Increase safety and improve efficiency by detecting wet steam

Endress+Hauser has recently introduced its new Proline vortex flowmeter family. This highly robust flowmeter has been mainly developed for steam applications, and it offers a broad scope of multivariable solutions for steam mass and energy measurement. An innovation that helps to increase safety and improve the efficiency of steam systems is the new optional feature designed to detect wet steam on a continuous basis.

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Steam is commonly used for process heating. Typically, saturated steam is produced in shell and tube (fire tube) boilers. Its advantages are obvious: The heat content is high and temperature can be regulated by controlling pressure. When looking at the properties of saturated steam it can be seen that it is exactly at the border line between liquid water and gaseous steam (vapor).

When dry saturated steam passes on its energy to a process, its “latent” energy is released. This energy can be found in steam tables as enthalpy (h_{fg}). Whilst this energy is released, the steam becomes wetter, i.e. its dryness fraction (x) is reduced from 1 down to 0. What doesn’t change, however, is the combination of pressure and temperature during this process. This means that ideally steam enters a heat exchanger at 3 bar g and +144 °C and condensate can be found at the exit at exactly the same pressure and temperature – but the steam has lost 2138 kJ/kg of latent heat (h_f). The problem now is: If both liquid and steam, and any state in-between, can exist at the same pressure and temperature, it is impossible to determine the dryness fraction by just measuring pressure and temperature. Therefore, today there is no solution available to easily determine if water is present in the steam line or not.

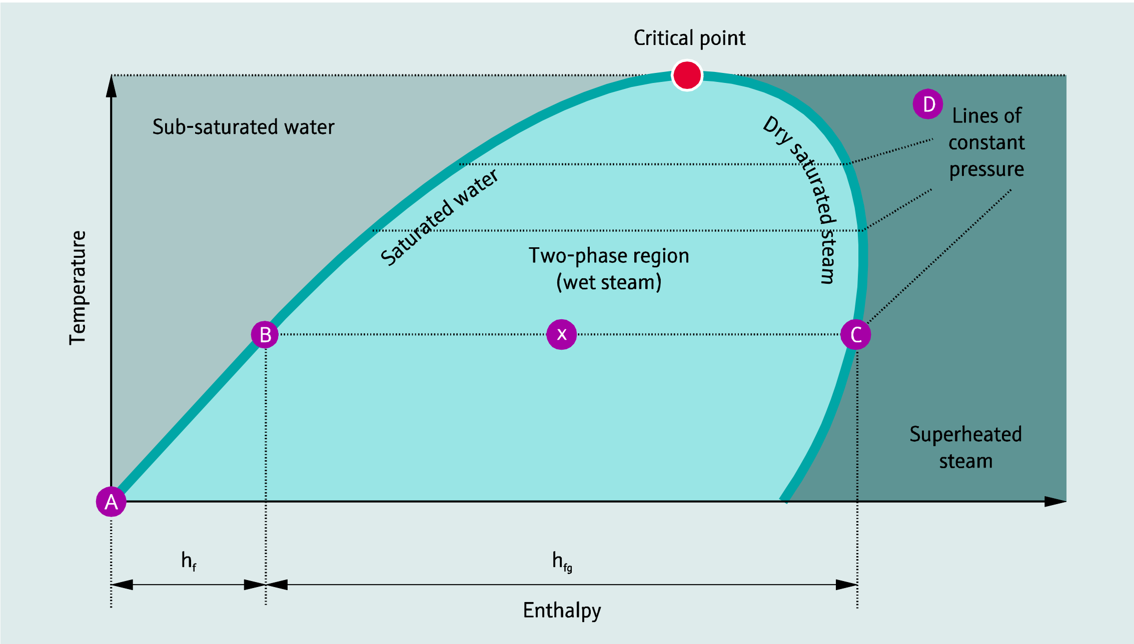

Fig.1: Mollier diagram for water.
Example: Heating liquid water from 20 °C (A) to 100 °C (B) requires about 4.2 kJ/kg·K of energy. In order to convert the water (B) to steam (C) at 100 °C and 1.013 bar abs., 2255 kJ/kg are required (h_f). During this process, the dryness (x-factor) is increased from 0 to 1.

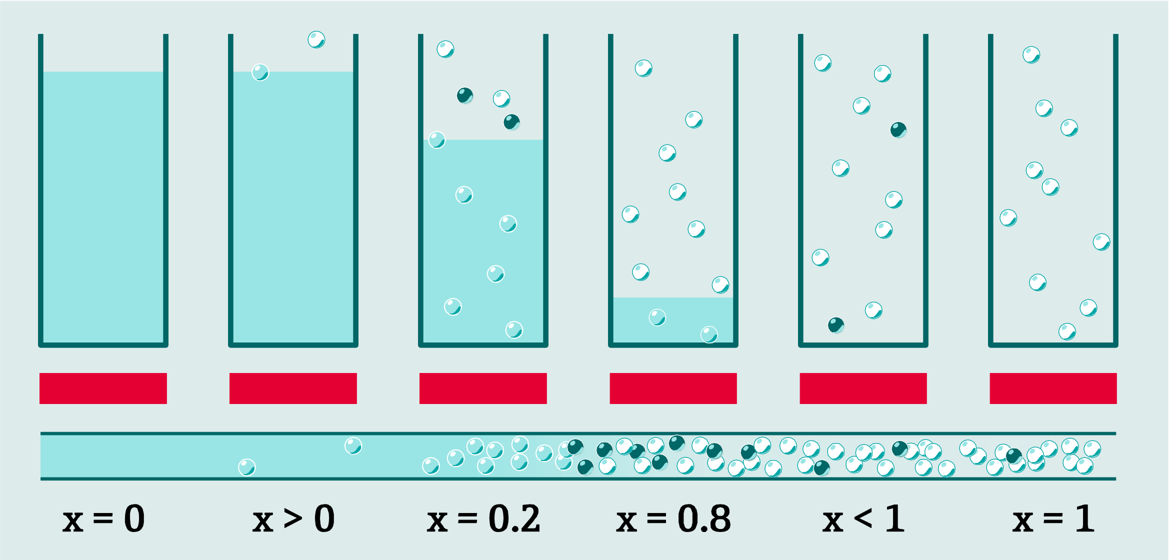

Fig. 2: The dryness of steam is defined by the "x-factor".
If x = 0: water is fully saturated. If x = 1, there is dry saturated steam. If x = 0.8, 80% of the mass of water is in a gaseous state and 20% in a liquid state.

Wet steam

Heat losses in steam piping, e.g. because of lack of isolation, will lead to a reduced dryness fraction. This wet steam can lead to the following problems:

- Water hammer/slug flow caused by the water entering the steam line
- Reduced efficiency of the steam system because wet steam contains less energy than dry saturated steam

If the wet steam is a result of carry-over from the boiler itself, stress corrosion cracking may result. Wet steam, however, is also an issue at the point of end-use. If the condensate trap at the outlet of a boiler does not work, the heat exchanger may drown, thus reducing the heat transfer efficiency drastically.

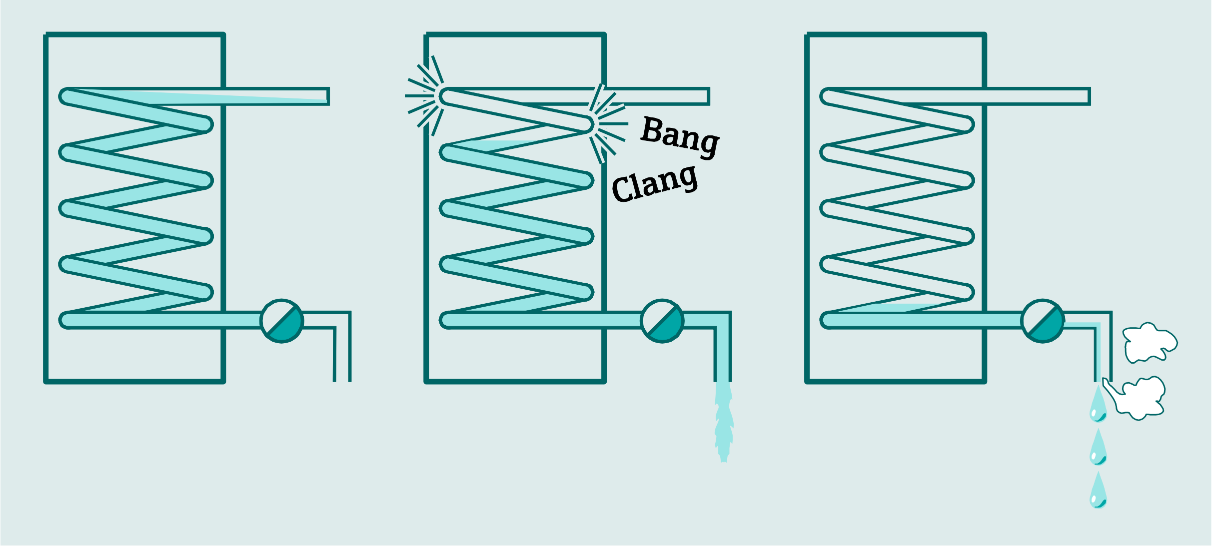

Fig. 3: Drowned heat exchanger (left) resulting in poor steam quality upstream

Another potential problem lies in separator equipment for producing saturated dry steam which is not working properly and which may also result in wet steam and reduced efficiency. All these examples show: Wet steam can occur anywhere in a process heating system – even if it is assumed that the steam has been superheated! Over the recent years, more and more customers have expressed their concerns about these issues to Endress+Hauser. The most commonly asked questions was “How can I find out if the steam is wet?”

Basic research – an investment in the future

The above repeated questions led Endress+Hauser to invest in a steam rig together with the University of Applied Sciences and Arts / Northwestern Switzerland in Windisch. This steam rig allowed us to create steam at different dryness levels and to investigate the effect of moisture in the steam on our new Proline vortex flowmeters. Dryness fractions between 80 and 100% can be generated for line sizes DN 25 (1"), DN 40 (1½"), DN 50 (2"), DN 80 (3") and DN 100 (4"). Steam pressures of up to 10 bar g can be achieved. The wet steam was created in different ways by injecting water as a “river flow”, “mist flow” and by means of a cooling pipe. In all three cases, the investigations showed that in horizontal pipelines increasingly wet steam first formed “channel flow” at the bottom of the pipeline and then “smeared” up along the pipeline walls, independent of how the liquid water was injected.

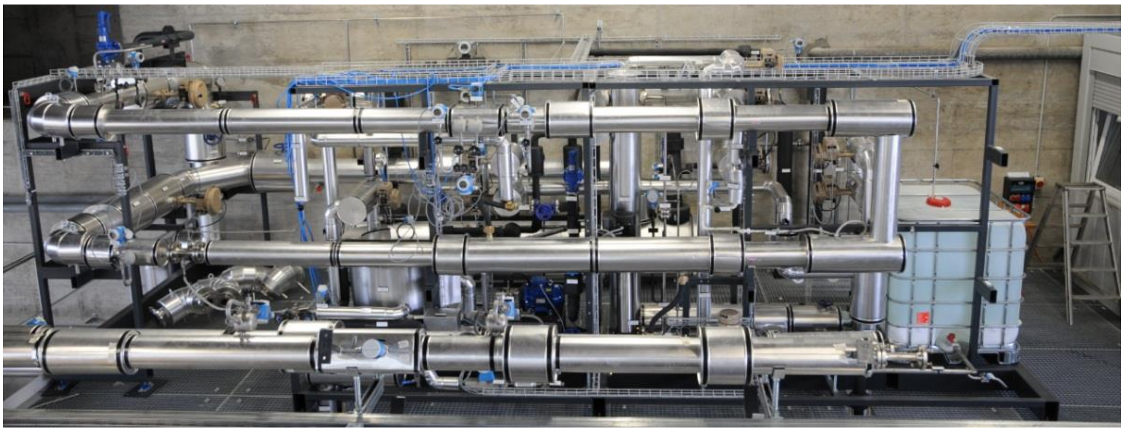

Fig. 4: Steam research facility from Endress+Hauser and the University of Applied Sciences and Arts/Northwestern Switzerland in Windisch

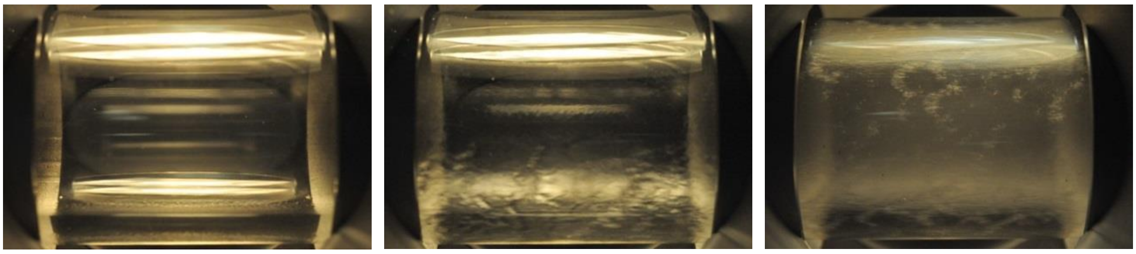

Fig. 5: Steam at different dryness fractions (from left to right: 100%, 95%, 90%). A dryness fraction of 90% means that 10% (mass) of the total water content is present as water containing much less energy than gaseous steam. Therefore, 10% less energy is available!

A wet steam warning

Further research showed that when installing a Prowirl 200 vortex flowmeter into a horizontal pipeline with the electronics head mounted in the "6 o'clock position", the "river flow" mentioned above had an influence on the sensor signal. Its kurtosis, i.e. the steepness of the amplitude, changes because of the changing state of the fluid. This simple fact has an exciting result: The meter can "decide" if the steam present in the pipe is dry or wet. The device even allows a value to be entered for the steam quality below which the device will give a "steam quality" warning.

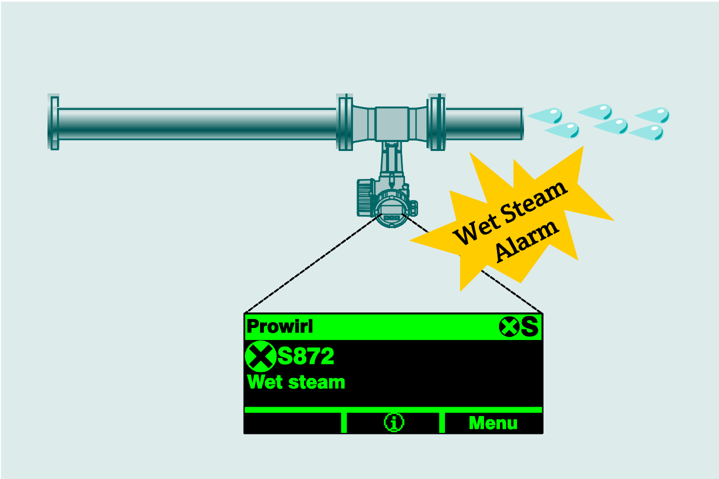

Fig. 6: As soon as "wet steam" is in the pipe, Prowirl 200 issues an alarm message.

The best solution for steam applications

Endress+Hauser has been producing vortex flowmeters for almost 30 years and has gained experience in more than 300,000 applications; more than half of these are in steam. About 10 years ago, the Proline Prowirl 73 was introduced, a multivariable two-wire vortex flowmeter. Even today, Prowirl – today's generation is the Prowirl 200 – is the only multivariable vortex flowmeter family worldwide that combines several benefits:

- Two-wire technology with the best entity parameters for intrinsically safe wiring in hazardous areas
- Mass and energy output, e.g. for steam and condensate according to the international standard IAPWS-IF97
- Ability to read in an external pressure for superheated steam – or saturated steam if desired – via current input, HART, PROFIBUS PA or FOUNDATION Fieldbus
- Ability to read in an external tempertaure to calculate energy added to the feedwater in the boiler via current input, HART, PROFIBUS PA or FOUNDATION Fieldbus
- Greatest known robustness on the market against temperature shocks, water hammer and vibrations – leading to a long life
- Life-time calibration of the meters

The multivariable Prowirl vortex flowmeter is now optionally available with "wet steam detection". We have already received positive feedbacks from several customers that this feature will strengthen Prowirl's position as the best solution available for steam measurement in process heating systems – increasing both safety and efficiency.

Endress+Hauser

Endress+Hauser is a global leader in measurement instrumentation, services and solutions for industrial process engineering. The Group employs more than 10,000 personnel across the globe, generating net sales of 1.7 billion euros in 2012. With dedicated sales centers and a strong network of partners, Endress+Hauser guarantees competent worldwide support. Production centers in 11 countries meet customers' needs and requirements quickly and effectively.

Endress+Hauser provides sensors, instruments, systems and services for level, flow, pressure and temperature measurement as well as analytics and data acquisition. The company supports customers with automation engineering, logistics and IT services and solutions.

Endress+Hauser works closely with the chemical, petrochemical, food & beverage, oil & gas, water & wastewater, power & energy, life science, primaries & metal, renewable energies, pulp & paper and shipbuilding industries.

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