Product Manual

Perma-Cyl 5500 LH_2 Storage Tanks

Designed and Built by:

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Contents

Revision Log

Revision Level	Date	Description
A	4/23/2026	Initial publication

Preface

Important Safety Note

Please make sure to read this entire manual before working on this system. This manual contains information regarding the safe operation and handling of LH2 (hydrogen, refrigerated liquid) and H2 (hydrogen gas). It should be read and understood thoroughly by anyone who operates this equipment. This manual is intended to provide the cryogenic Service Employee with information necessary to operate LH2 tanks.

Consult owner/operator's company policies for working in a liquid or gaseous hydrogen environment. Unless the system piping has been purged with nitrogen or other suitable gas, any gas (pressure) released from the system or any isolated piping, whether by normal action of a safety valve, relief valve or rupture disc, or by the removal of a component for repair/ replacement, will be hydrogen.

Liquid hydrogen, LH2, being stored or dispensed from the system presents the same hazards of low temperature and product under pressure that the more common compressed, liquefied industrial gases (nitrogen and argon) present, but has the additional hazard of being flammable.

Any and all Operators, Maintenance Personnel, or anyone else involved with using or working on this system must be fully aware of and fully trained to deal with these hazards. If you are not so aware and trained, DO NOT use or work on this system.

Please refer to the specific cautions listed in the Safety section of this manual and study the Safety Data Sheet (SDS) for Refrigerated Liquid Hydrogen before handling the product or operating the system. Contact your gas distributor for latest SDS.

General

The Perma-Cyl® MicroBulk Storage System is designed to store and deliver cryogenic liquid or gas. The tank can build and maintain pressure from the automatically regulated pressure building circuit and a continuous gas flow is provided from the tank. However, the Hydrogen Perma-Cyl is specifically designed to store liquid hydrogen (LH2) and provide LH2 to the downstream process.

Initial Inspection

Receiving inspection is one of the most important operations in the life of the tank and should be done thoroughly. Upon receipt of a Perma-Cyl tank, remove any protective wrapping and inspect for the following:

- Any shipping damage including dents, cuts, broken and bent plumbing components. Report any findings to the shipping company and Chart immediately.
- Examine welded and brazed joints on plumbing for cracks or deformation, especially on valves and fittings.
- Check burst discs and relief valves for dirt/damage.
- Check to ensure there is positive pressure on the inner vessel, normally about 20-25 psig. Tanks are shipped with NF purity nitrogen gas. Purging is necessary prior to filling.
- Do not proceed unless all of the above criteria are met.

Vacuum Test Procedures

The Hydrogen Perma-Cyl is equipped with Hastings 1415671S #DV-6R vacuum thermocouple gauge tubes. 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 quality should not be suspected deficient. In the event one of the above conditions exists, see Vacuum Check Procedures listed below.

1. Remove rubber cap on probe outlet to expose contact. Note that the probe housing does not need to be removed to do this.
2. Plug the instrument in to the probe and calibrate the instrument.
3. Open the vacuum probe isolation valve. Wait for five minutes and take vacuum reading. Note that valve handle protrudes through protective housing and can be turned without opening the housing.
4. 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.
5. Verify that the isolation valve is closed.
6. Replace the rubber probe cap.
7. If warm vacuum is above 20 microns, or if your last vacuum reading shows a steady increase from the first, consult factory.

Product Highlights

- Process piping constructed of 316/316L dual grade stainless steel.
- All stainless-steel bottle and pallet base construction.
- Vacuum jacketed fill line piping to keep liquid at the highest quality as delivered.
- Vent stack assembly conforms to industry standards.
- Easy to use instruments and controls located at user height.
- Isolation valves for regulator and liquid level gauge.
- Vacuum thermocouple gauge.

Acronyms / Abbreviations

The following acronyms/abbreviations may be used throughout this manual:

AOV	Air-Operated Valve
ASME	American Society of Mechanical Engineers
BARG	Pressure (Metric) Gauge
CGA	Compressed Gas Association
CV	Check Valve
DOT	Department of Transportation
FPT	Female Pipe Thread
H2	Hydrogen
HV	Hand Valve
ID	Inner Diameter
Kg	Kilogram
LH2	Liquid Hydrogen
MAWP	Maximum Allowable Working Pressure
N2	Nitrogen
NER	Normal Evaporation Rate
NFPA	National Fire Protection Association
Nm3	Nominal Cubic Meters
Nm3h	Nominal Cubic Meters/Hour
NPT	National Pipe Thread
O2	Oxygen
PB	Pressure Builder
PSI	Pounds per Square Inch
PSIG	Pounds per Square Inch (Gauge)
PSV	Pressure Safety Valve
SCF	Standard Cubic Feet
SCFH	Standard Cubic Feet/Hour
UFC	Uniform Fire Code

Storage Tank Specifications

Liquid Hydrogen Storage Tank, Perma-Cyl 5500 LH_2	
Inner Vessel	Maximum Allowable Working Pressure (MAWP): 250 psig [17.2 barg]
	Design Pressure: 265 psig [18.2 barg]
	Design Temperature: -423ºF to 100ºF [-253°C to 38°C]
	Code Compliance: ASME Section VIII Division 1
	Material of Construction: ASME SA240 T304 Stainless Steel
Outer Jacket	Code Compliance: Full Vacuum Per CGA-341
	Design Temperature: -40ºF to 150ºF [-40°C to 66°C]
	Material of Construction: ASME SA240 T304 Stainless Steel
	Insulation Type: Vacuum and Multilayer Insulation
	Evacuation Connection: 3.75” Diaphragm
	Vacuum Gauge Connection: Hastings DV-6R
Weight	Empty: 9,200 lbs. [4,173 kg]
	Full: 10,000 lbs. [4,536 kg]
Capacity	Gross (Cold): 1,360 gallons [5,148 liters]
	Net (Cold): 1,260 gallons [4,770 liters]
Gas Equivalent at 0 psig and 60ºF/ 0 barg and 0ºC	140,400 SCF [3,976 NM3]
Shipping Dimensions (L x W x H)	118-1/2 x 118 x 94-3/4 inches [3,010 x 2,997 x 2,407 cm]

Danger, Warning, and Caution Symbols

This manual uses the symbols below to signal potentially dangerous conditions. Read this information carefully and take the necessary steps to protect Personnel and property.

Danger! Is used to warn of immediate hazards that will cause severe personal injury or death.

Warning! Is used to call attention to a situation that could cause severe personal injury.

Caution! Is used to call attention to a situation that could cause minor personal injury, or damage to the equipment or other property.

Service

The Hydrogen Perma-Cyl tanks have been designed for safe and dependable operation. In the event service is required, contact Chart.

Design Modification

- DO NOT use these tanks in a manner inconsistent with the instructions outlined in this manual.
- DO NOT alter the tank design or perform any service inconsistent with the instructions outlined in this manual without the prior written approval of Chart Inc.
- ALWAYS use replacement parts authorized by Chart Inc. when replacing parts and components. Parts can be ordered from https://www.chartparts.com.

Operator Qualifications

Chart cryogenic tanks are designed for safe and simple operation. Operators are expected to be knowledgeable regarding the nature of the gas(es) with which they are working, as well as all applicable safety requirements. This manual contains several sections dealing with operating instructions, handling instructions, and maintenance procedures. To fully understand these procedures, we recommend that Operators and Maintenance Personnel first become familiar with the system components.

Manufacturer Liability Statement

The manufacturer believes the information presented in this manual to be accurate and up to date and assumes no liability concerning the use of information contained herein by any party. The information contained herein is not a recommendation to violate federal, provincial, state, or municipal laws or regulations.

Safety

Safety Summary

While Chart equipment is designed and built to the most rigid standards, no piece of mechanical equipment can ever be made failsafe. Strict compliance with proper safety and handling practices are necessary when using a cryogenic system or other compressed gas equipment. We recommend that all our customers re-emphasize safety and safe handling practices to all their employees and customers. While every possible safety feature has been designed into the Perma-Cyl® and safe operations are anticipated, it is essential that the customer carefully reads and fully understands all Warning and Caution notes listed below.

Warning! The Perma-Cyl tank, with its support system is designed, manufactured, and tested to function normally for many years of service. It is never safe to drop a liquid cylinder or let it fall over in any cryogenic service. In the event a liquid cylinder is inadvertently dropped, tipped over, or abused, slowly raise it to its normal vertical position and immediately open the vent valve to release any excess pressure in a safe manner. As soon as possible, remove the liquid product from the vessel in a safe manner. If damage is evident or suspected, return the unit to Chart prominently marked "LIQUID CYLINDER DROPPED, INSPECT FOR DAMAGE". Prior to returning, tank needs to be properly purged out of service.

Warning! Any welding that is done on the outside of the Perma-Cyl System can cause loss of vacuum and will VOID any warranty on the unit.

Warning! Before removing cylinder parts or loosening fittings, completely empty the liquid cylinder of liquid and release the entire vapor pressure in a safe manner. External valves and fittings can become extremely cold and may cause painful burns to personnel unless properly protected. Personnel must wear protective gloves and eye protection whenever removing parts or loosening fittings. Failure to do so may result in personal injury because of extreme cold and pressure in the cylinder.

Caution! Only use replacement equipment which has been cleaned for oxygen use. Do not use regulators, fittings, hoses, etc., which have been previously used in compressed air service.
Failure to comply with these instructions may result in serious damage to the liquid cylinder and personal injury.

Caution! All valves on an empty Perma-Cyl system should always be kept closed to protect the inner vessel and plumbing from being contaminated.

Caution! All replacement equipment should be acceptable for Hydrogen service.

Caution! Total tank system should be properly grounded for installation. System shall have a resistance to ground of 24 ohms or less. Reference NFPA 2 and CGA H-5.

Safety Bulletin

Portions of the following information are extracted from Safety Bulletin SB-2 from the Compressed Gas Association, Inc.

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.

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.). Under no circumstances should a damaged container be left with product in it for an extended period.

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.

In the event of known or suspected container vacuum problems (even if 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.

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.

Caution! Before locating equipment, become familiar with the NFPA standards No. 55 "Compressed Gases and Cryogenic Fluids Code" & No. 2 "Hydrogen Technologies Code" (www.nfpa.org), as well as with all local safety codes.

Intended Use

The LH2 storage tank in this system is designed only for the storage of LH2 as specified. LH2 is transferred into the fully installed tank, is stored in the tank until required, then is withdrawn for transfer to the downstream process. This LH2 storage tank is not intended for any other use.

If a storage tank is used for a different purpose (i.e., a purpose other than described herein), there is risk of accident, fatal injury, and extensive damage. Therefore, any use that is not intended is forbidden. Neither the manufacturer nor their associated firms or employees is liable for any damage caused as a result of using an LH2 storage tank for any purpose other than the intended purpose stated herein.

Oxygen Deficient Atmospheres

Warning! Nitrogen and argon vapors in air may dilute the concentration of oxygen necessary to support or sustain life. Exposure to such an oxygen deficient atmosphere can lead to unconsciousness and serious injury, including death.

Oxygen Cleaning

When replacing components, only use parts which are considered compatible with hydrogen and have been properly cleaned for oxygen service (Refer to CGA Bulletin G-4.1 "Equipment Cleaned for Oxygen Service"). Do not use regulators, fittings, or hoses which were previously used in a compressed air environment on these tanks. Only oxygen compatible sealants or Teflon tape should be used on threaded fittings. All new piping joints should be leak tested with an oxygen compatible leak-test solution.

Warning! Failure to comply with these instructions may result in serious damage to the system and personal injury

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.

While the tank is in operation, the cold temperatures of LH2 will cause air to condense on some outer process piping (mostly around the PB coil). This liquid air will consist primarily of oxygen and nitrogen. The condensed oxygen that evaporates as the liquid air warms, can lead to an oxygen-enriched environment which increases the risk of combustion and fires. It is important to locate the system in a well-ventilated location since oxygen-rich atmospheres may collect temporarily in confined areas.

System components and interconnecting equipment, including hoses, shall have appropriate compatibility with oxygen. 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.

Danger! If clothing should be splashed with liquid oxygen it will become highly flammable and easily ignited while concentrated oxygen remains. Such clothing must be aired out immediately, removing the clothing if possible, and should not be considered safe for at least 30 minutes.

General LH_2 Safety

It is recommended that all personnel involved with the handling of LH2 should be familiar with the characteristics of both the liquid and the gas produced. The potential hazards in handling LH2 stem mainly from three important properties:

- LH2 is an Extremely Cold Liquid – At atmospheric pressure, depending upon composition, LH2 boils at about --423°F (-253°C).
- A Small Quantity of Liquid Converts into a Large Volume of Gas – One volume of LH2 produces approximately 845 volumes of gas at standard conditions.
- Flammability – Hydrogen is extremely flammable. At ambient conditions the flammable mixture range with air is from 4% to 75% gas by volume.

Hydrogen, Refrigerated Liquid	
DOT UN Number	UN1966
Transport Hazard Class	2.1
Label	Flammable Gas

This equipment contains pressurized LH2 at cryogenic temperatures. The major components in the system generally consist of pressure-containing components (such as a vessel and pipes) encased within outer steel vacuum shells. The pressure vessel operates under medium pressure at extremely low temperatures. Personnel operating this equipment must always adhere to the safety precautions included in the section.

Warning! NEVER use components (valves, gauges, fittings, etc.) or piping as steps or footholds. Always use appropriate equipment to access components for maintenance or repair.

Wear Appropriate Clothing and Protective Gear

Accidental contact of LH2 with skin or eyes may cause a freezing injury similar to a burn. Personnel must wear the appropriate clothing and protective gear while working around the equipment, especially when making or breaking connections. Do not allow liquid to splash, spill or leak. Protect eyes and cover skin wherever the possibility of contact with liquid, cold equipment or cold gas exists. Use clean, easily-removable insulated gloves and long sleeves for arm protection. Cuff-less trousers should be worn over the shoes to allow spilled liquid to be shed away from the Operator's body.

Wear the following items whenever working on this equipment:

- Safety Glasses
- Clean Insulated Gloves
- Face Shield
- Apron
- Long-sleeved Shirt
- Cuff-less Trousers
- Appropriate Shoes
- Harnesses and Retrieval Lines (if entering confined spaces)
- Hard hats
- Hearing protection
- On-person gas monitors

For further information, reference CGA P-44.

Keep Away from Flame or Spark

Hydrogen is highly flammable due to its low ignition energy. All general-purpose electrical equipment (e.g., cellular phones, etc.) is prohibited in areas where LH2 is stored or handled and any storage tanks containing LH2 should be grounded from any static discharge. LH2 must be stored and transferred under positive pressure to prevent the infiltration of air or other gases. Hydrogen burns with a pale blue flame that is nearly invisible in daylight. Keep LH2 equipment away from open flames or electrical sparks. Never permit smoking in areas where LH2 equipment is used, repaired, or stored.

Warning! ***Due to the flammable properties and the risk of asphyxiation, LH2 must never be stored in confined areas or areas unsuitable for LH2 storage. Always exercise caution when storing LH2 containers or parking LH2 vehicles.***

Remove Excess Pressure and Liquid

This equipment is a pressurized system. LH2 will boil and build up pressure in the system. Isolate the affected section and empty the section of liquid before removing parts or loosening fittings. Always remove parts and fittings in a safe manner. Working on a pressurized section in an unsafe or careless manner can cause serious injuries, or even death. External valves and fittings can become extremely cold and can cause painful burns to personnel who are not adequately protected. Always empty LH2 and remove pressure from the system before removing any parts or components.

Warning! ***DO NOT trap LH2 between two shutoff valves without a relief device to protect piping. Trapped LH2 can vaporize and rapidly increase pressure, causing pipes to burst.***

Storage Overview

The following procedures describe the necessary steps that need to be taken to maintain equipment that has been in use and will become idle for an extended period of time (i.e., 3 to 24 months). The equipment is rated for outdoor use and can be kept idle indefinitely if the recommended procedures are followed.

Mechanical Isolation

The peripheral equipment should be isolated from the cryogenic gas supply to minimize thermal heat load, icing and boil-off gas. Cryogenic liquid and gas can be drained from the piping or allowed to boil off. As the equipment warms, pressure should be allowed to bleed off until the equipment is at ambient temperature and there is approximately 10 psig of gas remaining in the equipment.

When the equipment is at ambient temperature and pressurized to 10 psig, isolate the equipment to contain the internal gas pressure. The pressure should be expected to fluctuate with temperature variance but maintain a constant average.

Monitoring

Monitor the equipment to ensure the equipment is kept under positive pressure during non-use. Pressures above 5 psig are acceptable. If the pressure starts to decay too rapidly, the leak should be found and/or makeup gas provided so the system can be brought back up to approximately 10 psig average pressure.

Restart

If the equipment does not have a continuous positive hydrogen or nitrogen blanket pressure, the equipment must be purged to remove any ingress of moisture or other contaminants prior to being restarted.

Confined Space Safety

Danger! Hydrogen Perma-Cyl's should NEVER be installed indoors or in confined areas.

General First Aid

For first aid measures in the event of eye contact, inhalation, skin contact or ingestion, refer to the latest Safety Data Sheet for Hydrogen (Refrigerated Liquid) from gas distributor.

Introduction

Unloading and Placement of the Perma-Cyl Tank

The Hydrogen Perma-Cyl storage tanks have a stainless-steel pallet base and lifting lugs on the top of the tank. Check the tare weight of the Perma-Cyl tank and unload using a properly sized forklift or crane.

Caution! Hydrogen Perma-Cyl tanks are not designed to be lifted or transported over the road unless empty. Do not attempt to lift with the lifting lugs if the tank has product in it.

Tanks may be placed on a pre-cast concrete or on a properly compacted gravel bed if code and local regulations allow. NFPA requires a 'firm' concrete or masonry foundation.

The tank should be placed in a location with access to all sides of the unit. The tank should also receive a maximum amount of sunlight and airflow to assist in keeping the vaporizers and piping from accumulating large quantities of ice.

If surrounded by fencing, allow at least three feet around the entire perimeter of the tank for access. One must be able to check the gauges and controls.

Depending on local codes, the pallet base or the tank itself may need to be anchored to the foundation. Anchoring hole dimensions can be found on the spec drawing for the Perma-Cyl tank. Anchor bolt sizes and depths should be specified per local building codes.

Installation Common Codes and Standards

The installer will need to find out what local city ordinances and which rules they are mandated to follow. Along with building codes one of the following standards may apply: Uniform Fire Code (UFC), Compressed Gas Association (CGA), and the National Fire Protection Association (NFPA).

Note: Regulations vary in every part of the country. Always consult local codes!

Conducting a Site Evaluation

Before a Perma-Cyl System is installed, a site evaluation should be conducted. This trip to the customer's site will help identify any special needs that each site invariably has. While on site, note what application the Perma-Cyl system will be used for and that the Perma-Cyl location meets all local code requirements. When the placement has been set, take measurements of how much and where the piping will be run. Tanks filled with hydrogen should be installed outdoors in an open or wide area that is well ventilated. The tank should be at or above ground level.

Bolting to Concrete Foundation

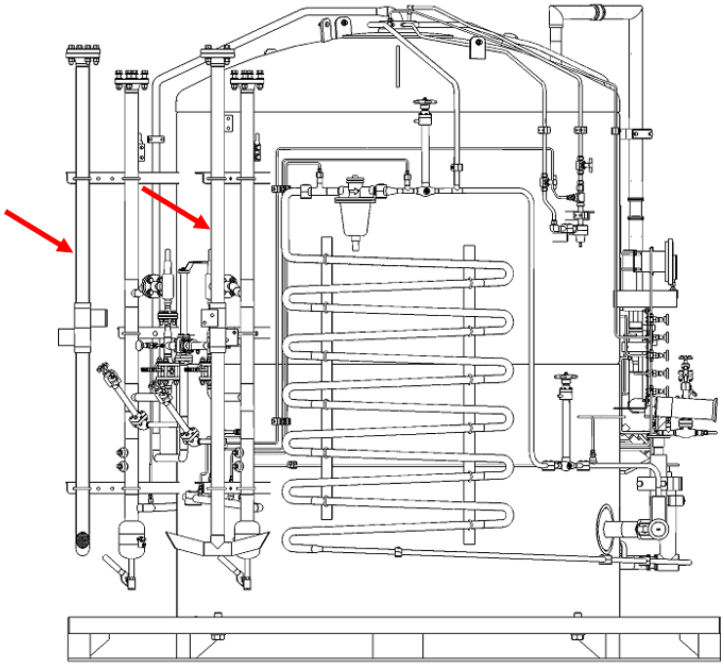
The Perma-Cyl tank is equipped with a flange on the bottom that has four holes for attachment. To ensure a safe environment, the tank or pallet base may be bolted to a concrete foundation.

1. Place tank in position with gauges facing forward.
2. Mark holes on floor, move tank.
3. Drill holes using the appropriate size masonry bit.
4. Blow out dust and insert masonry anchors.
5. Move tank back into position over holes and install lag bolts.
6. Tighten bolts.

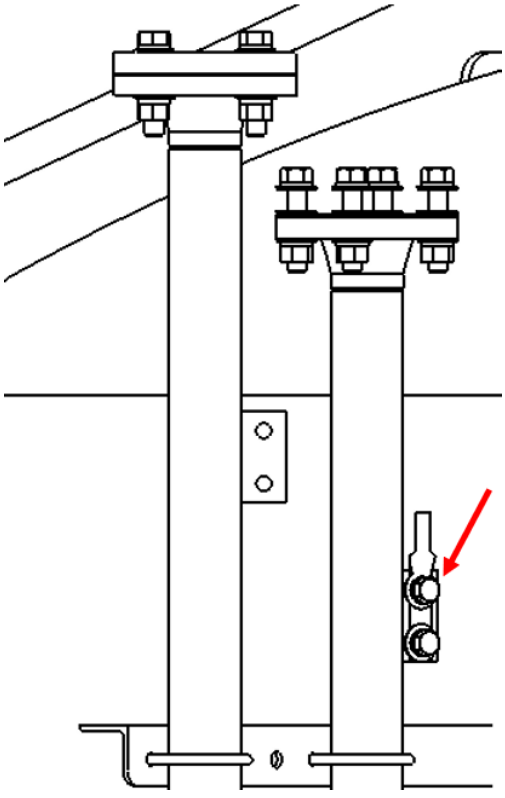
On-Site Installation of the Vent Stack

The tank will arrive with the vent stack in its shipping configuration. The vent stack must be disassembled from the shipping configuration and installed properly prior to the tank being filled with product. Follow the steps below for installation.

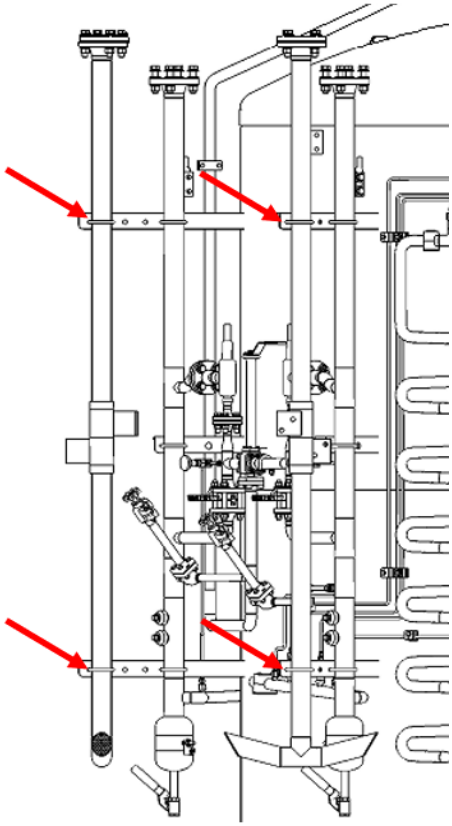
1. Locate the vent stacks at the rear of the tank.



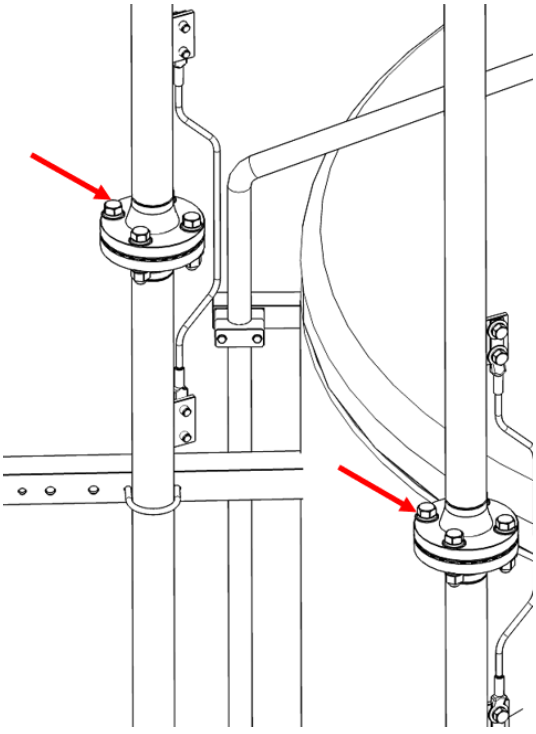
2. Disconnect one end of the grounding wire connecting the upper and lower vent stack pipes.



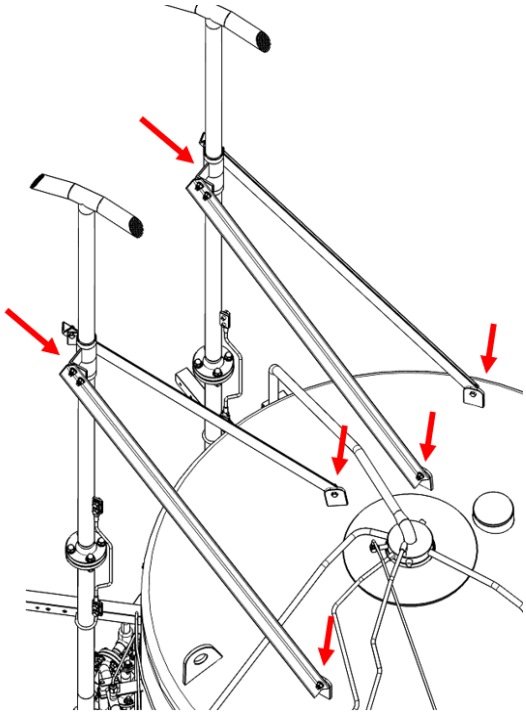
3. Ensure the vent stack pipes are secured safely using a hoist and/or lifting strap prior to disassembly. Unbolt the hardware securing the two vent stack pipes as well as the four support braces.



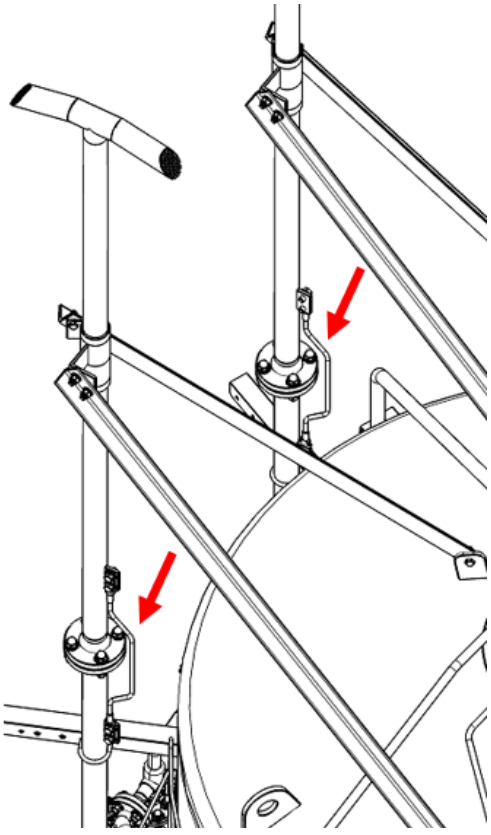
4. The protective flanges can now be unbolted and removed from each of the vent stack piping. Using lifting straps, hoist the vent stack pipe into place and align the flanges. Secure the vent stacks loosely with the mounting bolts. Do not tighten fully until the support braces are installed. Keep the vent stack safely supported and strapped in place while the support braces are installed in the next step. In a cross pattern, fully tighten the flange bolts to 80 ft-lbs



5. Align the support braces from the swivel brackets on the vent stack pipes to the mounting lugs on the top head of the tank. Once the bracing is in place, begin hand tightening all bolts in a cross pattern. Continuing in a cross pattern, incrementally tighten all bolts to 80 ft-lbs.



6. Reconnect the grounding wires between the vent stacks. At this point, the vent stack should be secured to the tank and the lifting straps can be safely removed. Perform a final inspection of all connections around the tank.



Operations

First Fill/Purge Procedure

Note: The Perma-Cyl tank is shipped with NF purity nitrogen gas. Purging is necessary prior to filling. During the first fill, only fill the vessel to 75% full to allow for liquid expansion experienced with a new (warm) tank. Each fill thereafter can be filled to 100% full. All valves on an empty Perma-Cyl tank should always be kept closed to prevent the inner vessel and plumbing from being contaminated.

Purging Into Service

1. Systems should be purged with inert gas before introducing gaseous hydrogen. The level of oxygen shall be less than 1.0% concentration as measured with a gas monitor.
2. Close and lockout the custody transfer valve to ensure product does not enter the user pipeline until all is ready.
3. Connect an inert gas source to the fill line on the hydrogen tank. The pressure of the inert gas should not exceed 30 psi.
4. Adjust all regulators so they are fully open during the purging process.
5. Open all valves to ensure that all piping legs are open, so all sections of piping are purged.
6. Ensure all valves to the atmosphere are closed.
7. Open the valve from the inert gas source.
8. Purge the fill line section through HV26.
9. Purge the tank through the fill valve HV2. Slowly pressurize inner vessel. Allow pressure to “soak” for 5 minutes. Soak time can start at first positive pressure. Slowly built pressure no greater than 30 psi.
10. Vent the inner vessel to just less than 1 psi with using all vent valves.
11. Repeat no fewer than 7 times or until vented gas is in specification. The gas sample should be taken during the latter part of the blow-down cycle to ensure the sample is representative of the gas in the vessel.
12. See CGA H-5, H-7 and NFPA 2 for more information about purging requirements.

First Fill

1. Connect liquid source to top fill connection, C1. Purge the hose and tank connection to the desired purity level. Slowly open the top fill valve, HV2, partially to allow flow into the tank. Pressurize tank to 30 psi and close Top Fill Valve. Hold for 30 seconds for cooling.
2. Open the vapor vent valve until the tank depressurizes to 5 psi.
3. Repeat steps 1 and 2 until the liquid level gauge reads at least 1” of liquid level. Then repeat the process but hold the pressure at 75 psi instead of 30 psi.
4. Once the tank is properly cooled, liquid should flow uninterrupted without the tank pressure reaching 75 psi.
5. Fill the tank until trycock full. See below for trycock instruction.
    a. Trycock gauge should be in green area before transfer begins. During transfer, after the Liquid Level Gauge, LI1, indicates the tank is half full, open the Trycock valve, HV5, slightly. The line will frost and the Trycock Fill Pressure Gauge needle, PI3, will move into the yellow region.
    b. Adjust Trycock valve so that gauge needle remains in orange area during transfer operation.
    c. When tank is full, the needle will fall into the red area. Stop the Hydrogen transfer by closing Top Fill Valve, HV2, then close the Trycock valve.

Components & Systems

Thermal Relief Valves

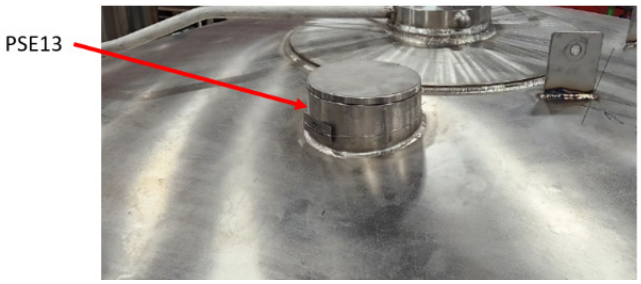
- The Thermal Relief Valves are set to open to vent if the pressure in the adjacent line exceeds 275 psi.
- Fill Hose Thermal Relief Valve PSV25 – is installed in the Top Fill Line (B) between the Fill Connection, C1, and the Fill Check Valve, CV101.
- Fill Line Thermal Relief Valve PSV26 – is installed in the Top Fill Line (B) between the Fill Check Valve, CV101, and the Top Fill Valve, HV2.
- PB Thermal Relief Valve PSV32 – is installed in the Pressure Build Line (C-D) between the PB Vaporizer, E131, and the PB Regulator, PCV132.
- PB Thermal Relief Valve PSV33 – is installed in the Pressure Build Line (C-D) between the PB Regulator, PCV132, and the PB Outlet Valve, HV41.
- Economizer Thermal Relief Valve PSV37 – is installed in the Economizer Line (J) between the Economizer Regulator, PCV135, and the Economizer Isolation Valve, HV36.
- Gas Use Thermal Relief Valve PSV61 – is installed in the Gas Use Line (K) between the Gas Use Valve, HV6, and the Gas Use AOV, UV102.
- Liquid Fire Thermal Relief Valve PSV63 – is installed in the Gas Use Line (K) between the Gas Use AOV, UV102, and the Gas Use Connection, C3.
- Liquid Withdrawal Thermal Relief Valve PSV64 – is installed in the Liquid Withdrawal Line (A) between the Liquid Withdrawal Valve, HV63, and the Liquid Withdrawal Connection, C2.

Relief Devices

- Rupture Discs PSE1 and PSE2 – are installed in the Dual Safety Relief Line (H) between the Diverter Valve, HV12, and the Vent Stacks. Rated to burst at 300 psi.
- Pressure Relief Valves PSV1 and PSV2 – are installed in the Dual Safety Relief Line (H) between the Diverter Valve, HV12, and the Vent Stacks. These are set to open to vent if the pressure in the adjacent line exceeds 250 psi.
- Vapor Pressure Regulator, PCV70 – in this application, acts as a pressure relief device. It is set to relieve vapor pressure in the Dual Safety Relief line (H) once the pressure exceeds 230 psi. This also prevents unnecessary cycling of the primary pressure relief valves (PSV1 & PSV2). This regulator can be isolated by closing HV70.

Vacuum Lift Plate

1. The Vacuum Lift Plat is designed to open and release trapped gas in case the vacuum in the Annular Space is lost or if the Annular Space becomes pressurized.
2. Vacuum Lift Plate PSE13 is integrated in the top head of the outer jacket at the highest point in the tank where hydrogen will accumulate if a leak occurs within the annular space.



Actuated Valve

- Gas Use AOV, UV102, controls gas flow exiting the Gas Use Connection C3.

Manual Valves

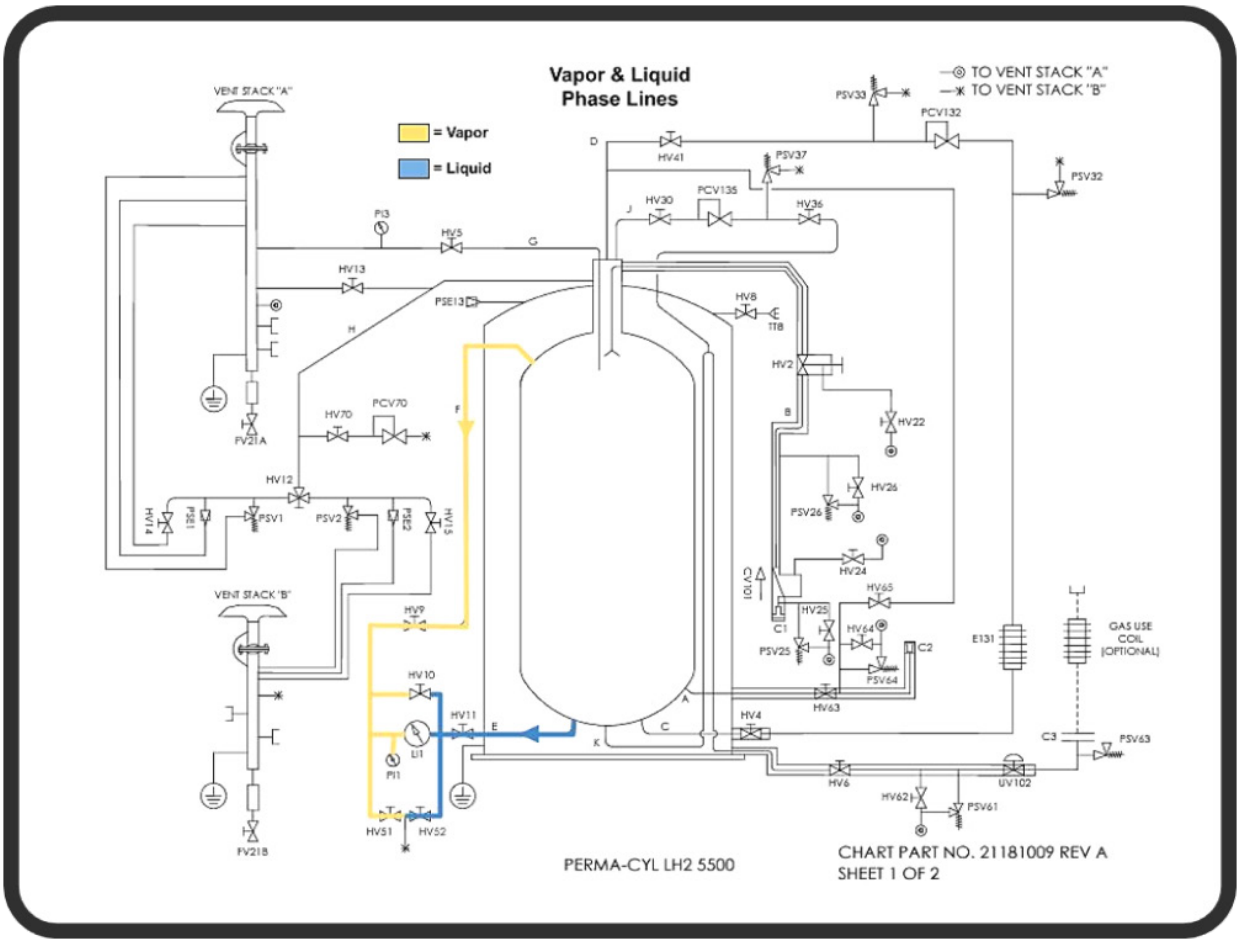
- Top Fill Isolation Valve, HV2 – acts as a shutoff valve on the Top Fill line (B) between the Top Fill connection and the tank.
- PB Liquid Isolation Valve, HV4 – acts as a shutoff valve on the PB Inlet line (C) between the tank and the PB Control Valve, PCV132.
- Trycock Isolation Valve, HV5 – acts as a shutoff valve on the Full Trycock line (G) between the tank and the downstream connection.
- Gas Use Valve, HV6 – acts as a shutoff valve on the Gas Use Line (K) between the tank and the AOV, UV102.
- Vacuum Gauge, HV8 – acts as a shutoff valve between the tank annular space and atmosphere.

- Vapor Phase Valve, HV9 – acts as a shutoff valve on the Vapor Phase Line (F) between the tank and the Pressure Gauge manifold. Pressure gauge, PI1, will read the vapor pressure inside of the tank when this valve is open. Vapor Phase Bleed Valve, HV51 is used to purge any vapor within the manifold coming from the Vapor Phase Line.
- Liquid Level Gauge Equalization Valve, HV10 – acts as a equalization shutoff valve between Vapor Phase Valve HV9, and the Liquid Level Gauge, LI1.
- Liquid Phase Valve, HV11 – acts as a shutoff valve on the Liquid Phase Line (E) between the tank and the Pressure Gauge manifold. Liquid Level Gauge, LI1, will read the differential pressure between the Vapor Phase Line (F) and the Liquid Phase Line (E). Liquid Phase Bleed Valve, HV52 is used to purge any liquid within the manifold coming from the Liquid Phase Line.
- Diverter Valve, HV12 – diverts flow coming from Dual Safety Relief Line (H) to either Vent Stack A or Vent Stack B.
- Vapor Vent Valve, HV13 – acts as a direct venting valve on the Dual Safety Relief Line (H) from the headspace of the tank to Vent Stack A.
- Safety Bleed Valves, HV14 and HV15 – act as direct venting valves on the Dual Safety Relief Line (H) between the Diverter Valve, HV12, and Vent Stacks A and B, respectively.
- Top Fill Purge Valve, HV22 – acts as a purge valve for the Top Fill Valve, HV2, feeding to Vent Stack A.
- Fill Check Vent Valve, HV24 – acts as a purging valve for the Fill Check Valve, CV101, feeding to Vent Stack A.
- PB Vapor Isolation Valve, HV41 – acts as a shutoff valve on the PB Outlet line (D) between the PB Control Valve, PCV132, and the tank.
- Fill Connection Purge Valve, HV25 – acts as a purge valve on the Fill Connection Purge Line between the Fill Check Valve, CV101, and Fill Hose Relief Valve, PSV25.
- Fill Line Purge Valve, HV26 – acts as a shutoff valve on the Fill Purge Line between the Fill Check Valve, CV101, and the Top Fill Valve, HV2.
- Economizer Isolation Valves, HV30 and HV36 – are placed on either side of the Economizer Regulator line (J), PCV135, and are used to isolate it on line (J).
- Gas Use Bleed Valve, HV62 – is placed on the Gas Use line (K) between the Gas Use Valve, HV6, and Gas Use AOV, UV102. This valve is used to vent remaining gases in the Gas Use line, once HV6 has been closed.
- Liquid Withdrawal Valve, HV63 – acts as a shutoff valve on the Liquid Withdrawal line (A), between the tank and the Liquid Withdrawal Connection, C2.
- Liquid Withdrawal Vent Valve, HV64 – acts as a vent valve on Liquid Withdrawal line (A), between the Liquid Withdrawal Valve, HV63, and the Liquid Withdrawal Connection, C2.
- Liquid Withdrawal Purge Valve, HV65 – acts as a purge valve on the Liquid Withdrawal line (A), between the Liquid Withdrawal Connection, C2.
- Vapor Pressure Regulator Valve, HV70 – acts as a shutoff valve on the Dual Safety Relief circuit (H) between the tank and the Vapor Pressure Regulator, PCV70.
- Vents A and B Drain Valve, FV21A and FV21B – are used to remove accumulated condensation in each of the vent stacks.

Regulators

- Vapor Pressure Regulator, PCV70 – is set to relieve vapor pressure in the Dual Safety Relief line (H) once the pressure exceeds 230 psi. This regulator can be isolated by closing HV70.
- Pressure Building Regulator, PCV132 – is located at the outlet of PB Vaporizer, E131 and allows flow once pressure reaches its set point (75 psi). This regulator can be isolated by closing HV41 and HV4.
- Economizer Line Regulator, PCV135 – is located on Economizer line (J) and is set at 90 psi, typically 15 psi above the pressure build regulator, to allow flow when gas is demanded downstream. This regulator can be isolated by closing HV30 and HV36.

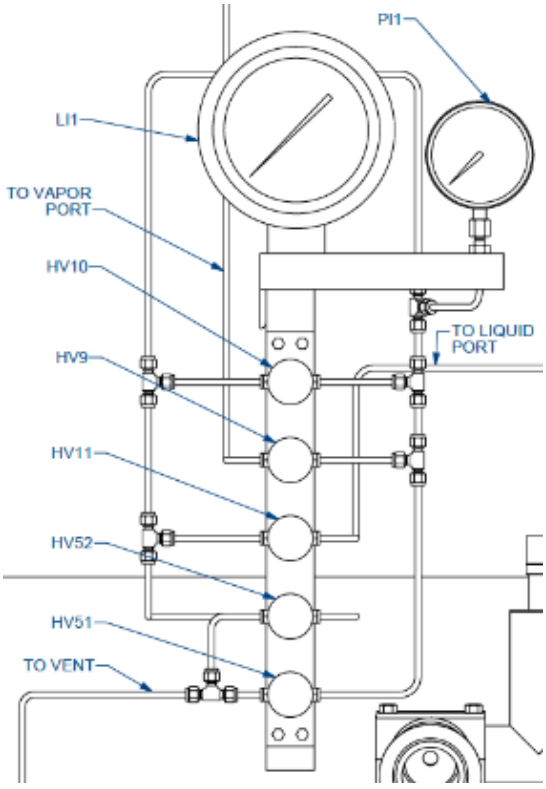
Primary Plumbing Circuits

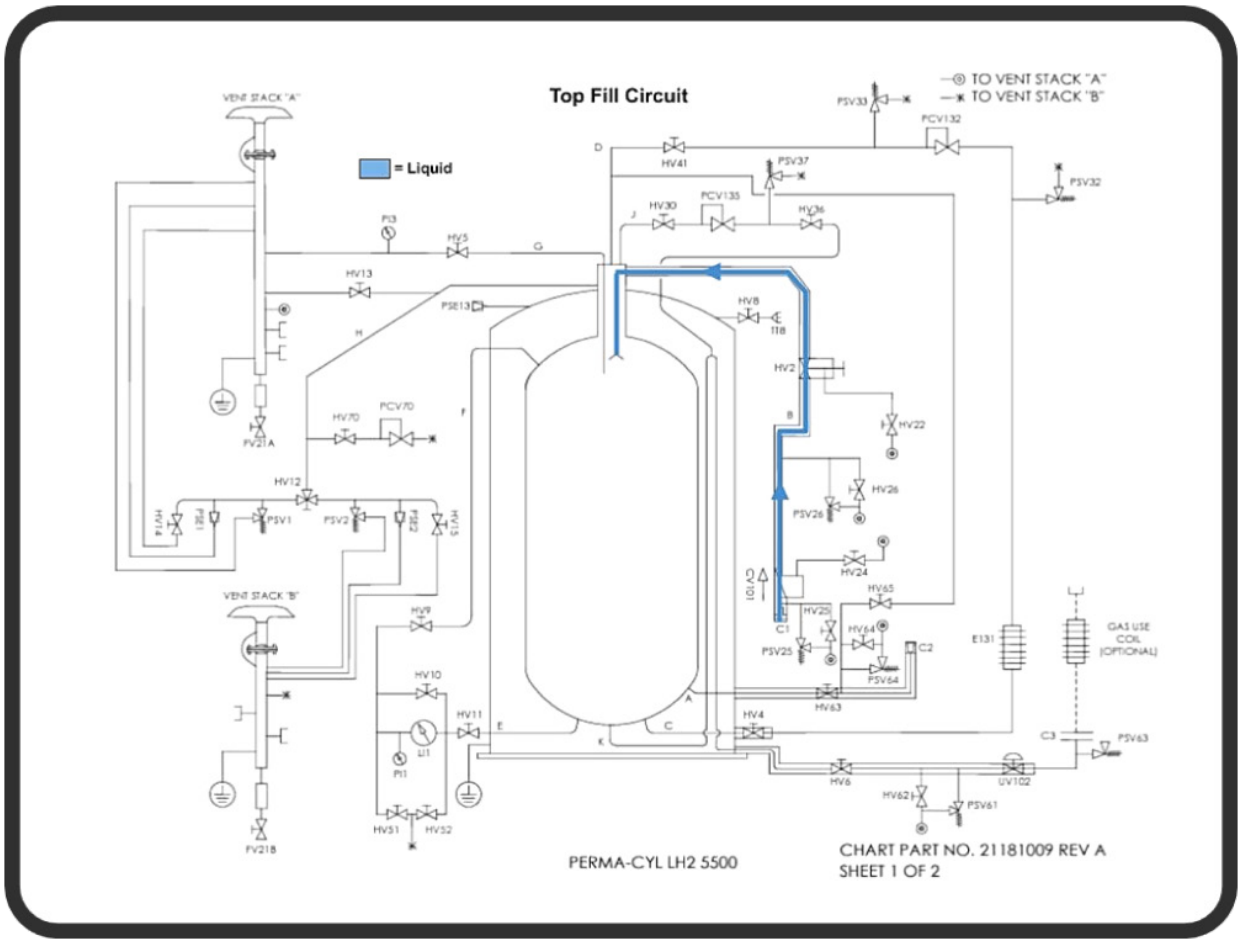


Phase Lines and Pressure Gauges

The Perma-Cyl tank is equipped with both a low-pressure Gas Phase Line (F) located on top of the tank, and a high-pressure Liquid Phase Line (E) located on the bottom of the vessel. These lines are connected to the Liquid Level Gauge, LI1, which is used to indicate the amount of product in the vessel.

- To isolate the valve for service or equalization, turn valves HV9 and HV11 to the CLOSED position. Keep other valves in this manifold open to vent any residual fluid/gas.
- A single Tank Pressure Gauge, PI1, is tied into the low gas phase line and gives the operator a pressure reading in the gas phase of the vessel. This pressure gauge can also be isolated by closing valves HV9 and HV11. Keep other valves in this manifold open to vent any residual fluid/gas





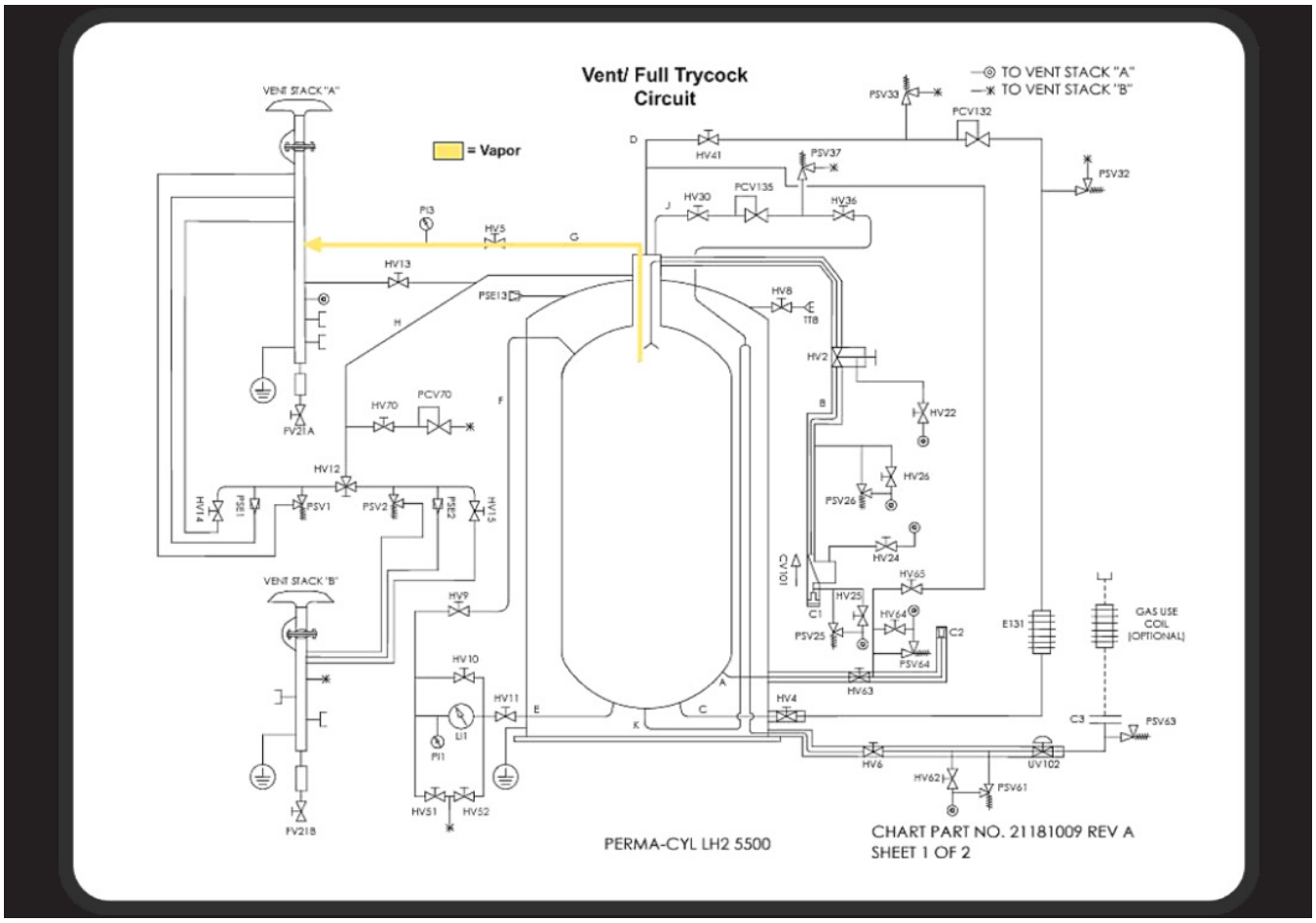
Fill

The Hydrogen Perma-Cyl top fill circuit consists of a top fill valve (HV2), and a fill check valve (CV101). The top fill connection, C1, is a 2" NPS HQK female bayonet connection.

The fill line purge valve (HV26) can be used to both purge the fill hose before filling the tank or to depressurize the fill hose after filling the tank.

During a first fill, only fill the vessel to 75% full to allow liquid expansion experienced with a new "hot" tank. Each fill, thereafter, can be filled to 100% full. Please refer to the Installation section of this manual for detailed filling procedures.

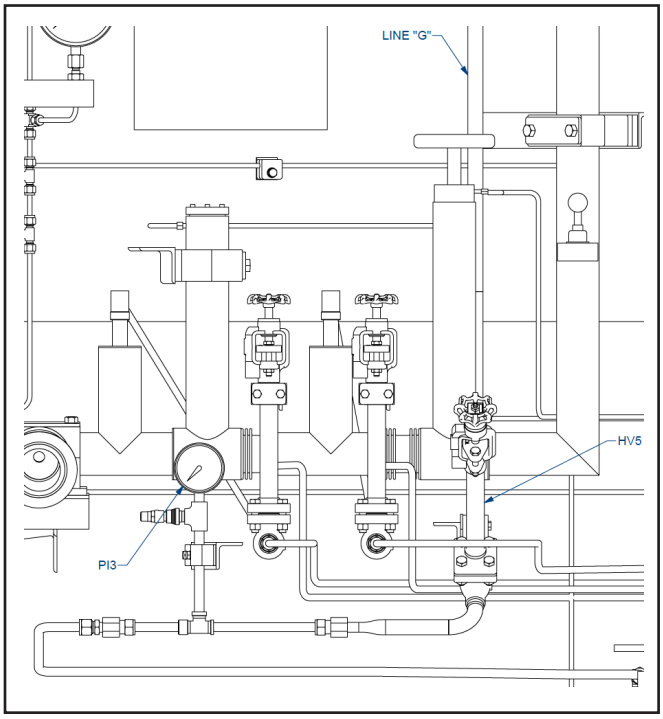
Caution! If liquid can be trapped in the transfer system, a suitable relief valve must be installed to prevent over pressurization.

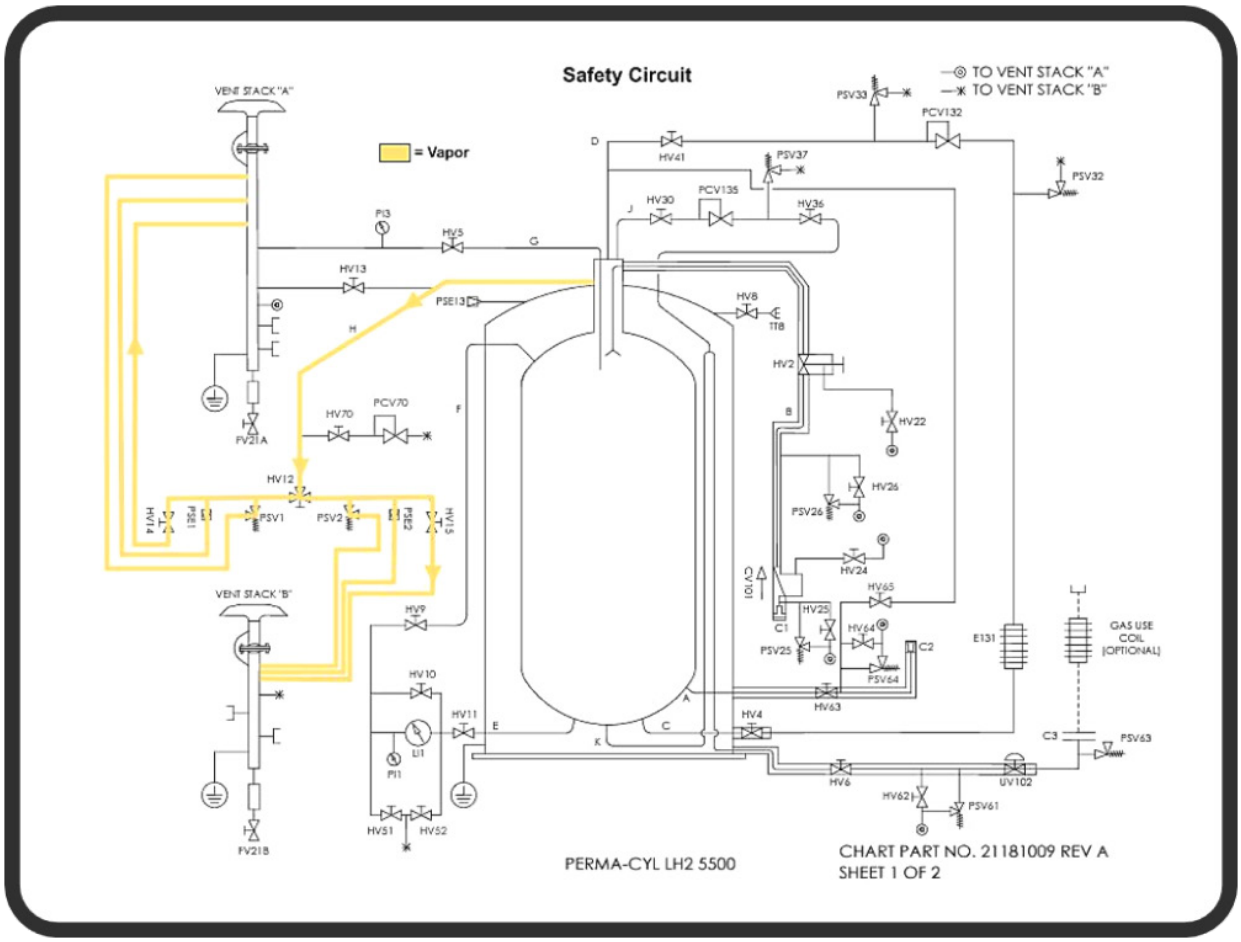


Vent/Full Trycock

The Full Trycock Valve, HV5, is used to relieve excess pressure in the tank and also serves as the full trycock during filling operations.

Once the tank is full, the Fill Pressure Gauge, PI3, needle will be in the red area of the dial. Avoid continuing to fill after the tank is full to avoid liquid flowing into the vent circuit.





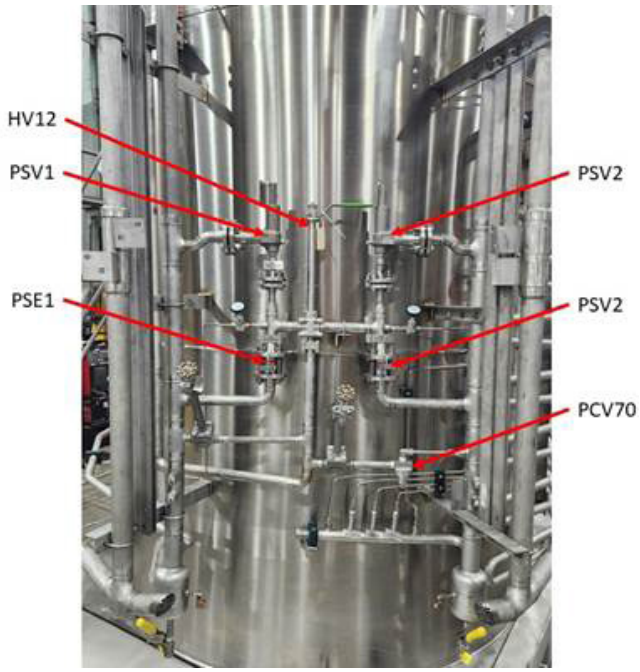
Safety Circuit

The Hydrogen Perma-Cyl tanks are equipped with dual spring-operated relief valves (PSV1 & PSV2) and dual burst discs (PSE1 & PSE2). The dual safety manifold with diverter valve (HV12) is standard on these vessels. This allows for the change out of safety relief devices without the need to empty the tank.

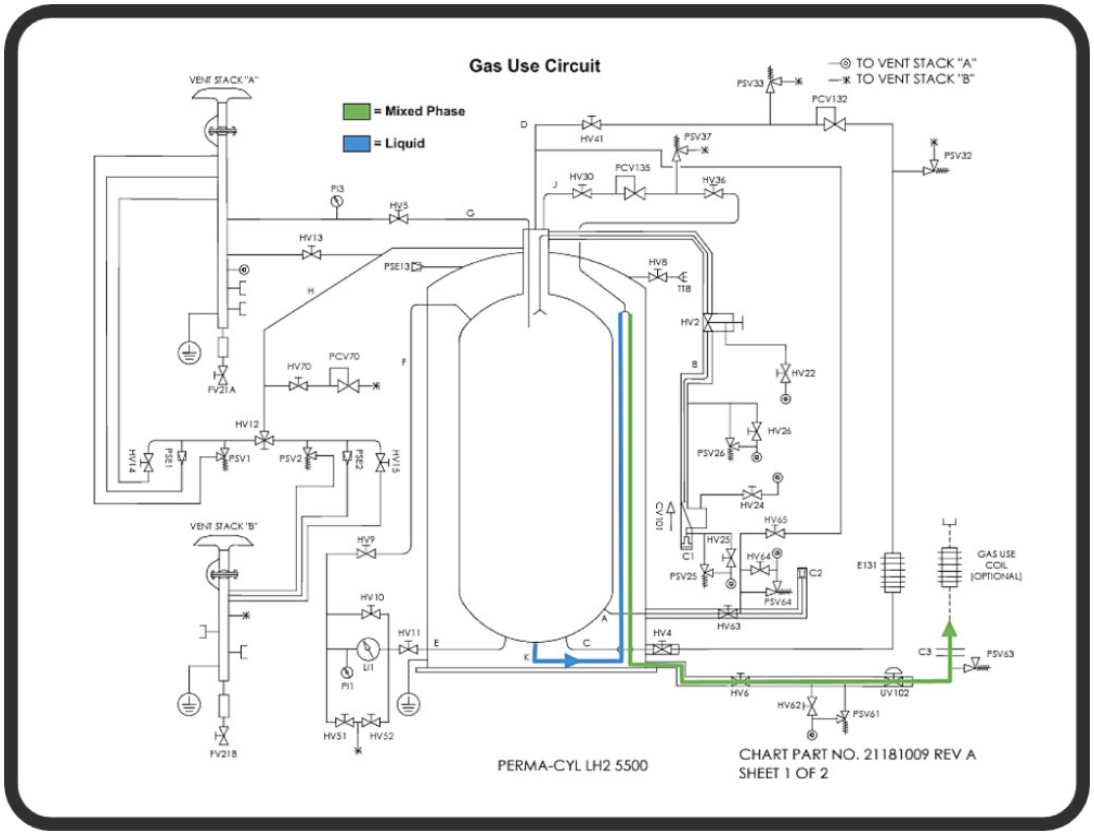
Built into the safety circuit is a Vapor Pressure Regulator, PCV70, at a set pressure below PSV1 and PSV2 to prevent cycling and increase their longevity.

All relief valves route to Vent Stack A or B, where any pressure buildup is then vented to atmosphere.

These devices are used to automatically relieve excess pressure in the vessel and cannot be isolated by use of a valve. Replacement of these relief devices should only be on a “like for like” basis. Substitutes should be avoided unless approved by the manufacturer. Purge valves (HV14 & HV15) can be used to relieve pressure before removing safety devices.



Warning! Never obstruct or otherwise modify the safety devices.



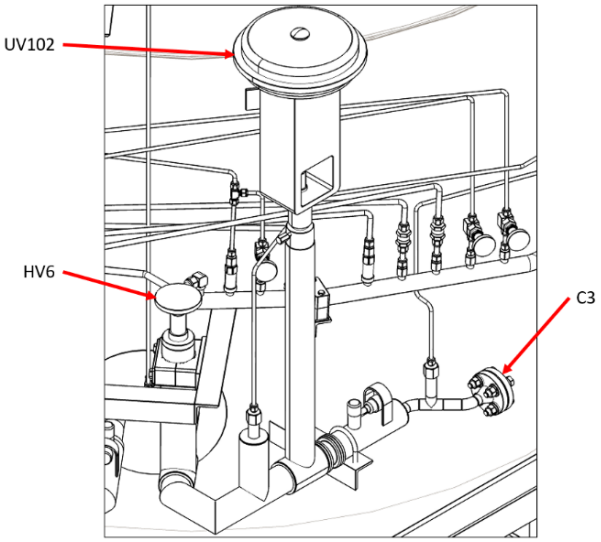
Gas Use

The gas use valve (HV6) supplies liquid or cold gaseous product to the end user. Optionally, for vaporizing to warm gas, it will require the use of an external gas use coil.

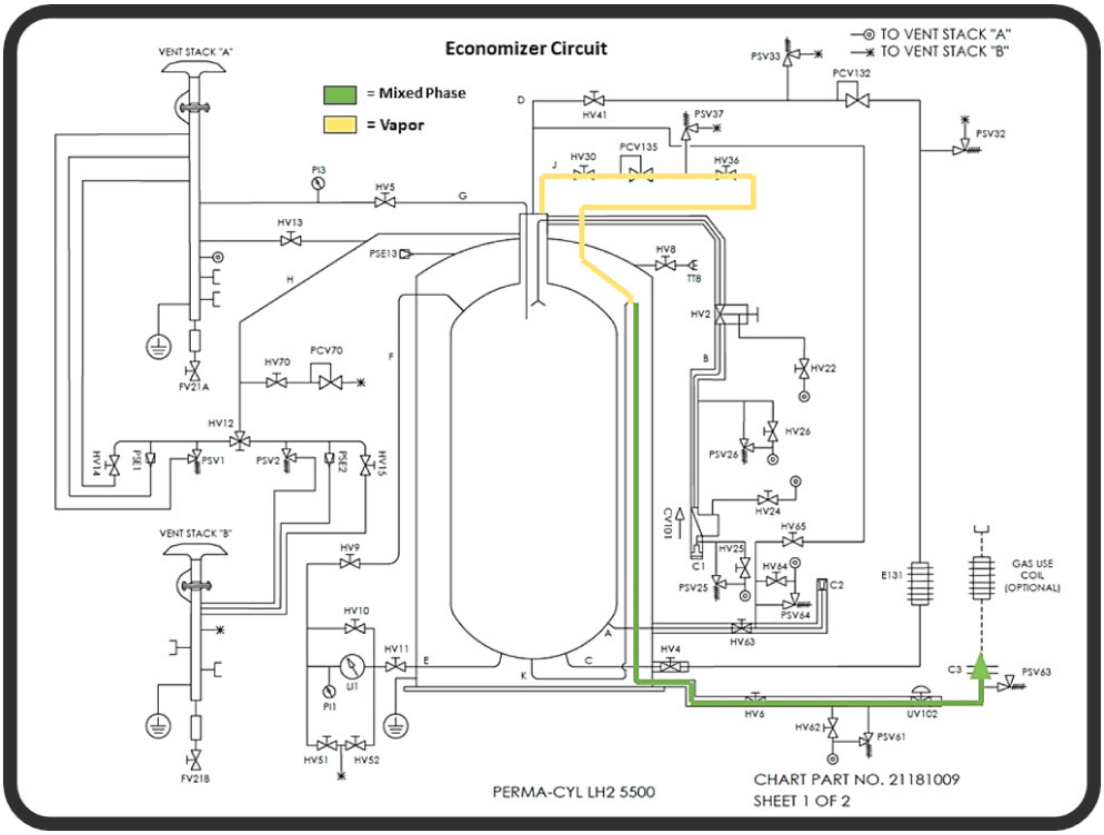
The gas use valve (HV6) used is a manual valve with a flanged connection at the outlet (C3). Between these components is an air operated valve (UV102) for precise control of gas flow through the supply line. When not in use, keep flange connection C3 capped off with a Class 300 1/2"NPS blind flange and appropriate gasket.

The Perma-Cyl tank will deliver gas at various flow rates and temperatures for different applications. The equipment that is being supplied gas from the Perma-Cyl tank controls the flow rate. Higher flow rates may provide very cold gas that could damage the equipment to which they are attached. To supply gaseous product, follow this step-by-step procedure.

- Connect a properly sized vaporizer.
- Connect the proper regulator/regulating manifold to the tank's gas use outlet.
- Connect the proper piping between the final line regulator and the receiving equipment.
- Open the pressure building valve.
- Allow pressure to build to the operating pressure (refer to gauge).
- Open the gas use valve.
- Adjust the gas use regulator for the proper delivery pressure.



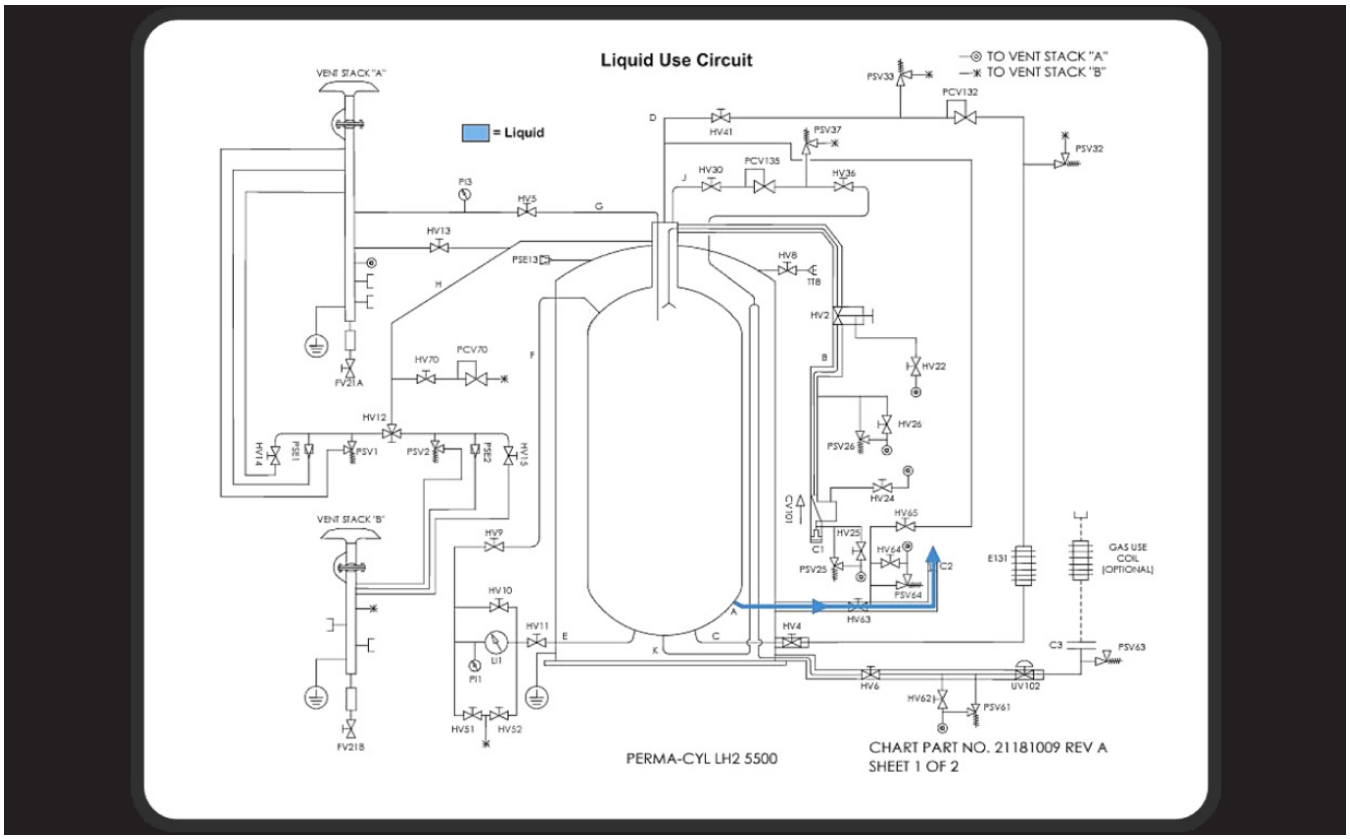
Warning! ***Do not open without vaporizer and flow control apparatus in place, otherwise risk of cold liquid exit.***



Economizer

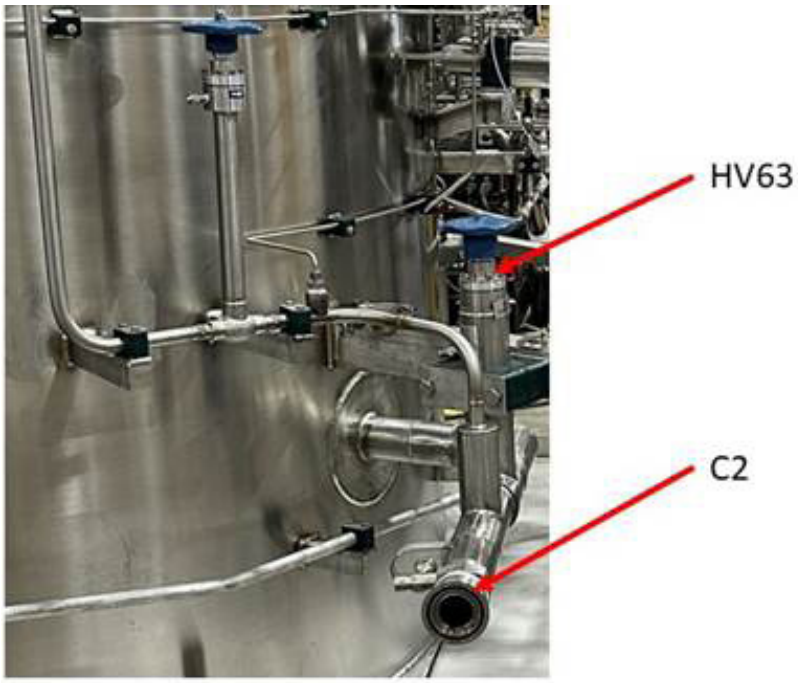
The economizer circuit allows the customer to utilize the natural heat leak that occurs in every cryogenic storage vessel. When the pressure is above the setpoint of the economizer regulator, the economizer regulator (PCV135) opens. This allows gas to be withdrawn directly off the headspace of the tank and travel out of the gas use valve, HV6. This will result in lowering the pressure of the tank. The economizer regulator can be isolated by closing valves HV30 and HV36.

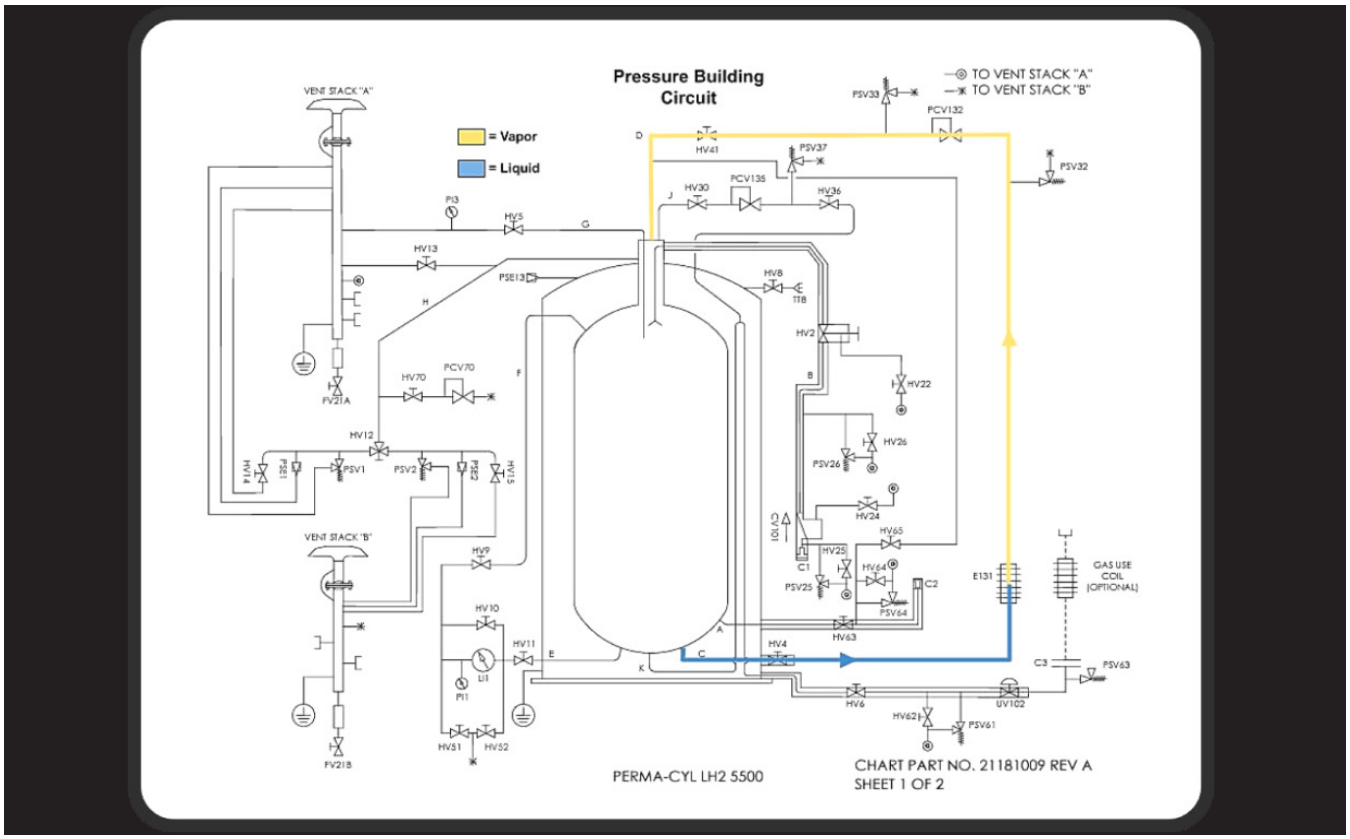
Note: The economizer circuit will only work if the customer is using product out of the vessel, i.e. HV6 is open with low pressure downstream.



Liquid Use

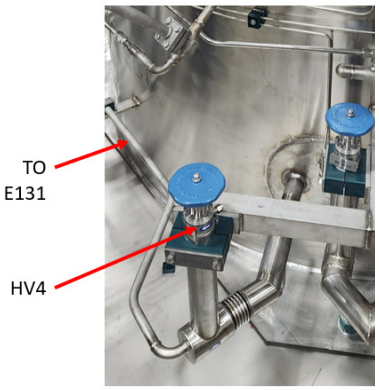
The liquid use circuit can be used for both a liquid application or a high flow gas use application. This circuit draws liquid directly from the bottom of the inner and out through the liquid use valve, HV63, to connection C2. Connection C2 is a 1” CVI female bayonet connection. When not in use, keep connection C2 capped off with included cover.

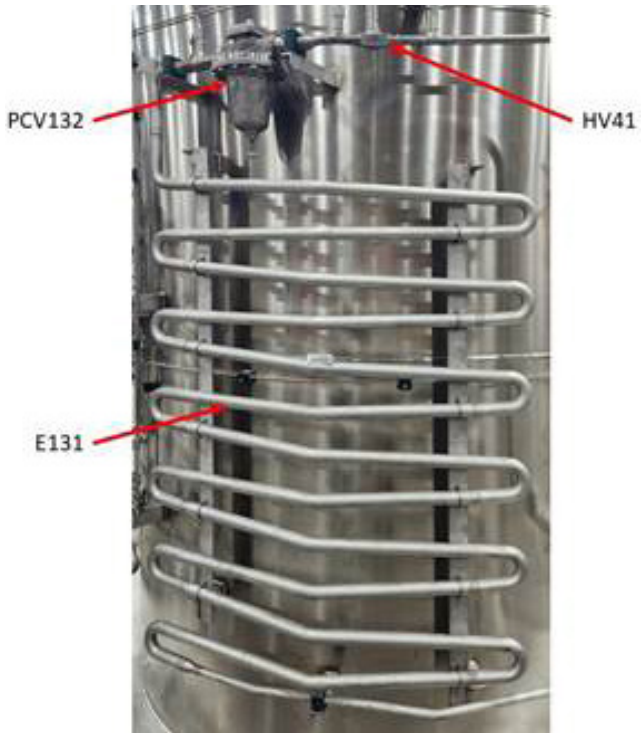




Pressure Build

The pressure build circuit is used to build pressure back in the vessel after a delivery or to maintain pressure as liquid is withdrawn from the vessel. The vessel pressure is set by adjusting the PB regulator (PCV132). As the tank pressure drops below the PB set point, the regulator opens and allows liquid to flow from the bottom of the tank, through the external PB vaporization coils (E131) through the regulator, and back into the top of the tank. The pressure build circuit can be isolated by closing valves HV4 & HV41.





Warning! During pressure building operation, the PB coil piping will be extremely cold and will cause air to rapidly condense and drip off the coil. Although this may look like a leak, it is completely normal, however, refer to the Safety section of for dangers of condensed air.

Vacuum Readouts

The Vacuum Readouts are Hastings DV-6R vacuum gauge tubes and are used to check the vacuum in the vacuum-jacketed piping, and in the tank annular space. These gauge tubes are located on each of the vacuum jacketed subassemblies and on the head of the tank.

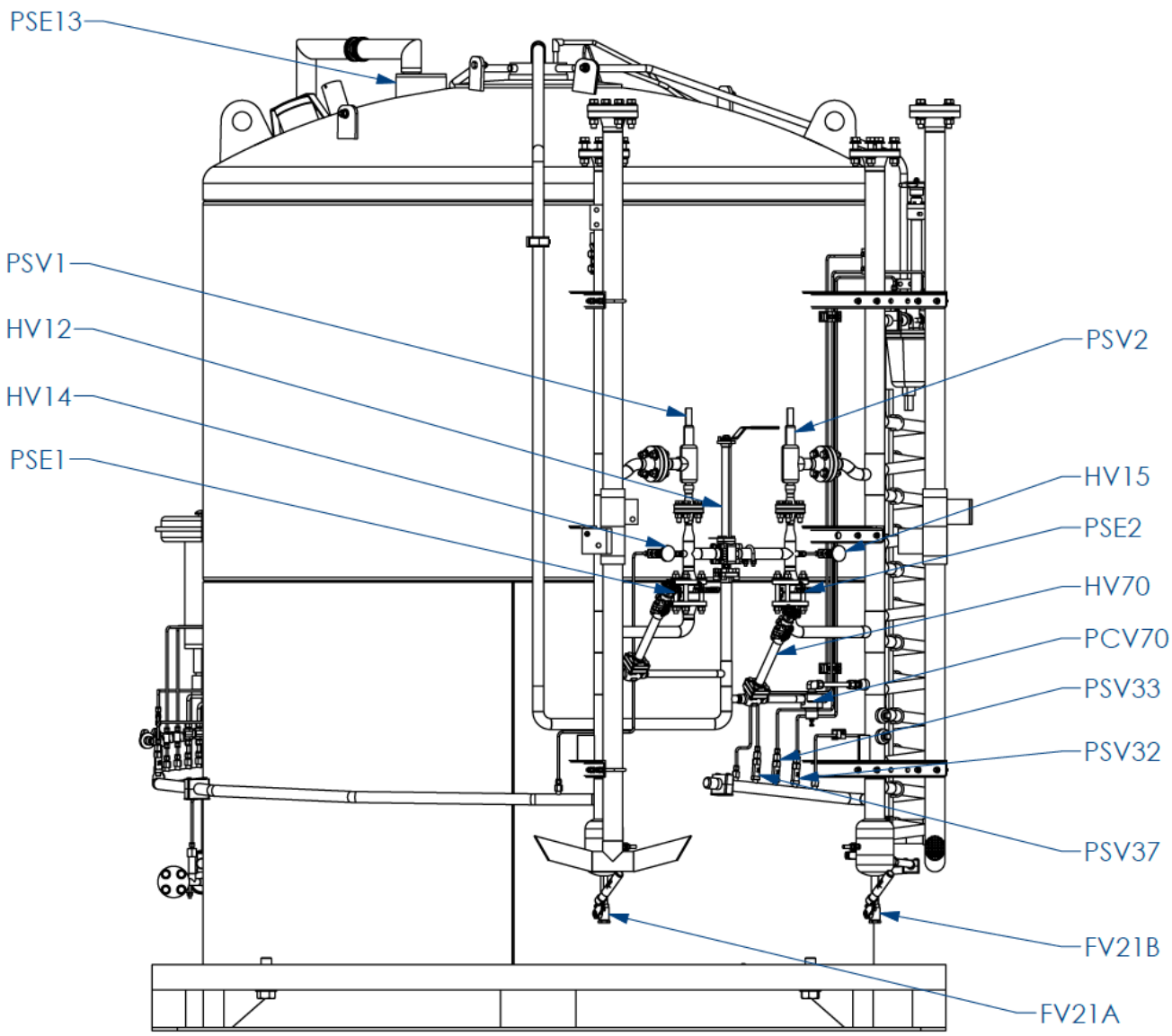
- Tank Vacuum Readout – allows the Operator to determine the condition of the tank annular space vacuum. The Vacuum Isolation Valve, HV8, acts as a shutoff valve between the tank annular space and this readout. HV8 should be closed when vacuum measurements are not being taken.
- Vacuum Jacketed Subassembly Vacuum Readout – is installed on all vacuum jacketed subassemblies and allows the Operator to determine the condition of the jacket vacuum.

Troubleshooting

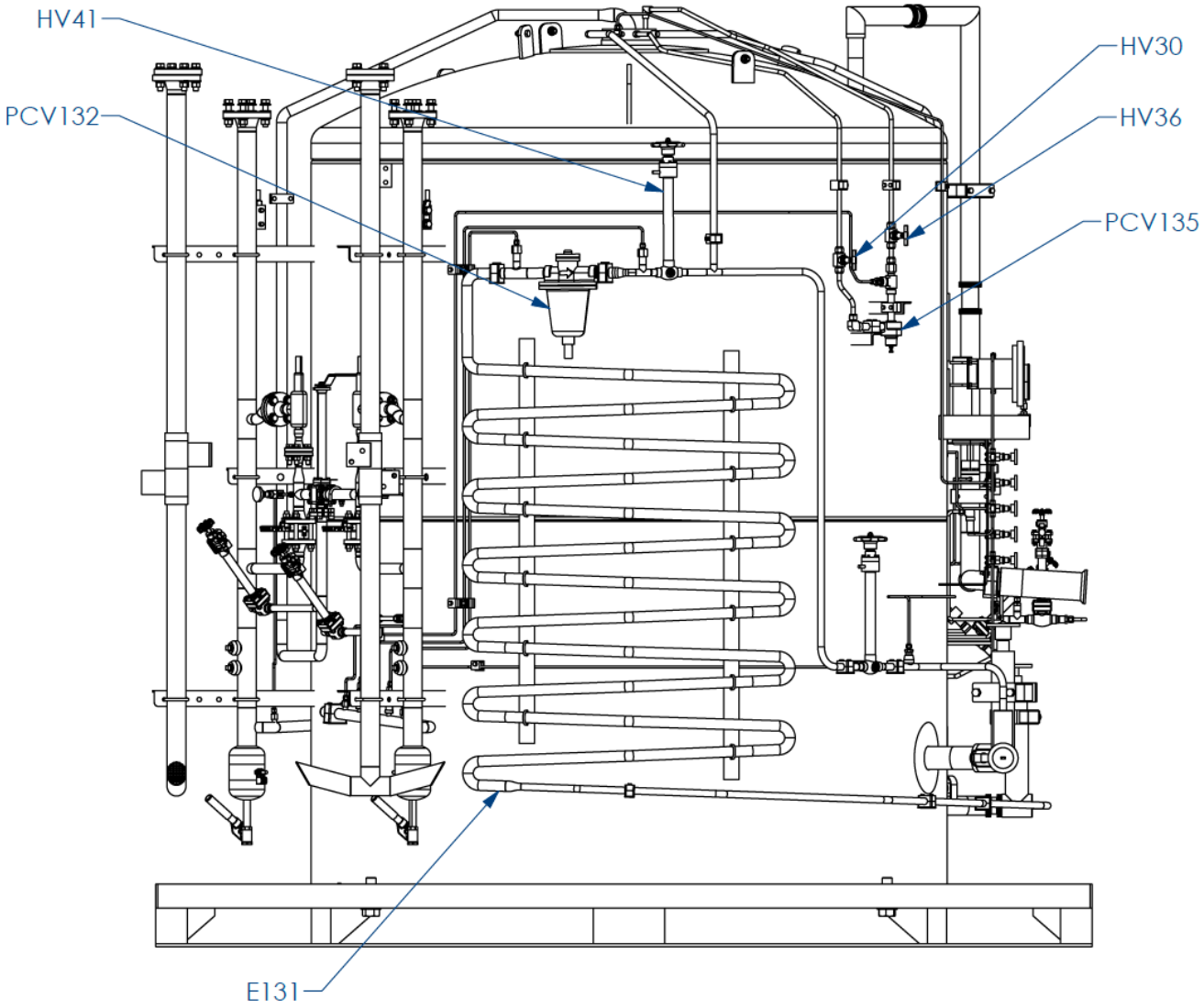
Note that probable causes for specific problems are listed in descending order of significance. It's recommended that you check out the first Possible Cause listed before proceeding to the next, and perform the procedures in the order listed and as stated.

Problem	Possible Cause	Diagnosis	Solution
The storage tank can't maintain pressure.	Leaking line or valve	Check for audible or visible leaks at the valves and connections.	Repair or replace as required.
	Inadequate pressure-building	The PB Liquid Isolation Valve, HV4, is closed.	Open HV4.
		The PB Outlet Valve, HV41, is closed.	Open HV41.
		The PB Control Valve, PCV132, is not operating correctly and is not allowing an adequate amount liquid to flow to the Pressure Build Coil, PBC (E131).	Check PCV132 and adjust/ repair as necessary.
Inability to hold annular vacuum	Incorrect Tank Vacuum Readout change (voids warranty)	Measure the vacuum rise in the gauge assembly.	Consult Chart Inc.
	Internal/external leak	Vacuum rises in the tank over a short time.	Consult Chart Inc.
	A corroded Jacket Safety Head, PSE13, or Evacuation Valve is causing a leaky seal.	Measure the vacuum rise in the gauge assembly.	Consult Chart Inc.
	Outgassing	Slow vacuum rise over a long time	Consult Chart Inc.
Excessive tank pressure	Leaks through the Vacuum Readout.	The Vacuum Readout is damaged/ defective or is not sealing on the Vacuum-jacketed piping.	Consult Chart Inc.
	Leaks through the VJ Evacuation Valve.	The VJ Evacuation Valve is not shutting off correctly.	Consult Chart Inc.
	Inadequate annular vacuum	Take a vacuum reading.	Consult Chart Inc.
	Excessive vapor to the tank.	The PB Control Valve, PCV132, is not operating correctly and is allowing too much liquid to the Pressure-build Coil.	Check PCV132, and adjust/ repair as necessary.
	The tank is not venting.	A tank pressure relief component is not operating correctly.	Check the Thermal Relief Valves and other tank pressure relief components (if present) and replace as necessary.

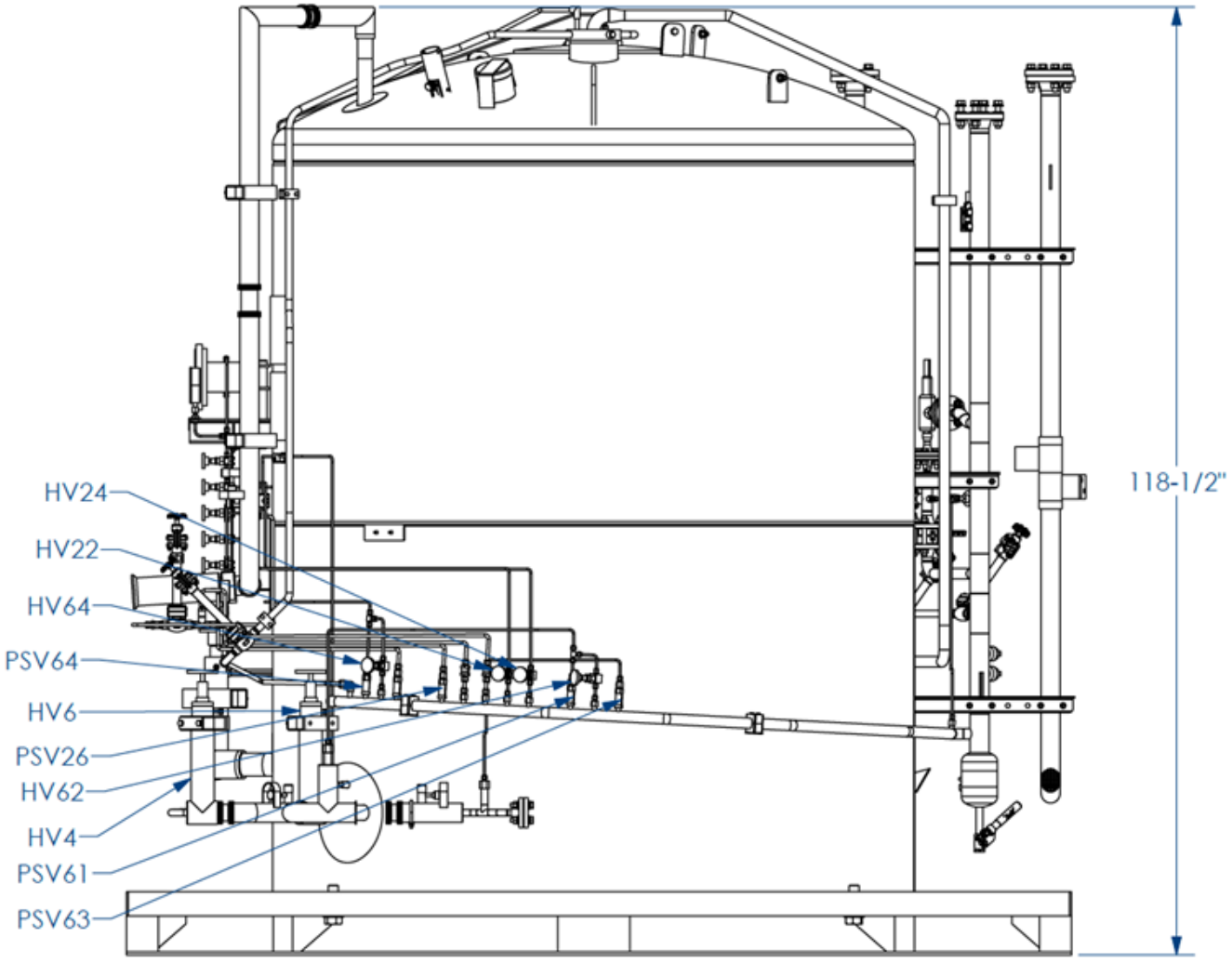
Illustrations & Parts Listing



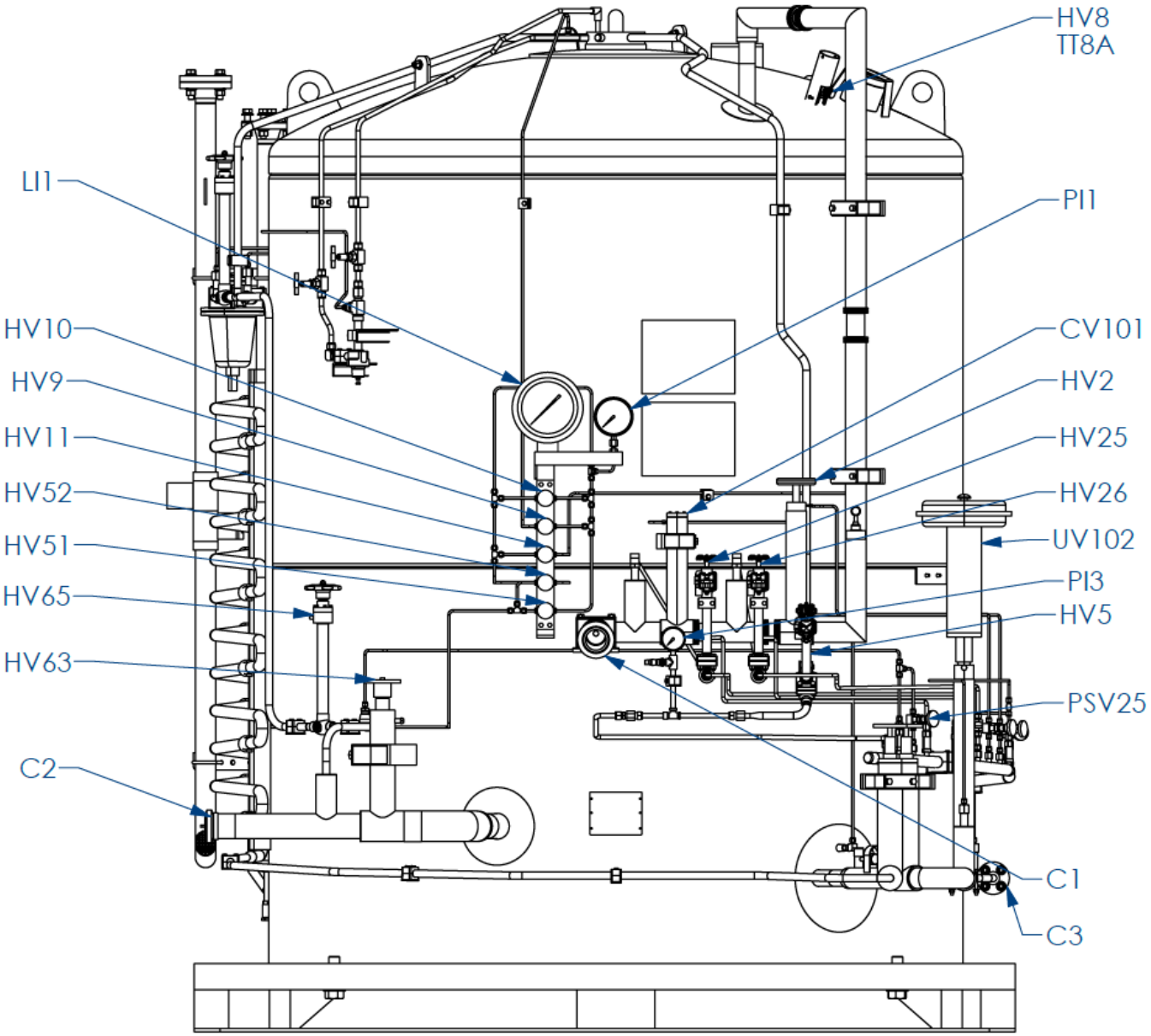
REAR VIEW



LEFT SIDE VIEW



RIGHT SIDE VIEW

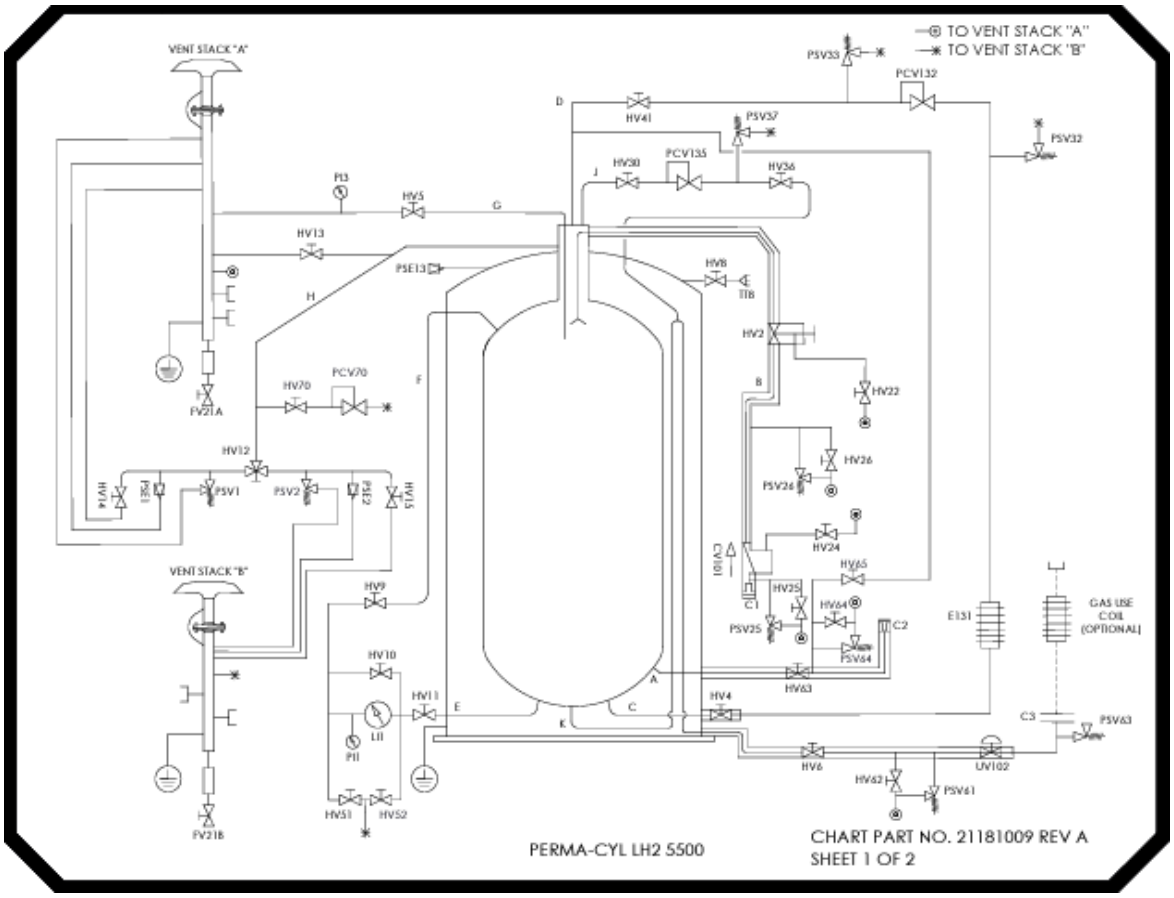

HV8
TT8A
LI1
PI1
HV10
CV101
HV9
HV2
HV11
HV25
HV52
HV26
HV51
UV102
HV65
PI3
HV5
HV63
PSV25
C2
C1
C3

FRONT VIEW

Item	Chart PN	Description
C1	20631665	FILL CONNECTION – 2" HQK FEMALE BAYONET
C2	11-2505-05106	LIQUID W/DRL CONNECTION – 1" CUI FEMALE BAYONET
C3	21896572	GAS USE CONNECTION – CLASS 300 ½" FLANGE
CV101	21163902	FILL CHECK VALVE
E131	22051538	PRESSURE BUILD VAPORIZER
FV21A	1714861	VENT STACK A DRAIN VALVE
FV21B	1714861	VENT STACK B DRAIN VALVE
HV2	21163903	TOP FILL VALVE
HV4	21163901	PRESSURE BUILD ISO VALVE
HV5	1716901	FULL TRYCOCK VALVE
HV6	21163901	GAS USE VALVE
HV8	10482381	VAC GAUGE VALVE
HV9	20958622	VAPOR PHASE VALVE
HV10	20958622	LI1 EQUALIZER VALVE
HV11	20958622	LIQUID PHASE VALVE
HV12	22046431	SAFETY RELIEF DIVERTER VALVE
HV13	1716901	VAPOR VENT VALVE
HV14	20958622	SAFETY LINE BLEED VALVE
HV15	20958622	SAFETY LINE BLEED VALVE
HV22	20958622	TOP FILL PURGE VALVE
HV24	20958622	FILL CHECK VENT VALVE
HV25	1716901	FILL CONNECTION PURGE VLV
HV26	1716901	FILL LINE PURGE VALVE
HV30	21163904	ECONOMIZER VALVE
HV36	21163904	ECONOMIZER ISO VALVE
HV41	20574868	PRESSURE BUILD OUTLET VLV
HV51	20958622	VAPOR PHASE BLEED VALVE
HV52	20958622	LIQUID PHASE BLEED VALVE
HV62	20958622	GAS USE BLEED VALVE
HV63	20619649	LIQUID WITHDRAWAL VALVE
HV64	20958622	LIQUID W/DRL VENT VALVE
HV65	20574868	LIQUID W/DRL PURGE VALVE
HV70	1716901	VAPOR PRESSURE REGULATOR VLV

Item	Chart PN	Description
LI1	14845303	LIQUID LEVEL GAUGE
PCV70	22133556	VAPOR PRESSURE REGULATOR
PCV132	21166813	PRESSURE BUILD REGULATOR
PCV135	21166814	ECONOMIZER REGULATOR
PI1	21168850	TANK PRESSURE GAUGE
PI3	2010272	FILL PRESSURE GAUGE
PSE1	21163897	RUPTURE DISC
PSE2	21163897	RUPTURE DISC
PSE13	20909215	VACUUM RELIEF
PSV1	21163894	PRESSURE RELIEF VALVE
PSV2	21163894	PRESSURE RELIEF VALVE
PSV25	20934771	FILL HOSE RELIEF VALVE
PSV26	20934771	FILL LINE RELIEF VALVE
PSV32	20934771	PRESSURE BUILD RELIEF VALVE
PSV33	20934771	PRESSURE BUILD RELIEF VALVE
PSV37	20934771	ECONOMIZER RELIEF VALVE
PSV61	20934771	GAS USE RELIEF VALVE
PSV63	20934771	LIQ FIRE RELIEF VALVE
PSV64	20934771	LIQ W/DRL RELIEF VALVE
TT8	10826906	VACUUM GAUGE
UV102	21168668	GAS USE AOV

A	LIQUID WITHDRAWAL
B	TOP FILL
C	PRESSURE BUILD INLET
D	PRESSURE BUILD OUTLET
E	LIQUID PHASE
F	VAPOR PHASE
G	FULL TRYCOCK
H	DUAL SAFETY RELIEF
J	ECONOMIZER
K	GAS USE


TO VENT STACK "A"
TO VENT STACK "B"
VENT STACK "A"
VENT STACK "B"
PSV33
PCV132
PSV37
PSV32
HV41
PCV135
HV30
HV36
PI3
HV5
HV13
PSE13
HV8
ITB
HV2
HV22
HV70
PCV70
FV21A
HV12
HV26
PSV26
HV14
PSE1
PSV1
PSV2
PSE2
HV15
HV24
HV65
CV101
C1
HV25
HV64
PSV25
C2
PSV64
HV63
E131
GAS USE COIL (OPTIONAL)
HV9
HV10
HV11
LI1
PI1
HV4
C3
PSV63
HV6
UV102
HV62
PSV61
FV21B
HV51
HV52
PERMA-CYL LH2 5500
CHART PART NO. 21181009 REV A
SHEET 1 OF 2

C1	FILL CONNECTION
C2	LIQUID W/DRL CONNECTION
C3	GAS USE CONNECTION
CV101	FILL CHECK VALVE
E131	PRESSURE BUILD VAPORIZER
FV21A	VENT STACK A DRAIN VALVE
FV21B	VENT STACK B DRAIN VALVE
HV2	TOP FILL VALVE
HV4	PRESSURE BUILD ISO VALVE
HV5	FULL TRYCOCK VALVE
HV6	GAS USE VALVE
HV8	VAC GAUGE VALVE
HV9	VAPOR PHASE VALVE
HV10	LII EQUALIZER VALVE
HV11	LIQUID PHASE VALVE
HV12	SAFETY RELIEF DIVERTER VALVE
HV13	VAPOR VENT VALVE
HV14	SAFETY LINE BLEED VALVE
HV15	SAFETY LINE BLEED VALVE
HV22	TOP FILL PURGE VALVE
HV24	FILL CHECK VENT VALVE
HV25	FILL CONNECTION PURGE VALVE
HV26	FILL LINE PURGE VALVE
HV30	ECONOMIZER VALVE
HV36	ECONOMIZER ISO VALVE
HV41	PRESSURE BUILD OUTLET VALVE
HV51	VAPOR PHASE BLEED VALVE
HV52	LIQUID PHASE BLEED VALVE
HV62	GAS USE BLEED VALVE
HV63	LIQUID WITHDRAWAL VALVE
HV64	LIQUID W/DRL VENT VALVE
HV65	LIQUID W/DRL PURGE VALVE
HV70	VAPOR PRESSURE REGULATOR VALVE

LI1	LIQUID LEVEL GAUGE
PCV70	VAPOR PRESSURE REGULATOR
PCV132	PRESSURE BUILD REGULATOR
PCV135	ECONOMIZER REGULATOR
PI1	TANK PRESSURE GAUGE
PI3	FILL PRESSURE GAUGE
PSE1	RUPTURE DISC
PSE2	RUPTURE DISC
PSE13	VACUUM RELIEF
PSV1	PRESSURE RELIEF VALVE
PSV2	PRESSURE RELIEF VALVE
PSV25	FILL HOSE RELIEF VALVE
PSV26	FILL LINE RELIEF VALVE
PSV32	PRESSURE BUILD RELIEF VALVE
PSV33	PRESSURE BUILD RELIEF VALVE
PSV37	ECONOMIZER RELIEF VALVE
PSV61	GAS USE RELIEF VALVE
PSV63	LIQ FIRE RELIEF VALVE
PSV64	LIQ W/DRL RELIEF VALVE
TT8	VACUUM GAUGE
UV102	GAS USE AOV

PIPING	
A	LIQUID WITHDRAWAL
B	TOP FILL
C	PRESSURE BUILD INLET
D	PRESSURE BUILD OUTLET
E	LIQUID PHASE
F	VAPOR PHASE
G	FULL TRYCOCK
H	DUAL SAFETY RELIEF
J	ECONOMIZER
K	GAS USE

PERMA-CYL LH2 5500

CHART PART NO. 21181009 REV A
SHEET 2 OF 2

Warranty Statement

Warranty only applies to original purchaser of Chart equipment and does not transfer to any other party.

Materials, components, and workmanship are warranted to be free of defects for 90 days from date of invoice.

Vacuum integrity as measured by conformance to Chart NER (Normal Evaporation Rate) specifications is warranted as follows:

- Perma-Cyl, liquid tanks - 5 years from date of invoice
- All Chart repaired liquid tanks - 2 years from date of invoice.

Damage or abuse caused by purchaser voids Chart warranty obligations.

Freight damage incurred during shipment from Chart to purchaser must be reported immediately to Chart, and before placing equipment into service.

In the event of a valid warranty claim, Chart reserves the right to repair, replace or refund the value of the equipment at its discretion. The warranty applies only to the purchased Chart equipment and in no case is Chart obligated to reimburse the purchaser for consequential damages resulting from the operation of Chart equipment.