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Val-Matic® Valve & Mfg. Corp. is a leading manufacturer of check valves, quarter turn shut-off valves and air valves for water/wastewater, industrial and building markets. Valve types include Tilted Disc®, Dual Disc®, Swing-Flex®, Surgebuster®, Silent Check Valves, Eccentric Plug Valves, AWWA Butterfly Valves, Air Valves, Foot Valves, VaultSafe® products, Ener-G® AWWA Rubber Seated Ball Valves, Smart Control Systems, and QuadroSphere® Trunnion-Mounted Ball Valves.

ENGINEERING: Val-Matic employs degreed mechanical, environmental, and civil engineers in its sales support, production, and R&D departments. We have registered Professional Engineers (PE) with decades of product knowledge and experience that can assist in designing systems and processes in many industries. Our engineers have developed specialized design tools for sizing and locating air valves and estimating the energy savings associated with valve selection. These tools are available on the website here. The basis for the design tools and background information on countless valve topics are also posted on our website. Finally, our engineers are dedicated to improving the industry by participating in various roles on ASME, MSS, and AWWA standards committees. You will commonly find our engineers to be the chairman and editor of many AWWA Manuals of Practice.

TESTING: Val-Matic's facility in Addison, Illinois contains a 7000 sq. ft. state of the art research and development facility dedicated to providing new technology, products, and solutions to serve our industries. A materials lab is used for testing metals, coatings, and elastomers in various environments. A flow lab equipped with a series of water pumps and a data acquisition system is used to perform dynamic valve tests in a wide range of pressures and flows. A high pressure air system is used to perform full-scale testing of large air valves. The materials lab is equipped with a portable X-ray Flourescence Analyzer (XRF) to identify the chemical composition of alloys and perform positive material identification (PMI) services. The labs are also used to provide hands-on training to industry organization members such as AWWA and conduct product proof of design testing.

White Paper

Air In Pipelines

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INTRODUCTION

The presence of air in a pipeline and its impact on operations is probably one of the most misunderstood phenomena in our industry today. Many operational problems are blamed on inadequate thrust blocking, improper pipeline bedding, etc. These problems include broken pumps, valves and pipe, as well as faulty instrumentation readings. In reality, many of these problems are not caused by improper installation of the equipment but by failure to de-aerate the pipeline. It has been said that if a pipeline is properly de-aerated, you can't guarantee against a line break. However, if you don't properly de-aerate a pipeline, you should be prepared for one.

SOURCES OF AIR

Air in a pressurized, operating pipeline comes from three primary sources. First, prior to start-up, the line is not empty - it is full of air. To entirely fill a pipeline with fluid, it is necessary to eliminate this air. As the line fills, much of this air will be pushed downstream to be released through hydrants, faucets, etc. But a large amount will become trapped at system high points (Figure 1). This phenomenon will occur because air is lighter than water and therefore, will gravitate to the high points. This volume of air will continuously be increased by the second and third sources as the system continues operation.

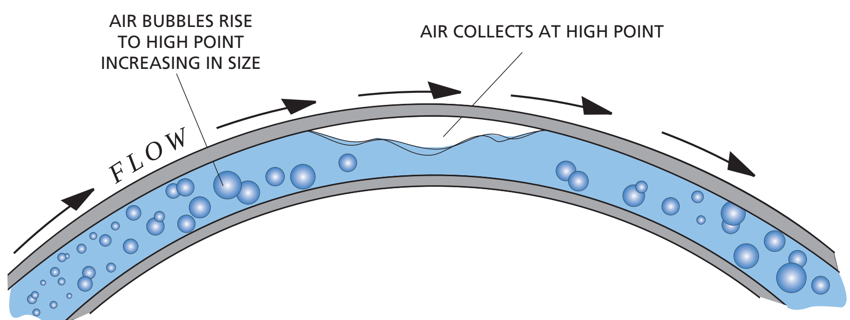

FIGURE 1. Air Collects at High Points

Source number two is the water itself. Water contains approximately 2% air by volume. During system operation, the entrained air will be continuously released from the water and once again accumulate at system high points. To illustrate the potential massive amount of air this 2% represents, consider the following: A 1000 ft. length of pipe could contain a pocket of air 20 ft. long if all the air accumulated in one location. Or a one mile length of pipe could contain a 100 ft. pocket. This would be true regardless of the size of the pipe.

The third source of air is that which enters through mechanical equipment (Figure 2). This includes air being forced into the system by pumps as well as air being drawn in through packing, valves, etc. under vacuum conditions. As one can see, a pressurized pipeline is never without air and typically the volume is substantial.

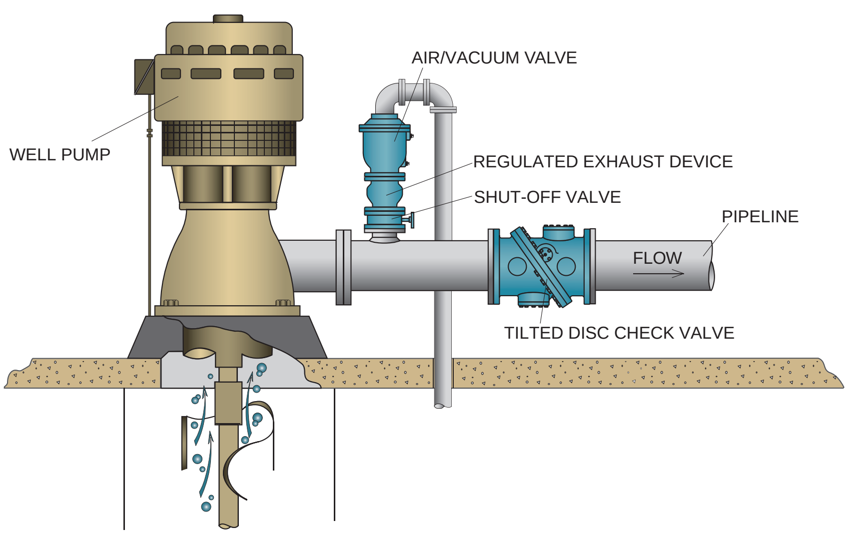

FIGURE 2. Air Through Mechanical Equipment

IMPACT OF AIR ON SYSTEM

Now that we have identified the air sources, let us consider the impact it will have on the system. Two problems are apparent. The pockets of air accumulating at high points can result in a line restriction (Figure 3). Like any restriction, the pockets of air increase headloss, extend pumping cycles and increase energy consumption. The presence of air can also promote corrosion of pipe and fittings. As air continues to accumulate at system high points, the fluid velocity increases as the fluid is forced through a smaller and smaller restricted pipe area.

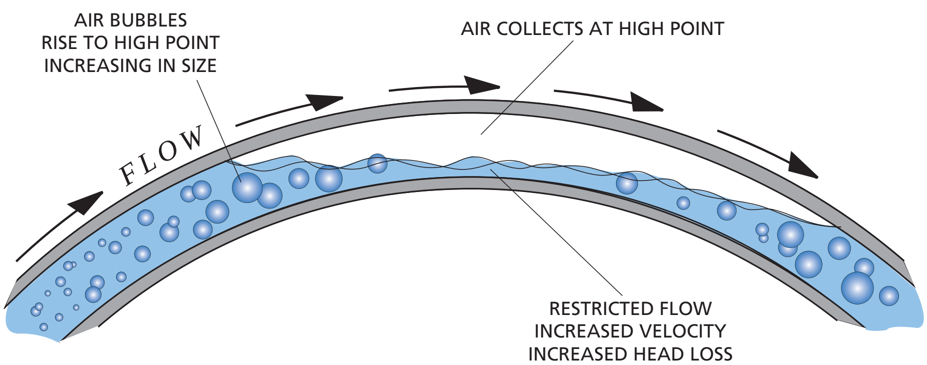

FIGURE 3. Pockets of Air

As the pockets grow, one of two phenomena will occur. The first possibility is a total stoppage of flow (Figure 4). If system dynamics are such that the air cannot be continuously removed by the increased fluid velocity and pushed downstream, then a pressure drop higher than pump capacity can develop, thereby stopping all flow.

The second, and more likely occurrence, is that the increased velocity will cause all, or part of, the pocket to suddenly dislodge and be pushed downstream (Figure 5). The sudden and rapid change in fluid velocity when the pocket dislodges and is then stopped by another high point, which can, and often will, lead to a high pressure surge (i.e., water hammer). Serious damage to valves, fittings, gaskets, or even breakage of the line can occur. This is the most serious of the possible consequences of air being allowed to accumulate in system high points.

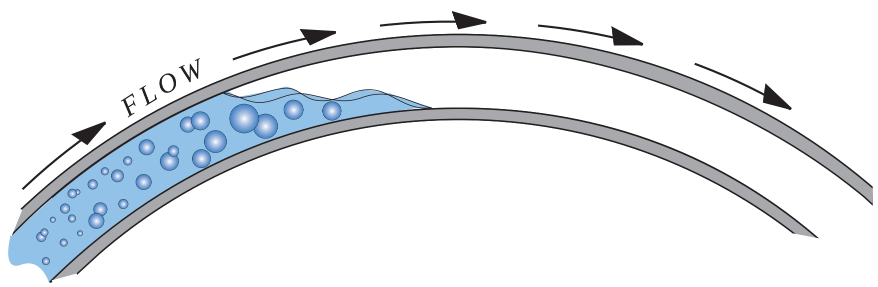

FIGURE 4. Total Stoppage of Flow

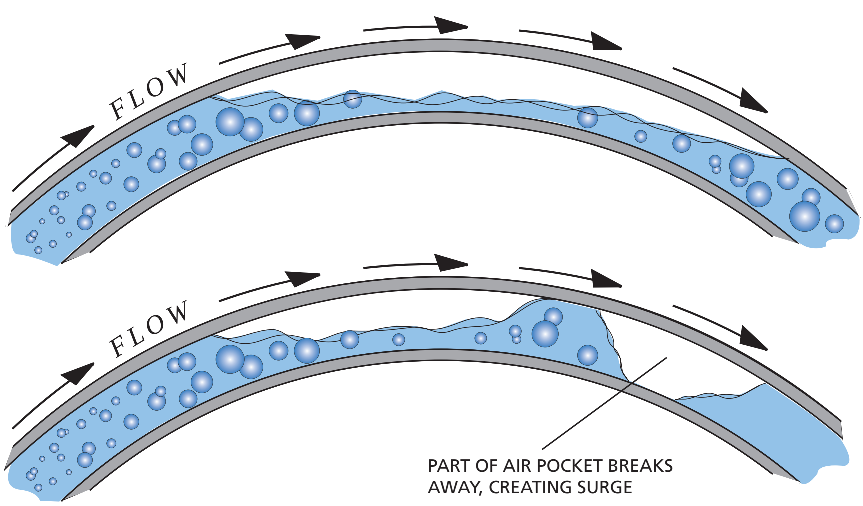

FIGURE 5. Air Pocket Can Result in a Surge

HISTORICAL SOLUTIONS

As we can see, air in a pressurized pipeline is a serious concern. Obviously, its removal will result in a more efficient, cost effective operation and potentially avoid more serious problems. In the early 1900's, engineers and waterworks personnel started developing an understanding of the problems associated with air and the search for a solution was on. Some depended on standpipes, believing that a large portion of the air would settle out through them. Many began placing manual vent valves at system high points to manually bleed off accumulated air. Unfortunately, it has proved impossible to predict when it is time to bleed the air. This proved impractical, especially on larger systems. Open fire hydrants (Figure 6) are frequently used under the assumption that all air in the pipeline will be released. Unfortunately, hydrants are generally connected to the side of the pipe leaving a substantial pocket of air trapped at the top. It should be noted that there are still a few municipalities using these methods.

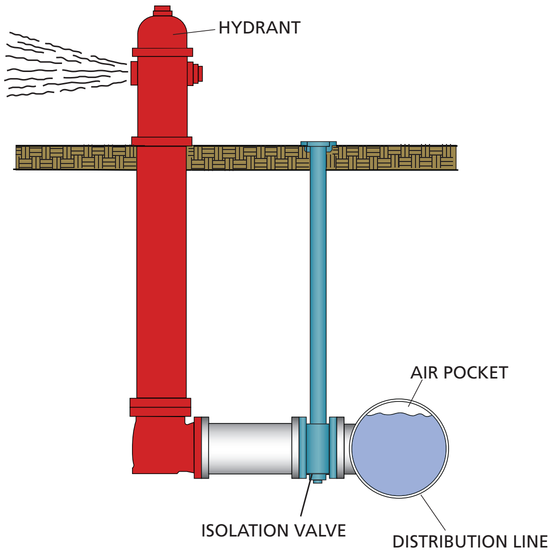

FIGURE 6. Open Fire Hydrant System

AIR VALVES: AN EFFICIENT, RELIABLE ALTERNATIVE

Today, most municipalities utilize Automatic Air Valves. They are available in many different designs and configurations for a wide range of applications. Their function is to automatically release and admit air without operator assistance. Today, countless Air Valves are performing this task around the globe on a daily basis. Air Valves are manufactured in accordance with AWWA Standard C512 and available in three basic configurations: (Figure 7)

- Air/Vacuum Valves
- Air Release Valves
- Combination Valves

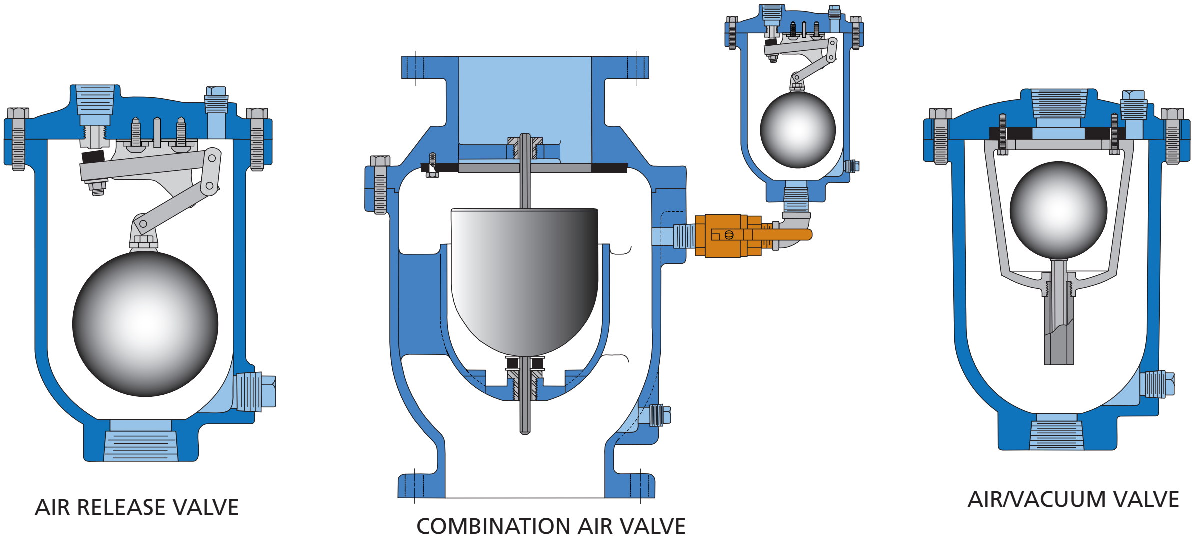

FIGURE 7. Air Valve Configurations

AWWA air valves are constructed of iron or stainless steel bodies with corrosion-resistant trim for water and wastewater service. The correct sizing and location of all three types are critical (Figure 8). Every high point where the pipeline converts from a positive grade to a negative grade should have an air valve. Even minimal high points with small air pockets can cause serious surge problems. In addition, it is recommended that air valves be installed every half mile or 2500 ft. on straight horizontal runs.

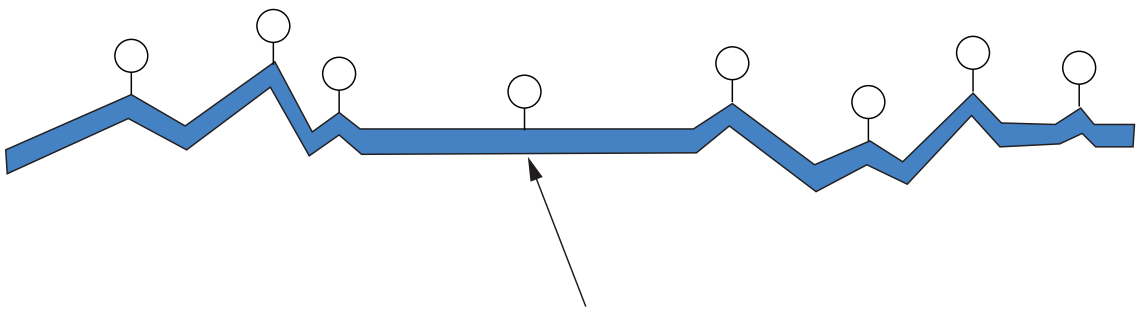

FIGURE 8. Air Valve Placement

AIR/VACUUM VALVES

Air/Vacuum Valves (Figure 9) have full-size orifices ranging from ½ to 20 in. and are used to exhaust large quantities of air upon system start-up, as well as allowing air to re-enter the line upon system shut down. As water enters the valve, the float will rise, closing the discharge port. The valve will remain closed until system pressure drops to near zero PSI. It will not open and release any accumulation of air while the system is under pressure.

An added benefit of an Air/Vacuum Valve is its ability to provide pipeline vacuum protection. If negative pressure develops, the valve will open, admitting air into the line, preventing a possible pipeline collapse or intensified surges.

While Air/Vacuum Valves will exhaust large quantities of air upon start-up, it should be remembered that they will not continuously release air during system operation. For this function, an Air Release Valve is required.

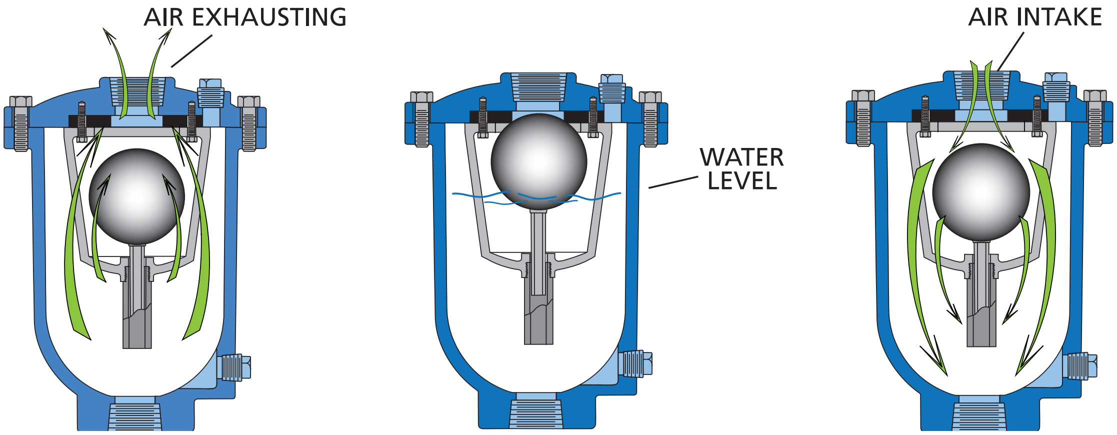

FIGURE 9. Air/Vacuum Valves

SLOW CLOSING DEVICE (REGULATED EXHAUST DEVICE)

When an Air/Vacuum Valve is used on vertical pump discharge or on a pipeline where column separation may occur, it is common to include a Slow Closing Device to prevent surges related to air valve slam. The Slow Closing Device automatically closes when high exhaust rates might occur. The device can be mounted on the inlet of a clean water air valve and on the outlet of a wastewater air valve (Figure 10).

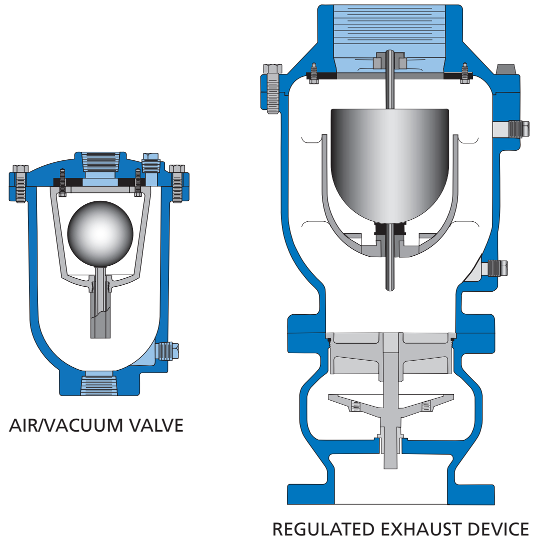

FIGURE 10. Slow Closing Device for Air Valves

AIR RELEASE VALVES

Unlike an Air/Vacuum Valve, an Air Release Valve (Figure 11) will continuously release accumulated air during system operation. When installed, Air Release Valves are "normally open" and automatically expel air until the valve fills with water. Then, as air from the pipeline enters the valve, it displaces the water, allowing the float to drop. The air is then released to the atmosphere through a small orifice that ranges in diameter from 1/16 of an inch to 1 inch. As the air is vented it is replaced by water, raising the float and closing the valve orifice. As air accumulates, the valve will continue to cycle in this manner to automatically remove collected air.

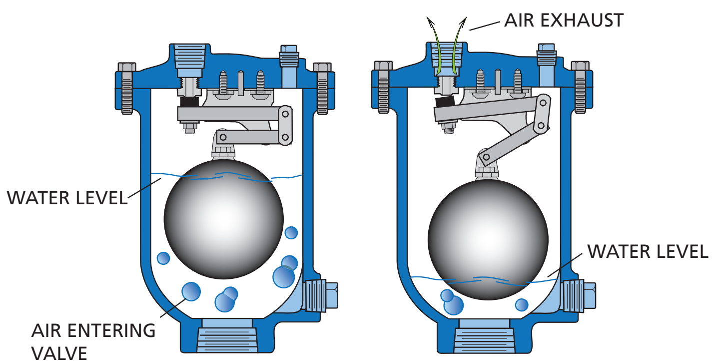

FIGURE 11. Air Release Valve

COMBINATION AIR VALVES

Combination Valves (Figure 12) perform the functions of an Air/Vacuum Valve (i.e., exhaust large quantities of air on startup, admit air on shut-down) and Air Release Valves (i.e., release air continuously under pressure during operation). Combination Valves are typically available in single body and dual body (an Air/Vacuum Valve and Air Release Valve piped together) configurations. The single body design can be more economical while the dual body design can provide design flexibility when sizing the orifices. Some pipeline designers use only combination air valves on a pipeline because all air valve functions are included; a mistake in field installation will not leave the pipeline unprotected. Other applications for Combination Air Valves include pump discharge headers and upstream of flow measurement devices.

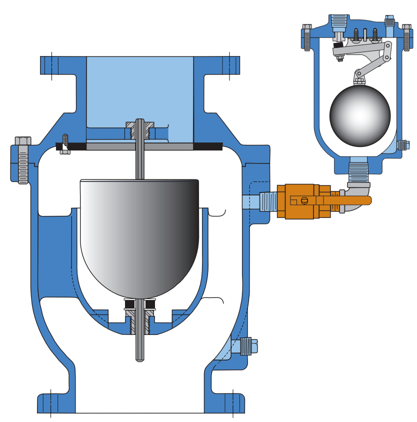

FIGURE 12. Dual Body Combination Air Valve

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SUMMARY

When air is allowed to accumulate in pressurized pipelines, efficiency is sacrificed and serious damage can occur. A properly de-aerated pipeline will not solve all surge problems. However, the elimination of air can solve one of their most common causes. Air Valves are a cost effective, reliable method of improving efficiency and solving air related surge problems.

NOTE: Additional copies of Air in Pipelines and the American Water Works Associations' Air Valve Standard C512 are available. An online computer program and a slide rule calculator are available to assist the reader in the correct sizing of air valves. Please contact Val-Matic Corporation for complimentary copies of the papers as well as the calculator.

White Paper

Theory, Application, and Sizing of Air Valves

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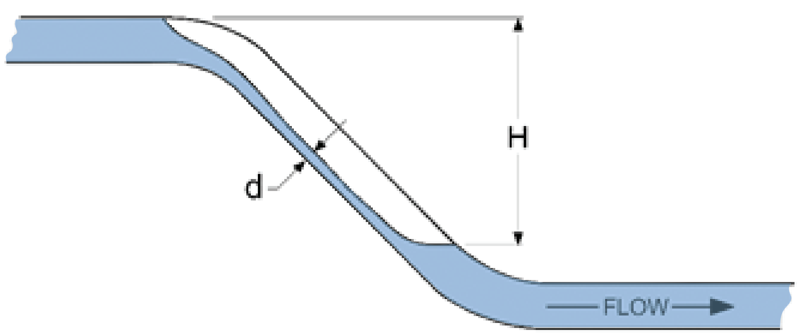
INTRODUCTION

One of the most misunderstood aspects of the water and wastewater industry is the presence of air in a pipeline and its impact on operations. Many operational problems, especially at the time of initial start-up, including damaged equipment, as well as faulty instrumentation readings, are blamed on inadequate thrust blocking, improper pipeline bedding, etc. But in reality, many of these problems are not caused by improper installation of the line, but by failure to de-aerate the line. Properly de-aerating the pipeline with the use of automatic air valves will safeguard it from air-related problems.

Air in a pressurized, operating pipeline has three primary sources. First, prior to start-up, the line is not empty; it is full of air. As the line fills with liquid, much of this air will be pushed downstream and released through hydrants, faucets, etc. but a large amount will become trapped at system high points. This phenomenon will occur because air is lighter than water and therefore, will collect at high points.

The second source of air is the incoming water itself. Water contains approximately 2% air by volume based on normal solubility of air in water (7). The dissolved air will come out of solution with a rise in temperature or a drop in pressure, which will commonly occur at high points due to the increase in elevation. Finally, air can enter through mechanical equipment such as pumps, fittings, and valves when vacuum conditions occur.

Trapped air can have serious effects on system operation and efficiency. As air pockets collect at high points, a restriction of the flow occurs which produces unnecessary headloss and energy consumption. As shown in the Figure, trapped air forms a long pocket along the pipe descent with a constant depth "d". Since the air is at the same pressure along the air pocket, it can be shown that the headloss is equal to the vertical height of the pocket or dimension "H" (1). A pipeline with many air pockets can impose enough restriction to stop all flow. Also, sudden changes in velocity can occur from the movement of air pockets. When passing through a restriction in the line such as a control valve, a dislodged pocket of air can cause surges or water hammer. Water hammer can damage equipment or loosen fittings and cause leakage. Finally, corrosion in the pipe material is accelerated when exposed to the air pocket, which can result in premature failure of the pipeline.



Air is sometimes removed from a line with a manual vent or fire hydrant during initial startup but this method does not provide continual air release during system operation nor does it provide vacuum protection. Today, municipalities use a variety of automatic air valves at the pump discharge and along the pipeline.

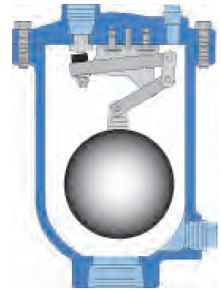
THREE BASIC TYPES OF AIR VALVES

There are three basic types of air valves standardized in American Water Works Association (AWWA) Standard C512-15: "Air-Release, Air/Vacuum, and Combination Air Valves for Water and Wastewater Service."

It is important to understand the functions and limitations of each valve type so that valves can be located and sized properly for a pipeline.

AIR RELEASE VALVES

Air Release Valves are probably the best known air valve and are typically furnished in sizes ½ in. (13 mm) through 3 in. (76 mm). The valve has a small precision orifice in the range of 1/16 in. (1.6 mm) to ½ in. (13 mm) to release air under pressure continuously during pipeline operation. The Air Release Valve has a float to sense the presence of air and a linkage mechanism that gives the float mechanical advantage in opening the orifice under full pipeline pressures.


Air Release Valve

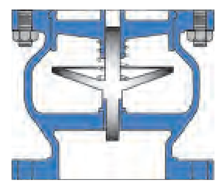
Air Release Valves have a limited capacity for admitting and exhausting air because of their small orifice. For this reason, most pipeline locations require both Air Release and Air/Vacuum Valves for exhausting and admitting large volumes of air.

AIR/VACUUM VALVES

An Air/Vacuum Valve is installed downstream of pumps and at high points to exhaust large volumes of air during pump startup and pipeline filling. The valve also will admit large volumes of air to prevent a vacuum condition from occurring in the pipeline and to allow for draining. A float in the valve rises with the water level to shut off the valve when the air has been exhausted. Upon the loss of pressure due to draining, line break, or column separation, the float will drop and allow air to reenter the pipe. It is important to note that under normal operation, the float is held closed by the line pressure and will not relieve accumulated air. An Air Release Valve is needed to relieve air during system operation.


Air/Vacuum Valve

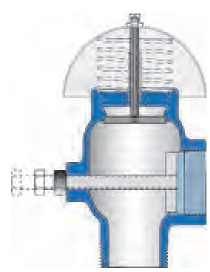
There are two variations of Air/Vacuum Valves that warrant discussion. First, Air/Vacuum valves can be equipped with a Slow-Closing Device which controls the flow into the valve to reduce surges in the valve. The Slow-Closing Device is useful at highpoints where column separation or rapid changes in velocity occur. Column separation can be predicted by computer transient analysis, but the following general guidelines can be used to help locate Slow-Closing Devices.


Slow-Closing Device

1. When the flow velocity is greater than 8 ft/sec (2.4 M/sec), the surge potential can be as high as 400 PSI (2760 kPa). Also, when the fill velocity exceeds 2 ft/sec (0.6 M/sec) high surges can result.
2. High points where a vacuum forms on pump shutoff may exhibit rapid flow reversal.
3. Systems where the time for the water column to reverse is less than the critical time will see high surges even from small changes in velocity. The critical time is defined as 2L/a, where "L" is the pipe length and "a" is the elastic pressure wave speed (3).
4. Fast closing pump discharge check valves may prevent slam but still cause line surges.
5. Systems with booster pump stations can see great fluctuations in line velocities on power failure.
6. If the pipeline discharge creates a siphon on shutdown, rapid flow reversal can be expected.

Second, a Well Service Air Valve is an Air/Vacuum Valve equipped with a Throttling Device or a Slow-Closing Device (4 in. and larger valves) for use with vertical turbine pumps. These pumps start against an empty pump column and a closed pump check valve and therefore start rapidly and accelerate the fluid. Well Service Air Valves require special consideration during sizing.

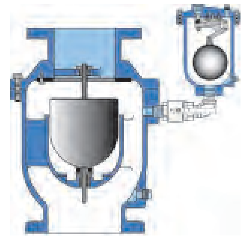
The Throttling Device (3 in. and smaller valves) controls the air discharge rate so that the pressure surge caused by the pump water column reaching the closed check valve is minimized. The Throttling Device has a second independent vacuum port to allow air flow back into the line after pump shutdown so that the static suction water level can be restored without allowing a vacuum to form in the pump column. The Dual Port Throttling Device should have an open vacuum port separate from the exhaust port so that the air flow into the device is not restricted by exhaust piping.


Dual Port Throttling Device

COMBINATION AIR VALVES

Single Body Combination

The Combination Air Valve combines the functions of both the Air/Vacuum and Air Release Valves and is an excellent choice for high points. A Combination Valve contains both a small air release orifice and a large air/vacuum port in one assembly. On smaller valves, usually less than 8 in. (200 mm), the float and lever mechanism are contained in a single body design. On larger sizes, a dual body design consisting of an Air Release Valve piped to an Air/Vacuum Valve is furnished as a factory assembled unit.



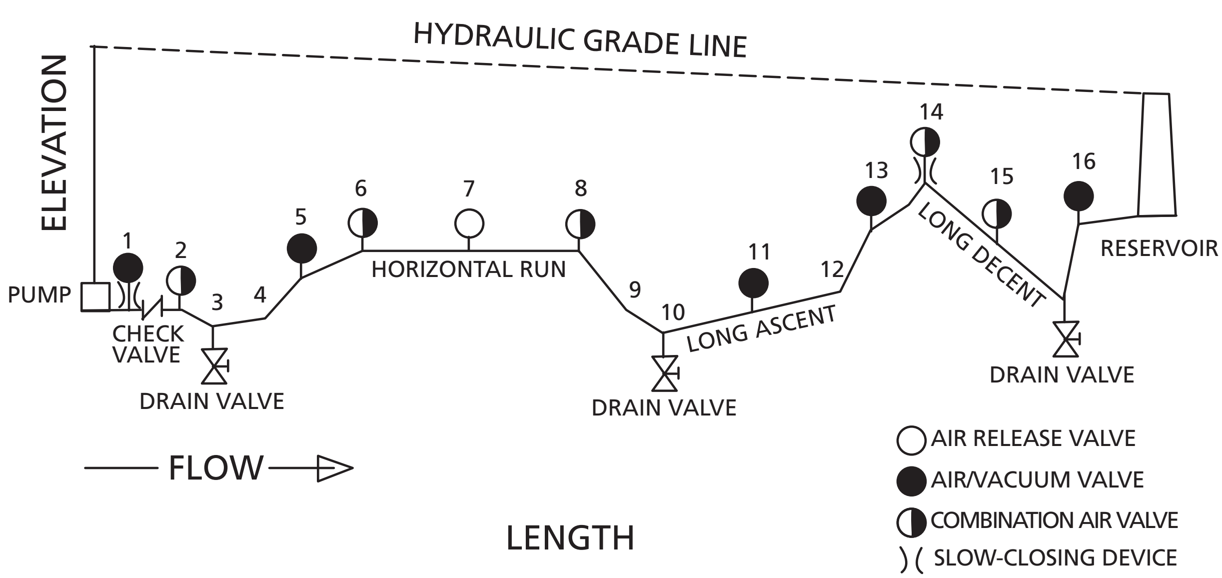
Dual Body Combination

Single body units have the advantage of being more compact and typically less costly. Dual body units are advantageous for Air Release Valve sizing and maintenance because the Air/Vacuum Valve is still in operation while the Air Release Valve is isolated and under repair. By combining various sized Air Release and Air/Vacuum Valves, a Dual Body Combination Valve can be made for almost any application. Some designers use only Combination Air Valves on a pipeline because all air valve functions are included and a mistake in field installation will not leave the pipeline unprotected.

AIR VALVE LOCATIONS ALONG A PIPELINE

Air valves are installed on a pipeline to exhaust air and admit air to prevent vacuum conditions and airrelated surges. The AWWA Air Valve Manual recommends Air Valves at the following points along a pipeline (4).

1. **High Points**: Combination Air Valve.
2. **Long Horizontal Runs**: Air Release or Comb. Valve at 1250 to 2500 ft. (380 to 760M) intervals.
3. **Long Descents**: Combination Air Valve at 1250 to 2500 ft. (380 to 760M) intervals.
4. **Long Ascents**: Air/Vacuum Valve at 1250 to 2500 ft. (380 to 760M) intervals.
5. **Decrease in an Up Slope**: Air/Vacuum Valve.
6. **Increase in a Down Slope**: Combination Air Valve.
7. **Transient Locations**: Combination/Slow-Closing Device or Vacuum Breaker/Air Release.
8. **Flow Meters**: Air Release upstream.
9. **Well or Vertical Turbine Pumps**: Air/Vacuum/Slow-Closing Device or Throttling Device.



SAMPLE PIPELINE PROFILE ILLUSTRATING VALVE LOCATIONS					
No.	**Description**	**Recommended Types**	**No.**	**Descrip-tion**	**Recommended Types**
1	Pump Dis-charge	Air/Vac & Slow-Closing	9	Decr. Downslope	No Valve Required
2	Incr. Downslope	Combination	10	Low Point	No Valve Required
3	Low Point	No Valve Required	11	Long Ascent	Air/Vac or Combination
4	Incr. Upslope	No Valve Required	12	Incr. Upslope	No Valve Required
5	Decr. Upslope	Air/Vac or Combina-tion	13	Decr. Upslope	Air/Vac or Combination
6	Beg. Horiz.	Combination	14	High Point	Combination & Slow-Clos-ing
7	Horizontal	Air Rel or Combination	15	Long Descent	Air Rel or Combination
8	End Horiz.	Combination	16	Decr. Upslope	Air/Vac or Combination

Also, on very long horizontal runs, Air Release and Combination Air Valves will be used alternately along the pipeline. It should be noted that Combination Valves can be used at any location instead of Air Release or Air/Vacuum Valves to provide added air release capacity on the pipeline.

It is important to establish a smooth pipeline grade and not follow the terrain or an excessive number of Air Valves will be needed. The designer must balance the cost of air valve locations with the cost of additional excavation. Finally, depending on the pipeline velocity and size, minor high points and changes in grade can be ignored because the velocity may scour the air from the pipeline (3).

AIR/VACUUM VALVE SIZING

Some publications list a rule of thumb that suggests Air/Vacuum Valves be 1 in. (25 mm) per 1 ft. (0.3 M) of pipe diameter (4). So a 4 ft. (1.2 M) diameter line would have a 4 in. (100 mm) diameter valve. Based on over thirty years of successful air valve application, ValMatic has developed sizing criteria that form the basis for the following methodology. The methodology is based on sizing the air/vacuum valve for two conditions: admitting air to prevent a vacuum in the pipeline and exhausting air during filling of the pipeline.

The Air/Vacuum or Combination Air Valve should be capable of admitting air after power failure or line break at a rate equal to the potential gravity flow of water due to the slope of the pipe. The flow of water due to slope can be found by the Darcy-Weisbach equation:

$$v = (2\,g\,H / K)^{1/2} \quad (5)$$

where:

v = Flow velocity, ft/sec
g = gravity, 32.2 ft/sec^2
H = Change in Elevation, ft.
K = Resistance coefficient, dimensionless
= $fL/d + 2.5$
(the 2.5 represents entrance, exit, and some piping losses)
f = friction factor of pipe (iron = .019, steel = .013, plastic = .007)
L = Change in Station Points (length of run), ft.
d = pipe ID, ft.

The gravity flow due to slope is calculated for every pipe segment. For stations where there is a change in up slope or down slope, the difference between the upstream and downstream flows is used for sizing because the upper segment feeds the lower segment and helps prevent a vacuum from forming.

When steel or any collapsible pipe is used, it is important to determine if there is a risk of pipeline collapse due to the formation of a negative pressure. The following equation finds the external collapse pressure of thin wall steel pipe using a safety factor of 4. A safety factor of 4 is recommended to take into account variances in pipe construction, variances in bury conditions, and possible dynamic loads.

$$P = 16{,}250{,}000 * (T / D)^3 \quad (6)$$

where:

P = Collapse Pressure, psi.
T = Pipe Thickness, in.
D = Pipe Diameter, in.

Collapse may also be a concern on large diameter plastic or ductile iron pipe. The pipe manufacturer should be consulted to provide maximum external collapse pressures.

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The air valve should be capable of admitting the flow due to slope without exceeding the lower of the calculated pipe collapse pressure or 5 PSI (35 kPa). 5 PSI (35 kPa) is used for sizing to remain safely below the limiting sonic pressure drop of 7 PSI (48 kPa). Manufacturers provide capacity curves for their valves which can be used to select the proper size. The capacity of an Air/Vacuum Valve can be estimated using:

$$q = 678 * Y * d^2 * C * [DP * P1 / (T1 * Sg)]^{1/2} \quad (5)$$

where:

q = Air Flow, SCFM
Y = Expansion Factor
.79 (for vacuum sizing)
.85 (for exhaust sizing at 5 psi)
.93 (for exhaust sizing at 2 psi)
d = Valve Diameter, in
DP = Delta Pressure, psi
The lower of 5 psi or pipe collapse pressure (for vacuum sizing)
2 or 5 psi (for exhaust sizing)

P1 = Inlet Pressure, psia
14.7 (for vacuum sizing)
16.7 or 19.7 psia (for exhaust sizing at 2 or 5 psi)
T1 = Inlet Temperature = 520 Rankine
Sg = Specific Gravity = 1 for air
C = Discharge Coefficient = .6 for square edge orifice

The air valve should also be sized for exhausting air during filling of the system. The flow rate used for venting should be the fill rate of the system. The fill rate may be the flow rate from a single pump in a multiple pump system. If there is only one pump in the system, then special filling provisions should be taken such as the use of a smaller pump for filling or the ability to throttle the flow from the pump to achieve a fill rate in the range of 1 to 2 ft/sec (0.3 to 0.6 M/sec). Higher fill rates may cause surges in the line and Slow-Closing Devices should be used to reduce the surges within Air/Vacuum or Combination Valves.

If a fill rate is not given, the Air/Vacuum Valve will be sized for the design flow rate which may cause the valve to be oversized. Every effort should be made to establish a reasonable system fill rate. The differential pressure used for sizing the Air/Vacuum Valve varies. 2 PSI (14 kPa) will be used in most cases. When the valve is equipped with a Slow-Closing Device, the differential pressure may be as high as 5 PSI (35 kPa). Higher differentials are not used because the possibility of water reaching the Air/Vacuum Valve with excessive fluid velocities and to eliminate the noise associated with sonic velocities.

The final Air/Vacuum Valve size must have a capacity greater than both the required exhausting and admitting requirements.

AIR RELEASE VALVE SIZING

The capacity of releasing air under line pressure through an Air Release Valve can be estimated by using the Air/Vacuum Valve formula except P1 will equal the operating pressure in the line. The differential pressure (DP) is limited by sonic velocity to about 0.47 * P1. The corresponding expansion factor (Y) is 0.71.

$$q = 330.7 * d^2 * C * P1 / (T1 * Sg)^{1/2}$$

where:

q = Air Flow, SCFM
d = Orifice Diameter, in
P1 = Pipeline Pressure, psia
T1 = Inlet Temperature = 520 R
Sg = Specific Gravity = 1 for air
C = Discharge Coefficient = .6 for square edge orifice

It is difficult to determine in advance the amount of entrapped air which must be released from a given system. Based on water containing 2% air (7), the maximum flow rate can be used to compute a nominal venting capacity.

$$q = Q * (0.13 \text{ cu ft/gal}) * .02$$

where:

q = Air Flow, SCFM
Q = System Flow Rate, GPM

In most cases, the size of the Air Release Valve is a judgment decision based on experience. The 2% air content can be varied depending on the potential for entrained air. The Air Release Valve inlet connection should be as large as possible to maximize the exchange of air and water in the valve. A helpful chart based on industry experience with average installations is shown below:

AIR RELEASE VALVE ORIFICE CAPACITIES

Max. Pipe Size	Maximum Pump Capacity GPM	Valve Series No.	System Pressure					
			1 to 50 PSI		1 to 150 PSI		1 to 300 PSI	
			Orifice Size	Capacity in CFM	Orifice Size	Capacity in CFM	Orifice Size	Capacity in CFM
6	800	15A	N/A	N/A	1/16	6	N/A	N/A
10	2,200	22	N/A	N/A	3/32	14	1/16	12
16	5,200	25	N/A	N/A	1/8	24	5/64	18
48	50,000	38	5/16	58	3/16	54	3/32	26
96	150,000	45	1/2	149	3/8	220	7/32	143

SUMMARY

When air is allowed to accumulate in pressurized pipelines, efficiency is sacrificed and serious damage can occur. Removal of air from a pipeline will not solve all surge and efficiency problems. However, the elimination of air can solve one of the most common causes of these problems.

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White Paper

Air Valves for Vertical Pump Applications

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INTRODUCTION

The purpose of this white paper is to provide guidance on specifying and installing Air/Vacuum Valves for vertical pumps. A vertical turbine or deep well pump (Figure 1), lifts water from a water reservoir or well into a pipeline. When the pump is off, the water level in the pump column is below the pump discharge pipe and the pump column refills with air after each pump stoppage.

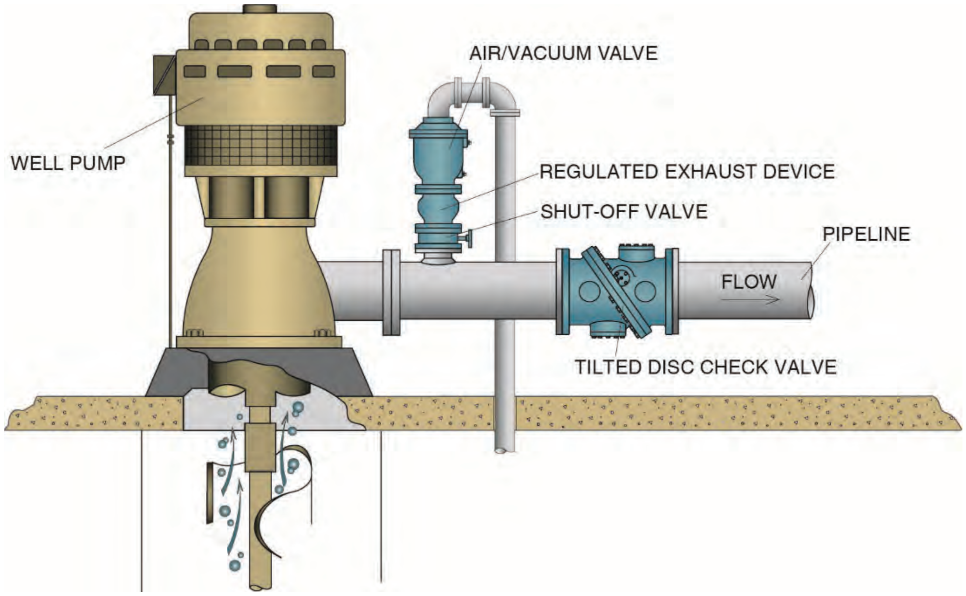

FIGURE 1. Vertical Pump with Well Service Air Valve

Air valves play an important roll in automatically venting air and controlling surges in pump columns. Air/Vacuum valves with optional devices are designed to slowly exhaust air on pump start-up and rapidly admit air upon pump shut down. Smaller Air/Vacuum Valves are equipped with Dual Port Throttling Devices on ½ to 3 inch sizes (Figure 2) and Regulated-Exhaust Devices on 4 inch and larger sizes (Figure 3). The Air/Vacuum Valve is normally-open and float-operated to automatically vent or admit air at high rates.

When water enters the air valve, the float automatically rises and closes to prevent discharge of the water. The requirements for Air Valves are described in American Water Works Standard AWWA C512. AWWA Air/Vacuum Valves have a large orifice equal to the inlet size for discharging air in large volumes at low pressures, typically 2 psi.

To properly select Air/Vacuum Valves for pump discharge, some fundamentals of surge control and entrapped air must first be understood.

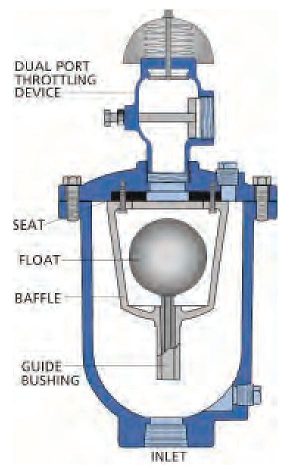

FIGURE 2. 1 in.-3 in. Air Valve

SURGES

Surges (or water hammer) result from sudden changes in flow velocity. The effects of surges can be devastating because the magnitude of surges are approximately 100ft (43 psi) for every 1 ft/sec change in flow velocity. And, the surge pressure is additive to the static pressure in the pipe.

For example, if a flow of 8 ft/sec is suddenly stopped in a pipe, a surge pressure as high as 350 psi above the static pressure may be produced. Hence, pumping systems are carefully designed with consideration to the starting and stopping sequences of the pumps.

Many pumps are furnished with variable frequency motor starters that ramp up and ramp down the speed of the pump so that the fluid velocity changes more slowly. Nevertheless, pumps starting with an air-filled pump column provide rapid flow initially and the discharge of the air in the pump column should be regulated, yet fully vented before the check valve opens.

ENTRAPPED AIR

For a pumping system to operate efficiently, any free air in the pipeline must be automatically removed. If air collects at the high points, a restriction occurs, which will cause headloss and potentially lead to surges when the pocket of air moves from one location to another. The combination of air and water will also accelerate corrosion of the pipe wall.

Air pockets can also move along the pipeline and pass through partially open valves causing sudden changes in the water velocity and surges. For example, if air is rapidly discharged from a hydrant, the high velocity water will be suddenly slowed because water is 200 times more dense than the air and cannot pass as quickly through the hydrant.

Finally, air that reaches the end of the main will disturb the water systems of the end user.

VERTICAL PUMPS

Vertical pumps have air-filled discharge columns when not running. For example, a well pump is typically submerged several hundred feet and isolated from the pipeline by a check valve mounted at ground level. When the pump is off, the water level drops to the normal water level in the well and a large column of air collects in the pump column (Figure 1).

Air is always present in the column of a vertical turbine pump installed over a wet well. If the vertical turbine pump is started without an air valve, the air in the pump column would be pressurized and forced through the check valve into the pipeline causing air related problems. All vertical pumps should have an air valve installed just upstream of the check valve.

AIR/VACUUM VALVE OPERATION

Air/Vacuum Valves are mounted on the pump discharge pipe upstream of the check valve and are designed to vent the air before the check valve is pushed open by the pump pressure. When the pump stops, the air/vacuum valve will reopen and admit air into the pump column to prevent the formation of a vacuum as the water column drains. When the valve is closed, the float is held upward tight against the resilient seat. The seat is contained in a precision register in the valve cover and held in place with a baffle assembly, which also guides the float.

Pump service is a severe application for air valves because when the pump is started, it runs for the first few seconds against little or no head. Hence, the actual flow rate is often as high as 150% of the normal flow rate while the air is being vented. Also, because of the high dynamics involved, the air discharge can reach sonic velocities and water may bypass the rapidly closing air valve. Therefore, the valve outlet should be piped back to the wet well or an open drain.

Not only is the flow high, but there is a moment of time when the last of the air is vented and the water reaches the air valve with virtually no place to go. The water column can crash into the closing air valve and the closed check valve disc. If the water velocity striking the closed check valve is high, high surges may occur in the pump column and discharge pipe.

Therefore, Throttling Devices (Figure 4) are provided to control the rate of air release. Surges in the pump column can also be minimized by using soft-start pump motor controls.

REGULATED-EXHAUST DEVICES

The purpose of a Regulated-Exhaust Device is to protect large Air/Vacuum Valves and the pump column from pressure surges while allowing the valve to vent air. It is mounted on the inlet of the valve as shown in Figure 3. When high airflow reaches the Regulated-Exhaust Device, a restrictor disc closes quickly controlling the rate at which the air is exhausted. The restrictor disc contains ports, which allow the water to flow through the disc when closed to fill the air valve with water at a controlled rate. The flow area of the ports is typically about 5% of the full port area and is adjustable.

When the pump is stopped, the Air/Vacuum Valve and Regulated-Exhaust Device provide full-ported reverse airflow to prevent a vacuum from forming in the pump column as the water level drops. A vacuum can damage the seals in the pump or cause pump damage if it is restarted while the water is still dropping in the well.

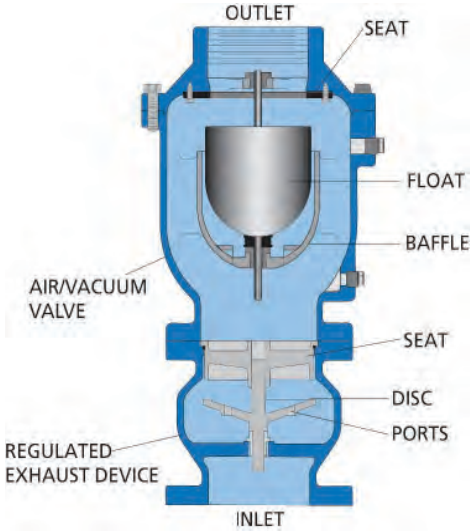

FIGURE 3. 4 in. Air Valve

If additional cushion is needed for the rising water column, then one of the ports should be plugged until the surge in the pump column is reduced. Regulated-Exhaust Devices are standard on 4 in. and larger valves and optional on smaller valves.

DUAL PORT THROTTLING DEVICES

The purpose of the Throttling Device is to slow the release of air and thereby slow the rise of water in the pump column and provide an air cushion. Dual Port Throttling Devices are standard on Air/Vacuum Valves sizes 1/2 to 3 inch for vertical pump applications.

A Throttling Device has an exhaust disc, which is typically adjusted between 5% and 30% open to control the venting rate. The valve needs to be set in the field and tuned to the operation of the pump. The Throttling Device should be opened just enough so that all of the air is discharged before the check valve opens. Opening the throttling device further will increase the pressure surge in the pump column.

The Throttling Device also allows air to re-enter the pump column when the pump is stopped to prevent a vacuum. A vacuum can damage the seals in the pump or cause pump damage if it is restarted while the water is still dropping in the well. To provide positive assurance against a vacuum, a Dual-Port Throttling Device is needed where the vacuum port is separate from the exhaust port. If there is a common outlet, then the vacuum flow will be greatly restricted through the air discharge pipe.

The discharge of vertical pump air valves are piped to drains and can be a source of cross connection. A Dual-Port Throttling Device reduces any potential for contaminated water being drawn into the system by vacuum during pump shut down. The separate hooded port allows entry of atmospheric air instead of suction from the discharge pipe.

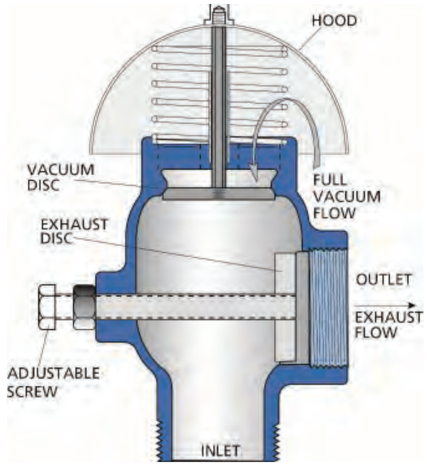

FIGURE 4. Dual-Port Throttling Device

APPLICATION CRITERIA

The general operating parameters for the vertical pump air valves are summarized in the table below. A comprehensive presentation of features and dimensions is presented in Val-Matic Air Valve Bulletin 1500.

Standard Operating Parameters Valve Series 100ST-112FSS	
Parameter	**Typical Range of Use**
Size Range	1/2 in. – 12 in.
CWP Ratings	150 and 300 psig
Max Temp	250F
Orientation	Vertical
Connection	½ to 3 in., NPT 4-12 in., Flanged

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SIZING PUMP SERVICE AIR VALVES

Traditionally, valves used for vertical pump service applications were sized very conservatively at a differential pressure of 0.5 psi so that the water velocity entering the valve was not excessive. When using a Dual Port Throttling Device or Regulated-Exhaust Device, a differential pressure of 2 psi is used as shown in the table below.

Air Valve Sizing For Pump Service			
Size (in.)	**Pump GPM (at 0 head)**	**150 PSI Model No.**	**300 PSI Model No.**
½	0-350	100ST	
1	351-1350	101ST	
2	1351-4000	102ST	
3	4001-7000	103ST	
4	7001-11,000	104SS	154SS
6	11,001-24,000	106SS	156SS
8	24,001-50,000	108SS	158SS
10	50,001-70,000	110FSS	160FSS
12	70,001-110,000	112FSS	162FSS

(T = Throttling Device, SS = Reg-Exhaust Device)

INSTALLATION GUIDELINES

General recommendations for Pump Service Air Valves are based on the following parameters:

1. **Type of Pump:** All Vertical pumps require Air/Vacuum Valves or air will be forced into the pipeline (Figure 1).

2. **Type of Check Valve:** Mechanical check valves such as Silent Check, Swing-Flex® or Tilted-Disc® Check Valves require an Air/Vacuum Valve. Power actuated check valves such as a control valve or butterfly valve may use either an Air/Vacuum Valve or an Air Release Valve with delayed opening.

3. **Sizing Pressure:** Vertical Pump Service Air/Vacuum Valves are sized using the pump no-load flow rate and a differential pressure of 2 psi.

4. **Piping:** Vertical Pump Air Valves should be piped to the top of the discharge pipe with an isolation valve. The pump discharge pipe should slope back to the well so that there is not water in the pipe when the pump starts or the air valve may close prematurely. The outlet of the air valve should be piped back to the wet well or to an open drain with an air gap.

5. **Below-Ground Discharge Pumps:** When the pump discharge elbow is several feet below the discharge head and the bearing is lubricated by the media, an Air Release Valve is needed on the top of the pump column as shown below. Otherwise, the water may not reach the top bearing and packing of the pump (Figure 5). Alternatively, the pump bearing can be lubricated with an external water source.

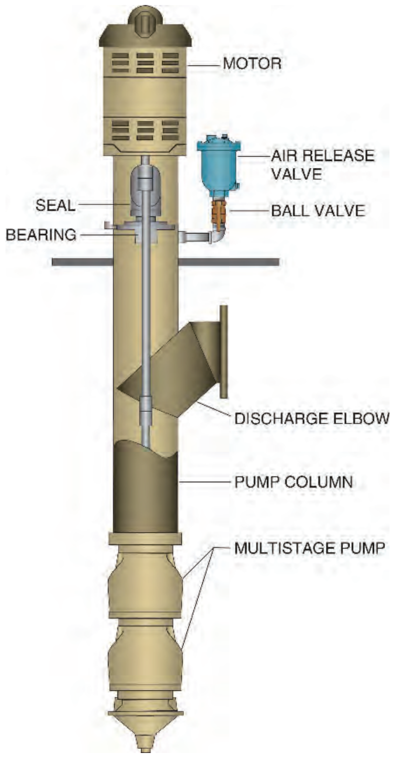

FIGURE 5. Vertical Pump with Below-Ground Discharge

Disclaimer

Val-Matic White Papers are written to train and assist design engineers in the understanding of valves and fluid systems. Val-Matic offers no warranty or representation as to design information and methodologies in these papers. Use of this material should be made under the direction of trained engineers exercising independent judgement.

White Paper

Air Valves for Fire Protection

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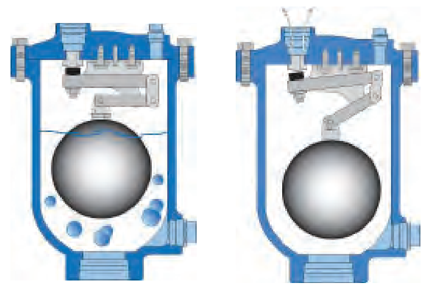
INTRODUCTION

Water systems used for fire protection in commercial buildings require release and admission of air for proper operation. Before their use, pumps, pipes, and sprinkler systems are filled with air, which must be automatically released during filling and operation. Conversely, when fire protection systems are drained, air must be admitted to allow proper drainage.

Air valves are automatic, float-operated, and in the installed condition, “normally open” to allow air in and out of the piping system. When water enters the air valve, the float rises, which closes the outlet orifice of the valve and prevents the discharge of water. Air valves for fire protection are typically constructed of cast iron with stainless steel trim and resilient seals. There are three basic types of automatic air valves used to control the flow of air in and out of fire protection systems: air release, air/vacuum, and combination. The proper selection, sizing, and installation of automatic air valves are essential in safeguarding life and property from fire.

AIR RELEASE VALVES

Air release valves are probably the most widely used type of air valve and are characterized by their small orifices, weighted floats, and leverage mechanisms. The combination of these three features allow air release valves to expel air or gas at full operating pressure of the system. Air release valves automatically vent small pockets of accumulated air during startup and as they accumulate in fire protection systems.



Closed Position　Open Position

FIGURE 1. Operation of Air Release Air Valve

Air Release Valves with a ½ in. NPT pipe connection and a 1/16 in. minimum orifice size are installed on the top of centrifugal pumps to release air from the top of the casing thereby improving efficiency and preventing pump cavitation, See Figure 2. Air release valves are also installed on wet pipe sprinkler system branch lines to allow filling of the lines with water.

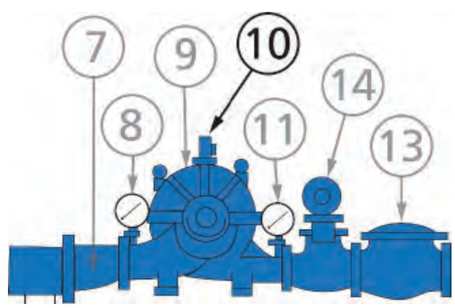
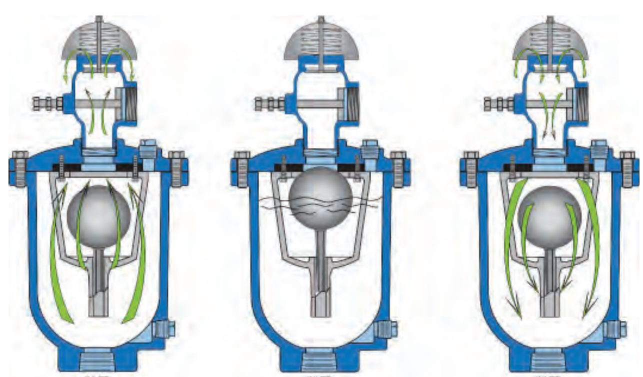


FIGURE 2. Installation of an Air Release Valve (10) on a split-case fire pump (9) (NFPA 20)

AIR/VACUUM VALVES

The second type of air valve is the air/vacuum valve, which has a large, full-size orifice ranging from 1/2 in. to 20 in. and as a result, can exhaust large volumes of air during filling. The valve will also admit large volumes of air to prevent a vacuum condition from occurring in the piping system during draining or after pump shut down. As shown in Figure 3, air/vacuum valves are normally open and a float in the valve automatically rises with the water level to seal the large orifice after the air has been exhausted. While the pipe is under pressure, the valve remains closed. Conversely, upon the loss of system pressure due to pump shut off or draining, the float will drop and allow air to re-enter the pipeline.

The rate of exhaust is controlled with an adjustable throttling device mounted on the top of the air valve. Since the pump can reach full speed in a few seconds, the throttling device is used to slow down the exhaust of air to prevent the water from rising too fast and slamming into the downstream check valve and causing a water hammer in the pump column.



Open Air Exhausted During Filling　Closed Pipe Under Pressure　Open Air Enters During Draining

FIGURE 3. Operation of an Air/Vacuum Valve

1-1/2 in. NPT or larger air/vacuum valves are installed on the discharge of vertical turbine pumps before the check valve to vent the air from the pump column during the starting of the pump and to admit air into the column to dissipate the vacuum upon stopping the pump, see Figure 4.

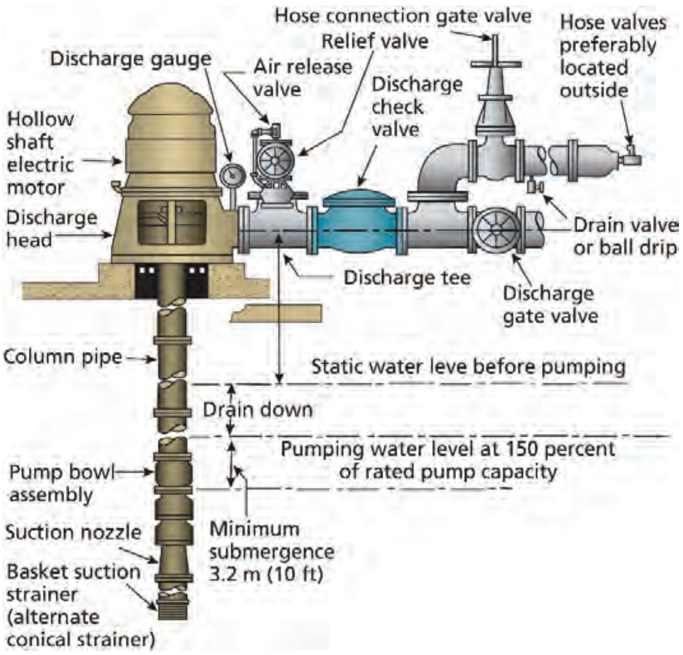


FIGURE 4. Installation of an Air/Vacuum Valve on a vertical turbine pump (NFPA 20)

COMBINATION AIR VALVES

It is important to note that under normal operation, the air/vacuum valve float is held closed by the line pressure and will not relieve accumulated air. Air/vacuum valves do not have mechanical linkage and because of the large diameter orifice, have no ability to open while the system is pressurized. Therefore, an air release valve is also needed to relieve air and gas during system operation. A combination air valve combines the functions of the air release and air/vacuum valves in one body.

Combination air valves equipped with throttling devices are intended for use in dry standpipe and similar applications where the (1) release of large volumes of air in a controlled manner is needed, (2) continuous release of air within the system is needed while the system is pressurized and (3) admission of air into the system is needed to minimize the development of vacuum conditions when the system is shutdown.

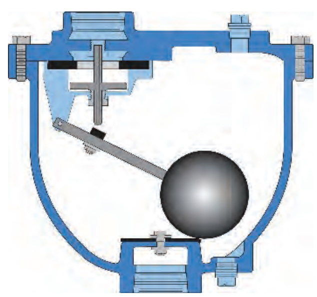


FIGURE 5. Construction of a Combination Air Valve

SAFETY REQUIREMENTS FOR AIR VALVES

Air valves for fire protection service are independently, tested and certified by Underwriters Laboratories (UL) in accordance with UL Subject 2573 and by Factory Mutual (FM) in accordance with Approval Standard FM 1344. These standards provide the testing and qualification requirements for fire protection air valves.

Requirements for installation of air valves in sprinkler systems are included in the Standard for the Installation of Sprinkler Systems, NFPA 13. Requirements for installation of air valves on fire pumps are included in the Standard for the Installation of Stationary Pumps for Fire Protection, NFPA 20. Requirements for the installation of dry standpipe systems are included in standards such as the Standards for the Installation of Standpipe and Hose Systems, NFPA 14.

WHY VAL-MATIC® AIR VALVES

There are few valve applications as critical as fire protection. Quality and dependability must be at the forefront when choosing components for a fire protection system. All Val-Matic® Air Valves are supplied standard with Type 316 Stainless Steel Trim. All Val-Matic® Air/Vacuum Valve floats are center guided to assure drop tight shut-off. All Val-Matic® Air Release and Air/Vacuum Valves are Underwriters Laboratories (U.L.) Listed. In fact, Val-Matic® is the only approved valve for vertical turbine pump applications. In addition to U.L. approval, Val-Matic® Air Release Valves are also Factory Mutual (F.M.) approved. Contact U.L. or F.M. for current listing information.

In addition to U.L. and F.M., Val-Matic® Air Valves fully comply with AWWA Standard C512 for Air Release and Air/Vacuum Valves.

AIR RELEASE AIR VALVES FOR SPLIT CASE FIRE PUMPS

Air Release Air Valves for use with split case fire pumps					
Rated Capacity GPM	Rated Pressure PSIG	Inlet Size NPT, In.	Orifice Size In.	Outlet Size NPT, In.	Val-Matic• Model No.
800	175	½	1/16	½	15A
800	175	¾	1/16	½	15A.2
800	175	1	1/16	½	15A.3
2200	175	½, ¾	3/32	½	22.4
2200	175	1	3/32	½	22.3
2200	300	½	1/16	½	22.7
2200	300	½, ¾, 1	1/16	½	22.9

Well Service Air Valves for use with vertical shaft turbine fire pumps.					
Rated Capacity GPM	Rated Pressure PSIG	Inlet Size NPT, In.	Orifice Size In.	Outlet Size NPT, In.	Val-Matic• Model No.
1350	300	1	1	1	101ST
4000	300	2	2	2	102ST
7000	300	3	3	3	103ST

Also available from Val-Matic® for Fire Protection Systems: Dual Disc® and Silent Check Valves

White Paper

Protecting Drinking Water Pipelines with Inflow Prevention

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FORWARD

Protecting Drinking Water Pipelines with Inflow Prevention was written to assist water distribution system design engineers in reducing the risk to public health from contaminated drinking water by understanding the use of inflow preventer assemblies in water distribution systems. This paper is not intended to provide all of the information necessary for specifying these devices, but rather to explain their function and performance criteria along with common engineering parameters associated with the application of air valves and cross connection control devices. Successful system design should consider the functions of the air valves and vents together with the need to protect the system from contamination and loss of efficiency.

With this knowledge, the design engineer can better apply American Water Works Standard C514 and American Society of Sanitary Engineering (ASSE) Standard 1063 Inflow Preventers and understand the application, sizing, installation guidelines and code applications that affect their use. The rating information provided is based on generally accepted products and standards which offer valuable information for predicting performance.

INTRODUCTION

A significant risk to public health exists when a drinking water distribution system is exposed to the inflow of contaminated water or toxins at air valve locations along the drinking water pipeline. While public drinking water systems are routinely protected from contamination at the points of service with backflow prevention devices, little attention has been paid to air valve and vent inflow locations in water pipeline vaults located throughout distribution systems.

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In order to maintain system design efficiencies and provide protection from transients, water pipelines and distribution systems require the installation of air valves at high points and regular intervals (i.e. every half mile) to exhaust and admit air during system operations including filling, draining, and critical conditions such as surges or line breaks. The risk of contamination cannot be mitigated by eliminating the valves. The function of air valves is critical to the safe and efficient operation of the water system.

Air valves are produced in accordance with the AWWA Standard C512, "Air Release, Air/Vacuum, and Combination Air Valves for Waterworks Service" and should be certified for use in drinking water systems in accordance with NSF/ANSI 61, "Drinking Water System Components – Health Effects." AWWA also publishes Manual M51 to provide guidelines for the use and installation of air valves including the design rule that air valves should be installed as close to the pipe as possible. AWWA advises that long interconnecting piping to the air valve should be avoided when possible and the piping shall be larger than the valve to accommodate the required flow of air, hence, most water pipelines have many planned openings for air release and air entry that can also allow the entry of contaminated water or harmful chemicals. Figure 1 shows a flooded valve vault and the same vault shortly thereafter where contaminated water was drawn into the pipeline due to a negative pressure transient in the pipeline.

FIGURE 1. Submerged Air Valve Vault (LeChevallier)

In colder climates and urban areas, water pipelines are typically buried and the air valves are installed in valve vaults below ground level as shown in Figure 2. If the vault becomes flooded and a vacuum occurs in the pipeline due to a power outage or negative pressure transient, the contaminated floodwater will be pulled into the water pipeline through the air valve [LeChevallier]. Moreover, valve vaults are rarely monitored and the contamination may go totally undetected.

The risk to public health is high so the EPA conducted studies and research on aspects of the distribution system that may create risks to public health. The EPA has published several white papers summarizing the work in this area. In fact, the 2001 EPA study on "Assessing and Reducing Risks" identified one of the causes of loss of physical integrity to be "appurtenances in a flooded meter or valve pit."

Until such time as federal guidelines are published, some waterworks regulations require the outlet of the air valve to be connected to a vent pipe that extends above grade and above the expected flood level [Great Lakes, 8.5.2] (Figure 3). Unfortunately, this type of vent pipe subjects the air valve and pipeline to freezing temperatures and external malicious tampering. Vent pipes inadvertently provide a vulnerable direct connection between public areas and the buried potable water line setting up a potential threat. A hazardous substance or toxin can be intentionally introduced into the vent pipe and when the air valve admits air, the contaminant will be drawn directly into the water pipeline. Given requirements from Homeland Security, potential threats such as these must be identified and mitigated. Finally, many water pipelines run under streets or in dense urban areas where such risers cannot be conveniently located adjacent to the pipeline.

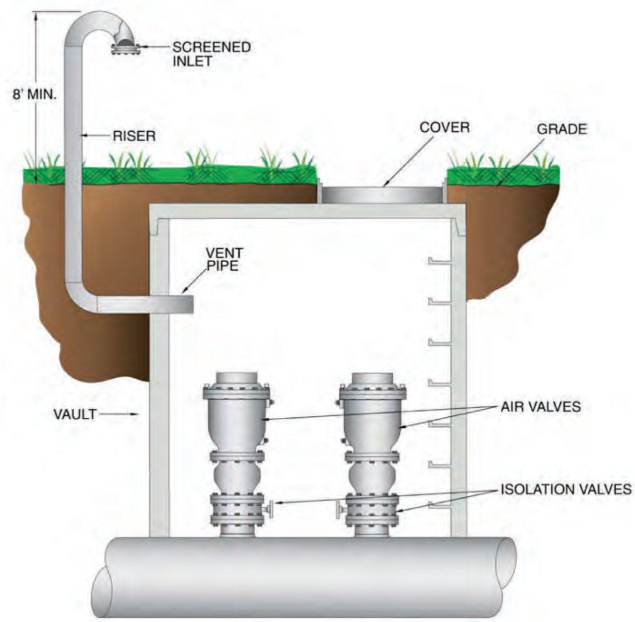

FIGURE 2. Typical Air Valve Vault Design

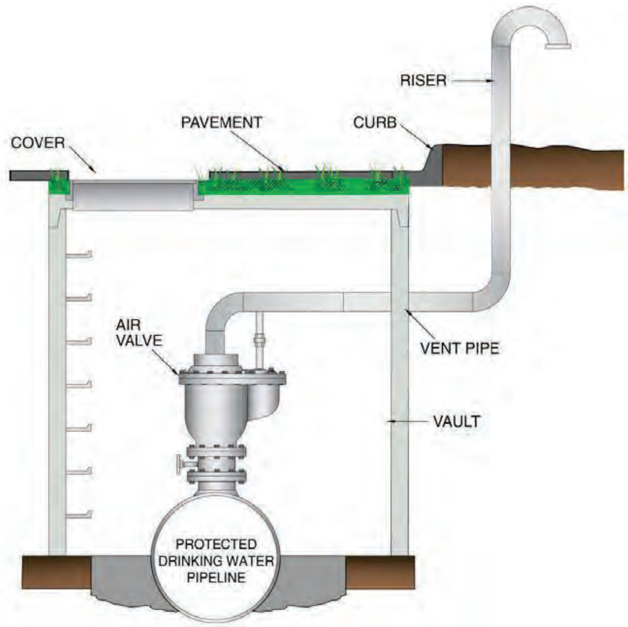

FIGURE 3. Vent Pipe Connected to the Air Valve

HISTORY OF THE INFLOW PREVENTER

As a prominent supplier of air valves for the water industry, Val-Matic Valve & Mfg. Corp. was asked by various utilities and consulting engineers to offer a solution that would avoid the use of air valve vent pipes, enhance the security of drinking water systems, and properly protect the system from contaminated floodwater and malicious sabotage. In collaboration with some water utilities and water system engineering consultants, Val-Matic developed the Inflow Preventer in 1997. An Inflow Preventer as shown in Figure 4 is a mechanical device mounted on the outlet of an air valve or vent pipe to allow normal flow of air in and out of the water system and prevent inflow of contaminated water into a water system as a result of flooding or malicious tampering.

FIGURE 4. Typical ASSE 1063 Inflow Preventer Installation

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When floodwater enters the bottom of the device, it raises the floats, which in turn, seal tightly against sensitive resilient seats with integral O-ring type sealing surfaces. The device has redundant sealing chambers for added reliability. Even with the vault flooded and the device closed, the air valve and device can still release air from the pipeline to maintain pipeline efficiency. However, when a vacuum occurs in the pipeline, floodwater will not be allowed to enter the pipeline so the vacuum protection feature of the air valve will be temporarily lost. If vacuum protection is critical to the structural integrity of the pipe, then an alternate scheme such as a closed surge tank should be considered.

Val-Matic worked with the American Society of Sanitary Engineering (ASSE) and requested that they develop a product standard for inflow preventers since ASSE publishes standards on many cross-connection devices. ASSE initiated the ANSI Product Identification Notification System (PINS) process and was granted the right to develop a consensus standard for the Inflow Preventer. An ASSE 1063 Working group was established in 2005 and a standard was promulgated in accordance with procedures developed by the American National Standards Institute (ANSI), ASSE Standard #1063-2008, "Air Valve and Vent Inflow Preventer." The ASSE Cross Connection Committee later reviewed and added the assembly to their Series 5000 Qualification Program and the field test instructions are now published in the 2015 edition of this Standard. This will enable certified maintenance and test personnel around the country to be trained and certified by ASSE to test these devices in the field.

In 2012, the American Water Works Association (AWWA) formed a subcommittee to write a congruent standard AWWA/ANSI C514, "Air Valve and Vent Inflow Preventer Assemblies for Potable Water Distribution Systems and Storage Facilities." The standard was published in 2015 for the water distribution industry. The Inflow Preventer was also added to American Water Works Association, AWWA M51, "Manual of Water Supply Practices, Air-Release, Air/Vacuum, and Combination Air Valves," in 2016 as a possible solution for flooded air valve vaults. During the development of these standards, production devices underwent an extensive testing program at a third-party independent test laboratory, Wyle Laboratories in Huntsville, Alabama. Wyle conducted tests in accordance with the ASSE standard to verify the performance test methodologies. Val-Matic submitted the test reports to ASSE and applied for and received ASSE Certification for the FloodSafe Inflow Preventer. In subsequent years, Val-Matic has provided hundreds of these devices in many water districts in the USA and Canada.

APPLICABLE REQUIREMENTS

ASSE Standard #1063-2008 provides the product requirements for Inflow Preventers including:

a) The purpose of the assembly is to exhaust and admit air but prevent the entry of contaminated water when the outlet of the air valve becomes submerged or is the target of malicious tampering.
b) The assembly shall have an outlet basket, redundant check devices, and the ability to be field tested.
c) The assembly shall be installed as prescribed and periodically tested, at least annually.

The California Department of Public Health (DHS) publishes requirements to protect air valves from flooding in Section 64576 of the Revised Waterworks Standards, "Each new air release, air/vacuum, or combination valve, and any such valve installed to replace an existing valve shall be installed such that its vent opening is above grade, above the calculated 100-year floodwater level, and, if recorded data are available, above the highest recorded water level." In 2008, Foster City, California filed a permit to install new air valves on their three-mile long, 24-inch diameter drinking water supply pipeline and included the use of inflow preventers because the pipeline and air valve vaults were beneath city streets thereby preventing the installation of air valve riser pipes (Figure 5).

FIGURE 5. Water Pipeline in Foster City, CA

The DHS approved the permit provided that the city conduct regular inspections and testing of the inflow preventers by certified technicians. In the permit dated December 10, 2008, the DHS stated that "The California Department of Public Health has evaluated the application and the supporting material and has determined that the alternate design and monitoring program proposed by the water system comply with Section 64576 of the California Waterworks Standards for Capital Improvement Project No. 760 will provide at least the same level of protection to public health." Since the installation, the City has conducted regular inspections and testing in all seven locations along the pipeline. A typical installation is shown in Figure 6 with the vault cover removed exposing the air valve equipment. The successful Inflow Preventer installation in Foster City, California demonstrates the benefits of the device in municipal water systems. The Inflow Preventer solves a defined problem by protecting the city drinking water system from contamination by floodwater and malicious tampering.

FIGURE 6. Air Valve Vault, Foster City, CA

According to AWWA M51 practices, a valve vault can be equipped with an inflow preventer per AWWA C514 to prevent contamination from flooding as shown in Figure 7. The vent pipe provides for regular air flow but is equipped with dampers to prevent the convection of cold air. When required by the water system, the dampers open fully to allow airflow in both directions. If the vault is subject to flooding, then the inflow preventer can be installed on the valve outlet as shown. The inflow preventer is normally open and allows normal air flow in and out of the water system and prevents the inflow of contaminated water into a drinking water system as a result of flooding.

PRODUCT APPLICATION AND PERFORMANCE

Inflow preventers are available in nominal sizes 1 inch to 4 inch threaded connections and 6 inch to 12 inch flanged connections with a maximum working pressure of 25 psig. The pressure rating of the device does not need to equal the pipeline rating because the device is "normally open" and cannot be pressurized by the pipeline. The only pressure that the device is subjected to is that pressure from the floodwater elevation which should not exceed 50 feet (22 psig). The size of the inflow preventer is selected to match the nominal size of the air valve or based on flow rates if that data is available.

The inflow preventer is piped to the outlet of the air valve or system vent pipe in the vertical position and will admit and vent air out its screened bottom. The device can be mounted adjacent to the air valve or several feet away on the side of the vault. The device is available with a side bracket for wall mounting on larger vaults.

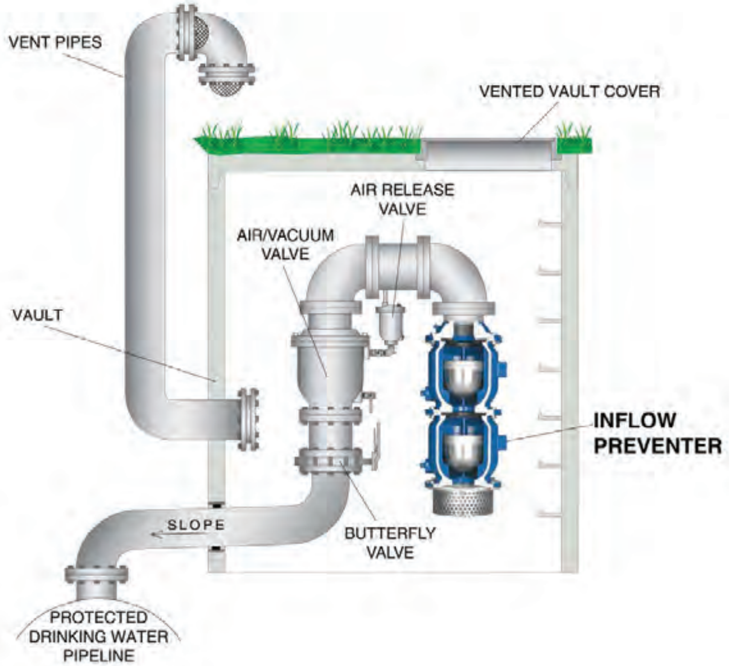

FIGURE 7. Suggested AWWA Design for Vaults Subject to Flooding

The installed inflow preventer should be initially tested by a certified tester and periodically tested thereafter as recommended by the local authority having jurisdiction but at least annually. According to the ASSE standard, the inflow preventer must seal drop tight with submergences as low as 12 in. water column. The device is equipped with test cocks for regular field testing in accordance with ASSE 5000 and as shown in Figure 8. Testing consists of removing the bottom screen, installing a test plug in the bottom of the unit, and applying a 12 inch water column to each chamber independently to verify that there is no leakage. See the online video for a demonstration of the testing protocol, YouTube: Making Your System Safe with the Val-Matic FloodSafe."

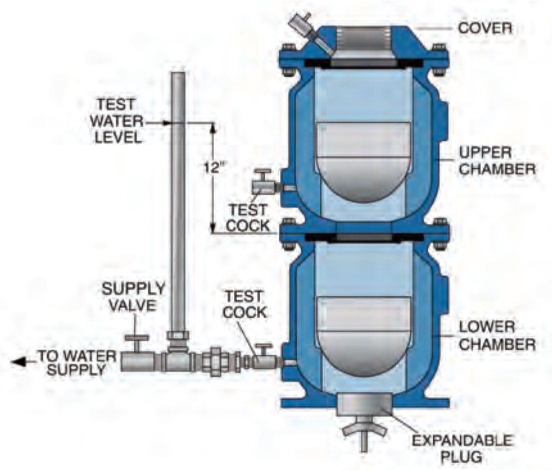

FIGURE 8. Inflow Preventer Field Test Diagram

CONCLUSION

Given the heightened demand for security and safe drinking water, inflow prevention is important because air valves and reservoir vents are vulnerable to flood contamination as well as malicious tampering. The use of vent pipes can worsen the problem by allowing cold air to enter the air valve and potentially make it inoperable due to freezing and directly exposing the pipeline to the outside and malicious tampering. AWWA C514 Inflow preventers can be applied to new or existing air valves and reservoir vents to substantially mitigate these threats.

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White Paper

Design and Selection of Check Valves

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INTRODUCTION

FIGURE 1. Typical Pumping System with Swing Check Valves

An essential element in the design of water and wastewater pumping systems is the proper selection of the pump discharge check valve, whose purpose is to automatically open to allow forward flow and automatically return to the closed position to prevent reverse flow when the pump is not in operation. Another function that is often overlooked is the valve's ability to minimize energy consumption. Patton estimated that water and wastewater plants in the United States consume 75 billion kW·h of energy annually and nearly 80% of that energy is consumed for high service pumping costs to overcome the static head and friction losses. But just as important, the valve should protect the pumping system and piping from pressure surges caused by sudden closure. Every pump station designer has witnessed check valve slam, which is caused by the sudden stoppage of reverse flow through a closing check valve. To prevent slam, an automatic check valve must either close very quickly or close slowly by using oil dashpot devices.

Three general categories of check valves will be presented in detail. First, Lift Check Valves such as the fast-closing silent and nozzle check valves, have spring-loaded discs, which move along the pipe axis over a short distance to close automatically in a fraction of a second. Because of their fast closure, these check valves rarely slam and hence have earned the name "silent". The second category of check valve is the Swing Check Valve such as the traditional swing check valve, which has a flat disc that pivots or swings about a hinge pin. Traditional swing check valves are by far the most common, can be equipped with various accessories such as a lever and weight, and unfortunately may be the most likely to slam. Lastly, Dashpot-Assisted Check Valves have controlled closure to control the changes in pipeline fluid velocity over a long period of time (i.e. 5 to 30 seconds) to help prevent surges in distribution systems. These three categories of check valves, Lift, Swing, and Dashpot-Assisted are each designed with unique features for specific applications and each contribute differently to the system response and costs. There is no "universal" check valve for all applications.

Even when all of the various categories and types of check valves are understood, it is still difficult to make a rational decision about which type of check valve is best for a given application. Buying a check valve is similar to buying a car. There are many to choose from because every model is designed to meet different needs. The best car is not necessarily the fastest one. You may be looking for compactness, high performance, low cost, or advanced features; whatever the case, just as there is a car that best meets your requirements, there will similarly be a check valve that best meets your requirements. This paper will therefore describe the various types of check valves and discuss the common selection criteria such as cost and fluid compatibility, which can be used to narrow down the field of selection. Finally, the check valves will be rated on every criteria so that a methodical decision process can be used to identify the best valve solution to meet a given application.

LIFT CHECK VALVES

Lift Check Valves are simple, automatic, and cost effective but can result in high energy costs in the long run. Examples of lift checks include nozzle check, silent check, and ball check valves. These valves have no external moving parts and can be economical to produce and reliable in operation. Unfortunately, they do not provide indication as to whether they are open or closed, which may be an important feature in a pumping system.

Silent Check Valves are commonly used in high-rise buildings and high head applications because of their quiet closure. They consist of a threaded, wafer, or flanged body; a corrosion resistant seat; and a disc with integral stems.

When the flow is initiated, the disc is pushed to the right to allow forward flow. When the pump is stopped, the compression spring in the valve forces the valve closed before the flow reverses, which provides silent closure. They close very quickly (in about one tenth of a second) because of a short linear stroke, which is equal to one fourth of their diameter. It is interesting to note that even though the stroke is short at D/4, the cylindrical area between the open disc and the seat ($\pi \cdot D \cdot D/4$) equals the full port area ($\pi \cdot D^2/4$) where D equals the port diameter. Unfortunately, because the disc remains in the flow stream, a Silent Check Valve has high head loss and is mostly used for clean water applications with high head.

Silent Check Valve

Nozzle Check Valves operate similar to Silent Check Valves but have a smooth venturi-shaped flow path and annular disc with lower head loss than the Silent Check Valve, but with a longer laying length. Like the Silent Check Valve, the nozzle check has a spring-assisted, short linear stroke, which provides the best non-slam characteristic of check valves. Nozzle Check Valves are commonly made in steel for high pressure classes to meet the rigors of industrial and power plant applications.

Nozzle Check Valve

Ball Check Valves are simple and compact and commonly used on small water or wastewater pumps where economy is important. A Ball Check Valve consists of a threaded or flanged body with internal features that guide a rubber-coated ball in and out of the seat as the flow goes forward and reverse. The ball rolls during operation and has a tendency to clean itself. The valve's top access port provides ease of maintenance without removal of the valve from the line. They can be used for both water and wastewater applications but have a high tendency to slam in high head applications or when there are parallel pumps because the ball has high inertia and must travel a long distance. In single pump and low head systems, Ball Check Valves may perform adequately and provide low head loss.

Ball Check Valve

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SWING CHECK VALVES

Swing Check Valves have historically been the most common category of check valve used in water and wastewater pumping systems. They are readily available, low cost, and have low head loss characteristics when full open. They are automatic in that they require no external power or control signal and operate strictly from the change in flow direction. However, there are many types of valves that fall into this category, and each has distinct advantages that should be understood. Swing Check Valves get their name because they generally consist of a body and a closure member or disc that pivots or "swings" about a hinge pin.

The most compact Swing Check Valve is the Dual Disc® Check Valve as defined in American Water Works Association (AWWA) Standard C518. The body is a wafer design (fits between two pipe flanges) and has a hinge pin about which two opposing D-shaped discs rotate. There is another pin called the stop pin, which centers and stabilizes the discs in the flow stream when the valve is full open. This valve can be subject to vibration and wear in service and should include stabilization spheres at the ends of the pins to prevent pin vibration. The resilient seat is typically molded to the body and the spoke that runs across the body. Given that the spoke is in the flow stream and can collect debris, the Dual Disc® Check Valve is not used in wastewater containing solids. The valve port is about 80% of the pipe size so the headloss should be considered. The closure is assisted by a torsion spring which wraps around the hinge pin and presses against the back faces of the disc. Like lift checks, this type of valve does not provide any indication of open and close but because of the spring has good non-slam characteristics.

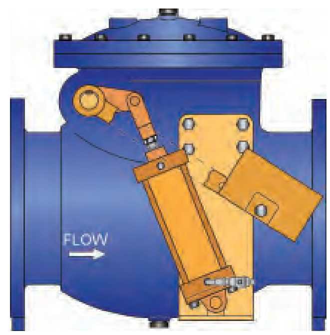
Dual Disc® Check Valve

The traditional Swing Check Valve is defined in AWWA Standard C508, has metal or resilient seats, and swings through a 60 to 90 degree stroke. Because of the long stroke, inertia of the disc, and friction in the packing, the valve may slam in multiple-pump and vertical-pipe installations. These valves are therefore often outfitted with a wide array of accessories, which are beyond the scope of the C508 Standard. Probably the most common accessory is a lever and weight. While it is normally assumed that the weight makes the valve close faster, it actually reduces slamming by limiting the stroke of the disc, but in return, may cause a significant increase in headloss.

However, manufacturers usually publish flow coefficients for full open valves and rarely for partially open ones. The valve closure is also slowed by the inertia of the disc and weight and the friction of the stem packing. Some Swing Check Valves have slanted seats (typically about 5 degrees) to promote closure and sealing at low pressures but as long as the center of gravity of the disc and arm assembly are upstream of the seating surface and pin, there will be a closing moment to provide adequate closure and sealing at low pressures. The external lever provides good indication of valve position and the full port provides good service in both water and wastewater.

Swing Check Valve

In more severe high head applications, an air cushion is sometimes used to prevent slamming. Everyone has experienced the positive effect of an air cushion on a slamming storm door. But the conditions in a water pipeline are significantly different. When a door slams, its momentum is smoothly absorbed by the air cushion because as the door slows, the forces from the closing spring and outside wind become less and less. Conversely, when a check valve in a water pipeline closes, the reverse flow is quickening at a tremendous rate so that every fraction of a second that the valve closure is delayed, the forces on the disc will increase by an order of magnitude. In actual practice, the air cushion holds the disc open long enough for the reverse flow to intensify thereby slamming the disc even harder into the seat. Since air cushions use air which is compressible, they provide very little positive restraint of the closing disc and cannot counteract the enormous forces being exerted by the reverse flow. If faster closure is needed or desired, a lever and spring is a better accessory. Springs inherently have little inertia and are very effective at accelerating the disc movement and providing fast closure and better slam characteristics. Swing Check Valves can also be equipped with oil dashpots to provide effective means of slam prevention.

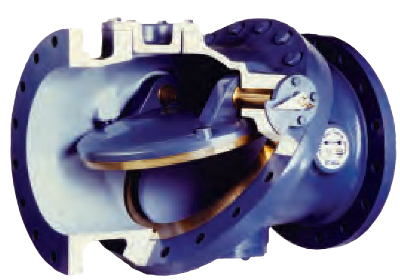


Air Cushion

The newest type of Swing Check Valve listed in AWWA C508 and the valve having the greatest impact in the water/wastewater industry today is the Resilient Hinge Check Valve. As the name implies, the swing action occurs from flex action in the rubber molded disc instead of rotation about a hinge pin. The Resilient Hinge Check Valve is highly dependable with virtually no maintenance because the only moving part is the flexible disc. This valve has a 100% port slanted at a 45-degree angle, which provides a short 35-degree stroke, quick closure, and low head loss. The valve is also available with a mechanical indicator and limit switches. A special model of this valve has even faster closure due to the addition of disc accelerators or springs which provide non-slam characteristics similar to that of a silent check valve.

Resilient Hinge Check Valve

On the other end of the swing check valve spectrum is the Tilted Disc® Check Valve, which has extremely low headloss because of its 140% port area and its butterfly valve-type disc design wherein the flow is allowed to pass on both sides of the disc. The Tilted Disc® Check Valve also has reliable aluminum-bronze metal seats and can be equipped with top or bottom mounted oil dashpots to provide effective means of valve control and surge control for medium length systems. Like other swing check valves, the Tilted Disc® Check Valve is fully automatic and requires no external power or electrical signal from the pump control system. It has an external position indicator and is limited to water or treated effluent because the pins extend into the flow stream and can collect debris.



Tilted Disc® Check Valve

DASHPOT-ASSISTED CHECK VALVES

A proven accessory for dampening swing check valve closure is an oil cushion, also referred to as a bottom-mounted oil dashpot. As shown in the figure below, when the check valve disc is near the closed position, it strikes a snubber rod, whose linear motion is controlled by a high-pressure oil hydraulic cylinder and flow control valve so that this last 10% of travel occurs over 1-5 seconds. The reverse velocity through the check valve will be dampened over a few seconds thus reducing the water hammer associated with sudden check valve closure. These dashpots can be a furnished with swing check and tilted disc check valves. While expensive, they positively prevent check valve slam.

FIGURE 2. Tilted Disc® Check Valve Bottom-Mounted Oil Dashpot

CHECK VALVE SELECTION CRITERIA

In order to match the best type of check valve with a given application, several operating parameters must be defined. These selection criteria may or may not be important for a given application, but they all play a role in the selection process. The criteria that will be discussed in detail are listed in Table 1.

SELECTION CRITERIA	SIGNIFICANCE
Initial Costs	Valve purchase costs can vary widely and should also include installation costs.
Maintenance Costs	The more complex the valve, the greater the maintenance costs.
Headloss and Energy Costs	Some valves can cost far more in energy cost than their initial cost.
Non-Slam Characteristics	It is essential to match the closing characteristic of the valve with the dynamics of the pumping system.
Fluid Compatibility	Only certain check valves can tolerate sediment and solids in the flow.

TABLE 1. Selection Criteria for Check Valve Selection

INITIAL COSTS

The purchase cost of various check valves are readily available from local distributors or manufacturers and can vary widely based on features and the level of quality. It is important to understand that the purchase cost only represents a portion of the initial cost. The installation cost may be even greater than the purchase cost. Some check valves are very compact (wafer type) with short laying lengths and may result in shorter piping runs and smaller dry wells or piping galleries. At the same time, however, many compact check valves require three to five straight diameters of straight pipe upstream to avoid vibrations and premature wear of the valve. The laying length should therefore include the additional piping recommended by the valve manufacturer. Some valves may not be suitable for vertical pipe runs and therefore may require an additional horizontal section of pipe to accommodate them. Again, extra pipe translates into larger pipe galleries.

Certain types of check valves and most large check valves will require some means of weight support. Lift Check Valves are typically supported just like a pipe fitting and are supported by the pipe itself. Large Swing Check Valves may have considerable weight and require concrete pads to support the valve weight. In summary, the initial cost of the check valve should consider its laying length and the laying length of required piping and the cost of installation and supports. Typical initial costs for 12 inch check valves are shown in Table 2.

Estimated 12 in. Check Valve Installed Costs			
TYPE OF VALVE	Purchase Cost	Mechanical Cost	Installed Cost
Ball Check Valve	$9,000	$300	$9,300
Silent Check Valve	$4,500	$300	$4,800
Nozzle Check Valve	$9,500	$500	$10,000
Dual Disc® Check Valve	$1,900	$200	$2,100
Swing Check Valve / Weight	$7,500	$500	$8,000
Resilient Hinge Check Valve	$5,500	$300	$5,800
Tilted Disc®, Bottom Dashpot	$18,000	$1500	$19,500

* Based on 2017 market pricing

TABLE 2. Estimated 12 In. Check Valve Costs

MAINTENANCE COSTS

It is usually safe to say that the more moving parts in a valve, the greater the need for maintenance. A simple Lift Check Valve can provide service for decades without maintenance because the disc stem slides through permanently lubricated bearings. Lift Check Valve springs are typically proof of design tested to at least 50,000 cycles and can last far longer. The only maintenance on Lift Check Valves would be to regularly listen to the valve when the pump is not running and try to hear for seat leakage. Leakage sounds like a hissing noise and can be easily detected with a doctor's stethoscope. Once leakage becomes steady, it will just be a matter of months before the metal seat trim begins to erode and allow excessive leakage. The leakage erodes the seat in localized areas and is often described as wire draw because it looks like a thin abrasive wire was pulled across the seating surface. Chattering should also be observed, which consists of clanking against the open stop or seat, which may be a result of swirling flow or insufficient velocity to peg the valve open. It is tempting for engineers to sometimes install a check valve that is three or more sizes larger than the pump discharge nozzle to reduce the headloss. That is admirable, but check valves require a minimum velocity for proper operation. Chattering or spinning of the disc during constant flowing conditions may reduce the bushing and spring life to less than one year. The use of variable frequency drives are sometimes dialed down to produce velocities less than 4 feet per second which can prevent full opening of the check valve and higher head loss through the valve.

Depending on the model selected, Swing Check Valves can require costly regular maintenance to adjust packing or lubricate bearings, which may drive up the cost of the valve, or on the other hand, be the best friend of the maintenance crew at the plant. Either way, the manufacturer's recommended maintenance plan should be reviewed and figured into the lifetime cost of the valve. Most manufacturers post their instruction manuals on the Web so it is a simple matter to review the applicable section on maintenance. More specifically, when a Swing Check Valve has an external lever and weight, there must be a seal around the stem where it penetrates the body. These seals tend to leak and require regular maintenance and if the adjustment is not done correctly, the packing may be too tight, causing excess friction thereby slowing the valve closure and causing valve slam.

The Resilient Hinge Swing Check Valve benefits from the fact that the hinge pin is contained within the resilient disc, and it does not penetrate the body; hence, no packing. This valve basically has only one moving part, the flexible disc, so there is no regular maintenance needed. Both types of swing check valves have a bolted top access port so if leakage is observed, the valve can be inspected and repaired without removing it from the line.

When Swing Check Valves are equipped with air or oil dashpots, additional maintenance will be needed. As was said before, the more moving parts, the more maintenance. The cylinders and controls are subject to external corrosion and can seize up so they should be inspected at least every six months. Oil systems often have accumulator tanks with a set air pressure in them that should be maintained. The air may be needed to assist in the operation of device (i.e. extend its rod) so if the air pressure is lost, the device may become inoperable and the valve may slam. And air always tends to find a way out of a pressurized system including fittings, cylinder seals, and even pressure gauge mechanisms. Spraying the air piping with soap solution is an easy way to detect minute leakage.

Table 3 illustrates the difference between the maintenance costs of the various types of check valves in the 12-24 in. size range.

CHECK VALVE TYPE		DESCRIPTION OF MAINTENANCE	ESTIMATED ANNUAL COST (Rate = $75/hour)
LIFT	Ball Check	Simple valve requires only annual check for leakage.	$150
LIFT	Silent Check	Simple valve requires only annual check for leakage.	$150
LIFT	Nozzle Check	Simple valve requires only annual check for leakage.	$150
SWING	Dual Disc® Check	Simple valve requires only annual check for leakage.	$150
SWING	Traditional Swing Check with Lever and Weight	Stem packing and accessories require regular maintenance.	$600
SWING	Resilient Hinge Swing Check	Simple valve requires only annual check for leakage.	$150
SWING	Tilted Disc® Check Valve with Oil Dashpot	Monthly lubrication and attention to the dashpot system are needed.	$1800

TABLE 3. Estimated Check Valve Maintenance Costs

HEADLOSS

The pump discharge head is needed to overcome the combination of the static head and the friction head of the distribution system. The static head represents the difference in elevation between the source and the highest point of water storage or service. The friction head is caused by roughness in the pipe and local flow disturbances such as fittings and valves. Pumping and distribution system valves come in many varieties, but they all cause some friction head.

Valve body geometry dictates the general flow area through the valve. Some valves restrict the flow area to below 80% of the pipe area. Also, the internal contours of the body and seat should be smooth to avoid creating excessive turbulence. Valve bodies and laying lengths are sometimes much greater than the pipe size to achieve a smooth flow pattern. If the port area is equal to the pipe size, then the closure member or disc needs to be somewhat larger to affect a seal. Then the body is contoured outward around the disc to achieve a full flow area through the valve such as the globe style Silent Check Valve. Other valves take advantage of an angled seat so that the pipe area can be maintained through the port without greatly increasing the size of the valve body such as the Resilient Hinge Check Valve.

The design of the closure member is also important in reducing headloss for two reasons. First, the lowest headloss will be achieved if the disc swings or rotates out of the flow path. Second, discs can also have special contours and shapes to fully open at low fluid velocities and create a smooth flow path through the valve.

There are many flow coefficients and headloss formulas in general use today for rating of various valves on the basis of headloss. Probably the most common flow coefficient for water valves is the C_v flow coefficient, which is defined as the amount of water in gallons per minute (gpm) that will pass through a valve with a 1 psi pressure drop. Hence, the more efficient the valve, the greater the valve C_v. Table 4 illustrates typical flow coefficients for 12 in. check valves in order of increasing C_v.

Typical 12 in. Valve Flow Data			
TYPE OF VALVE	PORT SIZE	C_v	K_v
Silent Check Valve	100%	2480	3.00
Swing Check Valve	100%	3395	1.60
Ball Check Valve	100%	3500	1.50
Dual Disc® Check Valve	80%	4100	1.10
Nozzle Check Valve	100%	4700	0.83
Resilient Hinge Check Valve	100%	4800	0.80
Tilted Disc® Check Valve	140%	5400	0.63

TABLE 4. Valve Types and Flow Coefficients

Another flow coefficient to use for evaluating valve headloss is the resistance coefficient K_v used in the general valve and fitting flow formula:

$$\Delta H = K_v v^2 / 2g$$

where:

ΔH = headloss, feet of water column
K_v = resistance coefficient (valve), dimensionless
v = fluid velocity, ft/sec
g = gravity, ft/sec^2

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The flow factor K_v can also be related to the C_v by the formula:

$$K_v = 890\, d^4 / C_v^2$$

where:

d = valve diameter, in.

K_v factors for various valves are similar in magnitude and similar from size to size. For example, a geometrical similar 12 in. valve and a 72 in. valve may have nearly identical K_v's. Because of this similarity, K_v's are ideal for use in comparing valves and fittings. With the understanding that a run of 100 feet of steel pipe has a K of 1.5, and a pipe exit has a K of 1.0, an engineer can easily understand the relative impact a valve has on the total piping system pressure loss. For example, the Silent Check Valve has a K_v of 3.0 which would be equivalent to the loss produced by about 200 feet of pipe.

Comparisons can also be made between various manufacturers for the same type of valve. For example, the published K_v's for 12 in. Silent Check Valves from three prominent suppliers in the US water industry varies from 2.7 to 3.0. The magnitude of this difference is not significant when compared to the total K of a piping system which may range from 50 to 200. The lesson here is that while it is important to consider the headloss between types of valves, the headloss between various suppliers of a given valve type does not typically produce significant changes in system operation. This fact is also the reason that piping system computer simulations accurately model system behavior based on generic valve characteristic data. Given that design differences between brands are small and testing methods can vary, slight differences in published flow data among manufacturers can usually be ignored.

ENERGY COSTS

The headloss from valves can be converted into an annual energy cost related to the electrical power needed by the pump to overcome the additional headloss from the valve with the equation from AWWA M49:

$$A = (1.65\ Q\ \Delta H\ S_g\ C\ U) / E$$

where:

A = annual energy cost, \$/yr
Q = flow rate, gpm
ΔH = head loss, ft. of water
S_g = specific gravity, dimensionless (water = 1.0)
C = cost of electricity, \$/kW·h
U = usage, percent x 100 (1.0 equals 24 hours per day)
E = efficiency of pump and motor set (0.80 typical)

For example, the difference in headloss between a 12 in. Tilted Disc® Check Valve (K = .63) and a Silent Check Valve (K = 3.0) in a 4500 gpm (12.76 ft/sec) system can be calculated as follows:

$$\Delta H = K\ v^2 / 2\ g$$

substituting:

$$\Delta H = (3.0 - 0.63)\ (12.76)^2 / 2 \cdot 32.2$$
$$= 6.0 \text{ ft. wc}$$

This difference in headloss can then be used to calculate the difference in annual operating costs assuming an electricity cost of $.08 per kW-hr. and 50% usage.

$$A = (1.65 \times 4500 \times 6.0 \times 1.0 \times 0.08 \times 0.5) / (0.8)$$
$$= \$2230$$

The calculation shows that the use of a 12 in. Tilted Disc® Check Valve in the place of a 12 in. Silent Check Valve can save $2,230 per year in energy costs. If the pump station had four such valves operating for forty years, the total savings would be about $356,000 over the life of the plant. It is clear that the pumping costs can be more significant than the installed costs. Further, the larger the valve, the greater the impact from the energy costs. A comparison of the 40-year energy costs for the various types of check valves is shown in Table 5.

TOTAL VALVE COST

The total valve cost is simply the sum of the initial cost, maintenance costs, and energy costs over the life of the valve as shown in Table 5 and Figure 3. By looking at the table of 40-year costs, it is clear that energy costs are significant in the overall cost of the valve.

12 inch Check Valve Total Cost over 40 Years

	TYPE OF CHECK VALVE	Installed Cost	Energy Cost*	Maintenance Cost	Total Cost
LIFT	Ball Check	$9,300	$56,300	$6,000	$71,600
LIFT	Silent Check	$4,800	$112,700	$6,000	$123,500
LIFT	Nozzle Check	$10,000	$31,100	$6,000	$47,100
SWING	Dual Disc®	$2,100	$41,300	$6,000	$49,400
SWING	Swing Check & Weight	$8,000	$60,100	$24,000	$92,100
SWING	Resilient Hinge	$5,800	$30,000	$6,000	$41,800
SWING	Tilted Disc® with Bottom Dashpot	$19,500	$23,600	$72,000	$115,100

*For 40 Years, based on 50% usage, $.08/kW-h, 12.76 ft/sec velocity.

TABLE 5. 12 in. Check Valve Projected Costs for 40 Years

NON SLAM CHARACTERISTICS

Pumping systems are often plagued from day one with the problem of check valve slam and the effects of the resultant system pressure surge. Significant research has been conducted to understand the dynamic closing characteristics of various automatic check valves including Ball Check, Swing Check, Tilted Disc®, Resilient Disc, Dual Disc®, and Silent Check Valves (Ballun). Check valve slam is a two-step process. First, after pump stoppage, the flow reverses and flows backwards through the check valve before it can fully close. Second, the closure member suddenly shuts off the reverse flow. When flow velocity is suddenly changed in a piping system, the kinetic energy of the flowing fluid turns into pressure. For every 1 ft/sec change in velocity, there will be approximately a 50 psig pressure spike. It only takes about a 0.5 ft/sec change in velocity or 25 psig to produce a mild slam. A 1 ft/sec change in velocity or 50 psig may produce an audible noise that will carry across the building annoying operating personnel or even neighboring houses. When a slam is observed, it sounds like the noise is caused by the closure member hitting the seat, but in actuality, the slam noise is caused by the pressure spike which instantaneously stretches the pipe wall causing the audible water hammer sound wave. Knowing that the sudden stoppage of reverse flow and the resultant pressure spike is the cause of the slam, an ideal check valve will close before any reverse velocity occurs. Unfortunately, all check valves allow some reverse velocity depending on the dynamics of the system.

The slamming potential of various check valves and their ability to prevent reverse flow can be understood with consideration to the valve geometry. As was said earlier, the best way to prevent slam is to close the valve very fast. But what makes a valve close fast?

The disc location contributes greatly to the closure. If the disc moves or pivots out of the flow stream when open, it will be difficult for the reverse flow to rapidly close the valve. Of the three Lift Check Valves discussed, it can be seen that the Ball Check's closure member is pushed out of the flow stream up an angled channel by the flow while the Silent Check Valve's disc remains in the flow stream. Hence, when the flow reverses, the reverse flow will immediately impact the Silent Check Valve disc causing it to close faster than the Ball Check Valve. Even though a Silent Check Valve closes in about one tenth of a second, reverse flow is still flowing through the valve, but at a negligible amount. When it comes to Swing Check Valves, they all have the closure member in the flow stream which will assist in rapid closure. A related geometric feature of the valve is the length of stroke. It only makes sense that the further the disc must travel, the longer it will take to close. Of the Lift Check Valves, the Silent and Nozzle Check Valves have the shortest stroke (one fourth of the diameter) and the Ball Check Valve has the longest (one diameter). Of the Swing Check Valves, the Resilient Hinge Check Valve has the shortest stroke (35 degrees) and the traditional Swing Check the longest (60 to 90 degrees).

2A

If the deceleration of the forward flow can be estimated, such as with a transient analysis of the pumping system, the slamming potential of various check valves can be predicted. The non-slam characteristics of check valves are shown for various system decelerations in Figure 3. The valves whose curves are furthest to the right have the best non-slam characteristics. The reverse velocities and resultant slams may be higher for larger size valves.

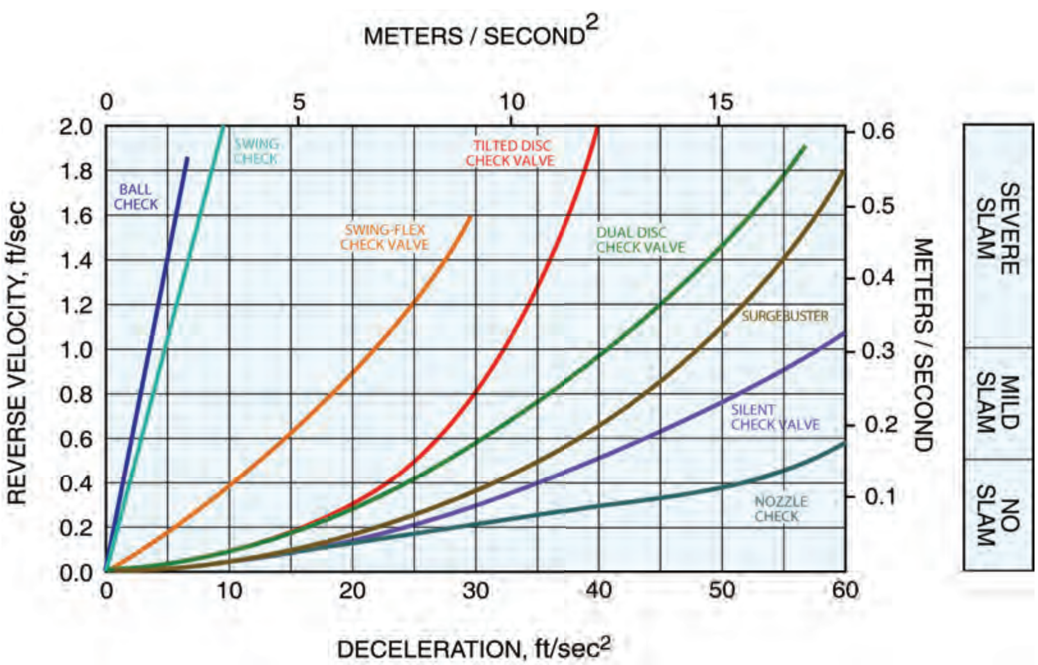

FIGURE 3. Non Slam Characteristics of Various 8 In. Check Valves

Finally, the non-slam characteristics of check valves can be affected by the orientation of their installation. Regardless of design, all check valves can be installed in the horizontal position even with a slight slope of the pipe. However, special considerations should be given to valves installed in vertical installations. In vertical flow-up applications, slamming problems can be amplified because a vertical column of water rapidly reverses. Also, in vertical pipes, the valve disc may be in the vertical plane and will have no gravity assistance in closing. While a lever may counterbalance the disc, the added inertia may cause the rapid reverse flow to force the disc violently into the seat. The best valves for vertical pipe applications are the valves with short linear strokes or valves with angled seats.

FLUID COMPATIBILITY

Line media is critical to check valve selection. The rule of thumb regarding check valve selection and suspended solids is the higher the concentration of suspended solids, the more care required when selecting a check valve. All check valves on the market today will handle water or treated wastewater, but as we move from potable to raw water to waste water to screened sewage to raw sewage, many valves must be excluded. There are several factors to consider. Will the valve seat properly if suspended solids are present? Are there shafts, stems, spokes, or discs in the flow stream? Geometry of the body is also important because voids or areas where solids can become trapped may impede operation. The higher the solids content the more desirable a full ported design becomes to avoid clogging. If the valve has a straight, smooth flow path, the potential for clogging is greatly minimized. With these concepts in mind, Nozzle Check, Silent Check, Dual Disc® and Tilted Disc® valves should not be used for wastewater containing high solids.

	CHECK VALVE TYPE	FLUID COMPATIBILITY
LIFT	Ball Check	Water or Wastewater
	Nozzle Check	Clean service only
	Silent Check	Clean service only
SWING	Dual Disc®	Clean Service Only
	Traditional Swing Check with Lever and Weight	Water or Wastewater
	Resilient Hinge Swing Check	Water or Wastewater
	Tilted Disc® Check Valve	Clean Service Only

TABLE 6. Check Valve Application Data

SELECTION METHODOLOGY

With the understanding of the three selection criteria for various types of check valves, the design engineer now needs a rational decision process to assist in narrowing down the field of available valves and identify the best valve for the given application.

Table 7 illustrates one possible methodology wherein each criterion is assigned a weight for the given application. The various criteria are listed across the top of the table. The types of valves under consideration are listed down the side of the table. In the example shown in the figure, the highest weight (5) was assigned to Non-Slam because the application was in a residential area where no noise can be tolerated. Next, based on valve data, a rating was given to each valve in each category. Finally, each rating is multiplied by the criteria weight and summed to the right for each valve. The engineer can then judge which valve is best for the given application. In this example, the engineer might give the nod to the Resilient Hinge Check Valve with spring. As the weights and ratings are assigned, the results will, of course, vary.

WEIGHT:	3	5	2	TOTAL SCORE
VALVE TYPE	TOTAL COST	NON-SLAM	FLUID COMP.	
Ball Check	5	1	5	30
Silent Check	5	5	2	44
Nozzle Check	5	5	2	44
Dual Disc®	5	4	2	39
Swing Check, Weight	4	2	5	32
Resilient Hinge (RH)	5	3	5	40
RH With Spring	4	5	5	**47**
Tilted Disc®, Dashpot	3	5	2	38

TABLE 7. Check Valve Selection Table with Sample Weights and Ratings

CONCLUSION

Now that the types of check valves and their performance characteristics are better understood, a rational decision process can be applied to selecting check valves for specific applications that satisfy individual preferences and system parameters. There is no single check valve that is the best for all applications. Every installation will require the selection criteria to be given different weights, so it follows that there are applications suitable for all of the check valves available.

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White Paper

Dynamic Characteristics of Check Valves

Table of Contents

Dynamic Characteristics of Check Valves was written to assist the design professional in predicting slam in basic check valves without dashpots and other specialized hydraulic controls. It is not intended to provide all of the information necessary for selecting a check valve but rather to explain in engineering terms the cause of check valve slam and the inherent closing characteristics of various check valves that contribute to this phenomenon.

With this knowledge, the design professional can predict before pump station start-up whether serious check valve problems will occur. Other design issues such as head loss and cost are equally important factors and should be considered in making the final valve selection.

The test data presented offers valuable information for predicting valve performance. It is based on independent tests conducted at the Utah Water Research Laboratory and remains the property of Val-Matic Valve & Mfg. Corp.

INTRODUCTION

When bringing a pump station on line for the first time, the design engineer has many concerns such as when the START button is pressed; will the pump produce the rated flow; when the STOP button is pressed; will the check valve slam? Check valve slam can range from a minor nuisance to a building-shaking, neighborhood-disturbing crash. The slam is the water hammer caused by the sudden stopping of reverse flow through the check valve as it closes. Check valve slam can delay final completion and approval of projects for months and therefore warrants careful study and understanding.

Val-Matic performed an exhaustive testing program at Utah Water Research Laboratory on several types of check valves and published this data in the form of dynamic check valve response curves. A methodology was developed to use the check valve data to predict check valve slam. This methodology is a useful tool when combined with field experience to predict check valve problems before the start-up of the pump station. Other design issues such as headloss, reliability, and installed cost are equally important factors and should be considered in making the final check valve selection.

CHECK VALVE SELECTION

There are several technical papers, valve handbooks, and software design tools available to assist in check valve selection. The process is often difficult because selecting a check valve can involve many criteria such as non-slamming characteristics, headloss characteristics, operating costs, controllability, maintenance costs, and installation laying length. Most of these criteria, however, are straightforward and can be calculated for the various types of check valves available. This methodology will focus on the non-slamming characteristics of check valves and match them to various systems. It is a fact that given a severe pumping application, all check valves will slam to some degree. It is also a fact that in normal applications, various check valves will not slam. It is the unpredictability of the middle ground between these extremes that makes the task of selecting check valves difficult.

Check valve slam occurs after pump stoppage when the system flow reverses back towards the pump before the check valve is fully closed (Figure 1). The reverse flow causes the check valve to close rapidly through the remaining portion of its travel. The reverse flow is then stopped instantaneously by the closed valve causing a loud water hammer in the pipe. The noise associated with the slam is not the impact of the disc into the seat, but rather the rapid stretching of the pipe due to the water hammer. Surprisingly, a resilient-seated check valve can make the same metallic slam sound as a metal-seated valve.

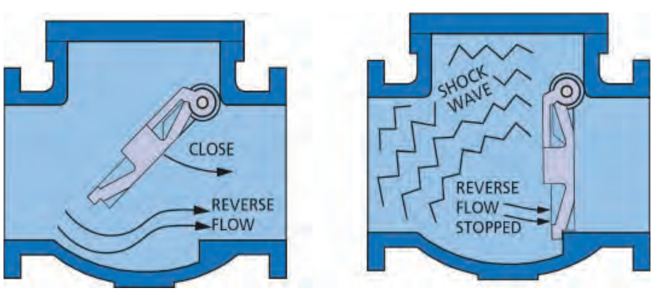

FIGURE 1. Check Valve Slam

To prevent check valve slam, a check valve must either close very rapidly before appreciable reverse flow occurs or very slowly once reverse-flow has developed. In order to close rapidly, studies (Thorley, 180) indicate that:

- the disc should have low inertia and friction,
- the travel of the disc should be short, or
- the motion should be assisted with springs.

To close slowly, a check valve needs to be equipped with external devices such as oil dashpots and the pump must be capable of withstanding some backspin. Oil dashpot devices have proven to be effective, but are beyond the scope of this methodology. The answer to preventing check valve slam is not to find the fastest closing check valve and make it the "standard". Instead, the non-slam characteristics of the check valve must be matched with the pumping system. Every check valve has inherent advantages such as low cost, low headloss, or special flow characteristics. The best check valve is not necessarily the one with the least potential to slam.

Probably the simplest pumping system is a water well application consisting of a single pump operating at low pressure and sending water to a ground reservoir several thousand feet distant. Because of the low operating pressure and high friction, after pump stoppage the flow will reverse or decelerate slowly. The rate at which the flow reverses, however, is important in gauging whether the check valve will slam. For a low head application with a long pipe length, there is less potential for rapid flow reversal and the simplest and lowest cost check valve may be used without slamming. On the other hand, a multiple-pump station sending water to a high head system with a nearby elevated or pneumatic surge tank will experience an extremely rapid flow reversal and only certain check valves can be used without slamming.

To select a non-slam check valve, the pump station designer must first analyze the pumping system and calculate the deceleration of the liquid column after pump stoppage. In other words, if the flow rate is 12 ft/sec and calculations show that the flow will stop in 2 seconds, then the average deceleration is 12 ft/sec divided by 2 sec or 6.0 ft/sec^2. Calculating the deceleration can be difficult because it is a function of many parameters such as pump inertia (provided by the pump manufacturer), length of the liquid column, friction losses in the piping system, and the static head or slope of the pipe. Engineers typically rely on a computer simulation of the system to compute deceleration.

It is the responsibility of the valve manufacturer to provide the dynamic characteristics of their valves so that the engineer can predict the maximum reverse velocity that may occur. It is suggested that for each type of check valve, a response curve should be generated to show the relationship between the deceleration of the liquid column and the maximum reverse velocity through the check valve (Provoost, 278). The deceleration is expressed in terms of dv/dt or change in forward velocity divided by change in time or ft/sec^2. The reverse velocity is developed from testing and is expressed in velocity terms or ft/sec.

For example, dynamic test data for a dual-plate wafer check valve is shown in Figure 2. The horizontal axis represents the deceleration of the piping system expressed in feet per second squared. The vertical axis is the maximum reverse velocity through the check valve expressed in feet per second. A single-pump, low-head system will have a deceleration of less than 20 ft/sec^2. A high-head system of a multiple-pump system may have a deceleration as high as 40 ft/sec^2. For this higher deceleration, the dual plate check valve of Figure 2 will allow a reverse velocity to develop equal to about 1.0 ft/sec. The reverse velocity can be converted directly into water hammer pressure using the equation [AWWA, 51]:

$$h = \frac{a\,v}{g}$$

Where: = pressure rise, ft of water
= wave velocity, ft/sec ≈ 3200 ft/sec (steel pipe)
= reverse velocity, ft/sec
= 32.2 ft ft/sec^2

The reverse flow of 1.0 ft/sec corresponds to a water hammer of 100 ft (43 psi). Field experience shows that water hammers in the range of 50 to 100 ft (or reverse velocities of 0.5 to 1.0 ft/sec) represent a mild slam and can be tolerated. Conversely, water hammers over 100 ft (or reverse velocities over 1.0 ft/sec) are extremely loud and should be avoided by either selecting a different check valve or modifying the check valve with heavier springs or hydraulic dashpots.

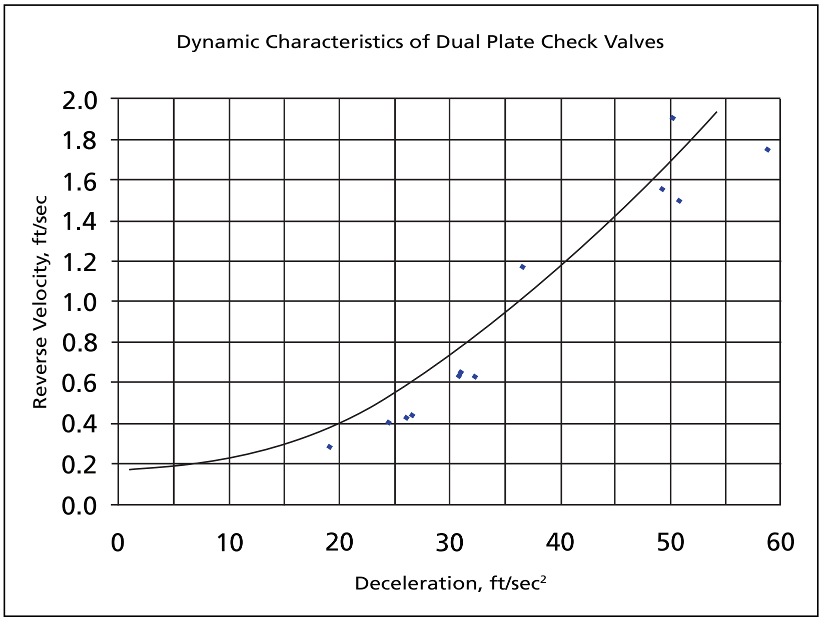

FIGURE 2. Dynamic Test Data

<u>TEST METHODOLOGY</u>

To develop dynamic characteristics for its check valves, Val-Matic contracted a series of valve flow tests at the Utah Water Research Laboratory in Logan, Utah. Several types of eight-inch check valves were water flow tested under dynamic conditions.

The check valves were installed in a horizontal test piping run and subjected to different initial forward flows and varying rates of flow reversals. The lab is supplied with a natural supply of mountain runoff water from a reservoir through a 48 inch pipeline so velocities in the range of four to twenty feet per second were easily attained. The lab is also equipped with a certified weigh tank system to record flow rates. Valve head loss was read using manometers and dynamic pressures were recorded using transducers and a high-speed data recorder.

Forward flow from the reservoir was established by opening the main valve shown in Figure 3. The supply flow at about 5 psig from the reservoir automatically opened the check valve fully and flow rates and head-loss data were recorded. Next, a secondary pump was started to supply additional flow at a higher pressure of about 20 psig. Both flows merged downstream of the check valve and exited through the Main Valve.

To trigger a check valve slam, the main valve was suddenly closed stopping the forward flow and the secondary pump would rapidly produce reverse flow and valve slam. Different rates of deceleration were achieved by closing the main valve at different rates.

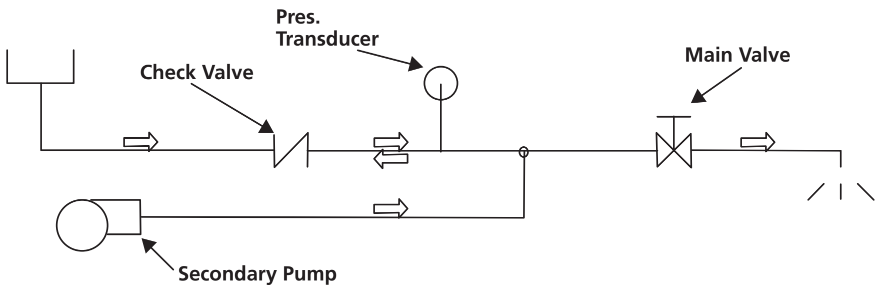

FIGURE 3. Check Valve Test Loop

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The pressure downstream of the valve was recorded and used to calculate the deceleration of the flow and the reversevelocity through the valve. A sample computer trace is shown in Figure 4.

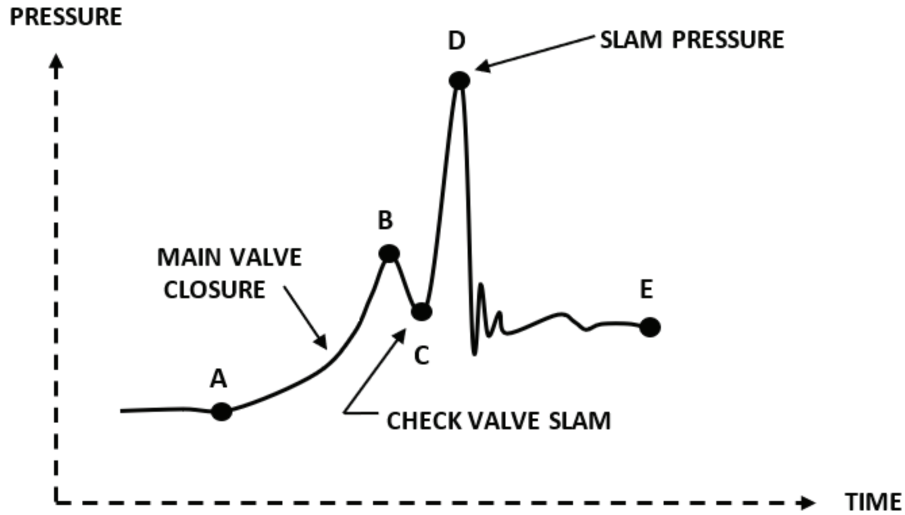

FIGURE 4. Sample Pressure Recording

The sequence associated with Figure 4 above is as follows:

A	=	reservoir pressure
A-B	=	main valve is closed stopping forward flow, check valve starts to close
B	=	flow is stopped, check valve continues to close
B-C	=	reverse flow builds
C	=	valve disc strikes the seat causing slam and water hammer
D	=	water hammer pressure resulting from sudden reverse flow stoppage
E	=	secondary pump pressure

Average decelerations were calculated by dividing the initial velocity by the A-B time interval. The reverse flow velocity was calculated based on the surge pressure measured between points C and D and the equation given above.

This test methodology has been applied by different researchers to many types of check valves. For example, Thorley (p. 23) tested and reported results for common ball check and swing check valves as shown in Figures 5 and 6. Provoost tested nozzle check valves in similar fashion as shown in Figure 7.

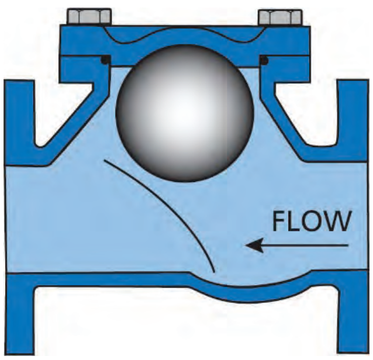

FIGURE 5. Ball Check

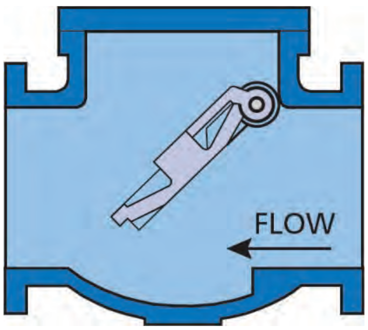

FIGURE 6. Swing Check

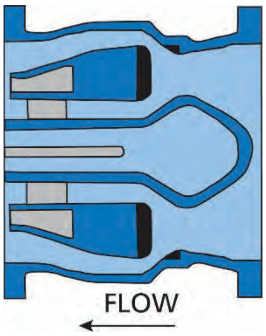

FIGURE 7. Nozzle Check

The test methodology was applied to five 8-inch flanged Val-Matic production check valves as shown in Figures 8 through 12 (Rahmeyer):

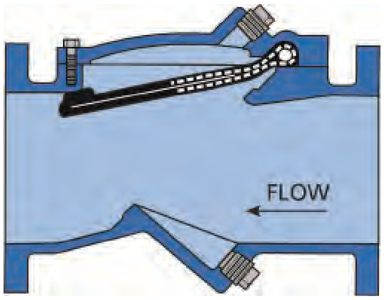

FIGURE 8. Val-Matic Model 508A Swing-Flex® Check Valve (SFCV). The SFCV features a resilient hinged disc, angled seat, and short stroke.

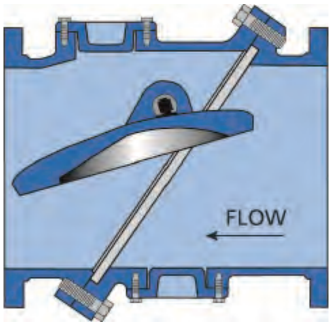

FIGURE 9. Val-Matic Model 9808 Tilted Disc® Check Valve (TDCV).

This valve features an offset butterfly type disc, angled seat, short stroke, and 140% port area for the lowest possible headloss.

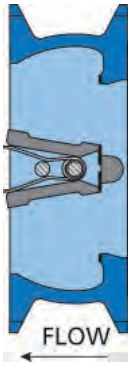

FIGURE 10. Model 8808W Dual Disc® Check Valve (DDCV).

The DDCV features two half-circle discs that pivot closed with the assistance of a strong torsion spring.

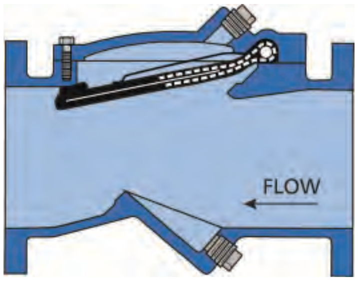

FIGURE 11. Model 7208 Surgebuster® Swing Check Valve (SB).

The Surgebuster® (SB) features a resilient hinged disc, angled seat, and short stroke, and a disc accelerator.

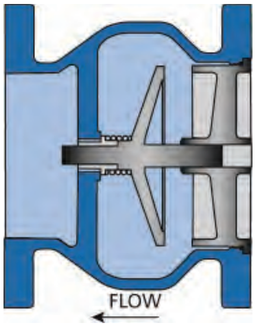

FIGURE 12. Model 1808A Globe-Style Silent Check Valve (SCV).

The SCV features a short linear stroke with a strong return spring.

TEST RESULTS

The test results for these valves are presented in graph form in Figure 13 together with similar data for swing check, ball check (Thorley, 23), and nozzle check (Noreva). The results clearly indicate that the best non-slam check valves are the Nozzle Check Valve, Dual Disc® Check Valve, Surgebuster®, and the Silent Check Valve, which all feature spring-assisted closure. The next best non-slam check valves are the Swing-Flex® Check Valve and Tilted Disc® Check Valve, which feature an angled seat and short stroke. Finally, the valves with long strokes and no spring assist, the ball check and swing check, have the greatest potential for slamming.

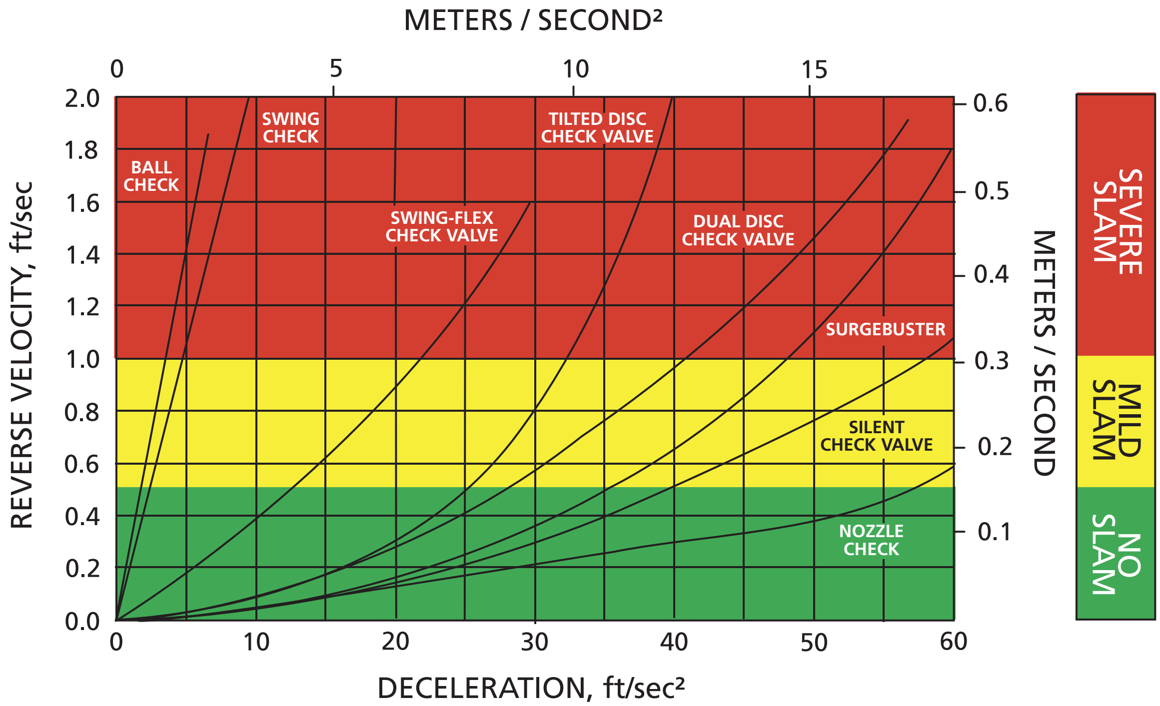

FIGURE 13. Dynamic Characteristics of Various Check Valves

The chart was divided into three ranges: NO SLAM, MILD SLAM, and SEVERE SLAM. These divisions are based on numerous field observations of valve slams and acceptable levels of noise and disturbance to the valve and pumping system. The designer can also convert the given reverse velocity to a quantitative surge pressure using the equation on page 4 and make a separate determination of system impact.

The designer uses Figure 13 by finding the system deceleration on the horizontal axis and then reading the reverse velocity for the various types of check valves. For example, given a multiple pump station with a calculated system deceleration is 30 ft/sec², the following predictions can be read from the graph:

Valve Type	Reverse Velocity	Type of Slam
Nozzle Check Valve	.20 ft/sec	none
Silent Check	.33 ft/sec	none
Surgebuster® Swing Check	.44 ft/sec	none
Dual Disc® Check	.60 ft/sec	mild
Tilted Disc® Check	.80 ft/sec	mild
Swing-Flex® Check	1.8 ft/sec	severe
Ball Check	>2.0 ft/sec	severe
Swing Check	>2.0 ft/sec	severe

The designer can go on to calculate an estimated slam pressure on the basis that there is about 100 ft of water hammer for every 1 ft/sec of reverse velocity. In the example above, the Surgebuster® would produce a slam pressure of about 0.44 x 100 or a 44 ft (19 psi) pressure surge, which would sound like a dull thud upon closure.

However, the designer can still consider using one of the valves in the “mild” or “severe” slam ranges by possibly changing to a speed-controlled pump or modifying the valve to include a stronger spring or an oil dashpot. At first glance, it may seem impractical to do so, but a characteristic of one of the valves such as the low headloss of a Tilted Disc® Check Valve may be important for this application and an oil dashpot could be economically justified.

Finally, it is important to note some limitations of using the dynamic characteristic data presented in Figure 2. First, the test data is based on installation in a horizontal pipeline. Some valves rely on gravity to accelerate disc closure such as the SWING, TDCV, and SFCV valves and when installed in a vertical pipe, may have a greater tendency to slam. Conversely, other valves such as the DDCV and the SCV will close faster in a vertical line due to gravity effects on their discs and have a lesser tendency to slam. Also, the dynamic characteristics of the valve are dependent on valve size but no data is available at this time to predict the exact effect of size. Larger valves have heavier discs and longer strokes and will likely produce somewhat higher reverse velocities than predicted from Figure 13. The manufacturer should be consulted for the potential impact of orientation and size on the performance of the selected valve.

CONCLUSION

It should be clear that dynamic characteristic data for check valves only offers the designer the tools necessary to evaluate the non-slam characteristics of various check valves. This information, combined with other readily available valve characteristics such as headloss, laying length, waterway design for fluids containing solids, and cost will provide the designer with all of the tools necessary to make reliable valve selections.

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White Paper

Tilted Disc® Check Valve Pump Discharge Service

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INTRODUCTION

The purpose of this guide is to provide background information on pump discharge applications and recommendations for specifying and installing Tilted Disc® Check Valves. The valve is energy efficient and also provides non-slam closure by utilizing a short disc stroke of 40°. The energy savings produced by its 140% flow area, streamlined body and hydrodynamically designed disc make it an excellent choice for pump discharge applications. The valve will pay for itself many times over in ease of maintenance and energy savings.

DESCRIPTION OF VALVE

Val-Matic®'s Tilted Disc® Check Valve is a rugged valve with excellent headloss characteristics. The valve is ideally suited for raw water, cooling water, and treated water/wastewater applications. The valve's tapered metal-to-metal seats are constructed of wear resistant aluminum bronze alloys and provide tight seating and long life even in the most severe applications. The operation of the valve is self-contained and fully automatic.

The valve can be equipped with bottom or top mounted oil dashpots for various applications. The bottom dashpot controls the last 10% of valve closure with a hydraulic cylinder. The top mounted dashpot also independently controls the full opening and closing strokes to reduce surges on longer systems.

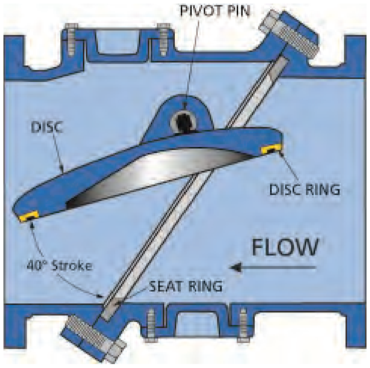

FIGURE 1. Tilted Disc® Check Valve Construction

VALVE FUNCTION

In pump discharge service, the valve must open wide during pumping and close tightly after pump shutdown to prevent reverse flow. To prevent slam during pump shutdown, the valve should either close rapidly before flow reversal, or with the use of oil dashpots, close slowly to provide soft seating action. Controlled opening and closing strokes are available with top mounted dashpots to reduce the potential for surges during operation.

HEADLOSS CALCULATION

The headloss across any valve in feet of water column is easily computed using the equation:

$$H = 2.31\left(\frac{Q}{Cv}\right)^2 S_g$$

Where:

H = headloss, ft.
Q = flow rate, gal/min
C_v = valve flow coefficient
S_g = specific gravity

For example, a 30 in. Tilted Disc® Check Valve with a Cv of 42,000 and operating at a flow rate of 26,500 gal/min (12 ft/sec), will have a headloss of only 0.92 ft. of water column. Compare that to a silent check valve with its headloss of 6.74 ft. in the same service.

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ENERGY CALCULATIONS

One of the primary reasons for selecting Tilted Disc® Check Valves for pump discharge is to obtain low energy consumption. The equation for calculating the yearly energy costs is as follows (AWWA M49):

$$A_{cost} = 1.65 \text{ x } Q \text{ x } H \text{ x } \text{ x } C \text{ x } U / E$$

Where:

A_{cost} = Annual energy cost, $/year
Q = Flow rate, gpm
H = Headloss, ft. of water
S_g = Specific gravity, dimensionless
C = Cost of electricity, $/kWh
U = Pump usage percentage, 100% (1.0) equals 24 hrs per day
E = Efficiency of pump a motor set, (0.80 typical), dimensionless

The equation can also be used to compare operating costs between two types of valves by using their corresponding headlosses (H). For example, the difference in headloss between a 30 in. Silent Check Valve and a Tilted Disc® Check Valve operating at 26,500 gpm (12 ft/sec) is 5.82 ft., and assuming a combined pump and motor efficiency of 0.8, and a cost of electricity of $.08/kWh, the annual energy savings gained by using the Tilted Disc® Check Valve is $25,450. Over the 40-year life of the valve, the savings would be over $1.0 million. It is clear that the energy savings alone justifies the investment in Tilted Disc® Check Valves.

SURGE CONTROL

Sudden changes in flow velocity will cause a pressure surge or water hammer in a piping system, which can damage equipment. As a rule of thumb, the magnitude of the surge is typically 50 psi for every 1 ft/sec of velocity change. For example, if a flow of 8 ft/sec is suddenly introduced or stopped in a pipeline, a surge pressure as high as 400 psi above the static pressure may be produced. On long systems, the change in velocity produces a pressure wave which travels at the speed of sound in water from one end of the system to the other. The elapsed time is called the **Critical Time**. Any change in flow velocity that occurs within the Critical Time has the same effect as if the change occurred instantaneously (AWWA M11). For example, on a 5000 feet steel pipe, the critical time is about 3.3 seconds. Hence, a flow stoppage within 3.3 seconds will produce the same surge as if the flow was stopped instantaneously. Because of this principle, long systems require careful analysis and are usually computer modeled. Most systems greater than 3000 feet will have a surge protection system and possibly a pump control valve set to open and close very slowly, typically 5-10 times the critical time.

SINGLE PUMP SYSTEM

A single pump system or one where only one pump is operated at a time is illustrated in Figure 2. Tilted Disc® Check Valves are commonly used with both centrifugal and vertical turbine pumps which produce flow rates in the range of 4-20 ft/sec. and pressures to 300 psig. The water level on the suction side of the pump can be either above or below the pump as shown in Figure 2.

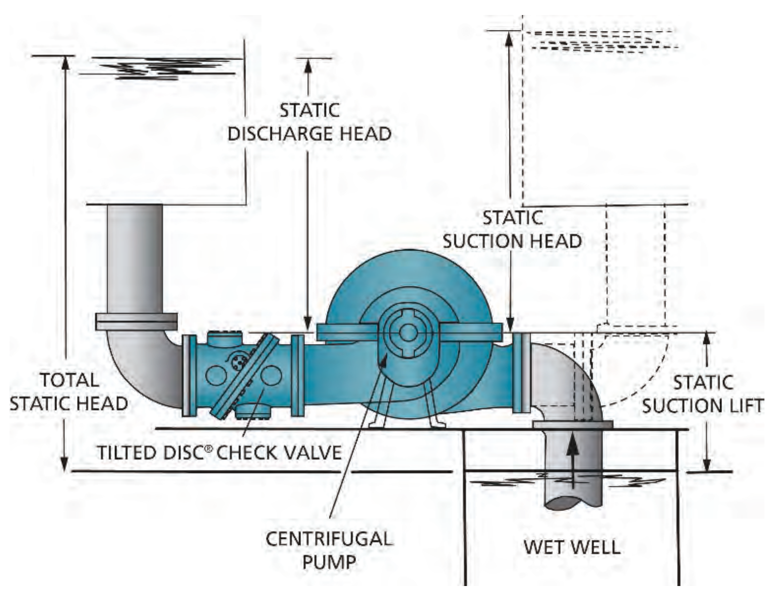

FIGURE 2. Single Pump System

The total static head and the system resistance (i.e., pipe friction) are used to determine the severity of an application. When the static head is high and the system resistance low, the system will have rapid flow reversal when the pump is stopped. Conversely, on low static head systems with high resistance, the flow reversal may take several seconds. On longer systems, the changes in velocity from starting and stopping pumps can cause surges which are relieved with the use of surge relief valves mounted on the discharge header. These valves typically sense the high and/or low pressure fluctuations and open to relieve water back to the wet well. On more severe applications, surge tanks can be employed.

MULTIPLE PUMP SYSTEM

Multiple pump systems are often used to help reduce surges, provide high system capacity, and provide for varying output flows to meet water demand. Surges are reduced in a multiple pump system because the pumps are started and stopped one at a time. The pumps, therefore, have a much smaller impact on the velocity changes in the main header. Also, by running a different quantity of pumps or different combinations of pumps, varying output flows can be produced. Depending on the system pressure, the check valves may need a dashpot because parallel pumps cause a rapid reversal of flow after shutdown. It should also be noted that after a power failure, the pumps stop simultaneously and cause a significant change in the pipeline velocity. For this reason, most multiple pump installations will often have surge relief valves or a surge tank.

CLOSED SURGE TANK APPLICATIONS

A common type of surge tank is called a hydropneumatic tank (Figure 3) because it is filled with both water and compressed air. The tank is connected to the discharge header. After pump shutdown or power failure, the tank forces water into the line to prevent column separation. A few seconds later, an upsurge in pressure occurs and water re-enters the tank dissipating the surge. In these applications, the check valve must close rapidly to prevent reverse flow through the pump after pump stoppage. Also, the surge tank pressure causes a rapid reversal of flow back toward the pump which may slam ordinary check valves. When used with surge tanks, check valves require a bottom mounted oil dashpot which will allow the valve to rapidly close, yet prevent slamming.

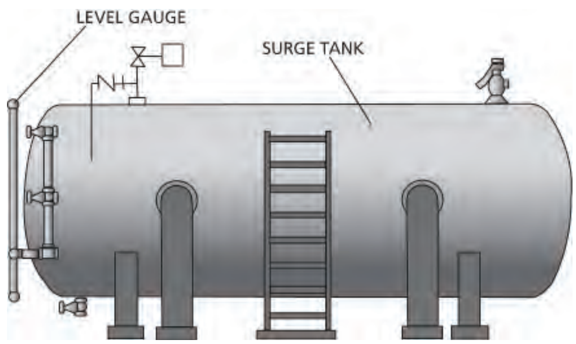

FIGURE 3. Typical Hydropneumatic Surge Tank

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APPLICATION CRITERIA

The general operating parameters for Tilted Disc® Check Valves are summarized in the table below. A comprehensive presentation of features and dimensions is presented in Val-Matic® Bulletin 9000.

The Tilted Disc® Check Valve is versatile and can be used in more demanding applications with the use of special materials of construction upon request. The valve is available in three configurations: base valve, bottom mounted oil dashpot and top mounted oil dashpot. It is important to note that the dashpot configurations include high pressure oil cylinders and full rated disc connections. With oil dashpots, the disc is rigidly controlled as opposed to an air cushion which only produces a mild damping effect.

Standard Operating Parameters	
Parameter	Typical Range of Use
Size Range	2 in. - 66 in.
Pressure Classes	125,150, 250, 300
Max Temperature	250°F
Flow Range	4-20 ft/sec.
Orientation	HORIZ OR VERTICAL
Connection	FLANGED: ANSI, ISO

TABLE 1. Operating Parameters

To select the proper valve configuration, several criteria must be considered. The number of pumps and the static head will affect how rapidly the water column will reverse when a pump is stopped. The type of pump control will affect the required closing characteristic of the valve. Typical types of control include on-off, soft-start, variable speed, and electrically operated control valves. The length of the piping system is used to estimate surges from changes in flow velocity. The type of surge relief system dictates the required closing time for the valve. Surge tanks require a quick-closing valve to prevent the loss of stored water back through the pump. The criteria listed in Table 1 are used to select the best valve configuration as follows.

1. Base Valve

The base valve features a short stroke angle of 40° which provides rapid disc closure in less than ½ second. This feature will provide non-slam closure in low service pumping applications. Basic valves are typically used when the static head is less than 100 feet in single or multiple pump applications. A common application is the filter backwash pumps in a water treatment plant.

2. Bottom Mounted Oil Dashpot

Dashpots are used on high service pumping applications where there is a propensity for rapid flow reversal. The bottom mounted dashpot (Figure 4) consists of a hydraulic cylinder and a snubber rod which contacts the disc during closing. A spring and oil accumulator are used to provide return force to the snubber rod and oil for the opening stroke to make up for the cylinder rod volume. The dashpot controls the last 10% of valve closure to reduce water hammer and prevent slamming of the disc. The valve is effective on shorter length systems with static heads up to the valve rating. The dashpot is also used on longer systems where rapid flow reversal occurs due to the use of surge tanks or in multiple pump systems. The dashpot is field adjustable with a speed control valve and typically set to control the last 10% of closure in 1-5 seconds. A greater closure time may produce excessive reverse flow through the pump.

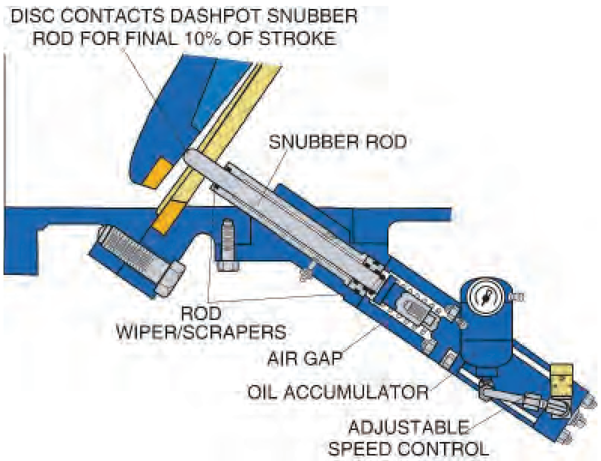

FIGURE 4. Bottom Mounted Oil Dashpot

3. Top Mounted Oil Dashpot

The top mounted oil dashpot (Figure 5) controls both the full opening and full closing stroke of the valve. Also, the last 10% of travel of valve closure is independently controlled by an adjustable internal hydraulic cylinder speed control. With the top mounted oil dashpot, the disc is mechanically linked to a hydraulic cylinder equipped with speed control valves. The high-pressure hydraulic cylinder and linkage are designed to withstand the full thrust of the disc when subjected to line pressure. An oil accumulator is used to provide return force to the linkage rod and oil for the opening stroke to make up for the cylinder rod volume.

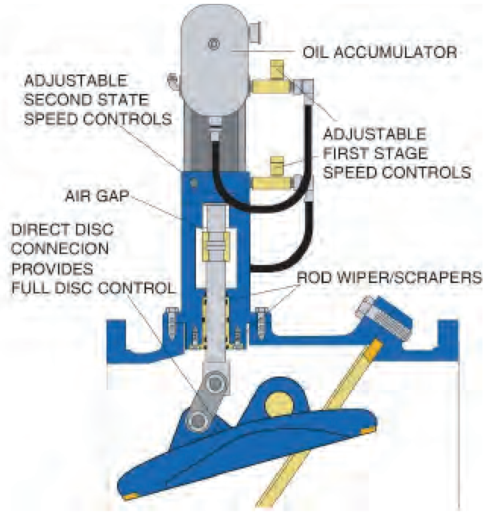

FIGURE 5. Top Mounted Oil Dashpot

Valves equipped with top mounted oil dashpots are used in high service applications up to the full flow and pressure rating of the valve. When there is insufficient space to provide the recommended 5 diameters of straight run of pipe between the pump and the valve, the top mounted dashpot will control the disc movement and prolong the life of the valve. The opening and closing strokes are field adjustable in the 5-30 second range. The final 10% of closure is adjustable in the 1-5 second range to prevent slam. By setting the valve opening time to 20 seconds, the system flow rate will rise to 50% in about 2 seconds which equates to the critical time period of a system 3000 feet in length. On longer systems, the dashpot may not have an appreciable effect on pressure surges; therefore, a surge analysis and surge equipment are recommended.

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On very long systems, where the critical time exceeds the 30 second closure of a top mounted oil dashpot, a power operated pump control valve is sometimes used. The control valve is electrically wired to the pump control and is programmed to slowly open and close to gradually change the flow rate in the system over a 60-300 second period. However, after a power outage, the control valve may not be capable of closing rapidly enough to prevent back spinning of the pump or loss of water from a surge tank. In these cases, a Tilted Disc® Check Valve is often installed upstream of the control valve.

INSTALLATION GUIDELINES

To ensure proper operation of the valve, several guidelines should be followed in the piping design. Table 2 presents general guidelines for valve selection.

1. The base valve can be installed in both horizontal or vertical flow-up runs. Valves in raw water service should be installed in horizontal runs to prevent debris from collecting on the disc.
2. The valve should be the same size as the discharge line and located a minimum of five straight pipe diameters from the pump or an elbow. If there is insufficient room to provide straight pipe, consider a top mounted oil dashpot to stabilize the valve operation.
3. An isolation valve such as an eccentric plug valve or butterfly valve should be installed downstream for servicing the pump and check valve. Butterfly valves should be located one diameter downstream to prevent disc interference.
4. A minimum velocity of 5 ft/sec is required to open the valve fully. If there is insufficient velocity, consider a top mounted oil dashpot to stabilize the valve operation.
5. Options include special materials for corrosive service, limit switches for remote valve indication, and bypass ports for backflushing suction lines.
6. For pipelines with velocities greater than 10 ft/sec and lengths exceeding 3000 ft, a water hammer or transient analysis should be conducted to determine the performance of the pump and valves together in controlling surges.

In Table 2, the application chart illustrates the range of use for three valve configurations: 1) basic valve, 2) bottom mounted oil dashpot, and 3) top mounted oil dashpot. For example, on a 2500 ft. long water transmission main operating at 150 ft. of head, a Tilted Disc® Check Valve with a top mounted oil dashpot would be selected. Or, if a surge relief system is provided, then the bottom mounted oil dashpot configuration can be used.

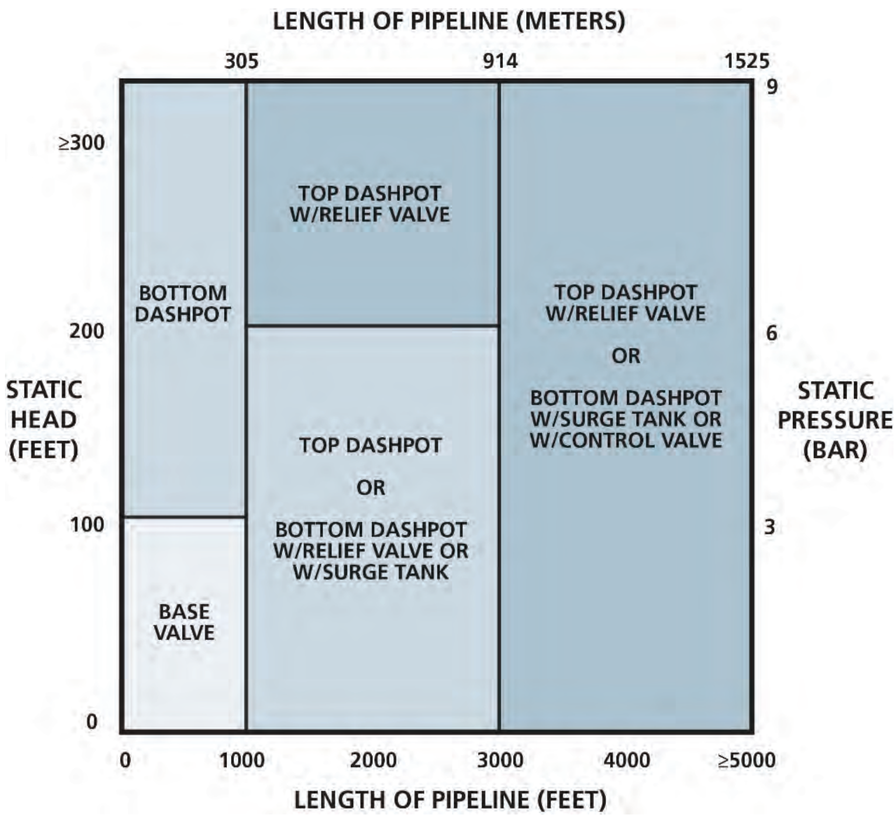

Table 2. Application Chart

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2. American Water Works Association, AWWA M49 “Quarter-Turn Valves: Headloss, Torque, and Cavitation Analysis”; 3rd ed., 2017, p 33.

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Disclaimer

Val-Matic White Papers are written to train and assist design engineers in the understanding of valves and fluid systems. Val-Matic offers no warranty or representation as to design information and methodologies in these papers. Use of this material should be made under the direction of trained engineers exercising independent judgement.

White Paper

Cavitation in Valves

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INTRODUCTION

Cavitation can occur in valves when used in throttling or modulating service. Cavitation is the sudden vaporization and violent condensation of a liquid downstream of the valve due to localized low pressure zones. When flow passes through a throttled valve, a localized low pressure zone forms immediately downstream of the valve. If the localized pressure falls below the vapor pressure of the fluid, the liquid vaporizes (boils) and forms a vapor pocket. As the vapor bubbles flow downstream, the pressure recovers, and the bubbles violently implode causing a popping or rumbling sound similar to tumbling rocks in a pipe. The sound of cavitation in a pipeline is unmistakable. The condensation of the bubbles not only produces a ringing sound, but also creates localized stresses in the pipe walls and valve body that can cause severe pitting.

Cavitation is a common occurrence in shutoff valves during the last few degrees of closure when the supply pressure is greater than about 100 psig. Valves can withstand limited durations of cavitation, but when the valve must be throttled or modulated in cavitating conditions for long periods of time, the life of the valve can be drastically reduced. Therefore, an analysis of flow conditions is needed when a valve is used for flow or pressure control.

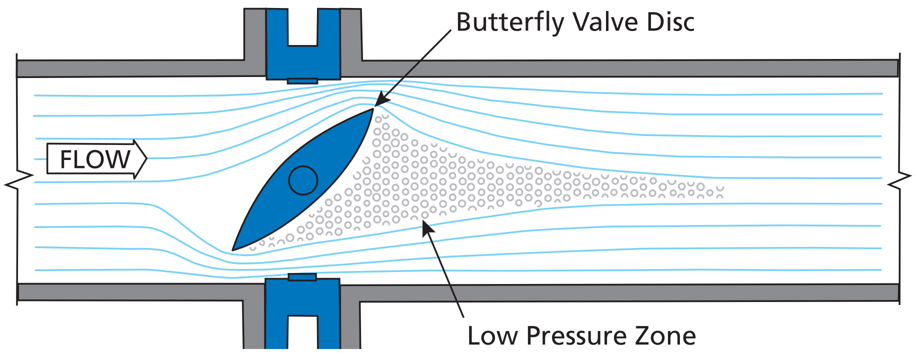

FIGURE 1. Cavitation

CAVITATION ANALYSIS

Three levels of cavitation have been defined:

- Incipient cavitation represents the beginning stage of cavitation where intermittent popping noises are heard.
- Constant cavitation is a steady rumbling sound associated with start of possible valve damage.
- Choked cavitation is the point where the vaporization of the fluid reaches sonic velocity in the valve port and limits the flow through the valve.

Val-Matic recommends that the constant cavitation data be used when judging the effects of cavitation on the life of the valve. If perfectly quiet operation is needed, then the factory should be consulted for incipient cavitation data. Only special control valves with cavitation trim (i.e. sleeve valves) should be used for choked conditions. A cavitation index can be calculated to predict whether cavitation will occur as follows:

$$\sigma = (P_u - P_v) / (P_u - P_d)$$

Where:

σ = cavitation index, dimensionless
P_d = downstream pressure, psig
P_v = vapor pressure adjusted for temperature and atmospheric pressure, psig
= -14.4 psig for water at 60°F, sea level
P_u = upstream pressure, psig

The lower the value for the cavitation index, the more likely cavitation will occur. As a rule of thumb, manufacturers typically suggest that when σ is less than 2.5, cavitation may occur.

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CAVITATION DATA

Val-Matic conducted flow tests on quarter-turn valves and developed cavitation coefficients for the valves as shown in the graph below. To use the graph, the required valve angle must be calculated using the flow coefficient data for the subject valve. Next, the cavitation index is calculated and plotted on the graph. If the point is below the graphed line, then constant cavitation will occur and prolonged throttling at that angle would not be recommended. Also, prolonged throttling below 10 degrees open regardless of the cavitation index is not recommended because high localized velocities may scour and wear the valve seating surfaces.

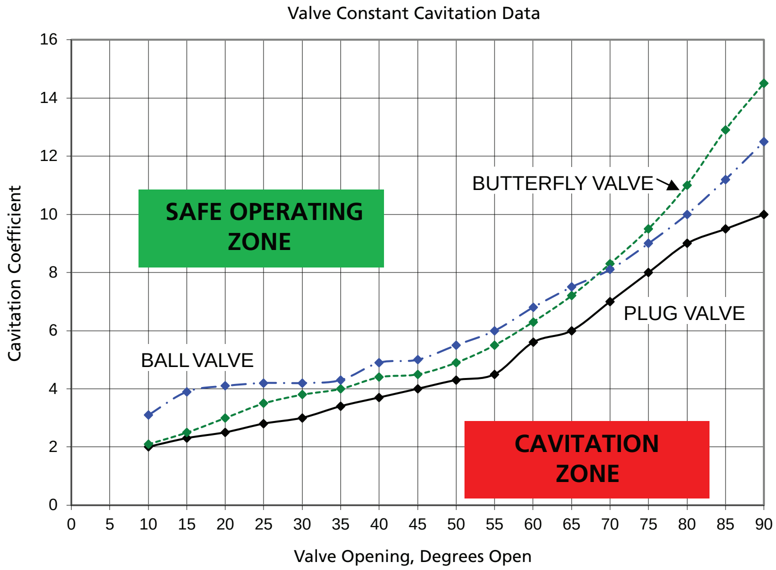

FIGURE 2. Cavitation Characteristics of Valves

VALVE COEFFICIENT DATA

To determine the required valve angle for a particular flow application, calculate the required valve Cv from the following equation:

$$\text{Required Cv} = Q / \sqrt{\Delta P}$$

where:

ΔP = valve differential pressure, psi
Q = desired flow rate, gpm

Given the required Cv, the angle of throttling can be found by dividing this required Cv by the full open Cv shown in the table below. This is the percent of full open Cv.

$$\% \text{ Cv} = 100 \times \text{Required Cv} / \text{Full Open Cv}$$

PLUG, BUTTERFLY, AND BALL VALVE FULL OPEN Cv FLOW COEFFICIENTS											
VALVE SIZE, in	3	4	6	8	10	12	14	16	18	20	24
Plug	524	932	1,840	2,680	3,770	4,800	7,170	8,600	12,600	15,400	25,600
Butterfly	380	590	1,430	2,750	4,300	6,550	8,350	11,800	15,000	18,600	27,000
Ball		1,910	4,310	8,520	14,700	22,800	30,500	42,700	56,100	70,500	106,000

VALVE SIZE, in	30	36	42	48	54	60	66	72
Plug	42,000	72,000	103,000	134,000	170,000	210,000	254,000	302,000
Butterfly	42,000	61,900	87,100	114,000	144,000	180,000	221,000	266,500
Ball	172,000	257,000	369,000	480,000	620,000	725,000		

Finally, by finding the percent of full open Cv on the vertical axis of the flow characteristic graph, the valve position in degrees open can be read off of the horizontal axis in Figure 3.

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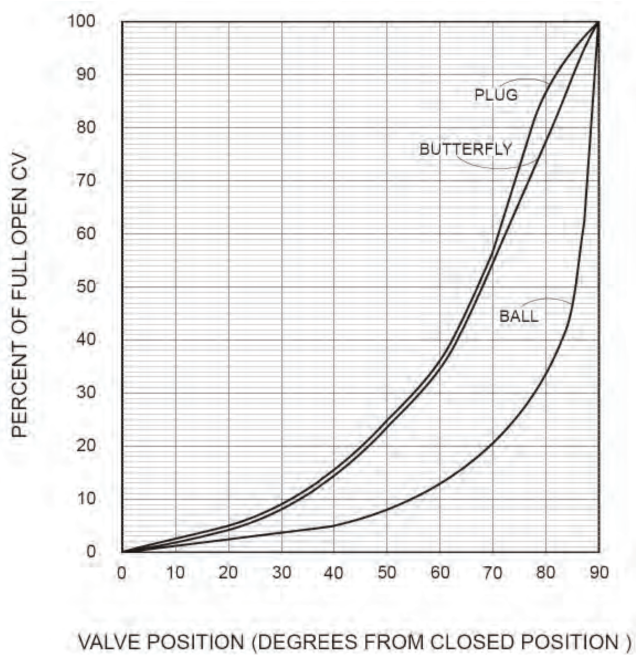

FIGURE 3. Flow Characteristics of Valves

The valve position in degrees obtained from Figure 3 and the cavitation index calculated above are then plotted on the graph in Figure 2. If the resultant point falls below the applicable valve curve, then serious cavitation may occur.

EXAMPLE APPLICATION

An 8 in. plug valve equipped with a modulating motor will be used in a backwash system to limit the flow rate to a sand filter. The upstream pressure is a constant 25 psig because the supply source is an elevated tank. The valve is mounted near the sand filter and will see a downstream pressure of 5 psig while controlling the flow rate to 300 gpm. At this flow rate, it was calculated that the valve must drop 6 psig. Therefore, P_u equals 5 + 6 or 11 psig.

1. Calculate the cavitation index:

   $\sigma = (P_u - P_v) / (P_u - P_d)$
   $\sigma = (11 - (-14.4)) / (11 - 5)$
   $\sigma = 4.2$

2. Calculate the required Cv:

   $Cv = Q / \sqrt{\Delta P}$
   $Cv = 300 / \sqrt{6}$
   $Cv = 122$

3. Determine the valve angle:
   The full-open Cv for the 8” valve is 2070.
   The percent of full open Cv is found by:

   % Cv = 100 x 122 / 2070 or 5.9%

   Referring to the plug valve characteristic curve in Figure 3, the throttling angle will be 22 degrees open.

4. Plot the cavitation index of 4.2 on the cavitation graph (Figure 2) with 22 degrees on the x axis. The point is above the cavitation line and is in the “Safe Operating Zone”, so cavitation will not be a problem.

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CONCLUSION AND RECOMMENDATIONS

Valve manufacturers can perform an analysis to predict when cavitation will occur based on flow test data. When cavitation is predicted, some available remedies include:

1. Increase the downstream pressure by throttling a downstream valve or installing an orifice.
2. Decrease the differential pressure by using two valves in series.
3. Use a small bypass line for low flow rates.
4. Install air inlet ports equipped with vacuum breakers immediately downstream of the valve to reduce the vacuum pocket.
5. Some valves can be furnished with cavitation reducing trim.

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VAL-MATIC®

White Paper

Pump Control Ball Valve for Energy Savings

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INTRODUCTION

An essential element in the design of water and wastewater pumping systems is the proper selection of the pump control valve, whose primary purpose is to prevent reverse flow when the pump is not in operation. A pump control valve must also be able to carefully and slowly control changes in fluid velocity to prevent water hammer or surges, especially in long pipelines. Another function that is often overlooked is the valve's ability to minimize energy consumption. It is estimated that water and wastewater plants consume nearly 80% of their costs to pump water and overcome pressure and friction losses. With proper valve selection to minimize valve headloss, significant energy savings can be achieved.

FIGURE 1. Pump Control Ball Valves in Ohio, USA

There are several types of pump control valves, including butterfly, ball, and eccentric plug valves, which are electrically wired to the pump control circuit to provide synchronized functions with the pump to systematically control the changes in pipeline fluid velocity over a long period of time (i.e. 60 to 300 seconds) to prevent surges in pipelines, force mains, and distribution systems. When selecting a pump control valve, you should consider performance, low headloss, and flow characteristics. This paper will therefore describe the advantages of using AWWA C507 ball valves for pumping applications.

PUMP CONTROL VALVES

When pumping systems are part of very long piping systems (i.e. 20,000 ft), pump control valves are necessary to control water hammer or pressure surges. Pump control valves are typically quarter-turn valves equipped with slow opening and closing electric motor or hydraulic cylinder actuators. The actuator is powered by an external electric or pressure source and must be electrically connected to the pump circuit for control purposes. The motion of the closure member in these valves is controlled by the power actuator so they are not subject to fluttering or slamming like automatic check valves. Battery systems or pressurized accumulator systems can be used to enable the pump control valve to close after a power failure. Alternatively, an automatic check valve such as an AWWA C508 Check Valve with low headloss can be used (see Figure 2) to prevent reverse flow after power failure. Finally, quarter-turn valves are designed to handle high fluid velocities (up to 16 ft/sec for butterfly valves and 35 ft/sec for ball valves) so they are often sized to be smaller than or equal to the pump discharge to provide improved flow characteristics.

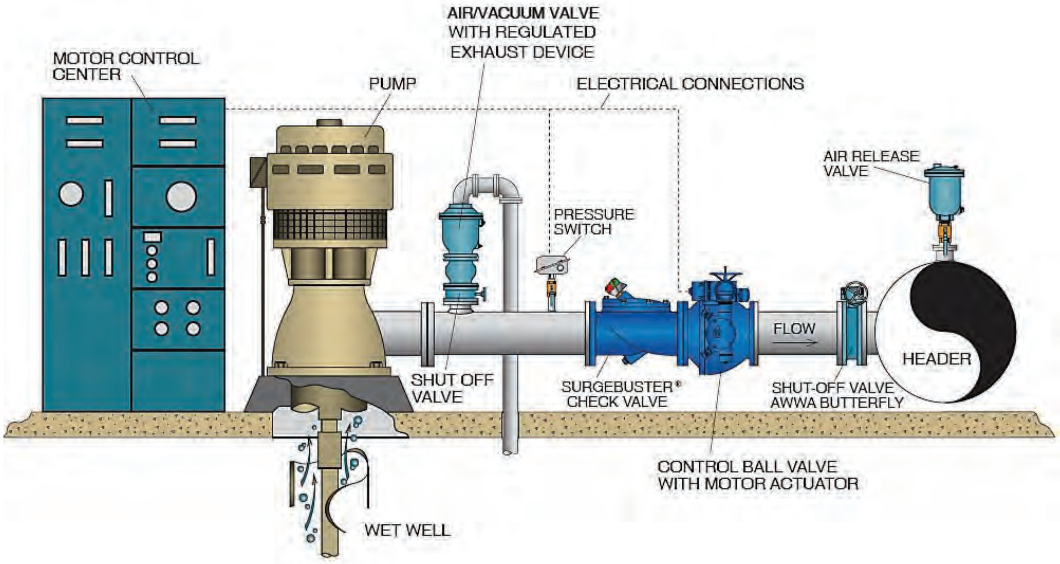

FIGURE 2. Typical Pump Control Ball Valve

Figure 2 illustrates a pump control ball valve installation. The ball valve is operated by rotating its shaft and closure member 90 degrees and is equipped with an electric motor actuator sized to operate the ball valve very slowly in five minutes. This ball valve is backed up by an AWWA C508 Check Valve for when all electrical power is lost. The ball valve works in harmony with the pump motor control center. When the pump is signaled to START, the pump develops pressure and a pressure switch signals the ball valve to slowly open. When the pump STOP signal is given, the ball valve closes, but the pump continues to run. When the ball valve is closed, or near closed, a limit switch signal from the valve actuator is given to the pump to STOP. This process assures that changes in fluid velocity from pump operation happen very slowly over several minutes thereby preventing surges.

When there is a power failure, the pump will stop in a few seconds and to prevent excessive back spinning, the pump control ball valve will close quickly in 5 to 10 seconds. This sudden closure of the pump control or check valve after power failure may cause a pressure surge, so surge relief equipment such as surge tanks or pressure relief valves are sometimes used. Because of the complexity of the pump inertia, valve closure, and pipeline hydraulics, a computer transient analysis is employed to verify that excessive surges will not occur.

HEADLOSS

The pump discharge head is needed to overcome the combination of the static head and the friction head of the distribution system. The static head represents the difference in elevation between the source and the highest point of water storage or service. The friction head is caused by roughness in the pipe and local flow disturbances such as fittings and valves. Pumping and distribution system valves come in many varieties, but they all cause some friction head.

Valve body geometry dictates the general flow area through the valve. Some control valves restrict the flow area to below 80% of the pipe area. Also, the internal contours of the body and seat should be smooth to avoid creating excessive turbulence. The design of the closure member is also important in reducing headloss. The lowest headloss will be achieved if the closure member rotates out of the flow path. The ball valve has the lowest headloss because when the valve is open, the flow path is the same as a straight length of pipe.

There are many flow coefficients and headloss formulas in general use today for rating various valves on the basis of headloss. Probably the most common flow coefficient for water valves is the C_v flow coefficient, which is defined as the amount of water in gallons per minute (gpm) that will pass through a valve with a 1 psi pressure drop. Hence, the more efficient the valve, the greater the valve C_v. C_v should only be used for computing headloss, not stating the valve's flow capacity. Table 1 illustrates typical flow coefficients for 12 inch pump control and check valves in order of increasing C_v.

Typical 12 inch Valve Flow Data			
Type of Valve	**Port Size**	**C_v**	**K_v**
MSS SP125 Silent Check Valve	100%	2,480	3.00
AWWA C508 Swing Check	100%	3,390	1.60
AWWA C517 Plug Valve	80%	4,770	0.81
AWWA C504 Butterfly Valve	90%	6,550	0.43
AWWA C507 Ball Valve	100%	22,800	0.03

TABLE 1. Valve Types and Flow Coefficients

Another flow coefficient to use for making comparisons is the resistance coefficient K_v used in the general valve and fitting flow formula:

$$\Delta H = K_v v^2 / 2g$$

Where:

ΔH	=	headloss, feet of water column
K_v	=	resistance coefficient (valve), dimensionless
v	=	fluid velocity, ft/sec
g	=	gravity, 32.2 ft/sec^2

The flow factor K_v can also be related to the C_v by the formula:

$$K_v = 890\, d^4 / C_v^2$$

Where:

d	=	valve diameter, inch

Finally, the flow conditions of the system can affect the valve headloss. From the ΔH equation, it is clear that headloss is a function of fluid velocity squared. Hence, a doubling of the line velocity will increase the pipe, fitting, and valve head losses four-fold. This is why pump discharge velocities are usually designed for 8 to 10 ft/sec fluid velocity and long pipeline velocities, 4 to 6 ft/sec. There is an optimum pipe size and velocity that provides the least installation costs and annual operating costs.

ENERGY CALCULATIONS

It has been estimated that the water and wastewater plants in the United States consume 75 billion kW·h of energy annually. Nearly 80% of that energy is consumed for high service pumping costs to overcome the static head and friction losses of distribution systems. The headloss from valves can be converted into an energy cost related to the pumping electrical power needed to overcome the additional headloss from the valve with the equation (AWWA, M49):

$$A = (1.65\, Q\, \Delta H\, S_g\, C\, U) / E$$

Where:

A	=	annual energy cost, dollars per year
Q	=	flow rate, gpm
ΔH	=	head loss, ft. of water
S_g	=	specific gravity, dimensionless (water = 1.0)
C	=	cost of electricity, $/kW·h
U	=	usage, percent x 100 (1.0 equals 24 hr per day)
E	=	efficiency of pump and motor set (0.80 typical)

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Alternatively, the energy consumption difference between two valve selections can be calculated by using the headloss difference between the two valves for the variable ΔH in the equation above. For example, the difference in headloss between a 12-in. silent check valve and an AWWA ball valve in a 4500 gpm system operating 50% of the time with an energy cost of $.08/ kW·h can be calculated as follows:

$$\Delta H = (3.00 - 0.03)\,(12.7)^2 / 2 \cdot 32.2$$
$$= 7.44 \text{ ft. wc}$$
$$A = (1.65 \times 4500 \times 7.44 \times 1.0 \times 0.08 \times 0.5) / (0.8)$$
$$= \$2{,}762$$

The calculation shows that the use of a 12-in. AWWA ball valve in the place of a 12 inch silent check valve can save $2,762 per year in energy costs. If the pump station had four such valves operating for forty years, the total savings will be $442,000 over the life of the plant. Therefore, it is clear that valve selection can play an important role is energy savings.

FLOW CHARACTERISTICS

When the fluid velocity is changed in a steel piping system, the kinetic energy of the fluid can generate high surge pressures equal to about 50 psi for every 1 ft/sec of sudden velocity change. The pressure spike causes the noise that shakes the pipes in a building when a valve is quickly closed. In piping systems, the surge pressure travels along the pipeline and is reflected back to the pump. This time period, often called the "critical period", can be calculated by the equation:

$$t = 2L / a$$

Where:

- t = critical period, sec
- L = length of the pipe, ft
- a = speed of the pressure wave, ft/sec

For a 12 inch pipeline, the critical period would be as follows for a 4 mile long steel pipeline:

$$t = 2\,(21{,}120 \text{ ft}) / (3{,}500 \text{ ft/sec})$$
$$t = 12 \text{ sec}$$

Surprisingly, any change in velocity that occurs within the critical period is the same as if it occurred instantaneously. Hence, when a pump is started and stopped in a long piping system, its 6 ft/sec change in velocity will automatically cause a surge equal to about 300 psi, which is added to the static pressure. Such a pressure is likely beyond the safe operating pressure of the system so a surge control strategy will be required.

Typical surge strategies can include multiple pumps, surge tanks, relief valves, variable speed pumps, pump control valves, or some combination of the above. When a pump control valve is used as the check valve, its flow characteristic contributes significantly to its effectiveness. The most desirable flow characteristic of a valve is one where the valve uniformly changes the flow rate when installed in the system.

The flow data typically published by valve manufacturers are inherent flow characteristics usually expressed in terms of the flow coefficient (C_v) at various positions. By assuming a constant pressure drop of 1 psi across typical valves at all positions, the inherent characteristics of the valves can be compared as shown in Figure 3 on the following page. On the left side is a quick-opening valve curve (such as a gate valve or swing check valve), which depicts a rapid change in the flow rate as the valve opens. On the other extreme is an equal percentage valve (such as a ball valve), which changes the flow rate uniformly with valve travel. However, these readily available curves only consider the valve headloss and ignore the system headloss. Inherent curves may be misleading when selecting a valve for a pumping system with long pipelines.

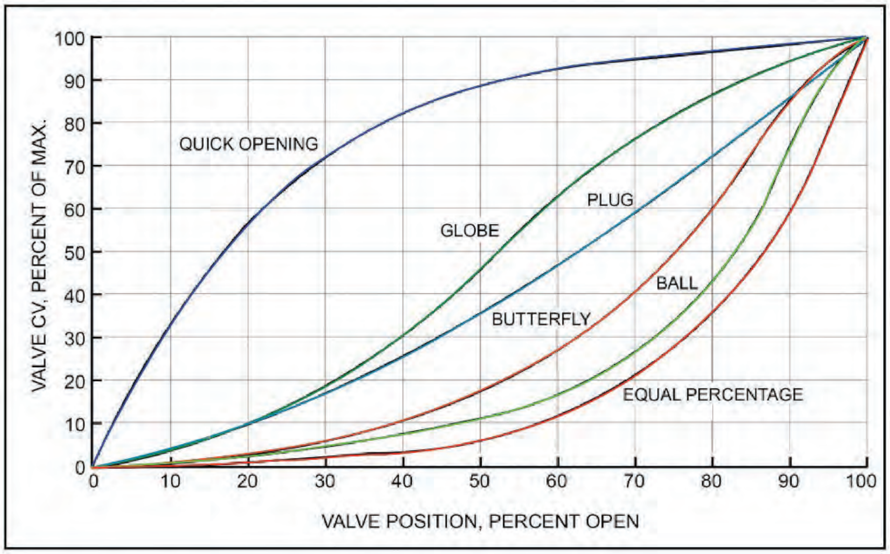

FIGURE 3. Inherent Flow Characteristics

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The inherent characteristic curves must be transformed for a given pipeline application to consider the relative headloss of the piping system. So when a valve such as a ball valve is installed in a pipeline, the location of the curve varies with the length of the pipeline as shown in Figure 4 on the following page. The curve shown on the right is the <u>inherent</u> flow characteristic curve because the system is zero feet long. The other curves are <u>installed</u> flow characteristic curves because they vary with the system length. As the length of the pipeline increases, the characteristic curves for the same valve shifts to the left. Hence, the same valve can be very close to equal-percentage in one system and quick-opening in another.

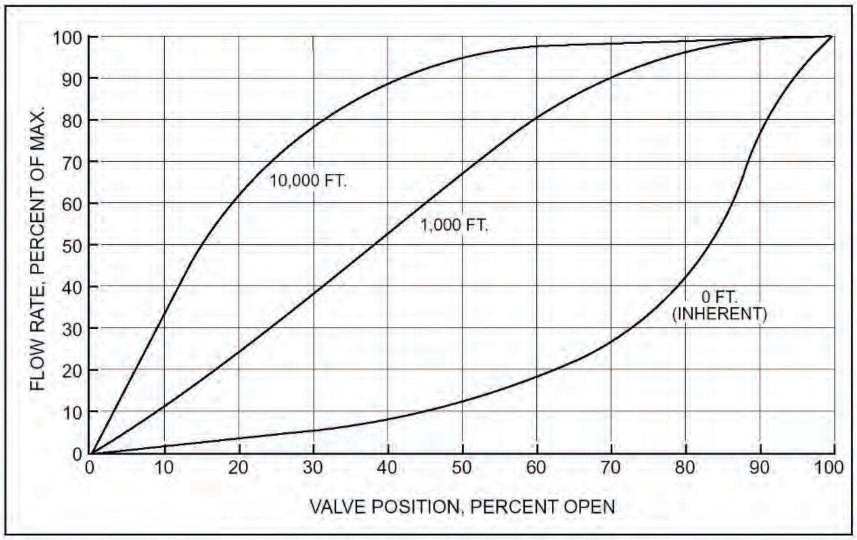

FIGURE 4. Installed Flow Characteristics

The longer the pipeline, the more the valve tends to be quick-opening. A quick-opening valve will change the flow suddenly and is more apt to cause surges because it effectively controls the flow for only one half of its travel. Ideally, the most desirable <u>installed</u> flow curve for a pumping system is linear such as the curve in the middle. Therefore, since inherent curves shift to the left when the system is included, the valve with an equal percentage <u>inherent</u> curve is the most desirable. Referring again to Figure 3, the most desirable valve for a long systems would be an equal percentage ball valve.

But the flow curves can also be affected by size in addition to type. For example, installing an 8 inch valve in a 12 inch system will shift the curve back to the right as shown in Figure 5. The shift is logical because an 8 inch valve will decrease the flow more rapidly than a 12 inch valve in the same system. So when selecting a valve, the size and its maximum flow velocity is as important as the type. Ball valves are commonly smaller than line size because of their low headloss and ability to operate at velocities up to 35 ft/sec.

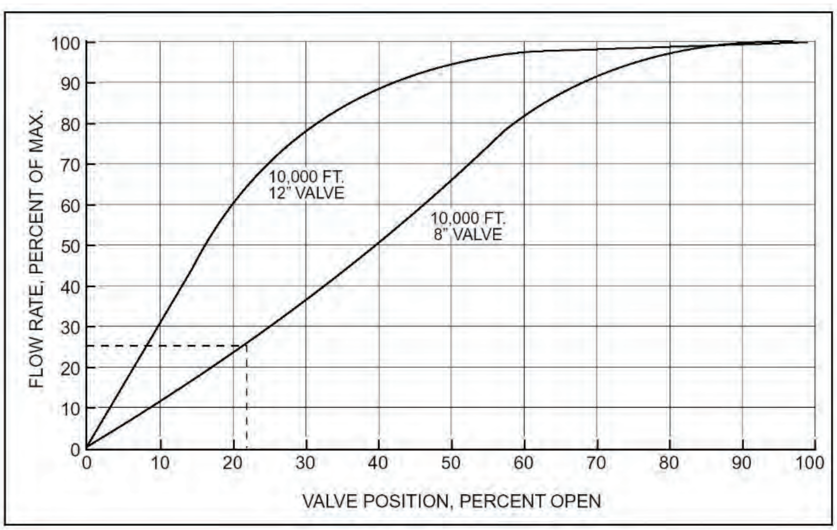

FIGURE 5. Installed Flow Characteristics By Size

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CONCLUSION

Because AWWA C507 ball valves have the lowest headloss and best flow characteristic, they are the preferred valve for pump control for both water and wastewater service. Ball valves can be equipped with electric motor or hydraulic actuators for reliable pump control service.

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VAL-MATIC®

White Paper

Manual Quarter-Turn Valve Actuators

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INTRODUCTION

Butterfly and ball valves are typically supplied with either a traveling nut or worm gear type actuator. Both types are listed in the applicable AWWA Valve Standards, C504 and C507. Each type has some important characteristics that affect the performance of the valve assembly and should be understood before selecting the best actuator for a particular application.

TRAVELING NUT ACTUATOR

A common type of actuator provided with quarter-turn valves is the traveling nut actuator. It has been around for over 50 years and is provided in two designs the slotted lever and the link and lever. The traveling nut actuator was created to match the torque characteristics of butterfly and ball valves which have high seating torque. Therefore, a higher mechanical advantage at the end of travel is often desirable.

The traveling nut actuator consists of a sealed housing, threaded stem, threaded nut, and either a slotted lever or a link and lever. As the threaded rod is turned with the handwheel, the nut is driven to the left and right and supported by milled slots in the housing and cover of the actuator. (Figure 1) The nut in turn drives the lever, which in turn drives the valve shaft through 90 degrees of travel.

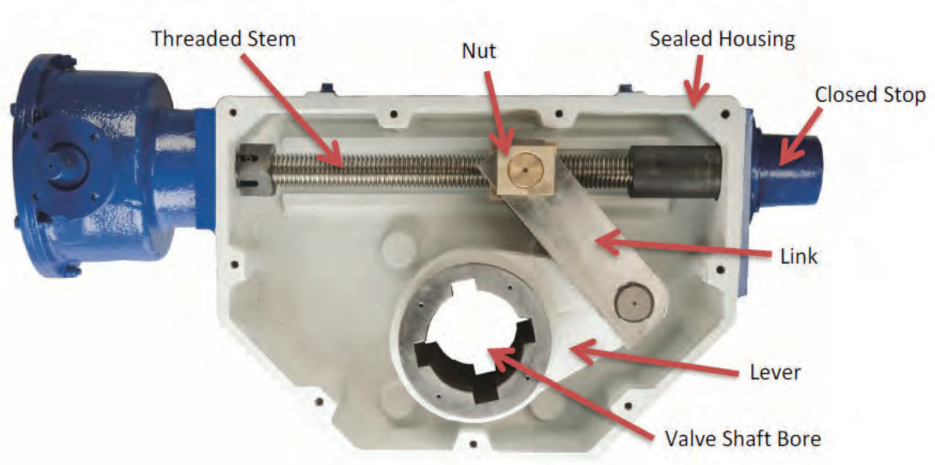

FIGURE 1. Link and Lever Traveling Nut Actuator

On a link and lever traveling nut actuator, the traveling nut is connected to the lever with a link. When the nut is at the right side of the housing in the photo, the link is near vertical orientation. At this location, travel of the nut provides a small change in lever rotation. Hence, at the right end (closed position) the mechanical advantage of the actuator can be twice that in the center or left position. The traveling nut actuator therefore matches the torque requirements of the valve.

On a slotted lever traveling nut actuator, the traveling nut acts directly on the lever. In this design, the lever as a slot in which the traveling nut slides as it moves along the threaded stem. On a standard slotted lever actuator, at either the left or right end of the stem, travel of the nut provides a small change in the lever rotation and resulting in greater mechanical advantage.

A traveling nut operation can vary from 10 to 100 turns, and for large valves (i.e. greater than 36 in.), spur gears or bevel gears are provided. The closed and open stops of these actuators are typically threaded nuts that are pinned to the threaded stem for link and lever actuators. Because a high amount of torque can be resisted between two nuts jammed together and because the stop design does not apply a load to the housing, the stops are usually rated to 450 ft-lbs. This high torque rating prevents many valve failures in buried service. Val-Matic offers a special externally adjustable closed stop where the adjustment nut extends through the housing for easy access (Figure 1). The stops of a slotted lever actuator are external bolts with lock nuts (Figure 2).

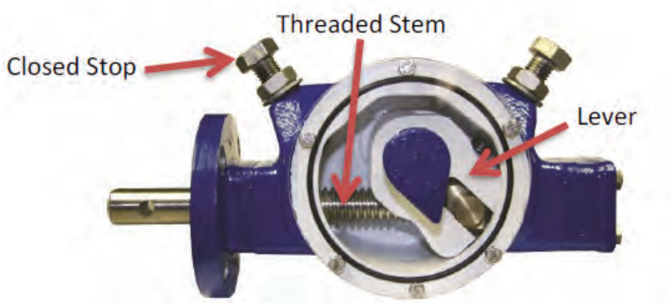

FIGURE 2. Slotted Lever Traveling Nut Actuator

Traveling nut actuators are usually constructed of an iron housing, steel links, and a ductile iron lever and are more economical than worm gear actuators. They are more economical than worm gears because the bronze worm gear is not needed, and they provide their greatest mechanical advantage at the closed position to match the requirements of the valve. Traveling nut actuators are the standard actuator for most AWWA butterfly and ball valve manufacturers. These actuators are designed and made by each valve manufacturer and designed specifically for these valves.

WORM GEAR ACTUATORS

Early butterfly and ball valves were provided with worm gear type actuators, which feature a sealed iron housing containing a hardened steel worm that drives a large gear, sometimes called a segment or sector gear. Adjustable bolts are provided to limit the travel of the actuator and precisely position the valve in the open and closed positions.

A basic worm gear actuator converts about 20 turns of the input shaft rotation into the 1/4 turn necessary to operate the butterfly valve. This operation translates into a mechanical ratio of about 80:1. However, with consideration to the friction in the gear faces, the efficiency of the actuator is only about 30% resulting in a mechanical advantage of about 25:1. Hence, if it takes 500 ft-lbs on the valve stem to operate the valve, then the input torque needed on the actuator is only 500/25 or 20 ft-lbs. When the input torque exceeds 150 ft-lbs or 80 lbs pull on the handwheel, spur gears are provided on the input side of the housing to provide additional mechanical advantage.

Worm gear actuators can be provided with handwheels for above ground service or 2 in. AWWA nuts for buried service. For buried service, the input shaft is made corrosion resistant stainless steel, the housing is packed with grease, and the indicator is replaced with a blind cover. One limitation of the worm gear actuator is that the closed stop design is usually limited to a torque of 300 ft-lbs because all of the torque is transmitted to the housing as force against the stop bolt. When a valve is buried, maintenance workers can sometimes exceed that torque and damage the actuator.

The worm gear actuator is a reliable actuator and is available from many alternate suppliers. However, its cost can be high given that its linear torque characteristic does not match the characteristic of the valve. It also provides external closed stop adjustment, which can be helpful in above ground applications.

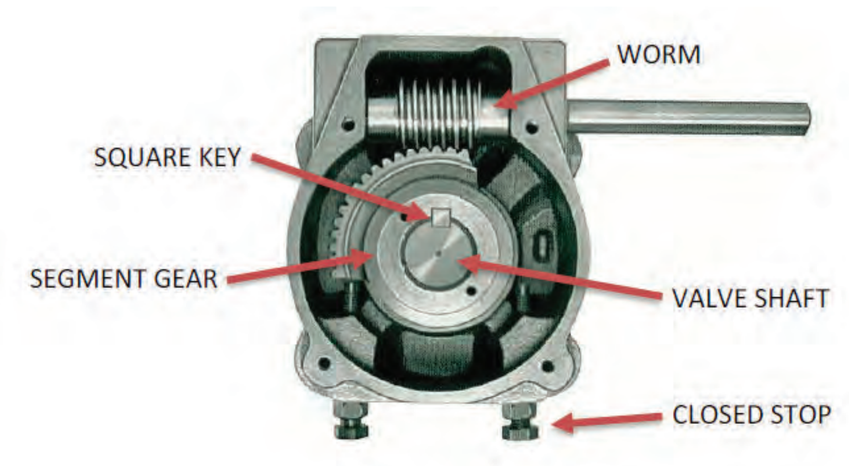

FIGURE 3. Worm Gear Actuator

ACTUATOR OPERATING CHARACTERISTICS

The last important consideration in selecting an actuator is the different operating characteristic of the two types. The worm gear has a linear characteristic which means that for every turn of the handwheel, the valve is rotated the same amount. Traveling nut actuators, on the other hand, exhibits “characterized closure.” For a link and lever actuator, characterized closure means that during the first half of closure, the valve shaft is rotated rapidly, and during the last half of travel, the valve shaft is rotated slowly toward the closed position. For a standard slotted lever actuator, characterized closure means that during the last portion of travel the valve is rotated slowly into the closed position. During the midstroke of travel, the valve is rotated more rapidly. This difference in travel is a result of the geometry of the link and lever or slotted lever mechanism. The benefit of characterized closure is that the valve is closed during its last portion of travel slowly, which can reduce pipeline surges or water hammer.

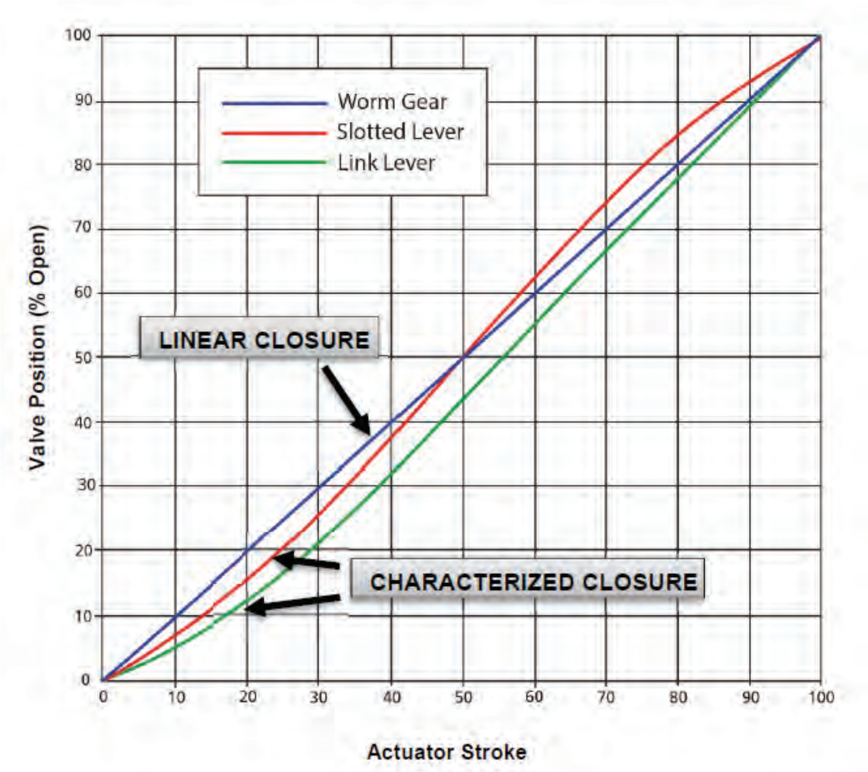

FIGURE 4. Actuator Operating Comparison

CONCLUSION

In the waterworks valve industry, about 75% of the manual actuators provided today are of the traveling nut type. In the wastewater industry it is predominately plug valves with worm gear actuators. Traveling nut actuators are more economical than worm gears, withstand higher input torques, and provide characterized closure. Given all of its advantages, the traveling nut actuator continues to be the most preferred actuator for butterfly and ball valves.

White Paper

The Case for Tangential Wedge Pins in Quarter-Turn Valves

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INTRODUCTION

There are many possible ways to attach the closure member of a quarter-turn valve to the valve's actuating shaft. This connection sees loads primarily based on the actuating torque requirements. Other tensile or compression loads from the fluid pressure, temperature, and flow are relatively small by comparison and for the purposes of this paper may be ignored.

This connection must transmit high torque loads which are often fluctuating from turbulent fluid flow and change rotation direction with each opening and closing stroke. This connection must also be tight and free of hysteresis as these valves are often used in throttling and even in on-off service must repeatedly position the closure member accurately into the seat.

Figure 1 depicts several of the most common shaft-to-disc connection methods. These are:

A	Square or rectangular key	G	Centered Taper Pin
B	Round Key	H	Centered Rivet Pin
C	Flat Key	I	Tangential Straight Pin
D	Kennedy Keys	J	Tangential Taper Pin
E	Centered Straight Pin	K	Tangential Wedge Pin
F	Centered Roll Pin		

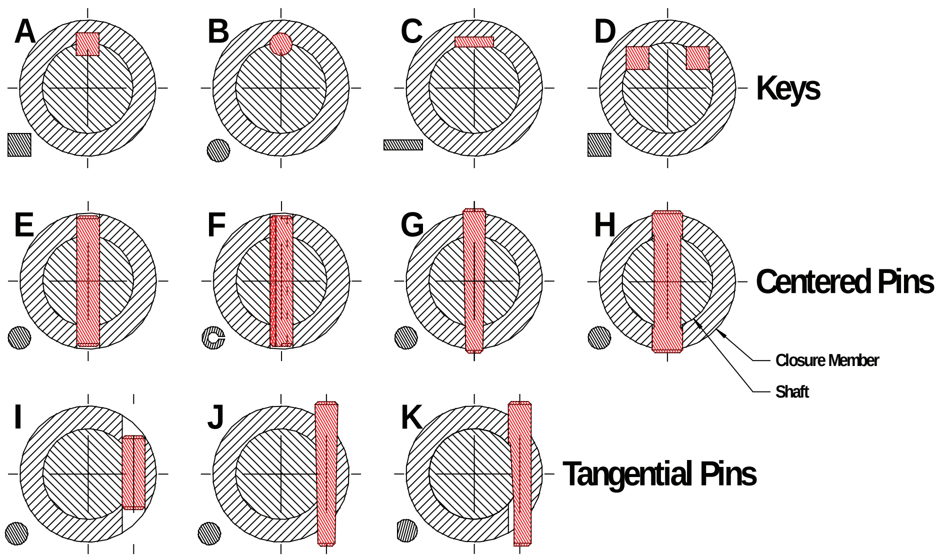

Figure 1: Typical Quarter-Turn Valve Shaft to Closure Member Connection Types

ANALYSIS

The first four keyed connections (<u>A through D</u>) are not typically used because the installation and removal of the key is often impossible in many valve designs. Even when the design is such that this connection can be used there is an amount of hysteresis in the connection unless the keys are tapered, interference, or shrink fitted. In either case, a hysteresis free connection is not well suited to mass production techniques, is not an interchangeable design or is not easily repaired in the field. Therefore these connections are not popular in quarter-turn valves.

The next two straight centered pin connections (<u>E and F</u>) also have some major drawbacks. First there is an amount of hysteresis when using the typical mass production machining fit dimensions. Use of precision fit dimension tolerances, interference, or shrink fit techniques here is also costly and not well suited for mass production and economy as well as parts interchangeability. Use of distorted locking, spiral rolled and "C" form spring type pins reduce the hysteresis initially but tend to loosen in service because of the highly reversing torque requirements. Next, the hole through the center of the shaft removes a large amount of the shaft's cross-sectional area and causes stress concentration factors in the valve shaft of values greater than 2.1 to as much as 4.6 for most optimal pin diameters of about 20% to 40% of the shaft diameter.

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This reduces the strength of the shaft significantly and the size of the pin must be balanced with the shaft diameter based on the relative strengths of the shaft, the closure member, and the pin materials to optimize the joint strength. As a result, these first six connections are not often used of quarter-turn valves.

The next two straight centered pin connections (G and H) are often used as they are tight fitting (little or no hysteresis) and are suitable for mass production. Like the E and F centered pin connections, these joints are susceptible to high shaft stress concentration factors and the relative size of the pin to the shaft should be optimized based on the relative strengths of the three materials (shaft, closure member, and pin).

The taper pin of the type G connection makes this assembly non-interchangeable as the shaft and closure member must be match taper reamed for the taper pin. Therefore the shaft, closure member, and taper pin(s) must all be replaced or repaired together and considered a single, matched set rather than three separate components. The tapered pin is often held in place with a secondary pin, set screw, nut or threaded fastener which keeps it from loosening in service.

The centered rivet pin of the type H connection is formed with the pin hole in the shaft being slightly larger than the diameter of the pin and the pin hole in the closure member being slightly greater than the pin hole in the shaft. When assembled in the valve body the entire valve assembly is placed in a press and the pin is loaded and is deformed. As the pin is loaded axially in the press above the yield point of the pin it increases in diameter to fill the pin holes in both the shaft and closure member. This connection is tight, does not have any hysteresis, and suitable for mass production. The drawback to this structure is that it cannot be disassembled without destroying the pin. Also reassembly requires the use of a large pin press. As with all centered pin connections (E through H), this connection reduces the strength of the shaft significantly and the size of the pin must be balanced with the shaft diameter based on the relative strengths of the shaft, the closure member, and the pin materials to optimize the joint strength. Also, if coupled with brittle shaft or closure member materials (e. g. cast iron) it is easy to induce fractures.

The connections I through K employ pins that are located tangentially to the shaft. This connection removes less than half of the shaft material necessary for a centered pin and tremendously reduces the stress concentration factors. Although this arrangement creates stress concentrations in the shaft and closure member, the magnitude of the concentration is much lower. In this case, stress concentration factors in the shaft are only about 1.35 to 2.1 for pin diameters from 20% to as high as 58% of the shaft diameter. This means that the joint strength is increased, the pin to shaft diameter ratio is not as critical and stronger (larger) pins can be used without reducing the shaft strength.

The type I, straight tangential pin, connection does still have issues with hysteresis and mass production like the other straight pin designs but the types J and K (tangential taper pin and tangential taper wedge pin are tight fitting connections.

The reason tangential wedge pins cause much lower shaft stress concentration factors than centered taper pins can be easily seen by comparing the amount of shaft area lost in both the installations. As displayed in Figure 2 the taper pin installation reduces the shaft cross-sectional area by 31.5% while the tangential wedge pin only reduces the cross-sectional area by 7.2%. Additionally, the diameter of the wedge pin can be increased for greater contact area with the shaft without changing the shaft cross-sectional area.

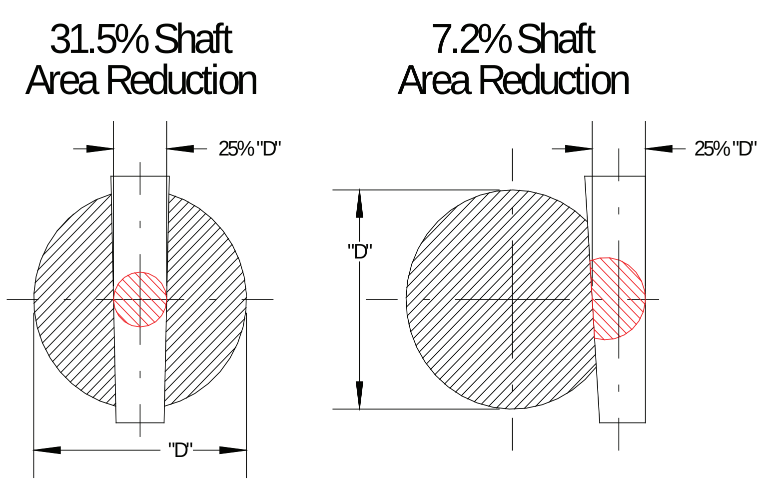

Figure 2: Shaft Cross-Sectional Comparison between Centered Taper Pin and Tangential Wedge Pin Installations

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DESIGN SELECTION

In the design of any product it is normal that there are many juxtaposed requirements or traits that can make selection of a specific element unclear. When confronted with such a task it is best to select the 5 most important design qualities and rate all of the designs for each of these on a three level ranking system (e.g. good, moderate, poor or good, better, best). In this case we selected the following 5 design characteristics for rating each connection type

1. Suitability for high production techniques
2. No or low joint hysteresis
3. Part interchangeability
4. Low stress concentration factors
5. Ease of field repair

The following table shows how we rated each design against each of these characteristics.

Type	Description	Suitability for High Production	Low Hysteresis	Parts Inter-changeability	Low Stress Concentration Factors	Ease of Field Repair
A	Square / rectangular key	Good	Moderate	Good	Moderate	Good
B	Round key	Good	Moderate	Good	Moderate	Good
C	Flat key	Good	Moderate	Good	Moderate	Good
D	Kennedy keys	Moderate	Moderate	Good	Moderate	Good
E	Centered straight pin	Good	Moderate	Good	Poor	Good
F	Centered roll pin	Good	Poor	Good	Poor	Good
G	Centered taper pin	Poor	Good	Poor	Poor	Moderate
H	Centered rivet pin	Good	Good	Good	Poor	Poor
I	Tangential straight pin	Good	Poor	Good	Good	Good
J	Tangential taper pin	Poor	Good	Poor	Good	Moderate
K	Tangential wedge pin	Good	Good	Good	Good	Good

CONCLUSION

The tangential wedge scored the highest in all of the characteristics selected as being the most important to the design of this critical valve joint. Val-Matic uses this connection as the preferred method for its quarter-turn valves.

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White Paper

Eccentric Plug Valves

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INTRODUCTION

Wastewater systems present many challenges to pumps and valves because wastewater can contain grit, solids, and debris depending where in the process the equipment is located. First used in the 1930's in paper industry, the eccentric plug valve can handle fluids with solid content like a gate valve, but also provide some important advantages of a quarter-turn valve such as modulating service. These plug valves consist of a cast iron body and bolted removable cover.

The plug has a resilient coating for sealing against a nickel welded seat in the body. The valve shaft is typically integrally cast as part of the plug and rotates in stainless steel bearings in the bottom of the body and the cover. In Figure 2, the plug valve is actuated with a worm gear actuator, which is necessary on valves larger than 8 in.

FIGURE 1. Installation of 24 in. plug valve in a vault in Collingwood, Ontario.

ECCENTRIC ACTION

The most unique feature of this valve is that its seat is offset from the valve shaft thereby providing eccentric action. Figure 3 illustrates the offset centerlines of the seat and shaft. A mid-size valve may have a ½ in offset. As the valve opens counterclockwise about the shaft, the plug will lift off the seat as it rotates. The lifting action helps prevent wear in gritty wastewater service. The sealing function of the valve is assisted by the "direct pressure", which pushes the plug tightly into the seat. The valve will also seal with pressure in the "reverse pressure" direction, but the plug will need to be turned clockwise past the center of the seat. Because of the eccentric action, the greater the closing rotation, the tighter the seal. In service, if the valve becomes worn, it can be closed further to restore a leak-tight seal.

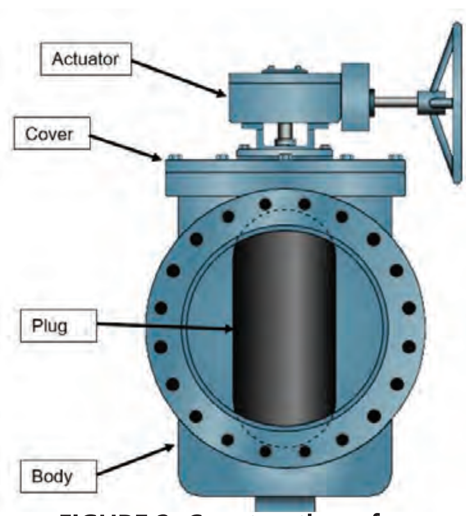

FIGURE 2. Construction of an Eccentric Plug Valve

PLUG VALVE STANDARDS

The eccentric plug valve was first standardized in MSS Standard SP-108 in 1991. As the American Water Works Association expanded into wastewater applications, they published AWWA Standard C517 in 2005. Both standards are congruent with similar materials of construction and scope. Eccentric plug valves are provided in the size range of 3 in through 72 in with a CWP pressure rating of 150 or 175 psig depending on size and have a flow rating of 8 ft/sec. The valves are provided in short-body and long-body configurations. The valves are seat tested in the direct pressure direction unless otherwise specified.

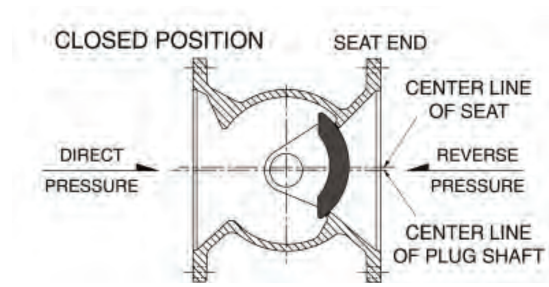

FIGURE 3. Eccentric Plug Valve Geometry

Despite published standards, there are alternate plug valve designs available that comply. The most common design has a cylindrical plug face and cylindrical seat, see Figure 2. The cylindrical seat provides a relatively wide sealing surface. Alternatively, the port and plug face can be round, similar to a half ball valve. While a round port can have a less restricted flow way, it may have a thinner seating surface contact area and be subject to greater wear and misadjustment than a cylindrical seat design. Both styles, rectangular and round, can be provided with standard 80% port openings or full 100% port openings. Finally, plug valves can be provided with metal-to-metal seats for severe applications such as activated sludge service.

PLUG VALVE INSTALLATION

Because of the geometry of the eccentric plug valve and its use in wastewater service, special installation recommendations should be followed. As shown in Figure 4, when settling solids are expected, the valve should be installed with the shaft horizontal so that when the valve is open, the plug is at the top of the pipe. Also, the seat end should be towards the pump so that when the pump is off, the system pressure pushes the plug into the seat.

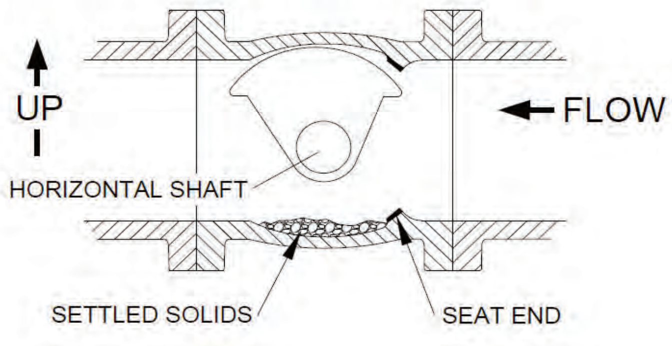

FIGURE 4. Horizontal Installation Guidelines

As shown in Figure 5, for vertical pipes regardless of flow direction, the valve should be installed with the seat end up so that settled solids will not collect in the valve when closed.

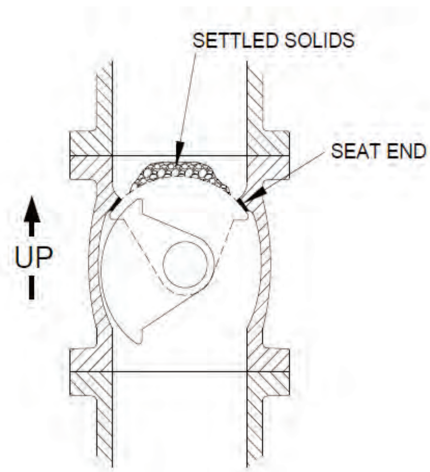

FIGURE 5. Vertical Installation Guidelines

Figure 6 illustrates the construction of a worm gear actuator. A worm gear actuator has a segment gear and worm that converts many turns of a handwheel or nut into one-quarter turn operation of the valve. The gear also provides mechanical advantage so that large valves can be operated easily with no more than 80 pounds pull on a handwheel. The gear is equipped with external open and closed stop bolts. The closed stop positions the plug in the seat to provide smooth operation and a leak tight seal. If leakage is found in the field, the closed stop bolt can be adjusted to allow the plug to rotate further closed and provide a tighter seal. The worm gear can be equipped with a multi-turn motor to allow the valve to be operated automatically or modulated in response to a process signal.

CONCLUSION

The resilient-seated eccentric plug valve is a unique valve in that it is designed to handle wastewater fluids and when equipped with rubber or glass lining, can handle abrasive fluids. Because it is a quarter-turn valve, it is easily automated for controlling process flow or pressure.

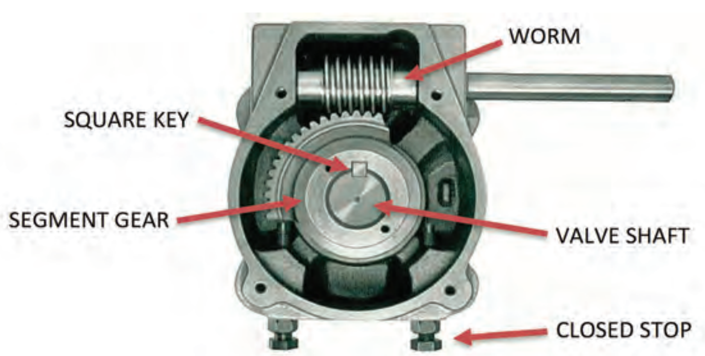

FIGURE 6. Plug Valve Worm Gear Actuator

White Paper

Surge Control in Pumping Systems

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INTRODUCTION

Water pipelines and distribution systems are subjected to surges almost daily, which over time can cause damage to equipment and possible contamination. Surges are caused by sudden changes in fluid velocity and can be as minor as a few psi to five times the static pressure. The causes and effects of these surges in pumping systems will be discussed along with equipment designed to prevent and dissipate surges. Only with the knowledge of all of the associated valves and surge equipment can a successful pumping system with acceptable surge levels be designed. Reference will be made to typical installations and examples so that an understanding of the applicable constraints can be gained.

Figure 1 illustrates a typical water pumping/distribution system where two parallel pumps draw water from a wet well then pump the water through check and butterfly valves into a pump header and distribution system. A surge tank and surge relief valve are shown as possible equipment on the pump header to prevent and relieve surges, respectively.

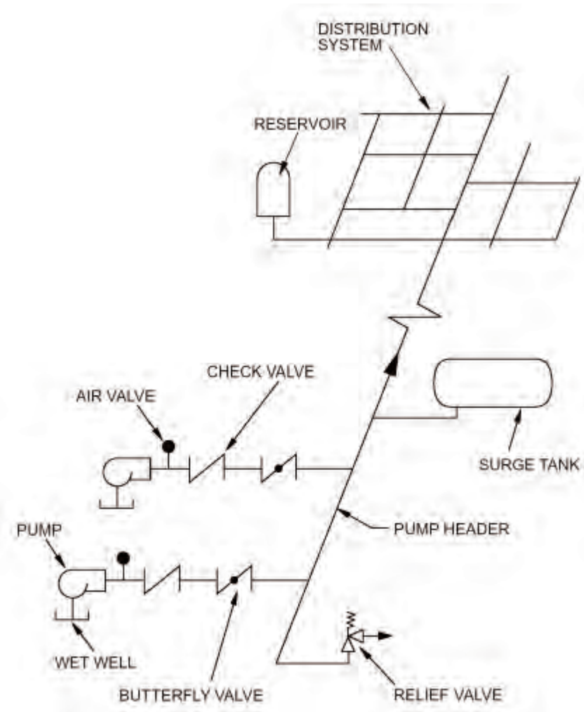

FIGURE 1. Typical Pumping/Distribution System

CAUSES AND EFFECTS

Surges are caused by sudden changes in flow velocity that result from common causes such as rapid valve closure, pump starts and stops, and improper filling practices. Pipelines often see their first surge during filling when the air being expelled from a pipeline rapidly escapes through a manual vent or a throttled valve followed by the water. Being many times denser than air, water follows the air to the outlet at a high velocity but is then rapidly restricted by the outlet causing a surge. It is imperative that the system fill flow rate be carefully controlled to less than 2 ft/sec fluid velocity and the air vented through properly sized automatic Air Valves. Similarly, line valves must be closed and opened slowly to prevent rapid changes in flow velocity. The operation of pumps and sudden stoppage of pumps due to power failures probably have the most frequent impact on the system and the greatest potential to cause significant and frequent surges.

If the pumping system is not controlled or protected, contamination and damage to equipment and the pipeline itself can be serious. The effects of surges can be as minor as loosening of pipe joints to as severe as damage to pumps, valves, and concrete structures. Damaged pipe joints and vacuum conditions can also cause contamination to the system from ground water and backflow situations. Uncontrolled surges can be catastrophic as well. Line breaks can cause flooding and line shifting can cause damage to supports and concrete piers and vaults. Losses can be in the millions of dollars so it is essential that surges be understood and controlled with the proper equipment.

SURGE BACKGROUND

Some of the basic equations of surge theory will be presented so that an understanding of surge control equipment can be gained. First, the surge pressure (H) resulting from an instantaneous flow stoppage is directly proportional to the change in velocity and can be calculated as follows:

$$H = a\,v / g$$

Where:

H = surge pressure, ft water column
a = speed of pressure wave, ft/sec
v = change in flow velocity, ft/sec
g = gravity, 32.2 ft/sec^2

The speed of the pressure wave (a) varies with the fluid, pipe size, and pipe material. For a medium sized steel line, it has a value of about 3500 ft/sec. For PVC pipes, the speed will be significantly less. For a 12 in. steel line with water flowing at 6 ft/sec, the magnitude of a surge from an instantaneous flow stoppage is:

$$H = (3500\ \text{ft/sec})(6\ \text{ft/sec}) / (32.2\ \text{ft/sec}^2)$$
$$H = 652\ \text{ft water column}$$

This surge pressure of 652 feet (283 psig) is additive to the static line pressure; therefore, the resultant pressure will likely exceed the pressure rating of the system. Further, the surge pressure will be maintained for several seconds as the wave reflects from one end of the piping system to the other end causing over pressurization of valves, pipe seals, and fittings. Then after a reflection, the pressure wave may cause a negative pressure and vacuum pockets for several seconds allowing contaminated ground water to be drawn into the system through seals or connections.

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Even higher velocities than the pumping velocity are attainable in long piping systems, especially when there are significant changes in grade. If the pumps are suddenly stopped due to a power failure, the kinetic energy of the water combined with the low inertia of the pump may cause a separation in the water column at the pump or at a highpoint in the pipeline. When the columns of water return via the static head of the line, the reverse velocity can exceed the normal velocity. The resultant surge pressure can be even higher than the 652 feet calculated above. Transient analysis computer programs are normally employed to predict column separation and the actual return velocities and surges. Transient programs can also model methods and equipment employed to control and prevent column separation such as the use of a Surge Tank, Vacuum Breaker, or Surge-Suppression Air Valve.

Thus far, the changes in velocity have been described as "sudden." But how sudden must changes in velocity be to cause surges? If the velocity change is made within the time period it takes for the pressure wave to travel the length of the pipeline and return, then the change in velocity can be considered instantaneous and the equation for surge pressure (H) given earlier applies. This time period, often called the "critical period", can be calculated by the equation:

$$t = 2L / a$$

Where:

t = critical period, sec
L = length of the pipe, ft
a = speed of the pressure wave, ft/sec

For the earlier example, (12 in. line), the critical period would be as follows for a 4 mile long steel pipeline:

$$t = 2\,(21{,}120\ \text{ft}) / (3500\ \text{ft/sec})$$
$$t = 12\ \text{sec}$$

Therefore, to cause surges, a pump does not need to stop quickly nor does the valve need to close instantaneously (or even suddenly). A normal flow stoppage of 5 or 10 seconds may cause the maximum surge (H) in long pumping systems. It follows that surge control strategies should be employed to slow down changes in velocity on all long pipelines.

PUMPS

Referring again to Figure 1, a key to controlling surges in pumping systems is to control the rate of increase and decrease of the flow velocity into the system. Pumps should be sized for the expected flow requirements. Oversized pumps can create havoc in certain pumping systems. Some pump station designs employ multiple pumps to match varying demand so that when one of the multiple pumps is started or stopped, it has a minor impact on the overall pipeline velocity. These systems control supply and can prevent surges during normal pump operation. Another option is to use specialized motor control equipment (i.e. variable frequency drives or soft start controls) to slow down the start and stop of a pump over 2 to 30 seconds. However, after a power failure the motor controls become inoperative and the pump will stop quickly and cause a sudden stoppage of flow. Almost all pumping systems need additional surge equipment to prevent surges after a power failure.

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VERTICAL PUMPS AND WELL SERVICE AIR VALVES

Vertical pumps, as shown in Figure 2, lift water from a tank or wet well into a pipeline. When the pump is off, the suction water level is below the pump discharge pipe. The pump column refills with air after each pump stoppage. Air Valves play an important role in automatically venting the pump column air and controlling surges in pump columns. If the vertical turbine pump is started without an Air Valve, the air in the pump column would be pressurized and forced through the check valve into the pipeline causing air related problems. Air Valves for pump discharge service, called "Well Service Air Valves", are similar to Air/Vacuum Valves but are equipped with either a throttling device or a regulated exhaust device and are designed to exhaust air on pump start-up and admit air upon pump shut down.

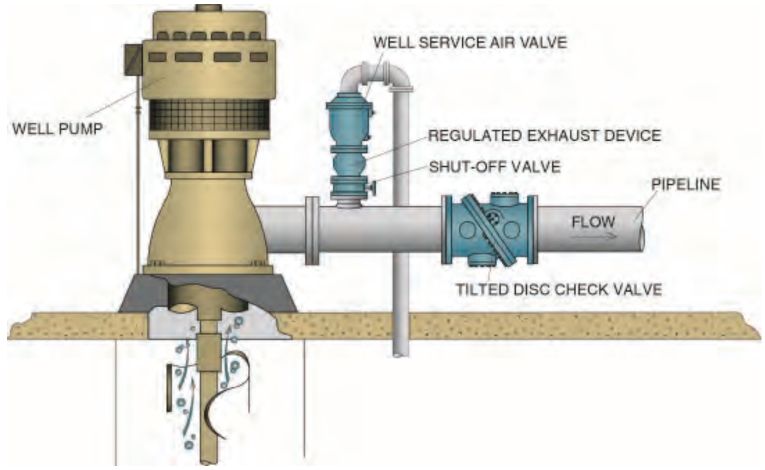

FIGURE 2. Vertical Turbine Pump

As shown in Figure 3, the Well Service Air Valve is a normally-open, float-operated valve which relieves the air in the pump column rapidly. When water enters the valve, the float automatically rises and closes to prevent discharge of the water.

Throttling devices are provided on the outlet of 3 in. and smaller valves to control the rate of air release, especially with slow opening pump control valves. The throttling device is adjusted with the external screw to slow the rise of the water in the pump column. However, after pump shutdown, a second port on the top of the throttling device provides full flow into the pump column to relieve the vacuum. The Dual Port Throttling Device is important because it provides full vacuum flow and prevents contaminated water from being drawn into the pipeline, which can happen if the device has a common exhaust and vacuum connection.

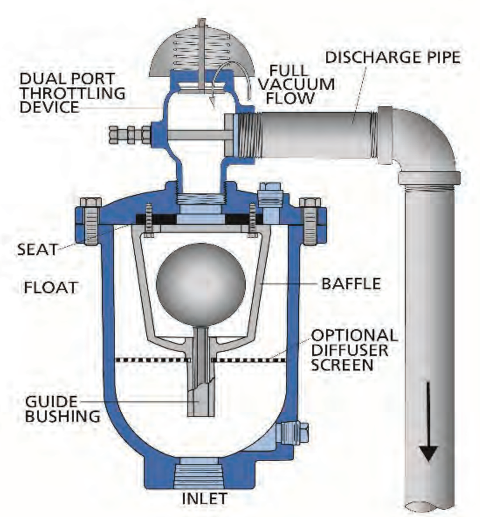

FIGURE 3. Well Service Air Valve

CHECK VALVES

Another key element in pumping system design is the proper selection and operation of the pump discharge check valve. Every pump station designer has been faced with check valve slam, which is caused by the sudden stoppage of reverse flow through a closing check valve. To prevent slam, the check valve must either close very quickly or very slowly. Anything in the middle is no-man's land and a cause for concern. But just as important, the valve should protect the pumping system and piping from sudden changes in velocity if it is within its functional capabilities. The check valve should also be reliable and offer low head loss.

Two categories of check valves will be discussed in detail. The first, fast-closing check valves, represent the general category of check valves that operate automatically in less than a second and without the use of external power or signals from the pumping system. The other category is pump control valves, which operate very slowly (i.e. 60-300 seconds) to carefully control the changes in pipeline fluid velocity.

FAST-CLOSING CHECK VALVES

Fast-Closing Check Valves are simple, automatic, and cost effective but often are plagued with the problem of check valve slam and a resultant system pressure surge. Significant research has been done to understand the dynamic closing characteristics of various fast-closing check valves including ball check, swing check, tilted disc, resilient disc, dual disc, and silent check valves. If the deceleration of the forward flow can be estimated, such as with a transient analysis of the pumping system, the slamming potential of various check valves can be predicted. Then, several non-slam valve options will present themselves, and the performance features and costs can be used to select the best check valve for the application.

The most ubiquitous type of check valve is the traditional swing check valve. Swing check valves as shown in Figure 4 are defined in AWWA C508 for waterworks service and are designed to rapidly close to prevent backspinning of the pump during flow reversal. Traditional swing check valves have 90-degree seats with long strokes and are subject to slamming. These valves are therefore outfitted with a wide array of accessories, which are beyond the scope of the AWWA C508 Standard. Probably the most common accessory is a lever and weight. While it is normally assumed that the weight makes the valve close faster, it actually reduces slamming by limiting the stroke of the disc, but in return, causes a significant increase in headloss. The valve closure is also slowed by the inertia of the weight itself and the friction of the stem packing.

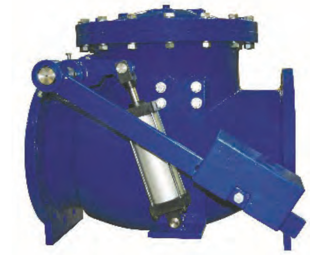

FIGURE 4. Swing Check

In more severe applications, an air cushion is sometimes used to slow down the impact of the valve closure. Everyone has seen how effective an air cushion works on a slamming storm door. But the conditions in a pipeline are significantly different. When a door slams, its momentum is smoothly absorbed by the air cylinder because as the door slows, the forces from the closing spring and outside wind become less and less. Conversely, when a check valve in a pipeline closes, the reverse flow is quickening at a tremendous rate so that every fraction of a second that the valve closure is delayed, the forces on the disc will increase by an order of magnitude. So while it may be true that an air cushion prevents the disc weight from slamming the disc into the seat of a valve in a product display booth, in actual practice, the air cushion merely holds the disc open long enough for the reverse flow to intensify and slam the disc even harder into the seat. Since air cushions are based on the use of air (which is compressible), they provide no positive restraint of the closing disc and cannot counteract the enormous forces being exerted by the reverse flow. The best use of an air cushion is to configure the device so that as the check valve opens, the air in the cylinder is compressed and is used to accelerate the closure of the check valve during closure.

A far more effective accessory for controlling swing check valve motion is an oil cushion, also referred to as an oil dashpot. Because oil is incompressible, the oil cushion will withstand the high forces exerted on the disc by the reverse flow and properly control the last 10% of valve closure. The pump must be capable of some significant backflow, though, because the oil dashpot will allow the check valve to pass flow back through the pump. Since the reverse flow forces on the valve disc are extremely high, the oil pressure often exceeds 2000 psig causing valves with these devices to be costly. The high-pressure oil cylinder is expensive and because it puts the valve stem under high loads, a special check valve with a large stem diameter is often needed. Because pumps can only withstand so much backflow, the closure time of dashpots are usually limited to 1 to 5 seconds. If the pipeline contains debris or sewage, a check valve with oil cushion can act as a screen during reverse flow conditions and quickly clog the line.

An even better solution is to select a check valve that closes before any significant reverse flow develops, thereby preventing a slam. One such valve is a spring-loaded, center-guided "Silent" Check Valve (SCV) as shown in Figure 5. A SCV is near slam-proof because of its short linear stroke, location of the disc in the flow stream, and strong compression spring. However, selecting a Silent Check Valve has several pitfalls such as high head loss, no position indication, and limitation to clean water applications.

FIGURE 5. Silent Check

On the other end of the spectrum is the Tilted Disc® Check Valve (TDCV). The TDCV as shown in Figure 6 has the lowest headloss because its port area is 140% of pipe size and its disc is similar to a butterfly valve disc where the flow is allowed to pass on both sides of the disc. The TDCV also has reliable metal seats and can be equipped with top or bottom mounted oil dashpots to provide effective means of valve control and surge minimization. The TDCV is fully automatic and requires no external power or electrical connection to the pump control.

FIGURE 6. Tilted Disc®

The newest check valve listed in AWWA C508 and the valve having the greatest impact in the water/wastewater industry today is the resilient disc check valve, the Swing-Flex® Check Valve (SFCV), Figure 7. The SFCV is highly dependable with virtually no maintenance because the only moving part is the flexible disc. This valve has a 100% port slanted at a 45-degree angle, which provides a short 35-degree disc stroke, quick closure, and low head loss. The valve is also available with a mechanical position indicator and limit switches. A special model of this valve, the Surgebuster® (SB) has even faster closure due to the addition of a disc accelerator giving closure characteristics similar to that of a Silent Check Valve.

FIGURE 7. Swing-Flex®

Hence, with all of the check valve possibilities, one is available for every system with low head loss and slam-free operation. The closing characteristics of all types of check valves are shown for various system decelerations in Figure 8. The valves whose curves are furthest to the right have the best non-slam characteristics. The use and derivation of this data is explained in greater detail in the Val-Matic white paper "Dynamic Characteristics of Check Valves."

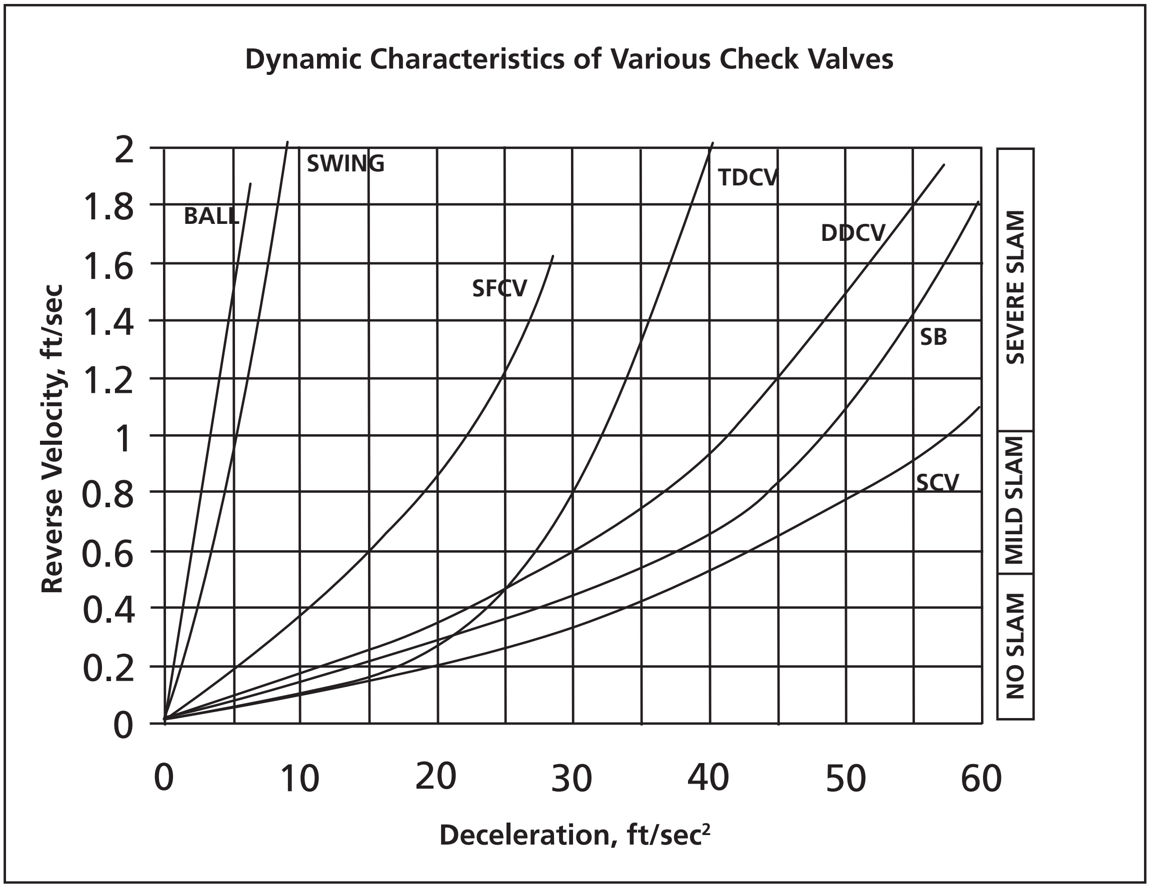

FIGURE 8. Dynamic Characteristics of Various Check Valves

PUMP CONTROL SYSTEMS

Even though a fast-closing check valve may prevent slam, it may not fully protect pumping systems with long critical periods from velocity changes during pump startup and shutdown. For pumping systems where the critical period is long, a pump control valve is often used. A pump control valve is wired to the pump circuit and provides adjustable opening and closing times in excess of the system critical time period. Pump control valves are hydraulically operated so the motion of the closure member of the valve (i.e. a butterfly valve disc) is unaffected by the flow or pressure in the line. Also, most pumps in service today have low rotating inertia and come to a stop in less than 5 seconds. The pump control valve can close rapidly during power outages or pump trips to protect the pump. However, when rapid closure is required, additional surge equipment may be needed.

The list of possible pump control valves is long because many valves can be equipped with the automatic controls necessary for pumping systems. Valves typically considered are butterfly, plug, ball, and globe-pattern control valves. Probably the most common criterion used to select a valve is initial cost, but for pumping systems, the selection process should be carefully undertaken with consideration given to:

- valve and installation costs
- pumping costs
- seat integrity
- reliability
- flow characteristics

The flow characteristics of pump control valves will determine how well they will prevent surges. The most desirable flow characteristic of a valve is one where the valve uniformly changes the flow rate when installed in the system. The flow data available from valve manufacturers are inherent flow characteristics usually expressed in terms of a flow coefficient (C_v) at various valve positions. By assuming a constant head loss across typical valves at all positions, the inherent characteristics of the valves can be compared as shown in Figure 9. On the left side is a quick-opening valve curve (such as a gate valve or swing check valve), which depicts a rapid change in the flow rate as the valve opens. On the other extreme is an equal percentage valve (such as a ball valve), which changes the flow rate uniformly with valve travel. However, these readily available curves only consider the valve headloss and ignore the system headloss. Inherent curves may be misleading when selecting a valve for a pumping system with long pipelines.

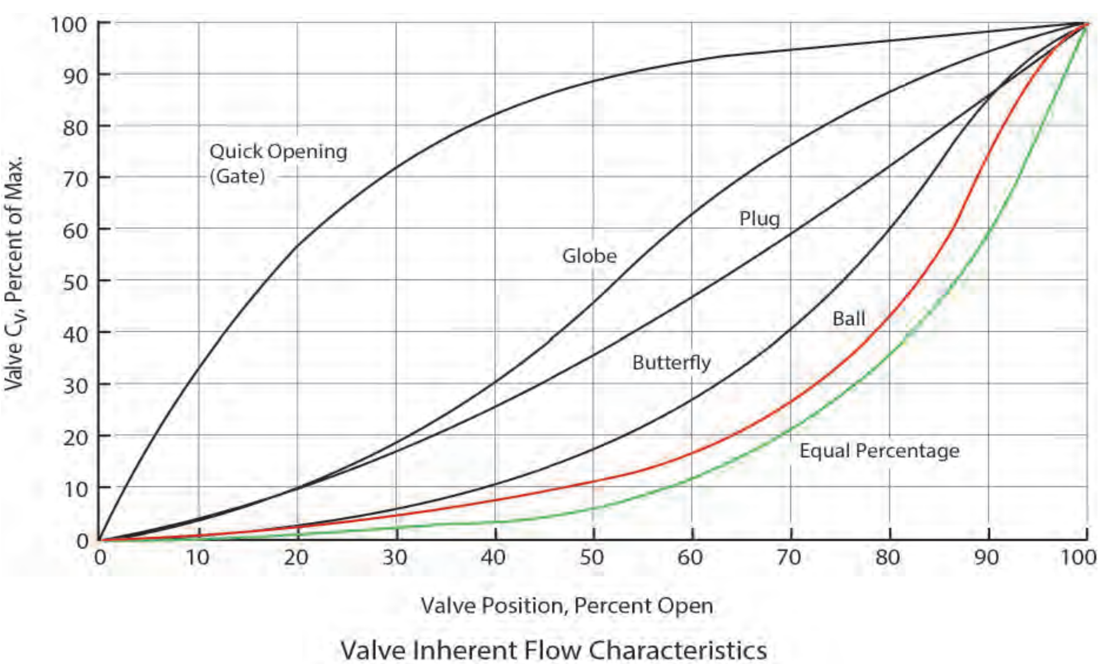

FIGURE 9. Inherent Flow Characteristics

The inherent characteristic curves must be transformed for a given pipeline application to consider the relative headloss of the piping system. When a valve such as a butterfly valve is installed in a pipeline, the location of the curve varies with the length of the pipeline as shown in Figure 10. The curve shown on the right is the inherent flow characteristic curve because the system is zero feet long. The other curves are installed flow characteristic curves because they vary with the system length. As the length of the pipeline increases, the characteristic curves for the same valve shifts to the left. Hence, the same valve can be very close to equal-percentage in one system and quick-opening in another. The longer the pipeline, the more the valve tends to be quick-opening. A quick-opening valve will change the flow suddenly and is more apt to cause surges because it effectively controls the flow for only one half of its travel. Ideally, the most desirable installed flow curve for a pumping system is linear such as the curve in the middle. Therefore, since inherent curves shift to the left when the system is included, the valve with an equal percentage inherent curve is the most desirable. Referring again to Figure 9, the most desirable valves for long systems would be butterfly and ball valves.

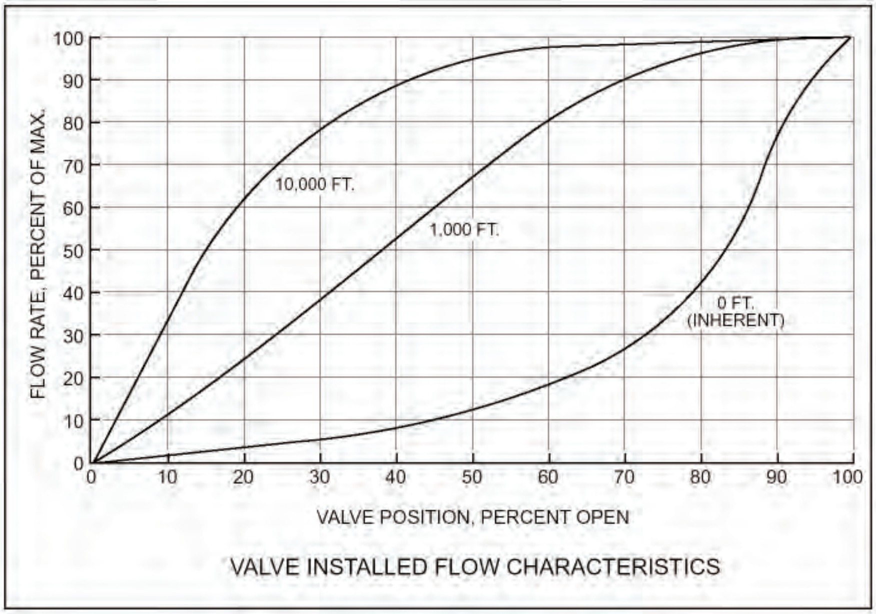

FIGURE 10. Installed Flow Characteristics

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PUMP CONTROL VALVE OPERATION

Utilizing a ball valve, let us consider the operation of a typical pump control valve. A ball valve is operated by rotating its shaft 90 degrees and is normally equipped with a hydraulic cylinder actuator. The cylinder can be powered with pressurized water from the line or from an independent oil power system. We learned earlier that negative surge conditions can occur for several seconds, so a backup water or oil system is appropriate. Figure 11 illustrates a typical installation. Mounted on the valve are hydraulic controls electrically wired into the pump circuit. Four-way and two-way solenoid valves (SV) direct the operating medium to the cylinder ports to cycle the valve. The speed of opening and closing is controlled by independently adjustable flow control valves (FCV). Flow control valves are special needle valves with a built-in reverse check valve to allow free flow into the cylinder but controlled flow out of the cylinder.

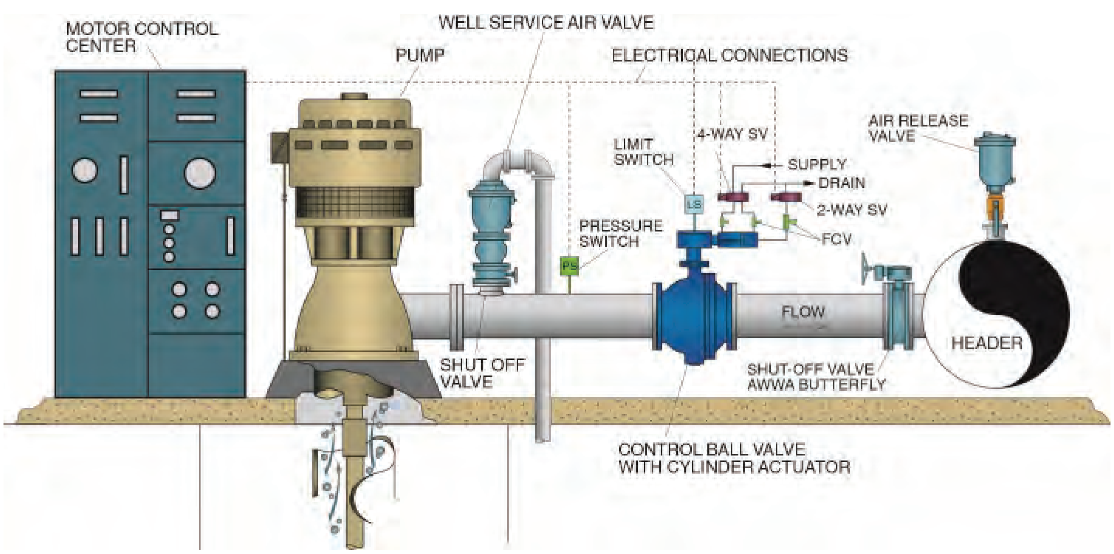

FIGURE 11. Pump Check Valve Installation

When the pump is started and pressure builds, a pressure switch (PS) located on the pump header signals the butterfly valve to open. During shutdown, the valve is signaled to close while the pump continues to run. When the valve nears the closed position, a limit switch (LS) located on the valve will stop the pump.

One additional function of the pump control valve must be considered; that is, to prevent the pump from backspinning after power failure or overload trip. Since pumps today no longer are equipped with flywheels, as with old diesel units, they have a low rotating inertia and come to rest in a just a few seconds. Therefore, after a power outage or pump trip, the pump control valve must close more rapidly to prevent backspinning. The valve hydraulic controls are equipped with a bypass line equipped with a 2-way solenoid valve (SV) to send the controlled cylinder flow around the normal flow control valve and through a large flow control valve (FCV), thereby closing the pump control valve automatically in 5-10 seconds after power failure. This is essential to prevent excess pump backspin and to prevent depletion of the hydro-pneumatic surge tank water back through the pump if one is utilized.

SURGE RELIEF EQUIPMENT

Since it is impractical to use pipe materials, which can handle high surge pressures or slow the operating flow velocity to a crawl, surge relief equipment is needed to anticipate and dissipate surges from sudden velocity changes after power outages. Surge relief equipment will also provide protection against malfunctioning valves, improper filling, or other system problems.

STAND PIPES AND SURGE TANKS

Many types of surge relief equipment are used to safeguard pumping systems. For low-pressure systems, a standpipe open to atmosphere will relieve pressure almost instantly by exhausting water. For systems with higher pressure, the height of a standpipe would be impractical so a surge tank with pressurized air over water can be used to absorb shocks and prevent column separations as shown in Figure 12. For typical pumping systems, however, these tanks tend to be large and expensive and must be supplied with a compressed air system. When used, an additional fast-closing check valve is also needed to prevent surge tank water from escaping back through the pump. This is a common example of when you will see both a pump control valve and a fast-closing check valve installed. Further, the surge tank creates extremely high deceleration rates (i.e. 25 ft/sec^2), so the fast-closing check valves must be equipped with springs or bottom-mounted oil cushions or dashpots to prevent slamming.

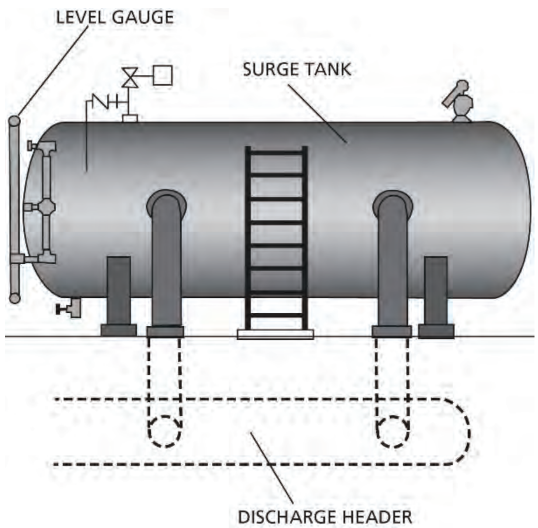

FIGURE 12. Hydro Pneumatic Surge Tank

SURGE RELIEF VALVES

Surge relief valves are often a more practical means of relieving pressure than a surge tank. In these valves, a pressure surge lifts a disc allowing the valve to rapidly relieve water to atmosphere or back to the wet well. Surge relief valves have the limitation that they may not open rapidly enough to dissipate surges in cases where column separation can occur. For these cases where the transient computer model predicts steep or rapid pressure surges, surge relief valves equipped with anticipator controls should be considered. A globe-pattern control valve equipped with surge relief and anticipator controls is shown in Figure 13. A surge anticipator valve will open rapidly upon the sensing of a high or low pressure event.

When a pump suddenly stops, the pressure in the header will drop below the static pressure and trigger the surge anticipator valve to open. The valve will then be partially or fully open when the return pressure surge occurs. Anticipator valves typically open in less than five seconds, pass high low rates, and reclose slowly at the pump control valve closure rate (60-300 seconds). The sizing of surge relief valves is critical and should be overseen by transient analysis experts.

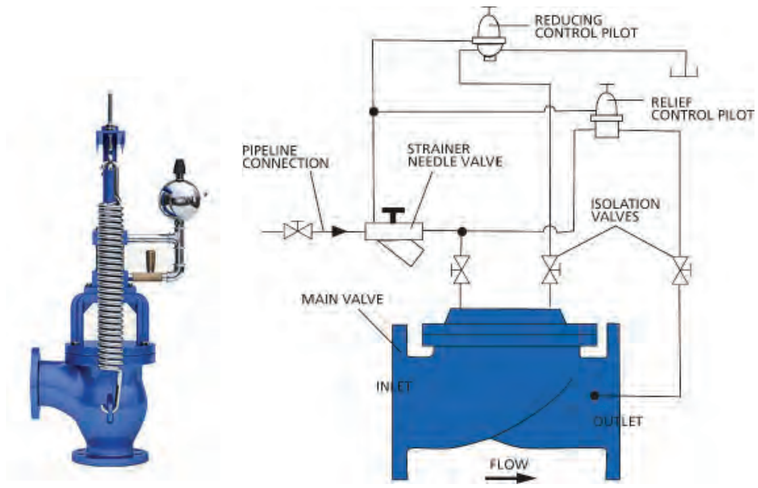

FIGURE 13. Surge Relief and Anticipator Valve

SURGE-SUPPRESSION AIR VALVES

Air Valves help reduce surges in pipelines by preventing the formation of air pockets in pipelines during normal operation. Air pockets can travel along a pipeline and cause sudden changes in velocity and adversely affect equipment operation such a flow measuring devices. Air Valves are also designed to open and allow air to be admitted to the pipeline to prevent the formation of a vacuum pocket associated with column separation. Transient analysis computer programs are equipped to analyze the surge reduction from using various size Air Valves.

When column separation is expected at the Air Valve location, the Air Valve should be equipped with a Regulated Exhaust Device to cushion the rejoining water columns, see Figure 14. The Air/Vacuum Valve and Regulated Exhaust Device allow air to enter the pipeline unrestricted to prevent a vacuum in the pipeline. When the water columns rejoin, the air is exhausted and the restrictor disc closes, which provides for the slow release of the air at about 5% of the full rate thereby dampening the returning water columns. When the air is exhausted, the Air/Vacuum Valve float rises to prevent water discharge. Any remaining air or entrained air is automatically exhausted through the Air Release Valve.

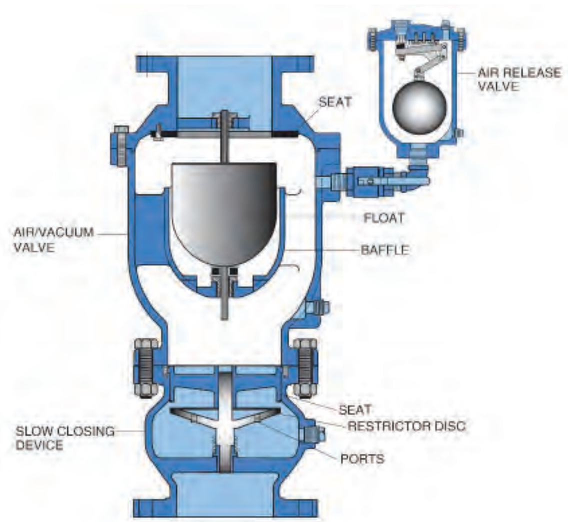

FIGURE 14. Float, Air Release Valve, Restrictor Disc and Regulated Exhaust Device

VACUUM BREAKER VALVES

Another type of Air Valve used at critical points in large pipelines or penstocks where column separation may occur is a Vacuum Breaker (VB) as shown in Figure 15. The VB has components very similar to the Regulated Exhaust Device, except the VB disc is held <u>closed</u> by a spring while the Regulated Exhaust disc is normally open. Hence, the Vacuum Breaker cannot expel air; only admit air to prevent the formation of a vacuum pocket. This keeps the pipeline at a positive pressure and reduces the surge associated with a column separation. In essence, a large cushion of air is admitted and trapped in the pipeline after a pump trip. The air is then slowly released over a few minutes through the adjoining air release valve, which has a small (i.e. 1/4 in) orifice. Again, transient analysis programs are designed to model this type of Air Valve solution as well.

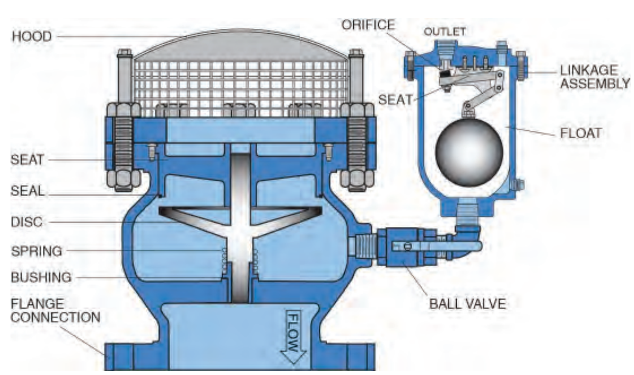

FIGURE 15. Vacuum Breaker and Air Release Valve

SUMMARY

Surges can cause contamination and damage to water systems and are prevalent in long pipelines. The importance of treating surge control as one integrated system cannot be emphasized enough. Consideration must be given to the Pump Control, Air Release, Check Valves, Air Valves, and Surge Relief equipment. Fast-closing check valves are an economical way of preventing pump back-spin without slamming, but may not be effective in preventing surges in long pipelines. Pump control valves such as hydraulically-operated ball valves provide more control of the velocity and are available in many types and several criteria should be evaluated to make the best selection.

Even with a control valve, though, a surge can be generated when the control valve closes rapidly after power failure to prevent pump backspin. Therefore, long pipelines may require additional surge control and surge relief equipment such as Surge Tanks, Surge Relief Valves, and Surge-Suppression Air Valves. Finally, it is important to use transient analysis software to model the system so that the system can be started up with confidence.

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White Paper

Minimizing Energy Consumption Through Valve Selection

Table of Contents

INTRODUCTION

Valves play an important role in water systems by controlling flow and pressure, releasing air, and preventing backflow. One important characteristic of valves in water pumping systems that is often overlooked is the valve's ability to minimize energy consumption. Most engineers are familiar with valve headloss calculations and how they can predict pumping costs but few are aware that the published headloss characteristics of valves presume optimum valve operation (i.e. full-open), which can be affected by valve sizing and flow velocities. Further, studies have shown that the use of air valves can improve the flow efficiency of a water pipeline and thereby reduce energy consumption.

While it is important to judge valves on the basis of their headloss characteristics, it will be shown that other characteristics are equally as important. In other words, to minimize energy consumption, an engineer should not simply always select the valve that has the lowest headloss. This paper will discuss the flow and operating characteristics of various check valves and pipeline valves and how they impact system performance. Further, the concept of placing and selecting air valves to prevent air binding will be explored.

With an understanding of the effect of various valves on the energy consumption of a system, engineers can calculate the life cycle costs of valve alternatives and make the best decision for the water utility.

HEADLOSS CALCULATIONS

The pump head is needed to overcome the combination of the static head and the friction head of the distribution system. The static head is the difference in elevation between the source and the highest point of water storage. The friction head is caused by roughness in the pipe and local flow disturbances in fittings and valves. Pumping and distribution system valves come in many varieties, but they all cause friction head in the same ways.

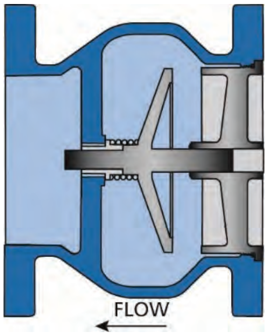

FIGURE 1. Silent Check Valve with Globe Style Body Provides 100% Flow Area

Body geometry dictates the general flow area through the valve. Some valves restrict the flow area to below 80% of the pipe area. Also, the internal contours of the body and seat should be smooth to avoid creating excessive turbulence. The valve body diameter and laying lengths are sometimes much greater than the pipe size to achieve a smooth flow pattern. If the port area is equal to the pipe size, then the closure member or disc needs to be somewhat larger to affect a seal. The body is contoured outward around the disc to achieve a full flow area through the valve. These types of bodies are called globe style (Figure 1). Other valves take advantage of an angled seat so that the pipe area can be maintained through the port without greatly increasing the size of the valve body (Figure 2).

The design of the closure member or disc is important for two reasons. First, the lowest headloss will be achieved if the disc swings or rotates out of the flow path (Figure 2). Discs can also have special contours and shapes to fully open at low fluid velocities and create a smooth flow path through the valve. Second, disc geometry is often designed to provide a short stroke as shown in Figure 1. The disc in Figure 2 has only a 35 degree stroke. The short stroke allows the valve to close faster to prevent check valve slam.

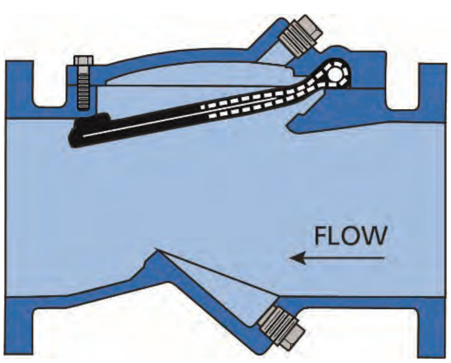

FIGURE 2. Resilient Hinge Check Valve with Angled Seat Provides 100% Flow Area

It is normally considered a simple matter to compute the headloss produced by various types of valves. There are many types of flow coefficients and headloss formulas in general use today for rating of various valves on the basis of headloss. Probably the most ubiquitous flow coefficient for water valves is the Cv flow coefficient, which is defined as the amount of water in gallons per minute (gpm) that will pass through a valve with a 1 psi pressure drop. Hence, the more efficient the valve, the greater the valve Cv.

Unfortunately, Cv's are rather large numbers and vary widely (Figure 3), which make comparisons between alternate valves difficult. Further, Cv's are approximately proportional to the square of the valve diameter, so large valves (i.e. 72 inch) have Cv's as high as 250,000 or more. Cv should not be confused with the valve capacity. For example, the 12 inch ball valve has a Cv of 21,500 which far exceeds its capacity of 8,500 gpm or 35 ft/sec (AWWA C507, 1), thus, Cv should only be used for computing headloss, not determining the valve's flow capacity.

12 inch Valve Flow Data			
Type of Valve	Port Size	Cv	Kv
Control Valve	100%	1,800	5.70
Silent Check Valve	100%	2,500	2.95
Dual Disc® Check Valve	80%	4,000	1.15
Swing Check Valve	100%	4,200	1.05
Ball Check Valve	100%	4,700	0.83
Eccentric Plug Valve	80%	4,750	0.81
Flex Hinge Check Valve	100%	4,800	0.80
Tilted Disc® Check Valve	140%	5,400	0.63
Butterfly Valve	90%	6,550	0.43
Ball Valve	100%	21,500	0.04

FIGURE 3. Valve Types and Flow Coefficients

A better flow coefficient to use for making comparisons is the resistance coefficient Kv used in the general valve and fitting flow formula:

$$\Delta H = K_v v^2 / 2g$$

Where:

ΔH = headloss, feet of water column

K_v = resistance coefficient (valve), dimensionless

v = fluid velocity, ft/sec

g = gravity, 32.2 ft/sec^2

The flow factor K_v can also be related to the C_v by the formula:

$$K_v = 890\, d^4 / C_v^2$$

Where:

d = valve diameter, inch

Not only are the Kv factors for various valves similar in magnitude, but they are similar from size to size. For example, geometrically similar 12 inch valve and 72 inch valves may have nearly identical Kv's. Because of the similarity, Kv's are ideal for use in comparing valves and fittings. With the understanding that a run of 100 feet of steel pipe has a K of 1.5, an engineer can easily understand the relative impact a valve has on the total piping system pressure loss. For example, the silent check valve has a Kv of 2.9 which would be equivalent to the loss produced by about 200 feet of pipe.

Comparisons can also be made between various manufacturers for the same type of valve. For example, the published Kv's for 12 inch silent check valves from three prominent suppliers in the U.S. water industry are 2.9, 2.8, and 2.7. The magnitude of these differences are not significant when compared to the total K of a piping system which usually exceeds 50. The lesson here is that, while it is important to consider the headloss between types of valves, the headloss between various suppliers of a given valve type does not typically produce significant changes in system operation. This is why piping system computer simulations can accurately model system behavior based on generic valve characteristic data. Given that design differences between brands are small and testing methods can vary, slight differences in published flow data among manufacturers can usually be ignored.

Finally, the flow conditions of the system can affect the valve headloss. From the ΔH equation, it is clear that headloss is a function of fluid velocity squared. Hence, a doubling of the line velocity will increase the pipe, fitting, and valve headlosses four-fold. This is why pipeline velocities are typically held in the 4 to 8 ft/sec range even though the pump discharge velocities are often higher. Further, the velocity may affect the open position of the valve. Swing type check valves may require between 4 and 8 ft/sec of velocity to be forced fully open by the flow. If the valve is not full open, the headloss can be significantly higher than the published headloss, even double. Hence, a curve of flow coefficient versus fluid velocity should be employed when computing headloss for swing-type check valves.

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Since valve coefficients and headloss are a function of velocity, the overall cost of energy consumption versus pipe costs must be evaluated. There is an optimum pipe size and velocity that provides the least present cost of installation costs plus annual operating costs. Many general guidelines and formulas are available for this analysis (Patton, 317).

ENERGY CALCULATIONS

It has been estimated that the water and wastewater plants in the United States consume 75 billion kW·h of energy annually. For water plants nearly 80% of that energy is consumed for high service pumping costs to overcome the static head and friction losses of distribution systems. Water utilities have the opportunity to employ various energy saving strategies that could result in a 20 to 50 percent reduction in energy consumption and likewise, operating costs (Oliver, 1). Energy costs typically have at least two main components, an energy charge and a demand charge. The energy charge represents the consumption of kilowatt hours of electricity with a typical cost of about $ 0.04 per kW·h. Surprisingly, the demand charge can be a higher charge and represents the cost of electrical generating capacity at a cost of about $10.00 per kW. The demand charge may also be affected by the time of the day with savings associated with pumping water during off-peak hours.

The headloss from valves can be converted into an energy cost related to the pumping electrical power needed to overcome the additional headloss from the valve with the equation (AWWA, 25):

$$A = (1.65\, Q\, \Delta H\, S_g\, C\, U) / E$$

Where:

A = annual energy cost, dollars per year

Q = flow rate, gpm

ΔH = head loss, ft. of water

S_g = specific gravity, dimensionless (water = 1.0)

C = cost of electricity, $/kW·h

U = usage, percent x 100 (1.0 equals 24 hr per day)

E = efficiency of pump and motor set (0.80 typical)

Alternatively, the energy consumption difference between two valve selections can be calculated by using the headloss difference between the two valves for the variable ΔH in the equation above. For example, the difference in headloss between a 12 inch silent check valve and a tilted disc check valve in a 4,500 gpm system operating 50% of the time can be calculated as follows:

$$\Delta H = (2.95 - 0.63)\,(12.7)^2 / 2 \cdot 32.2$$
$$= 2.50 \text{ ft. wc}$$

$$A = (1.65 \times 4500 \times 2.50 \times 1.0 \times 0.04 \times 0.5) / (0.8)$$
$$= \$464$$

The calculation shows that the use of a 12 inch tilted disc check valve in the place of a 12 inch silent check valve can save $464 per year in energy costs. If the pump station had four such valves operating for forty years, the total savings will be $74,240 over the life of the plant. Similar savings may also be achieved due to the reduced demand charges. Therefore, it is clear that valve selection can play an important role is energy savings.

VALVE CHARACTERISTICS

While important, headloss characteristics of valves cannot be the sole reason for making a valve selection. Headloss is only a contributing factor to the total cost of the valve. Other cost considerations are the purchase, installation, and maintenance costs. Also, various types of valves can have laying length dimensions that vary widely requiring an increase in the size of the pumping pit or valve vault. Many swing type-check valves require five straight pipe diameters upstream to prevent damaging vibration to the valve (MSS, 3). Maintenance costs can be high with some valves especially when the cost of system downtime is considered. These other costs need to be estimated and combined to provide the valve life cycle costs.

VALVE LIFE CYCLE COSTS

- Purchase Cost
- Installation Cost
- Maintenance Cost
- Energy Cost

A second characteristic of valves that is important is the inherent flow characteristic of the valve. Some valves will linearly reduce the flow rate in proportion to the movement of the closure member while some valves may only affect flow rate during their last 30% of closure. If the valve is merely an isolation valve, the flow characteristic is not important, but if the valve is used to control flow or pressure, then the flow characteristic will be of paramount importance.

Further, check valves can sometimes produce valve slam and water hammer, which can wreak havoc on a pumping system. In general, to avoid these problems, a check valve must close either extremely fast or extremely slow. Various types of check valves are available to provide either function and many are equipped with auxiliary equipment such as dashpots, power actuators, and springs to provide special functions. If the pump is not capable of withstanding backspin or the pump station is equipped with a hydro-pneumatic surge tank, then a slow closing check valve may not be appropriate. An automatic fast-closing check valve should be selected carefully, given proper consideration to its dynamic closing characteristic (Val-Matic).

Finally, valves may be differentiated by their capability of handling various fluids. Valves with spokes such as the silent check valve, dual disc check valve or valves with rotating discs such as the tilted disc check valve and the butterfly valve are not recommended for wastewater containing suspended solids. Valves have either metal-to-metal or resilient seats. Metal-seated valves can provide a long-reliable life but if zero leakage is required, then valves equipped with resilient seats should be used.

Valve selection is a complex process that involves detailed analysis of system operation and valve performance characteristics. Check valves and pipeline valves should be chosen with full consideration to the valve life cycle costs including energy costs, inherent flow characteristics, slamming characteristics, and seating characteristics.

AIR BINDING

Another family of valves that is important for energy conservation is the air valve. It often surprises a pipeline designer that the cause of a pumping system's inefficiency or even stoppage is a result of trapped air in the pipeline. One common misconception is that it is easier to pump against air instead of water. However, when a pipeline contains highpoints followed by descending runs, air can be trapped in pressurized pockets downstream of the highpoint due to the buoyancy of the air. As shown in Figure 4, trapped air forms a long pocket along the pipe descent with a constant depth "d". Since the air is at the same pressure along the air pocket, it can be shown that the headloss is equal to the vertical height of the pocket or dimension "H" (Edmunds, 272).

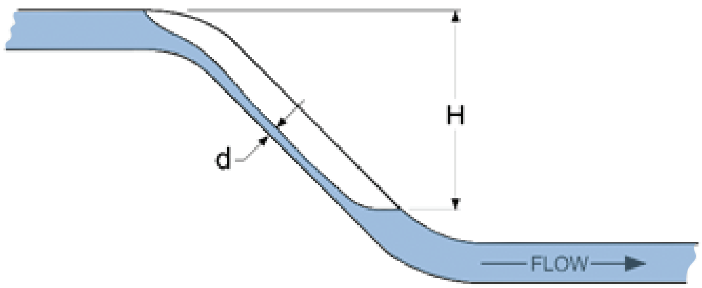

FIGURE 4. Headloss Due to Air Pocket

When there are several highpoints in a pipeline, the headlosses are additive. During initial pump startup, the line can appear to be blocked because the pump cannot overcome the sum of the headlosses in all of the highpoints, even at the pump shutoff pressure.

The length of the pocket, and hence, the magnitude of the headloss is a function of how much air accumulates. The source of the air can be from the system inlet, changes in water pressure, or intentional air entry through air valves. The air can be removed by entrainment of bubbles at the downstream end, sweeping the pocket downstream by the velocity, or by an automatic air valve located at the top of the pocket.

The entrainment process is a slow and inefficient process and often does not keep up with the supply of air from pumping and other sources. Better is the possibility of sweeping the air pocket downstream with velocity. As can be expected, the velocity necessary to move the pocket is related to the slope of the descending line. For a 24 inch diameter pipe, the velocities needed to sweep the air pocket are shown in Figure 5.

Required Velocities to Sweep Air from 24 inch Diameter Pipe Slopes			
0%	**5%**	**25%**	**100%**
6.6 ft/sec	7.1 ft/sec	7.6 ft/sec	8.3 ft/sec

FIGURE 5. 24 inch Pipeline Velocities (Sanks, p. 904)

Studies also show that as the size of the pipe diameter grows, the required velocities to sweep air pockets increases dramatically. Typically the required velocity is proportional to the pipe diameter. For a 48 inch pipeline, the velocities in Figure 6 would need to be doubled. The simplest solution around this problem includes the careful design of the pipe grade to avoid downslopes. Additional excavation in some areas can eliminate a highpoint and subsequent downgrade. Also, increased velocities can be used to help expel air from the high points. Alternatively, the use of automatic air valves can be used to eliminate the air and restore the pumping efficiency of the pipeline without the potentially high costs of extra excavation or flow velocities (recall that doubling the flow velocity quadruples the system energy costs).

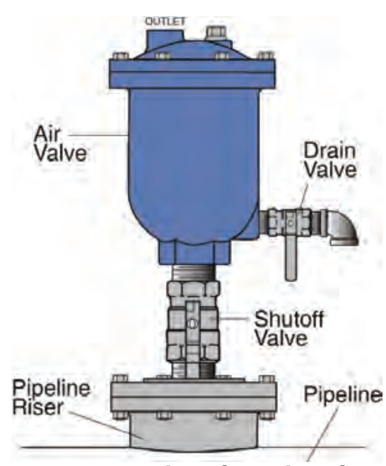

FIGURE 6. Air Valve Directly Mounted on Pipeline

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Air valves can be directly mounted to the top of the pipeline and serve several functions. An air/vacuum valve has a large orifice equal to about one-quarter the diameter of the pipeline and is used to vent large quantities of air during pipeline filling. The valve also allows the rapid entry of air to prevent a vacuum from forming in the pipeline during draining or after a power failure. Once pressurized and closed, an air/vacuum valve will no longer vent pressurized air. An air release valve is needed for that purpose. An air release valve has a small orifice (i.e. 0.125 in. diameter) and vents air while the pipeline is in operation and under pressure. The third type of air valve is the combination air valve, which performs all of the functions of the air/vacuum and air release valves. Combination air valves are usually installed at all high points and major changes in grade to automatically vent air and prevent the formation of vacuum conditions. The location and sizing of air valves are presented in the AWWA Manual M51.

The importance of air valves cannot be overlooked. They not only maintain the flow efficiency of a pipeline by venting accumulated air, but also perform many other functions including surge control and vacuum protection.

CONCLUSION

Valves play an important role in the operation of the piping system. Care in their selection and placement can greatly enhance the energy efficiency of the system. While it is important to calculate the headloss and energy costs associated with valves, many other valve characteristics must be considered to guarantee the best selection of valve type for a given application.

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White Paper

Protective Interior Coatings for Waterworks Valves

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INTRODUCTION

Since the 1990's, two types of epoxy coatings have been commonly specified and used for iron valves in the waterworks industry: fusion bonded epoxy (FBE) and liquid epoxy. Both coatings are based on thermo-set epoxy systems with similar corrosion resistance and are described in the American Water Works Association's Standard AWWA C550, "Protective Interior Coatings for Valves and Hydrants". Fusion bonded epoxy is applied to preheated components in powder form in an electrostatic or fluidized bed process followed by thermal curing. Liquid epoxy is a two-component mixed material that is applied by spray, brush or other methods and chemically cures after application. The purpose of this paper is to explain the typical requirements that apply to these coatings and compare some of their properties.

The resilient-seated gate valve manufacturers in Europe led the valve industry in the adoption of epoxy coatings starting in the 1970's. They realized that a corrosion resistant surface is critical in gate valves. The interior coating of the body serves as the mating sealing surface and must also resist abrasion and erosion for high localized fluid velocities. Conversely, it was not until 2010 that the quarter-turn ball and butterfly valve AWWA standards adopted epoxy as the standard interior coating.

Another driving force for the use of advanced epoxy coatings was environmental concerns. U.S. valve manufacturers must not only comply with air emission requirements but must also actively engage in activities that help mitigate the effects of climate change. Coating processes for valves have migrated from solvent-based coatings to epoxy coatings with high solids content to reduce volatile organic compounds (VOC's), which are a serious air pollutant. Similarly, powder-based coatings such as fusion bonded epoxy produce no VOC's.

VALVE COATING STANDARDS

AWWA set the standard for waterworks valve interior coatings to provide long-term corrosion resistance for water, wastewater, and reclaimed water service having a pH range of 4 to 9 (AWWA, 2013). The epoxy coatings are qualified for this service by subjecting test coupons to 90-day immersion tests at the full range of pH at 158°F. The coating is also tested for impact resistance by dropping a weight onto the surface in accordance with ASTM D2794. In production, coatings are visually examined for defects and randomly tested to verify coating thickness. The result has been the production of valves with highly reliable epoxy coatings for over 40 years.

Over the last decade, there has been significant debate among valve users and producers about setting standard requirements for epoxy coating thickness and holiday testing. Because of the intricate geometry of gate valves, providing uniform coating thicknesses and holiday testing on a production basis can be costly, therefore, the associated valve standards require only a minimum coating thickness of 6 mils for gate valves and 8 mils for quarter-turn valves (Figure 1). Project specifications and manufacturers' specifications typically indicate a higher coating thickness in the range of 8 to 16 mils depending on the coating and application. Holiday testing is important to guarantee the integrity of the coating but production holiday testing has been deemed an optional requirement based on the purchaser's ability to bear the cost.

FIGURE 1: Quarter-Turn AWWA C507 Ball Valve with Fusion Bonded Epoxy

Additional requirements were initiated by the U.S. Environmental Protection Agency, who in the 1990's, began regulating drinking water additives including treatment chemicals and water system components including valves and coatings. A consortium of organizations produced a standard ANSI/NSF 61, "Drinking Water System Components – Health Effects" which provides testing protocols for exposing products to test water and measuring contaminant levels extracted during a 14-day immersion test. Various state water authorities adopted the NSF 61 requirements resulting in an entire industry of testing authorities with labs dedicated to certifying products to this new standard.

From the start, the waterworks valve industry found the NSF 61 approval process to be burdensome and costly. Despite the fact that all of the materials in a valve, including the coating, could be independently tested to verify compliance with NSF 61, the standard required that actual production valves be tested by independent labs on a frequent interval. Ironically, NSF 61 does not consider the quality, impact strength, adhesion strength, and the corrosion resistance of the coating; only the coating's propensity to add contaminants to the water system.

Moreover, while treatment chemicals and pipeline coatings may have a significant impact on water quality because of their immense water contact surface area, a valve and its coating comprise an insignificant percentage of a water system's surface area. Normalization factors were developed in the standard to take this into account resulting in coating manufacturers certifying various coatings for either pipe or valve service. Finally, purchasers are warned in valve standards that specifying alternate coatings or materials will invalidate the valve's NSF 61 certification (AWWA, 2015).

COATING PROCESS

In general, the AWWA standards defer to that epoxy coating producers to publish a set of surface preparation requirements including surfaces that must be dry, clean, and free of oil, oxidation, and foundry dust. The substrate should have a minimum 1.5 mil roughness profile with no sharp edges to anchor the coating. Valve manufacturers typically employ a near-white grit blasting operation to meet these requirements and provide a good surface profile for the coating. Care is taken to prevent oxidation of the blasted surfaces before coating by performing the coating within the same work shift as blasting.

Liquid epoxy is furnished as a two-part kit that is thoroughly mixed and applied to the valve surfaces by spray, brush, or roller taking care to vent the vapors to promote the removal of the solvents from the coating. Because of the solvents involved, there is typically a limitation to the thickness of a single coat, such as 16 mils. If a greater thickness is required, additional coats are applied within a prescribed coating window. The mixture also has a finite pot life of 3-5 hours depending on temperature and humidity conditions. Dry time for handling is typically 7 to 10 hours, but water immersion may require 5-10 days of additional cure time to assure full dispersion of the solvents.

FIGURE 2. Infrared Thermometer with Laser Sight

The powder epoxy coating process involves a pre-heat process wherein the part is held in a large computer-controlled oven to 450°F for a prescribed period of time and monitored with an infrared thermometer (Figure 2) until the part reaches the desired pre-heat temperature; typically 400°F. The parts are either moved or conveyed to a spray booth where they are attached to an electrical source to achieve an electrostatic charge. The powder coating is then sprayed over the parts which are then returned to the oven for post for 10-20 minutes. In some factories the heating and spraying process are controlled with a conveyor system (Figure 3). Once removed from the oven, the parts are allowed to cool before installation and water immersion. Fusion bonded epoxy coatings do not require an additional 5-10 days of cure time as with liquid epoxy since no solvents are used.

FIGURE 3. Conveyor System for Fusion Bonded Epoxy Process

After either coating process, all parts are visually examined to ensure adequate coverage and the dry film thickness is measured in random locations. When required by the purchaser, a holiday test is conducted to identify any voids in the coating in accordance with ASTM G62. In a holiday test, a voltage is applied over the coated surfaces and any continuity between the test wand and substrate surface will be indicated on the detector unit. Epoxy coatings less than 20 mils in thickness can be checked using a low voltage (i.e. 22.5 to 80 volts) test unit while thicker coatings require the use of high voltage test unit in the range of 500 to 10,000 volts, depending on the thickness of the coating. When voids are identified, the coating is repaired and retested.

Figure 4. Typical High-Voltage Holiday Test Equipment

EPOXY COATING DURABILITY

Both liquid and fusion bonded coatings cure to a hard, smooth, and glossy finish, ideal for valve interiors. Their resistance to damage due to handling can be compared by reviewing their direct impact resistance in accordance with ASTM D2794 and adhesion strength in accordance with ASTM D4541. AWWA C550 requires a minimum impact strength of 20 in-lbs, which can be met by liquid epoxies, but is not typically reported quantitatively. Fusion bonded epoxy coatings typically have twice the impact strength and can be as high as 160 in-lbs. The adhesion strength is also rarely published for liquid epoxies but has been measured to be in the 1000 to 3000 psi range when good surface preparation practices are followed. In general, fusion bonded epoxy coatings exhibit twice the adhesion strength in the range of 3000 to 6000 psi (Val-Matic, 2013). Figure 5 illustrates the equipment used to perform the adhesion test.

FIGURE 5. ASTM D5451 Adhesion Testing Equipment

CONCLUSION

Epoxy interior coatings have proven to be a reliable product for waterworks valves over the last forty years due to developments in materials and standards. These coatings prevent corrosion, tuberculation, and wear in valves and promote efficient flow of fluids though piping systems.

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White Paper

Chemical Resistance Guide

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PURPOSE

This guide was developed by Val-Matic® Valve and Manufacturing Corporation as a convenience to its customers and should be utilized only as a guide for the selection of valve materials. Mixtures and other chemical concentrations of chemicals are beyond the scope of this guide. Performances of materials in existing systems also offer valuable information in predicting valve performance.

Information given in the table consists of the maximum recommended temperature for the listed material in °F or a letter designating:

A	=	resistant under normal conditions
B	=	conditional resistance, review performance
C	=	not recommended
blank	=	no data available

Val-Matic® offers no warranty or representation as to the accuracy or completeness of these tables. Use of these tables should be made under the direction of trained engineers or design professionals exercising independent judgment regarding the suggested use of the valve types and materials.

GENERAL PROPERTIES OF ELASTOMERS AND PLASTICS

Aflas® is a fluoroelastomer compound that has excellent heat resistance with continues service temperature capability of 450°F and good chemical resistance, including resistance to strong acids and bases. Aflas® also has excellent oil resistance.

Buna-N (Nitrile, NBR, HNBR), or copolymer of butadiene and acrylonitrile has excellent resistance to petroleum products, lubricants, and water over a wide temperature range of –50 to 200°F. Nitrile is a widely used elastomer for hydraulic system O-rings. Buna-N does not have good resistance to outdoor exposure to ozone, sunlight, or weather. High Nitrile Buna-N (HNBR) is formulated for high strength and resistance to H_2S and other harsh fluids.

Chemraz® A high temperature perfluoroelastomer with superior physical properties and chemical resistance. The compound excels in dynamic applications and exhibits unparalleled performance in high temperature steam. Temperature range is from 0°F to 600°F.

Devlon® Devlon® is among the toughest and hardest wearing thermoplastic available. It was designed for the valve industry as a seat material to provide a wide temperature and pressure range. Its resistance to chemical and corrosion attack is well documented, due to its use in various applications throughout most industries, such as oil and gas. Pressures up to 6000psi and temperatures from -50 to 250°F can be obtained.

EPDM (Ethylene Propylene Diene Monomer) exhibits strong resistance to ozone, certain hydraulic fluids, brake fluids, steam, and water over a wide temperature range of –50 to 250°F. EPDM has gained increased use in the municipal water industry because of its resistance to water disinfected with chloramines. It has poor resistance to petroleum-based fluids, mineral oils, and solvents.

Hypalon (Chlorosulfonated Polyethylene, CSM) is similar to neoprene in chemical resistance and useful in the range of –50 to 200°F for acid and ozone resistance.

Kalrez (Perfluoroelastomer) is similar to Viton but is formulated for long-term exposure to the harshest chemical environments and temperatures above 600°F.

Markez® is a high performance perfluoroelastomer compound that offers a broad chemical and temperature resistance up to 600°F. For demanding sealing applications, in various industries, like Petrochemical and where harsh solvents are required. The temperature range is -5°F to 600°F.

Natural Rubber (Natural Polyisoprene, NR) is produced from various plants with excellent wear properties and resistance to brake fluid, water, sewage, but not petroleum products. Natural rubber is economical and commonly used for lining trucks, railroad cars, and valves for abrasion resistance. Natural rubber has been mostly replaced by synthetic elastomers for industrial seals.

Neoprene (Chloroprene, CR) is one of the first commercially available elastomers and is low in cost. Neoprene is unique with its moderate resistance to both petroleum products and oxygen over a wide temperature range of –50 to 200°F. Neoprene is a widely used elastomer for seals with exposure to refrigerants, petroleum oils, and mild acids. Neoprene does not have good resistance to solvents such as MEK and acetone.

Nylon (Polyamide) is one of the first thermoplastics used as rubber cords, belts, sports apparel, and structural parts such as valve bearings. Nylon has excellent resistance to oils and solvents, but limited resistance to alkalis and Acids. Its application is limited to a maximum temperature of 250°F.

PEEK (Poly Ether Ether Ketone, CFFP) is a high performance engineered thermoplastic. PEEK is considered a premium seat material that offers a unique combination of chemical, mechanical, electrical and thermal properties. Its excellent water/chemical resistance makes it unaffected by continuous exposure to hot water/steam. PEEK is good for temperatures of -70°F to 500°F. PEEK is non-porous, high strength for high pressure applications and is suitable for high corrosion environments. Carbon Fiber Filled PEEK (CFFP) is reinforced to withstand elevated temperatures to 600°F.

RPTFE (Reinforced Polytetrafluoroethylene), is a compound with a percentage of fiber glass or filler material to provide additional strength, stability and resistance to abrasive wear, cold flow and permeation in molded seats. Reinforcement such as glass fiber permits applications at higher pressures and temperatures than unfilled PTFE. RPTFE should not be used in applications that attack glass, such as hydrofluoric acid and hot / strong caustics. Temperature range for RPTFE is -320 to 450°F.

Viton® (Fluorocarbon, FKM, FKM AED, FF200) possesses a strong resistance to chemicals and air at high temperature applications to 400°F. Viton is high in cost and is used in aircraft, automotive applications where resistance to petroleum oils, silicone fluids, and acids is needed. Viton also has superior chloramine resistance for drinking water applications. FKM Anti-Explosive Decompression (AED) formulation has a structure that reduces gas permeation in extreme pressure service so that the sudden decompression in gas pressure will not cause damage to the seal. The Viton FF200 formulation is designed to withstand long term exposure to heat at 625°F.

GENERAL PROPERTIES OF METALS

17-4 PH SS is similar to 304 SS except it is capable of being precipitation hardened (PH) using heat treatment, doubling its strength and making it a good choice for high performance valve trim. 17-4 PH withstands corrosive attack better than any of the 400 series stainless steels and in most conditions its corrosion resistance closely approaches that of 300 series stainless steel. 17-4 PH is primarily used as a stem material for high pressure butterfly and ball valves.

304SS is basic 18% chromium, 8% nickel austenitic stainless steel commonly used for valve trim. Its .08 max carbon content reduces intergranular corrosion usually associated with carbide precipitation that can occur during welding. It offers excellent resistance to a wide range of corrosives and atmospheric exposures.

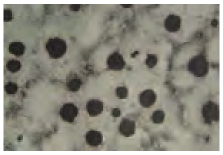
316SS is chemically similar to 304 SS except with the addition of molybdenum providing better corrosion and pitting resistance and higher strength at elevated temperatures. It is non-magnetic with greater ductility than 400SS. 316SS has excellent corrosion resistance in a wide range of environments, is not susceptible to stress corrosion cracking, and is not affected by heat treatment. Most common uses in valves are stem, body and ball materials.

Aluminum Bronze is the most widely accepted disc material used in many valves for liquid service. Aluminum bronze is heat treatable, is lead free and has the strength of steel. Formation of an aluminum oxide layer on exposed surfaces makes this metal very corrosion resistant.

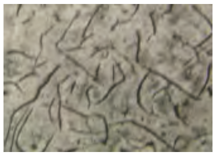
Bronze is one of the first copper alloys developed in the bronze age and is generally accepted as the industry standard for pressure-rated bronze valves and fittings. Bronze has a higher strength than pure copper, is easily cast, has improved machinability, and is very easily joined by soldering or brazing. Bronze is very resistant to pitting corrosion, with general resistance to most chemicals less than that of pure copper. Historically, bronze alloys have contained lead to improve machinability and leak tightness, but recently are being improved with the release of lead-free alloys for drinking water applications such as CA87600, Silicon Bronze.

Carbon Steel has very good mechanical properties, good resistance to stress corrosion and sulfides. Carbon steel has high and low temperature strength, is very tough, and has excellent fatigue strength. Steel can be easily cast or forged in making ANSI Pressure-Temperature rated valve bodies or structural parts for applications up to 850°F.

Ductile Iron has a chemical composition similar to gray iron, but special treatment during the casting process enhances its metallurgical graphite structure to yield higher mechanical properties and improved ductility similar to steel. It is standard material for bodies and bonnets of ASME Class 150 and 300 valves.



Gray Iron is an alloy of iron, carbon and silicon; easily cast; and has good pressure tightness in the as-cast condition. Because gray iron contains flakes of graphite, it is brittle but exhibits excellent dampening properties and is easily machined. It is standard material for bodies and bonnets of ASME Class 125 and 250 valves. Gray iron has corrosion resistance that is improved over steel in certain environments.



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Inconel is nickel-copper-molybdenum alloy with excellent corrosion resistance in a wide range of corrosive media and is especially resistant to pitting and crevice corrosion. Like Monel, it is a favorable choice for seawater applications but with far greater strength. Inconel is a common material for corrosion resistant springs.

Monel is a nickel-copper alloy used primarily as interior trim on valves. It is one of the most specified materials for corrosion resistance to sea and salt water. Monel is also very resistant to strong caustic solutions.

Nickel is an elemental metal common for chemical processing applications because of its corrosion resistance. Nickel is used for valve seats because of its good welding ability and lack of brittleness.

Nitronic 60 is a high-performance stainless steel alloy with excellent gall and wear resistance with corrosion resistance falling between 304SS and 316SS but with approximately twice the yield strength. Nitronic 60 is used for valve trim when extreme wear resistance or strength is required.

Val-Matic® Chemical Resistance Guide for Valves

CHEMICAL	ELASTOMERS AND PLASTICS												METALS										
	Buna-N	Neoprene	EPDM	Viton®	Hypalon	Natural Rubber	PTFE/ RPTFE	Nylon	PEEK	Devlon®	AFLAS®	Chemraz® Kalrez® Markez®	Carbon Steel	Nickel	Cast Iron	Bronze	Alum. Bronze	304 SS	17-4 PH SS	316 SS	Nitronic 60	Monel	Inconel
Acetic Acid (25%)	C	C	140	C	200	C	350	B	B	B	C	A	C	B	C	C	C	A	A	A	A	A	B
Acetic Anhydride	70	B	C	C	200	B	350	C	C		B	A	C	C	C	C	C	B	B	B	B	B	B
Acetone	C	C	130	C	B	B	350	70	A	A	C	A	A	200	A	A	A	A	A	A	A	A	A
Acetyl Chloride	C	C	C	185	C	C	200	C	B		A	A	A	A	C	A	A	A	A	A	A	A	
Acetylene	140	70	200	200	70	70	250	70	A	A	A	A	A	A	A	C	C	A	A	A	A	A	
Aluminum Acetate	B	C	200	C	C	70	350				A	A	C	B	C	C	C	B	B	A	B	B	
Alum (10%)	140	140	200	200	70	70	275	70	A		B	A	C	A	C	B	B	A	A	A	A	A	B
Aluminum Chloride	70	160	210	250	200	70	280	C	A		A	A	C	C	C	C	C	B	C	A	B	B	C
Aluminum Fluoride	180	160	210	250	200	B	250	B			A	A	C	B	C	C	C	B	C	B	B	A	B
Aluminum Hydroxide	180	100	210	200	70	70	250	B		A	A	A	C	200	B	C	C	A	A	A	A	B	B
Aluminum Nitrate	180	100	210	100	100	70	250				A	A	C	B	C	C	C	A	A	A	A	C	
Ammonia Anhydrous	C	100	200	C	B	C	250	70	A		B	A	A	500	A	C	C	A	A	A	A	A	A
Ammonia Liquid	B	70	210	C	70	C	400	70	A	A		B	A		A	C	C	B	A	A	A	A	A
Ammonium Bifluoride	180	140	200	200		B	400					A	C	50	C	C	C	C	B	B	C	B	B
Ammonium Carbonate		140	210	250	140	70	400	70	A	A	A	A	A	C	B	C	C	B	B	B	B	B	A
Ammonium Chloride	180	160	210	250	200	70	400	70	B		A	A	C	B	C	C	C	C	C	B	C	B	A
Ammonium Hydroxide (30%)	B	70	210	70	200	B	400	70	B	A	B	B	C	C	C	C	C	A	A	A	A	B	A
Ammonium Nitrate	180	160	250	100	200	150	400	70	B	A	A	A	B	50	B	C	C	A	A	A	A	A	A
Ammonium Phosphate	100	140	210	185	140	150	400	70	A	A	B	A	C	B	B	C	C	A	A	A	A	B	A
Ammonium Sulfate	180	160	210	200	200	150	400	70	A	A	A	A	C	B	B	C	C	B	B	B	B	B	A
Ammonium Sulfite	140	160	210	C	200	70	350	A				A	C	C	C	C	C	B	B	B	B	B	C
Aniline	C	C	140	C	70	C	200	C	A	C	B	A	C	B	B	C	C	A	A	A	A	B	B
Aniline Hydrochloride	C	C	B	1185	C	B	212	C			A	A	C	C	C	C	C	C	C	C	C	A	B
Arsenic Acid	160	180	185	200	200	150	400	70			A	A	C	B	C	C	C	A	B	A	A	A	C
Barium Carbonate	180	160	250	250	200	70	400	A	A			A	B		B	A	A	B	A	A	A	A	A
Barium Chloride	180	160	250	300	200	70	400	190	B	A	A	A	C	B	B	A	A	A	A	A	A	A	A
Barium Hydroxide	180	140	200	300	200	70	400	70	A		A	A	C	200	B	C	C	B	A	A	B	A	A
Barium Nitrate	180	160	200	300	200	C	250	A				A	A	B	A	C	C	B	B	A	B	B	B
Barium Sulfate	100	160	200	300	200	70	400	A	A	A	A	A	A	B	B	B	B	B	A	A	B	A	A
Barium Sulfide	C	160	140	300	200	70	400	B	A		A	A	C	50	B	C	C	B	A	A	B	A	A
Beer	70	140	200	200	200	70	300	140	A	B	A	A	C		C	A	A	A	A	A	A	A	A
Beet Sugar Liquor	100	160	210	185	200	70	70	A			A	A	B		B	C	A	A	A	A	A	A	A
Benzene	C	C	C	150	C	C	250	100	A	A	B	A	A	200	A	A	A	A	A	A	A	A	A
Benzyl Alcohol	C	B	C	B	140	C	400	C	B		B	A	B	50	B	A	A	A	A	A	A	A	A
Black Liquor	180	70	180	200	70	B	225				B	B	B	B	B	C	C	B	B	A	A	B	B
Bleach (5%)	C	C	140	185	70	C	200	C	B			A	C		C	C	C	B	B	A	B	A	A
Borax	140	140	210	185	200	185	300	70		A	A	A	B		A	A	A	A	A	A	A	A	A

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Val-Matic® Chemical Resistance Guide for Valves

CHEMICAL	ELASTOMERS AND PLASTICS												METALS										
	Buna-N	Neoprene	EPDM	Viton®	Hypalon	Natural Rubber	PTFE/ RPTFE	Nylon	PEEK	Devlon®	AFLAS®	Chemraz® Kalrez® Markez®	Carbon Steel	Nickel	Cast Iron	Bronze	Alum. Bronze	304 SS	17-4 PH SS	316 SS	Nitronic 60	Monel	Inconel
Boric Acid (5%)	140	140	210	185	200	185		C	A	B	A	A	B	50	C	B	B	B	B	A	B	A	A
Brine	180	160	250	300	180	70	400	A	A		A	A	C	B	C	A	A	B	B	A	B	A	A
Bromine Water	C	C	C	185	70	C	300	C	A		B	A	C	50	C	C	C	C	C	C	C	C	C
Butadiene	C	140	C	185	B	C	350	C	A	A	B	A	A	200	A	A	A	A	A	A	A	A	A
Butyl Acetate	140	C	C	C	C	C	175	140	B		C	A	B	300	B	B	B	A	A	A	A	A	A
Butyl Alcohol	B	140	200	200	140	A	300	B		A	A	A	A	A	A	B	B	A	A	A	A	A	A
Butylene	70	C	C	100	C	C	400	B	A		B	A	A	A	A	A	A	A	A	A	A	A	A
Butyl Stearate	100	C	C	185	C	C	250		A		A	A	B	B	B	A	A	A	A	A	A	A	A
Butyric Acid		C	140	70	C	C	300	C	A	B	A	A	C	C	C	A	A	A	A	A	A	A	A
Calcium Bisulfite	70	70	C	185	200	C	350	70	A		A	A	C	C	C	C	C	B	B	A	B	C	
Calcium Carbonate	100	70	210	300	70	A	350	A	A		A	A	B	B	B	C	C	A	A	A	A	A	A
Calcium Chlorate	70	70	140	185	70	A	350					A	B	B	B	B	B	A	A	A	A	A	A
Calcium Chloride	100	160	210	250	200	A	350	70	A	B	A	A	C	300	A	B	B	B	B	A	B	A	A
Calcium Hydroxide	140	70	210	250	200	A	250	120	B		A	A	C	B	C	C	C	A	A	A	A	A	A
Calcium Hypochlorite	C		70	185	140	C	200	C	B		A	A	C	C	C	C	C	B	B	B	B	C	
Calcium Nitrate	180	100	210	200	100	70	200	70	B		A	A	C	B	B	B	B	A	A	A	A	A	A
Calcium Sulfate	180	160	210	200	200	B	200	C	B			A	B	200	A	B	B	A	A	A	A	A	A
Camphor	100	C	210	250	70		350		A		A	A	B	B	B	B	B	A	A	A	A	B	
Cane Sugar	180	160	250	200	100	A	400	C			A	A	A	A	A	A	A	A	A	A	A	A	A
Carbitol	70	70	70	100	70		20				A	A	B	B	B	B	B	B	B	B	B	B	B
Carbon Dioxide (wet)	180	160	200	200	200	B	400	A	A		A	A	A	150	A	A	A	A	A	A	A	A	A
Carbon Monoxide (gas)	70	70	250	250	200	C	400	70	A			B	B	C	A	A	A	A	A	A	A	A	A
Carbon Tetrachloride	C	C	C	185	C	C	350	C	B	B	C	A	A	200	C	A	A	A	A	A	A	A	A
Carbonic Acid	180	70	210	200	70	C	350	70	A	B	A	A	B	B	B	C	C	A	A	A	A	A	A
Castor Oil	140	100	10	140	150	A	350	A	A		A	A	A	A	A	A	A	A	A	A	A	A	A
Caustic Potash- KOH	180	160	200	C	200	B	350	C	A		A	A	B	450	B	C	C	B	B	B	B	B	B
Caustic Soda-NaOH (20%)	C	160	180	C	140	70	350	A	A		B	B	B	300	B	B	C	A	A	A	A	A	A
Chloramine (5%)	B	B	A	A	B	70						A	C	50	C	B	B	B	B	B	B	B	
Chloric Acid (10%)		140		140	200		140	C				A	C	C	C	C	C	C	C	B	B	C	C
Chlorinated Water (10ppm)	140	C	210	185	B	B	400	C	A	B		A	C	A	B	B	C	A	A	A	A	A	A
Chlorinated Water (Sat)	C	C	70	185	B	C	400	C	A	B		A	C	A	C	C	B	B	A	A	A	B	B
Chlorine (Liq)		C	C		B	C		C	C			B	C	C	C	B		C	C				

Val-Matic® Chemical Resistance Guide for Valves

CHEMICAL	ELASTOMERS AND PLASTICS												METALS										
	Buna-N	Neoprene	EPDM	Viton®	Hypalon	Natural Rubber	PTFE/ RPTFE	Nylon	PEEK	Devlon®	AFLAS®	Chemraz® Kalrez® Markez®	Carbon Steel	Nickel	Cast Iron	Bronze	Alum. Bronze	304 SS	17-4 PH SS	316 SS	Nitronic 60	Monel	Inconel
Chloroacetic Acid (50%)	C	C	70	C	200	C	200	C	A		B	A	C	B	C	C	C	C	C	C	C	B	
Chlorobenzene	C	C	C	70	C	C	200	C	A	A	B	A	B	B	C	A	A	A	A	A	A	A	A
Chloroform	C	C	C	70	C	C	200	A	A	C	C	A	C	A	C	A	A	A	A	A	A	A	A
Chlorosulfonic Acid	C	C	C	C	C	C	200	C	C	C	C	A	C	C	B	C	C	C	C	C	C	A	
Chromic Acid (10%)	C		70	100	140	B	350	C	B	C	A	A	C	C	C	C	C	C	B	A	B	B	
Citric Acid	70	140	210	200	140	A	200	A	A	C	A	A	C	B	C	C	C	A	A	A	A	B	
Coconut Oil (5%)	70	100	C	185	B	C	400		A	A	A	A	B	A	C	B	B	A	A	A	A	B	
Coffee	100		140	200		A		A			A	A	C	A	C	A	A	A	A	A	A	A	A
Coke Oven Gas	B		70	185	140		400				A	A	A		A	B	B	A	A	A	A	B	
Copper Acetate	180	160	100	140	C		350		B		C	A	C	B	C	C	C			A	A	B	
Copper Chloride	180	160	210	200	200	C	350	C	A		A	A	C		C	C	C	C	C	B	B	B	
Copper Cyanide (25%)	180	160	210	185	C	A	350	C	B		B	A	C		C	C	C	B	B	A	B	B	
Copper Nitrate	B	160	210	200	200	C	A	C	B		B	A	C	C	C	C	C	A	A	A	A	C	
Copper Sulfate (5%)	180	160	210	200	200	C	A	C	B	A	A	A	C	B	C	C	C	A	A	A	A	C	
Corn Oil	180	C	C	300	C	C	400	A	A		A	A	B	A	B	B	B	A	A	A	A	B	
Cottonseed Oil	180		C	185	200	C	400	B	A		A	A	B	A	B	B	B	A	A	A	A	B	
Creosote	73	C	C	73	73	C	350	C	B		B	A	A	B	A	B	B	A	A	A	A	A	A
Cresylic Acid	C	C	C	185	C	C	200	C	B	C	A	A	B		A	A	A	A	A	A	A	A	A
Crude Oil	70	B	C	200	C	C	400	100	B	A	A	A	B	A	C	C	C	A	A	A	A	B	
Cyclohexane	C	C	C	185	C	C	300	A	B	A	A	A	A	B	B	C	C	A	A	A	A	A	A
Cyclohexanone	C	C	70	C	C	C	200	A	B		B	A	B	B	B	B	B			A		B	
Detergents	180	160	250	210	200	B	400	A	A	A		B	A	A	A	A	A	A	A	A	A	A	A
Dextrose	180	160	140	200	140		400					A	A	200	A	A	A	A	A	A	A	A	A
Diacetone Alcohol	C	C	70	C	A		350	70			C	A	A	A	A	A	A	A	A	A	A	A	A
Diesel Fuel	70	C	C	183	C	C	350	A	B	A		A	A	A	A	A	A	A	A	A	A	A	A
Diethylamine	70	A	70	C	C	A	200	A	A	A	C	A	B	B	A	C	C	A	A	A	A	B	B
Dimethyl Formamide	100	C	C	C	100	C	250	A	A		B	A	B		B	B	B	A	A	A	A	A	A
Dioxane	C	C	70	C	C				B	A	C	A	A	A	A	A	A	A	A	A	A	A	A
Disodium Phosphate	100		210	70	140	70	400	400						A	B	B	B	A	A	A	A	B	
Ether	C	C	C	C	C	C	A	A	A	A	C	A	B	A	B	A	A	A	A	A	A	A	A
Ethyl Acetate	C	C	70	C	C	C	200	200	B	A	C	A	A	A	A	A	B	A	A	A	A	A	A
Ethyl Alcohol- Eth-anol	180	70	170	A	200	A	300	300			A	A	A	200	A	A	A	A	A	A	A	A	A
Ethyl Benzene	C	C	C	70	C	C	350				B	A	B	200	B	B	B	A	A	A	A	A	A

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Val-Matic® Chemical Resistance Guide for Valves

CHEMICAL	Buna-N	Neoprene	EPDM	Viton®	Hypalon	Natural Rubber	PTFE/ RPTFE	Nylon	PEEK	Devlon®	AFLAS®	Chemraz® Kalrez® Markez®	Carbon Steel	Nickel	Cast Iron	Bronze	Alum. Bronze	304 SS	17-4 PH SS	316 SS	Nitronic 60	Monel	Inconel
	ELASTOMERS AND PLASTICS												METALS										
Ethyl Chloride	C	B	B	140	70	B	350	A	A		B	A	A	A	A	A	B	A	A	A	A	A	A
Ethylene Bromide	C	C	C	B	C	C	350					A	A		A	A	A	A	A	A	A	A	A
Ethylene Chloride	C	C	C	70	C	C	350	A	A	B		B						B	B	A	A	A	A
Ethylene Dichloride	C	C	C	120	C	C	350	70	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A
Ethylene Glycol	180	160	210	250	200	A	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A
Ethylene Oxide	C	C	C	C	C	C	400	70	B	A			B	A	A	A	A	A	A	A	A	B	B
Fatty Acids	140	140	C	185	C	C	400	70	A	A	A	A	C	A	C	C	C			A		A	
Ferric Chloride (sat)	180	160	225	200	200	A	400	A	A		B	B	C	C	C	C	C	C	C	C	C	C	C
Ferric Hydroxide	100	100	180	180	100		400		A			A	C		C	C	C	C		A		A	
Ferric Nitrate	180	160	210	200	140	A	400	70	B		A	A	C	A	C	C	C	B	A	A	A	C	
Ferric Sulfate	140	140	210	185	140	A	200	70	B		A	A	C	C	C	C	C	B	A	A	A	C	
Ferrous Chloride	180	A	200	200	A	A	400	C	B	C			C	C	C	C	C	C	C	C	C	C	C
Ferrous Nitrate	180	160	180	200	140		400		B									A	A	A	A		
Ferrous Sulfate (5%)	180	160	200	200	140	B	400	C	A			A	C	C	C	C	B	A	A	A	A	A	A
Fish Oil	70		C	300								A	A	A	A	A	A	A	A	A	A	A	A
Flue Gas	180		C	300									A	A	A	A	A	A	A	A	A	A	A
Fluoboric Acid	160	160	140	140	140	A	350	C				A	C	50	C	B	B	A	A	A	A	A	A
Fluorine (wet)	C		70	100		C	C	C	C				C	A	C	C	C	A	A	A	A	A	A
Fluorosilic Acid (25%)	100	100	140	210	200	A	300	C	C		A	A	C	50	C	B	B	B	B	B	B	A	B
Formaldehyde (40%)	C	140	140	C	200	B	300	C	B	B	C	A	B	200	C	A	B	C	C	A	B	A	A
Formic Acid	C	140	200	C	70	C	300	C	A	C	B	B	C	200	C	C	B	B	A	A	A	A	A
Freon	70	C	C	70	130	C	300	C	B				B	A	B	A	A	A	A	A	A	A	A
Fructose	140	160	175	225	140	C	300	A					A	A	A			A	A	A	A	A	
Furfural	C	70	140	C	70	C	300	B	A	A	C	B	A	B	A	A	A	A	A	A	A	A	A
Gallic Acid	C	70	70	185	70	A	300	A	B		A	A	C		C	B	B	A	A	A	A	A	A
Gasoline	70	B	C	100	70	C	200	A	B		B	A	A	A	A	A	A	A	A	A	A	A	A
Gasahol	70	B	C	100	70	C	200	A				A	A	A	A	A	A	A	A	A	A	A	A
Gelatin	180	160	200	250	200	A	300	70	A			A	C	A	C	C	C	120	A	C	C		
Glucose	180	160	250	300	200	A	400	A			A	A	A	A	A	A	A	A	A	A	A	A	A
Glue	140	160	100	250	200	A	400	120					A	A	A	A	A	A	A	A	A	A	A
Glycerin	70	160	200	300	200	A	400	70	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Glycol	140	160	200	250	200		300		B		A	A	A	A	A	A	A	A	A	A	A	A	A
Glycolic Acid	C	70	A	C	C	C	200		A			A	C	B	C	B	B	A	A	A	A	B	
Grease	150	100	C	200	C	C	A					A	A	A	A	C	C	A	A	A	A	A	A

Val-Matic® Chemical Resistance Guide for Valves

CHEMICAL	ELASTOMERS AND PLASTICS												METALS										
	Buna-N	Neoprene	EPDM	Viton®	Hypalon	Natural Rubber	PTFE/ RPTFE	Nylon	PEEK	Devlon®	AFLAS®	Chemraz® Kalrez® Markez®	Carbon Steel	Nickel	Cast Iron	Bronze	Alum. Bronze	304 SS	17-4 PH SS	316 SS	Nitronic 60	Monel	Inconel
Gypsum	180	160	210	200	200	C	350	A					A	A	A	B	B	A	A	A	A	A	A
Heptane	70	70	C	185	70	C	300	A	B	A	B	A	A	A	A	A	A	A	A	A	A	A	A
Hexanol	70	B	C	160	70		300						A	A	A	A	A	A	A	A	A	A	A
Hydraulic Oil	160	70	C	250	70	C	300	70	B			A	A	A	A	A	B	A	A	A	A	A	A
Hydrazine	70		70	C	70	C	250		B		A	B	C	C	C	C	C	A	A	A	A	A	
Hydrobromic Acid (20%)	C	B	140	185	100	A	250	C	C		A	A	C	C	C	C	C	C	C	C	C	C	C
Hydrochloric Acid (35%)	C		70	100	100	A	250	C	B		A	A	C	C	C	C	C	C	C	B	C	C	C
Hydrocyanic Acid (10%)	70		200	185	200	B	250	B	B		A	A	C	50	C	C	C	C	B	A	B	A	C
Hydrofluoric Acid (20%)	C	70	70	150	150	B	300	C	B			B	C	B	C	C	C	C	C	C	C	A	C
Hydrogen (Gas)	180	160	250	300	200	B	300	120			A	A	A	A	A	A	A	A	A	A	A	A	A
Hydrogen Peroxide (50%)	C	C	100	185	200	C	300	C	B	C	A	A	C	C	C	C	C	A	A	A	A	A	A
Hydrogen Sulfide (Gas)	140	140	140	C	70	70	A	C	A	B	A	A	B	B	B	B	C	C	B	A	B	A	A
Hydrogen Sulfide (Wet)	C	70	140	C	70	70	A	C	A	B	A	A	C	B	C	C	C	C	C	A	B	B	A
Hydroquinone	70	C	C	185	C	A	300	C			B	B	A	A				B	A	A	A	A	
Hypochlorous Acid (10%)	C	A	70	70			300					A	C	C	C	C	C	C	C	C	C	C	C
Ink	70	70	70	70		C	300	C				A	C	A	C	A	A	C	C	A	B	A	A
Iodine	70	C	70	70	70	C	200	A	B		A	A	C	A	C	C	C	C	B	B	B	A	A
Isobutane	70	C	C	B	C	C	140	B	A			A	A	A	A	A	A	A	A	A	A	A	A
Isobutyl Alcohol	70	70	140	140	70	A	300	A			A	A	B	A	A	A	A	A	A	A	A	A	A
Isooctane (5%)	70	70	C	185	200	70	300	70	A		B	A	A	A	A	A	A	A	A	A	A	A	A
Isopropyl Acetate	C	C	70	C	C	C	200	B	A		C	A	A	A	A	A	A	A	A	A	A	A	A
Isopropyl Alcohol	70	70	140	200	200		300						A	A	A	A	A	A	A	A	A	A	A
Isopropyl Ether	70	C	C	C	C	A	140	70	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A
Jet Fuel JP-4	70	C	C	185	C	C	200	C	A		B	A	A	A	A	A	A	A	A	A	A	A	A
Kerosene	140	70	C	300	C	C	250	A	B		B	A	A	A	A	A	A	A	A	A	A	A	A
Ketchup	140		210	200	B		250		A				C	A	C	C	C	A	A	A	A	A	A
Ketones	C	C	C	C	C	A	200	120	A	B			A		A	A	A	A	A	A	A	A	A
Lactic Acid (25%)		140	70	70	140	A	300	B	B			A	C	B	B	C	C	A	A	A	A	A	A
Lard Oil	140	70	C	85	C	C	300	70			A	A	B	A	B	C	C	A	A	A	A	B	
Latex	70	100	70	70	C	B	200	70					A	A	A	A	A	A	A	A	A	A	A
Lead Acetate	70	160	210	C	100	A	300	A	B	B	C	A	C	B	C	C	C	A	A	A	A	A	B
Lead Nitrate	188	140	175	225	A	70	300				B	A	A	B	A	A	A	A	A	A	A	A	A

Val-Matic® Chemical Resistance Guide for Valves

CHEMICAL	ELASTOMERS AND PLASTICS												METALS										
	Buna-N	Neoprene	EPDM	Viton®	Hypalon	Natural Rubber	PTFE/ RPTFE	Nylon	PEEK	Devlon®	AFLAS®	Chemraz® Kalrez® Markez®	Carbon Steel	Nickel	Cast Iron	Bronze	Alum. Bronze	304 SS	17-4 PH SS	316 SS	Nitronic 60	Monel	Inconel
Lead Sulfate	180	140	210	225	200	70	300	B					C	B	C	B	B	B	B	B	B	B	B
Lemon Oil	A	140	C	200	100	C	300						C	B	C			A	A	A	A	A	A
Lime Slurry	100	100	100	70	160	A		70	B				A	A	A	A	A	A	A	A	A	A	A
Linoleic Acid	B		C	140	C	C	300		A		A	A	C	C	C	C	C	B	B	A	A	A	
Linseed Oil	180	70	B	250	200	C	300	B	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A
Lithium Chloride	70	70	100	140	B	B	125	A	A			A	C	C	B	B	B			A		A	
Lubricating Oil	180	70	C	150	C	C	350	70	B	A	B	A	A	A	A	A	A	A	A	A	A	A	A
Magnesium Carbonate	140	140	170	210	140	70	225	70	A				B	B	B	B	B	A	A	A	A	A	A
Magnesium Chloride	180	160	170	170	200	A	400	70	B	A	A	A	C	C	C	B	B	C	C	C	C	A	
Magnesium Hydroxide	180	160	170	225	200	A	300	B	B	A	A	A	A	A	A	C	C	A	A	A	A	A	A
Magnesium Nitrate	70	160	140	225	140	A	300	70	A				B	B	A	C	C	A	A	A	A	B	
Magnesium Sulfate	180	160	175	200	140	B	300	70	B	A		A	A	A	A	A	A	A	A	A	A	A	A
Maleic Acid	C	C	70	200	C	B	250	A	A		A	A	C	B	C	C	B	B	B	A	B	B	
Malic Acid	100	70	C	200	70	B	250	A	B	A	A	A	C	B	C	B	B	A	A	A	A	A	A
Manganese Sulfate	180	160	175	200	140	120	300	120	A			A	A	B	A	A	A	A	A	A	A	A	A
Mercuric Chloride	140	140	210	185	140	A	300	C	B	C	A	A	C	C	C	C	C	C	C	C	C	C	C
Mercuric Cyanide	70	70	70	70	140	70	300	120	B			A	C	C	C	C	C			A			
Mercurous Nitrate	C	C	70	70	B	B	300		B				C	C	C	C	C	A	A	A	A	C	
Mercury	140	140	210	185	140	A	300	A	B	A	A	A	A	A	A	C	C	A	A	A	A	A	A
Methane	180	70	C	185	70	C	300	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A
Methanol	140	140	100	100	140	A	300	B	B		A	A	A	A	A	A	A	A	A	A	A	A	A
Methyl Acetate	C	C	B	C	C	C	300	120	A	A	C	A	B	B	B	B	B	A	A	A	A	A	A
Methyl Amine	B	70	70	100	70	70	300			A			A	A	A	C	C			A		C	
Methyl Bromide	70	C	C	185	C	C	300	B	B		B	A	B	B	C	C	B	A	B	A	A	B	
Methyl Chloride	C	C	C	70	C	C	250	B		C	C	A	A	A	A	A	C	A	A	A	A	A	A
Methyl Ethyl Keytone	C	C	70	C	C	C	200	70	B		C	A	A	A	A	A	A	A	A	A	A	A	A
Methyl Formate	C	70	100	C	C	C	70	C			C	A	C	B	A	A	A	A	A	A	A	A	A
Methylene Chloride	C	C	C	70	C	B	250	C	B	C	B	A	B	B	B	B	B	A	A	A	A	A	B
Milk	180	160	250	300	200	A	400	A	A	A	A	A	C	C	C	B	B	A	A	A	A	A	A
Mineral Oil	140	70	C	300	B	C	300	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Molasses	150	150	100	185	150	A	300	120	A			A	A	A	A	A	A	A	A	A	A	A	A
Monochloroacetic Acid (50%)	70	C	C	70	C	B	200	C				B	C		C	C	C	C	C	C	C	B	
Motor Oil	180	B	C	250	B		350	120	A			A	A	A	A	A	A	A	A	A	A	A	A
Morpholine	C	C	70	C	C	70	200	120				A	B	A	B	B	B	B	B	B	B	B	B
Naphtha	140	C	C	150	C	C	200	A	B	A	B	A	A	200	A	A	B	A	A	A	A	A	A

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Val-Matic® Chemical Resistance Guide for Valves

CHEMICAL	ELASTOMERS AND PLASTICS												METALS										
	Buna-N	Neoprene	EPDM	Viton®	Hypalon	Natural Rubber	PTFE/ RPTFE	Nylon	PEEK	Devlon®	AFLAS®	Chemraz® Kalrez® Markez®	Carbon Steel	Nickel	Cast Iron	Bronze	Alum. Bronze	304 SS	17-4 PH SS	316 SS	Nitronic 60	Monel	Inconel
Naphthalene	C	C	C	170	C	C	250	70	B	A	C	A	A	400	A	A	B	A	A	A	A	A	A
Natural Gas	140	140	C	185	140	C	300	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Nickel Chloride	180	160	210	210	200	A	400	C	B		A	A	C	200	C	C	B	A	A	A	A	C	B
Nickel; Nitrate	180	120	210	250	C	70	400	70	B			A	C	400	C	C	C	A	A	A	A	C	C
Nickel Sulfate	70	160	210	300	200	B	400	70	B	A	A	A	C	200	C	C	B	B	B	A	A	B	A
Nitric Acid (10%)	C	C	70	185	100	C	250	C	B	B	B	B	C	C	C	C	C	A	A	A	A	C	B
Nitrobenzene	C	C	C	70	C	C	400	B	B	C	A	A	A	B	A	B	B	A	A	A	A	A	A
Nitrogen (Gas)	140	140	140	185	100	A	300	A	B		A	A	A	A	A	A	A	A	A	A	A	A	A
Nitromethane	C	C	B	C		C	300	B			B	A	B	C	B	B	B	A	A	A	A	B	
Nitrous Acid	C	C	A	100		C	400		B			A	C	C	C	C	C	B	B	B	B	C	B
Nitrous Oxide	C	C	A	70	B	A	400	C	B		B	A	C	C	B	B	B	A	A	A	A	C	C
Oleic Acid	100	B	B	185	70	C	250	A	B	A	A	A	C	A	B	B	A	A	A	A	A	A	A
Oleum Acid	C	C	100	70	C	C	150	C	C		A	A	C		C	C	C	A	A	A	A	C	
Olive Oil	140	140	C	150	B	C	350	70	A		A	A	A		A	A	A	A	A	A	A	A	A
Oxalic Acid	C	100	150	100	C	B	300	B	B	C	A	A	C		C	C	C	A	A	A	A	A	A
Oxygen (Gas)	C	140	210	185	140	B	400		B	A	C	A	A		A	A	A	A	A	A	A	A	A
Ozone (Gas)	C	C	210	185	140	C	300	C	B	C	A	A	A		A	A	A	A	A	A	A	A	A
Palm Oil	140	C	C	70	C	C	200		A				C		C	C	C	A	A	A	A	A	A
Palmitic Acid	100	C	70	185	70	B	300	A	A	A	A	A	B	B	B	B	B	A	A	A	A	A	A
Peanut Oil	100	B	C	150	B	C	250				A	A	A		A	A	A	A	A	A	A	A	A
Perchloric Acid	C	70	70	70	70		250	C	B		A	A		C		B		C		A	B		
Perchloroetylene	C	C	C	200	C	C	200	C	B	B	C	A	B	A	B	B	B	A	A	A	A	A	A
Phosphoric Acid	70	140	140	200	200	B	300	B	A	B	B	A	C	50	C	C	C	A	A	A	A	C	
Picric Acid (10%)	C	70	140	140	70	C	300	C	B			A	C	C	C	C	C	C	A	A	B	C	
Potash-KOH (180)	70	140	200	180	B	400	C	A					B	A	B	B	A	A	A	A	A	A	A
Potassium Bicarbonate	70	160	170	200	200	A	400	70	B			A	A	B		B		B	B	B	B		
Potassium Bisulfate	180	140	170	200	140	70	400	B				A	C	B	C	B	B	A	A	A	A	C	
Potassium Bromate	180	140		250	140	70	400	B				B	A		A			A	A	A	A	A	A
Potassium Bromide	180	160	170	200	200	A	400	70	B	A		A	C	B	C	B	B	A	A	A	A	A	A
Potassium Carbonate	180	160	170	200	200	A	400	A	B	A		A	A	B	A	B	B	A	A	A	A	A	A
Potassium Chlorate	B	100	140	140	140		400	C	B			A	A	C	A	B	B	A	A	A	A	A	A
Potassium Chloride	180	160	210	200	200	A	400	70	B	A	A	A	C	B	B	A	B	A	A	A	A	A	A
Potassium Cyanide	180	160	140	185	200	A	400	70			A	A	B	B	B	C	C	A	A	A	A	A	B
Potassium Hydroxide	B	160	210	140	140	B	400	C	B	B	A	A	B	A	B	C	C	A	A	A	A	A	A
Potassium Nitrate	180	140	210	250	140	A	400	B	B	A	A	A	B	B	B	A	B	B	A	A	A	A	A

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Val-Matic® Chemical Resistance Guide for Valves

CHEMICAL	ELASTOMERS AND PLASTICS												METALS										
	Buna-N	Neoprene	EPDM	Viton®	Hypalon	Natural Rubber	PTFE/ RPTFE	Nylon	PEEK	Devlon®	AFLAS®	Chemraz® Kalrez® Markez®	Carbon Steel	Nickel	Cast Iron	Bronze	Alum. Bronze	304 SS	17-4 PH SS	316 SS	Nitronic 60	Monel	Inconel
Potassium Permanganate	C	200	210	140	100	70	400	C	B	C		A	A	B	A	B	B	A	A	A	A	A	A
Potassium Sulfate	140	140	210	250	140	A	200	70	B	A	A	A	A	B	A	B	B	A	A	A	A	A	A
Potassium Sulfide	100	70	A	100	B	B	300	A	B	A		A	C	C	C	C	C	B	B	B	B	C	A
Potassium Sulfite	70	70	140	200	B	B	300	B		A		A	C	C	C	B	B	A	A	A	A	B	
Propane	70	70	C	70	B	C	300	70	B	A	A	A	A	200	A	A	A	A	A	A	A	A	A
Propyl Alcohol	140	140	140	250	140	70	350	C					A	200	A	A	A	A	A	A	A	A	A
Rosin Oil	70	70		100	70		200	A	A			A	C	A	C	C	C	A	A	A	A	A	A
Salicylic Acid	C	C	210	185	70	A	300	70	C	C	A	A	C	200	C	B	B	A	A	A	A	B	B
Silicone Oil	140	70	140	185	140	C	350	70	B	A	A	A	A		A	A	A	A	A	A	A	A	A
Silver Cyanide	C	70	140	140		70	350		A			A	C		C	C	C			100		A	
Silver Nitrate	140	160	210	250	200	A	350	70	B	A	A	A	C	C	C	C	C	B	B	A		C	A
Soap	180	140	210	250	140	B	400	70	A	A	A	A	B	200	B	B	A	A	A	A	A	B	A
Sodium Acetate	C		170	C	70	A	400	B	B	B	B	A	C	A	B	A	B	A	A	A	A	A	
Sodium Aluminate	180	140	200	200	140	B	300	70	A			A	A	B	B	C	B	A	A	A	A	A	A
Sodium Bicarbonate	180	160	250	300	200	A	400	A	B	A	A	A	C	200	A	A	B	A	A	A	A	A	A
Sulfamic Acid	C	70	C	C	70	B	70		C			A	C		C	B	B			A		B	
Sodium Bisulfate	180	140	200	250	100	A	A	70	A	B	A	A	C	B	C	C	C	C	C	A	B	A	B
Sodium Bisulfite	180	140	200	250	200	A	400	C			A	A	C	C	C	B				A		C	B
Sodium Bromide	70	70	210	250	B	70	300	B		B		A	C	B	C	B	A	A	A	A	A	A	A
Sodium Carbonate	140	140	140	140	300	A	400	B	B	A	A	A	A	200	A	A	B	A	A	A	A	B	A
Sodium Chloride	140	160	140	200	100	A	350	70	B	A	A	A	C	B	B	A	B	B	B	B	B	A	A
Sodium Dichromate (20%)	C	C	140	200	200	B	300	C					B		B	C	C	A	A	A	A	B	A
Sodium Fluoride	70	70	140	140	140	70	350	B	A			A	C	B	C	A	B	A	A	A	A	A	B
Sodium Hydroxide (15%)	140	160	210	B	200	70	400	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Hypochlorite	C	C	70	140	150	C	350	C	B	C	A	A	C	C	C	C	C	C	C	A	B	A	C
Sodium Metaphos-phate	70		70	70	70	A		70	A		A	A	C	B	C	C	C	A	A	A	A	B	
Sodium Nitrate	140	140	210	225	140	B	400	70	B	A	A	A	A	200	A	A	B	A	A	A	A	A	A
Sodium Perborate	70	70	70	70	70	B	350	B	A	B	A	A	B	B	B	C	C	A	A	A	A	A	A
Sodium Peroxide	B	70	140	185	200	B	250	70	B		A	A	C	B	C	C	C	A	A	A	A	A	A
Sodium Phosphate	140	140	170	200	200	70	400	70	A	A	A	A	B	A	B	B	B	A	A	A	A	A	A
Sodium Silicate	140	140	200	200	200	A		70	B	A	A	A	A	A	A	C	B	A	A	A	A	A	A
Sodium Sulfate (SAT)	140	140	140	200	140	B	400	A	B	B		A	A	B	A	A	B	A	A	A	A	A	A
Sodium Sulfide	180	140	140	200	200	B	350	70	B	A		A	C	B	B	C	C	A	A	A	A	A	A
Sodium Sulfite	140	140	140	200	140	B	350	C	B	A	A	A	B	B	B	A	C	A	A	A	A	C	A

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Sodium Thiosulphate	140	160	200	200	200	B	350	B	A	A		A	C	B	C	B	C			A	A	A	
Soybean Oil	140	70	C	250	200	C	400	A			A	A	B		A	A	B	A	A	A	A	A	A
Stannic Chloride	140	C	100	200	70	A	350	B	B			A	C	C	C	C	C	C	C	C	C	C	C
Stannous Chloride	140	160	70	200	200	A	350	C	B		A	A	C	C	C	C	C			A		C	B
Starch	180	160	170	200	200	A	300	70	A			A	B		B	B	B	A	A	A	A	A	A
Steam	C	C	B	C	C	C	400	C	A	C		B	A	A	A	A	A	A	A	A	A	A	A
Stearic Acid	140	70	C	100	70	B	350	B	A	A	A	A	C	350	C	A	C	A	A	A	A	A	A
Sugar	100	140	140	200	140	A	350	70	B				A	A	A	A	A	A	A	A	A	A	A
Sulfur (Gas)	C	70		250	70	B	350		A	B			C	300	B	C	C	A	A	A	A	A	A
Sulfur Chloride	C	C	C	70	70	C	350	C	B		A	A	A	C	A	B	A	A	A	A	A	A	A
Sulfur Dioxide (Dry)	C	C	70	100	200	B	350	C	A	B	B	A	A	C	A	B	A	A	A	A	A	A	A
Sulfuric Acid (30%)	C	100	140	200	100	C	250	C	B	C		A	C	C	C	C	C	C	B	A	B	A	C
Tannic Acid	100	100	70	100	100	A	250	C	B		A	A	C	A	B	A	A	A	A	A	A	A	A
Toluene	C	C	C	70	C	C	200	A	B		C	A	A	A	A	A	A	A	A	A	A	A	A
Tomato Juice	C	70	200	200	C		350	70	A				C		C	B	C	A	A	A	A	A	A
Tributyl Phosphate	C	C	70	C	C	B	300	B			B	A	B	B	A	B	B	A	A	A	A	A	A
Trichloroethylene	C	C	C	185	C	C	200	C	B	B	C	A	B	A	B	A	A	A	A	A	A	A	A
Trisodium Phosphate	70	70	70	185	185	A	350	A	A			A	B		B	C	C	A	A	A	A	A	A
Turpentine	70	C	C	150	C	C	A	B	B	A	A	A	A	B	A	A	A	A	A	A	A	A	A
Urea	140	140	210	185	140	70	A	A	B	A		A	C	B	C	B	B	A	A	A	A	B	
Urine	140	140	210	70	140	C	400	B					C		C			A	A	A	A	A	A
UV Radiation	C	B	B	A	A	C	A	A					A	A	A	A	A	A	A	A	A	A	A
Varnish	70	C	C	70	C	C	350	A	A		B	A	C		C	A	B	A	A	A	A	A	A
Vegetable Oil	70	70	C	200	70	C	300	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Vinegar	C	70	140	C	200	B	300	A	A	C		A	C		C	C	C			A		A	A
Vinyl Acetate	70	C	70	C	C	D	350		A		C	A	B	A	B	B	B	A	A	A	A	A	A
Water, Acid Mine	180	160	200	70	180	B	400	A					C	B	C	C	C	A	A	A	A	B	B
Water, Brackish	180	160	250	200	200	A	400	A					C	C	C	B	C	B	A	A	B	A	B
Water, Deionized	70	160	200	70	200	A	400	A	A				C	C	C	B	C	A	A	A	A	A	A
Water Potable	180	160	250	A	200	A	400	A	A				B	A	B	A	A	A	A	A	A	A	A
Water, Chloramines	B	B	200	300		B	400	A					B	A	B	A	A	A	A	A	A	A	A
Water, Sea	180	160	250	200	200	A	400	A	B		A	A	C	B	C	B	C	B	A	B	B	A	B
Water, Waste	200	180	200	70	70	70	400	A					B	A	B	B	B	A	A	A	A	A	A
Whiskey	140	140	200	140	140	A	350	70	A	B	A	A	C		C	C	B	A	A	A	A	A	A

Val-Matic® Chemical Resistance Guide for Valves

CHEMICAL	ELASTOMERS AND PLASTICS												METALS										
	Buna-N	Neoprene	EPDM	Viton®	Hypalon	Natural Rubber	PTFE/ RPTFE	Nylon	PEEK	Devlon®	AFLAS®	Chemraz® Kalrez® Markez®	Carbon Steel	Nickel	Cast Iron	Bronze	Alum. Bronze	304 SS	17-4 PH SS	316 SS	Nitronic 60	Monel	Inconel
Wine	140	140	170	140	140	A	350	70	A	B	A	A	C		C	C	C	A	A	A	A	A	A
Xylene	C	C	C	150	C	C	350	120	B	A	C	A	A	A	A	A	A	A	A	A	A	A	A
Zinc Acetate	70	70	180	160	70	70	70				B	A	C		C	C	C	C	A	A	A	A	A
Zinc Chloride	70	160	180	200	200	A	400	A	B		A	A	C	B	C	C	C	C	B	B	B	A	B
Zinc Sulfate	140	140	180	200	200	B	400	A	B		A	A	C	B	C	C	B	A	A	A	A	A	A

White Paper

Valve Flanges for Waterworks Service
Part 1: Flange Design and Standards

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INTRODUCTION

Flanges play an important role in piping systems because they allow the assembly and maintenance of system components without the need for cutting and welding pipe. The structural integrity and leak tightness of waterworks piping systems are only as strong as the weakest element, which is often the flange connection between various valves and fittings. Because piping systems are subject to many types of loads and are constructed of various materials, it is difficult to understand and predict the rating and performance of flange connections. Further, the use of different sealing mechanisms such as gaskets, O-rings, and mechanical seals can significantly affect the performance of the connection. Finally, ASME B16.1 lists pressure ratings for Class 125 flanges from 50 to 200 psig depending on size, material, and temperature. Part One of this article will provide a thorough explanation of the variables and ratings that affect flange ratings. Part Two will describe how flanges are produced and the accepted methods for their use and installation.

FLANGE GEOMETRY

Figure 1 illustrates a basic flange that can be found on most waterworks valves and fittings. The connection consists of a circular ring or "flange" that is welded to or cast integral with the valve body and pipe. The basic dimensions of a flange consist of the Outside Diameter (OD), Bolt Circle Diameter (BC), Thickness (T), and the number and size of the bolt holes. It is customary for the bolt pattern in valves and fittings to straddle the vertical centerline. The flanges of two fittings mate together and are sealed with a resilient gasket, which is tightly compressed by the bolts located in a circle, concentric with the pipe OD. To obtain a tight seal, the bolts must withstand the hydrostatic end force of the pipe and compress the gasket to a multiple of the maximum pressure of the system.

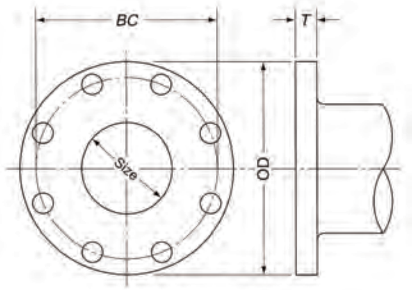

FIGURE 1. Typical Waterworks Flange Connection

Because of the body shape of some valves, valve flanges often contain tapped holes instead of through holes, which will affect the selection of bolting. The 24 NPS eccentric plug valve shown in Figure 2 requires four tapped holes on the top and four tapped holes on the bottom of the flange because the nuts behind the flange would interfere with the main part of the valve body.

A flange is a structural element of the piping system and must withstand the pressure and pipe loads related to the system since it is a rigid or restrained joint. The flange connection will not slip or pivot and must withstand the internal pressure forces without any external restraint. Certain push-on and mechanical joint connections, which are often used below ground, are not restrained. It is an important distinction that affects the supports, anchors, and thrust blocks needed in many systems. The flange must be of sufficient strength to transfer pipe loads, pressure forces, and gasket loads from the bolts to the connecting pipe, fitting, or valve. When a pipe is pressurized internally, the hydrostatic forces tend to stretch the pipe and pull the flanges apart. The bolts must maintain contact between the mating flanges and gaskets without excessive stretching.

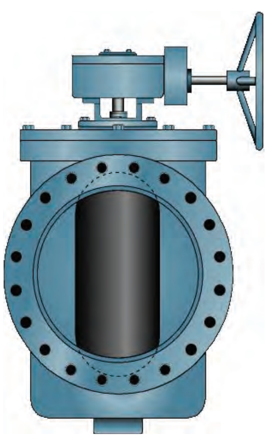

FIGURE 2. 24 NPS Plug Valve Flange with 8 Tapped Flange Holes

To absorb these loads, there are several types of flange shapes available to the designer as shown in Figure 3. The simplest is the ring flange, which consists of a flat plate of uniform thickness. The hub flange is similar to the ring flange but has additional material at the base of the flange so that the loads are distributed more uniformly to the pipe or fitting. Ring and hub flanges can be attached to the pipe by welding or by threading (companion flange). High pressure steel flanges often have a raised face and sloped hub that optimizes the strength to weight ratio of the flange and are attached to the pipe with a butt weld. The raised portion of the flange focuses the bolt load over a smaller gasket area improving the performance of the gasket. Finally, when the purpose of the flange is to block off the end of the pipe, a blind flange is used which consists of a solid flat plate. A flat plate is an inefficient shape to withstand pressure (dished heads are better), so blind flanges tend to be thicker than pipe flanges.

FLANGE MATERIALS

The pressure ratings of flanges are based on their material of construction. This makes sense because steel can be twice as strong as gray iron. But in order to understand how material strength affects flange ratings, it is important to understand some fundamental mechanical properties of metals.
Gray iron and ductile iron are both alloys of iron but their mechanical properties differ greatly. To produce a cast flanged fitting, pig or scrap iron is melted down and combined with other elements such as carbon and silicon to produce its unique properties. As shown in Figure 4, when gray iron solidifies, its grain structure includes graphite (carbon) in the form of flakes, which appear as jagged lines in the figure. These flakes of graphite give gray iron its strength and hardness, but at the same time, make it brittle. Nevertheless, gray iron is used extensively in fittings and many other products including engine blocks because the graphite structure absorbs noise and exhibits good wear resistance.

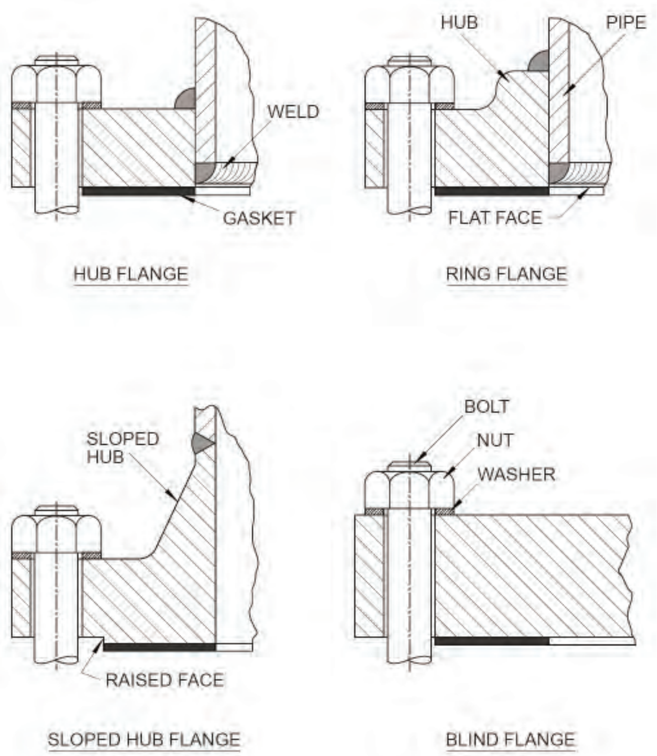

FIGURE 3. Examples of Flanges

Conversely, when ductile iron is cast, the molten metal is treated with magnesium, which causes the graphite to solidify into nodules, see Figure 5. The nodule shape gives ductile iron greater strength and less brittleness than gray iron. Materials like ductile iron tend to deflect significantly before fracturing. This tendency for a material to deflect before fracturing (like a rubber band) is called ductility. Granted, a rubber band may deflect 5 to 10 times its length before breaking, but by the same principle, ductile iron may deflect as much as 18% before breaking. Since ductile iron can bend like steel, it also has the ability to absorb shocks, which helps reduce line breaks in water main applications. This knowledge of materials and their mechanical properties allow engineers to establish safe and predictable flange designs for use in various industries.


FIGURE 4. Gray Iron at 400X

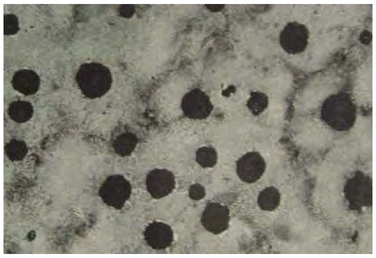
FIGURE 5. Ductile Iron at 400X

FLANGE STANDARDS

To allow interchangeability of components within an industry, engineers have developed standard dimensions over many decades for bolts and flanges for various pipe sizes and pressure ranges. The first such effort was undertaken by the American Society of Mechanical Engineers (ASME). The ASME is dedicated to ensuring the safety of the general public from the risks of pressurized systems like boiler piping. Beginning in 1920, the ASME "B16" committee assumed responsibility for developing codes and standards related to valves, pipe flanges and fittings. Their published body of work includes standard dimensions and pressure/temperature ratings for gray iron flanges and fittings given in ASME B16.1, ductile iron in ASME B16.42, and steel in ASME B16.5. They also recently produced a standard for large steel flanges, ASME B16.47, but its use is targeted for the petroleum industry. Compliance with these standards is voluntary but their application ensures safety at the stated pressures and temperatures and uniformity so that flanged valves and fittings from different manufacturers are interchangeable.

Similarly, the American Water Works Association (AWWA) A21 Committee publishes flange and fitting standards that mate with some of the ASME flanges, but are designed for cold water service. Most notably, AWWA C110 "Ductile-Iron and Gray-Iron Fittings" describes 3 in. to 48 in. fittings and flanged joints with Class 125 dimensions for waterworks service. These fittings and their ratings are based on extensive burst testing and provide a safety factor of at least three times the rated cold working pressure (AWWA C110). Because these products are intended for cold water, the ratings of AWWA fittings and flanges are higher that a similar ASME fitting. Keep in mind that the ASME fittings are also used for steam service which is far more hazardous than waterworks service. Finally, it is important to realize that while valves incorporate these flanges, their pressure ratings may differ based on different valve standards. For example, some butterfly valves with Class 125 flanges have flanges capable of 250 psig, but AWWA C504 "Rubber-Seated Butterfly Valves" limits the maximum working pressure of gray iron valves to 150 psig.

FLANGE CLASSES

ASME and AWWA standards provide sets of flange dimensions for various classes of flanges. Given these dimensions, the standards development organizations then establish pressure ratings for flanges and fittings based on the material from which they are made and the temperature at which they are used. Pressure classes such as 125, 250, 300 etc. cause considerable confusion in the industry because they are often interpreted as the rated pressure for the flange but there can be nothing further from the truth. These classes are "designations" that generally represent a pressure and temperature for saturated steam. For example, an ASME B16.1 Class 125 flange is rated for 125 psig at 353° F, which is the boiling temperature for water at that pressure. As temperature increases, the pressure rating of the flange decreases. For example, a Class 150 flange is rated about 270 psig at ambient conditions, 180 psig at 400°F, 150 psig at 600°F, and 75 psig at 800°F. At ambient temperatures (i.e. 100°F), it makes sense that the pressure ratings are higher than the saturated steam pressure. When the temperature rises, the rated pressure goes down, and vice versa. Pressure and temperature tables must be consulted in the applicable standards to apply them to a piping system.

A general summary of flange pressure ratings versus temperatures is shown in Figure 6. The ASME pressures represent nonshock pressure ratings, or in other words, steady pressures and not pressure spikes or cyclic water hammers. Conversely, AWWA fittings are adequate for the rated pressure plus a surge allowance of 100 psi or half the rated working pressure, whichever is less (AWWA C110). The table brings to light some important observations.

1. In all cases, as the maximum temperature increases, the pressure rating of the flange goes down. Metals are weaker at high temperatures.
2. Most of the time, the pressure ratings do not match the Class designation at 100°F.
3. As the Class designation increases, the pressure rating increases.
4. Ductile iron flanges are rated higher than gray iron flanges.
5. AWWA C110 only specifies Class 125 drilling.
6. The AWWA fittings are not rated for high temperatures.

Max Temp	ASME STANDARDS (ASME B16.1 and ASME B16.42)								AWWA STANDARDS (AWWA C110			
	Gray Iron ASTM A126 Class B				Ductile Iron ASTM A395 Gr 60-40-18				Gray Iron Class 25 or 30		Ductile Iron Gr 70-50-05	
	CLASS 125		CLASS 250		CLASS 150		CLASS 300		CLASS 125		CLASS 125	
	NPS 1-12	NPS 14-24	NPS 1-12	NPS 14-24	NPS 1-12	NPS 14-24	NPS 1-12	NPS 14-24	NPS 3-12	NPS 14-24	NPS 3-12	NPS 14-24
100°F	200	150	500	300	250	250	640	640	250	250	350*	350*
200°F	190	135	460	280	235	235	600	600				
300°F	165	110	375	240	215	215	565	565				

*With special gasket containing molded annular sealing elements.

FIGURE 6. Nonshock Pressure Ratings of Gray and Ductile Iron Flanges, Psig

There are many other standard pressure classes in ASME standards. But in the waterworks industry, Class 125 and Class 250 apply to gray iron flanges while Class 150 and Class 300 apply to ductile iron, steel and stainless steel (ASME B16.1, ASME B16.42). The bolting patterns of Class 125 and Class 150 match, as do Class 250 and Class 300. It is important not to mix the rating of the fitting with the drilling of the flange. Most AWWA fittings have Class 125 drilling, but a 250 psi rating even when made of gray iron (AWWA C110).

In the water works industry, AWWA publishes standards for flanged fittings and valves that are related to the ASME standards. Because AWWA fittings and valves are used with water, which is considered a safer media, the general safety factor may be lower than with hazardous high temperature steam applications. AWWA also allows several alternate grades of gray iron and ductile iron.

FLANGE SIZES

Even though every flange size and pressure class has an exact OD, flange sizes are denoted by the size of the pipe, expressed as nominal pipe size (NPS). It is often assumed that NPS stands for the inch size of a pipe, technically the NPS value is a dimensionless number and is related to the reference nominal diameter (DN) used in international standards. Similarly, the DN sizes are dimensionless and not millimeters. The general relationship is shown in Figure 7 (ASME B16.5).

US Customary Sizes	International Sizes
NPS 1	DN 25
NPS 1-1/2	DN 40
NPS 2	DN 50
NPS 2-1/2	DN 65
NPS 3	DN 80
NPS 4	DN 100
For NPS > 4, the DN is NPS x 25	

FIGURE 7. Flange Size Relationship

Each flange standard has limited size ranges and pressure classes. Figure 8 presents the scopes of the various standards. In addition to those listed, there are flange standards for stainless steel, copper, and international (metric) drilling. But the standards listed below are the most common in this industry. There are some general facts that should be understood when using these standards.

First, Class 125, Class 150, and AWWA Classes B, D, & E flanges have the same bolt pattern and can be joined together (AWWA C207). The same goes for Class 250, 300, and AWWA Class F.

The steel flanges given in ASME B16.5 only go up to NPS 24, so that standard is of little use for large flanges. Hence, AWWA C207 is used for large steel flanges in the waterworks industry. C207 is a relatively new standard and only just released dimensions for sizes up to NPS 144 in 1978 (AWWA C207). Therefore, there are many valves and fittings in the field with “special” flange drilling. Caution should be observed when fabricating replacement equipment for existing piping systems.

Class 125/150 drilling is the most common flange in the waterworks industry. It is so common that some projects specify iron valves with 250/300 flanges drilled special to mate with a Class 125/150 bolt pattern. This is done so that the valve can carry the same pressure rating as the steel mating flange. But this is not practical because it adds unnecessary weight to the valve and is unsightly when the flange diameters do not match in the pipeline. A better practice is to simply specify a Class 125/150 valve flange in ductile iron which will carry a similar pressure rating as the steel mounting flange.

Finally, Class 250/300 drilling is common, but only available up to size NPS 48. Above that size, flanges will have the 125/150 drilling with the pressure rating dependent on the material (ASME B16.1).

FLANGE STANDARD	MATERIALS	CLASSES	SIZE RANGE
ASME B16.1	Gray and Ductile Iron	25, 125, 250	NPS 1 to 96
ASME B16.5	Steel, Stainless Steel	150, 300, 400, 600, 900, 1500, 2500	NPS ½ to 24
ASMEB16.42	Ductile Iron	150, 300	NPS 1 to 24
ASME B16.47*	Steel, Stainless steel	75A, 150A, 300A, 400A, 600A, 900A, 75B, 150B, 300B, 400B, 600B, 900B	NPS 26 to 60
AWWA C110	Gray and Ductile Iron	125	NPS 3 to 48
AWWA C207	Steel	B (86 psi), D (175 psi), E (275 psi), F (300 psi)	NPS 4 to 144
MSS SP-44*	Steel	150, 300, 400, 600, 900	NPS 12 to 60

*CAUTION, These standards apply to steel petroleum pipelines and do not match B16.1 drilling in large sizes. The "A" designation indicates MSS SP-44 compatibility; the "B" designation indicates API-605 compatibility (ASME B16.47).

FIGURE 8. Applicable Water Works Flange Standards

CONCLUSION

Flanges are an important component of piping system that are provided by both valve and pipe manufacturers in many configurations and a full knowledge of their design and applicable standards is essential for the success of the piping system. Valve and pipe flange are provided in many alternate materials and conflicting pressure class designations in the waterworks industry. To avoid serious construction problems and costs, know your flange ratings and specify flange systems that meet the required pressure and temperature requirements of your piping system.

4E

REFERENCES

1. American Society of Mechanical Engineers, ASME B16-1-2010. *Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250*.
2. American Society of Mechanical Engineers, ASME B16-5-2013. *Pipe Flanges and Flange Fittings: NPS ½ through NPS 24 Metric/Inch Standard*.
3. American Society of Mechanical Engineers, ASME B16-42-2011. *Ductile Iron Pipe Flanges and Flanged Fittings: Classes 150, and 300.*
4. American Society of Mechanical Engineers, ASME B16-47-2011. *Large Diameter Steel Flanges: NPS 26 Through NPS 60*.
5. American Water Works Association, ANSI/AWWA C110/A21.10-12 *Ductile-Iron and Gray-Iron Fittings.*
6. American Water Works Association, ANSI/AWWA C207-13 *Steel Pipe Flanges for Waterworks Service – Sizes 4 In. Through 144 In.*
7. American Water Works Association, ANSI/AWWA C504-10 *Rubber-Sealed Butterfly Valves, 3 in (74mm) through 72 in (1800mm)*.
8. Manufacturers Standardization Society, MSS SP-44-2010. *Steel Pipeline Flanges.*

White Paper

Valve Flanges for Waterworks Service Part 2: Construction and Installation

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INTRODUCTION

Flanges play an important role in piping systems because they allow the assembly and maintenance of system components without the need for cutting and welding pipe. The structural integrity and leak tightness of waterworks piping systems are only as strong as the weakest element, which is often the flange connection between various valves and fittings. The selection of different sealing mechanisms such as gaskets, O-rings, and mechanical seals can significantly affect the performance of the connection. Part One of this article provided a thorough explanation of the variables and ratings that affect flange ratings. Part Two will describe how flanges are produced and the accepted methods for their use and installation.

FLANGE TOLERANCES

Since it is important that flanges mate together in the field, both the dimensions and flatness of flanges are important. Most flange standards (AWWA C110) provide a list of tolerances that the manufacturer must meet including:

- Bolt circle diameter: +/- 0.06 in.
- Bolt hole to hole: +/- 0.03 in.
- Flange thickness: + .13 in., - 0.0 in.
- Slope of back face of flange: 3 deg. maximum

Of note is the fact that the flange OD is not considered important and does not typically get a tolerance. Also, the flange thickness is typically considered a “minimum” dimension. Fabricated flanges (i.e. AWWA C207) have special requirements for flatness and layback. Finally, cast valves and fittings will have a slope on the back of the flange which is necessary for the casting process. If the slope exceeds the tolerance, the nut may not sit flat or the flange bolt may be bent during tightening. The back of the flange can be back-faced (machined) or back spot-faced so that the nut and washer have a flat surface to rest against. Some utilities specify back spot-facing as a regular practice because of previous bad experiences with sloped flanges. The diameter of the spot face should be sufficient to accept a heavy hex nut and washer.

FLANGE FACES AND SURFACE FINISH

Waterworks valves, flanges, and fittings have historically been constructed of gray iron for operation up to about 250 psig. Because gray iron is brittle, waterworks flanges have traditionally been flat faced to reduce the bending loads on the flange. That is, they mate to each other on the same plane radially from the inside diameter (ID) to the outside diameter (OD) as shown in Figure 1. When bolting a cast iron flange to a raised face steel or ductile iron flange, low grade carbon steel bolts (ASTM A307 Grade B) should be used to avoid breaking the cast iron flange when tightening the bolts.

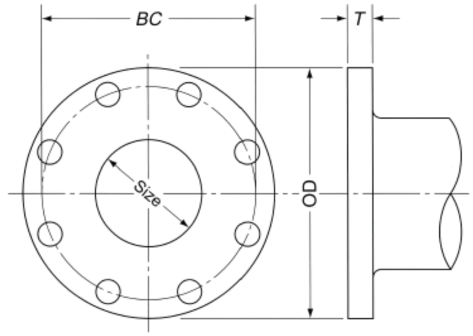

FIGURE 1. Typical Waterworks Flange Connection

The performance of the gasket seal is related to the surface finish of the flanges. Surfaces can vary from rough cast surfaces to lapped glass-like surfaces. Historically, waterworks flange faces are machined flat with shallow grooves to help the gasket seal and prevent gasket blowout. The AWWA C207 flange standard specifies a serrated finish having a surface finish of 250 to 500 micro-inch roughness. The micro-inch roughness is basically the vertical distance between the peaks and the valleys of the machined surface. 500 micro-inches is about one fourth the thickness of a piece of paper so it needs to be measured with an electronic quality instrument called a profilometer, which pulls a stylus or diamond needle across the surface to detect the peaks and valleys of the surface. Some inspectors also carry a metal inspection comparator plate which they use to compare the flange face to the surface plate visually or by touch.

It is customary that flange faces be free of lining and coating materials except for rust preventive compound. On the other hand, AWWA C110 iron fittings can be serrated or smooth and may be coated. Many waterworks fittings and gate valves are coated with fusion bonded epoxy (FBE) which because of the manufacturing process requires the flange faces to be coated. The flanges are smooth providing little friction for the gasket risking gasket blowout. Fabric reinforced gaskets, high tensile strength fiber gaskets, or special engineered gaskets may be needed for high pressure systems when the flanges are coated.

FLANGE GASKETS

It would be simple if all that was necessary would be to bolt two flanges together and a tight seal were obtained every time. Unfortunately, flanges are not perfectly flat so gaps, irregularities, and waviness between the mating surfaces allow fluid leakage. The purpose of the gasket is to fill those voids and withstand the pressure forces of the internal fluid. Gaskets need to be compressible to conform to the surfaces of the flanges yet have sufficient strength to prevent yielding from the bolt loads and pressure forces (ESA, 1998). Poor gaskets tend to relax or extrude causing gasket compression to be lost over time resulting in a leaky joint. In order for a gasket to maintain a seal, the compression force on the gasket from the bolts must be maintained even after the bolts are stretched from the hydrostatic end force tending to separate the mating flanges.

Gaskets therefore require certain properties that are needed for their performance in various applications. First, the material of the gasket must be compatible with the fluid media. In water systems, most gasket materials work well in cold water service. But the gasket material must still resist over-compression and extrusion, so its tensile strength is important. The tensile strength is related to the hardness of the gasket expressed in Shore A durometer. The durometer rubber hardness scale ranges between 0 and 100 where a rubber band is about 20 durometer and a hockey puck is 90 durometer. Rubber gaskets for flanges typically have a specified hardness of 70 or 80 durometer. The resilience of the gasket is measured by a compression set test where a load is applied and the recovery of the material is measured. Rubber is a unique material in that it does not compress, it displaces or cold flows. So if a rubber gasket is over compressed, it will flow into the ID or OD of the flange connection. The compression of rubber gaskets should be limited to 25% to avoid overflow. The rubber gasket will continue to bounce back and fill the voids and gaps in the flanges over time.

The AWWA C207 flange standard specifies the gasket to be 1/16 or 1/8 in. thick 80 durometer red rubber for pressures up to 175 psig and fiber type ring gaskets for 275 psig. Red rubber is typically a blend of styrene butadiene rubber (SBR). AWWA also specifies that fiber gaskets with rubber binder material shall be suitable for a seating stress of 3000 psi to 15,000 psi. The dimensions of standard "ring" type and "full face" type gaskets for waterworks service are shown in Figure 2. The ID of these gaskets differs from those of steel pipeline gaskets (ASME B16.21) because steel fittings and pipe have different ID's than AWWA fittings. For example, an NPS 12 ASME gasket has an ID of 12.75 in. to match the OD of steel pipe (ASME B16.21). AWWA fittings have ID's that match the nominal size, 12.00 in. (AWWA C111).

In general, the gasket should be as thin as possible (Czernik, 1996). When it is too thick, its diameter will change excessively when compressed. Also, a thicker gasket will be subject to deterioration from the fluid media due to the greater exposed area. Finally, gaskets can blow out of the flange from the internal pressure. The blowout forces are directly proportional to the thickness. So when a thick gasket is used on flanges faces with low friction, blowout or outward extrusion may occur over time.

If the valve or fitting will be used in a corrosive application such as desalinization systems, the valve or fitting may need to be protected from galvanic corrosion. Galvanic corrosion occurs in aggressive fluids between dissimilar metals such as iron and stainless steel wherein a battery-like electrical process occurs and the least corrosion resistant material (iron valve) is attacked. To prevent galvanic corrosion, special insulating gasket designs are used as shown in Figure 3. Insulating gaskets consist of full face gaskets, and insulating sleeves around the bolts and washers. The goal of an insulated joint is to break the metal-to-metal contact between the two flanges. When insulating gasket assemblies are specified, it is sometimes necessary to drill the flange holes oversize.

Finally, there are specially engineered gaskets designed for waterworks fittings that have the advantage of raised resilient beads or lips that seal with low gasket loads, see Figure 4. The body of the gasket is constructed of a hard plastic such as phenolic. The resilient portion is typically made of SBR rubber, which is common in the water industry. With this gasket, the bolts loads are low and the flange seal is therefore forgiving and reliable.

DIMENSIONS OF CLASS 125 WATERWORKS GASKETS, IN. (AWWA C110)

Nom. Size In.	RING TYPE		FULL FACE TYPE				
	ID	OD	ID	OD	BC	Hole Dia.	No. Holes
3	3	5.38	3	7.50	6.00	.75	4
4	4	6.88	4	9.00	7.50	.75	8
6	6	8.75	6	11.00	9.50	.88	8
8	8	11.00	8	13.50	11.75	.88	8
10	10	13.38	10	16.00	14.25	1.00	12
12	12	16.13	12	19.00	17.00	1.00	12
14	14	17.75	14	21.00	18.75	1.13	12
16	16	20.25	16	23.50	21.25	1.13	16
18	18	21.63	18	25.00	22.75	1.25	16
20	20	23.88	20	27.50	25.00	1.25	20
24	24	28.25	24	32.00	29.50	1.38	20
30	30	34.75	30	38.75	36.00	1.38	28
36	36	41.25	36	46.00	42.75	1.63	32
42	42	48.00	42	53.00	49.50	1.63	36
48	48	54.50	48	59.50	56.00	1.63	44

FIGURE 2. Waterworks Gasket Dimensions

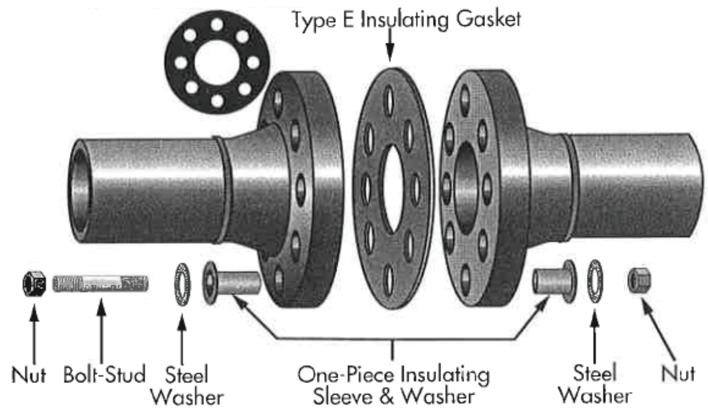

FIGURE 3. Insulating Gasket Assembly for Corrosive Service

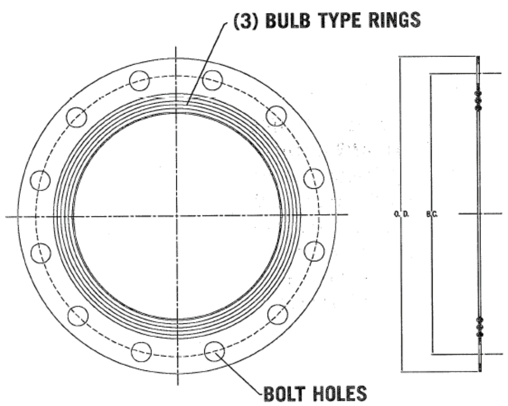

FIGURE 4. Special Engineered Gasket Resilient Rings

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FLANGE BOLT TORQUE

The bolts are an integral component of the flange assembly. The bolts must withstand the pressure load inside the pipe while maintaining a minimum load on the gasket. The pressure load is calculated by multiplying the area of the pipe and gasket times the maximum expected pressure. The calculated bolt load on an NPS 12 CLASS 125 flange at 250 psi can be as high as 50,000 pounds or 25 tons. The bolts clearly have an important structural role. The load is divided by the number of bolts, 12 in this example. So each bolt must be tightened such that a preload of at least 50,000/12 or 4190 pounds is developed. The target bolt torque to produce a given load can be calculated using the following formula:

$$T = K D F / 12$$

Where:

- T = target torque, ft-lbs.
- K = nut factor, dimensionless
- D = nominal bolt diameter, in.
- F = target bolt load, lbs.

For lubricated bolts, the nut factor is typically 0.20. Hence, for the subject example, the NPS 12 flange has 7/8 inch bolts whose torque can be calculated as follows:

$$T = 0.20 * 0.875 * 4190 / 12$$
$$= 61 \text{ ft-lbs}$$

This torque would be considered the minimum required to maintain a seal with a resilient gasket at 250 psig. A higher torque can be used, but at the risk of crushing the gasket. Most resilient gaskets are limited to a maximum load of 2000 psi, unless they are fabric reinforced, then 4000 psi. Based on the area of the NPS 12 ring type gasket, a 2000 psi gasket load corresponds to an individual bolt load of 14,500 lbs and a resultant bolt torque of about 210 ft-lbs. Therefore, the NPS 12 flange bolts for a rubber gasket should be tightened in the range of 60 to 210 ft-lbs. As the bolts are tightened the gasket compression should be monitored so that the gasket is not compressed more than 25% of its original thickness. Rubber is incompressible, so when the gasket is loaded, the rubber flows to the ID and OD of the joint.

If a fiber-type gasket were used, the gasket compression can be much higher that the resilient gasket, typically 4000 psi. Therefore the bolt torques in the previous example could be double the resilient gasket torque or 420 ft-lbs.

There is an additional upper limit to the maximum bolt torque based on the strength of the bolt. Flange bolts for waterworks flanges are typically heavy hex carbon steel fasteners made in accordance with ASTM A307, Grade B, which specifies a tensile strength of 60,000 psi. A safe load for this bolt is 40,000 psi. Each bolt size has a specific tensile stress area; the 7/8 inch bolt in the example has a tensile stress area of 0.462 square inches. The corresponding maximum bolt torque based on the strength of the bolt can be found by:

$$T = 0.20 * 0.875 * 40,000 * 0.462 / 12$$
$$= 270 \text{ ft-lbs}$$

Hence, the ASTM A307, Grade B bolts are suitable for the resilient gasket target torque range of 60-210 ft-lbs. However, the bolts may not be sufficient for the load needed for the fiber gasket, 420 ft-lbs. The next higher grade of bolt commonly used is ASTM A193 Grade B7, which is a chromium-molybdenum alloy steel with a tensile strength of 125,000 psi. The B7 grade is common for 275 psi applications and cases where high gasket loads are needed. ASME B16.1 recommends only B7 grade (low strength) bolts for gray iron flanges to prevent damage to the flange. ASME B16.5 also discusses bolting to gray cast iron flanges and recommends control of the bolt torque and piping loads, the use of elastomeric or fiber gaskets, and the use of low strength bolting.

Specially engineered gaskets are often used for waterworks fittings, see Figure 4. Engineered gaskets seal under low gasket loads because of their raised resilient beads or lips. The recommended bolt load for the NPS 12 engineered gasket is only 90 ft-lbs for 250 psi service and 110 ft-lbs for 350 psi service. With this gasket, the bolts really only need to support the pressure load and very little gasket load; hence the lower bolt torques. Also, since they have a hard shell, they cannot be over compressed.

The target bolt torque is the most common question asked of valve and fitting manufacturers but it is now clear that the target bolt torque is more a function of the gasket than the fitting or valve. The gasket manufacturer should provide a gasket load for the intended service. The gasket load can then be used to calculate the target bolt torque as described above.

INSTALLATION OF FLANGED FITTINGS AND VALVES

Care should be taken in the installation of flanged fittings and valves to prevent damage to equipment and to obtain a tight flanged connection. There are many obstacles to this endeavor including field conditions, misaligned pipe, valve weight, tolerances, etc. Unfortunately, few of the ASME or AWWA flange standards provide guidance on installation. The following guidelines are based on information provided in AWWA C110, ASME PCC-1, and general industry practices.

1. BOLTING: Standards such as AWWA C110 provide information on the material, size, length, and number of bolts. Certain valves have some threaded holes which may require shorter bolts or studs in these holes. An engagement of at least one bolt diameter is typically used for the flange bolts used in the tapped flange holes. When ring gaskets are used with gray iron flanges or when mating to raised face flanges, the bolt material should be low strength steel such as ASTM A307 Grade B or SAE Grade 2 Carbon Steel. Higher strength bolts such as ASTM A193 Grade B7 may only be used with full-face gaskets or when high pressure service is needed.

2. GASKETS: Gaskets for waterworks service are typically ring or full-face synthetic SBR rubber and are 1/16 in or 1/8 in thick. Ring gaskets are recommended for NPS 14 and larger to improve the sealing. Also available are special engineered gaskets with annular sealing rings, which greatly improve the gasket performance and reduce the bolt torque needed.

3. VERIFY DRILLING: Inspect the mating flanges with a tape measure to verify that the bolt circle diameters of the two mating flanges match and the bolt set is appropriate for the through and tapped holes in the flanges with consideration to the washer thickness. Hard steel washers should be used to provide a solid surface for the nut to seat against. Flange outside diameters and thicknesses often vary but should not affect fit up.

4. FLANGE FACES: Make sure flange faces are clean and not damaged. A scrape or mark across the flange face can cause a leaky joint. Do not use the flange to jack a fitting or pipe into place. Use large equipment anchored to the ground for positioning the pipe or fitting.

5. LUBRICATE: Lubricate the flange bolts or studs and insert them around the flange. Lubricate the internal nut threads and contact face. Lightly turn bolts until gaps are eliminated. Do not use the bolts to jack the flanges into alignment.

6. TORQUING: Starting with the bolt to the right of the vertical centerline, number the bolts in sequential order in a clockwise direction (i.e. 1, 2, 3, 4, etc.). The torquing of the bolts should then be done in three graduated steps (i.e. approximately 30%, 60%, and 100% of the target torque) using the cross-over tightening method. Cross-over tightening sequences for different number of bolts are shown in Figure 5.

Cross Over Tightening Sequences for Flange Bolts	
No. Bolts	Sequence
4	1-3-2-4
8	1-5-3-7 , 2-6-4-8
12	1-7-4-10, 2-8-5-11, 3-9-6-12
16	1-9-5-13, 3-11-7-15, 2-10-6-14, 4-12-8-16
20	1-11-6-16, 3-13-8-18, 5-15-10-20, 2-12-7-17, 4-14-9-19
24	1-13-7-19, 4-16-10-22, 2-14-8-20, 5-17-11-23, 3-15-9-21, 6-18-12-24
28	1-15-8-22, 4-18-11-25, 6-20-13-27. 2-16-9-23, 5-19-12-26, 7-21-14-28, 3-17-10-24

FIGURE 5. Typical Flange Bolt Tightening Sequences (ASME PCC-1)

7. CHECK TORQUE: When complete, check the torque on a rotational clockwise pattern until no further nut rotation occurs. If time permits, check the torque after 4-8 hours and repeat the clockwise pattern to restore the short-term relaxation of the gasket. Typical bolt torques for flanges with resilient gaskets are given in Figure 6. If leakage occurs, allow gaskets to absorb fluid and check torque and leakage after 24 hours. Do not exceed bolt rating or crush gasket more than 25 percent of its thickness.

125# FLANGE DATA Resilient Gasket 150 psig			250# FLANGE DATA Resilient Gasket 250 psi		
Size NPS	Bolt Dia. (in)	Bolt Torque (ft-lbs)	Size NPS	Bolt Dia. (in)	Bolt Torque (ft-lbs)
4	5/8	30-60	4	3/4	30-80
6	3/4	30-90	6	3/4	40-100
8	3/4	40-150	8	7/8	60-150
10	7/8	45-150	10	1	80-160
12	7/8	60-210	12	1 1/8	100-250
14	1	80-250	14	1 1/8	120-250
16	1	80-250	16	1 1/4	150-300
18	1 1/8	100-250	18	1 1/4	180-300
20	1 1/8	100-250	20	1 1/4	200-350
24	1 1/4	150-300	24	1 1/2	300-600
30	1 1/4	250-500	30	1 3/4	450-800
36	1 1/2	250-500	36	2	600-1000
42	1 1/2	300-600	42	2	750-1100
48	1 1/2	300-600	48	2	900-1500

FIGURE 6. Typical Flange Bolt Torques

8. RECORDS: Make a record of the flange connection for future reference including:

a. Equipment identification
b. Flange Size and Class
c. Date of assembly
d. Gasket material
e. Bolt material
f. Flange surface quality comments
g. Target bolt torque and tools used
h. Name of pipe fitter

By recording the flange installation information, future troubleshooting and repair of the joint will be facilitated. When complete, stand back and admire your work. You can see by the number of flanges shown in Figure 7, that flange design and installation plays an important role in piping systems.

FIGURE 7. Pipe Gallery in Treatment Plant in Morris, IL

CONCLUSION

The installation of valves and flanges can literally make or break a piping system. To avoid serious construction problems and costs, follow published guidelines on the installation of bolts, gaskets for your piping system.

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3. American Water Works Association, ANSI/AWWA C207-13 *Steel Pipe Flanges for Waterworks Service – Sizes 4 In. Through 144 In*.
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White Paper

Valve Inspection: An Essential Job

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Industrial valves perform key functions in fluid processes and their failure can be detrimental to any major piping system or process. Failure and an unplanned system shutdown can cost millions of dollars. Hence, a valve failure represents a real and significant risk to any fluid system and should be mitigated through quality inspection and testing.

Global sourcing of many components, the retirement of our most experienced personnel, and the increase in corporate acquisitions all affect valve factories today. Thus, purchasers of critical valves should embrace a robust quality-inspection program to mitigate the risks associated with the purchase and installation of industrial valves. Additionally, the manufacture of valves today may include advanced, complex technologies and features that require robust valve inspection programs. Figure 1 represents the shell test of a 126-inch Butterfly Valve.

FIGURE 1. Shell test of a 126-inch Butterfly Valve.

Hence, many system owners employ dedicated equipment inspectors or third-party inspection firms to travel to foundries and valve factories across the globe to verify compliance with industry valve standards, project specifications, and system plans.

Many of the valves manufactured today are required to have special materials, features, and configurations that must be verified. The list of requirements can be immense, and Murphy's law dictates that some items will be missed. As a result, conflicts between the valve properties and the project specification are inevitable and it is far better to resolve any conflicts at the valve factory than at the project site.

PROFESSIONAL INSPECTORS

Many system owners have a quality staff that includes certified inspectors. To learn more about the role of a valve inspector, VALVE Magazine reached out to the Philadelphia Water Department (PWD) with questions.

Richard Riddell is one of the department's certified inspectors and he explained that inspectors usually have related experience and receive on-the-job training and review all pertinent specs, past reports, and manufacturer's files. They are expected to be familiar with the applicable industry valve standards and the quality processes used to qualify valves, especially production testing.

When things go wrong, Riddell said that he "gives the manufacturer a chance to resolve the problem and retest the equipment. But, depending on the nature of the problem and required repair and its occurrence in the testing sequence, other tests may need to be repeated." Additionally, any variances in the specifications would be discussed with the engineers responsible for the (PWD) design.

INDUSTRY INSPECTION STANDARDS

To support the quality inspection process, industry organizations develop and publish standards. Two guiding standards for valve testing are API Standard 5981 Valve Inspection and Testing and MSS Standard Practice SP-612. Both standards define the terms and provide standards related to the inspection and testing of industrial valves. Standard test methods are presented for various shell, backseat, and closure tests together with test durations and definitions of acceptable leakage criteria, depending on the test fluid.

When tests are to be witnessed, these standards require the manufacturer "to provide free access to any part of the factory concerned with the manufacturer of the valves whenever work on the order is underway". The same rule applies to the suppliers, like foundries, of body components.

FOUNDRY INSPECTION METHODS

FIGURE 2. Verifying calibration and operation of a Trunnion-Mounted Ball Valve.

Foundry castings of valve bodies and closure members can be difficult to inspect because of their complex shape and varying thicknesses. One economical and common inspection process for castings is Ultrasonic Testing (UT) wherein sound waves are sent into the casting and the reflected wave is examined to verify thickness or hidden defects in the casting.

Another process is Radiographic Testing (RT) where the casting is exposed to an x-ray source and a film on the opposite side records images of defects in the casting. Another casting inspection process is Magnetic Particle Testing (MT), but this process does not work on non-magnetic materials such as stainless steel.

For stainless steel, liquid penetrant testing (PT) might be employed, where a penetrating die is applied to the surface and then removed. A white powder is then sprayed on the surface to pull any trapped die from defects in the surface such as cracks or pores.

With all these examination methods, standards provide acceptance criteria for both linear and circular indications (i.e. porosity).

Finally, surface defects such as cracks, shrinks, inclusions, porosity and casting irregularities can also be identified visually with standards such as MSS SP-55, "Visual Method for Evaluation of Surface Irregularities". Finally, the foundry will provide a Certified Material Test Report (CMTR) stating the chemical composition and physical properties of the casting, which can be compared to the applicable material specification and provide assurance of the casting's structural integrity.

THE FINISHING TOUCH

FIGURE 3. XRF Verification of an Alloy.

So far, we have only reviewed the structural aspects of valve quality, but the finishing features of valve constructions should also be examined. For example, the coatings and linings of the valve can be verified by measuring the blast profile, the coating thickness, and checking for voids or holidays in the coating with generally available tools.

Some valves see severe service require the use pf special corrosion resistant alloys. The chemistry of these can be verified with the Positive Material Identification Process (PMI). Most manufacturers own an x-ray fluorescence (XRF) gun that detects the energy strength level from emitted from each element in a metal and identifies the alloy of the metal. (Figure 3)

Therefore, it is a simple matter to verify the type of stainless steel. Portable hardness testers can also be used to estimate the tensile strength of materials as a final check against the CMTR. When the valve is equipped with motorized actuators or control equipment, it is essential to mount and calibrate all the equipment in the valve factory or a certified integrator's facility. (Figure 2) The verification of a sound coating, special alloys, and equipment calibration can provide the final assurance of valve quality.

VALVE INSPECTION CHECKLIST		
NO.	TASK	STRATEGY
1	Check Casting	UT, RT, MT, PT, Visual
2	Verify Model Number/Rating	Type, Size, ANSI Rating, End Connection
3	Verify Materials	CMTR, PMI Exam
4	Check Dimensions	Flange Connection, Laying Length
5	Check Coatings	Blast profile, Thickness, Holiday Test
6	Check Configuration	Actuator Mounting, Handwheel Rotation
7	Verify Control Function	Normall Open/Closed, Fail Postion
8	Witness Tests	Shell, Closure, Operational
9	Review Markiing/Tagging	Standard Tagging and ID Tag
10	Obtain Certifications	Signed Certification for the file

Once all the testing is successfully completed, the inspector is expected to sign the test certification for the manufacturer's file.

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White Paper

Rigging and Lifting of Large Valves

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INTRODUCTION

Lifting heavy and large loads is challenging enough. But when you add the complexity of large valve geometries, extensions, and oddly-shaped actuators, great care and understanding is required to perform safe load lifting operations, both in the factory and on the job site. This article will explain many of the challenges involved with lifting large valve assemblies weighing several tons and illustrate the industrial rigging equipment and lifting operations typically used for large valves, see photo of a 48-inch valve being installed in Norfolk, VA. The purpose of this article is not to provide comprehensive training on rigging, but instead to increase awareness of the special risks and care required to safely perform lifting operations for large valves.

VALVE CHARACTERISTICS

Rigging is defined as connecting a load to a source of power so that it can be lifted and moved safely and predictably. In order to rig a large valve, a basic understanding of valve construction must be understood. As shown in Figure 1, most large valves consist of a body, a closure member that either rotates or translates in the body, and an external actuator, which is used to operate the closure member. The body typically includes a flange with bolt holes that can facilitate lifting. If the valve is being installed with the actuator removed, the closure member must be secured from rotating or translating, which will shift the load. The interior of the valve is not to be used for lifting. Do not lift valves with straps, cables, or chains through the valve interior or the precision machined seating surface could be damaged (AWWA). When moving a valve with a fork lift, it is important to protect the valve flanges from scrapes or gouges. The flange surfaces are machined to accept and seal to pipe gaskets and should not be treated like structural beams. It is recommended to lift large flanged butterfly valves with eyebolts or rods through the flange holes and large gate valves with straps around the valve body.

FIGURE 1. Installation of 90-inch Butterfly Valve

Valves are surprisingly heavy. The 90-inch butterfly valve assembly shown in Figure 1 weighs 24,000 pounds or 12 tons. It is not an item that can be moved around with a typical fork lift truck or backhoe. Significant 20 to 40-ton crane power is required to handle large valves. It is also important to note that the center of gravity of the valve varies with the location of the closure member and the relative weight of the actuator. While it is logical to rig to the centerline of the valve, doing so may place the load out of balance. The center of gravity must be estimated and the slings or cables connected in such a way as to balance the load. In Figure 2, the lifting slings are placed toward the actuator on this 36-inch pipeline valve to balance the load.

FIGURE 2. Unloading of a 36" Pipeline Valve
(Courtesy of United Valve)

While it is tempting to simply connect the crane hook to any accommodating surface on the valve, the actuator or handwheel should never be used to lift a valve. They are not designed to support the weight of the valve. Figure 3 illustrates how NOT to lift a gate valve. Figure 4 illustrates wrapping the valve with rigging the slings to the body of the valve. Note that if the valve flanges were used to lift this 60-inch gate valve, its tall center of gravity would make the lift unstable and dangerous.

VALVE RIGGING EQUIPMENT

There are many common pieces of rigging equipment commonly used with valves. It is dangerous to simply insert the crane hook into the nearest flange hole or cavity of a valve. Valves can be made of grey iron, which can be brittle, and may not support the high localized stresses from a crane hook. The connection to the crane hook is typically made with a combination of shackles, synthetic slings, wire rope slings, and chain slings. It is recommended to employ a swivel eye bolt or hoist ring to connect to a valve flange as shown in Figure 5. These devices are simply inserted into two or more flange holes and automatically align to the lifting strap angle to prevent damage to the strap or the eye bolt. Alternatively, bars of diameter equal to the bolt holes can be inserted into opposite flange holes for lifting.

FIGURE 3. How NOT to lift a Gate Valve
(Demonstration by United Valve)

Large valves are easily flipped over with swivel rings. A large butterfly valve can be lifted and stood up on its edge. Then the swivel rings can be inserted into one side of the valve's flange face and re-lifted. The valve will then swing form the vertical and can be lowered down flat to the ground on the other side. Needless to say, the valve in figure 5 would need to have the closure member rotated to be within the interior of the valve laying length if not fully closed before laying the valve on its edge. Some valve closure members extend beyond the flange face even when fully closed. Hence, it is always advisable to have wood blocking under the flange faces before setting the valve down on the ground.

As shown in Figure 4, large nylon straps are used around the valve body for lifting. It is important to note that many valves have sharp edges as part of the body geometry, especially adjacent to flange faces. Slings must be padded or protected from sharp edges. Moreover, depending on how the strap is attached and at what angle will affect is load carrying capacity.

FIGURE 4. Hoisting a 60-inch Gate Valve
(Courtesy of J&S Valve)

FIGURE 5. Use of Swivel Rings to lift a 144-inch Butterfly
(Courtesy of United Valve)

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SAFETY

There are several publications from OSHA and organizations like the Mechanicals Contractors Association of America available to train personnel and provide for safe lifting practices and instructions on the use of rigging equipment. Figure 6 presents some of the common safety tips for lifting heavy loads.

SAFETY CHECKLIST FOR HOISTING		
How	H	heavy is the load?
What are the	O	operating limitations of the crane and rigging?
When was the last	I	inspection performed?
How will	S	sling angles affect lifting capacity?
Have you performed a	T	test lift to check stability?
Move the load with	S	smooth and steady actions.
Is the	A	area clear of personnel and obstructions?
Can the load be	F	flown and landed safely?
How will the	E	environment affect the safety of the lift?

FIGURE 6. Safety Guidelines for Hoisting (Hennepin)

The list reminds us to check the adequacy and condition of all equipment used. It is important to know your valve's weight and center of gravity. Similarly, the capacity of all of the lifting equipment must be confirmed. Make sure the lift zone and movement area is clear of personnel, power lines, and other equipment. But let's face it; valves are often handled outdoors in muddy trenches and horrible weather. These conditions affect the safe procedures and the strength of some equipment, such as fabric slings. It is best to work smoothly and with care at all times no matter the conditions.

By understanding the special characteristics of valves and following safe rigging and lifting practices, we can all have many successful valve installations.

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White Paper

Glossary of Valve Terms and Acronyms

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A

ACCUMULATOR TANK: Enclosed volume that contains a compressible fluid (gas) to provide standby energy in the event of loss of system pressure.

ACCUMULATOR, HYDRAULIC: A pressure storage reservoir in which a non-compressible hydraulic fluid is held under pressure to provide standby energy in the event of loss of system pressure.

ACTUATOR: Mechanical, hydraulic, electric or pneumatic device or mechanism used to open, position, or close a valve.

AIR BOUND: Obstructed, as to the free flow of water, because of air entrapped in a high point; used to describe a pipeline or pump in such condition.

AIR RELEASE VALVE: A hydro-mechanical valve designed to slowly vent/release air automatically and continuously from liquid piping systems.

AIR VALVE: Generic name used to describe a family of valves used to control the release and admittance of air to a pipeline or liquid handling system. Common names for specific types include Air Release, Air/Vacuum and Combination.

AIR VENT: An opening in a penstock or other pipeline, covered tank, or well, that allows inflow or outflow of air.

AIR/VACUUM VALVE: A float operated valve designed to exhaust large volumes of air upon pump start up and provide vacuum protection by admitting large volumes of air upon pump shut down or if a column separation occurs.

ALLOY STEEL: A steel consisting primarily of iron with some percentage of one or more other elements such as chromium, nickel, manganese, or vanadium deliberately added to enhance its properties.

ALTITUDE-CONTROL VALVE: A valve that automatically shuts off flow when the water level in an elevated tank reaches a predetermined elevation and opens when the pressure on the system side is less than that on the tank side.

AMBIENT TEMPERATURE: Prevailing temperature of the environment immediately surrounding an object.

ANSI: American National Standards Institute-standard development organization responsible for coordinating the work of U.S. standards writing groups with each other and with other national standards organizations. Known as ASA until 1967.

ANTI-BLOWOUT STEM: A valve stem that is made with a shoulder, positively retained by the body or bonnet (to avoid under certain operating conditions, that the stem could accidentally blow out).

ANTI-SLAM DEVICE: Device used on Air/Vacuum valves to regulate the valve's closure and prevent the valve from being slammed closed during critical operation. Sometimes referred to as a slow closing device, surge check valve or regulated exhaust device.

ANTI-STATIC DEVICE: A spring-loaded component of a pipeline ball valve which provides contact between stem and ball, and stem and body to eliminate static electricity.

API: American Petroleum Institute-organization that develops standards for materials and articles used in the petroleum and gas gathering (production) industry, and also the hydrocarbon-processing industry.

ASME: American Society of Mechanical Engineers - organization responsible for maintaining several codes and large numbers of standards, covering numerous different industries.

ASSE: American Society of Sanitary Engineering – organization responsible for certifying plumbing and mechanical products and is also a third-party certifier for professionals in the plumbing and mechanical industries.

ASTM: American Society for Testing and Materials-organization responsible for maintaining standards covering materials, testing methods, and in some cases such as plastics, the dimensional and manufacturing standards for finished products.

ATMOSPHERIC PRESSURE: External pressure exerted on a body by the atmosphere: 1.0 Bar (14.7 psia) at sea level.

AUSTENITIC STAINLESS STEEL: A common stainless steel, where the primary microstructure is austenite and the composition primarily iron but also includes both chromium and nickel. The steels are designated as 300 series such as 304, 316, CF8M, etc.

AWWA: American Water Works Association, Inc. – organization responsible for maintaining standards related to water treatment and water and wastewater treatment products.

B

BACKFLOW ACTUATOR: Optional accessory for the Swing-Flex® Check Valve. Provided for opening and holding open the valve disc to allow backflow through the line. Used to backwash a line, drain a system or fill a wet well.
BACK PRESSURE: The pressure exerted on the downstream side of a valve.
BACK SEAT: A shoulder on the stem of a gate or globe valve which seals against a mating surface inside the bonnet to prevent leakage of media through the bonnet stuffing box when the valve is fully open.
BACKFLOW PREVENTER: Any mechanical device, whether used singly or in combination with other controls, designed to automatically prevent an unintentional reversal or flow in a potable water distribution system.
BACKFLOW: The reversal of flow from that normally intended.
BACKWASHING: The act of flowing clean water backwards through a valve or filter for the purpose of cleaning.
BALL VALVE: A valve that has a spherical, or section of a spherical, closure element that opens and closes by rotating one-quarter turn.
BARE-SHAFT (STEM): A valve supplied without lever or hand wheel, where the end of the stem (shaft) is exposed and ready for others to install their own actuator.
BEARING: A cylindrical machine located in the body hubs that is used to radially support the valve shaft(s).
BELLEVILLE SPRING or **BELLEVILLE WASHER:** A disc-shaped washer, which provides axial spring force along its own centerline.
BERNOULLI'S LAW: A physical law of hydraulics that states that under conditions of uniform steady flow of water in a conduit or stream channel, the sum of the velocity head, pressure head, and head due to elevation at any given point along such conduit or channel is equal to the sum of these heads at any other point along such conduit or channel plus or minus the losses in head between the two points due to friction.
BEVEL GEAR ACTUATOR: Device facilitating operation of a gate or globe valve by means of a set of bevel gears having the axis of the pinion gear at right angles to that of the larger ring gear.
BHN: Brinell Hardness Number - a dimensionless indicator of material hardness.
BI-DIRECTIONAL: A shut off valve capable of sealing in both direct and reverse pressure.
BLOCK AND BLEED: A valve configuration in which the flow through the valve, from the inlet port to the outlet port, is blocked, while another small port is provided for the purpose of bleeding down (draining or depressurizing) the cavity in between.
BLOW DOWN VALVE (BDV): A small ball valve that is installed to vent body cavity pressure.
BLOWOFF VALVE: A valve installed in a low point or depression on a pipeline to allow drainage of the line. Also called washout valve.
BODY: The principle pressure containing shell of a valve or fitting.
BOLTED CONSTRUCTION: Describes a valve construction in which the pressure shell elements (such as body and closures of a trunnion ball valve) are bolted together and so can be taken apart and repaired in the field.
BONNET: The cover or removable top component of a valve, containing the packing gland and stem opening. Generally, gate and globe valves are considered to have a bonnet.
BRONZE: An alloy of copper and tin. For special purposes other metals such phosphorus, lead, zinc, silicon or aluminum are added. Most bronze alloys resist corrosion.
BSI: British Standards Institution-organization responsible for standards in Great Britain and Northern Ireland.
BUBBLE-TIGHT: A seat leakage condition in which, during the allotted time of the test, no perceptible leakage comes past the seat being tested. Applies to air-under-water testing-the same test using water-under-air is referred to as drop tight.
BUNA-N: Common term for nitrile rubber.
BUSHING: A lining or sleeve of metal or other material inserted into a hole to limits its size, resist wear, or act as a guide.
BUTT WELD: Weld where the adjoining edges to be welded are parallel and facing each other.
BUTTERFLY VALVE: A valve that has a circular disc-shaped closure element that pivots one-quarter tum about its vertical centerline to open and close.
BYPASS: A smaller line containing a valve that comes off a larger line just upstream of a major valve and rejoins the same line just downstream of the valve.

C

CAST IRON: The common term for cast gray iron or iron containing flake carbon in the range of 1.0 to 1.5 %. Cast iron is brittle, exhibiting very little ductility before fracturing.
CASTING: A product or the act of producing a product made by pouring molten metal into a mold and allowing it to solidify, thus taking the shape of the mold.
CAVITATION: The phenomenon in which the local pressure at a point in a flowing fluid becomes lower than the vapor pressure of the fluid, thus causing small bubbles to form. The bubbles then implode when the local pressure rises again, causing shock waves that are very destructive to the walls of the passageway or the valve trim in the area of the cavitation.
CENTRIFUGAL PUMP: A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing and having an inlet and a discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.
CHAINWHEEL: Device that is shaped like a handwheel but has a chain guide around its periphery either attached to or in place of a handwheel for operating valves higher than a person's reach.
CHARPY TEST: A destructive mechanical test conducted on a precisely machined coupon of steel to measure of the toughness of the steel or its resistance to shock or impact.
CHECK VALVE: A unidirectional valve which is opened by the fluid flow in one direction and which closes automatically to prevent flow in the reverse direction.
CHEVRON PACKING: Packing that consists of stacked rings of molded plastic or fiber, with a V-shaped cross section such that pressure from under the chevron tends to force the edges of the packing ring more tightly against the walls of the packing chamber, thus increasing the seal.
CHEZY FORMULA: A basic hydraulic formula developed by Chezy in 1775 for determining the flow of water in open channels. See Manning Formula, Manning Roughness Coefficient.
CLAPPER: Another name for the disc in a swing check valve.
CLASS: A designation of pressure capability expressed as a dimensionless number. The class rating charts give maximum allowable pressure at a given temperature.
CLOSURE MEMBER: The device or object that is placed into or across an opening in a pressure-retaining body for the purpose of closing it off.
COLD WORKING PRESSURE (CWP): The maximum allowable pressure under non-shock conditions at ambient temperature, typically 125°F (52°C).
COLUMN SEPARATION: Phenomena which occurs when a column of water in a pipeline separates creating a vacuum.
COMBINATION AIR VALVE: Air Valve which combines the function of an Air Release valve with that of an Air/Vacuum valve. Available in both single body and dual body configurations.
COMPANION FLANGE: A pipe flange threaded internally to receive a pipe length and drilled so it may be bolted to another like flanges.
CONTROL VALVE: Valve that has an automatic actuator that responds to signals sent by pneumatic, electrical, or other means for the purpose of controlling or varying the fluid flow in the pipeline.
CONTROLLER: A device that measures a controlled variable, compares it with a predetermined setting and signals the actuator to re-adjust the opening of the valve in order to re-establish the original control setting.
CORROSION: The deterioration of a material due to chemical action or environmental conditions.
CRACKING PRESSURE: The pressure required to lift a check valve disc off its seat.
CROSS CONNECTION CONTROL: The use of assembly, devices, methods and procedures to prevent contamination or pollution of a potable water supply through cross-connection.
CROSS CONNECTION: A connection between two pipes in the same water supply system or between two water supply systems containing potable water.
CRYOGENIC VALVE: A term used to describe valves designed generally to operate below -150°F (-101°C).
CUSHION SWING CHECK VALVE: A Swing Check Valve designed to reduce slamming by providing an external cushion to dampen the disc's closure.
Cv: Flow coefficient expressed as the number of gallons of water that would flow through an opening, such as a valve port, in 1 minute under a differential pressure of 1 psi.
CYCLE: A single complete operation or process returning to the starting point. A valve, stroked from full open to full close and back to full open, has undergone one cycle.
CYLINDER ACTUATOR: An actuator which converts hydraulic or pneumatic pressure action on a piston within a cylinder into mechanical force which moves the valve or gate closure member.

D

DASHPOT: A device used to dampen and control a motion, in which an attached piston is fitted to move slowly in a cylinder containing oil.
DEEP-WELL TURBINE PUMP: A centrifugal pump adapted for deep well use and consisting of a series of stages. Each stage comprises a set of vanes in a case or bowl, and the number of stages increases with the operating head.
DESIGN PRESSURE: The pressure used in calculating required wall thicknesses, flange ratings, and other variables. Generally, the design pressure is set at a value higher than the operating pressure, to include all the reasonable allowances for surge pressures and variation in operating conditions.
DESIGN TEMPERATURE: The temperature that is used to determine allowable stresses for the purposes of design calculations. Generally, the design temperature is set at a value higher than the operating temperature and includes allowances for upsets and variation in operating conditions.
DIAPHRAGM ACTUATOR: A pressure-operated, spring-opposed diaphragm assembly which positions the valve stem in response to an input signal.
DIFFERENTIAL PRESSURE OR ∆P: The difference between the upstream and downstream pressures.
DIN: Deutsche Industries Norme German national standard organization.
DIRECT ACTING: An actuator in which the actuator stem extends with an increase in diaphragm pressure.
DIRECT PRESSURE: Pressure applied by the flow against the back of the valve closure member and/or opposite the seat end of the valve.
DISC STROKE: The movement of a valve disc from the closed to open position or vice versa.
DISC: The closure member in a gate, globe, check, or butterfly valve.
DISCHARGE HEAD: A measure of the pressure exerted by a fluid at the point of discharge, usually from a pump.
DISTRIBUTION SYSTEM: A system of fittings and fixtures used to convey liquid or gas from one point to another.
DN: Nominal Diameter-standard abbreviation for pipe size used in ISO standards.
DOUBLE ACTING ACTUATOR: Characteristic of a piston or diaphragm system in which the energizing pressure acts on both faces of thepiston or diaphragm and operates the system in forward and reverse to open or close.
DOUBLE BLOCK & BLEED (DBB): A single valve with two seating surfaces that, in the closed position, provides a seal against pressure from both ends of the valve with a means of venting/bleeding the cavity between the seating surfaces.
DOUBLE ISOLATION & BLEED (DIB): A single valve with two seating surfaces, each of which, in the closed position, provides a seal against pressure from a single source, with a means of venting/bleeding the cavity between the seating surfaces.
DUAL DISC®: A check valve utilizing two discs. The discs are half circle in shape, hinged on their straight edge and mounted to a hinge pin on the valve's centerline.
DUCTILE IRON: A type of cast iron with special treatment during the casting process to enhance its metallurgical graphite structure to provide carbon nodules and higher mechanical properties and improved ductility similar to steel.
DUROMETER: A device for measuring hardness's of resilient materials.
DUTY CYCLE: Percentage of time a device is allowed to operate over a given period of time. Expressed in percent, it equals time on divided by time off multiplied by 100.
DYE PENETRANT INSPECTION: Also known as Liquid Penetrant Inspection. A non-destructive method of detecting the presence of surface cracks and imperfections through use of a special colored dye.
DYNAMIC TORQUE: Flow-induced valve torque.

E

ECCENTRIC ACTION: The movement of a valve plug or disc which has a pivot axis off center from the seat or body. Allows movement in and out of the seat without rubbing.
ECCENTRIC PLUG VALVE: A quarter-tum shut-off valve in which the plug or disc has a pivot axis off center from the valve's seat or body. The Eccentric Action of the disc allows movement of the plug in and out of the seat without rubbing.

EFFLUENT: (1) A liquid which flows out of a process or confined space. (2) Wastewater or other liquid partially or completely treated, or in its natural state, flowing out of a reservoir, basin, treatment plant, or industrial treatment plant, or part thereof. (3) An outflowing branch of a main stream or lake. (4) An emission of gas.
ELASTOMER: A natural or synthetic elastic material, often used for O-ring seals.
ELECTRIC ACTUATOR: Also known as an Electro-Mechanical Actuator which uses an electrically operated motor-driven gear train or screw to position the actuator stem. The actuator may respond to either a digital or analogue electrical signal.
ELECTROLYTIC CORROSION: Corrosion resulting from stray DC currents in underground pipe.
ELEVATION HEAD: The energy possessed per unit weight of a fluid because of its elevation above some datum.
EMERGENCY SEAT SEAL: A fitting on the valve body through which sealant can be injected to affect a seat seal in an emergency situation.
END CONNECTION: The type of connection supplied on the ends of a valve which allows it to be connected to piping.
END TO END DIMENSION: The dimension from the end of one port to the end of the opposite port of a valve, fitting or pipe.
ENERGY HEAD: The height of the hydraulic grade line above the center line of a conduit plus the velocity head of the mean-velocity water in that section.
EROSION: The mechanical wear of a metal surface or part due to fluid impingement. The presence of entrained solid particles accelerates this process.
EXPANSION JOINT: A pressure tight connection device installed in a piping system to provide for changes in length due to expansion or contraction resulting from changes in temperature.
EXPLOSION-PROOF: Characteristic of a device or enclosure that inherently contains or prevents an explosion.
EXTENSIONS: The equipment applied to buried valves or valves below walkways to provide above grade accessibility to operating gear.
EXTERNAL COATING: Coating applied to protect valves against various arduous environments – sea water/air, etc. (not normally a requirement for corrosion resistant valves).

F

FACE-TO-FACE DIMENSION: The dimension from the face of the inlet port to the face of the outlet port of flanged valves or fittings.
FACING: The finish of the gasket contact surface of a flange.
FAIL SAFE VALVE: A valve designed to fail in a preferred position (open, closed or in-place) in order to avoid an undesirable consequence in a piping system.
FAIL-OPEN: A condition in which a valve or other component that is normally in some position, open, closed, or in between, will open if power or signal is lost.
FAILURE MODE: Upon electric power failure or air pressure loss to the actuator, the valve is operated to a predetermined position (fail open, fail close, fail in last position).
FEEDBACK: Signal indicating the actual position of an element in a control system.
FIRE SAFE: A valve design that is capable of passing a fire test with specified limits on leakage to the atmosphere and downstream after being closed subsequent to fire exposure.
FLANGE: A cast or formed pipe fitting with bolt holes to provide means of attachment to piping components having a similar fitting.
FLANGELESS: A valve that does not have integral line flanges, sometimes referred to as a Lug or Wafer Style valve.
FLAP VALVE: A valve that is hinged at one edge and that opens and shuts by rotating about the hinge.
FLAT FACE: (FF) A flange surface in which the gasket sealing area is the entire surface from the inside diameter to the outside edge of the flange.
FLOAT VALVE: A valve in which the closure to an opening, such as a plug or gate, is actuated by a float to control the flow into a tank.
FLOATING BALL VALVE: A ball valve where the ball is free to float between the seat rings.
FLOW AREA: The total area minus obstructions at a given cross sectional point in a valve.
FLOW CHARACTERISTICS: The curves relating to the percentage of flow versus the closure member travel. Inherent flow characteristics assume a constant pressure across the valve while the installed flow characteristic includes the impact of the system on the valve's performance.

FLUID: Substance that is characterized by low resistance to flow and the tendency to assume the shape of its container or conduit.
FM: Factory Mutual Association - an organization that certifies products used in fire- or other safety-related industrial installations.
FOOT VALVE: A check valve with an inlet screen placed in the bottom of the suction pipe of a pump, which opens to allow water to enter the suction pipe but closes to prevent water from passing out of it at the bottom end.
FORCE MAIN: A pressure pipe joining the pump discharge at a water or wastewater pumping station with a point of gravity flow.
FORGING: A metalworking process that involves hammering or forming, with or without a die, at hot working temperatures to form a specific shape.
FRICTION LOSS: The head lost by water flowing in a stream or conduit as the result of the disturbances set up by the contact between the moving water and its containing conduit and by intermolecular friction.
FUGITIVE EMISSIONS: Named used by the EPA for the external leakage of hazardous gases from piping components such as valve and pumps.
FULL BORE or **FULL PORT:** A valve or other component in which the seat area has substantially the same cross section and cross-sectional area as the end connections have.
FULL PENETRATION WELD: Describes the type of weld wherein the weld metal extends through the complete thickness of the parts being joined.

G

GALLING: The tearing of metal surfaces when two elements rub against each other. Usually caused by lack of lubrication or extreme contact pressure of materials of a similar hardness value.
GALVANIC CORROSION: Corrosion that occurs where dissimilar metals are in close proximity in an electrolytic solution, such as water. The anode side is the one that loses metal.
GAS: A compressible fluid – such as air, hydrogen, nitrogen, etc.
GASKET: A component whose purpose is to seal a joint between two larger components, softer than the surfaces of the joint being sealed and usually compressed by means of bolting to affect the seal.
GATE VALVE: A valve whose closure member is a gate, wedge, disc or double disc which moves on an axis perpendicular to the direction of flow.
GEAR OPERATED: The actuation of a valve thru a gear set which multiplies the torque applied to the valve stem.
GLAND FOLLOWER: The flange that is used to hold down or retain the gland on a packing chamber.
GLAND or **GLAND BUSHING:** The ring that compresses or retains the packing.
GLOBE VALVE: A valve, originally somewhat globe shaped, in which the closing member is circular in cross section and moves along a line concentric with the seat axis to open and close.
GRADIENT: The rate of change of any characteristic per unit of length, or slope. The term is usually applied to such things as elevation, velocity, pressure. See slope.
GRAPHITE: Flexible carbon material used to make gaskets and packing. The gaskets may be flat graphite sheet or have metal inserts for added strength.
GRAY IRON: Cast iron which has a high carbon content which causes a fractured section to appear to be dark gray.
GREASE FITTING: A device which permits injection of grease into a bearing surface.
GRIT SEAL: A resilient contact used to minimize valve bearing and shaft seal contact with flows containing suspended solids.
GROOVED END: Circumferential recess that is cast, cut, or otherwise formed onto a pipe, fitting, or valve end to form a restrained joint when used with the proper gasket and coupling.

H

HANDWHEEL: A wheel-shaped valve operating device intended to be grasped with one or both hands which allows turning the valve stem or operator shaft to which it is attached.
HARD FACING: A surface preparation in which an alloy is deposited on a metal surface usually by weld overlay to increase resistance to abrasion and or corrosion.

HAZEN-WILLIAMS FORMULA: An equation developed in 1902 by Gardner Williams and Allen Hazen to express flow relations in pressure conduits.
HEADLOSS: Energy losses due to the resistance of flow of fluids. May be classified into conduit surface and conduit form losses.
HEAD: (1) The height of the free surface of fluid above any point in a hydraulic system; a measure of the pressure or force exerted by the fluid. (2) The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. It is used in various compound terms such as pressure head, velocity head, and loss of head.
HEADER: A large pipe installed to intercept the ends of a series of pipes; a manifold.
HEAT TREATMENT: Describes any process or procedure by which the internal structure of steel is altered by heating to produce desired physical and mechanical characteristics.
HIGH POINT: The location on a pipeline or piping system where the grade changes from upward to downward.
HIGH-PERFORMANCE BUTTERFLY VALVE: Common name for a double offset disc design, which the butterfly valve conforms to the ASME pressure/temperature rating, using materials of construction to accomplish the ratings.
HOLIDAY: A void in a coating such as a paint or a wrapping where the coating is not adhered to the substrate.
HORIZONTAL PUMP: - (1) reciprocating pump in which the piston or plunger moves in a horizontal direction. (2) A centrifugal pump in which the pump shaft is in a horizontal position.
HORIZONTAL SCREW PUMP: A pump with a horizontal cylindrical casing in which operates a runner with radial blades like those of a ship's propeller. The pump has a high efficiency at low heads and high discharges and is used extensively in drainage work.
HOT TAP: A connection made to a pipeline while the line is under pressure or in service. A special procedure is required to make an opening in the pipe without leaking any of the line contents.
HOT TEARS: A defect occurring in castings caused where partially solidified or weak, newly solidified sections are subjected to a pull resulting from the contraction of thinner parts that have solidified earlier.
HRB or **HRC:** Rockwell B or C hardness - hardness measured on scales comparing the sizes of indentations made in the tested material. The larger the number, the harder the material.
HUB: An integrally cast raised area or ''boss" on the valve body used to support the valves shaft(s) and bearings. Sometimes called a trunnion.
HYDRAULIC GRADE LINE: A hydraulic profile of the piezometric level of water at all points along a line. The term is usually applied to water moving in a conduit, open channel, or stream, but may also be applied to free or confined groundwater. In and open channel, it is the free water surface. See also hydraulic grade.
HYDRAULIC GRADE: In a closed conduit under pressure, artisan aquifer, or groundwater basin, a line joining the elevations to which water would rise in pipes freely vented and under atmospheric pressure. In an open channel, the hydraulic grade is the water surface.
HYDRAULIC GRADIENT: The slope of the hydraulic grade line; the rate of change of pressure head; the ratio of the loss in the sum of the pressure head and position head to the flow distance. For open channels, it is the slope of the water surface, and is frequently considered parallel to the invert. For closed conduits under pressure, it is the slope of the line joining the elevations to which water would rise in pipes freely vented and under atmospheric pressure. A positive slope is usually one which drops in the direction of flow.
HYDRAULIC HEAD: The height of the free surface of a body of water above a given point beneath the surface. See also head.
HYDRAULIC JUMP: (1) The sudden and usually turbulent passage of water in an open channel, under conditions of free flow, from low stage below critical depth to high stage above critical depth; during this passage the velocity changes from supercritical to subcritical. It represents the limiting condition of the surface curve, in which that curve tends to become perpendicular to the stream bed. (2) In a closed conduit, the sudden rise from part-full flow at a supercritical velocity to full flow under pressure; the depth plus the pressure head downstream from the hydraulic jump equals the high stage obtained for open-channel flow.
HYDRAULIC MOTOR ACTUATOR: A device by which rotation of a hydraulically powered motor is converted into mechanical motion.

HYDRAULIC PROFILE: (1) A profile along the axis of flow of a stream or conduit showing elevations of the bottom and of the energy line. (2) A profile along the axis of flow through a wastewater or water treatment plant, showing elevations of the free water surface.
HYDRAULIC SLOPE: The slope of the hydraulic grade line. See also hydraulic gradient.
HYDROFOIL DISC DESIGN: A check valve disc designed to come off its seat, quickly reach its full open position and become fully stabilized under minimal flow conditions.
HYDROPNEUMATIC SYSTEM:- A water system, usually small, in which a water pump is automatically controlled by the air pressure in a compressed-air tank.
HYDROSTATIC TEST: A static pressure test using water, in which the item or system to be tested is filled with water and pressurized to detect leaks and verify structural integrity.

I

IBBM: Iron body, bronze mounted-common term for valves with iron body and bonnet (pressure-retaining parts) and bronze trim (seats, stem, bushings).
ID: Inside diameter-the distance, either nominal or actual, from the inside wall of an annular surface to the opposite inside wall.
INCOMPRESSIBLE FLOW: A fluid such as water, which has no significant change in volume and density as the pressure increases.
INFLUENT: Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment plant, or treatment process. See also effluent.
INLET PORT: That end of a valve which is connected to the upstream pressure zone of a fluid system.
IN-PLANT: That which is within the property lines of a water or wastewater treatment plant.
INSIDE THE FENCE: That which is within the property lines of a water or wastewater treatment plant.
INSTALLED FLOW CHARACTERISTIC: Flow characteristic when the pressure drop across the valve varies as dictated by flow and related conditions in the system in which the valve is installed.
INTERNAL PRESSURE RELIEF: A self-relieving feature in non-independent seating valves that automatically relieves excessive internal body pressure caused by sudden changes in line pressures. By means of the piston effect principal the excessive body pressure will move the seat away from its seating surface and relieve it to the lower pressure side.
INVERTED SIPHON: A pipeline crossing a depression or passing under a structure and having a reversal in grade on a portion of the line, thus creating a V- or U-shaped section of conduit. The line is under positive pressure from inlet to outlet and should not be confused with a siphon.
ISO: International Standards Organization-worldwide standards coordinating organization.
ISOLATION VALVE: A shut-off valve used to isolate part of a pipeline, a process or piece of equipment.
ISRS: Inside screw, rising stem - common term for any valve design in which the stem threads are exposed to the fluid below the packing and the stem rises up through the packing when the valve is opened.

J

JIS: Japan Industrial Standard-designation for standards published by the national standards organization of Japan.

K

KINETIC ENERGY: Energy available from a flowing column of water due to its velocity.
KINETIC HEAD: The theoretical vertical height through which a liquid body may be raised by virtue of its kinetic energy. It is equal to the square of the velocity divided by twice the acceleration due to gravity. See also velocity head.
KINETIC: Relating to the motion of material bodes and to the force and energy associated therein.
KNIFE GATE VALVE: Type of gate valve using a thin, flat gate usually used in controlling slurries.

L

LAMINAR FLOW: The flow of a viscous fluid in which particles of the fluid move in parallel layers each of which has a constant velocity but is in motion relative to its neighboring layers. Also called streamline flow, viscous flow.

LANTERN RING: A rigid spacer ring used in the Lantern Ring type of Packing Chamber to permit lubrication of the Packing, purging of the Shaft or Stem area, or a leak-off system.

LEVER: An operating device for quarter-turn valves.

LIFT PUMP: A pump used to elevate wastewater flow in a sewer to facilitate gravity flow in a portion of a collection system, before treatment, or afterwards, before effluent discharge.

LIFT STATION: A structure that contains pumps and appurtenant piping, valves, and other mechanical and electrical equipment for pumping water, wastewater, or other liquid. Also called pump station.

LIFTING LUGS: Lugs that may be provided on large valves, for lifting and positioning. Also called lifting eyes.

LIMIT SWITCH: An electrical device providing a signal to a remote observation station indicating when the valve is in the fully open or fully closed position. Usually a component of a valve operator.

LINE VOLTAGE: Voltage existing between the two lines of an electric supply.

LINEAR ACTUATOR: Device which provides valve thrust in a linear motion.

LINEAR DISC TRAVEL: A valve disc which opens and closes in a straight line. The valve disc orientation is perpendicular to the valve seat providing flow area equal to disc stroke position.

LINEAR FLOW CHARACTERISTIC: Inherent flow characteristic which can be represented ideally by a straight line on a rectangular plot of flow coefficient versus percent rated travel. (Equal increments of travel yield equal increments of flow coefficient change at a constant pressure drop).

LIQUID PENETRANT INSPECTION: Also known as Dye Penetrant Inspection. A nondestructive method of detecting the presence of surface cracks and imperfections through use of a special red dye. Abbreviated as LPI or PT.

LIQUID: A substance that flows freely. Characterized by free movement of the constituent molecules among themselves, but without the tendency to separate from one another characteristic of gases. Liquid and fluid are often used synonymously, but fluid has the broader significance, including both liquids and gases. See also fluid.

LIVE LOADING: is the application of a spring load to the gland follower of a packed valve. A Belleville spring between the gland follower and its fastening studs and nuts provides an effective way to establish and maintain a controlled amount of stress in the packing set.

LOCKING DEVICE: Any valve attachment whose purpose is to prevent the operation of the valve by unauthorized persons.

LUBRICATED PLUG VALVE: Type of plug valve in which the plug rotation and sealing can be assisted by sealant applied under external pressure.

LUG TYPE VALVE: A valve with short face-to-face dimension in proportion to the fluid passage diameter designed to be bolted to one or both flanges in a line by the use of fasteners, which are threaded into lug protrusions of the valve body.

M

MAGNETIC PARTICLE INSPECTION: A nondestructive method of detecting the presence of surface cracks and imperfections through use of fine iron particles in an electrical field. Abbreviated as MPI or MT.

MAIN SEWER: (1) In larger systems, the principal sewer to which branch sewers and submains are tributary; also called trunk sewer. In small systems, a sewer to which one or more branch sewers are tributary. (2) In plumbing, the public sewer to which the house or building sewer is connected.

MANHOLE: (1) A structure atop an opening in a gravity sewer to permit entry for servicing. Usually placed at all points of change in sewer grade and at least every 300 to 400 feet along the line. (2) An opening in the top or side of an enclosed vessel to permit human entry.

MANIFOLD: A pipe fitting with numerous branches to convey fluids between a large pipe and several smaller pipes or to permit choice of diverting flow from one of several sources or to one of several discharge points. See also header.

MANNING FORMULA: A formula for open-channel flow, published by Manning in 1890, which gives the value of C in the Chezy Formula.

MANNING ROUGHNESS COEFFICIENT: The roughness coefficient in the Manning Formula for determination of the discharge coefficient in the Chezy Formula.

MANOMETER: An instrument for measuring pressure. It usually consists of a U-shaped tube containing a liquid, the surface of which in one end of the tube moves proportionally with changes in pressure in the liquid in the other end.

MANUAL OVERRIDE: A mechanical device provided on actuators that allows the manual positioning of the actuator.

MATERIAL TEST REPORTS: Certificates provided by the steel manufacturer or foundry indicating the chemical analysis and mechanical properties of a specific batch of steel or castings traced by sequentially assigned heat numbers or codes.

MAWP: (Maximum Allowable Working Pressure or Cold Working Pressure). The maximum working pressure (Bar or Psi) at which a valve is designed to be operated up to.

MDS – MATERIAL DATA SHEET: The material data sheet defines the minimum requirements for the required materials, i.e., chemical requirements, manufacturing, qualification of supplier, mechanical testing and properties, non-destructive examination, repair, marking, and certification.

MEAN VELOCITY: The average velocity of a stream flowing in a channel or conduit at a given cross section or in a given reach. It is equal to the discharge divided by the cross-sectional area of the section, or the average cross-sectional area of the reach. Also called average velocity.

MECHANICAL JOINT: A bolted pipe joint utilizing a compressed gasket and gland.

MECHANICAL SEAL: The wedging action of a gate against the seats or the seat springs pushing the seat against the ball or gate are examples of mechanical seals in a valve.

METAL TO METAL: A seating design characterized by the lack of any soft deformable seating material. Metal-to-metal seats can withstand much higher pressures and temperatures than soft seats, but leakage rates are usually greater except in special valve designs.

MIXED-FLOW PUMP: A centrifugal pump in which the head is developed partly by centrifugal force and partly by the lift of the vanes on the liquid. This type of pump has a single inlet impeller; the flow enters axially and leaves axially and radially.

MODULATE: Function of a controller which causes a valve to continuously respond to position signal and position the valve between the closed and full open positions.

MOTOR-OPERATED VALVE: Any valve which is opened or closed by a motorized actuator.

MSS: Manufacturers Standardization Society of the Valve and Fitting Industry-trade organization responsible for issuing voluntary standards for valves and piping material.

MUD VALVE: A plug valve for draining out sediment, inserted in the bottom of settling tanks.

N

NACE – NATIONAL ASSOCIATION OF CORROSION ENGINEERS: This technical association publishes papers, articles and standards on all aspects of corrosion, and has written the definitive standards for valve materials for sour gas service.

NDE: (NON-DESTRUCTIVE EXAMINATION): See NDT.

NDT: (NON-DESTRUCTIVE TESTING): Inspection tests which are not destructive to the component structure or function. Tests such as radiography, dye penetrant and magnetic particle testing.

NEEDLE VALVE: A multi-turn device with a needle-shaped closing element through which the flow is controlled by means of a tapered needle which extends through the outlet, reducing the area of the outlet as it advances and enlarging the area as it retreats.

NEGATIVE PRESSURE: A pressure less than the local atmospheric pressure at a given point.

NEMA CLASSIFICATION: Code established for the construction of electrical components by the National Electrical Manufacturers Association.

NET POSITIVE SUCTION HEAD: The amount of energy in the liquid at the inlet of the pump expressed in feet of water, absolute.

NFPA – NATIONAL FIRE PROTECTION ASSOCIATION: Organization responsible for maintaining standards that are designed to minimize the risk and effects of fire by establishing criteria for building, processing, design, service, and installation around the world.

NICKEL PLATED: Coated with nickel by electroplating or other means

NON-POTABLE WATER SYSTEM: Water not safe for drinking, personal or culinary use.

NON-RISING STEM INSIDE-SCREW: Type of gate valve design in which the disc rises on the threaded part of the stem, instead of the stem rising through the bonnet (the stem does not rise or descend as the stem turns).

NON-RISING STEM: When the stem turns in a gate Valve, the gate moves but the stem does not rise. Stem threads are generally exposed to process fluids.
NON-SLAMMING VALVE: A check valve designed to close prior to reverse flow taking place or, close very slowly in the presence of reverse flow allowing the flow energy to dissipate.
NORMALLY CLOSED: A state in which a valve or other component stays closed in the absence of a signal or manual intervention. Any such outside action will open the valve.
NORMALLY OPEN: A state in which a valve or other component stays open in the absence of a signal or manual intervention. Any such outside action will close the valve.
NPS: Nominal pipe size--dimensionless number used as designator for sizes of pressure pipe.
NPT - NATIONAL PIPE THREAD: standard tapered thread for pressure pipe and components. Requirements defined in ASME B1.20.1.
NSF INTERNATIONAL: Industry sponsored testing laboratory and standards organization.

O

OD: The measurement of the outside diameter of a circular part.
ON-OFF VALVE: any number of valve types used for either full open or shutoff service.
OPEN LEFT: Indicates CW rotation to close valve.
OPEN RIGHT: Indicates CCW rotation to close valve.
OPERATING CYCLE: Actuation of a valve from one limit of its operation position to the opposite limit and return to its original position. Example: full-closed to full-open to full-closed.
OPERATING NUT: The square, tapered nut that fits on top of a valve shaft and allows it to be turned by a tee-handle from above. Usually installed on buried valves.
OPERATING PRESSURE: The pressure that a component normally sees during the course of day-to day operation. This pressure, plus any other factors such as upsets that may occur, is used to determine the design pressure.
OPERATING TEMPERATURE: The temperature that a component normally sees during day-to-day operation. This temperature, plus any other factors such as excursions that may occur, is used to determine the design temperature.
ORIFICE BUTTON: The resilient closure element in an Air Release Valve. Sometimes referred to as needle.
O-RING: An elastomeric or synthetic seal ring of circular cross section.
OS&Y - OUTSIDE SCREW & YOKE: A valve design in which the stem threads are above the packing gland or outside the valve body and there is a yoke to support the top or outer end of the stem.
OSCILLATION: A periodic movement to and fro, or up and down.
OUTFALL SEWER: A sewer that receives wastewater from a collecting system or from a treatment plant and carries it to a point of final discharge. See also outfall.
OUTFALL: (1) The point, location, or structure where wastewater or drainage discharges from a sewer, drain, or other conduit. (2) The conduit leading to the ultimate disposal area. Also see outfall sewer, wastewater outfall.
OUTLET PORT: the end of the valve which is connected to the downstream pressure zone of a fluid system.
OUTSIDE THE FENCE: Water or wastewater lines and appurtenances located outside the boundaries of a water or wastewater treatment plant.
OZONATION: The process of contacting water, wastewater, or air with ozone for purposes of disinfection, oxidation, or odor control.
OZONIZER: A device for producing ozone from pure oxygen or air. It consists essentially of two electrodes between which a current of the dry gas is passed. High voltage electric discharges pass through the air between the electrodes and cause the formation of ozone.

P

PACKING GLAND: A device installed on a packing chamber to retain the packing and to maintain pressure on it.
PACKING: Any soft substance used to seal the area of a shaft where it protrudes from inside a pressure boundary, such as a valve or pump.

PARSHALL FLUME: A calibrated device developed by Parshall for measuring the flow of liquid in an open conduit. It consists essentially of a contracting length, a throat, and an expanding length.
PARTIAL VACUUM: The description of a space condition in which the pressure is less than atmospheric.
PATTERN: A duplicate made of wood or metal of a part to be cast. Used to form the mold into which the molten metal is poured.
PEEK: Polyether Ether Ketone is a crystalline thermoplastic with excellent mechanical and chemical resistance properties that are retained to high temperatures.
PENSTOCK: The pipeline or conduit which carries water under pressure from the forebay or last free water surface to the turbines in a power generating facility.
pH: A measure of the hydrogen-ion concentration in a solution, expressed as the logarithm (base ten) of the reciprocal of the hydrogen-ion concentration in gram moles per liter. On the pH scale (0-14), a value of 7 at 25°C represents a neutral condition. Decreasing values, below 7, indicate increasing hydrogen-ion concentration (acidity); increasing values, above 7, indicate decreasing hydrogen-ion concentration (alkalinity).
PIEZOMETER: An instrument for measuring pressure head in a conduit, tank, or soil. It usually consists of a small pipe or tube tapped into the side of the container, with its inside end flush with, and normal to, the water face of the container, and connected with a manometer pressure gage, mercury or water column, or other device for indicating pressure head.
PIG: Also known as a scraper-the solid object placed in a pipe line, to be pushed along by line pressure, for the purpose of separating one fluid from a different one being shipped through the same line or to clean (scrape) the walls of the pipe.
PIG IRON: An intermediate product of the iron industry obtained from melting. Is intended for re-melting.
PILOT VALVE: Device acting between the source of air pressure and the actuator that directs air flow to the required actuator air inlet ports.
PINCH VALVE: A valve having a flexible center tube or hose which is “pinched” to effect closure.
PINHOLE: Numerous small gas holes at the surface or just below the surface of castings, generally occurring in the thicker parts of the casting as a reduction in the solubility of gases in the metal as the metal cools.
PINION SHAFT: The external input shaft of certain gear operators which drive the internal reduction gearing.
PIPE COLLAPSING PRESSURE: The internal negative pressure at which a pipe will collapse in on itself.
PIPE GRADE: The slope or fall of the pipe in the direction of flow.
PIPELINE PROFILE: A cross-sectioned view of a pipeline slowing elevation and length.
PIPELINE: A line of pipe including fittings, valves and control devices for conveying liquids, gases or finely divided solids.
PISTON PUMP: A reciprocating pump in which the cylinder is tightly fitted with a reciprocating piston.
PITOMETER: A device operating on the principle of the Pitot tube, principally used for determining the velocity of flowing fluids at various points in a water distribution system, and to ascertain waste, leakage, or clogging of pipes.
PLASTICS: A broad classification covering a variety of non-metallic, synthetic or organic materials capable of being molded or formed into desired shapes.
PLUG VALVE: A type of valve in which a cylindrical or tapered cylindrical (truncated cone) section turns one quarter-tum to close and open the flow passageway.
PLUG: (1) A fitting for the bell end of cast iron pipes to close the opening. (2) A fitting that has an exterior pipe thread and a projecting head by which it is screwed into the opening of a fitting. (3) The movable part of a tap, cock, faucet, plug, valve.
PMI - POSITIVE MATERIAL IDENTIFICATION: A method for verifying the identity of a material, often using a portable spectrometer, usually with x-rays or an optical spectrometer.
PN: Nominal pressure-standard abbreviation for pressure rating used in ISO standards.
PNEUMATIC ACTUATOR: Device that converts pneumatic pressure into mechanical motion and force to move a valve’s closure member.
PNEUMATIC EJECTOR: A device for raising wastewater, sludge, or other liquid by alternately admitting it through an inward swinging check valve into the bottom of an airtight pot and then discharging it through an outward swinging check valve by admitting compressed air to the pot above the liquid.
PNEUMATIC PUMPING: Pumping by means of an air-lift pump.
POPPET VALVE: A valve consisting of a flat disk which raises and lowers without rotation about the valve opening and which is kept in position and on its path of travel by a rod or shaft attached to the disk at right angles to it and extending through the valve opening into a groove or hole which guides its movement. Also called a mushroom valve.

POROSITY: A defect found in castings or welds consisting of gas bubbles or voids in the solidified metal.
PORT: An opening in a valve body or closure element, usually used in control valve terminology.
POSITION INDICATOR: Any external device which visually indicates the open and closed position of valve.
POSITIONER: A device used to position a valve with regard to a signal. The positioner compares the input signal with a mechanical feedback link from the actuator.
POSITIVE HEAD: The energy possessed per unit weight of a fluid, due to its elevation above some datum. Also called elevation head.
POSITIVE ROTARY PUMP: A type of displacement pump consisting essentially of elements rotating in a pump case which they closely fit. See also rotary pump.
POTABLE WATER: Water that does not contain objectional pollution, contamination, minerals, or infective agents and is considered satisfactory for domestic consumption.
PPM: Parts per million, a unit of concentration on a weight or volume basis.
PRESSURE: The force exerted by a fluid on the surfaces containing it.
PRESSURE CLASS: A designation of pressure capability. E.g. ANSI 150, 300, PN10, PN16, etc.
PRESSURE GAUGE: Instrument for measuring the pressure of fluids, gases or air.
PRESSURE HEAD: The head represented by the expression of pressure over weight. The head is usually expressed as height of liquid in a column corresponding to the weight of the liquid per unit area; for example, feet head of water corresponding to pounds per square inch.
PRESSURE MAIN: Pressurized sewer lines that deliver wastewater from a pumping station to a treatment plant, a receiving stream, or a higher point in the system. Also called force main.
PRESSURE SEALED BONNET: A type of bonnet design where the fluid pressure is used to produce the seal between the body and bonnet.
PRESSURE TANK: A tank used in connection with a water distribution system, for a single household, for several houses, or for a portion of a larger water system, which is airtight and holds both air and water, and in which the air is compressed, and the pressure so created is transmitted to the water.
PRESSURE-REDUCING VALVE: A valve with a horizontal disk for reducing pressures automatically, according to the setting of the pressure-regulating valves.
PRESSURE-REGULATING VALVE: A valve placed at either end of a pressure-regulating apparatus inserted in a water main to regulate the pressure in a water line either upstream or downstream from the valve.
PRESSURE-RELIEF VALVE: A valve that opens automatically to ample area when the pressure reaches an assigned limit, to relieve the stress on a pipeline.
PRESSURE-TEMPERATURE RATINGS: The maximum allowable working pressures at specified temperatures. For steel valves, the ratings are defined by "classes" and found in ASME B16.34. For iron and bronze valves, the ratings are defined in the applicable MSS specifications.
PRESTRESSED CONCRETE PIPE: A reinforced concrete pipe placed in compression by a highly stressed, closely spaced helical wire winding. The reinforcement permits a concrete pipe to withstand tension forces at the same time it is under compression from surrounding wires.
PRIMING: (1) The first filling with water of a canal, reservoir, or other structure built to containing water. (2) The action of starting the flow in a pump or siphon.
PSIA: Pounds per square inch, absolute-pressure force expressed without reference to ambient pressures.
PSIG: Pounds per square inch, gage-pressure force expressed with reference to standard atmospheric pressure. Standard atmospheric pressure is defined as 14.7 psi.
PSI: Pounds per square inch-measure of force, either pressure force or tensile or compressive stress in a material.
PUMP CAPACITY: The ability of a pump to pump against a given head, usually stated in flow and/or pressure.
PUMP EFFICIENCY: The ratio of energy converted into useful work to the energy applied to the pump shaft, or the energy difference in the water at the discharge and suction nozzles divided by power input at the pump shaft.
PUMP PIT: A dry well or chamber, below ground level, in which a pump is located.
PUMP PRIMER: - A vacuum pump attached to the suction end of a pump for priming the pump automatically.
PUMP STATION: A structure containing pumps and appurtenant piping, valves and other mechanical and electrical equipment for pumping water, wastewater, or other liquids. Also called lift station.
PUMP STRAINER: A device placed on the inlet of a pump to strain out suspended matter that might clog the pump.
PUMP SUBMERGENCE: Vertical distance of pump inlet or suction below water level in pump pit or after bay.

PUMP VALVES: The opening through which water enters and leaves the cylinders of a displacement pump.
PUMPING HEAD: The sum of the static head and friction head on a pump discharging a given quantity of water.
PUMPING LEVEL: The elevation at which water stands in a well when the well is being pumped at a given rate.
PUMPING LINE: The discharge pipe from a pump.
PURGING AIR: The removal of air from a pipeline through an Air/Vacuum valve or Combination Air Valve.
PUSH-ON JOINT: Joining design for valves and pipe that utilizes a rubber gasket that fits in the annular recess between the bell end of a pipe or valve and the spigot end of the adjoining pipe.

Q

QUALITY ASSURANCE: Planned regular and/or preventive actions which are used to ensure that materials, products, or services will meet specified requirements.
QUARTER-TURN VALVE: Shut-off valve that pivots one-quarter tum about its vertical centerline to open and close.

R

Ra: Abbreviation for "arithmetic average roughness height" - the measure of the roughness of a surface expressed in micro inches. The higher the number, the rougher the surface. Used to designate the desired surface finish for end flange raised faces.
RAISED FACE (RF): A flange sealing surface in which the gasket seating area is a portion of the diameter covering the region from the inside diameter to some radius lying just inside the bolt holes, with that portion raised slightly above the remainder of the flange surface. This increases the effective load on the gasket and increases the sealing effectiveness.
RECIPROCATING PUMP: A type of displacement pump consisting essentially of a closed cylinder containing a piston or plunger, as the displacing mechanism, drawing liquid into the cylinder through an inlet valve and forcing it out through an outlet valve. When the piston acts on the liquid in one end of the cylinder, the pump is termed single-action, and when it acts in both ends, it is termed double-action.
RECLAIMED WATER: Treated wastewater now suitable for a direct beneficial or controlled use. Although, not safe for human consumption.
REDUCED PORT: A valve port opening that is smaller than the line size or the valve end connection sizes.
REDUCER: A pipe fitting designed to be the transition from one pipe size to another size. The term increaser is used only for fittings with end connections that are one-way, such as male and female or bell and spigot, and the fitting is designed to be installed in the direction that the line size increases.
REDUCING VALVE: A spring- or lever-loaded valve similar to a safety valve, by which a lower and constant pressure may be maintained beyond the valve.
REFLUX VALVE: A nonreturn valve used in a pipeline at a rising gradient to prevent water that is ascending the gradient from flowing back in the event of a burst lower down.
RELEASING AIR: The removal of air from a pipeline. See Air Valve.
RELIEF VALVE: A self-actuating valve designed to open when the pressure under the seat reaches a preset value, by means of a spring or a poppet or any one of several other devices.
RESILIENT SEAT: A valve seat containing a soft seal such as an O-ring or plastic to assure tight shut-off.
REVERSE FLOW: A flow in which the fluid is traveling in the opposite direction of the systems normal operating condition.
REVERSE PRESSURE: Pressure applied by the flow against the face of the valve's closure member and/or the seat end of the valve.
RISER PIPE: (1) In plumbing, a water supply pipe in a building, that extends vertically one full story or more to convey water to branches or fixtures. (2) The vertical supply pipe to an elevated tank.
RJ or **RTJ:** Ring joint or ring-type joint-a flange sealing surface in which the gasket seating area is two narrow lines of metal-to-metal contact along a metal ring, softer than the flange, that is set into a groove in each flange face.

ROTARY PUMP: A type of displacement pump consisting essentially of elements rotating in a pump case which they closely fit. The rotation of these elements alternately draws in and discharges the water being pumped. Such pumps act with neither suction nor discharge valves, operate at almost any speed, and do not depend on centrifugal forces to lift the water.
ROUGHNESS: A measure of the resistance to fluid flow of a channel, pipe, or other conduit, as a result of its fabrication, scale formation, biological growth, or other causes.
ROUGHNESS COEFTICIENT: A factor, in the Chezy, Darcy-Weisbach, Hazen-Williams, Kutter, Manning, and other formulas for computing the average velocity of flow of water in a conduit or channel, which represents the effect of roughness of the confining material on the energy losses in the flowing water.
RTFE (REINFORCED POLYTETRAFLUOROETHYLENE): Reinforced PTFE (typically fiber glass 20-25%) and used for valve seats. It is suitable for valves with higher pressures but may still be limited in Class 900 and 1500 valves which might not be able to have full flange rating.

S

SADDLE: (1) A steel or concrete structure used for supporting a pipe or penstock laid above the surface of the ground. (2) A depression in a ridge. (3) An assembly of circumferential metal straps on a pipe where a connection is to be installed.
SAFE DRINKING WATER ACT (SDWA): Act of 1974 the Federal Government established, through the Environmental Protection Agency (EPA), national standards of safe drinking water.
SAFETY FACTOR: The ratio between an ultimate property (typically strength) and that required under design conditions.
SAFETY VALVE: A valve design to relieve overpressure. Mechanically the same as a relief valve, but the reasons for locating one versus the other are not always the same.
SCRAPER: (1) A device for insertion in pipelines that is pushed or hauled through by some method or device such as water pressure, rope, cable, to remove accumulated organic or mineral deposits. Scrapers are used principally in pipe too small for access by man and are of various designs and sizes. (2) A device used in the bottom of a sedimentation tank to move settled sludge to a discharge port. (3) A blade used to separate accumulated sediment from filter or screen surfaces. See also squeegee.
SCREW-FEED PUMP: A pump with either horizontal or vertical cylindrical casing, in which operates a runner with radial blades like those of a ship's propeller. See also horizontal screw pump, vertical screw pump.
SEAT: The fixed component, mounted in the valve body, that the closure element contacts in order to close off flow.
SECTIONALIZING VALVE: A large valve installed in a pipeline to shut off flow in a section for the purpose of inspection or repair. Such valves are usually installed in the main lines.
SEWAGE AIR VALVE: Air Valve used in sewage applications.
SHAFT: The valve component through which outside motion is applied to the closure member.
SHAFT-MOUNTED BALL VALVE: The configuration in which the body bearings support the shaft and ball as a complete assembly and the shaft sees both torsional operating loads and differential pressure loads.
SHUTOFF PRESSURE: The actual differential pressure against which the valve's closure member is closed.
SHUTOFF VALVE: A valve whose primary purpose is to act as a main block valve, usually as an emergency shutdown but not necessarily integrated into the control system as a true emergency shutdown valve would be.
SIPHON: A closed conduit a portion of which lies above the hydraulic grade line, resulting in a pressure less than atmospheric and requiring a vacuum within the conduit to start flow. A siphon utilizes atmospheric pressure to effect or increase the flow of water through the conduit.
SLOPE: A measure of pipe rise expressed as rise divided by run.
SLUDGE: (1) The accumulated solids separated from liquids, such as water or wastewater, during processing. (2) Organic deposits on bottoms of streams or other bodies of water. (3) The removed material resulting from chemical treatment, coagulation, flocculation, sedimentation, flotation, and/or biological oxidation of water or wastewater. (4) Any solid material containing large amounts of entrained water collected during water or wastewater treatment. See also activated sludge, settleable solids.
SLUICE GATE: A gate, used for sluicing, constructed to slide vertically and fastened into or against the masonry of dams, tanks, or other structures.

SLUICE: (1) A conduit for carrying water at high velocity. (2) An opening in a structure for passing debris. (3) To cause water to flow at high velocities for wastage, for purposes of excavation, ejecting debris, and other purposes.
SLURRY: A thin watery mud, or any substance resembling it, such as a lime slurry.
SOLENOID VALVE: A valve which is open or closed by the action of an electrically excited coil wire magnet upon a bar of steel attached to the valve disc (or seat).
SPLINE: A set of grooves somewhat similar to gear teeth, for the purpose of interlocking male and female members such as a shaft and an internal splined coupling.
SPUR GEAR: The simplest of gears - in a gear set, the pinion and ring gear are aligned on parallel shafts. Can be added to another gear operator to further increase the mechanical advantage afforded by the gear.
STANDARD PORT: Also known as regulator port valve or standard bore valve. Type of valve equipped with a reduced flow-passageway at the closure member for a given end connection size. In a ball valve, this valve is usually considered to be one pipe size smaller flow port than a full port opening. A standard port is characterized by a typical bore size (as opposed to full bore) and its flow coefficient. Also considered a reduced ported valve.
STANDPIPE: (1) A pipe or tank connected to a closed conduit and extending to or above the hydraulic grade line of the conduit. It is often installed to afford relief from surges of pressure in pipelines. (2) A tank resting on the ground having height greater than diameter and used for storage of water in distribution systems. (3) In a building or structure, a fixed vertical pipe equipped with valve hose outlets, usually at each floor, to provide water for hose lines for firefighting.
STATIC HEAD: (1) The total head without reduction for velocity head or losses; for example, the difference in elevation of headwater and tail water of a power plant. (2) The vertical distance between the free level of the source of supply and the point of free discharge or the level of the free surface.
STATIC SUCTION HEAD: The vertical distance from the source of supply when its level is above the pump to the center line of the pump.
STATIC SUCTION LIFT: The vertical distance between the center of the suction end of a pump and the free surface of the liquid being pumped. Static lift does not include friction losses in the suction pipes. Static suction head includes lift and friction losses.
STEM: See shaft.
STOP VALVE: A large valve installed in a pipeline to shut off flow in a section to permit inspection or repair. Such valves are usually installed in the main lines. Also called sectionalizing valve.
STORM SEWER: A sewer that carries storm water and surface water, street wash and other wash waters, or drainage, but excludes domestic wastewater and industrial wastes. Also called storm drain.
STORM WATER: Surface water from rain, snow, or ice melting and running *off* from the surface of a drainage area. It is normally collected in sewers separate from the sanitary sewers, and receives minimal, if any, treatment prior to discharge to a receiving water. When collected in a combined sewer system, the resulting mixture of sewage and stormwater is called combined wastewater.
STROKE: The distance the valve plug, valve stem, or cylinder piston moves to go from a fully closed to a fully open position or from fully open to fully closed. A stroke comprises one half of a cycle. Also called Travel.
STUFFING BOX: Also known as packing box, the volume surrounding a shaft at the area on the shaft where it emerges from a pressurized or isolatable space, used to contain the packing.
SUBMAIN SEWER: A sewer into which the wastewater from two or more lateral sewers is discharged and which subsequently discharges into a main, a trunk, or other collector.
SUCTION HEAD: The head at the inlet to a pump.
SUCTION LIFT: The vertical distance from the liquid surface in an open-top tank or reservoir to the centerline of a pump drawing from the tank or reservoir and set higher than the liquid surface.
SUCTION PUMP: A pump set above the surface of the body of water which supplies the pump, necessitating the *lifting* of the water from such surface to the pump cylinder or casing.
SURGE TANK: A tank or chamber located at or near a hydroelectric powerhouse or pump station, which absorbs water and cushions the increased pressure on the penstock which is caused by the rapid deceleration of the water flow.
SURGE: A sudden rise or drop in line pressure due to a change in fluid velocity.
SWING CHECK: A check valve in which the closure element is suspended from the top and swings out of the flow way.

T

TENSILE STRENGTH: The maximum stress a material subjected to a stretching load can withstand without fracturing.
TEST COCK: An appurtenance on an assembly or valve which is used when testing the assembly.
THREE WAY VALVE: Type of valve with three ports arranged to control the direction of flow through the valve.
THROTTLING DEVICE: A device mounted on the discharge of an Air/Vacuum Valve to control the rate of discharge of air upon system pressurization.
THROTTLING: The act of reducing the pressure or flow rate of a fluid passing through a partially closed valve.
THRUST BEARING: A flat, washer shaped device used to support axial loads on the valve shaft.
THRUST: A linear force applied to the shaft of a valve, usually expressed in units of pounds (kilograms).
TILTED DISC®CHECK VALVE: A check valve with an eccentrically mounted disc allowing flow above and below the disc. It can be supplied with top or bottom mounted dash pots to further reduce any slamming potential, especially in high head applications.
TORQUE: The rotational force imposed on or through a shaft.
TOTAL DYNAMIC HEAD: The difference between the elevation corresponding to the pressure at the discharge flange of a pump and the elevation corresponding to the vacuum or pressure at the suction flange of the pump, corrected to the same datum plane, plus the velocity head at the suction flange of the pump.
TRANSFER PUMP: A pump specifically designed to convey water, wastewater, or chemical solutions from one tank to another.
TRANSIENT: A pulse, damped oscillation, or other temporary phenomenon occurring in a system prior to reaching a steady-state condition. See surge.
TRANSIENT ANALYSIS: The study of transients in a pipeline.
TRUNK MAIN: A large pipe serving as a supply main or feeder main in a water distribution system.
TRUNK SEWER: A sewer that receives many tributary branches and serves a large territory.
TRUNNION: The part of a ball valve which holds the ball on a fixed vertical axis and about which the ball turns.
TRUNNION-MOUNTED BALL VALVE: The configuration in which the body bearings directly support the ball and differential pressure loads while the shaft supports torsional operating loads but not differential pressure loads.
TUBERCULATION: The formation of tubercules or mineral deposits in pipe, with an increase in frictional coefficient.
TURBIDITY: (1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light. (2) Any suspended solids imparting a visible haze or cloudiness to water which can be removed by filtration. (3) An analytical quantity usually reported in turbidity units determined by measurements of light scattering.
TURBINE PUMP: A centrifugal pump in which fixed guide vanes partially convert the velocity energy of the water into pressure head as the water leaves the impeller.
TURBULENCE: (1) The fluid property that is characterized by irregular variation in the speed and direction of movement of individual particles or elements of the flow. (2) A state of flow of water in which the water is agitated by cross currents and eddies, as opposed to laminar, streamline, or viscous flow. See also turbulent flow.
TURBULENT VELOCITY: The velocity of water flowing in a conduit above which the flow will always be turbulent, and below which the flow may be either turbulent or laminar, depending upon circumstances.

U

UL: Underwriters Laboratories-organization that test materials intended for use in fire and safety applications.

V

VACUUM BREAKER: A device for relieving a vacuum or partial vacuum formed in a pipeline, thereby preventing back siphonage.
VACUUM RELIEF VALVE: A valve which admits air to the system if and when the system is attempting to reduce its pressure to less than atmospheric.

VALVE BOX: A metallic or concrete box or vault set over a valve stem and rising to the ground surface, to allow access to the stem in opening and closing the valve. A cover is usually provided at the surface to keep out dirt and debris.
VALVE KEY: A metal wrench with a socket to fit a valve nut and with a long handle for operating a gate valve from a distance of several feet.
VALVE STEM: The rod by means of which a valve is opened or closed; the rod lifts and pushes down the gate.
VALVE: A device which isolates or controls fluid direction, or flow rate.
VELOCITY HEAD: The energy of a liquid as a result of its motion. It is the equivalent head in feet through which the water would fall to acquire the same velocity.
VELOCITY: The time rate of change of position of a body; it is a vector quantity having direction as well as magnitude. Also known as linear velocity.
VENT PIPE: A pipeline, usually vertical, to allow venting of air or other gases from another pipe or a chamber, or to prevent negative pressures due to siphoning of a pipeline.
VENTING CAPACITY: The maximum capacity an air valve can vent air. Usually stated in CFM.
VENTURI FLUME: An open flume with a contracted throat which causes a drop in the hydraulic grade line. It is used for measuring flow. See also Parshall flume.
VENTURI METER: A differential meter for measuring flow of water or other fluid through closed conduits or pipes, consisting of a Venturi tube and one of several proprietary forms of flow registering devices. The difference in velocity heads between the entrance and the contracted throat is an indication of the rate of flow. See also Venturi tube.
VENTURI TUBE: A closed conduit or pipe, used to measure the rate of flow of fluids, containing a gradual contraction to a throat, which causes a pressure head reduction by which the velocity may be determined. The contraction is usually, but not necessarily, followed by an enlargement to the original size.
VENTURI VALVE: A reduced bore valve. A valve having a bore smaller in diameter than the inlet or outlet. The flow through a venture valve will be reduced because of the smaller port.
VERTICAL PUMP: A centrifugal pump in which the pump shaft is in a vertical position.
VERTICAL SCREW PUMP: A pump, similar in shape, characteristics, and use to a horizontal screw pump, but which has the axis of its runner in a vertical position.
VISCOUS FLOW: A type of fluid flow in which there is a continuous steady motion of the particles, the motion at a fixed point always remaining constant. Also called a streamline flow. See also laminar flow.
VOLUTE PUMP: A centrifugal pump with a casing made in the form of a spiral or volute as an aid to the partial conversion of the velocity energy into pressure head as the water leaves the impellers.

W

WAFER: A flangeless valve designed for installation between mating pipe flanges.
WASTEWATER: The spent or used water of a community or industry which contains dissolved and suspended matter.
WASTEWATER COLLECTION SYSTEM: The sewer and pumping system used for the collection and conveyance of domestic, commercial, and industrial wastewater.
WATER: A transparent, odorless, tasteless liquid, a compound of hydrogen and oxygen, H_2O, freezing at 32°F or 0°C and boiling at 212°F or l 00°C which, in more or less impure state, constitutes rain, oceans, lakes, rivers, and other such bodies.
WATER COLUMN: (1) The water above the valve in a set of pumps. (2) A measure of head or pressure in a closed pipe or conduit.
WATER HAMMER: The phenomenon of oscillations in the pressure of water about its normal pressure in a closed conduit, flowing full, which results from a too-rapid acceleration or retardation of flow. Momentary pressures greatly in excess of the normal static pressure may be produced in a closed conduit by this phenomenon.
WATER MAIN: The water pipe, located beneath a street, from which domestic water supply is delivered to the service pipe leading to specific premises.
WATER TOWER: A tower containing a tank in which water is stored, normally for providing local storage in a distribution system where ground-level storage would provide inadequate pressure. Also see standpipe.
WEDGE GATE: A type of gate valve in which the gate or disc is wedge shaped, thinner at the bottom, to wedge itself tightly between the two seats when closed.

WELL SERVICE AIR VALVE: A modified Air/Vacuum Valve designed to withstand the critical pressure thrust during pump startup.
WET WELL: A compartment in which a liquid is collected, and to which the suction pipe of a pump is connected.
WOG: Water-oil-gas---one of the early rating designations, still in use today for small valves, chiefly in low ratings. Also called nonshock rating. Normally this rating is meant to be the maximum working pressure at ambient temperature (32 to 100°F).
WP: Working pressure-synonym for operating pressure.
WORKING PRESSURE HEAD: The actual head of water flowing at any point in a conduit; the vertical height from the center line of a conduit to the hydraulic grade line.
WORM GEARS: A gear set in which the input shaft is offset from and perpendicular to the output shaft, and driving gear is very small and perpendicular to the driven gear. Worm gear operators are used on ball valves.

Y

YOKE: That part of a valve assembly used to position the Stem Nut or to mount the valve actuator.

ACRONYMS

A-C: Asbestos-Cement
ANSI: American National Standards Institute
API: American Petroleum Institute
ARV: Air Release Valve
ASME: American Society of Mechanical Engineers
ASTM: American Society for Testing and Materials
AV: Air Valve
AVV: Air/Vacuum Valve
AWWA: American Water Works Association
AWWARF: American Water Works Association Research Foundation
BAT: Best Available Technology
BFA: Back Flow Actuator
BHN: Brinell Hardness Number
BSI: British Standards Institution
CAV: Combination Air Valve
CCW: Counterclockwise
CFM: Cubic Feet per Minute
CFS: Cubic Feet per Second
CI: Cast Iron
CS: Carbon Steel or Cast Steel
CSA: Canadian Standards Association
CSO: Combined Sewer Overflow
CW: Clockwise
CWA: Clean Water Act
CWP: Cold Working Pressure
DI: Ductile Iron
DIN: Deutsche Industrie Norme
DN: Nominal Diameter
FBE: Fusion Bonded Epoxy
FF: Flat Face
FLG: Flange
FM: Factory Mutual Association
FPS: Feet Per Second
GPM: Gallons Per Minute
HRB: Rockwell B Hardness
HRC: Rockwell C Hardness
HW: Handwheel
IBBM: Iron Body, Bronze Mounted
ID: Inside Diameter

IPS: Iron Pipe Size
ISO: International Standards Organization
JIS: Japan Industrial Standard
MCL: Maximum Contaminant Levels
MFD: Mechanical Flow Diagram
MGD: Million Gallons per Day
MIL: Designation for United States Military Standards
MIL: 1/1000th of an inch
MJ: Mechanical Joint
MOV: Motor Operated Valve
MRO: Maintenance and Repair Order
MSS: Manufacturers Standardization Society
NACE: National Association of Corrosion Engineers
NDE: Non-Destructive Examination
NEMA: National Electrical Manufacturers Association
NFPA: National Fire Prevention Association
NPDES: National Pollutant Discharge Elimination System
NPS: Nominal Pipe Size
NPT: National Pipe Thread Taper
NST: National Straight Thread
OD: Outside Diameter
OS&Y: Outside Screw and Yoke
PN: Nominal Pressure
POT: Point of Treatment
PSI: Pounds per Square Inch
PSIA: Pounds per Square Inch, Absolute
PSIG: Pounds per Square Inch, Gage
PVC: Polyvinyl Chloride
RF: Raised Face
RJ or RTJ: Ring Joint or Ring-Type Joint
RMS: Root Mean Square Roughness Height
RPM: Revolutions Per Minute
SCADA: Supervisory Control and Data Acquisition
SCV: Silent Check Valve
SCFM: Standard Cubic Feet per Minute
SDO: Standard Development Organization
SDWA: Safe Drinking Water
SPDT: Single Pole Double Throw
SS: Stainless Steel
SSPC: Steel Structures Painting Council
SSU: Seconds Saybolt Universal
STP: Sewage Treatment Plant
SWP: Steam Working Pressure
TDCV: Tilted Disc® Check Valve
TIR: Total Indicator Reading
UL: Underwriters Laboratories
UV: Ultraviolet
WEF: Water Environment Federation (formerly WPCF)
WOG: Water-Oil-Gas
WP: Working Pressure - Synonym for operating pressure
WPCF: Water Pollution Control Federation (named changed to WEF)
WTP: Water Treatment Plant
WWTP: Wastewater Treatment Plant

White Paper

Flow and Conversion Formulas

Table of Contents

VAL-MATIC COMMON FORMULAS

Darcy-Weisbach Formula for headloss in a pipe:

$\Delta H = f (L / D) \times (v^2 / 2g)$ $\Delta H = K (v^2 / 2g)$

Flow equation using Cv Flow Coefficient:

$Q = Cv (\Delta P / S_g)^{1/2}$ $\Delta P = (Q / Cv)^2 S_g$

Collapse pressure of thin walled steel pipe for Air/Vacuum valve sizing:

$P= 16{,}250{,}000 (T/d)^3$

Annual pumping costs for a given headloss and flow rate:

$A = (1.65 Q \Delta H S_g C U) / E$

Where:

A = annual energy cost, $
C = cost of electricity, $/kW-hr
CFS = flow rate, cu-ft/sec
Cv = flow coefficient defined as gpm of 60F water with 1 psi pressure drop
d = diameter of pipe or valve, in
D = diameter of pipe or valve, ft
E = efficiency of pump and motor set, percent /100 (0.80 typical)
f = pipe friction factor (.019 for 12 in iron)
g = acceleration due to gravity, 32.2 ft/sec2
ΔH = head loss, ft of water
K = resistance coefficient, dimensionless
L = length of pipe, ft
P = collapse pressure, psi
ΔP = pressure drop, psi
Q = flow rate, gpm
S_g = specific gravity, dimensionless (water = 1.0)
T = wall thickness, in
U = usage, percent / 100 (1.0 equals 24 hrs per day)
v = flow velocity, ft/sec

VAL-MATIC CONVERSION FORMULAS

LIQUID FLOW:

GPM = FPS x 2.448 x d^2
GPM = CFS x 448.83
GPM = MGD x 694.4
GPM = Bbl/day x .02917
GPM = L/SEC x 15.853
FPS = GPM x .4085 ÷ d^2
FPS = M/SEC x 3.2808
FPS = CFS x 183.35 ÷ d^2
LPS = CFM x .4719
CFS = CMS x 35.315
CFS = L/MIN ÷ 1699.3
CFS = GPM x .002228
CFS = MGD x 1.5472
C_v = 29.82 x d^2 ÷ $\sqrt{K}$
K = 889.2 x d^4 ÷ $(C_v)^2$
K_v = C_v x .865

PRESSURE:

FT(W) = PSI x 2.3106
PSI = FT(W) x .43278
PSI = IN(Hg) x .49115
PSI = KPa x .14504
PSI = MPa x 145.04
PSI = BAR x 14.504
PSI = Kg/cm^2 x 14.223
BAR = MPa x 10

TEMPERATURE:

°F = 9/5 x °C +32
°F = °R - 459.69
°C = 5/9 x (°F - 32)
°C = °K - 273.16

LENGTH:

IN = M x 39.37
IN = CM ÷2.54
IN = MM÷25.4
IN = MICRON ÷ 25400
MIL = IN x 1000
MIL = MICRON ÷ 25.4
FT = CM x .03281
FT = M x 3.281
FT = KM x 3281

VOLUME:

FL OZ = ML x 0.0338
FL OZ = GAL x 128
FL OZ = 100 DROPS
CU IN = GAL x 231
CU IN = L x 61.025
CU FT = GAL x .13368
CU FT = CU M x 35.315
CU FT = L x .035315
GAL = L x .2642
ML = CC

WEIGHT:

LB = KG x 2.2046
LB = GRAMS ÷ 453.59
LB = TON x 2000
LB = METRIC TON x 2205
LB = N x 0.2248
LB(W) = GAL x 8.3453
LB(W) = CU FT x 62.425
LB(W) = CU IN x .0361
MG/L = PPM
OZ = LB x 16

4K

TORQUE:

FT-LB = N-M x 0.7376

WHERE:

Bbl = Barrels

CFM = Cubic feet per minute

CFS = Cubic feet per second

°C = Degrees Celsius

CC = Cubic centimeter

CM = Centimeter

CMS = Cubic meter per second

C_v = Flow coefficient, GPM @ 1 Psi

d = diameter of pipe or valve, in

°F = Degrees Fahrenheit

FL OZ = Fluid ounce

FPS = Feet per second

FT = Feet

FT(W) = Feet of Water

GAL = Gallon

GPM = Gallons per minute

IN = Inch

IN(Hg) = Inches of Mercury

K = Flow coefficient dimensionless

K_v = Flow coefficient, M^3/hr @ I Bar

KG = Kilogram

KM = Kilometer

KPA = Kilopascal

°K = Degrees Kelvin

L = Liter

LB = Pound

LB(W) = Pounds of Water at 60F

LPS = Liters per second

M = Meter

MG = Milligram

MGD = Million gallons per day

MIL = mil (1000th of an inch)

ML = Milliliter

MM = Millimeter

MPA = Megapascal

N = Newton

PPM = Parts per million

°R = Degrees Rankin

OZ = Ounce, weight

PSI = Pounds per square inch

SEC = Seconds

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