It is evident that the MAP reaction product and DCPD were similar while the DAP reaction product resembled hydroxyapatite. Our DCPD spectrum agreed closely with the brushite (DCPD) spectrum obtained by Jones and Cruickshank[5].

From these results it appears that the major initial reaction products of MAP and DAP in the Bradwell soil were DCPD and hydroxyapatite, respectively. Further investigations are being conducted to determine if infra-red absorption analysis can be used to identify reaction products from other fertilizers and soils.

J. D. BEATON
T. L. CHARLTON
R. SPEER

Research and Development Division,
Consolidated Mining and Smelting Co. of Canada, Ltd.,
Trail, British Columbia.

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MISCELLANEOUS

Estimating the Thickness of Pulped Wood Fibres

IN examining the mechanical properties of dry, pulped wood fibres which comprise most papers, the dimensions of the fibres must be known. For quantitative purposes, their cross-sectional shape (Fig. 1) is best represented by the rectangle. The 'width' of the fibre is readily measured by the micrometer eyepiece of a microscope as is the length, the largest dimension by orders-of-magnitude. However, the thickness of the fibre is awkward to measure for a number of reasons:

(1) The thickness is in the μ range.

(2) The thickness is generally non-uniform at any one point along the length of the fibre because of the incompleteness of collapse; vestiges of the lumen are generally present along the edges. (Wood fibres are initially more or less circular, but the large pressures applied in the paper-making process cause their collapse.)

(3) Appreciable variations exist in the cross-sectional shape and thickness along the length of the fibre.

(4) Dimensional variations among fibres of any one pulp are extremely large.

(5) The top and bottom of fibres are difficult to define.

Clearly such conventional techniques for measuring the thickness of microscopic-sized particles as the vertical focusing of a microscope stage are unsatisfactory. The use of cross-sections, which require embedding, introduce an additional uncertainty in the possible changes in dimensions caused by swelling and microtoming. Thus a precise technique is not available.

We have applied two techniques, entirely different from each other, which give essentially the same results. These techniques have the further advantage of being quite rapid.

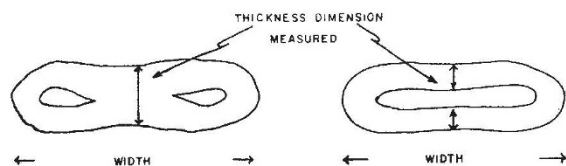(1) *Retardation Method.* The cellulose chains in wood are aligned more or less parallel to each other and the central fibre axis: hence, fibres are birefringent. When examined between crossed Nicols and a first-order quartz retardation plate, fibres exhibit first-order retardation colours. The equivalent wave-length of the retardation colours, R, is related to the thickness of the cellulose of the fibre (double the wall-thickness), $\bar{\delta}$, by the relationship, $\bar{\delta} = R/(\eta_\gamma - \eta_a)$, where η_γ and η_a are the indices of refraction parallel and perpendicular, respectively, to the principal axes of the fibre[1-3].

In the investigation recorded here we noted the colour of the central portion of the fibres where pits were absent. The selection of points of measurements is described later. Each value reported in Table 1 is the average of 200 measurements, requiring about 2 h.

(2) *Density Method.* Assuming fibres to have a rectangular cross-section, $\bar{\delta}$ can be calculated from the density equation, $\delta = w/\gamma\bar{\omega}$, where w is the mean weight per unit length of fibre; γ, the density of cellulose; and $\bar{\omega}$, the mean fibre width. w, γ, and $\bar{\omega}$ are easily measured.

We measured γ of standard handsheets[4] with a Beckman air comparison pycnometer, model 930. In this instrument, the volume displaced by cellulose is measured.

Using 0.05 g of pulp instead of 1.2 g and large pressures in the standard sheet-forming process[4], ultra-thin (2–D) sheets were produced, the fibres of which are clearly visible. We scanned along a straight line of the 2–D sheets, noting the width and retardation colour of every fibre. w was calculated from the equation $w = 2W/(1.1)\pi(N/L) = 0.578W/(N/L)$, where W is the weight per unit area of the sheet; N, the number of fibres intersected in scanning along a line of length L; and 1.1, a factor taking into account the slight curvature of the fibres[5]. Three 15-cm scans, 60° apart, were made on each sample. A complete determination, excluding the retardation measurements, takes about 2 h. The results of the measurements on eight pulps are shown in Table 1. Agreement between the results of the two techniques is surprisingly good.

Table 1

Pulp	γ (g/cm³)	w (g/cm) × 10⁶	$\bar{\omega}$ cm × 10³	$\bar{\delta}$ cm × 10⁴ Retardation method	$\bar{\delta}$ cm × 10⁴ Density method
Spruce sulphite	1·63	1·3	3·7	2·7	2·2
Spruce kraft No. 1	1·60	1·5	3·5	2·6	2·7
Spruce kraft No. 2	1·60	1·4	3·5	2·6	2·5
Spruce magnifite	1·60	1·5	3·7	2·4	2·5
Southern pine kraft (U.S.)	1·59	2·2	4·5	3·5	3·1
Western mixed softwood kraft (U.S.)	1·56	1·6	3·5	3·4	2·9
Jack pine	1·62	1·5	3·3	3·0	2·8
Mixed bleached hardwood	1·59	1·2	2·0	3·8	3·8

All samples mechanically untreated.

The retardation method requires a high-quality microscope and considerable training, but the density method involves only generally available equipment; where a pycnometer is not available, a value of = 1·6 g/cm³ can be used confidently. Thus the density technique is a simple and rapid means of estimating the wall thickness of pulped wood fibres.

O. J. KALLMES
G. A. BERNIER

St. Regis Paper Co.,
Technical Center,
West Nyack,
New York.

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Fig. 1. Typical cross-sectional shapes of fibres