Applications

Air Service

Air service can include applications for underbalanced drilling, air feed for air separation, and seismic applications. Many air services have high discharge pressures. Air compression has a few technical details for consideration when sizing an air application.

The k-value for air is relatively high, resulting in gas discharge temperatures being higher at lower compression ratios. The higher k-value will also result in faster discharge temperature rises with changes in pressures. Off conditions need to be reviewed to confirm maximum operational temperatures are within the Ariel discharge temperature limits. Refer to the Packager Standards for information on Instrumentation.

Mineral oil auto ignition temperatures in Air service are relatively low at higher pressures and drop significantly as pressures and temperatures increase. An ester based lubricant must be used in air service. The lube oil auto ignition temperature must exceed the compressor discharge temperatures at discharge pressure. The user must confirm the lube oil auto ignition temperature is well above potential discharge temperatures. Ariel limits air applications to no more than 5000 psi. Above this pressure, nitrogen can be applied, with no more than 5% oxygen content.

Refer to the Packager Standards for information on Cylinder and Packing Lubrication.

Due to the potential for auto ignition of the lube oil in air service crank case relief doors are mandatory on JGJ frames with cylinder working pressures greater than 1500 and short coupled distance pieces are provided. Crank case relief doors are highly recommended on all other short coupled guide arrangements, such as on JGM:N:P:Q:I, JG:A and JGR:J:W frames.

When selecting a compressor for air service, lower piston speeds may be necessary in order to allow the heavier gas to flow through the valves with proper valve dynamics. The lower piston speeds will lower the pseudo-q values as well as improve the efficiency of the unit (lowering the power per unit flow value).

Package and Operational Recommendations:

1. Ariel recommends discharge valve temperature sensors to detect higher temperatures due to leaking or failed valves.
2. Deactivation of cylinder ends is discouraged due to the potential for higher heat build up. Discharge temperature devices will not measure internal heat build-up due to end deactivation.
3. Where available, provide water cooling to packing cases to reduce packing heat.
4. Gas piping systems must be designed to eliminate low points where lube oil can accumulate. Any low point must be set up for continuous draining, including (but not limited to) low points at each elbow-up and gas cooler sections.
5. Separators are to be configured for continuous draining.

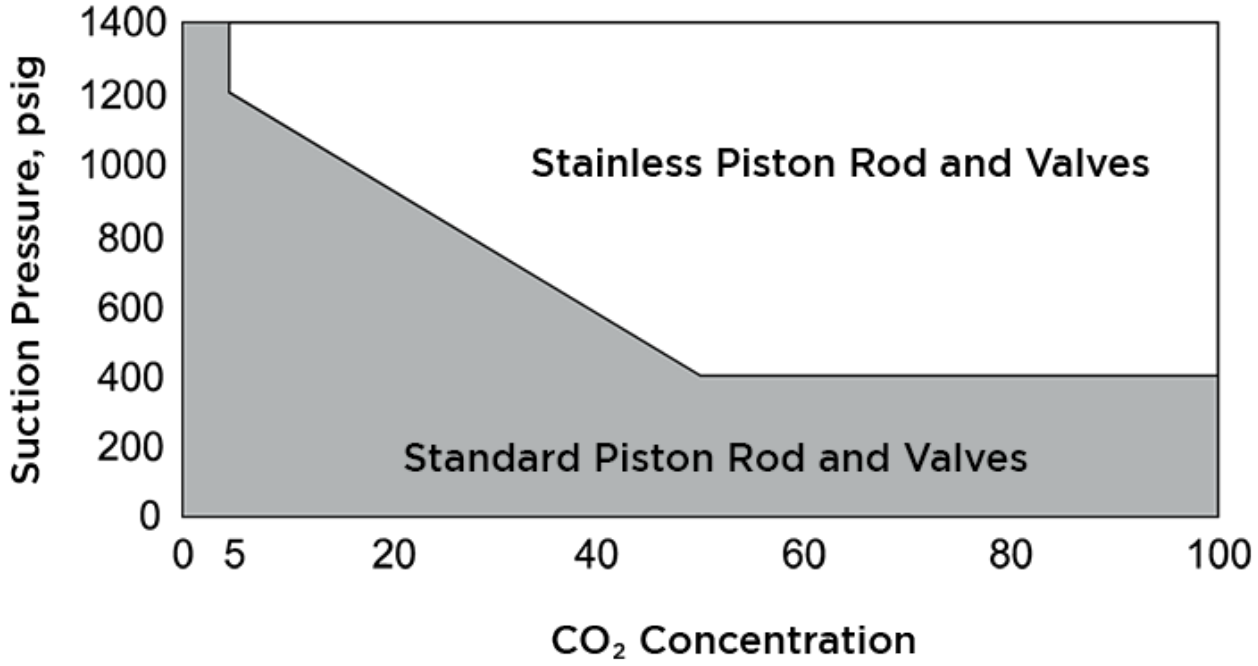
Carbon Dioxide

Carbon Dioxide (CO_2) may combine with water to form carbonic acid. Carbonic acid is mildly corrosive and at higher pressures can condense into a liquid which will act as a solvent and dilute the cylinder lubrication. The gas properties of the CO_2 mixture should be reviewed at the required operating conditions. Gas properties of CO_2 can be found under the Gas Properties topic.

See the chart below for recommended materials of construction for piston rods and valves based on suction pressure and CO_2 concentration.

Figure: Suction Pressure vs. CO_2 Concentration

Standard or Stainless Piston Rod and Valves Chart



When the standard valve body materials are 416 stainless steel, these are suitable and meet the recommendations of the above chart for CO_2 service. Some valves have carbon steel body material, and would not meet the recommendations for the above chart. The valve material can be found on the cylinder data sheets.

The recommendations for compressor piston rod and valve materials are:

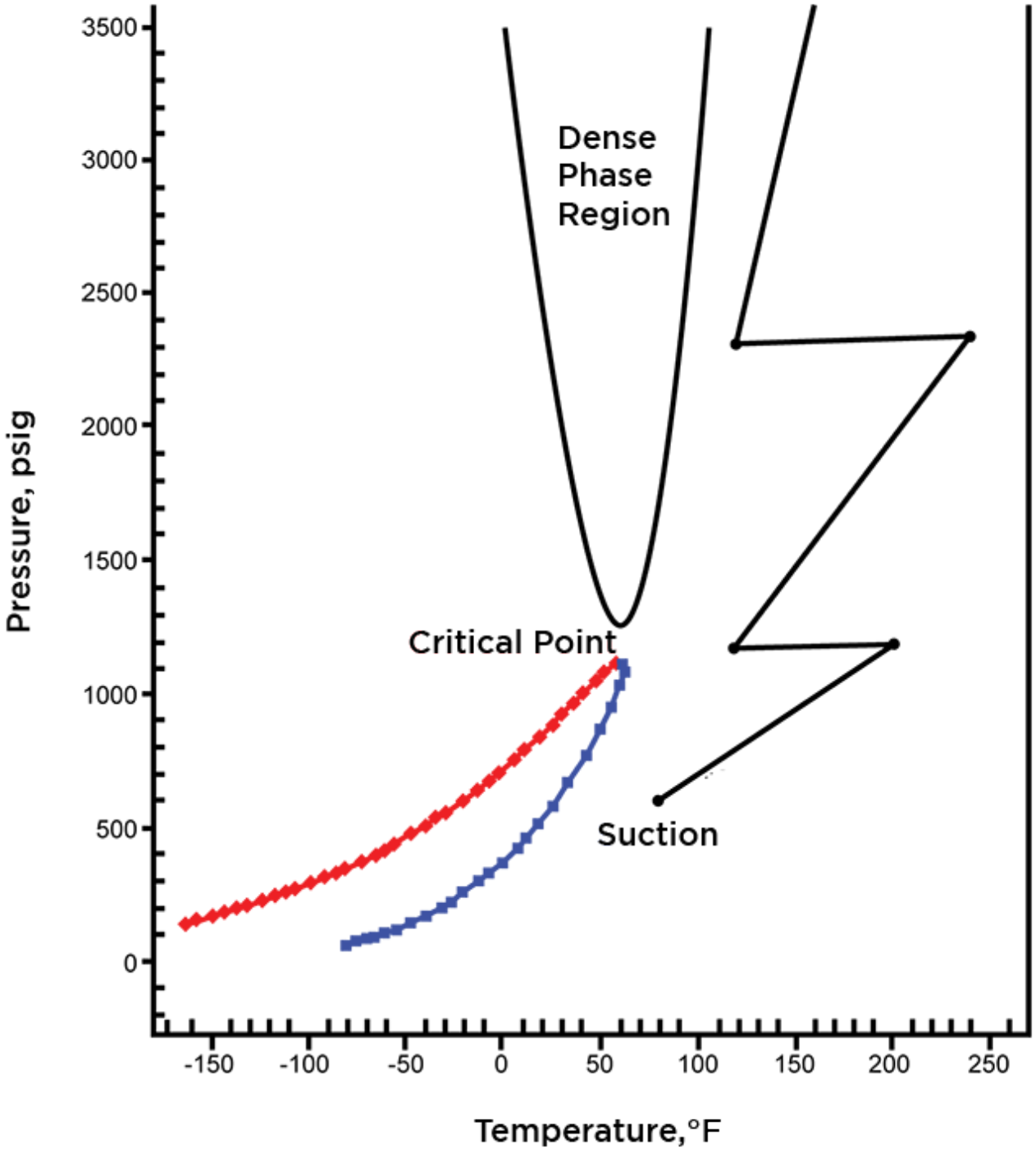
For sweet natural gas with a carbon dioxide concentration less than 5%, or at 5% with a suction pressure less than 1200 psig, or with a carbon dioxide concentration up to 50% with a suction pressure less than 400 psig, or with any suction pressure lower than 400 psig, use standard piston rod and valve materials.

For sweet natural gas with a carbon dioxide concentration outside the above limits, use 17-4PH stainless steel piston rods and stainless steel compressor valves. Most valve bodies are 416 stainless steel material and will meet the recommendations for stainless steel in CO_2 service. When the standard valve body material is carbon steel, the 17-4PH stainless steel valve option should be chosen. (When changing to the 17-4PH valve material option, it is recommended that standard valves be used for unit start-up. Once the system is confirmed clean, the stainless steel valves should be installed).

CO_2 is soluble in mineral oils, thereby reducing the oil / gas mixture viscosity. Mineral oils are completely miscible into CO_2, which reduces the effectiveness of the oil. Compounding mineral oils or PAG (poly-alkaline-glycol) synthetic lubricants are commonly used. See Cylinder and Packing Lubrication Requirements in the Ariel Packager Standards and contact Ariel in Mount Vernon for a recommendation.

Compression of carbon dioxide often involves operating conditions that are near or above the critical point of the gas. The gas properties will be very sensitive to small changes in pressures and temperatures when near and above the critical point. When a stage suction pressure is near the critical pressure, allow a greater margin from the critical temperature for more stable gas properties. This may mean operating at a suction temperature of 40 to 50 F (20 to 30 C) above the critical temperature. When a stage suction pressure is above the critical pressure, allow enough suction temperature to maintain proper gas properties. Proper gas properties means maintaining a suction compressibility (Z) value above 0.4, and preferably above 0.5. In this "dense phase" region above the

critical pressure the gas can have properties of either a gas or a liquid and the density of the gas will fluctuate greatly with small changes in pressure or temperature.



Due to the sensitivity of the gas properties to small changes in pressure and temperature in this "dense phase" region, near and above the critical point, the interstage temperature may need to be controlled. If the gas suction temperature is allowed to vary, the gas density will fluctuate widely and can cause large changes in the acoustical response of the gas piping system. This can lead to acoustic force driven shaking of the equipment.

Critical pressure and temperature are provided on the phase envelope within the Ariel Performance Program.

A controlled temperature system can be accommodated during higher ambient temperature swings through gas cooler louvers and fan control. If this is not enough to control the gas temperature out of the cooler, hot air recirculation or heaters may need to be provided in the cooler design. Controlling with a bypass around the gas cooler with a temperature control valve allowing mixing of hot and cold gas may not be suitable, if the cooled gas condenses in the cooler.

When selecting a compressor for carbon dioxide service, lower piston speeds may be necessary in order to allow the heavier gas to flow through the valves with proper valve dynamics. The lower piston speeds will lower the pseudo-q values as well as improve the efficiency of the unit (lowering the power per unit flow value).

Carbon Monoxide

Gas properties of CO can be found under the Gas Properties topic.

Carbon Monoxide presence in the gas stream will require a lubricated cylinder construction. Non-lubricated applications should be avoided. This is due to the increased risk of Carbon Dissociation. Carbon Dissociation may cause the formation of hard carbon deposits and CO_2. This process can also result in carbon dust accumulating in the piping. This dust may be pyrophoric, combusting when coming in contact with air.

Discharge temperatures should be limited to 255° F (124° C).

When the combined content of carbon monoxide and hydrogen approaches 50%, PRC guidelines will govern the selection of equipment.

Ariel does not provide non-lubricated cylinder construction for carbon monoxide applications.

Gas Storage Service

Gas Storage service includes applications where gas is injected at relatively high pressures into formations, wells, caverns for future use or sale. Gas storage applications may also include the compression for withdrawal from these storage sites during periods of demand for the gas. Discharge gas pressures will swing widely during the injection process, while suction pressure will remain relatively stable. Suction gas pressures will swing widely during the withdrawal process, while the discharge pressure will remain relatively stable.

Due to the wide range of pressures, compressor valves are often required to be low lift for proper dynamics.

The elevated storage pressures often require two stages of compression as the storage sites fill. However, much of the injection process and most of the withdrawal process can be done with a single stage of compression. Many gas storage applications are designed to operate all cylinders in parallel for a single stage of compression during the early phase of injection and during withdrawal. The gas piping is then reconfigured through valving to operate with two stages of compression at the final phase of injection. This one stage / two stage operation allows for much greater use of the installed power and much more flow during the lower ratio phase of the processes.

Gas storage compressors are often installed in highly automated systems. Capacity control devices are often pneumatically operated rather than manually operated. This would include pneumatic actuated fixed volume clearance pockets and suction valve unloaders.

High Gas Molecular Weight

It is always recommended to use a gas analysis for the highest accuracy for predicted performance. For the normal natural gas mixtures with .56 to .80 specific gravity a specific gravity entered for performance predictions is acceptable. If the gas contains gas constituents outside the normal pipeline gas mixtures (ie., carbon dioxide, nitrogen, hydrogen sulfide, hydrogen...) a gas analysis will provide more accurate performance results.

When gas mixtures are lighter than .35 specific gravity (10 mole weight) or heavier than 1.35 specific gravity (39 mole weight) it is recommended to contact Ariel Applications Engineering. The VMG gas method should be used for gasses outside the use of natural gas.

When only a specific gravity is specified, the gas properties (K value and compressibility) are based upon a generalized hydrocarbon mixture. This could lead to inaccurate compressor performance predictions when other gas constituents are present outside the normal natural gas mixture. Air should never be entered by a specific gravity.

Heavier gasses will create higher pressure losses through the valves. This pressure loss is calculated through the pseudo-Q values. When the pseudo-Q values are high, reaching or exceeding 15, a slower piston speed will be necessary.

Often times heavy gas applications are also wet gas or low suction pressure applications.

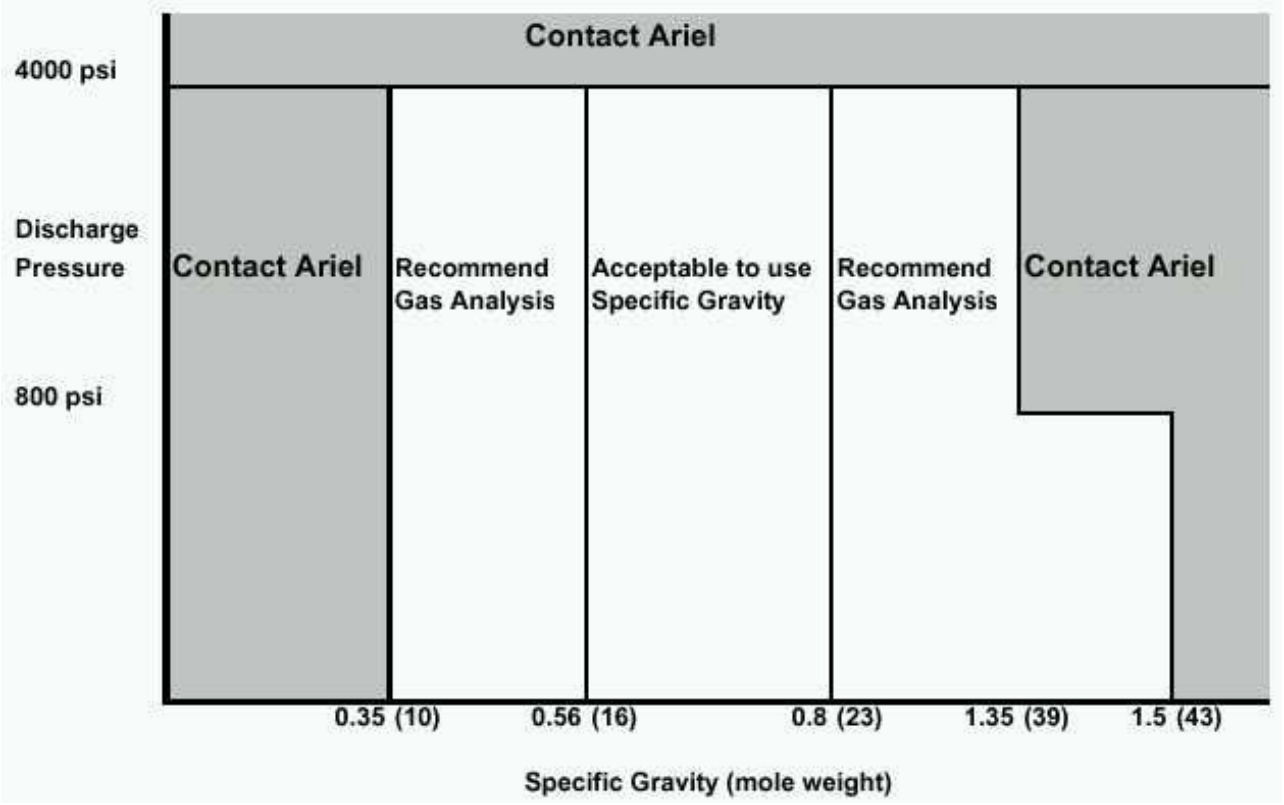
See the Packager Standards Section 6: Lubrication for information on applying the appropriate cylinder lubricant and rates for high gas molecular weight applications.

Heavier gasses may approach the dew point at the higher pressure interstages. If so, temperature controls for the interstage may be necessary to avoid gas product condensates.

Light gasses, molecular weight less than 12 (specific gravity less than 0.4), are considered low molecular weight applications and must be reviewed by Ariel Application Engineering. A valid gas analysis must be provided for these applications. The VMG gas method should be used for light molecular weight gasses.

Special attention will be paid to the selection of compressor valves for low molecular weight applications. The pseudo-Q-value must exceed 1.0 for all operating conditions. The application will be reviewed with the valve supplier to select the proper compressor valve. Ariel will also adjust the expected compressor capacity to account for higher piston ring blow by. It must be noted that any changes to the compressor valves that may be required to increase the pseudo-Q-value and any capacity adjustments may result in an increased HP (kW) requirement.

Applications that involve higher than 50% by volume of hydrogen shall be sized to limit the internal discharge temperature to 275 °F. Cylinders in these applications must have a helium leak test and packing cases with lapped cups.



Hydrogen Service

Hydrogen is a diatomic gas used in a number of refining and petrochemical processes.

Hydrogen has a high ratio of specific heats, therefore will increase in discharge temperature with smaller increases in compression ratio. Temperature limitations are 250 F (121 C) for selection purposes and no greater than 275 F (135 C) in operation. Shutdown setting should be no greater than 300 F (149 C). Additional stages of compression may be necessary to maintain these lower discharge temperatures.

PRC cylinders and application guidelines are necessary for hydrogen applications. The application guidelines include lower discharge temperatures and lower piston speeds. Helium leak testing is required for cylinders used in Hydrogen service.

Non Lube Compressor Cylinders

Please refer all non-lube applications to the Ariel Application Engineering Department.

Non lube applications will be limited to the following compressor frame and cylinder classes:

- Frames – JGA, JGJ, JGK, JGT, KBK, KBT, JGD, JGF, KBU and KBB
- Cylinders - JG, RJ, JGK, JGT, KBK, KBT, JGD, JGF, KBU and KBB

Non-lube applications will require that the following application guidelines be strictly adhered to:

- Use a long two compartment distance piece (API – 618 Fourth edition Type C) with oil slingers in both compartments;
- Piston rod materials for non lube service will be as follows:
  - For non-corrosive applications – ETD 150 with a Tungsten Carbide coating.

  - For corrosive applications – 17-4 PH Stainless Steel with a Tungsten Carbide coating.
- Limit cylinder internal discharge temperature to 275°F (135°C) for selection, 325°F (163°C) for maximum shutdown limit
- Limit cylinder discharge pressure to 1500 psig (103 barG)
- All non lube cylinders are provided with water cooled packing and must be connected to a packing cooling system.
- Compressor valves, pistons (and piston trim) are specifically designed for non-lube service.

Non lubricated cylinder construction can be applied for sour gas services, but is limited to sour level 1, less than 2% H2S content by volume. NACE Stainless Steel Valves are required along with the Sour Level 1 trim (stainless steel piston rods, purged packing, proper purge / vent system, long two compartment distance piece).

Internal piston ring blow-by is accounted for in the Ariel performance program as a relation to the gas mole weight.

Rubbing speed is a factor that must be considered for all Non-Lube applications. The piston speed limit for Non-Lube applications is 750 feet per minute (3.81 meters per second). Refer to Process Rotative Speeds for maximum allowable rotative speeds for each frame model.

Offshore Applications

Offshore production applications carry additional considerations for compressor selection, packaging and analytical studies. A conservative approach to the selection will offer the benefit of longer time between maintenance, for less maintenance work and replacement parts in this remote environment. This would include reduced speeds, lower discharge temperatures and conservative rod load usage.

Offshore structures do not carry the immense mass of earth and concrete to absorb the many forces and couples associated with reciprocating compressors. Therefore, selecting a compressor for offshore installation must keep this in mind. When possible, a four throw compressor will carry lower forces and couples than a two throw compressor. A six throw compressor will carry even lower forces and couples.

The forces and couples associated with reciprocating compressors can come from a number of sources. The offset distance along the crank centerline between opposing throws creates a couple. Different reciprocating weights on opposing throws, or between pairs of opposing throws creates forces and couples. Ariel balances the reciprocating weight on opposing throws to a very tight margin to limit the unbalance forces. The reaction to the conversion from rotating to reciprocating motion at the crosshead guide creates vertical forces at the crosshead guides. Torsional vibration forces can resolve into lateral vibration forces on some configurations.

A heavier skid structure will be necessary for greater rigidity with offshore packages. This includes a "full pedestal width" construction, tying the structure under the crosshead guide support to the frame supporting structure.

Along with the torsional and acoustical analyses, a full mechanical analysis of the skid and surrounding supporting structure is necessary.

Gathering, vapor recovery, gas lift, gas re-injection and fuel gas booster for gas turbine generator are most common FPSO applications.

Dry sump is recommended for vessel pitch, roll and yaw. Most often, 316SST tubing and fittings as well as duplex oil filter are specified by end user customers for offshore environments.

Third party certification is often required for FPSO, or offshore applications. These would include:

- FPSO - Floating, Production, Storage, Offloading Vessels
- FSO - Floating, Storage, Offloading vessels, without the processing facilities
- FSRU – Floating, Storage, re-gasification and offloading vessels
- FLNG – Floating Liquid Natural Gas Production vessels

- FDPSO – Floating, Drilling, Production, Storage and Offloading vessels

The third party certification requirements for FPSO applications are specified by FPSO Classification Organizations as listed here.

- ABS (American Bureau of Shipping) in USA
- DNV (Det Norsk Veritas) in Norway
- Lloyd's Register of Shipping in United Kingdom
- Bureau Veritas in France

FPSO documentation as required by all the third party certification is termed Design Review by the classification organization.

1. For each compressor, an affidavit is required from the manufacturer stating that design and fabrication have fully complied with an applicable API standard, except as noted. All exceptions shall be listed and if no exceptions are taken to the specifications, then the affidavit should indicate as such.
2. Compressor performance runs information shall be provided indicating maximum allowable suction and discharge pressures and corresponding temperatures (both maximum and minimum), as well as maximum rated discharge pressure.
3. For compressors handling hydrocarbons, casing (cylinder) drawings and casing (cylinder) strength calculations may be required. The casing strength calculation shall include cylinder thickness calculation and inlet/outlet nozzle reinforcement calculation. If casing drawings cannot be submitted due to confidentiality, a sketch of casing drawing including diameter and thickness and inlet/outlet diameter and thickness information is acceptable.

- Ariel requirements to FPSO documentation are compilation and documentation of
- Compressor configuration with serial numbers and general model ratings
- Compressor frame and cylinders outline drawings
- Compressor frame and cylinders data sheets
- Cylinder casing design data
- Compressor performance data sheets
- Comments and exceptions to API-618 and 11-P Specifications
- ASME Code Calculations for Special Flanges

Offshore environments can be corrosive due to salt water spray. Cylinder and valve cap bolts can be provided in 17-4PH stainless steel if salt water corrosion is a concern. The NACE Cylinder Bolting option will apply 17-4PH bolting and studs for the cylinder heads and valve caps.

Oxygen

Oxygen service requires special cleaning processes during manufacturing of the compression equipment. Ariel does not provide compression for oxygen service.

Oxygen in a hydrocarbon based gas stream can be a concern for combustion. Ariel limits the oxygen content in a hydrocarbon service to 5% to ensure the lower explosion limit is not reached.

Oxygen can be introduced into the gas stream when suction pressures are near or below atmospheric pressure. When considering suction pressures near atmospheric pressure, an oxygen sensor downstream of the first stage of compression is recommended. Oxygen content will be limited by either the 5% listed above, or the limits by the gas composition requirements by the client, whichever is lower.

In inert gas based compositions, such as nitrogen, oxygen content will impact the auto ignition temperature and pressure for the lubricating oil. Any composition of inert gas and oxygen above the oxygen content of air (21% oxygen) should be reviewed for auto ignition temperature and pressure, and lubricating oil selection.

Propane

Propane (C_3H_8) applications will typically be classified under the application guidelines for High gas molecular weight, low suction temperature applications or low gas suction pressure (The most stringent of these criteria shall apply).

There are several special application considerations for propane service. The minimum suction temperature for gray and ductile iron is -40°F (-40°C). Ariel Application Engineering should review all applications with suction temperatures below 0 degrees F (-18 degrees C).

Some applications utilize propane in a closed loop refrigeration service. These applications must be reviewed to insure that the settle out pressure of the system is less than the MAWP of the system or that adequate controls and protection are provided to protect the compressor cylinders. In closed loop refrigeration service, cylinder lube rates should be monitored and may require adjustment.

High Pseudo-q values are common in Propane applications. Valve selection is critical in these applications, therefore a valid gas analysis is required.

Gases with high propane content tend to dilute standard compressor cylinder lube oils, thereby reducing the gas/oil mixture viscosity. Propane is oil soluble and tends to wash the lubrication film away.

Refer to the Propane Gas Properties for information on propane gas.

See Cylinder and Packing Lubrication Requirements--6 in the Ariel Packager Standards for guidelines regarding cylinder and packing lubrication for Propane service.

Sour Gas

Hydrogen sulfide is considered corrosive, toxic, and lethal. As such, Ariel has specific recommendations as to the materials and compressor configuration options when compressing gas that contains H_2S. Hydrogen Sulfide (H_2S) can embrittle high strength, high hardness carbon steels, and most martensitic stainless steels (for a full and specific list of material compatibility with H_2S refer to NACE MR-0175, ISO-15156).

Ariel's equipment configuration recommendations for sour gas service are based upon field experience and the NACE guidelines for the protection of the equipment.

It is the End Users responsibility to be aware of the level of H_2S present, and to take all necessary precautions for the protection of personnel from harmful leakages of gas to the atmosphere.

Selection Recommendations / Requirements for Sour Gas Service

Several considerations should be made when selecting compressors in sour gas service. As the gas is both corrosive and toxic, special safety requirements are necessary for the maintenance of the equipment. It may be suitable to provide a more conservative selection to lengthen the time between maintenance. This would include operating at slower piston speeds and allowing for lower discharge temperatures.

The toxic and lethal nature of the gas dictates the use of an appropriate purge and vent system to ensure the gas leakage at the packing case and distance pieces is not vented to the atmosphere. Please refer to the Packager Standards Section 8 Packing and Distance Piece Vent Systems for this topic..

With higher percentages of H_2S in the gas stream, a review of the phase envelope and dew point of the gas constituents (not including water vapor) is recommended. At higher levels of H_2S and higher pressures, the

interstage cooling can easily reach the dew point for the H_2S in the gas stream. Most often, condensation of the H_2S is to be avoided.

Sour Gas service, Level 1, can be applied with non-lubricated cylinder construction. NACE SS Valves will be required along with the requirements and recommendations of Sour Level 1 trim below.

Recommendations / Requirements for Sour Gas Service:

	100 ppm to 2% H_2S **Sour Level 1**	**> 2% H_2S** **Sour Level 2**
Distance Piece Arrangement (Requirement)	S2C / L2C / Single with purge wiper	L2C (Recommend)
Piston Rod Material (Requirement)	Stainless Steel	Stainless Steel
Purge Packing (Requirement)	Purged	Purged
Flushing Lube	N/A	Flushing Lube on Stage 1 (Recommend)
Stainless Steel Valves	Standard Valves	Stainless Steel
Forged Steel (-VS) Cylinders (Requirement)	Use lower strength 22Rc cylinder bodies, or stainless bodies even as low as 5-10 ppm of H_2S content	

Optional Equipment:

- Cylinder Bolting Material
- Cylinder Body Material
- Lubrication Tubing and Fitting Materials
- Separate Lube Supply

Distance Pieces Arrangement

A two compartment distance piece, or a long single distance piece with wiper seal purge are required for sour gas service. These configurations offer the ability to create a purge and vent system which segregates the crankcase and operator atmosphere from the packing leakage.

Long two compartment distance piece, "L2C", is recommended above 2% H_2S content as this provides better containment of the gas leakage. S2C distance piece and long single compartment distance piece with purged wiper seal can be used above 2% H_2S content, but do not offer the same level of protection and flexibility for the vent / purge system design.

Two compartment distance pieces are available for all units except for the JGM:N:P:Q and KBE frames.

The long single compartment distance piece with wiper purge is available on the KBE:K:T, KBU:Z and KBB:V frames.

Refer to Packager Standards Section 8 Packing and Distance Piece Vent Systems for notes on a purge system for sour gas.

Piston Rod Material

Ariel standard piston rod material is 4100 series carbon steel heat treated for strength. These are not suitable for sour gas service as defined by NACE MR-0175. For sour gas service with 100 ppm and greater H_2S content stainless steel piston rods are required. Ariel stainless steel piston rod material is 17-4PH in the double H1150 condition, UNS S17400, (per NACE MR-0175), Rc 33 maximum, chromium-nitrided in the packing travel area for a surface hardness of 2500 Vickers. The chromium nitride process has a length limitation due to manufacturing constraints. Longer stainless steel piston rods will be tungsten carbide coated.

Purge Packing

Ariel requires the use of "Purge packing" for sour gas services with 100 ppm and greater H_2S content. The purpose of purge gas is to block and contain hazardous, toxic, flammable or corrosive gases, and to prevent such from entering the compressor frame where damage to the running gear, or personnel safety hazards can occur. The purge gas must be sweet natural gas or an inert gas, such as nitrogen. Purge packing refers to a packing case modified to accept an external purge pressure 15 to 20 psi above the primary packing vent/drain pressure with no more than 5 psi external system back pressure. Refer to Ariel's recommendations in Packager Standards Section 8 Packing and Distance Piece Vent Systems for a purge system for sour gas. See also "Packing Leakage".

When the purged packing option is selected on a long two compartment distance piece, the intermediate and wiper seal sets will be configured for purge along with the pressure packing case. When the purge packing option is selected on a long single compartment for the KBE:K:T, KBU:Z or KBB:V frames, the wiper seal will be configured for purge along with the pressure packing case.

Flushing Lube

Ariel recommends the use of cylinder flushing lube for first stage cylinders for sour gas services with 2% and greater H_2S content. An atomizer for flushing lube injection can be constructed of tubing inserted into the gas stream at the suction pulsation cylinder nozzle with the end opened with a diagonal cut. The Packager would provide the lube lines from the end of the guide to the suction pulsation vessels cylinder nozzle. Flushing lube lines will be tubed to the end of the crosshead guide from the distribution block. Flushing oil is used to ensure corrosion protection for the suction valves, both the valve bodies and springs. Flushing oil is available as an option on all units. If the first stage flushing recommendation for Sour Level 2 is not taken, provisions for flushing on the pulsation vessel nozzle are recommended.

Some cylinders have two nozzles at the suction (dual nozzle and peanut flange). Flushing lube for these two nozzle cylinders is configured for one flushing lube point per cylinder. This is sufficient, considering the flushing lube connection is in the suction pulsation vessel nozzle. If a client wants to apply flushing to both pulsation vessel nozzles, the packager can install a pipe tee to split the single line provided.

Stainless Steel Valves

Ariel standard valve body material is 400 series stainless steel and 1040 carbon steel. These are not suitable for sour gas applications per NACE-MR0175. Ariel recommends the use of NACE compliant stainless steel valves for sour gas services with 2% and greater H_2S content.Stainless steel valves generally consist of:

- Seats and guards: 17-4PH - H1150
- Plates: Nylon, MT or PEEK. 17-7PH or 15-7PH if metallic plates
- Coil springs: Nimonic 90
- Spring plates: stainless steel (equivalent to 420)

It could be prudent to start up a unit with standard valves and replace those with the stainless steel valves after any start up problems have been solved and piping debris has passed through the unit.

NACE Stainless Steel valves are required for Sour Level 1 service in non-lubricated cylinder construction.

Optional Equipment for Sour Gas Service

Cylinder bolting

Standard cylinder bolting for sweet and sour gas services consists of Grade 8 valve cap, head end head, crank end head and packing case cap screws. Cylinder bolts are outside the gas containment and not considered "wetted".Ariel provides an option to replace these bolts with 17-4PH stainless steel bolts for the valve caps, head end head, crank end head and packing case bolting.The 17-4PH fasteners for the heads and packing case are bolts. The 17-4PH fasteners for the valve caps are studs.

Cylinder Body Materials

Standard cylinder body materials are:

- ASTM A278 Grade 40 gray iron
- ASTM A536 Ductile iron 80-55-06
- ASTM A395 Ductile iron 60-40-18
- AISI 4340 Forged steel
- ASTM A668 Class J forged steel

Forged Steel Cylinder Body Materials

Attention must be paid to forged steel cylinder selections for hydrogen sulfide content. The NACE MR-0175 Stress Cracking Region will be used to determine how much H_2S is allowed for AISI 4340 cylinder bodies.Most Ariel forged steel cylinder bodies are manufactured from AISI 4340 high strength carbon steel.This material is not suitable for H_2S content, even as low as 5 to 10 ppm. When even small amounts of H_2S is present, forged steel cylinders will need to be either softened to 22 RC or manufactured of 17-4PH Stainless steel.This will impact most Ariel double acting forged steel cylinders.

Double acting forged steel cylinders that are not suitable for sour gas service, will be flagged in red in the performance software when H_2S is entered into the gas analysis. Most forged steel tandem cylinder arrangements are suitable for H_2S content due to the controlled hardness of 22 RC maximum.

Lube Tubing

Ariel standard cylinder and frame oil system is 304 / 304L stainless steel tubing with zinc plated carbon steel fittings. An option is available to use 316 / 316L stainless steel tubing and 316 stainless steel fittings. This would encompass the frame and cylinder tubing and fittings on a unit. A separate option is available for upgrading welded frame oil piping from carbon steel to 316L stainless steel, both on the pump suction and downstream of the filter on larger units. Fittings and plugs outside the frame and cylinder oil flow are not included in these stainless steel options.

Separate Lube Supply

Provision is made on all units to use a separate oil source for the cylinder bores and packing cases. Ariel standard is to tube from the main frame oil header to the inlet of the cylinder lubricator pumps. The packager can remove this tube, plug the connection at the main frame oil header and connect the separate supply to the inlet of the lubricator pumps. Sour gas services typically require a special lubricant through this separate lube supply. Refer to Section 6 of the Packager Standards for lubrication recommendations.

Wet Gas

Wet Gas is any gas or gas mixture in which one or more of the constituents is at or very close to it’s saturated vapor pressure. The constituent may or may not be water vapor. A valid gas analysis is required to verify gas properties.

Special attention must be paid to the gas separation and piping upstream of the compressor. They must be designed such that no free liquids are permitted to enter the compressor or accumulate in the piping or bottles, causing "slugs" of liquid to carry over.

Consideration should be taken for two-phase flow between the gas cooler and the stage inlet separator, if liquids are dropping out between stages. Gas flow rate between stages will also be lowered by the gas equivalent amount of liquids dropping out due to interstage cooling.

When gas condensates are to be avoided, it is appropriate to raise the interstage temperature to create a separation between the interstage temperature and the dew point of the gas. A 20 to 30 F (10 to 15 C) separation is recommended.

Wet gas will tend to dilute the cylinder lube oil. See Cylinder and Packing Lubrication Requirements--6 in the Ariel Packager Standards for guidelines regarding cylinder and packing lubrication in wet gas service.