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Dust controls for a wood shaper

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The purpose of this study was twofold: first, to characterize the wood dust emissions from a shaper; second, to see if a usable control could be developed to reduce emissions from the shaper. The study showed that a hardwood (red oak) generated about eight times as many dust particles as a soft wood (white pine), and particle board generated about ten times as much dust as white pine. Relatively simple controls were shown to significantly reduce emissions. Huebener, D. J.: Dust controls for a wood shaper. *Appl. Ind. Hyg.* 2:164-169; 1987.

Background

The Control Research Section, Division of Physical Sciences and Engineering, of the National Institute for Occupational Safety and Health (NIOSH) has been studying emissions and controls for woodworking machinery since 1981. Based on NIOSH surveys of furniture manufacturing plants and auto model shops, the greatest wood dust emissions from stationary woodworking machines were from belt sanders and wood shapers. A device for reducing emissions from belt sanders was developed by Hampl *et al.*⁽¹⁾ The topic of this paper is the other targeted machine: the wood shaper.

Wood dust has been proven or implicated as the cause of many diseases. These include nasal cancer, allergic reactions (dermatitis, asthma) to some woods, and greater than expected rates of colon, rectal, and salivary gland cancers.⁽²⁾ Because these diseases involve the digestive system and the upper respiratory tract, it indicates that the inspirable mass (all particles which can enter the nose or mouth when breathing) of wood dust may be more important than the respirable (inspirable particles small enough to penetrate deep in the lungs) fraction. The inspirable fraction includes particles up to 180

micrometers (μm) aerodynamic diameter.⁽³⁾ One 180 μm particle has the mass of six million 1.0 μm particles of the same density.

There is a very little literature relevant to the control of dust emissions from wood shapers. The American Conference of Governmental Industrial Hygienists (ACGIH) *Industrial Ventilation* manual recommends ventilation rates of 12.5–39.6 m^3/min (440–1400 cfm) for a wood shaper.⁽⁴⁾ There are no further details such as hood size, hood location, flow relation to wood type or cutter head, etc. This study defines some of these details.

The primary purpose of this study is to evaluate dust control for a wood

shaper. The absolute quantity and size of particles emitted will vary with depth of cut, cutter sharpness, wood feed rate, and many other parameters. The measurements made for this study are all relative and are intended to show the approximate effect of a change in exhaust ventilation rate, hood type and location, and type of wood.

Test configuration

Two configurations were tested. The first setup, shown in Figure 1, is used to shape straight cuts of wood such as window and door trim. For this type of work, a fence may be used to set the cutting depth, guide the work, and protect the operator. For this test configuration, the most logical location for the hood was next to the cutting head.

The second test configuration is commonly used for nonstraight cuts (when a pattern is used to make the desired shape). Here, the guide is a ball bearing. The shaping stops when the pattern rests against the bearing's surface. The safety guide over the cutter also serves to prevent any particles from

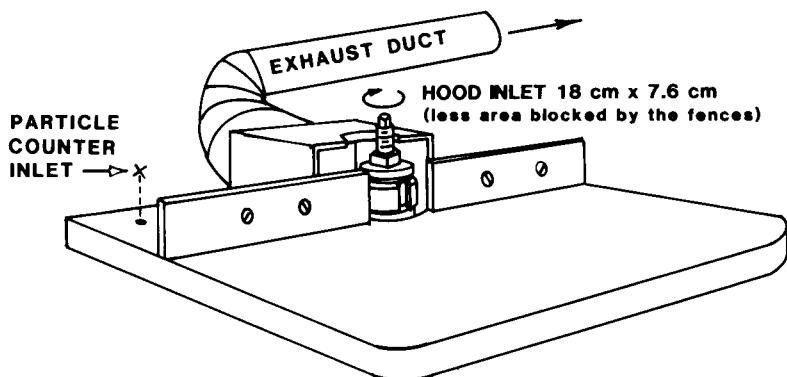


Figure 1—Test setup #1.

going straight up. For this test configuration, tests were run with the exhaust hood in two locations (Figures 2 and 3). One commonly observed exhaust hood location is on the back edge of the table. In this location, the operator can freely move the work piece over most of the table. For maximum dust collection, a more desirable location for the exhaust hood is nearer the cutting head; however, this would appear to restrict the operator's freedom to move work around the table because it would hit the hood. To overcome this problem, the hood extension which was put on the exhaust hood was built with a flexible side. Figure 3 shows some of the detail of this hood extension. The chains provide flexibility so wood can pass through the sides in all directions, and the cloth covering over the chains prevents high speed wood particles from passing through the chains. Thus, the operator's freedom of movement is only minimally restricted.

The shaper was a Powermatic model 26 with a five hp motor. It was located in a $3.7 \times 4.0 \times 2.4$ meter (12 ft $\times$ 13 ft $\times$ 8 ft) room. The room's only air inlet was from a filtered air supply, and the only room air outlet (other than leakage) was through the shaper exhaust hood. The dusty air was filtered by a bag house, then vented to the outside via the building's exhaust system. In both test configurations, the cutting head used was an 89 mm (3.5 in.) diameter square cutter.

A Royco light scattering particle counter (model 218) was used to monitor the concentration of small particles in the test room. The threshold particle diameter (the smallest particle that the instrument will count) was set at $1.0 \mu\text{m}$ because at a lower setting, many of the counts are really electronic noise. No upper limit on particle size was speci-

fied by the manufacturer. Using this Royco on normal room air resulted in background concentrations of about 500 particles per 0.28 L (0.01 ft³). However, when the filtered air was turned on in the room, the background count dropped to about 20 particles per 0.28 L (0.01 ft³) (Royco sampling rate is 0.28 lpm).

The Royco sampling location was different for the two test configurations. For the first test configuration, it was located at table height in the direction which particles would be thrown if they escaped the pull of the exhaust hood (the left-rear corner of the table). This location was used because few particles were detected in the breathing zone. For the second test configuration, the Royco was located in the operator's breathing zone. Also in the operator's breathing zone were the glass slides used to determine particle size distribution. The slides laid flat, and gravity was the only force which collected the particles. Although the slides are located in the operator's breathing zone, the size distribution is not directly related to that which would be inhaled by the operator.

To get a rough idea of the relative difficulty encountered by capturing

various size particles, the cutter speed was 10,000 rpm which corresponds to a maximum theoretical particle speed (same velocity as the cutter's surface speed) of 2800 m/min (9200 fpm). Small particles (less than $100 \mu\text{m}$) will not travel far in still air.⁽⁵⁾ However, the situation is more complicated because 1) the small particles seem to be carried for various distances by millimeter size dust particles and 2) the cutter head acts as a small blower wheel. Air velocity caused by the cutter wheel will be discussed later.

Test procedure

The ultimate goal of the project was to improve the collection of dust from the shaper. However, it is not certain whether the improvement should be measured in reduced numbers of particles per unit volume or mass per unit volume, so measurements (or relative measurements) of each type were made.

Wood feed rate was the number of cuts per minute which was comfortable for the operator. Naturally, this depended on the depth of cut, the height of cut, and the wood type. For the tests using the fence as a guide, the cuts were 1.6 mm ($\frac{1}{16}$ in.) deep by 1) 19 mm ($\frac{3}{4}$ in.) high by 8.5 m (335 in.) long—white pine and 2) 25 mm (1 in.) high by 6.8 m (268 in.) long—red oak. For tests using the ball bearing as the guide, the cuts were 13 mm ($\frac{1}{2}$ in.) deep by 1) 9.5 mm ($\frac{3}{8}$ in.) high by 2.4 m (96 in.) long for white pine, 2) 13 mm ($\frac{1}{2}$ in.) high by 1.2 m (48 in.) long for red oak, and 3) 9.5 mm ($\frac{3}{8}$ in.) high by 2.4 m (96 in.) long for particle board.

Absolute mass per unit volume numbers were not obtained. They would only be relevant for this cutter, room size, feed rate, wood type, etc. Therefore, all mass numbers are relative—the numbers for one wood type can only

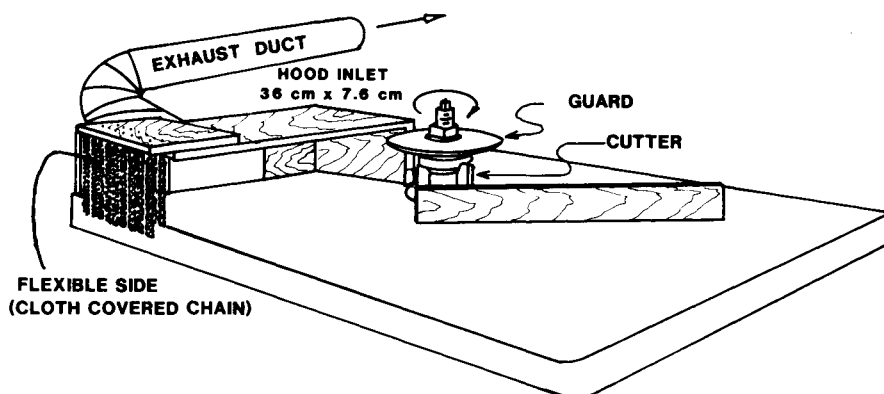


Figure 3—Test setup #2 (with hood extension).

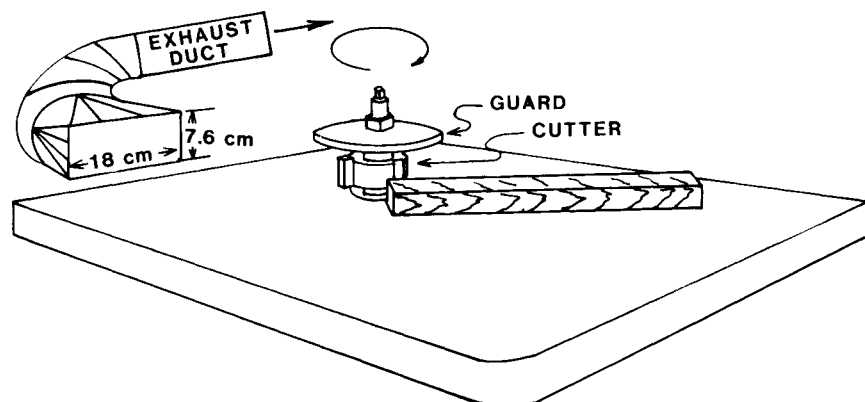


Figure 2—Test setup #2 (without hood extension).

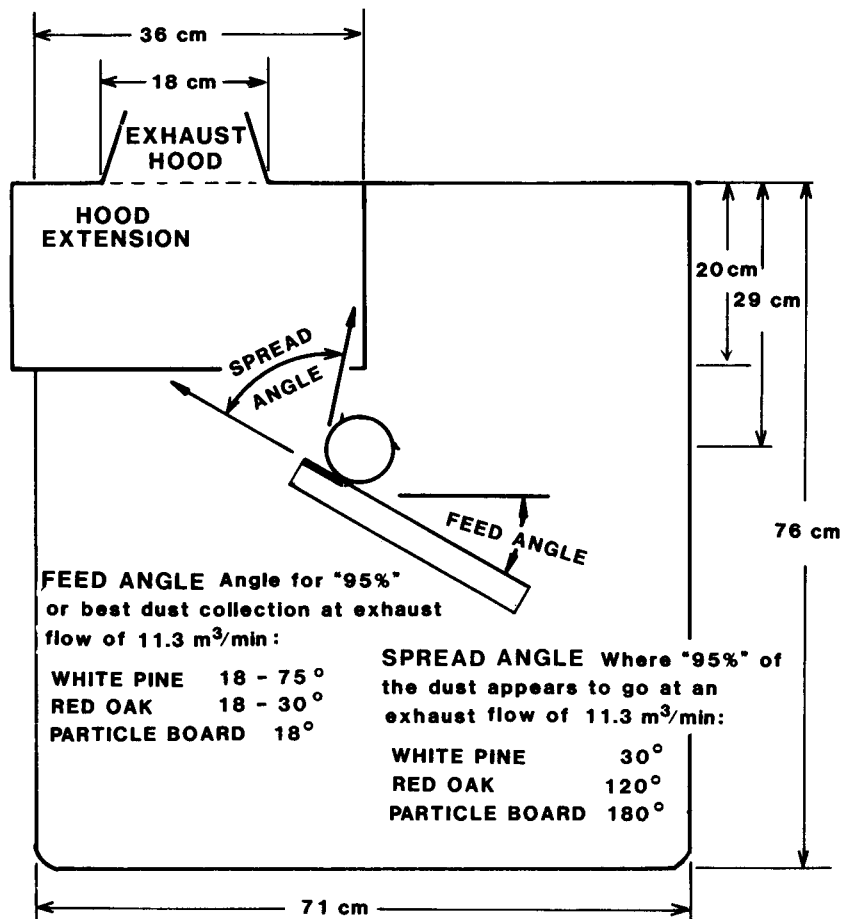


Figure 4—Wood feed angle and approximate dust spread angles for various wood types.

be compared to that of another type observing these constraints.

For the first test configuration (Figure 1), the particle counter inlet was located as shown rather than in the operator's breathing zone. This was done because preliminary tests showed that when the inlet was in the operator's breathing zone, there was no significant change in particle count when wood was being shaped.

Wood was fed to the shaper against the cutter's rotation. The procedure was to 1) set the desired exhaust flow rate; 2) adjust the clean air input to the room so it is under slightly positive pressure; 3) start the particle counter on its one minute cycle; 4) feed the shaper the appropriate length of wood (depending on the wood type) during the one minute period; 5) record the particle counter reading during a 20-second time span after the counting period, and wait for the balance of the 20 seconds to pass; and 6) finally, repeat the procedure starting at step number 3.

For the second test configuration (Figures 2 and 3), the particle counter was located in the operator's breathing

zone. On both sides of the counter were glass slides. These slides were used to determine the relative particle size distribution and the relative mass per cut for each set of test conditions. For this test configuration, the variables were

wood feed angle, cutting depth, cutting rate, exhaust flow rate, hood extension on/off, wood type, and clean air input flow rate.

The operator can partially control the amount of dust escaping into the room by adjusting the wood feed angle. Essentially, this aims the dust being generated in a particular direction. Because this is under the operator's control, preliminary tests visually determined the optimum feed angle for each wood type, and this angle was used to feed the wood toward the cutter. Figure 4 shows the angle chosen for each wood type and also shows the spread angle for the various woods. This spread angle (the direction that a majority of wood particles go) was also determined visually and is subjective. It is included because it was confirmed by the particle counts during the tests.

Wood was fed with the cutter rotation rather than against it, and the cutting depth was 13 mm (½ in.). For tests using red oak, the cut height was 13 mm (½ in.), and the feed rate was 1.2 m (48 in.) during the one-minute counting period. For tests using white pine, the cut height was 9.5 mm (¾ in.), and the feed rate was 2.4 m (96 in.) during the one-minute counting time. For tests using particle board, the cut height was 9.5 mm (¾ in.), and the feed rate was 2.4 m (96 in.) during the counting time.

Exhaust flow was determined by calibrating the exhaust duct using a pitot traverse. Exhaust flow was set at either 11.3 or 25.5 m³/min (400 or 900 cfm). Whenever the exhaust flow was

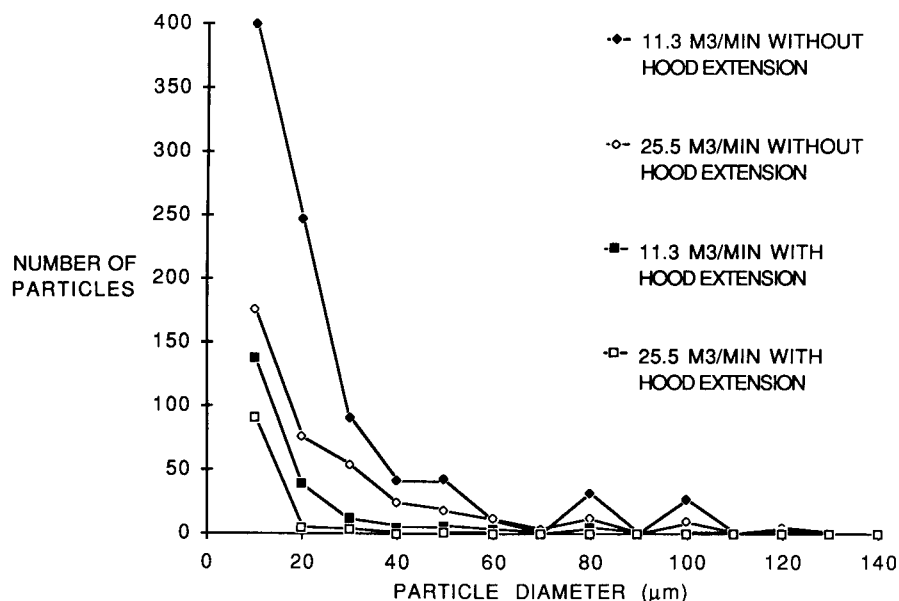


Figure 5—Particle size distribution of red oak dust.

changed, the clean air input to the room was adjusted to cause the room to be under slightly positive pressure. Positive pressure was necessary to prevent infiltration of outside air which would raise the background to about 500 counts per minute. This would mask the results in some tests. However, since excessive clean air flow could cause an artificially low dust reading, care was taken to maintain the room at only "slight" positive pressure.

The test procedure was similar to that used for the first test configuration. The direction of feed into the cutter was with the rotation rather than against it. The feed angle was that determined earlier to provide optimum particle collection. The number of cuts was the same for each wood type at each set of test conditions. The procedure was to 1) set the desired exhaust flow rate; 2) adjust the clean air input to the room so it is under slightly positive pressure; 3) install or remove the hood extension (depending on the test); 4) put the glass slides in their location; 5) start the particle counter on a one-minute cycle; 6) feed the appropriate length and type of wood into the cutter during the one-minute cycle; 7) record the particle counter reading during the 20-second time span after the counting period, and wait for the balance of the 20 seconds to pass; 8) repeat the process beginning at step number 5 until the desired number of cuts have been accomplished; and 9) remove and count the particles on the slides.

To check for repeatability (instrument, drift, cutter sharpness, etc.), the

particle counter readings were taken for a specific set of test conditions several times during the series of tests. The differences in results were negligible.

The particles on the glass slides were manually counted on a Zeiss microscope. This microscope has a calibrated graticule in place to make particle sizing easier and more accurate. No particles smaller than 10 μm were counted

because their mass is insignificant relative to the other inspirable particles. Since none of the particles were round, the diameter of a spherical particle with an equivalent cross-sectional area was estimated. A particle with an estimated diameter equivalent to 10 to 19 μm was counted as a 10 μm particle. Similarly, particles were grouped by diameter in 10 μm increments up to 180 μm . See Figures 5 and 6 for the red oak and particle board size distributions. All particles in the field of view (approximately 380 μm) were counted; particles which were only partially in view were counted as if they were chopped off at the edge of the view field. Thirty view fields were counted to get a reasonably accurate estimate of the actual particle size distribution. Finally, the relative mass of the particles was calculated assuming the mass of a red oak particle with a 1.0 μm diameter had a mass of one weight unit. This assumed density is not important since the ratio of the masses is the important factor. Similarly, the mass of a particle board particle with a 1.0 μm diameter was assumed to have a mass of 1.08 weight units (the ratio of the bulk densities is 1.08).

The relation between aerodynamic and optical diameter is not simply the

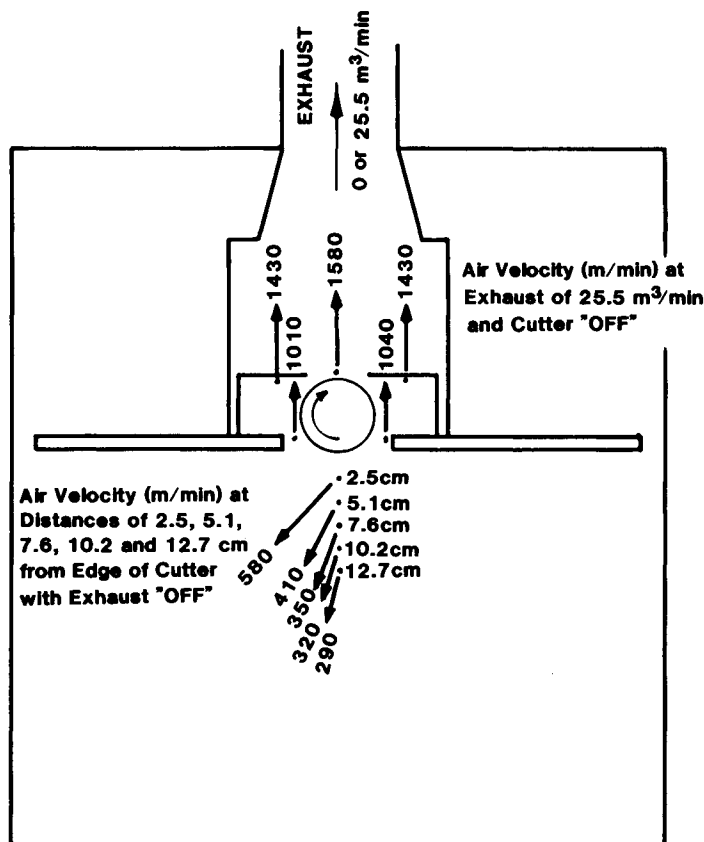


Figure 7—Air velocities for test setup #1.

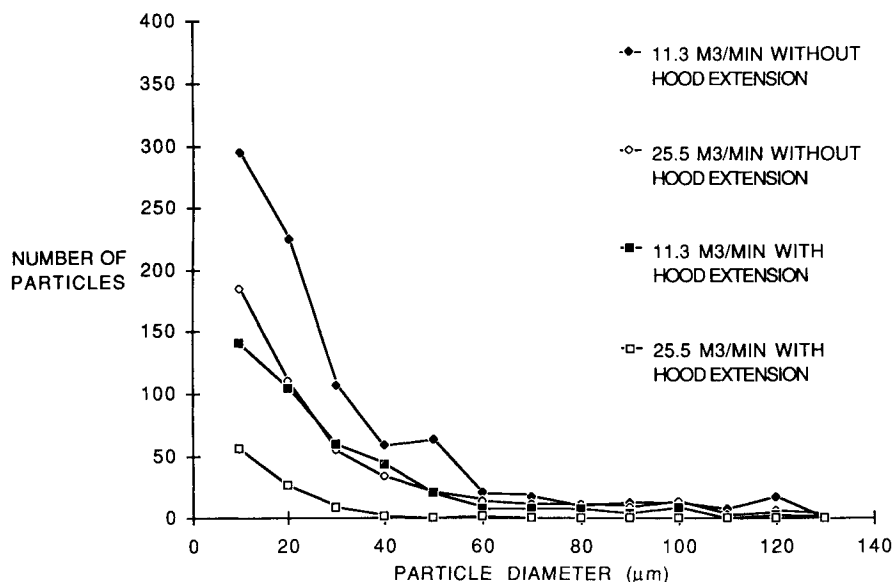


Figure 6—Particle size distribution of particle board dust.

TABLE I

Dust count levels for test setup #1 (relative to normal background)

Exhaust rate		Relative particle count	
m ³ /min	cfm	White pine	Red oak
13.5	475	1.9	1.9
24.8	875	1.3	1.4

NOTE: Dust counter inlet was not in the breathing zone.

ratio of the density of wood to the density of standard latex spheres; it is also a function of particle shape and refractive index. All the particle sizes shown are optical diameter, but the inspirability limit is an aerodynamic diameter. No attempt will be made here to relate the two except to state that it is reasonable to assume the aerodynamic diameter is less than the optical diameter since the wood bulk density is considerably less than that of standard spheres. Therefore, all of the particles shown in Figures 5 and 6 are in the inspirable range.

Results

In test setup number 1 (Figure 1), very little dust escaped the exhaust system. When sampling in the operator's breathing zone, it was difficult to distinguish background fluctuations from changes in exhaust flow settings, wood type, etc. Therefore, the inlet of the particle counter was located on the left-rear corner of the table.

Figure 7 gives some insight as to why very little dust escaped from test setup number 1. Air velocities (due to the cutter) were measured with the exhaust system off. The velocity at 25 mm (1 in.) from the edge of the cutter is 580 m/min (1900 fpm). Although this seems fairly high, it is much less than the exhaust hood velocities measured with the exhaust system set at 25.5 m³/min (900 cfm)—these were measured with the cutter off. Another reason for the low dust levels is that the hood (including fences) encloses about 240 degrees of

the cutter's rotation, and the other 120 degrees are partially enclosed by the wood being shaped. Thus, even the particles not thrown by the cutter in the desired direction are likely to hit a part of the hood, lose their initial velocity, and then be very easily captured by the exhaust flow.

Results of the tests on setup number 1 are shown in Table I. As can be seen from this table, there is no difference in dust emissions due to wood type. However, there is some difference in emissions due to changes in flow rate. At an exhaust flow of 24.8 m³/min (875 cfm), the number of particles is 30 percent above the normal room background (500 counts per minute). At 13.5 m³/min (475 cfm), the number of particles is 90 percent above normal room background, but these samples were not in the operator's breathing zone.

Test setup number 2 (Figures 2 and 3) yielded interesting results. Figures 5 and 6 show the number of particles versus optical particle size (greater than 10 μ m) versus exhaust conditions. These were the number of particles which settled on glass slides located in the operator's breathing zone during 10 cuts (size specified earlier). The number of particles is the sum of those counted in 30 view fields of the microscope.

Figure 4 shows the spread angles observed under exhaust conditions of 11.3 m³/min (400 cfm) and hood extension on. The spread angles shown are based

TABLE III

Dust weight levels for test setup #2 (relative to the weight of red oak collected at exhaust conditions of 900 cfm, hood extension on)

Exhaust rate		Hood ext.	Relative weight collected	
m ³ /min	cfm	Yes/No	Red oak	Particle board
25.5	900	Yes	1	3
11.3	400	Yes	21	97
25.5	900	No	97	162
11.3	400	No	160	262

on observation, and they tend to support and be supported by the quantitative results. Most of the white pine dust was emitted over a narrow angle, and it was, therefore, easy to aim the dust at the hood and capture it. Conversely, the particle board dust and red oak dust had much wider spread angles, and it was more difficult to aim the dust at the hood and capture it.

Table II shows the relative particle count (particles larger than 1 μ m) for various exhaust conditions. All of the numbers were normalized to the number of particles found in "normal" room air at our facility. Thus, for exhaust conditions of 25.5 m³/min (900 cfm) and hood extension on, the particle count for white pine and red oak were almost indistinguishable from normal background fluctuations. However, under the same exhaust conditions, particle board puts a significant number of particles into the operator's breathing zone. For all three types of wood, the value of the hood extension and the higher exhaust flow rate is obvious.

Table III shows the relative weight of the samples collected on glass slides in the operator's breathing zone. Only particles larger than 10 μ m were counted. Results are shown relative to red oak at exhaust conditions of 25.5 m³/min (900 cfm) and hood extension on for two reasons: 1) particle count data shows that under these exhaust conditions, the total particle count is only slightly higher than background and 2) there were no particles 10 μ m or larger on the background (normal room) air slides, thus there was a need for a non-zero standard for the denominator when calculating the ratios.

Recommendations

When shaping straight pieces of wood (as in test setup number 1) into door trim and similar operations, an exhaust system can be designed to prevent sig-

TABLE II
Dust count levels for test setup #2 (relative to normal background)

Exhaust rate		Hood Ext.	Relative particle count		
m ³ /min	cfm	Yes/No	White pine	Red oak	Particle board
25.5	900	Yes	1.1	1.3	7.4
11.3	400	Yes	11.4	84.2	127.8
25.5	900	No	16.2	149.2	164.8
11.3	400	No	34.8	216.0	292.2

nificant wood dust emissions. This was done at exhaust flows as low as 13.5 m³/min (475 cfm).

When shaping other than straight pieces of wood, the data show that having an exhaust hood close to the shaper cutter is more important than high exhaust flow rates. In this paper, a design is suggested which will minimize operator inconvenience and maximize dust control. The height of the hood was higher than the top of the cutter. A side was flexible so wood, but not dust, could pass through. The width of the hood was half table. However, based on the observed spread angles, it appears that the hood would have worked better if

it was the full table width and both sides were flexible. As can be seen from the ratios in Tables II and III, dust reductions of 16:1 up to 120:1 can be expected (ratios calculated from the 25.5 m³/min data). In an actual field installation, similar reductions could be expected, but the actual dust levels would depend on the parameters of the installation.

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Words of wisdom

In "Personal Strategies for Health" (1979), the late Ruell Stallones, MD, Dean, University of Texas, School of Public Health said . . .

"In this presentation I have followed an honored tradition: I spoke for a short time about things that I think you are interested in, and for a longer time about things that I am interested in, hoping that you might not notice the inequity. Since I have been engaged in the field of preventive medicine all of my professional life, I have given some thought as to the best ways to achieve a long, healthy, and productive life, and have reduced a large and confused field to a few simple central precepts.

1. Choose your parents wisely. One of the strongest predictors of health and longevity is a family history of long-lived parents and grandparents.
2. If that is not practical, become wealthy. Poor people have more illness and disability than rich people have.
3. Once you become wealthy, live frugally. A rich person whose parents lived to a ripe old age has little to fear unless he insists on enjoying personally the excesses and frivolities that the money can buy. Plan on leaving large sums to support a philanthropic foundation.
4. Stay away from doctors and stay out of hospitals. An extraordinary proportion of the people in hospitals are quite ill, so obviously they are not suitable places for people who wish to be well.
5. Be medium careful. A person who is doing just fine can be swept away by an untimely misjudgment. One of the best practical applications of this principle of preventive medicine was expressed in an article in the Los Angeles Times a few years ago. An underemployed reporter went out to interview a lady who was celebrating her birthday, and the headline over his report read: 'Woman, 90, Credits Long Life to Decision to Leave the Titanic'.

"We do have some control of our destinies, and our individual decisions are important determinants of health and longevity."