

WHITE PAPER

Steam Flow and Quality Metering to Meet Sustainable Development Goals



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Introduction

Steam plays a crucial role in various industries, serving as an efficient means of transporting energy throughout a facility. This energy is used for a range of purposes, including heat transfer, power generation, mechanical work, sterilization, and humidification. There has been a growing emphasis on energy production and conservation in recent years, driven by environmental regulations and financial incentives. This emphasis has led to increased attention toward steam generation and usage.

Phases of steam

When heat is added to liquid water at constant pressure, its temperature increases until it reaches boiling point. As the heating continues, the water molecules break down, causing a phase change from liquid to gaseous steam at a constant saturation temperature. This mixture of liquid water and gaseous steam is called “wet steam” or “saturated steam.” With further heating, the percentage of steam to liquid water in the mixture increases. When the heating has converted all the liquid water to steam, additional heating starts to raise the temperature of this superheated steam, as shown in Figure 1 below.

In most process facilities, wet steam is the most common type of steam available. When a boiler produces steam, it typically contains water droplets that weren’t vaporized and carried over into the steam piping.

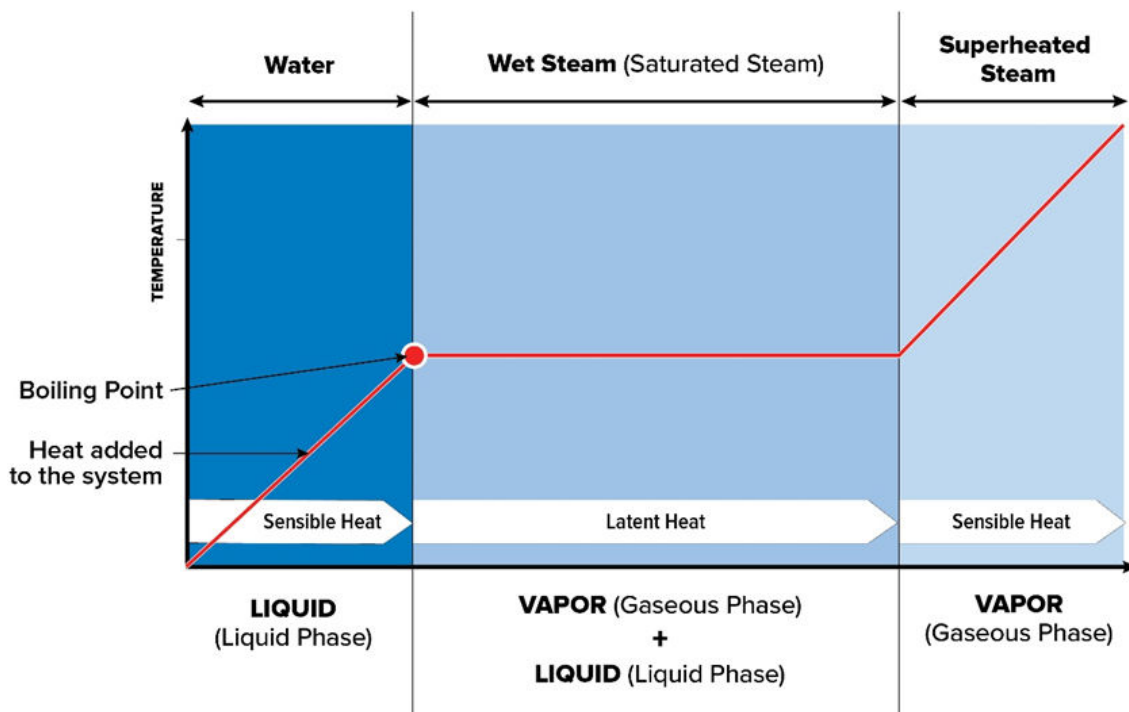


FIGURE 1: PHASES OF STEAM CHART

Steam Quality Defined

Steam quality is a measure of how much moisture there is in steam, not to be confused with steam purity which refers to the amount of contaminants (solids, liquids or gases) that are present in steam.

It is expressed as a percentage (X), which is calculated by dividing the mass of steam by the total mass of both steam and water.

$$X = \frac{\text{Mass of Steam}}{\text{Mass of Steam} + \text{Mass of Water}} (100)$$

Adding more heat to the steam causes more evaporation and reduces the amount of liquid in the mixture. This leads to an increase in steam quality (X) as the percentage of vapor increases and the percentage of liquid decreases. The steam quality continues to rise until it reaches dry steam (X=100%), as shown in Figure 2 below.

Wet Steam (Saturated Steam) Quality

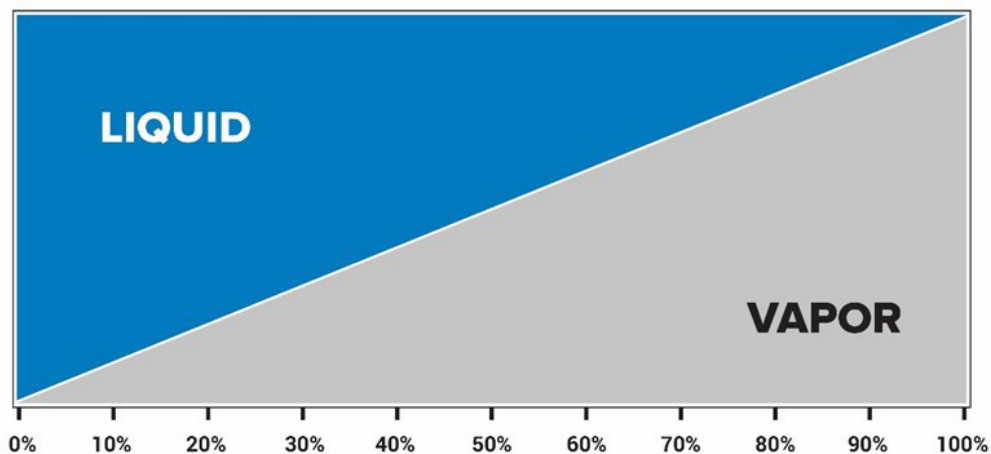


FIGURE 2: SATURATED STEAM QUALITY CHART

Steam is a crucial component of many modern process facilities, and ensuring steam quality meets acceptable standards is essential. However, steam quality is often not closely monitored and is assumed to be 100%, which can lead to problems. When issues arise from poor steam quality, they are often attributed to other system components. This often leads to serious safety and economic consequences.

United Nations Sustainable Development Goals

The 2030 Agenda for Sustainable Development, unanimously embraced by all United Nations Member States in 2015, outlines a collective vision for global peace and prosperity for both people and the planet, both now and in the future. Central to this agenda are the 17 Sustainable Development Goals (SDGs), representing a pressing call to action for every country, regardless of their development status, to engage in a global partnership. These goals emphasize the interconnected nature of poverty eradication, improved health and education, reduced inequality, and economic growth. Simultaneously, they address the critical challenges of climate change and the preservation of our precious oceans and forests.

Steam flow and quality metering can help organizations meet the following SDGs:

- **SDG 7.** Ensure access to affordable, reliable, sustainable and modern energy for all
- **SDG 12.** Ensure sustainable consumption and production patterns
- **SDG 13.** Take urgent action to combat climate change and its impacts

SDG 7. Ensure access to affordable, reliable, sustainable and modern energy for all

Enhancing Reliability and Preventing Power Outages

Steam turbines are responsible for generating most of the world's electricity, regardless of the fuel source. To bolster the reliability of these power generation systems, steam flow and quality metering play a vital role in identifying and resolving issues before they lead to outages.

Steam turbines have specific requirements for inlet steam flow rates for optimum efficiency and power output. Deviations from these requirements can lead to reduced efficiency, decreased power output, or damage to the turbine. Continuous monitoring of inlet steam flow rates to the turbine enables the prompt identification of sudden deviations from these requirements. Maintaining high-quality steam is also essential for the optimal functioning of a steam turbine. Low-quality steam diminishes turbine efficiency and can result in erosion, corrosion, and fouling of turbine components. Detecting these issues with steam flow rates and steam quality early empowers plant personnel to investigate and address problems proactively, thereby preventing costly and disruptive outages.

Ensuring Affordability and Reliability Through Effective Steam Distribution

Effective steam distribution within a facility is essential to maintaining the affordability and reliability of a steam system. Steam quality metering plays a crucial role in this process. Identifying areas in the distribution system where steam quality is low allows operators to make the necessary adjustments to ensure that all parts of the facility receive high-quality steam.

A common issue within steam distribution systems is the failure of steam traps. Steam traps are designed to remove condensate from steam lines to ensure high-quality steam. However, when these traps fail, they can lead to energy wastage by allowing live steam to escape or preventing condensate from escaping, depending on whether they fail open or closed. Either way, these failures lead to inefficiencies, increased energy consumption, and potential damage to the overall steam system. Steam quality metering can help detect malfunctioning steam traps, enabling prompt repairs or replacements and optimizing energy efficiency and distribution effectiveness throughout the facility.

SDG 12. Ensure sustainable consumption and production patterns

Improve Energy Efficiency

Promoting sustainable consumption and production patterns in industrial processes relies on data-driven decision-making. Steam flow data collected through metering systems is a crucial resource, allowing operators to analyze trends, patterns, and areas for improvement in their production processes. This informed decision-making can help to identify efficient resource use and waste reduction opportunities and foster sustainable consumption and production.

Steam quality is a reliable indication of the energy content of the steam. Higher-quality steam contains greater enthalpy and, therefore, more useable energy. More useable energy translates to greater efficiencies of the work being performed. This increased energy efficiency ultimately reduces boiler load and the associated costs.

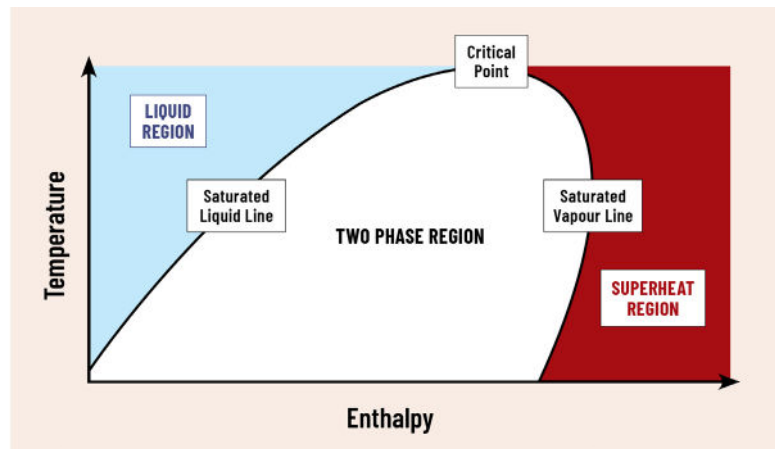


FIGURE 3: Steam Enthalpy Temperature Graph

Extend the lifespan and reduce maintenance costs of steam equipment

Ensuring high-quality steam is vital for extending steam equipment's lifespan and reducing maintenance costs. Low-quality steam can cause corrosion, erosion, and water hammer in piping systems. All of which can damage piping and equipment, leading to premature failures. Steam quality metering is crucial in identifying and addressing steam quality issues early on. By maintaining high steam quality, facilities can significantly reduce the frequency of equipment repairs and replacements, reducing costs and minimizing the environmental impact of their operations.

Improve product quality and prevent batch rejections

Direct steam heating is a process where steam is injected directly into a fluid or material to raise its temperature. Direct steam heating is a versatile and efficient method employed across various applications where rapid and precise temperature control is paramount. Some common examples of direct steam heating applications include cooking in food processing, sterilization in medical facilities, and drying in paper manufacturing.

Steam quality metering is crucial in identifying and addressing issues with poor-quality steam. Maintaining high-quality steam in direct steam heating applications benefits facilities by reducing quality issues and batch rejections, leading to increased throughput.

SDG 13. Take urgent action to combat climate change and its impacts

Reduce greenhouse gas emissions and improve air quality

Regardless of its end use, whether for heating, industrial processes, or electricity generation, fossil fuels remain the predominant fuel source for steam production. The combustion of these fuels unavoidably results in the emission of greenhouse gases, which in turn contribute to climate change.

Steam flow and quality metering allow for precise measuring of steam consumption throughout a facility, enabling organizations to identify inefficiencies and capitalize on energy-saving opportunities to increase energy efficiency. This increased energy efficiency reduces greenhouse gas emissions, especially in industrial facilities with much larger scales of steam production.

Moreover, by reducing greenhouse gas emissions and other pollutants, steam flow and quality metering help improve air quality and reduce the adverse health impacts of poor air quality.

Monitoring, Reporting, and Benchmarking

Many governments have implemented initiatives and laws to reduce carbon emissions created by heating and cooling large commercial buildings. These laws vary, but broadly speaking, they require the monitoring, reporting, and benchmarking of various energy use and emissions-related data. Compliance with the laws and regulations is often monitored by government officials, with potential fines or penalties for non-compliance.

Steam heating systems consume substantial energy in large buildings, making them a key target for energy reduction efforts. Integrating steam flowmeters with a modern Building Automation System (BAS) enables real-time monitoring of steam consumption at various locations in the distribution system, offering precise data on steam usage within specific building zones. This allows building operators to analyze and pinpoint inefficiencies within the system. Submetering individual building tenants also allows building owners to allocate energy costs accurately.

Policy Development and Incentives

Steam flow and quality metering data plays a crucial role in policy development and incentives for sustainable practices. Policymakers can leverage this data to create targeted policies and incentives, such as tax breaks or subsidies, encouraging industries to invest in energy-efficient steam systems. Aligning these initiatives with climate change goals allows countries to integrate specific measures into their national strategies, fostering the transition towards environmentally friendly practices. Enforcing compliance with these standards not only ensures the efficiency of steam systems but also aligns with climate change policies, promoting the integration of emission reduction measures and enhancing overall environmental sustainability efforts.

How to measure steam quality

In the past, measuring steam quality was only feasible using a throttling calorimeter. This process involves taking a steam sample through a throttling orifice into an insulated expansion chamber and using temperature and pressure measurements to determine the steam quality value through steam table calculations. This method has several inherent drawbacks. There is a high potential for operator error since the results depend heavily on the technician's skill. It is also time-intensive, potentially unsafe, and does not allow for data trending over time.

Fortunately, recent advancements have led to more practical and innovative methods of steam quality measurement. Some vendors now offer automated sampling methods that communicate with modern control systems. Other vendors have moved away from sampling altogether and developed inline designs allowing continuous and automated steam quality measurement. These new methods are more accurate, efficient, and safer than the traditional throttling calorimeter method.

The Azbil VorTek VorCone® Steam Quality & Flowmeter provides automated and continuous steam quality metering. The VorCone meter utilizes two different flowmeter technologies in combination; vortex and differential pressure.

See Figure 4 (right). This combination allows for the prediction of the fluid density, volumetric flow rate, and mass flow rate without any fluid density information being required from an external source. This ability to measure fluid density allows the meter to provide a reliable steam quality (dryness) measurement and mass flow rate reading.

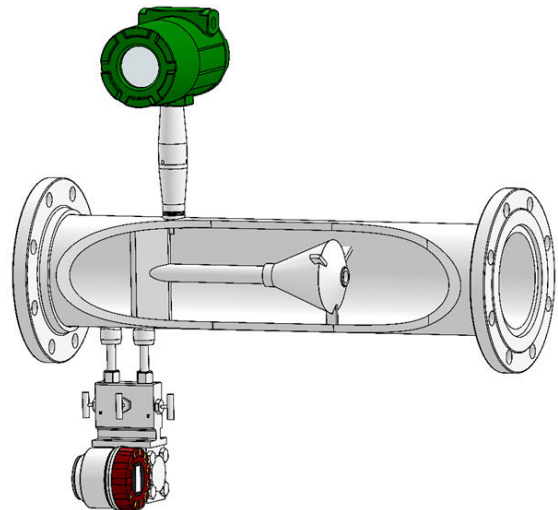


FIGURE 4: Cutaway view of the Azbil VorTek VorCone® Steam Quality & Flowmeter

Unlike other steam quality measurement systems that are limited to high-quality ranges where X is greater than 80%, the VorCone meter measures steam quality across a much wider range from 40% to 100%.

Common steam flow metering issues

Measuring steam is difficult due to the high pressures, high temperatures, varying quality, and different phases. In addition, seasonality issues arise when steam is used as a heating medium since flows vary significantly between colder and warmer months. For example, if a steam flowmeter is sized for maximum flows in the colder months, it may miss low flow conditions in the warmer months.

Poor quality steam, which contains liquid water, poses additional challenges. Pressure surges of liquid water can damage flow metering equipment, including primary elements, turbine blades, and velocity sensors. Moreover, the presence of liquid water can lead to overreading steam flow rates. Most single-phase steam flowmeters assume only the vapor phase is present and, therefore, do not capture the water component of the steam and water mixture. However, some flow metering technologies are better suited to deal with these issues.

Flowmeter technologies for steam metering

Various flow metering technologies are available for measuring steam flows, but the most commonly used ones are vortex, differential pressure, and turbine flowmeters. Each technology has advantages and disadvantages, and selecting the most suitable technology depends on the intended application.

Inline vortex steam metering

Inline vortex flowmeters measure steam flows by detecting the frequency at which vortices are shed from a bluff body, as shown in Figure 5. The frequency of these vortices is directly proportional to the flow velocity.

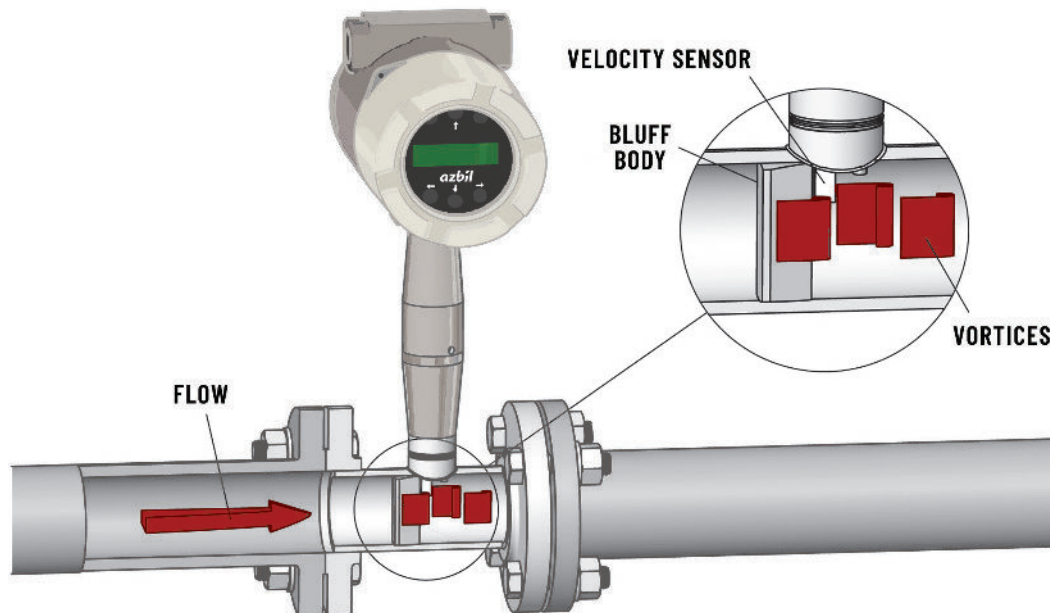


FIGURE 5: Cutaway view of an Azbil® AX24 Inline Vortex Flowmeter

A compensated mass flow rate can be calculated by adding temperature and pressure measurements and a flow computer. Some vendors offer these additions in the form of a multivariable inline vortex flowmeter. Azbil offers multivariable options on its AX24 Series Inline Vortex Flowmeters.

Key advantages of inline vortex steam metering:

- Simple and robust construction, no moving parts.
- Multivariable models can provide a compensated mass flow measurement.
- Relatively low permanent pressure drop.
- Relatively high turndown ratio.
- Requires very little maintenance.

Key disadvantages of vortex steam metering:

- Poor performance at low flow rates.
- Requires unobstructed upstream and downstream straight piping lengths.
- External vibrations can cause measurement errors.

Insertion vortex steam metering

Like inline vortex flowmeters, insertion vortex flowmeters measure steam flows by detecting the frequency at which vortices are shed from a bluff body, as shown in Figure 6. The frequency of these vortices is directly proportional to the flow velocity.

A compensated mass flow rate can be calculated by adding temperature and pressure measurements and a flow computer. Some vendors offer these additions in the form of a multivariable insertion vortex flowmeter. Azbil offers multivariable options on its AX23 Series Insertion Vortex Flow

Key advantages of insertion vortex steam metering:

- Economical option on large line sizes such as steam headers.
- Can be installed under full process conditions (hot tapping).
- Simple and robust construction, no moving parts.
- Multivariable models can provide a compensated mass flow measurement.
- Relatively low permanent pressure drop.
- Relatively high turndown ratio.
- Requires very little maintenance.

Key disadvantages of turbine steam metering:

- Poor performance at low flow rates.
- Requires unobstructed upstream and downstream straight piping lengths.
- External vibrations can cause measurement errors.

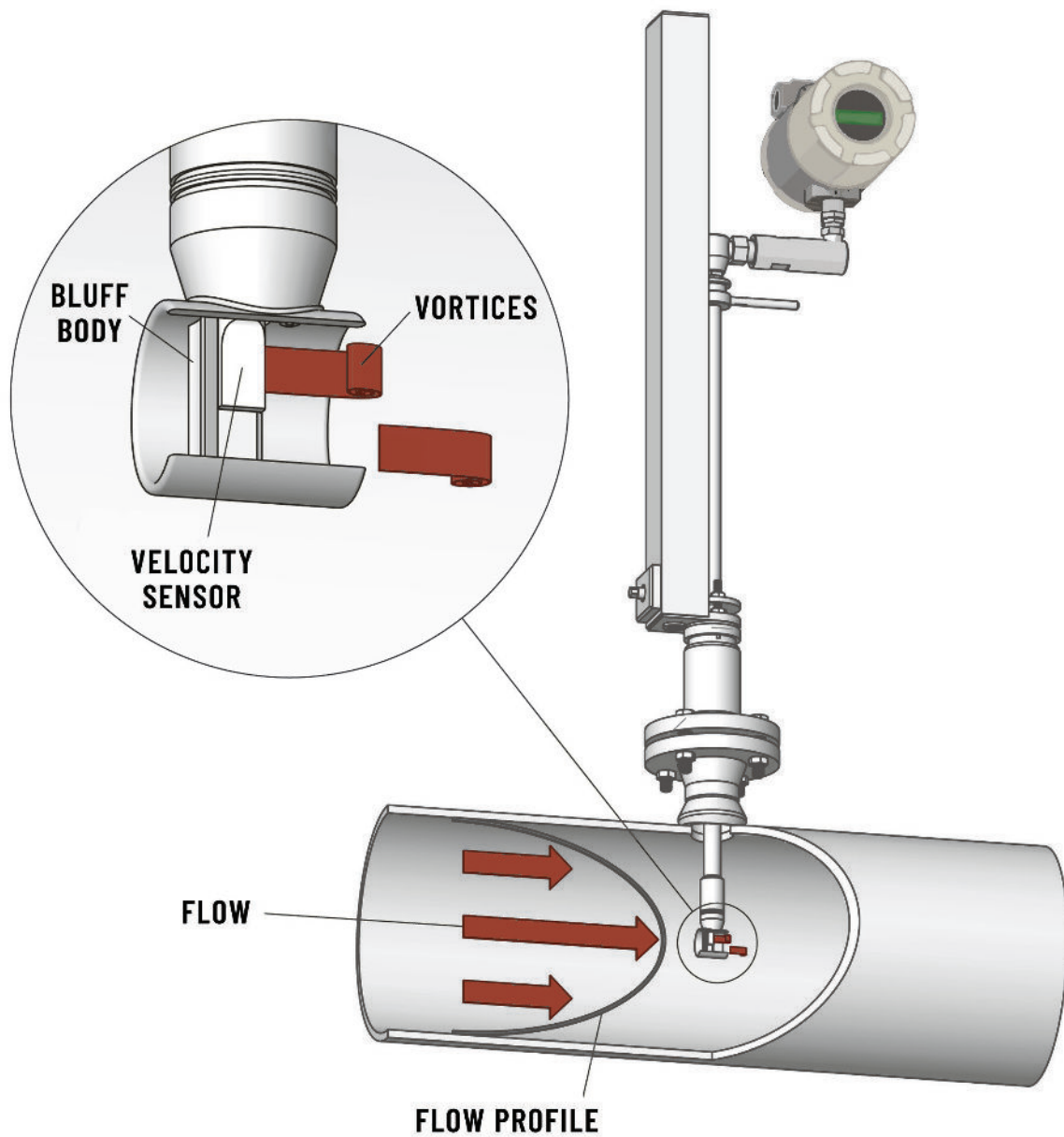


FIGURE 6: Cutaway view of an Azbil® AX23 Insertion Vortex Flowmeter

Differential pressure steam metering

Differential pressure flowmeters measure steam flows using Bernoulli's equation. A primary element introduces a constriction in the pipe, creating a pressure drop across the flowmeter. Impulse piping routes the upstream and downstream pressures of the flowmeter to a differential pressure transmitter, which calculates a volumetric flow rate using Bernoulli's equation. A compensated mass flow rate can be calculated with a multivariable differential pressure transmitter, which includes temperature and pressure sensors.

Key advantages of differential pressure steam metering:

- Simple and robust construction, no moving parts.
- Relatively inexpensive.
- Multivariable models can provide a compensated mass flow rate.

Key disadvantages of differential pressure steam metering:

- Relatively high permanent pressure drop. Dependent on the type of primary element used.
- Limited turndown ratio.
- Interference with the flow stream.
- Primary element will wear over time.
- Requires unobstructed upstream and downstream straight piping lengths. Dependent on the type of primary element used.

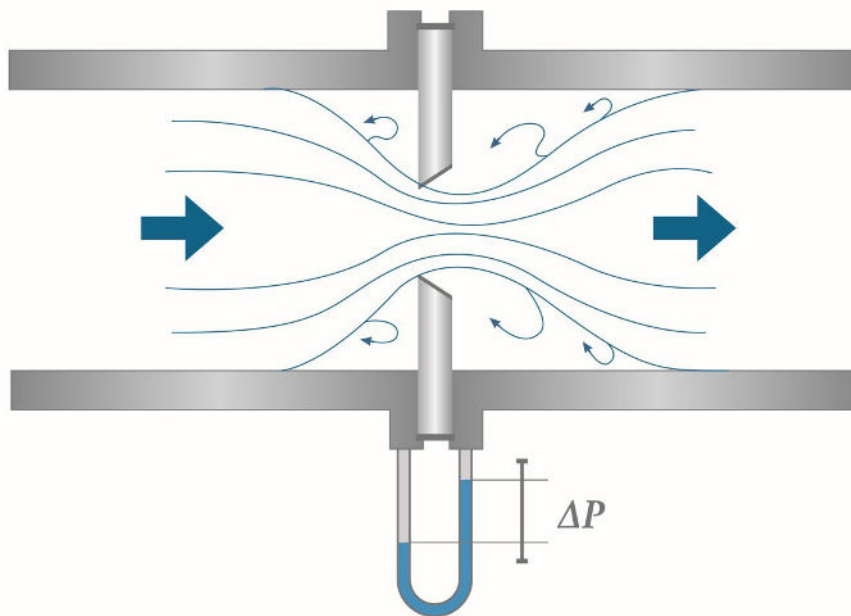


FIGURE 7: An orifice plate primary element restricts flow in a pipe, creating a pressure differential.

Conclusion

Steam use remains an essential part of modern process facilities and will continue to be so in the foreseeable future. To effectively utilize the benefits of steam, it is crucial to understand its different states. Steam quality can significantly affect both safety and economic considerations in steam systems. Adopting steam flow and quality metering is critical in achieving the United Nations' Sustainable Development Goals (SDGs).

Measuring steam quality has been a challenging manual process, but recent advancements have led to more innovative, practical, and automatic methods. High pressures, high temperatures, and varying degrees of steam quality all contribute to the high degree of difficulty of steam flow metering. But despite the challenges, several suitable technologies exist for steam metering. Each technology has merits and limitations; the specific application should determine the most suitable technology.


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