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Diaphragm or Piston Flushometers? It Depends…

An ongoing debate within the plumbing industry on flushing technologies has had resurgence recently with comparisons of piston valve technology to diaphragm valve technology. Although both have been around for decades, the debate heightens when trying to determine which is "better." In actuality, one technology is not inherently "better" than the other, but instead the best choice depends on the specific application.

Picking the correct flushometer technology for an installation calls for good, current information about how and where the valve will be used. The more information that can be collected ultimately ensures successful valve operation.

For a better understanding on how to select the right type of flushometer technology, this paper will investigate the factors that help determine which valve is a better choice depending on the operating conditions. Note that manual or electronic activation has no bearing on a technology's suitability.

Technology Overview

In a flushometer installation, water flows under pressure from the supply piping directly to the fixture. The vitreous china fixtures with which flushometers are most commonly associated are the water closet, urinal or service sink. The required flow rate, measured in gallons per minute (gpm), is established by the hydraulics of the fixture, not the valve. If the supply pipes are properly sized, an adequate volume of water will pass through the flushometer and permit the fixture to operate efficiently.

Diaphragm

It is the use of the pressurized water supply that gives a flushometer a performance advantage over a tank toilet in commercial applications. In a tank toilet, the water used for the flush is first accumulated in the tank. The water flows by gravity into the fixture when the tank toilet is flushed. The energy behind the flush is created by the weight of the water in the tank. Because flushometers rely on the pressure and flow from the supply piping, there is more energy behind the flush, which is important in a commercial application. Flushometers also reset faster than gravity toilets (there is no refill time), another important requirement in a commercial installation. Gravity tanks will not be the subject of this white paper.

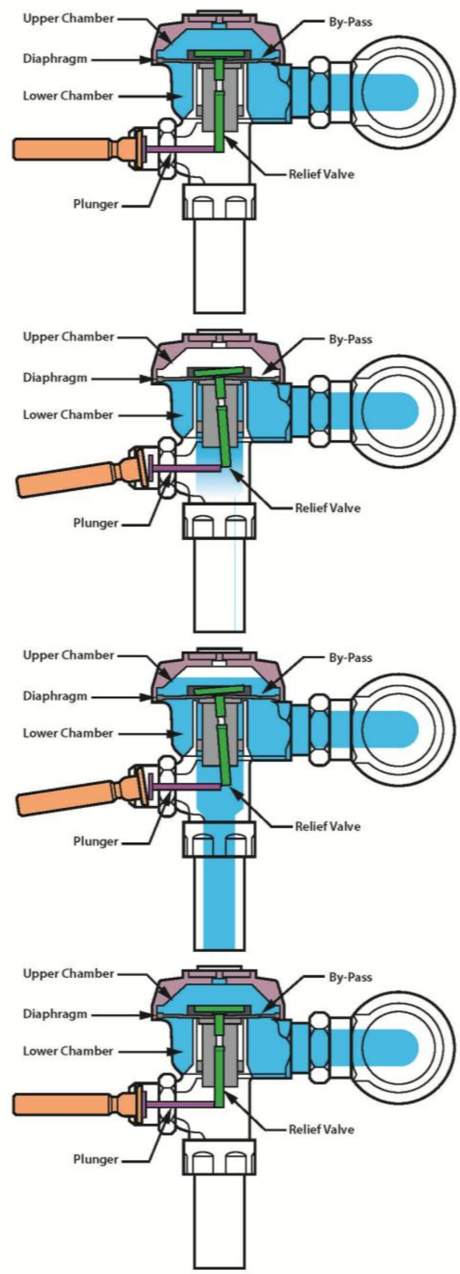
Piston

Flushometers are manufactured in two different technologies -- diaphragm and piston. The theory of operation in each is fundamentally the same. Each has an upper control chamber and a lower chamber connected by a bypass. The bypass connecting the upper control and lower supply chambers in both the diaphragm and piston valves is a small hole or orifice that is no larger than a pin hole, typically measuring between 0.020 inches and 0.030 inches in diameter. A flexible rubber disk separates the upper from the lower chambers in a *diaphragm* flushometer; a molded cup separates the upper from the lower chambers in the *piston* flushometer.

Note: Slow-closing flush valves, often used in saltwater and ship board applications, do not self-compensate for changes in water pressure or flow rate and do not hold flush delivery constant. As such these valves are not considered true flushometers and are not included in the scope of this white paper.

Diaphragm

Diaphragm Operation



In the diaphragm flushometer, a flexible rubber diaphragm sits between the chambers. A small amount of the supply water makes its way to the upper control chamber through a bypass hole in the diaphragm. The pressure of the water above the diaphragm creates force and compresses the diaphragm and the relief valve over the valve barrel's opening.

When flushed, the handle plunger shifts the stem of the relief valve, which causes it to tilt. This tilting allows a small amount of water to exit the upper control chamber through the valve barrel.

When the relief valve is tilted, a pressure imbalance is created between the upper and lower chambers of the valve. The pressure in the upper chamber becomes less than the pressure in the lower chamber. This lower chamber pressure forces the diaphragm and the relief valve to rise up from the barrel opening, thereby allowing high velocity water to flow directly from the water supply into the toilet bowl. At the same time, the relief valve re-seats and a small amount of water begins to refill the upper chamber via the bypass hole. Pressure builds up, creating force, depressing the diaphragm and closing the opening of the barrel.

As the pressures in the upper control and lower supply chambers equalize, the upper control chamber side of the diaphragm, which has more area than the lower side, compresses against the barrel opening and shuts off the water flow.

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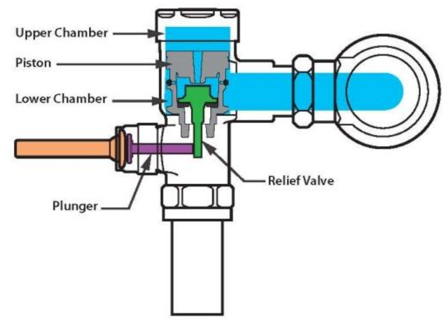
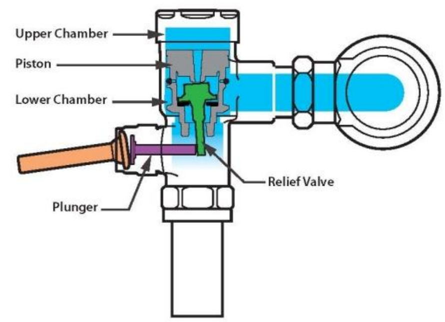
Piston

Piston Operation

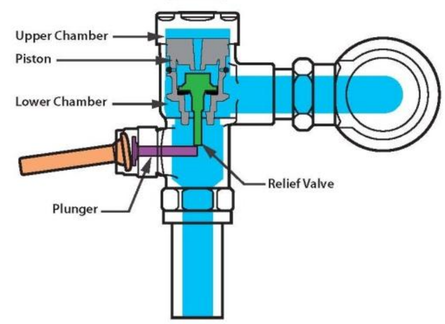
A piston flushometer features a molded cup with the upper and lower chambers separated by a rubber lip seal. This seal is extended inside a hollow piston, and the bypass hole can be found on the piston side wall. The relief valve seals the upper chamber from the lower chamber.



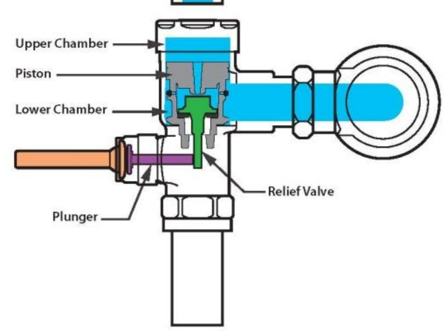
Pressing the handle causes the plunger to push against the relief valve, making it tilt and release water from the upper chamber. This causes a reduction in the water pressure above the relief valve.



When the pressure above the relief valve is reduced, the high pressure under the molded cup lifts the piston, allowing the piston to rise up from the main seat. Water continues to flow from the inlet pipe, under the piston, to the fixture. Once the piston lifts, the relief valve re-seats and a smaller stream of water flows through the bypass hole, restoring the pressure within the piston, above the relief valve.



This creates enough force to push the piston assembly back down, and shut off the water supply.



It should be noted that both the diaphragm and piston include a number of components and design characteristics which control the rate at which the valve opens and shuts as well as the amount of water that flows to the fixture during this operation. This allows both valve technologies to accurately deliver a controlled amount of water to the fixture under a variable range of water pressures and flow rates.

Choosing the Right Technology

When selecting and installing any flushometer, it is important that the valve model matches the pressure and water volume requirements of the plumbing fixture. The key to successful valve operation is to understand the type of installation and its environment, and then match the correct flushometer to the installation requirements.

Let's look at types of installations and which flushometer is best based on the environment. There are three main factors to consider: restroom traffic, water quality and operating conditions.

Restroom Traffic

The deciding factor is performance, and identifying restroom traffic is the first step in determining which flushometer will best deliver for an application. Restroom usage can be classified under two basic traffic patterns: high traffic and low traffic.

In high traffic situations (such as airports and sports stadiums), the diaphragm technology can accommodate the quick recovery needed to immediately flush again, whereas low traffic situations can benefit from either diaphragm or piston technologies. More information is needed to influence the optimal choice.

Water Quality

Another important consideration is water condition, because poor water quality often compromises performance and reliability. Dirty water, corrosive (salt) water, aggressive water, severe water conditions, treated water, and low water pressure are all factors.

Some of the characteristics of the water supply that affect long-term flushometer operation are the following:

- **pH of water**: Whether or not water is acidic or basic can affect how long the rubber material remains compliant.
- **Solid particulate in water**: Size and solubility of the particles in the water can affect the wear of the sealing surfaces and their ability to form a seal.
- **Chlorine concentration in the water**: Chlorine in high concentrations can deteriorate some elastomer compounds, requiring service earlier than expected.
- **High levels of conductivity** can cause metal sealing surfaces that elastomers seal against to deteriorate (dezincification). Over time, this results in a poor seal for the elastomer on the flush valve body.
- **Soluble "biomass"** in water can clog small orifices by slowly building up in high flow channels.

In this case, the wear and tear is to the physical material of the flushometer. Both will deteriorate over time. Piston deterioration is influenced by the sealing material composition and the operating water supply conditions. As the main piston lip seal deteriorates from constant abrasion, bowl flushing performance slowly decreases as the main high pressure seal becomes compromised and develops small leaks.

Diaphragm valves can also deteriorate over time as the constant flexing rubber material breaks down. As diaphragms age they may become more flexible, causing more water to be delivered as the elastomer continues to yield with wear. The main surface area or seat over time may begin to weaken, adding very small distances to the relief valve travel and more water to each flush.

Operating Conditions

Harsh operating environments can cause a flushometer that is not engineered to perform under these conditions, to malfunction or operate at low efficiency, which wastes water. Operating conditions, such as the following, can impact choosing one flushometer type over the other:

- System could have a very high static pressure condition, but not recover quickly after a flushometer initiates a cycle, and the system struggles to recover to the high initial pressure.
- Fixture downstream of the flushometer may have very extreme back pressure coming back up the vacuum breaker tube, affecting the metering device.

Similar to water quality factors, operating conditions play a significant role in choosing the best flushing technology. The piston technology has stronger capabilities in low pressure and weak system situations. Yet, if it is a high pressure system, the diaphragm may be a better choice.

Evaluating Conditions

Any combination of influencing elements, such as restroom traffic, water quality and operating system, may tip the scale in favor of one flushometer type over another. Because varying influences affect whether a diaphragm or piston valve is the better fit, the only real way of selecting the optimum technology is to go through a checklist of operational conditions outlined in the chart below.

As a job site is detailed with information on the water and system, conditions can be highlighted, and the appropriate technology can be selected. All factors involved collectively will point to the technology better suited for that job site installation.

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PISTON VS. DIAPHRAGM

BASIC DESIGN	PISTON	DIAPHRAGM	ADVANTAGE	COMMENTS
Sealing Mechanism	Dynamic	Static	√ Diaphragm	Reciprocating cup seal wears more rapidly
Stroke Length	Long	Short	√ Piston	Longer stroke can have more forgiveness to system abnormalities
Wear Surface	One	N/A	√ Diaphragm	Diaphragm alternates between compression and tension modes with no rubbing (no real wearing surface)

OPERATING CONDITIONS				
Low Pressure	BETTER	GOOD	√ Piston	Pressures that "sag" around 20 psi and below
"Weak" System	BETTER	GOOD	√ Piston	Piston has slightly better performance (dynamic pressure) GPM
Fixture Back Pressure	GOOD	BETTER	√ Diaphragm	Piston technology susceptible to fluctuations
High Chloramine Water	GOOD	BETTER	√ Diaphragm	Thicker diaphragm sections hold up longer
Flexibility Options to Auto Retro	POOR	BETTER	√ Diaphragm	More after purchase change options
Solids/Grit/Abrasive Water	POOR	BETTER	√ Diaphragm	Sliding dynamic seal can deteriorate
High Flow	GOOD	BETTER	√ Diaphragm	Larger main bore in valve body
HET Fixture Performance	GOOD	BETTER	√ Diaphragm	Better against fixture back pressure

Operating Condition Definitions

- **Low pressure** is an operating system within the 20 to 30 psi range and no higher.
- **Weak system gpm** is the operating system usually in low pressure areas, where the flow tends to be at a fixture required minimum or periodically below the minimum fixture requirements.
- **Fixture back pressure** is the force exerted back up the column of water in the vacuum breaker caused by some low-consumption fixtures.
- **High chloramine water** is operating conditions that have elevated chemical concentrations to treat the water, chlorine and ammonia NH2CL.
- **Flexibility** is those options available to an end user to convert the manual flushometer product to automatic operation.
- **Solids/grit/abrasive water** is operating conditions that have sand, calcium deposits or small particles of rock.
- **High flow** means those conditions that require large amounts of water quickly and may be associated with High Efficiency Toilets (HET). Diameter flow area of main valve seat on diaphragm flushometer is larger.
- **HET fixture performance** is based on a fixture with an average flush volume of 1.28 gpf or less, and must meet the performance requirements of ASME 19.2/CSA B45.1 and pass the 350 grams MaP. Dual-flush devices (1.6/1.1 gpf) are considered HET.

HET fixture performance is another variable that narrows the flushing technology choices. Although both diaphragm and piston technologies have HET options, there are more choices available in the diaphragm technology.

In the best case scenario all the relevant information can be collected from a building site in order to make a good decision. The key differences to remember are: diaphragm technology is better in high traffic, poor water conditions, high back pressure and has a greater variety of flushometer options. Piston technology is better in low and weak pressure systems with cleaner water conditions.

Conclusion

The key to making the best choice between diaphragm and piston technology is understanding the application environment and knowing each technology's strengths. Both technologies are excellent when used in the right situation. It is not a one-size-fits-all type of solution or a matter of one flushing mechanism being better than the other. Instead, the best decision depends on the application and environment. Restroom traffic, water quality and operating conditions are all determining factors that assist in selecting the proper valve to ensure successful flushometer operation.

About Sloan

Sloan Valve Company founder William E. Sloan invented the flushometer over 100 years ago and patented diaphragm and piston flushometer technology in 1929/1930. More recently, Sloan pioneered the introduction of hands-free electronic flushometers and has led the drive towards improved water efficiency and overall environmental sustainability. Today Sloan continues its innovation and industry leadership, manufacturing and servicing over 1500 different diaphragm and piston flushometer variations to meet the evolving needs of its customers. For more information, please visit www.sloanvalve.com or call 1-800-9-VALVE-9.