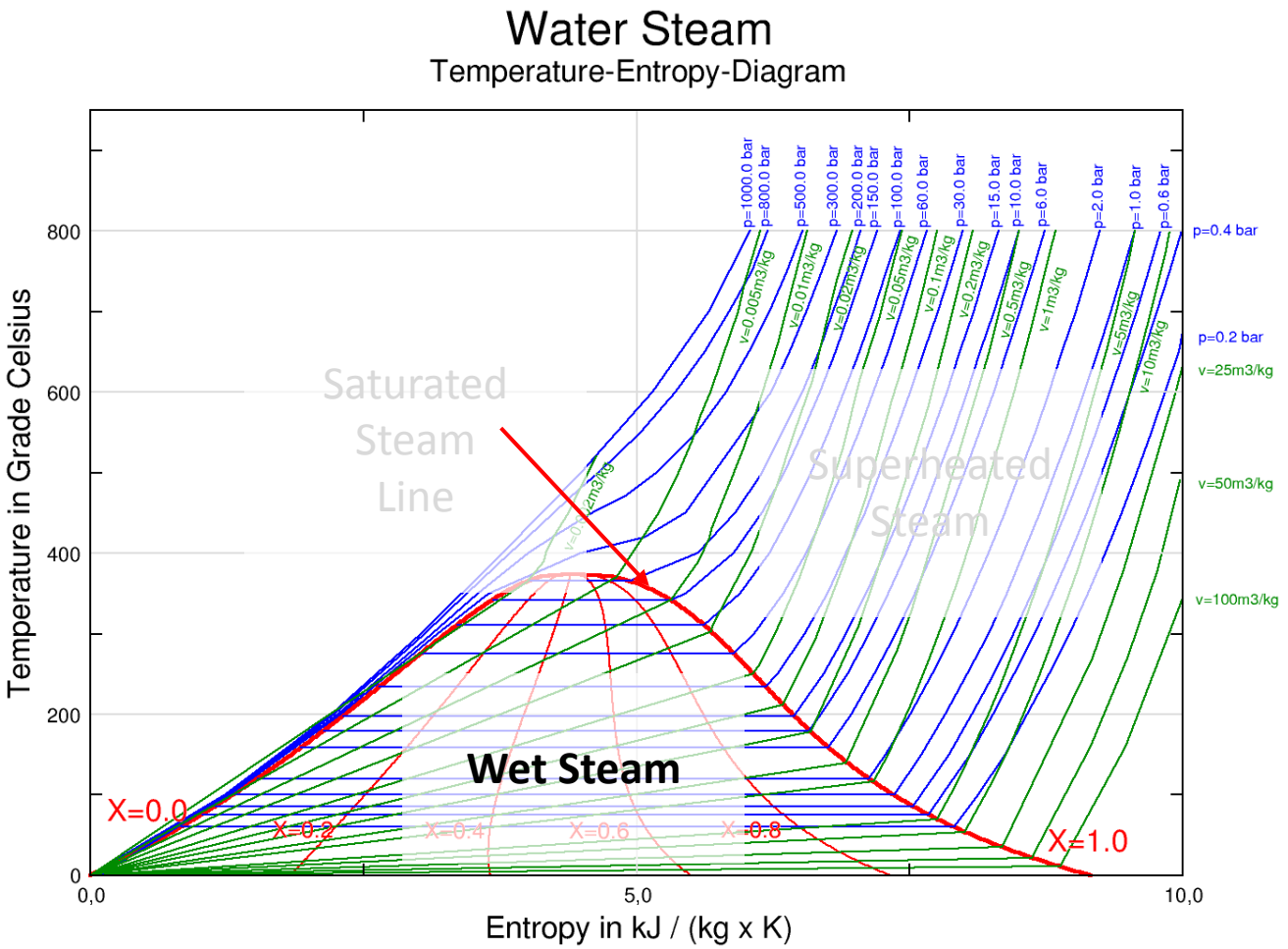
Specialties in Steam Flow Measurement



Flow Measurement in:
Wet Steam: Only with severe limitations

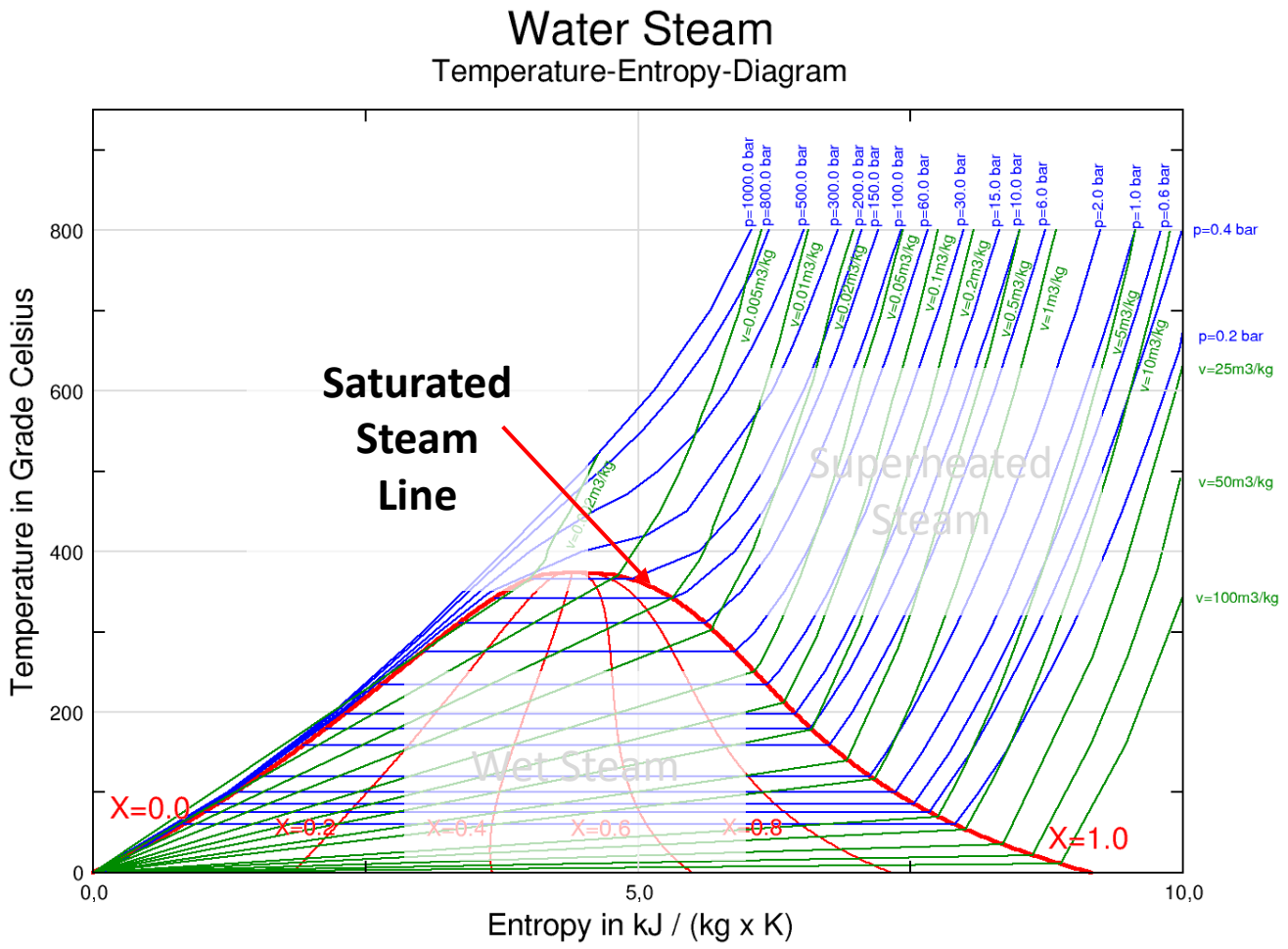
Water content cannot be measured from pressure and temperature because:

Water content x is NO function of p or T

But: Considerable influence of water content on wet steam density

Density cannot be calculated
→ Mass Flow Measurement only with limited accuracy

Specialties in Steam Flow Measurement



Flow Measurement on:
Saturated Steam Line: Possible

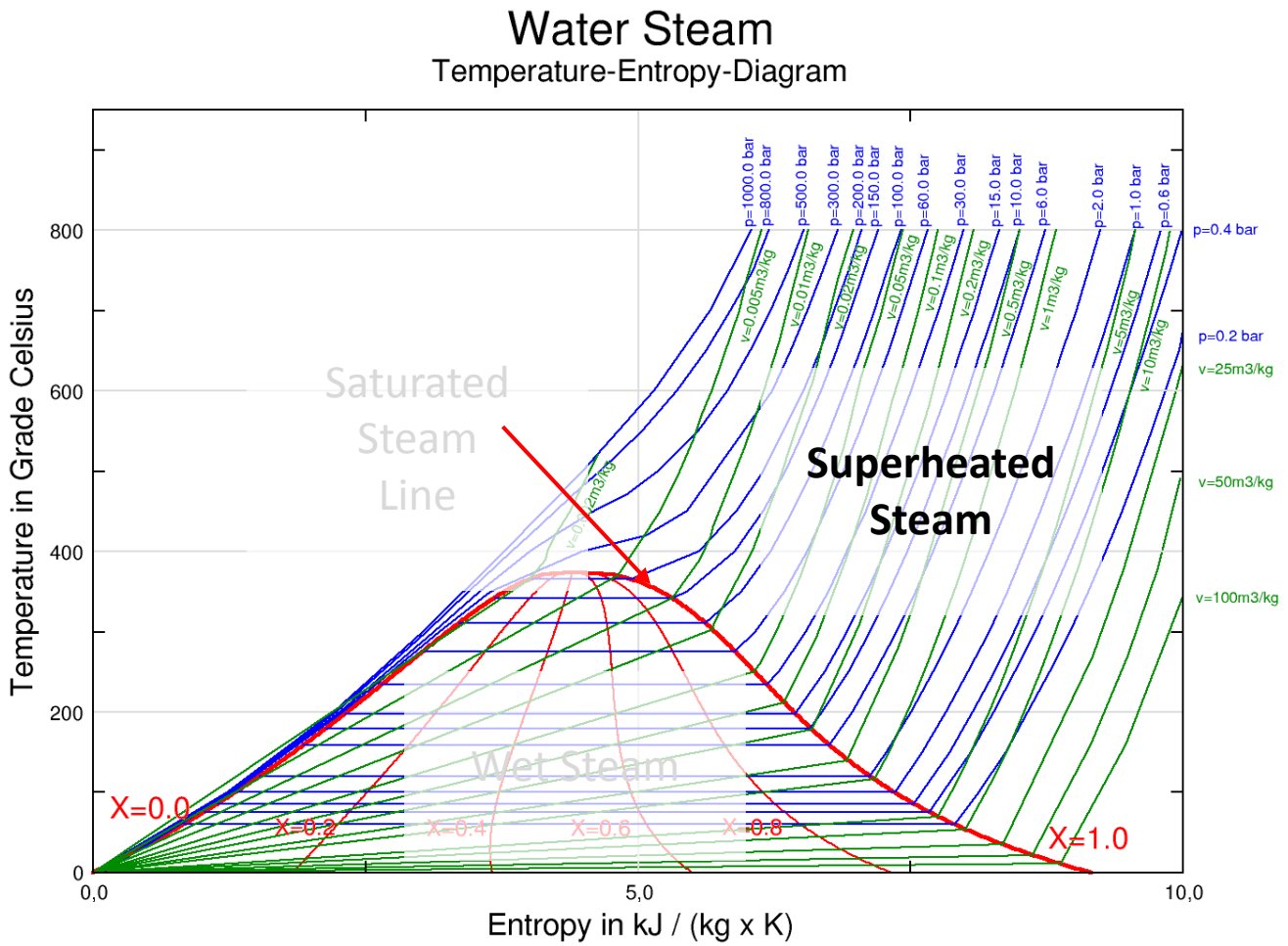
But: Saturated steam is unstable because it is a theoretical concept only valid for specific combinations of temperature/pressure

Theory: Measurement of p or T is sufficient → exact density can be calculated

Practice: very small changes in pressure lead to big change in density (5 mbar pressure loss in pipe, outlet conditions of saturated steam boiler, etc.)

→ In practice operation conditions are not stable enough to treat steam as „saturated“
→ e.g. Saturated Steam Meters operate with temperature measurement → if steam is not 100% saturated → measurement error due to wrong calculated density

Specialties in Steam Flow Measurement

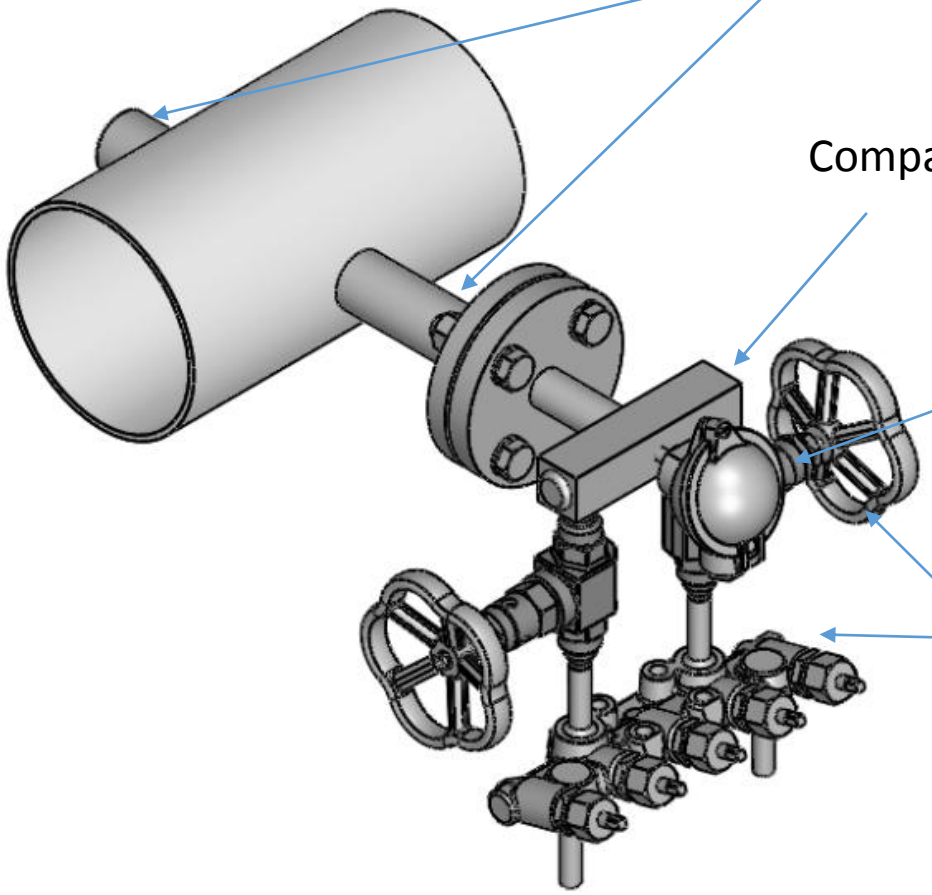


Flow Measurement in:
Superheated Steam: Possible

Superheated steam is very stable

- Pressure and Temperature compensation is required → Density calculation acc. to IAPWS-IF97
- Careful of selection of materials (high temperature, high pressure)

Standard Design of Steam Flow Measurement with SDF-Flow Sensor



Two Point Installation: Flange socket & Counter Support

Compact sensor head: Easy Installation, Minimization of Installation Errors

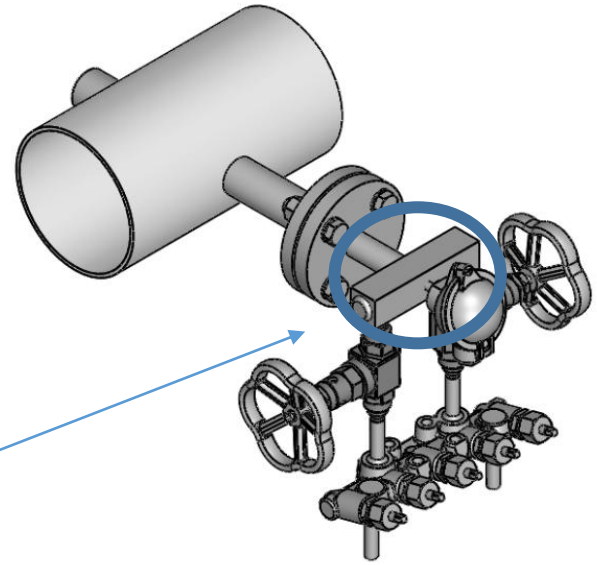
Integrated temperature sensor (optional)
Integrated pressure tap for absolute pressure sensor (optional, not shown)

Direct welded high temperature isolation valves and five-way-manifold for direct installation of dp transmitter and double block isolation for safety

Particularity of Steam Flow Measurement with dp flow meters

- Phase change between inside and outside of the pipe
- Phase change occurs in differential pressure lines or the so called „condensate tanks“
- Density difference between steam and water is in practice > 1:200

  Problem in practice: Different altitude of condensate in the condensate tanks (due to unbalanced installation or uneven internal design of sensor head)
  → wrong dp signal due to water column (1 mmH2O = 0.1 mbar)
  → no problem at full flow
  → if dp at low flow is small, the water column error („wet leg error“) will become the highest error influence



- **Solution**: SDF Compact Sensor head reduces wet leg error considerably
  Allows for placement of spirit level → very balanced installation
  No edges or seams inside → no level difference between both dp-sides

Steam Flow Measurement with SDF-Flow Sensor Design Limits

- Steam Pressure: Up to 300 bar
- Temperature: Up to 660 °C
- Pipe material P235, 16 Mo3 (1.5415), 13CrMo4-5 (1.7335), 10CrMo9-10 (1.7380), , 1.4903 (P91)
- Sensor material 1.4571, 16 Mo3 (1.5415), 13CrMo4-5 (1.7335), 10CrMo9-10 (1.7380), 1.4903 (P91)
- Line Size: up to DN 3.000
- Accuracy: 1% of measured value (0.6% with calibration in spool piece)
- Easy Installation Short inlet section (7*D), no cutting of pipe
- Cost efficient for diameters > DN150
- Pressure drop: Very low (example: DN300 / 200 °C, 10 bar / 30 t/h, 20 m/s → 2,7 mbar)

SDF-Sensors for Steam

Comparison SFD-Sensor to Primary Elements

	SDF Sensor	Orifice	Nozzle	Venturi	Vortex
Max. Size	>1000“	60“	40“	80“	12“
Max. Pressure	PN250	PN400	PN400	PN400	PN64
Accuracy	<1%	0.5-1.3%	0.8-1.2%	1-3%	1.5-2%
Measurement method	Multipoint Average	Single Point	Single Point	Single Point	Single Point
Straight Pipe Sections	7*D inlet 3*D outlet	6-44*D inlet 4-8*D outlet	6-44*D in 4-8 d outlet	8-16*D inlet 3-8*D outlet	15-25*D inlet 5*D outlet
Spool Piece Length	None	65 mm + Flanges	Depends on size		Up to 500 mm
Pressure Loss	0.2-29%	42-95%	23-84%	5-20% of dp	(5-100 mbar)
Cost	Low-Medium	Low-High	Medium		Medium-High

SDF-Sensors for Steam

Comparison SFD-Sensor to other Sensors

Advantages against ISO 5167 primary elements:

- Much Lower pressure loss than orifice and nozzle
- Higher accuracy than venturi
- Considerably shorter straight inlet and outlet sections
- Considerably lower cost, especially for high pressure/high temperature/larger pipe size
- Easier installation and handling (due to weight of sensor, no flanges)

SDF-Sensors for Steam

Comparison SFD-Sensor to Vortex Flow Meter

	SDF Sensor	Vortex
Max. Size	120“	12“
Max. Pressure	PN250	PN64
Max. Temperature	600 °C	400 °C
Accuracy	<1%	1-2%
Measurement method	Multipoint Average	Single Point
Straight Pipe Sections	7*D inlet 3*D outlet	15-25*D inlet 5*D outlet
Spool Piece Length	None	Up to 500 mm
Pressure Loss	0.2-29%	(5-100 mbar)
Handling	Easy installation, no flanges required, low weight	Separation of pipe and installation of flanges necessary, weight can be very high

SDF-Sensors for Steam

Comparison SFD-Sensor to other Sensors

Advantages against Vortex:

- Less required straight inlet and outlet sections
  → Much higher flexibility (Vortex: 15*D / SDF-Sensor: 7*D)
- Can operate at much higher temperature/pressure
- Much higher accuracy:
  Vortex for p < 40 bar: 1,7% error
  Vortex for p < 120 bar: 2,6% error
- Easier installation and handling (due to weight of sensor, no flanges)
  Comparison: 6” 300 lbs Vortex weight 60 kg, SDF-Sensor 5 kg
- Lower cost of sensor, particularly at sizes > DN150

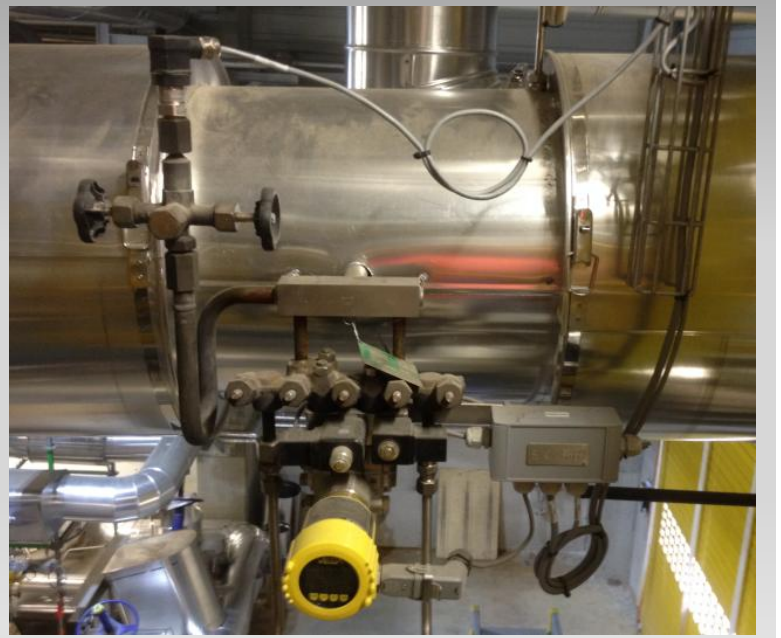
Industry:Gas Fired Power Plant
Client: UPM, Schongau, Germany
Application: Steam Flow Measurement

UPM erected a new gas fired power plant at their facility in Schongau in 2013. The goal was to double the steam output and increase overall efficiency. The power plant supplies not only the paper factory but also nearby households and public institutions.

To fulfill requirements concerning high accuracy as well as large dynamic measurement range.

S.K.I. Scope of Supply:

- 3 Fiscal Steam Measurements: Calibrated AccuFlo-ST
- DN 150, DN 250, DN 800, up to 130 t/h)
- Bidirectional measurement
- 4 Middle and High Pressure Steam Measurement
- 7 AccuFloZero: Automatic Zero-Point Calibration (increasing dynamic range to 1:40 for AccuFlo-ST)
- Supervision and Final Inspection of Technical Installation
- Commissioning of all Measurements



UPM Paper Manufaction, Schongau, Germany

Client: UPM

Location: Schongau, Germany

Year: 2014

Industry: Combined Cycle PP - High Pressure Steam
Client: Siemens, Worldwide
Application: Steam Flow Measurement

Siemens works as an EPC contractor for Combined Cycle Power Plants worldwide. Thanks to modern technology they feature power generation efficiency of 60% and more.

They utilize SDF-Sensors for metering high pressure steam going to the steam turbine to measure efficiency of the power plant.

S.K.I. Scope of Supply:

- 21 High Pressure Steam Measurement for Steam Turbine Performance Test for combined cycle power plants

  Line Size: DN400 to DN600 (16” to 24”)
  Pressure: 35-45 bar
  Temperature 400-500 °C

Siemens Gas Turbine Power Plant, Posco, South Korea

Client: Siemens

Location: Erlangen, Germany

Year: 2009-2015