Cylinder and Vane
Actuators and Controls—Design and Installation

American Water Works Association
Introduction

Hydraulic and pneumatic actuators are externally mounted on ball, plug, and butterfly valves, and on slide gates to provide automatic control of these devices in water and wastewater applications. When combined with control devices such as solenoid valves or positioners, the valves and gates can be used to remotely control water and wastewater treatment processes or process variables including flow and pressure. Many of these actuators also have the feature of providing field-adjustable operating times and, when equipped with pneumatic or hydraulic power systems, can continue to operate after loss of electrical power.

HISTORY

Simple gate valves date back to ancient times in Greek and Roman water and irrigation systems. These gates were mostly operated by manual levers or screws. It was not until the industrial revolution and the use of steam power that valves became automated with power actuators. Since then, hydraulic and pneumatic actuators have been a staple in water and wastewater systems, particularly as valves grew in size and became extremely difficult to operate manually. The advent of automation made it desirable to operate valves remotely with computerized process control systems. Figure 1-1 illustrates a ball valve equipped with a pneumatic vane-type actuator that controls the flow from a high-service water pump.

Given the increased use of automatic process systems, the use of power actuators continues to grow. The power actuator positions the valve in response to system-control signals to complete a system-control loop. When flow or pressure must be controlled as part of a process, a sensing device such as a pressure transmitter or flowmeter sends a signal to a process controller, which in turn compares the signal to the desired system parameter and sends a position signal to the power actuator. The power actuator is directly coupled to the closure member of the control valve and is therefore an essential element of the control loop (Skousen 1997).
Since a number of valve types are used to control processes, a similar number of various actuator types are used to control these valves. In response, the valve industry has developed actuators for both linear and rotary valves. When automated valves are needed, either hydraulic actuators or electric motor actuators are specified. Electrical actuators provide great versatility in valve automation, but hydraulic actuators provide the ability to store energy and operate the valve without electrical power. Hydraulic systems also provide safe operation of valves, which may be located in hazardous environments. Furthermore, in the event of an electrical power outage, hydraulic and pneumatic systems can still function to provide safe shutdown or isolation of the system.

Electric and hydraulic actuators are used regularly in many industries, including oil, gas, and power, but the use for the waterworks industry was standardized by AWWA Standard C540 in 1987. In 2008, AWWA C540 was withdrawn and replaced by standards AWWA C541, Hydraulic and Pneumatic Cylinder- and Vane-Type Actuators for Valves and Slide Gates, and AWWA C542, Electric Motor Actuators for Valves and Slide Gates. Note, like all AWWA standards, C541 and C542 are updated regularly, as necessary depending on new technology and requirements.

**PURPOSE**

The purpose of this manual is to explain the fundamental concepts of hydraulic and pneumatic power actuators so users with a technical background can understand, specify, and install these actuators on valves and slide gates. The information in this manual must be used in conjunction with data from actuator and valve manufacturers to select and size the correct actuator models for specific applications.

Sizing parameters such as thrust and torque is explained so the sizing methodologies recommended by actuator manufacturers can be applied to specific applications. Also, the effects of certain valve application parameters, such as flow rate or differential pressure, on actuator operation are discussed.
Finally, installation and operation guidelines are presented for startup procedures and troubleshooting power actuators in the field.

**GENERAL APPLICATION**

Cylinder-type actuators produce a linear motion to operate a slide gate. Hydraulic or pneumatic pressure is applied to either side of the cylinder piston to generate linear force or thrust. The cylinder rod is attached to the gate and causes it to rise and fall inside the gate frame.

Quarter-turn cylinder-type actuators produce a rotary motion to turn the valve stem and operate the closure member of the butterfly, plug, or ball valve. Quarter-turn cylinder actuators convert the linear motion of a cylinder to rotary motion using link-and-lever, rack-and-pinion, or scotch-yoke mechanisms. Each of these mechanisms is discussed in chapter 2, “Principles of Operation”.

Quarter-turn vane-type actuators also produce a rotary motion. However, instead of a cylinder, the vane acts like a lever and generates rotation from the pressure applied to either side of the vane.

When specifying power actuators, consideration should be given to the effects of valve operational speed on the creation of pipeline hydraulic transients (surges), especially on long pipelines. The power actuator stroke time may vary based on actual pipe operating fluid conditions (e.g., pressure, flow, and pipe size) and the power source capacity.

**SUPPLY MEDIUM**

All of these actuators are powered with a supply medium of air, water, or hydraulic oil pressure. Specific requirements for the supply media, including pressure, flow, and cleanliness, will be discussed further in this manual. When accessories and control devices such as solenoid valves are added to the actuator, the supply media requirements become more critical.

All three supply media—air, water, and oil—provide reliable sources of energy to operate valves, even after loss of electrical power. The supply systems can be installed near the valves or up to several hundred feet away if required. Both indoor and outdoor installations for these systems are available from either the valve or control system supplier. A comparison of the most relevant properties of these three supply media is summarized in Table 1-1.

**Air Supply Medium**

Air is a common power supply medium because it is relatively inexpensive and often readily available at water and wastewater plants to operate pneumatic power tools. Compressed air systems consist of an electric motor–driven compressor and a receiver tank for air storage. These systems commonly provide air pressure in the 80–100 psig (552–689 kPa) range with a maximum recommended pressure of 150 psig (1,034 kPa).

The supply output from the compressor system should be equipped with filters and dryers so debris down to a size of 40 microns and water droplets are removed from the air supply before distribution. When the valve is equipped with modulating controls or positioners, filtration down to 5 microns is recommended to prevent clogging of the control orifices. When recommended by the valve or actuator manufacturer, lubricators can be used to add lubrication to the cylinder actuator, but they should not be added to vane actuators or when positioners are employed. It is important to check with the actuator manufacturer first because most vane actuators are permanently lubricated and lubricated air may displace the manufacturer’s supplied lubricant from the actuator.
While air is an economical and reliable power supply medium, its use should be limited to smaller valves. If used on large valves, the size of the actuator cylinders can become too large to dispense the required actuator force because of the 80–100 psig (550–690 kPa) pressure range limitation. Also, if the valve needs to be moved slowly (i.e., over one minute), the motion of the cylinder may not be smooth. Air is compressible, and the forces from the valve vary with position, which causes the pressures in the cylinder to fluctuate, preventing smooth motion of the cylinder piston. Also, when air is released from the cylinder, it can produce uncomfortable or irritating noise levels if not fitted with proper sound-reducing mufflers.

Water Supply Medium
Water is also a common power supply medium because it is typically available at plants and pumping stations, especially if the plant or pumping station is feeding the water distribution system. A reliable water supply for powering actuators can often be obtained by connecting to a pump discharge header. However, it is important to realize that during system startup, the water source may not yet be available, and a temporary water supply source may be needed to operate the valves. If potable water is used as the supply medium, care must be taken to prevent backflow of the supply and drainage water back into the potable water system. Depending on the source of the water, providing filtration to remove particles larger than 20 microns may also be necessary. Other properties of the water, such as salinity, hardness, pH, and conductivity, should be reviewed to protect the cylinder and controls from corrosion, degradation, and excessive maintenance. A minimum water pressure of 60 psig (414 kPa) is common and a maximum pressure of 150 psig (1,034 kPa) should be used to match the standard pressure rating of the cylinders.

While water is not compressible and therefore can provide smooth operation of cylinders at extremely slow operating times, such as five minutes. It may be necessary to open or close a valve this slowly to prevent surges in long distribution pipelines. Water in general is corrosive, so its use dictates the need for corrosion-resistant supply tubing and cylinders. Water supply tubing to the actuator is usually brass and copper. Similarly, the cylinder barrel should resist corrosion and be constructed of materials such as stainless steel, bronze, fiberglass, or coated steel. The cylinder rod should be of corrosion-resistant material as well, such as hard-chrome or electroless-nickel-plated stainless steel. Water-powered actuators are not generally certified to drinking water standards such as NSF.

Table 1-1  Summary of media properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Air</th>
<th>Water</th>
<th>Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative cost of media equipment</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Pressure ranges</td>
<td>80–100 psig (552–689 kPa)</td>
<td>60–150 psig (414–1,034 kPa)</td>
<td>60–150 psig (414–1,034 kPa)</td>
</tr>
<tr>
<td>Speed control</td>
<td>Poor (large cylinders)</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Required cylinder maintenance</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>
61, Drinking Water System Components – Health Effects, so the exhaust media from the actuator should not be returned to the potable water source.

**Hydraulic-Oil Supply Medium**

The hydraulic-oil supply medium is typically a petroleum-based fluid, but it can also be certified as food grade per FDA requirements for cases where it may possibly infiltrate into the water system. Hydraulic oil is typically filtered and the piping cleaned to a specified level of cleanliness recommended by the equipment manufacturer and furnished with a viscosity of 135 to 165 Saybolt Seconds Universal (SSU), similar to automatic transmission fluid in vehicles. Hydraulic oil systems can be obtained in the low-pressure range of 60 to 300 psig (414 to 2,070 kPa) for smaller valves or in high-pressure systems ranging from 1,000 to 2,500 psig (6,890 to 17,200 kPa) for large valves. Standard heavy-duty hydraulic cylinders have a minimum working pressure rating of 3,000 psig (20,680 kPa). The use of the higher-pressure systems greatly reduces the size of the cylinders and the cost of the hydraulic power system required to operate large valves. The construction of oil power systems is explained in chapter 5.

Hydraulic oil offers superior operating characteristics because it inherently lubricates all of the cylinder and control components that it contacts. Like water, hydraulic oil is not compressible, and therefore it can provide smooth cylinder motion during slow valve operating times.

Hydraulic oil must be ultra clean, especially for high-pressure systems, to avoid clogging or scoring of cylinders and solenoid valve surfaces. Manufacturers may specify a cleanliness level in accordance with industry standards such as ISO 4406. A typical ISO 4406 cleanliness level may be “19/17/14” where the three numbers specify that there shall be less than 5,000 4-micrometer, 1,300 6-micrometer, and 160 14-micrometer or larger particles per 100 milliliter of fluid. The ISO standard contains tables with many levels of cleanliness. The cleanliness level is measured by looking at a small sample of the fluid under a microscope to size and counting the particles. New hydraulic oil rarely meets this level; hence, new oil should be filtered before use. Users contemplating a hydraulic oil system should familiarize themselves with other standards and practices concerning cleanliness, such as SAE J1165 and ASTM D4174.

Fluid used for flushing or filling hydraulic systems should be filtered using at least a 10-micron pressure filter system. Hydraulic tanks, fittings, and tubing should also be flushed thoroughly before installation. Once the system is running, it stays clean and trouble-free because of the lubricity and noncorrosive properties of hydraulic oil.

**REFERENCES**


SAE J1165, “Reporting Contamination Levels of Hydraulic Fluids.”

This page intentionally blank.