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NATIONAL SAFETY COUNCIL
INCORPORATED
20 NORTH WACKER DRIVE
CHICAGO 6, ILLINOIS

Exhaust Systems

Published by National Safety Council, Inc.
20 North Wacker Drive, Chicago 6

Exhaust Systems

1. One of the dangers encountered by workers in many industries is the exposure to dusts, gases, vapors and fumes that are generated by various machines and industrial operations. It is difficult to enumerate all the different potentially harmful substances that are met with in modern industry, but the following general classification may suggest many with which we are more or less familiar:

a. Some dusts have a mechanical or irritating action affecting the parts of the body which may be directly exposed. For instance, sharp-pointed particles of metal or rock may harm the eyes, nose, throat and skin. If inhaled into the lungs some dusts may cause fibrosis or chronic inflammation.

b. Corrosive dusts from such substances as soda, lime, and others cause inflammation of the skin and other exposed parts of the body.

c. Poisonous dusts such as lead, arsenic or mercury may, upon entering the body, cause general poisoning, or they may attack certain parts of the body, such as blood, bones or nerves.

d. Dusts from fur, feathers and hair may carry disease germs which may infect the worker.

e. Irritating fumes from substances such as ammonia or acids act locally upon the eyes and upon the mucous membrane of the throat, nose and lungs.

f. Poisonous fumes from benzol, wood alcohol, aniline, lead, and other substances often affect the blood, heart, eyes, or nerves.

2. Dusts, gases, vapors and fumes are the direct or indirect cause of many of the so-called "occupational diseases" and they can be removed or rendered harmless by employing such methods as the following:

a. Mechanical exhaust system.
b. Installing automatic or closed machinery methods.
c. Using wet processes.
d. Natural ventilation. (See N.S.C. pamphlet No. 37.)
e. Isolating in a separate room or building the process or machine that creates dust, gas, vapors or fumes.
f. Providing and requiring exposed workers to wear respiratory protective equipment. (See N.S.C. pamphlet No. 64.)

This pamphlet is one of a series of more than 150 Safe Practices and Health Practices pamphlets. As a compilation of experience from many sources, it should not be assumed to include every acceptable procedure in the field covered. It must not be confused with federal, state or insurance requirements, or with American Standard safety codes. Attention is called to the American Standard Regulations for the Installation of Blower and Exhaust Systems for Dust, Stock and Vapor Removal, to which reference should be made; the code was formulated under the sponsorship of the National Fire Protection Association and under the procedure of the American Standards Association, 29 W. 39th Street, New York City. The suggestions contained in this pamphlet do not conflict with the requirements of that code. *Price: 35c each to members; non-member and quantity prices on request.*

3. Methods b, c, and e are possible in many cases, but they require special engineering revision in each case, and cannot, therefore, be discussed in detail in this pamphlet.

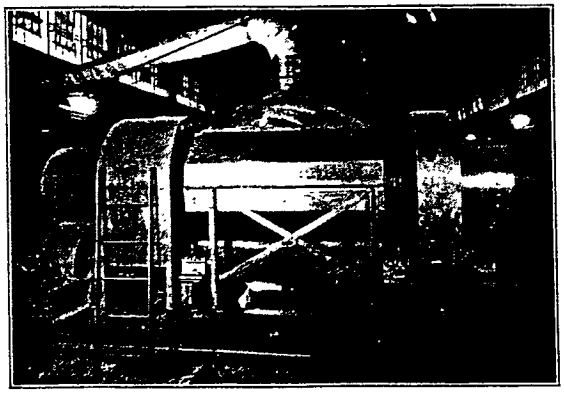


Figure 1. Tumbling barrel, properly guarded and equipped with exhaust system. (See paragraph 10.)

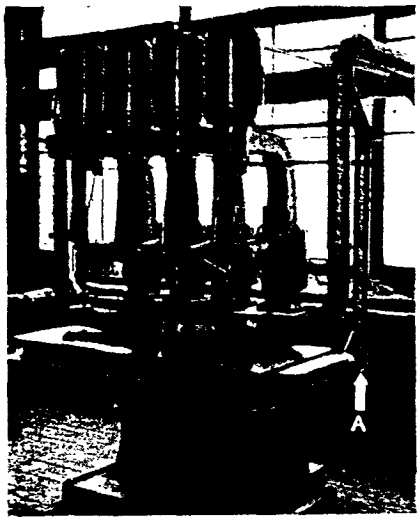
4. Natural ventilation in eliminating dusts, gases, vapors and fumes is practically limited to the installation of vertical flues or pipes that convey to the outside those substances which are lighter than air or which are warm enough to rise. In some cases, where the natural draft is not sufficient, steam pipes run through such a flue may be a simple and effective means of producing the necessary draft without the use of a mechanical fan. It is important, however, to have a suitable arrangement at the top of the flue, perhaps turning with the wind, to prevent the wind from reversing the current of air in the flue. For more detailed information see N. S. C. pamphlet No. 37, "Industrial Ventilation."

5. Each installation of a mechanical exhaust system presents special problems that may require expert and technical knowledge as well as an understanding of existing conditions, but there are a number of important factors, common to all installations, that are discussed in this pamphlet at least in outline form.

6. There are two general types of exhaust systems, the general and the local.

7. General exhaust systems provide for drawing the air (and dust, gases, vapors or fumes) from a room by means of screw-propeller fans operating at windows or at other openings in the wall. One manufacturer, instead of purchasing the ordinary type of fan usually employed for this purpose, has installed a large electric motor fitted with an aeroplane propeller. This is used at a point where

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Courtesy, General Electric Company
Figure 2. Exhaust system on multiple-spindle drill for slate panels. A false top is mounted over the regular table; this has holes to provide clearance for the drills after they go through the slate; the space under the false top is connected to a special exhaust hood. Note the dust trap at "A"; heavy particles drop into this trap and are removed at regular intervals. (See paragraphs 14 and 37.)

dense fumes may be evolved suddenly, and is capable of clearing the air in an emergency in about one minute. In another plant where fumes that are heavier than air are liberated, the floor in a certain room is made of cast-iron grids. Ventilation is secured by downward displacement.

8. The general exhaust system usually involves low initial cost and comparatively low cost of maintenance. It may be especially desirable in laundries, foundries and other places where there is a great amount of heat and where large quantities of steam are created. The general system however, is not always satisfactory particularly where harmful dusts, fumes, gases and vapors are involved. In many cases it is necessary to install local exhaust systems instead of, or in addition to, the general systems.

9. Fans used for general exhaust should be placed well out of reach and if there is any possibility of persons coming into contact with the revolving blades of the fan, the blades should be enclosed with wire mesh or other guards that will exclude a hand or finger. The exhaust from such fans is usually direct to the outside atmosphere, and it is necessary that care be exercised to prevent the exhausted dust, gas, vapor or fumes from returning into the room or from entering any other place where their presence would be objectionable.

10. Local exhaust systems require the installation of hoods for the collection of the substance to be removed, a fan and metal pipes or ducts for conveying the contaminated air to the outside or to some properly provided place for disposal. Such systems, if correctly designed and operated, can be installed to remove objectionable dusts, gases, vapors or fumes at the exact point of origin, with uniform and satisfactory results. If such substances are allowed to disperse in the workroom, it usually becomes practically impossible to reduce the concentration to satisfactory limits. (Figure 1.)

The Hood

11. Much of the success of any local exhaust system depends upon the design and installation of the hood.

12. For removing heavy gases, fumes, vapors and such substances as metal particles and sand, the downward system of ventilation is usually the most effective. In such installations the hood may be a hopper placed directly beneath the work-table. The pipe leading to the exhaust fan is usually led from the side of this hopper (not the bottom) and is thus forced to handle only the lighter particles which do not drop into the trap at the bottom. (Figure 2.)

13. An upward system of ventilation is usually used to remove fumes, gases, and vapors that are lighter than air or which have a tendency to rise. The hood may then be flared, or shaped like an inverted funnel, the small end of which is connected to the pipe leading to the exhaust fan.

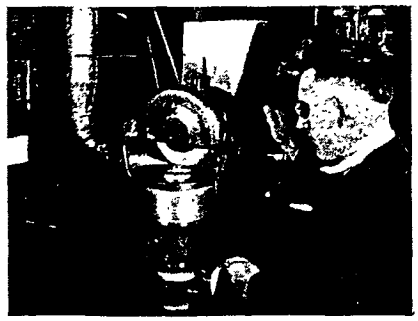


Figure 3. Exhaust on small grinder. The hood catches dust particles at the point of greatest velocity. (See paragraph 16.)

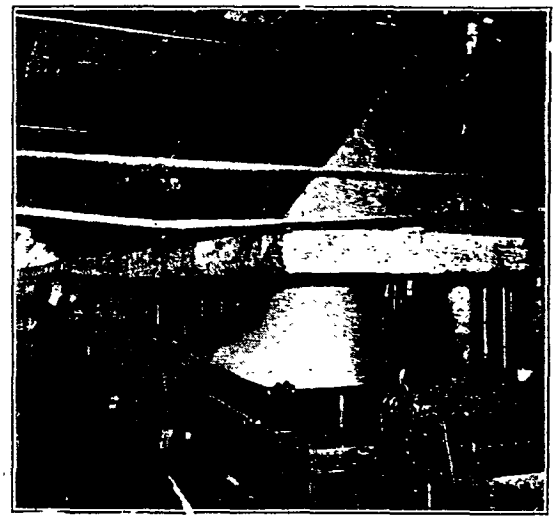


Figure 4. One large hood over a series of tanks. (See paragraph 19.)

14. Sometimes conditions are such that hoods or pipes cannot be installed directly over vats, machines, or other sources of dust, gas, vapors or fumes because they would interfere with overhead cranes or some other operation. It then becomes necessary to provide lateral hoods or those in which the substances to be removed must travel in a horizontal direction instead of vertically. (Figure 2.)

15. Frequently, the lateral hood may be of the suction box type in which the front of the box is perforated with numerous small-sized intake openings providing a high velocity of air.

16. If the particles to be removed are already in motion, as is the dust thrown from a grinding wheel, the hood, if possible, should be installed in the path of the waste particles so the velocity of the particles assists the force of the exhaust draft. (Figure 3.)

17. It is important, in general, that every exhaust system be designed to draw the dust or fumes away from the face of the operator. In some installations an additional fan is placed in the open room to direct an air current away from the worker and toward the exhaust hood. Such installations, however, should be made with care, otherwise the air to be exhausted may rebound from the surface of the hood or blow past the hood entirely.

18. For most processes, hoods are constructed of galvanized sheet metal, the gage of which, depending upon the size of the hood and the strength and rigidity required, should ordinarily be 2

gages heavier than the gage of the exhaust pipe to which it is connected. (See paragraph 29.) For grinding wheels, the exhaust hood should be made of heavy enough material that it will at the same time serve as a protection hood in case the wheel breaks. (See N. S. C. pamphlet 13.) If acid fumes are present and there is danger of the metal of the hood being corroded, the hood may be made of aluminum or lined with lead, or coated with special non-corrosive paint. Or, it may be made of wood properly pitched and joined together with non-corrosive wood screws, or of some other material that will not corrode.

19. In most instances each hood serves a single machine or a single unit; in other installations large hoods extend over groups of such apparatus. (Figure 4.) Most authorities agree that in the majority of installations the individual type is more satisfactory.

20. To be most effective the hood should be as close as possible to the source of dust, gas, vapor or fumes. Wherever possible, the hood should entirely enclose the operation that is producing the objectionable substance. If it is necessary to have one side open, it may be possible to close this side, at least part of the time, by a sliding door. It might be still more convenient if this door were made of shatterproof or wire glass. Even work that must be done by hand can sometimes be enclosed; this may be accomplished by making a box-like hood with padded armholes and with the top or one or more sides made of glass. Ventilated tables can also be used for this purpose, having mesh tops through which the waste materials are drawn into a hood underneath the table.

21. If it is impossible or impracticable to enclose completely the point of origin of the air contaminant, the mouth of the hood should extend over the machine or operation at least 6 inches in every direction if the hood is not elevated more than 2 feet. For each additional 2 feet of elevation, the size of the hood should be increased 6 inches in all directions.

22. One type of hood that is effective for some installations is one made with double walls, in which the space between the two walls is about 1 inch. The outer wall of the hood should be extended about 1½ inches below the inner wall; rising fumes are then more readily caught than if both walls are of the same length. Air currents from windows and doors do not affect the upward movement of the air in these hoods as much as in single-wall hoods.

23. Hoods with telescopic pipe are convenient and desirable in many installations. The pipe directly attached to the hood can be of slightly smaller diameter than the section above it. The smaller portion slips into the larger and is held in position by a sliding ring clamp. The hood if provided with counterweights can easily be raised or lowered, like a window. (Figure 5.)

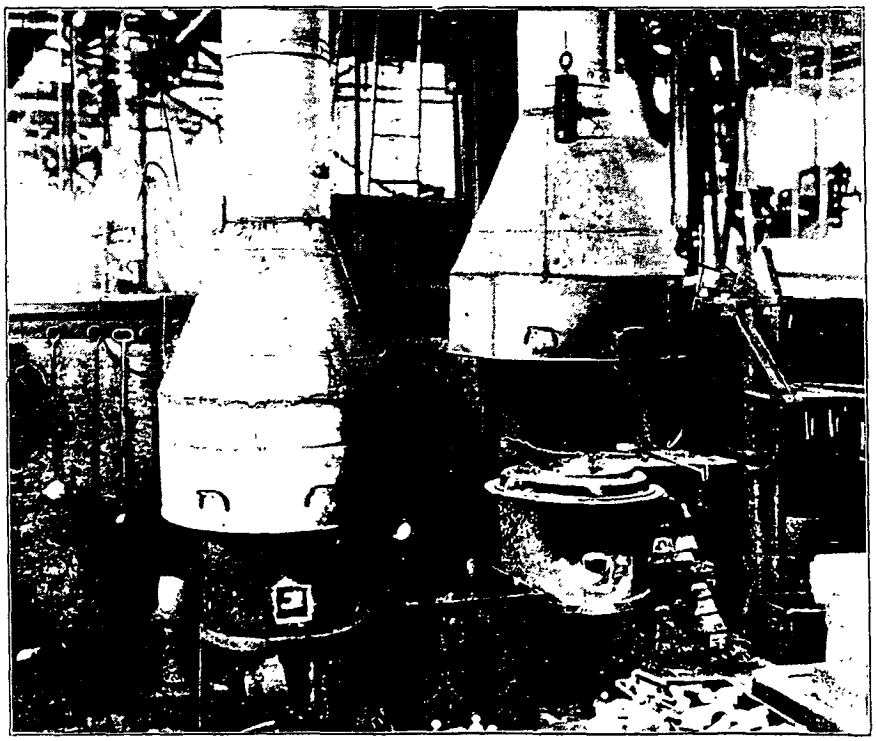


Figure 5. Hoods with counterweighted telescopic pipes. Hoods can be readily raised and lowered like a window. (See paragraph 23.)

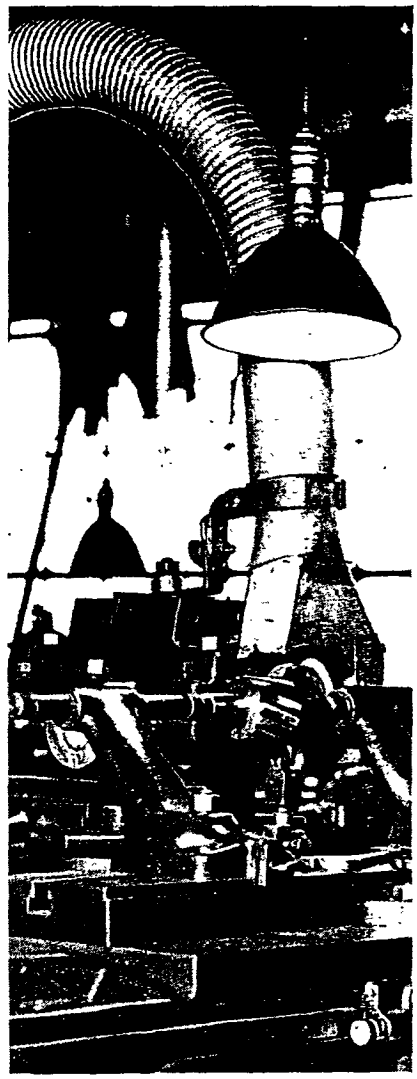


Figure 6. Exhaust system applied to a cutter grinder. Exhaust pipe is a large-size flexible metallic hose. (See paragraph 24.)

24. Some employers have made use of a "universal" ("knuckle" or "ball and socket") joint which, being placed in the pipe directly over the hood, enables the operator to change the location or direction of the hood whenever necessary. Flexible metallic hose can frequently be used to advantage as shown in Figure 6.

25. In some installations the effectiveness of the hood can be increased by providing covers over vats, tanks or other equipment. Covers may be made

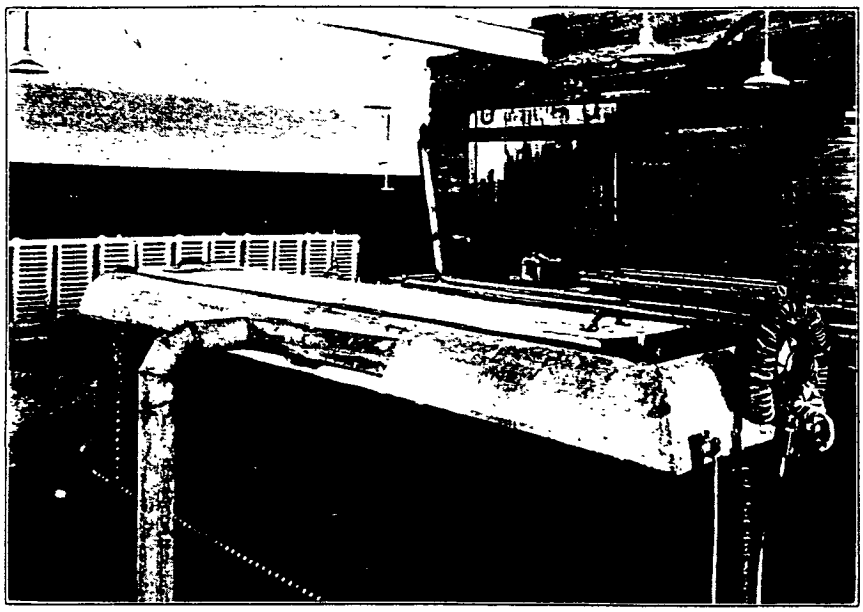


Figure 7. A tank with telescopic cover. Lateral exhaust hood removes fumes horizontally from between cover and surface of liquid. (See paragraph 25.)

in sliding sections which telescope each other, as shown in Figure 7. The exhaust is so arranged that it removes the air from below the cover.

26. Small hoods provide greater suction than large ones (with the same size of fan), but all hoods should be large enough to catch the greatest possible part of the contaminant to be exhausted. Ordinarily, the area of the hood face for natural draft hoods should not be greater than 10 times the area of the pipe to which it is connected. The hood face area for mechanically exhausted hoods may be somewhat greater, depending upon other factors, but it should not exceed 16 times the area of the pipe to which it is connected.

27. In some instances, where the hood provides for downward ventilation, a portable cover or screen has been suspended from the ceiling and so arranged that it can be raised or lowered. This may increase the suction in a horizontal direction as well as deflect some of the contaminant that might otherwise escape into the atmosphere of the workroom.

28. All exposed edges of metal hoods should be rolled and wired. This strengthens the hood and also prevents the workers from receiving cuts and scratches from raw edges of the metal. If the sheet metal of the pipe is heavy enough, raw edges may be protected with split rubber hose held in place by wire encircling the hose and going through the holes punched for the purpose near the edge of the metal pipe.

Pipes or Ducts

29. The pipes or ducts leading from the hood to the exhaust fan are usually made of galvanized sheet metal; the thickness of the pipe walls according to pipe diameter should be not less than that recommended by the National Fire Protection Association, as shown in Figure 8. If pipes are to carry flammable vapors, the thickness of the pipe walls should be not less than that shown in Figure 9.

30. In exhaust systems that carry materials having abrasive or wearing characteristics, the elbows should be made of metal that is heavier than the pipes to which they are connected. Exhaust pipes should be of such strength and fastened securely enough that in case they become clogged and filled to their capacity with the dust they are designed to handle, they will not fall or be damaged by the additional weight.

31. All pipes should be designed to conduct the air with as little resistance as possible. They should, therefore, be made as short and straight as possible.

32. Frequently pipes are reduced to a minimum by installing a separate or unit exhaust system for each machine or operation. The spray booth with its built-in fan and connected motor is a good example.

33. If bends must be provided in exhaust pipes, elbows should be used that are made on a radius in the center line of at least 1½ times the diameter of the elbows.

34. Some engineers state that approximately 10 per cent of the power loss in exhaust systems is due to air leakage. Thus, all straight seams and elbows should be made as air-tight as possible by welding, riveting or soldering. If rivets are used, they should be tinned.

35. If pipe joints are riveted or welded, the rivets or welds should be spaced as indicated in Figure 10. The spacing between spot welds or rivets on longitudinal lap joints should not exceed 3 inches, and such joints should also be soldered and edge coated. When locked seams are used they should be double locked.

36. Pipes should never be restricted in area. They should be free from dents, and the inner surfaces should be smooth so the dust will not adhere to the sides and clog up the pipe. At joints, all piping should have at least 1 inch lap made in the direction of the flow of the air current. This further prevents dust clogging and friction loss.

37. In general, vertical runs are undesirable and should be avoided if possible. Where vertical runs are unavoidable, it may be desirable to install a trap at the bottom of the vertical pipe; then all material that is not elevated by the suction of the fan, falls into this trap

Size of pipes in greatest dimension	U. S. gage of metal
8″ or less	24
9″ to 20″	22
21″ to 30″	20
30″ or more	18

Figure 8. If exhaust pipes are used to convey dust, starch and refuse, the thickness (in fractions of an inch) of the pipe walls should be not less than that corresponding to the U. S. Metal gage as indicated. (See paragraph 29.)

Size of pipes in greatest dimension	U. S. gage of metal
20″ or less	20
21″ to 29″	18
30″ or more	16

Figure 9. If pipes are to carry flammable vapors, the thickness (in fractions of an inch) of the pipe walls should be not less than that corresponding to the U. S. metal gage as indicated. (See paragraph 29.)

Pipe diameter	Minimum number of spot welds or rivets per joint
8" or less	4
More than 8" to 12"	5
More than 12" to 18"	6
More than 18" to 24"	7
More than 24"	7 to 9

Figure 10. If the exhaust pipe joints are riveted or welded, the number of rivets or spot welds per joint should be not less than that indicated. (See paragraph 35.)

from which it can be removed at regular intervals. (Figure 2.)

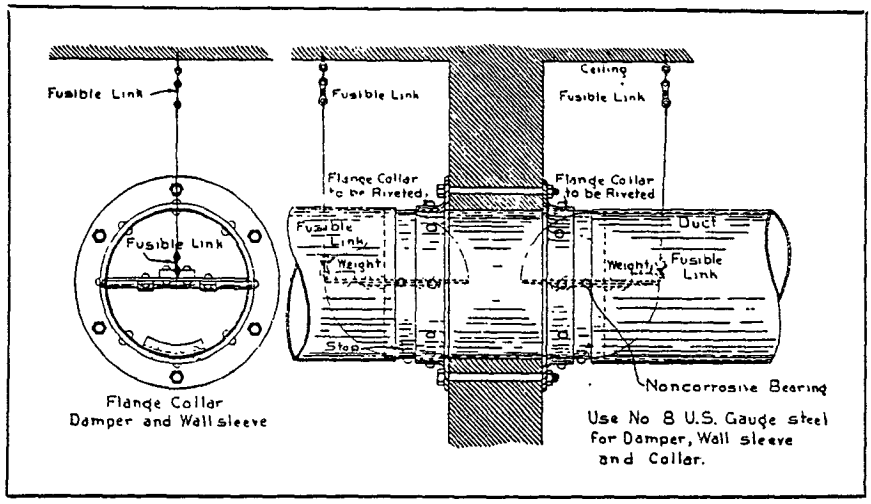
38. If an exhaust system has a main duct and a number of branch pipes, dampers or blast gates are sometimes installed. Experiments indicate, however, that exhaust systems are most efficient if all dampers and blast gates are left open.

39. All telescopic slip-joints and ends of metal pipe should be made with a wired outer edge, or protected as explained in Paragraph 28. Some persons use felt packing between the two pipes to prevent air leakage. This requires upkeep and can be dispensed with if the pipe is sufficiently heavy and if, when in operating position, the two pipes overlap a great enough distance.

40. At the point where the piping connects to the suction side of the exhaust fan, there should be a detachable sleeve, not less than 18 inches long, so that ready access is provided to the interior of the fan. The far end of the main duct should be a dead end, closed with a removable cap.

41. Where piping passes through a fire-wall, it is desirable to install an automatic fire damper or fire door in the pipe, especially if the exhaust system contains flammable dust or gases which upon ignition might spread a fire. (Figure 11.)

42. No branch pipe should enter a main duct at an angle greater than 45 degrees; 30 degrees usually gives satisfaction, but a smaller angle is still better. Openings for branch pipes should be made at the top or side of the main duct, never at the bottom. Branch pipes should not enter a main duct directly opposite one another; openings in the main duct for branch pipes should be staggered. Each branch pipe should be riveted and soldered or welded at the point where it enters the main duct.



Courtesy, National Fire Protection Association

Figure 11. Automatic fire damper. This is a suggested type of automatic damper for exhaust duct not over 12 inches in diameter, to be installed where exhaust duct passes through firewall. (See paragraph 41.)

43. At certain places in the pipe, traps should be provided to catch the heavier dust which may settle and never reach the exhaust fan. Hand holes with tight-fitting covers should be provided for the purpose of cleaning out the pipe and for removing any solid material that may lodge and obstruct the air flow.

44. To facilitate the cleaning out of dust that may settle behind, underneath or on top of pipes, the distance between the pipe and the wall, floor or ceiling should at no point be less than 6 inches. If the pipes are near the floor, it is wise to provide openings and hoods for the purpose of removing floor sweepings.

Size of Pipe

45. The diameter of the pipe is another important detail that must be determined in exhaust system design. A few of the points to be considered in determining pipe sizes are: (a) the size and weight of the particles to be removed; (b) the volume of air to be exhausted; (c) the type and size of the fan and the amount of suction that must be maintained; (d) the size of the hood.

46. In general, pipes of large diameter are costly, but they offer less resistance and therefore require less motive power for the exhaust of air and

Diameter of Pipe Inches	Area of Pipe Square Inches	Diameter of Pipe Inches	Area of Pipe Square Inches
2	3.141	25	390.8
2½	4.908	26	530.9
3	7.068	27	572.5
3½	9.621	28	615.7
4	12.56	29	660.5
5	19.63	30	706.8
6	28.27	31	754.7
7	38.48	32	804.2
8	50.26	33	855.3
9	63.61	34	907.9
10	78.54	35	962.1
11	95.03	36	1017.0
12	113.1	37	1075.0
13	132.7	38	1134.0
14	153.9	39	1194.0
15	176.7	40	1256.0
16	201.0	42	1385.0
17	226.9	44	1520.0
18	254.4	46	1661.0
19	283.5	48	1809.0
20	314.1	50	1963.0
21	346.3	52	2123.0
22	380.1	54	2290.0
23	415.4	56	2463.0
24	452.3	58	2642.0

Figure 12. Pipe areas for corresponding pipe diameters. (See paragraph 46.)

Diameter of Buffing Wheels	Maximum Grinding Surface Sq. Ins.	Minimum Diameter of Pipe Inches
6 in. or less, not over 1 in. thick	19	3
7 in. to 9 in., inclusive, not over 1½ in. thick	43	3½
10 in. to 16 in., inclusive, not over 2 in. thick	101	4
17 in. to 19 in., inclusive, not over 3 in. thick	180	4½
20 in. to 24 in., inclusive, not over 4 in. thick	302	5
25 in. to 30 in., inclusive, not over 5 in. thick	472	6

Figure 13. Minimum diameters of exhaust pipes for buffing wheels. (See paragraph 47.)

Diameter and Thickness of Wheel in Inches	Maximum Grinding Surface in Square Inches	Minimum Diameter of Branch Pipe Inches
6 in. or less, not over 1 in. thick	19	3
6 in. to 9 in.—1½ in. thick	43	3½
9 in. to 16 in.—2 in. thick	101	4
16 in. to 19 in.—3 in. thick	180	4½
19 in. to 24 in.—4 in. thick	302	5
24 in. to 30 in.—5 in. thick	472	6

Figure 14. Minimum diameters of exhaust pipes for grinding wheels. (See paragraph 47.)

dust through them. Pipes should not be too small, for they unduly increase the resistance and the cost of motive power, and decrease the efficiency of the exhaust system. The cross-sectional area of a pipe connected directly to an exhaust hood should never be smaller than $\frac{1}{16}$ of the area at the mouth of the hood. If the diameter of a pipe is given, Figure 12 may be used to find the area, or vice versa.

47. In some states, certain sizes of exhaust pipe are specified for certain operations, and manufacturers should comply with the regulations of their respective states. Figures 13, 14 and 15 give a few typical requirements of New York State..

48. The area of any main duct into which a number of branch pipes enter is usually equal to the combined areas of the branches entering, plus 20 per cent. Following this general practice, Figure 16 gives the diameter in inches of the main duct at any point for any number of uniform size branch pipes. Enlargements in the size of a pipe should be made on a taper, 5 inches long for each inch change in diameter, and not by an abrupt change.

Self feed table rip saw up to 16" diameter	4½" pipe on bottom 4" pipe on top
Swing saw up to 20" diameter	4"
Disc sander up to 12" diameter	4"
Jointer up to 6" knives	4"
Single planer up to 20" knives	5"

Figure 15. Minimum diameters of exhaust pipes for various woodworking operations. (See paragraph 47.)

49. In determining sizes of pipe and in designing other parts of an exhaust system, many engineers make a certain allowance for any normal increase in the number of machines or operations installed.

50. Exhaust pipes conveying heated air from certain machines, vats and furnaces may radiate so much heat that they become objectionable. It may then be necessary to cover the pipes with material that will decrease the radiation. Some of the coverings in common use are mineral wool, magnesium carbonate, aluminum foil, cork and asbestos. Purchasers have a choice of plastic coverings or those made in sections. Such coverings may also be necessary to prevent condensation in the pipes when exhausting high temperature air containing quantities of steam or moisture.

The Fan

51. Many makes and varieties of fans are used for ventilating purposes. They may, however, all be divided into two principal types; (a) the propeller or

Number of branch pipes	Diameter of Branch Pipes in Inches: 3	3½	4	4½	5	5½	6	6½	7
	Area of Each Branch Pipe in Square Inches: 7.07	9.62	12.560	15.9	19.635	23.758	28.274	33.183	38.485
	Area of Each Branch Pipe Plus 20 Per Cent (Square Inches): 8.484	11.544	15.08	19.08	23.562	28.51	33.93	9.82	46.182
1	3⅜	3⅞	4⅜	5	5½	6	6⅝	7⅛	7¾
2	4¾	5½	6¼	7	7¾	8⅝	9¼	10⅛	10⅞
3	5¾	6⅝	7⅝	8⅝	9½	10½	11½	12⅜	13¼
4	6⅝	7¾	8¾	9⅞	11	12⅛	13⅛	14¼	15¾
5	7⅜	8⅝	9⅞	11	12¼	13½	14¾	16	17⅛
6	8⅛	9½	10¾	12⅛	13½	14¾	16⅛	17½	18¾
7	8¾	10¼	11⅝	13⅛	14½	16	17½	18⅞	20¼
8	9⅜	10⅞	12⅜	14	15½	17⅛	18⅝	20⅛	21¾
9	9⅞	11½	13⅛	14⅞	16½	18⅛	19¾	21⅜	23
10	10½	12⅛	13⅞	15⅝	17⅜	19⅛	20¾	22½	24¼
11	11	12¾	14⅝	16⅜	18¼	20	21⅞	23⅝	25½
12	11½	13⅜	15¼	17⅛	19	20⅞	22¾	24¾	26⅝
13	11⅞	13⅞	15⅞	17⅞	19¾	21¾	23¾	25¾	27¾
14	12⅜	14⅜	16½	18½	20½	22⅝	24⅝	26¾	28¾
15	12¾	14⅞	17	19⅛	21¼	23⅜	25½	27⅝	29¾
16	13¼	15⅜	17⅝	19¾	22	24⅛	26⅜	28½	30¾
17	13⅝	15⅞	18⅛	20⅜	22⅝	24⅞	27⅛	29⅜	31⅝
18	14	16⅜	18⅝	21	23¼	25⅝	27⅞	30¼	32⅝
19	14⅜	16¾	19⅛	21½	23⅞	26¼	28¾	31⅛	33½
20	14¾	17⅛	19⅝	22⅛	24½	27	29½	31⅞	34⅜
21	15⅛	17⅝	20⅛	22⅝	25⅛	27⅝	30⅛	32¾	35⅛
22	15½	18	20⅝	23⅛	25¾	28⅜	30⅞	33½	36
23	15¾	18½	21⅛	23¾	26⅜	29	31½	34¼	36¾
24	16⅛	18⅞	21½	24¼	26⅞	29⅝	2¼	34⅞	37⅝
25	16½	19¼	22	24¾	27½	30⅛	2⅞	35⅝	38⅜
26	16¾	19⅝	22⅜	25⅛	28	30¾	33½	36⅜	39⅛
27	17⅛	20	22⅞	25⅝	28½	31⅜	34⅛	37	39⅞
28	17½	20⅜	23¼	26⅛	29	32	34¾	37¾	40⅝
29	17¾	20¾	23⅝	26⅝	29½	32½	35½	38⅜	41⅜
30	18	21	24	27	30	33	6	39	42

Figure 16. Diameter in inches of main exhaust pipe at any point for any number of branch pipes. (See paragraph 48.)

Fan Size	Diameter of Main—Inches	SUCTION 1.5 Inches		VELOCITY 2745 Feet per Minute		SUCTION 1.75 Inches		VELOCITY 2965 Feet per Minute		SUCTION 2.0 Inches		VELOCITY 3170 Feet per Minute		SUCTION 2.5 Inches		VELOCITY 3540 Feet per Minute	
		Revolutions per Minute	Cubic Feet per Minute	Horsepower		Revolutions per Minute	Cubic Feet per Minute	Horsepower		Revolutions per Minute	Cubic Feet per Minute	Horsepower		Revolutions per Minute	Cubic Feet per Minute	Horsepower	
30	12	1060	2012	2.11		1145	2172	2.80		1227	2320	3.26		1368	2595	4.56	
	13	1056	2346	2.40		1141	2539	3.18		1220	2710	3.70		1363	3035	5.18	
	14	1052	2680	2.74		1135	2890	3.63		1216	3095	4.22		1360	3461	5.91	
	15	1050	3012	3.13		1131	3254	4.14		1215	3480	4.82		1356	3890	6.76	
	15	1053	3350	3.57		1136	3640	4.71		1219	3870	5.48		1362	4330	7.66	
35	14	908	2730	2.87		984	2955	3.80		1054	3160	4.43		1175	3530	6.20	
	15	906	3195	3.27		981	3455	4.33		1050	3690	5.05		1168	4125	7.04	
	16	902	3645	3.73		977	3945	4.94		1046	4210	5.74		1165	4710	8.04	
	17	901	4059	4.26		976	4425	5.63		1044	4730	6.57		1163	5290	9.20	
	18	903	4553	4.84		980	4925	6.41		1048	5260	7.47		1167	5890	10.40	
40	16	797	3575	3.75		860	3860	4.97		920	4125	5.79		1028	4610	8.10	
	17	794	4170	4.27		857	4510	5.65		917	4820	6.59		1025	5390	9.20	
	18	791	4770	4.87		854	5150	6.45		914	5500	7.50		1022	6150	10.50	
	19	790	5350	5.56		853	5780	7.35		913	6180	8.58		1020	6910	12.00	
	20	792	5950	6.33		855	6430	8.37		916	6875	9.75		1024	7690	13.60	
45	18	708	4520	4.75		765	4880	6.29		818	5220	7.34		915	5830	10.24	
	19	706	5280	5.41		763	5730	7.15		815	6100	8.35		910	6820	11.63	
	21	703	6030	6.17		760	6510	8.16		811	6970	9.50		907	7780	13.28	
	22	702	6780	7.04		759	7310	9.30		810	7830	10.87		905	8740	15.18	
	23	704	7530	8.02		762	8130	10.57		813	8700	12.35		909	9730	17.20	
50	20	638	6582	5.86		689	6030	7.76		736	6450	9.06		823	7200	12.64	
	21	635	6530	6.67		687	7048	8.83		734	7540	10.30		820	8420	14.36	
	23	633	7442	7.61		684	8040	10.07		731	8600	11.72		817	9610	16.40	
	24	632	8370	8.68		683	9040	11.47		730	9670	13.40		815	10780	18.75	
	25	634	9300	9.89		686	10040	13.06		733	10740	15.22		819	12000	21.25	
55	22	579	6750	7.09		626	7290	9.40		670	7800	10.90		748	8715	15.32	
	23	577	7900	8.07		624	8520	10.68		667	9120	12.45		745	10180	17.38	
	25	575	9000	9.21		622	9720	12.18		665	10400	14.20		743	11620	19.85	
	27	574	10130	10.52		621	10920	13.89		664	11700	16.20		740	13050	22.70	
	28	576	11250	11.97		623	12150	15.82		666	13000	18.45		744	14530	25.70	
60	24	526	8030	8.43		574	8680	11.18		614	9280	13.00		685	10370	18.22	
	26	524	9390	9.60		572	10130	12.72		611	10840	14.80		681	12120	20.70	
	27	522	10700	10.95		570	11570	14.52		609	12370	16.90		677	13830	23.63	
	29	521	12030	12.51		569	13000	16.53		608	13900	19.30		675	15530	27.00	
	30	523	13370	14.21		571	14470	18.83		610	15450	21.90		680	17300	30.60	
70	28	456	10930	11.50		493	11820	15.22		526	12630	17.70		588	14075	24.80	
	30	454	12760	13.10		492	13820	17.30		524	14750	20.20		585	16470	28.20	
	32	452	14580	14.92		490	15750	19.75		522	16850	23.00		583	18780	32.15	
	34	452	16380	17.20		490	17700	22.50		522	18930	26.30		582	21100	36.75	
	35	453	18220	19.40		491	19680	25.64		523	21050	29.80		584	23500	41.65	
80	31	398	14280	15.00		430	15440	19.87		460	16500	23.20		514	18430	32.40	
	34	397	16700	17.10		429	18030	22.60		459	19300	26.40		512	21550	36.80	
	36	396	19030	19.47		428	20530	25.80		457	22000	30.00		510	24600	42.00	
	38	395	21400	22.25		427	23100	29.40		457	24720	34.40		509	27640	48.00	
	40	396	23800	25.30		428	25700	33.50		458	27500	39.00		511	30750	54.40	
90	35	354	18080	18.97		382	19520	25.15		409	20900	29.30		457	23300	41.00	
	38	352	21100	21.60		381	22800	28.60		408	24400	33.30		456	27250	46.55	
	41	351	24150	24.65		379	26030	32.60		407	27900	38.00		453	31100	53.10	
	43	351	27100	28.15		378	29250	37.20		407	31300	43.50		452	34950	60.80	
	45	352	30130	32.00		380	32530	42.35		407	34800	49.40		455	38900	68.80	

Fan Size	Diameter of Main—Inches	SUCTION 3.0 Inches		VELOCITY 3880 Feet per Minute		SUCTION 3.5 Inches		VELOCITY 4190 Feet per Minute		SUCTION 4.0 Inches		VELOCITY 4480 Feet per Minute		SUCTION 4.5 Inches		VELOCITY 4750 Feet per Minute		SUCTION 5.0 Inches		VELOCITY 5010 Feet per Minute	
		Revs. per Min.	Cu. Ft. per Minute	Horsepower		Revs. per Min.	Cu. Ft. per Minute	Horsepower		Revs. per Min.	Cu. Ft. per Minute	Horsepower		Revs. per Min.	Cu. Ft. per Minute	Horsepower		Revs. per Min.	Cu. Ft. per Minute	Horsepower	
30	12	1496	2843	6.00		1619	3072	7.43		1723	3280	9.18		1833	3485	11.00		1931	3670	12.90	
	13	1492	3320	6.24		1614	3585	8.56		1724	3840	10.40		1827	4070	12.50		1925	4285	14.70	
	14	1487	3795	7.76		1610	4100	9.80		1717	4380	12.00		1821	4645	14.30		1918	4895	16.70	
	16	1485	4262	8.90		1607	4605	11.20		1715	4920	13.60		1820	5220	16.30		1916	5503	19.10	
	15	1490	4749	10.10		1611	5125	12.80		1720	5478	15.50		1825	5830	18.50		1920	6138	21.70	
35	14	1285	3865	8.15		1390	4180	10.10		1486	4460	12.47		1592	4740	14.92		1658	4990	17.45	
	15	1282	4520	9.26		1386	4875	11.63		1482	5220	14.15		1572	5535	17.00		1654	5830	19.90	
	16	1279	5160	10.57		1381	5536	13.30		1478	5960	16.23		1566	6320	19.36		1651	6655	22.70	
	17	1277	5796	12.08		1380	6260	15.15		1476	6690	18.52		1553	7100	22.10		1649	7490	25.95	
	18	1280	6455	13.70		1385	6970	17.30		1480	7450	21.05		1568	7925	25.20		1652	8340	29.45	
40	16	1125	5050	10.65		1217	5460	13.20		1300	5830	16.30		1378	6190	19.50		1452	6520	22.80	
	17	1122	5900	12.10		1214	6370	15.20		1296	6820	18.50		1374	7230	22.20		1447	7620	26.00	
	18	1119	6740	13.80		1210	7280	17.40		1292	7780	21.20		1370	8250	25.30		1442	8690	29.70	
	19	1170	7570	15.80		1208	8180	19.80		1290	8740	24.20		1368	9270	28.90		1440	9780	33.90	
	20	1120	8430	17.90		1212	9100	22.60		1294	9730	27.50		1372	10350	32.90		1444	10900	38.50	
45	18	1000	6385	13.47		1082	6895	16.75		1155	7370	20.70		1225	7820	24.75		1291	8250	28.90	
	19	997	7460	15.30		1078	8060	19.27		1151	8560	23.50		1221	9140	28.13		1287	9640	32.93	
	21	994	8515	17.45		1073	9200	22.07		1147	9840	26.80		1217	10475	32.05		1284	10980	37.63	
	22	993	9570	20.10		1072	10330	25.10		1146	11040	30.71		1215	11720	36.60		1282	12360	42.95	
	23	996	10630	22.75		1076	11500	28.65		1150	12300	34.90		1219	13030	41.70		1286	13730	48.80	
50	20	900	7890	16.63		974	8510	20.62		1040	9110	25.45		1102	9660	30.45		1162	10170	35.60	
	21	897	9220	18.90		970	9950	23.75		1036	10630	28.90		1098	11270	34.66		1158	11880	40.60	
	23	894	10500	21.55		967	11350	27.17		1033	12130	33.20		1095	12870	39.50		1155	13570	46.40	
	24	893	11820	24.66		966	12750	30.90		1032	13630	37.80		1094	14450	45.10		1154	15250	52.95	
	25	896	13150	27.95		969	14200	35.60		1036	15170	42.94		1097	16100	51.40		1157	16950	60.10	
55	22	918	9540	20.13		886	10300	24.95		945	11020	30.80		1002	11680	36.85		1056	12320	43.10	
	23	815	11150	22.86		881	12030	28.73		941	12875	34.96		999	13650	41.95		1052	14400	49.13	
	25	813	12730	26.08		877	13730	32.90		939	14680	40.10		996	15580	47.80		1050	16430	56.15	
	27	812	14300	29.85		876	15440	37.40		938	16500	45.73		995	17500	54.60		1049	18460	64.10	
	28	814	15900	33.83		879	17180	42.70		940	18360	52.00		998	19450	62.20		1051	20500	72.80	
60	24	750	11360	23.95		811	12260	29.70		866	13120	36.70		918	13920	43.90		968	14670	51.30	
	26	748	13270	27.25		808	14330	34.20		864	15330	41.65		916	16250	50.00		966	17150	58.50	
	27	745	15150	31.05		805	16350	39.15		861	17500	47.70		912	18550	56.95		963	19550	66.85	
	29	744	17020	35.56		804	18380	44.56		862	19650	54.50		911	20830	65.00		962	21980	76.30	
	30	747	18930	40.30		807	20450	50.90		864	21860	61.90		914	23080	74.10		965	24400	86.70	
70	28	643	15425	32.60		695	16650	40.40		743	17800	49.90		788	18870	59.70		830	19900	69.80	
	30	641	18020	37.05		693	19450	46.50		740	20820	56.60		787	22080	68.00		828	23270	79.60	
	32	639	20570	42.25		691	22200	53.30		738	23750	64.90		785	25200	77.50		826	26550	91.00	
	34	638	23100	48.40		690	24950	60.60		737	26680	74.10		784	28270	88.50		825	29850	103.80	
	35	640	25700	54.80		692	27750	69.20		739	29700	84.20		786	31450	100.80		827	33140	118.00	
80	31	563	20200	42.60		609	21800	52.80		650	23320	65.20		689	24730	78.00		726	26070	91.20	
	34	561	23600	48.40		607	25470	60.80		648	27250	74.00		687	28900	88.80		724	30470	104.00	
	36	559	26920	55.20		604	29070	69.60		646	31100	84.80		685	33000	101.20		723	34730	118.80	
	38	558	30250	63.20		603	32670	79.10		645	34920	96.80		684	37050	115.60		722	39070	135.60	
	40	560	33650	71.60		605	36350	90.30		647	38900	110.00		686	41200	131.60		724	43370	154.00	
90	35	500	25550	53.90		542	27550	66.80		578	29500	82.50		613	31300	98.70		646	32000	115.30	
	38	499	29840	61.20		539	32200	76.90		576	34500	93.60		611	36550	112.30		643	38550	131.50	
	41	497	34080	69.80		537	36750	88.10		574	39350	107.30		609	41720	128.00		641	43970	150.30	
	43	496	38250	80.00		536	41300	100.20		573	44200	122.50		608	46850	146.20		640	49450	171.50	
	45	498	42560	90.50		538	45970	114.30		575	49200	139.20		610	52100	166.50		642	54900	195.00	

Figure 17. Typical performance tables for centrifugal fans. These tables are compiled, assuming that the area of the main duct is equal to the sum of the areas of all the branch pipes, plus 25 per cent; and assuming that the total resistance of the exhaust system is 2½ times the suction at the hood. Fan sizes usually indicate the diameter in inches of the fan casing. (See paragraph 55.)

low-pressure fan, and (b) the centrifugal or high-pressure fan.

52. Propeller fans have curved screw-shaped blades that produce a low pressure draft and move the air in a direction parallel to the axis of the fan. The current of air set in motion travels at a relatively low speed, but such fans are capable, if properly designed and installed, of moving large volumes of air.

53. With centrifugal fans, the air enters at one end of the axle, and is thrown by the rapid rotation of the fan, between numerous straight or concave radial spokes or blades to the outside or box-like casing where the outlet is located and from which the current of air passes. As this type of fan moves a volume of air with considerable velocity and at high pressure, it operates effectively and efficiently against high resistances.

54. Fans should preferably be electrically unit driven.

55. The type and size of fan selected in practice for certain exhaust systems depend upon the pressure in inches of water of the system, the volume of air or gas to be handled in cubic feet per minute (CFM), and the size of the header pipe adjacent to the fan. Figure 17 shows the average performance of centrifugal fans and may be used in selecting a fan that will meet the requirements just outlined.

56. In general a branch pipe velocity of 3,000 feet per minute will satisfactorily exhaust most fumes, vapors, gases and light dusts; a velocity of 4,500 feet per minute is usually needed for grinding and polishing systems, and about 5,000 for casting tumbling barrels. A fair average for dust-collecting systems is from 3,000 to 5,000 feet per minute. (Volume of air moved equals velocity multiplied by the area of the pipe measured in square feet.)

57. There are several methods for determining pressure in inches of water in exhaust systems. In discussing pressure, it is necessary to differentiate between resistance pressure, velocity pressure, and total pressure. The most common method of measuring is by means of a U-tube. The tube is made of glass and is about 8 or 10 inches long. If pressure is to be measured in a branch pipe, a hole ⅛ of an inch in diameter is made in the pipe approximately 10 diameters of the pipe from the hood, but in no case less than 1 foot from the hood or an elbow. One end of a rubber hose is placed over this hole and the other end attached to the U-tube, which has been half filled with water. The pressure in inches of water, is determined by measuring the difference in height between the surfaces of the water in the two branches of the tube. (Figure 18.) Such tests should be made with all branch pipes open. The majority of regulations call for sufficient static pressure in every branch pipe to produce a difference of level of at least 2 inches of water. This is usually satisfactory for most industrial operations, although a difference of 4 inches is required for removing dust created by granite working tools or machines.

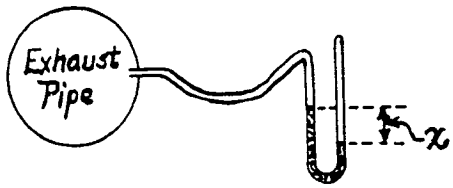


Figure 18. Determining the amount of suction in exhaust pipe. Suction, in inches of water, is measured at the point indicated by letter "X." (See paragraph 57.)

58. Some dust when comparatively dry, and all dusts if moist, will stick to the fan blades. This not only decreases the efficiency of the exhaust system but it may also ruin the bearings and in time destroy the fan. It is necessary, therefore, to clean the fan at regular intervals. If, however, it is necessary to clean the fan at too frequent intervals, it may be an indication that the fan should be placed on the discharge end of the dust or fume collector.

59. It is sometimes advantageous to install two small single fans instead of one large fan. Double fans are particularly desirable where one fan would take up too much head room, or where main pipes come from opposite directions. In the latter case, elbows and bends are eliminated, as the main pipes are run directly to the fan inlet.

60. Exposed openings in the motor housing should be covered with substantial wire mesh.

61. Fan bearings should not extend into the fan housings or exhaust pipes.

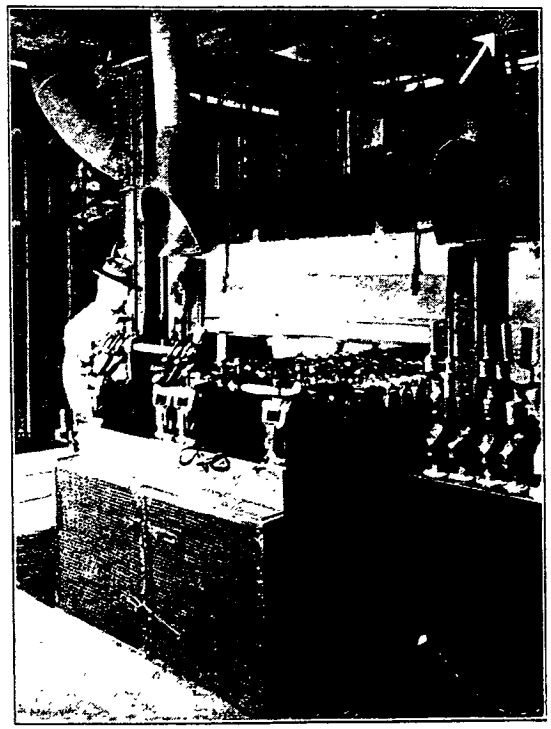
62. If any flammable materials are drawn through the fan, the fan blades and spider should be of bronze, aluminum, or similar material to avoid the possibility of sparks and fire or explosion, or the fan casing should consist of or be lined with such material.

Discharge Pipe

63. The discharge pipe leading from the fan to the place of disposal should be as short as possible so the resistance of the system may not be unnecessarily high. In practice, this pipe is usually larger than or of the same size as the duct leading to the fan.

Dust and Fume Disposal

64. The method of disposing of the dust or fumes gathered through an exhaust system depends largely upon the character of the waste materials. In a few cases they may be exhausted directly to the outside atmosphere. Great care, however, should be observed to prevent such materials from returning into the workroom or any place where they would be harmful.



Courtesy, Ford Motor Company

Figure 19. Fresh air supply. At points where operations generate excessive heat, fresh air is drawn in by blowers through ducts, directly upon the workmen. The cold air supply can be controlled by regulating the damper indicated by the white arrow. The exhaust pipe is installed at the rear of the furnace (See paragraph 79.)

65. Cyclone collectors may be used to separate solid particles from the exhausted air. In general, the air is led into the cyclone on a tangent and as it swirls around in the cylindrical chamber the solids are centrifuged or driven to the chamber walls where they slide by gravity into the conical shaped bottom. The clean air escapes from the top of the chamber through a central exhaust tube. Simple cyclones, skimmer cyclones, high efficiency cyclones and multiple cyclones are various types of dry material collectors, all of which use adaptations of the simple cyclone principles.

66. Dust, fumes, viscous matter, fog and mist may be collected by electrical precipitators which utilize high voltage direct current for ionizing and electrically charging the collected materials. Liquids drain from the electrodes, while solids are removed from the electrodes by gravity or by washing, blowing, scraping, or rapping devices.

67. Dry dust may be separated from the air by cloth arrestors. Means must be provided to shake or otherwise remove the dust that builds up to form a mat on the surface of the cloth. Usually this is done only when the exhaust system is shut down. It is sometimes advisable to install dampers just ahead of the arrestors, so the dust will not back up into the exhaust system.

68. Dynamic precipitators have fan blades so designed and arranged that dust particles in the exhausted air are rotated so rapidly that they are ejected at the tips of the blades into a by-pass and from there into a hopper. A small percentage of air goes along with the dust particles and this is drawn back into the fan casing. Some dynamic precipitators are so arranged that the exhausted air first passes through a water spray.

69. In impingement collectors the exhausted air is subjected to several changes in direction and velocity and impinged against wet surfaces. Here the waste matter is washed away by a continuous flow of liquid.

70. Fumes and mists are sometimes removed by passing the exhausted air through one or more water sprays.

71. Some vapors can be condensed. In condensing apparatus, the vapor is passed through coiled channels or pipes which are artificially chilled, usually by means of water sprays.

72. Absorption is another means of disposing of some dusts and fumes. Absorption chambers and vessels are constructed in various ways and are often arranged in series. Gas or fumes may be allowed to bubble up in a vessel filled with water or some other absorbing liquid. In absorption towers, the air to be purified or the dust to be absorbed is admitted below, while water trickles down from above, acting on the countercurrent principle. The introduction of coke, lime, activated alumina or other materials may also aid in the absorbing process.

73. It is possible to neutralize some objectionable gases, fumes or vapors by the addition of certain substances which change their chemical composition and render them harmless. Furthermore, useful by-products may sometimes be recovered in this way.

74. Separators should be installed outside the building when conditions permit. They should be constructed of and supported by non-flammable materials. They should have clean-out doors to permit examination of the interior. Vent pipes should extend above

EXHAUST SYSTEM SURVEY FORM

Plant..... Location.....

Building..... Date..... Surveyed by.....

GENERAL DATA:

Exhaust System No..... Departments served by system (1).....

(2)..... (3)..... (4).....

Changes made since last survey.....

.....

AIR FLOW DATA:

Point of measurement	Duct diam. (inches)	Pitot or static reading (in. water)	Air velocity (FPM)	Air flow (CFM)	Remarks
1.					
2.					

EXHAUST SYSTEM SURVEY FORM

(Reverse side)

ENVIRONMENTAL DATA:

Point of sampling	Material sampled	Concentration found (State units)	Remarks
1.			
2.			

CONSTRUCTION DATA: (Cite parts of system needing attention)

Hoods .....

.....

Ducts .....

.....

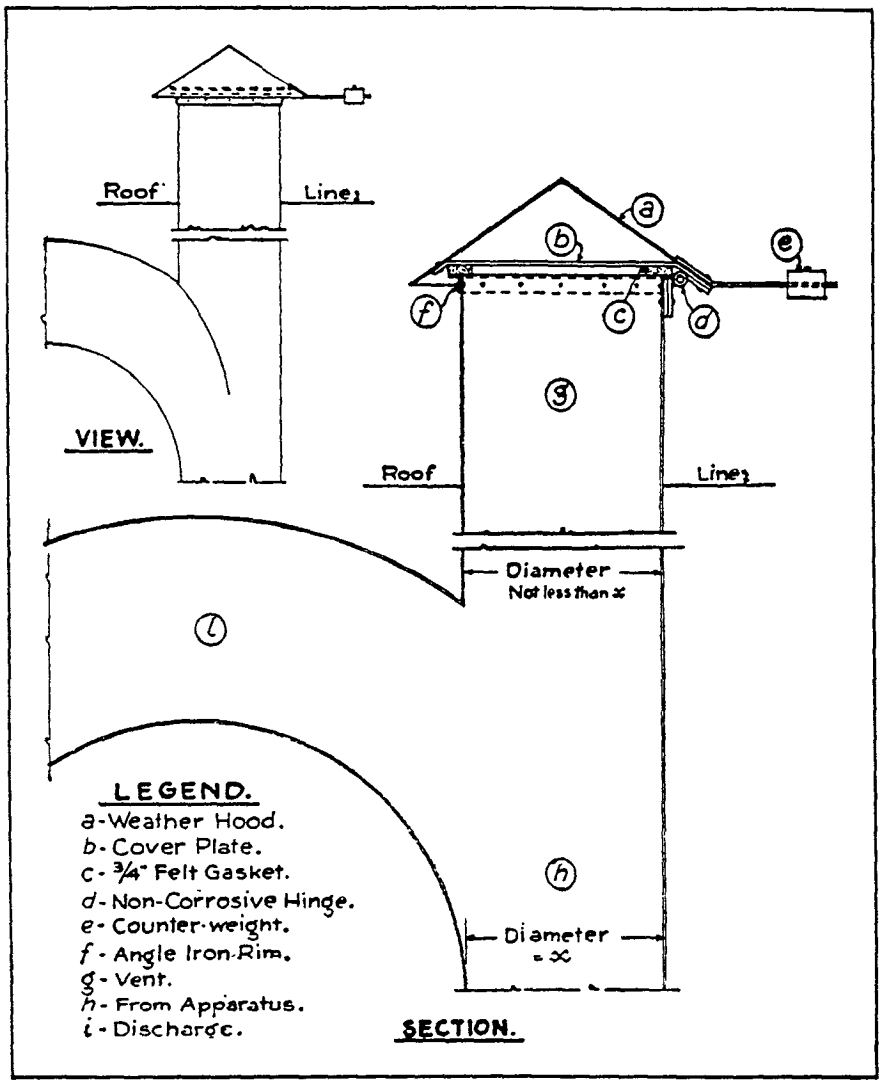
Elbows .....

Collectors (check filters if used).....

.....

Fan and Motor.....

Figure 20. A suggested form for report of the inspector who makes the surveys of exhaust systems. (See paragraph 81.)



Courtesy, National Fire Protection Association

Figure 21. A suggested design of safety relief vent for exhaust system. (See paragraph 82.)

adjacent buildings, especially if located less than 10 feet from them.

75. In general, the recirculation of air after it has been cleaned is not recommended.

General

76. Many manufacturers succeed in utilizing the dust or fumes that are collected by one of the methods herein described. For instance, wood dusts may be burned under the boilers; or blast furnace gases and others containing carbon monoxide may be used to heat "stoves," or be burned for other purposes. One manufacturer in the lead industry states that he has saved enough lead to pay more than the entire cost of installing and operating his exhaust systems.

77. Care should be exercised to prevent different fumes, dusts, vapors and gases from entering a common main where they may chemically react on each other and form explosive mixtures. It is sometimes advisable to install a compact, individual exhaust system for each room or building, especially where the system handles flammable dusts or fumes. Otherwise the exhaust ducts may simply serve as a fuse or conductor to lead a fire to a number of different points.

78. If an exhaust system is used for flammable dusts, fumes or gases, the metal parts of the system should be electrically grounded. This and other specifications to eliminate or reduce the fire and explosion hazards inherent in exhaust systems and to prevent exhaust systems from spreading fires are discussed in "Blower Systems," by the National Fire Protection Association and approved by the American Standards Association. This publication should be referred to for detailed data.

79. It must always be remembered that sufficient openings should be provided in the workroom to allow for the entrance of additional air. Removal of air through an exhaust system creates a partial vacuum in the workroom which must be offset by the free entrance of fresh air from the outside. Figure 19 illustrates one method of securing a fresh air supply that has proved successful. In some cases, before admitting this incoming air, it may be necessary first to have it purified by filtering and washing, or its temperature may have to be modified; perhaps its humidity should be regulated. These are problems more nearly associated with general ventilation than with exhaust systems, and are therefore discussed in detail in the pamphlet on "Industrial Ventilation."

80. It is sometimes necessary to remove dusts locally by portable apparatus without the installation of permanent hoods, pipes, fans, etc. The cleaning of dusty places by blowers, dry rags, brushes and feather dusters may be harmful to health. There are at present various kinds of portable vacuum cleaning apparatus with instruments fitted for every special kind of cleaning.

81. Systems that were originally installed satisfactorily have been known to fail because hoods became detached from ducts, holes were broken into pipes and pipes were found clogged with dust and all sorts of debris. It is, therefore, necessary in every plant where there is an exhaust system to appoint an inspector or supervisor whose duty it is to see that the entire installation is inspected at regular intervals and that all defects are speedily remedied. Figure 20 shows a suggested form to be filled out by the inspector each time he makes a survey of an exhaust system.

82. If an exhaust system is used to convey refuse or stock, it should be vented to the outside of the building, either directly by flues or separators, or indirectly by bins or vaults into which it discharges. If the refuse or stock is combustible, vertical safety relief vents should be installed in such a manner that they do not deviate more than 22½ degrees from the direction of the pipes from which they lead. (Figure 21.)

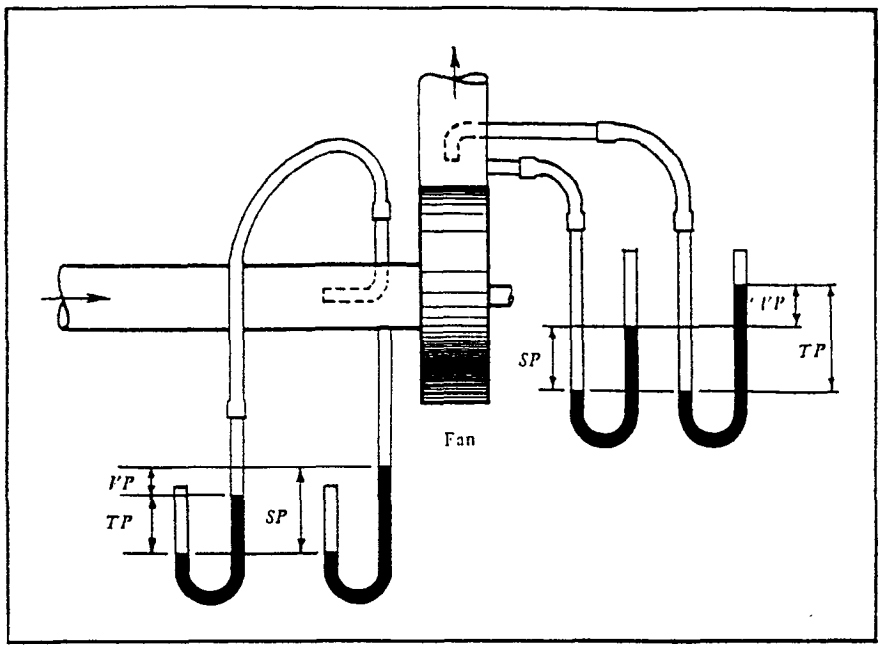


Figure 22. Measuring static, velocity and total pressures. (See paragraph 83.)

Testing Exhaust Systems for Effectiveness

83. The ultimate means of determining the effectiveness of any exhaust system is to measure the concentration of the contaminant in the workroom atmosphere. In addition, measurements of air-flow through the system should be made at regular, frequent intervals to make sure it is functioning in accordance with the original design. The following suggestions are quoted from the A.S.A. report entitled, "Fundamentals Relating to the Design and Operation of Exhaust Systems":

"Measurement of static suction (pressure) at the throat of the exhaust hood provides the simplest index of operation but it may be safely employed for this purpose only when the coefficient of restriction is not changed by damage to the hood. The measurement of the velocity pressure by means of a pitot tube (see Figure 22) in the branch pipes and in the main pipe as well provides a more exact means of determining the volume of air flowing into the various hoods and through the system and in addition gives direct information concerning the transporting velocities in the system. The accurate determination of average velocity at any cross-section, however, requires more skill and time than is required for the determination of static suction. Care must be exercised to keep the pitot tube from plugging when used in measuring the velocity of dust-laden air. (Pitot tubes of special design have been used for this purpose.) In certain cases it is desirable to provide a flowmeter of some type in the main line to indicate the total volume of air handled by the system. A pitot tube may be employed for this purpose although a meter section of the venturi type provides a more permanent measuring apparatus."

References

"Fundamentals Relating to the Design and Operation of Exhaust Systems"—American Standards Association.

"Fundamentals of Design, Construction, Operation and Maintenance of Exhaust Systems"—American Foundrymen's Association.

The American Society of Heating and Ventilating Engineers Guide.

Publications of various companies that manufacture exhaust equipment.

New York State "Rules Relating to the Removal of Dust, Gases and Fumes."

"Regulations for the Installation of Blower and Exhaust Systems for Dust, Stock and Vapor Removal"—National Fire Protection Association and American Standards Association.

ACKNOWLEDGMENT

This pamphlet was prepared by the Industrial Division, National Safety Council. It has also been reviewed by the Safe Practices Conference Committee, manufacturers of exhaust system equipment, consulting engineers and others. The Council gratefully acknowledges their assistance.

Rep. 844—3M