



Double Diaphragm Pumps Concept and Theory

Double Diaphragm Pump

Double Diaphragm Pumps use compressed air as the power source. They are frequently used for fluid transfer, low pressure spray, and other lower pressure applications requiring less than 120 psi (.85 MPa, 8.5 bar).

Component Identification and Function

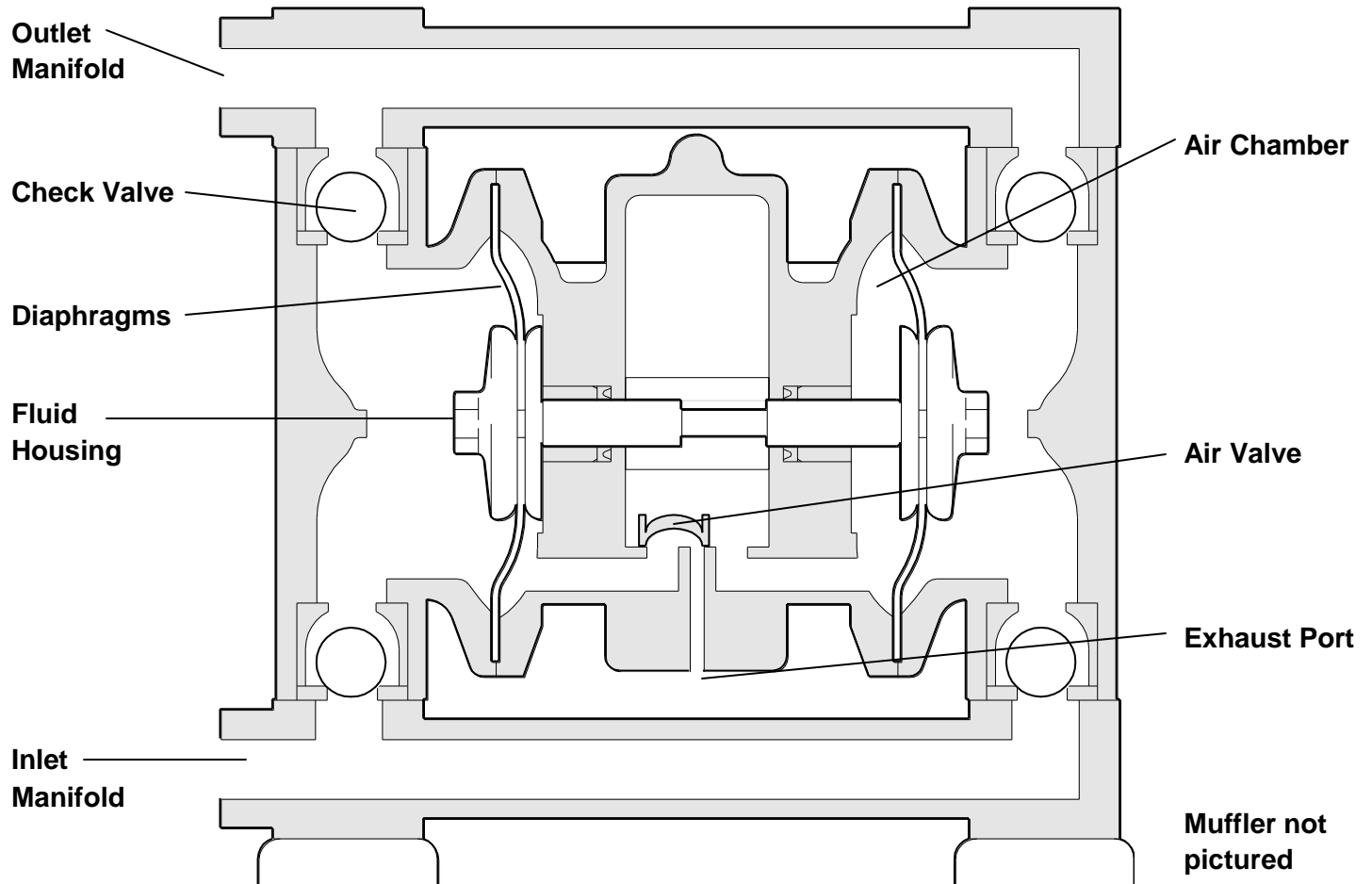


Figure 1 Double Diaphragm Pump Component Identification

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Air Chambers

Compressed air flows into or out of the air chambers. The pump has a right and a left air chamber.

Fluid Housings

The fluid being pumped will flow through the fluid housings. Each pump has a right and a left fluid housing.

Diaphragms

Diaphragms separate the air chambers and fluid housings in the pump. The diaphragm is a material that will flex with increasing or decreasing air pressure. A common shaft connects the two diaphragms.

Inlet Manifold

Fluid flows from the fluid container through the inlet manifold either to the right or left fluid housing.

Outlet Manifold

Fluid flow out of the right or left fluid housing past the check valves, then through the outlet manifold.

Air Valve

The air valve directs compressed air to either the right or left air chamber. The air valve consists of a triggering mechanism, a valve cup, and a valve plate. The air valve directs compressed air through a port to one of the air chambers while the opposite air chamber is directed to the exhaust port.

Check Valves

A double diaphragm pump has four fluid check valves, two inlet check valves, and two outlet check valves. The check valves control the fluid through the fluid housings and manifolds of the pump. Most double diaphragm pumps use ball type check valves. For a thorough explanation of check valve operation refer to the Fluid Controls module.

Muffler

The muffler minimizes the noise of the exhaust air. Different mufflers provide different levels of noise reduction.

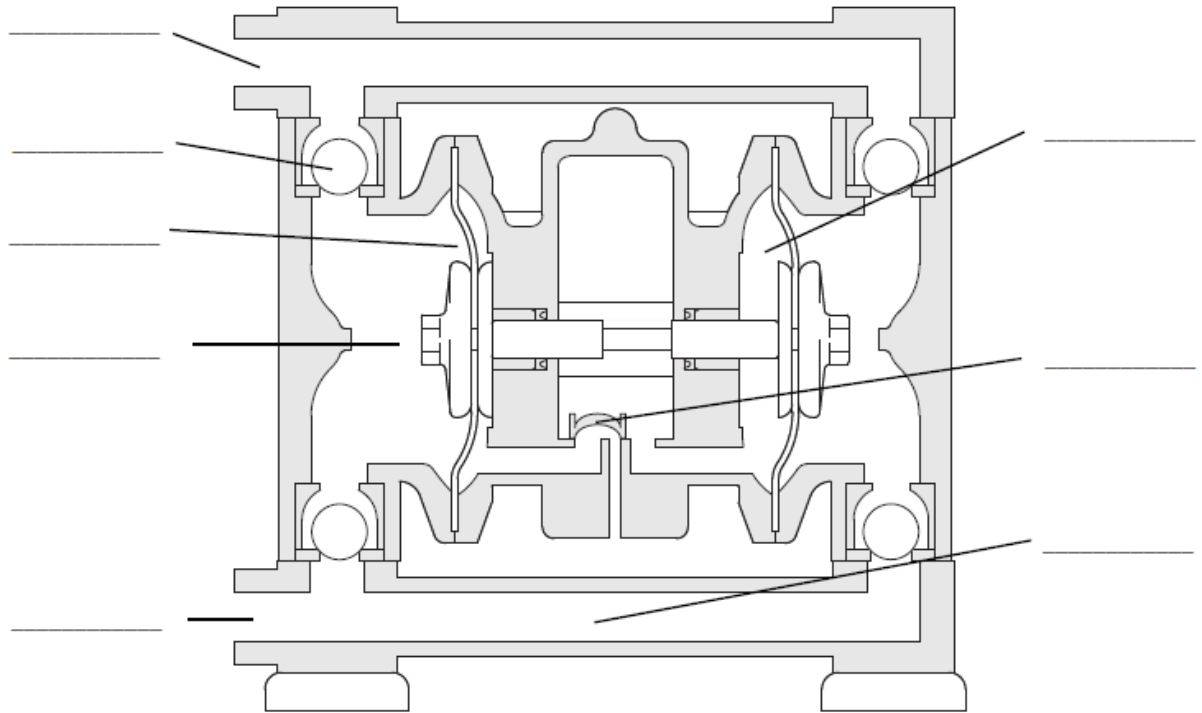
Wetted Parts

The wetted parts include all parts that come into contact with the pumped fluid. They include the inlet manifold, ball checks and seats, diaphragms, fluid housings, and outlet manifold.

Progress Check

Directions: After answering the following questions, compare your answers with those provided in the answer key following the progress check. If you respond to any items incorrectly, return to the text and review the appropriate topics

1. Fill in each space provided with the name of the component.



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Answers to Progress Check

1. (See Figure 1.)

Double Diaphragm Pump Operation

To help clarify the operation of the Double Diaphragm Pump we will divide the operation as follows. First we will describe the fluid flow. Then we will describe the air flow. Then we will describe the air valve triggering mechanisms used in Graco Double Diaphragm pumps. We will refer to the pump operation as the “right” or “left”. This is to aid in description only and bears no significance in real application.

Part 1: Moving Fluid

Compressed air flows into the right air chamber, causing the right diaphragm to flex. This expansion creates a high pressure in the right fluid housing equal to the air pressure applied to the pump. The inlet check valve (4) of the right fluid housing closes, the outlet valve (2) opens, and the fluid is pumped through the outlet manifold. The pump shaft moves right, creating a vacuum in the left fluid housing. The left inlet check valve (3) opens, the left outlet valve (1) closes, and the fluid flows into the left fluid housing. See Figure 2 for an illustration of the cycle.

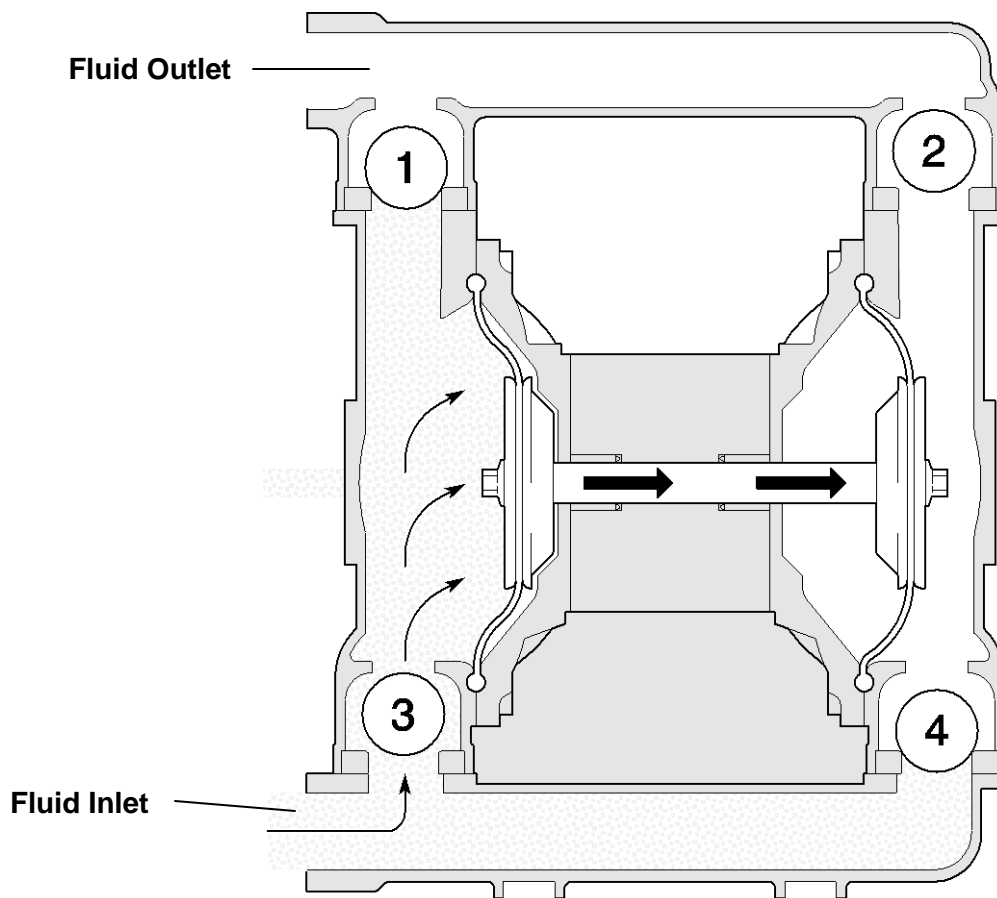


Figure 2 Pumping Fluid: movement to the right

At the end of the pump stroke the air valve switches and compressed air will flow into the left air chamber, causing the left diaphragm to flex. The inlet check valve (3) of the left fluid housing closes, the outlet valve (1) opens, and the fluid is pumped through the outlet manifold. The pump shaft moves left creating a vacuum in the right fluid housing. The right outlet valve (2) closes, the right inlet check valve (4) opens, and the fluid flows into the right fluid housing. See Figure 3.

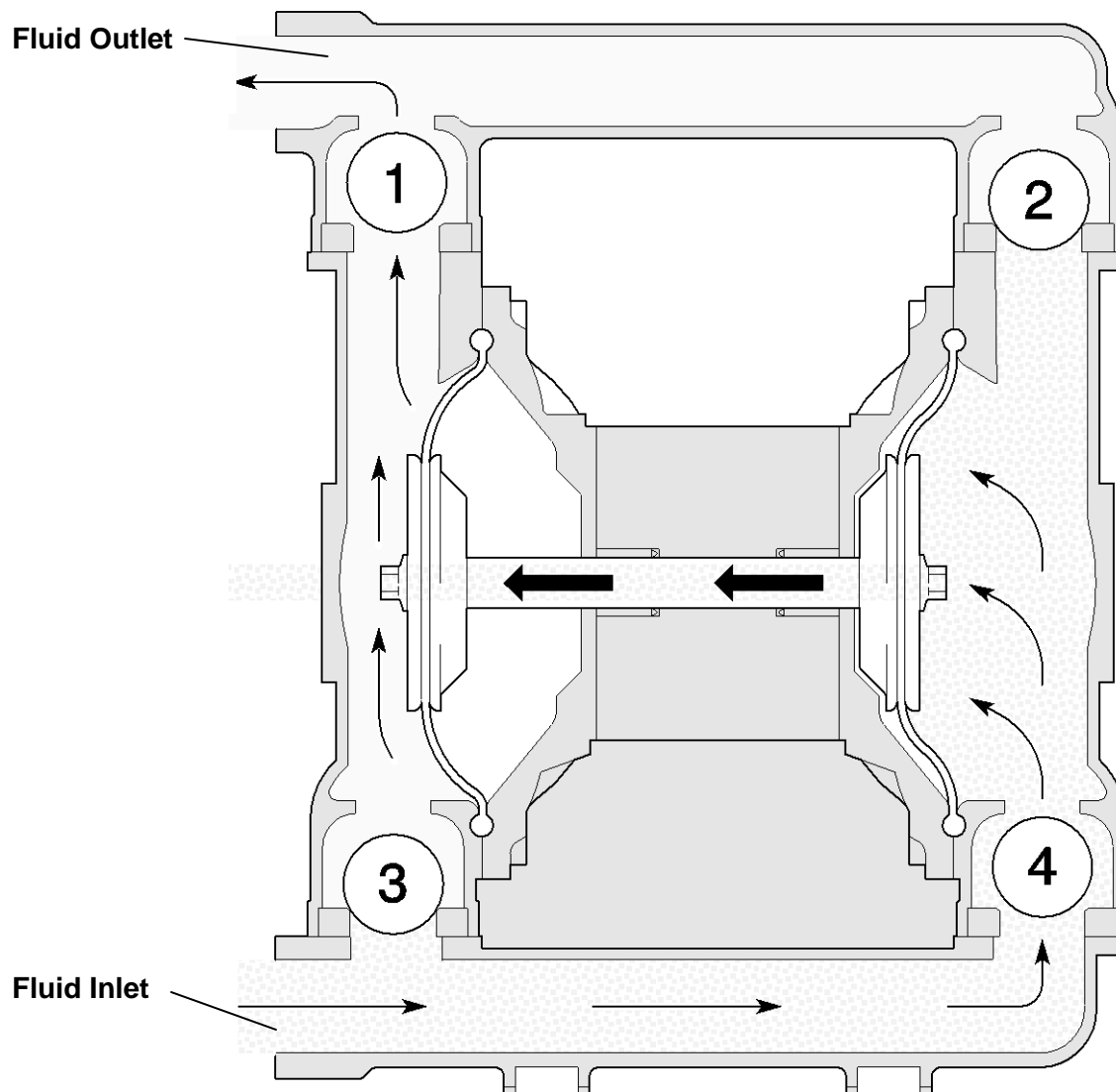


Figure 3 Pumping Fluids: movement to the left

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Progress Check

Directions: After answering the following questions, compare your answers with those provided in the answer key following the progress check. If you respond to any items incorrectly, return to the text and review the appropriate topics.

1. The flow of fluid is controlled by:
 - a. Check valves
 - b. Valve cup
 - c. The muffler
2. Compressed air pressurizes the pump fluid to a pressure _____ the applied pressure.
 - a. equal to
 - b. much higher than
 - c. much lower than

Answers to Progress Check

1. A.
2. A.

Part 2: Air Flow Operation

To understand how the pump functions, you must understand how it is controlled or triggered. There are two types of air valve triggering mechanisms used in Graco pumps: mechanically actuated and pilot operated.

Air Flow with Mechanical Triggering

With the air valve in the left position, the left air chamber is connected to the exhaust port; compressed air will flow directly into the right air chamber. The diaphragm shaft moves to the right.

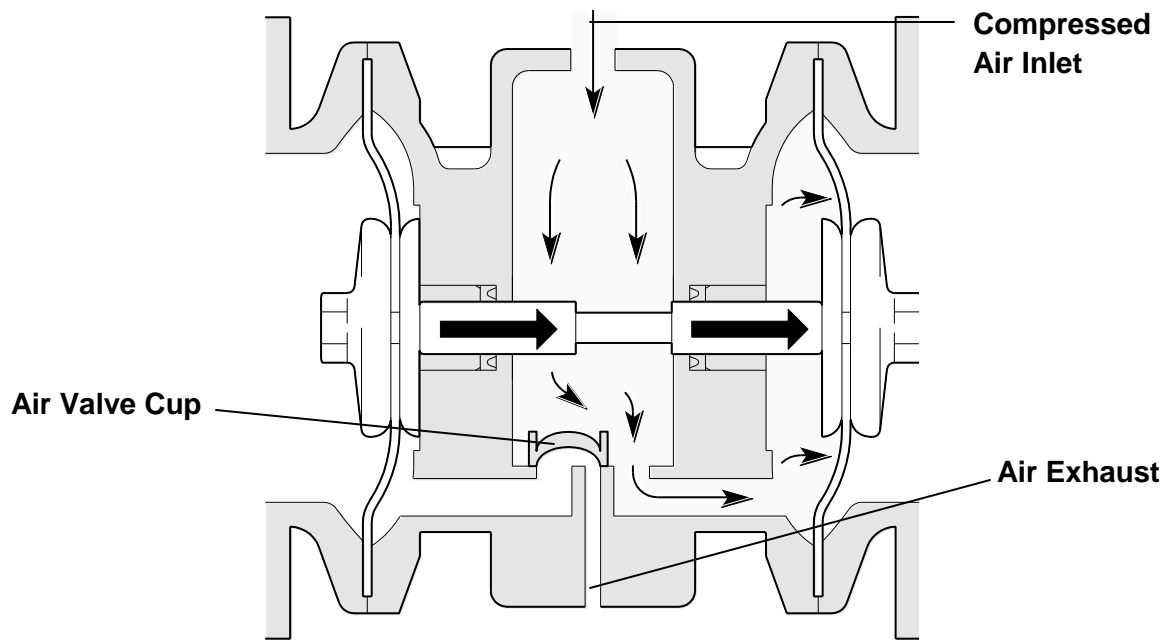
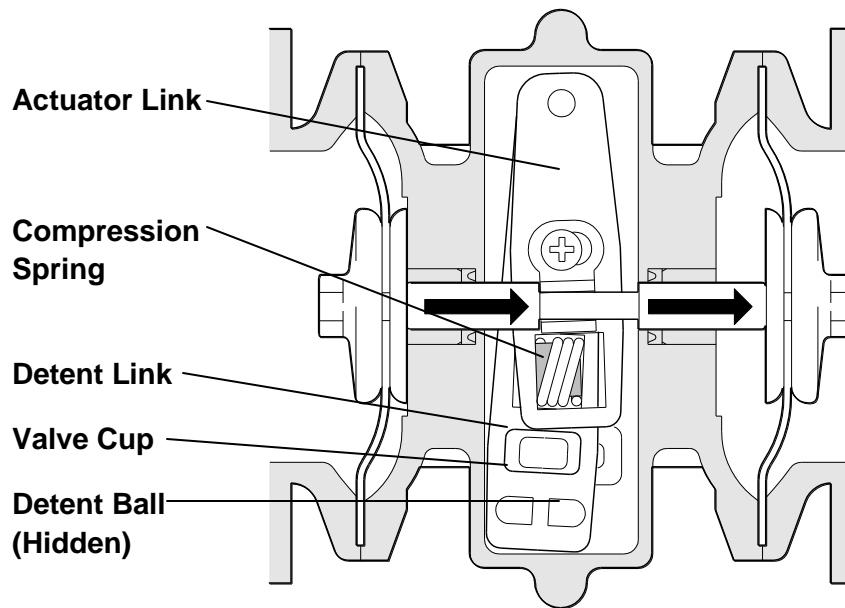


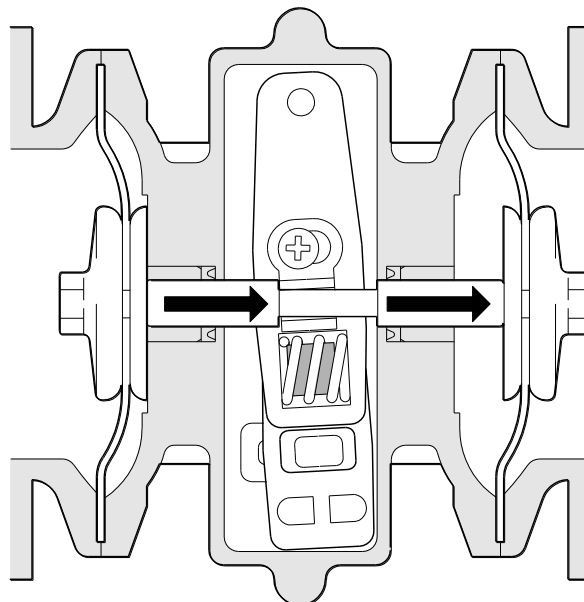
Figure 4 Air Valve in the Left Position

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In the illustration in Figure 5, the air pressure moves the diaphragm shaft to the right and through mechanical contact pushes the actuator link. The actuator link contacts a compression spring which contacts the detent link. The detent link carries the valve cup and is held in position by a ball and spring creating a mechanical detent. When the spring force between the actuator and detent links is great enough, it will overcome the force of the detent and the detent link will snap over to the right side. Now the valve cup is connecting the right air chamber port and exhaust port.



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Figure 5 Mechanical Air Valve Triggering

With the air valve in the right position, connecting the right side air chamber with the air exhaust, inlet air will flow directly into the left air chamber. As the diaphragm shaft moves to the left, it contracts the actuator link. As the shaft moves, force increases until the actuator overcomes the detent spring force. Then the detent link snaps over to the left and the cycle repeats itself.

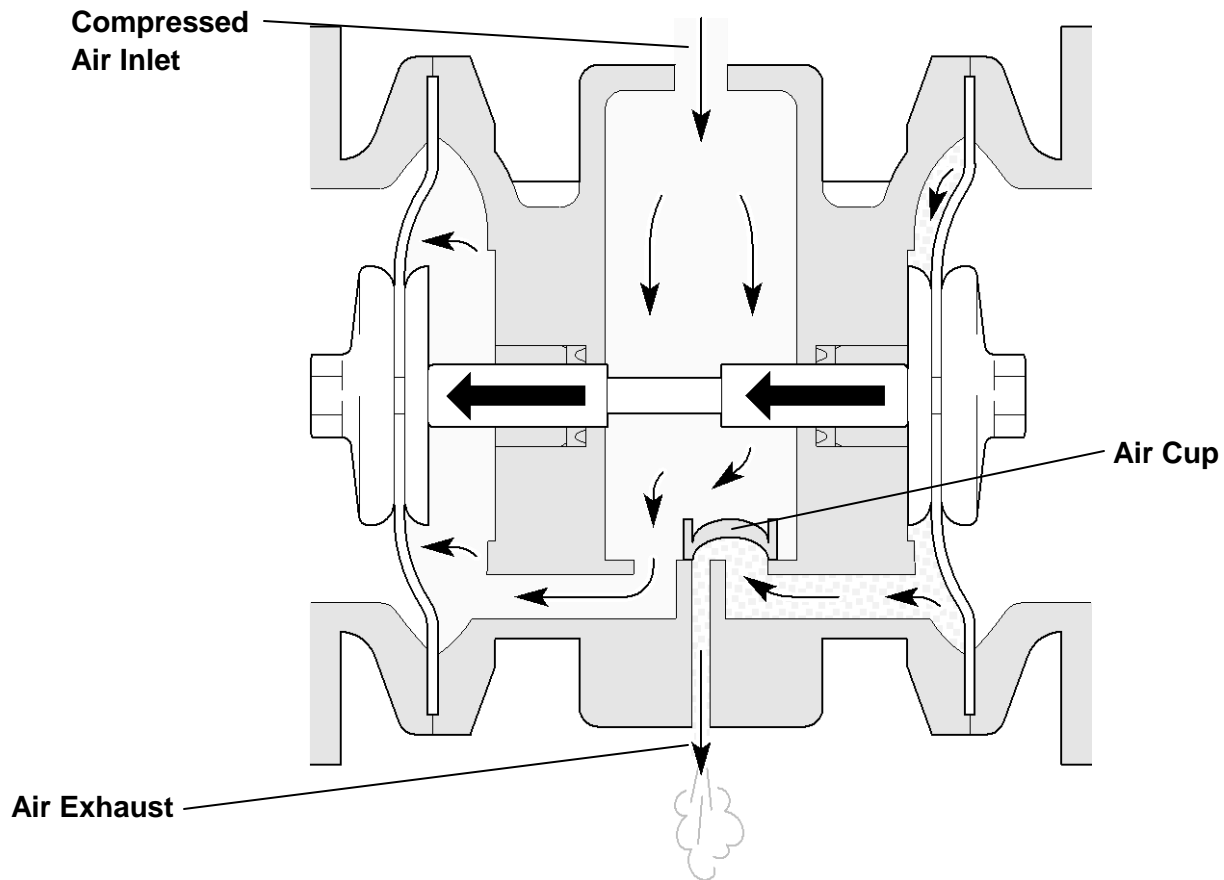


Figure 6 Air Valve in the Right Position

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Progress Check

Directions: After answering the following questions, compare your answers with those provided in the answer key following the progress check. If you respond to any items incorrectly, return to the text and review the appropriate topics.

1. The air flow is directed by the _____.
2. When the valve cup connects the right air chamber with the exhaust port, what is happening to the left air chamber?

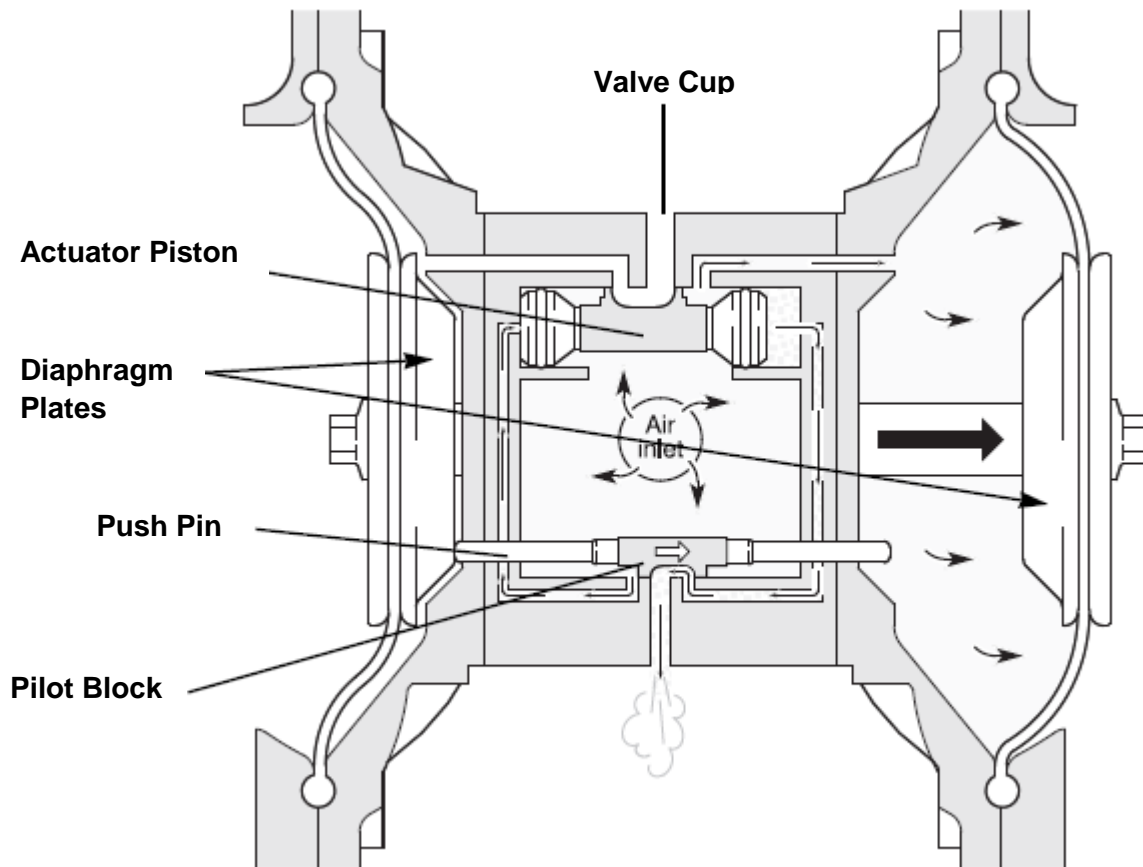
3. The valve cup is attached to the actuator link on a mechanical triggering mechanism.
 - a. True
 - b. False

Answers to Progress Check

1. Valve Cup
2. It is pressurized by compressed air flowing into it through the left inlet port.
3. True

Pilot Operated Triggering

In Figure 7 the diaphragm plates move to the right and the left side contacts the push pin and pushes it to the right. The push pin is attached to a cup that is similar to the valve cup previously covered. This cup is called the pilot block. When the pilot block is in the right position, it connects the right pilot port to the pilot exhaust port.

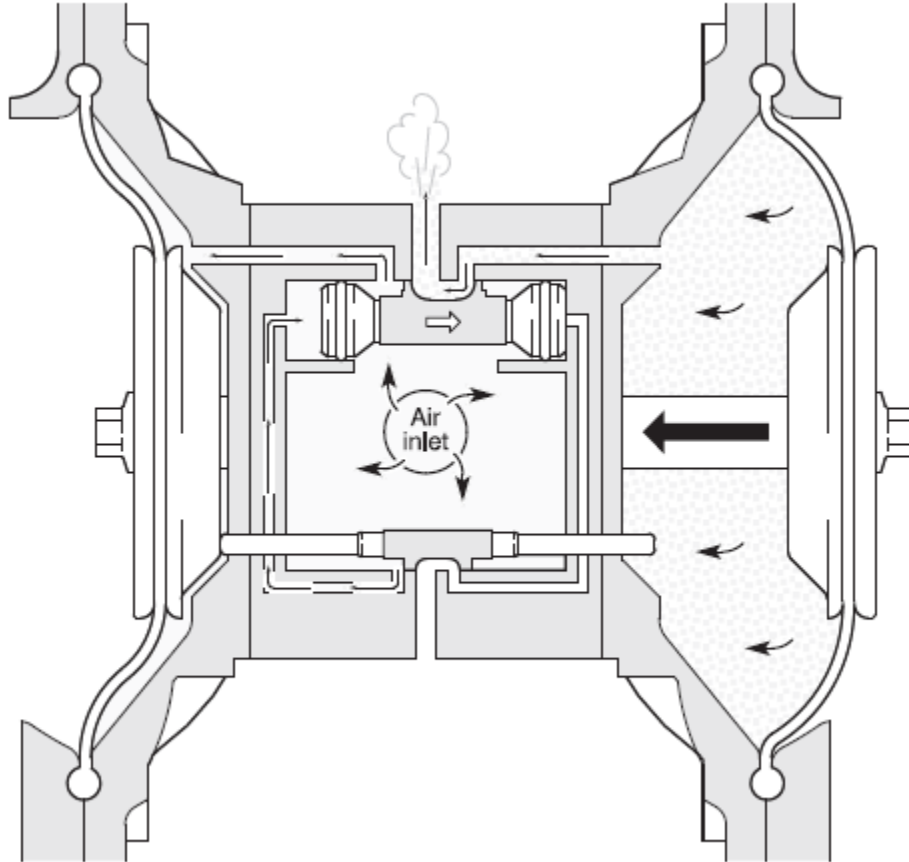


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Figure 7 Pilot Valve Triggering Mechanism: Pilot Block Moves to the Right

The exposed left pilot port allows the compressed air to flow through the channel to the left side of the actuator piston. Since the right side is open to exhaust the air pressure in the left chamber forces the actuator piston to move to the right.

As the actuator piston moves to the right, the right air chamber is exposed to the exhaust port through the air valve cup. Now the compressed air will flow through the left air chamber port and pressurize the left air chamber. The diaphragm assembly will move to the left. See Figure 8.



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Figure 8 Pilot Valve Triggering Mechanism: Actuator Piston and Valve Cup Move to the Right

In the next cycle the diaphragm plates move to the left and as the right plate approaches the end of its stroke pushes the push pin and pilot block along with it. See Figure 9. When the pilot block is in the left position it connects the left pilot port and the exhaust port. The exposed right pilot port allows the pressurized air to flow through the channel to the right side of the actuator piston.

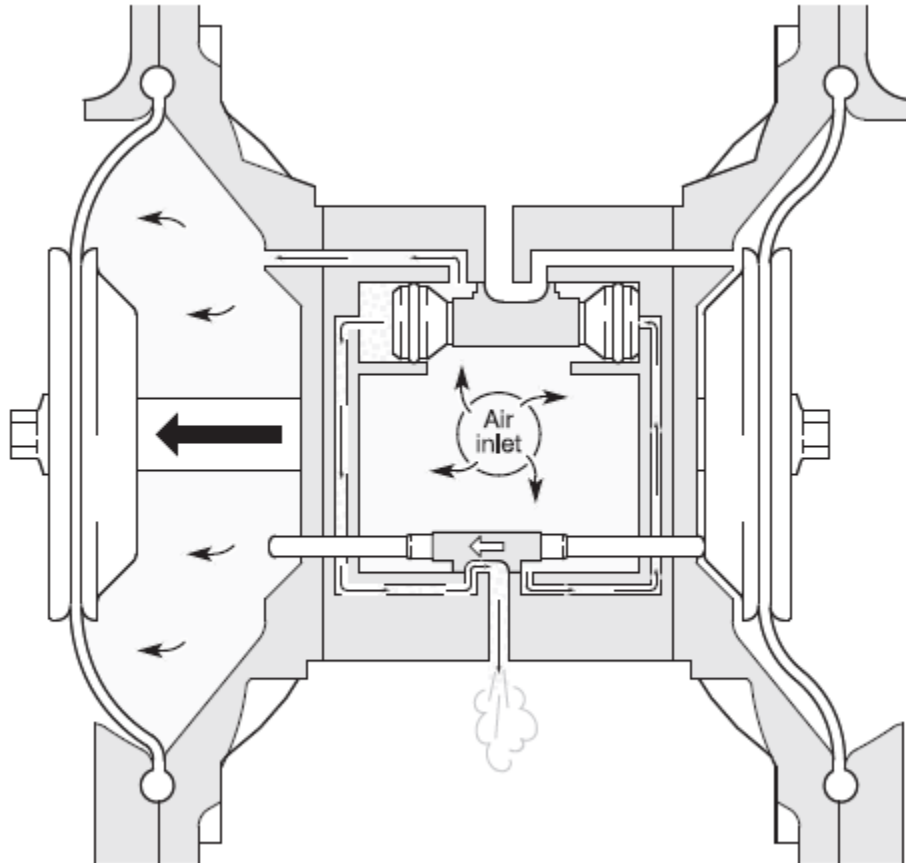
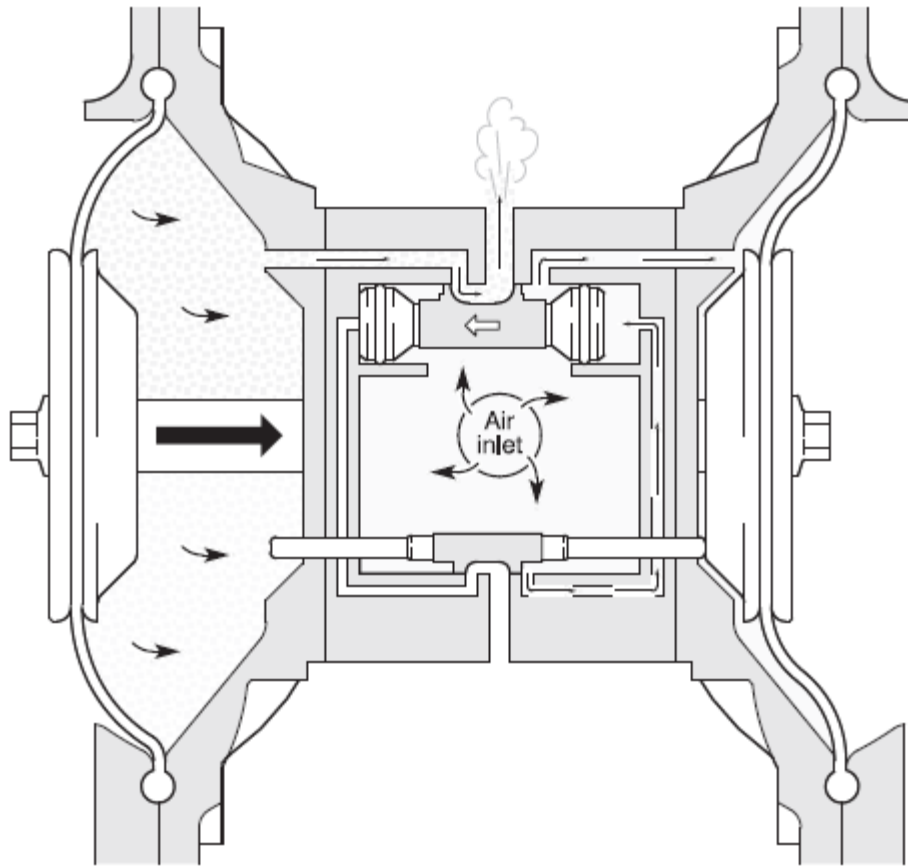


Figure 9 Pilot Valve Triggering Mechanism: Pilot Block Moves to the Left

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Since the left side is open to exhaust the air pressure in the right chamber forces the actuator piston to the left. The air valve cup connects the left air chamber port to the exhaust port.



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Figure 10 Pilot Valve Triggering Mechanism: Actuator Piston and Valve Cup Move to the Left

Now the compressed air will flow through the right air chamber port and pressurize the right air chamber, causing the diaphragm to move to the right. See Figure 10.

In this type of triggering, the large area of the diaphragm has only a small pilot block to move, making it easy to direct the air valve to move. The link between the diaphragm movement and the air valve movement occurs pneumatically (air pressure).

Whole Pump Operation

Up until now, we have treated the fluid movement and the air operation separately, but these operations work together. The following section discusses the two operations together. The following figures are of the pilot triggered mechanism.

Air flows through the air inlet of the pump to the right air chamber port and into the right air chamber. The diaphragm flexes, pressurizing the fluid in the right fluid housing. As in Figure 11, the inlet check valve of the right side manifold closes and the outlet check opens. The diaphragms, connected by a shaft, flex together; when the right air chamber is pressurized, the left air chamber exhausts. When the shaft pulls back it creates a vacuum in the left fluid housing. The outlet check valve closes and the inlet check opens allowing fluid to flow in through the inlet manifold and into the left fluid housing. The movement of the diaphragm to the right triggers the air valve so the valve cup moves to connect the right air chamber port with the exhaust port.

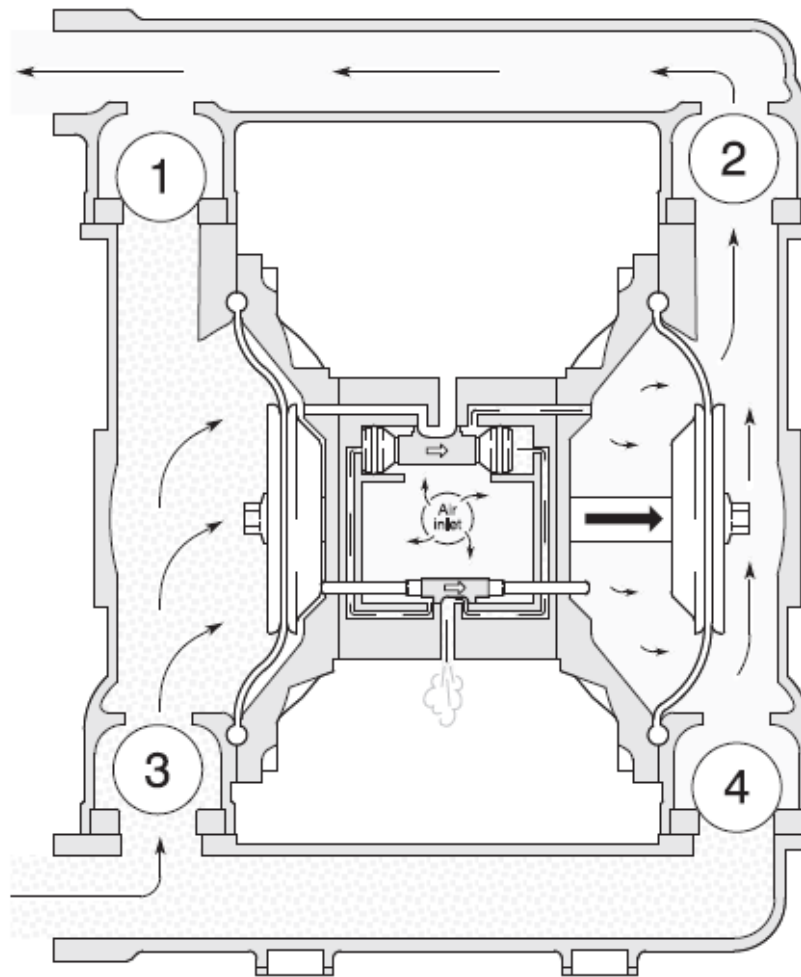


Figure 11 Whole Pump Operation (right). Pilot Triggered

Air now exhausts from the right chamber. The compressed air flows into the left air chamber and flexes the diaphragm. The air causes the left diaphragm to flex, pressurizing the left fluid housing. As in Figure 12, the inlet check in the left fluid housing closes and the outlet check opens, causing fluid to flow through the outlet manifold of the pump.

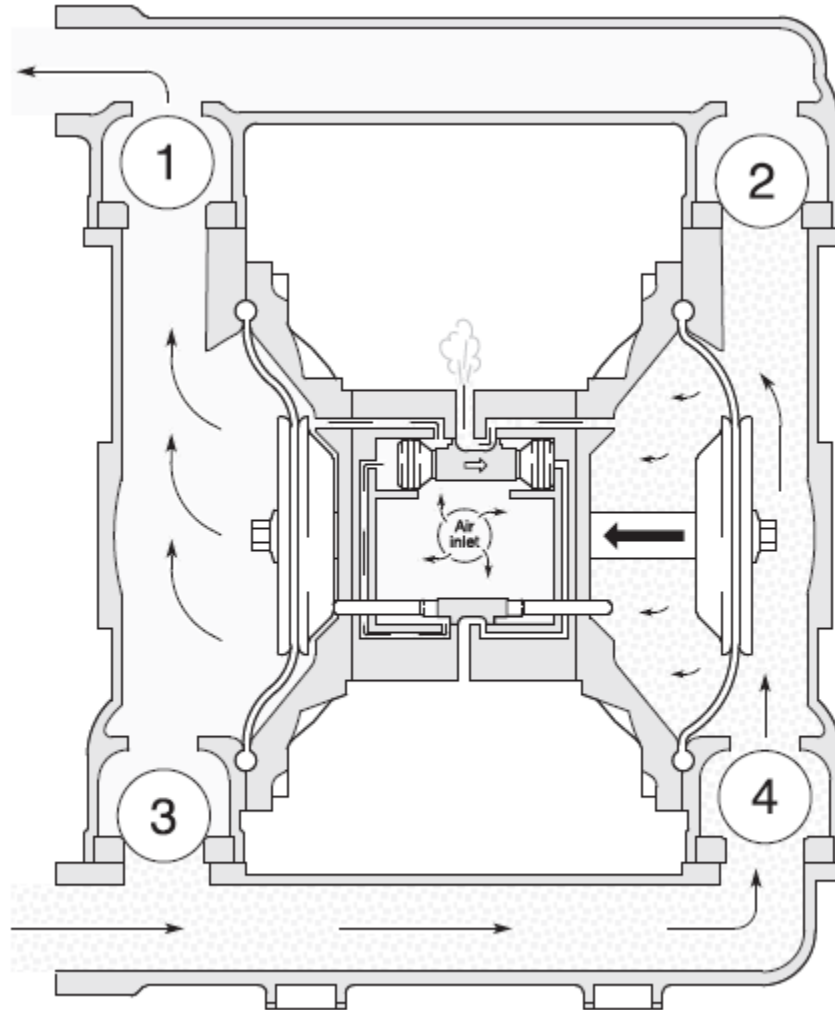


Figure 12 Whole Pump Operation (left). Pilot Triggered

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Progress Check

Directions: After answering the following questions, compare your answers with those provided in the answer key following the progress check. If you respond to any items incorrectly, return to the text and review the appropriate topics.

1. Name two types of triggering mechanisms.
_____ and _____.
2. When the valve cup changes direction, the diaphragm pump changes direction.
 - a. True
 - b. False
3. In a pilot operated triggering mechanism, there is a direct mechanical linkage between the diaphragm movement and the valve cup.
 - a. True
 - b. False

Answers to Progress Check

1. Mechanical and air pilot
2. True
3. False

Summary

Compressed air drives double diaphragm pumps. Compressed air, directed by the air valve, enters either the right or left air chamber and exhausts from the opposite chamber. This causes the diaphragms to reciprocate back and forth, causing fluid to be loaded and dispensed.

Materials of Construction

The following is a list of materials used in Graco Double Diaphragm Pumps. The list tells you which components may be made of these materials and advantages and disadvantages of each. Not all materials are available for all models. Refer to product literature for availability.

Acetal – Material used for balls and seats. (Grounded acetal is used for housings.)

- Wide range of solvent resistance
- Withstands extreme fatigue
- Good levels of abrasion resistance
- Low friction
- Low moisture absorption

Aluminum – Material used for air motor (air valve) and wetted parts.

- Strong – withstands impact
- Heat resistant
- Resists abrasion
- Medium corrosion resistance – fluid housings are anodized
- Epoxy coated when used as an air motor housing
- General purpose
- Not for use with HHCs (Halogenated Hydrocarbons)

Groundable Acetal – Material used for wetted parts.

- Good solvent and coating resistance; water borne compatible
- Groundable for use with flammables

Hardened Stainless Steel – Material used for seats.

- Moderate chemical resistance
- High abrasion resistance

Poly-vinylidene fluoride (PVDF) – Material used for wetted parts and seats.

- Strong chemical resistance – close to Polytetrafluoroethylen (PTFE)
- Excellent compression strength
- Good abrasion resistance
- Acceptable with higher temperatures

**Virgin Polypropylene – Material used for wetted parts and seats.
(Air motor – glass filled polypropylene.)**

- Moderate abrasion resistance
- Wide chemical compatibility
- General purpose

Stainless Steel – Material used for wetted parts, seats, and balls.

- High level of corrosion resistance (316 grade)
- Best for abrasion resistance
- Passivated for use with water base coatings
- Rugged

Buna-N – Material used for balls and diaphragms.

- Resists petroleum based fluids
- Not for strong solvents or materials
- Best at room temperature

Thermoplastic polyester elastomer (TPE) – Material used for seats, balls, and diaphragms.

- Good with abrasion
- Handles general mild fluids
- Lowest price
- Often substituted for Buna-N
- Not for high temperatures

Santoprene – Material used for seats, balls, and diaphragms.

- High abrasion resistance
- Wide chemical resistance
- Not for use with solvents
- Higher temperatures than TPE
- Can substitute for EPDM or EPR

PTFE – Material used for seats, balls, and diaphragms.

- Chemically inert to most fluids
- Excellent when used with solvents
- Can use for high temperature
- Poor abrasion resistance
- Widest compatibility with fluids
- Highest price

Fluoroelastomer – Material used for seats, balls, and diaphragms.

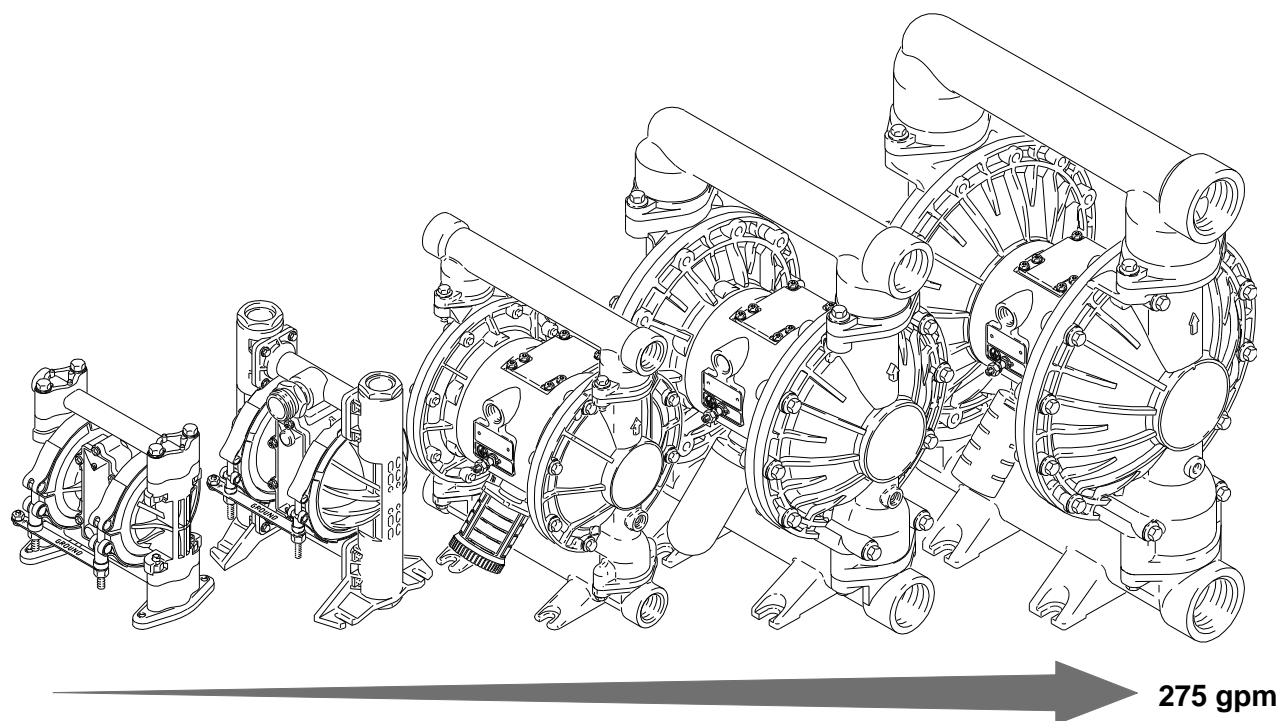
- High level of corrosion resistance with acids
- Resists unleaded fluids

Ceramic – Material used for balls.

- Good abrasion resistance
- High density for high viscosity fluids
- Fast ball close for smoother flow

Pump Application

Graco sells a variety of double diaphragm pump models with different fluid delivery capability. Fluid delivery can exceed 275 gpm (1040 lpm) with larger pump models. All double diaphragm pumps have a fluid to air ratio of 1:1. This means the fluid pressure of the pump will be approximately equal to the air inlet pressure. Maximum air inlet pressure can be 50 to 120 psi (.34 to .83 MPa, 3.4 to 8.3 bar) depending on pump model. See product information.



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Figure 13 Graco Double Diaphragm Pump Line

The large fluid delivery capability of this pump makes it ideal for transfer applications. The low pressure operating feature makes this pump ideal for low pressure supply including spraying applications. Common applications of this pump include bulk tank supply, waste fluid evacuation, sludge evacuation, spraying or dispensing adhesives, conventional air spray supply pump for paints and coatings, and for transferring acids, and caustics.

Advantages

Pump Advantages:

- High fluid delivery rates at low fluid application pressure; less than 120 psi (.85 MPa, 8.5 bar). This large fluid delivery capability makes double diaphragm pumps ideal for transfer applications
- Easy to install on a cover, pail, wall, or submerged
- Many diaphragm options for fluid versatility with extended pump life
- Air power offers convenience for many installations, no electrical hazard, an stall against pressure efficiency
- Extremely portable
- Handles a wide variety of fluid viscosities, abrasive, and corrosive qualities
- Seal-less, leak-proof design prevents fluid waste, mess, and hazard
- Can run dry without damage

Air Valve Advantages

- The air valve is the principal feature that differentiates this pump from the competition
- Not dependent on the air being clean, dry, or containing oil
- Allows for easy on line maintenance of the pump; decreased repair time and cost
- Uses fewer seals compared to other designs; reduces mechanical friction within the valve, eliminating the need for lubricated air
- Operates on very little air pressure, 15 psi (.1 MPa, 1 bar) or less, allowing the pump to cycle at low flow rates
- Creates a more gentle pumping action during high flow rates. Some applications require a more gentle pump action such as more shear sensitive fluids like flexographic ink and water base adhesives, which can froth or foam if agitated or sheared too aggressively
- The low operating pressure is useful when spraying materials at very low flow rates, such as applying stains for shading or specking on wood furniture
- Works well when there is fluid inlet head pressure

Limitations

- Not for high pressure applications. The fluid to air rotation relationship of all Double Diaphragm Pumps is 1:1, meaning if 100 psi (.69 MPa, 6.9 bar) of compressed air is applied to pump, theoretically we will only achieve 100 psi (.69 MPa, 6.9 bar) of fluid output. Graco does not recommend operating the pump at air pressures higher than the pump rating.
- More surge than other pumps. An accumulator (surge suppresser) will reduce surging in applications where surging is not acceptable.
- Air consumption in a continuous duty operation may result in higher energy consumption than other pump styles
- Cannot pump stringy, viscous fluids

Trade Names

Graco sells the Double Diaphragm Pump under the trade name Husky.

Self Check

Instructions: Answer each of the following questions. The answers to this self check are at the end. Cover the answers while completing the self check. If you get less than 80% correct, you may want to review the module for reinforcement.

1. Double diaphragm pumps are low volume and high pressure pumps.
 - a. True
 - b. False
2. The fluid chambers of double diaphragm pumps are driven by differential air motors.
 - a. True
 - b. False
3. Identify the major market application(s) for a double diaphragm pump.
 - a. Grease
 - b. Sealants and adhesive
 - c. Transfer
 - d. Foods
4. What is Graco's trade name for double diaphragm pumps?
 - a. Check Mate
 - b. Dura-Flo
 - c. Husky
 - d. High-Flo
5. A double diaphragm pump will load both chambers at the same time.
 - a. True
 - b. False

6. A double diaphragm pump exhausts compressed air on the side of the pump that is loading material.
 - a. True
 - b. False
7. In a pilot operated triggering mechanism, the pilot block directs air into and out of the air chambers.
 - a. True
 - b. False
8. The shaft retracting the diaphragm creates a _____ in the corresponding fluid housing.
9. Air flow is directed by the _____.
10. Check valves will prevent pump fluid from flowing back into the source container.
 - a. True
 - b. False
11. A double diaphragm pump with 50 psi (.34 MPa, 3.4 bar) supplied will have an output pressure closest to:
 - a. 100 psi (.69 MPa, 6.9 bar)
 - b. 50 psi (.34 MPa, 3.4 bar)
 - c. 25 psi (.17 MPa, 1.7 bar)
 - d. Need more information to answer
12. The air valve in the Graco double diaphragm pump is a key feature that distinguishes the pump from the competition.
 - a. True
 - b. False

Answers to Self Test

1. False
2. False
3. C.
4. C.
5. False
6. True
7. False (The pilot block changes the direction of the actuator piston)
8. Vacuum
9. Air Valve
10. True
11. B.
12. True