Capacity Control

The pressure and flow conditions for which the compressor is designed and/or operated can vary across a wide range. The three primary reasons for changing the capacity of a compressor are process flow requirements, suction or discharge pressure management, or load management due to changing pressure conditions and driver power limitations. Several methods can be used to reduce the effective capacity of a compressor. The “best practice” order of the unloading method is included in the table below.

Preferred Order of Unloading Method	
Required Action	**Method Of Unloading**
Reduce Flow	1 Reduce Speed 2 Add Clearance 3 Single Acting Cylinders 4 Bypass to Suction 5 Throttle Suction Pressure
Reduce Torque	1 Add Clearance 2 Single Acting Cylinders (speed dependent) 3 Throttle Suction Pressure
Maintain Suction or Discharge Pressure	1 Reduce Speed 2 Add Clearance 3 Bypass to Suction 4 Single Acting Cylinders 5 Throttle Suction Pressure

1. The use of driver speed for control can be one of the most effective methods for capacity reduction and suction and/or discharge pressure management. The available power of the driver will decrease as the speed is decreased. The compressor power efficiency increases as the speed decreases due to lower gas velocities creating lower valve and cylinder losses.
2. The addition of clearance will reduce capacity and required power through a decrease in the volumetric efficiency of the cylinder. Methods of adding clearance are the following:
    - High Clearance Valve Assembly
    - Variable Volume Clearance Pockets
    - Pneumatic Fixed Volume Clearance Pockets
    - Double Deck Valve Volume Pockets
3. Single acting cylinder operation will reduce capacity through cylinder end deactivation. Cylinder head end deactivation can be accomplished by removing the head end suction valves, installing head end Suction Valve Unloaders, or installing a head end bypass unloader. Refer to Single Acting Cylinder configuration for further information.
4. Bypass to suction is the recycling (bypassing) of gas from the discharge back to suction. This reduces the downstream capacity. Bypassing gas from discharge back to suction does not reduce the power consumption (unless fully bypasses for zero flow downstream).

5. Suction throttling (artificially lowering the suction pressure) reduces the capacity by lowering the actual flow into the first stage cylinder. Suction throttling can reduce power consumption, but may have an impact on the discharge temperatures and rod loads generated by the higher compression ratio.

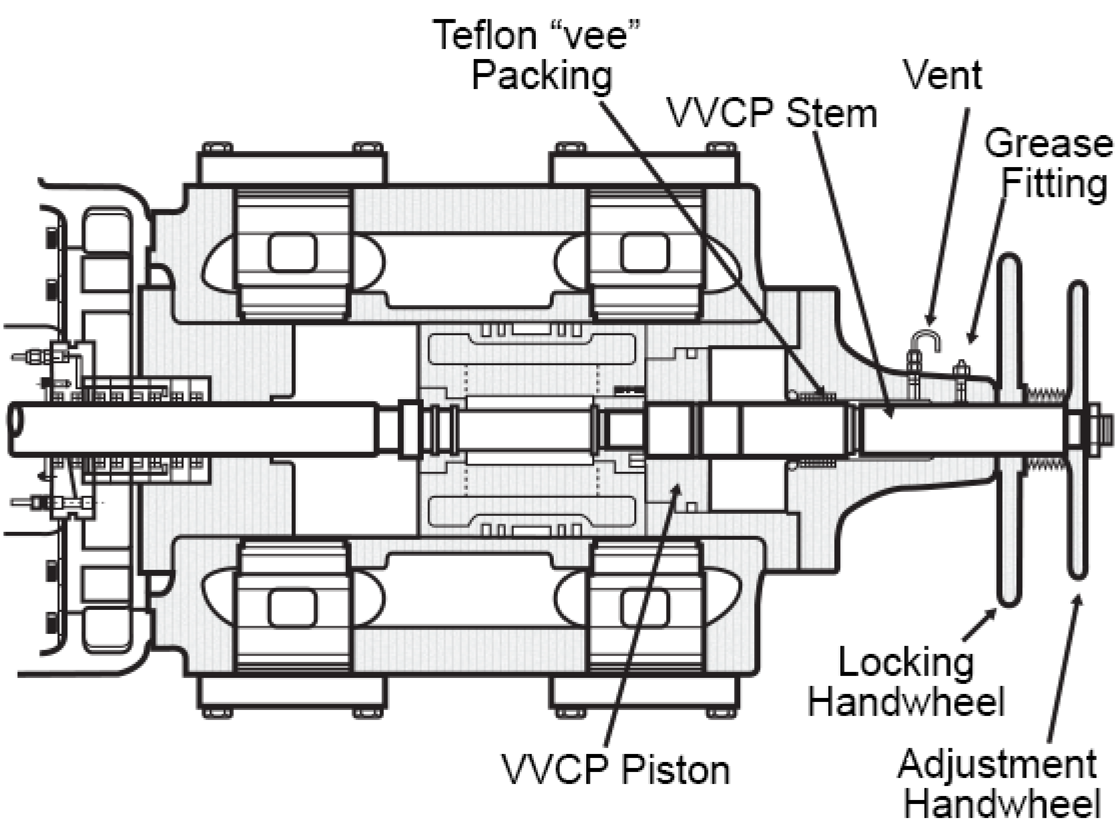
Capacity control methods can have an impact on various performance characteristics besides flow and power. Partial load conditions should be reviewed for acceptable performance including valve lift selection and dynamics, volumetric efficiency, discharge temperatures, rod reversal, gas rod loads, torsional and acoustical response.

Automated capacity control sequences must be communicated so that the same set of loading steps is considered in the acoustical analysis, torsional analysis and control panel logic.

Compressor valves are selected to have optimum dynamic motion at one operating condition, and have some flexibility for off conditions. A general rule of thumb for speed impacts on valve dynamics is that a single valve selection can be operated with a 2:1 maximum speed range. This may be limited with a minimum speed. Operation below half frame rated speed may see reduced valve life. Varying suction pressures, discharge pressures and gas analyses can further limit this speed range. Low lift valves may be necessary for speed ranges outside a 25% variation. When applying variations in speed and single acting cylinder configurations the torsional and acoustical response analysis will be much simplified by applying single acting configuration only at one given speed.

Variable Volume Clearance Pockets

A VVCP is used to change the clearance volume of the head end of a cylinder. The amount of clearance will vary depending upon the position of the clearance pocket piston. Clearance is added to the cylinder by turning the piston / stem assembly counter clockwise (CCW).

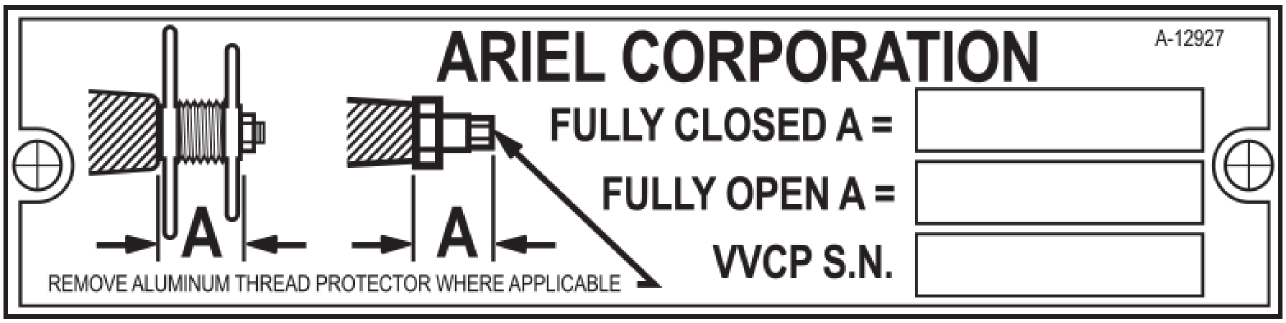


Most compressor cylinders can be equipped with variable volume clearance pockets. The VVCP is mounted in place of the head end cylinder head. The VVCP includes an adapter, piston, seal ring, stem, Teflon vee packing, turning handle and locking wheel.

The expected change in compressor flow and absorbed power will depend upon the application compression ratio and the properties of the gas being compressed. Always check to see that the head end suction volumetric efficiency or discharge event are within limit when setting the pocket.

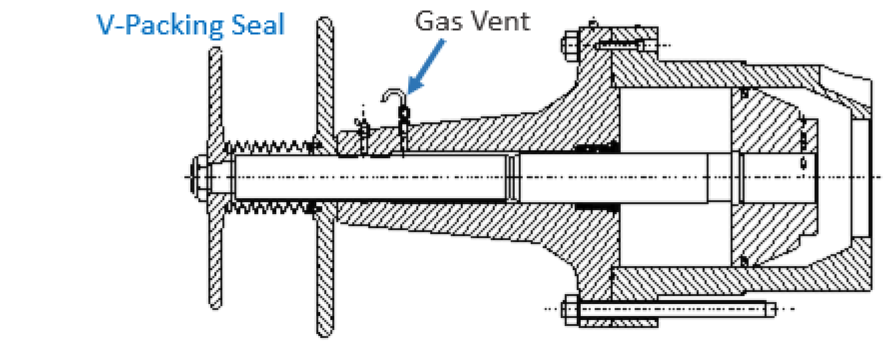
To set the VVCP at the desired percentage open, fully close the VVCP, and then fully open it, counting the number of turns to the full open position. Fully close the VVCP. Multiply the number of turns by the desired percentage open, and turn the VVCP open the resulting number of turns.

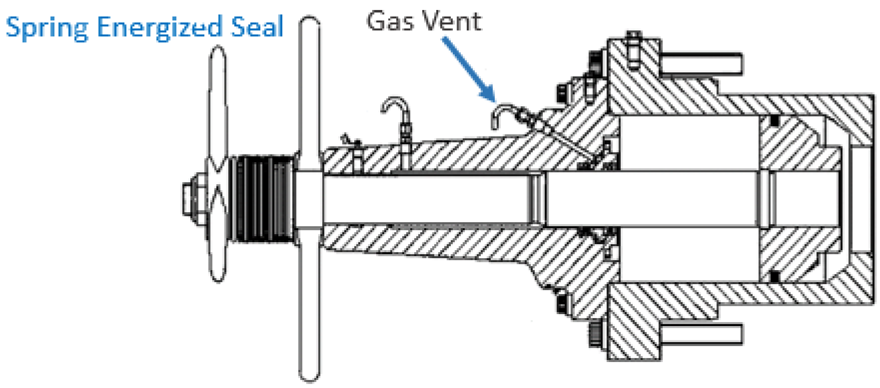
The pocket position can be measured with a ruler on site. A pocket position nameplate is attached to newer pockets showing the measurements for open and closed. This data can also be found in the Ariel Performance Software.



Refer to the compressor cylinder DataBook for available VVCP for each cylinder.

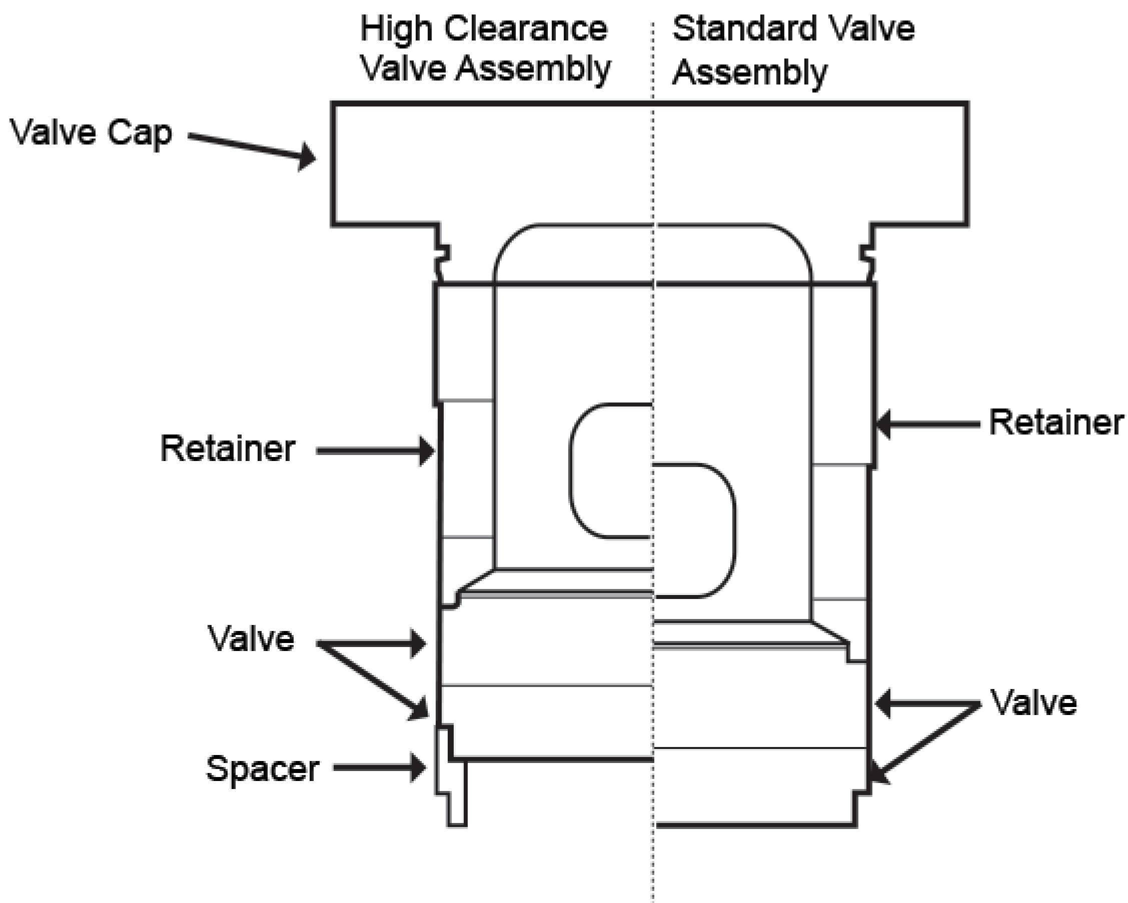
The vent on the VVCP will be one of two configurations. K, T, C, D, F, U, Z cylinder classes with models 8-3/8 and larger, will have two seals on the stem with a vent between. All other cylinder classes will have a vee packing for the stem seal and a vent downstream. Refer to the Packager Standards for information on routing these vents.





High Clearance Valve Assembly

A high clearance valve assembly is used to increase the fixed clearance volume of a cylinder end. A high clearance assembly is comprised of a valve spacer, a special retainer, and a gasket. The spacer is placed between the cylinder valve seat and the valve body.

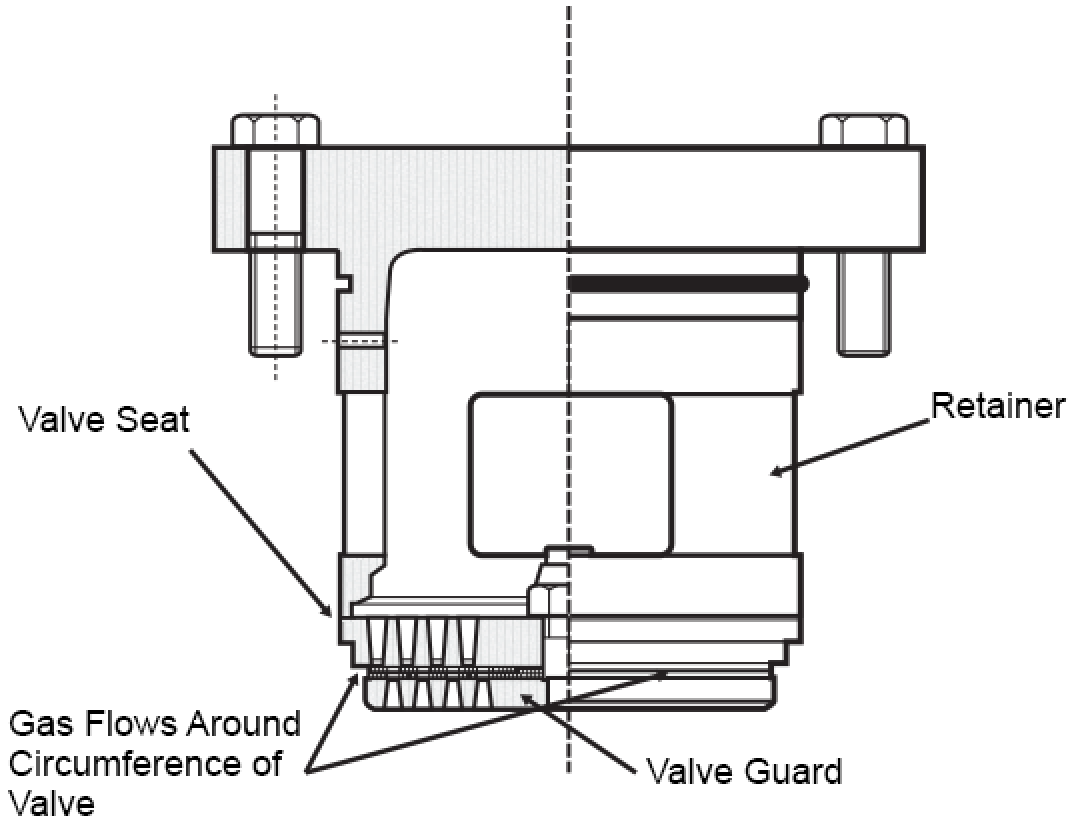


The cylinder DataBook lists the number of high clearance assemblies that can be provided with each cylinder and the percent of added fixed clearance for each assembly. A new cylinder purchased with high clearance assemblies will also be supplied with standard valve retainers.

Cylinders of the class 3SG-CE and 3-5/8SG-CE show the availability of high clearance valve assemblies in the performance software. These cylinder classes do not use the traditional spacers as shown above, but utilize high clearance crank end head designs to add the clearance. The clearance defined for these cylinder classes are machined as part of the cranks end head and are not removable valve spacers.

Hanging guard design valves cannot be outfitted with high clearance valve assemblies. Gas flows around the circumference of these valves. Installing a spacer would block the gas flow.

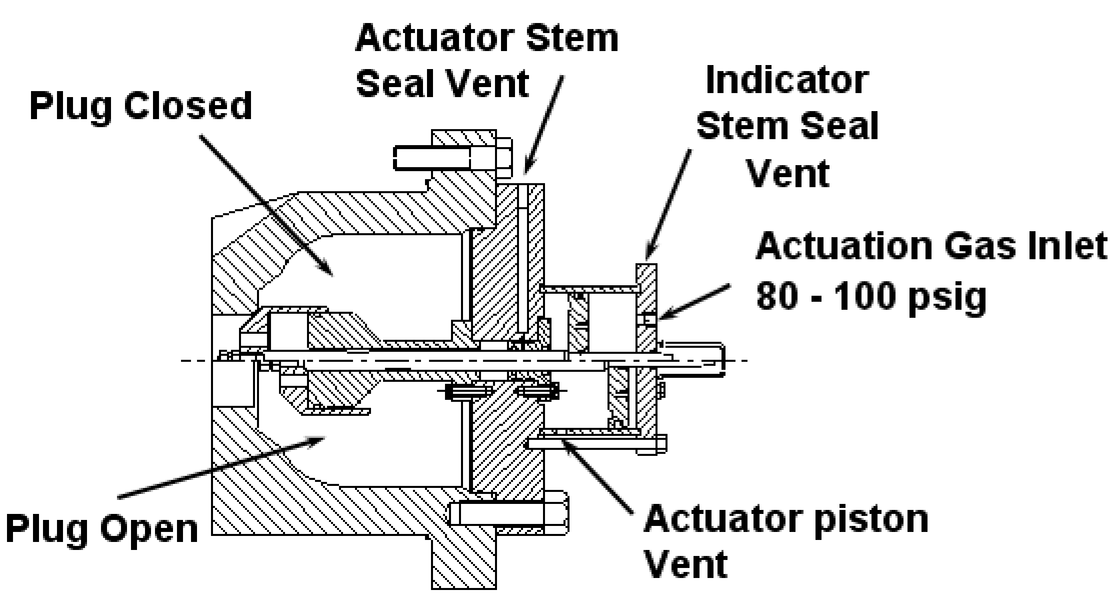
Below is a drawing of a hanging guard design valve.



Also see: Clearance Volume

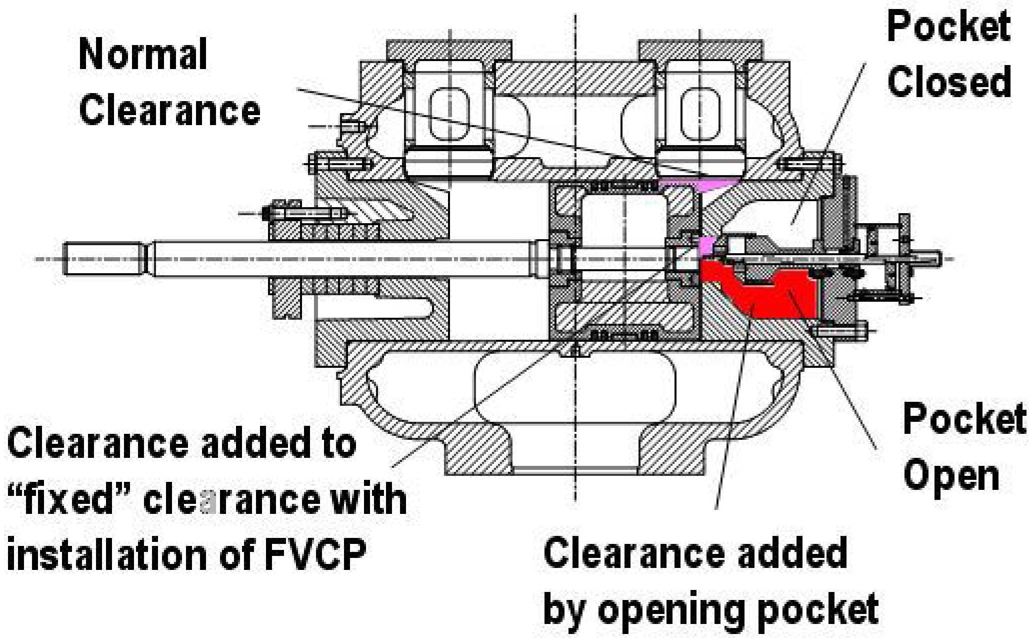
Pneumatic Fixed Volume Clearance Pockets

A FVCP is used to add clearance volume to the head end of a cylinder. A plug is pneumatically actuated to either fully open or fully close the pocket. The FVCP assembly is mounted in the head end of a cylinder.



The FVCP requires 80-100 psi of air or gas pressure to operate. Actuation of the pocket can be performed by the PLC controlling a solenoid valve. In most cases, the FVCP is normally unloaded (FVCP open), requiring air or gas pressure to load (FVCP closed).

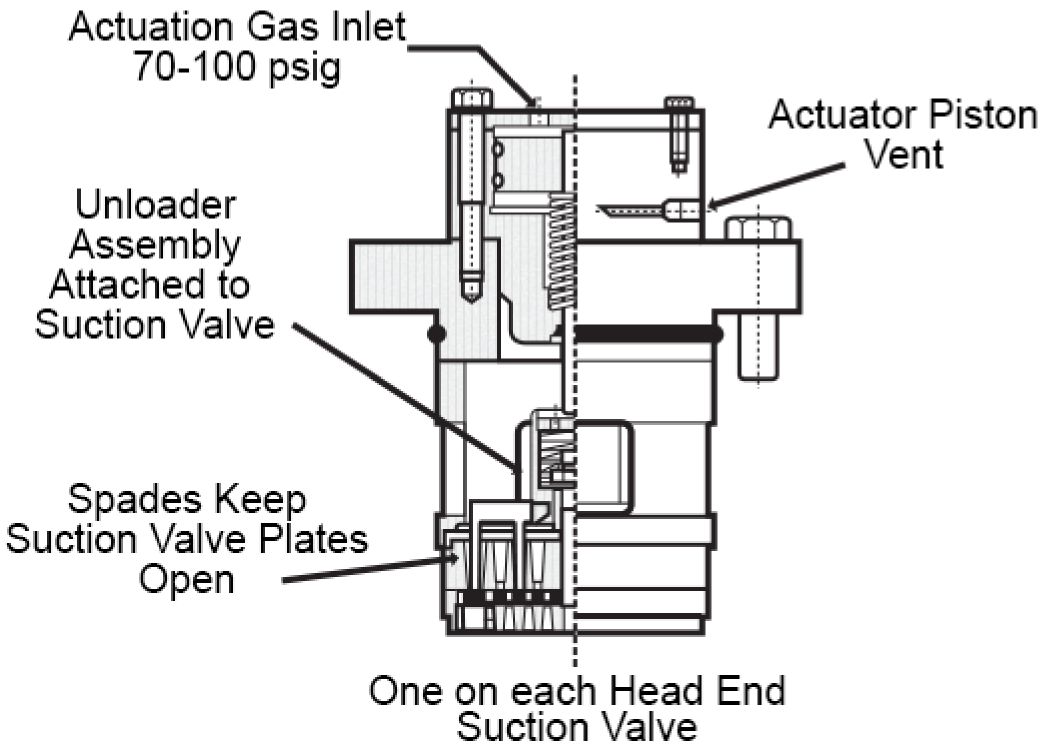
Data regarding FVCP designs and availability for each compressor cylinder is available in the Ariel Electronic Databook.



Suction Valve Unloaders

See Cylinder Action, Single Acting for a drawing of a suction valve unloader installed on a cylinder.

A valve plate depressor type suction valve unloader will depress the suction valve plate against the valve guard to hold the valve open, therefore deactivating the end of the cylinder by allowing gas to pass through the valve during both intake and compression stroke. A valve plate depressor type suction valve unloader is actuated using air or natural gas as actuation gas (usually 70 to 100 psig). In most cases, the suction valve unloaders are normally loaded, with air or gas actuation pressure required to unload the cylinder end. Suction valve unloaders may be used only on plate or ring valves (not poppets).



Applications that require suction valve unloaders must be reviewed by Ariel / Hoerbiger before quoting. The valve depressors are always in the seat flow passages. This will reduce the valve equivalent area and increase the horsepower losses of the valve. Temperatures may also be increased due to a recirculation of the gas on the deactivated end preheating the active end. It is important that data regarding the entire range of suction pressures and gas compositions be submitted for review. The review will specify the valve plate materials, lifts and valve equivalent flow areas to be used for the application. Suction valve unloaders must be installed on all suction valves of the end being deactivated.

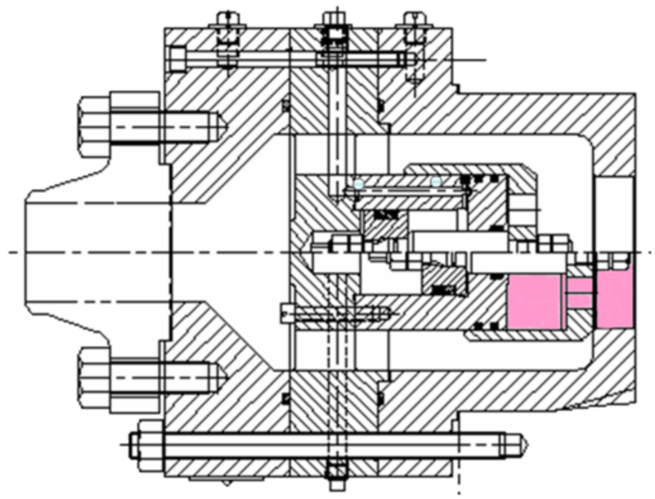
Ariel recommends using suction valve unloaders on the head end of cylinders only. Crank end deactivation may result in a non-rod load reversal situation. All deactivation configurations should be analyzed at all conditions to verify adequate rod load reversal.

Single acting cylinder operating cases should be considered when analyzing torsional responses and acoustical pulsation responses. Single Acting cylinders can present the worst case scenario for a torsional analysis due to a more dynamic torque effort curve and for an acoustical pulsation analysis due to a change in the number of pulses per cycle. High torsional vibration and / or high acoustically driven vibration can result from single acting cylinder operation when not considered in these analyses.

High torsional vibrations can increase coupling and shaft stresses, driver functionality and auxiliary driven equipment integrity. High acoustical pulsations can increase frame, cylinder, gas piping and equipment vibrations.

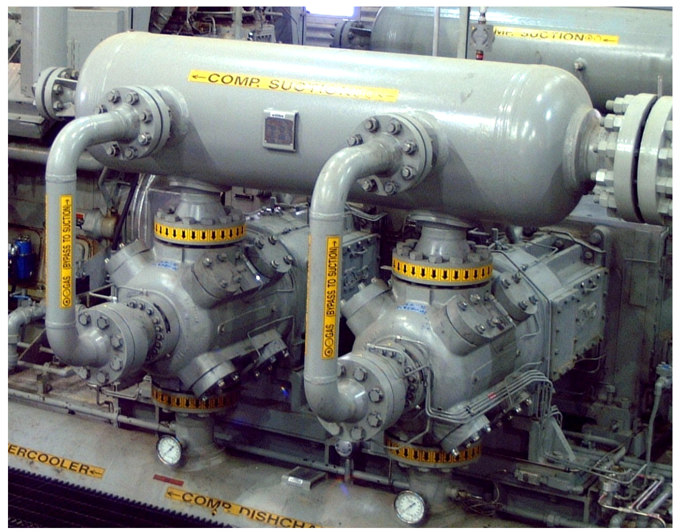
An alternate method of single acting a cylinder is by removing the head end suction valves on one cylinder end. Suction valve removal will result in less horsepower loss as the unloading flow area is greater. Cylinders with suction pressures above 750 psi and or small valve sizes may not be suitable for suction valve unloaders.

Head End Bypass Unloaders



Head end bypass unloaders are pneumatically actuated ports on the head end of the cylinder that allows the head end compression to be open to the suction gas pressure. This fully deactivates the head end of the cylinder for single acting configuration. Head end bypass unloaders are most often applied when the suction pressure is higher than suction valve unloaders can be applied (near 1000 psi and higher).

The pneumatic actuator is smaller, to fit within the unloader, so requires a higher actuation pressure, often in the few to several hundred psi range. Each application and cylinder size will require a specific actuation pressure. These can be found in the Ariel performance software on the device datasheet.



Most often, process gas can be regulated from a higher pressure stage discharge to the appropriate pressure and applied as the actuation gas. The actuation gas must be clean and dry. Sour gas cannot be used as actuation gas (greater than 100 ppm H_2S) for safety reasons. If the process gas contains hydrogen sulfide, nitrogen may be used for the actuation gas.

Actuation gas must be clean and dry. When regulating the higher pressure supply stream to the required actuation pressure, a liquid collection / separator device must be installed directly downstream of the regulator.

Head end bypass unloaders may not be as efficient as suction valve unloaders, but can be applied at higher suction pressures.

All deactivation configurations should be analyzed at all conditions to verify adequate rod load reversal.

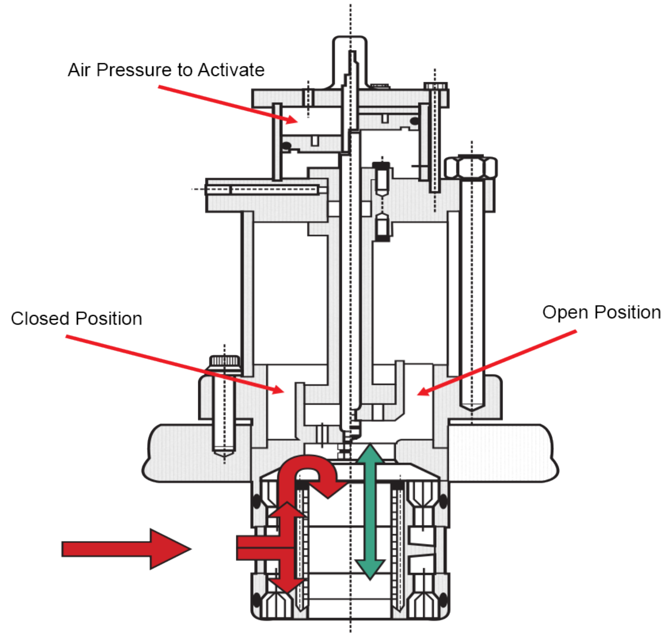
Single acting cylinder operating cases should be considered when analyzing torsional responses and acoustical pulsation responses. Single Acting cylinders can present the worst case scenario for a torsional analysis due to a more dynamic torque effort curve and for an acoustical pulsation analysis due to a change in the number of pulses per cycle. High torsional vibration and / or high acoustically driven vibration can result from single acting cylinder operation when not considered in these analyses.

High torsional vibrations can increase coupling and shaft stresses, and affect driver functionality or auxiliary driven equipment integrity. High acoustical pulsations can increase frame, cylinder, gas piping and equipment vibrations.

An alternate method of single acting a cylinder is by removing the head end suction valves on one cylinder end. Suction valve removal will result in less horsepower loss as the unloaded flow area is greater. Cylinders with suction pressures above 1000 psi and or small valve sizes may not be suitable for suction valve unloaders.

Double Deck Volume Pockets

A double deck volume pocket is used to add clearance volume to the end of a pipeline cylinder through the valve port. An unloader assembly is pneumatically actuated to either fully open or fully close the pocket. The volume pocket assembly is mounted in the valve port of the cylinder.



The unloader requires 80-100 psi of air or gas pressure to operate. Using a solenoid valve, it can be operated by electronic signals from a flow computer or PLC. In most cases, the pocket is normally unloaded with air or gas pressure required to load (close the pocket) the cylinder.

Contact Ariel Corporation for availability and data regarding double deck volume pocket applications.

Deactivated Stage

Every now and then a service changes to lower pressure ratios and requires fewer stages of compression on existing equipment. Deactivating a stage can be accomplished with allowing blowthru or by physically deactivating a stage. Deactivated stage methods are not to be confused with deactivating a cylinder within a multi cylinder stage (see Deactivated Cylinder below).

Blowthru occurs when the compression ratio across the compressor is not high enough to accommodate compression in all the available stages. The gas is compressed to full discharge pressure in the first several stages and physically blows thru the last stage without further compression. This blowthru gas flow holds the suction and discharge valves open. If the unit is close to allowing full compression on the last stage the valves can flutter during this blowthru condition. Blowthru is acceptable if the unit will not operate at extended periods of time at this condition.

If the unit will operate at this lower ratio for extended periods a stage of compression can be deactivated, or taken out of service. For shorter durations the cylinder can be deactivated by removing all suction and discharge valves from both ends of all cylinders on the deactivated stage. Extremely short durations may see only all suction valves removed to lower valve removal time, but will result in more power usage and higher temperatures. For longer periods the stage can be deactivated by removing all valves, removing the piston and rod, rerouting the cylinder and packing lubrication to the frame, replacing the packing with a solid plug and rebalancing the reciprocating weights.

Any changes in operating conditions warrants a review of performance to ensure proper operation within allowable limits is maintained. Changes in conditions requiring deactivating a stage can have impacts to rod reversal, rod loads, discharge pressure versus MAWP and potentially torsional responses.

These "extended periods of time" should be defined by the user based upon frequency of re-activating the stage, acceptable maintenance and the availability of manpower to change the unit configuration. In general, blowthru can be tolerated for days to a few weeks. Deactivating by pulling the suction valves can be tolerated for months. Deactivating by removing the piston and rod can be used for longer durations in the terms of half a year and up. The duration of deactivation by the blowthru and pulling suction valves are discussed due to the likelihood of higher maintenance if the durations are longer. Blowthru conditions can cause the valves to open and close, without preferable dynamics, resulting in possible broken valves before the next loading of the stage. Pulling the suction valves and leaving the piston and discharge valves in place can also result in failure of the discharge valves over time and will result in continued wear of the piston rings, wearbands and packing sealing rings.

Deactivated Cylinder

Deactivating a cylinder that is part of a stage is handled differently than deactivating an entire stage. An example would be if there are two first stage cylinders and typical unloading methods are not enough, one first stage cylinder can be deactivated while the other first stage cylinder continues to compress. If an entire cylinder within a stage needs to be deactivated, this can be done in one of two ways; Removal of the piston and rod, or non-acting the cylinder.

Removal of the piston and rod is the preferred method to deactivate a cylinder. This is accomplished by removing the piston and rod, installing blank flange blinds between the cylinder and pulsation vessels (suction and discharge), installing a plug in place of the packing case, rebalancing and removing the cylinder lubrication from the deactivated cylinder. Removing the suction valves from both ends of the cylinder can be done rather than installing flange blinds.

An entire single cylinder, when part of a multiple cylinder stage using a manifolded suction pulsation vessel, can be deactivated by removing the suction valves from both ends of the cylinder. This method is not recommended by Ariel, but has been performed successfully on specific installations. If this method is successful, it can save down time for shorter term deactivation. In this method, the gas will be recycled from head end to crank end through the suction gas passages and will heat up. In most cases, the heat generated will be greater than the maximum allowable average cylinder temperature of 285 F (140 C). If this methods is used, cylinder temperature measurements must be taken at the suction gas passages. The discharge temperature measurement location will not read the cylinder gas temperature.

Non-Acting Cylinders

A non-acting cylinder is a cylinder that is installed, but is not compressing gas. There are several ways a cylinder would be non-acting.

- Blowthru
- All Valves Removed
- All Suction Valves Removed
- Piston and Rod Removed
- Blank Throw
- Non-Acting for Startup

Blowthru occurs when the compression ratio across the compressor is not high enough to accommodate compression in all the available stages. The gas is compressed to full discharge pressure in the first several stages and physically blows thru the last stage without further compression. This blowthru gas flow holds the suction and discharge valves open. If the unit is close to allowing full compression on the last stage the valves can flutter during this blowthru condition. Blowthru is acceptable for short durations. Longer durations can lead to premature valve failure in the stage with blowthru.

All of the cylinder valves can be removed if a stage of compression will need to be disabled for an extended period of time. This allows a larger flow area for the gas to pass through the cylinder valve ports, reducing the pressure losses in the stage. This also removes the valves from the wear life equation. Removing all of the cylinder valves must be limited to deactivating an entire stage, not just one cylinder of a mutli-cylinder stage.

All Suction valves can be removed from a cylinder to disable a stage for much shorter periods. Some of the benefits of lower pressure loss are attained, while having a shorter downtime to remove valves.

All Suction valves can be removed if a single cylinder of a mutli-cylinder stage needs to be disabled. Though this method is not recommended by Ariel, it may be possible to non-act a single cylinder within a stage. In most cases, non-acting a cylinder within a stage will result in overheating the cylinder beyond the capabilities of the non-metallic components within the cylinder. If this method is to be used for non-acting a cylinder within a stage, the cylinder nozzle temperatures on the suction side (since suction valves are removed) must be closely monitored so as not to exceed 285 F (140 C). This method has been known to work in some specific circumstances, while in the greater majority is not successful. The cylinder to be non-acting must be part of a manifolded suction vessel with the other cylinder(s) active.

Removal of the piston and rod to disable a stage can be done when the unit will operate with a disabled stage for extended periods of time. Removal of the piston and rod allows the wearing components to be removed and the cylinder lubrication to be shutdown for the cylinder. This is accomplished by removing the piston and rod, installing blank flange blinds between the cylinder and pulsation vessels (suction and discharge), installing a plug in place of the packing case, rebalancing and removing the cylinder lubrication from the deactivated cylinder. Removing the suction valves from both ends of the cylinder can be done rather than installing flange blinds. The definition of "extended period" is determined by the end user and is a balanced of the time and equipment it takes to accomplish the removal of the piston and rod against the savings for wear parts and lubrication.

Removal of the piston and rod is the preferred method to non-act a cylinder within a stage.

Blank throws are locations on the frame that can accommodate a cylinder, but are not mounted with cylinders, ie., placing three cylinders on a four throw compressor. There are two different balancing configurations for a blank throw, an active crosshead guide and a balancing crosshead guide. An active crosshead guide is a guide that can accommodate the mounting of a cylinder and has standard crossheads and balance nuts installed. A balancing crosshead guide, also referred to as a dummy guide, is a special guide with added length to accommodate larger, special, balancing crossheads. Cylinders cannot be mounted on balancing guides. When applying a blank throw, the reciprocating weight is not offset by gas loads from compression. Therefore, the weight of the blank throw should be minimized by mounting the smaller of the cylinders on the opposing throw. Throws are locations on the frame that can accommodate a cylinder, but are not mounted with cylinders, ie., placing three cylinders on a four throw compressor.

Cylinders can be non-acting for start up purposes. When the available starting torque is not available for a fully bypassed compressor start, unloading ends of the cylinders will help reduce some of the starting torque. This will require the use of suction valve unloaders or head end bypass devices. Actuating suction valve unloaders on the head end can help reduce the staring torque. In some cases, the motor inrush current must be further limited; suction valve unloaders can be applied to both the head end and crank end to further reduce the starting torque. When both ends are non-acting for start up, a time limit of five (5) minutes should be applied for the non-acting duration.