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'Freeness' of Paper Pulps and the Forces of Capillary Water Retention

In the manufacture of paper, the cellulosic raw material is first dispersed into separate fibres by chemical or mechanical methods and is then subjected to a mechanical process called beating, which alters the properties of the fibres and has a profound influence on the quality of the finished paper¹. Standard methods which have been developed to give an objective measure of the degree of beating (for example, the Canadian freeness test²) all depend on the rate of drainage of water from the fibre suspension. A light beating gives a 'free' pulp, which drains quickly, whereas a heavy beating gives a 'wet' pulp, which drains slowly.

Experiments have been made in the past to see whether a wet pulp shows greater hygroscopicity than a free pulp in the usual (vapour pressure-moisture content) isotherm between zero and near saturation humidity. The results show either no difference³ or only a small increase with beating⁴. This suggests that beating is influencing only water held by capillaries at humidities which are too close to saturation to be controlled by conventional methods. Experiments have also been made in this capillary-range by using the centrifuge, and these show a correlation with beating times^{5,6}, but true equilibrium was probably not attained. Also, in centrifuging, the increased gravitational field directly affects the packing of the fibres themselves, whereas, on the wire of the paper-machine, the water drains away under gravity and is drawn out at the table rolls and suction boxes, so that the mat itself is subjected only to the normal gravitational pull, except for the hydrostatic tension of the water in the capillary spaces.

The porous plate technique, described in the preceding communication, affords a simple and reliable method of maintaining relative humidities very close to saturation, since the liquid tension is thermodynamically linked with the vapour pressure of the capillary water⁷. The distribution of pore size depends on the initial packing of the fibres in the mat, and a method had therefore to be evolved which assured a controlled and reproducible formation. Using this technique, curves of moisture content against hydrostatic tension were obtained on an easy-bleaching sulphate pulp which had been beaten for various times in the Lampén mill⁸. The results are given in Fig. 1. The curves all show hysteresis between desorption and adsorption, but for the sake of clarity the adsorption curve is shown only for the unbeaten sample. For the same reason, the desorption curves for the intermediate beating times are not shown at low tensions. It will be seen that at

Fig. 1

Fig. 2

the higher tensions the desorption curves are very similar in shape and are displaced parallel to the moisture-content axis according to the time of beating. Thus any arbitrary tension may be taken as standard (for example, 14 cm. mercury = 0.187 bar). In Fig. 2 the desorption moisture contents at this tension are plotted against the Canadian freeness figure. The general correlation is seen to be satisfactory.

The porous plate technique is a static method, but the Canadian test is dynamic and therefore involves the rate of percolation of the water through the fibre mat rather than the tenacity with which the water is held. It may be argued on this basis that the porous plate method gives more direct information about the properties of the pulp from which the paper is eventually made. However, the rate of drainage is itself an important factor in paper-making since, on the machine, the water in the paper web may have no more than a few seconds in which to drain through the machine wire.

The main interest attached to these experiments is that they give, probably for the first time, a measure of wetness or freeness in exact thermodynamic terms, and that the data so obtained when used in conjunction with other experimental results described in the preceding communication may give precise information about the properties of the wet paper web under the conditions of manufacture.

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