Kessler-Ellis Application Note F012

Why Measure Steam on a Mass Flow Basis?

The Nature of Steam

Steam is the gaseous form of water. When water is heated at sea level it turns to its gaseous state (boils) at a temperature of approximately 212ºF. If more heat is added the water continues to convert to its gaseous state until all of the liquid has disappeared.

If we carry out the same procedure at altitude (e.g.) boiling water for coffee whilst on a hiking trip in the mountains, we find that although the water still boils the coffee does not stay hot for as long as it does at sea level. This is because the boiling point of water is affected by pressure. In this application note we will refer to pressure in units of pounds per square inch absolute (psia).

As the pressure decreases the boiling point of water decreases, as the pressure increases the boiling point of water increases. Some examples will illustrate this point.

Pressure 14.696 psia (sea level atmospheric pressure)	Boiling point 212ºF
Pressure 50 psia	Boiling point 281ºF
Pressure 100 psia	Boiling point 328ºF
Pressure 200 psia	Boiling point 382ºF
Pressure 400 psia	Boiling point 445ºF
Pressure 800 psia	Boiling point 518ºF

The natural boiling point of water at any give pressure is known as the saturation temperature. Steam produced at these conditions is known as saturated steam. If the steam is heated above its saturation temperature it is known as superheated steam. The number of degrees above the saturation temperature that the steam is heated to is known as the number of degrees of superheat. (e.g.) 100 psia steam heated to 428ºF would possess 100 degrees of superheat.

Water, in all its forms, is one of the best documented fluids. The properties of steam are fully documented in steam tables, the above information on boiling points is derived from this source.

Enthalpy and Density

The enthalpy, or energy, of any substance is completely defined by its temperature, pressure and composition. If we confine our attentions to steam (gaseous water) as the substance then it follows that the energy of a body of steam is completely defined by its temperature and pressure.

From the steam tables it is seen that the density of steam is completely defined by its temperature and pressure. Therefore by making a continuous measurement of temperature and pressure in a steam line we can calculate the density of the steam on a continuous basis.

If we simultaneously make a measurement of the volumetric flow of the steam we can calculate the mass flow of the flow stream. This is done by multiplying the volumetric flow by the density.

Buying Steam or Accounting for its Use

Steam is used for heating, driving turbines etc. How much heating can be done depends on the energy of the steam, how fast a turbine can be driven depends upon the energy of the steam. It follows therefore that steam should be purchased and accounted for on an energy basis in order to avoid over or under charging. As was shown in the previous section density can be taken as an indication of energy.

Steam Mass Flow Versus Volumetric Flow

Most flow measurement devices measure the velocity of the flow stream and use the pipe dimensions in order to infer volumetric flow. A velocity based device cannot correct for changes in density that are caused by pressure and temperature changes. This means that if the velocity (inferred volumetric flow) remains constant but the density of the steam changes the flow meter output will not change.

The customer will be paying the same amount for less energy.

By measuring pressure, temperature and flow and using a SuperTROL-II to perform the mass calculation and compensation function any change in the properties of the flow stream will be detected.

The customer is therefore billed only for the energy that is used.

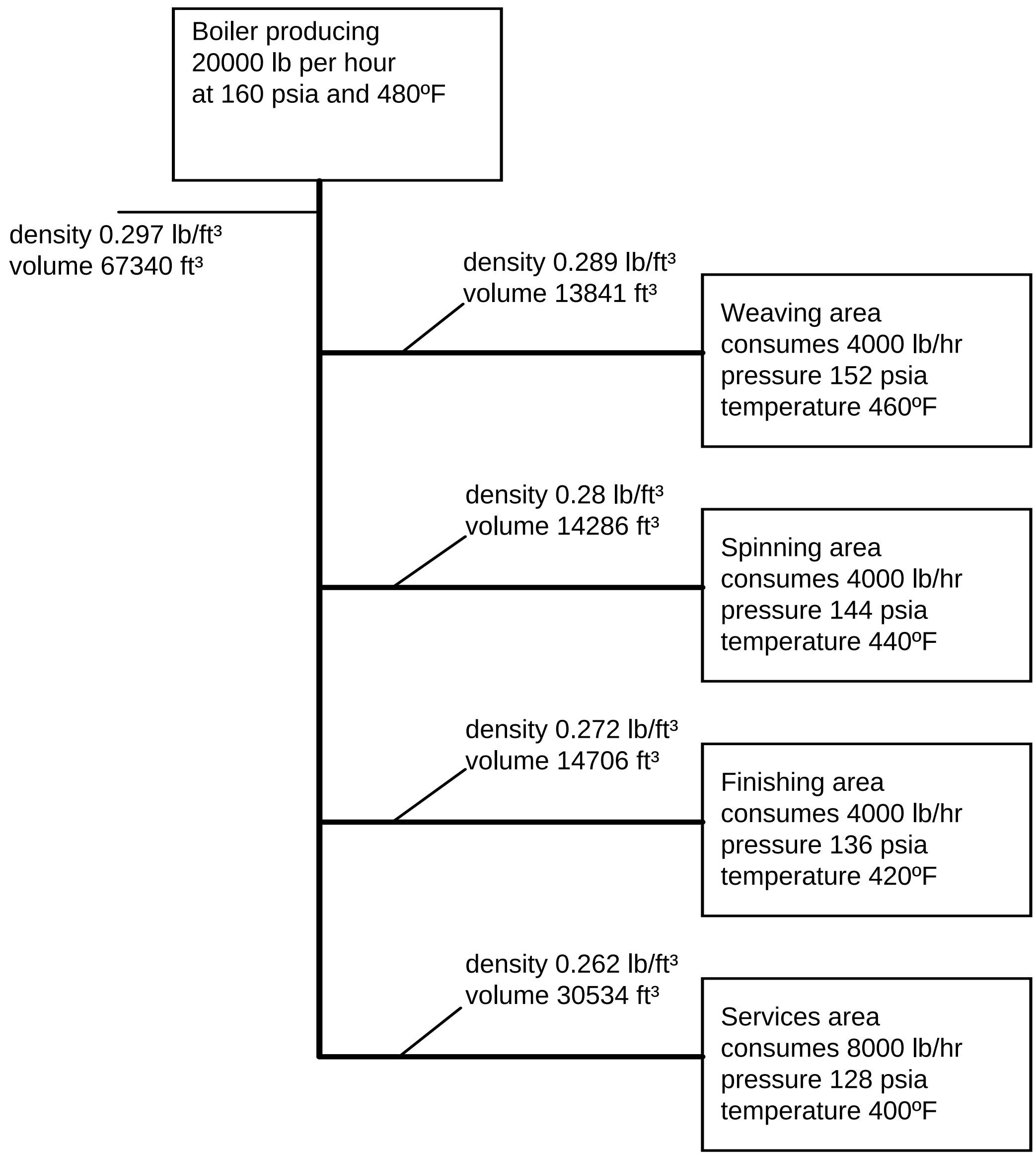
Causes of Temperature and Pressure Loss

There are many causes, the most common are:

- unlagged and poorly lagged pipes
- leaking valves and pipes
- long line lengths
- heavy steam consumption upstream

What Errors can be Caused by Measuring on a Volumetric Basis

The diagram overleaf gives an indication of typical errors that can be caused by measuring on a volumetric basis.



Plant Steam Balances

	VOLUMETRIC		MASS
BOILER OUTPUT	PLANT CONSUMPTION		PLANT CONSUMPTION
20000 lb/hr	weaving 13841 ft³/hr		4000 lb/hr
(67340 ft³/hr)	spinning 14286 ft³/hr		4000 lb/hr
	finishing 14706 ft³/hr		4000 lb/hr
	services 30534 ft³/hr		8000 lb/hr
	total 77367 ft³/hr	**total**	**20000 lb/hr**

As can be seen there is no error in the mass figures (20000 lb/hr into and out of the steam network), but the volumetric figures show a 9% error (67340 ft³/hr into the network but 77367 ft³/hr going out) The errors calculated here are conservative, actual figures on a plant are usually much worse.