Solving Common Vapor Recovery Challenges with Compact Compression's HCG Technology

Introduction

Vapor recovery is a common process in the oil and gas production, processing, and transportation sectors. Vapor recovery captures methane and longer chain hydrocarbons, carbon dioxide, volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) from various points in the oil and gas supply stream, preventing their uninhibited release into the atmosphere.

In many cases there is a clear economic proposition for vapor recovery since valuable long chain hydrocarbons like butane and pentane are commonly contained within the recovery stream. Instead of losing the value of these components they can be separated from the recovered gas stream and sold at a premium, in addition to the value of the captured methane. On commodity pricing alone, the installation and operation of a vapor recovery unit (VRU) can achieve payback in several months.

The economic benefit is less clear in other cases, for example, recovery of seal vent gas from large reciprocating compressors utilized in natural gas transmission and storage operations. Here, the gas stream is utility grade natural gas (~94% methane) and is of low volume, therefore the economic payback of a VRU may never be achieved based on the value of the captured gas alone.

Recently, more stringent national and sub-national regulations have been implemented, such as the 2012 amendments for New Source Emissions to the US EPA Clean Air Act and the Alberta Energy Regulator Directive 60 for Upstream Petroleum Industry Flaring, Incinerating, and Venting. Regulatory penalties on emissions creates additional incentive for companies to implement vapor recovery systems as standard practice.

The emissions regulatory framework is evolving rapidly alongside net-zero emissions and clean air targets set by various levels of government. One certainty though, is that regulations will become increasingly stringent. Forward looking companies will invest in vapor recovery and complimentary technologies to get their emissions footprint as low as possible

Common Vapor Recovery Technologies

Fundamentally, every vapor recovery system requires the use of a compressor to move gas from the source at low pressure to a gathering / processing system at a higher pressure. The three most common types of compressors used for VRU applications are reciprocating, rotary screw, and rotary vane. Blowers, another rotary machine, often find utility in vapor recovery applications at very low suction pressures as a first stage feeding a reciprocating compressor.

Reciprocating Compressors

By far the most mature and widely implemented technology for compression, reciprocating compressors use pistons and check valves to expand and contract compression chamber volume. Reciprocating compressors can be configured as either single or double acting, meaning there is either one compression & discharge cycle per piston stroke or two compression & discharge cycles per piston stroke. Compressors with multiple cylinders can be arranged so that cylinders are connected in series, increasing the overall compression ratio. All reciprocating compressors require scheduled maintenance such as oil changes, valve replacement and overhauls. The inherently large reciprocating inertial mass causes a high degree of vibration that must be managed with specialized mounting to structures.

Reciprocating compressors for natural gas applications fall into three categories: air compressor derivative, vertical frame, and horizontal frame.

Air Compressor Derivative

Air compressor derivatives have been used in low volume natural gas service primarily due to their low-cost.

Because these compressors were designed for air compression – not natural gas compression – there are several design characteristics that render them unsuitable for most natural gas compression applications. The most unsuitable characteristic is that there is no isolation of the compression chamber from the crankcase, meaning that any gas that leaks past the piston rings is vented to atmosphere and can contaminate the crankcase oil, reducing lubricity and resulting in catastrophic failure.

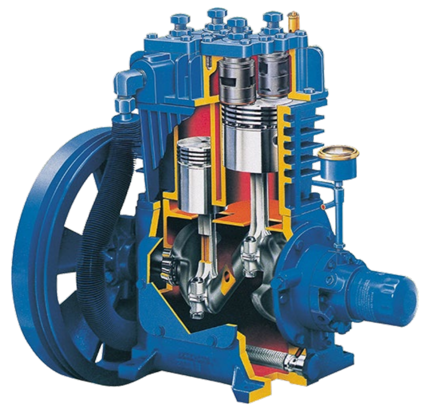

Figure 1 Air compressor derivative (source: Quincy)

Figure 2 Vertical frame compressor (source: PSG Dover)

Vertical Frame Reciprocating

Vertical frame reciprocating compressors were designed as process gas compressors and are available in both single and double acting configurations with one or two cylinders. A distance piece located between the compression chamber and the crankcase isolates the process gas from the crankcase, preventing the leakage of natural gas to atmosphere.

Vertical frame compressors can be configured with corrosion resistant materials for applications with H_2S or CO_2 content. These compressors can reach discharge pressures of up to 1,000 psi (6 970 kPa). They are applicable for relatively low flows from 9 – 127 MSCFD at suction pressures under 1 psi.

Horizontal Frame Reciprocating

Horizontal frame reciprocating compressors are widely used for high horsepower, high pressure natural gas applications. They are a horizontally opposed cylinder design and available with one to four stages, and with two to six cylinders. They are the only available option when gas must be compressed above 1,000 psi (6 970 kPa).

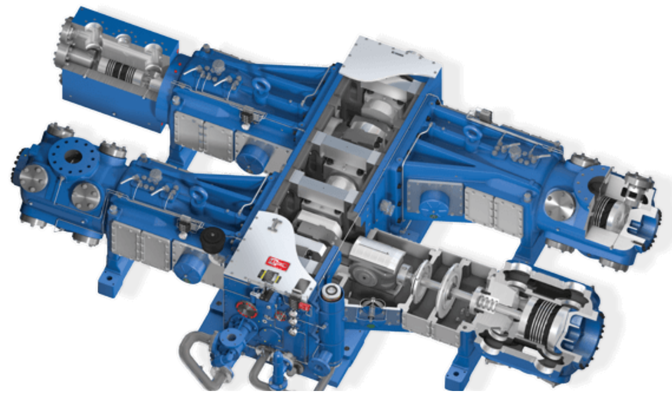

Figure 3 Horizontal frame compressor (source: Ariel Corp.)

Horizontal frame compressors are very flexible in their configuration; various cylinder sizes can be specified to fine tune compressor performance to the application, and they can be reconfigured if application requirements change. Inter-stage cooling is necessary to maintain temperatures within compressor limits and increase the effective compression ratio. Corrosion resistant materials are available.

The performance characteristics of the different types of reciprocating compressors are summarized in Table 1.

Table 1 Comparison of reciprocating compressor performance characteristics

	Air Derivative	Vertical Frame	Horizontal Frame
Stages	1 – 2	1 – 2	1 – 4
Action	Single	Single & Double	Single & Double
Max. Discharge	400 psi	1,000 psi	3,000 psi (or more)
Power	2 – 35 hp	5 – 50 hp	50 – 10,000 hp
Compression Ratio	3.5:1 per stage	4.5:1 per stage	4.5:1 per stage
Flow	Up to 225 MSCFD	Up to 180 MSCFD	140 MSCFD – 20 MMSCFD
Speed Turndown	2:1	2.5:1	2:1

Rotary Compressors

Rotary screw and rotary vane technology were both commercialized in the 1950's as an alternative to reciprocating air compressors. Rotary air compressors have some design features that make them advantageous over reciprocating compressors in certain applications, such as fewer moving parts, an absence of intake and discharge check valves and balanced rotational forces that result in very low vibration. They cost less than reciprocating compressors for the same capacity but are limited in output pressure

Rotary Screw

A rotary screw compressor is comprised of two counter-rotating helical rotors with an unequal number of lobes that mesh at high speed and tight tolerances to open and close compression volumes along the length of the rotor. Rotary screw compressors employed in natural gas compression applications are of the oil flooded type. The compressor oil provides lubrication, sealing, and cooling. The cooling effect of the compressor oil on the compressed gas permits much higher compression ratios than other compressors. Precise operating temperature control is another feature of rotary screw compressors. One and two stage rotary screw compressors are available, though single stage compressors are by far the most widely used for natural gas service.

The continuous sweeping motion of the compression chamber as the rotors intermesh results in a very smooth inlet and discharge pressure variation. This feature, along with the absence of intake and discharge valves, allows for tight pressure control at very low pressures which is important for low pressure vapor recovery applications. The rotary screw compressor is lightweight and compact relative to its capacity and is very flexible along a broad speed range. Some manufacturers of rotary screw compressors offer materials suitable for corrosive environments.

Figure 4 Male (R) and female (L) rotors of a screw compressor (Source: Kaishan USA)

Rotary Vane

A rotary vane compressor consists of a cylindrical housing inside which a cylindrical rotor turns. The center of rotation of the rotor is offset from the longitudinal axis of the cylindrical housing. The rotor contains multiple vanes symmetrically placed around its circumference. As the rotor turns, the vanes are free to move in and out and the centrifugal force of rotation, sometimes aided by a spring, holds the vanes tight to the inside surface of the housing. Oil is injected to lubricate the vanes and bearings of the compressor. Rotary vane compressors are available in one and two stage configurations.

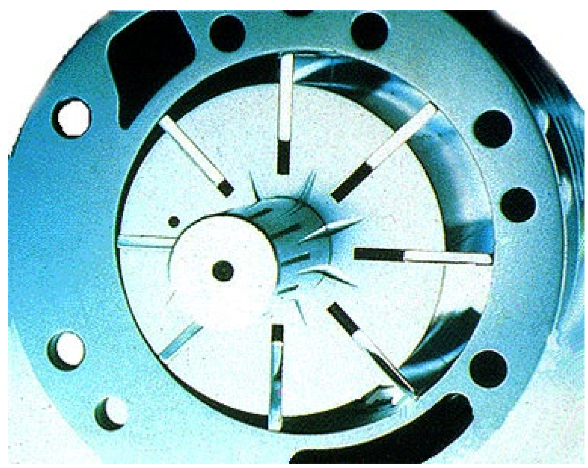

Figure 5 End view of rotary vane compressor housing and rotor (Source: VMAC)

Like the rotary screw compressor, the continuous sweeping motion of the compression chambers created by the vanes results in stable inlet and discharge pressures. No valves are present, resulting in good compressor efficiency at very low intake pressures and allowing for tight pressure control. Because the inlet and suction ports are located on the circumference of the compressor housing, there is no axial thrust generated along the shaft from pressure differential.

Rotary vane compressors are tolerant of small amounts of liquid ingestion and have a reasonably wide operating speed range. When configured with the proper materials, they are particularly good at handling high concentrations of H_2S.

Roots Blower

Although Roots blowers are not considered a compressor because they increase the velocity of gas rather than compress, they play a significant role in vapor recovery. Blowers can move substantial quantities of gas at very low suction pressures. In vapor recovery applications where suction pressure is <1 psi, the Roots blower can boost the pressure to 10-15 psi at its discharge. For this reason, it can be used as a first stage for reciprocating compressors, which require very large cylinder sizes at very low suction pressures.

Figure 6 Three lobe Roots blower cutaway (Source: Kaeser)

Roots blowers are simple machines, comprising of two identical profile counter-rotating rotors that mesh within a tight tolerance and are contained within a housing. The blower is oil free and require the rotors to be timed by gears so that the rotors do not contact. However, heat rise within the Roots blower limits the compression ration to below 2.

The performance characteristics of the different types of rotary compressors are summarized in Table 2.

Table 2 Comparison of rotary compressor performance characteristics

	Rotary Screw	Rotary Vane	Roots Blower
Stages	1 – 2	1 – 2	1
Max. Discharge	260 psi (single stage) 500 psi (two stage)	150 psi (single stage) 200 psi (two stage)	15 – 20 psi
Power	20 – 2,000 hp	5 – 500 hp	5 – 800 hp
Compression Ratio	20:1	7:1	2:1
Flow	20 MSCFD to 30 MMSCFD	5 MSCFD to 3 MMSCFD	14 MSCFD to 25 MMSCFD
Speed Turndown	7:1	3:1	4:1

Characteristics of Vapor Recovery Gas Streams

The term *vapor recovery* encompasses a wide range of applications in the oil and gas industry. It can be equally applied to the capture of dry utility grade natural gas from compressor seal vents, the capture of saturated gas from a production separator and the capture of saturated vapors from a storage tank battery.

It is simple to design a vapor recovery system for emissions sources of dry utility grade gas. These applications are typically within a climate-controlled environment and the homogeneity of the gas stream makes it possible to design a vapor recovery system without additional supporting systems to account for variability of conditions.

Designing a vapor recovery system for water saturated gas containing quantities of longer chain hydrocarbons poses a different set of problems. These applications are often on the upstream side of the production process and are subject to seasonal and diurnal changes in ambient temperature. As a result, the gas stream contains a degree of liquid content, which can vary on the ambient temperature and layout of the inlet piping. Cool ambient temperatures cause water vapor and longer chain hydrocarbons to precipitate from gas phase to liquid.

Table 3 Representative gas compositions of typical vapor recovery streams (Sources: Enbridge, Hy-Bon, Anova Resources)

	Dry Utility Gas		**Storage Tank Gas**		**Treater Gas**		**Casing Gas**	
Component	Mole Fraction	Liquid Volume gal/MSCF	Mole Fraction	Liquid Volume gal/MSCF	Mole Fraction	Liquid Volume gal/MSCF	Mole Fraction	Liquid Volume gal/MSCF
O_2	0.0001		0.0000		0.0000		0.0000	
H_2	0.0002		0.0000		0.0001		0.0001	
He	0.0000		0.0000		0.0001		0.0001	
N2	0.0050		0.0395		0.0377		0.0790	
CO_2	0.0030		0.0010		0.0224		0.0377	
H_2S	0.0000		0.0000		0.0014		0.0044	
C_1	0.9470		0.0829		0.5096		0.4132	
C_2	0.0420	1.116	0.2163	5.750	0.1840	4.892	0.1716	4.562
C_3	0.0020	0.055	0.2920	8.027	0.1439	3.956	0.1390	3.821
C_4	0.0004	0.013	0.2349	7.474	0.0691	2.199	0.0852	2.711
C_5	0.0002	0.007	0.1024	3.721	0.0231	0.839	0.0395	1.436
C_6+	0.0001	0.004	0.0310	1.348	0.0086	0.374	0.0302	1.314
Total	**1.0000**	**1.195**	**1.0000**	**26.319**	**1.0000**	**12.259**	**1.0000**	**13.843**

Table 3 shows the liquids content of various gas streams if process refrigeration at -130°F was used to strip out all hydrocarbons C_2 and above. Practically, most VRUs operate at inlet temperatures close to ambient conditions which can range from -40°F to 110°F in North America. Often, hydrocarbons C_4 and above are present as liquid, in addition to any liquid water that may be in the system. From the Table 3, a VRU for a storage tank gas application that processes 100 MSCFD will also need to process 1,254 gal/d of condensate if the inlet stream temperature is below 30°F (the boiling point of butane), not including any water that may be present.

Therefore, the majority of VRU designs for upstream applications require inlet separators, liquid pumps, and process valving to process the high quantity of liquids that accompany the gas stream. Stripping the liquids out of the stream results in drier gas, which results in higher outlet temperatures from the heat of compression, requiring outlet gas coolers to keep operating temperature within operational limits of the compressor. The additional hardware adds complexity and cost and introduces additional failure points in the system.

Technical Challenges of Compressors with Vapor Recovery

Reciprocating and rotary compressors have inherent design features that present challenges for vapor recovery applications. Liquids-rich vapor recovery gas streams introduce additional technical challenges described in the following sections.

Technical Challenges of Reciprocating Compressors

Reciprocating compressors are very versatile, especially for boosting pressures to over 1000 psi. However, they require exceptionally large and expensive cylinders to achieve reasonable throughput at the very low intake pressures typical of vapor recovery scenarios. Reciprocating compressors are typically used at inlet pressures above 60 psi. A reciprocating compressor cylinder would need to be five times the volume if inlet pressure were close to 0 psi rather than 60 psi.

Furthermore, reciprocating compressor performance at low suction pressures is negatively affected by the compressor clearance volume, which is the volume between the piston at the end of stroke and the cylinder head and valve plates. At extremely low pressures, the clearance volume becomes a significant percentage of the overall volume of compressed gas. These geometric constraints increase the clearance volume of the compressor and increase the overall cost of the compressor. For this reason, Roots blowers are often utilized as a first stage to feed a reciprocating compressor so that the negative effect of clearance volume and required cylinder volume at very low inlet pressures is lessened.

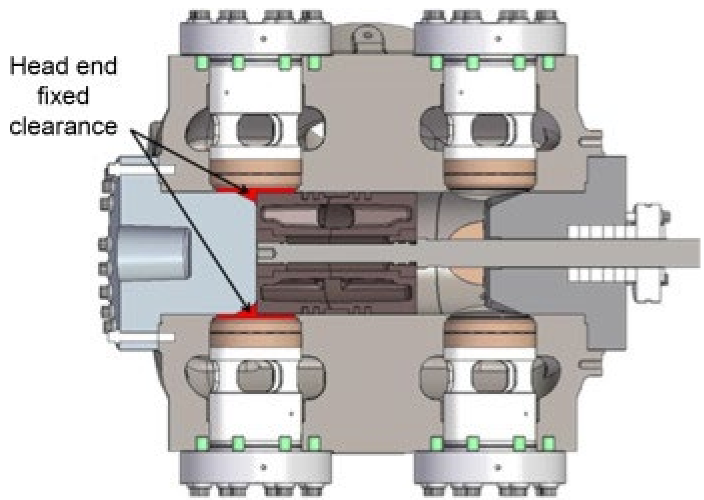

Figure 7 Clearance volume of reciprocating compressor (Source: Compression Machinery for Oil and Gas, 2018, Elsevier)

Liquids carried along with the gas stream pose a major problem for reciprocating compressors. Reciprocating compressors are high speed, high inertia machines designed to compress low density gas. Liquids entering the cylinder are unable to exit quickly enough through the valves because the density of the liquid is three orders of magnitude higher than the compressed gas. As the piston approaches top of stroke, the trapped incompressible liquid causes a large and instantaneous spike in pressure exceeding the capability of the components of the compressor. If fortunate, only the valves will fail. If less fortunate, pistons, connecting rods, cylinder heads and crankcases will experience catastrophic failure.

Therefore, it is critical that a robust liquids separation system is placed ahead of the inlet of the compressor if there is any possibility of liquids being present in the system. A further consideration is that if the compressor is installed where ambient temperatures can fall below the freezing temperature of water, freeze protection measures such as heat tracing, explosion-proof heaters and insulated enclosures become necessary.

Technical Challenges of Rotary Compressors

The absence of inlet and discharge valves in rotary compressors make them well suited for application at very low inlet pressures. Additionally, they are somewhat more tolerant of liquids present in the gas stream than reciprocating compressors. Nevertheless, there are some technical considerations that must be factored in when designing a rotary compressor system for vapor recovery applications.

Long chain hydrocarbons present in the vapor recovery gas stream dilute and contaminate the compressor lubricating oil. Unchecked oil dilution leads to premature bearing failure and accelerated wear of rotors and other compressor components.

Rotary vane compressors use a once-through lubricating system, and compensate for oil dilution with an increased oil injection rate, adding to operating expense. Rotary screw compressors compensate for oil dilution with temperature management. Operating the compressor at temperatures above 180°F keeps hydrocarbons up to C_5 in the gas phase, therefore limiting oil dilution to C_6 hydrocarbons and above which tend to be in low quantity. However, more frequent compressor oil changes and coalescing filter replacements are still required, increasing operating expense.

Any liquids present in the gas stream above nominal quantities pose a reliability challenge for rotary compressors. In the case of rotary vane compressors, liquids present in the compressor can cause breakage of the compressor vanes, necessitating their replacement. Slugs of liquids through a rotary screw compressor cause flooding of the entire compressor system, requiring draining of all fluids present and complete replacement of the compressor oil and coalescing filter.

Therefore, as with reciprocating compressors, a robust liquids separation system is required ahead of the inlet of the compressor. Figure 8 shows a manufacturer recommended inlet separator P&ID for a rotary vane compressor, which can also be applied to rotary screw and reciprocating compressors. Installation where ambient temperatures can fall below the freezing carry the same implications for freeze protection.

The addition of a liquids separation system for reciprocating and rotary compressors introduces complexity, cost, and additional potential points of failure.

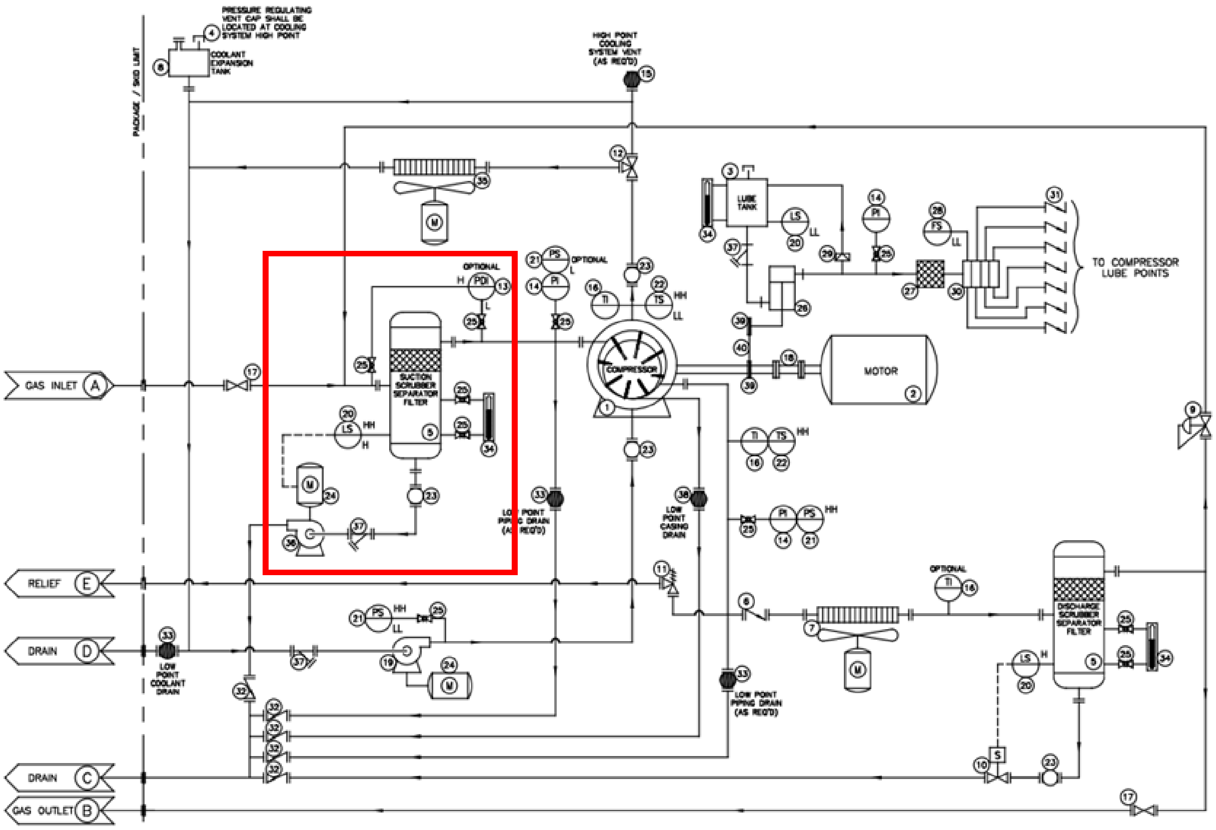

Figure 8 Typical inlet liquid separation system for rotary vane compressor (Source: Ro-Flo)

Compact Compression's HCG Technology

Compact Compression began development of the Hydraulic Casing Gas (HCG) compressor in 2014 to address the technical challenges of casing gas compression, which are mostly the same challenges present for vapor recovery compression. The primary technical objectives of the HCG development project were:

- Compress saturated hydrocarbon gas in the presence of liquids
- Eliminate the need for inlet liquids separation
- Eliminate the need for scheduled maintenance

The result is a hydraulically actuated, low speed, long stroke reciprocating compressor with advanced instrumentation and proprietary control logic capable of reliable operation across an ambient temperature range of -40°F to 110°F.

Figure 9 shows the operational schematic of the HCG compressor with key components identified. The description of operation is as follows:

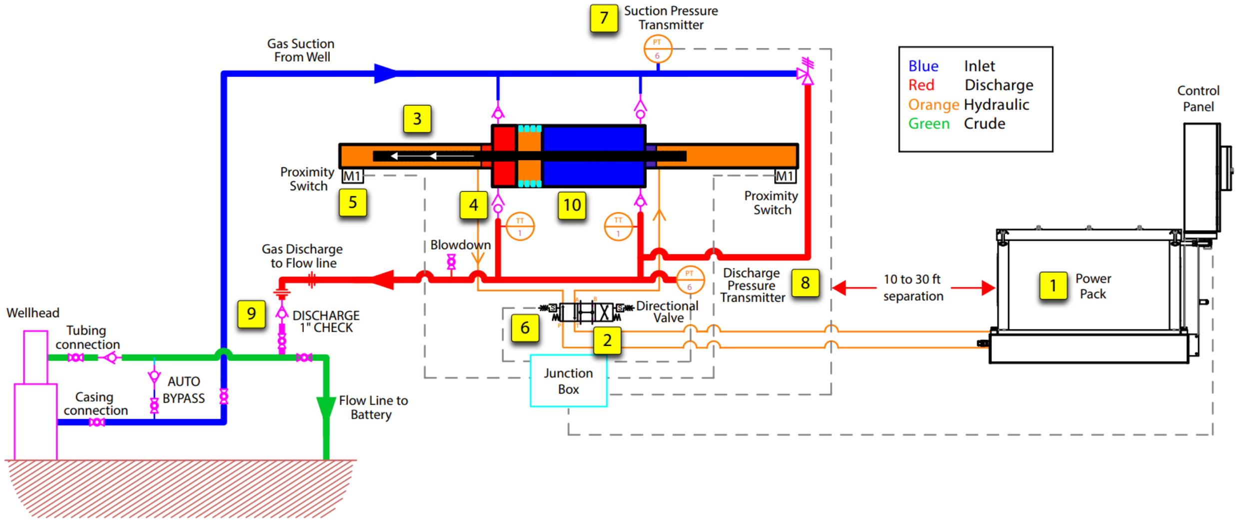

Figure 9 Operational schematic of HCG Compressor

1. The power pack provides hydraulic power for the compressor. The control panel governs the operation of the compressor using proprietary code.
2. The hydraulic fluid supply and return lines pass through a directional valve that directs the flow of power fluid to either side of the compression cylinder. In Figure 9, fluid is supplied to the right side of the cylinder and returned from the left side.
3. As the piston is driven through its stroke by the hydraulic ram, gas enters the compression cylinder through the suction check valve (blue).
4. At the same time, gas is compressed on the opposite side of the compression cylinder (red), exiting through the discharge check valve which opens when flowline pressure is reached during the compression cycle.
5. A position sensor registers the end of stroke and sends a signal to the control panel PLC.
6. The control panel PLC sends a signal to the directional valve to reverse the flow of hydraulic fluid to the cylinder. The piston reverses direction and the second half of a single compression cycle begins.
7. Suction pressure is continuously relayed to the control panel PLC by the suction pressure transmitter.
8. Discharge pressure is continuously relayed to the control panel by the discharge pressure transmitter. The control panel PLC logic ensures that maximum pressure differential for the cylinder is not exceeded. Three additional levels of redundancy exist to ensure maximum differential pressure is not exceeded; hydraulic system relief valve, pressure safety valve and electric motor overload.
9. The compressed gas passes through a check valve into the production flowline. A plunger or ball check valve is recommended over a flapper check valve due to higher cyclical reliability.

10. All liquids, including slugs of liquid that occupy the entire cylinder volume, are easily processed through the HCG compressor because of the following characteristics:
    - Long stroke and slow cycle rate
    - Large check valve port openings
    - Gravity assist from horizontal layout and orientation of suction and discharge ports.
    - Proprietary PLC control code

The HCG compressor is capable of 100% speed turndown without the use of a variable frequency drive or recycle loop. This is accomplished by the PLC, which automatically adjusts the end of stroke delay as well as pauses the cycling of the directional valve so that the hydraulic fluid circulates without actuating the hydraulic rams. Because the hydraulic power pack is in standby mode while the compressor is not engaged, lag time for the compressor to restart compression from a pause is measured in milliseconds.

The HCG compressor self-regulates for capacity control, meaning that the suction pressure rises and falls according to the flowrate of gas at the compressor intake. There are no minimum backpressure valves that other types of compressors may require. The self-regulating feature of the HCG means that the compressor must be sized for maximum expected flowrate for vapor recovery applications.

Advantages of the HCG Compressor in Vapor Recovery Applications

The typical challenges of vapor recovery can be summarized as follows:

- Very low suction pressures (<1 psig)
- Saturated hydrocarbon gas with liquids present
- Outlet cooling to keep operating temperatures within operating limits of traditional reciprocating and rotary compressors

Swept volume, or displacement, is an important characteristic of compressors at low suction pressures. High speed compressors, such as a rotary screw that can operate reliably at speeds in excess of 6,000 rpm, have a high swept volume relative to its physical size. The HCG Compressor is a low speed machine, therefore, swept volume is influenced to a higher degree by cylinder diameter and stroke length.

The low speed of the HCG Compressor is an advantage for handling liquids in the gas stream. The high relative density of liquids compared to gas results in a higher pressure drop across the inlet and discharge check valves. A high speed reciprocating compressor cannot adjust its speed quickly enough to compensate for the large increase in pressure across the valves due to its high inertial mass. Catastrophic damage to the valves and other compressor components is often the end result. Rotary compressors that ingest liquids experience challenges with oil contamination and flooding.

The HCG Compressor is able to self-adjust its operation so that liquids entering the compressor are processed without causing any damage to the valves or other components. Inlet liquids separation equipment is not necessary for the HCG to operate reliably.

Reciprocating and rotary compressors require outlet heat exchangers in order to keep operating temperatures within design limits. Recycle circuits that allow these compressors to achieve 100% turndown make the use of outlet coolers mandatory. Outlet and interstage coolers are especially important for multi-stage compression with reciprocating compressors.

The HCG Compressor does not normally require the use of an outlet cooler because much of the heat of compression is absorbed by the liquids present in the gas stream. Additionally, the HCG Compressor has a large surface area and therefore has a large convective and radiant heat loss relative to its internal heat generation. Outlet temperatures rarely exceed 160°F, even when compressing dry gas. The HCG Compressor has an operating temperature limit of 400°F with standard materials and 450°F with upgraded materials, making it suitable for application in thermal recovery operations.

If necessary, a simple outlet cooler can be placed after the compressor discharge so that gas temperatures do not exceed design limits for piping systems downstream of the compressor, such as for Polyethylene pipe.

HCG Vapor Recovery Suction Pressure Control

Vapor recovery often requires that suction pressure be maintained within a tight tolerance within the range of 6±2 in H_2O (0.22±0.07 psig). This is to prevent activating pressure relief sytems which protect against damage to atmospheric tanks due to overpressure or underpressure.

The HCG Compressor for vapor recovery uses a high resolution suction pressure transmitter of an appropriate pressure range that is installed at the compressor or remotely at the inlet to the piping system close to the tank.

Figure 10 shows a test that was performed on a standard HCG15 compressor to analyze the level of control that is achievable at very low suction pressures. The low pressure setpoint was set to 5 in H_2O and the high pressure setpoint was set at 6 in H_2O. At a flowrate of 2.3 MSCFD, the compressor engaged for approximately 1.8 seconds for each 14 seconds of pause, or an 11% duty cycle. The suction pressure varied between 4.35 to 6.15 in H_2O, demonstrating a high degree of inlet pressure control. If necessary, the threshold between the low and high suction pressure setpoints can be set closer together.

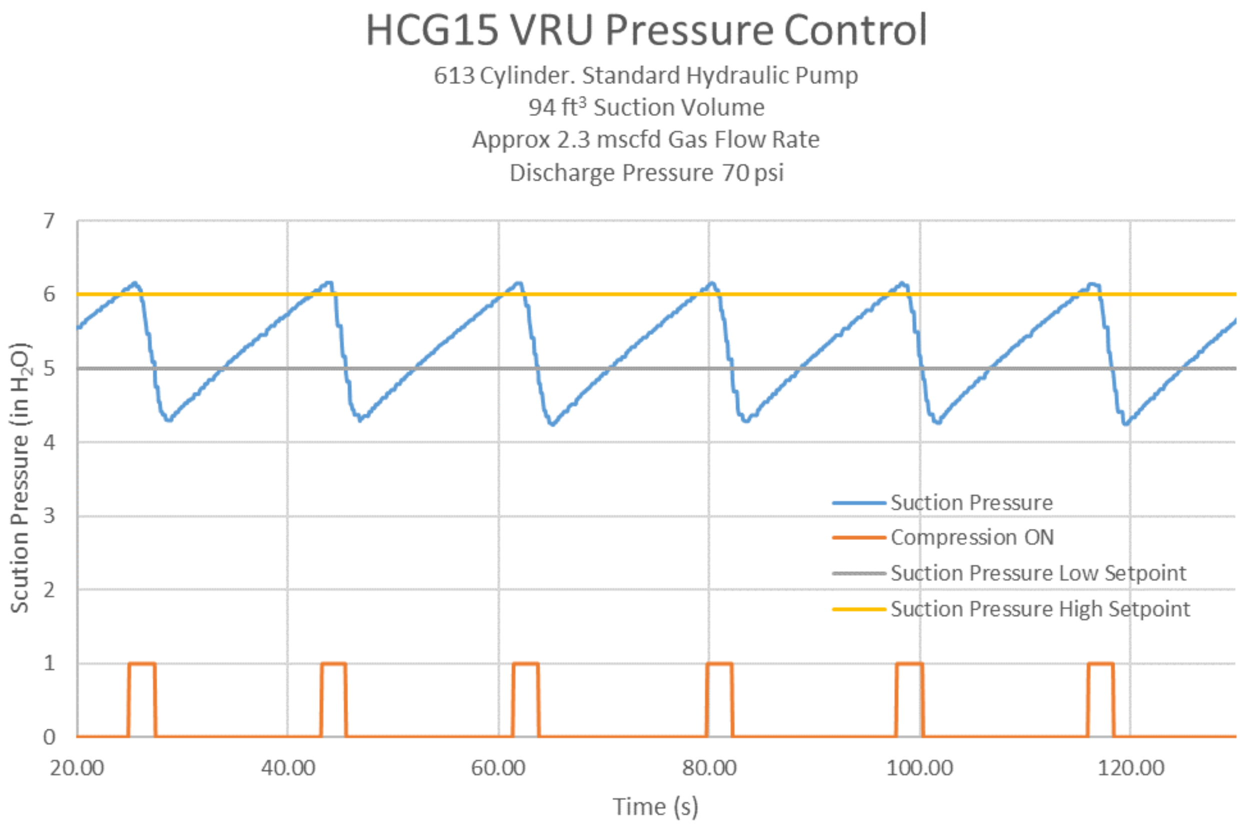

Figure 10 HCG15 Pressure Control Test

The variation in suction pressure is proportional to the ratio of the swept volume of the HCG Compressor and the volume of the tank and piping system feeding the compressor suction. In most vapor recovery applications, this ratio is extremely small, therefore finer control than shown in Figure 10 is possible.

HCG Compressor Capacity for Vapor Recovery

From the test in Figure 10, at 100% duty cycle the HCG15 compressor capacity is approximately 21 MSCFD at 70 psi discharge pressure. The compression ratio in this example is 5.74, however, the compressor is capable of compression ratios exceeding 15. Capacity can be further increased by using a higher displacement hydraulic pump in the power pack, but limits the possible compression ratio to about 10.

The next higher capacity HCG compressor is the HCG50 model with a cylinder diameter of 10 inches as opposed to 6 inches for the HCG15. Depending on the hydraulic pump displacement used in the powerpack, capacity up to 65 MSCFD can be attained. Using the versatility of multiple available options for motor, pump, cylinder and rod sizing as well as multi-stage HCG VRU configurations, Compact Compression is able to meet a wide range of capacity and discharge pressure requirements in vapor recovery applications.

Taking advantage of the low horsepower power requirements for most vapor recovery applications, Compact Compression has developed a tandem cylinder compressor run from a single power pack – the HVR50. The HVR50 has more than double the swept volume of the HCG50, making it suitable for vapor recovery applications up to 140 MSCFD at 6 in H_2O suction pressure. Figure 11 is a representative layout of the HVR50, shown without the enclosure around the electric motor and hydraulics for clarity.

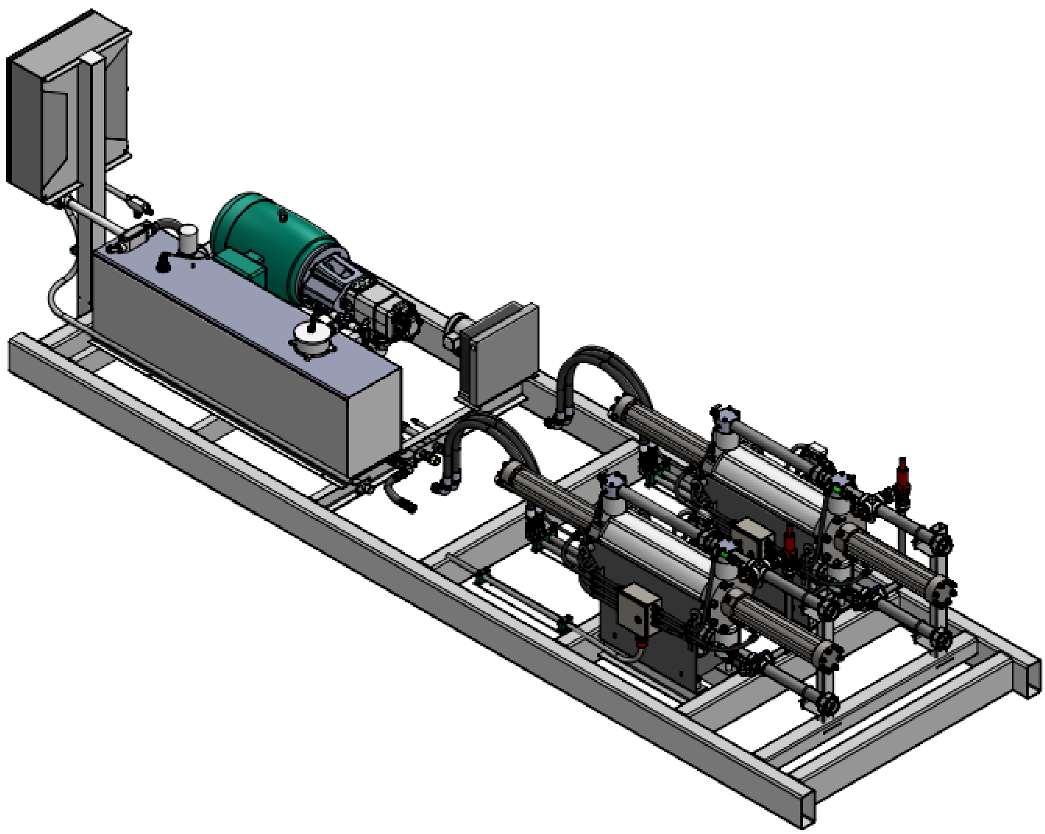

Figure 11 HVR50 layout without weatherproof enclosure for hydraulics

Standard Design and On-Demand Servicing Lowers Cost of Ownership

All HCG compressors are of standard design with a few configuration options. Reciprocating and rotary compressors are typically put together by any number of compressor packagers, and have a high degree of variability between them, even though the base compression element may be the same. Often, each vapor recovery compressor ends up being a EPCM-managed, custom-engineered product. Having a standard solution available for vapor recovery reduces the capital cost and engineering overhead cost for end users.

Over 1,000 HCG compressors are installed in Canada, the USA, and internationally. Compact Compression maintains an inventory of components and field service staff to maintain the entire fleet of HCGs in top condition. CCI's purchasing power of these components keeps the per unit cost down and ensures they are readily available.

The HCG compressor was developed with eliminating the need for scheduled service in mind. By outfitting the compressor with a number of sensors to monitor operating condition, the proprietary PLC code relays the operating status to field technicians vis satellite or cellular communication. This way, field technicians can respond to and correct abnormal operating conditions before progressing to a shutdown or failure state. Figure 12 shows the 30-day average uptime for 232 compressors with a single operator extending across an area approximately 20 miles by 100 miles. All of these compressors are serviced by a single field technician.

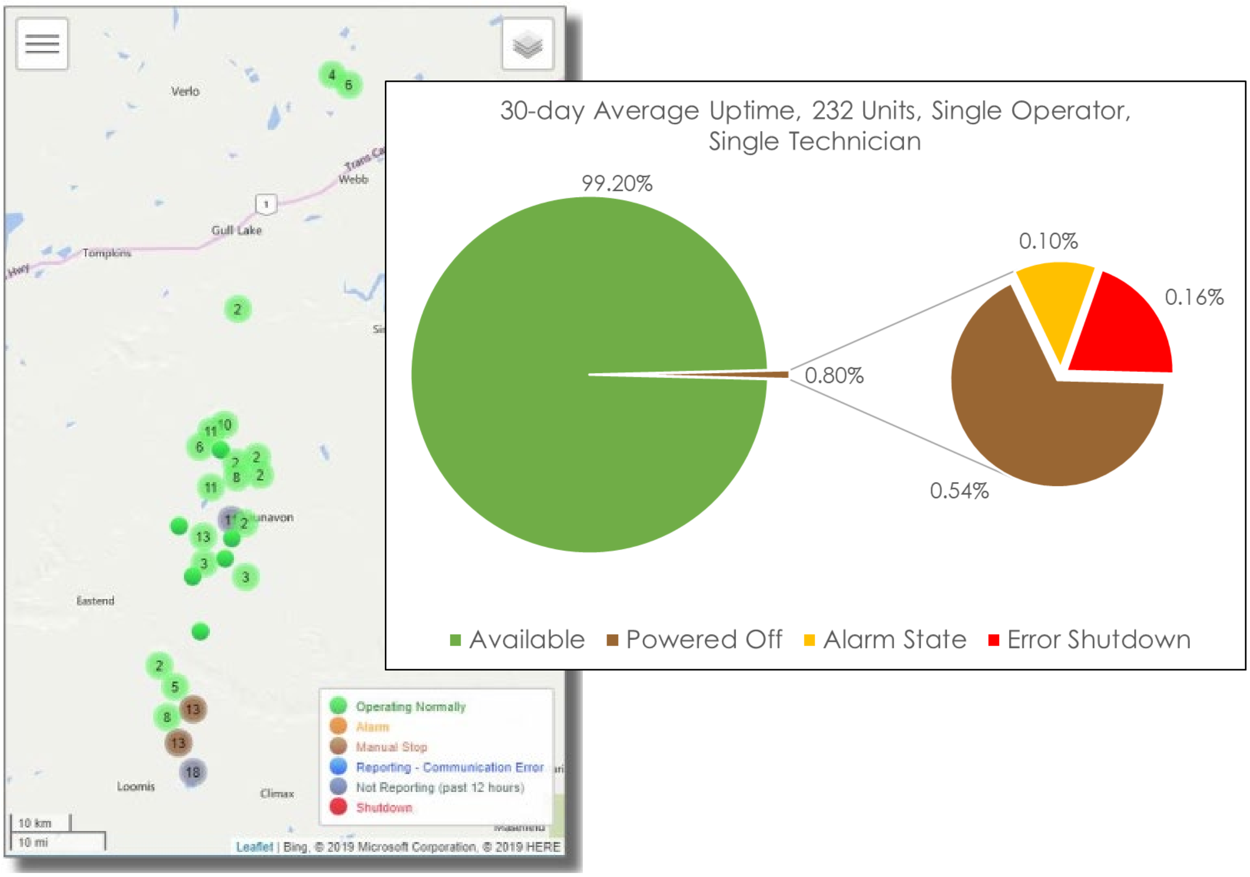

Figure 12 HCG uptime for 232 units for a single customer, serviced by a single field technician

Central to on-demand servicing of HCG Compressors is SkyView, a visual management tool developed by Compact Compression to provide technicians and end users an at-a-glance view of compressor status and performance. Concise reports can be generated from the SkyView platform to aid technicians with self-dispatching, measure operational uptime and assist production engineers with identifying additional optimization opportunities.

Conclusion

Vapor recovery is a familiar process in the oil and gas sector to capture methane, longer chain hydrocarbons, carbon dioxide, VOCs and HAPs. Regulators have implemented increasingly stringent emissions limits. Many oil and gas companies have implemented their own Net-Zero emimssions targets. This has resulted in a renewed focus on vapor recovery efforts and technologies.

Reciprocating and rotary compressor technology has existed for many decades and can be well suited for certain vapour recovery applications. When it comes to vapor recovery of liquids rich gas streams, these traditional technologies have inherent limitations and challenges. They require robust liquids separation systems ahead of the compressor inlet and heat exchangers at the compressor discharge to maintain the operating temperature below operating limits.

The HCG Compressor was developed with the following objectives:

- Compress saturated hydrocarbon gas in the presence of liquids
- Eliminate the need for inlet liquids separation
- Eliminate the need for scheduled maintenance

The result is a hydraulically actuated, low speed, long stroke reciprocating compressor with advanced instrumentation and proprietary control logic capable of class-leading reliability across an ambient temperature range of -40°F to 110°F. Over 1,000 HCG Compressors have been put into operation since the first was installed in 2015.

Because the HCG Compressor can process all liquids directly through the compression element, no inlet separation system is required. Due to the large surface area of the HCG compression element relative to its heat generation, outlet gas coolers are not usually required.

HCG Compressors are suitable for low pressure vapor recovery applications up to 140 MSCFD with 6 in H_2O suction pressure. HCG Compressors are capable of 100% turndown by PLC control and can maintain precise inlet pressure control at low suction pressure. Higher capacities are possible with higher suction pressures, such as for compressing gas from a treater vessel.

Cost of ownership of HCG Compressors is lower than other types of compressors because they are manufactured as a standard product, are backed by OEM purchasing power for components, and supported by well-trained, highly experienced field technicians. On-demand servicing, supported by Compact Compression's proprietary SkyView platform, further lowers cost of ownership compared to the scheduled maintenance intervals required by the traditional compression technologies. Best-in-class uptimes of >99% have been achieved across a large population of units, reducing the number of technicians required for service.

When considering a vapor recovery compressor for your company's emissions reduction efforts, the HCG Compressor from Compact Compression should be at the top of your list.