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# Exhaust Systems

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## 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:

- Mechanical exhaust system.
- Installing automatic or closed machinery methods.
- Using wet processes.

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.*

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.)

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.

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

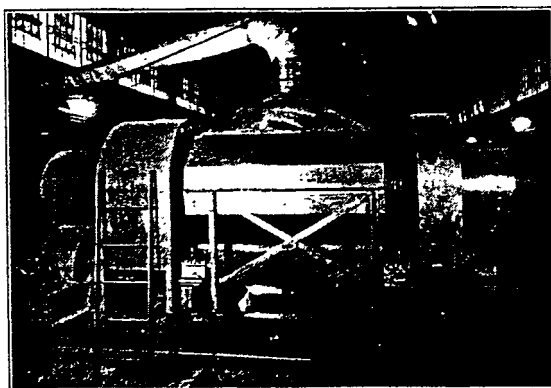
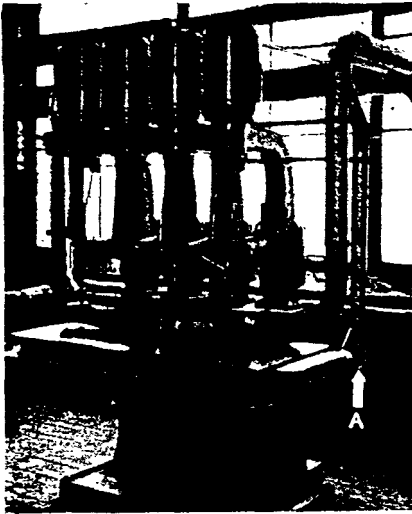


Figure 1. Tumbling barrel, properly guarded and equipped with exhaust system. (See paragraph 10.)



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.

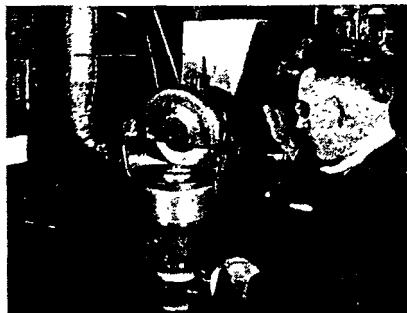


Figure 3. Exhaust on small grinder. The hood catches dust particles at the point of greatest velocity. (See paragraph 16.)

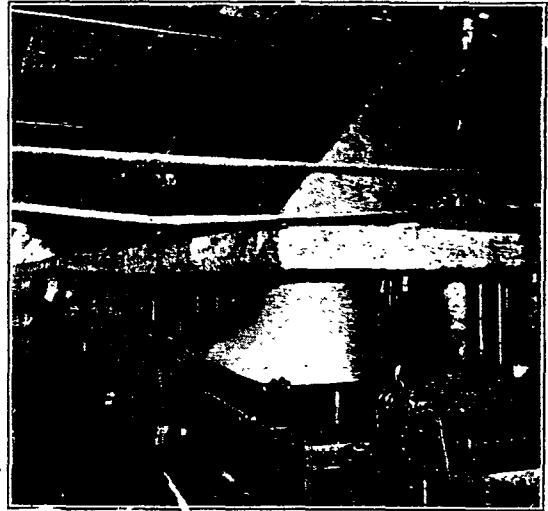


Figure 4. One large hood over a series of tanks. (See paragraph 19.)

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  $1\frac{1}{2}$  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 instal-

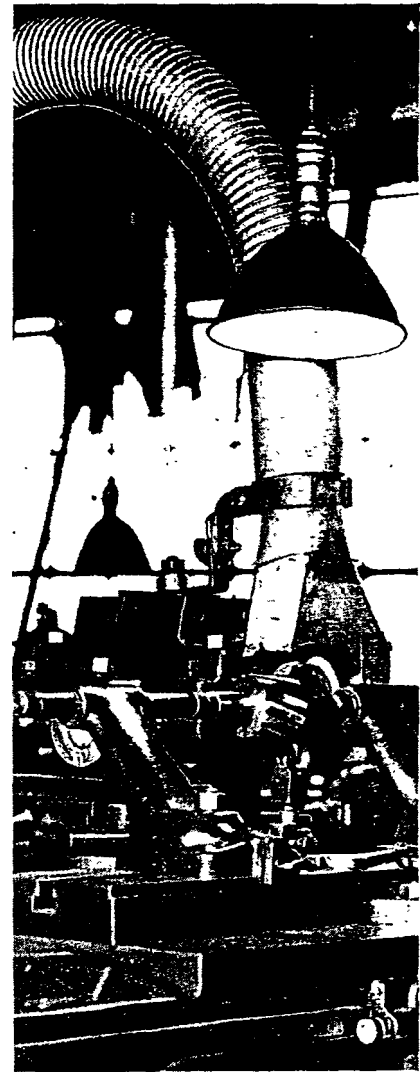


Figure 6. Exhaust system applied to a cutter grinder. Exhaust pipe is a large-size flexible metallic hose. (See paragraph 24.)

lations. 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.)

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

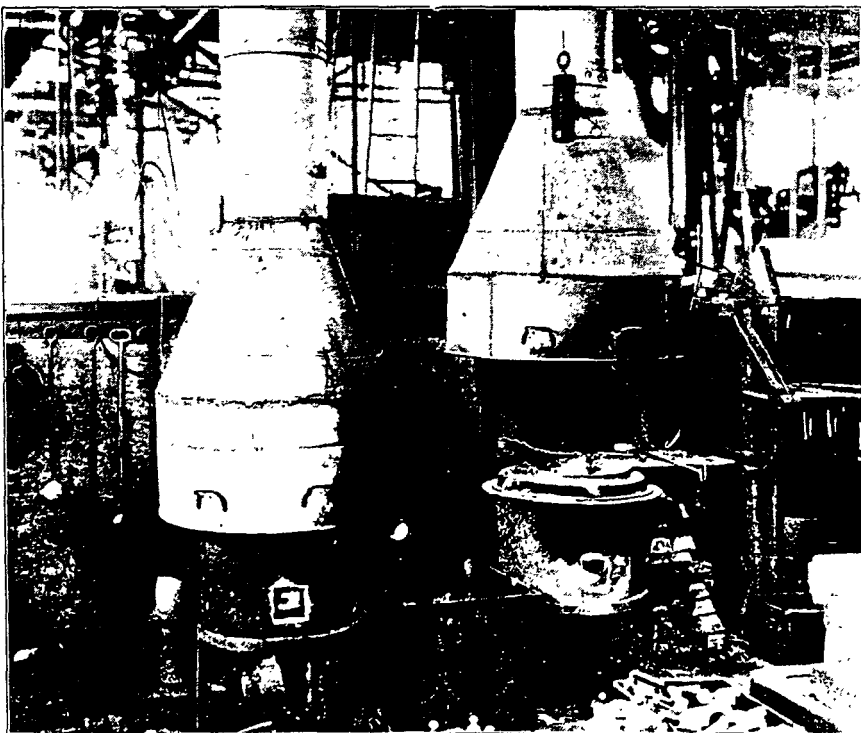


Figure 5. Hoods with counterweighted telescopic pipes. Hoods can be readily raised and lowered like a window. (See paragraph 23.)

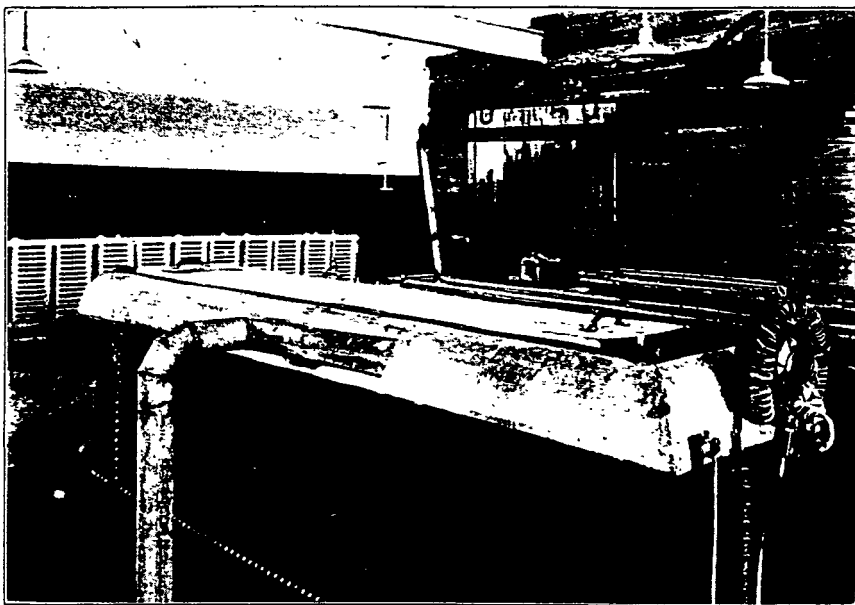


Figure 7. A tank with telescopic cover. Lateral exhaust hood removes fumes horizontally from between cover and surface of liquid. (See paragraph 25.)

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.

| 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.)

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  $1\frac{1}{2}$  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 |
|-------------------------------------|---------------------|
| 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.)

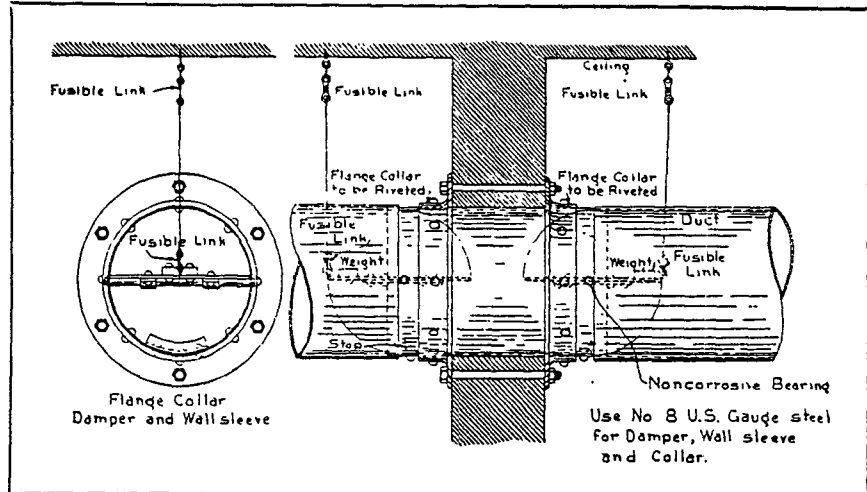
38. If an exhaust system has a main duct and a number of branch pipes, dampers or blast gates are sometimes installed. Experiments indicate, however, that exhaust systems are most efficient if all dampers and blast gates are left open.

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

|                                                  |                    |
|--------------------------------------------------|--------------------|
| Self feed table rip saw up to 16" diameter ..... | 4½" pipe on bottom |
| Swing saw up to 20" diameter .....               | 4" pipe on top     |
| 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.)

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.

| 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  | 39.82  | 46.182 |
| 1.....                 | 3¾                                                        | 3¾     | 4¾     | 5     | 5½     | 6      | 6¾     | 7¾     | 7¾     |
| 2.....                 | 4¾                                                        | 5½     | 6¾     | 7     | 7¾     | 8¾     | 9¾     | 10¾    | 10¾    |
| 3.....                 | 5¾                                                        | 6¾     | 7¾     | 8¾    | 9½     | 10½    | 11½    | 12¾    | 13¾    |
| 4.....                 | 6¾                                                        | 7¾     | 8¾     | 9¾    | 11     | 12½    | 13¾    | 14¾    | 15¾    |
| 5.....                 | 7¾                                                        | 8¾     | 9¾     | 11    | 12½    | 13¾    | 14¾    | 16     | 17½    |
| 6.....                 | 8¾                                                        | 9¾     | 10¾    | 12½   | 13¾    | 14¾    | 16½    | 17½    | 18¾    |
| 7.....                 | 8¾                                                        | 10¾    | 11¾    | 13¾   | 14¾    | 16     | 17½    | 18¾    | 20¾    |
| 8.....                 | 9¾                                                        | 10¾    | 12¾    | 14¾   | 15½    | 17½    | 18¾    | 20¾    | 21¾    |
| 9.....                 | 9¾                                                        | 11½    | 13¾    | 14¾   | 16½    | 18¾    | 19¾    | 21¾    | 23     |
| 10.....                | 10¾                                                       | 12¾    | 13¾    | 15½   | 17¾    | 19¾    | 20¾    | 22½    | 24½    |
| 11.....                | 11                                                        | 12¾    | 14¾    | 16¾   | 18¾    | 20     | 21¾    | 23¾    | 25½    |
| 12.....                | 11½                                                       | 13¾    | 15¾    | 17¾   | 19     | 20¾    | 22¾    | 24¾    | 26¾    |
| 13.....                | 11½                                                       | 13¾    | 15¾    | 17¾   | 19¾    | 21¾    | 23¾    | 25¾    | 27¾    |
| 14.....                | 12¾                                                       | 14¾    | 16¾    | 18¾   | 20¾    | 22¾    | 24¾    | 26¾    | 28¾    |
| 15.....                | 12¾                                                       | 14¾    | 17     | 19¾   | 21¾    | 23¾    | 25¾    | 27¾    | 29¾    |
| 16.....                | 13¾                                                       | 15¾    | 17¾    | 19¾   | 22     | 24¾    | 26¾    | 28¾    | 30¾    |
| 17.....                | 13¾                                                       | 15¾    | 18¾    | 20¾   | 22¾    | 24¾    | 27¾    | 29¾    | 31¾    |
| 18.....                | 14                                                        | 16¾    | 18¾    | 21    | 23¾    | 25¾    | 27¾    | 30¾    | 32¾    |
| 19.....                | 14¾                                                       | 16¾    | 19¾    | 21½   | 23¾    | 26¾    | 28¾    | 31¾    | 33¾    |
| 20.....                | 14¾                                                       | 17¾    | 19¾    | 22½   | 24½    | 27     | 29½    | 31¾    | 34¾    |
| 21.....                | 15¾                                                       | 17¾    | 20¾    | 22½   | 25¾    | 27¾    | 30¾    | 32¾    | 35¾    |
| 22.....                | 15¾                                                       | 18     | 20¾    | 23¾   | 25¾    | 28¾    | 30¾    | 33¾    | 36     |
| 23.....                | 15¾                                                       | 18½    | 21¾    | 23¾   | 26¾    | 29     | 31½    | 34¾    | 36¾    |
| 24.....                | 16¾                                                       | 18¾    | 21¾    | 24¾   | 26¾    | 29¾    | 32¾    | 34¾    | 37¾    |
| 25.....                | 16¾                                                       | 19¾    | 22     | 24¾   | 27½    | 30¾    | 32¾    | 35¾    | 38¾    |
| 26.....                | 16¾                                                       | 19¾    | 22¾    | 25¾   | 28     | 30¾    | 33¾    | 36¾    | 39¾    |
| 27.....                | 17¾                                                       | 20     | 22¾    | 25¾   | 28½    | 31¾    | 34¾    | 37     | 39¾    |
| 28.....                | 17¾                                                       | 20¾    | 23¾    | 26¾   | 29     | 32     | 34¾    | 37¾    | 40¾    |
| 29.....                | 17¾                                                       | 20¾    | 23¾    | 26¾   | 29½    | 32½    | 35¾    | 38¾    | 41¾    |
| 30.....                | 18                                                        | 21     | 24     | 27    | 30     | 33     | 36     | 39     | 42     |

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

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

| Fan Size | Diameter of Main Duct—Inches | SUCTION 1.5 Inches     |                    |             | VELOCITY 2745 Feet per Minute |                    |             | SUCTION 1.75 Inches    |                    |             | VELOCITY 2005 Feet per Minute |                    |             | SUCTION 2.0 Inches     |                    |             | VELOCITY 1710 Feet per Minute |                    |             | SUCTION 2.5 Inches     |                    |             | VELOCITY 1340 Feet per Minute |                    |             | SUCTION 3.0 Inches     |                    |             | VELOCITY 1090 Feet per Minute |                    |             | SUCTION 3.6 Inches     |                    |             | VELOCITY 890 Feet per Minute |                    |             | SUCTION 4.0 Inches     |                    |             | VELOCITY 745 Feet per Minute |                    |             | SUCTION 4.5 Inches     |                    |             | VELOCITY 650 Feet per Minute |                    |             | SUCTION 5.0 Inches     |                    |             | VELOCITY 5010 Feet per Minute |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |    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|          |                              | Revolutions per Minute | Cu. Ft. per Minute | Horse-power | Revolutions per Minute        | Cu. Ft. per Minute | Horse-power | Revolutions per Minute | Cu. Ft. per Minute | Horse-power | Revolutions per Minute        | Cu. Ft. per Minute | Horse-power | Revolutions per Minute | Cu. Ft. per Minute | Horse-power | Revolutions per Minute        | Cu. Ft. per Minute | Horse-power | Revolutions per Minute | Cu. Ft. per Minute | Horse-power | Revolutions per Minute        | Cu. Ft. per Minute | Horse-power | Revolutions per Minute | Cu. Ft. per Minute | Horse-power | Revolutions per Minute        | Cu. Ft. per Minute | Horse-power | Revolutions per Minute | Cu. Ft. per Minute | Horse-power | Revolutions per Minute       | Cu. Ft. per Minute | Horse-power | Revolutions per Minute | Cu. Ft. per Minute | Horse-power | Revolutions per Minute       | Cu. Ft. per Minute | Horse-power | Revolutions per Minute | Cu. Ft. per Minute | Horse-power | Revolutions per Minute       | Cu. Ft. per Minute | Horse-power | Revolutions per Minute | Cu. Ft. per Minute | Horse-power |                               |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |       |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |     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| 30       | 12                           | 1060                   | 2012               | 2.11        | 1145                          | 2172               | 2.80        | 1227                   | 2320               | 3.26        | 1368                          | 2595               | 4.56        | 1496                   | 2843               | 6.00        | 1619                          | 3072               | 7.43        | 1723                   | 3280               | 9.18        | 1833                          | 3485               | 11.00       | 1931                   | 3670               | 12.90       | 2027                          | 3848               | 14.88       | 2119                   | 4010               | 16.93       | 2207                         | 4160               | 19.15       | 2291                   | 4290               | 21.45       | 2371                         | 4410               | 23.91       | 2447                   | 4520               | 26.43       | 2519                         | 4620               | 29.00       | 2591                   | 4720               | 31.65       | 2659                          | 4810 | 34.35 | 2727 | 4900 | 37.10 | 2791 | 4980 | 39.90 | 2851 | 5060 | 42.75 | 2911 | 5140 | 45.55 | 2971 | 5220 | 48.40 | 3031 | 5300 | 51.10 | 3091 | 5380 | 53.85 | 3151 | 5460 | 56.55 | 3211 | 5540 | 59.30 | 3271 | 5620 | 62.00 | 3331 | 5700 | 64.65 | 3391 | 5780 | 67.35 | 3451 | 5860 | 70.00 | 3511 | 5940 | 72.65 | 3571 | 6020 | 75.30 | 3631 | 6100 | 77.95 | 3691 | 6180 | 80.60 | 3751 | 6260 | 83.25 | 3811 | 6340 | 85.90 | 3871 | 6420 | 88.55 | 3931 | 6500 | 91.20 | 3991 | 6580 | 93.85 | 4051 | 6660 | 96.50 | 4111 | 6740 | 99.15 | 4171 | 6820 | 101.80 | 4231 | 6900 | 104.45 | 4291 | 6980 | 107.10 | 4351 | 7060 | 109.75 | 4411 | 7140 | 112.40 | 4471 | 7220 | 115.05 | 4531 | 7300 | 117.70 | 4591 | 7380 | 120.35 | 4651 | 7460 | 123.00 | 4711 | 7540 | 125.65 | 4771 | 7620 | 128.30 | 4831 | 7700 | 130.95 | 4891 | 7780 | 133.60 | 4951 | 7860 | 136.25 | 5011 | 7940 | 138.90 | 5071 | 8020 | 141.55 | 5131 | 8100 | 144.20 | 5191 | 8180 | 146.85 | 5251 | 8260 | 149.50 | 5311 | 8340 | 152.15 | 5371 | 8420 | 154.80 | 5431 | 8500 | 157.45 | 5491 | 8580 | 160.10 | 5551 | 8660 | 162.75 | 5611 | 8740 | 165.40 | 5671 | 8820 | 168.05 | 5731 | 8900 | 170.70 | 5791 | 8980 | 173.35 | 5851 | 9060 | 176.00 | 5911 | 9140 | 178.65 | 5971 | 9220 | 181.30 | 6031 | 9300 | 183.95 | 6091 | 9380 | 186.60 | 6151 | 9460 | 189.25 | 6211 | 9540 | 191.90 | 6271 | 9620 | 194.55 | 6331 | 9700 | 197.20 | 6391 | 9780 | 199.85 | 6451 | 9860 | 202.50 | 6511 | 9940 | 205.15 | 6571 | 10020 | 207.80 | 6631 | 10100 | 210.45 | 6691 | 10180 | 213.10 | 6751 | 10260 | 215.75 | 6811 | 10340 | 218.40 | 6871 | 10420 | 221.05 | 6931 | 10500 | 223.70 | 6991 | 10580 | 226.35 | 7051 | 10660 | 229.00 | 7111 | 10740 | 231.65 | 7171 | 10820 | 234.30 | 7231 | 10900 | 236.95 | 7291 | 10980 | 239.60 | 7351 | 11060 | 242.25 | 7411 | 11140 | 244.90 | 7471 | 11220 | 247.55 | 7531 | 11300 | 250.20 | 7591 | 11380 | 252.85 | 7651 | 11460 | 255.50 | 7711 | 11540 | 258.15 | 7771 | 11620 | 260.80 | 7831 | 11700 | 263.45 | 7891 | 11780 | 266.10 | 7951 | 11860 | 268.75 | 8011 | 11940 | 271.40 | 8071 | 12020 | 274.05 | 8131 | 12100 | 276.70 | 8191 | 12180 | 279.35 | 8251 | 12260 | 282.00 | 8311 | 12340 | 284.65 | 8371 | 12420 | 287.30 | 8431 | 12500 | 289.95 | 8491 | 12580 | 292.60 | 8551 | 12660 | 295.25 | 8611 | 12740 | 297.90 | 8671 | 12820 | 300.55 | 8731 | 12900 | 303.20 | 8791 | 12980 | 305.85 | 8851 | 13060 | 308.50 | 8911 | 13140 | 311.15 | 8971 | 13220 | 313.80 | 9031 | 13300 | 316.45 | 9091 | 13380 | 319.10 | 9151 | 13460 | 321.75 | 9211 | 13540 | 324.40 | 9271 | 13620 | 327.05 | 9331 | 13700 | 329.70 | 9391 | 13780 | 332.35 | 9451 | 13860 | 335.00 | 9511 | 13940 | 337.65 | 9571 | 14020 | 340.30 | 9631 | 14100 | 342.95 | 9691 | 14180 | 345.60 | 9751 | 14260 | 348.25 | 9811 | 14340 | 350.90 | 9871 | 14420 | 353.55 | 9931 | 14500 | 356.20 | 9991 | 14580 | 358.85 | 10051 | 14660 | 361.50 | 10111 | 14740 | 364.15 | 10171 | 14820 | 366.80 | 10231 | 14900 | 369.45 | 10291 | 14980 | 372.10 | 10351 | 15060 | 374.75 | 10411 | 15140 | 377.40 | 10471 | 15220 | 380.05 | 10531 | 15300 | 382.70 | 10591 | 15380 | 385.35 | 10651 | 15460 | 388.00 | 10711 | 15540 | 390.65 | 10771 | 15620 | 393.30 | 10831 | 15700 | 395.95 | 10891 | 15780 | 398.60 | 10951 | 15860 | 401.25 | 11011 | 15940 | 403.90 | 11071 | 16020 | 406.55 | 11131 | 16100 | 409.20 | 11191 | 16180 | 411.85 | 11251 | 16260 | 414.50 | 11311 | 16340 | 417.15 | 11371 | 16420 | 419.80 | 11431 | 16500 | 422.45 | 11491 | 16580 | 425.10 | 11551 | 16660 | 427.75 | 11611 | 16740 | 430.40 | 11671 | 16820 | 433.05 | 11731 | 16900 | 435.70 | 11791 | 16980 | 438.35 | 11851 | 17060 | 441.00 | 11911 | 17140 | 443.65 | 11971 | 17220 | 446.30 | 12031 | 17300 | 448.95 | 12091 | 17380 | 451.60 | 12151 | 17460 | 454.25 | 12211 | 17540 | 456.90 | 12271 | 17620 | 459.55 | 12331 | 17700 | 462.20 | 12391 | 17780 | 464.85 | 12451 | 17860 | 467.50 | 12511 | 17940 | 470.15 | 12571 | 18020 | 472.80 | 12631 | 18100 | 475.45 | 12691 | 18180 | 478.10 | 12751 | 18260 | 480.75 | 12811 | 18340 | 483.40 | 12871 | 18420 | 486.05 | 12931 | 18500 | 488.70 | 12991 | 18580 | 491.35 | 13051 | 18660 | 494.00 | 13111 | 18740 | 496.65 | 13171 | 18820 | 499.30 | 13231 | 18900 | 501.95 | 13291 | 18980 | 504.60 | 13351 | 19060 | 507.25 | 13411 | 19140 | 509.90 | 13471 | 19220 | 512.55 | 13531 | 19300 | 515.20 | 13591 | 19380 | 517.85 | 13651 | 19460 | 520.50 | 13711 | 19540 | 523.15 | 13771 | 19620 | 525.80 | 13831 | 19700 | 528.45 | 13891 | 19780 | 531.10 | 13951 | 19860 | 533.75 | 14011 | 19940 | 536.40 | 14071 | 20020 | 539.05 | 14131 | 20100 | 541.70 | 14191 | 20180 | 544.35 | 14251 | 20260 | 547.00 | 14311 | 20340 | 549.65 | 14371 | 20420 | 552.30 | 14431 | 20500 | 554.95 | 14491 | 20580 | 557.60 | 14551 | 20660 | 560.25 | 14611 | 20740 | 562.90 | 14671 | 20820 | 565.55 | 14731 | 20900 | 568.20 | 14791 | 20980 | 570.85 | 14851 | 21060 | 573.50 | 14911 | 21140 | 576.15 | 14971 | 21220 | 578.80 | 15031 | 21300 | 581.45 | 15091 | 21380 | 584.10 | 15151 | 21460 | 586.75 | 15211 | 21540 | 589.40 | 15271 | 21620 | 592.05 | 15331 | 21700 | 594.70 | 15391 | 21780 | 597.35 | 15451 | 21860 | 600.00 | 15511 | 21940 | 602.65 | 15571 | 22020 | 605.30 | 15631 | 22100 | 607.95 | 15691 | 22180 | 610.60 | 15751 | 22260 | 613.25 | 15811 | 22340 | 615.90 | 15871 | 22420 | 618.55 | 15931 | 22500 | 621.20 | 15991 | 22580 | 623.85 | 16051 | 22660 | 626.50 | 16111 | 22740 | 629.15 | 16171 | 22820 | 631.80 | 16231 | 22900 | 634.45 | 16291 | 22980 | 637.10 | 16351 | 23060 | 639.75 | 16411 | 23140 | 642.40 | 16471 | 23220 | 645.05 | 16531 | 23300 | 647.70 | 16591 | 23380 | 650.35 | 16651 | 23460 | 653.00 | 16711 | 23540 | 655.65 | 16771 | 23620 | 658.30 | 16831 | 23700 | 660.95 | 16891 | 23780 | 663.60 | 16951 | 23860 | 666.25 | 17011 | 23940 | 668.90 | 17071 | 24020 | 671.55 | 17131 | 24100 | 674.20 | 17191 | 24180 | 676.85 | 17251 | 24260 | 679.50 | 17311 | 24340 | 682.15 | 17371 | 24420 | 684.80 | 17431 | 24500 | 687.45 | 17491 | 24580 | 690.10 | 17551 | 24660 | 692.75 | 17611 | 24740 | 695.40 | 17671 | 24820 | 698.05 | 17731 | 24900 | 700.70 | 17791 | 24980 | 703.35 | 17851 | 25060 | 706.00 | 17911 | 25140 | 708.65 | 17971 | 25220 | 711.30 | 18031 | 25300 | 713.95 | 18091 | 25380 | 716.60 | 18151 | 25460 | 719.25 | 18211 | 25540 | 721.90 | 18271 | 25620 | 724.55 | 18331 | 25700 | 727.20 | 18391 | 25780 | 729.85 | 18451 | 25860 | 732.50 | 18511 | 25940 | 735.15 | 18571 | 26020 | 737.80 | 18631 | 26100 | 740.45 | 18691 | 26180 | 743.10 | 18751 | 26260 | 745.75 | 18811 | 26340 | 748.40 | 18871 | 26420 | 751.05 | 18931 | 26500 | 753.70 | 18991 | 26580 | 756.35 | 19051 | 26660 | 758.95 | 19111 | 26740 | 761.60 | 19171 | 26820 | 764.25 | 19231 | 26900 | 766.90 | 19291 | 26980 | 769.55 | 19351 | 27060 | 772.20 | 19411 | 27140 | 774.85 | 19471 | 27220 | 777.50 | 19531 | 27300 | 780.15 | 19591 | 27380 | 782.80 | 19651 | 27460 | 785.45 | 19711 | 27540 | 788.10 | 19771 | 27620 | 790.75 | 19831 | 27700 | 793.40 | 19891 | 27780 | 796.05 | 19951 | 27860 | 798.70 | 20011 | 27940 | 801.35 | 20071 | 28020 | 804.00 | 20131 | 28100 | 806.65 | 20191 | 28180 | 809.30 | 20251 | 28260 | 811.95 | 20311 | 28340 | 814.60 | 20371 | 28420 | 817.25 | 20431 | 28500 | 819.90 | 20491 | 28580 | 822.55 | 20551 | 28660 | 825.20 | 20611 | 28740 | 827.85 | 20671 | 28820 | 830.50 | 20731 | 28900 | 833.15 | 20791 | 28980 | 835.80 | 20851 | 29060 | 838.45 | 20911 | 29140 | 841.10 | 20971 | 29220 | 843.75 | 21031 | 29300 | 846.40 | 21091 | 29380 | 849.05 | 21151 | 29460 | 851.70 | 21211 | 29540 | 854.35 | 21271 | 29620 | 857.00 | 21331 | 29700 | 859.65 | 21391 | 29780 | 862.30 | 21451 | 29860 | 864.95 | 21511 | 29940 | 867.60 | 21571 | 30020 | 870.25 | 21631 | 30100 | 872.90 | 21691 | 30180 | 875.55 | 21751 | 30260 | 878.20 | 21811 | 30340 | 880.85 | 21871 | 30420 | 883.50 | 21931 | 30500 | 886.15 | 21991 | 30580 | 888.80 | 22051 | 30660 | 891.45 | 22111 | 30740 | 894.10 | 22171 | 30820 | 896.75 | 22231 | 30900 | 899.40 | 22291 | 30980 | 902.05 | 22351 | 31060 | 904.70 | 22411 | 31140 | 907.35 | 22471 | 31220 | 910.00 | 22531 | 31300 | 912.65 | 22591 | 31380 | 915.30 | 22651 | 31460 | 917.95 | 22711 | 31540 | 920.60 | 22771 | 31620 | 923.25 | 22831 | 31700 | 925.90 | 22891 | 31780 | 928.55 | 22951 | 31860 | 931.20 | 23011 | 31940 | 933.85 | 23071 | 32020 | 936.50 | 23131 | 32100 | 939.15 | 23191 | 32180 | 941.80 | 23251 | 32260 | 944.45 | 23311 | 32340 | 947.10 | 23371 | 32420 | 949.75 | 23431 | 32500 |

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  $\frac{1}{8}$  of an inch in diameter is made in the pipe approximately 10 di-

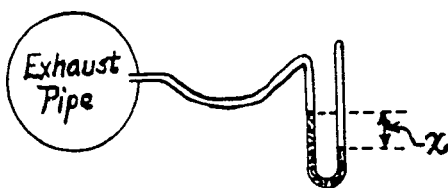


Figure 18. Determining the amount of suction in exhaust pipe. Suction, in inches of water, is measured at the point indicated by letter "X." (See paragraph 57.)

ameters 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.

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.

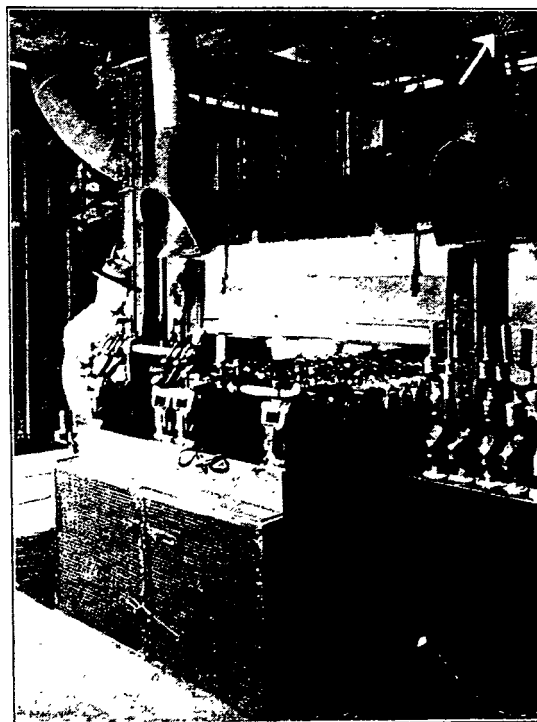
62. If any flammable materials are drawn through the fan, the fan blades and spider should be of bronze, aluminum, or similar material to avoid the possibility of sparks and fire or explosion, or the fan casing should consist of or be lined with such material.

### 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 counter-current 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<br>(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.)

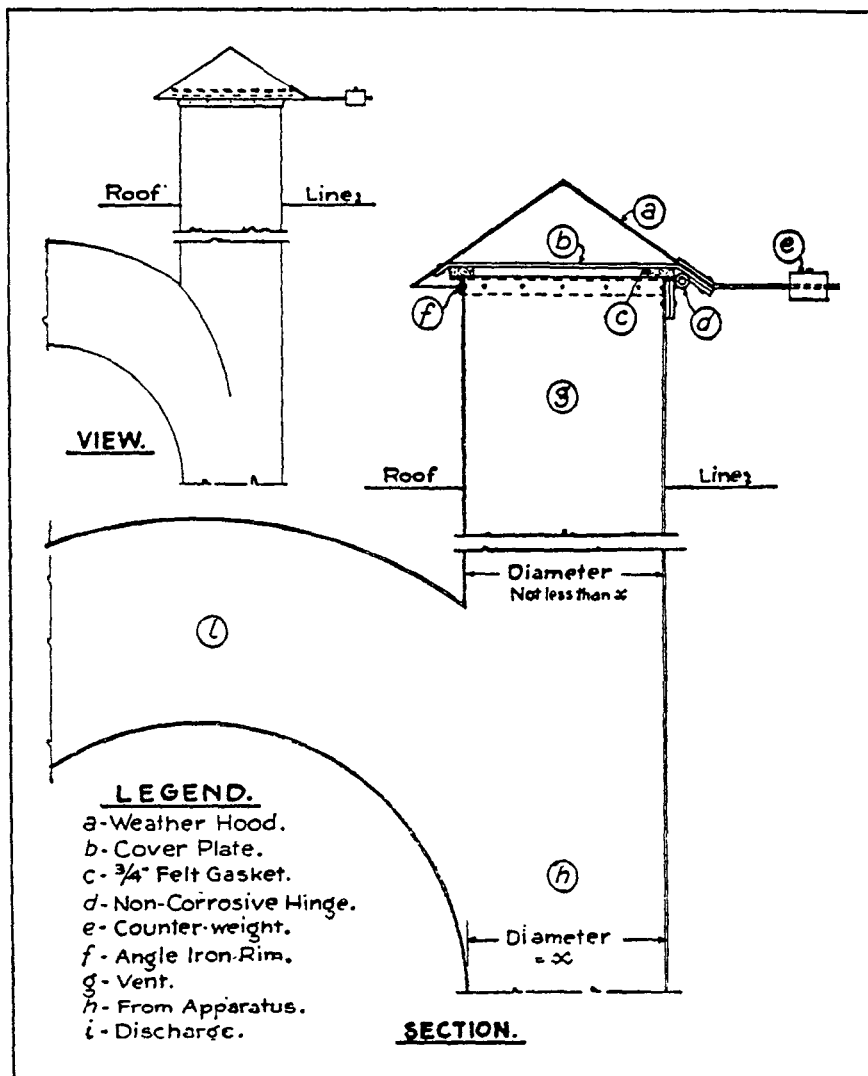


Figure 21. A suggested design of safety relief vent for exhaust system. (See paragraph 82.)

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  $22\frac{1}{2}$  degrees from the direction of the pipes from which they lead. (Figure 21.)

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 pre-

vent 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

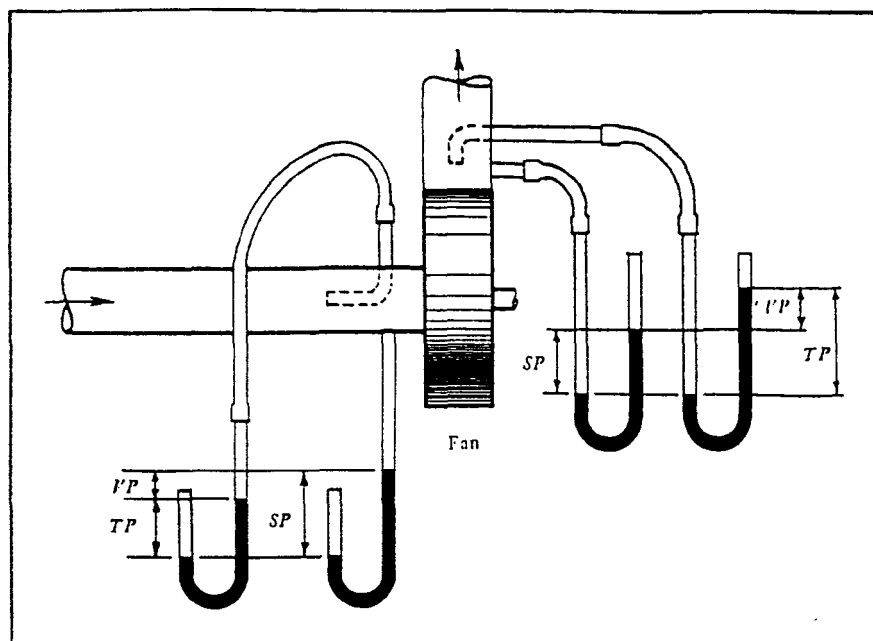


Figure 22. Measuring static, velocity and total pressures. (See paragraph 83.)

### 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

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