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## Through drying

### Scope

Through air drying (TAD) is a process in which hot air is forced through a wet, porous material by imposing a pressure differential across the material. As the air passes through the porous material, the air heats the material and supplies energy to evaporate water. The air leaves at a reduced temperature and increased water vapor concentration. It is the intimate contact between the hot air and the material, coupled with the large internal surface area of the porous material that gives the high drying rates and superior bulk qualities of paper. This process, however, often comes at the price of high energy consumption.

In the paper industry, this process has found greatest application in drying of lightweight, permeable webs, such as tissue, toweling, filter paper, and nonwovens, producing “structured tissue” products in which the fiber matt is formed or pressed to produce a bulky, embossed, contoured surface pattern. In such applications, the through dryer may be either a flat bed or rotary design (one or more drum arrangements), often followed by a steam-heated cylinder for the final drying and sheet creping. The flatbed configuration is illustrated in Fig. 1 and the rotary design in Fig. 2. In this second configuration, hot air can be forced through the web by pressurizing the porous cylinder, in which case a hood collects the exhaust air, or hot air can be drawn through the web by applying a vacuum to the porous cylinder, in which case the hood is used to distribute the hot air (as shown).

The air can be heated either indirectly through a heat exchanger or directly by mixing with products of combustion of a clean fuel (such as natural gas, LPG, or methane) in a burner or the hot air exhaust from a gas turbine or from the hood of a Yankee drying cylinder. Thermal efficiency is significantly increased by recirculating and reheating part of the through air dryer exhaust, or using the exhaust air in or from a subsequent air impingement dryer, if one is used in the process. Typical recirculation rates for stand-alone through air dryers range from 50 to 80% of the process air. This recirculation system is shown schematically in Fig. 1 and 2. Part of through dryer exhaust is removed from the recirculation system to take out evaporated water and, if direct fired, combustion water vapor. The air that is exhausted from the system is made up by fresh air intake, infiltration, and products of combustion.

Information in this paper serves as a general outline of conventional through air dryer machine parameters. Considerable progress has been made in analytical treatment of both the recirculation system and the through air drying process and several new (generally proprietary) drying processes have been developed. Drying rates, flow velocities and energy levels may be higher for new dryers than the ranges indicated in this paper. Abbreviated analytical descriptions of the through drying process are presented here to provide a basic knowledge of the process. Details on the TAD process may be found in the references listed at the end of this Technical Information Paper.

### Safety precautions

This TIP includes equations for calculating drying rates for through air dryers, using known values of basis weight, machine speed, moisture contents, and dryer area. Equations are also provided for calculating drying rates using known values of air flow rate and supply and exhaust humidity. Safety precautions, appropriate to the method

used, should be taken in working around through air dryers. Particularly, care should be taken to avoid direct contact with rotating components and with hot ducts, supports, burners, dampers, and fans.

### Definition of drying rate

For through drying applications, it is customary to define drying rate in terms of actual heat transfer or flow-through (contact) area of the web. This definition of drying area differs from that used for conventional steam cylinder drying of paper and packaging grades (TIP 0404-07 "Paper Machine Drying Rate"), where total cylinder area is used as the basis for the calculation. Wrap angle on rotary through dryers is typically about 230-320° of the dryer periphery. On a contact area basis, typical drying rates for through air drying applications range from 150 to 590 kg/h•m<sup>2</sup> (30 to 120 lb/h•ft<sup>2</sup>).

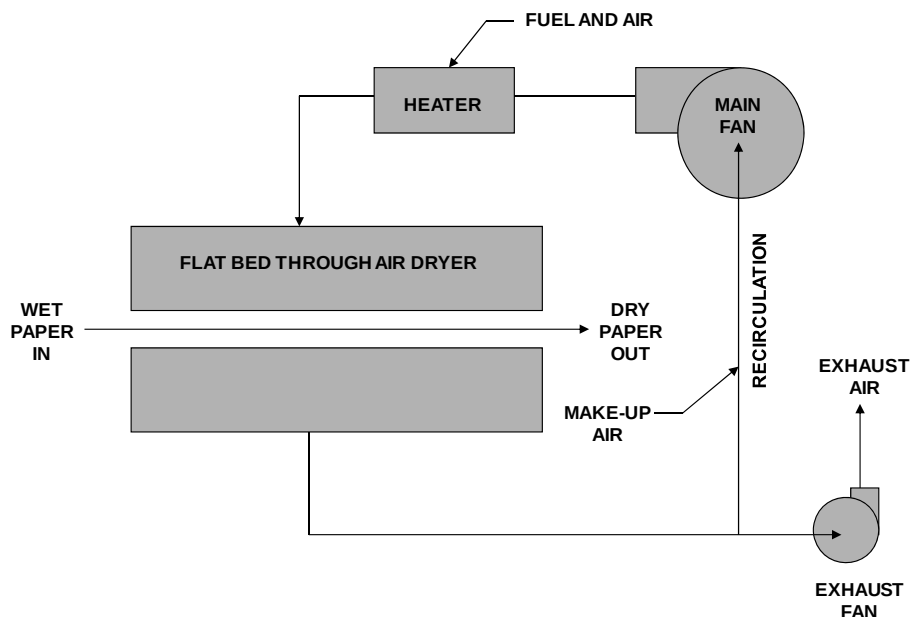


Fig. 1. Flat bed through dryer system.

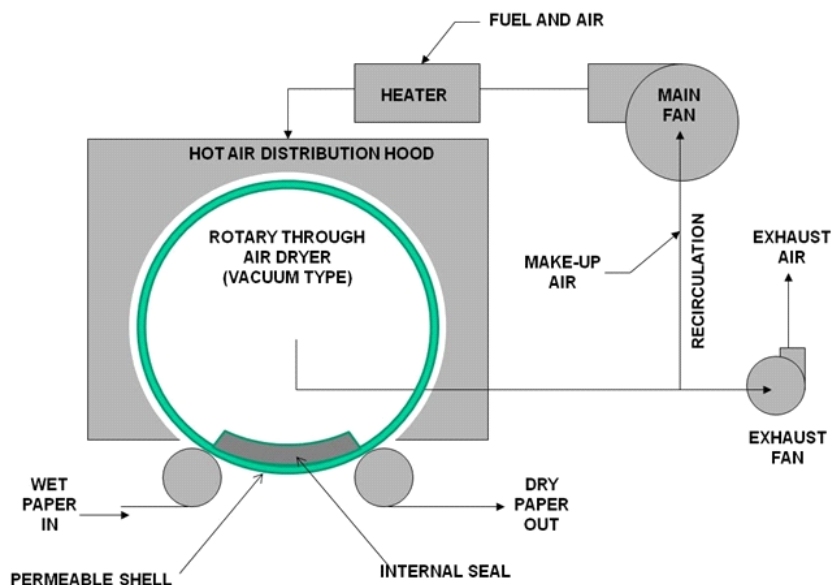


Fig. 2. Rotary through dryer system.

From operating data, drying rate  $R$  can be calculated by the following equation:

$$R = \frac{(M_i - M_o)SWC}{L} \quad (1)$$

where  $L = \pi D \theta / 360$  for a rotary through dryer. (2)

and the parameters are defined as follows:

| Parameter | Description                       | SI Units              | English Units          |
|-----------|-----------------------------------|-----------------------|------------------------|
| R         | Drying rate                       | kg/h • m <sup>2</sup> | lb/h • ft <sup>2</sup> |
| S         | Machine speed                     | m/min                 | ft/min                 |
| $M_i$     | Ingoing moisture content          | kg-water/kg-dry fiber | lb-water/lb-dry fiber  |
| $M_o$     | Outgoing moisture content         | kg-water/kg-dry fiber | lb-water/lb-dry fiber  |
| D         | Through dryer diameter            | m                     | ft                     |
| W         | Bone dry basis weight             | g/m <sup>2</sup>      | lb / ft <sup>2</sup>   |
| $\theta$  | Angle of sheet wrap               | degrees               | degrees                |
| C         | Conversion factor                 | 0.06 kg min/g h       | 60 min/h               |
| $\pi$     | 3.14159                           | None                  | None                   |
| L         | Length of dryer flow-through area | m                     | ft                     |

For example, through drying rate can be calculated for the following conditions and Equations 1 and 2:

| Parameter | Value (SI units)                                                                             | Value (English Units)                                                                             |
|-----------|----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| S         | 1220 m/min                                                                                   | 4000 ft/min                                                                                       |
| $M_i$     | 3.00 kg-water/kg-dry fiber                                                                   | 3.00 lb-water/lb-dry fiber                                                                        |
| $M_o$     | 0.50 kg-water/kg-dry fiber                                                                   | 0.50 lb-water/lb-dry fiber                                                                        |
| D         | 3.7 m                                                                                        | 12.0 ft                                                                                           |
| W         | 16.3 g/m <sup>2</sup>                                                                        | 10.0 lb/ 3000 ft <sup>2</sup>                                                                     |
| $\theta$  | 270° degrees                                                                                 | 270° degrees                                                                                      |
| C         | 0.06 kg min/g h                                                                              | 60 min/ h                                                                                         |
| $\pi$     | 3.14159                                                                                      | 3.14159                                                                                           |
| L         | = $\pi (270 / 360) 3.70 = 8.72$ m                                                            | = $\pi (270 / 360) 12.0 = 28.3$ ft                                                                |
| R         | = $(3.00-0.50) 1220 (16.3) 0.06 / 8.72$<br>= 342 kg/h • m <sup>2</sup> of heat transfer area | = $(3.00-0.50) 4000 (10.0/3000) 60 / 28.3$<br>= 70.7 lb/h • ft <sup>2</sup> of heat transfer area |

### Thermodynamic description of the drying process

Through drying of a wet web is essentially an adiabatic process. Although a small amount of water may be removed mechanically from very wet webs with high air velocities, by far the most important mechanism in commercial through air drying is thermal drying.

With air and water vapor at atmospheric pressure, the TAD drying process can be followed on a conventional air-water psychrometric chart, as shown in Fig. 3. Air is supplied at temperature  $T_1$  and absolute humidity  $H_1$  (g-water/g-dry air). As the air passes through the web, there is a simultaneous transfer of heat and mass. Air temperature decreases to  $T_2$  while the humidity increases to  $H_2$  and the process follows the adiabatic exchange line 1-2. If  $G$  represents mass flow rate of dry air per unit of flow area (kg/h-m<sup>2</sup>), then drying rate is computed by the following equation:

$$R = G (H_2 - H_1) \quad (3)$$