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Flotation Dryer Design

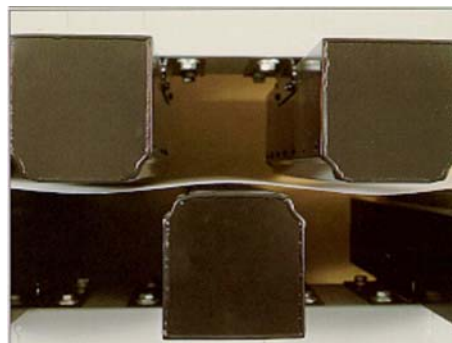
By William R. Henry,
Advance Systems, Inc.

Flotation drying is an evolving, increasingly complex technology. Fifty years ago, commercial dryers were little more than open-flame burners directed over a moving web. Today, a modern flotation dryer is an efficient, vital component in the manufacture of the most structurally complex and chemically sophisticated products. It is estimated that more than 125 patents have been issued throughout the world for flotation drying concepts and advancements in technology. As products and equipment have advanced in sophistication and capability, flotation dryer technology has become increasingly precise, efficient and flexible. Dryers now can float and dry products that range from the most delicate 0.25 mil optical-quality film to coated steel sheets with a thickness of 0.09" and weighing 3.75 lb/ft².

While today it can process a range of coatings, substrates and solvents, a noncontacting hot-air flotation dryer still performs three basic functions:



Modern flotation dryers such as this multizone pressure-sensitive adhesive (PSA) dryer will dry and cure coatings on both light- and heavyweight substrates while maintaining web alignment through the process.



The "sine wave" shape of the web in a flotation dryer serves to increase heat transfer efficiency while stiffening the product to aid in maintaining web alignment.

- Float the web, by carrying the web through the dryer without contacting the top and bottom surfaces.
- Transfer heat, by heating the web in such a way that the carrier solvent begins and continues to evaporate.
- Transfer mass, by carrying away the freed solvent and removing it from the coating and web surface.

The custom design of the dryer

will seek to optimize these three functions while achieving the required end-product specifications. The factors that affect and limit heat transfer and mass transfer are varied and complex. Therefore, an effective dryer design must be able to accommodate the combined effect and interaction of several factors, including:

- Physical and chemical characteristics of the web, coating and solvent.
- Drying limitations or requirements during the drying process.
- Equipment characteristics of the different drying mechanisms.

Some of these parameters such as heat capacity or coating viscosity are well known or easily obtained. Other information such as air-bar drying characteristics and the effect of air velocity and web speed on the rate of evaporation only can be determined empirically. In the past, with only one type of air bar and a given air velocity, it was not difficult to determine the effect of air temperature on drying a particular product. Modern dryer designers have a choice of 20 to 30 different drying elements, including air nozzles, bars and foils. Air velocities can range from 300 to 15,000 ft/min while air temperatures may vary from 100 to 1,000°F (38 to 538°C). The list of solvents,

substrates and coating solids also is increasing steadily.

With all of these variables in mind, the challenge to define an optimum drying solution requires that each of the three factors — product characteristics, drying limitations and equipment characteristics — be defined and modeled.

PRODUCT CHARACTERISTICS

The defining characteristics of the substrate, coating and solvent will serve to define the range of air temperature, air velocity, air exhaust and web-handling techniques to be used. The substrate or web conditions that will affect drying and flotation include line tension; web width, thickness and weight; heat capacity; percent moisture;

glass transition temperature, if applicable; and the temperature of entering web.

The amount of wet coating and its initial percent solids, viscosity and thickness all are used to compute the heat absorption of the solids and the evaporation rate of the solvent as the coated web passes through the dryer. A low coating viscosity may restrict the force of air that can be applied, and the chemical composition of the coating solids will determine its physio-chemical response to heat.

Similarly, the solvent's chemical and physical characteristics such as heat capacity, diffusion coefficient, heat of vaporization, eccentricity (non-ideal behavior), viscosity, and Antoine coefficients (vapor pressure-temperature

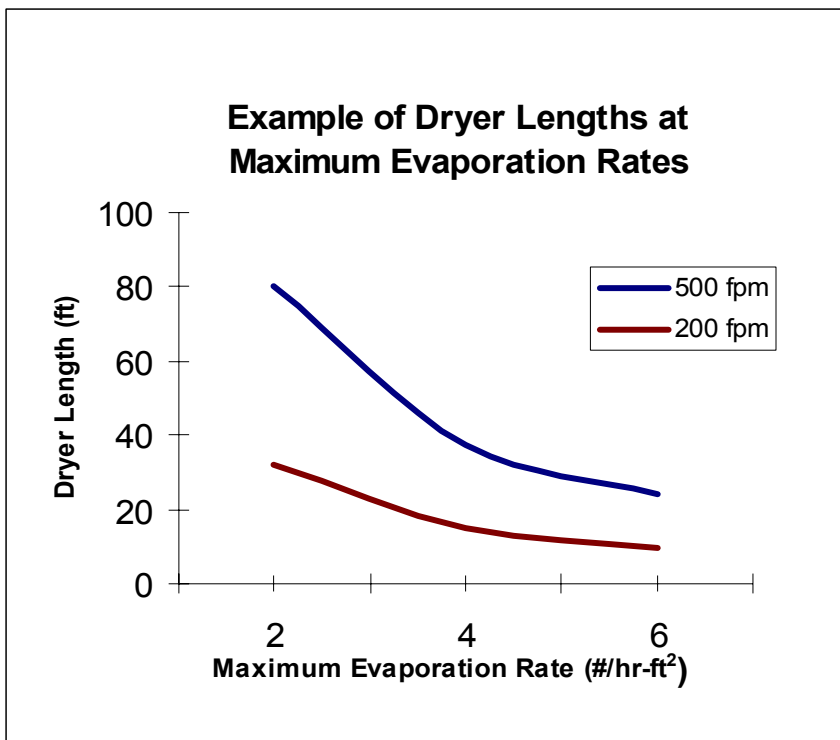
relationship) are used to predict the rate of temperature rise and evaporation. For obvious safety purposes, it is necessary to avoid reaching the autoignition temperature, the point at which the solvent will spontaneously combust.

Another important parameter is the low flammability level (LFL) of the involved solvent. By calculating the amount of evaporated solvent at each point of the drying process, the amounts of fresh and recirculated air will be regulated to ensure that the concentration of airborne solvent stays well below this flammability level.

DRYING LIMITATIONS

A number of products also may have drying limitations that directly impact dryer design. Coatings that contain a high volatility solvent (e.g., toluene, alcohols) cannot be allowed to evaporate at too high of a rate (measured in lb/hr-ft²) without causing blisters, bubbles, irregularities or discoloration. When a low "maximum evaporation rate" exists, it usually will become the single most important and direct factor in determining achievable line speed and dryer length (figure 1).

Figure 1. This is an example of the relationship between line speed, dryer length and maximum evaporation rates. The product is a water-based coating on 50 lb/ream paper substrate.



Similarly, if the pressure velocity of the impinging hot air is too severe, it may disturb the coating surface, resulting in ridging or mottling. Finally, physical limitations — for example, coating density, porosity and diffusion rate; the moisture migration rate from the coating and the web; and the absorption characteristics of the web — may be present. These limitations will determine how aggressively the product can be dried.

EQUIPMENT EFFECTS

While the dryer length, air supply temperature, humidity, air volume and web speed have a direct impact on the drying rate, it is the type and physical arrangement of the delivery mechanisms (air bars, airfoils, hole bars) that will determine the sum efficiency and effectiveness of the dryer. Each mechanism possesses an inherent ability to float the web, affect heat transfer and carry freed solvent away from the product.

Spacing or pitch of the air bars, the web-to-nozzle distance and the velocity of the air impinging on the web all have a dramatic effect on dryer performance. Unlike the physical and chemical specifications of the coating or solvent, the characteristics of each air bar, foil or nozzle must be determined empirically in lab trials and

then incorporated in a computer-based dryer sizing model that will predict accurately the individual product drying curves.

COMPUTER MODELING OF DRYING PARAMETERS

The purpose of the computer-based drying program is to integrate the product characteristics, drying limitations and unique performance characteristics of the drying mechanisms to determine a precise simulation of dryer performance.

model provides information on the required air supply volume, air exhaust rate, air humidity, web exit temperature and the drying load or energy consumption. Having established these critical parameters, it is then a relatively straightforward process to design an appropriately sized dryer enclosure, drying mechanisms, hot air plenums, fans and interconnecting ductwork that make up the dryer system.

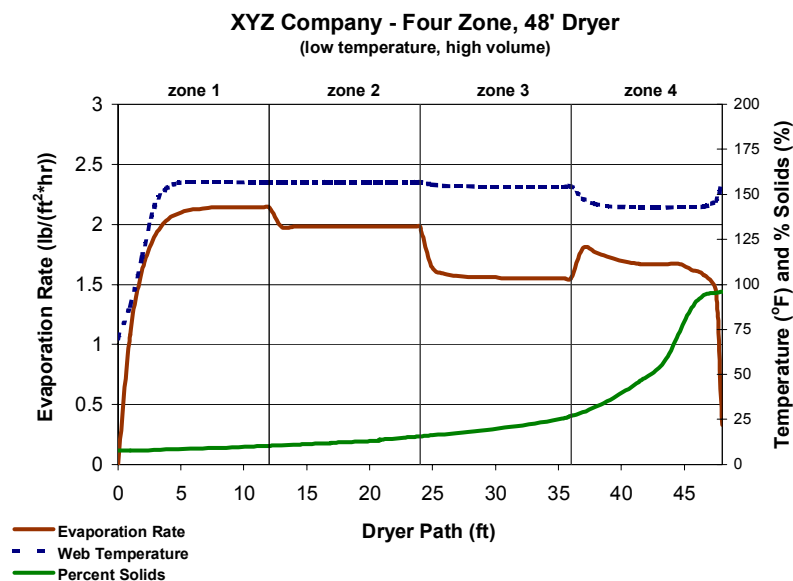


Figure 2. This example of a product of a computer simulation shows the evaporation rate, web temperature and percent of solids of the proposed dryer design.

Essentially, the program produces a plot of key variables such as web temperature, moisture content, LFL percentage, percent coating solids and rate of evaporation as the product moves through the length of the dryer. In addition, the

The determination of the appropriate dryer temperature, air velocity, air-

bar type or air volume often is an iterative process in which a certain level is selected and the model is run to see if all of the product and process criteria will be achieved. If the result is unsatisfactory, a new level is chosen and the model is run again. This process continues until all of the predetermined conditions can be satisfied. It should be noted that more than one "solution" can satisfy a particular set of process and product criteria. As such, the final dryer design selection should may consider secondary objectives such as space requirements, energy consumption or access for cleaning. The complexity of the drying application will determine the amount of product/process information to be gathered for the computer-modeling software (figure 2).

While in any given application, many different variables must be taken into account, a qualified dryer manufacturer will assist in establishing a list of key product characteristics and process limitations necessary to design the optimal dryer.

William R. Henry is President of Advance Systems, Inc., Green Bay, Wis. For more information on Advance Systems Inc.'s dryers:

Call (920) 468-5477.

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