Moisture Control in Drying Applications

(Metric units)

A major cost in the rapid drying of any product containing water, is the cost of the energy used in the process. By controlling the moisture level in the drying process, the amount of energy used can be controlled and minimized. Some examples of products that are dried using large amounts of energy are paper, paper products, wood, wood products, gypsum board (drywall, wall board, sheet rock), grains, cereals, and other food products.

The drying of paper will be used as an example since this process is very energy intensive.

Typical paper drying process

Paper is approximately 33% fiber and 67% water as it enters the dryer. The drying process reduces the water content in the paper to approximately 6% of the total weight of the paper. Approximately 1.8 Kg of water must be evaporated for each Kg of paper that is produced. The paper passes over a series of hot rolls which are heated from the inside by steam. The energy to evaporate the water from the paper comes from the hot rolls.

Air is used to carry away the water that is evaporated from the paper. Outside air is blown into the dryer. The water vapor that is evaporated from the paper is dissolved into the air, and the mixture is exhausted from the dryer through a duct to the outside of the building.

The intake air typically has a dew point of less than 20° C (2% water vapor by volume). The temperature of the intake air will vary depending on the geographic location of the paper mill and the season of the year. This intake air becomes heated to the exhaust temperature of the dryer. Energy must be supplied to the dryer to raise the temperature of the air from the intake temperature to the exhaust temperature. The exhaust temperature is usually above 200° C for paper dryers.

Absolute moisture scales

The moisture content of the exhaust air can be expressed by one of three popular moisture scales. These are "dew point temperature", "% moisture by volume", and "Kg of water per Kg of dry air". The third scale (Kg water per Kg dry air) is called Humidity Ratio (HR). Typical values for the moisture level of the exhaust could be a dew point temperature of 80° C which is 47% moisture by volume, which is a HR of 0.552Kg/Kg.

Table 1 –Absolute moisture data

Dew Point Temperature	%moisture by volume	HR (Kg water/Kg dry air)
20° C	2%	0.0127
75° C	38%	0.381
80° C	47%	0.552
85° C	57%	0.824
90° C	69%	1.38

Dryer adjustments

The amount of air entering the dryer is usually controlled by adjusting the position of a damper. If the position is set manually, the moisture content of the exhaust can vary over time due to variations in operating conditions. It is generally known that the higher the moisture level of the exhaust air, the lower the energy used in the process. However, If the moisture level of the exhaust is allowed to get excessively high problems can occur. These problems are things like equipment corrosion due to condensation, and poor product quality due to drops of water from condensation on the product. Because of the potential problems caused by excessive moisture levels, dampers are typically set at levels where the normal changes in operating conditions will never produce the problems associated with excessive moisture level.

If the moisture level can be controlled to a known constant value, then the level can be safely increased without risking the problems caused by excessive moisture levels. If the moisture level of the exhaust can be accurately measured, then the damper position can be automatically controlled by a motor that responds to the output of the instrument. In this way the moisture content of the exhaust can be automatically controlled to maintain optimum drying conditions.

Exhaust moisture level

From the data in table 1 we can see that for an exhaust dew point temperature of 80° C, 0.552 Kg of water is carried away by each Kg of dry air. The small amount of water by weight in the intake air can be ignored for the calculations that follow. At a dew point temperature of 85° C, 0.824 Kg of water is carried away for each Kg of intake air.

For each Kg of paper produced, 1.8 Kg of water must be removed. The weight of intake air to carry away this amount of water is shown in table 2.

Table 2 -Kg of intake air per Kg of paper dried

Exhaust Dew Point temperature	Kg of intake air per Kg of paper
75° C	4.72 Kg
80° C	3.26 Kg
85° C	2.18 Kg
90° C	1.30 Kg

If the intake air temperature is 25° C, and the exhaust temperature is 200° C, then the temperature of the intake air must be increased by 175° C. If the dew point temperature can be controlled at a higher value, then less intake air is needed for each Kg of paper that is produced.

Typical cost savings by using moisture control

We will now estimate the cost of the energy saved by controlling the exhaust dew point temperature to 85° C as compared to an exhaust dew point of 80° C. The difference in the amount of air required to dry a Kg of paper is 1.08 Kg (3.26Kg-2.18Kg).

A typical paper mill might produce 500,000 Kg of paper each day. The difference in the total air that must be heated each day is 540,000 Kg. This mass of air must be heated 175° C (200° C -25 °C). The specific heat of air is 1012 J/(Kg x °C)

The cost of energy can vary by geographic location and the type of fuel used. The cost of energy is always increasing as the world wide demand for energy increases. A typical value is $0.40 per 100 million Joules.

$$\text{Daily savings} = \frac{540{,}000 \text{ Kg X } 175\ °\text{C X } 1012 \text{ J/(Kg X °C)}}{100{,}000{,}000 \text{ J/\$0.40}} = \$\ 382.00 \text{ per day}$$

A typical paper mill may operate 350 days per year. The yearly savings is $ 133,700.00

The method of calculating the cost of energy saved that is described above can be used for any type of product that must be dried.

As can be seen from the above calculations, the cost of the hardware to automatically control the moisture of the drying atmosphere can pay for itself in a very short time.

Moisture measurement

The MAC125 moisture analyzer made by Mac Instruments Co. is used in many drying applications throughout the world. The MAC125 output signal can be configured by the user as either “% moisture by volume” or “Humidity Ratio (Kg of water per Kg of dry air)” The HR scale is used in most drying applications. Refer to the “Mac Humidity / Moisture Handbook” for data to convert between the absolute moisture scales of dew point, % moisture by volume, and Humidity Ratio. This document can be viewed on the Mac Instruments web site www.macinstruments.com.