AIR MOTORS HANDBOOK

(Revised Edition)

IDEX CORPORATION

Use of Air Motors in Hazardous Atmospheres

At the present time, there are no known standards governing the operation of air motors in hazardous atmospheres. However, there are several points regarding the safety of air motors.

First of all, an air motor is not a source of electric sparks. However, it is possible that an article which is not part of the air motor (e.g., wrenches, hammers, etc.) could create a spark by sharply impacting a cast iron or aluminum case or the steel shaft of the air motor. [Note that electric motor enclosures for both class I and 11 hazardous locations can be made of "...iron, steel, copper, bronze or aluminum..." (UL 674, Electric Motors and Generators - Hazardous Locations, June 23, 1989; paragraph 4.2, page 6)].

Second, an air motor housing is not designed to contain an internal explosion as is an explosion proof electric motor. The only possible internal source of ignition in an air motor is a contact between the stationary housing components and the rotating elements that might create a spark. The likelihood of this occurring is reduced by the fact that the contact must be made at precisely the same time as a flammable or explosive gas is introduced into the air motor in a sufficient quantity to achieve a flammable or explosive mixture while overcoming the positive pressure of the driving gas. In other words, although highly improbable, an internal explosion in an air motor is possible.

Finally, an air motor is designed to be operated by compressed air, the expansion of which in normal operation creates a cooling effect. As a result, the temperature of the air motor will not exceed the higher of the temperatures of the surrounding atmosphere or the air delivered to the inlet.

We do not guarantee the safety of every application, but to ensure the safe operation of an air motor in your application, always follow the product directions and consult with a qualified engineer.

Introduction

This handbook is about motors that are driven by fluid. More specifically, the fluid we're concerned with here is pressurized air. In short, then, this handbook is about air motors: what they are, how and why they work, their characteristics, their accessories, and, finally, how and when to use them.

Although electric motors seem to be available for every conceivable use, and hydraulic (the other half of fluid power) motors can be much more powerful for their size, air motors fill a unique niche in the aggregate of power sources. Air motors are compact, lightweight sources of smooth, vibration-less power. Air motors stop and start almost instantly, and they provide extremely variable torque and speed without complicated controls. They can operate in hot, corrosive, and wet environments without damage, and are unaffected by continuous stalling or overload. And they are instantly reversible and nonelectrical sparking. Unlike electric motors, air motors run cool and start without so shock. Therefore, there's no heat buildup or electric sparks to damage the motor. Compared with hydraulic motors, air motors have a lower torque and power-to-weight ratio. But compressed air offers special advantages that make air motors quite desirable: it's readily available in many plants, it's clean, and it can be directed to air motors with simple low-pressure piping.

There are literally hundreds of uses for air motors. Applications include the mixing of paints where stalling the motor might damage an electrically operated device. Hoist operations rely on air motors because their simple speed control and ease of reversing permits very accurate control of lifting, lowering, and traveling. Among other uses are driving belt conveyors, operating production machinery, and opening steel drums, to name just a few.

Organization of This Handbook

This handbook is organized to be a basic source of information on air motors and to help you choose an air motor that's best for a given application. Section I is a general discussion of some of the features of air motors, including a comparison with other motor types, especially electric. Section 11 summarizes air motor principles and describes the major types of air motors in existence today. Section III deals with other components of air motor systems -valves, pressure regulators, dryers, filters, and the like. Section IV then deals with general criteria to consider when selecting an air motor, and some very specific applications of air motors. These applications were chosen to demonstrate some of the unique features of air motors. Section V is devoted to air motor maintenance.

The appendix contains tables (in both U.S. and metric units) giving data on loss of air pressure because of friction, pipe bends, and components, and air flow through various-size orifices. An air motor selection chart and composite curves for both standard and geared motors plotting horsepower, torque, and air consumption against rpm also appear there to aid in selecting the proper air motor for some specified range of conditions. A glossary is at the end of the handbook.

The theory underlying pneumatic fluid power-that is, the development and utilization of pressure and vacuum for specific work needs-is treated in depth in another handbook, "Vacuum and Pressure Systems," available from Gast Manufacturing Corporation, P.O. Box 97, Benton Harbor, Michigan 49023-0097

IMPORTANT

Gast cannot and does not guarantee the safety of every application of its air motors. Rather, to ensure the safe operation of an air motor in your application, always followthe product directions and consult with a qualified engineer. Also, give one of our product engineers a call. We'll be happy to assist you.

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Air Motors - General Section I

The distinct features of air motors can be best described by comparing them with electric and, to some extent, with hydraulic motors (Table 1). The comparison in that table is intended to serve more as a frame of reference than as a guide for deciding "either/or," since air motors are not direct replacements for electric or hydraulic motors.

There is a tendency to compare air with electric motors on the basis of their horsepower versus size and weight. For instance, air motors develop more horsepower per pound and cubic inch than do most electric motors of standard design. Atypical rotary vane air motor-which is one of the two most widely used types of air motors (see Section II)-rated 21/2 hp at 1800 rpm and 90 psi weighs just 17 pounds. An electric motor that develops the same horsepower might be two to three times heavier.

But comparing air motors against electric motors purely on a weight/horsepower/size relationship does not consider the key advantages of air motors: The relationship between torque and speed.

An air motor slows down when load increases. Its torque increases at the same time until it matches the load. The air motor continues to provide increased torque until it stalls, then maintains the stalled condition without harming the motor.

As the load is reduced, an air motor increases speed and the torque decreases to match the reduced load. When the load is either increased or decreased, speed can be controlled by increasing or decreasing air pressure.

So although horsepower indicates, among other things, how fast the work will be done, and free air consumption tells how much air the motor will need, engineers generally check torque first when specifying an air motor.

An air motor's starting torque is lower than its running torque. This feature permits smooth, no-shock starting, but it's necessary to have additional air pressure for starting under heavy loads.

Among other air motor features, they can be stalled for indefinite periods. By contrast, a stalled electric motor without overload protection soon burns out, and a hydraulic motor may overheat. During a stall, air motors continue applying torque to whatever is being driven and resume rotation only when the stall is overcome by reducing the load or increasing air pressure.

Many air motors are reversible. Reversal causes little strain on the motor or shock on the load and can be accomplished in a few angular degrees of rotation. Practically all electric motors, by contrast, must be stopped completely before they can be reversed, and they must come up to speed before full load can be applied again.

A simple flow-control valve varies air motor speed from several hundred to several thousand rpm, or it varies power output when the load increases. Most a.c. electric motors run at constant rated speed, and their output speed can be varied more than ± 10% of rated speed only with gear reducers or with relatively sophisticated controls.

Air motors are nonelectrical sparking because they use compressed air as their energy source. They often can be chosen to run in wet or corrosive environments. Explosion-proof electric motors require special, more costly, construction.

The cool running of air motors is another plus, especially at high ambient temperatures-up to 250^{o}F (121^{0}C). Expanding air in the motors cools them. Air motors can sometimes be run at higher ambient temperatures if the air motors runs continuously. (Consult the air motor manufacturer for advice in such applications.)

Windings in electric motors heat up, by contrast, so special insulation is required for heavy loads or high temperatures. Even hydraulic motors heat up somewhat during operation.

Because the fluid used by air motors is at a lower pressure (under 125 psi) than is fluid for hydraulic motors (up to 3000 psig), air motors invariably cost less. The compressed air needed to power an air motor usually can be supplied by an existing compressed-air system. Hydraulic systems for plant use are far less commonplace. To use a hydraulic motor, it may be necessary to buy the hydraulic pump and other components to create the complete closed-loop system, adding considerably to the expense.

Air motors rarely break down suddenly. They usually just wear out slowly, producing less power as they wear. Because of this, maintenance can be planned well in advance. Maintenance and repairs are generally fairly simple (see Section V), as is testing and checking.

As the load increases, motor speed normally decreases. But its torque output increases to match the load until stall is reached. When equipped with governors, air motors hold a relatively constant speed under varying loads.

Since most of an air motor's noise comes from the exhaust, it can be easily quieted by up to 50% or more with an exhaust muffler. Because mufflers restrict air flow, they reduce motor efficiency, and, for this reason, motors may have their exhausts piped outside the room.

One drawback of air motors is that they are less efficient than their electric counterparts. Typically, an electric motor drives an air compressor, which supplies the air to drive an air motor. The efficiency of the system is usually less than 20%. The efficiency of fractional horsepower induction motors is usually from 45% to 70% when they are fully loaded. Most electric motors, however, are not run fully loaded; the efficiencies actually experienced are thus lower than these maximums. The point here is that air motors are selected over electric motors not for their efficiencies but, rather, for their many other features.

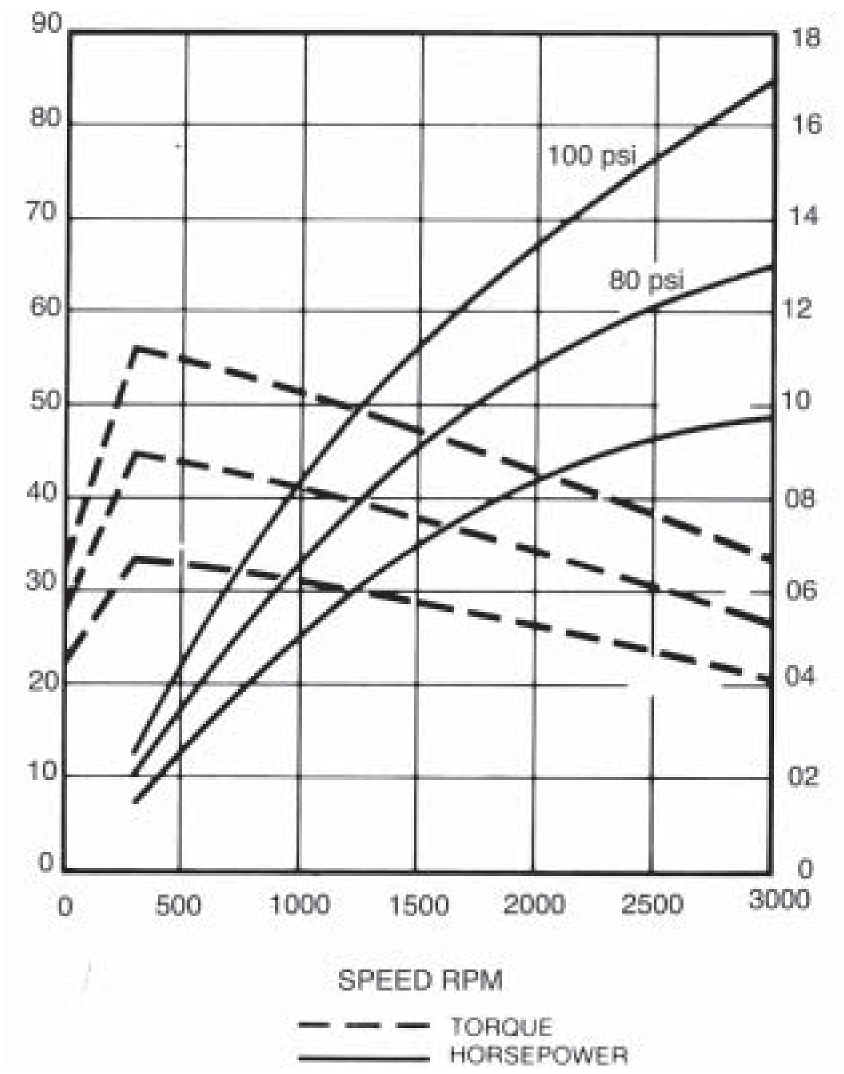
Selection Criteria

There is a rule-of-thumb for selecting an air motor: Choose a size motor that will produce the required starting torque and horsepower using about two-thirds of the available air line pressure (Section II). Another general rule is that an air motor's starting torque generally is lower than its running torque. Getting heavy loads started may require a momentary "shot" of higher line pressure. Where high starting torque is needed, an 8 vane motor should be considered.

Air motors produce power in patterns similar to those of series-wound d.c. motors**.** At a constant inlet pressure, power is zero at zero speed, builds up to a maximum at about 50% of free speed, and decreases to zero when free speed is reached. Avoid matching torque, power, and speed of an air motor and an electric motor with different patterns; an incorrect application would be an almost certain result.

"Rated" speed, or design speed, is the point at which maximum power is reach. It's generally about 50% of free speed -the maximum or no-load speed at a given pressure.

Figure 1



Horsepower-torque characteristics of typical rotary vane air motor

Stall torque of an air motor is greater than the running torque at a given pressure and occurs when the load on the motor matches the motor's maximum torque output. (See the curves in the appendix.) If you follow a torque curve in reverse as speed decreases with increasing load, you'll find the torque keeps increasing to a value above maximum running torque until stall is reached.

An air motor's power rating usually is the maximum horsepower produced at 90 psi line pressure. Remember, though, that torque and horsepower ratings are for pressure at the motor inlet, not for pressures at the compressor or elsewhere in the air lines.

Some manufacturers not only supply tables or graphs giving rated torque, horsepower, and air consumption versus. speed at maximum pressure rating, but also provide information at different pressures. Use of these curves or figures for different inlet pressures - even if interpolation is necessary - is a fairly accurate way of predicting operating performance. Fig 1 shows horsepower -torque versus. speed characteristics of a typical vane air motor at three pressures.

The main consideration in selecting an air motor for changing motor loads is the permissible variation in operating speed. Two air motors with the same power rating can have widely different speed variations when driving identical and changing loads. This can be understood by examining their torque versus. rpm curve. The steeper the torque curve, the more speed varies with a change in load.

Table 1
Motor Comparison

Characteristics	Air	Hydraulic	Electric
Power source	Plant air	Plant hydraulic system (if available) or individual pump	Plant electric system
Connections	Flexible, one-way air hose	Rigid, high-pressure two-way pipes	Cord/Cable
Speed Control	Flow or pressure regulator	Flow or pressure regulator	a.c.: wound rotor (limited) or inverter (wide speed) adjustment d.c.: SCR control
Speed regulation	Speed varies with load*	Depends on power unit	a.c.: speed independent of load d.c.: speed varies with load*
Reverse-ability	Easily reversed	Easily reversed	Reversing limited by inertia and heat buildup

Overload/stalling	Can be stalled indefinitely without damage	Stalling may waste energy (depends on power unit)	Requires thermal cutout to protect against overload or stall
Operating safety	Nonelectrical sparking	May be non-electrical sparking, but petroleum-based fluids are flammable	Nonelectrical sparking construction available at extra cost
Maintenance Safety	No electrical spark hazard in the use area.	No electrical spark hazard in the use area.	Shock hazard; maintained by special craftsmen.
Cleanliness	Clean	Fluid leaks (espec ially petroleum-based fluids) are messy	Clean
Temperature limits	To 250ºF (121ºC) in intermittent use; motor runs below ambient	To 120º - 150ºF (48.9º - 65.6ºC) (fluid decomposition limits) Heat exchange and additional pumps may be needed	To 104ºF (40ºC); motor runs hotter than ambient
Size and weight	Relatively light and compact, especially in smaller sizes	Best power/weight ratio, espec ially in larger sizes	Generally heaviest and bulkiest
Noise	Mufflers reduce up to 50%; this reduction takes the noise below OSHA-recommended level of 85 dB(A) for continuous eight-hour exposure		Relatively quiet
Convenience	Can be run in any position (horizontal) vertical, or at an angle), and are generally main-tenance-free	Generally horizontally mounted with maintenance needed for in-line filters strainers, and seals	Can be operated in any position al-though they're usually mounted horizontally; a.c. motors are generally maint-ennance-free, but d.c. motors require frequent brush replacements and commutator maintenance

*Constant-speed regulators available at extra cost.

Air Motors - Principles and Types Section II

Principles to keep in mind when using air motors include the conditions a pressurized air source must meet, air quality and quantity, motor lubrication, and noise control. The type of air motor to use is determined by operating pressure, torque and speed required for the job.

Air Pressure

The source of an air motor's energy - compressed air - must be regulated to within 5% or 10% of the operating pressure for which the motor is selected. There are two ways of supplying compressed air to an air motor: either directly from an air compressor, or from a pressure vessel or air receiver placed between the compressor and motor.

The compressor (or bank of compressors) should be chosen to meet demand. Down-time of equipment resulting from pressure loss is expensive and should be taken into account when laying out the pneumatic system. When pressure delivered to a receiver tank is high enough, it can be regulated before it enters the motor. The pressure should be checked at no load and maximum load conditions to make sure that enough air volume is being delivered to the motor.

Adjustment of the pressure of the air entering the motor is sometimes required. For instance, long small-diameter supply lines with many sharp bends may cause a severe pressure drop. In some air motors, a pressure drop of 11% could cause a 13.5% drop in motor efficiency, and a pressure drop of 22% could cause a 27% drop in efficiency.

This pressure drop results from friction (see appendix tables). Significant amounts of pressure can be lost in bends; the tables in the appendix give these losses for 90^{o} and 45^{o} bends.

Orifices can be used to restrict air flow to the motor, limiting the speed and guarding against a runaway situation. The appendix shows the relationship of air flow to orifice size and applied pressure.

When all the possible differences are considered, select an air motor that will provide the horsepower or torque needed using only two-thirds of the line pressure actually available. The full air line pressure is then available for overloads and starting.

Other considerations include:

• The air must be clean to maintain efficiency and eliminate downtime; a filter-separator with an automatic drain can be used for this purpose.
• Lubrication is achieved by installing a lubricator to inject atomized oil into the air before it enters the motor.
• Noise reduction is accomplished with a muffler. (See Section III for details of these and other air system components.)

Air Motor Types

There are several types of air mors, with the rotary vane version the most popular, followed by the radial/axial piston design. Turbine, V-type and diaphragm models are also available, but they are not commonly used. Therefore, the rotary vane version is emphasized here.

Rotary Vane Motors

Rotary vane air motors are comparatively simple in design. They are widely used and they are usually available in small sizes - 1/10 to 10 hp with maximum operating pressure of 100 psi. Free speeds up to 15,000 rpm are possible with rotary vane motors.

Figure 2

Typical rotary vane air motor. Vane-type motors are usually available in small sizes - 1/10 to 10 hp with maximum operating pressure of 100 psi.

Rotary Vane Motors

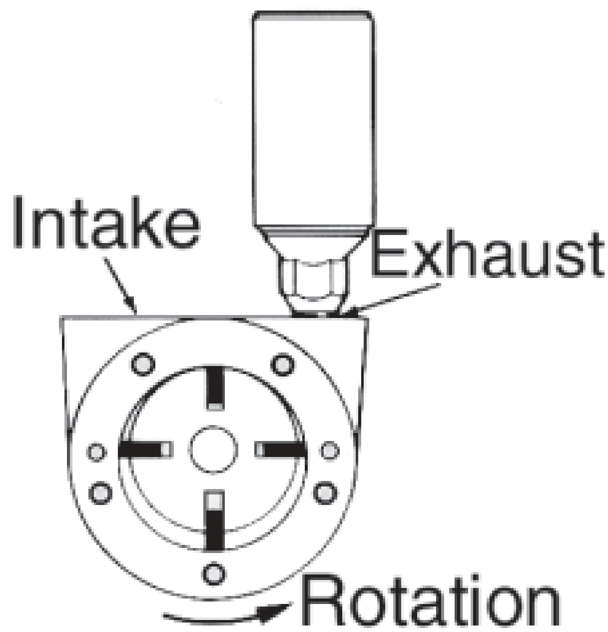
Fig. 2 show a typical rotary vane motor; Fig 3 is sectional drawing of the same motor and shows how it works. In the motor, the rotor in mounted eccentrically (off center) in relation to the cylinder bore; the vanes slide radially in the rotor slots as it turns. The vanes are kept constantly in contact with the cylinder bore via spring or pneumatic pressure applied to the vane edges closest to the shaft, or simply by centrifugal force.

Torque developed at the motor shaft is determined by

Applied air pressure	**x**	Vane Area exposed between the rotor's outside diameter and cylinder bore	**x**	Moment arms of the vanes

Although four vanes are considered standard, motors with more vanes are available for special application (see Section IV) calling for accurate inching control, low speed control, and minimum stalled blowby.

Figure 3



Vane-type motors are comparatively simple in design, as this sectional drawing shows. The four-vane motor is a common version. The rotor is mounted eccentrically in the cylinder bore, and the vanes slide radially in the rotor slots as it turns. The torque at the shaft is a product of pressure, vane area exposed between the outside diameter of the rotor and the bore, and the moment arm of the vanes.

Piston Motors

There are two categories of piston air motors: radial and axial. The axial design is generally limited to under 31/2 hp. Piston motors develop high torque, making them especially useful when that property is needed. They are well-balanced. They have four, five, or six pistons, providing for even torque at all speeds and smooth delivery of power with each revolution in either direction of rotation.

Radial Piston Motor

This type of motor operates at a much slower speed than does a vane-type motor because of the weight resulting from its reciprocating parts. Free speed is usually 3000 rpm or less. Maximum horsepower is usually developed at 1000 rpm or less. The smooth, overlapping power flow and accurate balancing of radial piston motors make them vibration-less at all speeds, a feature especially noticeable at lower speeds where maximum torque is developed. Fig. 4 shows a typical radial piston motor, and Fig. 5 is a sectional view.

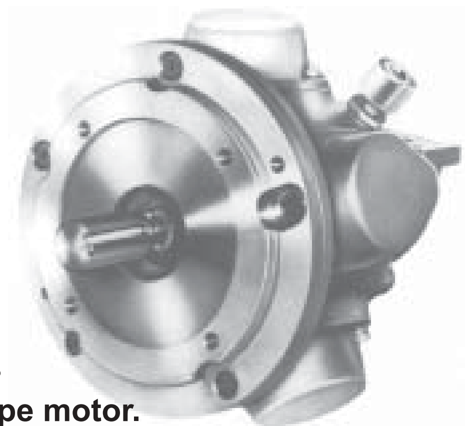


Figure 4
Radial piston air motor. This motor operates at slower speeds than a vane-type motor.

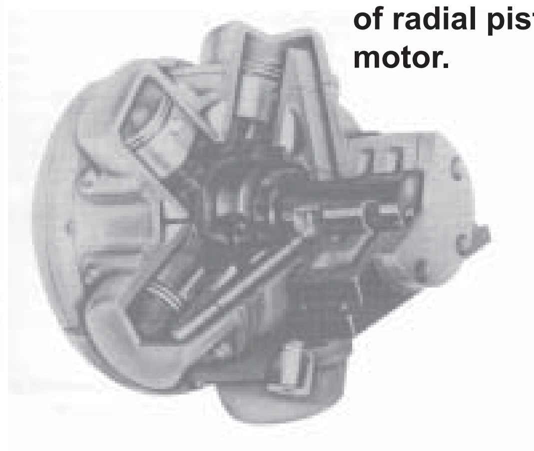


Figure 5
Sectional view of radial piston motor.

Axial Piston Motors

Axial piston air motors have small pistons that reciprocate axially (parallel to the drive shaft) in sequence. On the power stroke of a piston, its rod is driven against a wobble plate (Fig. 6), transferring the force of the stroke into rotary motion to turn the drive shaft.

Impulses of the pistons overlap, as with the radial piston motor. The axial piston motor is readily available in small sizes only, so its output is limited to 31/2 hp.

The high torque and low inertia of both types of piston motors mean they can reach full operating speed almost instantly. Piston air-powered gearmotors are also available where very high torques are needed.

Air-Powered Gearmotors

The function of any gear reducer is to bring a motor's base speed to a usable, or workable, speed and still produce the torque required for a given application. There are generally very few uses for a motor's base speed; and for applications requiring both high torque and rightangle configurations, the "modular" style worm-gear drive is perhaps the most widely used.

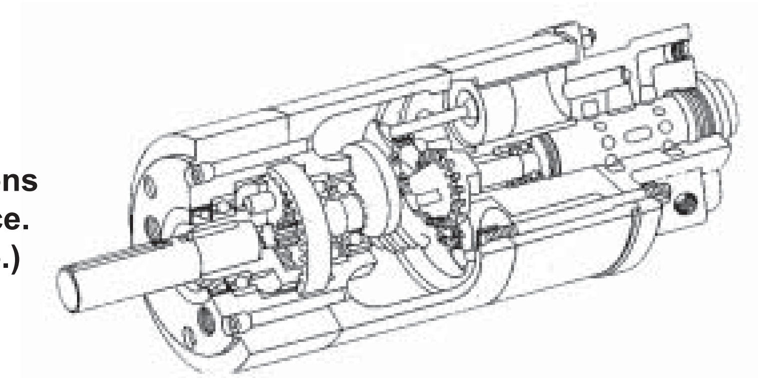


Figure 6
Cutaway view of an axial piston motor. The small pistons reciprocate axially in sequence. (Courtesy Gardner-Denver Co.)

Starting torque-the maximum torque produced from a standstill under load at a given air pressure-is the most important data point of any air motor performance curve. So the fundamental idea behind gearmotors involves starting torques.

Torque is generally discussed in terms of stall torque, the maximum torque achieved at a given pressure. Starting torque, however, cannot be predicted from stall torque. In a rotary vane air motor, the position of the vanes relative to the inlet and discharge ports plays an important role in how much torque will be delivered at start-up.

Unfortunately, there's no way to tell where the vanes are when a motor is started. So minimum starting torque is the recommended basis for discussing air-powered gearmotor performance.

Tables or graphs showing torque, horsepower, and air consumption as a function of speed are available from air motor manufacturers. Using these data, even if they require interpolation, will enable a fairly accurate prediction of operating performance.

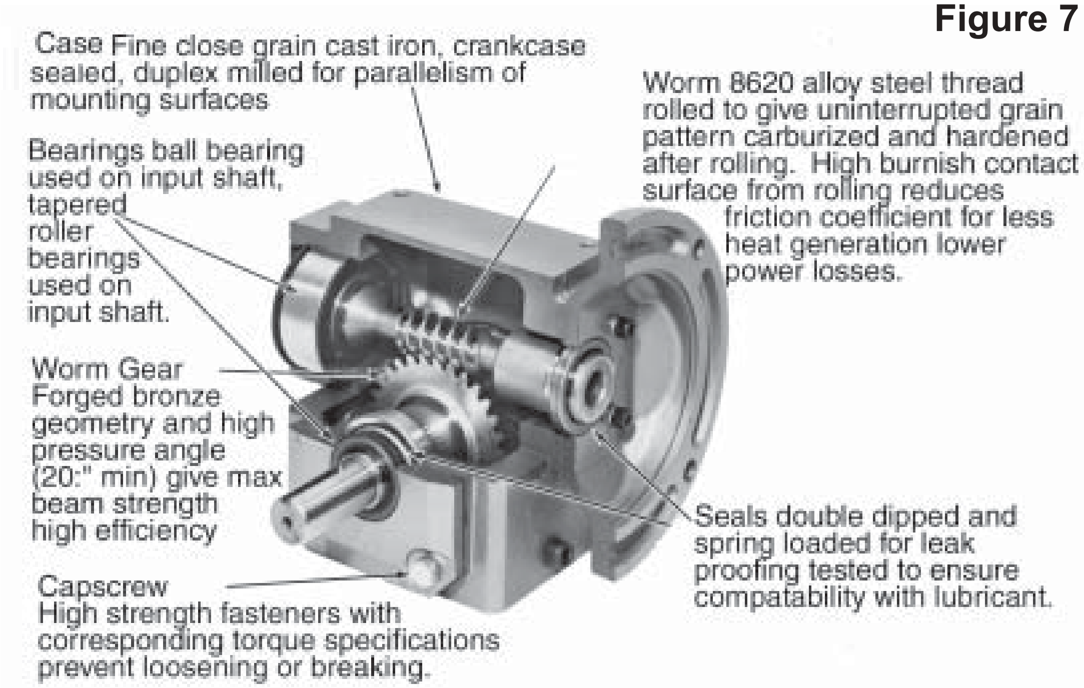
Curves in the appendix show how gearing affects torque of typical vane motors in the Gast line.

The most popular gearing mechanism used with rotary vane air motors is a worm-gear drive (Fig. 7) introduced by Gast in the late 1970's. To enable fitting the gearmotors in areas that may be hard to reach or have limited space, the gearmotors are available with four mounting bases (Fig. 8)

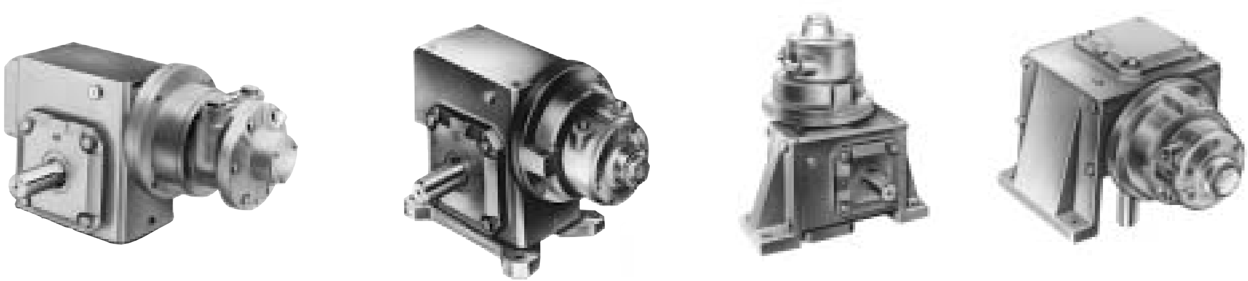
Other Types of Air Motors

Other types of air motors are occasionally used. Turbine air motors develop very high speeds with little torque and are used in such applications as dentists' drills. V-type piston motors (similar to a V-8 engine in design) perform well against lugging, but otherwise show differences from other piston motors. Relying on a ratchet to transfer power, reciprocating diaphragm motors supply high torque at very low speeds and are used in special applications requiring incremental motion. Percussive motors have linear drives only and are usually limited to pneumatic drills.

Figure 7



Cutaway view shows construction of worm gear drive mechanism typically used with air-powered vane gearmotors.



Four mounting styles are available for air-powered gearmotors. Starting clockwise from the upper left hand corner, the photograph shown the basic mounting configuration, a horizontal base with horizontal shaft and motor, vertical base with vertical shaft and horizontal motor, and vertical base with horizontal shaft and vertical motor. An mounts match those accepted for electric motors on a bolt-for-bolt basis.

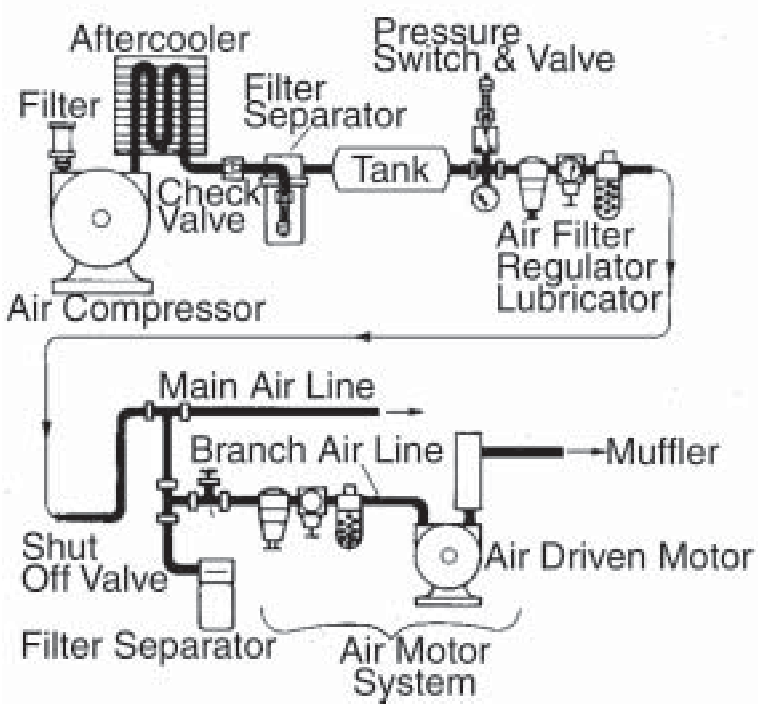
Air Motor System Components Section III

An air motor is the heart of a pneumatic work system. Such a system may include, in addition to a compressor, various other components; a pressurized air-storage tank, pressure-control devices, directional control valves, flow-control valves, mufflers, filters, moisture separators, lubricators, and gauges. This section briefly describes these components and their functions. (A detailed treatment of air line components appears in “Vacuum and Pressure System”, the handbook referred to in the introduction.)

Air Receiver

Fig. 9 is a line drawing of a typical hookup from a main compressed-air line to an air motor. The air receiver is usually a storage tank (Fig. 10) in which air is stored under pressure to provide a convenient source of pressurized air when needed. As compressed air is transmitted to an air receiver, the amount of air in the tank progressively increases and higher - pressures develop.

Figure 9



Typical hookup from a main compressor line to an air motor.

Figure 10

Typical tank for storing air under pressure. The tank provides a convenient source of pressurized air when needed; conditions the air somewhat; quiets pulsations from the compressor; and condenses moisture that may be carried over from the aftercooler unit. (The moisture is then drained.)

Figure 11

An air pressure gauge helps maintain a constant pressure.

Some sort of control device is therefore required to feed the air to the system at a desired pressure.

The air receiver is usually the last stop before air is transmitted to the distribution system. Its primary function is to act as a reservoir to accommodate sudden or unusually high system demands, preventing frequent starting and stopping of the compressor.

An air receiver also provides some conditioning of the air. It dampens pulsations from piston compressors, imparting a steadier pressure to the system. Moisture that may carry over from the compressor's aftercooler will condense here and can be drained from the receiver. In some systems, small air receivers are placed at regular intervals along the line to act as moisture collecting tanks.

Air Pressure Regulator

An air pressure regulator (Fig. 12) is necessary in most pneumatic systems to maintain a constant pressure for a particular application regardless of the rise and fall of line p sure or pressure variations in the air receiver. It is sometime necessary to reduce the pressure to a safe value for certair components.

The regulator is actually a pressure-reducing valve that operates by restricting or blocking air flow into the downstre leg of a circuit. It cannot relieve or regulate upstream pressu

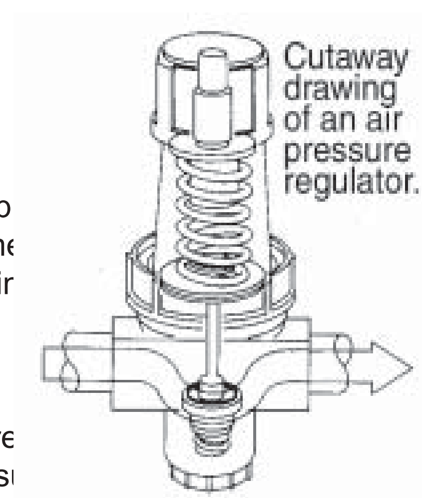


Figure 12

Safety Valve

Some compressed air systems may use simple safety (relief) valves such as those shown in Fig. 13 and Fig. 14. The valve can be set to open to its full capacity to provide a rapid and large reduction in pressure when excessive pressures are reached. The system and compressor are thus protected by expelling excess air pressure to the atmosphere.

Figure 13 and 14

Safety valves such as the two shown above protect the system and compressor by expelling excess pressure.

These valves are classified according to: the number of flow paths; the number of positions to which the valve can be actuated, moved, or shifted; the number of ports; and the type of actuator that shifts the valve (pilot-operated, for example). There are several types of directional control valves:

- Two-way valve-the minimum requirement for any valve is that it have no less than two ports so there is a flow path through the valve. The two-way valve is designed to open or block this single flow path; flow can be in either direction. These are essentially shut-off valves.

- Three-way valve-this valve usually has two extreme positions but may also have a center (neutral) position that can enable an air motor to stop, for example. Three-way valves could be used to control two air motors operating alternately.

- Four-way valve-this design has four working connections. Four-way valves are used with reversible air motors. A speed-control valve can be installed on each exhaust to permit individual speed adjustment for each direction.

Air-Flow-Rate-Control Valves

There are also valves that control the rate of air flow, as opposed to controlling the pressure and routing:

- Flow-control valve-this valve's main function is to permit a constant flow of air to an air motor where the speed must be closely regulated. These manual or automatic valves govern flow by restricting air movement and are classified as gate valves, ball valves, needle valves, etc. The restriction may be fixed or variable. Some sophisticated modulating valves can compensate for pressure and even temperature fluctuations.

• Check valve-in its simplest form, this valve is nothing more than a one-way valve. It permits free flow in one direction only, and blocks flow in the reverse direction.

Mufflers

Air motors, like all pneumatic equipment, can be somewhat noisy. There are many noise-attenuating devices available; Fig. 17 shows some of them.

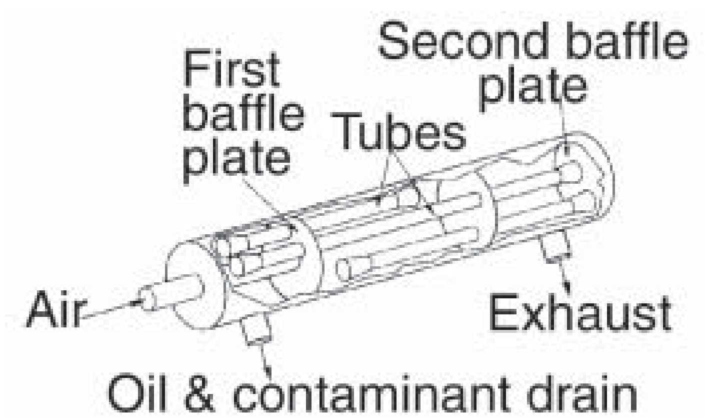
Some operate on the phase-shift principle (Fig. 18), analogous to the canceling out or stabilizing of three-phase alternating electric current. Others are of the baffle type, like some automobile mufflers, causing back pressure.

There are also absorptive and dissipating mufflers, in which the air passes over perforated surfaces with the perforations opening to chambers stuffed with sound absorption material. The absorptive mufflers offer much less resistance and pressure loss is quite small.

Figure 17

Examples

Figure 18



Some mufflers operate on the phase-shift principle others are of the baffle type. There are also absorptive and dissipating mufflers.

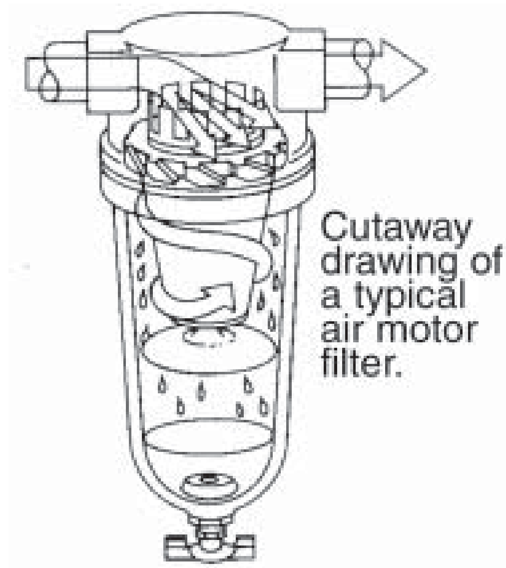
Pulsations from the compressor are controlled or smoothed out by the air receiver tank between the compressor and the air motor.

Filters and Moisture Separators

Air entering an air motor must be clean and dry for efficient operation of the motor as well as to prevent motor damage. (see section 5). Filters and separators of various kinds (Fig 19 & Fig 20) are used for this purpose.

Figure 19

Figure 20



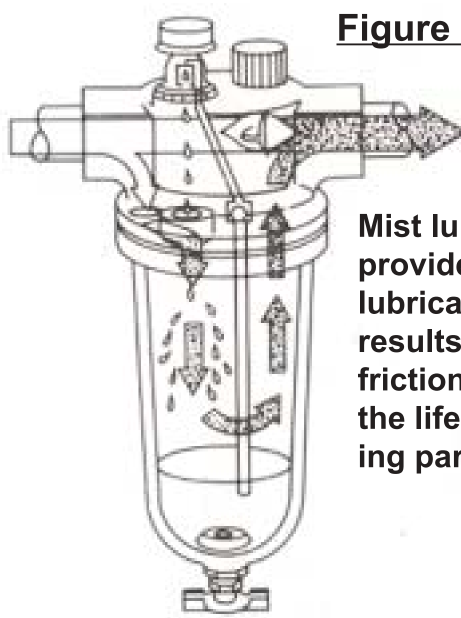
Lubricators

Lubrication is critical for efficient operation and long life of an air motor. Lubrication also prevents corrosion of a motor's interior, since moisture is often present in plant air lines. Figure 21 and Figure 22 are a photo and cutaway drawing respectively of a typical lubricator, which uses air to atomize the oil and move it as a fine mist to the motor.

Figure 21

The lubricator atomizes the oil entering the air motor. Lubrication is critical for the motor's efficient operation and to prevent corrosion.

Figure 22



Mist lubricator provides uniform lubrication. This results in reduced friction, extending the life of the moving parts.

Gauges

Gauges such as the one shown in Figure 23 are used for monitoring the pressure of air entering the motor, as opposed to pressure at the compressor, Variable air pressure at the motor could affect the device driven by the motor, possibly with damaging results.

Figure 23

Gauges help monitor air pressure entering the motor.

AIR MOTOR APPLICATIONS Section IV

Problem/Solution Examples

The number of possible applications of air motors seems limitless. Some typical uses are summarized in Table 2. In addition, six problem/solution examples are described in some detail in this section, showing how to take advantage of the unique features of air motors-variable speed, heat resistance, stalling capability, inching control, etc.

Normally, the choice of air motor to use is between the rotary vane and piston types. When working with vane-type motors, you may have the option of buying them with more than the minimum of four vanes and with gearing (see Section 11).

Knowing the particulars of the application can save headaches and money. For most, a four-vane model will do the job. When precise inching or slower speed control is desirable, more than four vanes should be used. More than four vanes do not increase the output torque but smooth out the peaks and valleys of the torque curve. Blowby of air around the vanes is minimized, but the "price paid" is less horsepower out for the same amount of air because of the increased frictional drag created by extra vanes.

Example I

Features utilized: Burnout proof, variable speed, heat resistance.

Problem An overhead power winch with a steel cable is used to lift a 400 lb. load-consisting of parts in a basket-from the floor and into an open-bottom furnace 15 ft. above the floor. The load is then suspended inside the furnace. The winch is mounted atop the furnace. The steel cable passes through a hole at the top of the furnace, allowing the load to be pulled directly into the middle of the furnace through the bottom.

The winch should be able to lift the 400 lb. from the floor to the furnace (115 ft.) in 20 seconds. And it is essential that the load be lowered back to the floor in 5 seconds. The winch's take-up reel is 4 in. in diameter; the power source couples directly to the reel's shaft or drives it by pulley.

Solution

An air motor is burnout proof when stalled; therefore, it will not be harmed when the load box reaches the "stop" inside the furnace. Being cool-running, the motor will not be affected by the furnace heat. Its variable speed allows easy control of winch speed.

NOTE: For applications over 250°F, consult factory.

The torque that must be overcome at the take-up reel to raise 400 lb. is calculated this way:

• Torque = length of lever arm (radius of take-up reel) x load
  2 in. x 400 lb. = 800 lb-in.

To overcome this load, a 25% safety factor can be used. Therefore, the torque required of the motor to raise the load would be 800 lb-in. x 1.25, or 1000 lb-in.

Calculations to determine input shaft speed to raise the load in 20 seconds are:

• Circumference of take-up reel =,π x diameter =3.14 x4 in. = 12.56 in.

The take-up reel thus lifts the load 12.56 in. for each revolution.

The winch must lift the load at a rate of 180 in. in 20 seconds (0.33 minute), or 540 in. per minute. Therefore:

• Shaft speed= 540 in. per minute/12.56 in. per revolution = 43 rpm

To lower the load in 5 seconds, or 2160 in. per minute:

• Shaft speed =2160 in./12.56 in. per revolution= 172 rpm

Therefore, the air motor operating through pulleys and a belt or gear reducer must be able to deliver up to 1000 lb-in. torque at about 40 rpm, and it must be able to operate at about 200 rpm when the load will overcome the reduced output torque of the air motor at the time the load is lowered.

The torque versus. speed versus. air pressure curves show the right gearmotor to use. To control the air motor to raise, hold, and then lower the load, a manually operated pressure regulator and flow control valve are installed in the motor's air supply line. To raise the load, pressure is increased until the motor develops enough torque to lift the load. The flow-control valve is then adjusted until the motor reaches the desired speed. When the load reaches the mechanical stop in the furnace, the motor simply stalls and holds the box in the furnace.

A brake arrangement installed within the system ensures that the load is held in place in case air pressure is lost.

Example 2

Feature utilized: Variable speed.

Problem The owner of a large milling machine decided to install what amounted to an oversized window-shade type of device to keep the ways from jamming with chips, etc. He also installed a drum 40 in. in diameter at the end of the machine to roll the material. But an ordinary spring (as in a window shade) did not seem feasible as the tension device, and an air motor seemed to be the answer, complicating the problem: The force used to roll the cover material cannot exceed 7.5 lb. Above that, the cover will stretch and probably tear.

Solution It was decided to design 80% of the manufacturer's force limitation (7.5 lb.) to prevent ripping the cover; 80% of 7.5 lb. is 6 lb. If the air motor operates on the shaft at the center of the drum, the maximum torque allowed is:

• Torque = force x moment arm (radius of drum)
= 6 1b. x 20 in.
= 120 lb-in.

The appropriate torque curve in the appendix shows the size air motor (model 8AM in the Gast line) that can provide a safe force using 60 psi air. Air line pressure in most industrial plants is 100 psi or less. To further ensure that the cover does not tear, a pressure regulator should be installed so that 60 psi to the motor is not exceeded.

An eight-vane motor would be best to minimize blowby at stall and thus conserve energy.

Another solution to this problem would be to use a much smaller air motor (Model 1 UP) with a reducer at 80 psi. Among Gast offerings, the Model 1 UP with a GR1 1 gear reducer fits the requirement. Such a choice actually might be preferred because of size of the unit, the air line size, and accessory size.

The 1 UP-GR1 1 gearmotor, which delivers up to 95 lb-in. of torque, is also an excellent choice for this job. Its minimum starting torque of 75 lb-in. at 80 psi is more than the 8AM's minimum starting torque of 70 lb-in.

Example 3

Features utilized: Variable speed, abrasion/corrosion resistance.

Problem Holes 0.5 in. in diameter are to be drilled in glass and ceramic materials. The drill motor requires 0.5 hp at 2800 rpm. The area around the drilling operation will be subjected to water spray mixed with abrasive particles resulting from the drilling.

Solution The ease of speed control of an air motor is an advantage here. An air motor eliminates pulleys and belts normally associated with changing standard motor speeds to 2800 rpm. In addition, the positive pressure in the air motor chamber reduces possible interior contamination with the abrasive powder and water spray. In this application, the air motor is fitted with special hollow shaft of corrosion-resistant materials to allow coolant or water feed through the motor shaft, making couplings more accessible.

A Gast Model 2AM air motor at about 65 psig will give the desired performance.

Since an air motor comes up to speed rapidly, it can be turned off when the drill bit is not engaged, reducing wear of rotating parts, conserving air, and not requiring coolant to keep the rotary coupling faces wet.

Example 4

Feature utilized: Nonelectric.

Problem Low-pressure, oil-free air is needed for breathing by Naval personnel inspecting 'moth balled' ships. Air quality in some areas of the ships is questionable-in anchor chain lockers, for instance, where oxygen may have been depleted during rusting of the chains. There is no on-board electricity available to power the compressor package. But the ships have an ample supply of 80 psi air provided by a shore-mounted, lubricated compressor. Air flow of 10 cfm at 10 psi is needed to supply air for cooling and for the breathing hoods to be worn by a team of three inspectors.

Solution A low-pressure separate-drive, oil-less vane compressor operating at 1725 rpm and requiring 1.5 hp produces 12.1 cfm and fills the air needs. (The actual horsepower required to drive the pump will vary with speed and pressure; but for this application, it will be between 1.1 and 1.4 hp.)

To power the compressor, an air motor that develops 1.5 hp at 1725 rpm at less than 80 psi is required. Since an air motor is a somewhat constant-torque device, it is important to select one that will produce the desired horsepower at the desired rpm, rather than at the motor's "rated rpm." (See the composite air motor curve in the appendix.)

From that graph, the horsepower requirements are met at about 50 psi, well below the 80 psi supply pressure, at 1700 to 1800 rpm.

It's quite probable that this compressor package will be used at the end of a long air line, so it is necessary to allow for some pressure drop in the lines. The difference between 50 and 80 psi should be an ample cushion for any changes in speed, duty, or, in particular, pressure loss from the compressor to the end of the air line.

Example 5

Feature utilized: Variable speed.

Problem A manufacturer wants to mechanize an assembly process in which a conveyor will bring parts to the area at preset speeds that vary according to part size and handling difficulty. He determined that he needs 3/4 hp at 1800 rpm. A variable-speed electric drive, however, costs more than he wants to pay. His local fluid-power component distributor told him his problem could be solved by an air motor. But if an air motor varies in speed according to torque applied or pressure of the air supplied, or both, how could it handle the job?

Solution
First calculate the torque at 3/4hp and 1800 rpm:

9 Horsepower $= \frac{Tn}{63,025}$ T=torque in lb-in.: unknown
n = speed in rpm: 1800 rpm

$T = \frac{(hp)\ 63,025}{n}$ hp =horsepower: 0.75

The torque needed at 1800 rpm is 26.3 lb-in. The starting torque of an electric motor is usually 200% (or less) of its running torque. To be sure the air motor will provide similar and sufficient torque to start the hard-starting conveyor, the air motor must also provide a starting torque twice the running torque needed at 1800 rpm, or 52.6 lb-in.

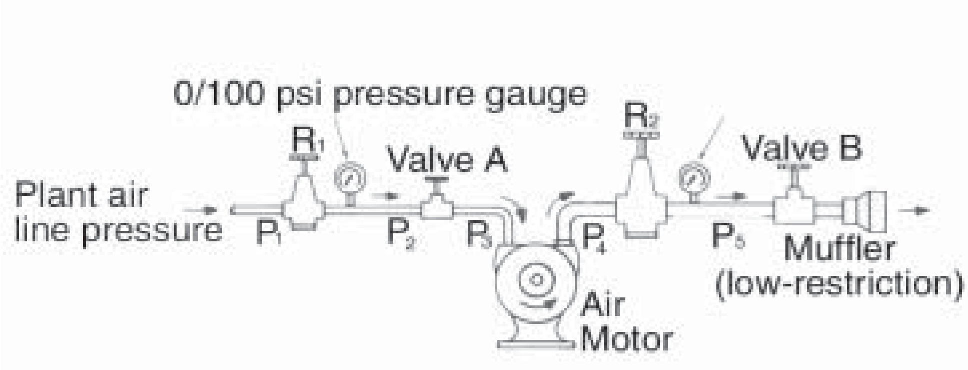
The composite air motor performance chart shows the performance characteristics of an air motor that will supply the needed starting torque with 60 psi (actually 55 lb-in.) and still have reserve starting torque, available with higher pressure. The Gast Model 6AM will require about 30 psi to supply 3/4hp at 1800 rpm. The best speed-regulation system is composed of two pressure regulators and two valves connected as shown in the sketch.

When the load decreases, the motor's speed increases. This increased speed causes more air to flow. But because P5 is constant and the flow through the orifice is also constant, P4 must increase. P3 increases until the pressure differential (P3 - P4) across the motor supplies only enough torque to maintain speed. Any adjustment of R1 will, of course, affect P2 and P3.

The start-up procedure is as follows:

- Close valve A; turn the larger regulator's (R2) adjustment all the way in and open valve B all the way.

- Turn the pressure adjustment on the small pressure regulator (Rl) until P2 = 70 psi (or slightly more).



R_1 Regulator sized for air motor's intake port
R_2 Regulator sized one size larger than R_1
P_1, P_2, P_3, P_4, P_5 = Inline pressures

Slowly open valve A until the conveyor is running at the desired speed with full load. If adequate speed regulation is achieved with just these components, the large regulator and valve B are not needed and may be removed. If not, go on to the next step.

- Adjust valve B so that P4 = 5 psig; readjust valves A and B so that a speed slightly greater than that desired is obtained.

- Adjust the large regulator until a slight drop in air motor speed is observed. The pressure across the air motor now will be automatically regulated to minimize the effect of load on the set speed.

Example 6

Features utilized: Variable speed, nonelectric.

Problem A hoist will be used to lift materials to the roof of a building during construction. The need is to lift a maximum of 500 lb. at a top speed of 30 ft. per minute. The winding drum's diameter is 4 in. Variable speed is needed because of the variety of articles to be lifted. The hoist must operate at a construction site in all kinds of weather, and electricity may not be readily available at all times.

Solution An air motor is a good choice for the variable-speed requirement, weather conditions, and lack of electricity. The air motor can provide the varied horsepower needed with the change in load.

To determine the best air motor for the job, horsepower must be calculated:

- $N = \frac{S}{27 \pi r} - \frac{(30)\,12}{2, \pi r} = 28.6$ rpm

- $hp = \frac{P(N \times r)}{63{,}025} = \frac{500 \times 28.6 \times 2}{63{,}025} = 0.455$ hp

In this solution, S is the speed of the load in in. per minute; P is the load in lb.; N is the drum speed in rpm; and r is the drum radius in inches.

If 30 ft. per minute is required, the necessary horsepower is 0.455. The composite air motor performance chart in the appendix indicates that there are several motors capable of producing the horsepower required.

The torque required to drive the drum is easily calculated this way:

Torque = P(r) = 500 (2) = 1000 lb-in.

To prevent slippage and to provide a speed reduction and torque advantage at the same time, a roller chain with a 60-tooth sprocket and a 12-tooth sprocket is used to obtain a 5:1 reduction. A Gast Model 4AM-GR20 gearmotor with the 12-tooth sprocket attached can then drive the 60 tooth sprocket for the desired results. The gearmotor shaft will operate at 143 rpm, five times the winding drum speed. The performance graph shows that this should take 45 psi at the motor. The gearmotor can supply 300 lb-in. for starting, producing 1500 lb-in. at the winding drum. A simple valve on the air supply line should provide adequate speed control.

Examples of Air Motor Uses Table 2

Application	Market or How Used	Features Utilized
Construction Machinery		
Concrete Vibrators	Drive flexible shafts that actuates vibrator used to settle wet concrete	Lightweight, portable corrosion resistant
Hose & cable feeders	Pull hose & cable through pipe or from 1 manhole to another	Variable horsepower burnout proof, portable
Pipe cutters & threaders	Drive chuck that holds and rotates pipe against stationary cutter or die head	Burnout proof, portable
Conveyors		
Automatic materials	Drive chain conveyor that delivers parts against stop so they can be machined, then withdraws & ejects parts.	Variable speed, reversible
Material movers	Drive belt conveyor	Variable speed
Handling of powders & granular materials	Drive vibrators to speed unloading of railroad cars, tanks, bins, etc.	Variable speed, nonelectric
General Machining		
Car wash machines	Oscillate water nozzles & power	Corrosion resistance reversible
Electric seam welders	Rotate contact rollers on portable resistance seam welders	Lightweight, reversible
Rock bit grinders	Hold grinding wheel for grinding rock bits	Variable speed, nonelectric nonelectric sparking

Application	Market or How Used	Features Utilized
General Machining etc.		
Power driven turntables	Drive a large-diameter turntable for handling variable loads	Variable horsepower burnout proof
Tumbling barrels	Regulate speed of tumbling	Variable speed
Electroplating barrel drive	Provide correct speed for quality plating	Variable speed
Parts washers	Move hangers or baskets carrying parts through flammable solvent	Nonelectrical sparking
Rapid tire changers	Rotate the mount/demount arm	Variable speed
Steel drum openers	Power giant "can opener"	Lightweight, variable speed, Nonelectrical sparking
Tank cleaners	Rotate nozzle in 2 planes so cleaning solution (hot, caustic or the like) reaches all interior surfaces	Nonelectric, corrosion resistance
Rotary index tables	Provide smooth rotary power and variable speed to machine tools	Variable speed
Air-hydraulic sawmill cartridges	Move log-feed carriage back & forth; drive hydraulic pump that operates log-holding spikes	Nonelectrical sparking reversible
Hoisting Equipment		
Power-driven tank scaffolds	Raise & lower scaffold & rotate it around circular tanks	Variable speed Nonelectrical
Traveling bridge cranes	Power bridge, trolley, and hoist drives; change direction of bridge, trolley, and hoist	Variable speed reversible
Vertical door openers/closers	Raise and lower waterproof ship bulkhead doors	Nonelectrical reversible

Application	Market or How Used	Features Utilized
Hoisting Equipment etc		
Molten metals circulators	Keep hot material circulating in bulk tanks so outer edges don't cool to congealing point	Heat resistance, nonelectric portable
Low temperature liquid test units	Drive agitators in liquid viscosity chambers	Variable speed temperature
Portable drum rotators	Supply power to rotate steel drum for mixing, blending, and cleaning	Lightweight variable speed
Packaging Equipment		
Box formers	Drive hot metal glue dispenser	Variable speed heat resistance
Packaging machines	Form packages and drive conveyor carrying packages to and from filling area	Variable speed
Explosive packagers	Mix and auger explosive mixture into containers	Variable speed nonelectric sparking
Paint Finishing Equipment		
Centrifugal enameling	Spin basket of parts coated by dipping to remove excess enamel by centrifugal force	Variable speed nonelectric sparking
Paint spray rotators	Rotate turntable and, when when turntable automatically indexes, rotates spindles carrying parts to spraying	Corrosion resistance nonelectric sparking variable speed
Portable paint mixers	Drive propeller at end of shaft to mix pigments with binders on job site	Variable speed nonelectric sparking
Paint heaters	Drive circulating pump on paint heater	Nonelectric sparking
Urethane dispensing units	Agitate and mix urethane before application	Variable speed
Plywood edge painters	Drive paint agitator and roller	Portable Variable speed nonelectric sparking

Application	Market or How Used	Features Utilized
Paint Finishing Equipment etc.		
Glass fiber spray molding guns	Drive chopper that cuts glass-fiber yarn	Lightweight variable speed
Epoxy dispensers	Maintain fillers in suspension	Nonelectrical sparking variable speed
Paint dip tanks	Drive circulating pump	Nonelectrical sparking variable speed
Printing Equipment		
Bar, barrel, & tube marking	Help passage of stock through offset printer	Variable speed nonelectrical sparking
Printing press	Supply power for raising and lowering stacks of paper at feed point	Burnout proof variable speed
Silk screen printers	Drive squeegee	Nonelectrical sparking Dust resistance
Pump Drive		
Chemical process Industries	Drive pumps in refineries, chemical manufacturing plants, and others where flammable or explosive liquids must be pumped	Nonelectrical sparking variable speed
Turbine-compressor starters & pre-lubricators	Start turbine that drives a booster compressor on a gas trans-mission line; small air motor that drives a pump that feeds oil to compressor bearing	Nonelectric nonelectrical sparking
Molten metal pumps	Drive pump	Heat resistance
Bolt tensioners	Drive hydraulic pump supplying hydraulic cylinders	Variable speed
Fan Drive		
Humidifiers	Drive fan to dispense steam	Heat resistance variable speed Moisture resistance

Application	Market or How Used	Features Utilized
Valve Operation		
Valve actuators	Automate any hand-wheel valve	Nonelectric burnout proof
Vehicular		
Rock breaking picks	Raise pick and allow it to free fall on the rock	Portable Dust resistance nonelectric
Gasoline truck	Rewind gasoline delivery hose sparking	Nonelectric variable speed
Rock drilling rig	Drive individual crawler tracks and drive hydraulic pump to supply power to cylinders that position drill boom.	Variable speed nonelectric
Road stripping equipment	Drive paddle-type agitator in paint tank; also drive gas-bead	Nonelectric Corrosion resistance
Moveable lifting and stacking equipment	Drive hydraulic pump that actuates lifting cylinder	Variable speed nonelectric
Miscellaneous		
Hot metal markers	Drive metal marker wheel, which traveling hot formed shapes	Variable speed Heat-resistance
Floating oil skimmers	Drive sponge-covered cylinders that pick up oil floating on water	Portable nonelectric
Automatic screw feeder for screw driver	Drive a hopper agitator and screw alignment device	Variable speed
High-vacuum evaporators	Rotate vacuum vessel to spread solution in a thin film over a large surface area	Variable speed
Sewer & drain pipe cleaners	Rotate and power the cleaner forward and back through the pipe	Nonelectric burnout proof

Air Motor Maintenance Section V

Among power-generating devices, none is more dependable or easier to keep running than an air motor, especially the rotary vane type. Its simple rugged construction makes it immune to many of the breakdowns its electric and hydraulic counterparts can fall victim to.

Yet if neglected or abused , air motors can develop ailments . And because of their simple construction, air motors will continue to operate during mistreatment until major damage is done.

It is therefore important to diagnose symptoms early so that minor problems can be kept from developing into major ones. Better still, preventive maintenance will stop even minor problems from occurring and help assure a long and productive life for the motor.

As a general guide materials of construction generally limit vane motors to service in locations where the ambient temperature does not exceed 250oF (1 21^{o}C). Check with the manufacturer for any proposed application of air motors above that. While running, an air motor could be used in higher ambient temperatures but never should be exposed to those temperatures while idle.

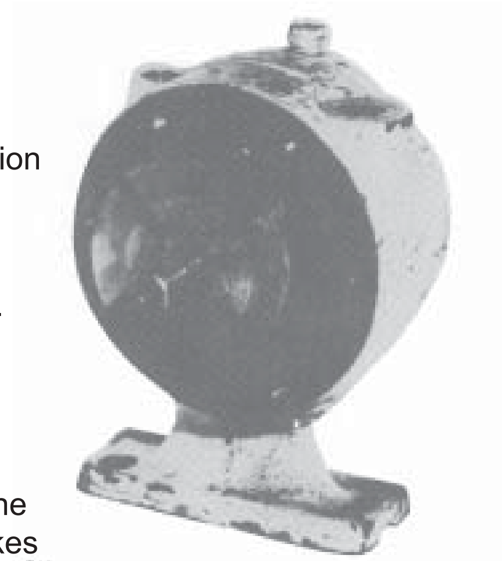
Keeping rotary vane air motors in good condition is a relatively simple process, but some elements of air motor construction and operation are worth restating at this; point.

Radial sliding vanes are mounted into slots in a cylindrical rotor, which is mounted eccentrically in the motor body bore. in reversible units, the vanes are spring-loaded to maintain contact against the body bore and prevent air blowby. Single rotation units have special porting to channel air against the bottom of the vane to give the needed vane-to-body bore contact.

Torque to turn the rotor against a load is developed when compressed air enters through an intake port and pushes against a vane, thus turning the rotor. As the rotor turns, the outlet port is exposed to the energizing air. The escaping air expands, resulting in heat reduction and making the air motor inherently cool-running.

Symptoms of a malfunctioning rotary vane air motor (see Table 3) are slow operation or low torque capability, or both. Problems can stem from one or more of our sources: dirt or foreign materials in the motor, misalignment caused by mishandling, corrosion, and improper lubrication.

Figure 24
The interior of this air motor is clogged with dirt. An air line filter would have prevented this condition



Dirt

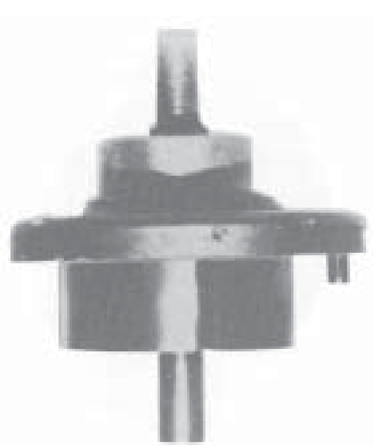
Most air motor problems are caused by dirt, either in particulate form or combined with lubricating oil and creating a sticky paste. Particulate dirt causes abrasion (Fig. 24),
eventually wearing grooves in the mating surfaces of the vanes and the body bore,
allowing air to escape. Sticky dirt can close the clearance between the vanes and the slots in which they slide, preventing free vane movement.

When a vane cannot move out to contact the body bore, air leakage and lost power result. When the vane can't slide back into the rotor, the extended vane strikes the top of the body bore (because of the eccentric mounting of the rotor), preventing further rotor movement and possibly causing the vane to break.

Misalignment,

The next most likely problem source is rotor misalignment, normally caused by applying excessive axial or radial thrust on the shaft. The symptom is a rotor that turns with difficulty, or one that will not turn at all. Both are caused by rotor-to-housing friction, which results from changes in the rotor-housing clearances. The "housing " consists of a body and two end plates.

Clearances between the rotor and the end plates of the motor housing-can be very small, down to 0.001 in. (Fig. 25) and are maintained by rigidly mounting the rotor assembly on two bearings, one at each end. When the positioning of these bearings on the shaft is changed through mishandling (such as pounding on the shaft to force-fit a coupling, pulley, etc.), the internal clearances can be reduced or eliminated, causing the rotor to bind against either of the end plates.



Corrosion

Corrosion is another source of air motor malfunctions. Condensed moisture in the air stream can corrode the internal parts (especially if poorly lubricated), as in Fig. 26.

These parts are generally made of cast iron and steel. Rust flakes may then be scraped off by the vanes, causing abrasion of vanes and all wear surfaces. The result is air leakage and lost power. The rotor could also become "rust-bonded" to the housing if permitted to sit idle.

Figure 25 Clearance between an air motor's rotor and end plates of the housing are very small, as this photo shows. Misalignment could close the clearance, causing the rotor in bind and turn with difficulty or not at all.

Lubrication

Improper lubrication is a fourth potential source of problems, although occurrences are relatively rare for a combination of reasons:

• The relatively cool operation of an air motor minimizes lubrication needs.
• There is often some oil blowby in the air stream from the compressor.
• The moisture in the air line acts as a lubricant, absorbing some of the heat generated by vane-body bore friction.

When the motor is operated virtually dry, rapid wear of the vanes and frictional heat results. The heat can break down the resin in the vanes, causing them to delaminate or chip (Fig 27) and result in air leakage. Also if the heat buildup is great enough, the rotor can expand, causing metal-to-metal contact with the body bore or the end plates.

Figure 26
Corrosion such as this is often caused by condensed moisture in the air stream

A poorly functioning air motor often exhibits symptoms that could be caused by one of several problems. To determine which one it may be, start with the most basic diagnostic approach: injection of a nontoxic, nonflammable industrial cleaning solvent. Remove the air intake piping, pour in the solvent, and manually turn the rotor, adding more solvent if needed.

If the rotor turns freely and the air motor performs up to specifications after this flushing operation, the problem was caused by dirt, corrosion deposits, or other foreign matter, and has been remedied. But if power output is still low even though the rotor now turns freely, assume there is internal damage from dirt, corrosion deposits, or improper lubrication.

The only solution to this problem is to replace the affected parts. Generally, field repairs should not be attempted because of the specialized training, knowledge, and equipment required. Return the unit to the manufacturer, where experts will perform needed repairs.

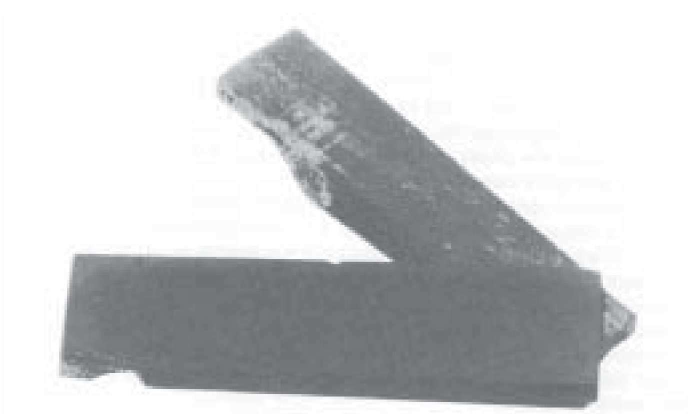


Figure 27
This chipped vane resulted from heat buildup in an air motor because of inadequate lubrication. Lack of lubrication will also promote corrosion of the motor's metal components.

If solvent flushing does not give free rotor movement, the problem is likely to be misalignment (mishandling) or misapplication of the motor. The remedy is to remove the rotor and realign the bearings so that proper clearances are restored. Again, this is a procedure best left to experts.

The simplest way to handle air motor malfunctions is to stop them before they occur. Each type of problem that besets air motors can be easily prevented by proper maintenance.

To prevent dirt and other foreign materials from entering the air motor, use an air line filter. Periodic cleaning or replacing of the filter element will keep the filter doing its job.

Misalignment is prevented by just being careful. Do not drop the motor on its shaft or try to force a coupling or pulley onto the shaft. A coupling or pulley should slip-fit onto the shaft. If it does not, lightly file the shaft or the inner diameter of the coupling until all burrs are removed.

In addition, make sure you use the right air motor for the job. If the unit is too small for the application, high radial loads might destroy the top clearance or cause bearing damage. To prevent such damage, size the motor to withstand operating loads.

When excessive amounts of moisture are present in the air stream, a moisture trap can be installed in the air line to help prevent corrosion. In most cases, the best defense against rust is proper lubrication, which will prevent water from penetrating to bare metal.

Lubrication can be provided most effectively by an in-line lubricator, which puts oil into the air stream in a mist. The lubricator should be as close to the air motor as possible to prevent oil condensation. Recommended oil usage is one drop per minute for every 50 to 75 cfm of air flow. Refer to air flow charts supplied by the manufacturer for specifics on flow rates.

Table 3
Trouble Shooting Guide for Air Motors

	Result				
Cause	Low Torque	Low Speed	Won't Run At All	Runs Hot	Runs Good Then Slows Down
Dirt, Foreign Material	x	x	x		
Internal Rust	x	x	x		
Misalignment	x	x	x	x	x
Insufficient Air Pressure	x	x			
Air line too Small		x			
Restricted Exhaust		x			x
Poor Lubrication	x	x	x	x	
Jammed Machine	x	x	x		x
Compressor too Small		x			x
Compressor too far from Unit		x			x

APPENDIX

Air Motor Selection and Performance Charts

Fig. A-1 is a composite chart showing the operating range of Gast air motors; other manufacturers issue comparable information. Fig. A-2 is a corresponding chart for air-powered gearmotors manufactured by Gast.

Since it's easy to change horsepower and speed of an air motor by valve-adjusting the inlet air, the best rule-of thumb is to choose a motor that gives the horsepower and torque needed using about two-thirds of the line pressure. Full line pressure is then available for overloads and starting.

Things to keep in mind concerning air motors:

1) Horsepower versus. rpm
   • Horsepower of an air motor depends on airline pressure and varies with rpm.

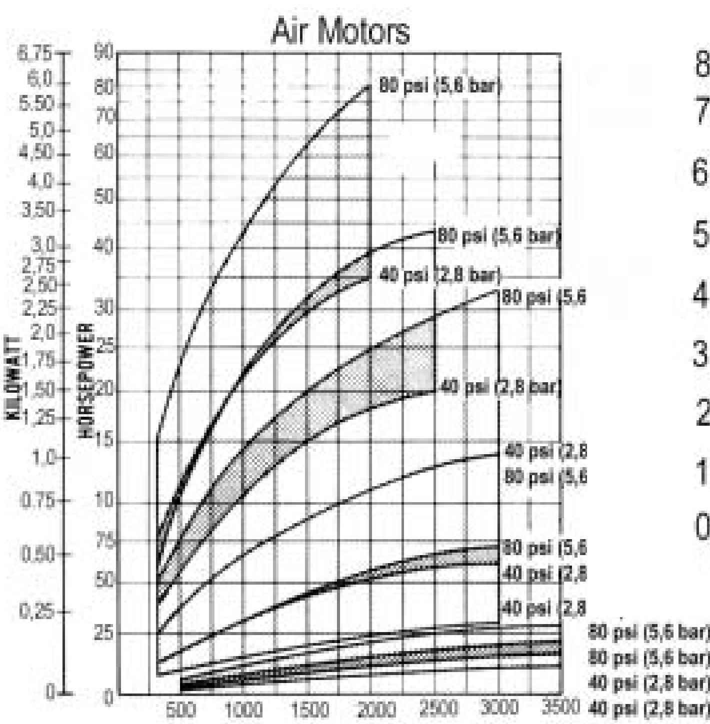
2) Torque vs. rpm

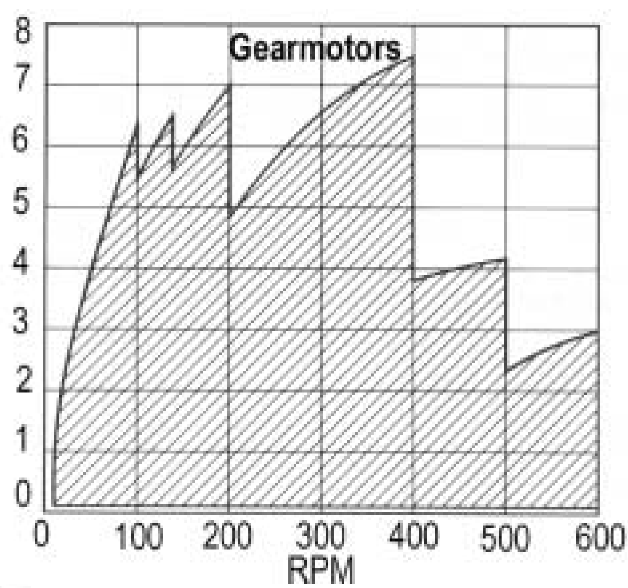
• An air motor slows down when its load increases. At the same time, its torque increases to where it matches the load. It will continue to provide increased torque up to stall, and it can maintain stall without harming the motor. As the load is reduced, the motor increases speed, and torque decreases to match the reduced load.

• When load is either increased or decreased, speed can be controlled by increasing or decreasing air pressure. Starting torque is lower than running torque; although this gives smooth, no-shock starting, it is necessary to have additional line pressure for starting under heavy loads.

3) Air consumption vs. rpm

• Air consumption increases with increased speed and pressure.





Air Pressure Tables

Air pressure losses (in U.S. and metric units) resulting from friction, pipe bends, and in components are given in tables A-1 through A-6. Tables A-7 and A-8 give air flow through orifices of various sizes.

Table A-1

Loss of air pressure (psi) because of friction (Per 100 feet of pipe, 100 psi initial pressure) (U.S. Units)

CFM Free Air (14.7 PSI)	Equivalent CFM Compressed Air (100 + 14.7 PSI)	Nominal Pipe Diameter, Inside Inches Loss of pressure (PSI)					
		½	¾	1	1¼	1½	2
10	1.28	1.38	0.09	0.03	0.007		
20	2.56	1.42	0.34	0.10	0.026	0.012	
30	3.84	3.13	0.74	0.23	0.056	0.026	
40	5.13	5.55	1.28	0.38	0.096	0.044	0.013
50	6.41	8.65	2.00	0.60	0.146	0.067	0.020
60	7.69		2.84	0.84	0.210	0.095	0.027
70	8.97		3.85	1.12	0.280	0.130	0.036
80	10.25		5.01	1.44	0.360	0.160	0.046
90	11.53		6.40	1.85	0.450	0.200	0.058
100	12.82		7.80	2.21	0.550	0.250	0.069
125	16.02		12.40	3.41	0.850	0.380	0.107
150	19.22		18.10	4.91	1.200	0.540	0.150
175	22.43			6.80	1.640	0.730	0.200
200	25.63			8.79	2.120	0.950	0.260
250	32.04				3.300	1.480	0.400
300	38.45				4.710	2.100	0.570
350	44.86				6.450	2.860	0.770
400	51.26				8.300	3.700	0.990
450	57.67					4.650	1.270
500	64.08					5.790	1.560
600	76.90					8.45	2.230
700	89.71						3.000
800	102.50						4.000
900	115.30						5.050
1,000	128.20						6.200

Table A-2

Loss of air pressure (Kg/cm^2) because of friction (Per 30 meters of pipe, and 7Kg/ cm^2 initial pressure) (metric units).

Liters Free Air Per Min	Equivalent Liters Per Minute Compressed Air	Nominal Pipe Diameter, Inside (Millimeters) Loss of pressure g(k/cm^2)					
		12.7 mm	19.1 mm	25.4 mm	31.8 mm	38.1 mm	50.8 mm
300	37	0.027	0.006	0.002	0.0005		
600	75	0.100	0.024	0.007	0.0018	0.0008	
850	110	0.220	0.053	0.016	0.0039	0.0018	
1,150	150	0.390	0.090	0.027	0.0067	0.0031	0.0009
1,400	180	0.608	0.140	0.042	0.010	0.0047	0.0014
1,700	218		0.200	0.059	0.015	0.0067	0.0019
2,000	255		0.270	0.079	0.020	0.0091	0.0025
2,300	290		0.350	0.100	0.025	0.0110	0.0032
2,550	330		0.450	0.130	0.032	0.0140	0.0041
3,000	364		0.550	0.155	0.038	0.0160	0.0049
3,500	455		0.870	0.240	0.060	0.0270	0.0075
4,250	540		1.270	0.346	0.065	0.0380	0.0105
5,000	640			0.480	0.115	0.0510	0.0140
5,700	730			0.615	0.150	0.0670	0.0180
7,000	900				0.232	0.1040	0.0280
8,500	1,100				0.332	0.1480	0.0400
10,000	1,300				0.455	0.2000	0.0540
11,000	1,500				0.585	0.2600	0.0700
13,000	1,700					0.3260	0.0890
14,000	1,855					0.4100	0.1090
17,000	2,250					0.5950	0.1560
20,000	2,620						0.2100
23,000	3,000						0.2800
25,000	3,400						0.3550
30,000	3,760						0.4350

Table A-3

Loss of air pressure due to pipe bends (Per 100 feet of straight pipe) (U.S. units).

Angle of pipe bend	Nominal Pipe Diameter, Inches (Inside) Loss of Pressure (PSI)					
	½	¾	1	1¼	1½	2
90°	1.60	2.00	2.50	3.40	4.00	5.10
45°	0.73	0.92	1.18	1.55	1.85	2.35

Table A-4

Loss of air pressure due to pipe bends (Per 30 meters of straight pipe) (Metric units).

Angle of pipe bend	Nominal Pipe Diameter, Inside Millimeters) Loss of Pressure (kg/cm^2)					
	12.7 mm	19.1 mm	25.4 mm	31.8 mm	38.1 mm	50.8 mm
90°	0.48	0.60	0.75	1.02	1.20	1.53
45°	0.22	0.28	0.35	0.47	0.56	0.71

Table A-5

Flow of air through orifice, cfm, with discharge of orifice at atmospheric pressure of 14.7 lb/in^2. Absolute and 70°F (U.S. units)

Supply PSI (gauge)	Orifice size (Inches) 1/32	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16
65	1.15	4.49	10.10	17.90	27.90	40.30	55.20	71.80	89.90	111.70
70	1.21	4.77	10.80	19.10	29.70	42.80	58.80	76.40	95.70	118.80
75	1.30	5.06	11.40	20.20	31.50	45.40	62.30	81.00	105.50	126.00
80	1.37	5.35	12.10	21.10	33.30	48.00	65.80	85.60	107.40	133.10
85	1.44	5.64	12.70	22.50	35.10	50.60	69.40	90.30	113.20	140.30
90	1.52	5.92	13.40	23.70	36.90	53.20	72.90	94.80	119.00	147.50
95	1.59	6.21	14.00	24.80	38.70	55.70	76.50	99.40	124.90	154.60
100	1.66	6.50	14.70	26.00	40.50	58.30	80.00	104.60	130.70	161.80
125	2.03	7.94	17.90	31.70	49.50	71.40	97.78	127.10	159.80	197.50
150	2.40	9.28	21.20	37.50	58.40	84.40	115.40	150.40	189.00	233.30

Table A-6

Flow of air through orifice, liters per minute with discharge of orifice at standard atmospheric pressure of and 20°C

Supply kg/cm^2 (gauge)	Orifice Size (Millimeters) 0.79	1.59	2.38	3.18	3.97	4.76	5.56	6.35	7.14	7.94
4.57	32.4	127.2	283.2	507.0	798.0	1,146.0	1,560.0	2,028.0	2,541.0	3,156.0
4.92	34.2	135.6	306.0	540.0	840.0	1,230.0	1,662.0	2,160.0	2,736.0	3,360.0
5.27	36.6	143.4	322.8	571.2	891.0	1,284.0	1,761.0	2,292.0	2,976.0	3,570.0
5.62	39.0	151.8	342.0	597.0	942.0	1,356.0	1,860.0	2,418.0	3,036.0	3,768.0
5.98	40.8	159.6	360.0	636.0	993.0	1,431.0	1,962.0	2,556.0	3,204.0	3,978.0
6.33	43.2	167.4	379.8	678.0	1,044.0	1,518.0	2,061.0	2,676.0	3,372.0	4,170.0
6.68	45.0	176.4	396.0	702.0	1,095.0	1,573.2	2,163.0	2,808.0	3,528.0	4,374.0
7.03	46.8	183.6	416.4	741.0	1,146.0	1,650.0	2,142.0	2,958.0	3,690.0	4,575.0
8.79	57.6	225.0	507.0	897.0	1,401.0	2,016.0	2,760.0	3,600.0	4,518.0	5,580.0
10.55	67.8	262.8	600.00	1,062.0	1,650.0	2,385.0	3,264.0	4,251.0	5,340.0	6,600.0

Conversion Factors

To convert units in the left-hand column to those in the right-hand columns, multiply by the factor given.

Conversion Factors

To convert units in the left-hand column to those in the right-hand columns, multiply by the factor given.

Length

	in.	ft.	yd.	mile	mm.	cm.	m.	km.
1 in.	1	0.0833	0.0278	—	25.40	2.540	0.0254	—
1 ft.	12	1	0.333	—	304.8	30.48	0.3048	—
1 yd.	36	3	1	—	914.4	91.44	0.9144	—
1 mile	—	5280	1760	1	—	—	1609.3	1.609
1 mm.	0.0394	0.0033	—	—	1	0.100	0.001	—
1 cm.	0.3937	0.0328	0.0109	—	10	1	0.01	—
1 m.	39.37	3.281	1.094	—	1000	100	1	0.001
1 km.	—	3281	1094	0.6214	—	—	1000	1

Area

	sq. in.	sq. ft.	acre	sq. mile	sq. cm.	sq. m.
1 sq. in.	1	0.0069	—	—	6.452	—
1 sq. ft.	144	1	—	—	929.0	0.0929
1 acre	—	43,560	1	0.0016	—	4047
1 sq. mile	—	—	640	1	—	—
1 sq. cm.	0.1550	—	—	—	1	0.0001
1 sq. m.	1550	10.76	—	—	10,000	1

Volume

	cu. in.	cu. ft.	cu. yd.	cu. cm.	cu. meter	liter	US gal.	Imp. gal.
1 cu. in.	1	—	—	16.387	—	0.0164	—	—
1 cu. ft.	1728	1	0.0370	28,317	0.0283	28.32	7.481	6.229
1 cu. yd.	46,656	27	1	—	0.7646	764.5	202.0	168.2
1 cu. cm.	0.0610	—	—	1	—	0.0010	—	—
1 cu. m.	61,023	35.31	1.308	1,000,000	1	999.97	264.2	220.0
1 liter	61,025	0.0353	—	1000.028	0.0010	1	0.2642	0.2200
1 US gal.	231	0.1337	—	3785.4	—	3.785	1	0.8327
1 Imperial gallon	277.4	0.1605	—	4546.1	—	4.546	1.201	1

Weight

	grain	oz.	lb.	ton	g.	kg.	metric ton
1 grain	1	—	—	—	0.0648	—	—
1 oz.	437.5	1	0.0625	—	28.35	0.0283	—
1 lb.	7000	16	1	0.0005	453.6	0.4536	—
1 ton	—	32,000	2000	1	—	907.2	0.9072
1 g.	15.43	0.0353	—	—	1	0.001	—
1 kg.	—	35.27	2.205	—	1000	1	0.001
1 metric ton	—	35,274	2205	1.1023	—	1000	1

Pressure

	lb./ sq. in.	lb./ sq. ft.	int. atm.	kg/ cm²	mm Hg at 32°F	in. Hg at 32°F
1 lb/sq. in.	1	144	—	0.0703	51.713	2.0359
1 lb/sq. ft.	0.00694	1	—	—	0.3591	0.01414
1 international atmosphere	14.696	2116.2	1	1.0333	760	29.921
1 kg/sq. cm.	14.223	2048.1	0.9678	1	735.56	28.958
1 mm. Hg.*	0.0193	2.785	—	—	1	0.0394
1 in. Hg.	0.4912	70.73	0.0334	0.0345	25.400	1

*Also known as 1 torr.

Power

	hp	watt	kw	Btu/ min.	Btu/ hr.	ft-lb/ sec.	ft-lb/ min.	cal/ sec.	metric hp
1 hp	1	745.7	0.7475	42.41	2544.5	550	33,000	178.2	1.014
1 watt	—	1	0.001	0.0569	3.413	0.7376	44.25	0.2390	0.00136
1 kw	1.3410	1000	1	56.88	3412.8	737.6	44.254	239.0	1.360
1 Btu/ min.	—	—	—	1	60	12.97	778.2	4.203	0.0239
1 metric hp	0.9863	735.5	0.7355	41.83	2509.8	542.5	32.550	175.7	1

GLOSSARY

Air
A gas mixture consisting of nitrogen, oxygen, argon, carbon dioxide, hydrogen, small quantities of neon, helium, and other inert gases.

Air, Compressed (Pressure)
Air at any pressure greater than atmospheric.

Air, Free
Air at ambient temperature, pressure, relative humidity, and density.

Air Motor
A device that converts pneumatic fluid Power into mechanical force and motion. It usually provides rotary mechanical motion.

Air, Standard
Air at a temperature of 68^{o}F (20^{o}C), a pressure of 14.70 pounds per square inch absolute, and a relative humidity of 36% (0.750 pound per cubic foot). In gas industries the temperature of "standard air" is usually given as 60oF (1 5.6oQ.

Back Pressure
The resistance to flow in a system.

Blow-By
Internal air leakage past vanes in a rotary-vane air motor and past pistons in a piston air motor resulting in less efficient operation.

Compressor
A device that converts mechanical force and motion into pneumatic fluid power.

Control
A device used to regulate the function of a component or system.

Flow Rate
The volume, mass, or weight of a fluid passing through any conductor per unit of time.

Free Speed
Maximum speed of an air motor with no load. For a governed motor, free speed means free governed speed, or the maximum speed at which the motor will run while the governor is operating.

Gauge (or Gage)
An instrument or device for measuring, indicating, or comparing a physical characteristic.

Gauge, Pressure
A gauge that indicates the pressure in the system to which it is connected.

Horsepower, Rated
For air motors, the maximum horsepower at a specified air pressure at the motor's inlet (not at the supply source).

Lubricator
Pneumatic components are lubricated with an airline lubricator that injects atomized oil into the air stream that powers the component.

Muffler (Exhaust)
A low-restriction flow-through device that reduces air line noise.

Pressure
Force per unit area, usually expressed in pounds per square inch.

Pressure, Absolute
The pressure above zero absolute-that is, the sum of atmospheric and gauge pressures. In vacuum-related work, it is usually expressed in millimeters of mercury (mm. Hg).

Pressure, Atmospheric
Pressure exerted by the atmosphere at any specific location. (Sea level pressure is approximately 14.7 pounds per square inch absolute).

Pressure, Back
The pressure encountered on the return side of a system.

Pressure, Differential (Pressure Drop)
The difference in pressure between any two points of a system or component.

Pressure, Gauge
Pressure differential above or below atmospheric pressure.

Pressure, Operating
The pressure at which a system is operated.

Pressure, Rated
The qualified operating pressure recommended for a component or a system by the manufacturer.

Pressure, Working
The pressure that overcomes the resistance of the working device.

Pressure Vessel
A container that holds fluid under pressure.

Regulator, Air Line Pressure
A regulator that transforms a fluctuating air pressure supply to provide a constant lower pressure output.

Stall Torque
Maximum torque of an air motor at a given air pressure.

Starting Torque
Maximum torque an air motor produces attempting to start under load at a given air pressure; it is always less than the stall torque.

Vacuum
Pressure less than atmospheric pressure. It is usually expressed in inches of mercury (in. Hg) as referred to the existing atmospheric pressure.

Valve
A device that controls fluid flow direction, pressure, or flow rate.

Valve, Directional Control
A valve whose primary function is to direct or prevent flow through selected passages.

Valve, Directional Control, Check
A directional control valve that permits flow of fluid in only one direction.

Valve, Directional Control, Four-Way
A directional control valve whose primary function is to pressurize and exhaust two ports.

Valve, Directional Control, Selector Diversion)
A directional control valve whose primary function is to selectively interconnect two or more ports.

Valve, Directional Control, Straightway
A two-port directional control valve.

Valve, Directional Control, Three-Way
A directional control valve whose primary function is to pressurize and exhaust a port.

Valve, Flow Control (Flow Metering)
A valve whose primary function is to control flow rate.

Valve, Globe
A seating action valve design that utilizes a disc to obstruct the flow path.

Valve, Pressure Control, Pressure Reducing
A pressure control valve whose primary function is to limit outlet pressure.

Valve, Pressure Control, Relief
A pressure control valve whose primary function is to limit system pressure.