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AN INDUSTRY STANDARD FOR FLUID POWER

Recommended practice for application guidelines of cylinders

Descriptors: hydraulic and pneumatic fluid power cylinders, industrial marine, mobile applications, velocity; square head tie rod; visual inspection.

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Foreword

This Foreword is not part of National Fluid Power *Association Recommended Practice for application guidelines of cylinders*, NFPA/T3.6.64-1998.

At the 19 May 1993 Steering Committee meeting it was recommended that each section/committee develop an application guideline to enhance the use of fluid power in the industry. This was reported at the 18 August 1993 T3.6 meeting.

At the 17 November 1993 T3.6 meeting, Patrick Maher, NORGREN, agreed to serve as Project Chairman. The TSP was approved at the 20 January 1994 Technical Board meeting. General information was distributed to the Project Group at the 9 February 1994 T3.6 meeting. At the 25 May 1994 Project Group meeting an outline was distributed and assignments were given to Project Group members.

Draft No. 1 was received at Headquarters on 18 January 1996. This was distributed with the 14 February 1996 meeting notice and put into NFPA format and distributed at the meeting. Changes to the document were received at Headquarters on 20 February 1996. The changes were incorporated into Draft No. 2 and sent to Project Chairman Maher to review on 27 February 1996. On 29 February 1996 additional changes were received at NFPA from Project Chairman Maher. These changes were incorporated into the document which became Draft No. 3. At the 22 May 1996 and at the 18 September 1996 Project Group meetings Draft No. 3 was reviewed. Additions were made to the document by Tom Hurley and Draft No. 4 was reviewed at the 12 February 1997 Project Group meeting. It was voted on at this meeting to incorporate additional changes into the document and then send it out for a Project Group review and then General Review.

The document was sent out for Project Group review on 25 March 1997. No comments were received from the Project Group so the document was sent out for General Review on 22 April 1997. The document was updated on 17 September 1997 and all comments were satisfied. The changes were incorporated into the document. The document was distributed for Ballot Draft 6 February 1998.

The ballot closed with no negative comments. However, one late negative was received. The NFPA Technical Board met on 9 April 1998 and approved the document with the stipulation that the project group review the comments. This was done at the 20 May 1998 project group meeting. Most of the editorial comments were incorporated into the document. The commentator signed off on 2 June 1998.

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Introduction

In fluid power systems, power is transmitted and controlled though a fluid under pressure within an enclosed circuit. The application of hydraulic and pneumatic cylinders requires precise communication between manufacturer and user. It is the intent of this recommended practice to provide basic guidance in cylinder applications and to promote communication. Users of this recommended practice are cautioned, however, to review each clause for applicability and to utilize sound engineering judgement

Recommended practice for application guidelines of cylinders

1 Scope

This recommended practice will apply to hydraulic and pneumatic fluid power cylinders for their use in hydraulic and pneumatic systems for industrial, marine, and mobile applications.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this NFPA document. At the time of publication, the editions indicated were valid. All documents are subject to revision, and parties to agreements based on this NFPA document are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. NFPA maintains registers of currently valid NFPA/ANSI standards.

ANSI/B93.2-1986, *Fluid power systems and products — Glossary.*

ANSI/(NFPA)T3.6.7 R1-1996, *Fluid power systems and products — Square head industrial cylinders — Mounting dimensions.*

ISO 5598:1985, *Fluid power systems and components — Vocabulary*.

3 Definitions

A description of different types of cylinders is given in this document several times. For their official definition as well as definition of other terms see ANSI/B93.2 and ISO 5598.

4 Operation and cylinder concepts

Cylinders are used when linear force and motion are required. Cylinders are broken down into two main categories: pneumatic and hydraulic. Pneumatic cylinders can be operated by several types of gases, however, compressed air is by far the most common. Hydraulic cylinders can be operated with a very large range of fluids. By far the most common is petroleum based hydraulic fluid. Fire-resistant fluids are also common, they may be synthetic or water based.

Cylinders can be broken down into two main components. The pressure containing envelope and the piston and rod assembly. Typically the pressure containing envelope is fixed on the machine and the piston and rod assembly is attached to the machine member on which motion and force need to be applied. In rare occasions the opposite is done. See figure 1.

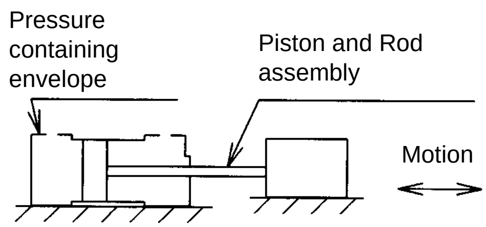


Figure 1 — Typical cylinder

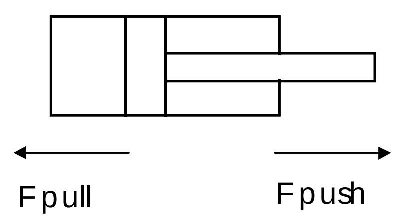
4.1 Force.

The amount of force applied to the machine member is the product of the fluid pressure multiplied by the effective area of the piston. Most cylinders contain a single piston rod. Assuming a constant value for the applied pressure, a cylinder would normally exert more force in the push stroke than it will in the retract stroke. The amount by which the retract force is less than the extend force depends on the cross-sectional area taken up by the piston rod. See figure 2.

For example, a 100 mm bore (10 cm) cylinder housing a 45 mm (4.5 cm) diameter piston rod operating at 1,000 kilopascals (1,000 kPa) will deliver 7,854 neutons (N) of force in the push direction and 6,264 N in the pull direction. Example: one neuton (N) of force = one pascal (Pa) applied to an area one meter square (M^2). N=Pa M^2

Calculation for push stroke surface area = $\frac{\Pi}{4}$ D^2 bore

Calculation for pull stroke surface area = $\frac{\Pi}{4}$ (D^2 bore - D^2 rod)



An area of 78.54 cm^2 = 0.007854 M^2

In push direction force (N) = 1,000 kPa x 0.007854 M^2=7,854 neutons

In pull direction force (N) = 1,000 kPa x 0.006264 M^2=6,264 neutons

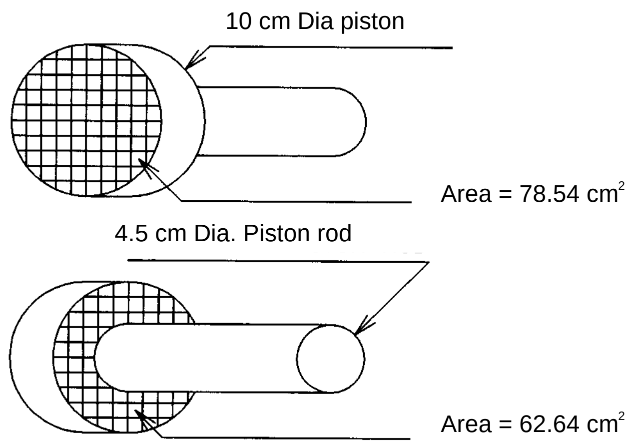
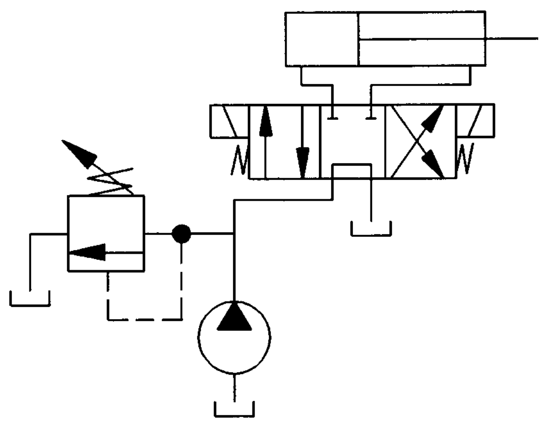


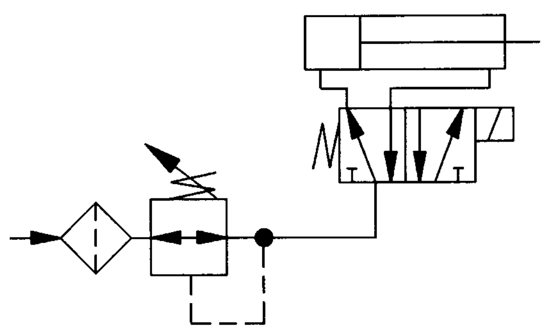
Figure 2 — Effective areas

4.2 Velocity

The velocity at which the piston and rod assembly moves is dependent on the rate at which the fluid is introduced into the cylinder. Normally a cylinder is connected to a directional valve and sometimes flow control valves. In a pneumatic system the maximum speed of the piston and rod assembly is dependent on the rate at which the air can flow through the valving. For a hydraulic cylinder, the maximum piston rod velocity depends on the ability of the hydraulic system to provide the hydraulic fluid to the cylinder. In most applications piston rod velocity is held in the .3 to .9 m/s. However, velocities up to 3 m/s have been achieved. See figure 3.



Hydraulic circuit



Pneumatic circuit

Figure 3 — Hydraulic and pneumatic circuits

5 Basic construction

The following three types of construction are the more commonly used types of cylinders.

5.1 Square head tie rod

This is a very common type of cylinder used in industrial applications. Head and cap enclosures are secured by tie rods that run the length of the cylinder. See figure 4.

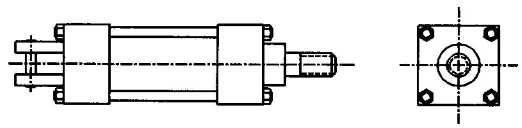


Figure 4 — Square head tie rod cylinder

5.2 Bolted end

These cylinders have flanges that are attached to the barrel. The end caps are attached to these flanges with bolts. See figure 5.

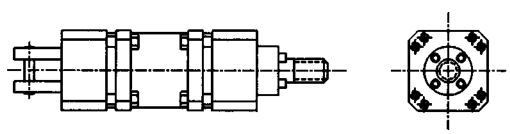


Figure 5 — Bolted end

5.3 Nonbolted end

This type of cylinder has end caps that are usually retained by welding or with a locking ring. In many cases these are used for mobile applications. Some pneumatic cylinders crimp the tube onto the end caps. See figure 6.

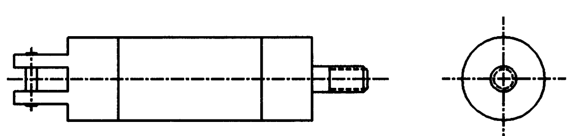


Figure 6 — Nonbolted end

6 Types of cylinders

Double acting, single piston rod cylinders are by far the most common types of hydraulic and pneumatic cylinders used in industry. However, there are other configurations which are used in special situations.

6.1 Double acting

By far, most cylinders are considered double acting. That is, when the cylinder is required to extend, pressure is applied to the cap end of the cylinder while pressure is exhausted from the rod end. When the cylinder is required to retract, pressure is applied to the rod end and the cap end is exhausted. See figure 7.

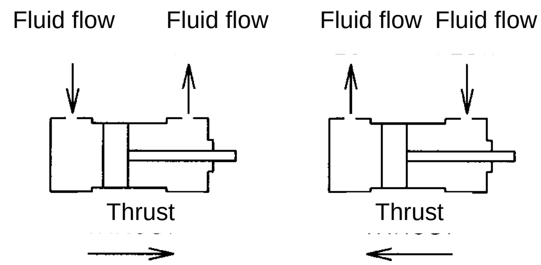


Figure 7 — Double acting

6.2 Single acting

In these types of cylinders pressure is applied only to one side of the piston, and some other force is used to move the piston and rod assembly in the opposite direction. In some cases it may be gravity; however, in most cases this is accomplished by a spring. Springs can be mounted on either side of the piston. However, most commonly a spring is mounted on the rod end of the piston and is used to retract the cylinder. Springs can be mounted in either hydraulic or pneumatic cylinders. Normally the mechanical force provided by a spring is rather small in comparison to the potential force which a hydraulic cylinder can apply. Therefore, most single acting cylinders tend to be pneumatic. See figure 8.

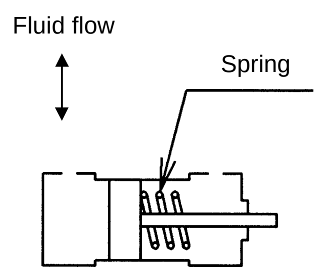


Figure 8 — Single acting

6.3 Double rod

Double rod cylinders can be used so that the applied load to the machine member is the same in both directions. Sometimes a smaller rod is used on one end to trip limit switches. See figure 9.

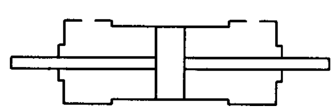


Figure 9 — Double rod end

6.4 Ram cylinders

The rod and piston are the same diameter. This type of cylinder is usually single acting, with an external force used to retact the cylinder. A typical application is a lift in a service station. See figure 10.

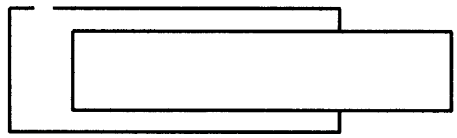


Figure 10 — Ram

6.5 Telescopic cylinders

Telescopic cylinders utilize multiple sections to achieve long strokes when short collapsed lengths are required. This type of configuration is sometimes used in cylinders for dump trucks or lift trucks. These are usually single acting. The net force is a function of the smallest section. See figure 11.

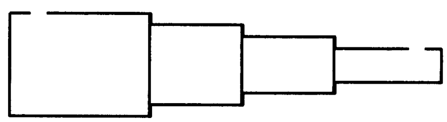


Figure 11 — Telescopic

6.6 Tandem cylinders

Tandem cylinders consist of two pistons attached to a common piston rod. These cylinders are used in situations where space requirements are very tight and the combined areas of two pistons can be applied to one piston rod. These are used to increase force. In some cases such as a press, a tandem cylinder is constructed of a large press cylinder with a small cylinder attached to the back. This configuration is used where the smaller bore cylinder is pressurized to rapidly advance the larger cylinder. See figure 12.

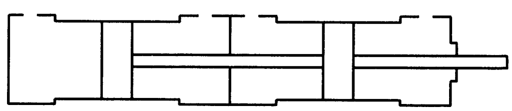


Figure 12 — Tandem

6.7 Duplex cylinders

Duplex cylinders consist of multiple piston and rod assemblies which are not connected to each other. This configuration is often used where more than two distinct stopping points are required. See figure 13.

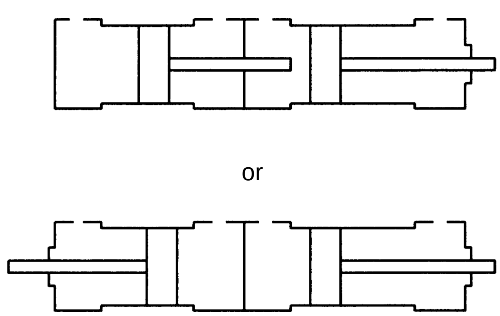


Figure 13 — Duplex

6.8 Rodless cylinders

These cylinders are typically used when limited space prohibits the use of a cylinder with a piston rod.

6.8.1 Direct coupled

The carriage and piston are directly connected. See figure 14 .

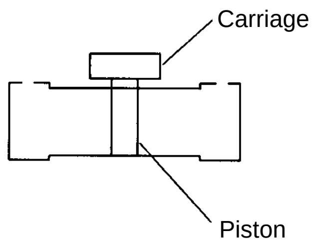


Figure 14 — Direct coupled

6.8.2 Magnetically coupled

The carriage is and piston are magnetically coupled. See figure 15.

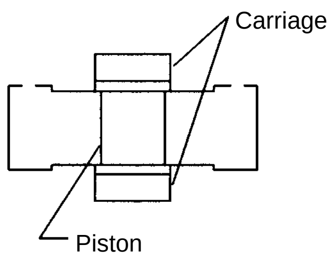


Figure 15 — Magnetically coupled

6.8.3 Cable connected

The carriage is connected to the piston by a cable or flexible band. See figure 16.

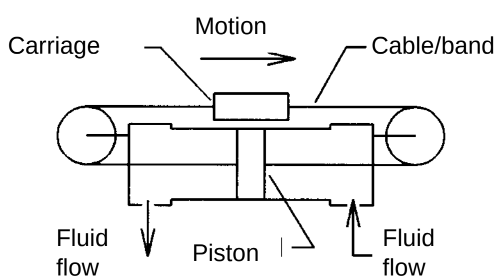
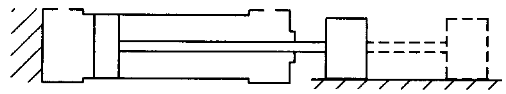


Figure 16 — Cable connected

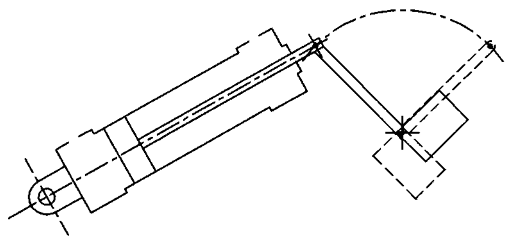
7 Mounting

7.1 Fixed and pivot

The pressure containing envelope is normally mounted to the machine. This is normally done with one of two types of mounting configurations. A fixed type mounting or a pivot type mounting. If the machine member moves in a straight line type motion, a fixed mount can be used. If the machine member is required to move in an arc a pivot mounting must be used. See figure 17.



Fixed mount



Pivot mount

Figure 17 — Fixed and pivot mounts

7.2 Types

Fixed mounts are available in many configurations. Typical mountings may be front or rear flange mountings, tie rod extended mounts, or foot mounts. Pivot mounts can be head, cap or center trunnions, or a rear cap pivot mount. For a more complete list of the mounts, consult the manufacturer or ANSI/(NFPA)T3.6.7 R1. See figure 18 for some examples.

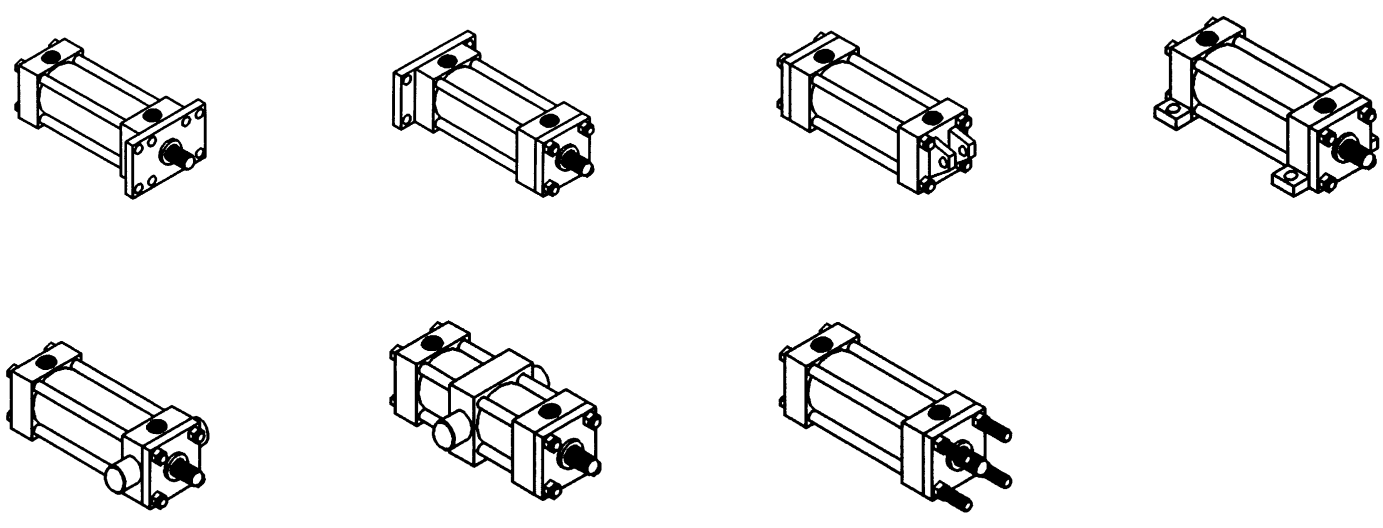


Figure 18 — Typical mounts

7.3 Mounting enhancements

Selection of any mounting style depends primarily upon the operating specifications of the application. Cylinder mounting directly affects the maximum operating pressure at which the cylinder may be used. Whether the cylinder is used in thrust (push) or tension (pull), its stroke length, piston rod diameter and method of connection to the load must be considered when selecting a mounting style.

Fixed mountings that absorb the force on the centerline of the cylinder are considered the best for straight line force transfer. The symmetrical mountings allow the thrust or tension forces to be distributed uniformly within the mounting framework. Flange mounts are considered the best mounting styles within this category. Front flange mounts are ideally suited when the piston rod is in tension (pull), while cap flanges are recommended for thrust (push) applications.

Fixed noncenterline mountings do not absorb forces on their centerline. The offset thrust introduces bending stresses and additional loads on the mounting bolts. This is especially true in short stroke applications. This type should be very well aligned for maximum service life. Use of shear pins or keys should be considered when these cylinders are subjected to high pressures or shock loads. These mountings are among the easiest to use for mounting and replacement ease.

If the path of the load is curved or misalignment is a problem, a pivoted centerline mounting should be used. These mounts offer compensation for non-linear travel in only one plane. Pivot mounts require a pivot type rod attachment.

Threaded rod end attachments should be torqued tightly against a threaded shoulder to minimize bending and reduce fatigue stresses.

8 Design considerations

8.1 Column strength

Piston rod column failure (buckling) can occur if the rod diameter is not sized to match the stroke and load. The manufacturer should be consulted for application assistance. Reference figure 19 for an example of piston rod column failure.

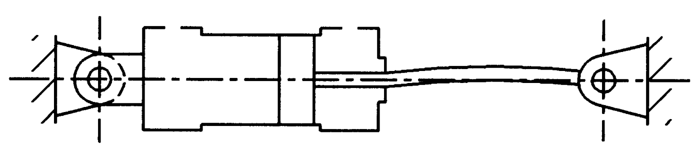


Figure 19 — Piston rod column failure

8.2 Bearing load

Cylinders are normally intended to push and pull without excessive side load. If a side load exists, the manufacturer should be consulted. Usually bearing load can be reduced with the addition of a stop tube. The use of a stop tube increases the distance between the piston bearing and piston rod bearing. See figure 20.

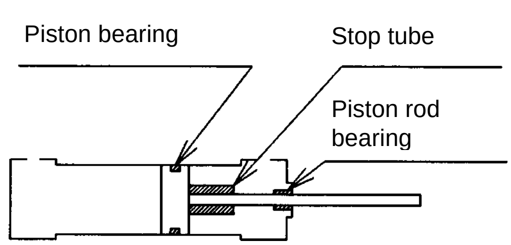


Figure 20 — Stop tube

8.3 Cushions

The purpose of a cushion is to decelerate the piston and rod assembly as it nears the end of stroke, preventing excessive mechanical stresses. Cushions may be of either a fixed or adjustable design. Both designs function by providing a bypass passage to remove the pressurized fluid trapped between the piston and the cylinder head when the cushion sleeve has entered the cushion bore. Varying the orifice opening with an adjustable cushion screw allows the user to select the best cushion rate for the system. A check valve in the cushion assembly allows for the free flow of fluid back to the piston face for quick acceleration when the rod is withdrawn. Heavy loads may also require an external device to stop the motion. Cushions are available on either or both ends of the cylinder. Consult manufacturer for the conditions under which cushions should be used. See figure 21.

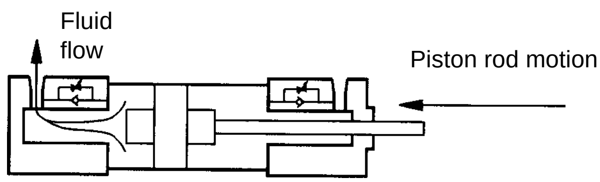


Figure 21 — Cushions

8.4 Eccentric Loads

A very important general consideration is to keep the cylinder thrust as close as possible to the centerline of the piston rod and free from misalignment or side thrust. Off-center thrust or side loads can substantially reduce the service life expected from the rod bearing and seals. Off-center thrust and side loading can be caused by cylinder deflection under load, machine frame deflection, rod bending or sagging, as well as by poor design of the machine. See figure 22.

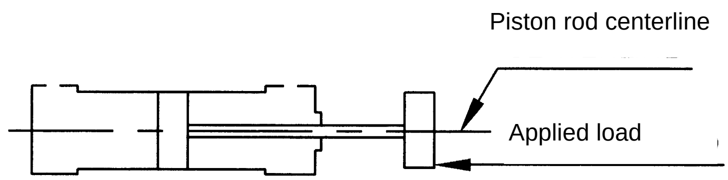


Figure 22 — Eccentric Loads

9 Compatibility

The temperature and fluid type must be considered in any application to ensure proper seal effectiveness and life. The manufacturer should be consulted for assistance.

10 Corrosion

Surfaces of either hydraulic or pneumatic cylinders can be corroded by water or other substances. Although paint may be suitable protection against corrosion for most indoor industrial uses, the cylinder specifier should be aware of corrosion potential in the operating environment. The material content and surface preparation of the piston rod must be considered in any application where a corrosive environment exists. Consult the cylinder manufacturer for corrosion protection recommendations.

11 Maintenance

Cylinder maintenance primarily involves replacing seals and/or bearings. Consult the manufacturer for maintenance guidelines.

11.1 Visual inspection

Degradation of cylinder thrust or erratic motion can indicate seal leakage. Prior to disassembly, visual inspection can be performed on the rod seal and tube end seals. This is accomplished by inspecting these locations for either oil or escaping air depending on whether the cylinder is hydraulic or pneumatic. Inspection of the piston seals and bearing require disassembly.

11.2 Disassembly

Prior to performing any maintenance that requires the disassembly of the cylinder, the pressure within the cylinder must be zero. The machine manufacturer should be consulted for any lock-out requirements.

Follow the cylinder manufacture's recommended disassembly and reassembly procedures, paying particular attention to prescribed fastener torque values and internal springs. While the cylinder is disassembled, inspect all components for evidence of unusual wear. Signs of internal corrosion may indicate the presence of water or lack of lubrication. Signs of contamination may indicate improper filtration. Proper preventative maintenance will extend seal and bearing life. Wear can be caused by misalignment of the cylinder and load, or other problems that should be remedied before the cylinder is returned to service.

11.3 Preventative maintenance.

Preventative maintenance such as hydraulic oil filtration and compressed air filtration/drying will extend cylinder service intervals.