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Section 1

Section 2:

Service Guide 2.1

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CHECKING PERFORMANCE OF LOCAL EXHAUST SYSTEMS

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1. Changes in manufacturing procedures in the last few years have resulted in the use of more toxic materials and in the generation of more finely divided particles and greater quantities of smoke and fume. At the same time, there has been a greater effort to maintain a safe, comfortable atmosphere for the employee.

2. It has been estimated that about 80 per cent of the contaminants are controlled by ventilation, and today many operations have ventilation included in the original installation. Although a ventilation system is considered necessary for safety and comfort on new installations, responsibility for its satisfactory performance is seldom assigned to any one individual. Therefore, it frequently is not tested when put into operation and is allowed to become inoperative from lack of maintenance.

3. Excellent handbooks have been written on installation of local exhaust systems, but too little has been given on how to maintain them in top operating condition. There are two reasons for this lack of information.

4. First, a local exhaust system usually is not a piece of production equipment. Its maintenance may be slighted in favor of machines essential to the manufacturing process. Second, a local exhaust system has a dual aspect.

5. Strictly, it is an engineering or mechanical device, consisting of sheet metal, fans, motors, arresters, etc., whose performance is specified in terms of rate of air flow, static pressure, rpm. etc. This aspect is the responsibility of the engineer.

6. Yet the basic purpose of a local exhaust system is maintenance of health or comfort, and sometimes fire prevention. Its effectiveness is measured by how well it removes dust, fume, vapor, or gas that would otherwise make working conditions unsafe or unhealthful. This aspect is the concern of the industrial hygienist, who has been mainly responsible for developing exhaust and dilution ventilation for the control of atmospheric contaminants.

7. In the absence of an industrial hygiene engineer, the safety engineer is usually responsible for the exhaust system. Whenever necessary, he should consult the industrial hygiene personnel of the state health or labor department, of his company's insurance carrier, or of the home office if he is in a plant of a large corporation.

8. Management should try to develop in the plant engineer greater interest in the principles of local exhaust ventilation. Because these systems have been installed for health reasons, the plant engineer may not feel responsible for their satisfactory performance. The safety engineer, on the other hand, who does have an interest in the safety of work places, is generally unfamiliar with the principles of such systems.

9. Therefore, in a plant which does not have an industrial hygiene engineer, neither the plant engineer nor the safety engineer pays much attention to ventilation systems designed for the control of air contaminants. In such a plant, the safety engineer should be concerned with the satisfactory performance of ventilation systems. With the guidance of outside industrial hygiene engineers, he can become sufficiently familiar with ventilation equipment and terminology to check, to some extent, the performance of local exhaust systems.

10. The purpose of this data sheet is to suggest methods by which a local exhaust system can be checked when first put into operation, to determine if it fulfills the specifications, and by which it can be rechecked at intervals, to determine when, where, and what kind of maintenance is needed for maximum efficiency.

11. The performance of the system should be the responsibility of the plant engineering and maintenance departments. If, as in many cases, this responsibility is not now assigned and the equipment is not maintained, then it may be well for the safety engineer to try to interest management in assigning the responsibility to the proper people.

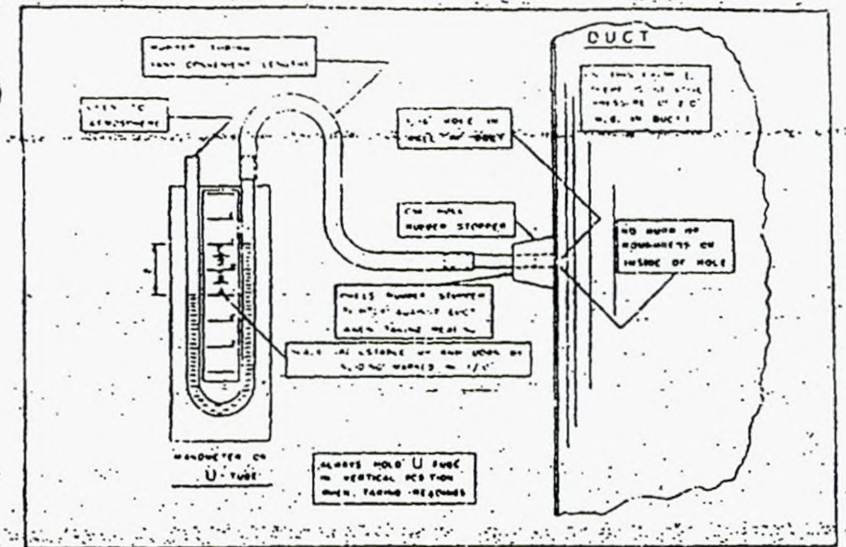


Figure 1. How to use U-tube (manometer) for measuring air pressure in ducts.

Definition of Terms

12. A **local exhaust** system is one that removes an air-borne contaminant, such as dust, fume, vapor, gas, odor, or hot air, as near its source as possible. A general exhaust system, or general ventilation, by contrast, removes air from the room after the contaminant has spread. The general exhaust method merely dilutes the room air by bringing in clean outside air, while the local exhaust traps the material at its source before it is dispersed throughout the room.

13. A **hood** is a specially designed fitting at the entrance of the duct to cause the flow of air to form a pattern that will best control the contaminant. It is a partial enclosure around the source where the contaminant is produced, connected with an exhaust duct, usually round sheet-metal pipe, to an exhaust fan.

14. A **booth** is a hood, usually rectangular or box-shaped, that encloses the operation on the two sides, the top and bottom, and the back, with only the front or face open.

15. A **collector** (arrester) is a device for removing the air-borne material from the air stream. It may be a cyclone or centrifugal collector for large-size particulate material like rough-grinding dust, or a cloth filter for finer dust, or a water-wash, fog or spray device, electrostatic precipitator, dynamic precipitator, or other type.

16. Every exhaust fan operates by inducing a suction or negative pressure in the duct leading from the hood. This means that the air in the duct is below atmospheric pressure so that room air rushes into the duct. This negative pressure is an indication of the air flow, commonly expressed in cubic feet of air per minute (cfm), that enters the duct. The negative pressure may be directly related to air flow or, in the case of a plugged duct, inversely related.

17. The negative pressure is easily measured by gauges of various types, the basic one being a U-tube or manometer (a piece of glass tubing shaped like a U, the legs being about 8 inches long) half filled with water. A rubber tube from one leg is held at the point where negative pressure is to be measured, and the other leg is left open to the atmosphere (Figure 1).

18. The **unit of pressure**, which may be positive ("blowing out") or negative ("sucking in") is inches of water, abbreviated w.g. (water gauge). It is the elevation of one water column above the top of the other.

General

19. A good local exhaust system is a well-engineered project, based on precise design data—not merely a collection of piping.

20. Many states have codes that specify duct sizes and velocity of air in these ducts (hence, air flow in cfm) for different industrial processes and industries. These are minimum standards that must be met. Good engineering practice often calls for even larger air flows than those indicated in the codes. The engineer should have a copy of state regulations. Plans for new exhaust systems often have to be approved by the state before installation, and he should find out if this is the case in his state.

21. The engineer should secure a blueprint showing piping layout, if possible, together with data giving the cfm the designer intended to exhaust from each hood. For new systems, blueprints will be available. For old systems, the plant maintenance or engineering department may not have a drawing. It is still possible, however, that he can get the layout and data by writing to the sheet metal company from which his plant bought the equipment.

22. From this material he can determine whether an old system is the same today as it was when it was installed, or whether it has suffered the fate of all-too-many exhaust systems — has had extra branches added or changes made that may now render parts of it less effective.

23. Rare is the exhaust system that does not require understanding and cooperation on the part of the man who works at the process. Sometimes he has to modify his work habits to permit certain hoods to be used. The engineer should always find out just how the designer of the system intended it to be used. The engineer can often help by seeing that the men know the why of their exhaust systems and know how to use them.

Air Samples

24. If the equipment handles silica dust, asbestos fibers, or other toxic materials, such as chromic acid mist, lead fumes or dust, or solvent vapors, the system may be exhausting the "correct" volumes of air (according to the blueprint), the fan and collector may be in A-1 condition—yet a health hazard may still exist. The final and all-important measure of whether an exhaust system

is controlling a hazard is whether the air in the working region is clean enough to breathe without injury. This question can be answered only by taking air samples and analyzing them to find out if the contaminant is below the maximum allowable limit.* These tests are needed because a person cannot look at a dust cloud or smell toxic vapor and tell if the condition is unsafe.

25. Collection of air samples, both in general working areas and in ventilation ducts, is a principal activity of the industrial hygienist. It is, therefore, imperative that the safety engineer have such personnel secure this information. Not only does the collection of samples require extensive experience, but also the interpretation of the results and, equally important, the analytical procedures from which the results are obtained involve detailed and exacting methods for which experience and judgment are necessary. In the plant where an industrial hygienist is employed, the problem falls within his jurisdiction.

26. In the absence of a staff industrial hygienist, the safety engineer may obtain the services of the state bureau of industrial hygiene (in either the health or labor department), the services of the insurance carrier or of private consultants. Such services may also be found in institutes of industrial health or divisions of industrial hygiene in some of the medical schools or in schools of public health.

27. Once it has been determined through air samples that an exhaust system is keeping an exposure within safe limits, the negative pressure or "suction" in each branch duct, the pressure drop across the collector (if one is used), and the negative pressure at the fan inlet may be measured. At any future date, if rechecks show that these pressure readings are the same and if no changes have been made in the process, the hoods, or raw materials handled, it can be assumed that the hazard is still under control. (Cross drafts, as from a mancooler, will change the control.)

28. Arranging for air samples and suction tests is the responsibility of the safety engineer rather than the maintenance engineer. (It is also frequently considered a responsibility of the designer.)

29. When the air contaminant is not toxic but causes merely a comfort problem, little is gained by air sampling.

Checking the System

30. For two reasons, it is well to make a complete check of the exhaust system. First, it can be determined whether it is meeting specifications for air volumes, resistance of ducts, horsepower, etc. Second, this information will be available for reference when the system is rechecked at later dates.

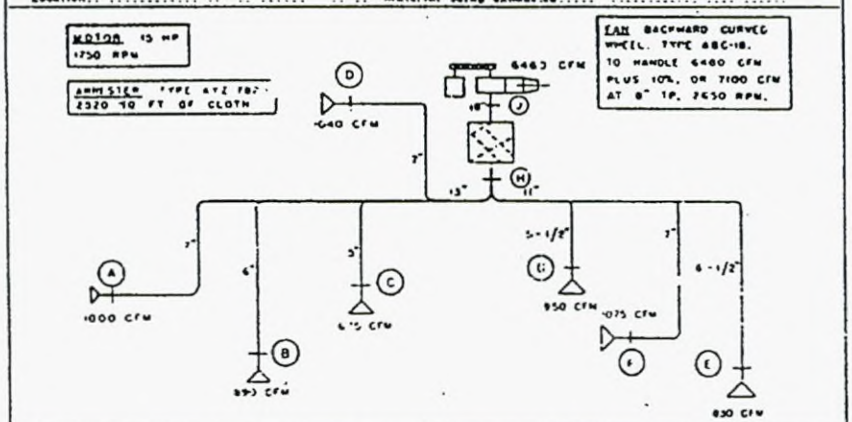
31. Some of the measures which will provide the safety engineer, in the absence of an industrial hygienist, with a program for checking the performance of a local exhaust system are discussed below.

32. **Layout.** The safety engineer should get or make a simple line drawing showing the layout of each main duct and branch, together with the location of the arrester, fan, and motor. He should measure the duct diameters and note them on the drawing. He should also secure the open face dimensions of hoods and record them. He should note on the sketch the type and size of fan, motor, drive, and arrester. This drawing need not be elaborate, or even to scale, and can be taken from the drawing of the system mentioned earlier.

33. **Test holes** should be drilled in each branch. The easiest and cheapest method is to make a 1/16-inch hole, leaving no burrs on the inside of the duct. (See Figure 1.) It is not necessary to cover or plug such a test hole when it is not in use. Sometimes a one-inch length of small copper tubing or even a small brass petcock is fastened permanently over the hole, but these refinements are not necessary. Each hole should be circled with a ring of white or yellow paint, and its

*Most state labor or health departments have now incorporated maximum allowable limits in their codes: these limits should be observed. Engineers in states which do not have such limits are referred to "Table of Chemical Hazards," Section 41, *Accident Prevention Manual for Industrial Operations*, 3rd edition (1955), published by the National Safety Council.

EXHAUST SYSTEM NO.......... CHECKED BY............ DATE.........
Location.............................. Material being exhausted.....................



Test point	Condition of hood and branch (Battered? Removed? Plugged? Repair?)	Hood Suction (inches water) Originally	Checked
A		2.0	
B		2.1	
C		2.5	
D		2.0	
E		1.9	
F		2.1	
G		2.2	
H		5.0	
J		8.0	
Collector resistance (J)-(H)		3.0	

Material collected since last check ....lbs. Hours of operation .... Interval betwn. reg. shakings ....hrs.

COMMENTS of men, and YOUR comments (use back, if necessary):

Figure 2. Safety director's inspection report.

number or letter painted on the duct—the test points for the whole system being numbered serially. On the sketch, each test hole, with its number, should be marked.

34. **Balancing the system.** Before routine inspections are begun, and even before air samples are taken on a newly installed system, the system must be "balanced," that is, the proper amount of air must be flowing through each hood. Also, in the case of dust exhaust systems, the air velocity in branches and main ducts must be high enough to prevent settling of material, which leads to plugging.

35. In the original design, one of two means of balancing a system is used. The more common is to provide blast gates (dampers) in each branch which can be opened or partially closed so that each hood, regardless of whether it is near the fan or at a distance, handles its proper amount of air.

36. The other method is to size the diameter of the branches so that more or less air is introduced to serve the same purpose as blast gates. This must be done before the system is installed, since once the duct work is in, the duct diameters are fixed. Figure 2, adapted from Brandt, *Industrial Health Engineering*, shows a balanced system that does not rely on blast gates.

37. Each method has advantages. If blast gates are used, they should be bolted or welded after the system is balanced, to prevent tampering. Blast gates should not be used on a long, complicated system.

38. A record form (Figure 2) can be mimeographed for each exhaust system, with a suction pressure reading printed for each test hole. These readings are made immediately after the system has been balanced and dust counts (or other air samples) have been made to show that the air contaminant is under control.

39. **Periodic checks.** Each time the safety engineer makes an inspection, he fills out a report form. He compares the suction pressure readings he finds on recheck with the original readings printed on the report. He makes the following observations and records the results:

a. Look at all hoods. See if they are battered, partially removed, missing, or mangled in any way.
b. See if the manufacturing process and machines have been altered in any way. Make certain that strong cross drafts are not preventing the air contaminant from entering the hoods.
c. Whatever the provision for make-up air, make sure that replacement air has ample opportunity to enter the room.
d. Tap the duct at various points with a screwdriver or other metal object and listen to hear the pipe "ring," showing there is no appreciable settlement of material in it.

The frequency of periodic checks will vary with the type of service performed by the system. Some systems will need checkups weekly; others, monthly.

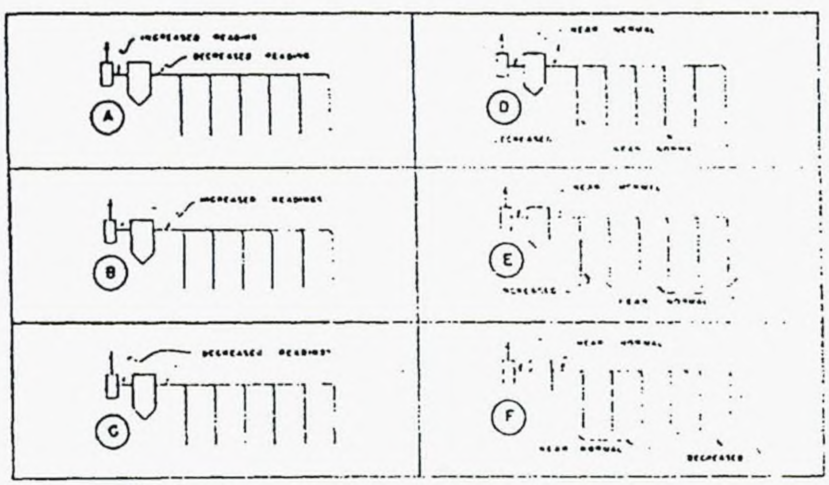
40. **Interpreting suction pressure readings.** If the suction pressure at a test hole differs by more than 10 per cent from the original readings (printed on the report form), the reason can generally be figured out without difficulty. Figure 3 shows how to interpret the U-tube values.

41. **Estimating control velocities or velocity contours.** One of the most important factors is that the control velocity at the source of the contaminant or the face of the booth (where the source is inside the booth) can be quickly measured by a sensitive direct reading instrument such as the velometer or thermo-anemometer. Where the source may cover a considerable area, the maximum and minimum should be indicated.

42. **Source, location, direction, and velocity of make-up air.** In addition to the amount and temperature of the make-up air, its source and method of distribution may be almost as important to successful control of the hazard as the design of the exhaust system itself. Since air blowing out of a duct carries 30 times as far as the same volume of air moving toward a similar exhaust duct (Figure 4), it is very important that the make-up air be diffused in such a way that no disturbing cross currents interfere with proper functioning of the exhaust hood. Frequently, such a disturbance can be anticipated if the essential facts are noted, and smoke tests may confirm its presence.

43. **Maintenance orders.** When the system needs mechanical repairs, such as replacement of worn ducts or hoods, filter cleanout, duct cleanout, fan belt adjustment, etc., the safety engineer should see that work orders are processed to the maintenance department according to the plant's customary procedure.

44. **Record filing.** The safety engineer should keep a file of his inspection reports and reports of air samples.



(A) Dust arrester partially plugged, causing increased resistance. Needs cleaning.

(B) Increased resistance or plugging in header pipe or in branch.

(C) Decreased fan capacity, open cleanout door, or disjointed pipe.

(D) First branch pipe partially plugged somewhere between header and test hole near hood.

(E) First branch pipe partially plugged somewhere between test hole and hood face.

(F) Increased resistance due to plugging in header pipe at "X."

Figure 3. How U-tube readings can be used to show where plugging has occurred. (Courtesy "Tennessee Industrial Hygiene News," 1950.)

45. **Periodic air samples.** If toxic material is handled by the system, in addition to the initial air samples, the industrial hygienist or safety engineer should arrange for periodic samples of the air-borne contaminant in the workroom.

Inspection by Maintenance Engineer

46. The maintenance engineer should check and lubricate the fan, motor, and drive on schedule just as he would any other piece of machinery. If the exhaust system has any special interlocking gates, motor-driven dampers, solenoids, or the like, these parts should come under this inspection and should be observed through a cycle to assure that they are operating.

47. He should check the inside of the collector with a flashlight each week, using an access door in the casing. The clean-air side of the collector should be examined to see that there are no accumulations of dust, which would mean that the collector was not functioning properly. He should look in the hoppers to see that they are not overfilled and should check bag collectors for torn or leaky bags.

48. Wet collectors should be checked for plugged spray nozzles, plugged drain pipes, sludge accumulation, and proper water level.

49. Fan speed should be checked monthly with a tachometer. Fan blades and scroll should be examined for wear and dirt accumulation. For this check, a hinged inspection door in the side of the fan casing or in the outlet duct near the fan discharge is necessary.

Design for Maintenance

50. Good first design will hold down maintenance problems later.

51. **Hoods and ducts.** The hood should be placed as close to the source of contamination as possible. The source should be enclosed if possible, with enough openings left for air to enter. Canopy hoods should be used sparingly. Too often the operator puts his head between the hood and the contaminant so that he may get an even greater exposure than he would if there were no hood. If particles are thrown off by the machine (e.g. a grinder), the hood and the exhaust duct should be placed so that material will be thrown into them. Accessible cleanout doors should be provided in ducts, collector, and fan housing.

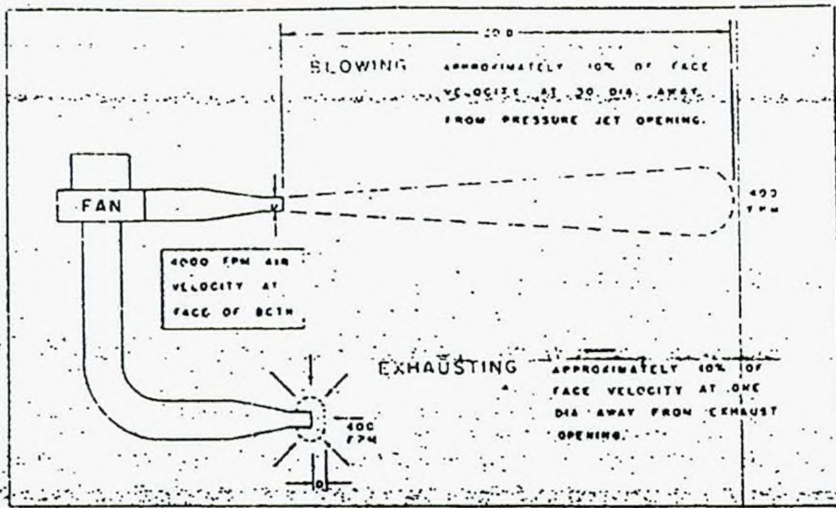


Figure 4. Effect of air blowing OUT of a pipe is felt many feet away, but an exhaust pipe has no effect beyond a few inches from pipe end. Thus it cannot "pick up" material unless pipe and hood are close to the dust source. (Courtesy "Industrial Ventilation—A Manual of Recommended Practice.")

52. Sheet metal thick enough to minimize erosion should be used. For corrosive materials, ducts should be lined with resistive coatings or made from suitable corrosion-resistant material. If condensation may be a problem, the need for thermal insulation, "drip" elements, water traps, etc. should be considered. The possibility of a fire hazard, depending upon the material to be handled,* should also be considered.

53. Construction details are of utmost importance: gradual tapers, baffled hoods, wide-sweep elbows, 30 degree angle of entry to main, etc. Design of a "balanced" system, instead of relying on blast gates, should be considered. Total pressure loss should be calculated carefully, not guessed at. Natural drafts and cross currents of room air that may keep the contaminants from entering the hood should be noted. The hood should be arranged so that it will interfere as little as possible with the worker and still be effective.

54. **Collectors.** The collector should be selected for the substance to be handled, considering such factors as particle size, dust loading, wettability, corrosion, etc. Thought should be given to community air pollution that may result if there is no collector or if too much contaminant is exhausted to the outside.

55. If a bag-type filter is selected:

a. Consider size, storage hopper capacity, free-flowing hoppers.

b. Provide a permanent outside ladder and catwalk for easy access; with nonflammable dusts, light the inside of the filter housing for ease of inspection.

c. Provide a motor-driven shaker rather than a manually-operated one wherever possible.

d. Provide time-delay relays and interlocks so that when the fan wheel comes to rest, after the fan motor has been turned off, the shaker motor starts operating and continues for two or three minutes, after which it stops and the fan can then be restarted.

56. **Fan and motor.** The fan should be put on the clean-air

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**Standards for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying.* Pamphlet No. 91, National Fire Protection Association and National Bureau of Fire Underwriters, American Standards Association, Z33.1-1950.

Although the basic purpose of ventilating systems is to serve health and comfort, the use of these standards will result in a system which is also of value from the fire prevention standpoint since it will not transmit smoke and flame through fire walls and throughout the premises. The standards also provide valuable reference with regard to the other components of the system and related fire extinguishing apparatus.

side of the collector. When flammable solid materials or vapors are passed through the system, the provisions of NFPA and NBFU Bulletins No. 91* should be followed.

57. Fan guards and a test hole for a tachometer to take speed readings of the fan should be provided. Service and inspection doors should be placed in the side of the fan housing, or in ducts at the inlet and outlet of the fan. Resistance of the fan discharge stack should be kept low. A weather cap should be omitted wherever possible.

Points on Testing

58. Here are some over-all considerations that should be kept in mind in the testing of local exhaust systems.

59. One of the initial steps that may be taken is to ensure that outside vendors or contractors provide a meaningful guarantee of performance for their equipment or system. Then the vender is made responsible for equipment or systems which do not perform properly.

60. Many a good exhaust system has been overloaded and made ineffective by the addition of hoods in later years. Before hoods are added, it should be ascertained that the present equipment can handle the additional air flow which will be needed without robbing the existing hoods.

61. **Make-up air** is sometimes a bigger problem than the exhaust system itself. Provision should be made for the air to get into the room to replace the air exhausted. In winter the make-up air may have to be tempered. A room should never be closed up tight and "air bound."

62. The man on the job must know the reason for the exhaust system and must understand how to use it. Better yet, the safety engineer should consult with him before the installation is made, to make sure that hoods, enclosures, and other parts of the system will interfere as little as possible with his work.

63. For testing exhaust systems visually, smoke tubes are commercially available (or may be made by dipping cotton into titanium tetrachloride). The smoke given off reveals the path of the air currents as they enter a hood. Smoke tubes are a boon to the safety engineer. Using them, he can show the operator how a hood works and thus often convince him how important baffles are, how necessary it is to have the hood close to the dust source, and so on.

64. Two common fallacies need clearing up. First, because people can feel air blowing out of an air line some feet away from the end of the pipe, they think dusty air can be "sucked into" an exhaust hood from several feet away. It cannot. Air can be "sucked" only 1/30 the distance it can be blown (Figure 4). In exhausting, the air velocity at a distance of one diameter from the pipe end is about 10 per cent of the velocity in the pipe; in blowing, this 10 per cent figure is reached 30 diameters from the pipe.

65. Suppose, for example, that a pipe 6 inches in diameter has air traveling through it at a velocity of 4,000 feet per minute. *Six inches* from the "sucking" end, the air velocity will be 400 feet per minute (hardly detectable by feel); at the blowing end, the 400 fpm velocity is reached some *15 feet* from the end of the pipe.

66. A second fallacy is that downdraft ventilation or hoods at floor level are required because organic solvent vapors, like benzene (benzol), trichloroethylene, carbon tetrachloride, and the like, are heavier than air. Heavy gases introduced into air tend to fall before they become mixed with the air. Thus, a vapor train of pure gasoline can form and travel along the floor many feet.

67. However, as vapors are given off from industrial processes, the atmosphere contains not pure vapor, but a mixture of vapor and air. Even air saturated with the vapor remains saturated for a very short time; it soon becomes diluted with more air because of random convection and wind current in the room.

68. A concentration of 1,000 parts per million of benzene, which is 25 times the maximum allowable health limit, is only 1.0017 times as heavy as air (although pure benzene vapor is three times as heavy as air). That is, the ratio of weight of air to weight of the benzene-air mixture is only 100 to 100.17. There could never be any sinking or stratifying of even this dense (1,000 parts per million) benzene concentration. Consequently, a side or back hood would be just as effective as a downdraft hood.

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*Bulletin No. 91, *Blower and Exhaust Systems*, National Fire Protection Association, 60 Batterymarch St., Boston 10. Bulletin No. 91, *Exhaust Systems for Dust, Stock, and Vapor Removal*, National Board of Fire Underwriters, 80 John St., New York.

REFERENCES

Perhaps the best technical reference not only for design of exhaust systems, but also for checking of them, is: *Industrial Ventilation—A Manual of Recommended Practice*, published by the American Conference of Governmental Industrial Hygienists (3rd ed., 1954), available from the Committee on Industrial Ventilation, P. O. Box 453, Lansing, Mich.

The following give information on design of exhaust systems for various processes, as well as information on the toxicity of industrial materials:

Accident Prevention Manual for Industrial Operations, National Safety Council, 3rd Edition (1955).

Industrial Health Engineering, Allen D. Brandt. John Wiley & Sons, Inc.

Heating, Ventilating, Air Conditioning Guide. The American Society of Heating and Air Conditioning Engineers (published annually).

Plant Process Ventilation, W. C. L. Hemeon, Industrial Press, 1955 edition.

Industrial Dust, Drinker and Hatch, 2nd edition (1954).

Excellent references for fire prevention considerations are listed below:

Flammable Liquids and Gases, Vol. I; *Combustible Solids, Dusts, Chemicals and Explosives*, Vol. II, National Fire Codes, 1955, National Fire Protection Association.

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