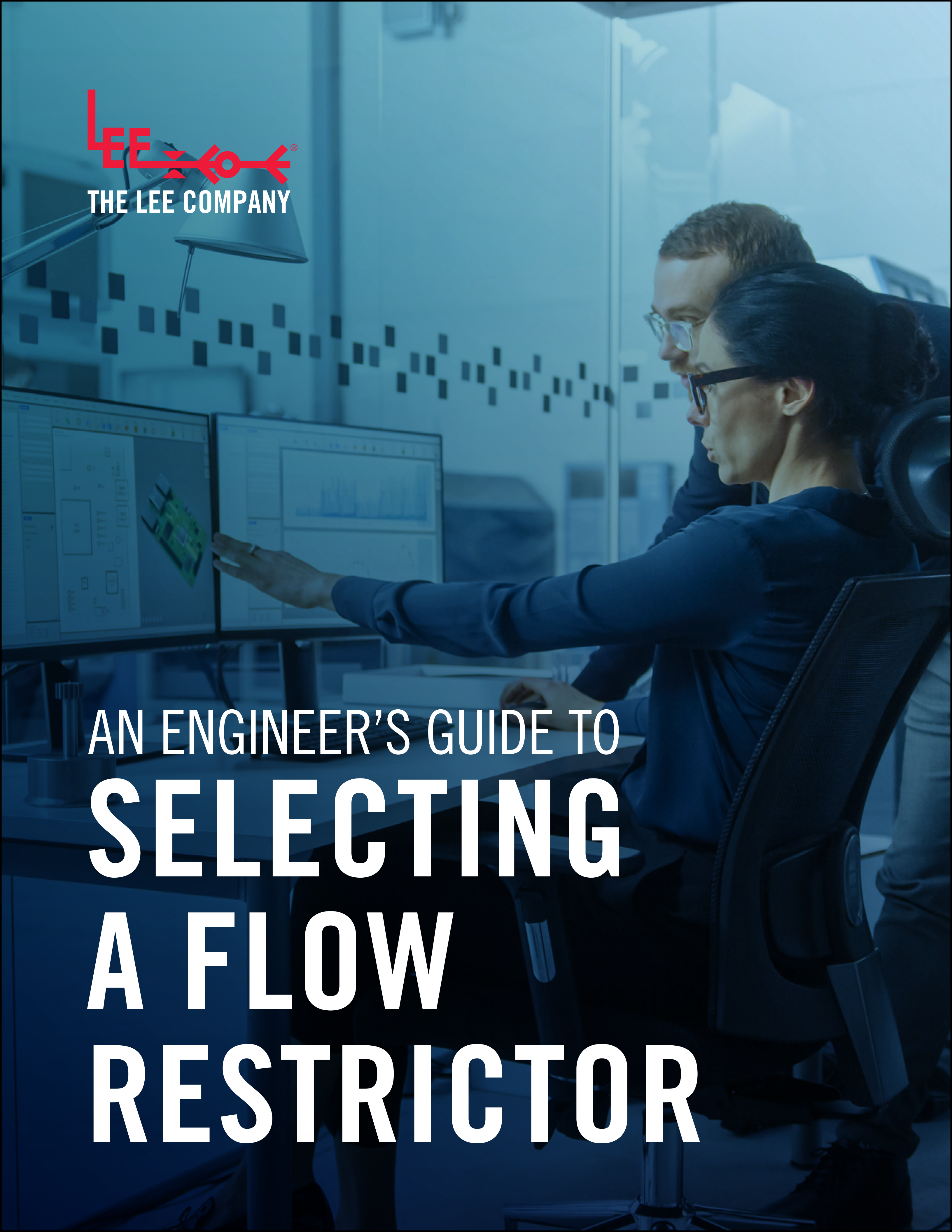

THE LEE COMPANY

AN ENGINEER'S GUIDE TO SELECTING A FLOW RESTRICTOR

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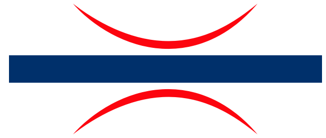
WHAT IS A FLOW RESTRICTOR?

A flow restrictor is any device that restricts or limits the flow of a fluid—generally a liquid or a gas. Such devices may also be referred to as flow limiters. Calibrated orifices are one example of flow restrictors. They are used in systems we encounter daily. For example, they control how fast water flows from a faucet, how quickly foam sprays from a bottle of carpet cleaner, and how much fuel is flowing into the engine of a car.

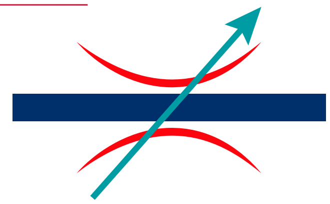
Engineers tasked with managing fluid flow may refer to holes and to calibrated orifices, two very distinct entities. A hole can be any opening; a calibrated orifice is specially designed to precisely control fluid flow, and its diameter, length, and geometry are critical to its intended operation. With the proper design, an orifice can provide the desired control of fluid flow rates and pressure spikes.

COMMONLY USED GRAPHIC SYMBOLS REPRESENTING FLOW RESTRICTORS IN HYDRAULIC AND PNEUMATIC SYSTEMS

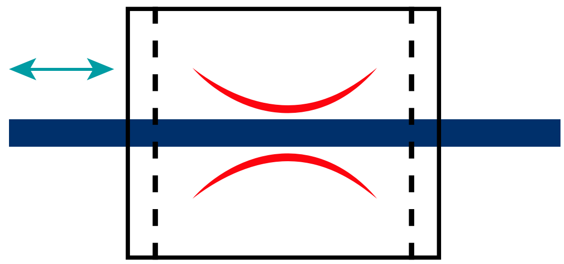
RESTRICTION



ADJUSTABLE RESTRICTOR



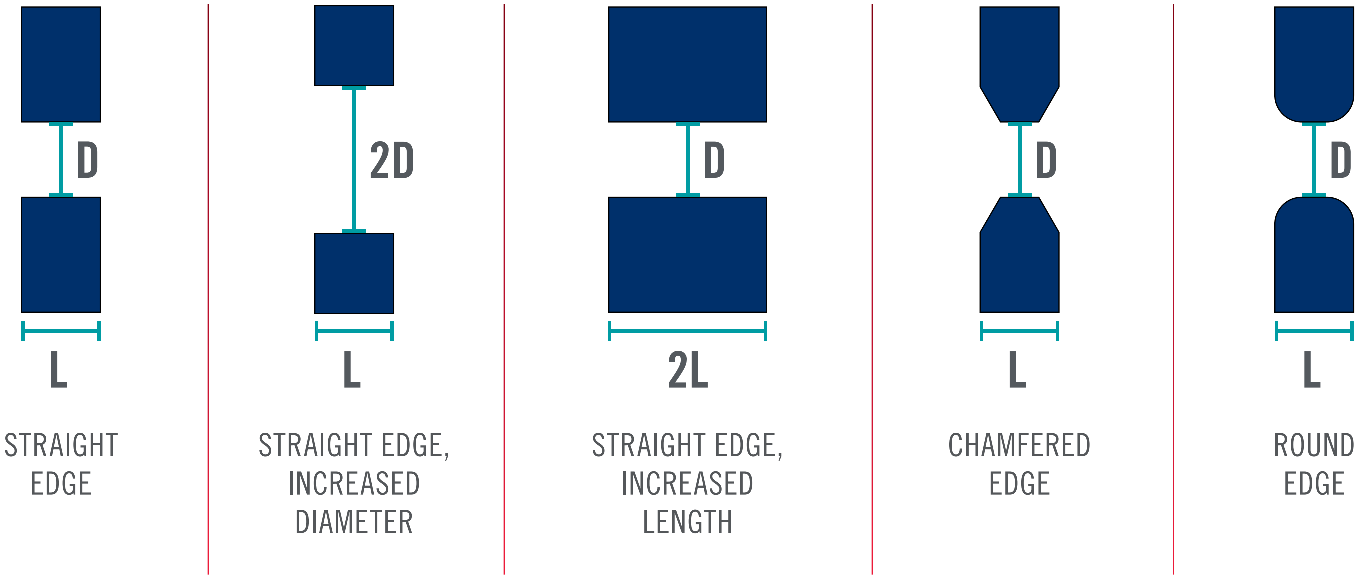
SCREENED 2-WAY RESTRICTOR



HOW DOES A FLOW RESTRICTOR WORK?

When a fluid, either liquid or gaseous, passes through an orifice, its pressure increases upstream of the orifice. As the fluid is forced to converge and pass through the orifice, the velocity increases, and the fluid pressure decreases. This occurrence is based on the principle of conservation of energy and is used to derive Bernoulli's equation, which is discussed in greater detail in the Flow Equations portion of this eBook.

A calibrated orifice is the most basic flow restrictor. Orifice diameter, length, and geometry all impact the restriction of the orifice. As the diameter is increased, the amount of restriction decreases. As the length of an orifice increases, the amount of restriction increases. Two orifices with identical lengths and diameters may have a wide variation in flow based on the geometry of an orifice. For instance, an orifice with a sharp-edged entrance results in a lower flow rate than one with a chamfered edge or a radiused edge. In addition to flow rate, the geometry of an orifice can be used to create specific fluid behavior: for example, spin the fluid to help generate an atomized, conical spray pattern or focus the fluid to hit a specific target point.



TYPES OF FLOW RESTRICTOR CONFIGURATIONS

There are several restrictor configurations applied in industry today. The selected configurations are determined by the performance characteristics required of the system, ranging from simple to complex. A simple configuration may be a single orifice restrictor used in a system to reduce the acceleration of a cylinder. A more complicated configuration may be a multi-orifice design used to help reduce cavitation in a pump or to protect sensitive components from system pressure spikes. Each configuration has some limitations that restrict or preclude its use in a particular system.

CALIBRATED ORIFICE

The most basic flow restrictor is a single orifice plate; it is highly adaptable, low cost, and widely used in controlling liquid and gas flow rates. The orifice plate can be attached to a housing in a variety of ways for retention. The orifice designer varies the diameter, length, and geometry of the orifice to create the desired restriction.

CAPILLARY TUBE

A single orifice may have to be very small to achieve extremely high levels of restriction. Such small orifices are susceptible to clogging from contamination or debris. Engineers have created capillary tubes to increase the size of the minimum passage. Friction caused by fluid viscosity creates a pressure drop as the fluid passes through the capillary tube. Capillary tubes are, therefore, unique as compared to a single orifice restrictor; they will not behave the same in a dynamic system or when fluid properties change. By varying the length of the tube, the restriction can be either increased or decreased. Glass capillary tubes are commonly used in medical devices, and copper capillary tubes are typically used in refrigerators and air conditioners. The disadvantage of using a capillary tube is that it must be much larger than a single orifice plate to create the same restriction.

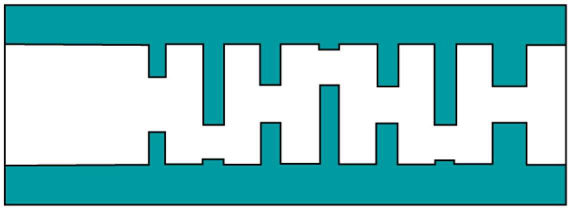
DIFFERENT CAPILLARY TUBES

TYPES OF FLOW RESTRICTOR CONFIGURATIONS (CONT.)

MULTI-ORIFICE RESTRICTOR

A flow restrictor may employ multiple orifices in series to increase the total combined restriction. Similar to the use of a capillary tube, a device may have a larger minimum passage size for an equivalent restriction as compared to a single orifice device. A multi-orifice device may use orifices offset from one another to create a more rigorous flow path and further increase the restriction.

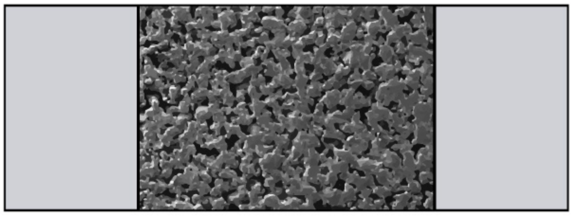
MULTI-ORIFICE RESTRICTOR



POROUS RESTRICTOR

Some flow restrictors use a porous element rather than an orifice plate. The porous elements are often manufactured through a sintering process. As with a multi-orifice restrictor, the sintering process enables the device to provide a higher level of restriction in a relatively small package. The fluid can travel through multiple paths in series and parallel, and the device becomes less likely to clog from a single piece of rogue contamination. However, due to the number of flow pathways, minimum passage size through individual orifices may be smaller than that of a comparable single orifice flow restrictor. In most cases, a porous restrictor element is also less economical to manufacture than a single orifice plate that would create the same level of restriction.

POROUS RESTRICTOR



TYPES OF FLOW RESTRICTOR CONFIGURATIONS (CONT.)

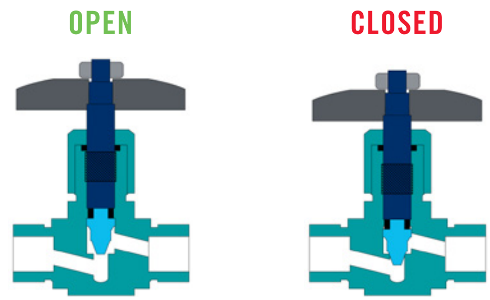
ADJUSTABLE RESTRICTOR

Flow restrictors may include a moving component that can be manually or electrically adjusted to change the flow restriction; the user can tune the flow restrictor to the optimal level as needed. There are flow restrictors intended to have the flow adjusted regularly; others may be tuned to a certain flow rate and then set permanently.

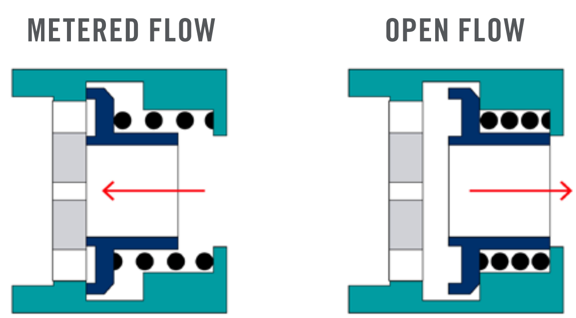
FLOW METERING VALVES

Flow metering valves are devices that perform a function similar to that of a flow restrictor. However, they provide additional functions and are, therefore, more complex. One-way restrictors, or restrictor checks, perform the function of a flow restrictor in one direction and a check valve in the opposite direction. Other valves have mechanically variable restrictions to mitigate factors such as viscosity, temperature, or pressure conditions. These valves merit a separate explanation that is not included within this document.

ADJUSTABLE RESTRICTOR



BIDIRECTIONAL FLOW METERING VALVE



Provides the flow equivalent of a check valve and a flow restrictor in parallel

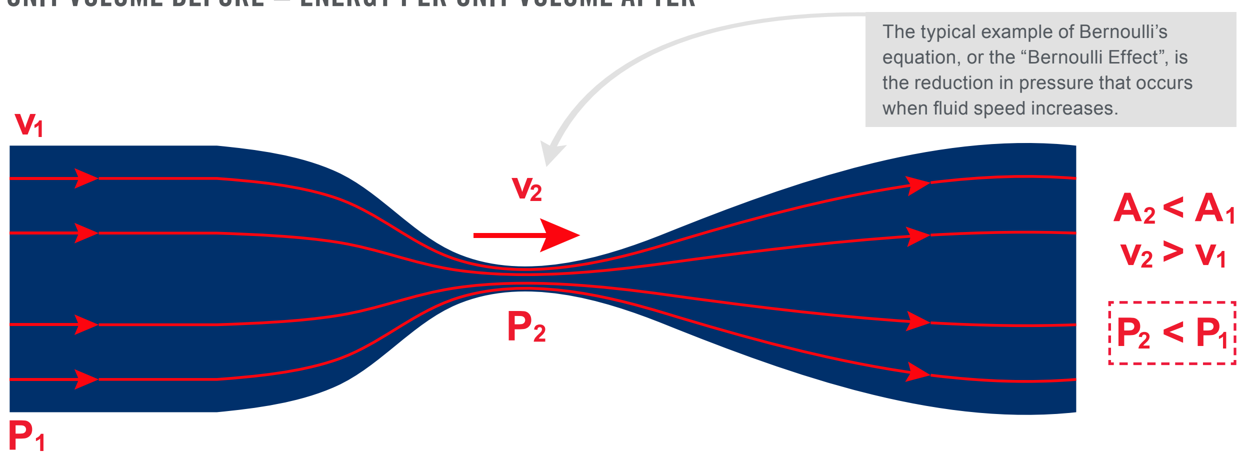
FLOW EQUATIONS

CALCULATING FLOW THROUGH AN ORIFICE

Bernoulli's equation relates the flow rate and pressure conditions of a fluid stream. Bernoulli's principle states that at points along a horizontal flow of fluid, points of higher fluid speed will have less pressure than points of lower fluid speed. The simplified form of Bernoulli's equation can be summarized in the following word equation: static pressure + dynamic pressure = total pressure. The equation and its graphic representation are highlighted below.

BERNOULLI'S EQUATION

ENERGY PER UNIT VOLUME BEFORE = ENERGY PER UNIT VOLUME AFTER



$$P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g h_2$$

WHERE:

P	ρ	v	g	h	A	1/2pv12	Pgh1
= Pressure at a Chosen Point	= Fluid Density at All Points	= Flow Velocity at a Chosen Point	= Acceleration Due to Gravity	= Hydraulic Head	= Area	= Kinetic Energy per Unit Volume	= Potential Energy per Unit Volume

Flow rate through the orifice is derived from Bernoulli's equation and can be calculated by the equation:

$$Q = CA\sqrt{(2\Delta P/\rho)}$$

WHERE:

Q	C	A	ΔP	ρ
= Flow Rate	= Discharge Coefficient	= Orifice Area	= Pressure Differential	= Fluid Density

The discharge coefficient (C) is a dimensionless number used to characterize the flow and pressure loss behavior of orifices in fluid systems. It accounts for variations in fluid flow that occur as flow is constricted through the orifice—including a reduction in discharge area (D vs. d) and fluid friction as the flow converges and diverges. Ultimately, C is a function of the ratio D/d and the upstream Reynolds number. The Reynolds number, in turn, depends on the state of the fluid (liquid or gas), temperature, pressure, and viscosity.

FLOW EQUATIONS (CONT.)

CALCULATING FLOW THROUGH A FLOW RESTRICTOR

The equation for calculating flow through an orifice may appear to an engineer to be relatively simple. However, discharge coefficients were determined through extensive research and do not remain constant or perfectly predictable in actual application. This uncertainty is due to variations that occur during the manufacturing process of an orifice, impacting its dimensions and geometry. It is also due to changing temperature and pressure conditions throughout the operating life of a system. With the changes in temperature and pressure, changes occur in the viscosity and specific gravity of a fluid.

A liquid and a gas do not behave in the same manner when they travel through orifices; this is so because gas is compressible. As a result, it may be very difficult to calculate the amount of restriction created by a flow restrictor. To simplify the process and to aid system designers, flow restrictor manufacturers provide one of multiple reference values. Widely applied conventions include using the equivalent orifice diameter or a flow coefficient (C_V).

The Lee Company developed a simple system of defining the fluid resistance of Lee hydraulic components. Just as the Ohm is used to express resistance in electrical engineeing, the liquid Ohm or “Lohm” aids with hydraulic and pneumatic computations. When they use the Lohm system, designers need not worry about coefficients of discharge and dimensional tolerances of drilled holes. These factors are automatically compensated for in the Lohm calculations and are confirmed by testing each component to establish flow tolerances. The resistance to flow of any fluid component can be expressed in Lohms. A 1 Lohm restriction will permit a flow of 100 gallons per minute of water with a pressure drop of 25 psi at a temperature of 80°F. The Lohm formula is derived from Bernoulli’s equation.

FOR LIQUID FLOW

VOLUMETRIC FLOW UNITS

$$L = \frac{KV}{I}\sqrt{H/S}$$

GRAVIMETRIC FLOW UNITS

$$L = \frac{KV}{w}\sqrt{HS}$$

WHERE:

- **L** Lohm Rate (Lohms)
- **H** Differential Pressure
- **I** Liquid Flow Rate: Volumetric
- **S** Specific Gravity
- **V** Viscosity Compensation Factor
- **w** Liquid Flow Rate: Gravimetric
- **K** Units Constant – Liquid

FOR GAS FLOW

SONIC CONDITION

$$L = \frac{K f_T P_1}{Q} \qquad \text{i.e } P_1/P_2 \geq 1.9$$

SUBSONIC CONDITION

$$L = \frac{2 K f_T \sqrt{\Delta P\, P_2}}{Q} \qquad \text{i.e } P_1/P_2 < 1.9$$

WHERE:

- **L** Lohm Rate (Lohms)
- **K** Units Constant – Gas
- **f_T** Temperature Correction Factor
- **P_1** Upstream Absolute Pressure
- **P_2** Downstream Absolute Pressure
- **Q** Gas Flow Rate
- **ΔP** $P_1 - P_2$

To learn more about Lohm rates, reference values necessary for Lohm calculations, and equations for determining combined impact of flow restrictions in series and parallel, visit the engineering section of our website.

LEARN MORE >

FLOW RESTRICTOR FUNCTIONS

A flow restrictor can serve a few different functions. It is, therefore, important to select an appropriate flow restrictor to ensure proper functionality during system operation.

METER (REDUCE) FLOW

The most common function of a flow restrictor is to meter the flow rate of the fluid or gas traveling through it. A simple example is a faucet used to control the speed of water flow into a kitchen sink or out of a showerhead. A flow restrictor is also commonly used within an actuator; it meters fluid and controls the rate of piston travel to influence the speed required to extend or retract. One application for an actuator is the opening and closing of a car door. A flow restrictor can be used to reduce the speed at which the door slams shut.

CONTROL PRESSURE

A flow restrictor may be installed to reduce pressure. For example, a gas may be stored at a high pressure to compress it and reduce the required size of the container or tank. A flow restrictor placed at the outlet can precisely reduce pressure and protect or optimize the performance of downstream components. A flow restrictor may also be used to attenuate pressure pulses in a system. Alternatively, a flow restrictor may be installed in a system to increase upstream or back pressure; this may be done to ensure a certain section of a system has enough pressure to function properly.

CONTROL FLOW DIRECTION

A flow restrictor may be required to increase fluid velocity or control the pattern and direction of flow; such a flow restrictor is often referred to as a nozzle. Nozzles may create a smooth, straight stream of flow, which is useful when the fluid is directed at a target. An example is the use of oil to lubricate gears as they mesh together. A flow restrictor may also be used to spray or atomize fluid, as with a plastic bottle that sprays cleaner on a surface. Atomized spray is beneficial in fuel systems, because small droplets of fuel dispersed evenly provide more efficient combustion than a solid stream of flow.

WHAT ARE THE CRITICAL PERFORMANCE CHARACTERISTICS OF A FLOW RESTRICTOR?

There are several factors that must be considered to ensure the proper operation of a restrictor within a system. If these factors are not addressed, it can lead to reduced restrictor or system performance, damage to other components within the system, or to a total system failure. The following performance characteristics should be defined prior to the selection of a flow restrictor:

SYSTEM PRESSURES

There are four pressure ratings that should be considered for any restrictor:

- **Operating Pressure**: pressure levels to which the restrictor will be subject during normal operation throughout its life.
- **System Pressure**: the maximum nominal pressure anticipated for the system in which the restrictor is installed.
- **Proof Pressure**: the pressure the restrictor should be able to withstand without permanent deformation when the system returns to operating pressure.
- **Burst Pressure**: the pressure at which the restrictor should survive without rupturing or bursting.

These four pressure ratings must be considered during design to ensure the restrictor is sufficiently durable for the application. Conventional hydrostatic and burst pressure testing applies equal pressure to all parts of the metering element of the restrictor, and it is therefore unaffected. Thus, maximum hydrostatic pressure is limited only by the strength of the restrictor housing.

METERED FLOW RATE AND DIRECTION

A precision orifice must provide an optimal flow rate of fluid to an appropriate location. The target flow rate should be specified, and the following conditions identified: type of fluid, upstream pressure, downstream pressure, and temperature. This ensures the manufacturer and user have the same points of reference. A system without the proper flow rate may result in reduced system efficiency, damage to the system, or damage to other components.

It is also necessary to note the metered flow direction. Some flow restrictors flow equally in both directions, while others are only intended for and tested to flow at a certain level in one direction.

INLET AND OUTLET PRESSURE CONDITIONS

It is important to understand the pressures at the inlet (directly upstream) and outlet (directly downstream) of the flow restrictor. As the differential pressure between the inlet and outlet of the orifice increases (or decreases), the flow rate through the flow restrictor will increase (or decrease). Too great a pressure differential may result in excess flow, while too little may result in too much pressure downstream. Performance requirements must take into account all potential pressure variations. In a closed system, the pressure may remain relatively constant. In an open system that consumes fluid, such as a fuel system, pressure may decrease over time. The flow restrictor needs to withstand and perform appropriately over the full range of pressures for the life of the system.

WHAT ARE THE CRITICAL PERFORMANCE CHARACTERISTICS OF A FLOW RESTRICTOR? (CONT).

FLOW RATE TOLERANCE

In a mass production environment, there will inevitably be some variation from orifice to orifice. A critical system requirement is an understanding of the way production tolerances of individual orifices influence the total tolerance.

RESISTANCE TO DEBRIS AND CONTAMINATION

The smaller an orifice, the more susceptible it becomes to clogging due to debris introduced during handling, manufacturing, or operation. It is important to know the minimum passage size of the metering device and whether any integral protection is required.

MATERIALS

A restrictor may be comprised of several sub-components. The materials of each component and anything used to join the components—for example welds and brazes—must withstand the various forces applied during the restrictor's operating life. This includes the pressures applied internally and externally, along with the associated pressure rise rates.

Materials must also be compatible with their environment, including external fluids, temperatures, and the system fluid that will flow through the restrictor. It is possible that a flow restrictor may be subject to extreme humidity or be incorporated in a system submerged in other liquids or gases. Failure to consider material compatibility may also create issues related to thermal expansion and corrosion.

ENVELOPE

Criteria for selecting a restrictor must include the envelope. A prime consideration is the location of the restrictor within the system and the desired flow path. The system may require that the restrictor be located within a specific area, limiting external dimensions or overall size. The envelope must also account for installation, retention, and maintenance requirements. For example, some envelopes incorporate threaded fitting ends, while others are installed into manifold housings. It is also important to determine whether the installation must be permanent or removable. Finally, there's a need to evaluate if the restrictor may be used in a system in which weight is a factor, such as a portable system.

VARIETY OF FLOW RESTRICTORS

WHAT ENVIRONMENTAL FACTORS IMPACT THE DESIGN OF A FLOW RESTRICTOR?

Once the required performance characteristics of a flow restrictor are determined, it is critical to identify other variables that will influence the restrictor's performance. The internal and external environment of the system will affect the performance in a variety of ways—impacting every aspect of its functionality and limiting options for its construction. The following aspects of the system and environment must be considered for the design of a flow restrictor:

OPERATING FLUID

The performance of a flow restrictor is greatly affected by the operating fluid's viscosity and specific gravity. Liquids and gases have different fluid properties that impact flow performance. The operating fluid also introduces other variables that must be considered, such as material compatibility. A fluid that is incompatible with the restrictor's materials or coatings could cause damage to the valve, including corrosion or other harmful effects. Such damage will negatively affect the restrictor's performance, and subsequently may harm the system. It is also possible that the restrictor's materials may alter the fluid's properties, negatively affecting system performance. For example, a system analyzing blood or chemicals must use components that are inert to the fluid being analyzed. Similarly, a system flowing a flammable gas may need to avoid metals that may spark when making contact.

TEMPERATURE RANGE

The fluid's temperature and the ambient temperature can impact a restrictor's performance. Changes to fluid temperature will alter its properties, including viscosity and specific gravity. Liquids will thicken and increase in viscosity with decreases in temperature and will impede fluid flow. Conversely, increased temperatures will cause the fluid to thin and lower its viscosity. These factors can influence the calibrated flow rate of a restrictor.

OPERATING LIFE

It is important to consider how long the flow restrictor must withstand the conditions to which it will be exposed during operation. This includes the maximum length of time the device will be in service and the number of impulses it must survive. A flow restrictor may experience wear or erosion due to exposure to its environment. Excessive erosion over an extended operating life could lead to performance or installation and retention issues.

WHAT ENVIRONMENTAL FACTORS IMPACT THE DESIGN OF A FLOW RESTRICTOR? (CONT).

EXTERNAL PRESSURES

A restrictor's flow performance is typically based on changes in pressure and temperature within the system for which it was designed. However, the restrictor's envelope may be subject to other environmental pressures, such as the high pressure found deep underwater or the vacuum of outer space. A restrictor must be capable of withstanding such external pressures.

CLEANLINESS

A restrictor may have trace amounts of fluids, debris, or dust on or within the device. Contamination may occur during the manufacturing, transportation, or storage processes. If the end use cannot tolerate contamination, the restrictor may need to go through special cleaning and packaging procedures. An example of a low-tolerance application is a restrictor used in an oxygen system that provides breathable air to a person. Some industries, such as space and medical, have defined cleanliness levels that specify these requirements for components and systems.

VIBRATION, SHOCK, AND G-FORCES

Flow restrictors can be subject to forces external to the system in which they are installed, and to forces generated by the system's operation; typically, they are vibration, shock, and g-forces. For example, some systems or vehicles that use flow restrictors generate levels of vibration during normal operation; a shock may occur if the system or vehicle in which the flow restrictor is installed suddenly encounters another object; or the system or vehicle may generate g-forces during operation due to a sudden forceful movement. The magnitude, frequency, and direction of the potential forces must be considered.

A flow restrictor typically does not include moving components; it can, however, be constructed of multiple components. Both the construction of the flow restrictor and its method of retention within the system must be able to perform as intended when subjected to these forces. An adjustable flow restrictor is more susceptible to shock and vibration due to the incorporation of moving components.

FLOW RESTRICTOR PERFORMANCE TRADE-OFFS AND DESIGN CHALLENGES

Once optimal performance requirements are identified and environmental factors are considered, the appropriate flow restrictor is selected for the application. It may, however, be difficult to find a solution that meets every requirement. As with most decisions, there are trade-offs that must be considered. Some of these trade-offs are common sense. For example, changing the material from plastic to metal will increase operating or burst pressure capability but will also increase the restrictor's weight. There are other performance aspects specific to restrictors that may require more careful consideration during the selection process.

ACCEPTANCE TESTING CORRELATION

During development, it is critical to test the performance of a flow restrictor with the intended fluid under actual system conditions. However, some fluids are expensive, dangerous, or difficult to obtain. For acceptance testing in mass production, it may be more economical to test on a reference fluid and correlate performance to the actual fluid. For example, it may be acceptable to test a restrictor used in a blood analyzer with water rather than the expensive reagents necessary to perform the actual blood analysis. It is also impractical to acceptance test component hardware for every possible combination of system or environmental conditions. The cost and complexity can be reduced while verifying performance by correlating design requirements to an appropriate manufacturing acceptance test. The challenge is that correlations are not perfect and typically require empirical data rather than perfect equations.

FLOW TOLERANCE

The tolerance for a flow rate can sometimes prove to be a challenging design element. There are applications that require very tight tolerances on flow rates. For example, a device used to mix two chemicals may use flow restrictors to create the necessary ratio of different fluids. An incorrect ratio might reduce the efficiency or performance of the mixture; however, the cost to manufacture and validate a tighter tolerance flow restrictor may increase significantly.

It is also worth noting that as the number of individual restrictions increases, it may become more difficult to control the tolerance of the complete flow restrictor. This is the case whether orifices are in series or parallel. The total tolerance in the stack up of multiple orifices in parallel adds further complications. It is described by the following equation:

$$\pm\%_{total} = \frac{\dot{m}_1}{\dot{m}_{total}}\left|\pm\%_1\right| + \frac{\dot{m}_2}{\dot{m}_{total}}\left|\pm\%_2\right| + \cdots + \frac{\dot{m}_n}{\dot{m}_{total}}\left|\pm\%_n\right|$$

$$\text{Where } \dot{m}_{total} = \dot{m}_1 + \dot{m}_2 + \cdots + \dot{m}_n$$

The tolerance of the higher flow rate orifice will have the greatest impact on the total flow tolerance.

FLOW RESTRICTOR PERFORMANCE TRADE-OFFS AND DESIGN CHALLENGES (CONT.)

SINGLE VERSUS MULTI-ORIFICE OR POROUS RESTRICTOR

If a single orifice restrictor offers an identical level of restriction to that of a multi-orifice or porous restrictor, the single orifice restrictor will offer a few advantages. It is typically simpler to design and manufacture, smaller in size and lighter in weight, and has a reduced cost. However, the multi-orifice or porous restrictor offers some distinct performance advantages.

The main advantage of multi-orifice restrictors is that they can be used to help mitigate some of the failure modes discussed in more detail below. They offer a larger minimum passage size for an equivalent restriction. This makes them less susceptible to clogging due to debris. In addition, the pressure drop across each individual orifice is less than that across a single orifice. This can reduce the potential for cavitation in liquid flow.

While it is typically easier to manufacture a single orifice, once the desired orifice size decreases beyond a certain point, it becomes more difficult to manufacture using traditional, low-cost methods. For example, drills may break more easily in extremely small diameters or may not be available at all. Manufacturing tolerances in a small orifice may also result in wider flow tolerances.

POTENTIAL FAILURE MODES

Despite being designed to meet the performance criteria and withstand the environmental factors previously discussed, restrictors may become damaged and fail to perform properly in service. It is important to be aware of certain failure modes to ensure the appropriate measures are in place within the system to mitigate the risk of failure. Below are some examples of potential failure modes. This is not a complete list—all potential failure modes for a specific application must be evaluated.

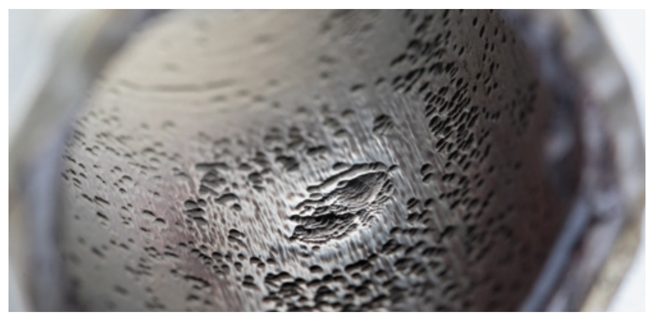
CONTAMINATION / FOREIGN OBJECT DAMAGE (FOD)

The most common failure mode for a restrictor is damage due to ingestion of foreign material or, simply stated, contamination. Fluids can contain contaminants of various sizes and materials. Such contamination can clog the orifice and stop or lessen the required fluid flow. Excessive, uncontrolled contamination can also erode the orifice. The erosion is typically seen at the edges of the orifice; over time, it may potentially increase the size and flow rate of the orifice. Adequate protection against contamination should be incorporated upstream of the restrictor to reduce the risk of such occurrences. Some flow restrictors may integrate a form of protection as part of the device.

CAVITATION

This occurs when a high fluid velocity through an orifice reduces pressure within the orifice throat below a fluid's vapor pressure. It chokes the flow and creates vapor pockets. The result is a larger-than-expected pressure drop across the orifice that may erode the orifice or any downstream components located too close. Cavitation is most common when the pressure upstream of the orifice is much higher than the downstream pressure. Cavitation only occurs with liquid flow and is not an issue with pneumatic flow.

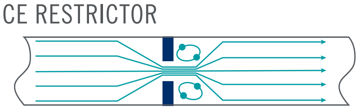
DAMAGE CAUSED BY CAVITATION



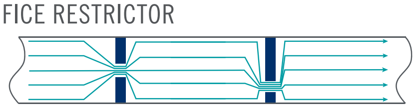
The figure below depicts the cross sections of a single and a multi-orifice system. The pressure graph shows the pressure in a single orifice system dropping below the vapor pressure line and creating a possible choking condition. Whereas, in the multi-orifice system, a much smaller pressure drop is created across each of the orifices; and the individual drops are never below the vapor pressure. Therefore, multi-orifice restrictors are used more frequently when cavitation is a concern in a system.

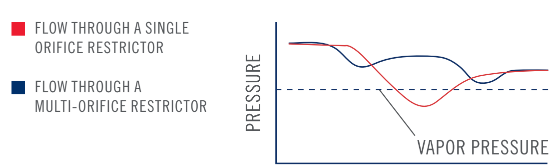
ELIMINATING CAVITATION WITH MULTIPLE FLOW RESTRICTORS IN SERIES

SINGLE ORIFICE RESTRICTOR



MULTI-ORIFICE RESTRICTOR





A general rule-of-thumb used to predict the possibility of cavitation in a system is the coexistence of very high upstream pressure and very low downstream pressure. Physical signs of cavitation include abnormal noise, high fluid temperatures, choked fluid flow, and physical erosion of any downstream component near the orifice. Any of these indicators may warrant the installation of a multi-orifice restrictor.

IMPROPER INSTALLATION

Improper installation of a restrictor can result in poor performance. For example, if the restrictor is not properly installed, its envelope may become damaged during installation and may lead to an external leakage path. It's also possible that damage to the restrictor could interfere with its internal components. To avoid these issues, it is critical that restrictor installation instructions are followed closely.

ARE THERE UNIQUE INDUSTRY REQUIREMENTS FOR FLOW RESTRICTORS?

Many industry associations have documented recommendations or requirements for the validation and verification of restrictor performance to ensure safety within a specific system. Compliance with these specifications is usually required by governing bodies and passed down to suppliers of systems and components. The selection of a restrictor must meet industry standards required for the application. Some examples of industry associations with restrictor guidelines include:

ISO

International Organization for Standardization

ASME

American Society of Mechanical Engineers

ANSI

American National Standards Institute

SAE

SAE International

API

American Petroleum Institute

HOW CAN THE LEE COMPANY HELP?

For more than 70 years, The Lee Company has been a leading supplier of miniature, precision fluid control products to a wide range of industries including aerospace, oil & gas, automotive, industrial equipment, medical devices, and scientific instruments. Lee products are recognized worldwide for superior quality, reliability, and performance.

The Lee Company offers a wide range of single and multi-orifice flow restrictors designed to be the smallest and most reliable available. Each flow restrictor is 100% tested to guarantee performance. The Lee Company also offers a wide range of lubrication and atomizing nozzles.

One of The Lee Company's greatest innovations is the Lee Visco Jet®. Lee Visco Jets integrate a complex fluid passage with numerous orifices in series to create a multi-orifice restrictor in a miniature package. The combined effect of taking pressure drops across a series of orifices offers very high restrictions with a large minimum passage size. For example, a Visco Jet can replace a single 0.0006 inch diameter orifice with an equivalent restriction that includes a minimum passage of 0.005 of an inch in an envelope less than 0.5 of an inch in diameter and 0.6 of an inch long; this allows for a more reliable device that is much less susceptible to contamination.

Lee flow restrictors are currently operating miles beneath the Earth's surface in tools used to explore for oil and thousands of miles above it for rocket and satellite propulsion. They are also found in the cars and airplanes used every day for transportation.

CLICK HERE TO LEARN MORE ABOUT LEE FLOW RESTRICTORS >

The Lee Company offers a team of technical sales engineers available around the world to work one-on-one with our clients to solve their unique fluid control problems. Contact The Lee Company today to learn more about restrictors and find out how The Lee Company can customize a solution for your unique needs.

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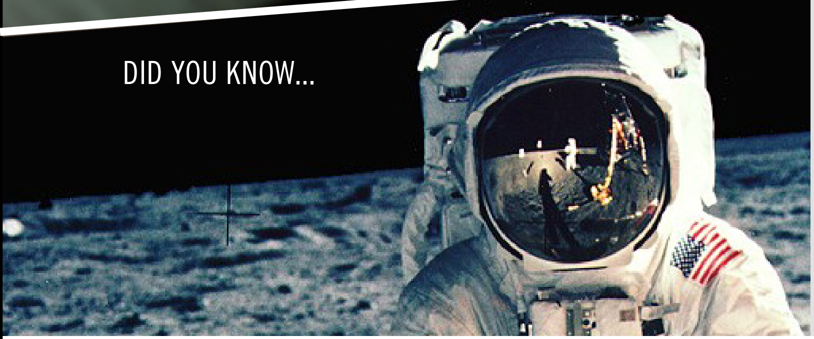
DID YOU KNOW...



Lee components served critical roles in the historic **Apollo 11** mission. They were used in the **Saturn** rocket propulsion system that launched the astronauts into space, the orbital maneuvering system on the lunar lander which set astronauts on the moon's surface, and to control the flow of oxygen needed by astronauts when they walked on the moon.

LEARN MORE ABOUT OUR HISTORY IN SPACE >

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