Diaphragm Compressors

Designed and Constructed for High Reliability and Low Maintenance
Providing World-Class Diaphragm Compressors

Utilizing a powerful combination of engineering and manufacturing excellence and a dedication to working with our customers, Pdc provides engineered solutions to satisfy difficult gas compression needs.

The leak-tight and contamination-free features of Pdc’s diaphragm compressors provide numerous benefits. When toxic or hazardous gases are being processed, these compressors protect the health of workers and the environment, and maintain a safe operating area. Since the process gases are totally isolated and have no contact with hydraulic, lubricating, or cooling fluids, high-purity and expensive gases can be processed without any contamination or losses.

Some of the other features and benefits of Pdc’s diaphragm compressors include:
- Design pressures to over 4,100 bar / 60,000 psig
- Gas flow rates over 1,500 Sm<sup>3</sup>/hour / 880 Scfm
- Fast-acting leak detection systems to indicate diaphragm and seal failure
- Safe, non-flammable hydraulic fluid used for oxygen and other oxidizing gas applications
- Single and multiple stage configurations for high compression ratios
- Horizontally opposed designs available for high-efficiency operation
- Electric and air-driven models
- Process contacting metals are available in a variety of alloys for compatibility with process gases
- Process contacting seals are available in a variety of elastomers and ductile metals for compatibility with process gases
- Unique cavity design feature for low or high-pressure operations

Experience, Reliability & Service

Pdc is committed to continuous product improvement and the development of innovative designs and manufacturing processes to maximize compressor performance and value. Drawing on our decades of experience and the use of our proprietary software for sizing, stress analysis, and detailed engineering drawings, Pdc provides high reliability and low maintenance diaphragm compressors. These compressors demonstrate superior diaphragm life as a result of our cavity contour design, our exclusive diaphragm manufacturing process, and critical quality control. All models include automatic positive priming and injection pumps to reduce knocks, cavitation, and vibration for smooth start-up and operation. Critical components are manufactured and verified to exacting tolerances utilizing computer numerical controlled (CNC) machining and coordinate measurement (CMM) quality control.

After assembly, every compressor is subjected to rigorous in-house testing and is made available for customer inspection. Each unit also includes an O & M Manual with drawings and component details. Pdc stocks critical spare parts for quick shipment and offers responsive technical and field support when the need arises.

Technological Leadership

The advanced horizontally-opposed crankcase designs used in many of Pdc’s duplex and 2-stage compressors yield numerous advantages.
- Energy efficiency
- Easy maintenance
- Minimal unbalanced forces
- All compression loading on rod
- Reduced load on crankshaft bearings
- No troublesome transition assembly
- Duplex units that start up under high inlet pressure without unloading
- Low horsepower requirements
- Duplex units are capable of compressing different gases simultaneously
A Wide Range of Compressor Solutions

Based on our extensive experience in compressor technology and our state-of-the-art engineering and manufacturing capabilities, we work with our customers to provide the optimum solution to satisfy their gas compression needs. Pdc provides both standard and custom-designed compressors with a comprehensive assortment of options. We furnish a wide range of equipment from basic units to turnkey, skid-mounted, and computer controlled systems.

“We work with our customers to provide the optimum solution to satisfy their gas compression needs.”

We also offer:

- Modular field expandable designs that can be effected with minimal effort and cost for changing gas compression needs
- The shortest turnaround in the industry. Popular models can be delivered in as few as 6 to 8 weeks
- Control system design and configuration
- On complex compressor systems, Pdc provides a 3-D solid modeling of your system so you can easily visualize the equipment layout, process arrangement, and serviceability of our design before construction begins
- Compressors designed and constructed to comply with American and international applicable codes and standards such as ASME, CE (ATEX, PED), CSA, UL, KHK, etc.
- Complete compressor construction and assembly in-house
- Exceptional product value

Diaphragm Compressors

Compressors for a wide spectrum of gases

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<th>Gases</th>
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<td>Ammonia</td>
<td>Oxygen</td>
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<td>Argon</td>
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<td>Carbon monoxide</td>
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<td>Nitrogen trifluoride</td>
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Diaphragm Compressors are used in virtually every industry in which high-purity, rare, or hazardous gases are utilized. Some specific uses include:

- Flammable, oxidizing, toxic, and radioactive gases
- Gas cylinder filling
- Gas blending and mixing systems
- Gas transfer and filling and off-loading of tube trailers
- Chemical and petrochemical gas processing systems
- Gases for electronics, semiconductor, and fiber optics manufacturing
- Pressure boosting and storage of gases from on-site gas generation systems
- Pressure boosting for gas recycling systems
- High-pressure gas storage systems
- Hydrogen gas systems at electric power plants
- Hydrogenation systems
- Supercritical fluids and solvent extraction systems
- Research and Development

Two independent PDC-4-600-3000 (150) compressors mounted on a common skid. Two, 20 hp motors, 18” & 20” diameter heads, Compressors are used in the semi-conductor industry.

PDC-4-40-200 & PDC-4-800-800. (2) 30 hp motors, 35”, 26” & 18” diameter heads, Development & validation of hydrogen purification equipment (PSA).

12,000 psi (827barg) discharge pressure, for fuel cell applications.
General Compressor Specifications:

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<th>Series</th>
<th>Maximum Discharge Pressure</th>
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<td>PDC-13 Duplex</td>
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Pdc provides a wide variety of compressor options to satisfy your particular application. We furnish gas conditioning hardware, process instrumentation, dryers, accumulators, closed-loop cooling systems, other ancillary equipment, and systems controls. Controls may be simple relay based, PLC, or PC systems.
Why Diaphragm Compressors?

Pdc’s metallic diaphragm compressors are ideal for compressing all types of gases without incurring any contamination of the process media or leakage of gas to ambient air that results from reciprocating and other types of compressors. Traditional reciprocating compressors are subject to leakage past the piston rings which can result in contamination of the process gas with the hydraulic oil.

This is accomplished by isolating the process media from the piston and related components with a set of metal diaphragms. The piston moves a column of hydraulic fluid, which in turn moves the diaphragm-set, and displaces the process media. The process side of these units is constructed of corrosion-resistant materials to prevent further contamination.

Diaphragm compressors are well-suited for applications ranging from vacuum to pressure as high as 60,000 psig. Because of the large surface areas of the heads and diaphragms, the presence of pulsing oil and cooling of the upper heads (process side) Pdc compressors typically run considerably cooler than conventional piston-type reciprocating compressors.

Our compressors are more isentropic than adiabatic. The exponent runs between isothermal and adiabatic. This makes it possible for higher compression ratios to be achieved that would be difficult or impossible to achieve with conventional units. In some cases, compression ratios as high as one hundred to one is possible.

Cavity And Its Design –

The deflection and inherent stresses of the metal diaphragms are controlled by a carefully designed cavity contour.

We use state-of-the-art design and analysis with the assistance of sophisticated computers to create these cavity contours. Optimum displacements are obtained while assuring maximum fatigue life for the diaphragms. Finite element analysis is used to calculate the deflections of the compressor heads that house these cavities. The effects of head deflection on diaphragm stress are superimposed to determine their effect on fatigue life.

Oil Relief Valve -

This relief valve will accomplish the following:

A. Limits maximum oil and gas pressure generated by the diaphragm unit.

B. Assures that diaphragms completely sweep the cavity and contact the upper cavity contour, thus maximizing displacement. This is achieved by creating oil pressure that is slightly higher than the process discharge pressure. Additional plunger movement accomplishes this after the diaphragms contact the upper cavity contour and the relief valve setting. Once the relief valve pressure setting is achieved, the excess oil is discharged through the relief valve and returned to the crankcase. This oil flow is referred to as “over pump”.

Injection Pump -

Pdc provides an automatic plunger type injection pump on all motor-driven diaphragm units. The pump’s function is to inject a specific volume of oil during the suction stroke of the machine. This volume of oil compensates for the following losses:

1. Normal leakage of oil across the hydraulic piston.

2. Compressibility of oil under pressure.

3. Over pump as defined above.

Boot Strap-

As the design pressure approaches 10,000 psig, very high loads are generated between the upper and lower heads. On lower pressure design, this load is offset by a series of bolts torqued to a specific value. Attempting to accomplish this on high-pressure designs results in impractical bolt sizes and torques.

The best solution is a boot strap design.

With a boot strap configuration, there is an annular area greater than the cavity seal area that is subjected to the same hydraulic oil pressure providing a higher load than the load developed on the cavity seal area.

This offsetting load will keep the heads clamped together without the need for large bolts and high torques. We perform detailed, finite element analysis to study the stresses and deflections that could adversely affect normal operation under these high-pressure conditions.
Why Diaphragm Compressors? continued

Unique Design features of Pdc Compressors

1. To achieve maximum fatigue life for the diaphragm set, we carefully design the cavity contours in the head assembly (process and oil side). Different philosophies are used for suction like vacuum, atmospheric and high pressures. Unique cavity configurations are used for pressures above 3000 psi.

2. Critical consideration are inherent in sizing cavity volume and piston displacement at various pressure levels to assure uniform movement of diaphragms, equalization of gas and oil pressures, and smooth start-ups, and subsequent starts.

3. Special processing of diaphragms. Customers are reporting diaphragm lives of 10,000, 25,000 and 42,000 hours of operation.

4. Unique hydraulic oil distribution enables the compressor to run smoothly and quietly without soundproofing enclosure.

Process Head –
At Pdc, we machine process heads from a wide variety of materials, such as stainless steel, Hastelloy®, Inconel®, and Monel®, to best suit the process gas you require.

Triple Diaphragm Construction –
This is comprised of a stack of three metal diaphragms. The top diaphragm (process side) is made of a material compatible with the process media (stainless steel, Monel, etc.). The bottom diaphragm (oil side) is made of the same material as the upper and the middle diaphragm is made of brass. Without the brass-bearing surface of the middle diaphragm, the similar materials of the upper and lower diaphragms would exhibit a tendency to galling together.

Process Contacting Seals –
We offer an extensive variety of static elastomeric O-ring seals, such as Viton®, Buna, Vespel®, Teflon, Peak, and Kalrez®, to suit the process gas you specify.

Leak Detection System –
We make a leak-detection system standard on every stage of compression for Pdc diaphragm compressors. This system detects diaphragm failure, (cracked diaphragm), gas and/or seal failure. Diaphragm failures are normally attributed to particles or contamination in the gas or oil systems of the compressor, moisture condensation inside the cavity, or improper tightening of the compressor head bolts.

We use triple diaphragm construction to detect diaphragm and main seal (gas or oil) failure. The middle brass diaphragm has radially scribed lines on both sides of the diaphragm. These serve as leak paths for moving any media that have leaked through a crack in either the upper or lower diaphragm to the leak collection area. Any failure of either the main oil or gas seal (O-ring) would also be detected in the leak collection area.

The leak detection system is attached to the access port and used to monitor the status of the diaphragms and seals. In addition, the pressure switch can be used to provide automatic shutdown when the pressure in the collection area exceeds the switch setting (set at 20 psig). The pressure gauge (0-30 psig) is used for visual indication of a leak. The relief valve protects the system from excessive pressure. And the manual valve allows the operator to vent off the leak for maintenance and verification purposes.

Diaphragm Life & Maintenance –
Pdc is continuously striving to extend diaphragm life. Our goal is to minimize down time, spare parts, and maintenance costs for our customers. We are committed to extensive R&D to develop new techniques to further reduce diaphragm stresses and extend fatigue life through advances in engineering design and manufacturing processes. Increasing diaphragm life reduces downtime and the cost of spares.

Process Inlet & Outlet Check Valves –
Pdc uses either cartridge or flat disc valves manufactured from Vespel®, Peek, or Monel®. We select the size and type of valves that will best suit the specific operating conditions and process gas. Incompatible materials of construction and or improperly sized valves can seriously degrade compressor performance. We have also designed our valves to be easily removable for maintenance without the need to dismantle the head assembly.

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Warminster, PA 18974 USA
Tel. 215-443-9442
Fax 215-443-8530
E-mail: info@pdcmachines.com

www.pdcmachines.com
Advantages

- All process-wetted components are constructed from corrosion resistant materials. Proper oil and suitable construction materials insure safe handling of compressors serving explosive gases.
- Design pressures from atmospheric to 65,000 psig. Self-clamping boot strap designs for pressures over 10,000 psig.
- Fast-acting leak detection system to indicate diaphragm and seal failure.
- Superior diaphragm life due to proprietary cavity contour designs and manufacturing process. This reduces diaphragm stress and extends diaphragm life to potentially exceed 40,000 hours of operation.
- All of our models are equipped with automatic positive priming and injection pumps to minimize knocks, cavitation, and vibration for smooth start-up, operation, and re-priming during subsequent start-ups.
- Self energizing seals (O-rings).
- Ductile metal seals to meet low leak rate specifications (10^-8 SCCS Helium).
- Off-loading to local storage is possible without the need for a regulator and reduced suction. This conserves energy and lowers costs.
- Reliable, state-of-the-art components are procured from industry-respected suppliers who are recognized for the performance, quality, and durability of their products.
- High compression ratios per stage. An application that would require two stages on a reciprocating compressor can be handled with one stage by a diaphragm compressor. This reduces capital costs and maintenance.
- Cutting-edge technology in design, manufacturing, and testing results in competitive pricing and lower maintenance costs when compared with standard piston compressors with clean-up systems and non-lube compressors.
- Pdc offers the fastest turnaround in the industry. We can typically deliver popular models in as little as 6 to 8 weeks.

Horizontally Opposed Designs for High-Efficiency Operation:

- Simplex, duplex, and multi-stage compression.
- Easy to install and maintain.
- Reduced rod load lowers torque and horse power.
- Only compression loading is on the rod.

Purity of Inlet Gas

Diaphragm compressors, by design, cannot tolerate any free liquids in the gas stream. So it is important for the source gas to be clean and dry, i.e. it does not contain water mist, droplets, oil mist, water vapor, or other gases that could condense during any phase of compressor operation through final discharge. To help maintain gas purity, we install single or dual 10-micron inlet filter systems.

Electrical/Systems Integration

- Can meet American, Japanese and European Codes and Standards.

Highly Reactive Gases Service

For compression of oxygen, fluorine, and other highly reactive gases, Pdc performs rigorous cleaning procedures in a clean, dust-free environment. We use fire-resistant Halocarbon oil for the hydraulic system.

Stainless Steel Versus Carbon Steel Fabrication Materials

Pdc’s standard material for all wetted-process components is stainless steel. Carbon steel heads and piping, though seemingly cost-effective, can result in rust formation and migration of gas in the cavity, leading to premature failure of diaphragms—increasing the cost of spares, maintenance frequency, and causing more down-time.
Benefits

The unique design of our diaphragm compressors provides the user with an exceptional product that delivers significant operational benefits, including:

- High product purity – The design and construction materials do not contaminate the process gas
- High reliability and uptime resulting in low maintenance – Customers experience life of 10,000 to 40,000 hours without the need for spare parts replacement
- Safer operation – Compressed gases cannot leak into the atmosphere or crankcase and the crankcase requires no purging
- Extremely low noise levels – 85 dbA without sound-proofing
- Compact design – Requires minimal floor space
- Multiple service – Can be used with hydrogen, CNG, and blended fuels
- Horizontally-opposed designs for optimal power consumption

Exceptional product value leads to high throughput, high productivity, and high uptime, which translates to a cost-effective product.
Applications

- Fueling fuel cell powered cars, buses, and forklifts
- Power back-up using hydrogen fuel cells for telecommunication towers and power plants
- Residential re-fuelers for fuel cell cars and power generation
- Solar power to hydrogen power
- Filling and off-loading of gases from tube trailers
- Filling gas cylinders and bulk storage tanks
- Life cycle testing of on-board tanks
- Feedstock for chemical, petrochemical and pharmaceutical industries
- Wind power to hydrogen power

Auto and Bus Fueling

- Auto fueling – Models are available for applications ranging from single auto demo sites to full-scale production sites designed to fuel 25 and more vehicles per day. Pdc offers a wide selection of compressor models that are compatible with typical compressor inlet and discharge conditions for most fueling applications. Inlet pressures of 100-200 PSIG (0.7-1.4 MPa) and discharge pressures of 3600, 7000 and 12,000 PSIG (25, 48, 83 MPa) are available with flow rates from 50 to 2000 SCFH (1 to 54 Nm$^3$/hr). Suction source can be from generators, reformers or tube trailers
- Bus fueling – Pdc offers a model featuring up to 3000 PSIG (21 MPa) suction and 6000 PSIG (41 MPa) discharge pressures with a flow rate 74,640 SCFH (2000 Nm$^3$/hr). This compressor will fill a bus in 10 minutes

Features of Pdc Compressors

- Triple diaphragm construction – Isolates process gas from hydraulic oil
- Compatible materials of construction – All process-wetted components are constructed from corrosion-resistant materials
- Filters and oil removal systems are not necessary
- Advanced cavity contour design and unique proprietary manufacturing process reduces diaphragm stresses, prolongs fatigue life and extends maintenance intervals
- Automatic positive priming – Minimizes knocks, cavitation, and vibrations, resulting in smooth start-up and operation
- Soft, high-strength plastics for check valves – Reduces leakage, improves efficiency, extends equipment life, and reduces noise levels
- High compression ratio per stage – When compared to reciprocating compressors – helps reduce capital costs
- Unique oil distribution system – Assures pressure equalization

Horizontally-Opposed Designs

- Duplex and multi-stage designs are available to accommodate a wide range of pressures and flows
- Duplex units are capable of compressing different gases simultaneously
- Simplex units are field-convertible to duplex units to increase flow
- Duplex units provide twice the flow and 1/3 Hp consumption
- Horizontally-opposed and balanced-horizontally-opposed designs reduce vibration and require minimal foundation

Electrical & Systems Integration

Complies with U.S., Japanese, and European codes and standards for electrical and piping systems for high-pressure flammable gases.
Two PDC-13-500-500 duplex compressor fully automated systems with room for third to be added later mounted on a common skid. Recirculate carrier gas for polysilicon production.

“...The solar industry will advance through a rapid transition in the development and research of materials, devices, and processes. Pdc Machines, Inc. compressors enable further advancements in our production efficiencies and enable us to decrease fabrication costs beyond that of traditional compressors, ultimately building a more cost competitive solar industry.”

Dr. York Tsuo
President and CEO, AE Polysilicon Corporation

Applications

Pdc Machines provides an extensive line of compressors with a comprehensive assortment of options. From basic units to fully-automated PLC controlled compression systems, Pdc can meet the pressures and purity needed for a wide variety of applications such as:

- Compressing high purity and specialty gases for the production of polysilicon and other solar panel coatings and substrates
- Compressing gases for crystalline and thin film photovoltaic (PV) modules for solar energy applications
- Compressing and re-cycling process gases from renewable sources
- Compressing hydrogen for fuel cell applications
- Converting wind power to hydrogen power
- Converting waste to energy
- Typical gases include hydrogen, hydrogen chloride, trichlorosilane, disilane and silane

www.pdcmachines.com
Benefits

The unique design of our diaphragm compressors provides the user with an exceptional product that delivers significant operational benefits, including:

- **High product purity** – The design and construction materials do not contaminate the process gas
- **High reliability and uptime** resulting in low maintenance – Customers experience life of 10,000 to 40,000 hours without the need for spare parts replacement
- **Safer operation** – Compressed gases cannot leak into the atmosphere or crankcase and the crankcase requires no purging
- **Extremely low noise levels** – 85 dbA without sound-proofing
- **Compact design** – Requires minimal floor space
- **Energy Efficient**-Horizontally opposed designs for optimal power consumption

Packaged Equipment

For the past 30 years, Pdc has packaged simple to complex skid mounted bench scale and pilot plant process systems. Our extensive expertise range from alternative energy catalyst research, polymer and specialty chemical development to innovative process gas development research.

Our experience spans a wide range of clients with unique and challenging process requirements. Based upon our client’s process design Pdc’s team approach to engineering, manufacturing and total project management provides the most cost effective, technically optimal and high quality solution available.

- **Our complete turnkey capabilities** encompasses concept development, engineering design, fabrication, testing, installation, commissioning, start up and training.

Electrical & Systems Integration

Complies with US and international codes and standards.
**Pdc Triple Metal Diaphragm Compressors—Feature and Benefits**

Pdc’s Diaphragm compressors are the preferred choice when contamination-free and leak-tight gas compression is required. Pdc was selected because its compressors earned a reputation for high quality, reliability, low maintenance and extended service intervals. Several customers have reported they ran the compressors from 15,000 to 40,000 hours without any parts replacement except for oil changes.

State-of-the-art engineering and manufacturing, stringent quality control procedures allowed Pdc to successfully market the most reliable compressors in the industry. To cite an example, Pdc has captured about 85% of the world hydrogen fuel cell segment, supplying compressors to 61 fueling stations.

Following is a list of features that are applicable to Pdc’s diaphragm compressors:

**State-of-the-art manufacturing facility:** All critical components are manufactured at Pdc, assuring the highest levels of quality control. This also allows us the flexibility to accommodate tight delivery schedules.

**Superior diaphragm life:** All aspects of diaphragm compressor design are intended to enhance component life, improve operability and reduce and simplify maintenance. Diaphragm cavity contours, which control stress in the diaphragms, are carefully controlled to provide uniform stress distribution. These cavity contours are computer engineered utilizing Finite Element Analysis techniques, which results in our state-of-the-art design. Special manufacturing processing is used on the diaphragm surfaces to enhance fatigue life.

**Automatic unloading system:** The compressor is automatically re-primed at start-up. Manual start-up requires an experienced compressor technician to be present all the time to re-prime the compressor. Incorrect priming will cavitate the compressor and damage the heads, bolts, diaphragms, o-rings, process and hydraulic system.

**Hydraulic oil system:** The hydraulic system is designed in such a way as to assure uniform diaphragm deflection, prevent knocks, vibration, cavitation and yield smooth, quiet compressor operation. Unique, oil distribution techniques are employed to eliminate pressure differentials and gradients. The system utilizes an automatic priming pump, positive displacement high-pressure injection pump and oil relief valve with bypass valve for easy and smooth starting.

**High Product purity:** Triple diaphragms isolate the process gas from the hydraulic oil.

**Environmentally safe:** Pdc uses static seals. Therefore the crank-case does not require purging or vented. Therefore, there is no leakage to the atmosphere.

**Corrosion resistant wetted materials:** All process contacting parts are made from stainless steel and high strength polymers. This insures no rust or gas migration into the cavity leading to pre-mature failure of the diaphragms, increasing the cost of spares, increasing maintenance frequency and more down-time.

**Safety interlocks:** Features include alarms and shutdowns for low suction, high discharge, low oil, low water coolant, diaphragm and or o-ring failure. The compressor will be completely instrumented for automatic operation.

*For additional information please refer to the Technical Bulletin and Compressor Brochure*