GUIDELINES

on Occupational Safety and Health for Design, Inspection, Testing and Examination of Local Exhaust Ventilation System

Department Of Occupational Safety and Health
Ministry of Human Resources
Malaysia
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Foreword

LOCAL exhaust ventilation system is one type of engineering control equipment that preferred and commonly used in workplace to control exposure to chemicals hazardous to health. Occupational Safety and Health (Use and Standards Exposure of Chemicals Hazardous to Health) Regulations 2000 have specified requirements in term of design, commissioning, inspection and testing of local exhaust ventilation system. The effectiveness and efficiency of the local exhaust ventilation system depend on the design, usage and maintenance of the system.

This guideline highlights the design factors that need to be considered during selection or testing as to ensure that local exhaust ventilation system will work efficiently and effectively. The guideline also discuss the required inspection, testing and examination to be carry out in order to ensure proper commissioning and maintenance of the system.

For further detail information on design and maintenance of the ventilation system, employers are advised to refer to other references such as the ''Industrial Ventilation - A Manual of Recommended Practice" edited by the American Conference of Governmental Industrial Hygienists.

The guideline will be reviewed from time to time. If there is any comment for improvement of the guideline, please do not hesitate to contact the department.

I would like to thank and acknowledge those who have assist in the development of the guideline.

DIRECTOR GENERAL
DEPARTMENT OF OCCUPATIONAL SAFETY AND HEALTH
MINISTRY OF HUMAN RESOURCES
2008

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Definitions

Absolute Humidity is the weight of water vapor per unit volume, pounds per cubic foot or grams per cubic centimeter.

Aerosol is an assemblage of small particles, solid or liquid, suspended in air. The diameter of the particles may vary from 100 microns down to 0.01 micron or less, e.g., dust, mist, smoke.

Air cleaner is a device designed for the purpose of removing atmospheric airborne impurities such as dusts, gases, vapors, fume and smokes. (Air cleaners include air washers, air filters, electrostatic precipitators and charcoal filters).

Air Filter is an Air cleaner to remove light particulate loadings from normal atmospheric air before introduction into the building. Usual range: Loadings up to 3 grains per thousand cubic feet (0.003 grains per cubic foot). Note: Atmospheric air in heavy industrial areas and in plant air in many industries has higher loadings than this and dust collectors are then indicated for proper air cleaning.

Air, **Standard** mean dry air at 70 ^{o}F and 229.92 in (Hg) barometer. This is substantially equivalent to 0.075 Ib/cu ft. Specific heat of dry air - 0.24 BTU/lb/F.

Atmospheric Pressure is the pressure due to the weight of the atmosphere. It is the pressure indicated by a barometer. Standard Atmospheric Pressure of Standard Atmosphere is the pressure of 29.92 inches of mercury.

Blast Gate is a sliding damper or flap commonly for isolating hood when not in use.

Blow (throw) in air distribution, mean the distance an air stream travels from an outlet to a position at which air motion along the axis reduces to a velocity of 50 fpm. For unit heaters, the distance an air stream travels from a heater without a perceptible rise due to temperature difference and loss of velocity.

Capture Velocity is the air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.

Coefficient of Entry is the actual rate of flow caused by a given hood static pressure compared to the theoretical flow which would result if the static pressure could be converted to velocity pressure with 100% efficiency. It is the ratio of actual to theoretical flow.

Density is the ratio of the mass of a specimen of a substance to the volume of the specimen. The mass of a unit volume of a substance. When weight can be used without confusion, as synonymous with mass, density is the weight of a unit volume of a substance.

Density Factor is the ratio of actual air density to density of standard air. The product of the density factor and the density of standard air (0.075 lb/cu ft) will give the actual air density in lbs per cu Ft. d x 0.075 = actual density of air, lbs per cu ft.

Dust is small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.

Dust Collector is an Air cleaner to remove heavy particulate loadings from exhaust systems before discharge to outdoors. Usual range: Loadings 0.003 grains per cubic foot and higher.

Entry Loss is loss in pressure caused by air flowing into a duct or hood. (Inches H20).

Fumes are small solid particles formed by the condensation of vapors of solid materials.

Gases are formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.

Hood is shaped inlet designed to capture contaminated air and conduct it into the exhaust duct system.

Manometer is an instrument for measuring pressure essentially a U tube partially filled with a liquid, usually water, mercury or a light oil, so constructed that the, amount of displacement of the liquid indicates the pressure being exerted on the instrument.

Mists are small droplets of materials that are ordinarily liquid at normal temperature and pressure.

Plenum is a pressure equalizing chamber.

Relative Humidity The ratio of the actual partial pressure of the water vapor in a space to the saturation pressure of pure water at the same temperature.

Slot Velocity is linear flow rate of contaminated air through slot, fpm or m/s.

Smoke is an air suspension (aerosol) of particles, usually but not necessarily solid, often originating in a solid nucleus, form combustion or sublimation.

Specific Gravity is the ratio of the mass of a unit volume of a substance to the mass of the same volume of a standard substance at a standard temperature. Water at 39.2 F is the standard substance usually referred to. For gases, dry air, at the same temperature and pressure as the gas, is often taken as the stand and substance.

Static pressure is the potential pressure exerted in all directions by a fluid at rest. For a fluid in motion it is measured in a direction normal, to the direction of flow. Usually expressed in inches water gauge when dealing with air. (The tendency to either burst or collapses the pipe.)

Temperature, **Wet Bulb** Thermodynamic wetbulb temperature is the temperature at which liquid or solid water, by evaporating into air, can bring the air to saturation adiabatically at the same temperature. Wetbulb temperature (without qualification) is the temperature indicated by a wet bulb psychrometer constructed and used according to specifications.

Threshold Limit Values (TLV): The values for air borne toxic materials which are to be used as guides in the control of health hazards and represent time weighted concentrations to which nearly all workers may be exposed 8 hours per day over extended periods of time without adverse effects.

Total Pressure is the algebraic sum of the velocity pressure and the static pressure (with due regard to sign).

Transport (Conveying) Velocity is velocity that has to be sufficient to overcome energy losses along the duct to avoid clogging.

Vapor Pressure is the pressure exerted by a vapor. If a vapor is kept in confinement over its liquid so that the vapor ran accumulate above the liquid, the temperature being held constant, the vapor pressure approaches a fixed limit called the maximum or saturated, vapor pressure, dependent only on the temperature and the liquid. The term vapor pressure is sometimes used as synonymous with saturated vapor pressure.

Velocity Pressure is the kinetic pressure in the direction of flow necessary to cause a fluid at rest to f low at a given velocity. Usually expressed in inches water gauge.

Vapor The gaseous form of substances which are normally in the solid or liquid state arid which can be changed to these states either by increasing the pressure or decreasing the temperature. Vapors diffuse.

1. DESCRIPTION OF LOCAL EXHAUST VENTILATION SYSTEM AND DESIGN PARAMETER

1.1 Introduction

Local exhaust ventilation system is the most common type of engineering control equipment used to control exposure of employees to chemicals hazardous to health. Local exhaust ventilation system operate on the principle of capturing a contaminant at or near its source before they are dispersed into the workroom environment. Contaminants can be in the form of dust, smoke, mist, aerosol, vapour and gas.

1.2 Component of Local Exhaust Ventilation System

Local exhaust ventilation system are comprised of up to four basic elements: hood, duct system, air cleaner and fan.

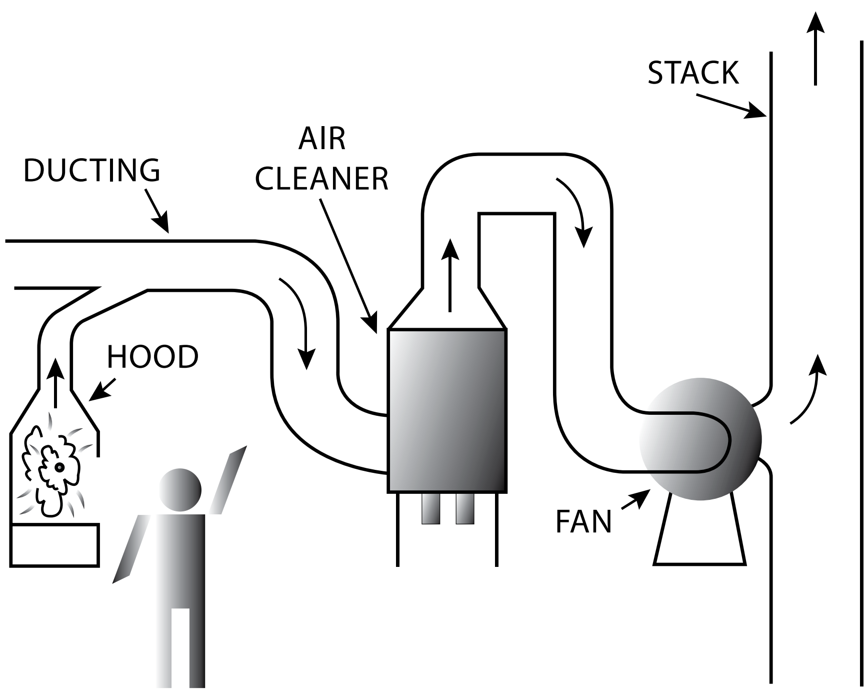


Figure 1: Components of Local Exhaust Ventilation

1.2.1 Hood

The purpose of the hood is to collect the contaminant generated in air stream directed toward the hood. The hood is the most important component of the local exhaust ventilation system because local exhaust ventilation system will not be effective unless enough of contaminants are retained or captured by the hoods as to ensure that the concentration of contaminants in the workroom is below the acceptable limits. Hoods can be categorised into two categories which is enclosure hood and exterior hood.

1.2.1.1 Enclosure hood

Enclosure hood are hood that surround contaminants sources as much as possible with wall and doors with minimum opening area. The hood may also form a total enclosure around the source of contaminants. Example of enclosure hood are fume booth, asbestos debagging booth and spray painting booth.

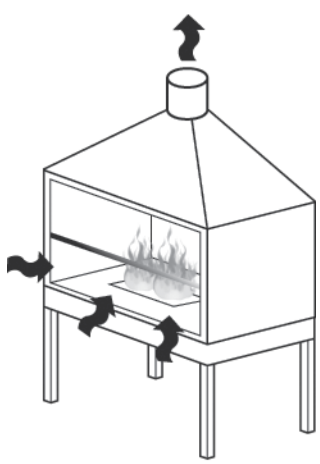


Figure 2: Fume Booth

Design parameters to be considered are -

a) Face velocity

   i. Must be sufficient enough to ensure contaminated air would not leak out of the hood; and

   ii. Uniform distribution of suction across the face of the hood.

b) Rate of flow

   i. Rate of suction must be more than rate of contaminated air produce;

   ii. Rate of flow must be equally distributed as to ensure there is no null point. This can be achieved by installing guide such as baffles or plenum; and

   iii. Coefficient of entry will determine the efficiency of the hood.

c) Size of enclosure

   i. Must be large enough to accommodate contaminated air.

1.2.1.2 Exterior hood

Exterior hood are hood that "reach out" to capture contaminants in the work room and located adjacent to source of contaminant and not enclosing it. Example of exterior hood are side hood, slot hood, downdraft hood, push - pull system hood, low volume and high velocity hood and canopy hood.

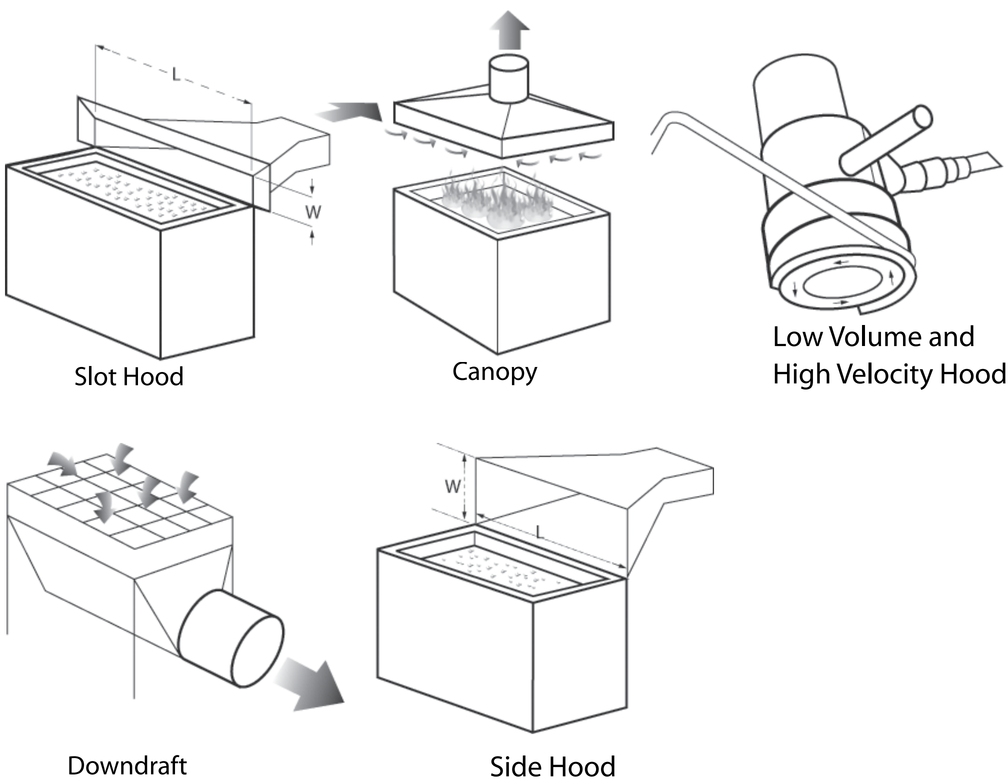


Figure 3: Example of Exterior Hood

Design parameters to be considered are:

a) Capture velocity

i. Must ensure sufficient capture velocity that will capture all contaminated air and flow into the hood; and

ii. Must be able to overcome cross draft.

b) Hood flow rate

i. The distance between the hood and source of contaminant will determine the efficiency and effectiveness of the suction;

ii. Type of hood will affect the hood flow rate; and

iii. Coefficient of entry will determine the efficiency of the hood.

c) Effect of flanges and baffles

i. A flange can provide barrier to unwanted air flow from behind the hood; and

ii. Flange can reduce suction rate required by 25%.

d) Air distribution

i. Must ensure suction air distribute uniformly across the opening of the hood; and

ii. Slot and plenum can distribute suction air uniformly.

e) Shape and size of the hood

i. The process and how the worker work relative to the hood must be considered in design of the hood.

f) Worker position effect

i. Worker position and direction of flow of air in a room need to be consider when positioning the hood; and

ii. Preferable airflow is from the side of the worker.

g) Location and position of the hood

   i. Must ensure the hood does not interfere with the task that worker has to carry out;

   ii. Must avoid cross draft; and

   iii. Ensure no blower or fan does not effect the efficiency of the hood.

1.2.2 Ducting System

A ducting system is a network of ducts that connect the hood and other components of the local exhaust ventilation system. The ducting system transport contaminated air to the Air Cleaner. Duct on the fan outlet usually discharges the air to the atmosphere.

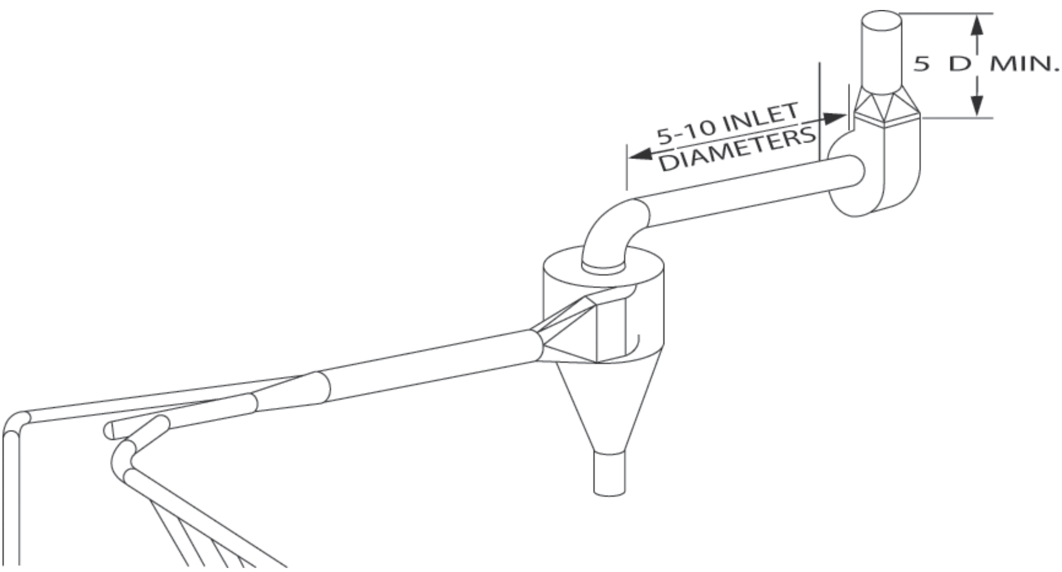


Figure 4: Ducting System

The most important consideration in ducting system design is to reduce losses of energy that will affect the flow of contaminated air in the duct. Reduction of flow in the duct will cause dust to settle in the duct and resulting in plugging problem and this will reduce rate of suction at the hood. Design parameters to be considered are -

a) Flow in the duct

   i. Transport velocity must be sufficient to overcome energy losses along the duct to avoid clogging.

b) Duct material

   i. Must be able to withstand abrasion and corrosive material; and
   ii. Corrugated pipe has high friction loss.

c) Shape and size

   i. Round duct is prefer than rectangular duct because more energy loss in rectangular duct.

d) Components of ducting system

   i. Such as branch, elbow, enlargement and other component has to be design properly to avoid energy losses e.g. bend in the system should has large radii; and
   ii. Any local exhaust ventilation system which has more than one hood will need to be balanced so that each branch will extract just the right amount of air through the hood. The air flow in each branch will be determined by the resistance of the hood, the length, diameter and flow of the branch duct and the flow conditions at the junction with the main duct.

e) Fitting attach to ducting system

   i. Damper cannot be tempered by worker;
   ii. Smooth hole to reduce friction loss; and
   iii. Internal flanges not to be used.

1.2.3 Air Cleaner

Air cleaner is a device to remove contaminants that are carried in the contaminated air from hood which cannot be discharged into the community environment or to recover materials that have a salvage value. Air cleaner is also required to clean exhaust air when the exhaust air is to be re-circulated back to workplace. Some examples of air cleaner filter bag, cyclone and wet scrubber.

Figure 5: Air Cleaner

Design parameters to be considered are:

a) Contaminant characteristic

   i. Will determine the type of air cleaner to be used; and

   ii. To take into consideration that wood dust from most machining processes or other type of dust that contain explosible fraction.

b) The amount of contaminant extracted

   i. Will determine the size of the air cleaner require.

c) Gas stream characteristic

   i. The temperature, the amount of water and other characteristic of the gas stream will determine the type of air cleaner.

d) Efficiency of the air cleaner

i. The efficiency of the air cleaner will determine the amount of contaminant still remain in emission air to the environment.

e) Pressure losses

i. Will determine the amount of energy of auxiliary energy required at the fan. The designer has to specify pressure limit for clean up or check out of the air cleaner.

1.2.4 Fan

Fan is the air moving device that provides the energy to draw air and contaminants into the hood by inducing a negative pressure or suction in the ducts leading to the hoods. The fan converts electrical power or other form of energy into negative pressure and increased air velocity.

Figure 6: Example of fans.

The fan must overcome all the losses due to friction, hood entry, losses in the ducting system and losses due to air cleaner while producing the required flow rate that is enough to extract and transport contaminated air. Design parameters to be considered are -

a) Required flow rate

i. Based on total flow rate require by the hold system.

b) Fan pressure requirement

   i. To over come overall resistance of the system; and
   ii. Express as fan static pressure or total fan static pressure.

c) Material handled through the fan

   i. Will determine the type of fan selected.

d) Location and position

   i. The size of the location also will determine the type of fan to be used.

e) Other consideration

   i. Expected noise level.

f) Fan curve

   i. Three curves that can be used to describe the performance of a fan are static pressure curve, brake horsepower curve and mechanical efficiency curve;
   ii. Static pressure curve will indicate the quantity of air that the fan will deliver at a given rotating speed depends on the resistance it is working against;
   iii. Brake Horsepower curve will indicate the amount of electrical power needed to spin the fan depends on the fan's output and the system resistance; and
   iv. Mechanical efficiency curve will indicate how much energy the fan uses at different points on the static pressure curve.

Well designed and good maintenance system is two important factors in ensuring effectiveness of local exhaust ventilation system.

2. LEGAL PROVISION

Occupational Safety and Health (Use and Standard Exposure to Chemicals Hazardous to Health) Regulations 2000 defined engineering control as any equipment which is used to control exposure of employees to chemicals hazardous to health and includes local exhaust ventilation equipment, water spray or any other airborne chemical removal and containment equipment.

Regulation 17 stipulated that any engineering control equipment has to be inspected at an interval not longer than one month and has to be examined and tested by Hygiene Technician at an interval not longer than twelve months.

Regulation 18 stipulated that local exhaust ventilation system has to design according to approved standard by registered professional engineer. This regulation also stipulated the responsibility of registered professional engineer to test the local exhaust ventilation system after construction and installation.

Regulation 19 stipulated the type of records the employer has to keep and produced for inspection when requested by Director General of Occupational Safety and Health.

3. APPROVED STANDARD FOR DESIGN OF LOCAL EXHAUST VENTILATION SYSTEM

There is no specific standard for designing of local exhaust ventilation system. Industrial ventilation – A Manual of Recommended Practice by ACGIH is the most common reference book used by designer of local exhaust ventilation system. So the designer has to submit standard to be used for approval by Director General of Occupational Safety and Health before can proceed with the design. Appendix D list out some of the standard that can be used.

4. INSPECTION, TESTING AND EXAMINATION OF LOCAL EXHAUST VENTILATION SYSTEM

Every local exhaust ventilation system should be inspected, tested and examined at regular interval to ensure the system works properly and efficiently. A new installed system should be thoroughly tested and examined as to ensure that the design specifications are met and airflow through each of the hood is sufficient to extract contaminant effectively away from the workroom.

4.1 Inspection of Local Exhaust Ventilation System

Inspection of local exhaust ventilation system has to be done at least once a month as required by the regulations or at shorter interval as specified by the designer. The purpose of inspection is to ensure the system functioning properly and effectively. The inspection can be done by any person that has been taught the procedure to carry out the inspection. Inspection of local exhaust ventilation system consists of -

a) Inspection of physical condition of all component of local exhaust ventilation system;
b) Observation of how the work carried out in relation to the utilisation of local exhaust ventilation system;
c) Smoke tube tracer test;
d) Identify any thing that can be obstruction of flow;
e) Observation of condition surrounding and near the hood;
f) Inspection on the air cleaner device; and
g) Maintenance of the fan's motor.

Testing and examination have to be carried out if there is indication reduction in flow or every 12 months. Detail on inspection procedure is in appendix A.

4.2 Testing and Examination of Local Exhaust Ventilation System

Testing and examination of local exhaust ventilation system has to be carried out at least every 12 months or at shorter interval as specified by the designer. The purpose of the testing and examination is to determine the effectiveness and efficiency of the local exhaust ventilation system and to detect malfunction of the system. Testing and examination also need to be done during commissioning of a new installed local exhaust ventilation system as to verify that the system is working as per design. These data are the baseline data that will be used for comparison when subsequent testing and examination to be carried out, in order to determine the effectiveness and efficiency of the system and to detect any malfunction in the system. Testing and examination of local exhaust ventilation system consist of -

a) Inspection of local exhaust ventilation system as specified in subsection 4.1;
b) Determination of capture or face velocity;

Fig. 7: Anemometer

Figure 8: Measurement of face velocity

c) Determination of hood static pressure;
d) Determination of duct static pressure along the ducting system;
e) Determination of hood velocity pressure and transport velocity;

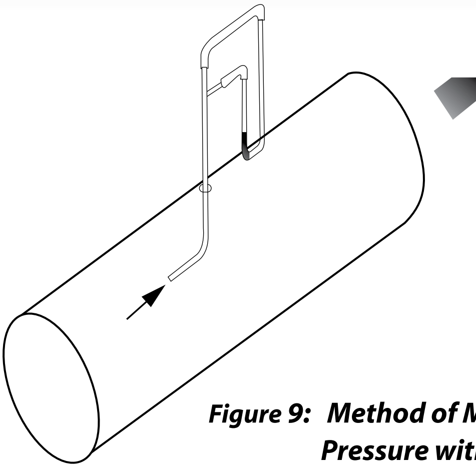


Figure 9: Method of Measurement Of Velocity Pressure with Pitot Tube

Figure 10: Measurement of duct velocity and temperature

f) Determination of air cleaner's efficiency; and

g) Determination of fan's capacity and efficiency.

Detail on inspection, examination and testing procedure is in appendix A.

5. ASSESSMENT OF THE EFFICIENCY OF LOCAL EXHAUST VENTILATION SYSTEM

Assessment of the efficiency can be done by analysing results of inspection, testing and examination of local exhaust ventilation system mentioned in section 4.0. Results of physical inspection and observation while the system is in operation are very important in the assessment of the system. The smoke tube tests will show how and where contaminants are escaping from the hoods into the workroom and the effect of cross draft. The design of the hood is very important because the efficiency of the hood will be affected. Assessment is carried out by comparing the result of the measurement with baseline data or standard. The result that is more than ± 10 % of the design specification or below the standard indicate that there is something wrong with the system and further investigation and analysis need to be carried out to determine the cause of the problem.

Baseline data can be compared with design specification or standard to ensure that the system will be effective in the future. Filter for the air cleaner will increase the resistance if not clean regularly. The fan inlet is important in getting proper fan performance. Spinning or non-uniform flow pattern will reduce the fan's air volume or static pressure output. The result that is more than ± 10 % of the design specification or standard indicate that there is something wrong with the system and further investigation and analysis need to be carried out to determine the cause of the problem.

Balance system is very important to ensure all hood will work effectively. The pressure loss in each duct that meets at same junction must be equal. If one duct has larger diameter and the other is narrow, then more air will flow through the wider duct. If both of the same diameters but one is longer then the other, more air will flow through the shorter duct because the resistance is lower. The result that is more than ± 10 % of the design specification or below the standard indicate that there is something wrong with the system and further investigation and analysis need to be carried out to determine the cause of the problem. Rectification to the system has to be made and retesting has to be carried out.

6. MAINTENANCE

Maintenance is practically an important aspect in ensuring that local exhaust ventilation system will continuous operating effectively and efficiently as intended, if not at par with when newly installed. The employer has to plan periodic maintenance at regular interval to ensure all components of local exhaust ventilation are in good and operational condition. This will ensure that the local exhaust ventilation is always operational while any plant or process is in operation.

The employer also needs to look into the requirement of contingency plan to overcome power failure or breakdown of the system.

7. RECORD KEEPING

The employer has to keep record specify below -

a) Design;
b) Construction;
c) Testing, inspection and examination; and
d) Maintenance.

8. CONCLUSION

Effectiveness and efficiency of the local exhaust ventilation system depend on design, regular maintenance, proper usage and regular inspection of the system.

9. REFERENCE

a) ACGIH Ventilation Manual edition 23.
b) Handbook of Ventilation for Contaminant Control by Henry J. Mc. Dermott.
c) Occupational Safety and Health (Use and Standard of Exposure of Chemicals Hazardous to Health) Regulation 2000.
d) Guidelines on inspection, testing and examination of local exhaust ventilation system by Department of Occupational Safety and Health.
e) HSE web site.
f) OSHA web site.
g) NIOSH web site.

Appendix A: DETAIL INSPECTION, TESTING AND EXAMINATION OF LOCAL EXHAUST VENTILATION PROCEDURE

1.0 Precaution During Inspection, Testing And Examination

Precautionary measures that should be taken during inspection, testing and examination local exhaust ventilation system are as follow -

a) Inspection, testing and examination on inside of ducts

Precautionary measure should be taken to prevent chemical poisoning or exposure to chemical hazards during inspection of inside the duct.

b) Inspection, testing and examination on motors

Precautionary measure should be taken to prevent contacts with dangerous part of motor that can hurt and injured a person during inspection, testing and examination.

c) Inspection, testing and examination on passages and scaffolds

Precautionary measure should be taken to prevent slip or fall down during inspection, testing and examination.

d) Inspection, testing and examination on electrical parts

Precautionary measure should be taken to prevent electrical shock.

2.0 Instruments Use For Inspection

Instruments and tools needed for inspection of a local exhaust ventilation system are as follow.

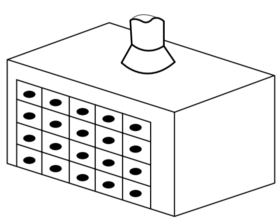
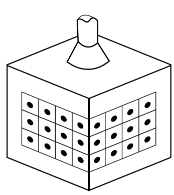
TOOLS	INSPECTION
a) Smoke tube	use to indicate direction of air flow
b) Manometer	use for measuring static pressure
c) Traverse pitot tube connected to manometer	use for measuring velocity pressure
d) Surface thermometer or glass thermometer	use for measuring bearing box surface temperature
e) Test hammer	use for sound test of thick wall ducting
f) Wooden or bamboo bar	use for sound test of thin wall ducting
g) Tachometer	use for measuring fan speed
h) Anemometer	use for measuring air velocity

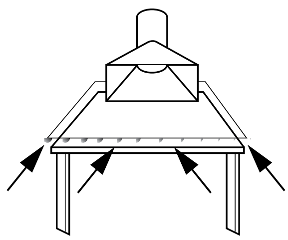
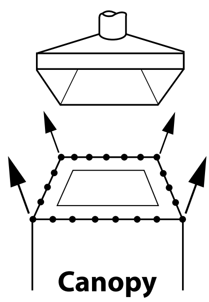
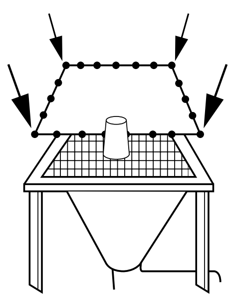
3.0 Inspection, Examination and Testing Procedure

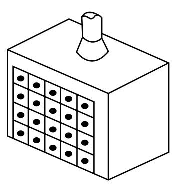
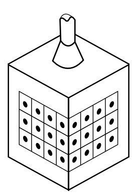
a) Hood

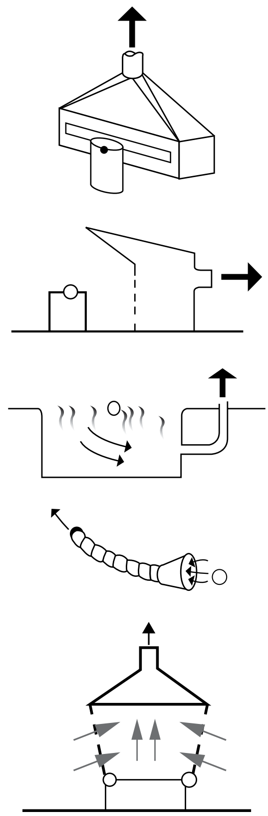
Inspection Item	Inspection Procedure	Inspection Indicator
1. Physical appearance of the hood	Inspect outer and inner surface of the hood.	The following condition should not occur - • Abrasion, corrosion and dents and other damages which can affect air flow; and • Damage of coating which can cause corrosion of the hood. Rectification has to be done before inspection can be proceed
2. Obstruction of flow	a. Observe how the employee work with respect to hood.	The design - • should be suitable for the process or work; and • should not hinder employee from carry out work

Inspection Item	Inspection Procedure	Inspection Indicator
	b. Inspect for obstructions to the opening of the hood by structure such as pole, wall that other that can obstruct the flow of air.	The hood opening should not be blocked or obstructed by any structure such as pole, wall or other which can obstruct the flow or air into the hood.
	c. Inspect if any instrument, tool, material being fabricated, raw material, etc. that is place in such a way that can obstruct the flow of air into the hood.	The hood opening should not be blocked or obstructed by any instruments, tools, materials etc in such a way that can obstruct the flow of air into the hood.
	d. The exhaust system is in operation. Carry out smoke tracer test. The smoke from the smoke tube will follow the air current and its movement will show how air flow into the hood. Observe smoke movement at the test positions.	The test – • Show the movement and dispersion of air flow from a source of contaminant. Smoke must not flow out of the hood or lingering around the hoods but must be sucked completely into the hood; • Determine the approximate capture distance for hoods;

Inspection Item	Inspection Procedure	Inspection Indicator
	i. Enclosure Hood Opening of the hood is divided into at least 16 equal areas. For narrow opening, the area must be divided into more than 2 equal areas. Dotted mark is the centre of equal area and smoke is blown at the centre of equal area and smoke is blown at the centre of equal area.  	• Determine the approximate capture distance for hoods; and • Determine the effect of cross drafts on hood performance.

Inspection Item	Inspection Procedure	Inspection Indicator
	Same procedure for other types of enclosure hood. ii. Exterior Hood Smoke should be blown from the position of the source of contaminants The dotted line shows positions.  **Side Hood**  **Canopy**  **Downdraft Hood** Same procedure apply to other types of exterior hood.	

Inspection Item	Inspection Procedure	Inspection Indicator
3. Direction and size of opening area for exterior hoods	Observe the performance of the hood when the process is in operation. Look at the size, the positioning and location of the hood relative to source of contaminant and the way the worker work relative to the hood.	Contaminated air must be sucked into the hood completely and away from the worker.
4. Velocity	Measure air velocity with an anemometer. i. Enclosure Hood Opening of the hood is divided into at least 16 equal areas. For narrow opening, the area must be divided into more than 2 equal areas. Dotted mark is the center of equal area and measurement should be done at the center of equal area.   Same procedure for other types of enclosure hood	Measured air velocity must be within 10 percent of design value or standard.

Inspection Item	Inspection Procedure	Inspection Indicator
	ii. Exterior Hood Measurement should be done from the nip point of the source of contaminants. The dotted mark shows the nip point 	
5. Environmental Monitoring	Check result of environmental monitoring.	Concentration of contaminant must not exceed Permissible Exposure Limit Value stated in the regulations.

Inspection Item	Inspection Procedure	Inspection Indicator
6. Hood Static Pressure	A manometer is used for hood static pressure measurement. Tapered hood-a hole of 1/16 to 1/8 in diameter is drill on the duct at about one duct diameter away from the hood. Flanged or plain hood- a hole of 1/16 to 1/8 in. In diameter is drill on the duct at about three duct diameter away from the hood. The manometer is connected to the hole with rubber tubing.	The difference between the static pressure reading and design static pressure must not exceed 10 percent.

d) Duct

Inspection Item	Inspection Procedure	Inspection Indicator
1. Physical condition of duct outer surface	Inspect the condition of the outer surface of the duct system. Start the inspection from the hood and inspect all duct connections. Inspect the main duct and branch duct.	a. The following condition should not occur - • Abrasion, corrosion and dents and other damages which can affect air flow or cause leakages. • Damages of coating which can cause corrosion of the duct. • Deformation which can cause an increase of the air flow resistance or piling up of dust, etc. b. Rectification has to be done before inspection can proceed.

Inspection Item	Inspection Procedure	Inspection Indicator
2. Physical condition of inner surface of the ducts.	a. Inspect the condition of the inner surface of the duct system through the inspection holes. If there is no inspection holes, disconnect duct joints for inspection.	The following condition should not occur - • Abrasion, corrosion and dents and other damages which can affect air flow or cause leakages. • Damages of coating which can cause corrosion of the duct. • Piling up of dust, etc. Rectification has to be done before inspection can proceed.
	b. When inspection as in (a) cannot be done, hit the duct gently and listen to the sound make by the duct. This hammer test should be done at a position near the elbow or other position where dust tend to pile up. Instrument use foe this test -	No abnormal noise caused by dust accumulation, etc, should be heard.

Inspection Item	Inspection Procedure	Inspection Indicator
	i. Thick wall-use test hammer; and ; ii. Thin wall- use a wooden or bamboo bar.	
3. Loose joints	a. Inspect for any crack, missing and uneven tightness of tightening bolts and nuts, gaskets, etc. b. Test for leakages at joints with smoke when in LEV system is in operation. c. Check if there is any abnormal sound cause by inflow or out flow of air at duct joint.	Should not have any crack, missing, uneven tightening bolt and nut, missing or damaged gasket, etc. Smoke from a smoke tester must not be sucked or blown out There should be no abnormal sound present.
4. Condition of inspection holes.	a. Inspect whether inspection holes can be open or close easily. b. Test the leakages at joints with smoke when in LEV system is in operation.	The inspection holes be opened and shut smoothly and must be closed without leak.

Inspection Item	Inspection Procedure	Inspection Indicator
5. Static pressure	a. Measure the static pressure in the duct with a manometer at the inspection holes which are equipped on the duct before and after the position where dust tend to be piled up such as at position just before the duct stands upward. The holes should be at least 7.5 duct diameters down stream from any disturbance. If this is not possible then four holes should be drilled 90^{o} apart around the duct and static pressure are measure at each holes and averaged b. Measure the static pressure in the duct with a manometer at measuring holes which are equipped on the duct line, e.g. near joints.	Static pressure in the duct must be within the range of ± 10% of baseline static pressure (SP ± 10%).

Inspection Item	Inspection Procedure	Inspection Indicator
6. Duct velocity (sample of measurement in appendix B)	Measure velocity pressure in the duct with a traverse pitot tube connected to a manometer (refer to appendix C for method of velocity pressure measurement). Velocity pressure can be converted to velocity by using conversion formula $V = 1096 \sqrt{\frac{VP}{\rho}}$ where V = air velocity ft/min. VP + Velocity pressure in inches of water. For standard condition (70^{o} and 29.29 " Hg) $V = 4005 \sqrt{VP \text{ corrected}}$ (refer to table conversion)	Duct velocity in the duct must be within the range of ± 10% of baseline duct velocity (V ± 10%)
7. Temperature in the duct	Measure temperature in the duct and if the temperature is out of 40 ^{o}C - 100 ^{o}C, make correction for density with this formula: $C_t = \frac{530}{t + 460}$	

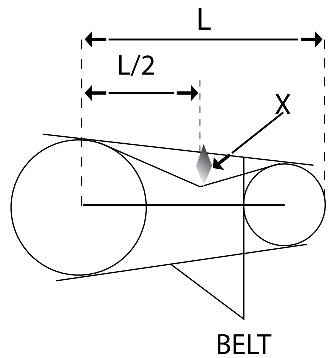
c) Damper

Inspection Item	Inspection Procedure	Inspection Indicator
1. Condition of damper	a. Inspect the opening degree and fixing condition of the damper.	The damper must be fixed at an open position at which the air flow rate is adjusted to maintain adequate performance of the local exhaust ventilation system.
	b. Smoke from smoke tube should be sucked into the hold when the damper is open and not when the damper is closed.	The damper must be manipulated easily with a weak force. Smoke must sucked into the hood when air flow path is open and not be sucked into the hood when the air flow path is closed.
2. Static pressure	Measure static pressure at least 7.5 duct diameter downstream from any disturbance. If this is not possible then four holes should be drilled 90^{o} apart around the duct and average static pressure values.	The reading must be within ± 10% of design SP

c) Fan

Inspection Item	Inspection Procedure	Inspection Indicator
1. Condition of outer casing surface	Inspect the condition of the casing surface.	a. The following condition should not occur - • Abrasion, corrosion and dents and other damages which can decrease the performance of the fan. • Damages of coating which can cause corrosion of the fan. b. Rectification has to be done before inspection can proceed.
2. Condition of inner surface of casings, impellers and guide vanes	If the results of the inspection on suction and exhaust capacities as inspection item 4 in subsection 1 does not meet the inspection indicator, inspect the condition of inner surface of casing, impeller and guide vane in accordance with the following procedure -	The following condition should not occur - • Abrasion, corrosion and dents and other damages which can decrease the performance of the fan. • Damage of coating which can cause erosion of the fan.

Inspection Item	Inspection Procedure	Inspection Indicator
	a. Inspect the condition of the inner surface of casing, impellers and guide vanes through inspection hole. If inspection hole is not provided, disconnect fan and duct joint.	Rectification has to be done before inspection can proceed.
	b. Inspect the states of adhesion of dust by scraping the surface of the impeller blades and guide vanes with a scraper.	Dust should not stick to fan vanes and blades because fan performance will drop.
3. Condition of belts, etc	a. Inspect whether belts are of damage or uneven. Inspect also the setting position of pulley	The following condition and abnormalities should not be present - • Belt damage. • Mismatch between the belts and groove shape of pulley. • Different types of belts are used or tightness of belts are uneven in the case of multi-belt type driving units. • Damage, eccentricity or deviation of setting position of the pulley • Loose key.

Inspection Item	Inspection Procedure	Inspection Indicator
	b. Check the sag (x) of the belts. The belt is pushed down word and the sag is measured.	The following condition must be satisfied 0.01 L< x < 0.02 L L and x are as shown in the figure - 
	c. Check slippage and vibration of the belts when fan is in operation.	Slippage and vibration of the belts must not be present.
	d. In case the result of the face or capture velocity does not meet the inspection indicator, measure the fan speed with a tachometer.	Rotating speed of the fan must not be less than 10 percent of the design speed.
4. Rotating direction of fan	Examine fan rotating direction if the face or capture velocity does not meet the inspection indicator.	It must be as specified in design.

Inspection Item	Inspection Procedure	Inspection Indicator
5. Condition of bearings	a. Start the fan and listen if there is any abnormal noise at the bearing box.	Abnormal noise must not be present.
	b. Stop the fan after one hour operation and touch the bearing box with hand.	The temperature of the bearing box surface should be low that it can be touch by hand.
	c. If the result of inspection procedure 2 does not meet the inspection indicator, measure the bearing box surface temperature and the surrounding temperature. Surface temperature of the bearing box is measured with surface thermometer or a glass thermometer which is attached on the bearing box surface with putty.	The bearing surface temperature must be below 70 ^{o}F, and the temperature difference between the bearing surface temperature and surrounding temperature must be less than 40 ^{o}F.
	d. Inspect the amount of oil and grease in oil cups and grease cup, and inspect condition of oil and grease too.	

e) Air Cleaner

Inspection Item	Inspection Procedure	Inspection Indicator
1. Physical appearance	a. Inspect the outer surface of the air cleaner.	The following abnormalities should not be present: • Abrasion, corrosion or crack which can cause leakage. • Damage to coating which can cause corrosion. • Loose of supporting part.
	b. Inspect the inner surface of the air cleaner through inspection holes or by disconnecting joint to duct.	The following abnormalities should not be present: • Abrasion, corrosion or crack which can cause leakage. • Damage to coating or dent which can cause corrosion. • Pile up of dust, which can decrease the performance of the dust collector.

Inspection Item	Inspection Procedure	Inspection Indicator
	c. When inspection procedure (b) cannot be done, hit the air cleaner gently with a test hammer and listen to he sound at a position most likely dust will pile up.	Abnormal sound should not be heard.
2. Static pressure	When inspection procedure (b) and (c) could be done, measure static pressure inside the air cleaner with a manometer. Static pressure should be measured at each side of the equipment.	Any reading which is 10 percent above or below design pressure will indicate plugging, wear, damage to collector parts or need of clearing.

APPENDIX B: **MEASUREMENT OF VELOCITY PRESSURE**

Location of Measuring Point

A pitot traverse involves measuring the velocity at a number of points across the duct area because velocity distribution is not uniform within the duct. The number and location of measuring points within the duct depend on the duct size and shape. The idea is to divide the duct into enough zones of equal area to give accurate results.

a) For round ducts - Two traverses at right angle should be made. Refer to ACGIH Ventilation Manual for pitot traverse points for various size of duct.

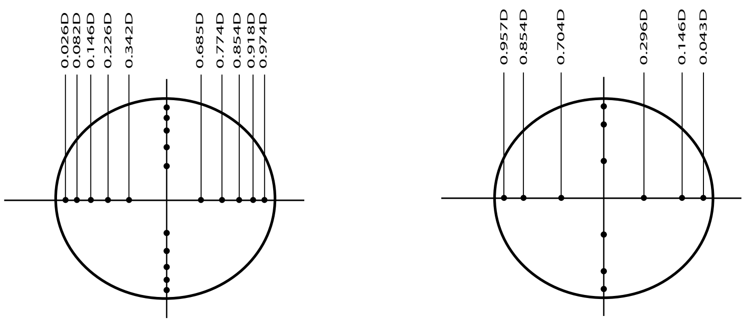


Figure 11: Shows Measuring Location For A 10 And 6 Points Pitot Traverse

b) For rectangular - The cross-section is divided ducts into equal areas and a reading is taken at the centre of each area. At least 16 readings should be taken, but the distance between measuring points should not exceed 6 inches.

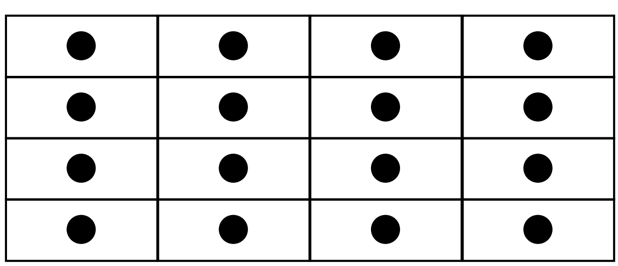


Figure 12: Shows Measuring Location For Rectangular Duct

Regardless of duct shape, the best location to perform a traverse is at least 7.5 diameters downstream from any major disturbance such as dampers or elbows. This is to ensure laminar airflow at the point of measurement. If you must traverse at a point less than 7.5 diameter, another traverse has to be made at a second location and compare the results. If the calculated volumetric flow rates are within 10% of each other, the results are acceptable.

Non Standard Air

a. Correction for density if temperature is out of the range 40 ^{o}F – 100 ^{o}F

$$C_t = \frac{530}{460 + t}$$

Where,
C_t = Correction factor for temperature
t is temperature in Kelvin

b. Correction for pressure in the duct if pressure greater than 20 in. wg

$$C_\rho = \frac{407 + SP}{407}$$

Where,
C_ρ is the correction factor for pressure
SP is the static pressure in the duct

c. Correction for elevation if elevation is greater than ±1000 ft

$$C_e = [1- (6.73 \times 10.6)\ Z]^{5.528}$$

Where,
C_e is the correction factor for elevation
Z is the height of elevation

Correction for density for non standard air if no significant change in moisture content

$\rho = 0.075\ C_\rho\ C_e\ C_t$

If moisture exceeds about 0.2 lb of water per lb of air, density factor is obtained from directly from the psychometric.

Example: **Pitot traverse calculation**

1) Standard condition: Air Temp. = 79 ^{o}F ; Wet Bulb Temp. = 50 ^{o}F

Environmental condition in acceptable range, so no need for density correction.

PITOT TRAVERSE 1			PITOT TRAVERSE 2		
Traverse Point	Velocity Pressure VP (mm Hg)	Velocity (ft/min)	Traverse Point	Velocity Pressure VP (mm Hg)	Velocity (ft/min)
1	0.22	1879	1	0.23	1921
2	0.28	2119	2	0.27	2081
3	0.32	2260	3	0.33	2301
4	0.33	2301	4	0.34	2335
5	0.34	2335	5	0.34	2335
6	0.35	2369	6	0.35	2369
7	0.33	2301	7	0.34	2335
8	0.31	2230	8	0.32	2260
9	0.30	2193	9	0.31	2230
10	0.24	1962	10	0.25	2003
		21949			**22170**

$$\text{Average Velocity} = \frac{21949 + 22170}{20} = \frac{44119}{20}$$

$$= 2205.9 \text{ fpm} = 2206 \text{ fpm}$$

2. Elevated Temperature

Air Temp = 150 ^{o}F;

Wet Bulb Temp = 80 ^{o}F

Barometer = Std.; 24" Duct diameter

PITOT TRAVERSE 1			PITOT TRAVERSE 2		
Traverse Point	Velocity Pressure VP (mm Hg)	Velocity (ft/min)	Traverse Point	Velocity Pressure VP (mm Hg)	Velocity (ft/min)
1	0.22	2016	1	0.23	2062
2	0.28	2275	2	0.27	2234
3	0.32	2432	3	0.33	2470
4	0.33	2470	4	0.34	2507
5	0.34	2507	5	0.34	2507
6	0.35	2543	6	0.35	2543
7	0.33	2470	7	0.34	2507
8	0.31	2394	8	0.32	2432
9	0.30	2355	9	0.31	2394
10	0.24	2106	10	0.25	2149
		23568			**23805**

Where

$$C_t = \frac{530}{460 + 150} = 0.869$$

$$\rho = 0.075\ C_t = 0.075 \times 0.869 = 0.065$$

$$V = 1096\sqrt{\frac{VP}{\rho}} = 1096\sqrt{\frac{VP}{0.065}}$$

Use the formula to convert each of VP to V

$$\text{Average Velocity, } V = \frac{23568 + 23805}{20} = \frac{47373}{20} = 2368.65 = 2369 \text{ fpm}$$

Qs = VA = 2369 x 3.142 = 7443.4 = 7443 fpm

APPENDIX C: **METHOD OF MEASUREMENT**

TOTAL PRESSURE = STATIC PRESSURE + VELOCITY PRESSURE

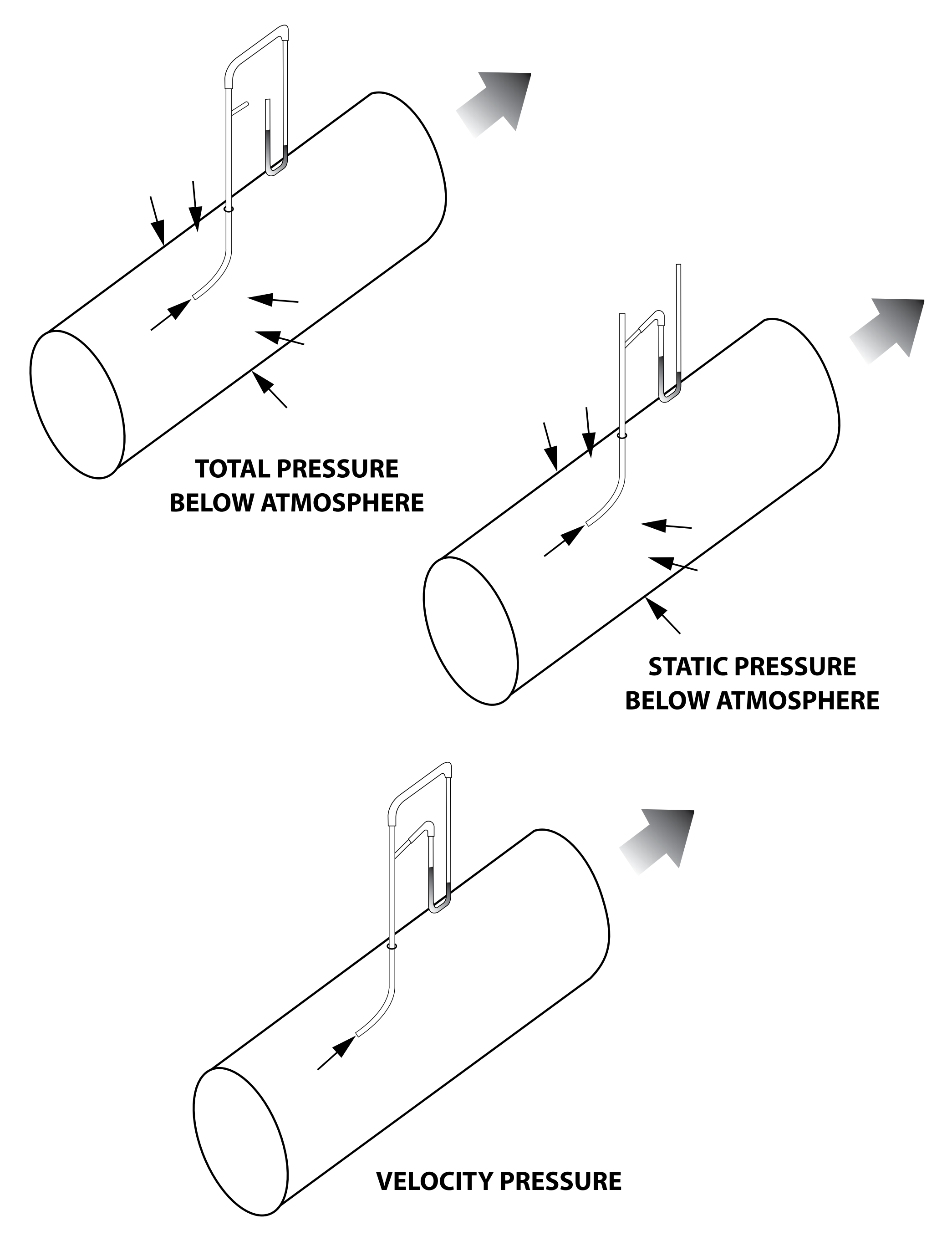


Figure 13 : Method Of Measurement With Pitot Tube

APPENDIX D: **LIST OF STANDARD FOR DESIGNING OF LOCAL EXHAUST VENTILATION SYSTEM**

Exhaust systems		
ANSI Z33.1-1982 NFPA 91-1983	NFPA	Installation of Blower and Exhaust Systems for Dust, Stock, Vapour Removal or Conveying (1983)
ANSI Z9.2-1979	AIHA	Fundamentals Governing the Design and Operation of Local Exhaust Systems
ANSI Z9.1-1977	AIHA ASHRAE	Practices for Ventilation and Operation of Open-Surface Tanks
ANSI Z9.3-1964	ANSI	Safety Code for Design, Construction, and Ventilation of Spray Finishing Operations (reaffirmed 1971)
ANSI Z9.4-1979 ANSI Z9.4A-1981	ANSI	Ventilation and Safe Practices of Abrasives Blasting Operations
ANSI Z9.5-1992	AIHA	Laboratory Ventilation
Fans		
AMCA 99-83 ANSI/UL 507-1976	AMCA UL	Standards Handbook Electric Fans (1977)
ASHRAE 51-75 AMCA 210-74	ASHRAE	Laboratory Methods of Testing Fans for Rating
ANSI/ASHRAE 87.7-1983	ASHRAE	Methods of Testing Dynamic Characteristics of Propeller Fans--Aerodynamically Excited Fan Vibrations and Critical Speeds
AMCA 210-74	AMCA	Laboratory Methods of Testing Fans for Rating Purposes
AMCA 99-2404-78	AMCA	Drive Arrangement for Centrifugal Fans
AMCA 99-2406-83	AMCA	Designation for Rotation and Discharge of Centrifugal Fans

AMCA 99-2407-66	AMCA	Motor Positions for Belt or Chain Drive Centrifugal Fans
AMCA 99-2410-82	AMCA	Drive Arrangement for Tubular Centrifugal Fans
Industrial Duct		
SMACNA	SMACNA	Round Industrial Duct Construction
SMACNA	SMACNA	Rectangular Industrial Duct Construction

SOURCES OF STANDARDS

Source	Organization
ACGIH	American Conference of Governmental Industrial Hygienists 6500 Glenway Ave., Bldg. D-5 Cincinnati, OH 45211
AIHA	American Industrial Hygiene Association 2700 Prosperity Ave., Suite 250 Fairfax, VA 22031-4319
AMCA	Air Movement and Control Association 30 W. University Dr. Arlington Heights, IL 60004
ANSI	American National Standards Institute 1430 Broadway New York, NY 10018
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA 30329
NFPA	National Fire Protection Association Batterymarch Park Quincy, MA 02269
SMACNA	Sheet Metal and Air Conditioning Contractors’ National Association 8224 Old Courthouse Rd. Vienna, VA 22180
UL	Underwriters Laboratories Inc. 333 Pfingsten Rd. Northbrook, IL 60062

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