Press drying/impulse drying: the author's answer to Lindsay

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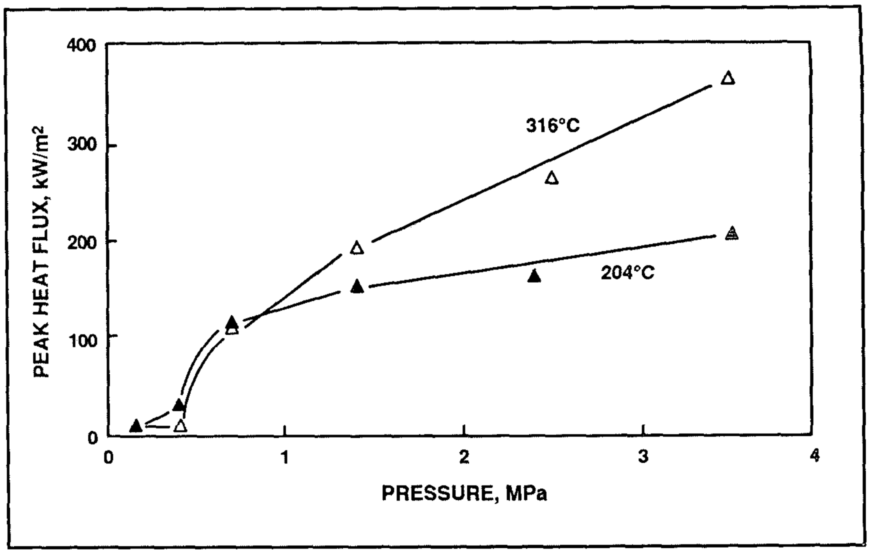
1. The peak heat flux values over a range of applied mechanical pressure at two platen temperatures. Corrected figure provided by Sprague (2).



The issue of heat flux

My discussion of the peak heat flux in press drying/impulse drying was based on the corrected data. These data are presented in **Fig. 1**, which is the same as the plot on the left in Fig. 16 of the paper in March (*1*). These data were provided by Clyde Sprague (*2*) after I pointed out the misprint in his earlier article (*3*). These data are then in good agreement with Fig. 3 of his paper, showing a maximum heat flux of 0.37 MW over a very few milliseconds, just after the mechanical nip pressure is applied. Thereafter, the heat flux falls off rapidly to about 0.1 MW, in agreement with data of Lindsay and Burton (*4*).

Besides Fig. 1, a few peak heat flux values up to 8-10 MW have been reported by IPC/IPST, but there has been no discussion on the significant differences between these values. During the few milliseconds when the hot platen pressure is first applied to the cold wet web—i.e., during the heating period—the heat flux is the product of a heat transfer coefficient α and the temperature difference ΔT between the hot platen or roll and the ambient web temperature. Such a heat transfer coefficient, when calculated from Fig. 1 in the pressure range of 1.3-3.5 MPa, varies from 0.7 to 1.1 W/°C per square meter. The increase in heat transfer coefficient with increasing applied mechanical pressure is natural and has also been observed over the pressure range of 2-30 kPa by Ahrens and co-workers (*5*). The contact heat transfer coefficients thus calculated here are in agreement with those measured as well as those calculated for cylinder drying under normal drying conditions for this range of ingoing solids content — i.e., 1-3 kW/m² per °C, varying somewhat with paper qualities (*6, 7*).

Whenever a higher hot platen temperature is applied, not only does ΔT increase, but so does the mechanical pressure necessary to counteract the vapor pressure formed in a layer against the hot platen. Thus, the 316°C platen temperature in Fig. 1 corresponds to a vapor pressure of 10.4 MPa, while the applied mechanical pressures are much lower here. Either the vapor formed has lifted the platen and escaped, or the vapor pressure and corresponding vapor temperature are much lower, below 245°C at 3.5 MPa and below 193°C at 1.3 MPa.

Consider as an alternative that the peak heat flux values reported by IPC/IPST refer to evaporation—i.e., to vapor phase formation. The heat flux of boiling at a solid surface in a stationary water phase around 100°C with ΔT = 35°C is about 1.0 MW. It falls off as the temperature of the hot solid surface increases to a minimum at 200°C. The heat flux then slowly rises again to 1.0 MW, when the solid surface temperature is above 1000°C (*8, 9*). For convective boiling, a maximum heat flux value of 7 MW has been reported at steam pressures of about 3 MPa, decreasing again with higher steam pressures (*8*). With a solid bed in the water (such as glass particles), much lower heat flux values for boiling are reported (*10*). Very high values for peak heat flux reported in the IPC/IPST work may indicate the complexity of this heat transfer of boiling as an alternative to

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the heating period and may also indicate the difficulty of assessing it. Once this vapor film is formed, the heat flux drops rapidly.

How can such heat flux values of vaporization provide information on the action of the vapor layer against the paper web—that is, against a water phase in the fiber network?

Lindsay emphasizes the paradigm of Sprague (*3*) plotting the energy requirement per gram of water removed against the press platen temperature. This paradigm is said to show a different mechanism of impulse drying—short press drying pulses as compared to long press drying pulses up to complete dryness. Wet pressing of a cold or preheated web in this paradigm consumes no heat energy in spite of a large water removal. Press drying pulses consume some energy for heating the web and maybe some to form a steam layer, while most of the water is removed by hot pressing. With longer nip retention, naturally more heat is consumed for evaporation in the later part of the nip. Thus, there is a gradual increase in heat consumed at wet pressing of a web preheated to 100°C to the heat consumed in superhot wet pressing above 100°C and press drying to complete dryness.

This does not prove that steam blows water out of the wet web. The mechanism gradually changes with nip retention time, which is already within the range of nip retention times used by IPC/IPST. I have retained the expression "press drying pulses" as originally used for 100-ms pulses over temperatures up to 450°C in work published (*11*) before the patent of Wahren (*12*) was applied for. This is a semantic question only.

The effect of vapor phase on the hydrodynamic or hydraulic pressure

Lindsay responds to my question on the pressure equilibrium within each layer of the wet web.

The expression is valid in any layer of the paper network:

$$P_f = P_{app} - P_h \qquad (1)$$

Only the hydraulic pressure can act on the water flow. Lindsay apparently admits that vapor formed has to act with water or superheated water accordingly to build up this hydraulic pressure. This means it cannot blow out water by a separate mechanism.

As mentioned, the vapor pressure in a layer near the hot roll surface must be below the mechanical pressure applied in order not to lift the roll and to be in equilibrium with the temperature prevailing. In a press nip of 6 MPa at 200°C, the vapor pressure can only be 20% of the applied pressure, but it could take over some of the rather small network pressure prevailing at this side of the web. Thereby, it would reduce the local network pressure and keep the local network structure more open. This would mean a more porous surface layer on this hot paper side. All data, however, indicate increased densification and smoothness of this hot side with press/impulse drying pulses. Further analysis of the data of Burton and Sprague on densification over the nip retention time (*13*) can provide a better understanding.

Summary

The mechanism of so-called "impulse drying"—that is, of very short press drying nips—is naturally included in any longer press drying nips. The mechanism gradually changes with time while water is pressed out, and the web temperature increases in the direction toward the felt. Later in an extended nip, more drying takes place with a heat pipe mechanism from the hot roll surface to the inner part of the web. With the retention time available in commercial extended nips at current machine speeds for respective grammages (basis weights), this latter drying effect is small.

I have therefore explained press drying/impulse drying at current nip retention times by superhot wet pressing. I also point out that the commercial potential of press drying/impulse drying has to be compared to extended double-felted press nips for webs preheated to about 90°C.

Papers and data presented at the Helsinki Conference on "Alternative Methods of Pulp and Paper Drying," June 4-7, 1991, did not contradict my interpretation (*1*). J. Lindsay, on the other hand, presented data on displacement drying with gas pressure in an extended nip.□

Literature cited

1. Back, E. L., Tappi J. 74(3): 135(1991).
2. Sprague, C. H., private communication, 1989.
3. Sprague, C. H., Fundamentals of Paper Making II, Mech. Eng. Publ. Ltd., London, 1989, p. 639.
4. Lindsay, J. D., Fundamentals of Paper Making II, Mech. Eng. Publ. Ltd., London, 1989, p. 679.
5. Ahrens, F., Kartounes, G., and Ruff, D., Pulp Paper Can. 85(3): T63(1984).
6. Soininen, M., Fundamentals of web drying *in* New Technologies in Web Consolidation, Pira Conf., May 1986, Brighton, U.K.
7. Karlsson, M.S. thesis, Abo Akademie, Turku, Finland, 1978.
8. Collier, J. G., Convective Boiling and Condensation, 2nd edn., McGraw Hill, New York, 1980.
9. Stenstrom, S., Impulse drying of paper: a literature review and evaluation of heat transfer means to the paper web, STU (Swedish Technical Res. Council) project, Lund Inst. of Technology, 1989.
10. Fukusako, S., Komoriya, T., and Seki, N. J., Heat Transfer 108: 117(1986).
11. Back, E. L. and Andersson, R. G. 18th EUCEPA Conference Proceedings, EUCEPA, Helsinki, 1977, p. 165.
12. Wahren, D., U.S. Patent 4,324,613 (April 13, 1982); first applied for in Sweden in 1978.
13. Burton, S. W. and Sprague, C. H., J. Pulp Paper Sci. 13(5): J145(1987).