FIBRE CROSS-SECTION DIMENSIONS OF UNDRIED AND DRIED PINUS RADIATA KRAFT PULPS

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ABSTRACT

A procedure has been developed for the measurement of undried (uncollapsed), and dried and reconstituted (collapsed) fibre cross-sections in unbleached and bleached kraft pulps made from **Pinus radiata** D. Don wood of low and medium basic density. The data obtained show that pulp drying causes fibres to be collapsed and fibre walls to be somewhat reduced in thickness. The widths of unbleached kraft fibres are generally unchanged by pulp drying although those of corresponding bleached fibres are significantly decreased by the drying process.

INTRODUCTION

In the characterisation of different pulp furnishes it is often necessary to consider fibre dimensions (length, diameter, and wall thickness) and fibre population dimension distributions (Kibblewhite 1982). For undried *P. radiata* chemical pulps (Kibblewhite 1982) and both undried, and dried and reconstituted mechanical pulps (Kibblewhite 1981, 1983) the methodology for obtaining such data has been described and tested. For dried chemical pulps reconstituted without refining, the fibre populations contain high proportions of collapsed fibres. The fibre cross-section data for such pulps are not comparable with those of undried pulps since in the earlier measurements circular fibre cross-sectional shapes were assumed for the undried fibres (Kibblewhite 1982). It is often necessary for a purchaser of market pulp to measure fibre cross-section dimensions to ascertain pulp quality and/or the quality of the original wood. To be able to do this, a comparative method is required for measuring the dimensions of collapsed and uncollapsed fibre cross-sections.

This paper describes an alternative method of measuring fibre cross-section dimensions which allows for fibre collapse and does not assume a circular fibre cross-section shape. The procedure is used to determine the fibre cross-section dimensions of undried, and dried and reconstituted unbleached and bleached kraft pulps made from *P. radiata* wood of low and medium basic density.

MATERIALS AND METHODS

Pulp Samples

Two sets of pulp samples were used. For the first part of the study which was designed to evaluate alternative measurement procedures, the following pulps were examined:

(1) Four dried, commercial, *P. radiata* kraft pulps, three unbleached and one bleached. The unbleached pulps were prepared from wood of basic density about 375 kg/m^3 and the bleached furnish was made from wood of basic density about 410 kg/m^3;

(2) Six undried laboratory pulps made from the corewood and slabwood of Trees 3, 4, and 9 of a previous study (Kibblewhite 1982). Embedded and sectioned pulp fibres prepared as part of this earlier investigation were remeasured in the present study.

For the second part of the study, which was designed to measure the cross-section dimensions of undried, and of dried and reconstituted fibres, three pairs of undried and dried, commercial, *P. radiata* kraft pulps were examined. These pulps were collected so that the dried and undried samples of each pair were representative of the same pulp material. The following pairs of undried and dried pulps were examined:

(1) Unbleached kraft made from wood of basic density about 375 kg/m^3;

(2) Unbleached kraft made from wood of basic density about 410 kg/m^3;

(3) Bleached kraft made from wood of basic density about 410 kg/m^3.

Dried pulps were reconstituted in accordance with Appita method of 203s-80: the procedure involves reslushing in water without refining.

Fibre Length Measurement

Fibre length was estimated for each pulp by tracing projected fibre images and recording their length with a measuring wheel. A total of 300 fibres were measured for each pulp, 50 fibres on each of six microscope slides. The shortest fibre included in the length measurements was 0.2 mm. "Intact" fibres were defined as complete or shortened fibres with definite or collapsed lumens. Thus, split fibre fragments or fibrillar debris were excluded from the fibre length analyses (Kibblewhite 1983).

Weighted average fibre length was defined as:

$$\frac{\Sigma l_i^2 n_i}{\Sigma l_i n_i}$$

where l_i was the length of a fibre in the sample, and n_i the number of fibres of length l_i.

Fibre Cross-sectional Dimensions

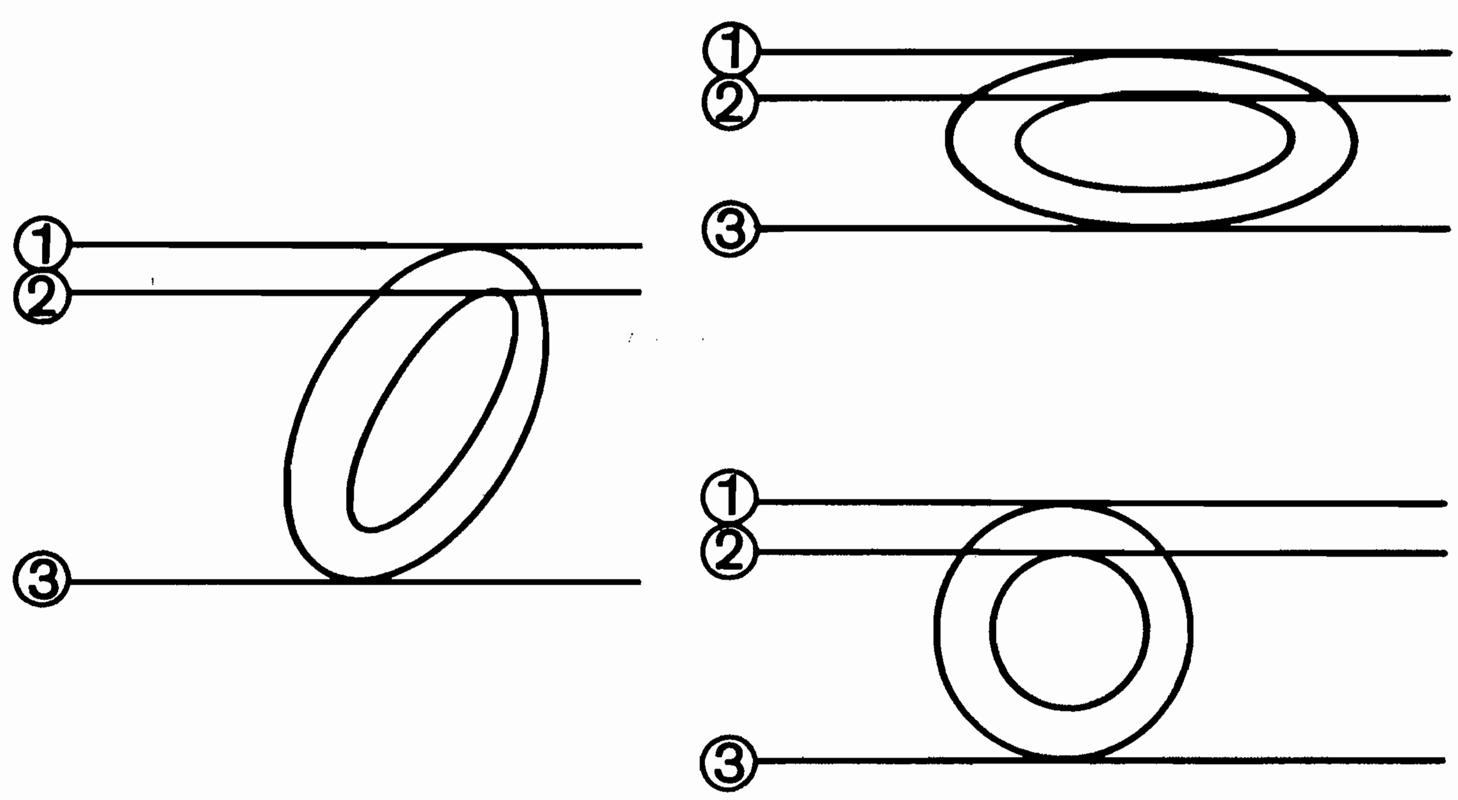
Undried, and dried and reconstituted fibres were dehydrated, embedded in Epon, and sectioned according to procedures described previously (Kibblewhite 1983).

Fibre dimensions were measured using alternative procedures.

(1) A circular fibre cross-section shape was assumed and fibres were measured at points of contact with a horizontally mounted slide-wire which traverses fibre cross-

sections in a vertical direction (Fig. 1). All fibres visible at any one time on a Reichart Visopan screen were measured as they were traversed by the slide-wire. Measurements were recorded automatically through connection of the slide-wire to a potentiometer. A total of 300 fibres were measured for each sample. This method has been found to be applicable for the uncollapsed fibres of undried chemical pulps (Kibblewhite 1982) and for dried and reconstituted mechanical pulps (Kibblewhite 1981).

(2) The presence of non-circular fibre cross-section shapes in pulp populations was acknowledged and taken into account using the measurement procedures shown in Fig. 2. For these measurements the slide-wire was oriented according to fibre shape rather than moved in a vertical direction only. Estimates of both degrees of fibre collapse and fibre cross-section dimensions were therefore obtained. A total of 300 fibres were measured for each sample.



FIBRE DIAMETER = ① - ③

FIBRE WALL THICKNESS = ① - ②

FIBRE LUMEN DIAMETER = (① - ③) - 2(① - ②)

FIG. 1—Fibre cross-section dimensions for three randomly oriented fibre cross-sections. Slide-wire positions are indicated for each fibre.

RESULTS AND DISCUSSION

Methodology Evaluation

Fibre cross-section configurations of the reconstituted but unrefined pulps are shown in Fig. 3. The pulps made from low-density wood contained higher proportions of collapsed fibres than those made from medium-density wood. For the dried pulps the thin-walled, large-diametered fibres are most readily collapsed, as expected (Kibblewhite 1982).

Fibre cross-section dimension data obtained using the measurement procedures detailed in Fig. 1 and 2 are listed in Table 1. For the undried laboratory pulps, similar trends but not similar wall thickness and diameter values were obtained using the two methods of measurement. In contrast, the method of Fig. 1 which assumes circular fibre cross-sections is clearly inappropriate for the highly collapsed fibres of the dried and reconstituted pulps (Table 1, Fig. 3). This method of measurement is unable to quantify the very definite visible fibre dimension and collapse differences which exist between the dried and reconstituted pulps made from wood of low and medium basic density. The method of Fig. 2, on the other hand, takes the extent of fibre collapse into account and gives realistic values for fibre cross-section dimensions (Fig. 3, Table 1). The following conclusions can be drawn from the fibre cross-section data of Table 1.

(1) Mean fibre wall thicknesses of dried and reconstituted pulps are significantly less than those of undried laboratory pulps.

(2) Mean fibre wall thicknesses of dried and reconstituted pulp from medium-density wood are significantly greater than those of the corresponding pulps made from low-density wood.

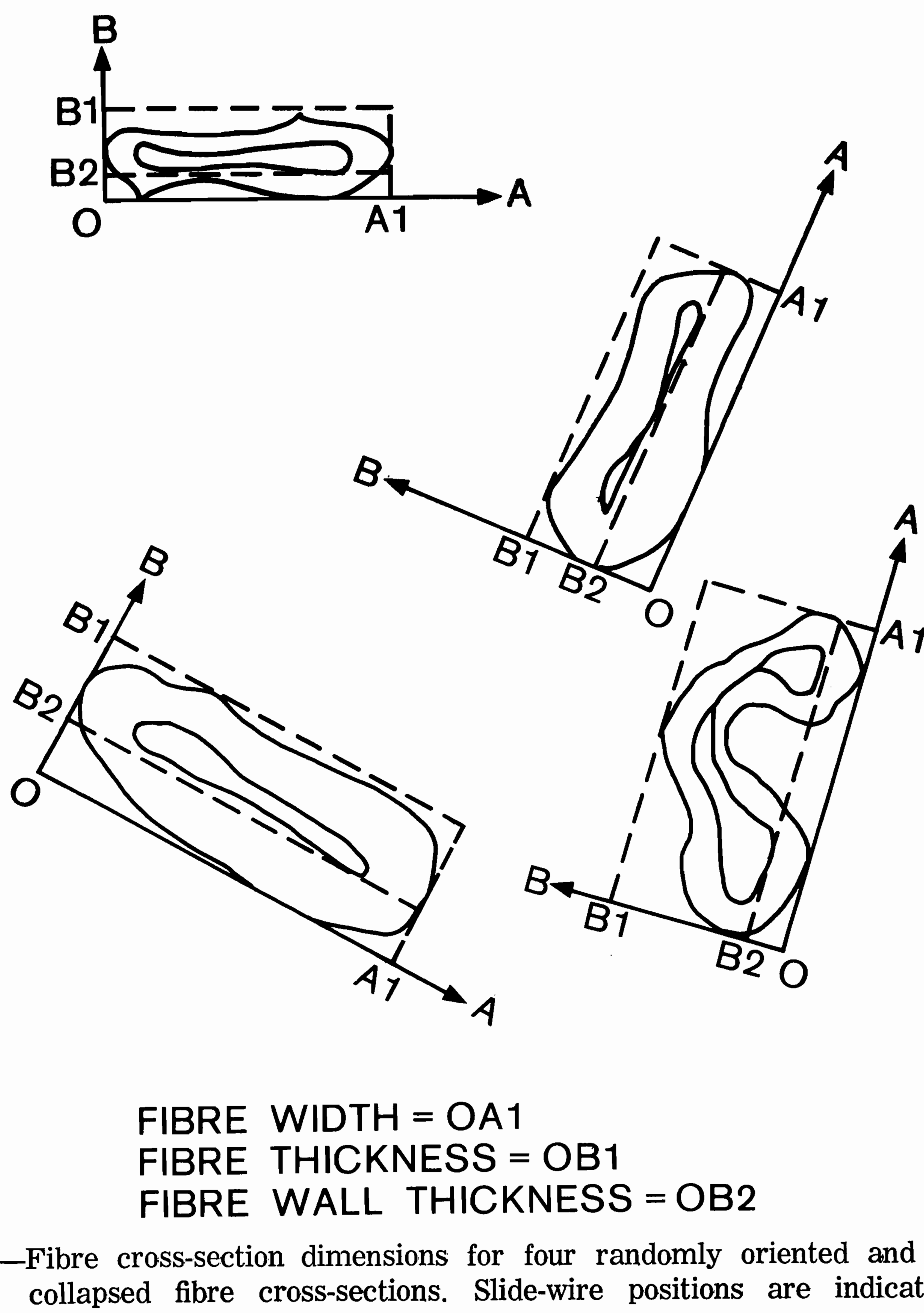


FIG. 2—Fibre cross-section dimensions for four randomly oriented and partly collapsed fibres cross-sections. Slide-wire positions are indicated for each fibre.

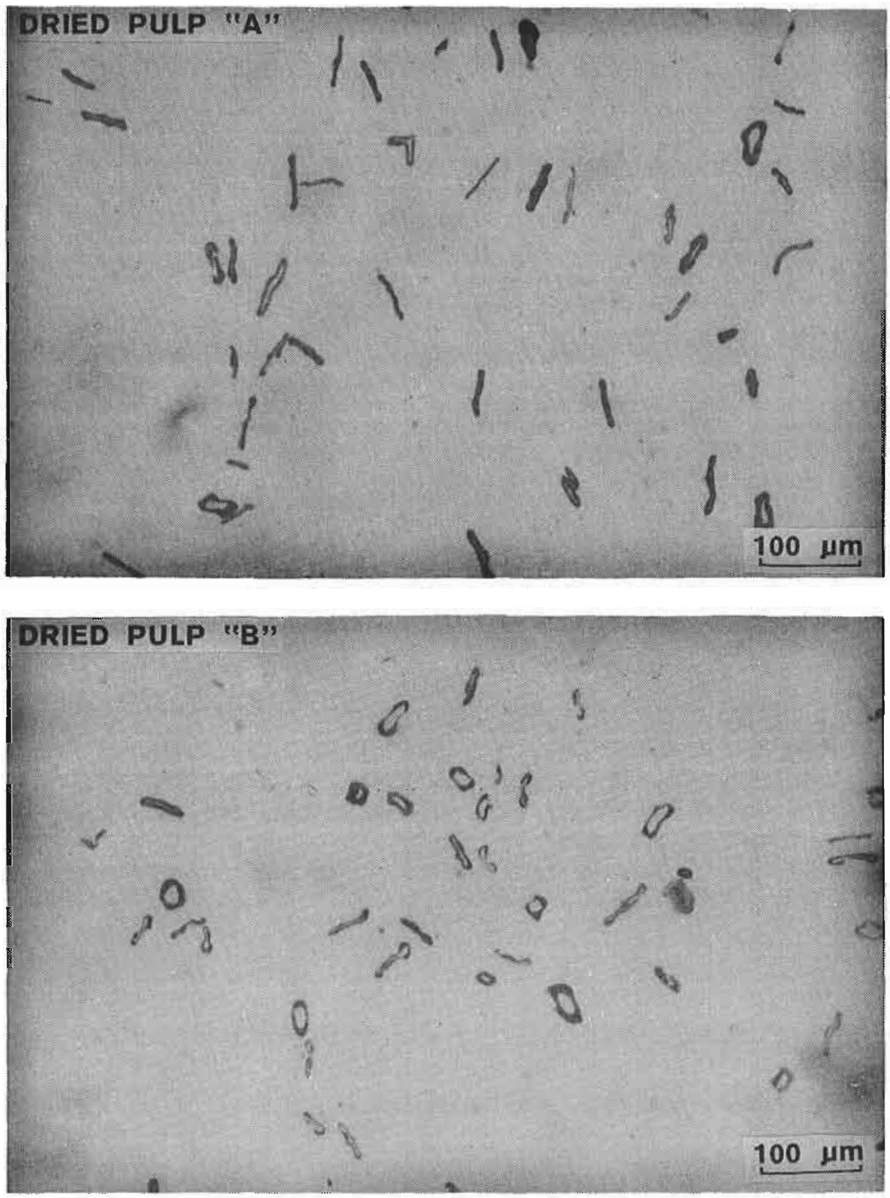


FIG. 3—Cross-sectional views of dried and reconstituted kraft pulp fibres, Pulp "A" from low-density wood and Pulp "B" from medium-density wood.

(3) Dried and reconstituted pulp fibres from low-density wood are wider and more collapsed than those in pulp from medium-density wood.

Few other comparative conclusions are possible since the undried, and the dried and reconstituted pulps were of very different origins.

TABLE 1—Fibre dimension data

Kraft pulp wood supply		Pulp treatment	Weighted average fibre length* (mm)	Circular fibre cross-section shape assumed (Fig. 1)†: Wall thickness (μm)	Circular: Diameter (μm)	Circular: Lumen diameter (μm)	Non-circular fibre cross-section shape assumed (Fig. 2‡): Wall thickness (μm)	Non-circular: Fibre width (μm)	Non-circular: Fibre thickness (μm)	Non-circular: Lumen thickness (μm)
Corewood	(Tree 3)	Unbleached & undried	2.88	7.75	42.3	26.8	5.98	47.7	29.5	17.5
	(Tree 4)		2.88	6.99	40.6	26.6	5.38	43.6	26.9	16.1
	(Tree 9)		2.81	7.45	42.9	28.0	5.36	46.4	26.7	16.0
Slabwood	(Tree 3)		3.69	9.87	42.1	22.3	6.53	44.3	27.4	14.3
	(Tree 4)		3.52	8.23	42.1	25.6	5.98	48.4	27.8	15.8
	(Tree 9)		2.99	6.82	36.9	23.2	5.45	42.8	25.5	14.6
Low-density wood	(1)	Unbleached & dried & reconstituted	2.74	3.84	29.8	22.1	3.34	42.1	9.8	3.0
	(2)		2.71	3.81	31.5	23.9	3.25	42.6	9.7	3.2
	(3)		2.73	4.00	29.9	21.9	3.23	42.0	8.8	1.8
Medium-density wood		Bleached & dried & reconstituted	3.10	4.08	29.8	21.6	3.88	38.1	13.4	5.5

Statistical significance

* Mean pulp fibre length different at the 5% level if differs by more than 0.2 mm.

† For circular fibre cross-sectional shape:

Mean fibre wall thickness different at the 5% level if differs by more than 0.56 μm.

Mean fibre diameter different at the 5% level if differs by more than 2.89 μm.

Mean fibre lumen diameter different at the 5% level if differs by more than 2.84 μm.

‡ For non-circular fibre cross-sectional shape:

Mean fibre wall thickness different at the 5% level if differs by more than 0.38 μm.

Mean fibre width different at the 5% level if differs by more than 3.05 μm.

Mean fibre thickness different at the 5% level if differs by more than 1.76 μm.

Cross-section Dimensions of Undried, and Dried and Reconstituted Fibres

The fibre cross-section dimensions of three pairs of undried, and dried and reconstituted kraft pulps measured in accordance with the method of Fig. 2 are presented in Table 2. Fibre cross-sections of paired undried, and dried and reconstituted pulps made from low- and medium-density wood are shown in Fig. 4.

Based on fibre thickness values, the dried and reconstituted fibres are clearly more collapsed than those in the corresponding undried pulps (Fig. 5). Furthermore, relative to the respective undried fibres, the dried and reconstituted pulp fibres from low-density wood are substantially more collapsed (47%) than those in either the unbleached (35%) or bleached (27%) furnishes from medium-density wood (Table 2). The low degree of collapse of the bleached fibres is probably related to these relatively soft (lignin-free) fibres being more collapsed in the undried furnish than those in the corresponding unbleached pulp (Table 2).

Fibre wall thicknesses are significantly reduced by pulp drying (Table 2, Fig. 6). Of the various pulps examined, the walls of the undried bleached fibres are most swollen and are therefore most reduced by pulp drying. The walls of the undried fibres from low-density wood are clearly swollen to a significant extent when compared with those of fibres in the corresponding dried and reconstituted furnish.

Fibre widths for the undried, and the dried and reconstituted unbleached pulps are similar (Table 2, Fig. 7). Such a trend is in general accordance with that obtained for the fibre diameters of *P. radiata* corewood and slabwood undried pulps measured by the method of Fig. 1 (Kibblewhite 1982). Again, trends for the undried, and the dried and reconstituted bleached pulps are somewhat different, probably because these fibres are essentially lignin-free and their walls contain substantially less wood substance than do the unbleached fibres. The narrow width of the dried and reconstituted bleached fibres is noteworthy, particularly since it is a consistent trend for different batches of pulps (Tables 1 and 2).

CONCLUSIONS

Measurement of the fibre cross-section dimensions of fibre diameter, lumen diameter, and wall thickness using a method based on an assumed circular fibre cross-section shape is inappropriate for the collapsed fibres of dried *P. radiata* kraft pulps. Such a method is, however, suitable for the measurement of the cross-section dimensions of undried chemical pulp fibres, and of both undried and dried mechanical pulp fibres.

For the collapsed fibres of dried and reconstituted kraft and other chemical pulps, values can be obtained for the fibre cross-section dimensions of width, wall thickness, and thickness. Such values can also be obtained for undried fibres and this allows the effects of pulp drying and reconstitution, and other pulp processing treatments to be determined. Some effects of pulp drying are to cause fibres to be collapsed and fibre walls to be somewhat reduced in thickness. The widths of unbleached kraft fibres are generally unchanged by pulp drying although those of bleached kraft fibres are substantially decreased by the drying process.

TABLE 2—Cross-section dimensions of undried, and dried and reconstituted pulps

Kraft pulp wood supply	Pulp description	Pulp treatment	Weighted average fibre length* (mm)	Fibre thickness† (μm)	Fibre width‡ (μm)	Fibre wall thickness§ (μm)
Low-density	Unbleached	Undried	2.51	21.56	44.38	4.02
		Dried & reconstituted	2.52	11.36	44.34	3.06
Medium-density	Unbleached	Undried	3.01	24.38	45.32	4.66
		Dried & reconstituted	3.06	15.95	44.10	4.26
Medium-density	Bleached	Undried	3.22	20.69	45.06	5.01
		Dried & reconstituted	3.09	15.11	41.51	3.90

Statistical significance

* Different at the 5% level if fibre lengths differ by more than 0.13 mm.

† Different at the 5% level if fibre thicknesses differ by more than 1.51 μm.

‡ Different at the 5% level if fibre widths differ by more than 2.58 μm.

§ Different at the 5% level if fibre wall thicknesses differ by more than 0.47 μm.

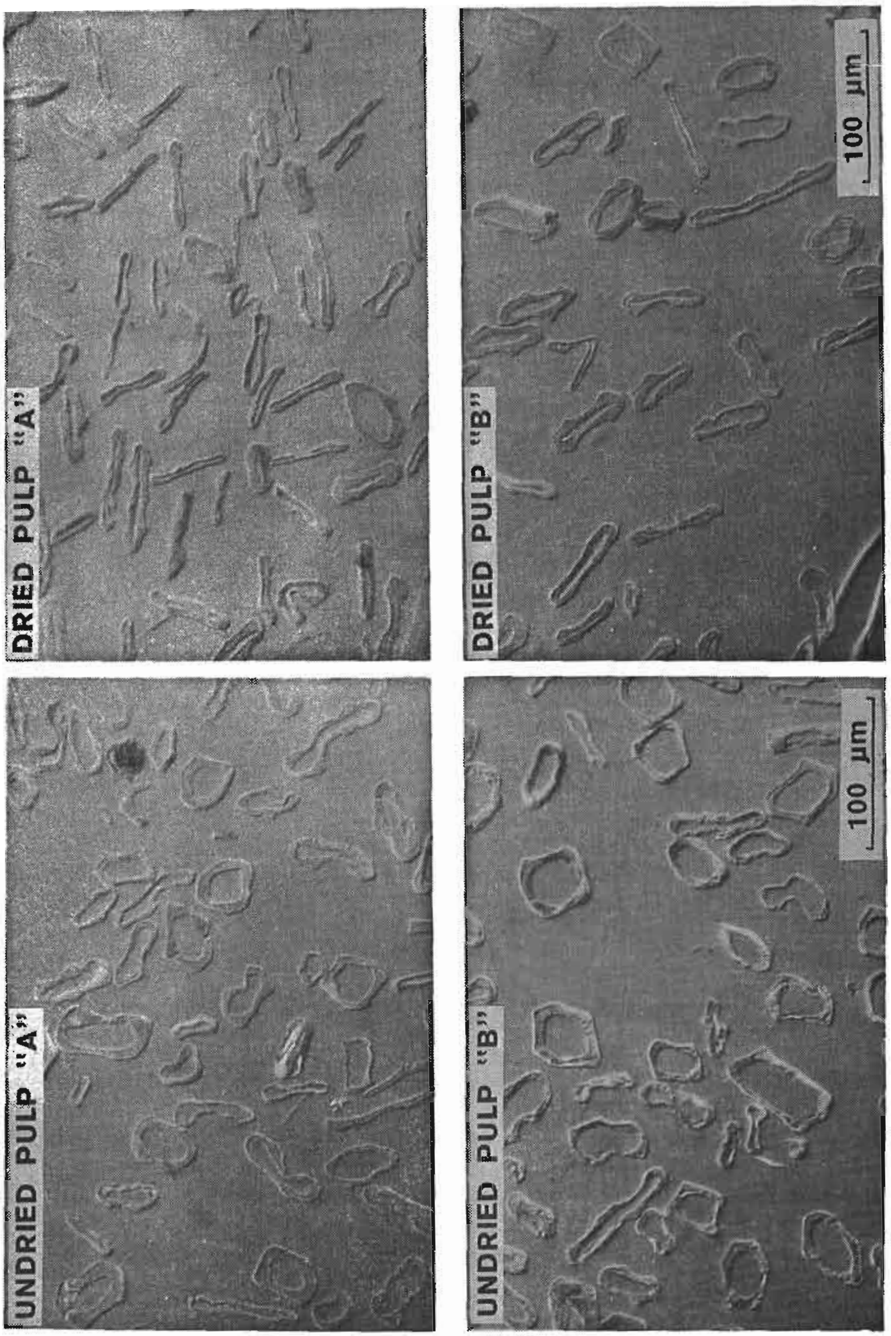


FIG. 4—Cross-sectional views of undried and of dried and reconstituted kraft pulp fibres, Pulp "A" from low-density wood and Pulp "B" from medium-density wood.

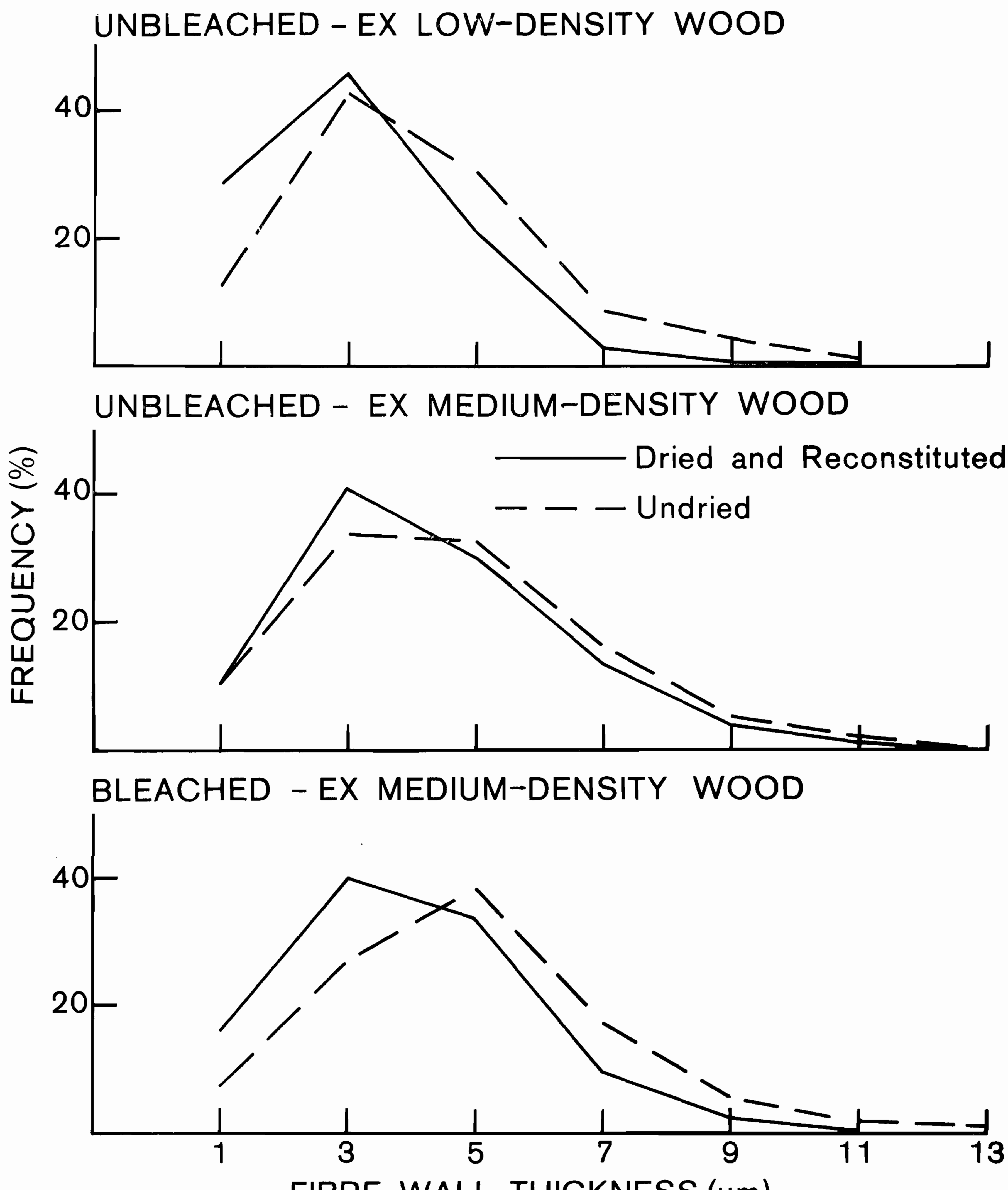


FIG. 5—Fibre thickness frequency distributions for undried, and dried and reconstituted pulps.

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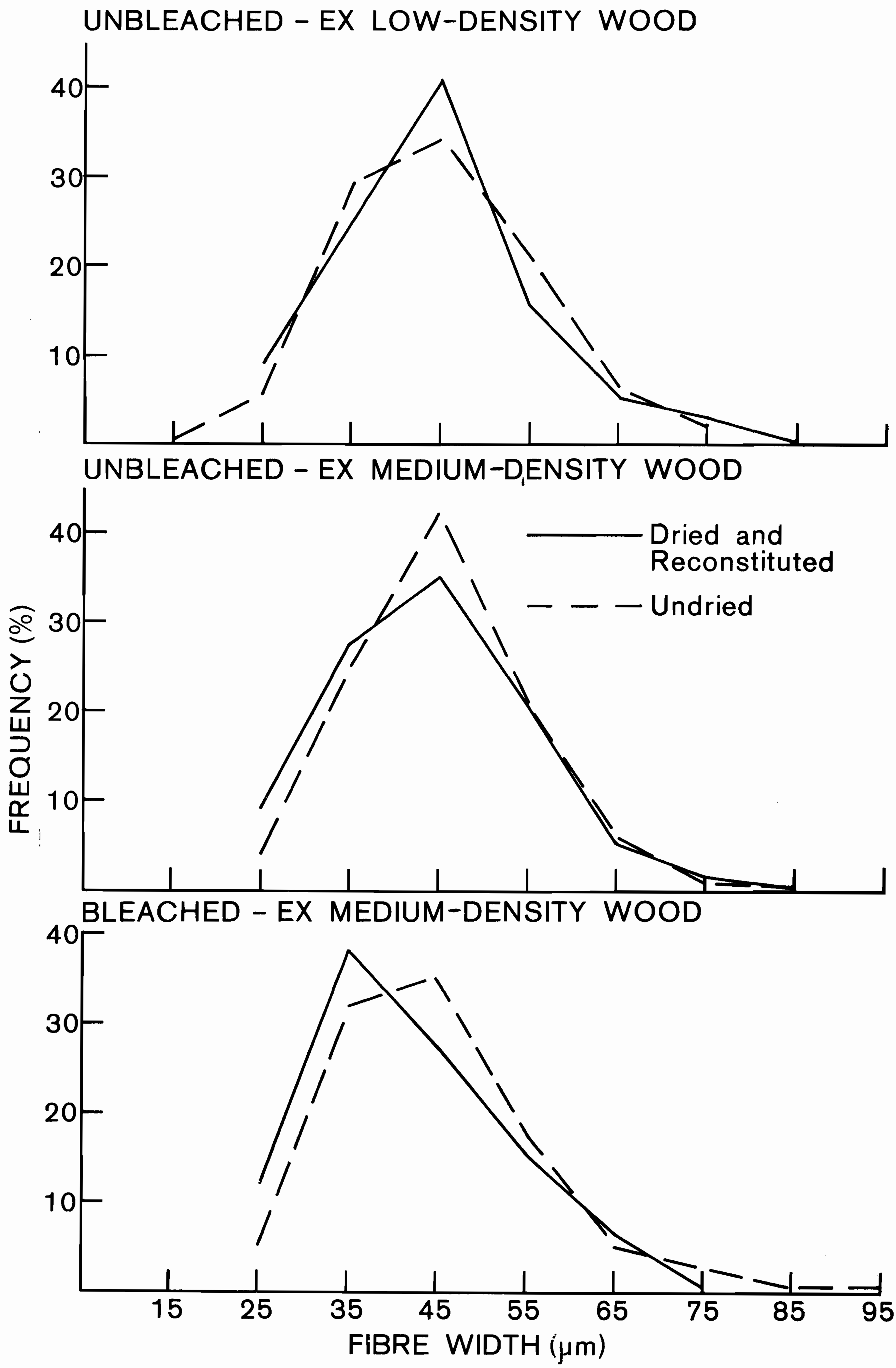

FIG. 6—Fibre wall thickness frequency distributions for undried, and dried and reconstituted pulps.

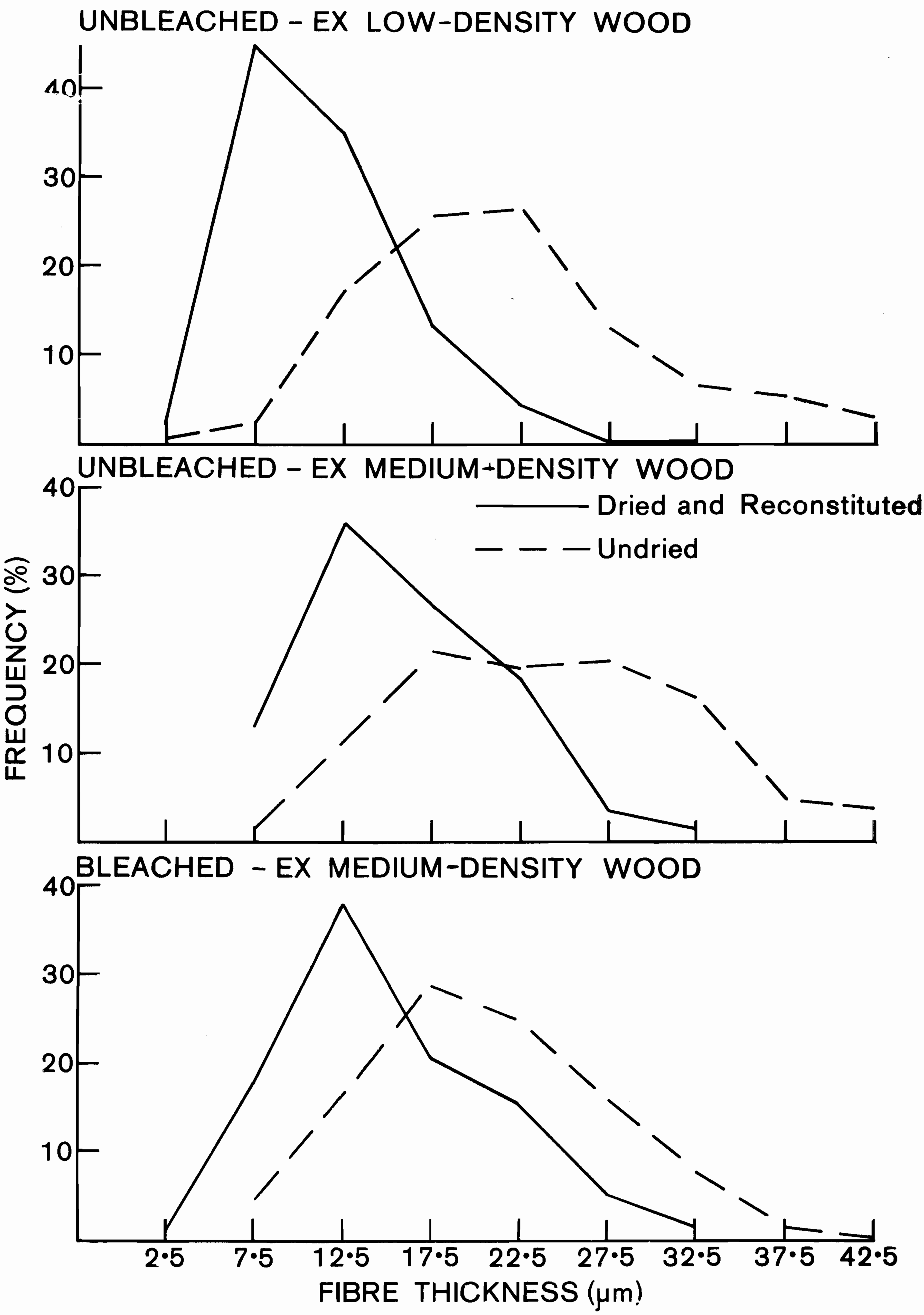

FIG. 7—Fibre width frequency distributions for undried, and dried and reconstituted pulps.