# Application Note

## Wet Steam - Quality & Flow Metering with VorCone™

### Steam use in industry

Steam use is an essential part of most modern process facilities. Steam provides a convenient way of transporting energy throughout a facility. That energy is most commonly used for heat transfer, mechanical work, sterilization, and humidification.

### What is wet steam?

As heat is added to liquid water at constant pressure, it's temperature increases until the boiling point is reached. Further heating breaks the bonds between water molecules and changes liquid water into vapor (steam) at constant saturation temperature. This mixture of liquid water and gaseous steam is referred to as "wet steam" or "saturated steam". As more heat is added the percentage of steam to liquid water increases. When the heating has converted all the liquid water to steam, further heating starts to raise the temperature of this superheated steam. See figure 1 below.

Wet steam is the most common type of steam experienced by most process facilities. When a boiler produces steam it usually contains some percentage of water droplets that were not vaporized and carried over into the steam piping.

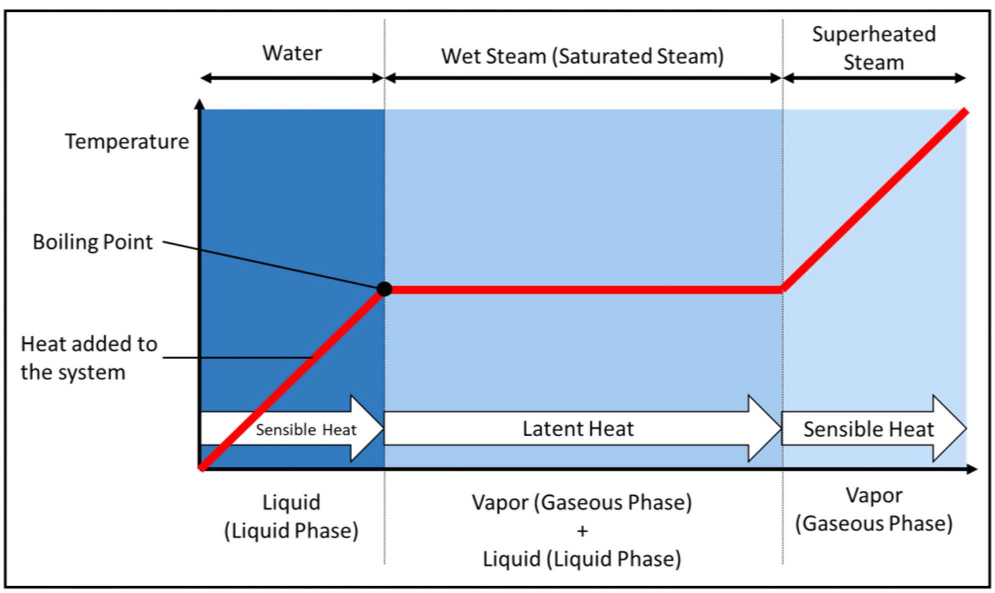



Figure 1

### What is steam quality?

Steam quality is a measure of the wetness of steam. Typically steam quality is expressed as a percentage (X). Where the mass of steam is divided by the sum of the mass of steam and water.

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

As more heat is added to the steam the evaporation increases, this causes the percentage of vapor to increase as the percentage of liquid decreases. This results in the steam quality (X) increasing until it reaches dry steam (X=100%). See figure 2 below.

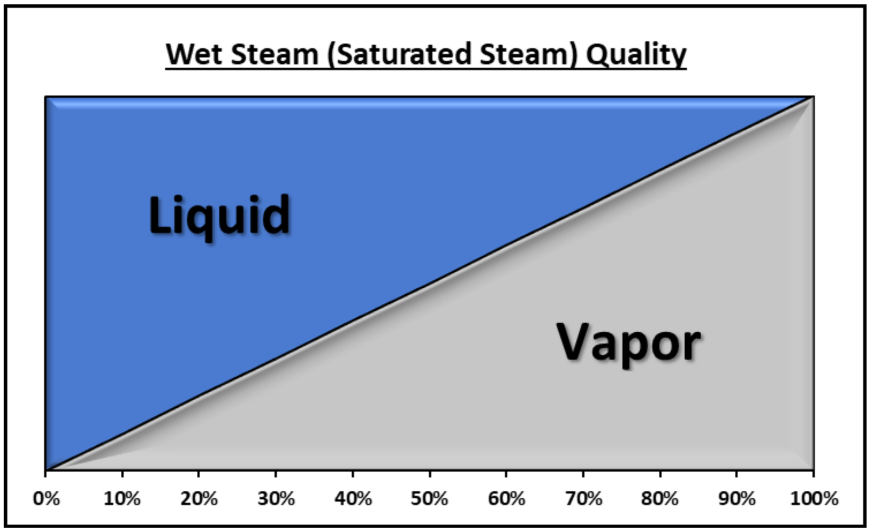



Figure 2

## The importance of steam quality

Steam use is a vital part of most modern process facilities. As such, steam quality should be measured and controlled to acceptable standards. Unfortunately, steam quality is typically not monitored closely and is assumed to be 100%. Therefore, issues that arise from poor steam quality are often attributed to some other component in the system. This often leads to disastrous safety and economic consequences.

### Safety considerations

Poor quality steam has a significant percentage of liquid water present. This liquid water can severely damage piping and process equipment. Erosion of critical components such as valves, pressure regulators, and turbine blades. Corrosion of piping caused by the increased presence of carbonic acid. Pressure surges of liquid water creating severe impacts; also known as water hammer. In extreme cases, water hammer can damage piping components so severely dangerously hot steam and water spew out into the surrounding environment.

### Economic considerations

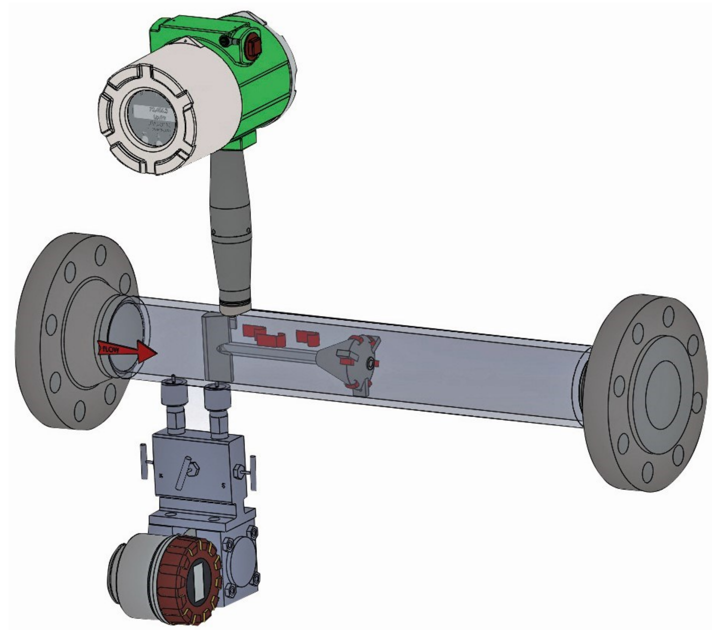
Steam quality is a reliable indication of the energy content of the steam. Higher quality steam contains more useable energy. More useable energy translates to greater efficiencies of the work being performed. This ultimately allows for reducing boiler load and the associated costs.

Process operations can also benefit from higher-quality steam by increasing throughput. Direct steam heating applications benefit from higher-quality steam by reducing quality issues and preventing batch rejections.

## VorCone steam quality and mass flow metering

Wet steam is two-phase flow and two-phase flow metering is notoriously challenging. The few steam quality measurement systems available tend to operate over limited high-quality ranges (e.g., x is greater than 80%). The VorCone meter measures both steam quality and total mass flow across a wide range of quality.

The VorCone meter is a fully integrated hybrid vortex and cone flow meter. These two dissimilar metering principles complement each other giving far more information than either standalone meter.



## VorCone principle of operation

The VorCone meter models the wet steam flow as a pseudo-homogenous mixed flow. The vortex meter measures the mixture volumetric flowrate ($Q_h$) by reading the vortex shedding frequency (f) and relating it to the meter factor (K):

$$Q_h = \frac{f}{K}$$

The mixture volumetric flowrate is substituted into the cone meter volumetric flowrate equation, the resulting expression rearranged to produce a mixture density ($\rho_h$) measurement. Where E & $A_t$ are cone geometry terms, $C_d$ is the cone meter discharge coefficient, and ΔP is the cone meter primary signal.

$$\rho_h = 2\Delta P\left(\frac{K}{f} E A_t C_d\right)^2$$

The VorCone meter has pressure and temperature sensors, and a flow computer with steam tables. The liquid water ($\rho_l$) and steam vapor ($\rho_g$) densities are therefore known. Thus, we can calculate the steam quality:

$$x = \frac{\rho_g\left(\rho_l - \rho_h\right)}{\rho_h\left(\rho_l - \rho_g\right)}$$

With known steam quality (x), the ISO published cone meter wet gas correlation is applied to correct for the liquid induced cone meter vapor flowrate prediction to the correct steam vapor mass flow ($m_{sv}$). The water flowrate ($m_w$) is then:

$$m_w = \frac{1 - x}{x} m_{sv}$$

## VorCone measuring range

Most wet steam quality measurement systems operate over a very limited high-quality range only (e.g. x is greater than 80%). The VorCone meter measures both steam quality and total mass flow across a wide range of quality (e.g. 40% < x ≤ 100%). See figure 3 below.

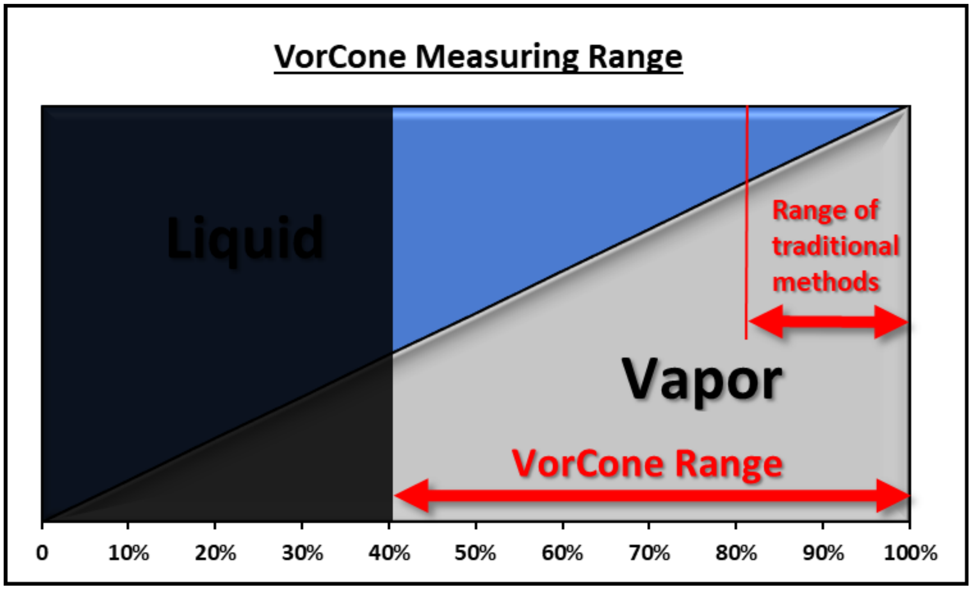
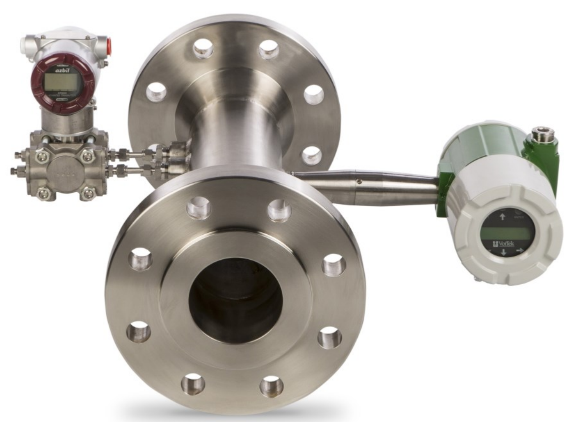



Figure 3

## Advantages of the VorCone meter

VorCone meters measure steam quality and flowrate allowing operators to know the true condition of their steam in real-time. Operators no longer have to assume steam quality and face the consequences of inaccurate assumptions. This allows for correct identification of steam system related issues. VorCone meters facilitate optimal steam system management, reducing both safety and economic concerns.



**For more information visit**

www.vortekinst.com

or contact your local VorTek Instruments sales representative

**VorTek Instruments**
8475 W I-25, Suite 300
Longmont, CO 80504, USA

(303) 682-9999
info@vortekinst.com