

Flat Plate and Differential Air Motors

Concept and Theory Training



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Graco, Inc.
P.O. Box 1441
Minneapolis, MN 55440-1441

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Introduction

Welcome to Graco's *Flat Plate and Differential Air Motors*, a learning module in Graco's concept and theory sales training series. Your understanding of the information in this module provides the basis for further study on specific Graco products. Your ability to successfully promote and sell Graco products depends in part on how well you learn the basics and then apply this knowledge to addressing your customers' needs.

While this curriculum best fits the requirements of Graco and distributor sales people, it will also benefit anyone whose job function depends on knowledge of Graco's products.

Overview

Graco manufactures a complete line of air-powered reciprocating piston pumps. Each of these pumps is driven by an air motor operating on compressed air. Air motors supply the force required to reciprocate the pump by converting air pressure, up to 180 psi (12.4 bar), into mechanical force.

Graco's air motors are divided into two basic families: Differential Air Motors and Flat Plate Air Motors. This module covers the basic components and operational design features of both types of air motors.

Graco offers six differential air motor models, the Fast-Flo™, Fast Ball, Standard, Monark, Fireball and President. Graco differential air motors are very similar in design. The biggest variation is their physical size.

Graco also offers five flat plate air motor models, the Eagle, Senator, Bulldog, King and Premier. The Senator, Bulldog and King models are the most commonly used. They are similar in design, but differ in size.



How to Use this Module

The basic concept and theory curriculum consists of a series of self-study modules. As the term self-study implies, you work through the materials on your own at a comfortable pace. Plan sufficient time (approximately 30 minutes) to complete at least one section of a module in a working session.

This module combines a variety of features to make the learning process convenient and productive:

- Learning Objectives
- Text
- Charts, illustrations
- Progress checks
- Additional resources

Learning Objectives

Each section of material offers a set of learning objectives. Read the objectives and use them to guide you to the most important concepts. After you finish each section and before you complete the progress check, reread the objectives to confirm that you understand the key concepts.

Text

Definitions, examples and explanations comprise the learning module text. Read it carefully and return for review if necessary.

Charts, Illustrations

An important element of any instruction is visualizing the concepts. This module contains graphics and illustrations to enhance the text material and aid your learning. Where appropriate, the module also contains charts that help you organize or summarize information.

Progress Checks

Progress checks are self-tests that provide reinforcement and confirm your understanding of important topics. After completing each section of the module, return to review the objectives, and then work through each of the progress checks items. Upon completion, check your answers against those provided. If you answered any incorrectly, return to the text and reread the pertinent information.

Additional Resources

This module may refer you to other documents or sources that expand on the concepts covered in the module. The reference will include the name of the source and how you can obtain it.

Reference Materials:

Graco's Concept and Theory Training Modules:

- Pump Ratio and Performance Charts - Module #321-042
- Two-Check and Priming Piston Pumps - Module #321-044
- Four-Check Piston Pump - Module #321-045

Air Motor Operation and Component Identification

Learning Objectives

Understanding how flat plate and differential air motors operate will help you recommend Graco equipment. After completing this section, you will be able to:

- Identify the components of the flat plate and differential air motor and describe their function.
- Identify and explain the operating cycle of the flat plate and differential air motor.
- Describe the flow of compressed air through a flat plate and differential air motor from the air inlet to the exhaust.

Flat Plate Air Motor - Component Identification

The *Air Inlet* connects the motor to the compressed air supply.

The *Air Manifold* provides air passages for compressed air to the air valve and exhaust air out of the motor.

One of the unique characteristics of Graco air motors is the large porting which allows air to pass quickly to the top or bottom side of the piston. This results in a very rapid change-over and smoother fluid flow and pressure from the pump.

Figure 1 shows the air inlet, the air manifold, the air valve assembly and the valve plate of a flat plate air motor.

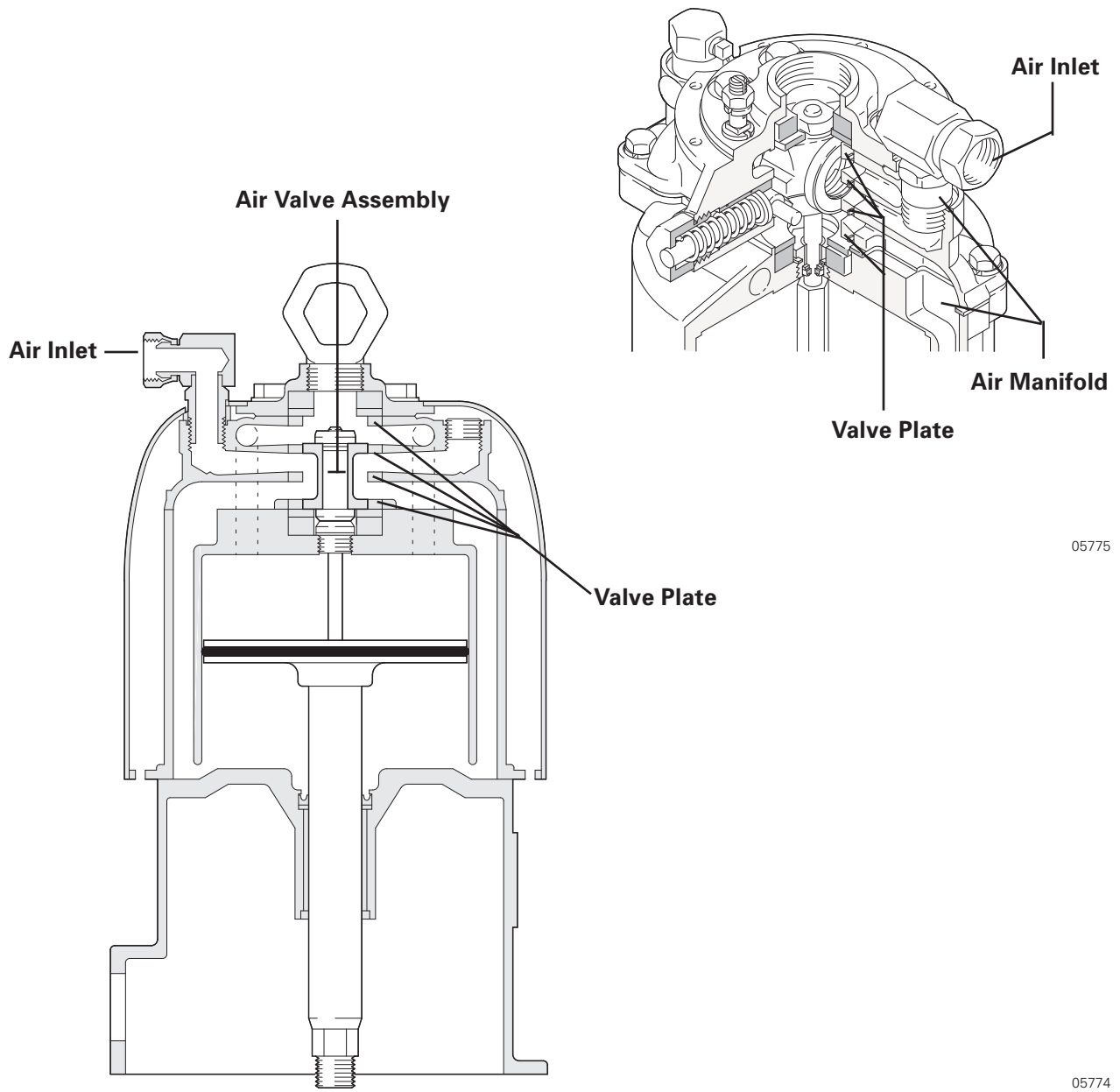
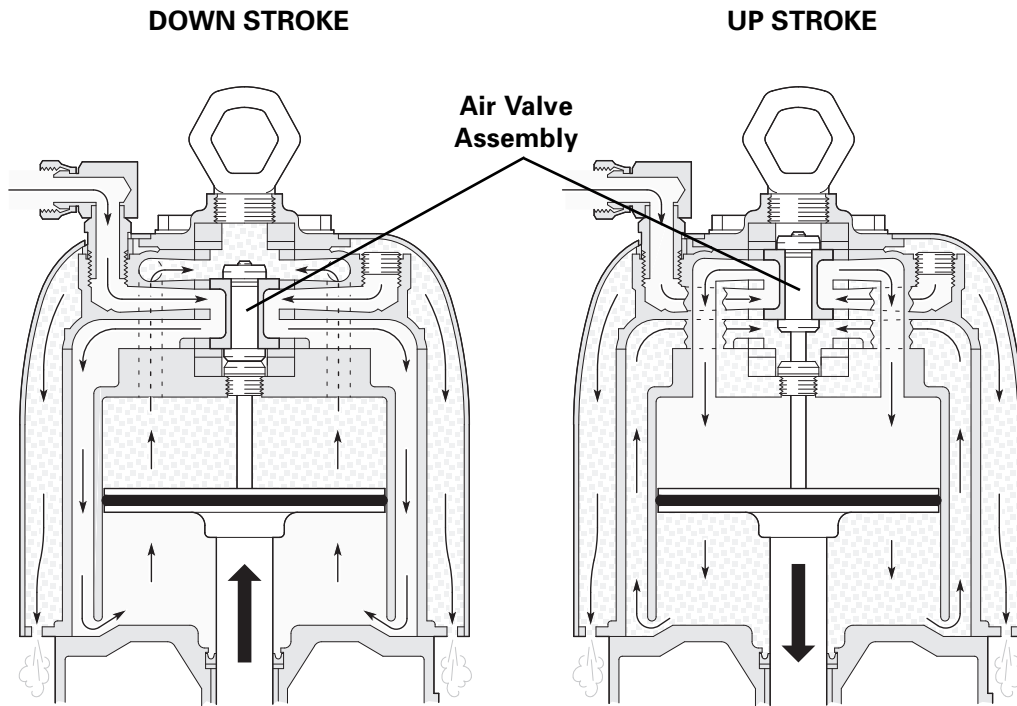


Figure 1 Component Identification.

The *Air Valve Assembly* provides directional control of air flow through the motor. Valve position determines whether the motor piston goes up or down (Figure 2).

The *Valve Plate* acts as a bearing surface upon which the air valve assembly slides upon and seals against. The valve plate contains the ports that direct air to the air valve assembly.



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Figure 2 Air Valve Assembly Directional Control.

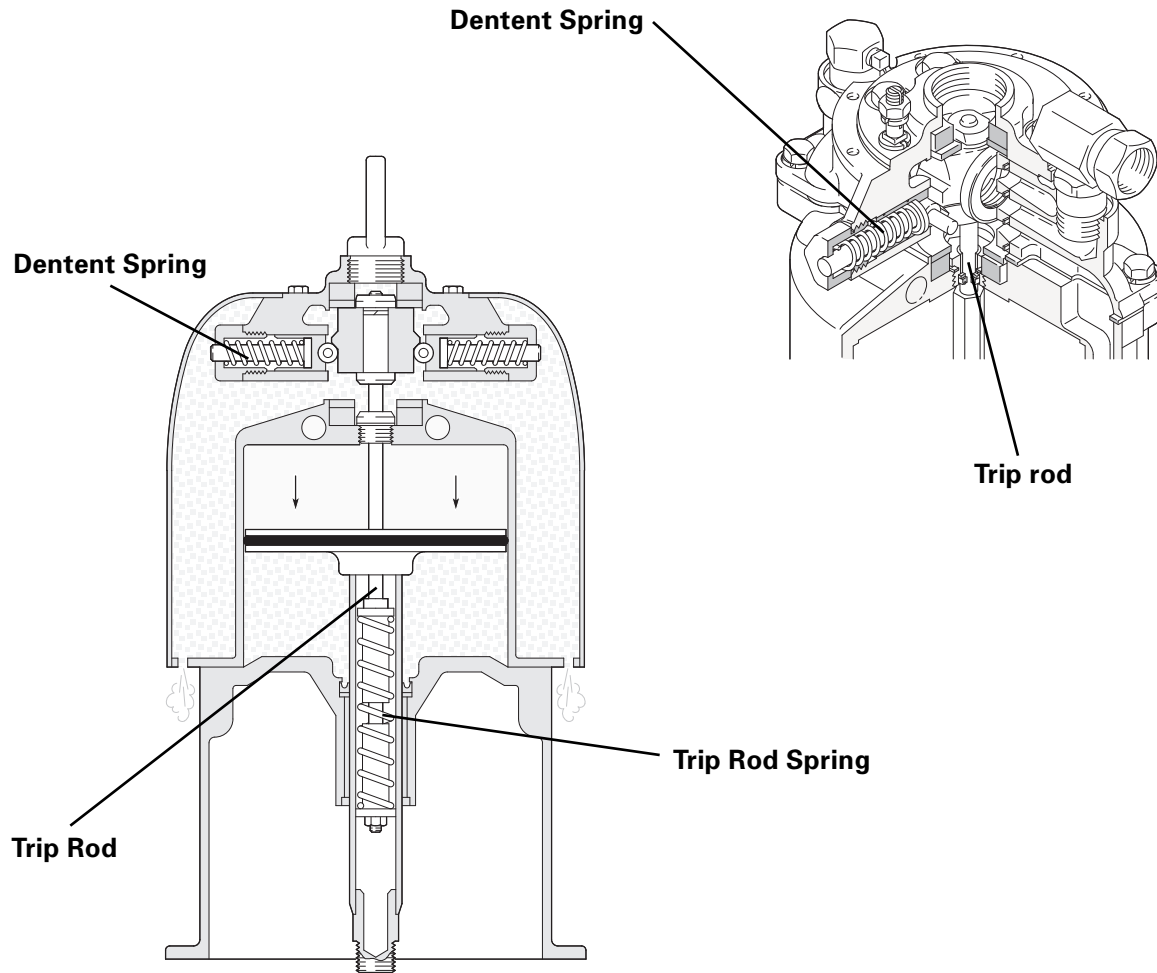
The *Detent Assembly* (Figure 3) keeps the air valve assembly in one position until the next change-over occurs. This assembly contains the detent springs.

The *Detent Spring* provides the spring pressure to make the air valve assembly move rapidly over center. The detent spring works together with the trip rod spring.

The *Trip Rod* controls the position of the air valve assembly by actuating the detent assembly. This assembly contains the trip rod spring.

The *Trip Rod Spring* insures that the air valve assembly moves quickly and completely from one position to the other without “centering” the valve.

Centering is a condition which allows air to pass through the valve without any motor piston movement. The air valve is not properly positioned. As a result, air pressure is directed to both sides of the air motor piston.



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Figure 3 Flat Plate Air Motor Detent and Trip Rod Components.

The Piston Assembly (Figure 4) converts air pressure into mechanical force. The following formula illustrates the process:

$$\text{FORCE} = \text{Compressed Air Pressure} \times \text{Effective Motor Piston Area}$$

Note: For additional information on the *air pressure into mechanical force* conversion process refer to Graco's Concept and Theory Training Module; **Pump Ratio and Performance Charts** (Module #321-042).

The *Piston O-Ring* seals the piston plate to the cylinder.

The *Piston Plate* provides the surface area for high pressure to work against.

The *Base* is the lower structural component of the air motor. It houses the piston rod bearing and seal and serves as the mount for the pump.

The *Cylinder* is the upper structural component of the air motor. It provides the surface upon which the piston O-ring seals against and contains air passages.

The *Shield* protects the cylinder and air valve assembly from damage and directs exhaust air to the exhaust ports. It also functions as a safety shield and a muffler.

Note: The shield is not found on the Premier or the Eagle air motor.

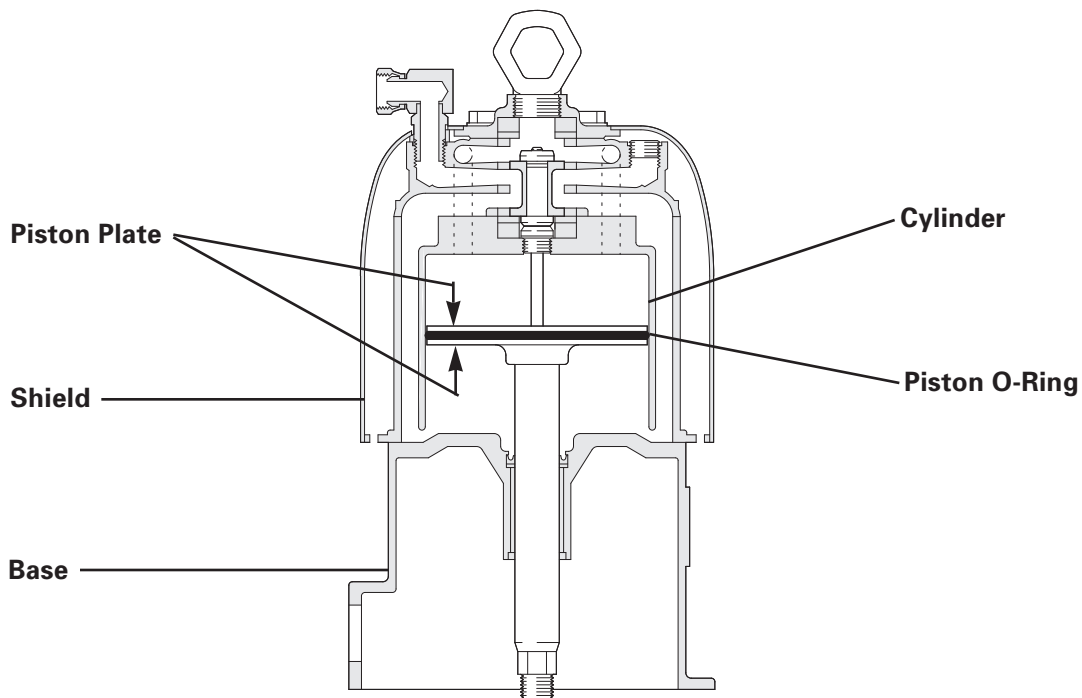
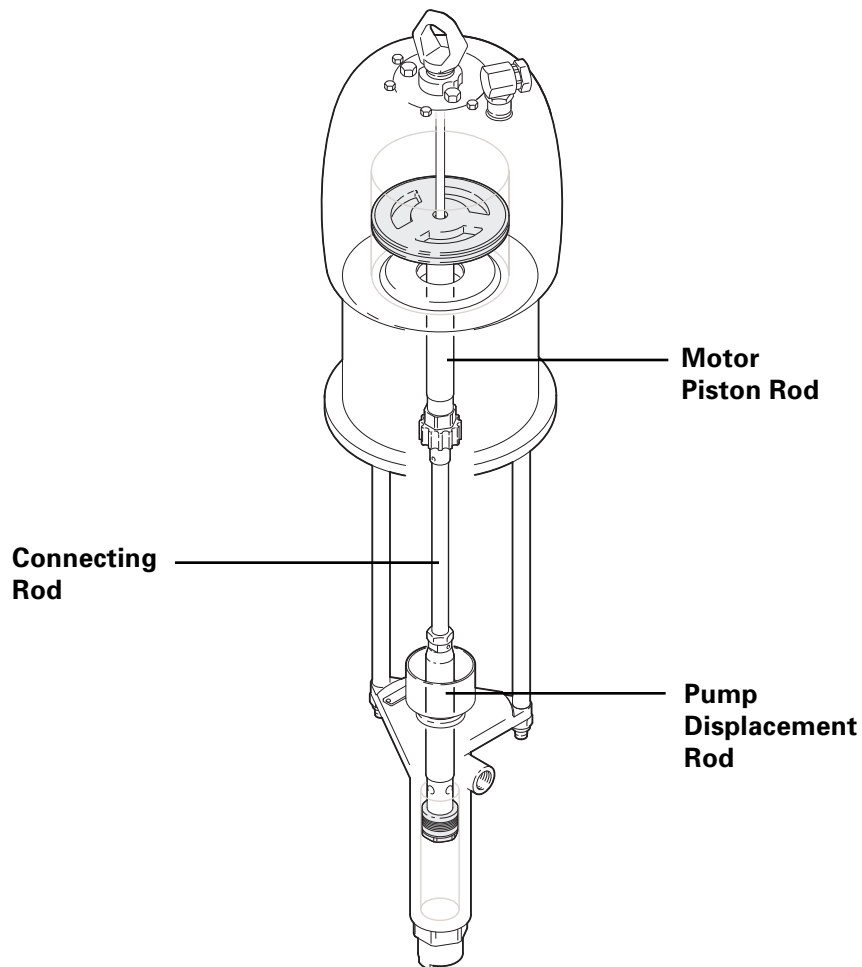


Figure 4 Flat Plate Air Motor Piston Assembly and Structural Components.

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How Flat Plate Air Motors Work...The Operating Cycle

The flat plate air motor is a reciprocating mechanism that provides force for the pump. Extending from the lower end of the motor is a piston rod which attaches to a connecting rod. (Figure 5.) The connecting rod joins the motor piston rod to the pump displacement rod. The up and down action of the motor's piston unit moves the pump's displacement rod and converts the available air pressure into mechanical force to drive the pump.



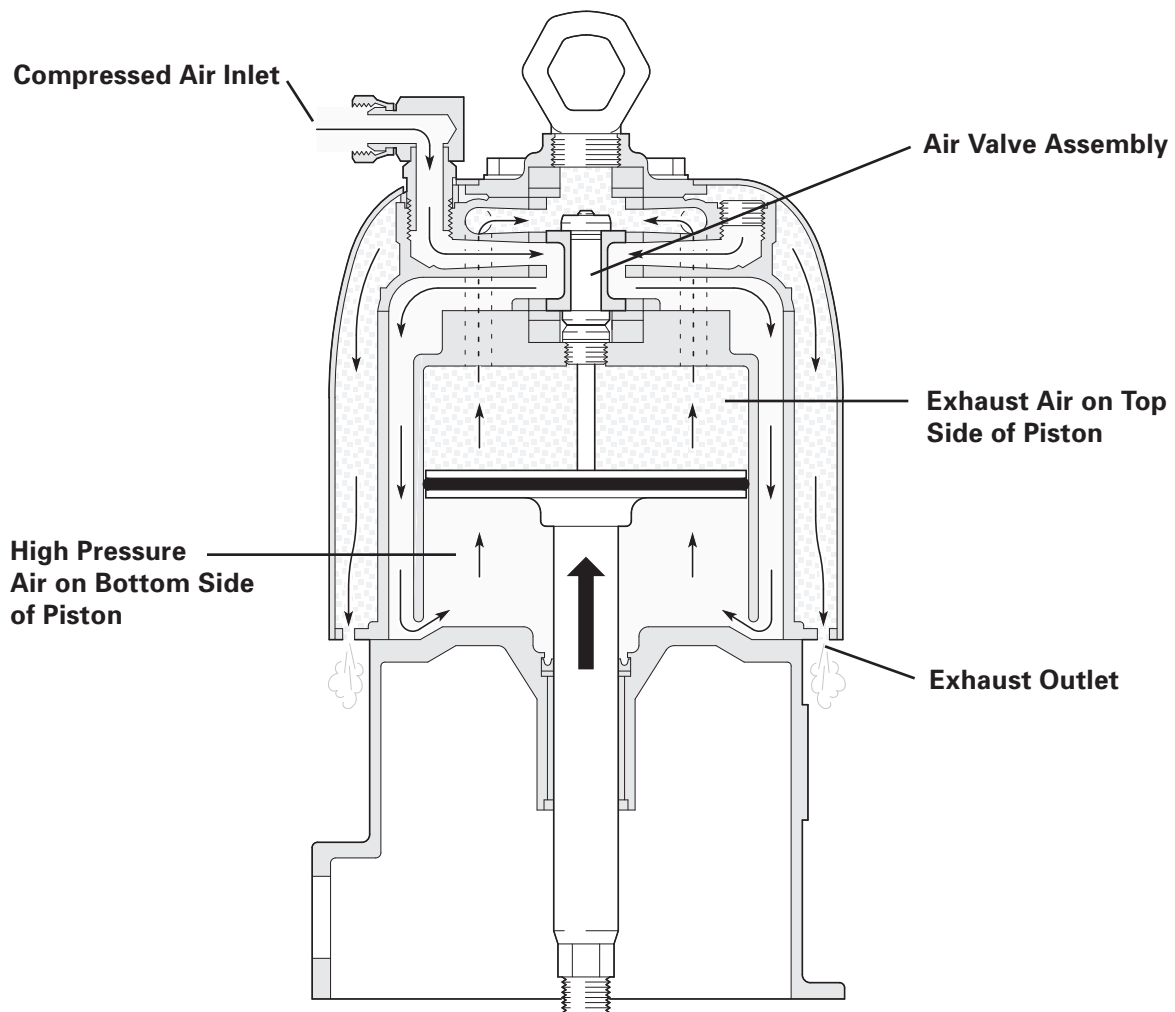
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Figure 5 Connecting rod joining the motor piston rod and the pump displacement rod.

The operating cycle for the flat plate air motor includes *Up Stroke*, *Top Change-Over*, *Down Stroke* and *Bottom Change-Over*.

During *Up Stroke*, compressed air flows into the motor through the air inlet. (Figure 6.) The internal porting of the air manifold directs compressed air to the air valve assembly. The air valve assembly directs air flow to the bottom side of the piston and routes exhaust air from the top side of the piston to exhaust. The compressed air forces the piston to travel up.

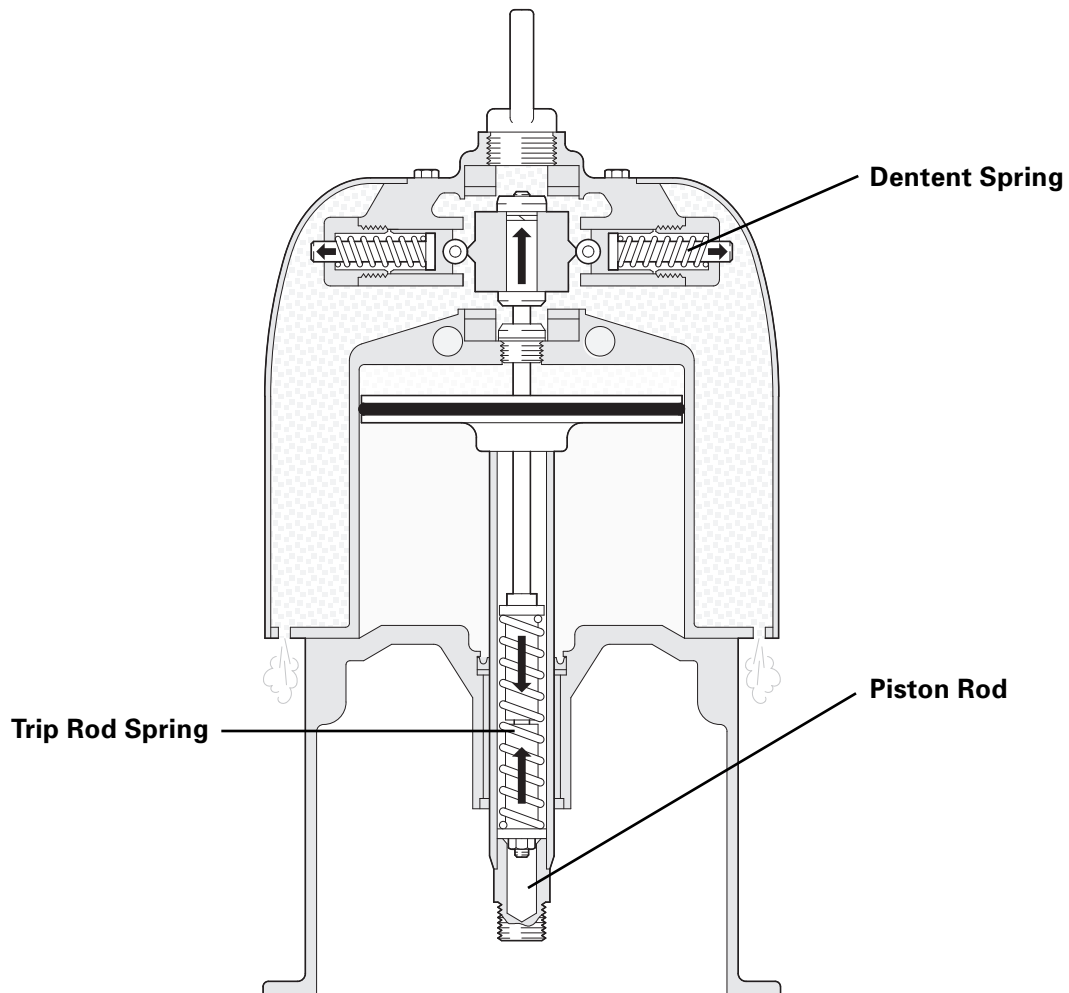
Note: The routing of compressed air in Quiet design air motors is different from the Standard air motor design being discussed in this section. See page 33 for more information on Quiet air motor design.



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Figure 6 Flat Plate Air Motor *Up Stroke*.

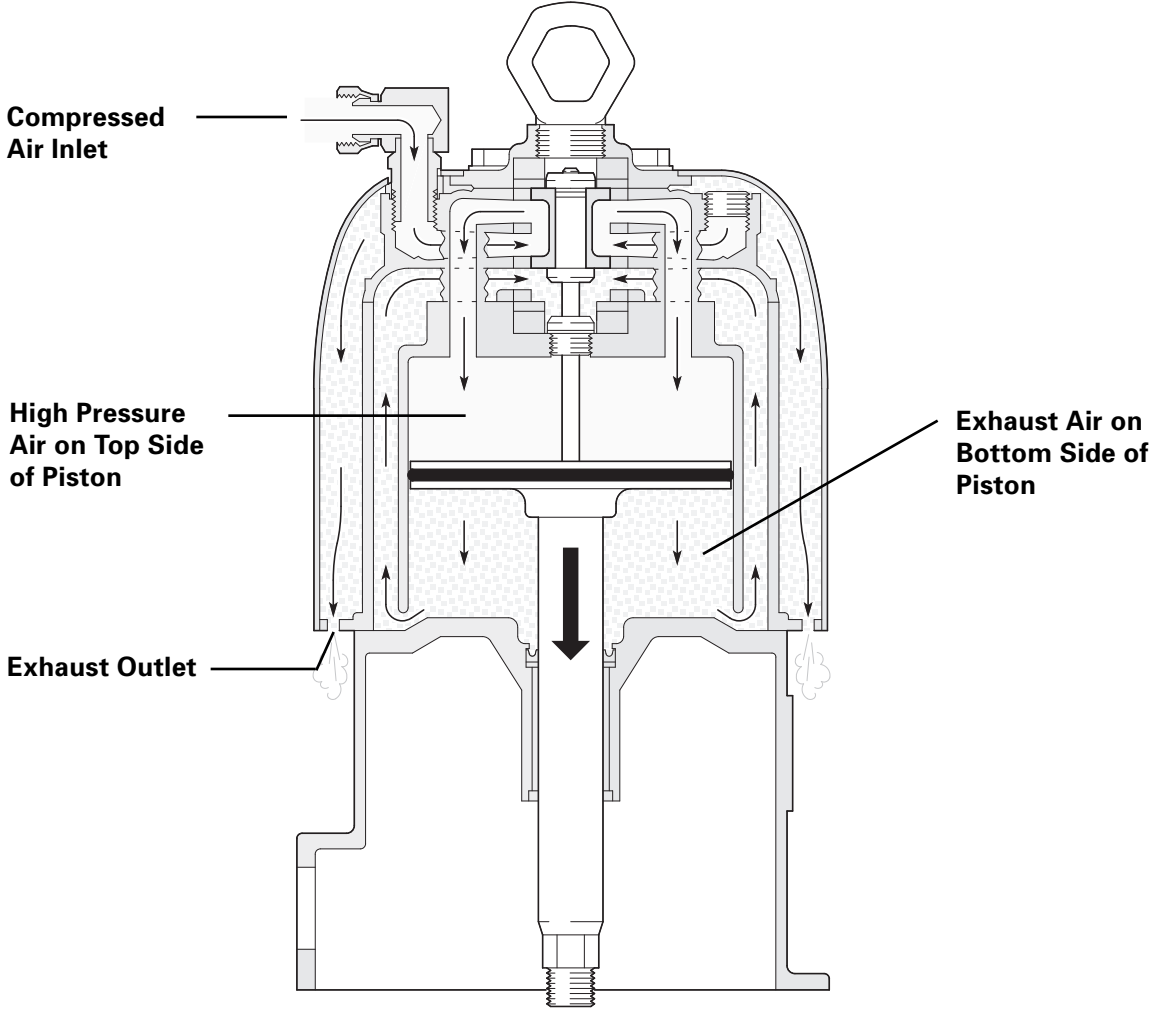
Top *Change-Over* occurs when the piston is near the top of its stroke and the bottom of the piston rod contacts the trip rod spring. The piston continues to travel upward, compressing the spring until enough force is generated to exceed the detent spring force. Then the air valve assembly quickly shifts up and directs high pressure air to the top side of the piston. Air from the bottom side of the piston is channeled to exhaust. Figure 7 shows the positioning of the detent spring, the trip rod spring and the piston rod during top change-over.



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Figure 7 Flat Plate Air Motor *Top Change-Over*.

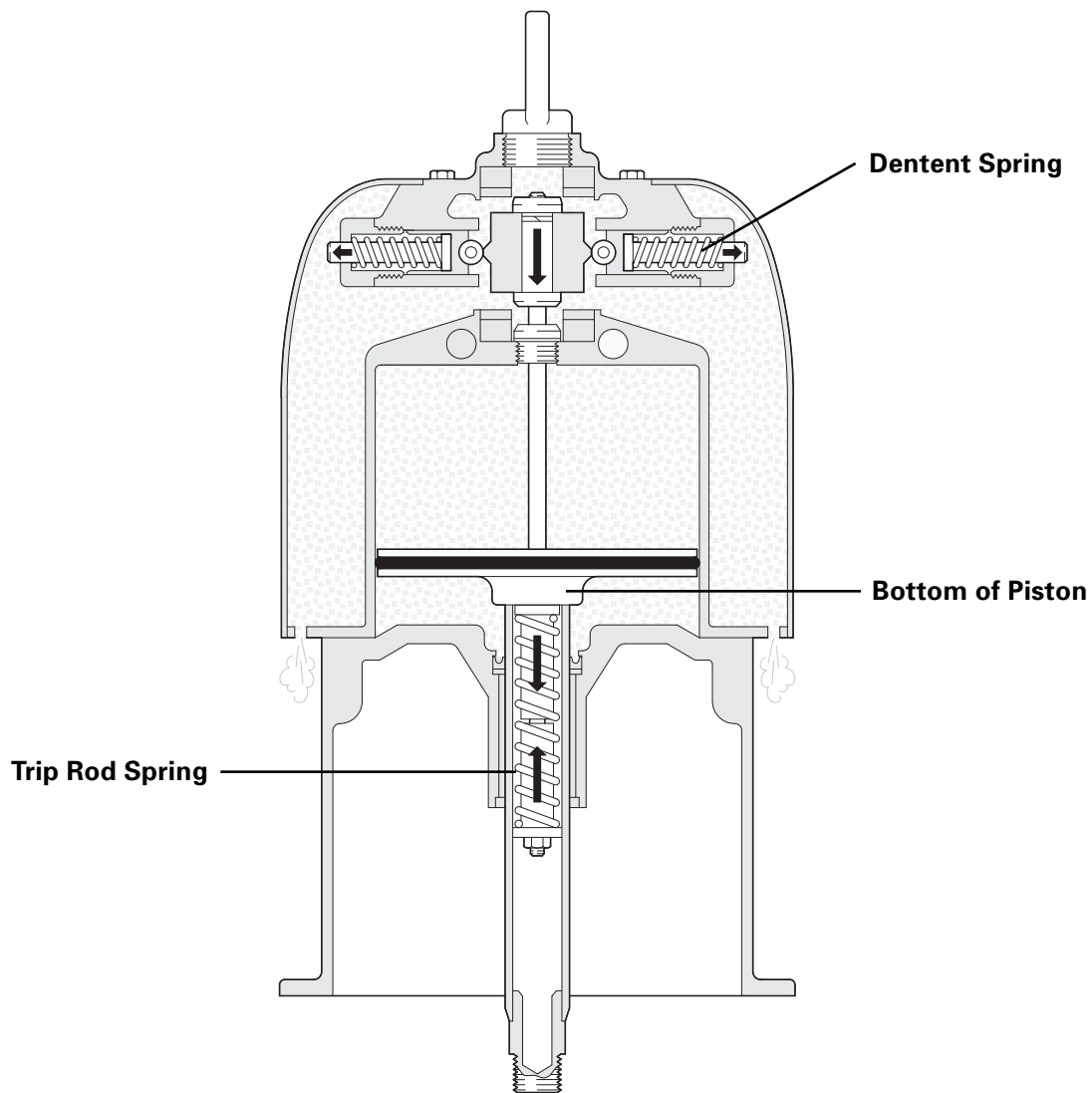
During *Down Stroke*, compressed air builds up above the piston forcing it down, while low pressure air below the piston exhausts to atmosphere (Figure 8). Compressed air forces the piston to travel down.



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Figure 8 Flat Plate Air Motor *Down Stroke*.

Bottom Change-Over (Figure 9) occurs when the piston is near the bottom of its travel and the bottom of the piston contacts the trip rod spring. The piston continues to travel downward, compressing the spring until enough force is generated to exceed the detent spring force. Then the air valve assembly quickly shifts down and directs high pressure air to the bottom side of the piston and directs air from the top side of the piston to exhaust. Once the piston changes direction, the entire operating cycle begins again.



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Figure 9 Flat Plate Air Motor *Bottom Change-Over*.

Differential Air Motors - Component Identification

The *Air Valve Assembly* controls air flow through the motor. Valve position determines whether the piston goes up or down. The air valve assembly consists of the valve bar, exhaust valves and intake valves.

Figure 10 shows the location of the air valve assembly, the valve bar, the spring clip and the exhaust and intake valves.

The *Valve Bar* holds the intake and exhaust poppet valves in the proper position.

Note: Poppet style valves are rubber stoppers that push on the ports to stop air flow. Graco differential air motor design builds air pressure behind the intake and exhaust poppet valves to help with valve seating.

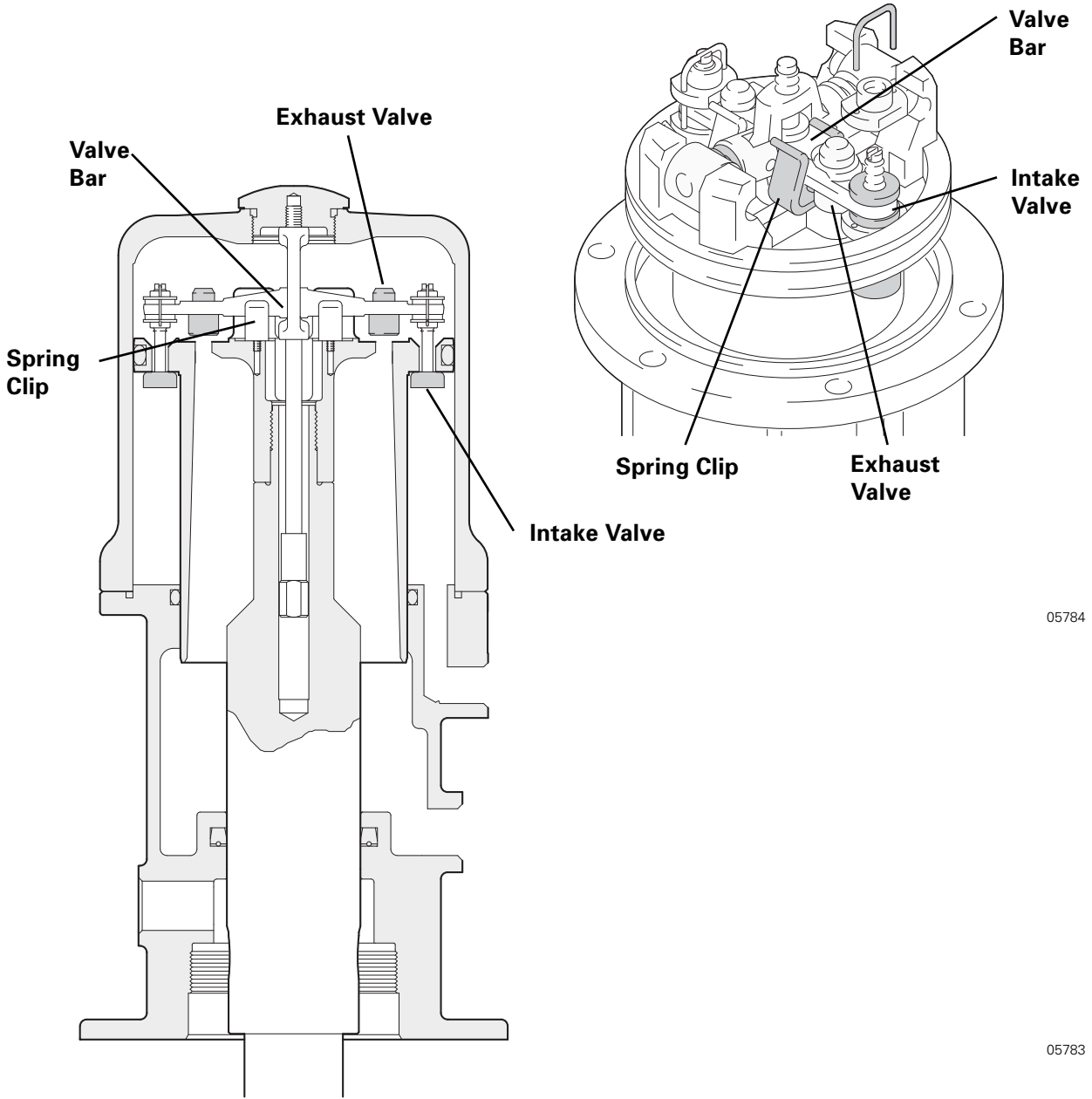
The *Spring Clip* aligns the valve bar to insure the intake and exhaust valves seal properly.

The *Exhaust Valve* prevents high pressure air from escaping from the top side of the piston to exhaust when closed and lets high pressure air escape to exhaust when open.

It should be noted that differential air motors exhaust to atmosphere only once per cycle during bottom change-over. Flat plate air motors exhaust to atmosphere twice per cycle; during bottom and top change-over.

The *Intake Valve* seals high pressure air on the underside of the piston crown when closed and lets high pressure air pass through to the top side of the piston when open.

Note: Differential air motors always have air pressure on the bottom side of the piston.



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Figure 10 Differential Air Motor Air Control Components.

The *Detent Assembly* (Figure 11) trips over center very rapidly at change-over to insure that the motor quickly changes direction at the end of the piston stroke. It also provides the pressure that keeps the valves seated during up and down strokes and prevents “centering” of the valve. It consists of the detent spring, arm, pin, and rocker.

The *Detent Spring* provides the tension that helps the detent assembly change positions quickly.

The *Rocker* serves as the pivot point for the detent assembly. It holds the detent arm and spring in place.

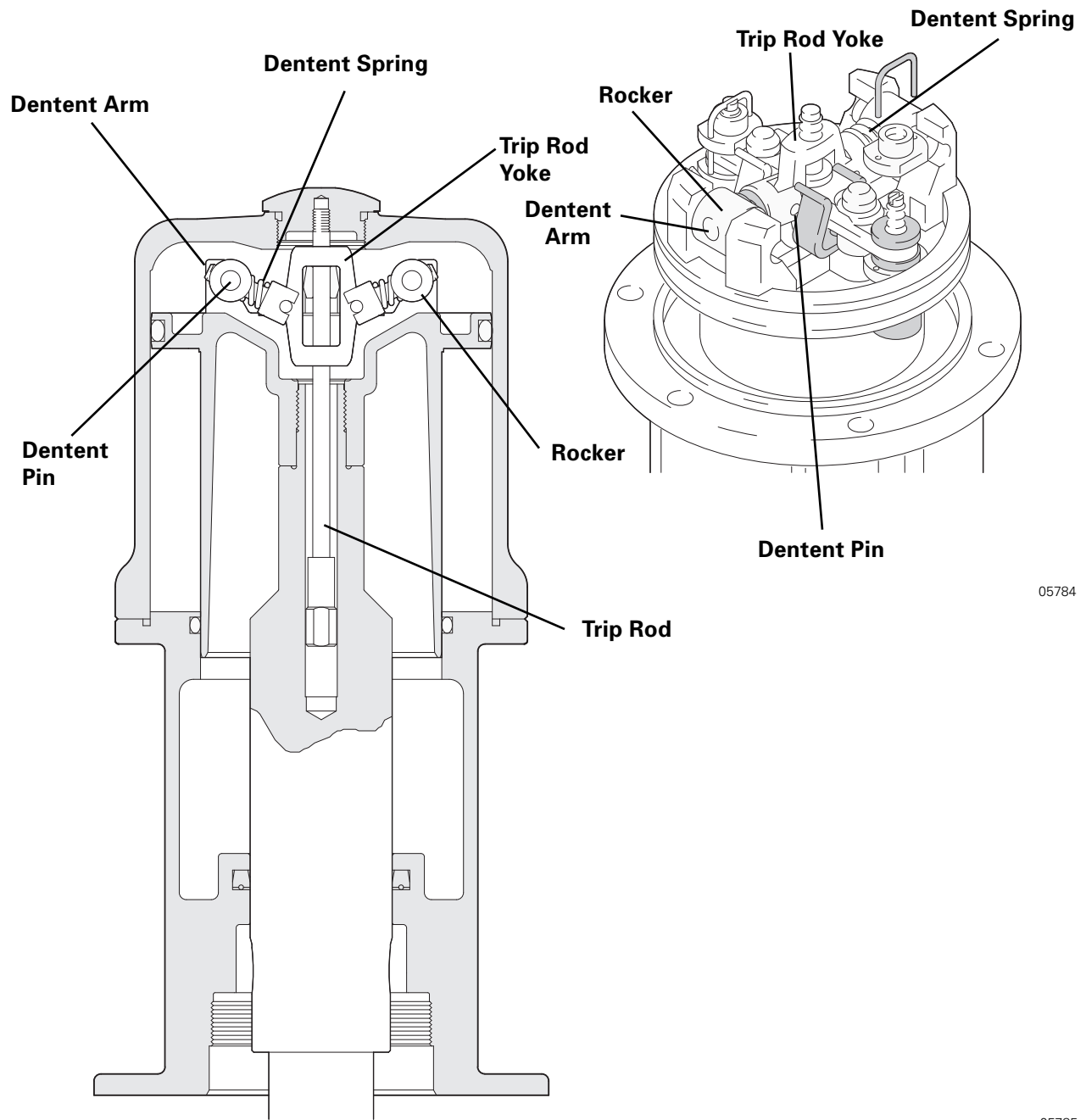
The *Detent Arm* connects the detent pin to the detent rocker and contains the detent spring.

The *Detent Pin* connects the detent arm assemblies to the trip rod yoke.

The *Trip Rod Assembly* controls the position of the air valve assembly by causing the detent assembly to change positions. It consists of the detent spring, arm, pin, and rocker.

The *Trip Rod Yoke* makes contact with the trip rod or the cap nut at change-over and causes the valve bar to change positions.

The *Trip Rod* contacts the trip rod yoke when the piston reaches the lower end of its travel.



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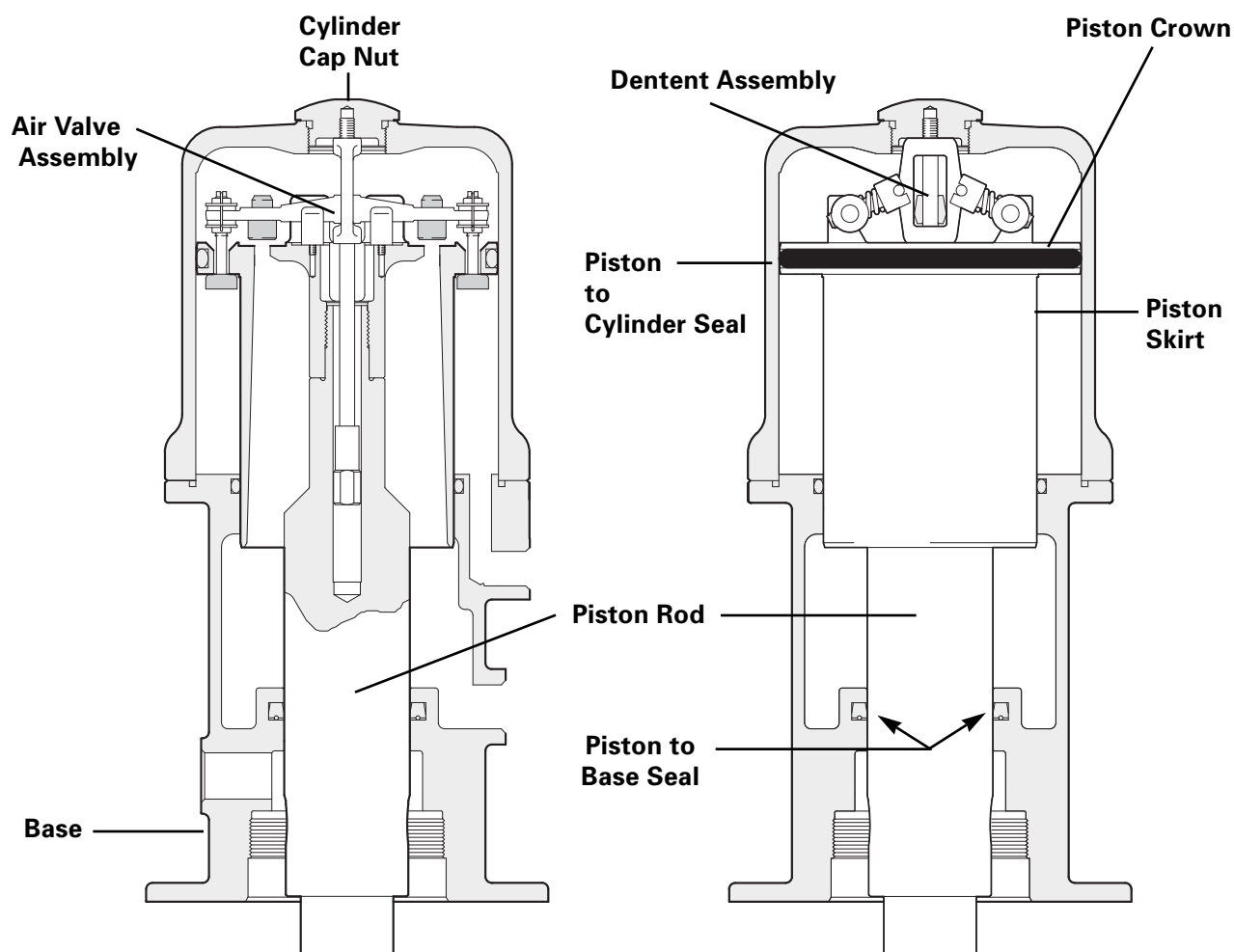
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Figure 11 Differential Air Motor Detent and Trip Rod Components.

The *Piston* (Figure 12) transforms air pressure into mechanical force. The air valve assembly and the detent assembly are mounted onto the piston.

The *Piston Crown*, which is the upper part of the piston, carries the o-ring that seals to the cylinder wall. The piston crown separates the cylinder into two chambers; one above the piston crown and the other below it.

The *Piston Skirt* is the lower part of the piston. The skirt reduces the surface area of the lower side of the piston crown to one-half the surface area of the upper side and separates the inlet air from the exhaust air. The inside section of the piston skirt exhausts air, while the outside section is always pressurized with compressed air. Figure 13 illustrates the piston crown and skirt relationship.



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Figure 12 Differential Air motor Piston and Structural Components.

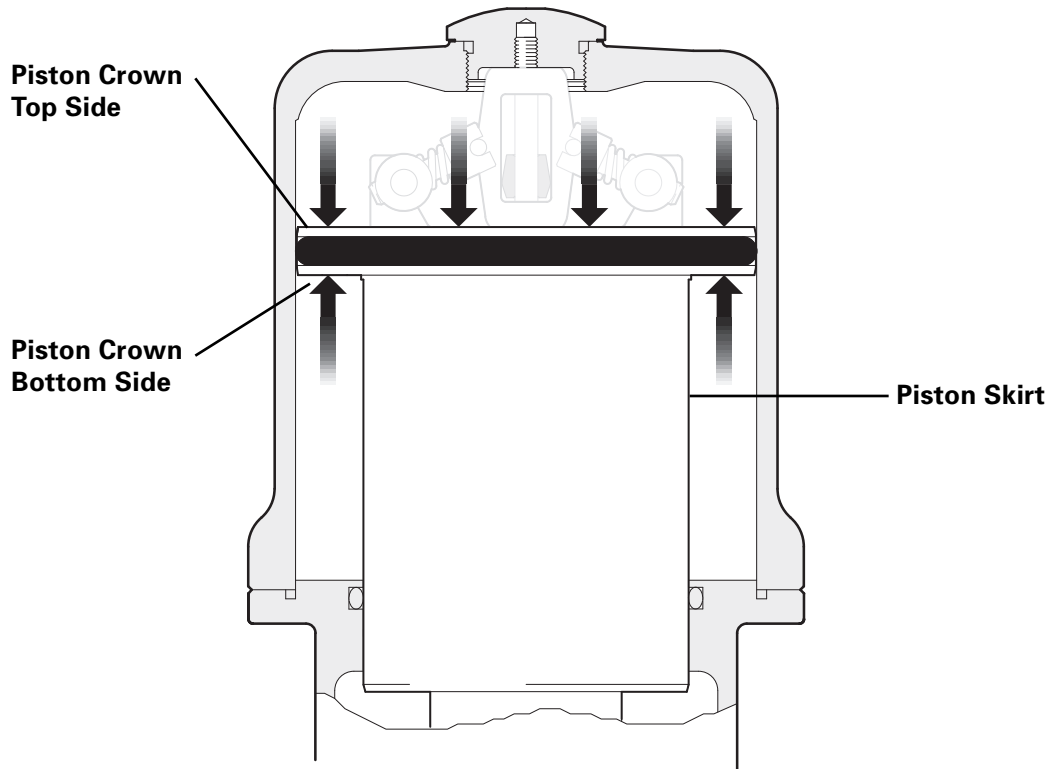
The *Piston Rod* connects the piston to the pump rod.

The *Piston to Base Seal* seals the piston skirt to the air motor base to prevent air leak.

The *Piston to Cylinder Seal* seals the piston crown to the cylinder wall to isolate the top of the piston from the bottom of the piston.

The *Base* is the lower structural component of the air motor. The base contains the piston rod bearing and packing, the air inlet, mounting holes, ground lug, the riser tube, and the exhaust ports.

The *Cylinder Cap Nut* serves as the upper stop for the trip rod yoke and covers the hole in the top of the cylinder.



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Figure 13 The piston skirt reduces the bottom side of the piston crown by one-half. For example, if the top side of the piston crown is 14 sq. in. (90 cm²), the bottom side is 7 sq. in. (45 cm²).

How Differential Air Motors Work...The Operating Cycle

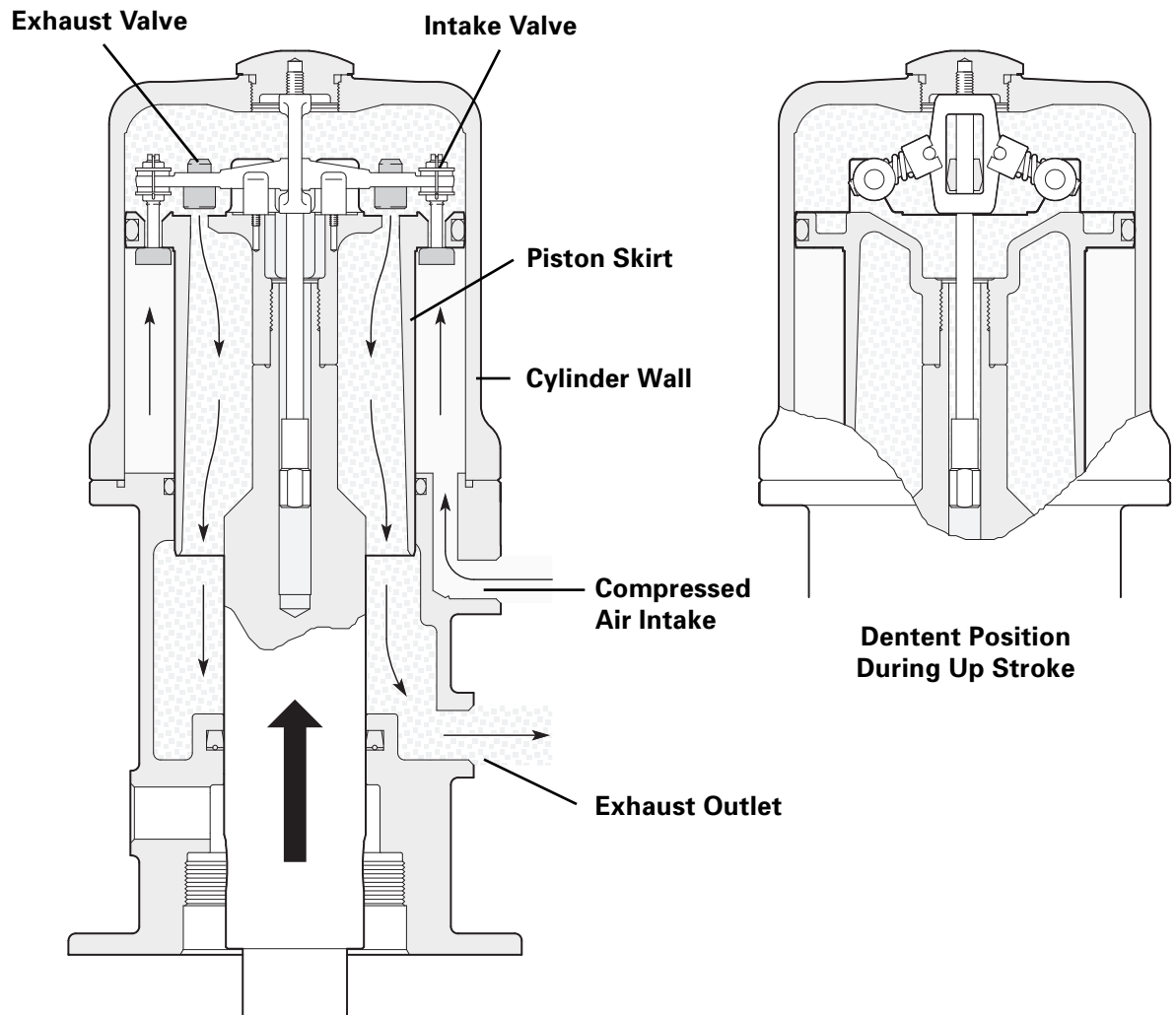
The differential air motor is similar to the flat plate air motor in that its piston also moves the pump lowers' displacement rod up and down. It is similar because the piston's vertical movement is still created by compressed air flowing through an air valve assembly. The differential air motor also has a somewhat different operating cycle.

Compressed air flows into the motor through the air inlet located in the air motor base. Once inside, the internal porting of the base channels the air to the area between the piston skirt and the cylinder wall on the lower side of the piston (Figure 14).

Note: Compressed air (inlet air pressure) is always present in this location.

During *Up Stroke*, air is trapped below the piston crown by the closed intake valves. Air above the piston crown is allowed to escape through the open exhaust valves into the center of the piston skirt and out to atmosphere through the exhaust ports in the air motor base.

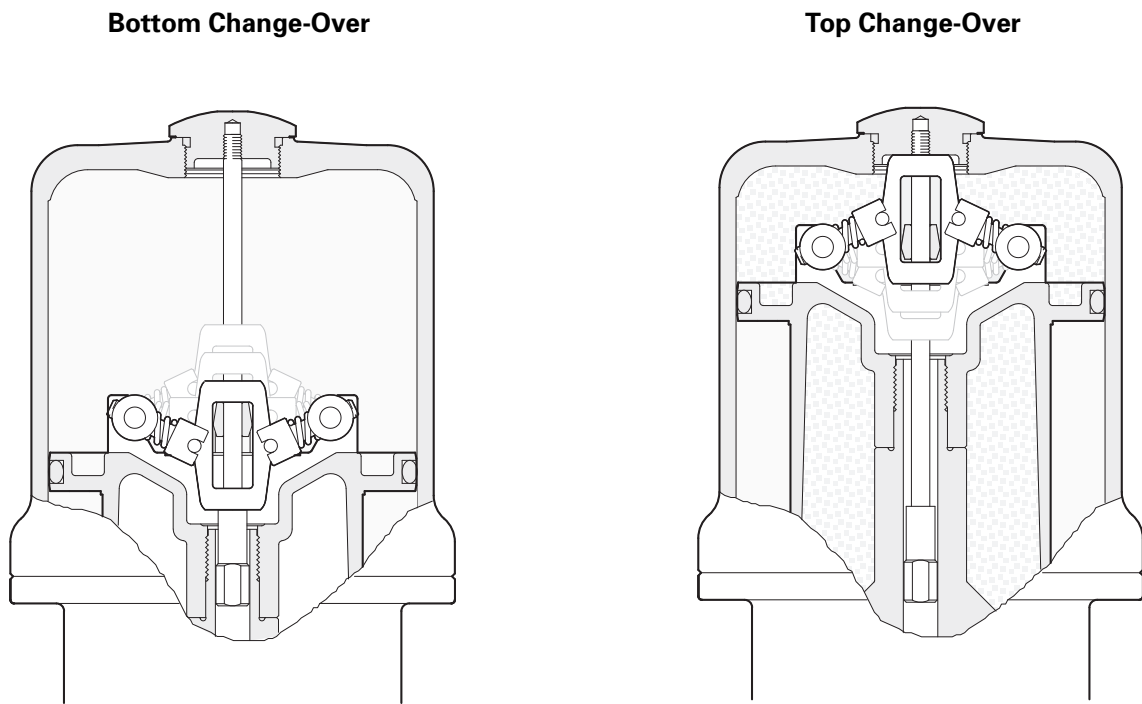
Since the air pressure below the piston crown is at a higher pressure than the air pressure above the piston crown, the piston is forced to move up. The yoke, valve bar assembly and the piston slide up the trip rod during this phase.



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Figure 14 Differential Air Motor *Up Stroke*.

During *Top Change-Over*, as the piston gets near the top of its travel, the yoke strikes the cap nut, exerting downward force on the detent springs. As the piston continues to travel up, the force builds until it exceeds the detent spring force. This causes the yoke to change position and forces the valve bar assembly to quickly change positions as well; closing the exhaust valves and opening the intake valves. The valve bar is held in the new position by the spring clips. Now compressed air is present on both sides of the piston and the piston changes directions. Figure 15 shows the positioning of the trip rod and detent spring assemblies during top and bottom change-over.



05789

Figure 15 Differential Air Motor *Top* and *Bottom Change-Over*.

During *Down Stroke* (Figure 16), compressed air is directed from the cavity surrounding the piston skirt to the top side of the piston through the open intake valves.

The air pressure above the piston crown rises to inlet pressure because the closed exhaust valves stop air from flowing to the center of the piston skirt (exhaust air).

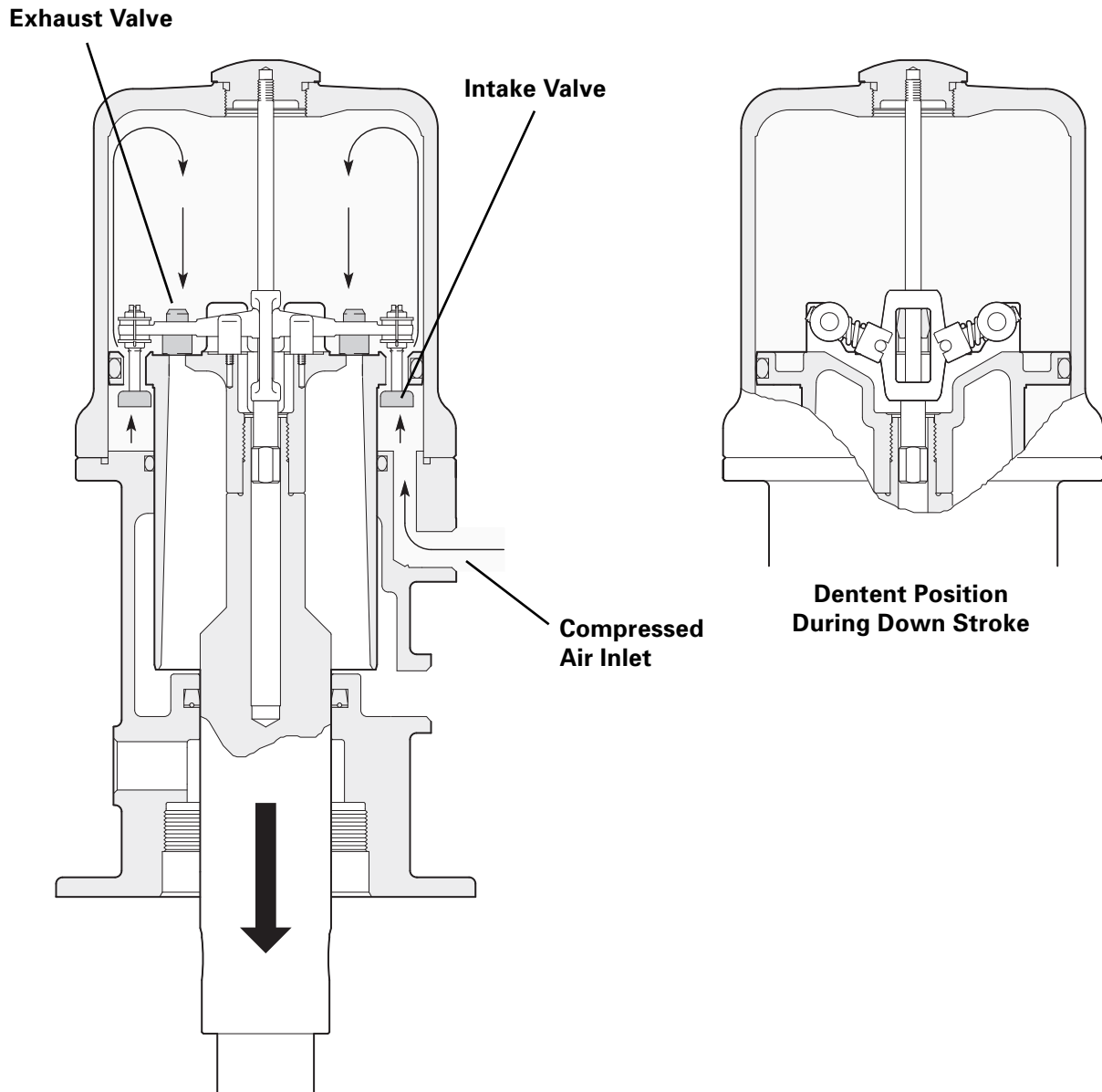
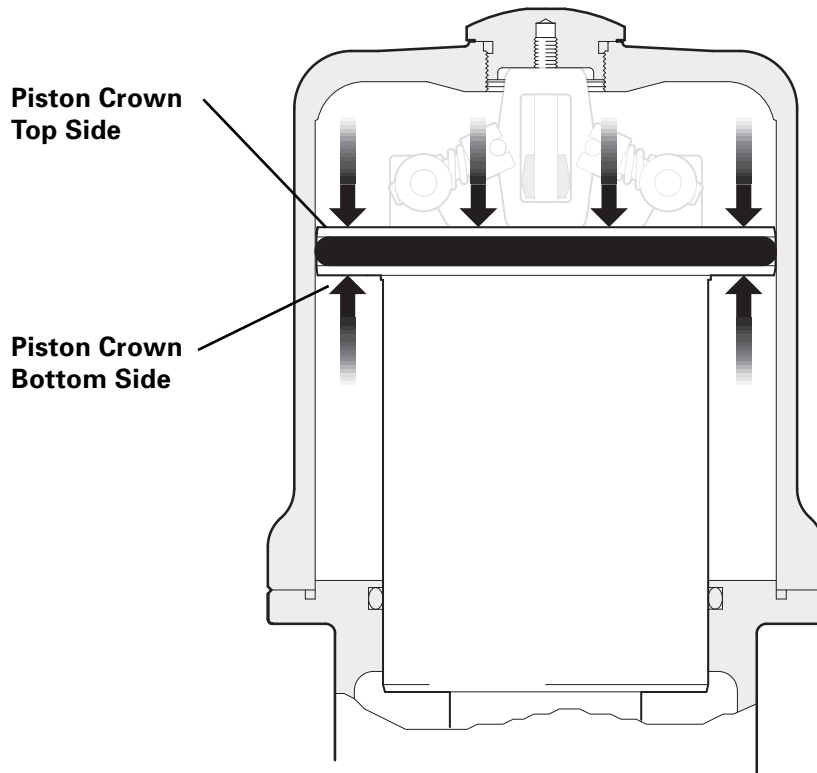


Figure 16 Differential Air Motor *Down Stroke*.

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Since the top of the piston crown has twice as much surface area exposed to high pressure air as the bottom (Figure 17), the piston moves down because there is twice as much force pushing on the top side of the piston as compared to the bottom side.



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Figure 17 The name “Differential Air Motor” is based on the different amounts of effective surface area between the top part of the piston crown and the bottom part of the piston crown.

During *Bottom Change-Over* (Figure 15), when the piston gets near the bottom of its travel, the trip rod yoke strikes the larger area of the trip rod and starts to build up force against the detent springs. As the piston continues to move down, the force builds until it exceeds the detent spring force. This causes the yoke to change position and forces the valve bar assembly to quickly change positions; opening the exhaust valves and closing the intake valves. The valve bar is held in the new position by the spring clips. There is an exhaust pulse to atmosphere when the exhaust and intake valves change position. The piston changes direction and the entire operating cycle begins again.

Note: An exhaust pulse to atmosphere occurs only during bottom change-over because compressed air from above the piston crown is channeled to exhaust.

The movement of a differential air motor's piston (Figure 17) is best explained by the following formula:

$$\text{Pressure X Area} = \text{Force}$$

For example: 1. Inlet pressure to the air motor is 100 psi (7 bar).

$$\text{Inlet pressure} = 100 \text{ psi (7 bar)}$$

2. Surface area of the top side of the piston crown is 14 sq. in. (90 cm²).

$$\text{Top side surface area} = 14 \text{ sq. in. (90 cm}^2\text{)}$$

3. Surface area of the bottom side of the piston crown is 7 sq. in. (45 cm²).

$$\text{Bottom side surface area} = 7 \text{ sq. in. (45 cm}^2\text{)}$$

4. Force is determined by multiplying the pressure and given surface area:

a. The force on the top of the piston:

$$\text{Pressure at 100 psi (7 bar)}$$

$$\text{X Area of 14 sq. in. (90 cm}^2\text{) .}$$

$$= \text{Force of 1400 lbs. (635.60 kg)}$$

b. The force on the bottom of the piston:

$$\text{Pressure at 100 psi (7 bar)}$$

$$\text{X Area of 7 sq. in. (45 cm}^2\text{) .}$$

$$= \text{Force of 700 lbs. (317.80 kg)}$$

c. The force above the piston crown is twice as great as the force beneath, so the piston moves down.

$$\text{Above Piston Force is 1400 lbs. (635.60 kg)}$$

$$\text{— Below Piston Force is 700 lbs. (317.80 kg)}$$

$$= \text{700 lbs. (317.80 kg) Net Force on Down Stroke}$$

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.

Flat Plate Air Motors

1. One of the unique characteristics of Graco air motors is the large porting which allows air to pass to the top or bottom side of the piston quickly. This results in a very rapid change-over and smoother fluid flow from the pump.
 - a. True
 - b. False

2. Select the statements that are correct:
 - a. During Up Stroke, the air valve assembly directs air flow to the bottom side of the piston and routes exhaust air from the top side of the piston to exhaust.
 - b. During Up Stroke, the air valve assembly directs air flow to the top side of the piston and routes exhaust air from the bottom side of the piston to exhaust.
 - c. During Down Stroke, high pressure air builds up below the piston forcing it up, while low pressure air above the piston exhausts to atmosphere.
 - d. During Down Stroke, high pressure air builds up above the piston forcing it down, while low pressure air below the piston exhausts to atmosphere.

3. Explain the term, "Centering of the valve".



For items 4 through 8, match the terms with their definitions:

Terms

- a. trip rod spring
- b. air manifold
- c. detent assembly
- d. valve plate
- e. cylinder
- f. piston assembly

Definitions

- ___ 4. Acts as a bearing surface upon which the air valve assembly slides on and seals against.
- ___ 5. Insures that the air valve assembly moves quickly and completely from one position to the other without “centering” the valve.
- ___ 6. Converts air pressure into mechanical force.
- ___ 7. Provides air passages for inlet air to the air valve and exhaust air out of the motor.
- ___ 8. Keeps the air valve assembly in one position until the next change-over occurs.
- ___ 9. The flat plate air motor is a ___ mechanism that provides force (power) for the pump lower.
 - a. diaphragm displacement
 - b. hydraulically powered
 - c. reciprocating
 - d. vacuum displacement

10. The _____ provides the surface area for high pressure to work against.
- a. piston plate
 - b. piston o-ring
 - c. base
 - d. valve plate

Differential Air Motors

11. Differential air motors always have air pressure on the bottom side of the piston.
- a. True
 - b. False
12. The bottom side of the piston crown has twice as much surface area exposed to high pressure air as the top.
- a. True
 - b. False
13. The intake valves are open and the exhaust valves are closed during _____.
- a. up stroke
 - b. top change-over
 - c. down stroke
 - d. bottom change-over
14. The _____ seals high pressure air on the underside of the piston when it is closed.
- a. valve bar
 - b. intake valve
 - c. exhaust valve
 - d. detent spring

For items 15 through 19, match the terms with their definitions:

Terms

- a. base
- b. piston skirt
- c. detent arm
- d. piston crown
- e. trip rod assembly
- f. rocker

Definitions

- ___ 15. Serves as the pivot point of the detent assembly. It holds the detent arm and spring in place.
- ___ 16. Lower structural component of the air motor.
- ___ 17. Upper part of the piston.
- ___ 18. Controls the position of the air valve assembly by causing the detent assembly to change position.
- ___ 19. Lower part of the piston.
- 20. The trip rod yoke strikes the cap nut and exerts downward force on the detent springs during ____.

 - a. up stroke
 - b. top change-over
 - c. down stroke
 - d. bottom change-over

Answers to Progress Check

1. a. True
2. a. During Up Stroke, the air valve assembly directs air flow to the bottom side of the piston and routes exhaust air from the top side of the piston to exhaust.
and
d. During Down Stroke, high pressure air builds up above the piston forcing it down, while low pressure air below the piston exhausts to atmosphere.
3. Centering is a condition which allows air to pass through the valve without any motor piston movement. The air valve is not properly positioned. As a result, air pressure is directed to both sides of the air motor piston.
4. d. valve plate
5. a. trip rod spring
6. f. piston assembly
7. b. air manifold
8. c. detent assembly
9. c. reciprocating
10. a. piston plate
11. a. True
12. b. False (The top side of the piston crown has twice as much surface area exposed to high pressure air as the bottom.)
13. c. down stroke
14. b. intake valve
15. f. rocker
16. a. base
17. d. piston crown
18. e. trip rod assembly
19. b. piston skirt
20. b. top change-over

Air Motors - Applications

Learning Objectives

Understanding the typical uses or applications for flat plate and differential air motors will enhance your ability to correctly identify sales opportunities. After completing this section, you will be able to:

- Identify the types of pump that can be driven using flat plate and differential air motors.
- Describe the kinds of pumping operations that work well with flat plate and differential air motors.
- Describe steps that can be taken to control air motor noise.
- Describe steps that can be taken to control air motor icing.
- Explain Adjust-A-Stroke Metering.

Typical Uses

Flat plate and differential air motors used with two-check, four-check, and priming piston pumps. These pumps can operate with an extremely wide range of fluids and viscosities. Two-check, four-check pumps and priming piston pumps represent the core of Graco's product pumping line.

Flat plate air motors are preferred for jobs needing a large air motor. Paint circulation systems, high pressure pumping operations (i.e., viscous fluids) and large volume pumping operations are well suited to flat plate air motors.

Differential air motors are preferred for jobs needing a small air motor. In-line pumps, small paint circulation systems, small portable sprayer packages and small-volume transfer applications are well suited to differential air motors.

Note: For additional information on pumps suited to differential air motors refer to Graco's Concept and Theory Training Modules; *Two-Check and Priming Piston Pumps* (Module #321-044) and *Four-Check Pumps* (Module #321-045).

Air Motor Noise

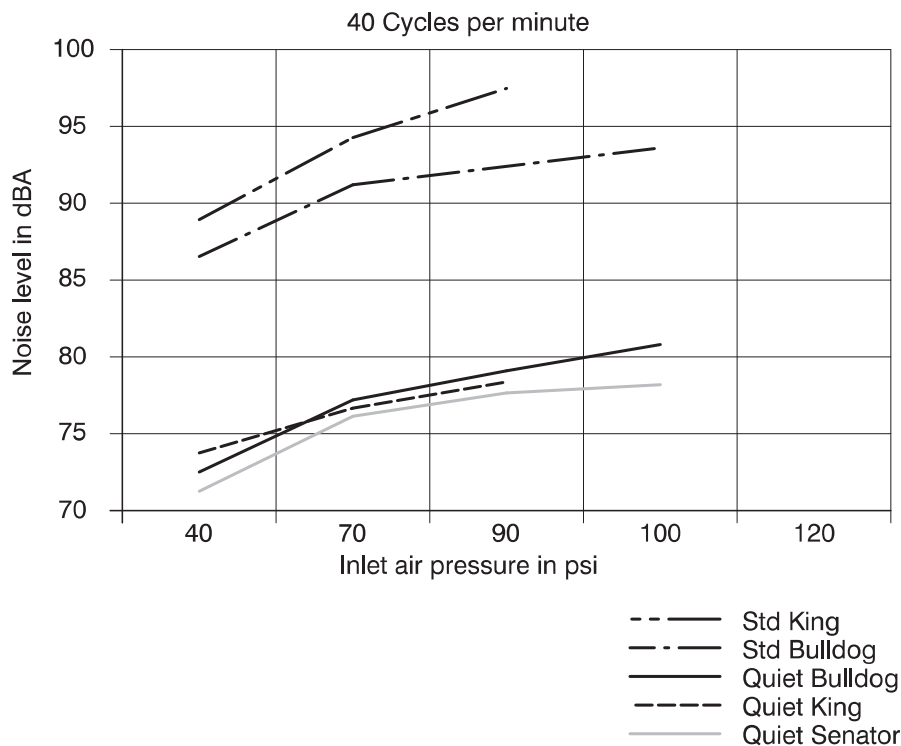
Graco's Quiet Flat Plate Air Motor Series includes the Quiet Senator air motor, the Quiet Bulldog air motor and the Quiet King air motor. The main design difference in the quiet units is that the porting is almost exactly opposite from the Standard Senator, Bulldog and King flat plate air motors. What was the exhaust outlet in the standard models is now the air inlet and what was the inlet is now the exhaust. The quiet design routes exhaust out a port to a hose.

Note: A muffler or a hose attachment to the exhaust outlet can also be fitted to the Standard Senator, Bulldog and King air motors as well as the Quiet series.

General noise reduction factors for all air motors would include:

- Locating the pump away from populated areas in the plant.
- Reducing the amount of hard plumbing to minimize vibration.
- Use of rubber mounts to reduce air motor noise levels.
- Remote exhaust piping for exhaust air.
- Mufflers on the air motor exhaust ports.

Figure 18 shows a graph comparing Graco Flat Plate Air Motor noise levels for Standard air motors and the Quiet series air motors.



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Figure 18 Graco Flat Plate Air Motor Noise Level.

Air Motor Icing

Why do air motors have an icing problem in the first place? Air is a gas. Gases tend to heat when they are compressed and cool when they are expanded. Air motors use compressed air at 20 to 180 psi (1.4 to 12.4 bar) and exhaust the same air at 14.7 psi (1.0 bar) or atmospheric pressure. This is an extremely high percentage pressure drop with an equivalent degree of cooling; up to -100° F (-56° C). Ice forms because the rapidly expanding compressed air freezes any moisture in the compressed air supply into ice. This is the same basic principle on which household refrigerators are made.

Icing can be a problem for all air motors; especially for those located in high humidity regions. The best solution is an air compressor system that can hold the dew point and air temperature to optimum levels. Graco recommends the moisture level in the air being supplied to our air motors be at a dew point of 55° F (11° C) and an air temperature of 70° F (21° C) to minimize air motor icing.

The Premier model flat plate air motor has been designed with a heat exchanger that takes advantage of outside free air and incoming compressed air to warm the out going exhaust air to control icing.

Other solutions that can help to reduce air motor icing include:

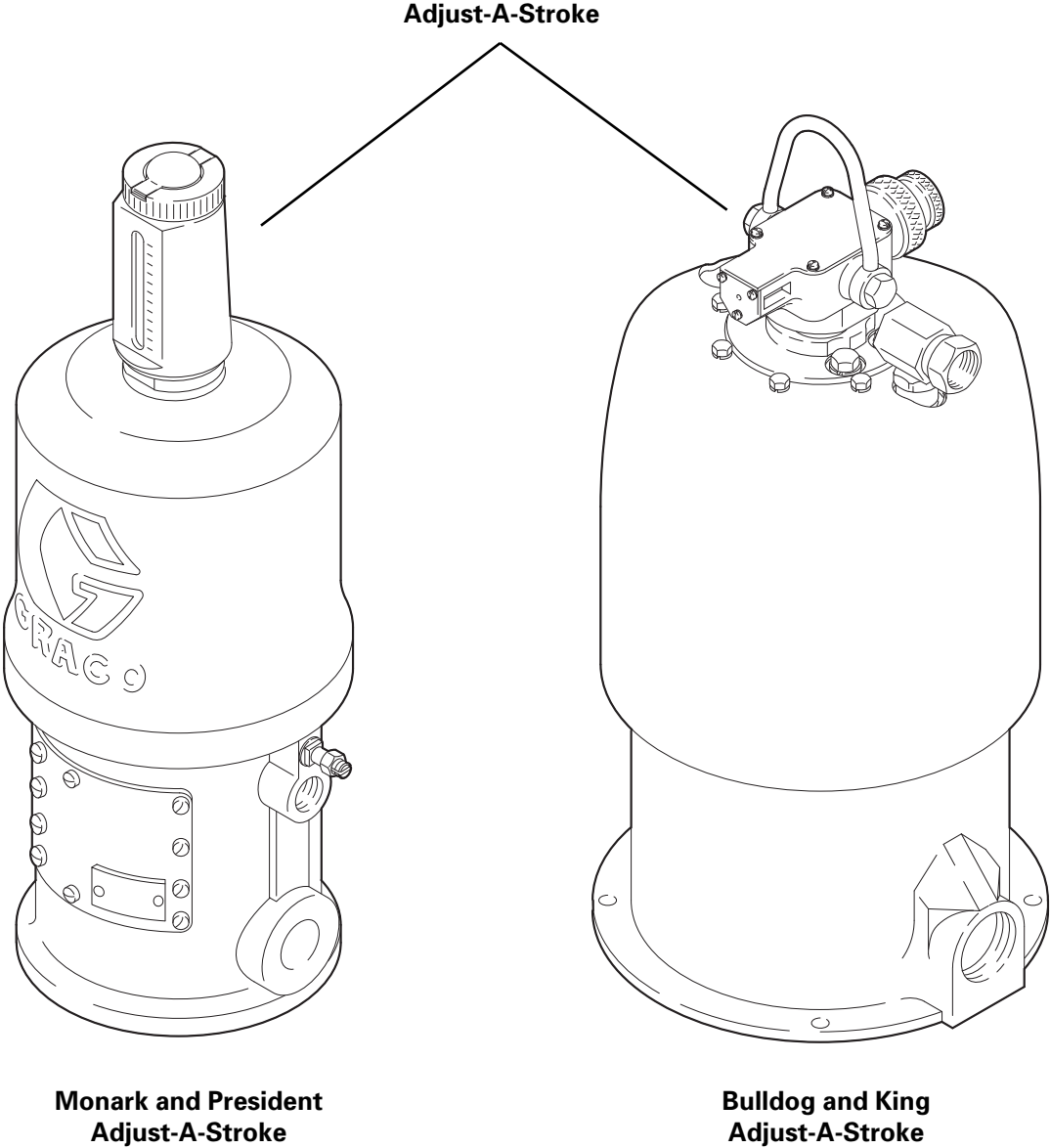
- Aftercoolers and air dryers in the air compressor system to remove moisture and cool the compressed air.
- Reduce the air motor's cycle rate.

Mechanically actuated air motor control valves will not decrease the amount of icing, but will limit its effect by chipping off ice that forms on the ports. Most Graco differential and flat plate air motors are mechanically actuated. The only exception is the Eagle model flat plate air motor which incorporates an air actuated control valve design.

Adjust-A-Stroke Metering

Adjust-A-Stroke allows the stroke length of the air motor to be varied for metering applications. This is done by replacing the trip rod nut with the Adjust-A-Stroke (Figure 19), then adjusting the Adjust-A-Stroke using the crank at the top to set the stroke length of the motor. Since the motor stroke length is changed, the fluid displacement from the fluid pump will be changed.

The Adjust-A-Stroke can be adjusted from 20 to 100 percent of full stroke and incorporates the use of a pneumatic counter which will count the number of strokes from the air motor exhaust signal.



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Figure 19 Adjust-A-Stroke Metering.

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. What three types of pumps are used with flat plate and differential air motors?

2. Flat Plate air motors are preferred for jobs needing a _____ air motor.

- a. hydraulic
- b. small
- c. large
- d. continuous duty

3. Differential air motors are preferred for jobs needing a _____ air motor.

- a. hydraulic
- b. small
- c. large
- d. continuous duty

4. The main design difference between the Quiet Series and Standard Series flat plate air motors is that the compressed air porting is almost exactly opposite from each other.

- a. True
- b. False

5. Name four factors that would reduce air motor noise levels.

6. Graco recommends the moisture level in the air being supplied to air motors be at a dew point of _____ and an air temperature of _____ to minimize air motor icing.

a. 70° F (21° C), 55° F (11° C)

b. 55° F (11° C), 70° F (21° C)

c. 75° F (26° C), 50° F (6° C)

d. 50° F (6° C), 75° F (26° C)

7. The _____ model _____ air motor has been designed with a/an _____ that takes advantage of outside (free) air and incoming compressed air to warm the out going (exhaust) air to keep icing down.

a. Premier, differential, after-cooler

b. King, flat plate, heat exchanger

c. Eagle, differential, after-cooler

d. Premier, flat plate, heat exchanger



8. _____ actuated air motor control valves will not decrease the amount of icing, but will limit its effect by chipping off ice that forms on air motor ports openings.
- a. Pneumatically
 - b. Mechanically
 - c. Hydraulically
 - d. Air
9. The Adjust-A-Stroke can be adjusted from _____ to _____ percent of full stroke length.
- a. 20, 100
 - b. 40, 60
 - c. 40, 100
 - d. 30, 85

Answers to Progress Check

1. Two-Check Pump, Four-Check Pump, Priming Piston Pump
2. c. large
3. b. small
4. a. True
5. Any four of the five statements listed below:
 - Locating the pump away from populated areas in the plant.
 - Reducing the amount of hard plumbing to minimize vibration.
 - Use of rubber mounts to reduce air motor noise levels.
 - Remote exhaust piping for exhaust air.
 - Mufflers on the air motor exhaust ports
6. b. 55° F (11° C), 70° F (21° C)
7. d. Premier, flat plate, heat exchanger
8. b. Mechanically
9. a. 20, 100

Air Motors - Advantages and Limitations

Learning Objectives

Understanding the advantages and limitations of flat plate and differential air motors will help you correctly and reliably recommend Graco systems to your customers. It will also increase your ability to answer customer questions and objections about air motors. After completing this section, you will be able to:

- List the advantages and limitations of flat plate and differential air motors relative to other power sources for reciprocating pumps.

Air Motors - Advantages

Air motors are extremely reliable and sturdy. Graco air motors, in particular, are known for their high quality and performance standards. A unique design characteristic of Graco air motors is the large porting for air passage. This results in a faster change-over and smoother pump operation

Flat Plate Air Motors - Advantages

Flat plate air motor pistons are simpler to manufacture than differential air motors. This results in a lower production cost than differential air motors of comparable power and a lower initial purchasing investment by your customer.

Flat plate air motors are also more compact than differential air motors of comparable power because they use practically all of their piston surface area in each direction to generate force.

So when you factor in lower production cost and smaller size with comparable power, large air motors are usually flat plate air motors.

Another feature that helps with ease of serviceability is that the control valves on flat plate air motors can be mounted externally.

Flat Plate Air Motors - Limitations

Different sized piston or pump shafts change the theoretical ratio balance of the motor when used with a pump, because the pressurized area is slightly larger on top of the piston than on the bottom.

Flat plate air motors do not provide balanced thrust on up and down strokes. The piston rod reduces the surface area of the bottom side of the piston compared to the top. Therefore, a flat plate air motor will provide less force on the up stroke than on the down stroke. A pump hooked to a flat plate air motor may provide less fluid pressure during the up stroke than during the down stroke.

Note: In large air motors the difference in force between up and down strokes may be insignificant. If it is significant, fluid pressure fluctuations from the pump can be reduced by a fluid pressure regulator or other control devices.

The metal to metal slide valves of flat plate air motors can also be a problem. While they normally slide and rub on very smooth metal-to-metal surfaces, they still will eventually wear themselves down; especially if contaminants introduced into the air motor scratch the valve plate surface.

Flat plate air motor slide valves also tend to freeze more readily than the poppet valve arrangement of differential air motors.

The valve plate is one of the more critical components of the flat plate air motor. The seal between the air valve assembly and the valve plate prevents air leakage. Any scratches or gouges on the valve plate will cause leakage and reduce motor efficiency. Air plate damage can result from dirt, scale, metal flakes and other contaminants in the compressed air system. Inlet air filters and “blowing out” new air lines prior to unit installation will help prevent this kind of damage.

Differential Air Motors - Advantages

Differential air motors are very reliable. They only work on demand and are an excellent choice for intermittent duty applications.

Differential air motors are a good motor design for in-line pumps. Small differential air motors can be easily designed to provide equal force (balanced thrust) on the up stroke and down stroke. When hooked to a volumetrically balanced pump, a differential air motor will provide equal fluid pressure and flow on the up and down strokes. The fluid flow and pressure from the pump will be relatively constant with minimal pulsation.

Some other advantages of differential air motors are the poppet valve design which works to prevent icing of valve ports by chipping away ice formations on each change-over and the fact that different pump shaft sizes have no impact on the ratio of up stroke to down stroke.

Differential Air Motors - Limitations

The differential air motor size is limited by the intake and exhaust port size. Large differential motors would not breathe well.

Differential air motors must be dismantled to make valve repairs. While the poppet valves may prevent some internal icing problems, icing that occurs inside the piston skirt and around the trip rod cannot be manually removed.

Differential air motors also cost more than flat plate air motors of comparable power.

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. Differential air motors are more compact than flat plate air motors of comparable size because they use practically all of their piston surface area in each direction to generate force.
 - a. True
 - b. False

2. Flat plate air motors will provide _____ force on the upstroke than on the down stroke.
 - a. equal
 - b. more
 - c. less
 - d. neutral

3. Differential air motor size is limited by the _____ and _____ port size.

Answers to Progress Check

1. b. False (Flat plate air motors are more compact than differential air motors of comparable power.)
2. c. less
3. intake and exhaust

Trade Names

Learning Objectives

Knowing the trade names and some specific details of Graco's flat plate and differential air motor lines is a must for doing your job successfully. After completing this section, you will be able to:

- List the trade names for Graco's flat plate air motor line according to size.
- List the trade names for Graco's differential air motor line according to size.

Graco Flat Plate Air Motors

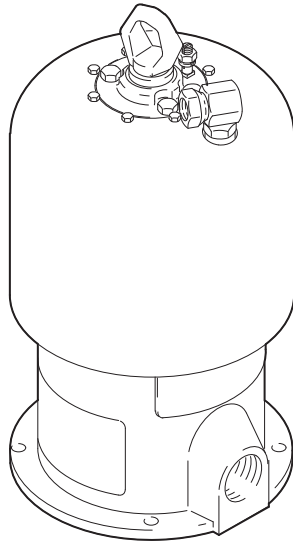
Note: The flat plate air motors discussed in this section are listed according to size; smallest to largest. Figure 20 shows Graco's family of flat plate air motors.

The *Eagle* Air Motor is the smallest flat plate air motor. An equivalent size range comparison would be the differential Monark and Fireball motors. The Eagle model has a 2.9 inch (7.4 cm) motor size diameter and a 3.25 inch (8.3 cm) stroke length. It is primarily used for intermittent duty applications with lubrication pumps. The unique feature on the Eagle model is an air triggered spool valve design. As mention earlier, the Eagle is the only Graco air motor with air actuated control valves.

The *Senator*, *Bulldog* and *King* Air Motors are identical in design. Their only difference is unit size. The Senator has a 5.5 inch (14 cm) motor size diameter. The Bulldog has a 7 inch (17.8 cm) motor size diameter. And the King has a 10 inch (25.4 cm) motor size diameter. All three have mechanically actuated valving and a 4.7 inch (12 cm) stroke length. The Senator, Bulldog and King models are the most commonly used flat plate air motors. Each model offers Standard series and Quiet series designs.

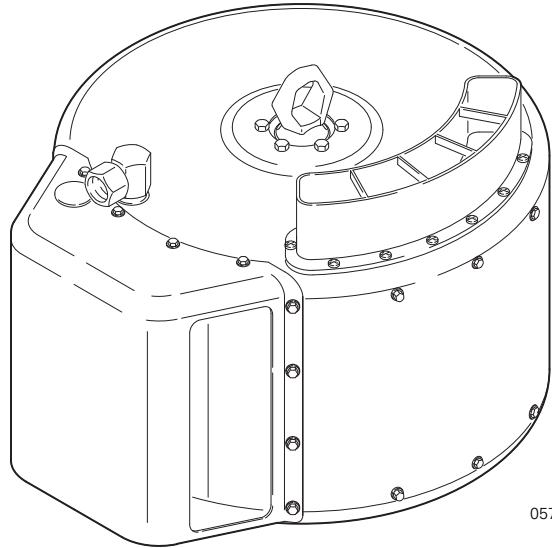
The *Premier Air Motor* is the largest in Graco's line of flat plate air motors. In fact, it is the largest air motor that Graco manufactures. The Premier model has a 12.625 inch (32 cm) motor size diameter and a 4.7 inch (12 cm) stroke length. The Premier features a side mounted valving design that is mechanically actuated and a built in heat exchanger to reduce icing problems.

King Air Motor
10 in. (25.4 cm) Diameter
4.7 in. (12 cm) Stroke



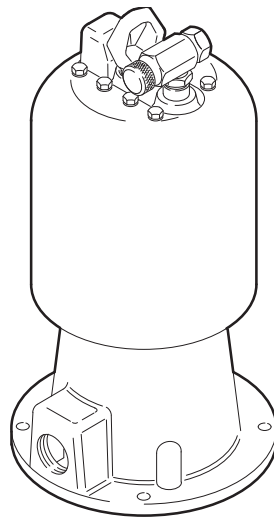
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Premier Air Motor
12.625 in. (32 cm) Diameter
4.7 in. (12 cm) Stroke



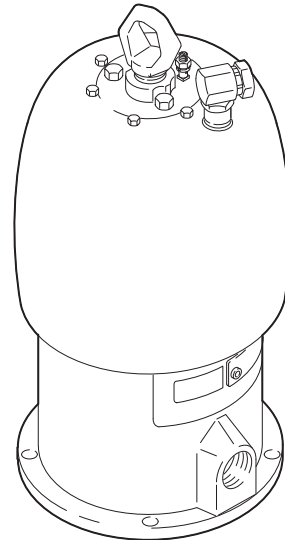
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Senator Air Motor
5.5 in. (14 cm) Diameter
4.7 in. (12 cm) Stroke



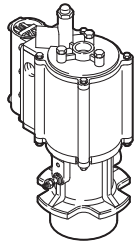
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Bulldog Air Motor
7 in. (17.8 cm) Diameter
4.7 in. (12 cm) Stroke



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Eagle Air Motor
2.9 in. (7.4 cm) Diameter
3.25 in. (8.3 cm) Stroke



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Figure 20 Graco's Family of Flat Plate Air Motor.

Graco Differential Air Motors

Note: The differential air motors discussed in this section are listed according to size; smallest to largest. Figure 21 shows Graco's family of differential air motors.

The *Standard Air Motor* is the smallest differential air motor. It has the same motor size diameter as a FastFlo™ air motor, but a shorter stroke length. The Standard's motor size diameter is 1.4 inches (3.6 cm) and the stroke length is 3 or 4 inches (7.6 or 10.2 cm). This model uses mechanically actuated valving.

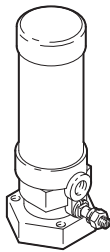
Note: All Graco differential air motors feature a mechanically actuated valving design.

The *FastFlo™* and *Fast Ball Air Motors* have the same 1.4 inch (3.6 cm) motor size diameter as the Standard air motor and a 4 inch (10.2 cm) stroke length. The FastFlo™ is a divorced pump and the Fast Ball is an inline pump.

The *Monark and Fireball Air Motors* are different names for the same size air motor. These models have a 3 inch (7.6 cm) motor size diameter and a 3 inch (7.6 cm) stroke length. Monark air motors are painted gray and used with divorced pumps. Fireball air motors are painted white and used with inline pumps.

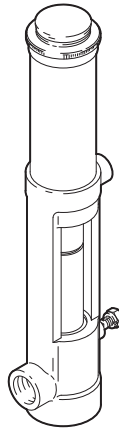
The *President Air Motor* is the largest differential air motor. This model has a 4.25 inch (10.8 cm) motor size diameter and a 4 inch (10.2 cm) stroke length.

FastFlo™ Air Motor
1.4 in. (3.6 cm) Diameter
4 in. (10.2 cm) Stroke



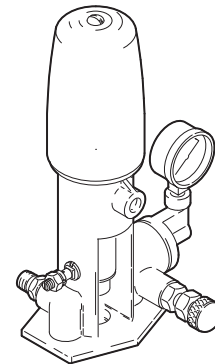
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Fast Ball Air Motor
1.4 in. (3.6 cm) Diameter
4 in. (10.2 cm) Stroke



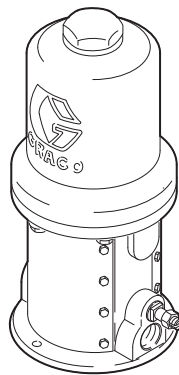
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Fast Ball Air Motor
1.4 in. (3.6 cm) Diameter
4 in. (10.2 cm) Stroke



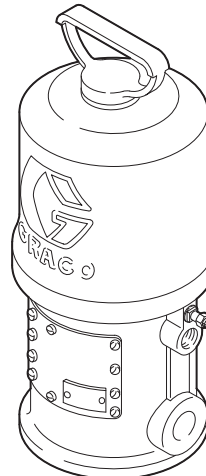
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**Monark and Fireball
Air Motors**
3 in. (7.6 cm) Diameter
3 in. (7.6 cm) Stroke



05801

President Air Motor
4.25 in. (10.8 cm) Diameter
4 in. (10.2 cm) Stroke



05800

Figure 21 Graco's Family of Differential Air Motors.

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. List the trade names for Graco's flat plate air motors according to size; smallest to largest.

2. List the trade names for Graco's differential air motors according to size; smallest to largest.

Answers to Progress Check

1. Eagle, Senator, Bulldog, King, Premier.
2. Standard, FastFlo™, Fast Ball, Monark, Fireball, President.

Glossary

Air Compressor: A device that provides compressed air at specified pressure and flow to operate devices such as air motors. It consists of a motor, usually electric or gasoline, an air compressor “pump”, reservoir, air lines, control valves, and filters.

Air Motor Icing: Ice builds up in and near the exhaust ports of air motors when operated continuously at certain temperatures with a damp air supply. The ice buildup interferes with normal motor operation. In extreme cases, the motor may stop.

Air Motor Lubricant: Oil is injected into the high pressure air powering an air motor to prolong the life of the motor.

Balanced Thrust: A term to compare the force provided by a reciprocating air or hydraulic motor on its up and down strokes. If the forces exerted on the up and down strokes are equal, then the motor provides balanced thrust. If the forces are different on the up and down strokes, then the motor does not provide balanced thrust.

Change-Over: The process that a reciprocating air or hydraulic motor goes through to stop one stroke, change directions and start the next stroke in the opposite direction.

Continuous Duty: An application where the motor and pump are used for long periods of time. The meaning of “Continuous Duty” may vary from industry to industry. Example: In paint circulation, it means 24 hours a day, 7 days a week. In other industries it may mean operating continuously for 1/2 hour or more. It usually means that the motor and pump will operate continuously over a defined period of time.

Exhaust Pulse: The release of compressed air that occurs in an air motor at change over.

Fluid-Pressure Fluctuation: Pressure from a pump can fluctuate due to fluid flow changes at change over. This occurs because fluid flow momentarily stops at change over. Fluid pressure fluctuation is directly related to motor change over speed. Faster motor change over results in less fluid pressure fluctuation.

Horsepower: A standard measurement of power, equal to 550 foot-pounds (ft. lbs) per second. Abbreviated as hp. Also equals 745.7 watts.

In-Line Pumps: A low cost pump design used in the lubrication industry. The pump throat packing doubles as the motor piston rod packing.

Intermittent Duty: An application where the motor and pump are used for short periods of time. The meaning of “Intermittent Duty” may vary from industry to industry. It usually means that the motor and pump will start up and stop repeatedly over a defined period of time.

Operating Cycle: One operating cycle equals one up stroke, plus one top change over, plus one down stroke, plus one bottom change over.

Paint Circulation System: A continuous duty application where paint is circulated in a system of lines and control valves 24 hours a day, 7 days a week to insure proper mixing and agitation.

Pneumatic Cycle Counter: A device used to meter fluids based on the volume dispensed on each pump stroke. The counter is triggered by the exhaust pulse at change-over. Every time it counts a motor pulse it assumes that the pump has displaced a given volume of fluid. When it counts the specified number of strokes, it shuts off the inlet air to the pump until it is reset.

Reciprocating Pump: A pump that operates using a “back and forth” motion. The internal components of the pump may move up and down, or from side to side.

Transfer Application: An application where fluid is moved from one location to another. This application may be continuous or intermittent duty.

Viscosity: The resistance of a fluid to flow.

Notes

Module Evaluation

The purpose of this Module Evaluation is to help the Graco Technical Communications department determine the usefulness and effectiveness of the module.

*Instructions: Please complete the evaluation, tear it on the perforation, and return to:
Graco Technical Communications Department, P.O. Box 1441, Minneapolis, MN 55440-1441, USA.*

1. *Based on the objectives, this module:*

- Significantly exceeded my expectations
- Exceeded my expectations
- Met my expectations
- Was below my expectations
- Was significantly below my expectations

2. *Why did you select the above rating?*

3. *How do you plan to use the module information in your job?*

4. *How do you think the module could be improved?*

I verify that I have successfully completed Module No. 321-041, Flat Plate and Differential Air Motors

Signature _____

Date _____



Graco

Technical Communications Dept.

P.O. Box 1441

Minneapolis, MN 55440-1441 U.S.A.

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This module was developed by the Graco Technical Communications Department with assistance from the following individuals:

Al Brus
Tom Ruff
Dirk Johnson

The Graco Concept and Theory Training program consists of the following topics:

Fluid Basics
Atomization
Electrostatic Spray Finishing
Safety
Airspray Technology
Fluid Types: Paints and Other Coatings
Fluid Types: Lubricants
Fluid Types: Sealants and Adhesives
Airless Atomization
Spraying Techniques
Transfer Efficiency
Fluid Movement
Fluid Controls
Pumps
Motors and Power Sources
Plural Component Paint Handling
Plural Component Sealant and Adhesive Handling
Paint Circulating Systems
Automatic Finishing
Lube Reels and Dispense Valves
Lube Metering Systems
Electronic Fluid Management Systems

