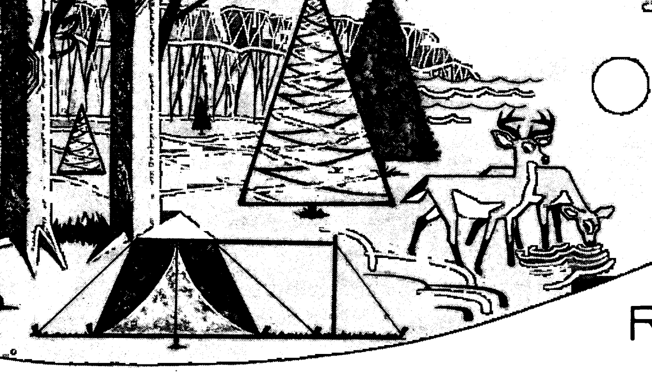

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U. S. FOREST SERVICE

RESEARCH NOTE NC-131

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

DETERMINING THE TERMINAL VELOCITY OF WOOD AND BARK CHIPS

ABSTRACT.—Designing an efficient air flotation segregator to segragate bark chips from wood chips requires that the terminal velocities be determined for chips of various pulpwood species. The technique described here uses forced air in a vertical wind tunnel with the chip initially at rest on a stationary screen; when the terminal air velocity is reached, the chip begins to float. A unique flow straightener was designed to give uniform air velocity distribution in the center portion of the vertical tube and a higher velocity near the tube wall, thus preventing the chip from moving up on its edge against the wall. A calibration curve correlating the air velocity to the voltage applied to the blower motor eliminated the need of the pitot tube and manometer in each velocity measurement, thus making the test procedure much simpler and more efficient. Preliminary results show a significant difference between terminal velocities of aspen wood and bark chips, thus air flotation is a promising segregation method.

OXFORD: 825.71:892.43:833. KEY WORDS: segregation, pulpwood, air flotation.

One process being investigated in separating and segregating bark chips from wood chips is air flotation. In this process the segregation principle is based in part on the difference in terminal velocity between wood and bark chips. Thus, knowing the terminal velocities of wood and bark chips of different pulpwood species is required to design an efficient air flotation segregator. Much information is available on the aerodynamic properties of agricultural materials (Hallee 1970, Kinze *et al.* 1968, Rumble and Lee 1968, Soule 1968, Wolf 1970). Also, some research has been conducted on pneumatic classifiers in the metal powder industry (Leschonski and Rumpf 1969) and the wood particleboard industry (Ruckwitz 1967). The latter has determined the terminal velocity of paper and cardboard chips as a group, but I have not been able to find any references that include the terminal velocities of individual wood and bark chips.

The terminal velocity of a particle is commonly defined as the maximum velocity the particle attains in free fall under the action of gravity. This occurs when the net accelerating force (gravity) equals the upward resisting force (drag) acting on the particle. One method that has been used to determine terminal velocity is measuring and recording the displacement-time curve of the particle in free fall. The method described here uses forced air in a vertical wind tunnel with the particle (a wood or bark chip) initially at rest on a stationary screen; when the terminal air velocity is reached, the chip begins to float in the air stream.

EXPERIMENTAL APPARATUS AND PROCEDURES

The experimental setup included a DC blower motor controlled by a DC power supply, a digital voltmeter, a vertical plexiglass tube (5-inch inside diameter) with a flow straightener, a 16-mesh screen in the tube, a pitot tube, and a Dwyer

Microtector[1] manometer (fig. 1). The air velocity was varied by changing the voltage supplied to the blower motor. This voltage was monitored by the digital voltmeter.

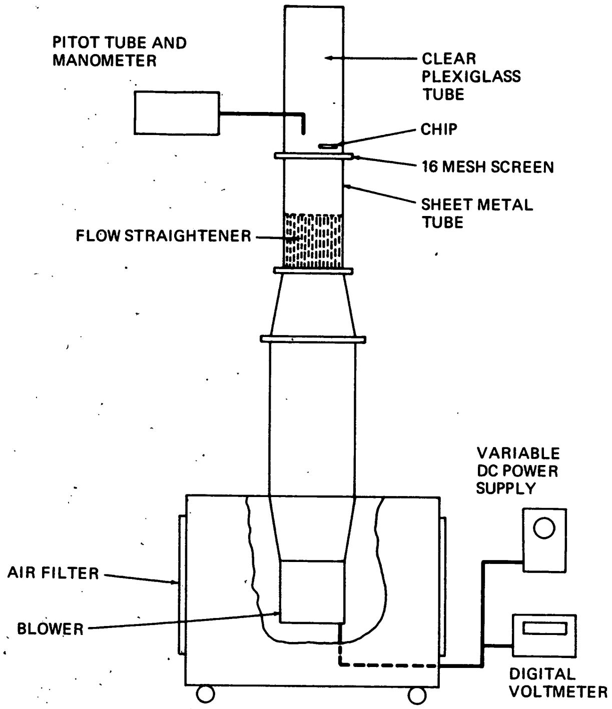

Figure 1.—Experimental setup used to measure the terminal air velocities of the wood and bark chips.

The pitot tube and manometer were used to determine the velocity profile of the air stream across the tube, and also to calibrate the voltage output of the DC power supply in terms of the air velocity through the test section at the center of the screen. The measured velocities were determined by the pitot tube equation:

$$V = C\sqrt{2g_c\Delta p/\rho}\ ,$$

where: V = velocity in ft./sec.
C = calibration coefficient
g_c = proportionality factor = $32.174\ \mathrm{lb._m - ft./lb._f - sec.^2}$
Δp = velocity head in $\mathrm{lb._f/ft.^2}$
ρ = density of air in $\mathrm{lb._m/ft.^3}$

The flow straightener is designed to give a uniform air velocity distribution in the center portion of the vertical tube and a higher velocity near the tube wall (fig. 2). This higher velocity keeps the chip in the center of the tube instead of moving and rotating up on its edge against the wall. The flow straightener is made of plastic straws with two different diameters and lengths. The longer and smaller-diameter straws make up the greater portion of the flow straightener, but they are surrounded by two concentric rows of the shorter and larger-diameter straws. Therefore, the air flow is restricted more in the center portion of the tube than near the wall, giving the desired velocity profile (fig. 2).

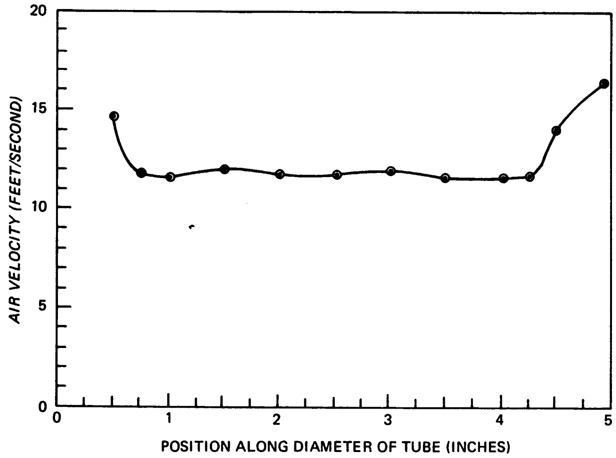

Figure 2.—Velocity profile of the airstream across the diameter of the tube.

The calibration procedure consisted of calibrating the voltage supplied to the blower in terms of air velocity in feet per second. The air velocity was measured in the center of the tube at 1-volt increments from 0 to 27 volts. A calibration equation was developed from five calibration test runs by the least squares method (fig. 3). From this equation the air velocity could be determined for any voltage setting on the variac of the DC power supply. The calibration curve eliminated the use of the pitot tube and manometer in measuring the terminal velocity of each chip, thus making the test procedure much simpler and more efficient.

The procedure used to determine the terminal velocities of individual chips was as follows:

1. The chip was placed on screen inside the tube.

2. The variac on the power supply was adjust-

[1] *The manufacturer of equipment is mentioned for identification only, and no endorsement by the USDA Forest Service is implied.*

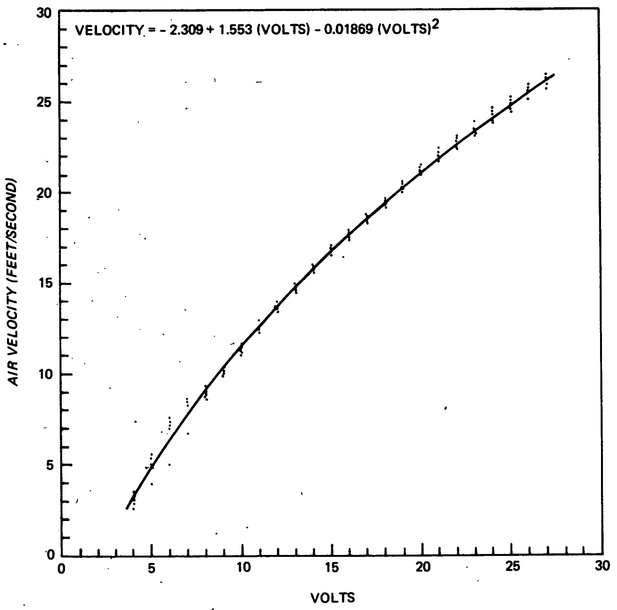

Figure 3.—Calibration curve used to calculate the terminal air velocity for any voltage setting.

ed to increase the air velocity until the chip was floating.

3. The voltage that registered on the digital voltmeter was recorded.

4. The terminal velocity in feet per second was determined from the calibration curve.

RESULTS

The technique was tested with aspen wood and bark chips made by chipping unbarked logs with a commercial chipper. The chips were classified on a Sweco[1] classifier and the following three chip sizes were tested: − 1⅛-inch + ⅝-inch (passed through the 1⅛-inch screen and retained on the ⅝-inch screen), − ⅝-inch + ⅜-inch, and − ⅜-inch + 3/16-inch. The weight, length, width, thickness, terminal velocity, and moisture content of 100 wood and bark chips of each nominal size were measured (table 1). Terminal velocities of wood and bark chips differed by approximately 5 to 7 feet per second, due to differences in specific gravity and shape. This is shown by comparing the weight and thickness of the wood and bark chips in each size class. More research is being done to develop prediction equations for terminal velocity in terms of the chip dimensions and specific gravity. By using the normal distribution as an approximation of the terminal velocity, the percentage of the total wood and bark chips that would be lifted at any given air velocity were calculated (table 2). The bark content in the wood product (that is, the chips that were lifted) at the specific air velocities was determined. Comparing these figures with the input bark content shows the amount of bark that could be removed by air-flotation methods. Also, the percent of the total wood chips lifted gives an indication of the amount of wood recovery in each size class.

In a production process the wood product from each chip size would be combined to form a single product. The high bark content in the 3/16-inch wood product would have little effect on the combined product because of the small percentage of chips that this size represents in terms of the total mix. For example, let us assume that the weighted fractions are as follows: 60 percent of the chips in the ⅝-inch fraction, 30 percent in the ⅜-inch fraction, and 10 percent in the 3/16-inch fraction. Also, let us choose the following air velocities: 18 feet per second for the ⅝-inch chips, 15 feet per second for the ⅜-inch chips, and 12 feet per second for the 3/16-inch chips. The combined wood product would then contain 91 percent of the total wood with a bark content of 2 percent. These results indicate that

Table 1.—Mean measurements of aspen wood and bark chips

Nominal chip size (Inches)	Chip type	Weight	Length	Width	Thickness	Moisture content	Terminal velocity: Mean value	Terminal velocity: Standard deviation
		Grams	Inches	Inches	Inches	Percent	Ft./sec.	Ft./sec.
5/8	Wood	0.77	0.78	1.14	0.13	50	13.9	2.0
5/8	Bark	1.72	.81	.90	.23	45	21.4	2.7
3/8	Wood	.31	.72	.54	.11	40	13.2	2.3
3/8	Bark	.52	.77	.40	.19	44	20.3	3.3
3/16	Wood	.11	.68	.30	.08	44	11.7	2.7
3/16	Bark	.15	.62	.24	.11	51	17.0	3.6

Table 2.—Possible results of segregating aspen wood and bark chips by air flotation methods

Nominal chip size (Inches)	Input bark content	Air velocity	Total wood lifted	Total bark lifted	Output bark content in wood product
	Percent	Ft./sec.	Percent	Percent	Percent
5/8	7.6	16.0	86.2	2.4	0.2
	7.6	17.0	94.5	5.4	.5
	7.6	18.0	98.3	10.8	.9
3/8	32.4	14.0	63.6	2.8	2.1
	32.4	15.0	78.3	5.4	3.2
	32.4	16.0	88.8	9.6	4.9
3/16	53.9	11.0	39.3	4.7	12.3
	53.9	12.0	54.0	8.1	14.9
	53.9	13.0	68.2	13.1	18.4

air flotation is a promising method of segregating aspen wood and bark chips.

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1972

☆U.S. GOVERNMENT PRINTING OFFICE: 1972—760397/32
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