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T 232

BALLOT NO. 03 SARG

DRAFT NO. 02

DATE 6/1/2023

WORKING GROUP
CHAIR To be determined

SUBJECT
CATEGORY Pulp Properties

RELATED
METHODS See "Additional Information"

Fiber length of pulp by projection

(Proposed Reconfirmation of Classical Method T 232 cm-13)
(Draft 2, no changes from previous draft)

1. Scope and summary

1.1 This is a projection method (*1*) by which the weighted average fiber length of a pulp may be measured relatively quickly and easily.

1.2 If *1* is the length of any fiber in a sample of pulp, *w* its weight, and if *N* fibers are measured, their total length ($\Sigma 1$) being *L*, the numerical or arithmetical average length is $\Sigma 1/N$ or L/N; their weighted average length by length = $\Sigma(l^2)\ \Sigma\ l$ and their weighted average length by weight $\Sigma(lw)/\Sigma\ w$.

1.3 The numerical or arithmetical average fiber length of paper pulps is a not a commonly used value, since the pulps consist of whole tracheids and shorter elements down to submicroscopic lengths, which are included in the arithmetic fiber length and there tends to be a larger quantity of them as fiber length decreases. The stated average is especially meaningless if the least length arbitrarily adopted as the lower length limit for a "fiber" or particle is not also given. The shortest fibers contribute very little to the total measured length, but numerically they are just as important and influence the final result of an arithmetical average just as much as the longest fibers. On the other hand, the weighted average fiber length is a fundamental property of pulps and relates directly to paper properties (*2*). The shortest fibers in an average specimen of pulp contribute very little, either to length or to weight in the calculation of the weighted average length and hence have an almost negligible effect on most test results. This corresponds in many cases to their almost negligible effect on the common properties of a pulp other than groundwood, except for its freeness and the transverse tensile strength, light scattering, or the air permeability of test sheets made from it. Fines and short fiber influence paper properties in a very different way from long fibers, thus, it is generally best to look at fines and longer fiber separately.

2. Summary

2.1 For the most accurate determination of the weighted average fiber length of a pulp, the sample should be fractionated and the result calculated from the individual fractions as described in TAPPI T 233 “Fiber Length of Pulp by Classification.” In any case, if any appreciable portion of the sample consists of very short fibers or debris, it is necessary to find the weight of the portion that does not contribute to the property of length so that the weighted average length by length, or by weight, may be decreased accordingly.

2.2 A companion method for measuring the coarseness, or weight per unit length of the sample, is described in TAPPI T 234 “Coarseness of Pulp Fibers.” Although for the present method it is not necessary to employ a quantitative procedure to prepare specimen slides as there described, if this is done, measurements of both fiber length and fiber coarseness may be made using the same slide.

3. Significance

3.1 This is a non-automated historical method for determining the weighted average fiber length. It is important in that it provides a benchmark for comparison with the more automated methods.

3.2 If an ordinary horizontal projector or a vertical projector such as shown in Fig. 2 is used, the grid may then comprise thin lines drawn in permanent ink on a screen made of hard paper or a sheet of white plastic with a matte surface.

3.3 The ground plate-glass grid for the arrangement shown in Fig. 1 may be made as follows: On its underside, preferably the smooth or unground side, stretch threads across the plate parallel and 25 mm (1 in.) apart, fastening their ends with adhesive tape. Across the other two sides of the plate, stretch similar threads at right angles to the others. The thread shown at a distance of 212 mm ($8^1/_3$ in.) is to define the length of the lines for coarseness measurements according to T 234. For hardwood or short-fibered pulp, have the threads spaced 12.7 mm (0.5 in.) apart if a projector is used.

3.4 *Multiple tally counter* (desirable but not essential). One with eight keys and preferably also with a totalizer, for example, the counter commonly used for recording the numbers of the different cells in a specimen of blood.

3.5 *Screen* (for pulp containing an appreciable quantity of debris), preferably a pulp classifier with a 100 to 150-mesh screen, or, if not available, a small 200-mesh sieve.

3.6 *Magnification scale.* A short piece of transparent millimeter scale or a slide scratched with two parallel lines 0.5 ± 0.005 cm apart.

3.7 *Other equipment:* Microscope slides, preferably large size, 3.8 × 7.6 cm (1½ by 3 in.); microscope needle; 2.5 × 10 cm test tube; coarse fritted glass crucible; 30-50 mL weighing bottle (for 1 g moist pulp).

4. Apparatus

4.1 *Projector* to project the images of fibers on a glass slide to a screen, the magnification and distances preferably such that 1 mm on the slide equals 1.0 in. on the screen (25.4:1). A standard 35-mm slide projector or enlarger may suffice and provide an enlarged image on a vertical or horizontal screen. For some purposes a more convenient design of the apparatus is shown in Fig. 1. The projector (1) accommodates a slide at least 50 mm wide. Its rays are turned by a prism (2) into a room (dark room or constant humidity room) then turned up by a chromium-plated and polished, rolled-brass plate (3) to the underside of a 30.5 × 30.5 cm (12 × 12 in.) ground plate-glass screen *(4)* with its upper surface frosted. Figure 2 shows an arrangement using a vertical projector.

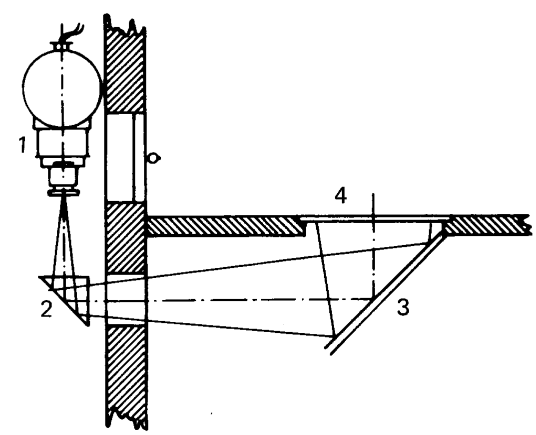

Fig. 1. Diagram of projection apparatus

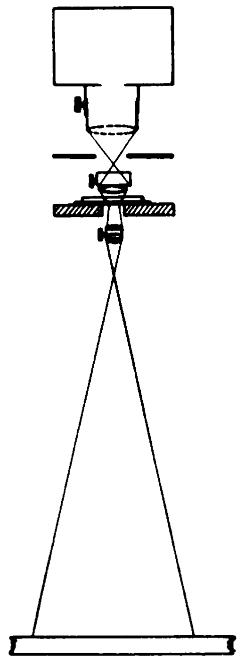

Fig. 2. Vertical projector

4.2 *Image grid for screen* (see Fig. 3). The one illustrated is a composite one suitable for both fiber length and fiber coarseness measurements. Distinguishing marks are made to identify the 9 (as shown) or preferably 16 squares in the center of the field which are used as the basic area for the length measurement. For samples of hardwood or any other pulps with the majority of fibers 1.5 mm or less, it is a good idea to use a grid having the equivalent of 0.5 mm spacings.

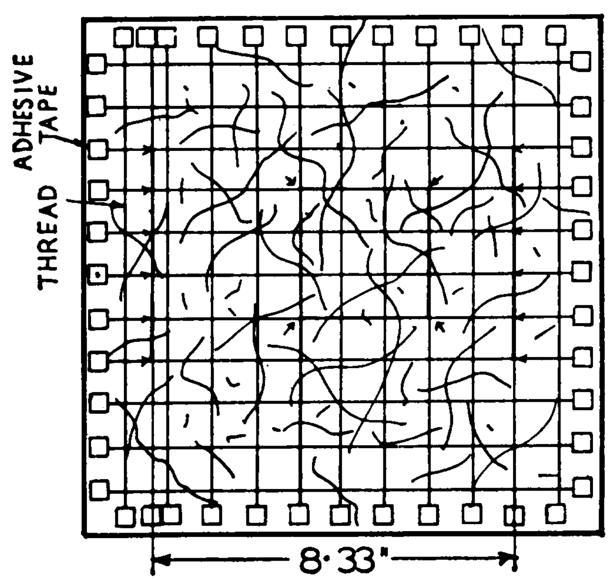

Fig. 3. Grid for fiber lengths and weight per unit length.

5. Test specimen

Required is a representative specimen of a dispersed sample of pulp weighing a few milligrams. The sample is required to be either free from debris or its percentage of debris known. If this percent is not known, one gram or more of pulp is needed.

6. Procedure

6.1 The preferred and most accurate procedure for determining the weighted average length of a pulp by weight is as follows: Classify 5-10 g of the pulp, take about 50 mg of the fibers from the wet pad of each fraction disperse, make into slides, estimate the length of the fibers in each, and calculate the result as here described.

NOTE 1: If the weighted average fiber length in each compartment is determined for a particular sample, these values may be used directly for subsequent similar samples.

6.2 Make slides as described in T 234 except that no more than about 2 mg of the fibers, if over 2 mm long, should be deposited on the filter paper on the sheet machine. If there are too many, the ends of individual fibers become difficult to distinguish.

6.3 An alternate method of preparing slides is as follows: With the microscope needle, pick out about a milligram of fibers from a sample of wet pulp, place on a microscope slide, add a few drops of water and disperse over the whole or a portion of the slide as described in TAPPI T 401 "Fiber Analysis of Paper and Paperboard."

NOTE 2: Using a needle to take a specimen of fibers may give a disproportionately large number of long fibers. Accordingly, unless very wet, add a few drops of water to the center of the pad before picking up the specimen as a single bunch of fibers from the watered spot.

6.4 If a classifier is not available, disperse dry pulp in water by thoroughly soaking the fibers for at least 1 h, and use a disintegrator as described in TAPPI T 205 “Forming Handsheets for Physical Tests of Pulp” for the minimum period required to separate the fibers, otherwise the propeller may appreciably reduce their length (*3*). **Caution:** Do not use a high-speed disintegrator.

6.5 Make a 0.1% dispersion with 1 or 2 g of the sample and divide the dispersion into two accurately measured volumes. Filter one volume through a small Gooch crucible with coarse fritted glass. Remove the wet pad and all loose fibers from the crucible with a microscope needle, place the pad in a weighing bottle, dry the fibers in an oven, and weigh.

6.6 Add the other measured volume to a small 200-mesh sieve and wash for at least ½ min or so with a stream of water from a faucet or hose, catching a specimen of the filtrate in a small beaker soon after the washing has started. Wash the remaining fibers to one edge of the screen. Allow the debris caught in the small beaker to settle, decant the water, prepare a slide from a portion of the residue and observe the proportion of long fibers present. This proportion should be negligible or very small. Discard this slide.

6.7 With the microscope needle, pick out the fibers remaining in the screen, place in a tared weighing bottle, dry, weigh, and compare with the dry weight of the fibers from the fritted glass crucible to obtain the percentage of debris present in the original sample.

6.8 When examining the specimen slide, if softwood pulp, use the screen with grid spacings the equivalent of 1 mm apart, and if for hardwood or equally short fibers, use a screen with grid spacings the equivalent of 0.5 mm apart. Place or fix the magnification scale in the projector with the graduations adjacent to the top surface of a clear slide, and focus and adjust its image on the grid on the screen that a 5-in. distance on the grid exactly coincides with 5 mm on the scale.

NOTE 3: It is not essential to have this correspondence or magnification provided that the equivalent distance between the lines of the grid is accurately known.

6.9 Remove the scale and clear slide and place the specimen slide in the projector. Starting with the upper left-hand square of the selected base area situated in the center of the screen [9 or 16 of the 25-mm (1-in.) squares, or 36 or 64 of the 12.7 mm (½-in.) squares], record the number of grid lines crossed in any direction by each fiber over 0.1 mm in length, having an end in that square. If the fiber is over 0.1 mm long and does not cross a grid line, record the presence of both ends as 2 on the zero counter or zero tally line. If both ends of any fiber lie in the square being examined and it is looped over one or more grid lines, record twice the number of times it crosses the grid lines on the appropriate tally, because it has two ends in that square. After recording the crossings for each having one or both ends in that square, proceed to record the crossings for all the fibers having an end in the adjacent square to the right, then in the next. Continue systematically in this manner until all the fibers having at least one end in any square in the base area have been examined and the number of crossings of each recorded.

6.10 Move the slide along to cover another base area and repeat the count of all the fibers having one or two ends in that area until the crossing of at least 200 and preferably 300 fibers have been tallied.

7. Calculation

7.1 Write in the numbers of fibers in Column B for each tallied group of crossings, as shown in Table 1. Multiply Column B by Column A to give the values entered in Column AB, using the factor of 0.3 for the first line as the average unit length of the fibers over 0.1 mm long that had no crossings. Multiply the AB column by A to give the values in column A^2B. Sum the third and the fourth columns, divide the sums and multiply the result by π/4 and by the distance between the grid lines, which in this case is 1.0 mm (0.5 mm if the ½ mm grid is used) For example, (1495/459) x (π/4) x 1.0 mm = 2.57 mm.

Table 1. Calculation for weighted average length by length for whole TAPPI reference sulfite pulp (1958)

Number of fiber crossings (A)	*Number of fibers (B)*	*AB*	*A^2B*
0 (0.3)	20	6	2
1	58	58	58
2	42	84	168
3	38	114	342
4	23	92	368
5	16	80	400
6	3	18	108
7	1	7	49
		459	1495

7.2 In this example, the pulp contained 17.4% of debris (fibers having a length of less than 0.1 mm). Since this portion of the sample adds nothing to its effective fiber length *per se*, the weighted average length of the pulp is 2.57 × 0.826 = 2.12 mm. This result requires a further correction to transform it to weighted average fiber length by weight, which is believed to be the most significant measurement, as follows:

7.2.1 *Correction for increased weight per unit length of the longer fibers.* The longest fibers in a sample may have two or three times the weight per unit length of the shortest, so that this must be taken into account when calculating the weighted average length by the weight of the fibers.

7.2.2 This may be done as shown in Table 2 by multiplying Columns A and B by factors proportional to the decigrex or weight per unit length for each length class (*1*). The values shown in Column G were experimentally obtained for that particular pulp but it is probable that the proportionate values do not vary greatly for other softwood pulps, and perhaps are similar also for hardwood pulps.

7.2.3 The last column is obtained by multiplying the ABG column by A. The weighted average length by weight is therefore (3365/935) x (π/4) x 1.0 mm = 2.86 mm and, taking the 17.4% debris into account, = 2.86 x 0.826 = 2.36 mm.

7.2.4 Using a classifier and measuring the length and weight of each fraction separately, the actual weighted average length by weight of the fibers of this pulp was found to be 2.44 mm.

7.2.5 Since insufficient data are presently available to confirm that the average length weighted by length to that weighted by weight is properly corrected by the procedure shown in Table 2, for simplicity use an arbitrary factor of 1.15 when dealing with a whole pulp sample that has not been fractionated to convert the result weighted by length (after corrections for the debris) to get the result weighted by weight.

7.2.6 For example, in this case, 2.12 × 1.15 = 2.43 mm as the estimated weighted average fiber length by weight.

Table 2. Calculation for weighted average length by weight of whole TAPPI reference sulfite pulp (1958)

Number of fiber crossings (A)	*Decigrex/10 (G)*	*Number of fibers (B)*	*ABG*	*$A^{-}BG$*
0 (0.3)	1.2	20	7	2
1	1.3	58	75	75
2	1.5	42	126	252
3	1.9	38	216	648
4	2.3	23	211	844
5	2.7	16	217	1085
6	2.9	3	52	312
7	3.0	1	21	147
			925	3365

8. Report

Report the weighted average fiber length by weight of the sample to the nearest 0.1 mm.

9. Precision

Although an adequate study has not been made, repeated tests on a sample should be within a range of about 10%.

10. Keywords

Pulp, Fiber length, Projection

11. Additional information

11.1 Effective date of issue: To be assigned.

11.2 From the tables, it will be seen that the influence of the shortest fibers (0 category) on the final result is minor. On the other hand, the single fiber with seven crossings influences the result by over 2%. It is therefore important to count fibers to be sure that an accurate proportional measure of the largest fibers is obtained. Furthermore, when counting a limited number of fibers, it is well to see that the number of crossings of a single particularly long fiber which happens to weave back and forth over a grid line is not, because of this coincidence, unduly high. The maximum number of crossings it should make normally should not exceed about twice its equivalent length in millimeters.

11.3 In place of using the projector and grid screen to count the fiber crossings, some may prefer instead to use an eyepiece in a microscope with an inscribed grid micrometer. If so, the concentration of fibers on the specimen slide should be kept low enough so that it is not too difficult to account for every fiber with an end in the selected base area.

11.4 This method has been slightly revised from the previous version. The number of squares to be examined in a portion of the grid with the projected fiber images has been increased.

11.5 This method was revised in 1958 and 1964. Editorial revisions were made in 2013.

11.6 This method had been placed in the Classical Method category due to lack of timely review. In 1995-96, the Test Methods Subcommittee of the Quality and Standards Management Committee required all committees to review such methods and either confirm as Classical or revise as Official or Provisional. The responsible committee for this method confirmed that this version is properly classified as a Classical Method, in accordance with the current test method regulations.

Literature cited

1. Clark, J. d'A., *Tappi* **45** (1): 38 (1962; *Pulp Paper Mag. Can.* **63**(2): T53 (1962).
2. Clark, J. d'A., *Tappi* **45** (8): 628 (1962).
3. Pfäffli, I., and Sisko, M., *Norsk Skogind.* **14**(6): 1 (1960).

Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Standards Department. ■