	• To meet DOT requirements and CGA - 341 the storage pressure must be below 25.4 psig during transit. • This regulator is set at 17psig and vents the storage to this pressure when the road relief valve is open.
SV-01	SAFETY RELIEF VALVE, VENT	• Main storage vessel safety valve set at 600 psig. • This is an ASME relief valve and has a + or - 10% tolerance.
SV-02	SAFETY RELIEF VALVE, VENT	• Main storage vessel safety valve set at 600 psig. • This is an ASME relief valve and has a + or - 10% tolerance.
BD-01	BURST DISC, VENT CIRCUIT	• Main storage vessel secondary safety (burst disc) set at 900 psig. • This is sized to satisfy the relief during a fire condition. • There is no need to meet CGA over fill requirements due to the high main safety setting.
BD-02	BURST DISC, VENT CIRCUIT	• Main storage vessel secondary safety (burst disc) set at 900 psig. • This is sized to satisfy the relief during a fire condition. • There is no need to meet CGA over fill requirements due to the high main safety setting.
DIV-01	VALVE DIVERTER, DUAL RELIEF	• This diverter ball valve shuts off the flow to the burst disc or relief set that needs servicing : - It is recommended to leave the diverter valve in a mid position. This will keep pressure on both sets of reliefs/burst discs. This will give some assurance that one set will be OK when servicing.

3.7 TOP AND BOTTOM FILL ASSY

This is a classic top and bottom fill assembly. See section 5 for fill procedures. The system allows for simultaneously fill and gas withdrawal if use pressures are less than supply pressures.

The top and bottom fill valves are throttled to maintain vessel pressures above use pressures. Basic operation is to top fill to reduce pressures (entering cold liquid will collapse vapor space) and increase pressure by bottom filling (reduction of vapor space increases vessel pressure).

Figure 6 - Top and Bottom Fill Assembly

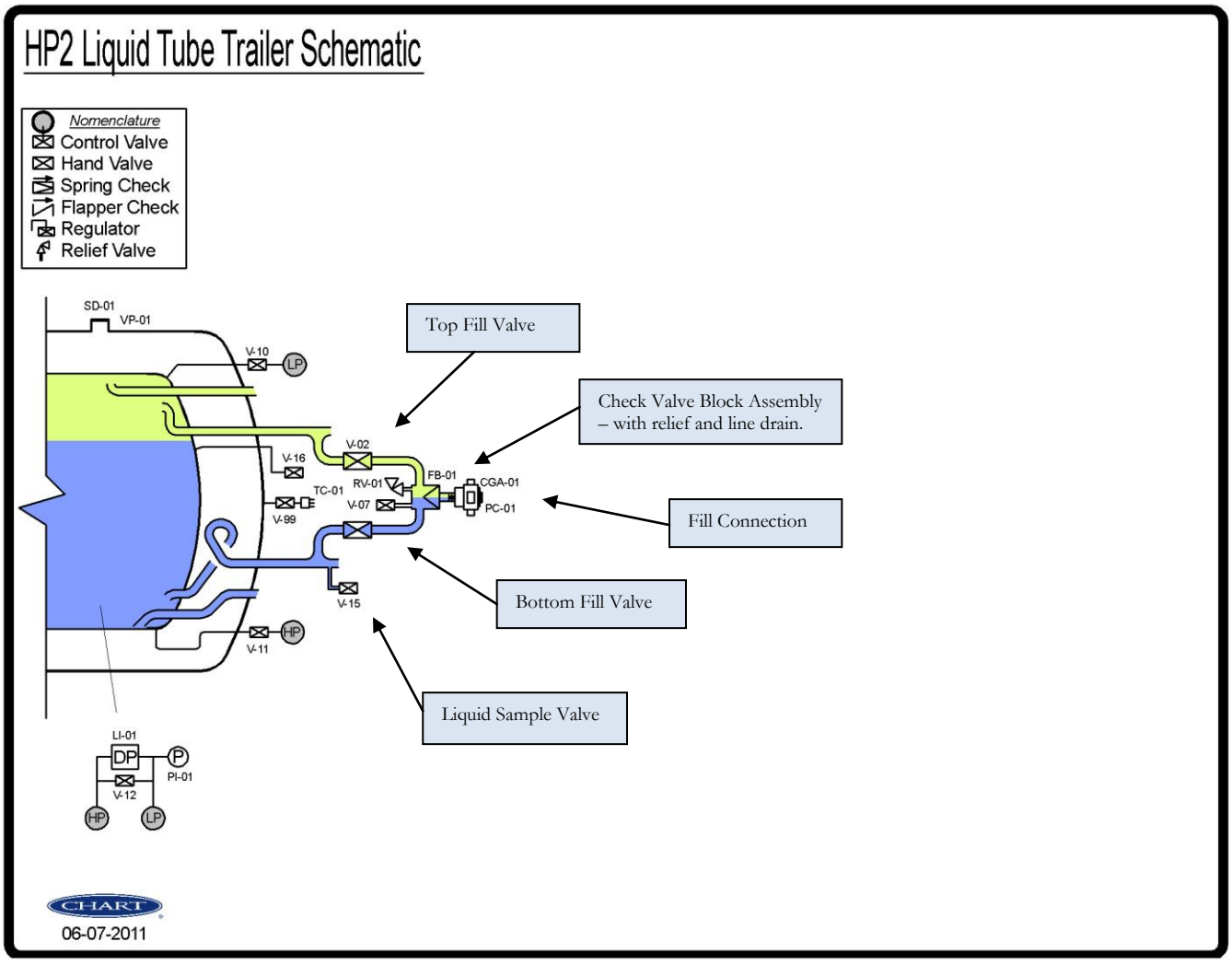


Table 3 - Top and Bottom Fill Components

Code	Description	Function
V-01	VALVE, BOTTOM FILL	• Classic Bottom Fill Valve. • To direct the flow to the bottom/liquid side of the tank, this valve is opened. • Used during filling when transferring liquid that is warmer than the stored liquid.
V-02	VALVE, TOP FILL	• Classic Top Fill Valve. • When open, flow is directed to the top/vapor side of the tank. • Used during filling when transferring liquid that is colder than the stored liquid.
V-07	VALVE, FILL LINE DRAIN	• Classic Top and Bottom fill circuit line drain. • To assure that the pressures are low enough to safely remove the fill hose, this valve is opened. • The liquid drains through the valve and is directed outside the cabinet on the curbside.
V-15	VALVE, LIQUID SAMPLE	• To check purity
RV-01	VALVE RELIEF, TOP AND BTM FILL	• To protect the fill hose and associated fittings : - This is set at 450 psig due to the limitation of the Brass CGA fittings. - Assure fill hose (not supplied) is rated to 450psig if not, replace with appropriate relief.
FB-01	FILL BLOCK WITH CHECK VALVE	• The check valve prevents reverse flow and potential contamination during filling. • Fill block has multiple ports for top, bottom fill lines, thermal relief, line drain and fill connection.
PC-01	CAP CGA PRESSURE	• CGA Liquid fill connection pressure cap. • Acts as a secondary shut-off and dust cap.
CGA-01	CGA FITTING 1-1/2" MALE	• Standard CGA fill connection.

3.8 PRESSURE BUILDING CIRCUIT

HP2 pressure building uses vertical coils to change the state of the liquid source, vaporizing coils to warm the gas to near ambient temperatures, check valves to assure flow to the vapor side of the tank and control valves (pneumatic operated ball valves) that create high flow and precise control. The vertical coils are located on both sides of the piping cabinet and the horizontal warming coil is mounted to the vessel on the driver's side. Along with supplying PB gas to tank, the PB circuit supplies gas to the use circuit. The coils are optimized for space available.

The PB liquid feed line is a dedicated line. The line has minimal trapping to assure performance at lower levels. Due to this minimal trapping the pipe is insulated from its exit point to the PB isolation valve.

Figure 7 - Pressure Building Circuit

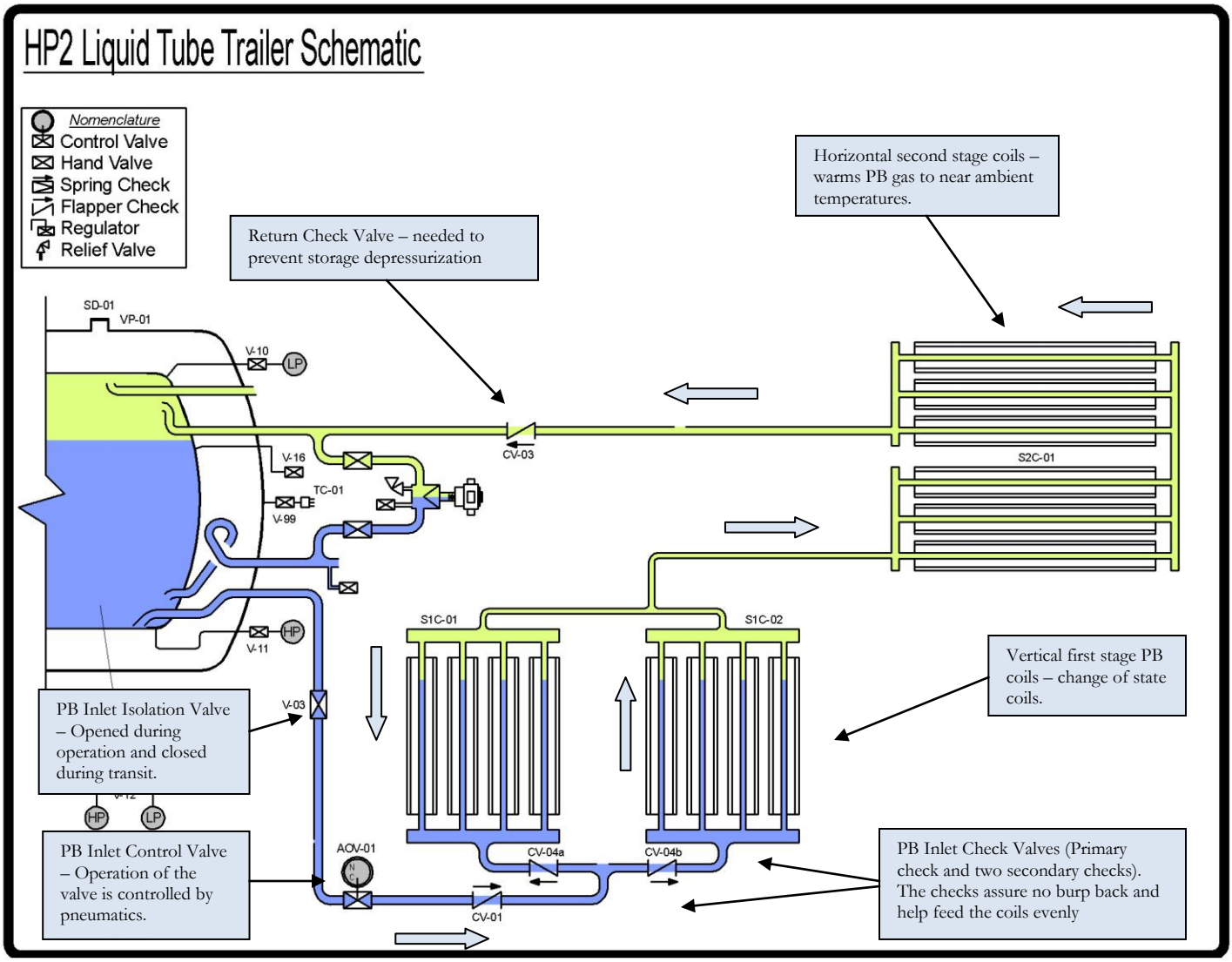


Table 4 - Pressure Building Circuit Components

Code	Description	Function
V-03	VALVE, P. B. FEED	• PB inlet isolation Valve. • Open valve to allow flow to PB. • Closed for transit and service.
CV-01	VALVE CHECK, P. B. FEED	• Forces the "liquid surges" to flow to the vertical PB coils located on the side of the cabinet • Prevents "burping" into the liquid from the PB.
CV-03	VALVE CHECK, GAS RETURN	• Allows flow into the storage space only. • Allows flow from the PB and prevents flow from the storage vapor space.
CV-04A	VALVE CHECK, P. B. FEED LEFT	• Forces the "liquid surges" to flow to the vertical PB coils located on the driver side (left) of the cabinet.
CV-04B	VALVE CHECK, P. B. FEED RIGHT	• Forces the "liquid surges" to flow to the vertical PB coils located on the curb side (right) of the cabinet.
AOV-01	AIR OPERATED VALVE, P. B.	• This is an Air Operated Ball valve : - The actuator uses gas between 75 and 150 psig to rotate the ball valve. - The valve is configured to be normally closed or pressure to open. • When open, liquid from the storage tank is allowed to flow to the PB coils.
S1C-01	COIL, PRESSURE BUILD	• Driver side Vertical Pressure Builder. • First stage/phase separation coil.
S1C-02	COIL, PRESSURE BUILD	• Passenger/Curbside Vertical Pressure Builder. • First stage/phase separation PB coil.
S2C-01	COIL, VAPORIZER	• Driver side Horizontal Pressure Builder. • Second Stage/Gas Warming coil. • Warm PB gas as warm as possible. (The warmer the return gas is, the faster the pressure build)

3.9 VAPORIZING CIRCUIT

High flow vaporization is challenging due to entrainment, pressure drop and heat transfer, all being complicated by space limitations. Entrainment was solved using a vertical coil (S3V-01 located at the front of the trailer) design to phase separate the gas/liquid mixture. A header in the inlet manifold evenly distributes the flow and the multiple fins reduce the flow velocities trapping (by gravity) the entrained liquid. The trapped liquid is vaporized before exiting the top manifold. The horizontal final stage coil (S4C-01) is designed with parallel coils in series to minimize pressure drop. Large single finned coils optimize heat transfer in horizontal orientation.

Figure 8 - Vaporizing Circuit

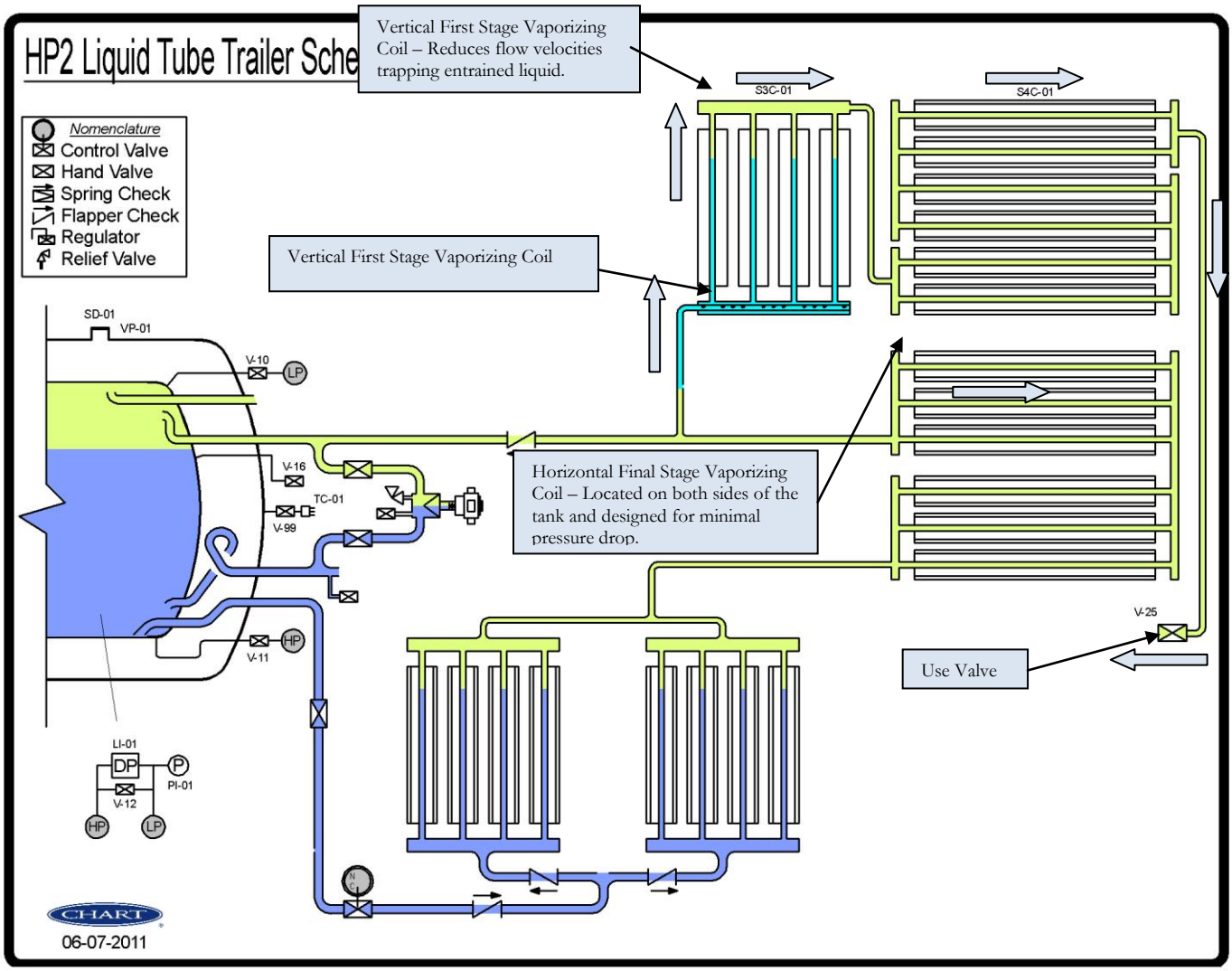


Table 5 - Vaporizing Coil

Code	Name	Function
S3C-01	COIL PRE VAPORIZER	• Front vertical vaporizing coil. • First stage/phase separation coil.
S4C-01	COIL, VAPORIZER	• Driver's side/Curbside horizontal vaporizing coil. • Feed from the first stage vaporizing coil on the driver's side and ends on the curbside. • The coil warms the use gas to near ambient temperatures.
V-25	VALVE, HOSE REEL FEED	• Isolation valve to the use manifold. • Closed for transit.

3.10 LIQUID ASSIST CIRCUIT

During high flow demands a small amount of liquid is allowed to flow into the gas use flow stream. The amount of liquid is controlled with an orifice (R-02) and a spring check valve (CV-02). The liquid is drawn from the PB inlet piping. The liquid assist feed piping has a reverse trap to help promote liquid flow into the PB during liquid assisting.

Figure 9 – Liquid Assist Circuit

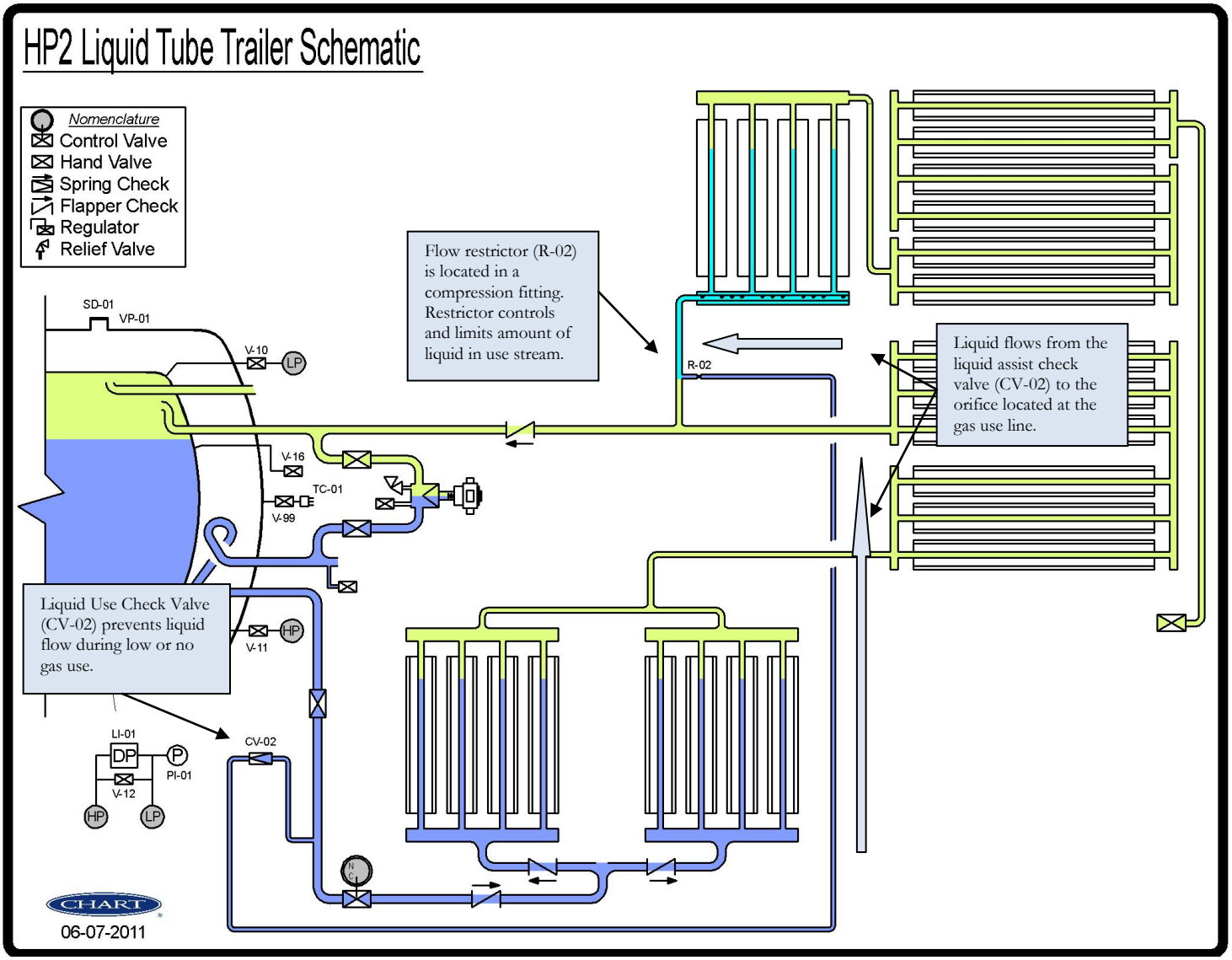


Table 6 - Liquid Assist Components

Code	Description	Function
CV-02	VALVE CHECK, LIQUID ASSIST	• This is a spring check with a 5 psi cracking pressure. • Allowing the flow of liquid into the gas use stream "super charging" the gas stream. (During high gas withdrawal flows, this check valve opens)
R-02	RESTRICTOR ORIFICE	• Allowing a small amount of liquid to enter the gas stream. - This small amount of liquid super charges the gas withdrawal making the extreme flows possible.

3.11 ECONOMIZING CIRCUIT

When pressures reach the high set point of the PB controls, the economizing control valve (AOV-02) opens drawing gas from the vessels vapor space. The economizing gas is directed to the inlet of the vertical PB coils. Gas mixes with the residual liquid in the PB causing it to flash and warm the coils.

Figure 10 - Economizing Circuit

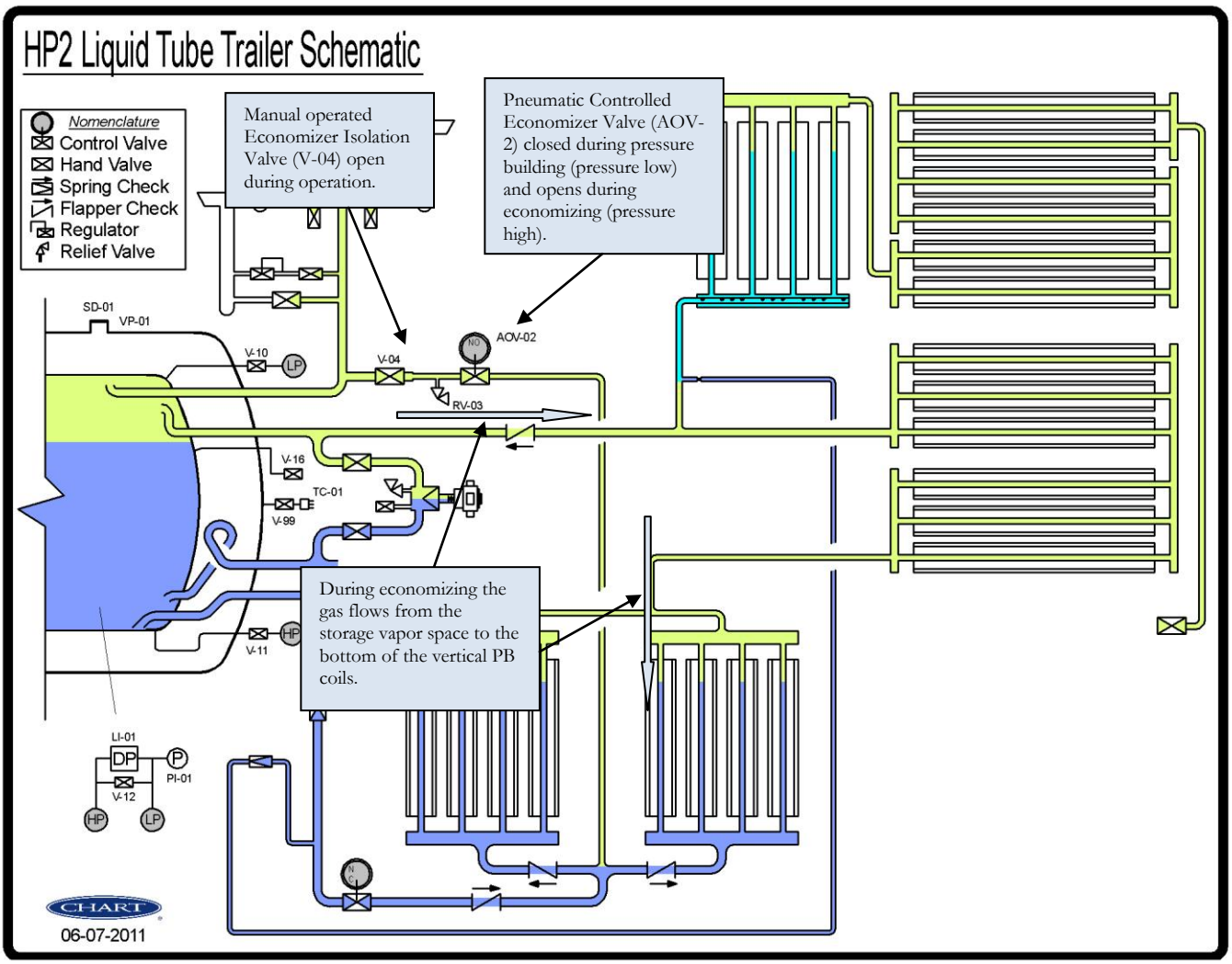


Table 7 – Economizing Circuit Components

Code	Description	Function
V-04	VALVE, P. B. ISOLATION	PB outlet isolation Valve. Opened to allow flow from the PB to the top of the storage. Also, economizing gas passes through this valve Closed for transit and service.
RV-03	VALVE RELIEF, P. B.	Thermal/Line safety to protect piping, PB return isolation valve and PB return control valve.
AOV-02	AIR OPERATED VALVE, ECONO.	This is an Air Operated Ball valve. The actuator uses gas between 75 and 150 psig to rotate the ball valve. The valve is configured to be normally opened or pressure to close. When open gas from the storage tank is allowed to flow to the use coils.

3.12 LIQUID USE CIRCUIT

Liquid withdrawal is possible through the Liquid Use Circuit. The pressure building circuit is capable of maintain pressures long term at flows around 10 gallons per minute and short term at 40 gpm.

Figure 11 – Liquid Use Circuit

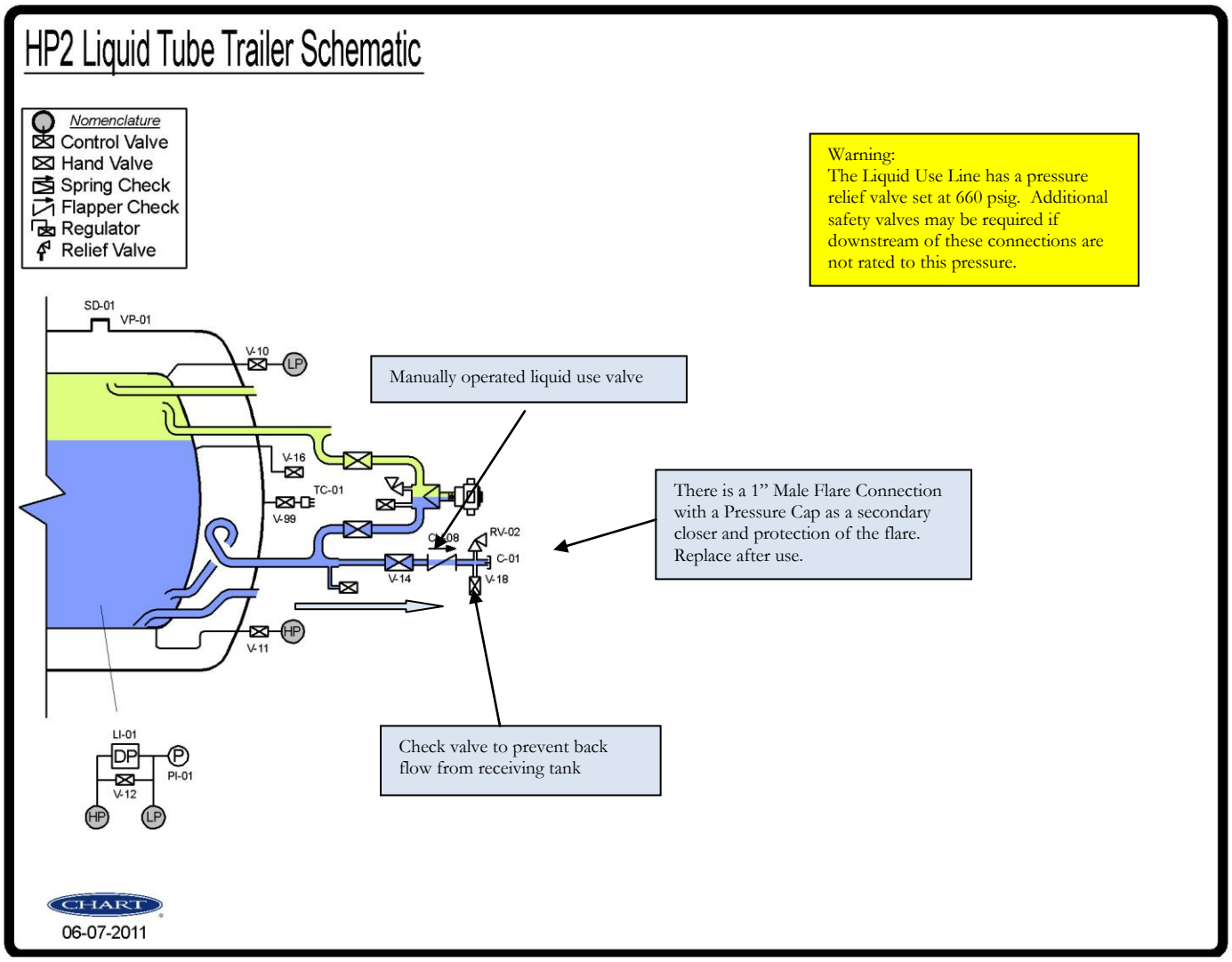


Table 8 - Liquid Withdrawal Components

Name	Description	Function
V-14	VALVE, LIQUID WITHDRAWAL	• Allowing liquid to flow out of storage when it is opened.
V-18	VALVE, LIQUID USE DRAIN	• Vents liquid use line and hose to atmosphere : - Allowing for safe hose removal.
CV-08	VALVE CHECK, LIQUID USE	• Prevents reverse flow and potential contamination during liquid transfer.
RV-02	VALVE RELIEF, LIQUID USE	• Thermal or line safety to protect the transfer hose and associated fittings: - This is set at 660 psig. - Assure that the transfer hose used is rated to 660psig if not, replace with appropriate relief.
C-01	CAP, LIQUID USE	• Liquid use connection (1" flare) pressure cap. • Acts as a secondary shut-off

Chapter 4

4 SYSTEM CONTROLS

The system achieves high flow rates, fast pressure building and fully pneumatic controls using a unique pressure switch and pneumatic controlled ball valves. The system is unique to our industry but is simple and hopefully easy to understand and operate. Gas from the storage (or brake system at low storage pressure) is the pneumatic gas that is used to open and close the control valves. The operator turns on the PB by pulling the PB On Valve (pushing to turn off system). Set point is set by turning the Pressure Control Valve knob. The details will be explained in the following sections.

4.1 FULLY PNEUMATIC PRESSURE CONTROL

The heart of the system controls is a fully pneumatic pressure switch. The pressure switch is connected to the vapor space of the storage. The pressure switch is a 3-way valve that is controlled by the vapor space pressure. This pressure connection drives an internal piston against a spring (adjustable to set pressure). When the piston moves due to high pressure position supply pressure is closed to the switch output and the output port vents to atmosphere. At low pressures the spring drives the piston to the open position, supply gas is directed to the output and the air operated ball valves.

The system uses the pneumatic gas to drive a vibrator to knock off the ice on the coils. This "Rattle Valve" (RAT-01) is located under the trailer and is connected to both vertical PB coils. The Rattle Valve is operated when the PB control valve closes and Economizer control valve opens. The coils are the coldest at this time and the ice is at its driest condition. The goal is to prevent the melting and re-freezing at the bottom of the coils. Ice dramatically reduces the heat transfer of the coils.

To increase the response time of the pneumatics additional pneumatic valves and actuators are used. These addition components are described in table 8.

Figure 12 - Fully Pneumatic Pressure Control Circuit

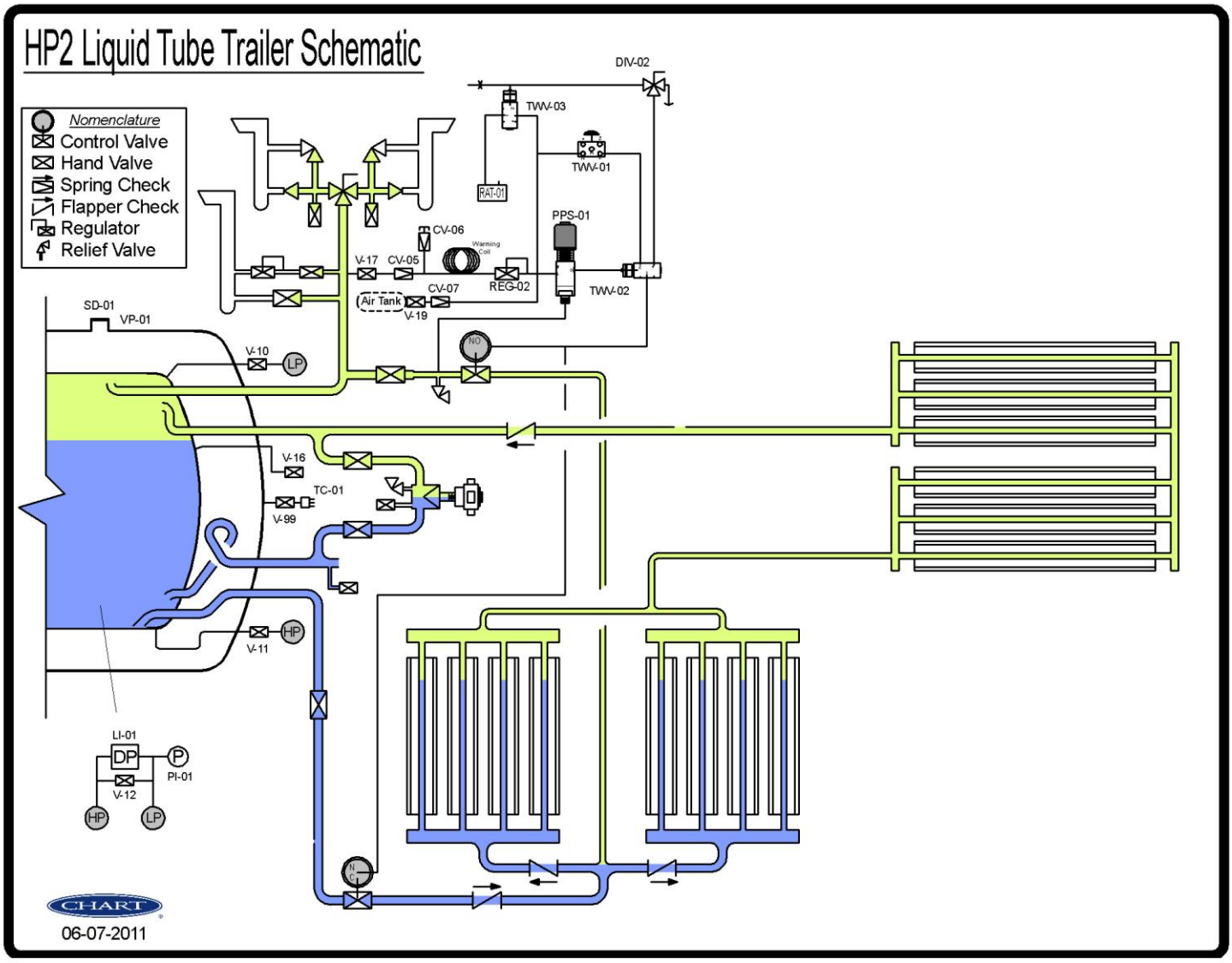


Table 9 - Control Circuit Component Listing

Code	Description	Function
V-17	VALVE, PNEUMATIC SUPPLY	• Isolation valve for pneumatic gas supply for controls.
V-19	VALVE, PRESSURE PROTECTION	• Protects air brake air supply from leaks. (Set at 55psig)
CV-05	VALVE CHECK, PNEUMATIC SUPPLY	• This check valve prevents flow to the storage from the air system. • At low storage pressures the pneumatic controls use air pressure from the trailer air brakes.
CV-06	VALVE CHECK, AUXILARY AIR	• This check valve provides an access point from emergency supply gas. • If the pressure is too low in the storage and in the air brakes, pneumatic control gas will need to be supplied from an external source. Remove the plug from the check valve (CV-06) and supply 100 psig dry gas to the exposed connection to activate the controls.
CV-07	VALVE CHECK, TRAILER AIR	• This check valve prevents gas flow from the storage to the air brakes.
REG-02	REGULATOR, PNEUMATIC ASSIST	• Prevents over-pressurization of the actuators. - The control valves operate using a pneumatic actuator. The actuator requires a minimum of 75 psig to open/close and is limited at a maximum pressure of 150 psig.
DIV-02	VALVE DIVERTER, PNEU. SUPPLY	• This valve turns on and off the rattler (vibrating de-icer) : - Position 1 allows the pneumatics discharge to flow to rattler operator. - Position 2 directs the discharge to atmosphere.
PPS-01	PNEUMATIC PRESSURE SWITCH	• Fully pneumatic pressure switch is settable from 200 to 750 psig (option available in a lower range). • A storage gas phase line is connected to the bottom of the switch (PPS-01) which drives a 3 way valve: - At low pressures, gas is directed to the pneumatic control valve TWV-02 opening the PB control valve (AOV-01) and closing the economizer control valve (AOV-02). - At high pressures, the pneumatic control gas at TWV-02 is vented to atmosphere closing the PB control valve (AOV-01) and opening the economizer control valve (AOV-02)
TWV-01	PNEUMATIC CONTROL ON/OFF	• Pulling this valve activates the PB control pneumatics. • Pushing in the valve de-activates the control pneumatics. • Allowing flow of gas to the control actuators when this valve is opened.
TWV-02	PNEU.C CTRL AOV-01 AND AOV-02	• This is a 3 way valve : - Controlled by a small pneumatic actuator that opens the 3 way valve when a pressures source higher than 5 psig is supplied
TWV-03	PNEUMATIC CONTROL RAT-01	• This is a 3 way valve : - Controlled by a small pneumatic actuator that opens the 3 way valve when a pressures source higher than 5 psig is supplied controlling the gas supply to the ice management system (rattler).
RAT-01	VALVE, RATTLER	• To vibrate the PB coils to knock off the ice : - The rattler operates at the end of a PB cycle when the ice is at its coldest. - An off balanced turbine rotates when gas is supplied to its inlet. The rotating off balanced turbine vibrates.

4.2 OPTIONAL GAS USE MANIFOLD

The optional Gas Use Manifold assembly is designed to give the end user safe gas use control. Gas temperature, Flow Rates, final line pressure and throttling tree of valves help to safely control the gas flow.

The final line pressure is controlled by a dome loaded regulator. The dome pressure is controlled (along with the final line pressure) with a small venting style regulator that is simple to adjust. The regulators can be by-passed by opening a by-pass valve.

The "Throttling Tree" allows the operator to adjust the flow rate up or down slowly to minimize excess flow conditions. The operator simply opens valves to maintain flows at safe conditions (flow and temperature).

A variable area gas flow meter gives the operator an accurate measure of the current flow rate. A final line pressure gauge, a look up table and the flow meter display are used to determine the final line flow rate. See section 6.3, Table 19, figure 58 and Example 1 for details.

Figure 13 - Optional Gas Use Manifold

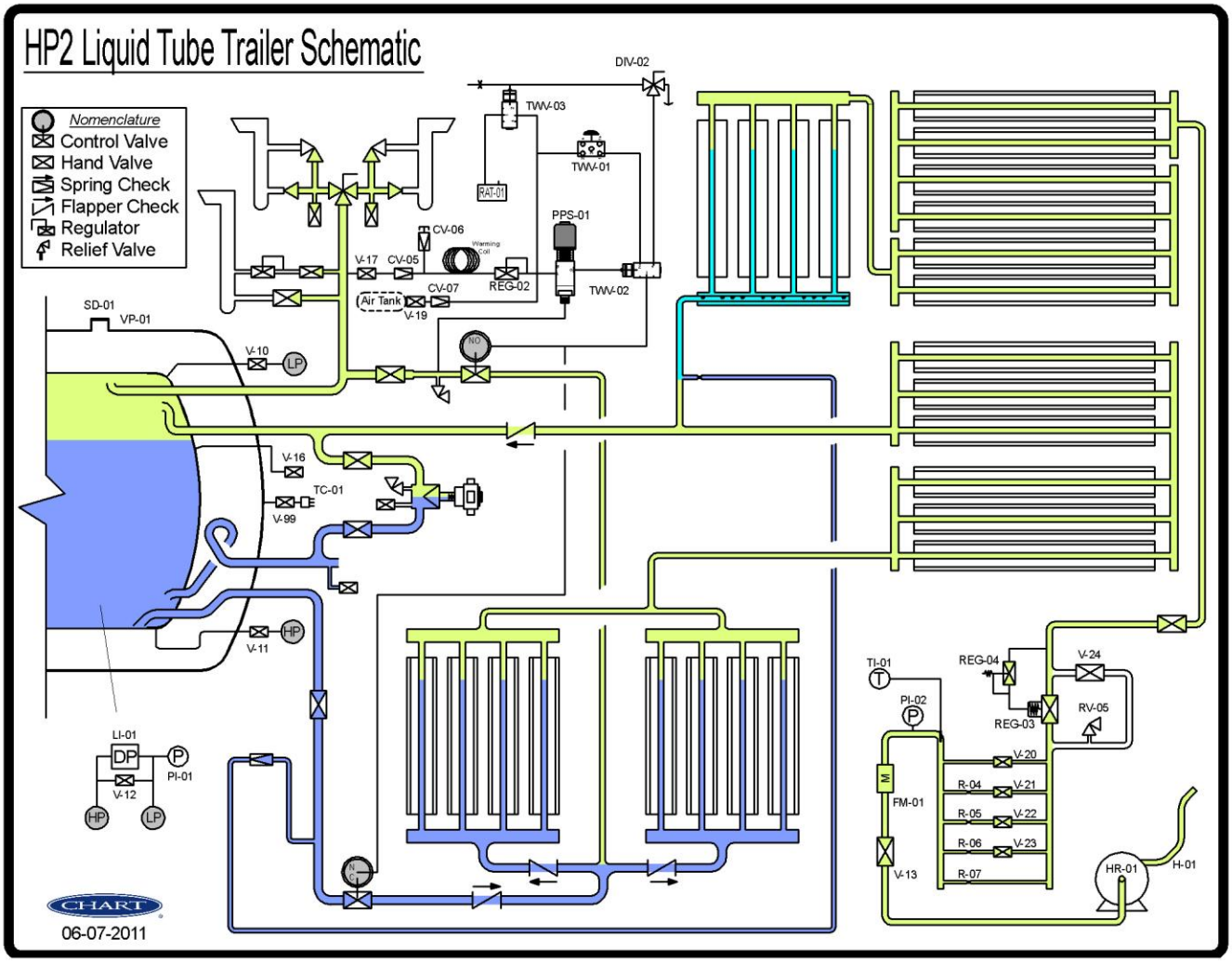


Table 10 - Optional Gas Use Manifold Component Listing

Code	Description	Function
V-13	VALVE, GAS USE	• Used to control gas withdrawal from system.
FM-01	FLOW METER	• This is a variable area gas flow meter : - Flow rates are calculated based on gas pressures, temperatures and product pass thru. There is a lookup table near the meter for nitrogen at 50 degrees F and the system operating pressures.
H-01	HOSE 3/4"MPT * 50 FT 1000PSI	• Optional use 50 foot use hose. Rated to 1000 psi and -40 degF.
HR-01	HOSE REEL	• Optional hose reel for hose
PI-02	PRESSURE INDICATOR, USE	• Use pressure indicator downstream of regulation.
TI-01	TEMPERATURE INDICATOR, USE	• Use gas temperature indication with thermo well.
R-04	RESTRICTOR ORIFICE	• Orifice in the gas use line. • When use control valve V-20 is opened, flow passes through the orifice. Allows operator to step up flow by simply opening inlet valve. The restriction helps with preventing hose whip, keeping safe line temperatures and maintaining appropriate flow rates.
R-05	RESTRICTOR ORIFICE	• Orifice in the gas use line. • When use control valve V-21 is open flow passes through the orifice. Allows operator to step up flow by simply opening inlet valve. The restriction helps with preventing hose whip, keeping safe line temperatures and maintaining appropriate flow rates.
R-06	RESTRICTOR ORIFICE	• Orifice in the gas use line. • When use control valve V-22 is open flow passes through the orifice. Allows operator to step up flow by simply opening inlet valve. The restriction helps with preventing hose whip, keeping safe line temperatures and maintaining appropriate flow rates.
R-07	RESTRICTOR ORIFICE	• Orifice in the gas use line. • With the Manifold Feed Valve (V-25) open and the Gas Use Valve (V-13) open flow passes through the orifice. Allows operator to start a flow at a flow rate that is safe for initial leak checking. The restriction helps with preventing hose whip, keeping safe line temperatures and maintaining appropriate flow rates.
REG-03	REGULATOR, USE	• The use regulator is Dome loaded which allows for easy setting with a control regulator on the dome • Allowing for high system flow rates with minimal pressure drop due to the design
REG-04	REGULATOR, USE CONTROL	• Control regulator is used to set the dome loaded regulator : - Increase setting by rotating clockwise - Decrease setting rotating counter clockwise.

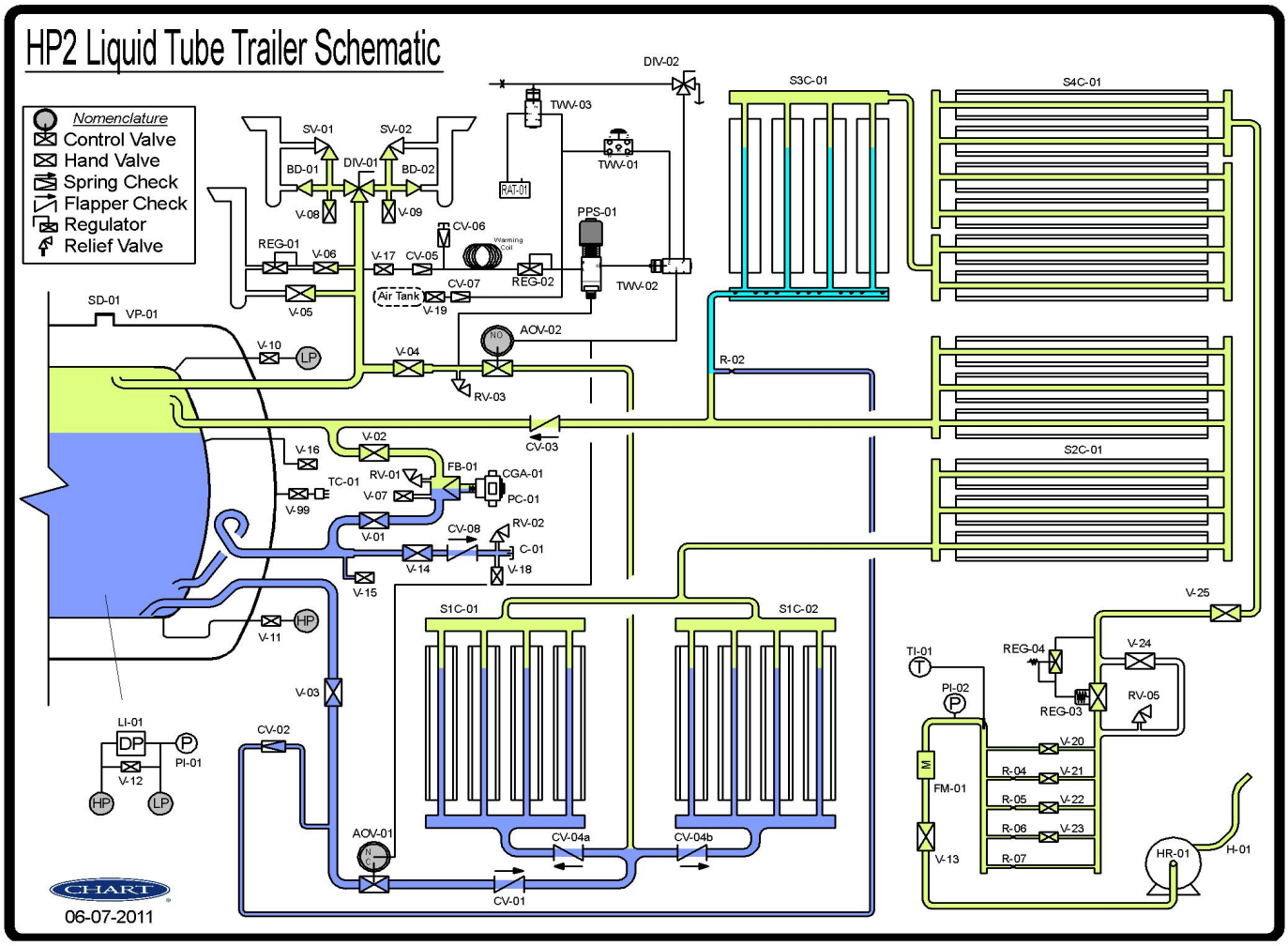
RV-05	VALVE RELIEF, REG. BY-PASS	• It is possible to have liquid or very cold gas within the use manifold. • This relief is set at 660 psi and protects the assembly when all valves are closed.
V-20	VALVE, USE CONTROL	• The use control valves allow the operator to slowly increase (or decrease) the flow by simply opening a ball valve. • This valve has no restrictor and when open maximizes flow.
V-21	VALVE, USE CONTROL	• The use control valves allow the operator to slowly increase (or decrease) the flow by simply opening a ball valve. • This valve directs the flow to restrictor orifice R-04.
V-22	VALVE, USE CONTROL	• The use control valves allow the operator to slowly increase (or decrease) the flow by simply opening a ball valve. • This valve directs the flow to restrictor orifice R-05.
V-23	VALVE, USE CONTROL	• The use control valves allow the operator to slowly increase (or decrease) the flow by simply opening a ball valve. • This valve directs the flow to restrictor orifice R-06.
V-24	VALVE, REGULATOR BY-PASS	• This valve is a by-passes the use regulating assembly. • This valve is used when the PB controls are adequate pressure control or when use pressures need to be above 500psig with minimal pressure drop.

Chapter 5

5 FILLING PROCEDURES

This chapter provides the initial fill, gas use, liquid delivery, and refilling procedures for the vessel described in this manual. Before performing any of the procedures contained in this chapter, become familiar with the location and function of the controls and indicators.

Table 11 Schematic Reference



5.1 INITIAL FILL

The initial fill is usually performed on a warm vessel, one that has not been in use for an extended period. The warm container must be purged to ensure product purity.

When preparing the tank for filling or when changing service, the following items should be considered:

1. The vessel should be inspected for possible damage or unsuitability for intended use. If damage is detected (e.g. serious dents, loose fittings, etc.) remove the unit from service and perform repairs as soon as possible.

2. The vessel may be filled by pumping or pressure transfer. If vessel pressure is at least 50 PSI (3.5 kg/cm^2) less than the maximum allowable pressure of the supply unit, liquid may be transferred by pressure transfer. If the normal working pressure of the station is equal to or greater than the maximum allowable pressure of the supply unit, liquid must be pumped into the tank.

3. To remove the moisture or foreign matter from the tank or tank lines, the vessel must be purged. Use a small amount of new product for purging when changing service and a small amount of the same product if the purge is to ensure purity or remove contaminants.

4. When changing service, the approved CGA (or other keyed) fitting will have to be installed for connection FC-1.

Table 12 Vessel Purging Procedure

STEP NUMBER	Purging Procedure
	CAUTION
	Purge pressure should be greater than 75 psig to assure operation of the control valves. To prevent drawing atmospheric contaminants back into the tank, a positive pressure of at least 5 PSI (0.4 kg/cm^2) must always be maintained in the tank.
	Attach the source of liquid purge to the fill connection (CGA-01).
1	Close all valves except the pressure build isolation valves (V-03,V-04) and liquid level gauge vapor phase and liquid phase shutoff valves (V-10, V-11).
	NOTE
2	To assure a proper purge occurs between PB Feed Check valves (CV-01,CV-04a and CV-04b) and the PB Feed control valve (AOV-01) activate the PB Circuit by: Turn On the controls by pulling the PB On/Off switch (TWV-01) and reduce the current pressure setting by turning the Pneumatic Pressure Switch (PPS-01) counter-clockwise to minimum setting. Open hose drain valve (V-07), and allow source to vent through hose. Vent until slight frosting appears on hose. Close hose drain valve (V-07).
3	Open the bottom fill valve (V-02) enough to allow liquid to flow slowly into the tank through the bottom fill line. The gradual flow enables the liquid to vaporize in the line and pressure buildup coil and slowly build up pressure in the inner tank.
4	Shut off the liquid supply source when the pressure in the tank is greater than 75psig as indicated on tank pressure gauge (PI-1).
5	Open the fill line drain valve (V-07) slowly to avoid splashing of the liquid. Drain all liquid from the tank. The appearance of gas (vapor) at the drain indicates that all liquid has been drained.
6	Close drain valve (V-07) and bottom fill valve (V-02).
7	To purge the gauge lines: Open the liquid level gauge equalization valve (V-12), close HP and LP isolation valves (V-10 and V-11) and slightly loosen a gauge panel fitting to allow the trapped pressure to vent. Re-tighten the fitting when pressures (PI-01) approaches 5psig). Open HP and LP Isolation valves and close the equalization valve (V-12).
8	To purge the internal gauge lines: Loosen fittings on both sides (high and low) of the liquid level gauge and allow gas to purge. Allow several minutes to purge and tighten fittings.

STEP NUMBER	Purging Procedure
	NOTE
09	Purge Vent Assembly by: Open and allow flow and then close, the vapor vent valve (V-05), Road Relief Valve V-06 and gas purge valves (V-08 and V-09). Open Full Trycock Valve (V-16) and allow venting for several minutes then close the Trycock Valve (V-16).
10	Purge Use Circuit by: Secure hose H-01, Open Use Valves (V-25, V-24, V-23, V-22 and V-20) and then slowly open V-13 for several minutes. Close V-13, V-25, V-24, V-23, V-22 and V-20.
11	Repeat purge procedure 2 through 10 at least three times to ensure product purity.
13	After purging the tank, but before filling, verify that the following valves are open or closed as indicated.
	Valve — **Position** Bottom Fill Valve V-01 — Closed Top Fill Valve V-02 — Closed Vapor vent valve V-05 — Closed Road Relief Valve V-06 — Open Full Trycock Valve V-16 — Closed Liquid level gauge Equalizing Valve V-12 — Closed Supply valves V-13,V-20,V-21,V-22 and V-23 — Closed Pressure building Isolation valves V-03 and V-04 — Closed Economizer isolation valve V-12 — Closed Liquid level gauge liquid phase valve V-11 — Open Liquid level gauge vapor phase valve V-10 — Open Turn Off PB (TWV-01) — Off (press in button)

Table 13 Initial (Warm Tank) Filling Procedure

STEP NUMBER	Initial (Warm Tank) Filling Procedure
1	Assure the tank has been purged (Table 14).
2	Verify that the contents of the supply unit are the proper product to be transferred.
3	Verify that all valves except liquid phase-high (V-11) and gas phase-low (V-10) are closed.
4	Connect the supply unit transfer hose to tank fill connection (CGA-01).
5	Cool down the transfer hose prior to filling by: open hose drain valve (V-07), open source discharge valve and venting the supply unit through the hose for approximately three minutes or until liquid is present at the line drain valve (V-07). Open the Bottom Fill Valve (V-01), Close the sources Discharge Valve and Close Drain Valve (V-07).
6	Pump Transfer - With the pump cooled and primed and the Bottom Fill Valve open (V-01), open the supply unit transport discharge valve slowly. Maintain pump discharge pressure from 50 PSI to 100 PSI higher than the tank pressure. (or) With the Bottom Fill Valve open (V-01), open the supply unit discharge valve slowly. Maintain supply tank pressure from 50 PSI to 100 PSI higher than the tank pressure to assure liquid transfer.
7	Monitor pressure in tank during filling. As the pressure rises above desired pressures open the Top Fill Valve (V-02) and Close the Bottom Fill Valve (V01). If the pressure cannot be managed by top filling, Open the Manual Vent Valve (V-05). If Top Filling and an open Manual Vent Valve (V-05) does not manage the pressure, stop the transfer (stop pump and close discharge valve). Continues to Vent the tank through the Manual Vent Valve (V-06) to desired pressures and restart the transfer.
8	Monitor liquid level contents gauge (LI-1). When the gauge indicates approximately three-quarters full, open full Trycock Valve (V-16)
9	When liquid spurts from Full Trycock Valve (V-16), immediately stop fill at the supply source and close Full Trycock valve (V-16).
10	Close Top and Bottom Fill Valves (V-01 and V-02).
11	Drain residual liquid in the fill hose via Hose Drain Valve (V-07).
12	Relieve fill hose pressure by loosening the hose at fill connection, and then disconnect the hose. It is recommended that the fill hose be allowed to defrost to prevent moisture from being drawn inside the hose.

Table 15 Vessel Refilling Procedure (No Gas or Liquid Use During Filling)

STEP NUMBER	Vessel Refilling Procedure
	NOTE Filling a cryogenic vessel through the bottom fill line tends to raise the pressure in the vessel as gases in the vapor space are compressed. Filling through the top fill line tends to lower the pressure in the vessel as gases in head space are cooled down and re-liquefied.
1	Verify that the contents of the supply unit are the proper product to be transferred.
2	Verify that the Bottom and Top Fill Valves are closed (V-01and V-02).
3	Vent the vessel to the desired fill pressure (approx. 50 psi lower than the transfer unit's pressure capabilities).
4	Connect the supply unit transfer hose to tank fill connection (CGA-01).
5	Cool down the transfer hose prior to filling by: open hose drain valve (V-07), open source discharge valve and venting the supply unit through the hose for approximately three minutes or until liquid is present at the line drain valve (V-07). Open the Bottom Fill Valve (V-01), Close the sources Discharge Valve and Close Drain Valve (V-07).
6	Pump Transfer - With the pump cooled and primed and the Bottom Fill Valve open (V-01), open the supply unit transport discharge valve slowly. Maintain pump discharge pressure from 50 PSI to 100 PSI higher than the tank pressure. (or) With the Bottom Fill Valve open (V-01), open the supply unit discharge valve slowly. Maintain supply tank pressure from 50 PSI to 100 PSI higher than the tank pressure to assure liquid transfer.
7	Monitor pressure in tank during filling. As the pressure rises above desired pressures open the Top Fill Valve (V-02) and Close the Bottom Fill Valve (V01). If the pressure cannot be managed by top filling, Open the Manual Vent Valve (V-05). If Top Filling and an open Manual Vent Valve (V-05) does not manage the pressure, stop the transfer (stop pump and close discharge valve). Continue to Vent the tank through the Manual Vent Valve (V-06) to desired pressures and restart the transfer.
8	Monitor liquid level contents gauge (LI-1). When the gauge indicates approximately three-quarters full, open full Trycock Valve (V-16)
9	When liquid spurts from Full Trycock Valve (V-16), immediately stop fill at the supply source and close Full Trycock valve (V-16).
10	Close Top and Bottom Fill Valves (V-01 and V-02).
11	Drain residual liquid in the fill hose via Hose Drain Valve (V-07).
12	Relieve fill hose pressure by loosening the hose at fill connection, and then disconnect the hose. It is recommended that the fill hose be allowed to defrost to prevent moisture from being drawn inside the hose.
13	Drain residual liquid in the fill hose via drain valve (V-07).
14	Stow Hose and replace Pressure Cap at CGA-01

Table 16 On-site Vessel Refilling Procedure

STEP NUMBER	Vessel Refilling Procedure
	NOTE Filling a cryogenic vessel through the bottom fill line tends to raise the pressure in the vessel as gases in the vapor space are compressed. Filling through the top fill line tends to lower the pressure in the vessel as gases in head space are cooled down and re-liquefied.
1	Verify that the contents of the supply unit are the proper product to be transferred.
2	Verify that the Bottom and Top Fill Valves are closed (V-01and V-02).
3	Verify and note minimum required operating pressure in vessel.
4	If minimum operating pressures exceeds the transfer units pressure capabilities, Turn off the PB by pressing the PB On/Off switch (TWV-1) and Vent the vessel to the desired fill pressure (approx. 50 psi lower than the transfer units pressure capabilities). Assure that the end user is aware of the temporary drop in pressure. (or) If the transfer unit's pressure capabilities exceed minimum operating pressures, verify that all other valves are in normal operating positions.
5	Connect the supply unit transfer hose to tank fill connection (CGA-01).
6	Cool down the transfer hose prior to filling by: open hose drain valve (V-07), open source discharge valve and venting the supply unit through the hose for approximately three minutes or until liquid is present at the line drain valve (V-07). Open the Bottom Fill Valve (V-01), Close the sources Discharge Valve and Close Drain Valve (V-07).
7	Pump Transfer - With the pump cooled and primed and the Bottom Fill Valve open (V-01), open the supply unit transport discharge valve slowly. Maintain pump discharge pressure from 50 PSI to 100 PSI higher than the tank pressure. (or) With the Bottom Fill Valve open (V-01), open the supply unit discharge valve slowly. Maintain supply tank pressure from 50 PSI to 100 PSI higher than the tank pressure to assure liquid transfer.
8	Monitor pressure in tank during filling. As the pressure rises above desired pressures open the Top Fill Valve (V-02) and Close the Bottom Fill Valve (V01). If the pressure cannot be managed by top filling, Open the Manual Vent Valve (V-05). If Top Filling and an open Manual Vent Valve (V-05) does not manage the pressure, stop the transfer (stop pump and close discharge valve). Continues to Vent the tank through the Manual Vent Valve (V-06) to desired pressures and restart the transfer.
9	Monitor liquid level contents gauge (LI-1). When the gauge indicates approximately three-quarters full, open full Trycock Valve (V-16)
10	When liquid spurts from Full Trycock Valve (V-16), immediately stop fill at the supply source and close Full Trycock valve (V-16).
11	Close Top and Bottom Fill Valves (V-01 and V-02). Assure all valves are in the correct condition for use (if the PB was turned off to complete the fill, pull the PB On/Off switch (TWV-01) to start pressure building.
12	Drain residual liquid in the fill hose via Hose Drain Valve (V-07).
13	Relieve fill hose pressure by loosening the hose at fill connection, and then disconnect the hose. It is recommended that the fill hose be allowed to defrost to prevent moisture from being drawn inside the hose.
14	Drain residual liquid in the fill hose via drain valve (HCV-7).
15	Stow Hose and replace Pressure Cap at CGA-01

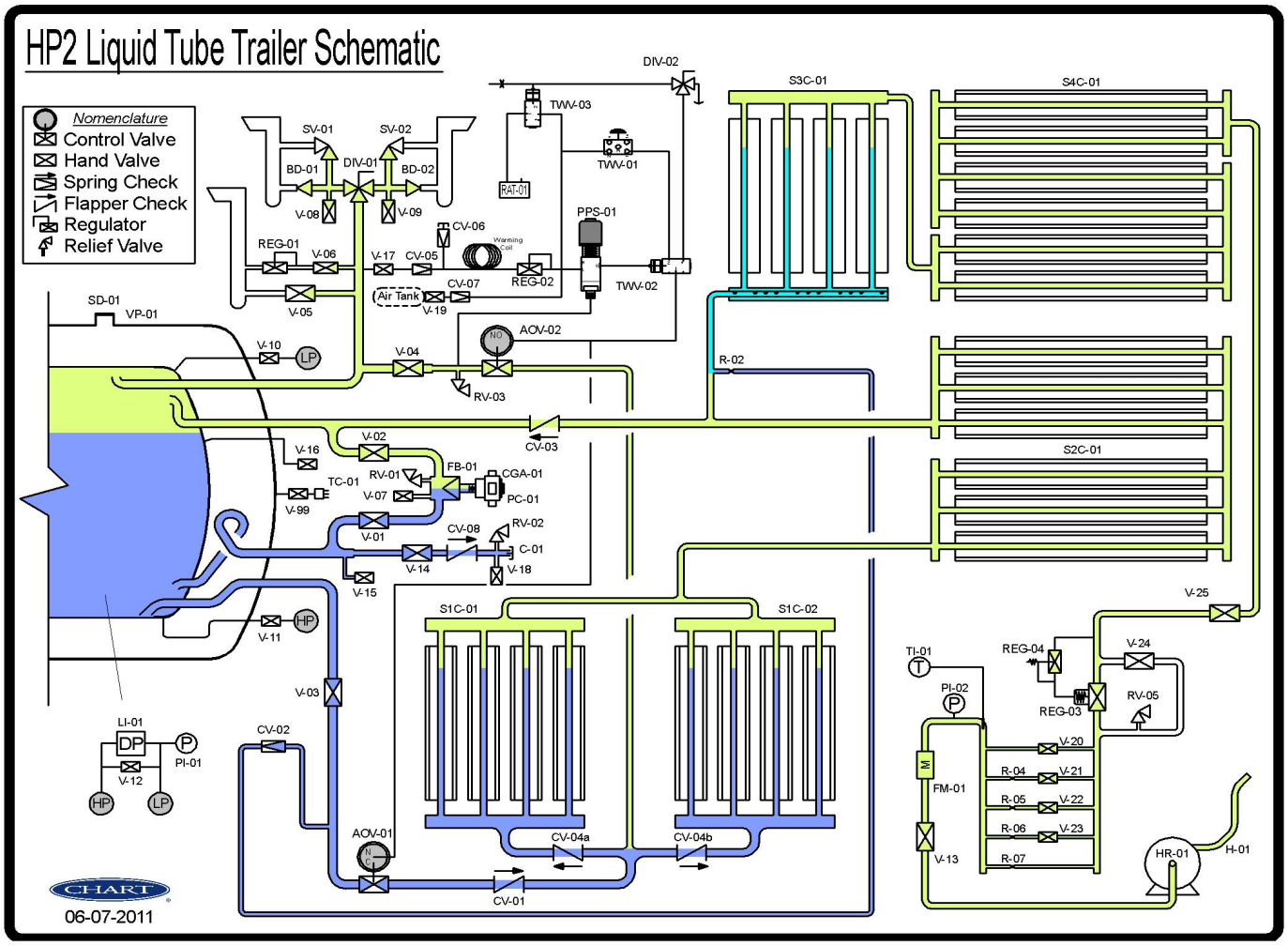
Chapter 6

6 WITHDRAWAL PROCEDURES

NOTE

The system is designed to maintain pressures in the system at flows that do not exceed 15000scfh. Flow conditions that exceed the flow rating will result is pressure decay..

Figure 14 - Schematic Reference



Notice For Continuous Duty (24/7) Gas Use Applications

When the HP2 Liquid Tube Trailer is parked for an extended period of time and the gas is withdrawn continuously, it is recommended that the economizer feed line be insulated with closed cell polyethylene (Air Conditioning material) and wrapped with an overlay of aluminum foil tape for durability and water resistance. This is necessary to prevent an ice ball on this line, which is the piping circuit that comes from the top of the tank, past the safety tree tee, to isolation valve V-4, automatic valve AOV-02 and to the tee that feeds the pressure building coils.

6.1 PRESSURE BUILDING

OPERATIONAL VIDEO

http://www.screencast.com/t/6PjWLrDQG
(click on the link to watch the video on how to start pressure building)

Table 17 Pressure Building

STEP NUMBER	Ref.	Pressure Building
1		Position trailer, open cabinet doors
2	Figure 4	Close the road relief valve (V-06)
		To Start pressure building:
3	Figure 5	Open the PB feed valve (V-03)
4	Figure 6	Open the PB return valve (V-04)
5	Figure 7	Open (pull) pneumatic control ON/OFF valve (TWV-01)
	Figure 8 Figure 9 Figure 10	PB control valve (AOV-01) opens at low pressure At the PB set point, AOV-01 closes at high pressure Pneumatics sends a pulse of gas to the PB rattle value as PB Feed Control Valve AOV-01 Closes.

Figure 15 - Closing the Road Relief Valve V-06

Figure 16 - Opening the PB Feed Valve V-03

Figure 17 - Open the PB Return Valve V-04

Figure 18 - Open Pneumatic Control TWV-01

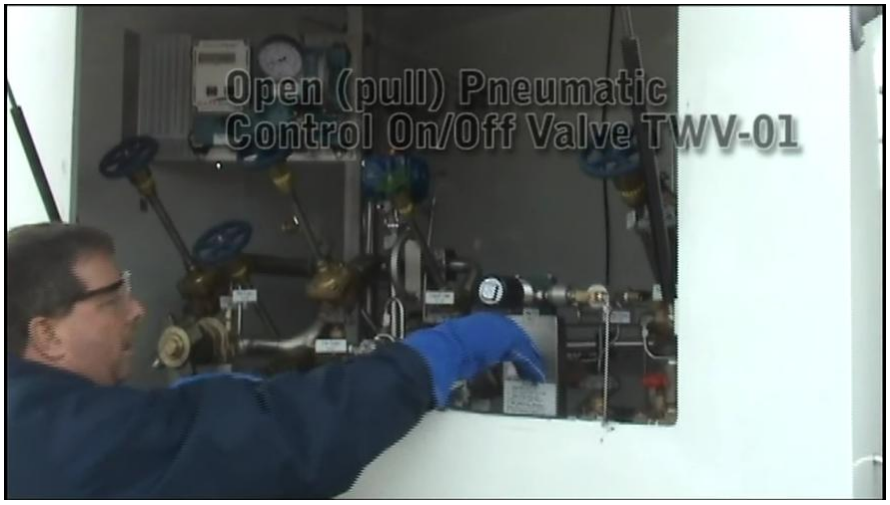


Figure 19 - PB Control Valve AOV-01 opens

Figure 20 - Pressure Builds

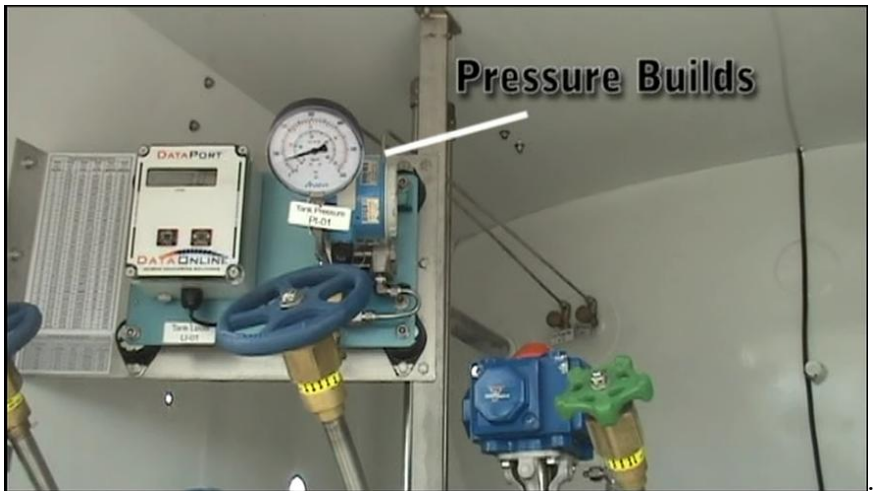
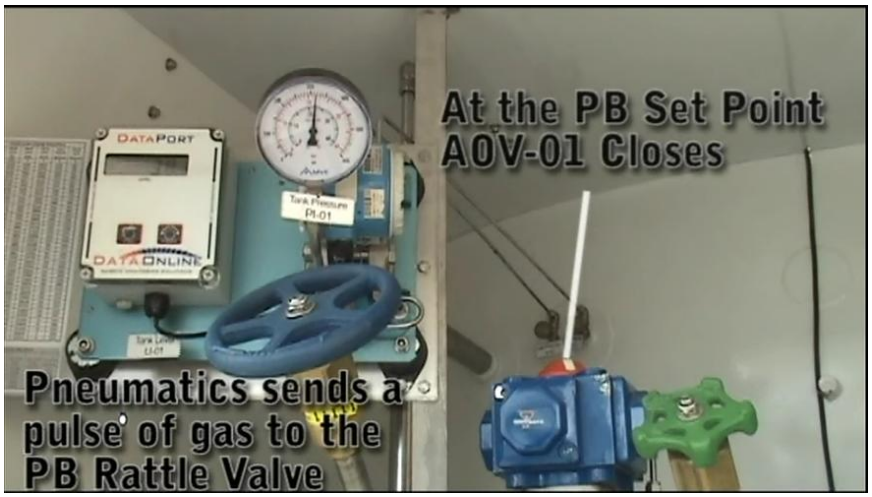


Figure 21 - AOV-01 closes at the PB set point



6.2 PRESSURE BUILDING ADJUSTMENT

OPERATIONAL VIDEO

http://www.screencast.com/t/adpBOGeqg
(click on the link to watch the video on how to increase and decrease the Pressure Building)

NOTE:

Pressure adjustment is simply. However, it is a pressure switch that is new to our industry.

The systems PB setting should be set high enough to allow for the switch hysteresis and pressure drop to the use. Ideally the PB is set at 50 psi higher than the final line pressure. If the final line pressure is needed higher than 500 psig, the final line regulator (REG-03) is by-passed using the Regulator By-Pass Valve (V-24). Once set the end user should have no need to adjust..

Table 18 - Pressure Building Adjustment - Increase Setting

STEP NUMBER	Ref.	Pressure Building Regulator Adjustment (Increase)
1	Figure 11	With the tank pressure at the current set point, rotate PPS-01clockwise - One turn for each 80 psi changed
	Figure 12	AOV-01 opens, pressure builds
		AOV-01 closes at the PB high set point
2		Repeat as needed

Figure 22 - Rotate PPS-01 Clockwise for each 80 psi additional needed

Figure 23 - AOV-01 opens and pressure builds

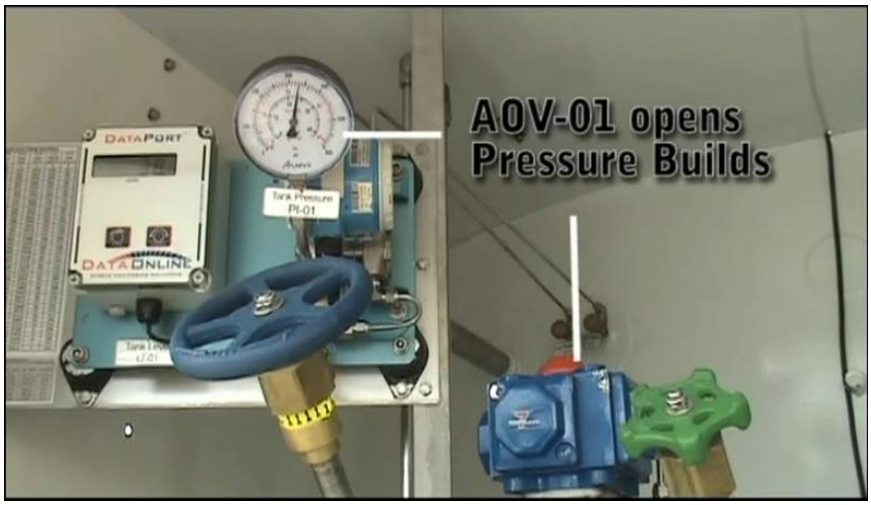


Table 19 - Pressure Building Adjustment - Decrease Setting

STEP NUMBER	Ref.	Pressure Building Regulator Adjustment (Decrease)
1	Figure 13	With the tank pressure at the current set point, rotate PPS-01counterclockwise - One turn for each 80 psi changed
2	Figure 14	Drop tank pressure to new set point by opening manual vent valve (V-05)
	Figure 15	AOV-01 opens at the set point
3	Figure 16	Close manual vent valve V-05
	Figure 17	Allow pressure to build to new set point
	Figure 18	AOV-01 closes at the new set point
4		Repeat as needed

Figure 24 - Rotate PPS-01 counter clockwise for each 80 psi changed

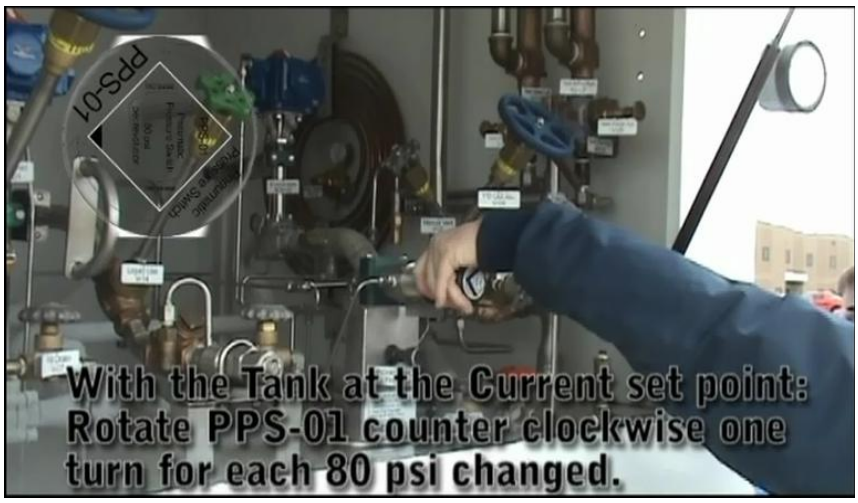


Figure 25 - Drop tank pressure to new set point by opening V-05

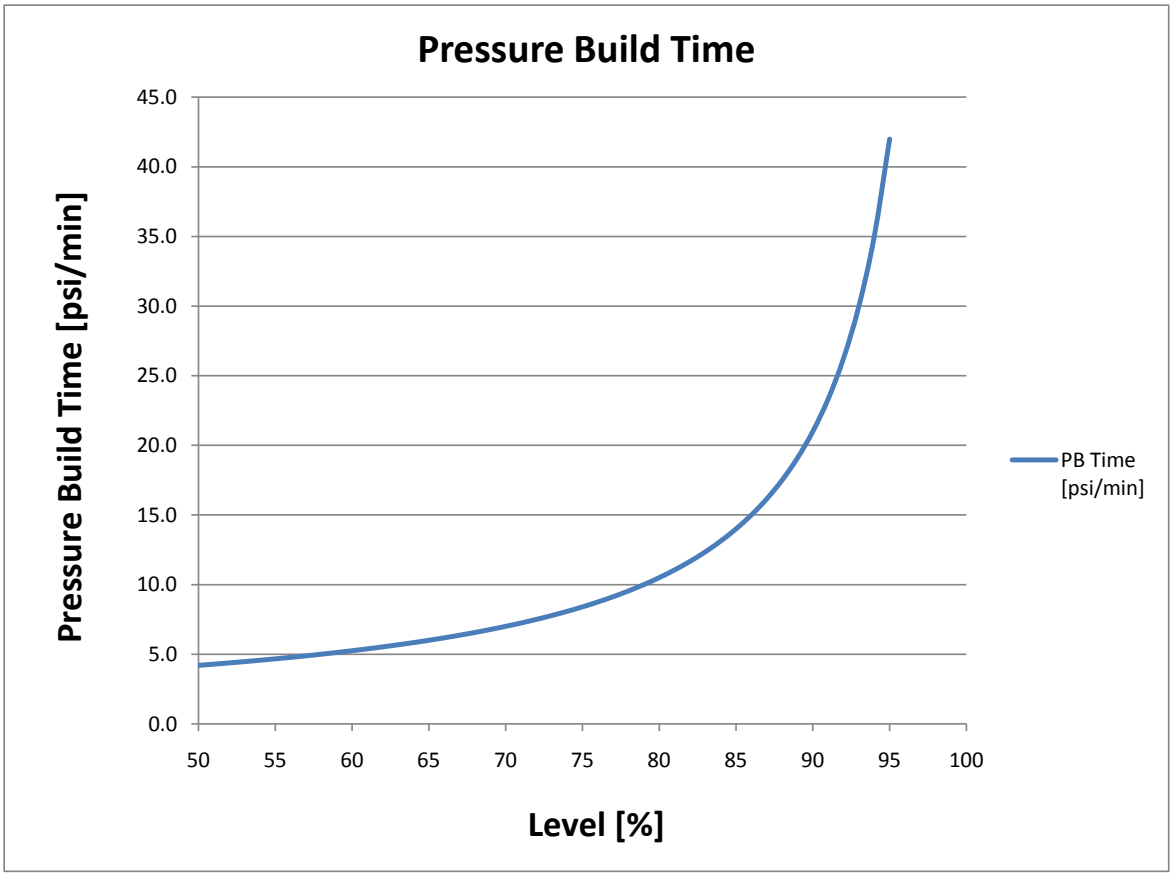
Figure 26 - AOV-01 opens at the set point

Figure 27 - Close Manual Vent Valve V-05

Figure 28 - Allow Pressure to build to new set point

Figure 29 - AOV-01 Closes at the new set point

Graph 1 Pressure Build Time vs. % Volume



Note: Data was produced from test data and actual time may vary

6.3 GAS DELIVERY

OPERATIONAL VIDEO

http://www.screencast.com/t/8bsb5u35BU
(click on the link to watch the video)

Table 20 Gas Withdrawal Procedure

STEP NUMBER	Ref,	Gas Withdrawal Procedure

		BEGIN DELIVERY:
1	Figure 19 & 20	Remove the hose (H-01) from Hose Reel (HR-01)
2	Figure 21	Connect the hose to the receiver (receiver valve closed)
		Note: Receivers pressure temperature ratings.
3	Figure 22	Open manifold inlet valve (V-25)
4	Figure 23	Open valve V-13 (V-20, V-21, V-22, V-23 are still in closed position)
	Figure 24	Flow starts through manifold orifice (R-07)
5	Figure 25	Leak check new connections
6	Figure 26	If there are no leaks, open receiver valve
7	Figure 27	Open V-23 (open manifold valves from the bottom up)
8	Table 11, figure 47, example 1	Determine flow rate using the Flow Meter (FM-01) assuring the flow does not exceed 15000 SCFG
9		Monitor exit gas temperatures (TI-01)
10	Figure 28	Open V-22 (open as needed to increase flow rates to near 15000scfh –close if temperatures approach limits)
11	Figure 29	Open V-21 (open as needed to increase flow rates to near 15000scfh –close if temperatures approach limits)
12	Figure 30	Open V-20 (open as needed to increase flow rates to near 15000scfh –close if temperatures approach limits)
		END DELIVERY:
13	Fig. 31-33	Stop the flow by closing the gas management valves that are in open position (V-20, V-21, V-22, V-23) and gas use isolation (V-25)
14	Figure 34	Close the receiver valve
15	Figure 35	Crack loosen hose (H-01) at receiver to allow pressure to vent.
16	Fig. 36,37	It is safe to remove the hose when the pressure is has dropped to safe levels as indicated at the Manifold pressure gauge (PI-02)
17	Figure 38	Stow hose (H-01)
18	Figure 39	With hose reeled into place, latch the reel lock
19	Figure 40	Close gas use valve (V-13)
20	Figure 41	Prepare for transit by turning off the pneumatics (press TWV-01)
21	Fig. 42,43	Isolate the PB or vaporizer by closing PB return isolation (V-04) and close PB feed isolation (V-03)
22	Figure 44	Depressurize by opening manual vent valve (V-05) until storage pressure (PI-01) drops below 25 psig
23	Fig. 45,46	At a pressure below 25 psig, close manual vent valve (V-05) and open road relief valve (V-06)
24		Close the cabinet doors
25		Proceed to next location

Figure 30 - unlatch reel lock

Figure 31 - Remove the hose

Figure 32 - connect the hose

Figure 33 - Open Manifold Inlet Valve

Figure 34 - Open Use Valve V-13

Figure 35 – Flow starts thorough manifold orifice

Figure 36 - leak check

Figure 37 - leak free, open receiver

Figure 38 - Open V-23

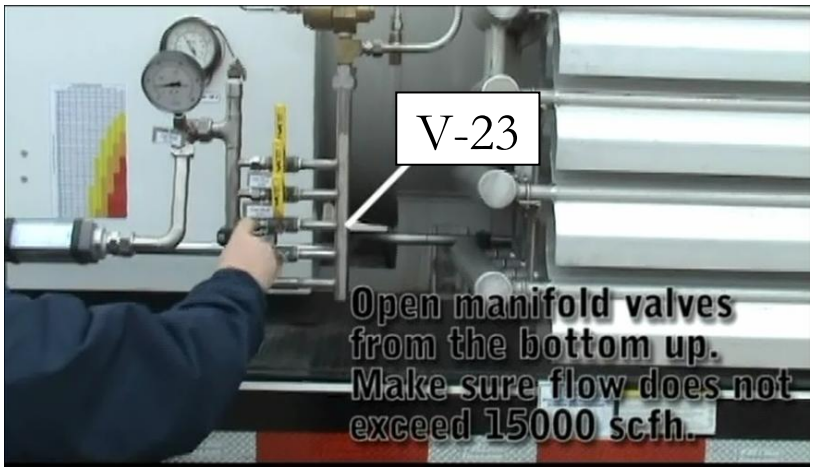


Figure 39 – Open V-22

Figure 40 - Open V-21

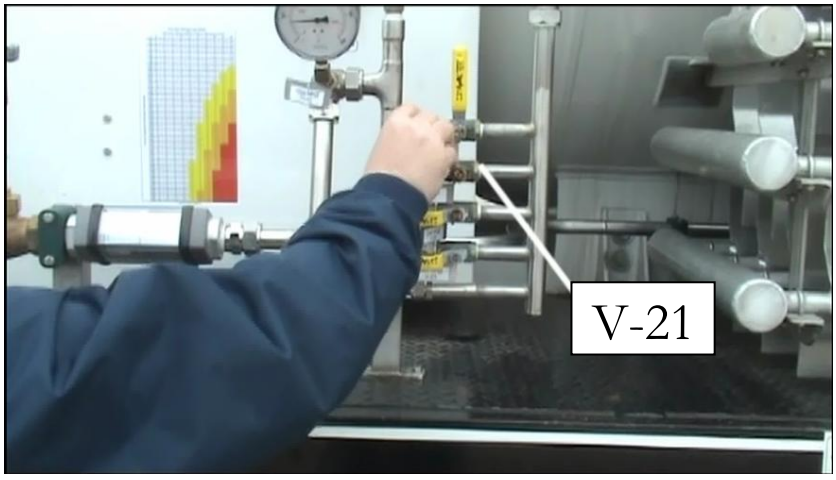


Figure 41 - Open V-20

Figure 42 – close open gas management valve

Figure 43 – close open gas management valve

Figure 44 – close Gas Use Isolation V-25

Figure 45 - close the receiver valve

Figure 46 - crack open hose end

Figure 47 - safe pressure to remove the hose

Figure 48 - remove the hose

Figure 49 - stow hose

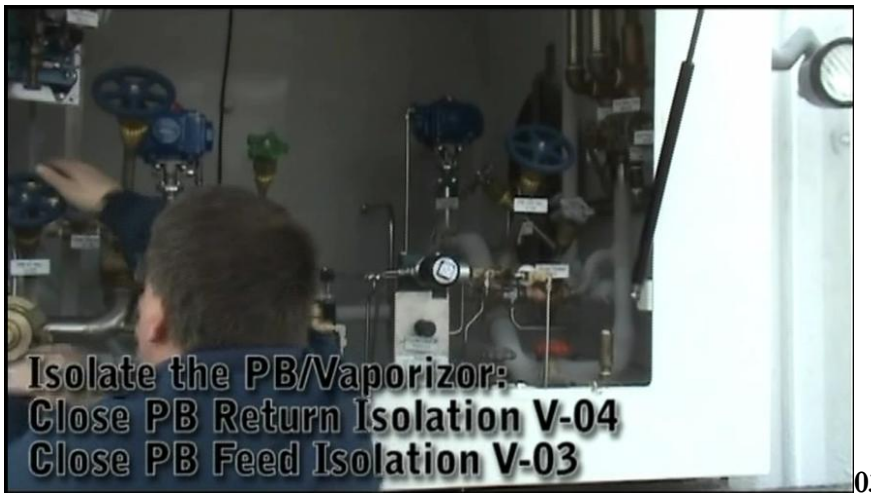
Figure 50 - With hose reeled into place, latch the reel lock

Figure 51 - close Gas Use Valve V-13

Figure 52 - Turn off pneumatics, press TWV-01

Figure 53 - close PB Return Isolation V-04

Figure 54 - close PB Feed Isolation V-03



03

Figure 55 – Open Manual Vent Valve V-05

Figure 56 - close Manual Vent Valve V-05

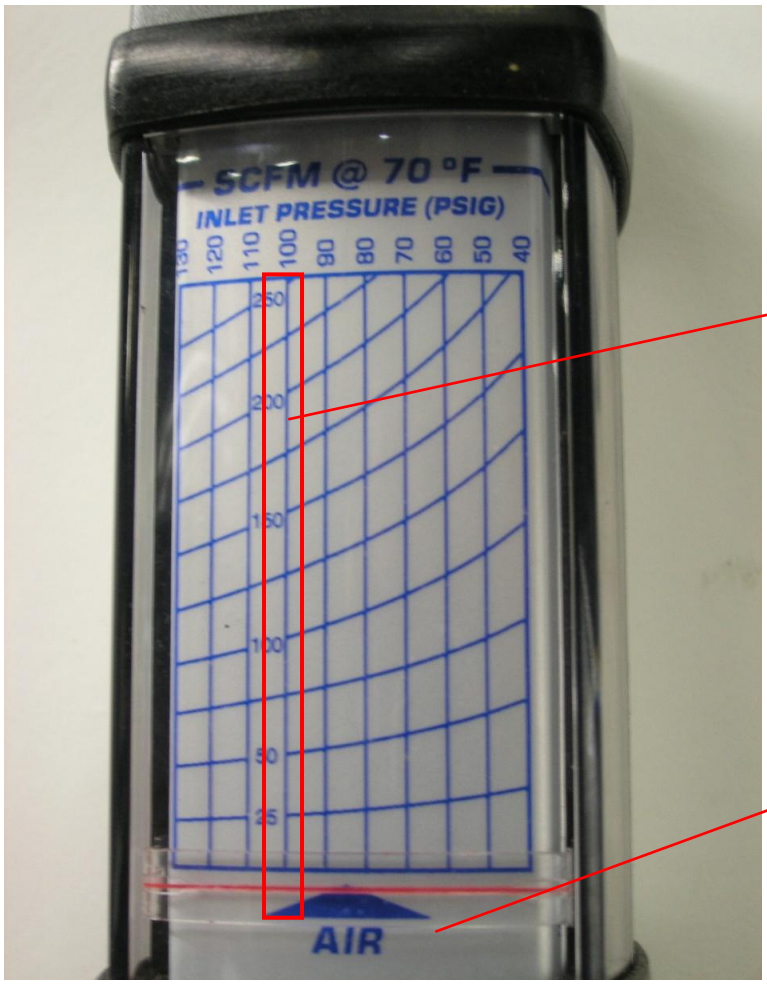
Figure 57 - open Road Relief Valve V-06

Table 21 - Flow Rate Nitrogen Gas (SCFH)

Flow Rate Nitrogen Gas (SCFH)											
		Flow Rate Indicated (SCFM at 100 psi inlet pressure line)									
		25	50	75	100	125	150	175	200	225	250
Pressure Indicated at Discharge Gauge (psig)	10	721	1441	2162	2882	3603	4323	5044	5764	6485	7205
	20	854	1708	2562	3416	4270	5124	5978	6832	7686	8540
	30	969	1939	2908	3877	4846	5816	6785	7754	8724	9693
	40	1072	2144	3217	4289	5361	6433	7506	8578	9650	10722
	50	1166	2332	3498	4665	5831	6997	8163	9329	10495	11661
	60	1253	2506	3759	5012	6265	7518	8771	10024	11277	12530
	70	1334	2669	4003	5337	6671	8006	9340	10674	12008	13343
	80	1411	2822	4232	5643	7054	8465	9876	11287	12697	14108
	90	1483	2967	4450	5934	7417	8901	10384	11868	13351	14834
	100	1553	3105	4658	6211	7763	9316	10869	12421	13974	15527
	110	1619	3238	4857	6476	8095	9714	11333	12952	14571	16189
	120	1683	3365	5048	6730	8413	10096	11778	13461	15143	16826
	130	1744	3488	5232	6976	8720	10464	12208	13952	15696	17439
	140	1803	3606	5410	7213	9016	10819	12622	14426	16229	18032
	150	1861	3721	5582	7442	9303	11163	13024	14885	16745	18606
	160	1916	3832	5749	7665	9581	11497	13414	15330	17246	19162
	170	1970	3941	5911	7881	9852	11822	13792	15762	17733	19703
	180	2023	4046	6069	8092	10115	12138	14161	16183	18206	20229
	190	2074	4148	6223	8297	10371	12445	14520	16594	18668	20742
	200	2124	4249	6373	8497	10621	12746	14870	16994	19119	21243
	210	2173	4346	6520	8693	10866	13039	15212	17386	19559	21732
	220	2221	4442	6663	8884	11105	13326	15547	17768	19989	22210
	230	2268	4536	6804	9071	11339	13607	15875	18143	20411	22679
	240	2314	4627	6941	9255	11569	13882	16196	18510	20824	23137
	250	2359	4717	7076	9435	11794	14152	16511	18870	21228	23587
	260	2403	4806	7209	9611	12014	14417	16820	19223	21626	24029
	270	2446	4892	7339	9785	12231	14677	17123	19570	22016	24462
	280	2489	4978	7466	9955	12444	14933	17422	19910	22399	24888
	290	2531	5061	7592	10123	12653	15184	17715	20245	22776	25307
	300	2572	5144	7716	10287	12859	15431	18003	20575	23147	25719
	310	2612	5225	7837	10450	13062	15674	18287	20899	23512	26124
	320	2652	5305	7957	10609	13262	15914	18566	21219	23871	26523
	330	2692	5383	8075	10767	13458	16150	18842	21533	24225	26917
	340	2730	5461	8191	10922	13652	16383	19113	21843	24574	27304
	350	2769	5537	8306	11075	13843	16612	19380	22149	24918	27686
	360	2806	5613	8419	11225	14032	16838	19644	22451	25257	28063
	370	2844	5687	8531	11374	14218	17061	19905	22748	25592	28435
	380	2880	5761	8641	11521	14401	17282	20162	23042	25922	28803
	390	2917	5833	8750	11666	14583	17499	20416	23332	26249	29165
	400	2952	5905	8857	11809	14762	17714	20666	23619	26571	29523
	410	2988	5975	8963	11951	14939	17926	20914	23902	26889	29877
	420	3023	6045	9068	12091	15113	18136	21159	24182	27204	30227
	430	3057	6115	9172	12229	15286	18344	21401	24458	27515	30573
	440	3091	6183	9274	12366	15457	18549	21640	24732	27823	30914
	450	3125	6251	9376	12501	15626	18752	21877	25002	28127	31253
	460	3159	6317	9476	12635	15794	18952	22111	25270	28428	31587
	470	3192	6384	9575	12767	15959	19151	22343	25534	28726	31918
	480	3225	6449	9674	12898	16123	19347	22572	25796	29021	32246
	490	3257	6514	9771	13028	16285	19542	22799	26056	29313	32570
	500	3289	6578	9867	13156	16445	19735	23024	26313	29602	32891
	510	3321	6642	9963	13284	16604	19925	23246	26567	29888	33209
	520	3352	6705	10057	13410	16762	20114	23467	26819	30171	33524
	530	3384	6767	10151	13534	16918	20302	23685	27069	30452	33836
	540	3415	6829	10244	13658	17073	20487	23902	27316	30731	34145
	550	3445	6890	10335	13781	17226	20671	24116	27561	31006	34451

Chart for 50 degF Nitrogen Gas

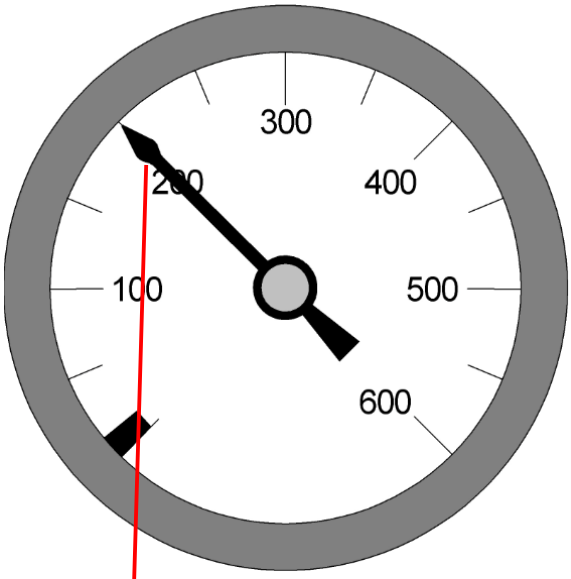
Figure 58 - Flow Meter

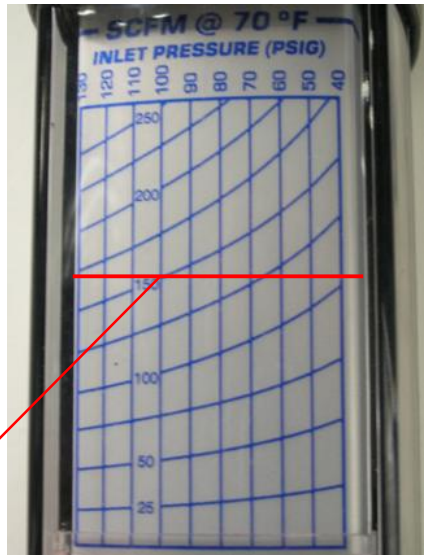


The blue line (vertical) in the red box indicates "flow rate indicated (SCFM at 100 psi inlet pressure line)" in Table***

This red line moves up and down. The point where the red line (horizontal) and the blue line (vertical) intersect each other represents "Pressure indicated at Discharge Gauge (psig)" in Table***

Example 1





	Flow Rate Nitrogen Gas (SCFH)						
	Flow Rate Indicated (SCFM at 100 psi inlet						
	25	50	75	100	125	150	175
10	721	1441	2162	2882	3603	4323	5044
20	854	1708	2562	3416	4270	5124	5978
30	969	1939	2908	3877	4846	5816	6785
40	1072	2144	3217	4289	5361	6433	7506
50	1166	2332	3498	4665	5831	6997	8163
60	1253	2506	3759	5012	6265	7518	8771
70	1334	2669	4003	5337	6671	8006	9340
80	1411	2822	4232	5643	7054	8465	9876
90	1483	2967	4450	5934	7417	8901	10384
100	1553	3105	4658	6211	7763	9316	10869
110	1619	3238	4857	6476	8095	9714	11333
120	1683	3365	5048	6730	8413	10096	11778
130	1744	3488	5232	6976	8720	10464	12208
140	1803	3606	5410	7213	9016	10819	12622
150	1861	3721	5582	7442	9303	11163	13024
160	1916	3832	5749	7665	9581	11497	13414
170	1970	3941	5911	7881	9852	11822	13792
180	2023	4046	6069	8092	10115	12138	14161
190	2074	4148	6223	8297	10371	12445	14520
200	2124	4249	6373	8497	10621	12746	14870
210	2173	4346	6520	8693	10866	13039	15212
220	2221	4442	6663	8884	11105	13326	15547
230	2268	4536	6804	9071	11339	13607	15875
240	2314	4627	6941	9255	11569	13882	16196
250	2359	4717	7076	9435	11794	14152	16511
260	2403	4806	7209	9611	12014	14417	16820
270	2446	4892	7339	9785	12231	14677	17123
280	2489	4978	7466	9955	12444	14933	17422
290	2531	5061	7592	10123	12653	15184	17715
300	2572	5144	7716	10287	12859	15431	18003

ted at Discharge Gauge (psig)

Flow Rate Nitrogen Gas (SCFH) = **12746**

6.4 LIQUID DELIVERY

OPERATIONAL VIDEO

http://www.screencast.com/t/TTEkyju9wb
(click on the link to watch video to withdraw liquid)

Table 22 - Liquid Withdrawal Procedure

STEP NUMBER	Ref.	Liquid Withdrawal Procedure
1		Open cabinet doors
2	Figure 48	If opened, Close road relief valve (V-06)
3	Figure 49	Start pressure building by opening PB feed Isolation (V-03)
4	Figure 50	Open PB return Isolation (V-04)
5	Figure 51	Turn on pneumatic by pulling ON/OFF switch (TWV-01)
6	Figure 52	Connect hose by removing pressure cap
7	Figure 53	Connect inlet side of hose
8	Figure 54	Connect hose to receiving tank
9	Figure 55	Open hose valve (if optional Hose Assembly is used)
	Figure 56	AOV-01 closes at the PB set point
10	Figure 57	With the hose purged, start flow by opening liquid use valve (V-14)
11	Figure 58	Close the hose valve to terminate the delivery(if optional Hose Assembly is used)
12	Figure 59	Close liquid use valve (V-14)
13	Figure 60	Open line drain (V-28)
14	Figure 61	Remove hose from receiving tank
15	Figure 62	Remove hose at flare connection (Located at C-01)
16	Figure 63	Replace pressure cap (C-01)
17		Close line drain (V-18)
18	Figure 64	Turn off the pressure builder by pressing TWV-01 (turn off pneumatic)
19	Figure 65, 66	Isolate PB by closing PB feed (V-03) and PB return (V-04)
20	Figure 67	Prepare for transit (depressurize) by opening manual vent valve (V-05) and close V-05 at pressure less than 25psig
21	Figure 68	With manual vent valve (V-05) closed, open road relief valve (V-06)
22		Close cabinet doors
23		Proceed to next stop

Figure 59 - close Road Relief Valve V-06

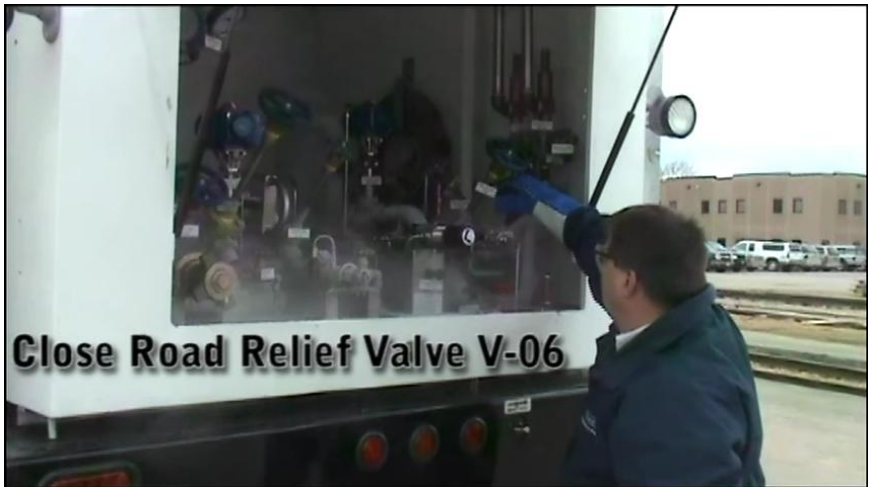


Figure 60 - open PB feed Iso V-03

Figure 61 - open PB Return Iso V-04

Figure 62 - turn on Pneumatics

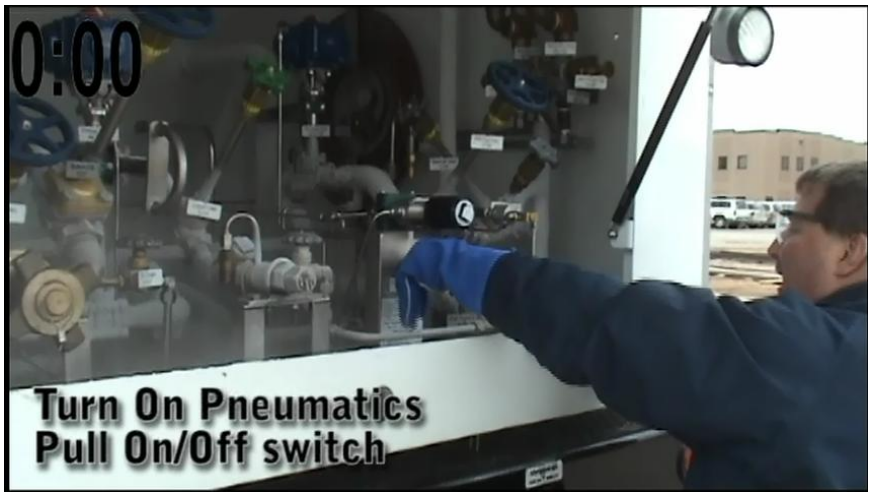


Figure 63 – remove pressure cap

Figure 64 – connect inlet side of hose

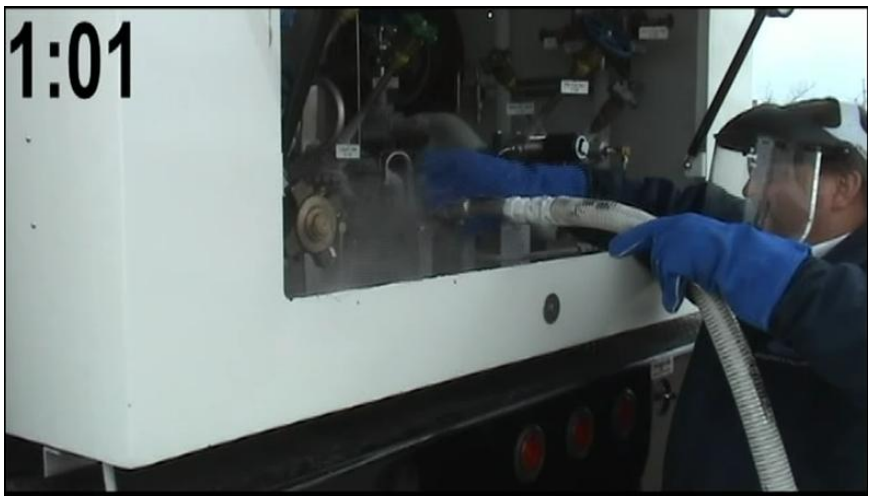


Figure 65 - connect to receiving tank

Figure 66 - open hose valve

Figure 67 - AOV-01 closes at PB set point

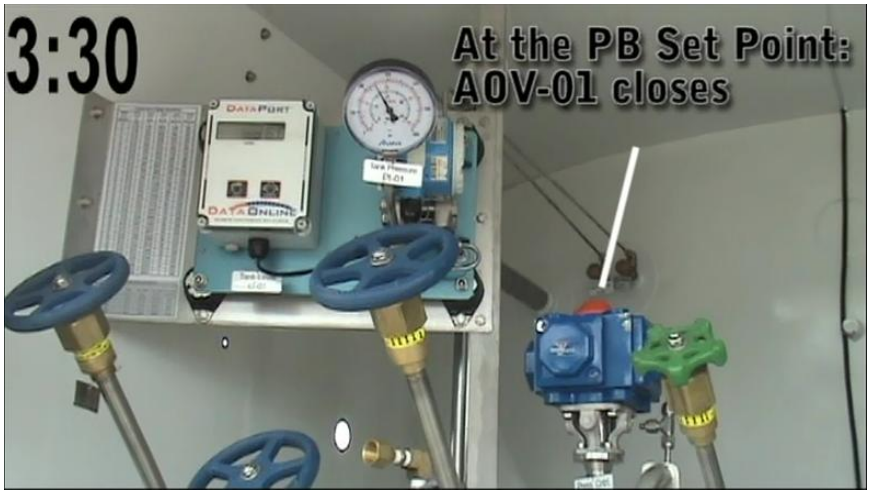


Figure 68 - open Liquid Use Valve V-14

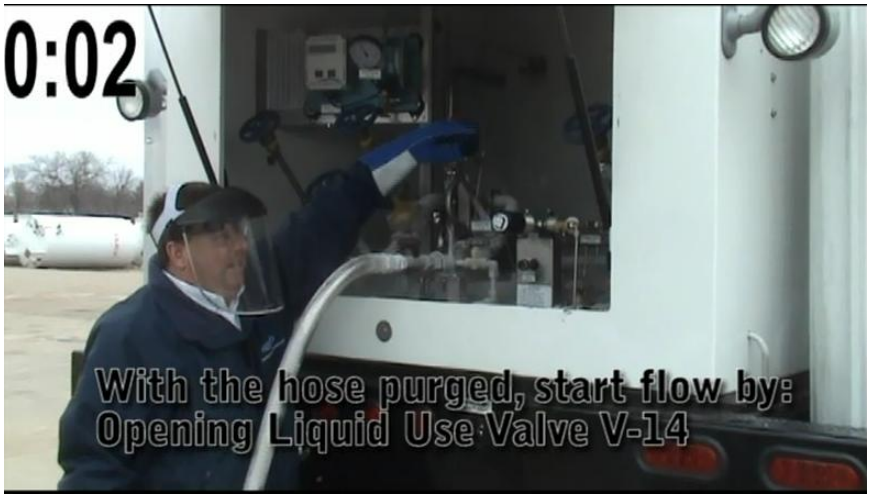


Figure 69 - closing the hose valve

Figure 70 - close Liquid Use valve V-14

Figure 71 - open Line Drain V-26

Figure 72- remove hose from receivintank

Figure 73 – remove hose at flare connection

Figure 74 – replace pressure cap, close line drain

Figure 75 – turn off pneumatic

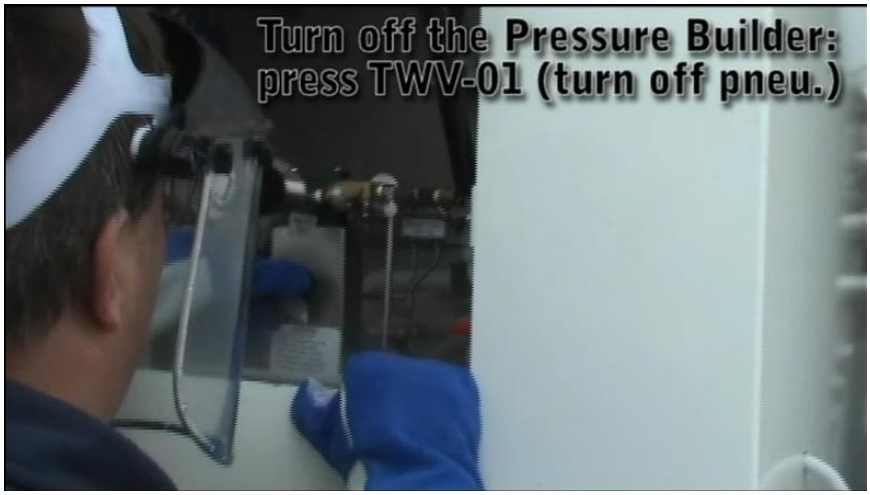


Figure 76 – close PB feed V-03

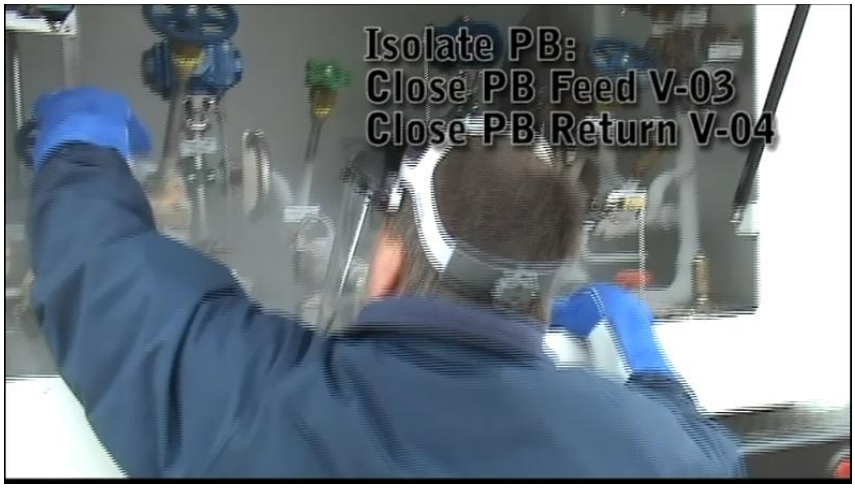


Figure 77 – close PB Return V-04

Figure 78 – open Manual Vent Valve V-05, close V-05 at less than 25 psig

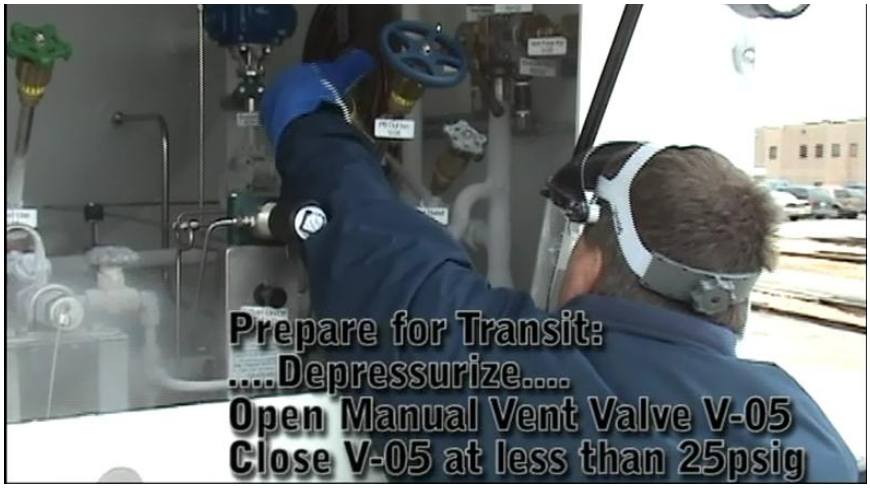


Figure 79 – open Road Relief Valve V-06 with V-05 closed

Chapter 7

7 GENERAL

This chapter contains system maintenance information, including troubleshooting and repair procedures. Before performing any of the procedures in this chapter, be sure you are familiar with the location and function of controls and indicators discussed in other chapters.

7.1 MAINTENANCE

7.1.1 COMPATIBILITY AND CLEANING

It is essential to always keep the vessel clean and free of grease or oil. This is particularly important for units used in nitrogen and argon service since the temperature of liquid nitrogen or argon is below the liquefaction temperature of air; thus making it possible to condense liquid oxygen from air on the piping and vaporizer surfaces.

Replacement components should be compatible with liquid oxygen and have been properly cleaned for oxygen service. (Refer to CGA Bulletin G4.1 "Equipment Cleaned for Oxygen Service".) Do not use regulators, fittings, or hoses that were previously used in a compressed air environment. Only oxygen compatible sealants or virgin Teflon tape should be used on threaded fittings. All new joints should be leak tested with oxygen compatible leak test solution. Use a suitable solvent for cleaning and de-greasing metallic parts.

7.1.2 PERIODIC INSPECTION

In order to maintain a cryogenic vessel in good operating condition, certain system components should be inspected on a periodic basis. Components listed in Chapter 8 should be on a periodic inspection program. For extreme conditions (extreme hot, cold or wet climates) inspection intervals should be shortened.

7.1.3 SOLDERING

Before performing any soldering work, always exhaust oxygen from oxygen lines and purge with nitrogen gas. Verify that lines are inert.

7.1.4 VACUUM INTEGRITY

The vessel is equipped with a vacuum thermocouple gauge and vacuum integrity may be tested with a vacuum meter. Deterioration or loss of vacuum will be apparent by cold spots, frost, or condensation on the jacket, or evidenced by abnormally rapid pressure buildup. Unless one of these conditions is evident, the vacuum level should not be suspected. In the event one of the above conditions exist, contact the factory for advice on vessel vacuum testing.

7.2 TROUBLESHOOTING

The Table 22 provides some troubleshooting procedures. The table is arranged in a Trouble/ Probable Cause/Remedy format. Note that probable causes for specific problems are listed in descending order of significance. That is, check out the first cause listed before proceeding to the next. Repair procedures required, as listed in the remedy column, may be found in the Repair portion of this chapter. Perform procedures in order listed and exactly as stated (Refer to drawings as required to locate system components identified in the troubleshooting guide.)

Table 23 Troubleshooting

PROBLEM	POSSIBLE CAUSE	REMEDY
Excessive tank pressure (Vessel vents through relief valve frequently).	Leaking valves to PB assembly. (Constant frosting of pump lines even when pump is not operating).	Check that valves are closed.
		Repair or replace.
Cannot pressure transfer liquid adequately.	Pressure below receiving tank pressure.	Increase PB Setting (Gauges may not be accurate).
Failure to maintain tank pressure.	Relief valve (SV-1 or SV-2) leaking or frozen open.	Reduce vessel pressure and allow relief to warm and re-seat.
	Piping leak.	Soap test and repair.
	Low liquid level.	Refill tank.
	Excessive withdrawal rate.	Consult factory (Chart).
Vacuum loss	Annular space relief device is open.	Inner vessel or piping leak. Remove all product from the container and return to Chart.
	Leak in the O-ring seal of annular space relief device.	Remove all product from the container and return to Chart.
	Sweat or frost appears on outer vessel, indicating marginal vacuum levels..	Perform a NER test on the container. If unsatisfactory, return to Chart.
Erratic or erroneous contents gauge readings.	Leaking gauge lines.	Soap test and repair leak.
	Gauge needle is stuck.	Lightly tap gauge. If this fails to correct the problem, inspect the needle and bend slightly, if necessary.
	Needle is not zero adjusted.	Refer to Gauge Adjustment.
	Gauge damaged or faulty.	Replace gauge.
Leaking safety relief valve (SV-01/ SV-02)	Dirt or ice under seat.	Reseat or replace valve as required.
	Valve improperly seated	Reseat or replace valve as required.
	Damaged seat.	Replace valve.
Ruptured tank bursting disc (BD-01/BD-02).	Excessive tank pressure.	Replace disc.
	Atmospheric corrosion and/or fatigue.	Replace disc.
	Interior corrosion.	Replace disc after blowing out line.
	Defective disc.	Replace disc.

7.3 REPAIR

CAUTION:

Plumbing should always be allowed to return to ambient temperature before repair work is performed. Vent or drain the vessel as necessary before replacing any component(s) exposed to pressure or to cryogenic liquid.

When repair of damaged components is required (in those instances when a spare part is not readily available), follow the instructions below.

When disassembly is required, removed parts should be coded to facilitate reassembly. Reassembly of components should always be performed in the reverse manner in which they are disassembled. Parts removed during disassembly should be protected from damage, thoroughly cleaned, and stored in protective polyethylene bags if not immediately reinstalled. Clean all metal parts with a good industrial cleaning solvent. All rubber components should be washed in a soap and warm water solution. Air dry all cleaned parts using an oil-free, clean, low-pressure air source. Before reassembly, make sure that all parts are thoroughly cleaned and have been degreased. Cleaning will prevent valves and regulators from freezing while in service and prevent contamination of the liquid product.

After removing components plug pipe openings as soon as possible to prevent contamination. Plastic pipe plugs of a clean plastic film may be used for this purpose.

7.4 VALVE REPAIR

When a defective valve is suspected, remove and repair the assembly as described in this manual. If a valve is leaking through the packing, tighten the packing nut first to see if the leakage will stop before removing the valve. Packing is best tightened when the valve is warm. If a safety relief valve fails, the defective assembly should be discarded and a new valve installed.

NOTE:

Globe valves used on containers vary in tube size from 3/8" to 1-1/2". While internal valve components may vary from valve to valve, the functional operation and repair procedures for these valves are the same.

Table 24 Valve Repair

STEP NUMBER	PROCEDURE
	NOTE Unless valve component parts are available in inventory, a defective valve should be replaced with a new assembly.

1	Release pressure in the vessel by opening vent valve (V-05).
2	Remove the valve seat assembly.
3	Disassemble the valve and inspect all piece parts
4	Clean all metallic parts with a good industrial cleaner, and all rubber & teflon parts in a warm water and soap solution.
5	Air dry all components using a clean low pressure air source.
6	Replace all worn, deformed or damaged parts.
7	Repack the valve using a replacement packing kit from the valve manufacture. Follow the valve manufactures recommended replacement instructions. Reassemble the valve. Make sure that mating surfaces are clean and properly seated. If the repaired valve is not to be reinstalled immediately, seal it in a polyethylene bag for storage. Apply a label to the bag such as "CLEAN VALVE. DO NOT OPEN BAG UNLESS UNIT IS TO BE INSTALLED."

7.5 REGULATOR REPAIR

When a defective pressure building regulator/ economizer regulator or final line regulator is identified, remove and repair the units as detailed in this manual.

NOTE:

Replacement regulators should be obtained from Chart to ensure compatibility.

Table 25 General Regulator Repair

STEP NUMBER	PROCEDURE
	NOTE Unless regulator component parts are available in inventory, a defective regulator should be replaced with a new assembly.
1	Release pressure in the vessel by opening vent valve (V-05).
2	Depressurize the regulator.
3	It is possible that the body of the regulator is permanently installed in the vessel; in this case the seats, domes, pistons, springs, gaskets, etc. can be removed and replaced.
4	Disassemble the regulator, making sure to identify all piece parts removed.
5	Inspect all parts for wear, deformation, nicks, or damage. Replace all gaskets and O-rings.
6	Clean all metal parts with an industrial cleaning solvent. Air dry with a clean, low-pressure air source.
7	Reassemble the regulator in the reverse order of disassembly.
8	Bench test the rebuilt unit to make sure that it actuates properly at the set pressure. The pressure builder/economizer and final line regulators close to regulate downstream pressure.
9	If the regulator is to be reinstalled on a vessel, do so as soon as possible following repair. If it is to be returned to inventory, seal the unit in a polyethylene bag for storage. Apply a label to the bag such as "CLEAN REGULATOR, DO NOT OPEN BAG UNLESS UNIT IS TO BE INSTALLED. "

10	Pressurize the regulator by opening the applicable pressure building and isolation valves. Allow pressure to build up in the system and verify the reliability of the rebuilt unit.

7.6 GAUGE REPAIRS

Since a special instrument is normally required for making gauge repairs. It is advised that a defective gauge be replaced with a new unit and the defective one returned to your local Chart distributor or to the factory for repairs. However, before replacing a gauge there are a number of checks that can be performed.

CAUTION:

Before removing (or calibrating) the tank pressure gauge or liquid level gauge, make sure gauge isolation valves are closed and that the equalizing valve is open.

The major cause of gauge malfunction is a leakage in the gauge line. Therefore, as a first check, make certain that gauge lines are leak tight. Other gauge tests include:

1. Check gauge lines of obstructions.
2. Check leaky equalizer valve.
3. Ensure that connection lines are properly mated.
4. Verify that the gauge is properly zeroed.
5. Ensure that the pointer doesn't stick.

If the above checks fail to correct the problem, remove and replace the gauge. When returning the gauge to Chart for repair, indicate the nature of the difficulty experienced with the gauge in your letter of transmittal.

7.7 INNER TANK BURST DISC REPAIR

The tank burst disc is a safety relief device that will rupture completely to relieve inner tank pressure in the event tank relief valve fails or is unable to accommodate sufficient flow. Due to changes in pressure in the vessel, the disc will flex, gradually harden, embrittle, and consequently rupture at a lower pressure.

The following table serves to describe replacement of the inner vessel burst disc for vessels equipped with a dual relief system. In the event that a component needs to be replaced in the dual relief system, simply switch the selector handle to the other side of the safety system to allow routine maintenance and repair.

Table 26 Tank Burst Disc Replacement - Dual Safety System

STEP NUMBER	PROCEDURE
1	Switch Vent Diverter Selector Valve (DIV-01) to other side, and depressurize the isolated side of the relief valve system, rather than venting vessel.
2	Assure pressure is at 0 psi (Low) by opening the Vent Purge Valve (V-08 or V-09).
3	Remove the damage Burst Disc (BD-01 or BD-02) and install the replacement burst disc, making sure that mating surfaces are clean and properly seated. Use an oxygen compatible liquid thread sealant to prevent leaking.
4	If open, close the Vent Purge Valve (V-08 or V-09)
5	Switch Vent Diverter Selector Valve to a Mid position and leak check.

7.8 TESTING AFTER REPAIR

After making repairs requiring disassembly or part replacement, leak test all valves and piping joints that were taken apart and reconnected. Do not return the vessel to service until all leaks have been corrected or retested.

Chapter 8

8 PARTS LIST

Figure 80 - Reference Schematic for Parts Listing

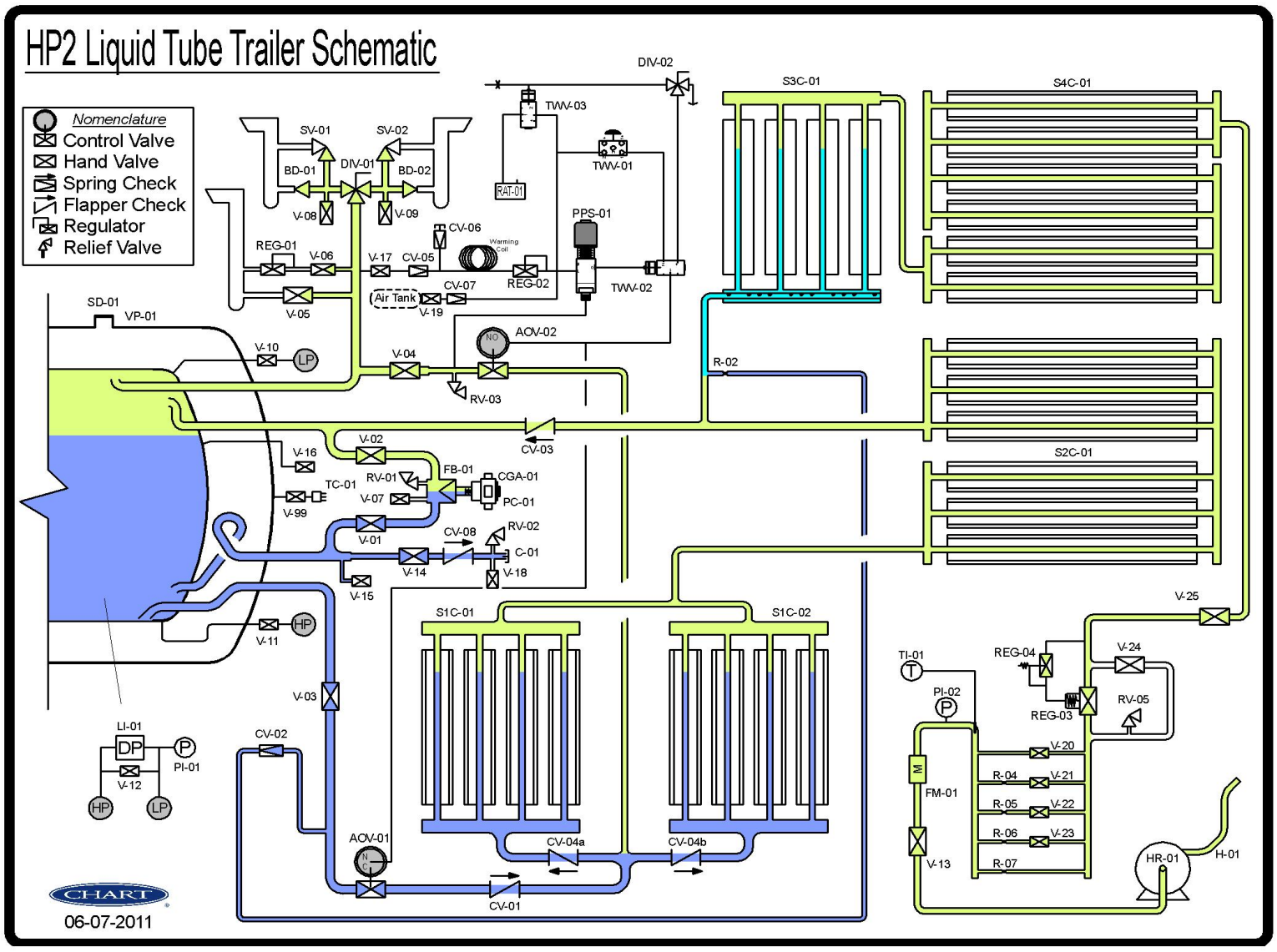


Table 27 - Component Listing

Component Listing					
REF #	Valve #	Description	Chart Part Number	Item Master Description	Manufacture info
1	V-01	VALVE, BOTTOM FILL	10927184	VALVE GLOBE BRZ 1-1/2PS W/3"SS STUBS	REGO #BK9412T-PC
2	V-02	VALVE, TOP FILL	10927184	VALVE GLOBE BRZ 1-1/2PS W/3"SS STUBS	REGO #BK9412T-PC
3	V-03	VALVE, P. B. FEED	10927184	VALVE GLOBE BRZ 1-1/2PS W/3"SS STUBS	REGO #BK9412T-PC
4	V-04	VALVE, P. B. ISOLATION	10927184	VALVE GLOBE BRZ 1-1/2PS W/3"SS STUBS	REGO #BK9412T-PC
5	V-05	VALVE, MANUAL VENT	10927192	VALVE GLOBE BRZ 1PS W/3"STUBS	REGO #BK9408T-PC
6	V-06	VALVE, ROAD RELIEF	10907221	VALVE GLOBE BRZ 1/2 W/1/2PS SS	STUB INLET*1/2NPT OUTLET REGO
7	V-07	VALVE, FILL LINE DRAIN	1713202	VALVE SHUTOFF 3/8FPT	REGO #T9453 REGO QUOTE
8	V-08	VALVE, DUAL RELIEF DRAIN	10907239	VALVE NEEDLE BRS 1/4MPT(ANGLE)	REGO #CMM250A B31.3
9	V-09	VALVE, DUAL RELIEF DRAIN	10907239	VALVE NEEDLE BRS 1/4MPT(ANGLE)	REGO #CMM250A B31.4
10	V-10	VALVE, GAS PHASE LOW	10907239	VALVE NEEDLE BRS 1/4MPT(ANGLE)	REGO #CMM250A B31.5
11	V-11	VALVE, LIQUID PHASE HIGH	10907239	VALVE NEEDLE BRS 1/4MPT(ANGLE)	REGO #CMM250A B31.6
12	V-12	VALVE, EQUALIZATION	10907239	VALVE NEEDLE BRS 1/4MPT(ANGLE)	REGO #CMM250A B31.7
13	V-13	VALVE, GAS USE	1718772	VALVE GLOBE BRS 1FPT	REGO #BK8408T B31.3
14	V-14	VALVE, LIQUID WITHDRAWAL	10927192	VALVE GLOBE BRZ 1PS W/3"STUBS	REGO #BK9408T-PC
15	V-15	VALVE, LIQUID SAMPLE	1710012	VALVE BRS SH 3/8FPT*3/8 SCH 10	*2-1/8 REGO T9464DA B31.3
16	V-16	VALVE, FULL TRYCOCK	1710012	VALVE BRS SH 3/8FPT*3/8 SCH 10	*2-1/8 REGO T9464DA B31.3
17	V-17	VALVE, PNEUMATIC SUPPLY	1710012	VALVE BRS SH 3/8FPT*3/8 SCH 10	*2-1/8 REGO T9464DA B31.3
18	V-18	VALVE, LIQUID USE DRAIN	1710012	VALVE BRS SH 3/8FPT*3/8 SCH 10	*2-1/8 REGO T9464DA B31.3
19	V-19	VALVE, PRESSURE PROTECTION	10601598	VALVE PRESSURE PROTECTION(NEW)	BENDIX #288323N 70PSI PR-4
20	V-99	VALVE, TC-01 ISOLATION	10482381	VALVE BELLOWS SEALED BRS 1/8	HOKE 4111L2B BRS 1/8MPT*1/8FPT
21	CV-01	VALVE CHECK, P. B. FEED	14801600	VALVE CHECK BRS 1-1/2"FPT	NIBCO #T-473-Y 1-1/2" CL300
22	CV-02	VALVE CHECK, LIQUID ASSIST	11051090	VALVE CHECK BRS 1/2FPT*1/2FPT	GENERANT CV-503B-T-5 O2 CLN
23	CV-03A	VALVE CHECK, GAS RETURN	14801600	VALVE CHECK BRS 1-1/2"FPT	NIBCO #T-473-Y 1-1/2" CL300
24	CV-04A	VALVE CHECK, P. B. FEED LEFT	11656072	VALVE CHECK BRS 1FPT	NIBCO #T-473-Y 1" CLASS 299
25	CV-04B	VALVE CHECK, P. B. FEED RIGHT	11656072	VALVE CHECK BRS 1FPT	NIBCO #T-473-Y 1" CLASS 300
26	CV-05	VALVE CHECK, PNEUMATIC SUPPLY	11889589	VALVE CHECK BRS 3/8FPT*3/8FPT	GENERANT CV-373B-T-8-X O2 CLN
27	CV-06	VALVE CHECK, AUXILARY AIR	11889589	VALVE CHECK BRS 3/8FPT*3/8FPT	GENERANT CV-373B-T-8-X O2 CLN
28	CV-07	VALVE CKECK, TRAILER AIR	11889589	VALVE CHECK BRS 3/8FPT*3/8FPT	GENERANT CV-373B-T-8-X O2 CLN
29	CV-08	VALVE CHECK, LIQUID USE	11656072	VALVE CHECK BRS 1FPT	NIBCO #T-473-Y 1" CLASS 300
30	RV-01	VALVE RELIEF, TOP AND BTM FILL	1811472	RV BRS 1/4MPT 450PSI	REGO #PRV9432T450
31	RV-02	VALVE RELIEF, LIQUID USE	12898487	RV BRS 1/4MPT 660PSI GENERANT	GENERANT #CRV-250B-K-660 B31.3
32	RV-03	VALVE RELIEF, P. B.	12898487	RV BRS 1/4MPT 660PSI GENERANT	GENERANT #CRV-250B-K-660 B31.3
33	REG-01	REGULATOR, ROAD RELIEF	14534610	REGULATOR BRZ .375NPS @ 17PSI	CASH FRM #11225-0017 B31.3
34	REG-02	REGULATOR, PNEUMATIC ASSIST	13355716	VICTOR SR 450E-580 REGULATOR	SINGLE STAGE 10-200 PSIG
35	SV-01	SAFETY RELIEF VALVE, VENT	11899111	RV BRS 3/4MPT*1FPT 600PSI	AGCO #81BM68-4 ASME SEC VIII TEFLON
36	SV-02	SAFETY RELIEF VALVE, VENT	11899111	RV BRS 3/4MPT*1FPT 600PSI	AGCO #81BM68-4 ASME SEC VIII TEFLON
37	BD-01	BURST DISC, VENT CIRCUIT	14796812	RPD ASSY 1/2"MPT*1/2"MPT 900PS	BRS W/316 SS DISK B31.3 ASME
38	BD-02	BURST DISC, VENT CIRCUIT	14796812	RPD ASSY 1/2"MPT*1/2"MPT 900PS	BRS W/316 SS DISK B31.3 ASME
39	C-01	CAP, LIQUID USE	15079532	CAP SS 1"ODT 37D FL	MCMASTER-CARR #50715K518

40	DIV-01	VALVE DIVERTER, DUAL RELIEF	10975557	VALVE BALL DIV BRZ 1"PS W/6"	STUB HEROSE #06510.2060.9999
41	DIV-02	VALVE DIVERTER, PNEU. SUPPLY	10730779	VALVE 3-WAY BALL 1/4FPT	WHITEY # B-43XTLF4-BKB-SC11
42	FB-01	FILL BLOCK WITH CHECK VALVE	259106	VALVE TEE CHECK BRS ASSY	REGO #CRT000001 W/TCV8512-8
43	R-02	RESTRICTOR ORIFICE	14867705	ORIFICE SS .500"OD * .187"ID	Chart
44	PC-01	CAP CGA PRESSURE	6510802	PRESS CAP ASSY BRS CGA NI-150	ACME #590-030-15 CGA V-6
45	PPS-01	PNEUMATIC PRESSURE SWITCH	14807315	PRESS SWITCH PNEU 1/4FPT 200-750	K-DYNE #P40LP3W2B0S 750 PSI
46	TWV-01	PNEUMATIC CONTROL ON/OFF	14816781	VALVE PTO CONTROL 1/4"ODT	PARKER #KVY8374BLK/WHT
47	TWV-02	PNEU.C CTRL AOV-01 AND AOV-02	13857901	VALVE SPOOL BRS 3-WAY	CLIPPARD #FV-3P-E COLD WEATHER
			13857855	ACTUATOR PILOT SINGLE SPRING	CLIPPARD #MPA-10P-E COLD
48	TWV-03	PNEUMATIC CONTROL RAT-01	13857901	VALVE SPOOL BRS 3-WAY	CLIPPARD #FV-3P-E COLD WEATHER
			13857855	ACTUATOR PILOT SINGLE SPRING	CLIPPARD #MPA-10P-E COLD
49	RAT-01	VALVE, RATTLER	11859700	VIBRATOR SS TURBINE W/MUFFLER	GLOBAL MFG #SST-25 W/T-3/8"
50	LI-01	LEVEL INDICATOR, INNER	14534791	DIFF PG 6"DIAL 0-100"H2O/CM MW	MIDWEST #116 O2 CLN 3/4"CBM
51	PI-01	PRESSURE INDICATOR, INNER	10737241	PG 4"DIAL 0-600PSI/BAR/KG/CM2	1/4"NPT LM NOSHOK #40.100.600
52	AOV-01	AIR OPERATED VALVE, P. B.	14806267	VALVE BALL SS 1"FPT W/PNEU ACT	HABONIM #10 C47C-6666/NPT-6.0
53	AOV-02	AIR OPERATED VALVE, ECONO.	14806267	VALVE BALL SS 1"FPT W/PNEU ACT	HABONIM #10 C47C-6666/NPT-6.0
54	CGA-01	CGA FITTING 1-1/2" MALE	10891417	FIXED END ASSY MACH BRS CGA NI-150 1-1/2"MNPT	ACME #590-013-15 CGA V-6
55	TC-01	THERMOCOUPLE, OUTER Vacuum	4210049	VACUUM GAUGE TUBE DV-6R	HASTINGS 1415671S #DV-6R
56	VP-01	VACUUM PORT	10731667	PUMPOUT PORT 3-1/2"	Chart
57	SD-01	PRESSURE SAFETY ELEMENT, OUTER	10731675	PUMPOUT PLUG 3-1/2"	Chart
58	S1C-01	COIL, PRESSURE BUILD	14511485	MDL PB COIL ROADSIDE HP2-2500	Chart
59	S1C-02	COIL, PRESSURE BUILD	14723023	MDL PB COIL CURBSIDE HP2-2500	Chart
60	S2C-01	COIL, VAPORIZER	14364930	PB PUSH CIRCUIT ROADSIDE	Chart
61	S3C-01	COIL PREE VAPORIZER	14861565	COIL LPT FIRST STAGE	Chart
62	S4C-01	COIL, VAPORIZER	14364921	PB PUSH CIRCUIT CURBSIDE	Chart
63	FM-01	FLOW METER	14906399	FLOW METER 1"FPT 25-250SCFM	HEDLAND #H790A-250
64	H-01	HOSE 3/4"MPT * 50 FT 1000PSI	15077220	HOSE 3/4"ID*50'LG ENDS	ABLE HOSE SUPER ORTAC 1000 PSI
65	HR-01	HOSE REEL	14915738	HOSE REEL 50' CAPACITY	HANNAY # 3016-26-26
66	PI-02	PRESSURE INDICATOR, USE	13591065	PG 4"DIAL 0-600PSI/BAR SS 1/4" LM	WIKA 232.54
67	TI-01	TEMPERATURE INDICATOR, USE	14920748	THERMOMETER REMOTE -40F/110F	MCMASTER-CARR #3960K91
			14920730	THERMOWELL BRS 1/2"NPT * 3/3/8	MCMASTER-CARR #3960K3
68	R-04	RESTRICTOR ORIFICE	14918251	ORIFICE SS .625"OD * .156"ID	Chart
69	R-05	RESTRICTOR ORIFICE	14918252	ORIFICE SS .625"OD * .156"ID	Chart
70	R-06	RESTRICTOR ORIFICE	14918253	ORIFICE SS .625"OD * .156"ID	Chart
71	R-07	RESTRICTOR ORIFICE	14918254	ORIFICE SS .625"OD * .156"ID	Chart
72	REG-03	REGULATOR, USE	14916925	REGULATOR BRS 1/2"NPT 600PSIG	DUNCAN #P73-B2A7-100M0000A
73	REG-04	REGULATOR, USE CONTROL	15077414	REG BRS .250NPT 5-500PSIG	SENSIFLO #P12-B1A7-16000SA
74	RV-05	VALVE RELIEF, REG. BY-PASS	12898487	RV BRS 1/4MPT 660PSI	GENERANT #CRV-250B-K-660 B31.3
75	V-20	VALVE, USE CONTROL	1714042	VALVE BALL BRS 3/8FPT	APOLLO #70-102-14,NON-EXTENDED
76	V-21	VALVE, USE CONTROL	1714042	VALVE BALL BRS 3/8FPT	APOLLO #70-102-14,NON-EXTENDED
77	V-22	VALVE, USE CONTROL	1714042	VALVE BALL BRS 3/8FPT	APOLLO #70-102-14,NON-EXTENDED
78	V-23	VALVE, USE CONTROL	1714042	VALVE BALL BRS 3/8FPT	APOLLO #70-102-14,NON-EXTENDED
79	V-24	VALVE, REGULATOR BY-PASS	1711152	VALVE BALL BRS 1/2FPT	APOLLO #70-143-14 B31.3
80	V-25	VALVE, HOSE REEL FEED	1711152	VALVE BALL BRS 1/2FPT	APOLLO #70-143-14 B31.3

Chapter 9

9 DRAWINGS

9.1 OUTLINE AND DRAWINGS C-15082256

9.2 SPEC SHEET PN: 14364868

9.3 SCHEMATIC/NOMENCLATURE C-14876572

GLOSSARY CROYOGENIC TERMS

Cryogenic: A branch of engineering that relates to the production and effects of very low temperature, usually -238°F and colder.

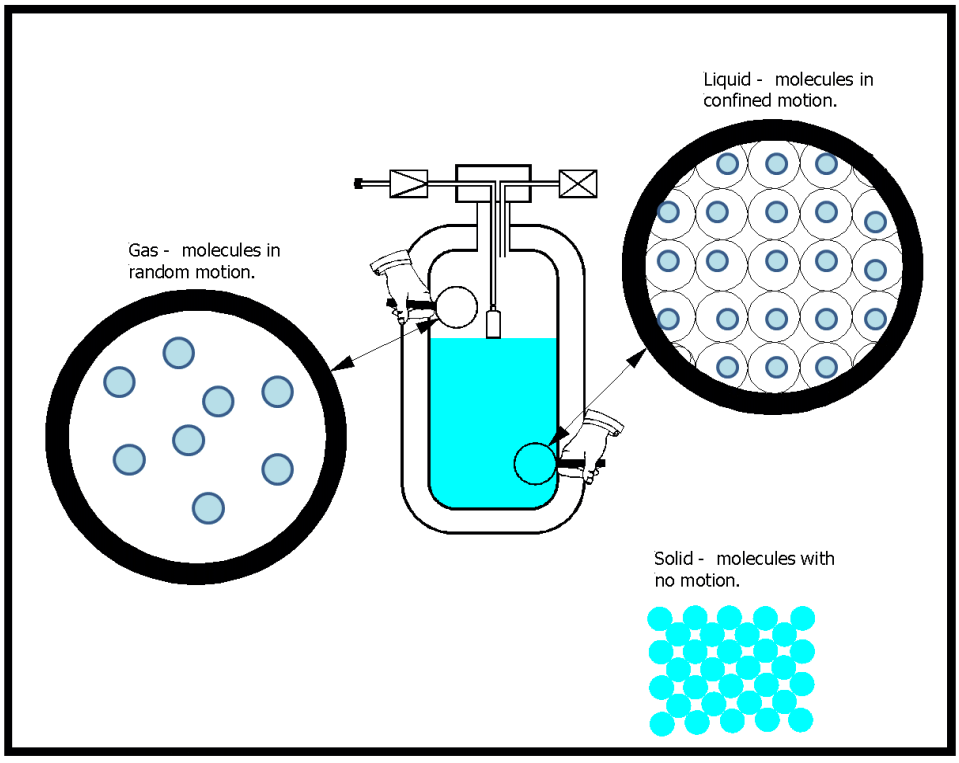
Gas	Boiling Temperature (at 0 psig) (°F)
Argon	-302
Nitrogen	-320
Oxygen	-297

A. Classical states of matter

Types of matter:

1. GAS
   - Molecules in random motion
2. LIQUID
   - Molecules in confined motion
3. SOLID
   - Molecules with no motion

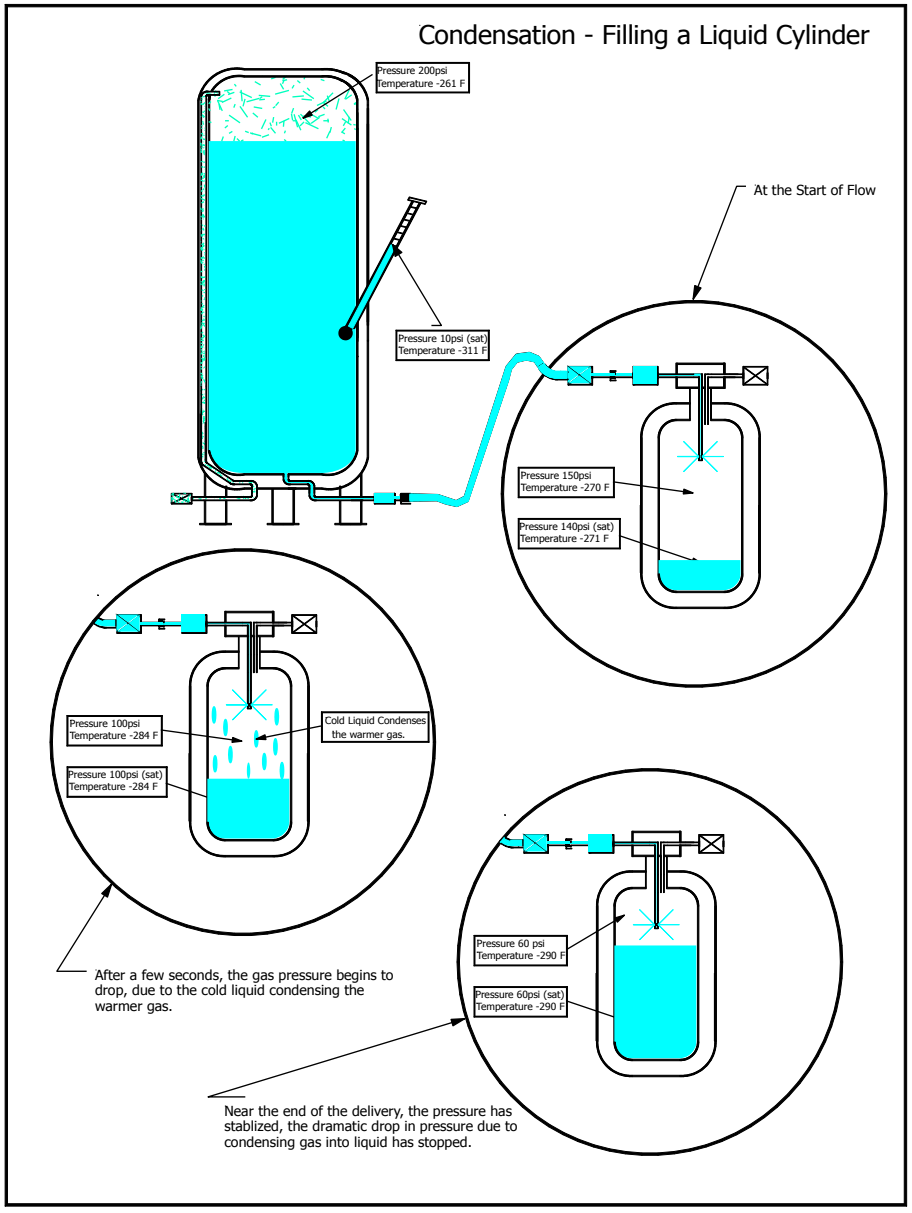
State of Matter - Solid, Liquid and Gas



B. Condensation

1. Definition:
   - The conversion of vapors into liquid phase by cooling the vapor.

2. **Top Filling** is possible due to condensation
   - The fresh cold liquid passing through the vapor space condenses the vapor back to Liquid form
   - This process causes the collapse of vapor pressure in the trailer

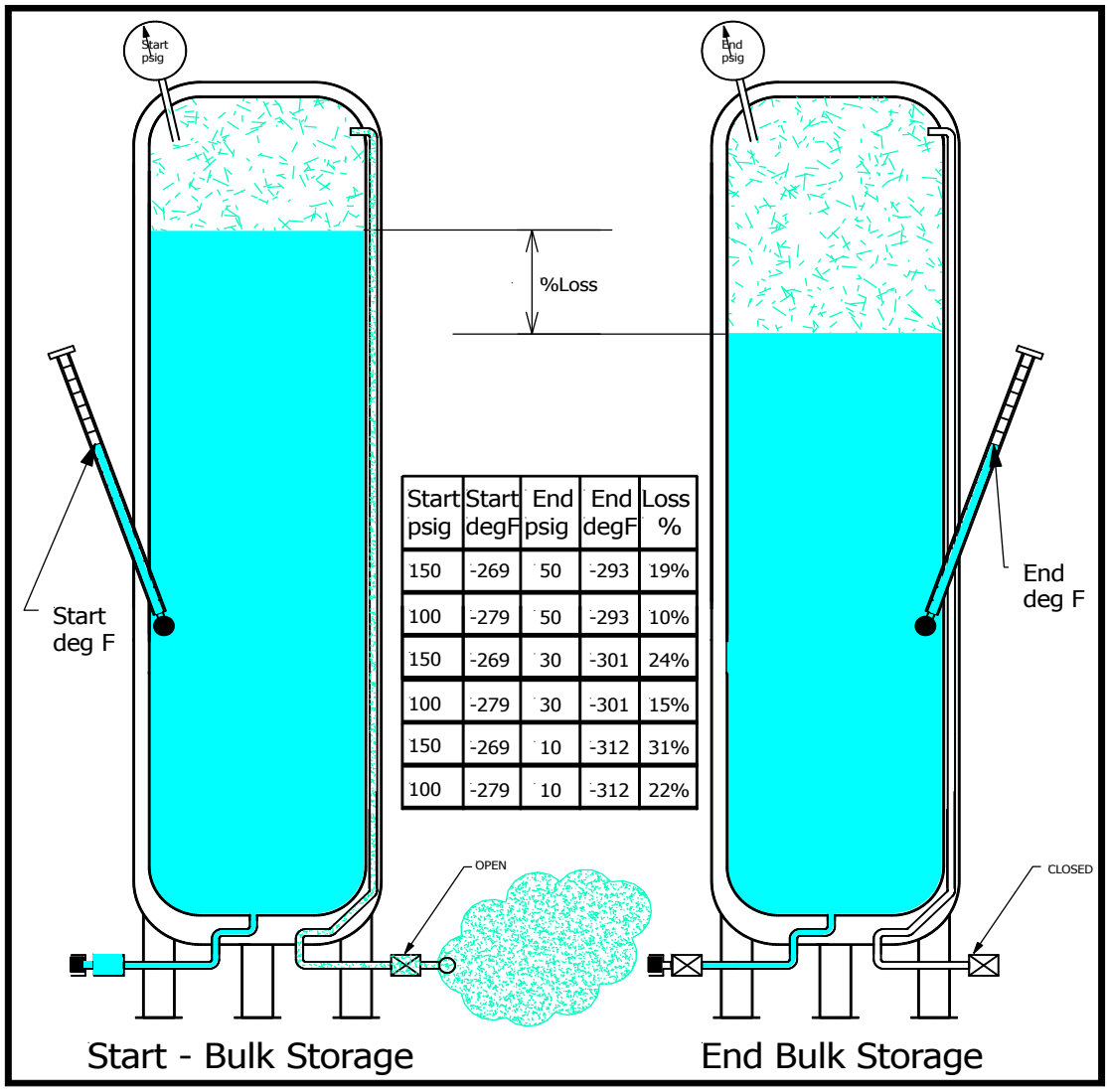


C. Depressurization flash loss

1. Vaporization caused by reducing the gas phase pressure to something less than the saturated vapor pressure of the liquid

2. During the venting of the tank below the saturation pressure of the liquid :
   - The liquid temperature will drop
   - The weight of the liquid decreases
   - The saturation pressure will drop

Depressurization (Flash) Losses - Product loss through Vent Valve



Start psig	Start degF	End psig	End degF	Loss %
150	-269	50	-293	19%
100	-279	50	-293	10%
150	-269	30	-301	24%
100	-279	30	-301	15%
150	-269	10	-312	31%
100	-279	10	-312	22%

D. Economizing

1. At high vessel pressures use gas is supplied from vapor side of storage.

2. Reduction in pressure reduces storage temperatures

E. Entrainment

1. Liquid droplets carried along with a flowing gas stream

2. Can occur during violent depressurization of a tank and during the top filling of a tank with the vent valve open

3. Large product losses will occur during this event

F. Equilibrium

1. Definition
   - A state where the liquid and gas phases co-exist at the same temperature and vapor pressure

2. If there is a temperature difference between the gas and the liquid (with the tank closed), the gas and liquid will change their temperatures until they are equal.

G. Flowing gas pressure drop

1. Pressure lost due to the flow of gas

2. The faster a gas flow through a piping circuit, the higher the pressure drop

Table of Pressure Drops

Pipe Length 200 ft

Pipe Diameter 1 in

# of Bends 40

* Pressure Drop given in psi.

Working Pressure (PSI)

Flow Rate (SCFH)	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625
500	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1500	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2000	0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
2500	1.3	1.1	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4
3000	1.8	1.6	1.5	1.3	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6
3500	2.4	2.1	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	1.0	1.0	0.9	0.9	0.8	0.8
4000	3.1	2.7	2.5	2.3	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.2	1.1	1.1	1.0
4500	3.8	3.4	3.1	2.8	2.6	2.4	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4	1.3	1.3
5000	4.6	4.1	3.8	3.4	3.2	2.9	2.7	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.8	1.7	1.6	1.6
5500	5.5	4.9	4.5	4.1	3.8	3.5	3.3	3.0	2.9	2.7	2.6	2.4	2.3	2.2	2.1	2.0	1.9	1.9
6000	6.5	5.8	5.3	4.8	4.4	4.1	3.8	3.6	3.4	3.2	3.0	2.8	2.7	2.6	2.5	2.4	2.3	2.2
6500	7.5	6.7	6.1	5.6	5.1	4.8	4.4	4.1	3.9	3.7	3.5	3.3	3.1	3.0	2.9	2.7	2.6	2.5
7000	8.6	7.7	7.0	6.4	5.9	5.5	5.1	4.8	4.5	4.2	4.0	3.8	3.6	3.4	3.3	3.1	3.0	2.9
7500	9.8	8.8	8.0	7.3	6.7	6.2	5.8	5.4	5.1	4.8	4.5	4.3	4.1	3.9	3.7	3.6	3.4	3.3
8000	11.1	9.9	9.0	8.2	7.5	7.0	6.5	6.1	5.7	5.4	5.1	4.9	4.6	4.4	4.2	4.0	3.9	3.7
8500	12.4	11.1	10.0	9.2	8.4	7.8	7.3	6.8	6.4	6.0	5.7	5.4	5.2	4.9	4.7	4.5	4.3	4.2
9000	13.8	12.3	11.2	10.2	9.4	8.7	8.1	7.6	7.1	6.7	6.4	6.0	5.7	5.5	5.2	5.0	4.8	4.6
9500	15.2	13.6	12.3	11.3	10.4	9.6	9.0	8.4	7.9	7.4	7.0	6.7	6.3	6.1	5.8	5.5	5.3	5.1
10000	16.7	15.0	13.6	12.4	11.4	10.6	9.9	9.2	8.7	8.2	7.7	7.3	7.0	6.7	6.4	6.1	5.8	5.6
10500	18.3	16.4	14.9	13.6	12.5	11.6	10.8	10.1	9.5	8.9	8.5	8.0	7.6	7.3	7.0	6.7	6.4	6.1
11000	20.0	17.9	16.2	14.8	13.6	12.6	11.8	11.0	10.3	9.8	9.2	8.8	8.3	7.9	7.6	7.3	7.0	6.7
11500	21.7	19.4	17.6	16.1	14.8	13.7	12.8	11.9	11.2	10.6	10.0	9.5	9.0	8.6	8.2	7.9	7.6	7.3
12000	23.5	21.0	19.0	17.4	16.0	14.8	13.8	12.9	12.1	11.5	10.8	10.3	9.8	9.3	8.9	8.5	8.2	7.9
12500	25.3	22.7	20.5	18.8	17.3	16.0	14.9	13.9	13.1	12.4	11.7	11.1	10.6	10.1	9.6	9.2	8.8	8.5
13000	27.2	24.4	22.1	20.2	18.6	17.2	16.0	15.0	14.1	13.3	12.6	11.9	11.4	10.8	10.3	9.9	9.5	9.1
13500	29.2	26.1	23.7	21.6	19.9	18.4	17.2	16.1	15.1	14.3	13.5	12.8	12.2	11.6	11.1	10.6	10.2	9.8
14000	31.2	28.0	25.3	23.1	21.3	19.7	18.4	17.2	16.2	15.2	14.4	13.7	13.0	12.4	11.9	11.4	10.9	10.5
14500	33.3	29.9	27.0	24.7	22.7	21.1	19.6	18.4	17.3	16.3	15.4	14.6	13.9	13.3	12.7	12.1	11.6	11.2
15000	35.5	31.8	28.8	26.3	24.2	22.4	20.9	19.6	18.4	17.3	16.4	15.6	14.8	14.1	13.5	12.9	12.4	11.9

Calculations made using Eqn 3-20 from "Flow of Fluids Through Valves, Fittings and Pipe" by Crane

****** Important Assumptions ******

Highest allowable pressure drop 10 psi.

Acceptable Pressure Drop
Unacceptable Pressure Drop

Note: The table above only valid for a predetermined condition. Contact Chart inc. for the pressure drops table calculator that will generate a new table for your specific application.

H. Flowing liquid pressure drop

1. Pressure lost due to the flow of liquid

2. The faster a liquid flows through a piping circuit, the higher the pressure drop

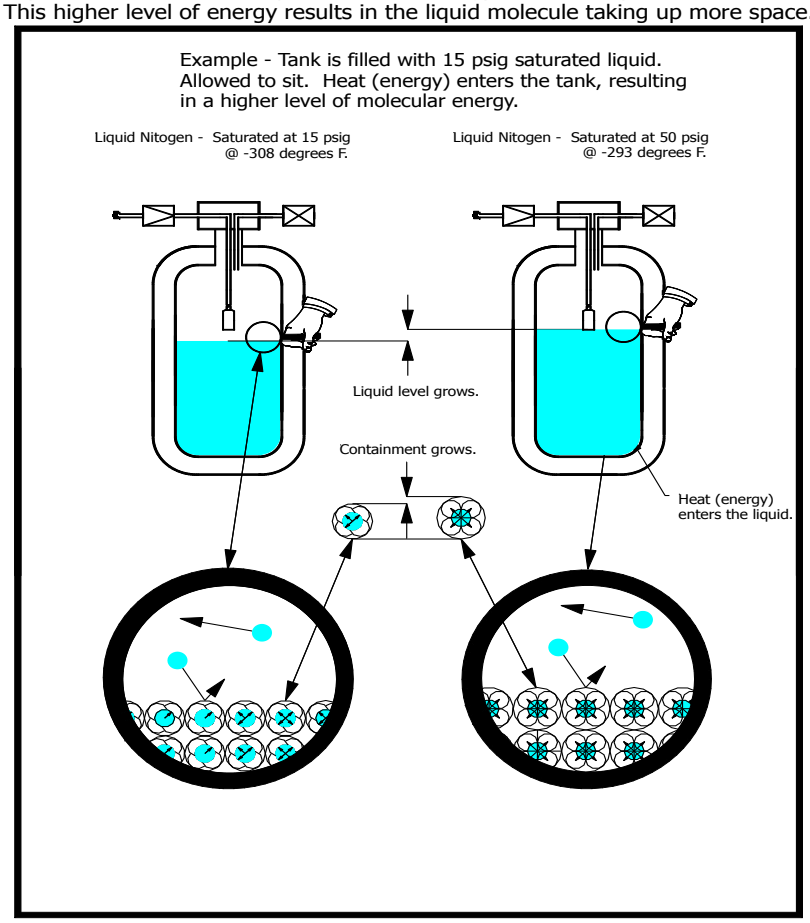
I. Liquid growth

1. Heat enters the tank (not perfect insulation) -> The liquid warms -> Vapor pressure slowly begins to build -> Decrease in liquid density -> **Increase in liquid volume (LIQUID GROWTH)**

2. Liquid growth is a safety concern

3. Liquid full or hydraulically full :
   * The liquid grow until it fills the entire storage vessel
   * The pressure rises rapidly
   * The safety valve will relieve and the tank will vent liquid

Liquid Growth - Warmer liquid has more energy and takes up more volume.
This higher level of energy results in the liquid molecule taking up more space.



J. Liquid head pressure

1. Definition
   - The internal energy of a fluid due to the pressure exerted on its container

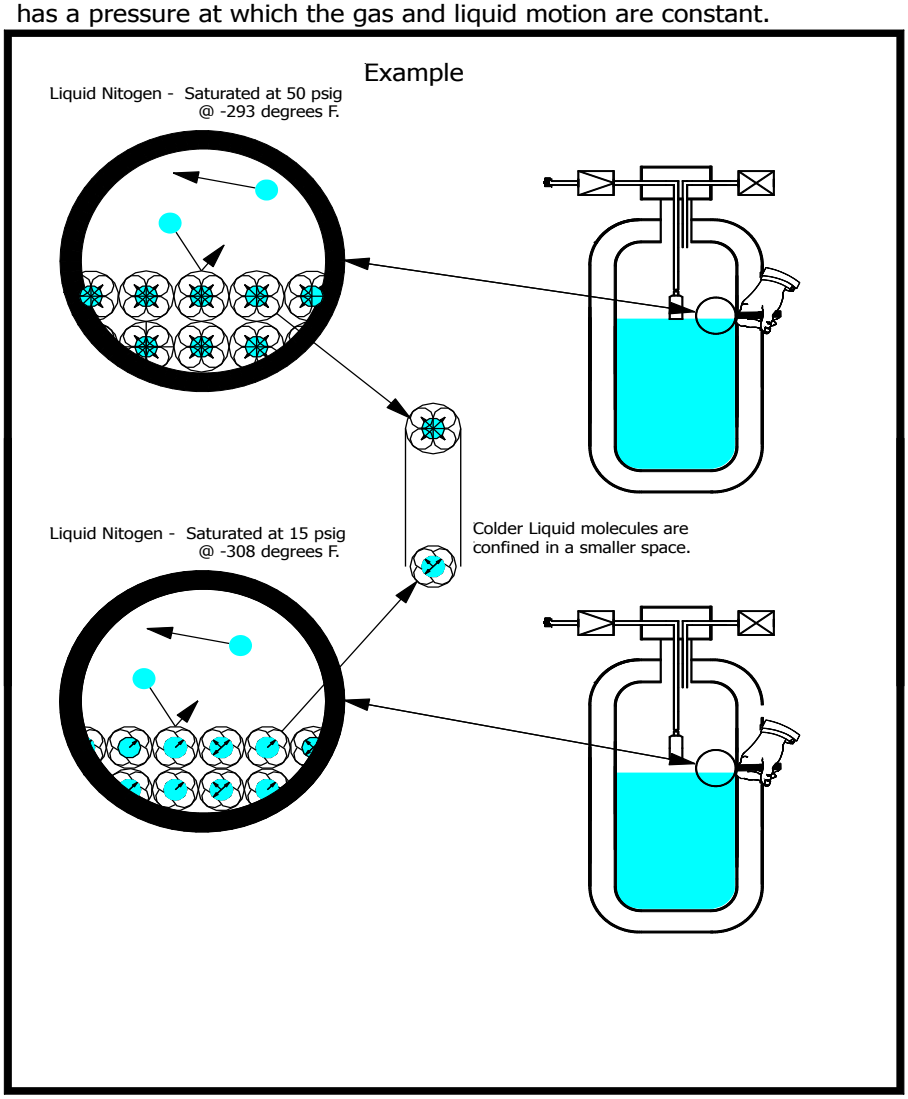
K. Liquid saturation

1. Definition:
   - A state where the liquid and gas phase co-exist at the same temperature and vapor pressure (in equilibrium)

2. Liquid density, temperature, and equilibrium pressure changes with the saturation level of the liquid

3. At a higher or warmer temperature, liquid molecules takes up more space

Saturation - Liquid can exist at a range of temperatures. Each temperature state has a pressure at which the gas and liquid motion are constant.



L. Net positive suction head

1. Definition
   - A pressure, associated with the intake of a pump, expressed in feet of pumped liquid, resulting from the algebraic evaluation of both the accretive and depletive aspects of that suction system

2. Usually denoted by the expression : **NPSH**

M. Pump cavitations

1. Definition
   - Partial or full loss of pump primarily due to insufficient sub-cooling or net positive

Suction head

2. Audible changes in the pump often are an indication of partial loss of prime

3. The pump will stop pumping during full loss of prime

4. Cavitations will cause damage to the pump

N. Saturation pressure

1. Definition
   - The pessure (usually in psi) that is used to describe the current condition of a liquid
     and gas within a closed container

O. Stratification

1. A vertical temperature gradient (temperature change) from top to bottom with colder product at the bottom and warmer product at the top

2. Warm liquid is <u>less</u> dense
   - Stay at the top of the tank

3. Cold liquid is <u>more</u> dense
   - Stay at the bottom of the tank

P. Sub-cool

1. Raising gas space pressure above the normal vapor pressure of a saturated liquid creating Net Positive Suction Head (NPSH)

2. When transferring liquid from a vessel, sub-cool is **<u>important</u>** to maintain the liquid in
   the liquid state as it travels from the tank through the piping circuit

3. Liquid leaving the pump must be replaced in the sump at the same rate

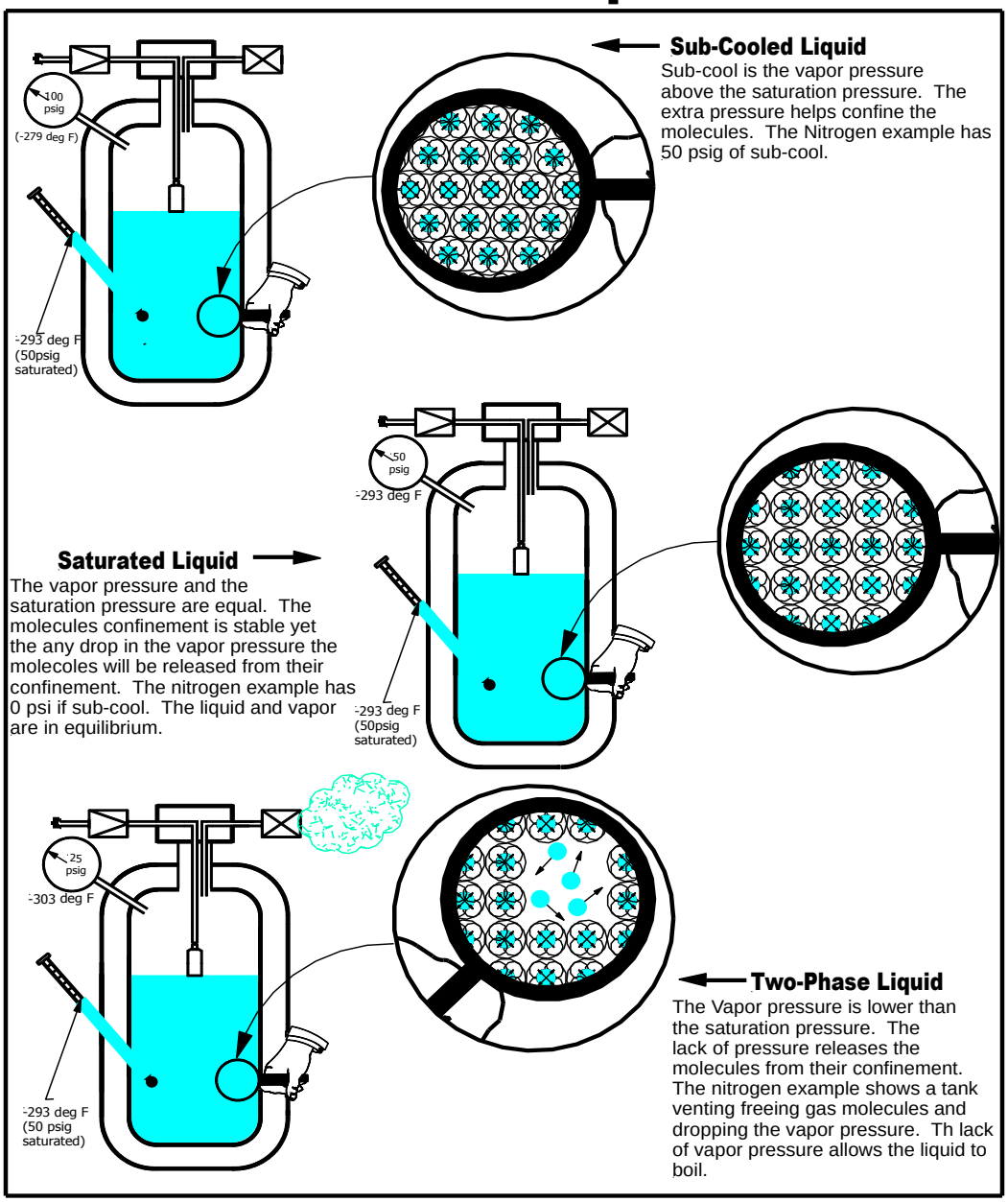
4. Liquid flowing creates pressure drop as it travels through the feed line

5. if the pressure drops below the saturation pressure of the liquid, the liquid will begin to boil

Q. Two phase liquid

1. Definition
    - The mix of liquid and gas due to the pressure dropping below the saturation pressure of the liquid

Two-Phase Liquid



Sub-Cooled Liquid

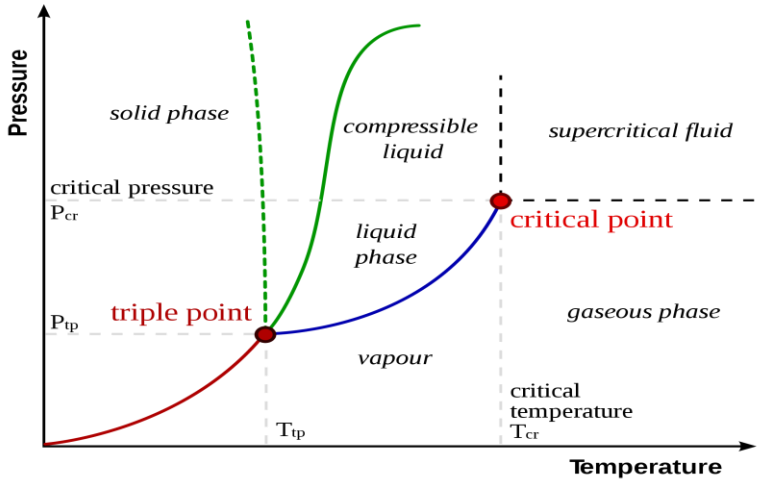
Sub-cool is the vapor pressure above the saturation pressure. The extra pressure helps confine the molecules. The Nitrogen example has 50 psig of sub-cool.

Saturated Liquid

The vapor pressure and the saturation pressure are equal. The molecules confinement is stable yet the any drop in the vapor pressure the molecoles will be released from their confinement. The nitrogen example has 0 psi if sub-cool. The liquid and vapor are in equilibrium.

Two-Phase Liquid

The Vapor pressure is lower than the saturation pressure. The lack of pressure releases the molecules from their confinement. The nitrogen example shows a tank venting freeing gas molecules and dropping the vapor pressure. Th lack of vapor pressure allows the liquid to boil.



R. Vapor pressure

1. Definition
   - The pressure of a liquid in equilibrium with its own vapor

2. The vapor pressure is a function of temperature

3. Measured by reading the tank pressure gauge

S. Vaporization

1. Definition
   - The converting of liquid into vapor by warming the liquid

2. This process is usually used for the purpose of sub-cooling or for gas use