Process Controls SalesNet

Moisture Applications

Moisture Control in Paper Drying

Background

This application note addresses Honeywell's Dew Point Solution Set, a moisture control package for energy optimization in paper-drying applications.

The Paper Web - The Existing Problem

A paper web typically enters a dryer as two-thirds water and one-third fiber and leaves the dryer with 6% moisture content. The pounds of water removed per pound of paper produced, including the 6% water, may be approximated as 1.85 pounds. It takes 971 BTUs to evaporate a pound of water at 100° C (212° F).

For a mill producing 1 million pounds (500 tons) of paper per day, the cost of evaporating water can be estimated as $7,185 a day:

1,000,000 lbs paper x [1.85 lbs water/lb paper] x

[971 BTU/lb water] x [1 therm/100,000 BTU] x [$0.40/*therm] =

$7,185 a day

*A therm is defined as 100,000 BTU, and a typical price for this amount of energy is 40 cents.

For a mill operating 350 days per year, the annual bill for evaporating water from paper would be $2.5 million. Reducing this cost by even a small percentage can result in significant dollar savings.

One way to save money using dew point control is to raise the process dew point so that the drying air is carrying away as much moisture as possible consistent with maintaining paper quality. Additional savings available through compensating for changes in ambient humidity are described but not estimated in this application note.

Raising the Process Dew Point

Adding dew point control allows a paper manufacturer to raise the process dew point while maintaining both production rate and paper quality. Raising the dew point simply means increasing the amount of water that the drying air absorbs before it is exhausted. This is accomplished by either decreasing the drying air flow or recirculating the drying air until the higher dew point is achieved. Described here is a method for estimating the potential savings. In the next section a control strategy for a simple dryer is outlined along with required hardware.

A Specific Example

As an example, we calculate the energy savings resulting from raising the dew point from 80° C (176° F) to 90° C (194° F) in two steps. First we calculate the total air flow saved resulting from the increase in dew point. Then we assume a process temperature and calculate the energy saved by not heating the saved air to the process temperature.

In a table of water vapor partial pressure vs. temperature, a dew point of 80°C corresponds to 355 mm Hg water vapor pressure, and a dew point of 90° C corresponds to 526 mm Hg water vapor pressure. Since total pressure is 1 atmosphere, or 760 mm Hg, a dew point of 80° C corresponds to a moisture content of 355/760 = 46.7% water and 53.3% air by volume, and a dew point of 90° C corresponds to a moisture content of 526/760 = 69.2% water and 30.8% air by volume.

In order to calculate the difference in the amount of water that will be carried away at these two dew points, these volume percentages must be converted to weight percentages. This is done by using the molecular weight of water (18 amu) and of air (29 amu—volume or mole fraction weighted average of components of air). AMU stands for "atomic mass units," a measurement system that defines the lightest isotope of the hydrogen atom as 1 (unity). The transformation from the two volume percentages to weight percentages involves the following calculations:

80° C dew point:

46.7% x 18

46.7% x 18 + 53.3% x 29

= 35.2 weight % water

90° C dew point:

69.2% x 18

69.2% x 18 + 30.8% x 29

= 58.2 weight % water

Finally, we calculate the pounds of water that can be carried away by each pound of initially dry air for each dew point:

80° C dew point: 35.2% / [1-35.2%] = 0.543 pounds of water per pound of dry air.

90° C dew point: 58.2% / [1-58.2%] = 1.39 pounds of water per pound of dry air.

Now we can calculate the pounds of dry air required per million pounds of paper at the two dew points:

80° C dew point:

1,000,000 lbs paper x 1.85 lbs water / lb paper

x 1 lb dry air / 0.543 lbs water =

3.4 million lbs of dry air

90° C dew point:

1,000,000 lbs paper x 1.85 lbs water/lb paper

x 1 lb dry air/1.39 lbs water =

1.3 million lbs of dry air

This corresponds to a savings of 3.4 - 1.3 = 2.1 million lbs of dry air per million pounds of paper produced.

An added complication here is the fact that the air actually used to dry the paper does not start as "dry air" but has some relative humidity at ambient temperature. In fact, compensating for changes in relative humidity is another source of energy savings with dew point control. For simplicity, however, we show that this effect is small and then neglect it. For instance, 100% RH at "room temperature" (25° C) corresponds to a water vapor partial pressure of 23.7 mm Hg, or about 3% by volume. Calculating weight percentage as above, this leads to about 2% by weight, corresponding to only about 0.02 lbs of water per lb of dry air. We can neglect this factor for two reasons: It is a small amount compared with the differences between the 80° C and 90° C dew point moisture contents, and the correction turns out to be in the same direction for each condition.

The resulting energy savings will depend on the temperature in the drying hood and that of the ambient air being heated. As an example, consider the savings if the ambient temperature is 25° C (77° F) and the drying temperature is 200° C (392° F). The specific heat of air over this temperature range is about 0.240 BTU/Lb^{0}F = 0.432 BTU/Lb^{0}C. The energy saved per million lbs of paper is:

2.1 million lbs of dry air x 0.432 BTU/Lb^{0}C x [200 - 25] ^{0}C =

159 million BTU.

If each therm [100,000 BTU] costs 40 cents, this translates to:

159 million BTU x [therm/100,000 BTU] x [$0.40/therm] =

$636 per million lbs of paper.

If 1 million pounds were the daily mill production and the mill operated 350 days per year, this would amount to yearly savings of $222,600, or almost one quarter of a million dollars.

A General Method

With this calculation, a mill operator could enter conditions and production rate to estimate the savings from dew point control. However, the savings rate is complicated by the fact that the results depend not only upon how many degrees the dew point can be raised but also critically upon exactly what temperatures are being compared. This is because the amount of moisture that air can hold increases progressively more rapidly as the dew point approaches the boiling point of water. For instance, we saw that as the dew point was raised from 80° C to 90° C, the pounds of water per pound of dry air increased from 0.543 to 1.39 for an increase of 0.847.

However, a dew point of 70° C corresponds to only 0.276 pound water per pound dry air. Therefore raising the dew point 10° C from 70° C results in an increase in moisture content of only 0.543 - 0.276 = 0.267 pounds of water per pound of dry air. This is only about one third of the increase in moisture content observed in raising the dew point from 80° C to 90° C.

Therefore, in order to apply the savings calculation to a given mill:

1. Start with $636 per day, or $222,600 per year.
2. Multiply by mill production divided by 1,000,000 lbs/day.
3. Multiply by the difference between the drying and ambient temperatures divided by 175^{0}C.
4. Estimate the present dew point and the new, higher dew point.
    - A. Calculate the resulting pounds of water per pounds of dry air for each dew point as shown above.
    - B. Calculate the pounds of dry air per million pounds of paper for the two dew points.
    - C. Calculate the savings in pounds of dry air required to dry 1,000,000 lbs of paper.
    - D. Multiply by the result from step C divided by 2.1 million lbs.
5. Multiply by the price per therm divided by $0.40.
6. For the yearly estimate, multiply by the number of days the mill is running divided by 350.

As an example: Calculate the savings possible for a mill producing 300 tons of paper per day with an average ambient temperature of 60^{0}F, a drying temperature of 450^{0}F, a present dew point of 160^{0}F, an anticipated new dew point of 180^{0}F, paying $0.36/therm, and operating 340 days per year.

1. Start with $222,600 per year.

2. Multiply by 300 tons per day x [2,000 lbs/ton]/1,000,000 lbs/day = 0.60.

3. Multiply by [450 - 60]°F x [10°C/1.80°F]/175°C = 1.24.

4. A. The present dew point = 160°F = 71°C.

The new dew point = 180°F = 82°C.

B. Calculate pounds of water per pound of dry air:

a. Partial pressure of water

71°C dew point = 244 mm Hg

82°C dew point = 385 mm Hg

b. Volume percent

71°C: 244/760 = 32.1%

82°C: 385/760 = 50.7%

c. Weight percent

71°C: 32.1% x 18 / [32.1% x 18 + 67.9% x 29] = 22.7%

82°C: 50.7% x 18 / [50.7% x 18 + 49.3% x 29] = 39.0%

d. Pounds water per pound dry air

71°C: 22.7% / [100% - 22.7%] = 0.293

82°C: 39.0% / [100% - 39.0%] = 0.639

C. Calculate the pounds of dry air per million pounds of paper

71°C dew point:

1,000,000 lbs paper x 1.85 lbs water / lb paper

x 1 lb dry air / 0.293 lbs water =

6.3 million lbs of dry air

82°C dew point:

1,000,000 lbs paper x 1.85 lbs water / lb paper

x 1 lb dry air / 0.639 lbs water =

2.9 million lbs of dry air

D. Savings in pounds of dry air required to dry 1,000,000 lbs of paper:

6.3 million - 2.9 million = 3.4 million lbs.

E. 3.4 million / 2.1 million = 1.6.

5. $0.36 / $0.40 = 0.9

6. 340 days / 350 days = 0.97

Resulting Projected Savings: [The product of the results in steps 1-6]:

$222,600 x 0.6 x 1.24 x 1.6 x 0.9 x 0.97 = $231,330

A Control Strategy

Figure 1 shows the dryer, hardware, inputs, and flows. It is assumed that temperature control for the rolls is operating independently of temperature control for the dryer air. It is further assumed that a blower with enough capacity to cover all drying requirements continually blows dry air into the intake manifold. Shown here is a dryer hood with the capability of recirculating the exhausted air. A strategy where recirculation is not available is described below.

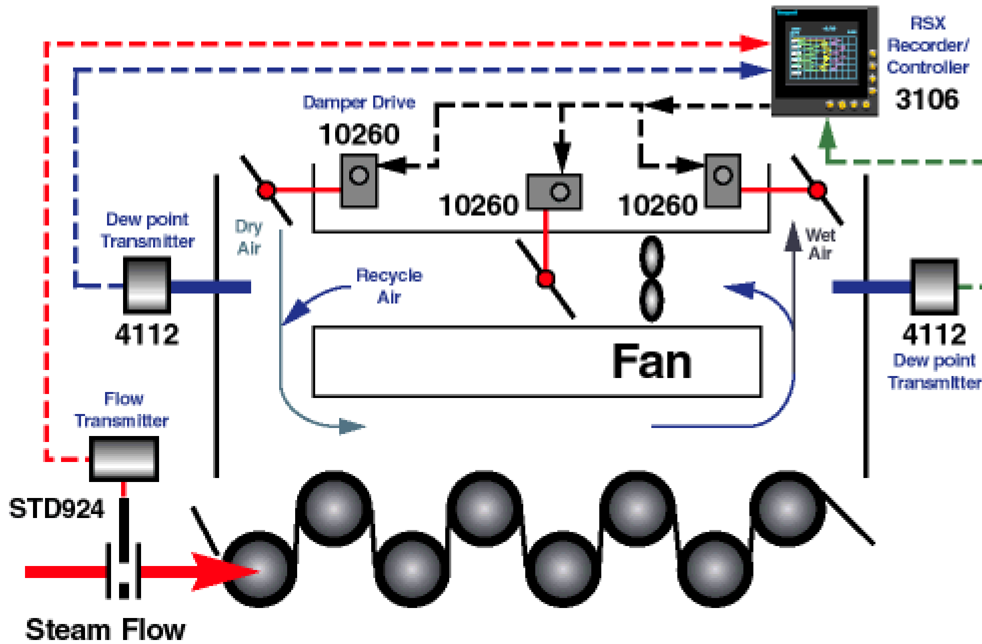

figure 1

The goal is to control the exhaust dew point. In practice, the operator may want to try to increase the dew point until he sees some problem with the paper quality and then decrease the dew point below that point by a "safety margin."

The exhaust air dew point sensor will provide dew point PV signal to the Recorder/Controller. The controller will operate the three dampers as follows:

1. When the dew point is below setpoint, the exhaust and inlet dampers will be driven toward the closed position, and the recycle damper will drive toward the open position. This will cause more air to be recycled, raising its dew point.
2. When the dew point is above setpoint, the exhaust and inlet dampers will be opened and the recycle damper will be driven toward the closed position, allowing more dry air to enter the dryer, lowering the dew point.

4112 Dew Point Guarded-layer Sensor

Taking advantage of the control strategy requires a dew point sensor that is accurate and reliable when exposed to drying hood conditions, which are hot, wet, and dirty and have high vibration levels. The guarded-layer sensor withstands these

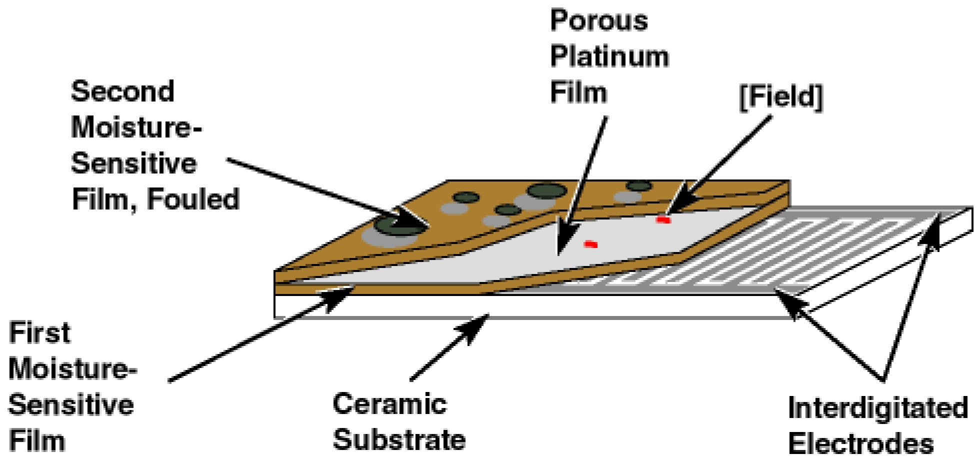

figure 2

conditions.

The guarded-layer sensor is constructed as indicated in Figure 2.

A pair of interdigitated electrodes is deposited on an inert, nonconducting ceramic substrate and covered with a moisture-sensitive thin film . The moisture in the surrounding atmosphere comes into equilibrium with that in the film, resulting in a moisture-dependent capacitance between the interdigitated electrodes. If the structure were complete at this point, a high-temperature moisture sensor would be the result. However, unless the film were very thick, accuracy would be affected by fouling. Material adhering to the top surface of the film would alter the capacitance and, thus, the inferred moisture concentration. If the film were made thick enough to avoid this problem, the response of the sensor to changes in moisture content would be unacceptably slow. To avoid these limitations, a thin, porous platinum film is deposited on the moisture-sensitive film. This structure is equivalent to two capacitors in series—providing a first capacitance from the first interdigitated electrode to the porous platinum film and a second capacitance from the film back to the second interdigitated electrode. Finally, a second moisture-sensitive film is deposited onto the platinum film.

The purpose of this final layer is twofold. First, the moisture-sensitive material is a mechanically strong, abrasion-resistant polyimide serving to protect the platinum film. Second, a small portion of the electric field of the double capacitor extends beyond the platinum film but not beyond the second moisture-sensitive film. Were it not for this second layer, dirt or oil depositing on the platinum film could alter the capacitance, providing a result that was dependent on sensor fouling. Thus the second moisture-sensitive layer provides a capacitance independent of material depositing on the sensor, providing results that are independent of fouling.

Hardware Options

Required for Dew Point Control are:

1 Honeywell 4112 dew point transmitter

1 Honeywell 3106 Progeny video recorder

3 Honeywell 10260 drive units

Required for full process monitoring are:

1 (additional) Honeywell 4112 dew point transmitter

1 Honeywell STD924 Flow Transmitter.

If the air temperature at either dew point transmitter location exceeds 185^{0}C [365^{0}F] then a cooler option is recommended. Consult Honeywell.

Dryers without Recirculated Air

The control strategy is to control dew point by controlling air flow: If the dew point exceeds setpoint, flow is increased to bring fresh dry air into the dryer; if dew point falls below setpoint, air flow is decreased to allow it to absorb enough moisture from the web to get back to setpoint.

Hardware requirements are similar to those above, except that the drive unit and damper for the recycled air plenum are not required.

Summary

Raising the dew point can yield significant savings in the energy used in paper drying. A specific example as well as a general method for estimating savings are described. A simple control strategy for paper drying is outlined. Required is an accurate and reliable sensor that withstands conditions in a paper drying hood. The Guarded-Layer Dew Point Sensor meets this challenge.

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