Penn West Energy – Sawn Lake Battery
Refrigeration Unit Addition
June 2009

Startup and Operating Manual

Prepared by Jonathan Huyer, P. Eng.
Tuxtla Gas Engineering Ltd.

Introduction

This project involves the installation of a three-stage compressor, refrigeration unit, NGL storage bullet, and VRU at the Sawn Lake battery in order to recover gas from the treater and oil tanks. The produced gas will be treated to pipeline specifications and delivered to the TCPL meter station. The C3+ product from the refrigeration unit will be stored in the new NGL bullet and offloaded by truck. The refrigeration unit will also provide a lean fuel gas stream for the existing generator, and a rich fuel gas stream for the existing treater. Please refer to the project Design Basis Memorandum for a full description.

This manual should be read in its entirety and fully understood by plant personnel before attempting to operate the facility.

Design Basis

Please refer to the Process Flow Diagram PFD-0001 and PFD-0002 for a material balance summary of the major flow streams. The gas composition from the treater (after the sweetening tower) is:

N2	0.0826
CO2	0.0046
C1	0.5479
C2	0.1340
C3	0.1499
i-C4	0.0210
n-C4	0.0425
i-C5	0.0073
n-C5	0.0064
C6	0.0024
C7+	0.0014

Design gas flow:	6,000 m3/d
Pressure:	207 kPag
Temperature:	40 C
Water Content:	Saturated
Free liquids:	None

Sales Gas Specification:	HC dewpoint of -10 C at sales pressure
NGL Product Specification:	C2/C3 ratio of 2 vol%

Process Description

Rich gas from the treater and VRU enter the first stage of the inlet compressor, together with recycled overhead gas from the deethanizer tower. The gas is compressed in two stages and then delivered to the refrigeration unit for dew point control.

The gas enters the tubeside of the gas/gas exchanger and is pre-cooled against the outgoing cold gas from the low temperature separator. Methanol is injected at the inlet of the gas/gas exchanger to prevent hydrate formation from water condensation in the chilling process. The gas then enters the tubeside of the chiller, where it is cooled by propane refrigerant to a target temperature of -15 deg C. The cold outlet stream from the chiller will contain NGLs plus a methanol/water mixture. This three-phase stream enters the low temperature separator where the liquids are removed. The methanol/water is level controlled from the bottom of the vessel to the slop tank. The cold NGL is level controlled from the middle of the low temp separator, where it flows to the top of the deethanizer tower after being preheated in the propane subcooler exchanger.

As the NGLs flow across the LTS level control valve to the deethanizer, the liquid flashes and thus drops in temperature. The two-phase stream then enters the top of the deethanizer tower. The vapour portion of the stream immediately exits the top nozzle, while the remaining liquid flows downward across the bed of random packing. This liquid contacts rising vapour from the reboiler, which causes the light hydrocarbon components (primarily methane and ethane) to be stripped from the liquid. At the bottom of the packed bed, the liquid drops onto a chimney tray and then flows by gravity to the reboiler. The reboiler is heated by an electric immersion coil submerged in a 50/50 glycol bath. The process fluid flows through a pipe coil inside the reboiler, and then returns to the tower below the chimney tray. The temperature in the bottom of the tower is controlled by a reboiler bypass control valve.

The liquid from the bottom of the tower flows by level control to the NGL storage bullet. Vapour from the top of the deethanizer tower is reheated through the E-206 propane subcooler exchanger, and then flows across a back pressure regulator to the first stage inlet compressor for recycle. A side stream of rich gas is sent to the treater for use as fuel.

In the gas chiller, propane refrigerant enters the shellside of the vessel across a level control valve. The drop in pressure causes the propane temperature to decrease, which enables it to extract heat from the gas. The liquid propane is completely vapourized on the shellside and exits the top of the chiller through a knock-back separator V-203. The cold, low pressure propane vapour then flows to the propane suction scrubber V-207. This vessel is equipped with a heating coil (using warm liquid propane as the heat medium) to vapourize any liquid propane that may have carried over from the chiller. The vapour then enters the refrigeration compressor where it is boosted to approximately 1000 kPag. The hot discharge gas then flows across a back pressure regulator and enters the condenser C-200, which is a forced draft aerial cooler located outside the building. The propane vapour is completely liquefied in the condenser, and the liquid then flows to the propane receiver V-208 inside the building. Liquid propane from the receiver is subcooled in the E-206 and E-207 exchangers, before returning to the chiller for use as refrigerant.

In the low temperature separator, cold natural gas exits the top of the vessel and returns to the shellside of the gas/gas exchanger for reheating against the warm inlet gas. At this point, lean fuel gas is drawn from the system. The remainder of the gas is sent to the third stage of the inlet compressor, to be boosted to final pipeline sales pressure.

Equipment Description and Operating Guidelines

NOTE: This operating manual is written with the assumption that plant personnel are fully trained and experienced with gas compression and refrigeration facilities, and understand the inherent hazards and safety risks associated with operating such a facility. The procedures in this manual do not represent approved safe work practices, and need to be reviewed in accordance with Penn West safe work practices before being implemented. The information included in this manual does not represent a complete instruction guide to refrigeration systems. Many other upset conditions and abnormal situations can arise, which will require corrective action or complete plant shutdown.

Inlet Compressor

Please refer to the compressor vendor operating manual for specific instructions on use and maintenance of this machine. The compressor is driven by a constant speed electric motor. The three stages of compression are handled by two throws. One throw handles the first stage on both the head end and crank end. The other throw handles the second stage on head end, and the third stage on crank end. The first and second stages have variable valve clearance pockets on the head end. The third stage has no adjustable pocket since it is on the crank end only.

Each stage includes an inlet scrubber with local level control and high level shutdown. A witches hat strainer is installed immediately downstream of each scrubber, to capture any solids that may otherwise damage the cylinder. Attention should be paid to the differential pressure across these strainers. The strainers can only be cleaned by removing the pipe spool.

The first and third stage coolers are equipped with manual louvres. The second stage cooler is equipped with an automatic louvre control. The second stage discharge temperature is more critical for control, since the gas from this point is entering the refrigeration package. The outlet temperatures from all coolers should be kept as low as possible, for optimum plant operation. However the outlet temperature should not drop below 20 C, to avoid hydrate formation. In addition, if this gas is overcooled, then there is an increased risk of liquid formation in the scrubbers.

The compressor is equipped with recycle control valves from second stage discharge to first stage suction, and from third stage discharge to third stage suction. Under normal operation, these valves will be in use at all times since the compressor capacity is greater than the gas production at the facility. The recycle valves will cause a drop in temperature at the first and third stage suction scrubbers. This is why it is necessary to monitor the scrubber temperatures and check for liquid formation.

Under normal operation, no liquids should appear in any of the scrubbers. If liquids do appear, it is an indication that the interstage coolers are likely operating too cold.

Since the third stage recycle valve controls suction pressure to third stage, it also controls the operating pressure for the refrigeration plant. The actual operating pressure for the refrigeration plant is not crucial, and it is more important to achieve a third stage suction pressure that is suitable for the compressor under the given flow conditions. The compressor mechanic's recommendations should be followed in this regard.

An inlet pressure control valve is provided immediately upstream of the first stage scrubber. During normal operation, this valve will be wide open. The valve is only required during startup, when the treater has pressured up to 40 psig and gas is going to flare. The inlet pressure control valve will throttle the incoming gas to 25 psig (175 kPag) and will gradually move to wide open as the gas is drawn down from the treater. Then the recycle valve will take over and hold the suction pressure at 25 psig.

An automatic blowdown valve is provided on third stage discharge. This valve provides blowdown for the entire facility, with the exception of the deethanizer overhead gas which is blown down from within the refrigeration unit. The valve is activated on a level 1 ESD (fire, high LEL, or manual pushbutton).

A manual blowdown valve is also provided for the second stage discharge. This is included for maintenance purposes, so that all stages of the compressor can be depressurized after having been isolated from the process.

Each stage of the compressor includes a high discharge pressure and high discharge temperature shutdown. The first and third stage also include a low suction pressure shutdown. The third stage low pressure switch may indicate hydrate formation in the refrigeration unit.

During normal operation, the gas flow through the third stage will be less than the first two stages due to the shrinkage through the refrigeration plant. When the refrigeration plant is not operational, the gas volume through third stage will increase and the recycle valve will throttle back slightly.

When the compressor is shutdown, the upstream treater pressure will build up to 40 psig at which point the back pressure regulator on the solution gas separator will open to flare. The deethanizer tower pressure will also increase, and will begin to divert gas to flare at 1400 kPag. However this volume will quickly reduce to zero, since the supply of NGL to the tower from the low temp separator will also cease when the compressor is shutdown.

Refrigeration Unit

The refrigeration unit is designed to chill the inlet gas to -15 deg C, causing NGLs and water to condense from the stream in order to meet pipeline specifications. The NGLs are treated in a deethanizer tower to make a spec LPG product. The water is separated and transferred to the slop tank.

The refrigeration package operates on 2nd stage discharge pressure, and the residue gas is then compressed to sales pressure in the 3rd stage.

E-205 Gas/Gas Exchanger

Warm gas from the second stage compressor discharge cooler enters the tubeside at the top of the gas/gas exchanger. At this point methanol is injected into the gas, to prevent hydrate formation as water is condensed. Cold dry residue gas from the low temperature separator enters the shellside at the bottom of the exchanger, to be reheated before third stage compression. There are no controls on the exchanger.

Operators should monitor temperatures and pressures across both the tubeside and shellside. The shellside outlet temperature is expected to be approximately 10 deg C colder than the tubeside inlet temperature. The shellside outlet pressure should be approximately 100 – 150 kPa less than the tubeside inlet pressure.

E-202 Gas Chiller

The gas chiller receives cool gas from the tubeside of the gas/gas exchanger and utilizes propane refrigerant to further lower the gas temperature to the target of -15 C. The chiller contains a U-tube bundle, with process gas on the tubeside and propane refrigerant on the shellside.

The desired gas outlet temperature of -15 C is dependent on the gas temperature from the inlet compressor, and the temperature of the propane refrigerant on the shellside. If the gas temperature is too cold, there are two options available: Increase the gas temperature from the second stage discharge cooler, or increase the suction pressure of the propane compressor. Raising the inlet gas temperature will increase the refrigeration load, and result in a higher temperature in the low temperature separator. Raising the refrig compressor suction pressure will result in a warmer temperature of refrigerant on the shellside of the chiller. The initial target for the inlet compressor second stage discharge temperature is 35 C, and the allowable control range is 20 C to 45 C. The temperature setpoint can be adjusted as needed to avoid over-chilling the gas in the refrigeration unit. The other means of gas temperature control is to increase the shellside temperature by adjusting the setpoint on the regulator PCV-2063, discussed below. This regulator directs hot propane gas to the chiller shellside, causing it to increase in pressure and become warmer. The normal operating temperature of the chiller shellside is -20 C, which is achieved at a refrigerant pressure of 140 kPag.

Oil Draining from Chiller Shellside:

If lube oil carryover occurs from the propane compressor discharge, it will eventually accumulate in the shellside of the chiller. From that point, the only way to remove it is through manual draining. Operators need to develop a safe work procedure for this exercise, as it involves exposure to propane vapours and cold fluids. A drain connection on the bottom of the chiller is piped outside the building, and can be used for removing lube oil. A sign that lube oil may be accumulating inside the chiller shell is if the frost on the drain nozzle vanishes. There is no other means of indicating the presence of oil in the system. However, if the propane compressor requires regular additions of lube oil, then that is also a very good sign that lube oil is likely being deposited in the chiller.

Since the chiller operates at low pressure and temperature, the lube oil will not flow freely from the drain valve. When it does, it will be saturated with propane and as such will be hazardous. One method to improve oil flow from the drain nozzle would be to shutdown the refrigeration compressor and allow the chiller shellside to increase in temperature (and consequently, also increase in pressure). This will reduce the oil viscosity and provide more driving force through the drain nozzle. However it will also increase the hazard associated with higher pressure propane being present. Oil draining should not ever be required on a routine basis. If it is needed, it is a sign of poor upstream equipment performance (either the compressor or the lube oil separator). As such the focus should be on rectifying those issues.

Adding Propane to the System:

The oil drain line can also be used as a makeup connection for propane. Any loss of propane from the system will be seen as a drop in level in the receiver (see the discussion on the Propane Receiver, below). It is more convenient to add propane to the chiller than the receiver, since it is at a lower pressure. However, this will bypass the level control valve and create the risk of a high level shutdown in the chiller or liquid carryover to the suction accumulator, if liquid is added too quickly. Therefore an operating procedure should be developed to ensure this task is done properly and safely. Note that any propane added to the chiller will take several minutes to appear in the receiver.

Gas Chiller Instruments and Controls:

LC/LV-2020: Level controller / control valve. This device combines the function of level controller and throttling valve into a common body. The level setpoint is fixed by the elevation of the controller, and therefore cannot be changed. Subcooled liquid propane enters the body of the controller and is flashed across the internal valve to approximately 140 kPag, where it drops in temperature and becomes partially vapourized. The cold two-phase mixture then enters the shellside of the chiller and refrigerates the gas flowing through the tubes. As heat is transferred to the gas, the liquid propane vapourizes and leaves the top of the chiller. The drop in propane level causes the level controller to admit more liquid propane to the chiller.

LSHH-2021 High level switch. The high level switch provides protection for the downstream refrigeration compressor, in the event of liquid carryover from the chiller. The switch may activate if the level controller failed open, or if propane makeup is added too quickly to the chiller. The switch causes the refrig compressor to stop, but the gas flow can remain on provided the methanol injection is also on. The sales gas will begin to drift off spec (become high in HC and water content) if the refrig compressor is not restarted.

PSHH-2020 High pressure switch. This switch is set at 25 psig, and provides protection to the refrigeration compressor in the event of a high suction pressure scenario. This could be caused by a leak in the chiller tube bundle, a leak in the suction scrubber heating coil, or a leak in one of the propane subcooler exchangers. All these events are unlikely to occur. After a shutdown, the pressure in the chiller shell will naturally increase as the system warms up. This will cause the high pressure alarm to trip, some time after the shutdown has already occurred.

PCV-2063 Hot gas bypass (or "phantom load") regulator. This regulator directs hot discharge gas from the refrig compressor and sends it directly to the shellside of the chiller, to prevent a low suction pressure scenario for the compressor during periods of low system load. If the suction pressure of the compressor is drawn down, the propane will be chilled to lower temperatures. This can be problematic since it can cause freezing within the chiller tubes. The normal setpoint for the regulator is 10 psig downstream pressure.

P-201 Methanol Pump

The methanol pump provides hydrate inhibition in the refrigeration unit. Water will condense from the gas during the chilling process, and will collect in the bottom of the low temperature separator. Methanol injection points are provided at the inlet of the gas/gas exchanger, inlet of the chiller, upstream of the LTS level control valve, and at the sweetening vessel. During normal operation, it is important that the only injection point that should be open is the inlet to the gas/gas exchanger. If any other injection points are open at the same time, the methanol will flow entirely to one point, and not distribute evenly to the others. The other injection points are provided only to allow operators to direct methanol specifically to a single location, in the event a hydrate has already occurred.

The methanol pump is programmed in the PLC to shutdown whenever the gas flow has stopped. Otherwise, methanol will collect at the bottom of the gas/gas exchanger and be wasted. If the refrig compressor is shutdown but gas is still flowing from the inlet compressor, the methanol pump must continue to operate.

The calculated methanol injection rate at design conditions (6000 m3/d inlet gas and -15 deg C chilling) is 2 gal/day. Depending on actual refrig conditions, it may be necessary to use a slightly higher rate. Operators should always monitor the differential pressure across the refrigeration unit. If the pressure drop increases at a constant gas flow rate, a hydrate has likely occurred in the chiller tubes. In that case, an increase in methanol will not help, since it will only flow to the open tubes. Shutdown the refrig compressor and conduct a "thaw job", allowing the system to warm up until the hydrate clears. Then restart the refrig compressor and set the methanol injection rate slightly higher than before.

V-202 Low Temp Separator

In the low temp separator, NGL and methanol/water liquids are removed from the gas in separate phases. The NGL floats on top of the methanol/water and is level controlled to the deethanizer tower by way of the E-207 subcooler. The methanol/water mixture is removed from the bottom of the vessel, and transferred to the slop tank. The gas exiting the top of the separator is reheated in the gas/gas exchanger before flowing to the third stage compressor and then TCPL sales.

Low Temp Separator Instruments and Controls

LC-2020	NGL level control. This controller must be set on throttling mode, to maintain a steady supply of liquid to the deethanizer tower. If the controller is allowed to fluctuate, then the tower will not be able to maintain the liquid product specification and the rate of recycle gas to the inlet compressor will fluctuate substantially.
LC-2021	Methanol/Water level control. This controller must also be set on throttling mode, since a drop in water level will also cause drop in NGL level. The water / NGL interface should be visible in the transparent level glass, although it may be difficult to distinguish clearly between the two streams.
LSHH-2020	High level shutdown. If NGL liquid is allowed to carryover to the gas/gas exchanger, the liquid will vapourize completely as it is reheated. As such, the sales gas dewpoint will rise. No other negative impact should be seen.
LSLL-202	Low level shutdown. This switch is to protect against the accidental gas blow-by of gas to the deethanizer tower or slop tank.

E-207 Propane Subcooler

The E-207 propane subcooler uses cold hydrocarbon liquids from the low temperature separator to cool the liquid propane upstream of the chiller. This reduces the refrigeration duty required, but more importantly it raises the temperature of the LTS liquids upstream of the level control valve. Without the preheating, the chance of hydrates across this valve is greatly increased. The cold LTS liquids are on the tubeside of the subcooler, and warm propane liquid is on the shellside.

V-209 Deethanizer

The deethanizer tower produces a spec LPG product by fractionating the light components (methane and ethane). Cold inlet liquids from the low temperature separator enter the top of the tower, after being preheated in the E-207 exchanger. Due to the drop in pressure across the LTS level control valve, this liquid stream flashes and partially vapourizes. The vapour immediately leaves the top of the tower through the outlet nozzle. The remaining liquid flows downward across the packing, towards the chimney tray. As it does so, it contacts rising vapour from the reboiler, which causes the light ends to be stripped from the liquid. When the liquid reaches the chimney tray, it flows by gravity to the reboiler where it is partially vapourized. The two phase stream reenters the tower below the chimney tray. The vapour then flows upwards across the packing, and the remaining liquid flows by level control to the NGL storage bullet.

The quality of the LPG product is controlled entirely by the tower pressure, and the temperature in the bottom of the tower. A spec LPG contains no more than a 2% ratio of ethane to propane. In other words, if the propane content is 50%, the ethane content can be no higher than 1%. Routine analyses should be taken to fine tune the tower operation and maintain the spec product. The initial setpoint for the tower should be a bottom temperature of 31 deg C at a pressure of 700 kPag. If analyses show that the ethane content is too high, the bottom temperature should be increased slightly.

It is very important for effective fractionation performance that the feed rate to the tower be kept constant. This means that the level controls on the low temperature separator for both the hydrocarbon and water phases must be in throttling mode. The tower reboiler is a “once-through” design, drawing liquid from the chimney tray. If the liquid flow stops, then no heat will be available to the bottom of the tower. When the liquid flow restarts suddenly, the sudden surge of fluid would create a rise in pressure in the tower and a large increase in recycle gas flow to the inlet compressor.

Deethanizer Instruments and Controls

LC-2090: Tower level control. This controller can operate in snap-acting mode, to improve accuracy of the downstream turbine meter.

LSHH-2090: Tower high level switch. Indicates that the LPG product has likely gone off spec, causing a pressure build up in the downstream bullet. Note that as the temperature in the bullet increases in the summer, the pressure will also increase and therefore reduce the driving force for LPG flow. This can be overcome by raising the tower bottom temperature setpoint a few degrees as needed. As long as the tower bottom is warmer than the bullet temperature, this problem should not occur.

TC-2090: Tower bottom temperature. This controller senses the liquid temperature and adjusts the reboiler bypass valve (1” V-ball) to maintain setpoint. The normal control point should be 31 deg C. If the valve is operating wide open, it is an indication that the reboiler bath is too hot and should be lowered (using the separate control on the reboiler heater). Likewise if the control valve is closed all the time and the setpoint is still not being achieved, the reboiler bath temperature should be increased. Note that the flow to and from the reboiler is by gravity. If the temperature of the fluid reentering the tower is higher than the actual tower bottom temperature, it is a sign that the chimney tray is flooding and causing cold liquid to bypass the reboiler. NOTE: Do not attempt to restrict the flow of fluid to the reboiler. Doing so will cause the tower chimney tray to flood, and the liquid product to go off spec.

PCV-2060 Rich fuel gas supply to treater. This regulator controls downstream pressure to the treater for use as fuel gas. It is normally set at 345 kPag. In the event that the deethanizer tower is not in operation, lean fuel gas will be required for treater fuel (connected outside of this package). The lean fuel gas supply regulator should be set slightly lower so that rich fuel is always used preferentially.

PCV-2061 Deethanizer back pressure control. This regulator controls upstream pressure, maintaining the tower at 700 kPag. Note that if the tower pressure needs to be increased (or decreased) then the bottom temperature setpoint will also need to be adjusted to keep the LPG on spec.

PCV-2062 Deethanizer pressure to flare. This regulator is set at 1400 kPag back pressure, to automatically relieve the tower to flare in the event of overpressure. This can occur during a shutdown situation, where the inlet compressor has stopped but vapour is still being generated in the tower (until the low temp separator level control valve closes fully). If the regulator does open, it should only occur for a brief period of time. If the tower has pressured up and the regulator is wide open during normal operation, it is a sign that the LTS level control valve may be blowing gas due to a level controller malfunction.

BDV-2090 Deethanizer blowdown valve. This control valve will fail open in a level 1 ESD (fire, high gas detection, or manual pushbutton), causing the deethanizer tower to depressurize. At the same time, the plant blowdown valve on the inlet compressor third stage discharge will also open, depressurizing the rest of the facility.

H-310 Deethanizer Reboiler

The reboiler consists of an atmospheric bath of 50/50 glycol/water, held at constant temperature by a 9 kW electric immersion heater. Liquid from the deethanizer tower flows through a pressure-rated coil in the bath to be heated to the desired setpoint. The bath temperature should be set to the point where the tower temperature controller TC-2090 is throttling the control valve (see above). The estimated starting point for bath temperature is 65 deg C. The maximum allowable operating bath temperature is 90 deg C. The reboiler includes a riser column to accommodate thermal expansion of the glycol. For startup, the unit should be filled only to the point where the low level switch LSLL-3100 has been cleared. If the unit is filled higher, it may overflow when heated. The main bath of the reboiler is insulated, but the expansion column is intentionally uninsulated to reduce vapourization losses.

The pressure on the deethanizer glycol bath is normally zero. An increase in pressure may indicate a tube leak inside the unit. The radiator cap will also vent gas in this situation.

Reboiler Instruments and Controls

TC-3100	Bath temperature controller. This needs to be set at a value that keeps TC-2090 in control range. The expected setpoint is approximately 65 C. Do not set above 90 deg C.
TSHH-3100	High bath temperature shutdown, set at 120 C. Note that this switch will only function if it is immersed in fluid. If glycol containment has been lost, the high temperature sensor on the immersion coil itself will still provide protection.
LSLL-3100	Glycol bath low level shutdown. This switch will trip off the heater, and shutdown the refrigeration compressor.
PVRV-3100	Radiator cap, to allow air in and out of the reboiler due to glycol thermal expansion.

E-206 Deeth Overhead Propane Subcooler

This double pipe exchanger is exactly the same design as the E-207 subcooler. Cold overhead gas from the deethanizer tower is reheated in the tubeside, while warm propane liquid is subcooled on the shellside.

V-207 Propane Suction Accumulator

This vessel provides secondary carryover protection for the refrigeration compressor. Primary protection is provided by the V-203 knock-back separator on top of the chiller. The suction accumulator has no controls, but is equipped with an internal coil for warm liquid propane. If carryover from the chiller does occur, the coil will cause the cold propane in the vessel to vapourize. This is obviously preferable to dumping the propane to drain, which would then be lost. The coil valves should be open at all times. Only a small temperature difference should be felt across the coil. If a noticeable amount of cooling occurs across the coil, it is a sign that carryover has occurred. Verify that the chiller level controller is working properly.

K-200 Propane Compressor

The propane compressor receives cold low pressure propane vapour from the suction accumulator at approximately 140 kPag and compresses it for reuse as a refrigerant at 1000 kPag. The compressor is reciprocating, and is belt driven by a 20 hp constant speed electric motor. For startup, a manual globe valve is provided on the suction inlet. To prevent a possible motor overload or belt slippage due to high torque, the globe valve should be pinched back if the suction pressure is higher than 200 kPag. This situation will occur if the shutdown has been long enough to cause the chiller to warm up. The propane pressure will increase in direct proportion to the temperature, to the point that it eventually matches the receiver pressure (approximately 850 kPag at 25 C). The manual globe valve must remain pinched back until the suction drum pressure drops below 200 kPag. For more specific startup instructions, please follow the directions of the refrigeration mechanics (from Toromont, Propak, etc) who provide service for this unit.

Propane Compressor Instrumentation and Controls

PSLL-2000 Low suction pressure shutdown. Set at 70 kPag, designed to protect the compressor from high differential pressure and the risk of pulling a vacuum (which would let air into the system). A low suction pressure scenario could occur if the chiller lost propane feed, due to a malfunctioning level control valve or other problem such as loss of pressure in the receiver, or loss of propane charge. The phantom load regulator PCV-2063 which feeds hot propane vapour to the chiller is set at 100 kPag, above the trip point of this switch.

TSHH-2000 High discharge temperature shutdown. Set at 121 deg C.

PSHH-2000 High discharge pressure shutdown. Set at 1900 kPag. A high discharge pressure can occur if a flow blockage exists, or if the propane condenser has shutdown. Without a means for cooling to occur, the propane will increase in pressure until it finally condenses. The discharge pressure will also increase if non-condensables (methane, ethane, or air) somehow enter the system. These components will collect in the vapour space of the receiver, and increase the back pressure on the compressor discharge. See the discussion on the propane condenser and receiver sections below.

VSHH-2000 Compressor vibration switch. Indicates a major mechanical failure, possibly resulting in loss of propane containment and subsequent risk of fire or explosion.

PCV-2001 Propane cooler regulator. This valve automatically supplies liquid propane to the integral compressor oil cooler. The vapourized propane then returns to the system via the compressor suction.

PV-2080 Compressor back pressure regulator. This regulator maintains a minimum discharge pressure on the compressor of 1034 kPag. Without this regulator, the discharge pressure would be entirely a function of the outlet temperature of the propane condenser (i.e., it would drop lower in the winter). A drop in discharge pressure could result in inadequate pressure in the receiver, restricting the ability of propane to flow to the chiller. This regulator works in conjunction with PCV-2080.

PCV-2080 Hot gas bypass. This regulator maintains a minimum downstream pressure in the propane receiver of 600 kPag by directing hot discharge gas upstream of PV-2080 directly into the receiver. This regulator should only function during winter months, when the propane condenser is creating a low outlet temperature (below 10 deg C).

V-210 Discharge Oil Separator

The discharge oil separator is located directly inline on the compressor discharge piping, and is designed to remove trace amounts of lube oil that may be entrained in the hot propane gas. The separator has an automatic float-type dump valve that redirects the lube oil back to the compressor. The separator typically operates with no operator intervention.

If the separator does not function properly, or if the compressor is carrying over excessive oil, then lube oil may enter the refrigeration system. In that case, it will eventually accumulate in the shellside of the chiller. Once lube oil enters the chiller, it can only be removed by manual draining. Refer to the section on the Gas Chiller above. A reciprocating compressor should not normally experience any observable oil carryover. If oil does appear in the chiller shell, it is a sign that compressor maintenance is likely required.

C-200 Propane Condenser

The condenser is a forced draft aerial cooler, with finned tubes and an electric driven fan. Hot discharge gas from the propane compressor enters the condenser and is completely liquefied. The outlet temperature from the condenser is of course strongly dependent on the inlet air temperature. When the outlet temperature rises, the pressure at which propane will condense also rises. Likewise in the winter, propane will condense at a lower pressure. This could create a problem in the system, where the propane pressure would be inadequate to flow from the receiver to the chiller. However with the presence of regulators for discharge pressure control and hot gas bypass, the need to control the condenser with automatic louvres or a VFD fan is reduced.

The condenser must be in operation at all times that the propane compressor is running. The loss of one should automatically shutdown the other.

A lack of condensing capacity will create a high discharge pressure for the compressor. This is the most common problem in summer months. However it may also be an indication that non-condensable components (methane, ethane, or air) have somehow entered the system.

V-208 Propane Receiver

The propane receiver collects liquid propane from the condenser, for subsequent delivery to the chiller. The pressure in the receiver is a function of the temperature of the propane inside. It is necessary to maintain a minimum pressure on the receiver in order to have sufficient driving force to flow propane to the chiller. If the upstream condenser has over-cooled the propane (common in the winter), then the receiver pressure will be maintained at 600 kPag by the hot gas bypass regulator PCV-2080.

Non-Condensables in the Refrigeration System:

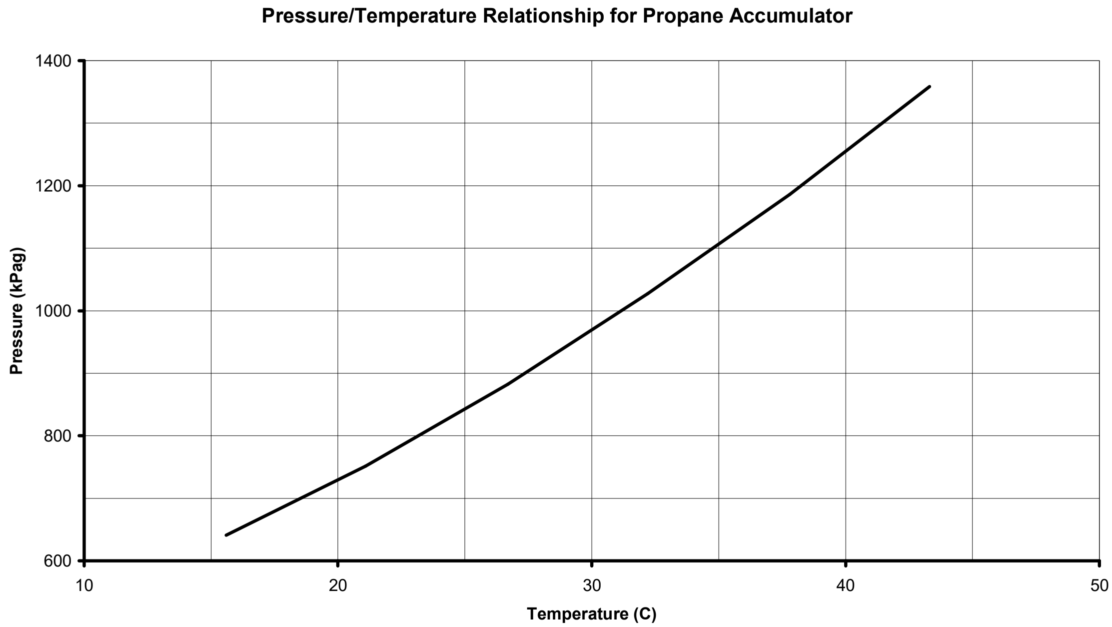
If non-condensables such as methane, ethane, or air enter the system, they will become trapped in the vapour space of the receiver. The presence of these components will register as a higher than normal pressure in the vessel. Since the pressure-temperature relationship of propane is fixed, we can detect non-condensables by comparing the receiver pressure to the chart below. If the receiver pressure is significantly higher (for example, more than 100 kPa higher) than expected for its temperature, then it may be necessary to bleed non-condensables from the system. If left unchecked, the pressure may continue to build up such that the compressor experiences high discharge pressure or high temperature shutdowns. At the very least, non-condensables will reduce the refrigeration system efficiency.

Non-condensables may enter the system through a variety of means:

- Makeup propane that is commercial grade instead of HD-5 purity
- An incomplete vacuum purge during startup
- A small leak on the tubesheet of the chiller (causing process gas to enter the refrigeration system)

Propane refrigerant can be sampled and analyzed to check on the system quality from time to time.

The best method to remove non-condensables from the system is to open slightly the bypass globe valve for the receiver PSV. The light components will then be released to flare. However, an unavoidable consequence of this action is that a volume of propane will also be lost along with the non-condensables. The valve should be left open for at least 30 minutes to allow the system to circulate during the purge. Watch the propane level in the receiver throughout the process. If the purge has been successful, the pressure in the receiver should be closer to the expected chart value.



The propane receiver also provides surge capacity for the refrigeration system, which operates in a closed loop. Any loss of propane refrigerant from the system will be reflected by a drop in level in the accumulator. Propane can be added directly to the receiver to make up volume, however it is more practical to add it directly to the chiller since it is at a lower pressure. Under normal circumstances, propane losses should be very small. If losses are observed, a thorough review of the system should be conducted to look for leaks. Common sources of leaks include threaded connections (especially level gauge unions) and valve packing. Use a soap solution and/or a gas monitor at close range to find the leaks.

A complete loss of propane level from the receiver will result in a low suction pressure shutdown of the propane compressor, once the chiller shellside has effectively boiled dry. A high level of propane in the receiver (from inadvertent overfilling) would result in high discharge pressure shutdown of the compressor.

Filter-Dryer

Immediately downstream of the propane receiver, a Sporlan filter-dryer cartridge is used to remove trace amounts of water or solids that may be present in the system. Under normal operation, this filter element will likely last for several months between change outs. However during the initial startup, the filter element may require one or more changes depending on the condition of the system. Regardless, once startup is complete, a fresh filter should be installed. The refrigeration mechanic should be consulted with regards to the supply of spare elements.

The filter will need to be slowly depressurized to change out, since this will cause a temperature drop as the propane flashes. A safe operating procedure for this practice needs to be developed by operations. To conserve propane and reduce venting, the filter could be hooked up to depressure into the chiller shellside initially, and then only the final blowdown would be to atmosphere.

V-800 Fuel Gas Scrubber

The primary supply of lean fuel gas to the plant is taken from the shellside outlet of the gas/gas exchanger, upstream of the third stage inlet compressor. The pressure is regulated down to 550 kPag across PCV-8000 for this purpose. The fuel gas scrubber will normally operate completely dry, and for this reason it has a manual dump valve only. If liquids do appear, it is an indication of a highly abnormal situation that should be discovered and remedied immediately. A high level switch is provided in the vessel as a final measure of protection. Operators should check the liquid level gauge during their daily rounds.

Gas from the scrubber is measured in a Roots-type flow meter and then directed to the plant where it is used primarily in the generator, and also for building heaters. In the event that the supply of lean fuel gas is interrupted, sales gas buyback will be used as backup (connected outside of this package scope). Note that it is preferable to draw fuel gas from upstream of the 3rd stage compression, to minimize the pressure drop and subsequent gas chilling.

V-9000 NGL Bullet

The NGL bullet is used to store liquid product from the bottom of the deethanizer tower. The bullet has a nominal capacity of 50 m3, which would give it at least 10 days storage volume at plant design inlet rate (6000 m3/d inlet gas). Truck loading connections are provided for product delivery. A branch from the vapour return line is also included, to allow vapour from the bullet to be recycled to the inlet compressor (via the solution gas separator). This line is useful if the bullet pressure has increased due to off-spec product, for example from prolonged low temperature in the deethanizer bottom. Under normal operation, the recycle line should always be closed.

The truck loading connections are equipped with safety valves installed directly in the bullet nozzles, to protect against non-stop leakage from a piping break. The bullet also has two 100% capacity relief valves with inlet block valves for servicing. This allows for one PSV to be removed for calibration without having to drain and depressurize the bullet.

NGL Bullet Instrumentation and Controls

LI-9000 Level Indicator. An internal float style level indicator with gauge readout.

PSHH-9000 High pressure switch, set at 1500 kPag. This switch should not trip except in a case of excessive heating of an off-spec product (i.e. high methane and ethane content). It will cause a shutdown of the refrigeration plant.

LSH-9000 High level alarm, set at 72% volume capacity

LSHH-9000 High level shutdown, set at the maximum allowable 80% volume capacity. This will cause a shutdown of the refrigeration plant.

Startup Procedure

Caution

This startup procedure provided by Tuxtla Gas Engineering Ltd. is intended as a guideline, and does not supersede normal safe operating practices. A pre-job safety meeting should be held, and none of the actions stated here should be followed until all personnel agree that it is safe to do so. As process conditions change, some unforeseen problems may arise forcing a deviation from this procedure. Again, discussion and agreement between all startup personnel should be obtained in such a situation before any actions are taken.

THE RESPONSIBILITY FOR A SAFE START UP AND OPERATION OF THIS FACILITY BELONGS TO THE OWNER, PENN WEST ENERGY.

During the startup, all personnel should be extremely vigilant towards the possibility of leaks. Throughout the entire process, soap solution should be repeatedly sprayed on all connections (especially threaded joints and unions) to reveal leaks. A connection that does not leak at 50 psig may still leak significantly at 500 psig. All personnel should also wear gas monitors.

Purging

Purging piping and equipment of air is one of the most hazardous activities in the start-up procedure. Initial purging with nitrogen gas is recommended, but if nitrogen is not readily available, purging with natural gas may be done with caution.

When purging with sweet fuel gas, the following procedures must be carefully observed at all stages of the purging process:

- Smoking must be strictly prohibited in the plant before purging commences.

- All sources of ignition such as open fires, fired heaters, welding and vehicles must either not be allowed on site or must be tightly controlled (hot work permit, explosives meter tests, etc.). The hazard of purging with natural gas occurs when hydrocarbon gas and air are mixed. The explosive limits of natural gas and air are quite narrow, and vary depending on the composition of the gas. If such a mixture is created and a source of ignition is present, an explosion or fire will occur.

- Internal sources of ignition may arise from one or more of the following:

  a) Sudden pressure rise (resulting in heat of compression) to the point of ignition. This can occur if the purge is turned into the system too rapidly.

b) Small objects such as gravel, rocks, pieces of metal left in piping from construction, can be flung about in piping or vessels and cause a spark. Again this can occur if gas is admitted too rapidly.

c) A falling liquid, such as water left in a line from hydrostatic testing, when pushed into a vessel too large by too large a volume of gas at too much pressure, could generate a static electrical discharge and cause sparks.

By adhering to strict safety procedures, practically all external sources of ignition can be eliminated.

- Tape all gas line flanges with masking tape and punch a hole in the tape for testing with a gas sniffer or a soap and water mixture during pressure purge. Be thorough. This will aid in leak checking during the pressure purge.

- Before the purge process, the flare stack and pilot light need to be extinguished since air will be entering the flare header. The flare cannot be re-lit until the oxygen content of the flare gas has been confirmed to be zero. Do not be in a hurry to re-light the flare.

- The instrument air system will need to be commissioned to conduct the purge process, since not all control valves have manual bypasses.

- The drain system should be isolated from the oil storage tanks, so that venting to atmosphere can be done through the drain header without sending air to the tanks.

- A properly calibrated and tested portable gas tester should be used to test for oxygen. Note that clip-on personnel monitors are <u>not</u> satisfactory for this purpose.

- The plant should be purged with sweet fuel gas in the normal direction of flow. The supply pressure of fuel gas should initially be as low as possible while still being sufficient to create adequate sweep velocity (for example, 75-100 kPag).

- Before beginning the purge, close all manual block valves, and ensure especially that all drain and flare valves are closed.

- The purge gas should initially be connected at the first stage inlet compressor. Slowly admit gas to the system and then manually open vent valves and drain valves in the order of normal process flow.

- Use a highlighter pen with a copy of the P&ID in order to keep track of which areas have been purged. Allow each purge point to flow for several seconds before closing the valve. A vessel will require a longer purge depending on size. All lines and vessels including drain lines, liquid lines, storage vessels, etc., must be purged.

- Use the portable gas tester to verify zero oxygen presence in vessels. A plastic bag can be used to contain gas from a vent source, to get a more accurate indication of oxygen content.

The purge process should be conducted in the following order:

- First stage inlet compressor
- Second stage inlet compressor
- Gas/Gas Exchanger tubeside
- Chiller tubeside
- Low temp separator
- Deethanizer tower and reboiler
- Gas/Gas Exchanger shellside
- Fuel Gas Scrubber
- Third stage inlet compressor
- NGL bullet

Of the entire purge process, the NGL storage bullet will take by far the most time. The drop in oxygen content will be rapid at first, but the elimination of the final amounts of air may require several hours. However a decision can be made to put the NGL bullet into service with trace amounts of oxygen present, since the bullet is not connected to flare or drain. The purge process can continue from the truck-out vent connection while NGL product is entering the vessel. The decision on when to put the bullet in service should be made by all startup personnel.

Note that the propane side of the refrigeration system is not part of the purge process. The refrigeration mechanic should remove air from the system by vacuum pump, before the system is charged with propane. Once the refrigeration compressor is in service, monitor the pressure in the propane receiver as described above to check for the presence of air or other non-condensables.

Once the purge is complete, the entire system should be pressured up to 350 kPag and a thorough leak test performed.

If possible, pressurize the deethanizer tower to 700 kPag with fuel gas in preparation for startup. Hold the NGL bullet at 350 kPag.

Equipment Startup

This checklist represents only a partial list of items that must be in order before startup. All startup personnel need to agree when it is appropriate to move forward with the work.

Prior to startup:

- Conduct a pre-job safety meeting
- Ensure ESD system has been completely function tested
- Ensure gas and fire detectors are operational, calibrated, and not in bypass

- Ensure fire extinguishers and other safety equipment is readily available
- Ensure all drain and flare valves are closed
- Reconnect the drain system to the oil storage tanks
- Ensure block valves at PSV locations, blowdown valves, and level switches are open
- Ensure all instrument needle valves are open to end devices
- Ensure all car seals are in place on appropriate valves
- All control valves are in service, with correct air supply pressure
- The refrigeration system has been charged with propane (chiller and receiver)
- The propane compressor has been charged with lube oil, and a new filter-dryer element is in place
- The deethanizer reboiler has been filled with 50/50 glycol mix to just above the low level shutdown switch.
- The methanol pump has adequate supply (normal injection rate is 2 gal/day)
- All motors have been bump tested to ensure proper rotation

Close manual block valves on the following control stations:

- Low Temp Separator NGL outlet
- Low Temp Separator Water outlet
- Deethanizer level control

Using a hand pump, pre-charge the Low Temp Separator with methanol to the normal interface level (below the NGL outlet nozzle). This step will enable the interface level controller to be put into service much sooner, since the methanol injection rate is very slow.

Inlet Compressor:

Commission the inlet compressor according to the instructions from the compressor vendor. Ensure all pressure control and recycle loops are functioning. During this time, gas will flow through the refrigeration unit (gas/gas exchanger, chiller, and low temp separator) but the refrigeration compressor will not be in operation.

As the system is brought up to pressure, check for leaks on a continuous basis.

Since the sales gas will be rich and wet initially, it will be necessary to direct gas to flare from third stage compressor discharge until the refrigeration plant is put in service.

NOTE: Light the flare only when confident that all air has been purged from the flare header. Failure to do so may result in an explosion.

Ensure all control valves in the compressor building are functioning properly. Check the scrubbers regularly for liquid accumulation. During normal operation, liquid should not be present. However the sudden introduction of gas to the compressor may cause liquid upstream of the unit to sweep into the first stage scrubber.

Monitor the differential pressure between stages, and especially across the witches hat strainers which are located at the outlet nozzle of each scrubber.

Ensure the gas cooler is working properly. Set the automatic louvre control on second stage discharge to maintain 35 deg C. The other louvres are manual control and should be set to achieve an outlet temperature range of 20 to 45 deg C.

Methanol Pump:

Start the methanol injection pump and set the flow to 2 gal/day. Open only the injection point to the tubeside inlet of the gas/gas exchanger. All other injection points should be closed.

Refrigeration System:

Turn on the electric heater to the deethanizer reboiler, and set the bath temperature to 40 C as an initial starting point. The glycol level in the expansion column should rise very slightly.

Start the refrigeration compressor according to instructions from the refrig mechanic. Start the propane condenser at the same time and leave the overhead louvres wide open.

Initially, the chiller pressure will be the same as the propane receiver (approximately 850 kPag). As the compressor draws propane from the chiller, the chiller pressure will gradually reduce and the shellside temperature will drop. The chiller pressure should stabilize at approximately 140 kPag (corresponding to a shellside temperature of -20 C).

As the chilling begins to occur, the gas temperature will drop. However once it enters the low temp separator, it may warm up again because the vessel steel has not been cooled down. For this reason the initial refrigeration startup may be slow.

Be aware that since the hydrate temperature of the gas is approximately +15 C in the refrigeration system, the pressure drop may increase if the methanol injection system is not working properly. As the gas temperature drops, monitor differential pressures across the unit continuously.

If the methanol in the low temperature separator is at the normal interface level, the control valve LCV-2021 can be put into service. Ensure it is operating in throttling mode, not snap-acting.

Once the outlet gas temperature from the low temp separator approaches 0 C, hydrocarbon liquids will be collecting inside the vessel and will eventually appear in the upper and lower level gauges.

Deethanizer Tower, Reboiler, and NGL Bullet

When the NGL in the low temp separator reaches the normal liquid level, the upper level controller LC-2020 can be put into service. This will cause liquids to flow to the top of the deethanizer tower. The pressure drop across LCV-2020 will cause a drop in temperature and the line will begin to show frost. Watch for the formation of hydrates at this valve or at the top of the tower. If this occurs, open the methanol injection point upstream of the control valve, and temporarily close the injection point at the inlet the gas/gas exchanger. Under normal operation, no methanol should be needed at LCV-2020.

The flow of flashing liquid to the deethanizer tower will cause the tower pressure to increase. The back pressure regulator PCV-2061 should be commissioned to allow gas to be recycled to the inlet compressor, holding a back pressure of 700 kPag on the tower. At this point the rich fuel gas regulator PCV-2060 can be commissioned to the treater, if desired (assuming this line has been completely purged of air).

Liquid from the deethanizer tower inlet nozzle will flow down the packing and enter the reboiler coil from the tower chimney tray. As the liquid flows through the coil, it will partially vapourize and then enter the bottom section of the tower. During the initial startup, the liquid level in the tower bottom will be too low for the temperature controller TC-2090 to operate. The controller should be set to keep the reboiler bypass valve TCV-2090 closed (provided the reboiler bath temperature remains at 40 C).

When the NGL in the bottom of the tower begins to rise to the normal liquid level, the temperature controller probe will be in contact with the fluid. At this point, the reboiler bath temperature can be increased to 65 C, and the bypass control valve TCV-2090 can be put into service. The target bottom temperature for the tower is 31 C at an operating pressure of 700 kPag. If the bypass valve is opening fully and yet the bottom temperature remains too hot, then the reboiler bath temperature should be reduced. Likewise if the bypass valve is fully closed and yet the bottom temperature is too cold, the bath temperature should be increased.

With the deethanizer bottom at normal liquid level, the tower level control valve LCV-2090 can be put into service. The controller can operate in snap-acting mode.

To test the function of regulator PCV-2062 (deethanizer to flare), close the block valve downstream of PCV-2061 and allow the tower pressure to increase to 1400 kPag. Ensure that PCV-2062 opens at this point, and then reopen PCV-2061 slowly to bring the tower pressure back down to 700 kPag.

As NGL liquids flow to the storage bullet, the pressure in the bullet will slightly increase. If the bullet purge was not fully completed before startup, gas can be vented from the truck vapour connection, provided it is safe to do so.

The initial batch of NGL from the bullet will likely be light (i.e., contain excess methane and ethane). Once the purge has been completed, the vapour recycle line from the bullet to the solution gas separator can be opened slightly to allow these light components to flow back to the refrigeration unit. This will cause the product in the bullet to become heavier over a period of time. Before trucking any NGL, have an analysis done on the liquid if possible, and check for the presence of water in the bottom of the bullet by carefully draining from the bottom of the level bridle.