How Pulp is Dried

The mechanism of drying involves two distinct operations:

1) **Heating Air in a Steam Coil** - In the coils: the re-circulating air is heated by steam

2) **Carrying Moisture Away from the Pulp Sheet** - at the surface of the sheet: hot air heats the sheet and carries away water vapour evaporated from the sheet

The Role of Heating Air in a Steam Coil

Temp ^{o}F	**Solubility of water vapour lb/100 lb air**
4	1
59	10
126	100
188	1000

Heating air in a steam coil is a common industrial operation. By heating the air, we increase its capability to accept water. The solubility of water in air is highly related to temperature, as shown in the adjacent table. At -40^{o} the solubility of water in air is 0.008 lb/100 lb air - we call this instrument air. At 188^{o}F (87^{o}C) air can carry its own weight of water vapour.

In the selection of a coil for pulp drying, there is a trade-off to be made between pressure drop and the outgoing temperature of the air. Greater pressure drop gives lower air flow, and a correspondingly higher temperature. A widely accepted misnomer is that higher temperature alone results in better drying. This is not entirely true. Drying a sheet of pulp is not only dependant on temperature but also on the dryer's ability to carry moisture away.

Optimizing the coil design can be detrimental to heat transfer at the pulp sheet surface. We now know the role of air flow in the heat transfer process at the pulp sheet has been under-estimated, and that in many dryers, <u>air flow is the controlling factor in drying capacity.</u>

The Role of Carrying Moisture Away from the Pulp Sheet

It is obvious that air supports the sheet, and conveys heat for the drying. What is less apparent is that the air also conveys the water vapour away from the sheet. And even less apparent is that it scours the boundary layer of cool wet air away from the surface of the sheet, and in so doing enhances the heat transfer. This will be shown below both pictorially and in terms of classic heat exchange theory.

We like to think of the air as a *solvent* for water vapour. On this basis one can see that a steam leak is more serious than just a loss of steam – not only is it a loss of driving force for the evaporation process, but it is also a vehicle for introducing more moisture which is counteractive to the role the dryer is playing.

Water in the pulp sheet is not boiled off - it evaporates at the wet bulb temperature of the air it is contacting, which typically would be between 110^{o}F in the bottom deck to 130^{o}F in the top deck. Think of clothes drying on a clothesline. Even in the shade, they dry on a day when the humidity is low. The water in the clothes is not boiled - dry air will draw the water out of the clothes naturally. <u>The only necessary action is to maintain a supply of *fresh dry air*</u>. Dry air has a powerful tendency to draw water out of any accessible source: puddles, the garden, wet clothes or a wet pulp sheet

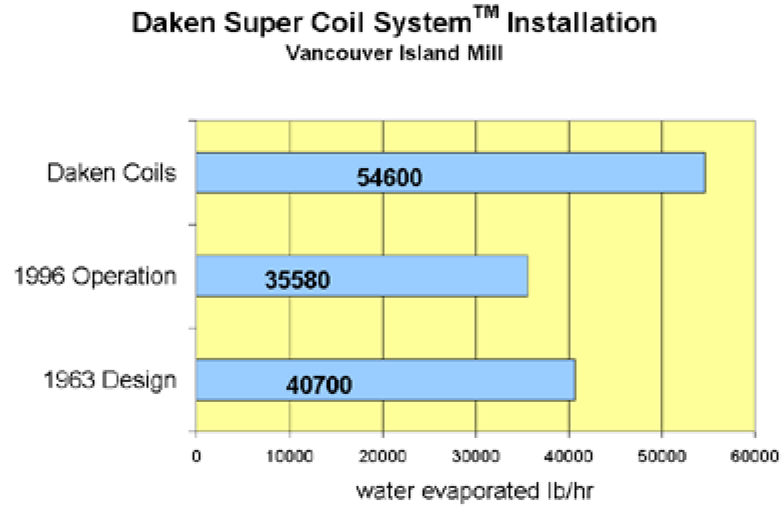
What is dry air? For our purposes, dry air is air which is not saturated. To continue the laundry analogy, if it is raining outside, we can still dry the clothes in a heated dryer. By heating the air, we increase its capability to accept water. This is exactly what we do in a pulp dryer, except that we re-circulate the air six or more times.

When water is evaporated from the sheet, even though it is not boiled, it still requires heat: at 120oF the heat of evaporation is 1025 BTU/lb of water. This cools the pulp sheet and the air. Water evaporates from the sheet at the wet bulb temperature. What is the wet bulb temperature, aside from a reading on the humidity gauge? The wet bulb temperature is the equilibrium which is reached when a steady supply of air contacts a wet medium, whether it be the sleeve of the wet bulb of a psychrometer (an instrument for measuring wet and dry bulb temperature) or a wet pulp sheet. As an analogy, think of standing in a dry wind wearing a wet tee-shirt. You will be cooled by the evaporation of water from the shirt. The temperature of your shirt is the wet bulb temperature of that air, and the cooling is the result of water vapour being evaporated from the shirt.

Little to no research has been done in our industry on the operation of conveying moisture away from a pulp sheet, which is amazing considering the vast tonnage of pulp that is processed in airborne dryers. As a result there is little understanding of the substantial potential for optimizing these dryers.

The **Daken Super Coils** tm and the **Daken Super Coil System** tm through their unique patented designs are the first to truly utilize a Flakt airborne dryer's capacity in delivering a continuous supply of fresh dry air. In addition to curing some known faults in the layout and design, The **Daken Super Coils** tm and the **Daken Super Coil System** tm will also provide longer coil life and easier installation.

The graph to the right shows the amount of latent capacity which was available in one pulp machine in an integrated newsprint mill. The upgrade included changes to the exhaust fans and conversion to the Daken Super Coil System™.

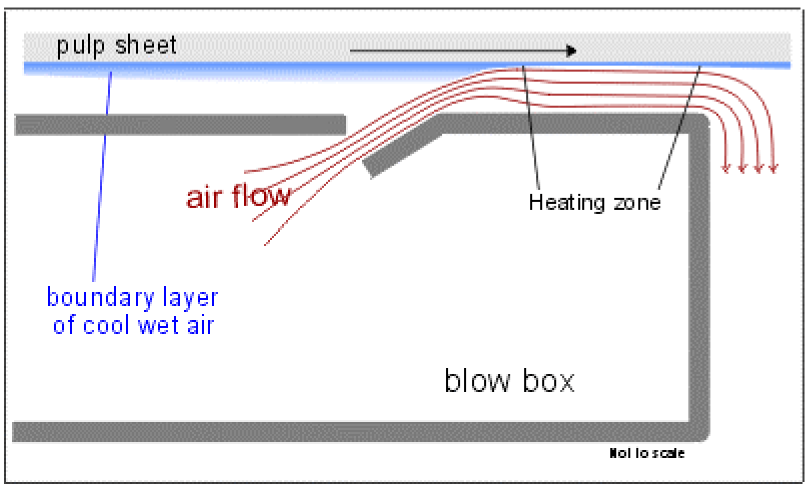


Visualisation of the Process

The actual mechanism of drying is when unsaturated air adjacent to the sheet surface draws water vapour out of the sheet. Since the water evaporates at this point, heat is drawn from the system, and the air is cooled. This cooler and wetter air now has less driving force to accept water vapour from the sheet, which slows down the evaporation process. Unless there is powerful turbulence to strip it away from the sheet, it forms an insulating "boundary" layer along the sheet surface.

This sketch shows the actions taking place at the blow box jets. The jet detail is typical of an FC type dryer. There are a series of small eyelet openings in the top of each blowbox, which create a semi-circular fan of air. Alternate jets point with or against the travel of the pulp sheet. The jets are intended to support and stabilize the sheet, not to propel it.

The distance between the blow box and the sheet is much exaggerated in this sketch. It is actually about 0.1"



The jets of air which support the sheet have two roles in the drying process. First they scour away the boundary layer, and then they transfer heat directly to the sheet, in that order. The air flow rate controls the amount of scouring and the temperature difference controls the heat transfer. The necessity to scour the sheet surface has never been fully recognized. There is a theory that a rough surface enhances heat exchange by providing more surface area - we are not sure whether this has ever been rigorously tested.

Heat exchange at the sheet

The classic heat exchange equation is $Q = U.a.\Delta t$, where, in English units:

- Q = heat exchange rate in BTU/hr
- U = the heat transfer coefficient, which is known for certain conditions, or can be experimentally derived.
- a = the area of the surface, usually of a tube, across which the heat travels, in sq. ft.
- Δt the temperature difference between the heating fluid and the fluid being heated, in ^{o}F

The U factor allows for the fact that there is resistance to heat flow, due largely to quiescent boundary layers of fluid on either side of the barrier separating the hot and cold fluids. Without these boundary layers, the flow of heat would be instantaneous and complete. U is the inverse of the R-factor used for housing insulation. The units, in English units, are BTU/hr/sq. ft./^{o}F. R-factor defines resistance to heat flow. U defines flow capability.

Other evidence of insufficient air

On some machines it has been found that changing to a higher density coil (more fin area and thus greater pressure drop) has resulted in the formation of ‘cigars’ by the sheet rubbing on the decks.

The typical older dryer is running 30% to 50% over its design capacity. Since the speed is often limited by the cutter/layboy, this has been accomplished mainly by increasing the basis weight. Thus the air pressure needed for support is increased, while the fan capacity has not changed.

In a normal heat exchanger, using steam coils as an example, the copper tubing normally has little resistance to heat flow. The real barriers to heat flow are mainly boundary air on the air side and the film of condensate on the steam side. For optimum heat transfer the air flow must be as turbulent as possible, which means a high flow rate.

The heat exchange process at the surface of a pulp sheet does not fit this model exactly, but the basic principles apply. For our purposes, the important question is whether U or Δt is the controlling factor. In fact the Δt is quite large, typically 150^{o}F for HP steam in the coils, while the air flow rate is marginal in many dryers.

Fan and screen maintenance

While we may speculate about the relative pressure drops to take in the coils or the blow box jets, there is no question that anything which increases the total air pressure available is desirable. Most mills have no documentation of the characteristics of the fans supplied with their dryers, so all we can do is make sure they are in good condition: clean blades, no chips out of the blade tips, minimal clearance from the shroud.

The lint screens are an unwanted necessity, in terms of pressure drop. We need to minimize the loss here, both by selection of the best design and by regular vacuuming. Daken considers good design to involve the following criteria: a taut screen with no projecting fasteners, a screen material which sheds lint easily, and the mesh selected to trap only the detrimental size of lint.