A surprising mixed air temperature

QUESTION: In one of our test rigs we mixed two air streams. The first stream was 900 kg/h of air with a temperature of 26 °C and relative humidity (RH) of 100%. The other stream was 800 kg/h at 24 °C and with 30 % RH. In both cases the air pressure was 0.1 MPa. There were also water droplets in the first air stream. When we measured the temperature of the mixture with a sheathed Pt100 sensor the reading was 23 °C, which was lower than any of the two streams. The entire measurement system has been tested and is faultless. The sensor is mounted at a right angle to the wall and protrudes 60 mm into the air channel, which has a diameter of 120 mm. Why are we getting too low a temperature reading?

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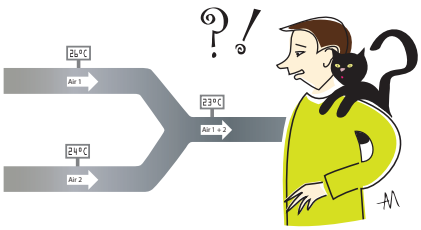

ANSWER: IIn this case we can rule out any fault in the measurement system. If the sensor's attachment to the wall is colder than the incoming air streams, a heat flow along the sensor to the wall could reduce the temperature reading. Radiation from the sensor to the cold walls of the pipe containing the mixed air stream could also cause this effect.

If we disregard the existence of water droplets in one of the air streams, the temperature of the mixture would be 25 °C, the relative humidity 70% and the mixture ratio 0.0139 kg of water vapour per kg of dry air. The incoming air stream with the relative humidity of 100% has a mixture ratio of 0.0213 kg of water vapour per kg of dry air and the air stream with the relative humidity of 30% has 0.0057 kg of water vapour per kg of dry air. [Ref. 1]

Water droplets in the air stream can affect the readings in two ways. First, the droplets that hit the sensor can be vapourised. This requires heat, which is drawn partly from the sensor and partly from the air. The result is a decrease in the temperature of the sensor itself, possibly down to lower than the mixed air temperature of 25 °C.

Questions should be of general interest and be about temperature measurement techniques and/or heat transfer.

QUESTIONS ANSWERS

The second way is that the mixed air stream becomes humidified via the water droplets. The mixed air stream is not saturated, which means that more moisture can be added. Vaporising of the droplets requires heat, which is drawn from the air, and the air temperature decreases. At the same time both the relative humidity and the mixture ratio increase. We would achieve the same effect by spraying water into the air. If the mixed air stream were to become saturated with water vapour, the relative humidity would be 100%, the mixture ratio 0.0155 kg of water vapour per kg of dry air, and the temperature 21 °C. Depending on how much water is added to the air from the droplets, the temperature of the air mixture will be within the interval of 21 – 25 °C. The cause of the temperature drop is probably a combination of both the vapourisation processes.

[Ref. 1] The thermodynamic concepts are explained in more detail in e.g. Pentronic News No. 2, 2009, page 3.

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