Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

The file name refers to the reference number, the AP42 chapter and section. The file name "ref02_c01s02.pdf" would mean the reference is from AP42 chapter 1 section 2. The reference may be from a previous version of the section and no longer cited. The primary source should always be checked.

AP42 Section:	10.5
Reference:	7
Title:	J. A. Danielson, ed., *Air Pollution Engineering Manual*, AP-40, Second Edition, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1973, pp. 372 - 374. 2002 supplement

Ref. 2

From the dust collector the vapors usually pass through a surface condenser where the solvent is collected in a barometric leg or a tank kept at a low pressure. The gases leaving the condenser consist of the inert gases that have leaked in plus enough solvent vapor to form a saturated mixture at the condenser's temperature and pressure.

Vacuum pumps, both rotary and reciprocating, and steam jets are used as vacuum sources. The vacuum at the condenser must be adjusted so that the boiling point of the solvent is well above the temperature attainable in the condenser. Otherwise, solvent recovery will be poor or will be reduced to zero if the boiling point is brought down to the condenser temperature. Sometimes, recovery can be improved by placing an additional small condenser on the outlet of the vacuum pump.

Drying with solvent recovery can be accomplished with direct drying under certain circumstances. Heated air or inert gases are used and the vaporized solvent is recovered in a condenser. The noncondensable gases are usually recirculated through a heater. If air is used, the solvent concentration must be kept well below the lower explosive limit. Since the amount of inflammable solvents that could be condensed at these concentrations and at feasible condenser temperatures is negligible, this method is restricted to noninflammable solvents such as perchlorethylene, carbon tetrachloride, and so forth. An inert gas atmosphere is needed for recovering inflammable solvents from direct driers. Since the cost of maintaining an inert atmosphere is considerable, this method is not widely used.

Smoke and Odor Emissions

Direct-fired rotary driers, when drying certain organic materials, sometimes emit smoke and odors. Cannery or brewery wastes used to produce fertilizer or animal food are examples. Most of these driers can be operated without excessive air-contaminating emissions under the proper conditions. If feed rate and temperature are properly adjusted, a dry product results without any localized overheating. If, however, the feed rate is excessive, the required higher temperature causes localized overheating and partial decomposition of the product, resulting in the emission of smoke and odors. Scrubbers are usually used to control dust emissions from these driers, but are not adequate for controlling smoke and odors.

Another drying operation that emits smoke is the removal of cutting oils from metal turnings and chips. This operation nearly always produces enough smoke to violate smoke prohibitions. An afterburner is the only feasible control. A temperature of at least 1,200°F is required in the afterburner for complete smoke control. Temperature control in the drier is rather critical. The temperature must be high enough to vaporize the oil but not high enough to cause it to burn in the drier since this would cause the chips to melt or oxidize. A mechanical feeder is almost a necessity to secure good control of the operation. Hand feeding nearly always results in poor temperature regulation and in undried and burned chips.

WOODWORKING EQUIPMENT

Woodworking machines produce large quantities of waste sawdust, chips, and shavings that must be removed from the equipment site. For this purpose, exhaust systems are constructed that also alleviate conditions tending to impair health of operating personnel, collect wastes that may have a resale value, and reduce fire hazards. The use of an exhaust system, however, requires a dust collector of some type to prevent an air pollution problem.

EXHAUST SYSTEMS

Exhaust systems are used with many types of woodworking machines capable of producing appreciable sawdust, chips, or shavings by drilling, carving, cutting, routing, turning, sawing, grinding, shredding, planing, or sanding wood. Machines include ripsaws, bandsaws, resaws, trim saws, mitre saws, panel saws, out-off saws, matchers, stickers, grinders, moulders, planers, jointers, spindle sanders, edge sanders, tenoners, mortisers, wood hogs (hammer mills), groovers, borers, dovetailers, and others. Exhaust systems serving wood hogs might more properly be termed pneumatic conveyors. In practice, however, wood hogs are most often found connected to exhaust systems that also serve other woodworking machines.

Exhaust systems serving various woodworking machinery are most frequently used at lumber mills, furniture manufacturers, planing mills, furniture-refinishing shops, model shops, maintenance shops, cabinet shops, sash and door manufacturers, and carpenter shops. Many of the larger systems handle several tons of waste products per day. One of the largest in the Los Angeles area burns 15 to 20 tons per day in a multiple-chamber incinerator. One ton of waste sawdust, chips, and shavings occupies approximately 150 to 200 cubic feet of space.

Construction of Exhaust Systems

A typical woodworking exhaust system consists of hoods for the pickup of wood dust and chips at the machines, ductwork, a collection device (usually a cyclone), a storage bin, and a fan blower to supply air for conveying purposes. Almost all exhaust systems are constructed of galvanized sheet metal.

THE AIR POLLUTION PROBLEM

Woodworking exhaust systems are somewhat unique in that they are almost always equipped with air pollution control devices. If they were not so equipped, the entrained sawdust would result in excessive opacities and dust loadings in exit gases and could easily cause a local nuisance. Air contaminant emissions from systems such as these are functions of the particular dust encountered and the particular control device employed. The dust particles are not excessively small in most systems, and elaborate devices are not usually required.

Particles emitted by woodworking machines vary in size from less than 1 micron to chips and curls several inches long. Hammer mill-type wood hogs emit particles running the complete size range, while sanders generate only very small dust particles. Wood waste particles from most other machines are of larger size and greater uniformity, seldom less than 10 microns. Other factors determining particle size are the type of wood processed and the sharpness of the cutting tool. Hardwoods tend to splinter and break, yielding smaller particles than soft woods do, which tend to tear and shred. A dull cutting tool increases tearing and shredding and produces larger particle sizes.

Generally, the configuration of waste particles is of little importance. There are, however, instances where toothpick-like splinters and curls have presented difficulties in collection and storage and in the emptying of storage bins.

HOODING AND VENTILATION REQUIREMENTS

Sawdust weighs from 7 to 15 pounds per cubic foot. The minimum recommended air volume for each pound of wood waste to be conveyed is 45 cubic feet or, expressed differently, is 1,500 cfm per ton-hour of waste. In actual practice the air volume is usually much higher because of exhaust velocity requirements.

Velocities recommended for conveying this material range from 3,500 to 4,500 fpm, with most ducts sized to give a velocity of 4,000 fpm. In practice, velocities of from 2,000 to 6,000 fpm are encountered.

Table 108 lists recommended exhaust volumes for average-sized woodworking machines. In each case the duct is sized to give a conveying velocity of 4,000 fpm. Some modern high-speed or extra large machines produce such large volumes of wastes that greater exhaust volumes must be used. Similarly, some small machines of the home woodshop or bench type may not require as large a volume as that recommended.

Hooding devices vary somewhat, depending upon the type of woodworking machine, and are of standard design throughout the industry. In most cases the hoods are merely scooped openings that catch the wood waste as it is thrown from the saws or blades of the machine. In design practice, no problems should be encountered if air volumes are chosen from those shown in Table 108, and if hoods are shaped to cover the area assumed by the thrown particles. Locating the hood as close to the saw or blade as possible is advisable.

AIR POLLUTION CONTROL EQUIPMENT

The simple cyclone separator is the most common device used for collecting wood dust and chips from woodworking exhaust systems. For these exhaust systems, cyclones outnumber all other devices by a large margin. Properly designed cyclones have been found satisfactory for use with exhaust systems at cabinet shops, lumber yards, planing mills, model shops, and most other wood-processing plants.

Higher efficiency centrifugal collectors separate smaller particles, but these devices are not common to woodworking systems. The main advantage of simple cyclones over most other collection devices is simplicity of construction and ease of operation. They are relatively inexpensive, require little maintenance, and have only moderate power requirements.

The size and design of woodworking exhaust system cyclones varies with air volume and the type of wood waste being handled. Where fine sander dust predominates, cyclones should be of high-efficiency design with diameters not greater than 3 feet. Coarse sawdust, curls, and chips, such as are produced with ripsaws, moulders, and drills, can be effectively collected with low-efficiency cyclones up to 8 feet in diameter. Most woodworking exhaust systems are employed to collect a mixture of wood waste including both fine and coarse particles. The exhaust system designer must, therefore, carefully consider the quantities of each type wood waste that will be handled. The presence of appreciable percentages of coarse particles in most systems allows the use of low- and medium-efficiency cyclones, in which the pressure drop does not normally exceed 2 inches of water column.

Baghouses are sometimes used with woodworking exhaust systems. Their use is relegated to those systems handling fine dusts such as wood flour or where small amounts of dust losses cannot be tolerated in the surrounding area. The efficiency of baghouses on woodworking exhaust systems is very high--99 percent or more. They can be used to filter particles as low as 1/10 micron in size. In some installations lower efficiency collectors such

Table 108. EXHAUST VOLUMES AND DUCT SIZES FOR WOODWORKING EQUIPMENT
(Committee on Industrial Ventilation, 1960)

	Exhaust volume, cfm		Duct diameter, in.	
	Bottom hood	Top hood	Bottom hood	Top hood
Self-feed table ripsaw:				
Saw diameter, in.				
Up to 16	440	350	4-1/2	4
Over 16	550	350	5	4
Self-feed, not on table	800	550	6	5
Gang ripsaws:				
Saw diameter, in.				
Up to 24	550	350	5	4
Over 24 up to 36	800	440	6	4-1/2
Over 36 up to 48	1,100	550	7	5
Over 48	1,400	550	8	5
ALL OTHER SAWS, including table saws, mitre saws, variety saws, and swing saws.				
Saw diameter, in.				
Up to 16	350		4	
Over 16 up to 24	440		4-1/2	
Over 24	550		5	
Variety saw with Dado head	550		5	
Vertical belt sanders: (rear belt and both pulleys enclosed) and top run horizontal belt sanders:				
Belt width, in.				
Up to 6	440		4-1/2	
Over 6 up to 9	550		5	
Over 9 up to 14	800		6	
Over 14	1,100		7	
Swing arm sander:	440		4-1/2	
Disc sanders: diameter, in.				
Up to 12	350		4	
Over 12 up to 18	440		4-1/2	
Over 18 up to 25	550		5	
Over 26 up to 32, 2 pipes	350 each		4 each	
Over 32 up to 38, 2 pipes	350 and 550		4 and 5	
Over 38 up to 48, 3 pipes	550		5	
	350		4	
Triple-drum sanders:				
Length, in.				
Less than 30	1,100		7	
Over 30 up to 36	1,400		8	
Over 36 up to 42	1,800		9	
Over 42 up to 48	2,200		10	
Over 48	3,100		12	
Horizontal belt sanders:				
Belt width, in.				
Where bottom run of belt is used				
Up to 6	440	350	4-1/2	4
Over 6 up to 9	550	350	5	4
Over 9 up to 14	800	440	6	4-1/2
Over 14	1,100	550	7	5

	Exhaust volume, cfm		Duct diameter, in.	
	Down run	Up run	Down run	Up run
Band saws and band resaws:				
Blade width, in.				
Up to 2	350	350	4	4
Over 2 up to 3	550	350	5	4
Over 3 up to 4	800	550	6	5
Over 4 up to 6	1,100	550	7	5
Over 6 up to 8	1,400	550	8	5
Jointers:				
Knife length, in.				
Up to 6	350		4	
Over 6 up to 12	440		4-1/2	
Over 12 up to 20	550		5	
Over 20	600		6	
Single planers:				
Knife length, in.				
Up to 20	500		5	
Over 20 up to 26	800		6	
Over 26 up to 36	1,100		7	
Over 36	1,400		8	

	Bottom hood	Top hood	Bottom hood	Top hood
Double planers:				
Knife length, in.				
Up to 20	550	550	5	5
Over 20 up to 26	550	800	5	6
Over 26 up to 36	800	1,100	6	7
Over 36	1,100	1,100	7	7

	Bottom hood	Top hood	Right hood	Left hood	Bottom hood	Top hood	Right hood	Left hood
Molders, matchers, and sizers:								
Sizes, in.								
Up to 7	440	550	350	350	4-1/2	5	4	4
Over 7 up to 12	550	800	440	440	5	6	4-12	4-1/2
Over 12 up to 18	800	1,100	550	550	6	7	5	5
Over 18 up to 24	1,100	1,400	800	800	7	8	6	6
Over 24	1,400	1,770	1,100	1,100	8	9	7	7

Sash stickers	550	5
Woodshapers	440 to 1,400	4-1/2 to 8
Tenoner	See moulder	
Automatic lathe	800 to 5,000	6 to 15
Forming lathe	350 to 1,400	4 to 8
Chain mortise	350	4
Dowel machine	350 to 800	4 to 6
Panel raiser	550	4-1/2
Dovetail and lock corner	550 to 800	4-1/2 to 6
Pulley pockets	550	4-1/2
Pulley stile	550	4-1/2
Glue jointer	800	6
Gainer	350 to 1,400	4 to 8
Router	350 to 800	4 to 6
Hogs		
Up to 12 in. wide	1,400	8
Over 12 in. wide	3,100	12
Floorsweep (6 to 8 in. dia)	800 to 1,400	6 to 8

as cyclones and impingement traps are installed upstream to remove the bulk of entrained particulates before final filtering in a baghouse. Filtering velocities of 3 fpm are satisfactory.

Disposal of Collected Wastes

Wood dust and chips collected with exhaust systems must be disposed of since they present a storage problem and a fire hazard. Very often a profit can be realized from this waste material. Wood wastes can be used productively for things such as:

1. Plastics bulking agent for products such as plastic wood, masonite, and so forth;

2. pressed woods such as firewood, fiberboard, Firtex, and others;

3. soil additives;

4. smokehouse fuel--hardwood sawdust is burned to produce smoke in the processing of bacon, ham, pastrami, and so forth;

5. floor sweep--sawdust with and without oil is spread on floors before they are swept to help hold dust particles;

6. wood filler--sawdust can be mixed with water resins and other liquids and used as wood filler;

7. floor cover in butcher shops, restaurants, and so forth;

8. waste heat boilers--heat can be recovered from incinerator flue gases to generate steam, hot water, and so forth.

When no productive disposal method can be used, wood waste is destroyed or removed in the most convenient manner. Wood dust and chips collected by the woodworking exhaust systems can be destroyed smokelessly by burning in a multiple-chamber incinerator. Single-chamber incinerators, for example, silo-type or teepee-type incinerators, cannot be controlled adequately for satisfactory air pollution abatement. Generally, wood waste is conveyed from the collection device to the incinerator by a pneumatic or a mechanical conveying system. In areas where the services of a cut-and-cover dump are available, disposal by incineration is usually not economical.

RUBBER-COMPOUNDING EQUIPMENT

INTRODUCTION

Rubber in its raw state is too plastic for most commercial applications, and its use is, therefore, limited to a few items such as crepe rubber shoe soles, rubber cements, adhesives, and so forth (Shreve, 1945). Through a curing process termed vulcanizing, raw rubber can be made to lose plasticity and gain elasticity. By compounding the raw rubber with various types and amounts of additives before the vulcanizing, tensile strength, abrasion resistance, resiliency, and other desirable properties can be imparted to the rubber. The proportions and types of additives (including vulcanizing agents) compounded into the raw rubber, and the vulcanizing temperature, pressure, and time are varied in accordance with the properties desired in the final product. After the rubber is compounded, it is formed into the desired shape and then cured at the required temperature. In the forming steps, large amounts of organic solvents are often used in the form of rubber adhesives. Since the solvent emissions are not controlled, they will not be discussed further in this section.

Additives Employed in Rubber Compounding

Types of additives that are compounded into the rubber may be classified as vulcanizing agents, vulcanizing accelerators, accelerator activators, retarders, antioxidants, pigments, plasticizers and softeners; and fillers. Examples of additives that may be encountered in rubber compounding are tabulated by type (Kirk and Othmer, 1947).

1. Vulcanizing agents. Sulfur was originally considered essential to vulcanizing and, though vulcanizing is now possible without it, sulfur or sulfur compounds such as sulfur monochloride are widely used. Selenium and tellurium can also be used for this purpose.

2. Vulcanizing accelerators. Aldehyde-amines, guanidines, and thiuram sulfides are used to decrease the time and temperature required for vulcanization.

3. Accelerator activators. Zinc oxide, stearic acid, litharge, magnesium oxide, and amines supplement the accelerators and, in addition, modify finished product characteristics, for example, they increase the modules of elasticity.

4. Retarders. Salicylic acid, benzoic acid, and phthalic anhydride retard the rate of vulcanizing.

5. Antioxidants. Several organic compounds, mostly alkylated amines, are used to retard deterioration of the rubber caused by oxidation and improve aging and flexing ability.

6. Pigments. Carbon black, zinc oxide, magnesium carbonate, and certain clays are used to increase tensile strength, abrasion resistance, and tear resistance. Iron oxide, titanium oxide, and organic dyestuffs are used to color the rubber.

7. Plasticizers and softeners. Resins, vegetable and mineral oils, and waxes are used to improve resiliency, flexibility, and mixing and processing characteristics.

8. Fillers. Whiting, slate flour, barytes, and some of the pigments previously mentioned are used to improve processing properties and lower the cost of the finished product.

In the compounding of blends, the accelerators are added first to the mass of raw rubber being milled or mixed. Then a portion of the plasticizers (if present in the blend recipe) are added, followed by the reinforcing pigments, the remainder of the plasticizers, the antioxidants, and any inert fillers or coloring agents. The vulcanizing agent is always introduced as the last ingredient.