



Back to Basics: A Framework for Leather Manufacture

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Leather drying and conditioning: The physics of drying

Thermal leather drying systems in current use are examined in terms of technology, method, function and effects upon the leather processed. The following essays deal with the subject:

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The physics of leather drying

There are two ways to enact thermal input into leather:

1. THERMAL INPUT BY CONVECTION: EVAPORATION IN AIR FLOW UNDER NORMAL ATMOSPHERIC PRESSURE

The removal of water from leather by thermal means is an evaporative process in which the water remaining in the leather after samm/setting is converted into vapour at temperatures below boiling point. The rate of evaporation increases with the rise of temperature. The heat input required to sustain evaporation is normally taken from the

Panel E18/I: Evaporation and Vaporisation

(Evaporation should not be confused with vaporisation which takes place at boiling point and above. In vaporisation the conversion to steam occurs in the whole of the liquid. The boiling point is the temperature at which the vapour pressure of the water equals the atmospheric pressure (the basis of vacuum drying technology).

liquid itself and/or the air flow.

Evaporation can take place only at the liquid to air interface. If no heat input whatsoever is available evaporation ceases.

The aim of the thermal drying of leather is to remove the necessary amount of free and bound water contained in it to arrive at a determined moisture content of the leather. In the convection drying system the water is evaporated from the leather surface and is discharged to the air flow. Speed of evaporation is governed by temperature, i.e. the amount of heat supplied in combination with the capacity of the air flow to absorb the evaporated water.

Managing drying by controlling these two governing factors at first sight appears simple enough. The reality is that the nearer the amount of water vapour (*the humidity*) contained in the air is to the dew point (*the normal saturation point for it*) the lower its capacity to absorb water. The dew point is not an absolute as it rises with increased air temperature and falls when air temperature falls.

During the drying cycle, for evaporation to proceed, the heat input normally required is supplied by the air flow thereby causing the temperature of the air to drop which reduces its capacity to absorb the water vapour.

The air is therefore heated for the two functions of:

- i) conducting heat to the leather.
- ii) maintaining its temperature at a level where it can absorb the evaporated water at an adequate rate.

In other words, the fresh air in contact with the leather surface has to have the lowest relative humidity value economically possible, always bearing in mind that the largely saturated exhaust

air ideally should retain the least amount of residual heat.

Generally, and in practical terms, the most energy efficient convection drying of leather occurs when the exhausted air has a moisture content equivalent to about 75% relative humidity. A higher level of saturation would require an uneconomical amount of energy as well as extending drying time.

The convection evaporation process is complex. The control parameters of the system are difficult to monitor adequately to ensure maximum drying effectiveness in terms of leather quality, productivity, energy consumption and residual water content.

The leather generally tends to be overdried to ensure good uniformity of water content across a given piece, hence the need to re-humidify in conditioning.

Controlled thermal energy (heat) is supplied to:

- heat the surface water.
- heat the leather and to maintain its desired temperature.
- sustain the evaporation process.
- replace the heat lost by the air flow during evaporation.
- maintain an optimum vapour absorption rate.

The rate of moisture laden air exhaust and admission of new air is controlled and monitored based upon sensing the relative humidity contained in the exhaust air. Ideally the new air admitted has the lowest relative humidity reading possible.

An assessment of total energy consumed is not meaningful as losses of heat in the drying system as a whole, related to non-controllable factors nullifies the results of measurements.

The effective water and leather to air



Panel E18/2: Water content in air at varying temperatures at saturation (100% Rh). Values in 25% and 75% columns are estimated by interpolation from known values

Air Temperature °C	Water Content at Saturation - g/m ³	Water Content at 25% Rh - g/m ³	Water Content at 75% Rh - g/m ³
20	17.2	4	12
30	30.2	7	28
40	51	10	30
50	82.7	20	60
60	130	32	95
70	197	49	150

flow interface is fundamental in the convection drying mode. A so-called boundary air layer adheres to the surface. This boundary layer requires agitation to remove it and this in leather convection drying is achieved by a combination of appropriate air flow velocity and pressure. These two parameters are not normally part of operational control and are predetermined by the design of the system.

1st-Phase evaporation

- In this phase free water contained in the fibrillar structure is rapidly evaporated from the leather surface. The speed of evaporation is affected by the type of tannage, by temperature, and by the humidity

gradient between the leather and the drying air, as well as the amount of leather surface exposed to evaporation.

- The quantity of water evaporated in a given time interval in this phase depends on the total water content and the quantitative relationship between free and physically bound water. Changes in the structure, mainly of the leather surface, during this phase can affect this.
- Assuming that heat supply to the air flow and the humidity absorption capacity of the drying air remain constant throughout the phase, the leather temperature will rise slowly as evaporation proceeds. A summation all these factors indicates that the rate

of drying is determined by the rate of heat transfer. At the end of phase one the hygroscopic curve exhibits a sharp change in direction.

2nd-Phase evaporation

- In the second drying phase the leather surface is largely dried out and the evaporation rate becomes much slower. This is because capillary water from the inner layers does not reach the surface at a speed matching the evaporation capacity. Physically held and chemically bound water (*where the release is affected by tannage, fatliquors and other substances*) also reaches the surface only at a slow rate.
- Leather temperature rises at a faster rate than during phase one: this factor should be taken into account when the process operates close to the maximum temperature allowable for the particular type of leather. Final water content is governed by the tannage and leather structure as well as by the drying system parameters. At this final stage no free water remains on the leather surface and most bound water has been removed.

2. THERMAL INPUT BY CONDUCTION: EVAPORATION IN REDUCED ATMOSPHERIC PRESSURE (VACUUM DRYING)

Drying in a vacuum rests upon the phenomenon that lowering atmospheric pressure reduces the boiling point of water. Atmospheric pressure at sea level is 760mm Hg where water boils at 100°C. At approximately 96% vacuum, equivalent to 30mm Hg, the boiling point is roughly 29°C. This degree of vacuum is commonly attained by most vacuum drying equipment. Applying temperatures, for example, in the 30°C to 50°C range results in much faster evaporation than under full atmospheric pressure. Conversely, the application of lower more leather-friendly temperatures still produces fast evaporation rates because the saturated vapour pressure of the water continues to be high as it is always near the boiling point.

Vacuum drying takes place in a hermetically sealed chamber, usually above the reduced boiling point of the water; therefore technically the evaporation is true vaporisation producing a large volume of gas which is condensed upstream of a vacuum pump.

Panel E18/3: Boiling point of water at varying atmospheric pressure

