DRYER MODEL

Introduction:

This document will outline the basis of a generic mathematical model of a dryer. The model may be used to solve unknown values associated with the drying process and thus form a feed-forward element in the control strategy for dryer operation. The general (simplified) format of the model may be applied to most of the commercial dryers used in industrial, agricultural and pharmaceutical applications, such as rotary, conveyor, flash, pulverizer and batch type dryers.

Dryer Model:

The dryer model is shown in the schematic below, Figure 1.

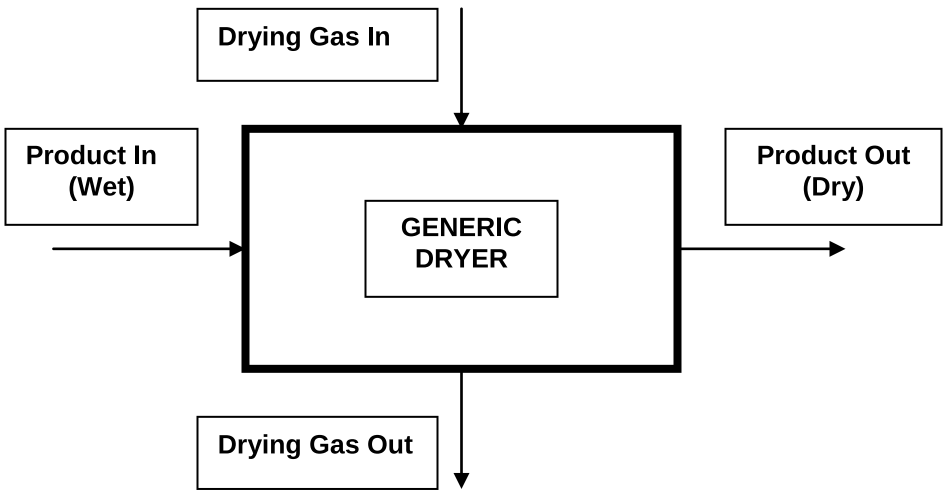

FIGURE 1.

The drying process within the model is based on the characteristics shown in Figures 2 & 3 for the product and the drying gas respectively.

Product Flow:

The product enters the dryer at a given temperature and some initial moisture content which may not be known. The wet product is initially heated by the drying gas to raise the temperature of the wet product to the wet bulb temperature. During this phase no drying occurs.

When the wet product reaches the wet bulb temperature, evaporation of moisture can occur. The heat of vaporization is provided by the drying gas and the drying process may continue until one of the following conditions is met. Either the available moisture in the product is evaporated or the drying gas reaches its saturation point. The available moisture is that moisture which is on the surface of the product or easily “wicked” to the surface. The remaining moisture in the product is water of hydration etc. which could only be removed by batch drying in an oven, for example.

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Assuming the drying gas contains sufficient energy to remain above the saturation temperature at the outlet, the product temperature will rise above the wet bulb temperature at which the evaporation took place.

The process for the product is shown below in Figure 2.

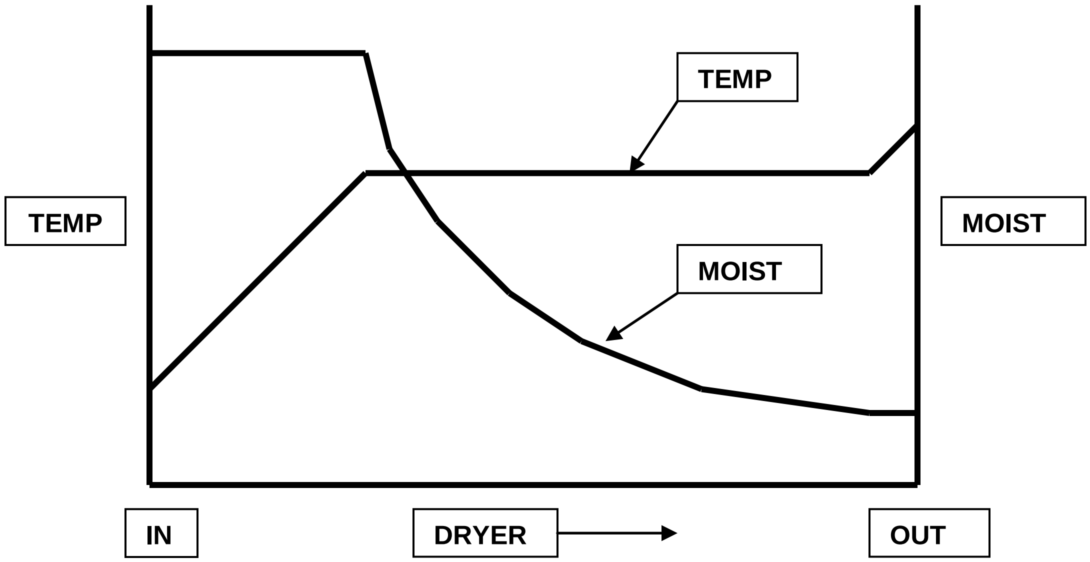

FIGURE 2.

If incomplete drying of the available moisture is desired, the product will leave the dryer at the wet bulb temperature.

<u>Drying Gas Flow:</u>

The drying gas enters the dryer at an elevated temperature with a relatively low humidity ratio (lbs of moisture per lb of dry gas) and leaves at a lower temperature with a higher humidity ratio. The leaving temperature must be higher than the wet bulb temperature at which the evaporation occurs.

The process for the drying gas is shown in Figure 3.

The psychometric chart for the actual process conditions is used to display the progress of the drying gas through the dryer. No assumptions are made regarding the orientation of the drying gas relative to the product flow, e.g., parallel, counter or cross flow.

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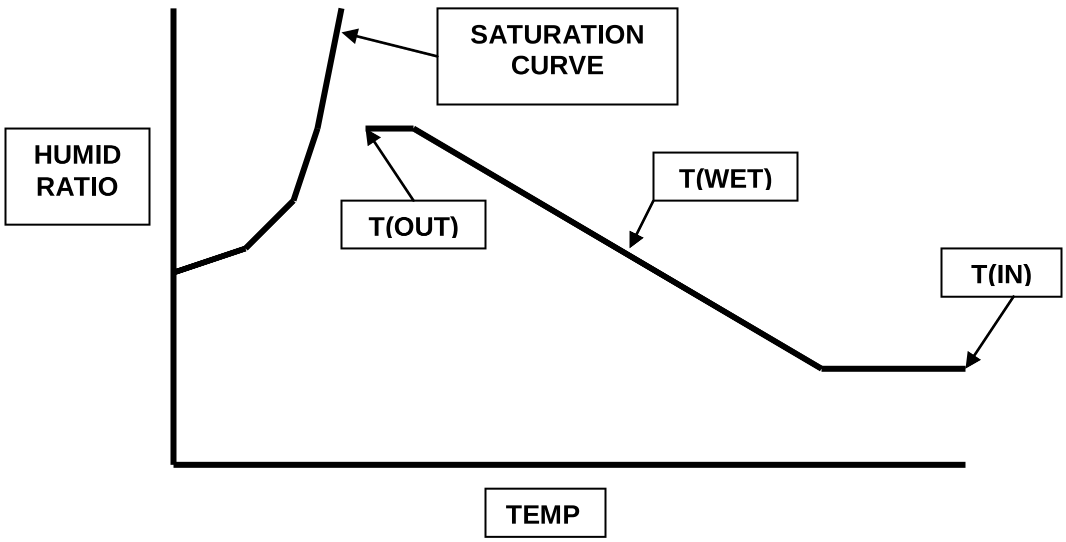

FIGURE 3.

Capabilities of the Model:

The model may be applied in various forms depending on the data available. The most useful, however, is to determine the product moisture entering and leaving the dryer. In order to provide these results; the product inlet flow and temperature to the dryer, the drying gas flow, temperature and humidity entering and leaving the dryer, the product temperature leaving the dryer and the specific heat of the bone dry product are required.

The model can handle incomplete or complete drying of the available moisture and provide a tool to compare differing drying strategies to establish the most energy efficient operating mode.

Running the model on-line within the control system provides the feed-forward signal to enhance operation of the dryer.

Alternative Application:

Where the mass flows of the product and the drying gas (air) are not known, the measurement of the humidity in the gas leaving the dryer together with its temperature may be used to determine the wet bulb temperature at which the drying occurs (refer to figure 3 above). A product temperature leaving the dryer which is greater than the wet bulb temperature of the gas signifies that all the drying possible has been achieved. The difference between these two temperatures may be safely reduced to a minimum value (< 10 ^{0}F typically) without affecting the dryer operation. This would permit savings in the fuel consumption per ton of product dried. The inclusion of this delta temperature within the control system ensures that the drying efficiency is maintained during all operating conditions.