ENGINEERING STANDARD

FOR

VENTING, VENTILATION AND PRESSURIZING SYSTEM

ORIGINAL EDITION

JULY 1995

This standard specification is reviewed and updated by the relevant technical committee on Feb. 2000(1) and July 2004(2). The approved modifications are included in the present issue of IPS.

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0. INTRODUCTION

The importance of Indoor Air Quality (IAQ) dovetailed with adequate ventilation is being greatly emphasized by both (ASHRAE) and (NIOSH) [(1)]. Per study conducted by NIOSH, inadequate ventilation and placement of contaminated outdoor air has been blamed as the main source of indoor air quality problems.

Important factors that contribute to the build up of indoor air contaminants are the placement of synthetic materials, the out-gassing of volatile pollutants, energy conservation measures that minimize the infiltration and introduction of outdoor air, lightly sealed building envelopes, inadequate design, unsafe operations and poor maintenance practices. Volatile pollutants include formaldehide, Volatile Organic Compounds (VOCs) and Semi-volatile Organic Compounds.

Since this Standard represents a wide range of paramount importance, subjects pertaining to the quantity and quality requirements of air, efforts have been made to briefly cover relevant subjects dividing them into following Parts:

Part I: General Engineering

Part II: Equipment and Systems

Part III: Application Guidelines

(1) NIOSH (National Institute of Occupational Safety and Health)

1. SCOPE

This Engineering Standard covers the minimum requirements of design and factors to be considered in the field of venting, ventilating and pressurizing systems for commercial and industrial buildings and spaces used in Oil, Gas and Petrochemical affiliated industries:

The guidelines outlined are for the awareness of the design engineer to consider the need of providing clean outside air free of pollutants and contamaninants, in the space being served. Status of air quality shall be given prime consideration when making selections of filters.

Note 1:

This standard specification is reviewed and updated by the relevant technical committee on Feb. 2000. The approved modifications by T.C. were sent to IPS users as amendment No. 1 by circular No 113 on Feb. 2000. These modifications are included in the present issue of IPS.

Note 2:

This standard specification is reviewed and updated by the relevant technical committee on July 2004. The approved modifications by T.C. were sent to IPS users as amendment No. 2 by circular No 235 on July 2004. These modifications are included in the present issue of IPS.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

ANSI / ASHRAE (AMERICAN NATIONAL STANDARD INSTITUTE / AMERICAN SOCIETY OF HEATING REFRIGERATING AND AIR CONDITIONING ENGINEERS, INC.)

ANSI / ASHRAE 62-2001	"Ventilation for Acceptable Indoor Air Quality"
ANSI SI-11-1966	"Octave Band Sets"
ANSI / AMCA-210	

AMCA (AIR MOVEMENT AND CONTROL ASSOCIATION, INC.)

AMCA 99-0066-83	"Classification of Fans"
AMCA 99-2408	"Performance Class of Centrifugal Fans"
AMCA 300	"Methods for Sound Testing of fans"
AMCA 301	“Methods for Calculating Fan Sound Ratings from Laborating Test Data”
AMCA 500	"Test Methods for Louvers Dampers and Shutters”

UL (UNDERWRITER’S LABORATORIES)

UL 555	"Safety Fire Dampers and Ceiling

		Dampers"
US	**FEDERAL STANDARD**	
	209 D	"Clean Room Definition"
BS	**(BRITISH STANDARD)**	
	BS 5295	"Environmental Cleanliness Lines in Enclosed Spaces"
IPS	**(IRANIAN PETROLEUM STANDARDS)**	
	IPS-C-AR-110	"Construction Standard for Installation, Testing, Adjusting and Commissioning of HVAC&R Systems"
	IPS-E-AR-120	"Engineering Standard for Building Air Conditioning Systems"
	IPS-M-AR-225	"Material and Equipment Standard for General HVAC&R Equipment"
	IPS-E-GN-100	"Engineering Standard for Units"
	IPS-G-ME-253	"General Requirements for Incinerators"
	IPS-G-SF-900	"General Standard for Noise Control and Vibration"
NFPA	**(NATIONAL FIRE PROTECTION ASSOCIATION)**	
	NFPA 496	
	NFPA 68	

3. DEFINITIONS AND TERMINOLOGY

3.1 Acceptable Air Quality

Air in which there are no known contaminants at harmful concentrations and with which a substantial majority (usually 80%) of the people exposed do not express dissatisfaction.

3.2 Air Cleaner

A device used to remove airborne impurities such as dusts, gases, vapors, fumes, smoke and mist.

3.3 Air Contaminants

Air contaminants are particulate or gaseous; organic or inorganic; visible or invisible; submicroscopic, microscopic, or macroscopic; toxic or harmless. Loose classifications based chiefly on the origin or method of formation of the material are;

1) dusts, fumes, and smokes, which are solid particulate matter, although smoke often contains liquid particulates;

2) Mists, which is liquid particulate matter; and

3) vapors and gases, which are non-particulate.

3.4 Air, Diffusion

Distribution of air within a space by an outlet discharging supply air in various directions and planes.

3.5 Air Horse Power

The theoretical horsepower required to drive a fan if there were no losses in the fan, that is if it's efficiency were 100%.

3.6 Aspect Ratio

In air distribution outlets the ratio of length to width of an opening or core of grille. In rectangular ducts, the ratio of the width to the depth.

3.7 Blow (throw)

In air distribution, the distance of an air stream travels from an outlet to a position at which air motion along the axis reduces to a velocity of 0.254 m/s (50 fpm). The fan used to force air under pressure is known as the blower.

3.8 Capture Velocity

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

3.9 Clean Rooms

A specially constructed, enclosed area environmentally controlled with respect to airborne particulates, temperature, humidity, air flow patterns, air motion and lighting.

3.10 Density Factor

The ratio of actual air density to density of standard air.

3.11 Dew

Moisture appearing in minute droplets condensed upon the surfaces of cool bodies.

3.12 Dust

An air suspension of particles of any solid material, usually with particle size less than 100 micrometers (µm)

3.13 Dust Collector

An air cleaning device to remove heavy particulate loading's from exhaust systems before discharge to outdoors.

3.14 Exfiltration

Air leakage outward through cracks and interstices and through ceilings, floors and walls of a space or building.

3.15 Fan Air Density

Fan air density is the density of the air corresponding to the total pressure and total temperature at the fan inlet.

3.16 Fan Brake Horse Power

The horsepower actually required to drive a fan shaft. This includes the energy losses in the fan and can be determined only by actual test of the fan. (It does not include the drive losses between motor and fan).

3.17 Fan Total Pressure

Fan total pressure is the difference between the total pressure at the fan outlet and the total pressure at the fan inlet.

3.18 Fan Velocity Pressure

Fan velocity pressure is the pressure corresponding to the average velocity at the fan outlet.

3.19 Fan Static Pressure

Fan static pressure is the difference between the fan total pressure and the fan velocity pressure.

3.20 Fan Speed

Fan speed is the rotative speed of the impeller. If a fan has more than one impeller, fan speeds are the rotative speeds of each impeller.

3.21 Fan Power Output

Fan power output is the useful power expressed in horsepower delivered to the air, based on fan volume and fan total pressure.

3.22 Fan Power Input

Fan power input is the power in horsepower required to drive the fan and any elements in the drive train which are considered a part of the fan.

3.23 Fan Total Efficiency

Fan total efficiency is the ratio of the fan power output to the fan power input.

3.24 Fan Static Efficiency

Fan static efficiency is the fan total efficiency multiplied by the ratio of fan static pressure to fan total pressure.

3.25 Fogs

Fogs are very fine airborne droplets usually formed by condensation of vapor. Many droplets in fogs or clouds are microscopic and sub-microscopic in size and may be considered as a transition stage between larger mists and vapors.

3.26 Fumes

Small solid particles formed by the condensation of vapors of solid materials.

3.27 Gases

Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.

3.28 Grain

Grains of moisture is the unit of measurement of actual moisture contained in a sample of air. (7000 grains equals one pound of water).

3.29 Impeller (wheel, rotor, propeller)

The rotating portion of the fan designed to increase the energy level of the gas stream.

3.30 Mists

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

3.31 Odors

A quality of gases, liquids or particles that simulates the olfactory organ.

3.32 Particulate

A state of matter in which solid or liquid substances exist in the form of aggregate molecules or particles. Airborne particulate matter is typically in the size range of 0.1 to 100 micrometers.

3.33 Radon

Invisible, odorless, tastless radioactive gas produced by the natural decay of uranium foil in soil and rocks. Radon transfers through the pores of soil and rocks to outdoor air and into houses. Radon can build up in the house can be inhaled and deposited in the respiratory tract which could develop lung cancers.

3.34 Smoke

It is defined (in ASHRAE) as follows:

a) Small solid and/or liquid particles produced by incomplete combustion of organic substances, varying in size often in the range of 0.1 to 0.3 micrometer.

b) Air bone solid and liquid particulates and gases that evolved when a material undergoes pryrolysis or combustion. (chemical smokes are excluded from this definition).

3.35 Soot

Unburned particles of carbon derived from hydrocarbons.

3.36 Threshold Limit Values (TLV)

The values of airborne toxic material which are to be used as guides in the control of health hazards-expressed in PPMparts of vapor or gas per million parts of air.

3.37 Ventilation

The provision of supplying and removing air by natural or mechanical means to and from any space, such air may or may not be conditioned.

4. UNITS

This Standard is based on International System of Units (SI), except where otherwise is specified.

Note:

For ease of calculation Attachment 1 covers English to Metric conversion units suitable for basic fan engineering.

PART I

GENERAL ENGINEERING

5. PRINCIPLES OF VENTILATION

5.1 Reason for Ventilating

The reason for ventilating a space are considered as follows:

a) to provide oxygen for human life processes;

b) the air shall act as a dilutant; the amount of air required depends on the permissible contaminant level for the room. The contaminant may be CO_2 from respiration, odors secreted through the human skin, or emission from any other process;

c) promoting air movement in the space, this being one of the environmental comfort factors;

d) controlling airborne contaminants and latent heat within occupied spaces.

5.2 Method of Ventilation

5.2.1 Natural ventilation

Causes for air motion through the building are by the wind and the differences in density between the inside and outside air. The two forces which act independently or in combination are wind effect and stack effect.

a) Wind effect

These are caused by the pressure differences in the atmosphere and when it is obstructed by trees or buildings, then an energy conversion takes place.

Velocity pressure is converted to static pressure, so that on the windward side an over pressure is produced (0.5 to 0.8 times the wind velocity) and on the leeward side an underpressure results (about 0.3 to 0.4 times the wind velocity). The pressure differentials arising across building cause infiltration of air through window, cracks and other openings.

b) Stack (thermal buoyancy) effect

Because of its low density warm air in room tends to rise and is replaced by cooler, denser air from outside. Since the pressure at the outlet or inlet can be affected by the wind, the extent to which the stack effect operates is governed partly by the wind pressure and partly by the design of the openings.

Stack effect occurs commonly in hi-rise buildings where the upper floors get little or no ventilation air while the lower benefit both from the ducted ventilation air and increased infiltration.

5.2.1.1 Types of openings

Types of opening pertaining to natural ventilation include:

- windows, doors, roof, monitor openings and skylights
- stack connections to registers
- specially designed inlet or outlet openings.

5.2.2 Mechanical Ventilation

5.2.2.1 General

5.2.2.1.1 Fans are used in mechanical ventilation systems to have control over air movement. In the risk areas of flammable concentrations and air contaminants, mechanical ventilation shall be capable to provide positive control in the interest of safety and health.

5.2.2.1.2 These systems vary in complexity from a single wall mounted fan to ducted air distribution from and to centrally located fans with the possible addition of filtration and acoustic attenuation.

5.2.2.2 Types

The basic types of mechanical ventilation systems are supply, exhaust and balanced type of ventilation.

a) Supply ventilation

In a supply system, the air is delivered by a fan to the treated space and allowed to exhaust through purpose provided or other openings. The slight positive pressure (relative to outside) established within the space helps to prevent inward leakage of air and so this type of system is advantageous when the extraneous entrance of outside air or air from other parts of the building is to be avoided. With suitable ducting systems, the supply air can be distributed throughout the building to give uniform ventilation and to match individual air flow rates to those areas requiring different ventilation levels.

b) Extract ventilation (exhaust)

In extract ventilation, fan power shall be applied to exhaust air from within the room or building to outside. Replacement air enters through any available gaps and purpose provided openings. This type of system is commonly used for the bath rooms and toilets, and in other situations where the uncontrolled escape of contaminated air from the room is to be prevented. Unless special precautions are taken, the incoming air may cause problems such as local drafts. The risk of noise being transmitted through the openings for the make-up air should also be considered.

c) Balanced ventilation

Balanced ventilation represents the combination of supply and extract systems by which control of both incoming and exhaust air can be achieved. Additionally, the particular advantages of a supply system can be obtained by having a slightly greater supply flow capability than extract or vice-versa.

Notes:

1) Mechanical ventilation systems are not totally immune from the effects of external climate particularly the pressure variations caused by wind. These effects should be considered in relation to the required stability of flow through the system and to the location on the facade of the building of the system inlets and outlets. For most systems it is necessary to pay particular attention to avoid exhaust air re-entering the building.

2) Because comfort and productivity issues are important in office environments, control for comfort is more appropriate than reliance on TLVs used in industrial hygiene.

5.3 Ventilation Efficiency Calculation Method

Effective ventilation efficiency can be calculated by the following methods.

i) Efficiency for contaminant control:

$$E_c = \frac{c_e}{c_o}$$

Where:

E_c **=** Efficiency for contaminant control (%)

C_e **=** Concentration of contaminant in exhaust (ppm)

C_o **=** Concentration of contaminant in occupied zone (ppm)

ii) Efficiency for heat exchange:

$$E_t = \frac{t_e \quad t_s}{t \quad t_s}$$

Where:

E_t **=**	Efficiency for heat exchange	%
t_e **=**	Exhaust air temperature	°C
t_s **=**	Supply air temperature	°C
t **=**	Average temperature in occupied zone	°C

Note:

Since associations affiliated to the government failed to provide the required air contamination analysis of major cities in IRAN, the "AR" Technical Committee, shall use all efforts to gain accesibility to the required data in order to be able to apply the above formulas.

6. INDOOR AIR QUALITY

6.1 General

6.1.1 As defined by ASHRAE Standard 62-2001 acceptable IAQ is indoor air; that contains no known contaminants at harmful concentrations as determined by cognizant authorities; and with which 80% or more of the people exposed do not express dissatification.

6.1.2 To avoid performance defects, the designer should: 1) document the design intent clearly in a suitably written form, 2) make it available throughout the design/construction process to concerned authorities; 3) and ultimately employ it as a vehicle to assist in the training of building operation and maintenance (O&M) personnel.

6.1.3 Probable causes of sick building syndrome (SBS) or building-related illness (BRI) as observed by occupants are related to some extent to the following environments:

- Fabric contamination

- Microbiological contamination
- Outside and inside contamination
- Inadequate ventilation

Notes:

1) SBS occurs when moisture and mould give rise to respiratory illness among a building's occupants. It is specially common in houses built directly on concrete slabs. Since some probable causes of SBS are known to cause non-specific symptoms such as headache, dizziness, nausea and eye irritation, it is strongly recommended that IAQ problems are thoroughly investigated.

2) For identification and size of particles in air, reference is made to Attachments 2 and 3.

6.2 Recommended Pollutant Prevention Procedures

To maintain adequate IAQ the following procedures are recommended:

a) Building materials, finishes and equipment shall be chosen carefully and selections reviewed by an outside interior decorator.

b) The emissions from the new interior construction materials should be vented to the atmosphere before gasses permeate other building materials, thus lengthening the off-gassing period.

c) Design of an energy-efficient HVAC system to provide a reasonably contaminant-free interior environment.

d) Proper access to all HVAC systems shall be allowed for ease of maintenance or replacement of potential microbial contaminant sources.

e) During construction phase the entire HVAC system shall be checked to ensure that the installation is in accordance with design.

f) During close-out phase the HVAC system shall be cleaned, all dust and debris removed from all interior equipment surfaces prior to start-up.

g) Regular monitoring of indoor air quality shall be practised.

6.3 Recommended Contamination Limits

To obtain performance criteria in occupied space, the following air contaminants are recommended as measurable variables. Each can be used as surrogate indicators of both the intensity of human activity and the adequacy by which the ventilation system dilutes contaminants.

a) Butyric acid, a human bio-effluent with an odor recognition threshold of 0.001 p pm (parts per million) and a recommended limit of 0.002 p pm at the ceiling.

b) Pyridine and furfural are volatile, odorous components of environmental tobacco smoke. Pyridine has an odor recognition threshold of 0.02 p pm, an occupational threshold limit value (TLV) of 5 p pm, and a recommended limit of 0.05 p pm at the ceiling. Furfural has an odor recognition threshold of 0.002 p pm, an occupational TLV of 2 p pm, and a recommended limit of 0.004 p pm at the ceiling.

c) Toluene, a component of products used in offices, has an odor recognition threshold of 2 p pm, an occupational TLV of 100 p pm, and a recommended limit of 3 p pm at the ceiling. The yearly average limit for suspended particulates is recommended at 50 micrograms per cubic meter.

d) Carbon dioxide, with an occupational TLV of 5000 p pm has a recommended air quality limit of 1000 p pm. The outdoor concentration of this naturally occurring atmospheric gas is normally about 325 p pm. In buildings, levels of carbon dioxide exceeding 1000 p pm in occupied spaces often are associated with sick building syndrome.

6.4 Recommended Design Procedures

The following factors shall be considered for establishing well designed ventilation system to provide comfort, safety, health and active employee efficiency.

a) Manufacturer's of interior building products shall furnish when instructed, data on chemical composition, possible emissions and manufacturing test methods prior to their selection, specification and approval.

b) Manufacturer's of filtration system shall conform to ASHRAE / EUROVENT test method, clearly defining the values of efficiency and arre stance of the filter capabilities.

c) The design engineer shall make a proper design and system solution through precise selection procedures per manufacturer's instructions.

7. AIR DENSITIES

7.1 General

7.1.1 There are many applications where the density of air is different from that of standard conditions. As the density changes, the fan performance also changes and must be taken into consideration.

7.1.2 For HVAC applications when the air temperatures are from 10°C (50°F) to 38°C (100°F) and the air pressure more than +2" or -2" of Hg, no correction need be made for temperature or pressure. The -2" pressure differential corresponds to approximately 606 meters (2000 feet) elevation, so above this level a correction should be made.

7.2 Standard Air

7.2.1 The conditions of standard clean dry air at sea level is considered to be:

a) Barometric Pressure :	101.325 k Pa absolute at 20°C (70°F) and (14.696 psi or 29.92" of mercury)
b) Air Density :	1.204 kg per cubic meter (0.075 lb/ft3)
c) Specific Air Volume:	0.83 m3/kg (13.3 cubic feet per pound).

7.2.2 The conditions of air volume and static pressure required for a given elevation are usually known and it is necessary to determine the blower RPM and motor BHP to provide it.

7.2.3 Manufacturer's blower or fan tables are available only at standard conditions, so it is necessary to convert to this condition and use known relationships to arrive at the blower performance for the higher elevation.

7.4 Effect on Capacity

7.4.1 The capacity produced by a ventilation system can be affected when operated with air densities other than standard conditions. A system operating in a location above sea level will be using less dense air across the fan. The effect decreases the outlet capacity of the system.

7.4.2 Selecting a fan to operate at conditions other than standard air requires an adjustment to both static pressure and brake horsepower.

7.4.3 A cubic meter of air has a constant volume regardless of temperature or elevation. The air density changes with non-standard conditions. Therefore, when selecting a fan to operate at a non-standard air density using standard air density tables and curves, corrections must be made to parameters (SP and BHP) affected by air density.

7.4.4 If a selected fan operates at low temperatures, the motor should be of sufficient horsepower to handle the increased load at any lower operating temperature where the air is more dense.

8. SOUND AND NOISE RATINGS

8.1 Sound

8.1.1 Sound is a disturbance which propagates through a medium having the properties of inertia (mass) and elasticity. The medium by which audible sound is transmitted is air.

8.1.2 Three forms of Licensed Sound Ratings are:

a) Decibels

The sound power ratings are in decibels (dB) for each of the eight octave bands to the reference power of 10-12 watts.

b) Lw (A)

Is a single sound power level rating in decibels adjusted to represent the effect of "A" weighted network in each octave band.

c) Sone

Is a single number sound rating value.

8.2 Sound Levels

8.2.1 Fan sound levels can be compared most accurately in terms of sound power. Sound power is a characteristic of the source generating the sound and is independent of any influence from its surroundings.

8.2.2 All sound power values shall be based on independent laboratory tests in accordance with AMCA Standard 300 and 301 test code for sound rate. For typical example on sound power calculation, reference is made to Appendix A.

8.3 Sound Pressure Levels

It is the acoustic power radiating from a sound source expressed in watts or in decibels. A listener does not hear sound power any more than he sees the candle power of an electric light.

Sound pressure level (LP), as heard by the human ear are determined by installation criteria such as room size and shape; material composition of wall, ceiling and floor surfaces, distance and direction from the sound source; other objects and other sound generators in the room. Determination of sound pressure levels shall be the responsibility of the professional acoustical engineer. Table 1 addresses the decibel equivalents of sound pressures.

TABLE 1 - DECIBEL EQUIVALENTS FOR VARIOUS SOUND PRESSURES

DECIBELS dBA	NEWTONS / METER ^{2}
0	0.00002
20	0.0002
40	0.002
60	0.02
80	0.2
100	2
120	20

8.4 Loudness

It is important to distinguish between sound pressure, a physical property, and loudness being a physiological sensation. The Table 2 relates changes in sound level to the average person's perception of loudness.

TABLE 2 - SUBJECTIVE RESPONSE TO CHANGES IN SOUND LEVEL

CHANGE IN SOUND LEVEL	CHANGE IN LOUDNESS
1 dB	REQUIRES CLOSE ATTENTION TO NOTICE
3 dB	BARELY PERCEPTIBLE
5 dB	QUITE NOTICEABLE
10 dB	DRAMATIC; NEARLY TWICE
20 dB	STRIKING, FOURFOLD CHANGE

8.5 Noise

8.5.1 Fan noise is generated by turbulence within the fan housing and will vary by fan type, flow rate, pressure and fan efficiency. Because each design is different, noise ratings must be obtained from the fan manufacturer. For recommended noise criteria ranges in unoccupied spaces with all systems operating, reference is made to Attachment 3.

8.5.2 Fan noise can be rated in terms of the specific sound power level, which is defined as the sound power level generated by a fan operating at a capacity of 1 liters per second (2 cfm) and a pressure of 1 pa.

8.5.3 By reducing all fan noise data to this common denominator, the specific sound power level serves as a basis for direct comparison of the octave band levels of various fans and as a basis for a conventional method of calculating the noise levels of fans at actual operating conditions.

8.5.4 On a specific sound power level basis, where small fans may sometimes be noisier than larger fans, special allowance should be made for objectionable tones by providing extra sound attenuation in the octave band containing the tone.

8.6 Attenuation

The amount by which the sound is decreased as it travels from the sound source to the listener. This may be due to duct absorption, room absorption, sound attenuators, sound traps, sound transmission loss or division of sound. Attenuators refer to the total amount of sound reduction between the source and the listener, or that of any particular part of the system.

8.7 Octave Bands

A sound level meter uses filters to determine noise levels for various frequency bands. The standard distribution is composed of 10 octaves. An octave band shown in Table 3 is a frequency range with the ratio of 2:1 between its high and low frequencies. The preferred octave band sets which have been used in acoustics shall conform to ANSI S1.11-1966.

TABLE 3 - STD OCTAVE BAND

CENTER FREQUENCY, Hz	OCTAVE BAND, Hz
31.5	22 - 44
63	44 - 88
125	88 - 177
250	177 - 355
500	355 - 710
1000	710 - 1420
2000	1420 - 2840
4000	2840 - 5680
8000	5680 - 11,360
16,000	11,360 - 22,720

- Hz REFERS TO THE FREQUENCY IN CYCLES PER SECOND-

Notes:

1) There is a difference between sone values certified by HVI for residential use and by AMCA for commercial/ industrial use. Exact comparison of these values is not possible. This difference is mainly due to the procedures used to convert measured sound to perceived sound. ANSI S3.4, used by both HVI and AMCA, specifies a procedure for calculating loudness as perceived by a typical listener under specific conditions. HVI establishes values at a distance of 1.5 meters from the fan in a "sperical free field", AMCA establishes values at a distance of 1.5 meters in a "hemispherical free field". HVI results are rounded to the nearest 0.5 sone; AMCA to the nearest 0.1 sone.

2) On noise and vibration control reference is made to standard IPS-C-AR-110 and IPS-g-SF-900.

9. CLEAN ROOMS

9.1 General

9.1.1 By definition according to US federal Standard 209D, a clean room is a room in which the concentration of airborne particles are controlled to specific limits.

9.1.2 Airborne contamination exists in microscopic level in atmosphere and in concentrations far too great for some requirements. A hospital operating theatre require extreme control of airborne contamination to prevent damage to parts or a hazard to health. Areas which employ this sort of control are called 'Clean room'.

9.1.3 Clean rooms are used in various areas and industries such as biotechnology, hospitals, pharmaceuticals, computing, laboratories, food processing, and finally the semiconductor industry which is considered the largest use of clean room technology today.

9.2 Classification

9.2.1 Controlled environments are classified according to levels of particle contamination, by standards including the US Federal standard 209D and BS 5295. A summary of the classification which these standards define are indicated in clean room classification table Nos. 4A through 4D .

TABLE 4A - US FEDERAL STANDARD 209D

CLASS	MAX. NUMBER OF PARTICLES PER ft^3				
	0.1 μ m	0.2 μ m	0.3 μ m	0.5 μ m	5 μ m
1	35	7.5	3	1	N/A
10	350	75	30	10	N/A
100	N/A	750	300	100	N/A
1000	N/A	N/A	N/A	1000	7
10000	N/A	N/A	N/A	10000	70
100000	N/A	N/A	N/A	100000	700

*** N/A: Not Applicable**

TABLE 4B - BS 5295: PART 1

CLASS	MAX. NUMBER OF PARTICLES PER m^3			
	0.3 μ m	0.5 μ m	5 μ m	10 μ m
C	100	35	<1	NS*
D	1000	350	<1	NS*
E	10000	3500	<1	NS
F	NS	3500	<1	NS
G	100000	35000	200	<1

***NS = no specific limit**

TABLE 4C - BS 5295 PART 1 APPENDIX C6

BS 5295 also requires filters for inclusion in clean room environments to be leak tested by scanning with a photometer. The following Table shows the requirements specified by BS 5295 part 1 Appendix C6.

CLASS OF ENVIRONMENTAL CLEANLINESS	MAX. PERMITTED CONCENTRATION%
C, D, E AND F	0.001
OTHER CLASSES WHERE HIGH EFFICIENCY FILTERS ARE FITTED	0.01

TABLE 4D - CLEAN ROOM CLASSIFICATION CHART

CLEAN AIR REQUIREMENTS	CLASS CLEAN ROOM			
	100	1000	10000	100000
Max. No. OF PARTICLES PER ft 0.5 MICRON AND LARGER	100	1000	10000	100000
Max. No. OF PARTICLES PER ft 5.0 MICRON AND LARGER	0	7	70	700
RECOMMENDED AIR FLOW VELOCITY m/s (fpm)	0.35-0.55 (70-110)	0.1-0.125 (20-25)	0.05- 0.075 (10-15)	0.02- 0.03 (4-6)
Min. No. OF ROOM CHANGES/HOUR	650	150	75	20

9.2.2 The cleanliness of highly specialized room is achieved by maintaining constant airflow and positive pressure through HEPA (High Efficient Particulate Air) filters. These filters shall be capable of removing 99.99% of all particles 0.3 microns and larger from circulated air.

9.2.3 The basis for clean room design is established in Federal Standard 209 D. Air cleanliness is defined in terms of particles 0.5 microns and larger per cubic foot of air. The lower the classification number (Class 100, Class 1000, Class 10000 or Class 100000) the cleaner the air.

9.2.4 Classes of clean rooms are identified as follows:

a) As-built Clean room (facility)

A clean room (facility) that is complete and ready for operation, with all services connected and functional, but without production equipment or personnel within the facility.

b) At-rest Clean room (facility)

A clean room (facility) that is complete and has the production equipment installed and operating but without personnel within the facility.

c) Operational Clean room (facility)

A clean room (facility) in normal operation with all services functioning and with production equipment and personnel present and performing their normal work functions in the facilities.

9.3 Air Filteration System

9.3.1 Filters are considered one of the major influences on the cleanliness of a clean room. Other factors to be considered are:

- The method of air supply to the room;
- air flow control;
- the people in the room (particle generators).

9.3.1.1 The method of air supply system for clean rooms are of three types:

a) Open plenum systems.

b) Individually ducted systems.

c) In-line housings.

9.3.1.2 Progressive air filtration

9.3.1.2.1 Air should always be progressively filtered to produce clean air. Therefore pre-filters should precede the high efficiency filters.

9.3.1.2.2 Air filtration systems in clean rooms must use some form of recirculation to reduce energy costs. This can be done by partly returning the air through a recirculation duct and appropriate filters to the final filters or by returning the air to a mixing box in the air handling unit. Air is returned by using grilles in the wall or by perforated floor exits, affecting the type of air flow.

9.3.1.3 Air flow control

9.3.1.3.1 In any clean room installation, Class 1 air for particles down to 0.12 µm shall be provided with individual filters. Operators performing tasks within the clean room generate contamination, and how this is removed by circulating air also affects the class of a room.

9.3.1.3.2 With good air flow control operations requiring a Class 10 environment could be performed in a Class 100 room. By precise control of air flow patterns, the cleanest air can be guided across workstations, where the tasks are actually performed.

9.3.1.3.3 Two type of air flow through a clean room, each of which provide a different standard of air control are:

a) Laminar flow clean rooms

In laminar flow cleanrooms, air enters the room through filters covering the whole ceiling or one wall, is exhausted through the entire opposite surface, with air flowing in parallel lines and at uniform velocity. Thus any air makes only one pass through the room and any contamination created in the room is carried out. This type of design is also called displacement flow. Basic design and operating considerations for laminar flow clean rooms are listed in Table 5.

Velocities of 0.45 m/s are necessary to prevent settling out. With this sort of direct flow, areas of different velocity are minimised, reducing turbulence. Laminar flow rooms come in two varieties:

1) Downflow room

2) Crossflow room

TABLE 5 - LAMINAR FLOW CLEAN ROOMS

ACHIEVABLE CLASS AREA PER OCCUPANT OCCUPANTS PROPERLY ATTIREDOCCUPANT ACTIVITYEQUIPMENT IN ROOMHOUSEKEEPING	**1 AND 10 40m^2 FULL GOWNS MINIMUM MINIMUM METICULOUS**	**100 30 m^2 FULL GOWNS MINIMUM MINIMUM METICULOUS**
ROOM PRESSURISED AIR CHANGES PER HOUR AIR LOCK	15 Pa 500-600 YES	15 Pa 500 YES
CLEAN AIR INLETS AS % OF CEILING AREA CLEAN AIR INLET LOCATIONS TERMINAL VELOCITY AT CLEAN AIR INLET RETURN AIR LOCATION	90-100% CEILING 0.45 m/s PERFORATED FLOOR	90% CEILING (WALL) 0.45 m/s LOW LEVEL OR FLOOR (OPPOSITE WALL)
PREFILTERS - FIRST STAGE - SECOND STAGE PREFILTER MAINTENANCE AND INSPECTION FINAL FILTERS ROUTINE PARTICLE COUNT INTERVAL	30% DUST SPOT EFF. 95% SODIUM FLAME MONTHLY MIN. 99.9995% SF (FOR CLASS 10) MIN. 99.99995% SF (FOR CLASS 1) DAILY	30% DUST SPOT EFF. 95% DUST SPOT MONTHLY MIN. 99.999% SODIUM FLAME WEEKLY

b) Non-laminar flow clean rooms

In non-laminar flow clean rooms, air enters the room through filters and is exhausted through grilles in the walls near the floor, there being no requirements on uniformity of air flow patterns.

In non-laminar flow clean rooms the air flows through irregular paths. To reduce the dust level the incoming clean air shall be mixed with dirty room air which is thereby diluted. Basic design and operating considerations for non-laminar flow clean rooms are listed in Table 6 below:

TABLE 6 - NON-LAMINAR FLOW CLEAN ROOMS

ACHIEVABLE CLASS	**1,000**	**10,000**	**100, 000**	**AVOID**
ROOM SIZE/m^2 **ROOM ASPECT RATIO** **ROOM HEIGHT/m AREAPER** **OCCUPANT/m^2** **EQUIPMENT IN ROOM**	**100** **NARROW** **MIN. 3** **20** **MINIMUM**	**300** **3:1** **MIN. 2.75** **10** **30% FLOOR**	**500** **2:1** **MIN. 2.25** **5** **50% FLOOR**	 **LARGE SQUARE** **ROOM**
OCCUPANT ACTIVITY TRAFFICIN-OUT PER HOUR OCCUPANTS PROPERLY ATTIRED PARTICLE GENERATION IN ROOM THERMAL UPDRAFTS HOUSEKEEPING	SEDENTARY 1-2 FULL GOWNS MINIATURE NONE METICULOUS	OCCASIONAL MOVEMENT 2-6 SMOCKS SLIGHT SLIGHT GOOD	CONSTANT ACTIVITY OVER 6 SMOCKS CONSIDERABLE CONSIDERABLE MEDIOCRE	FRIVOLOUS ACTIVITIES STREET CLOTHES
ROOM PRESSURE/Pa AIR CHANGES PER HOUR AIRLOCK	10-15 40-120 ADEQUATE	10-15 20-40 SMALL	5-10 10-20 NONE	NONE
CLEAN AIR INLETS AS % OF CEILING AREA CLEAN AIR INLET LOCATIONS TERMINAL VELOCITY AT CLEAN AIR INLET/ms^{-1} WALL RETURN SPACING MAXIMUM HORIZONTAL DISTANCE TO RETURN/m RETURNFACE VELOCITY/ms^{-1}	20-50 CEILING 0.15-0.45 LOW LEVEL OR FLOOR CONTINUOUS ON ALL 4 WALLS 3 0.5-1	10-20 CEILING 0.15-0.45 LOW SIDEWALL INTERMITTENT ON LONG WALLS 6 1-2.5	5-10 CEILING OR HIGH SIDEWALL 0.15-0.45 SIDEWALL NON UNIFORM 9 2.5	 FLOOR CEILING SINGLE
PREFILTERS -FIRST STAGE -SECOND STAGE PREFILTER MAINTENANCE AND INSPECTION FINAL FILTERS ROUTINE PARTICLE COUNT INTERVAL	 30% DUST SPOT EFF. 90% DUST SPOT EFF. QUARTERLY MIN. 99.99% SODIUM FLAME MONTHLY	80% ARRESTANCE 70-90% DUST SPOT EFF. SEMI-ANNUAL MIN. 99.99% SODIUM FLAME MONTHLY	80% ARRESTANCE 70-90% DUST SPOT EFF. ANNUAL MIN. 95% SODIUM FLAME QUARTERLY	DOORS OPEN NO SCHEDULE

10. VENTILATION FOR ACCEPTABLE INDOOR AIR QUALITY

10.1 The ANSI/ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc.) Standard 62-2001 shall apply to this Standard .

10.2 The ANSI/ASHRAE Standard 62-2001 focuses on respirable as a major component of air quality complaints and defines them as being less than 10 micron in size. Bacteria and virus clusters ten to attach to particles that exceed 1 micron and lung-damaging particles from 0.2 to 5 microns. For selecting filter effectiveness it is recommended that designer consider 10 microns, 1 micron and 0.3 microns as the target number. A range of filter efficiencies with their equivalent effectiveness at varying micron particle is shown in Table 7.

TABLE 7 - FILTER EFFICIENCY AT VARYING MICRON

FILTER TYPE (ASHRAE%)	EFFICIENCY AT 10 MICRONS	EFFICIENCY AT 1 MICRON	EFFICIENCY AT 0.3 MICRONS
20%-25%	98%	10%	1%
50%-55%	99%	30%	19%
80%-85%	99%	90%	49%
90%-95%	99%	99%	78%

10.3 Due to importance of "Outdoor Air Requirements for Ventilation" the pertinent Table (No. 8 in this Standard) is reproduced from the subject standard to act as a ready reckoner.

TABLE 8A - OUTDOOR AIR REQUIREMENTS FOR VENTILATION*

COMMERCIAL FACILITIES

(OFFICES, STORES, SHOPS, HOTELS, SPORTS FACILITIES)

Application	Estimated Maximum** Occupancy P/1000 ft^2 or $100m^2$	Outdoor Air Requirements				Comments
		cfm/ person	L/s person	cfm/ft^2	L/s.m^2	
DryCleaners,Laundries						Drycleaningprocessesmay requ more air.
Commercial laundry	10	25	13			
Commercialdrycleaner	30	30	15			
Storage, pick up	30	35	18			
Coinoperatedlaundries	20	15	8			
Coinoperateddrycleaner	20	15	8			
FoodandBeverageService						
Dining rooms	70	20	10			
Cafeteria, fast food	100	20	10			
Kitchens (cooking)	20	15	8			Make-up air hood exhaust may require more ventilating air. The sum of the outdoor air and transfer air of acceptable quality from adjacent spaces shall be sufficient to provide and exhaust rate of not less than 1.5 cfm/ft^2 (7.5 L/s.m^2).
Garages,Repair,ServiceStations						Distribution among people mus consider worker locationand concentration of running engines: stands where engines are run must incorporate systems for positive engine exhaust withdrawal. Contaminant sensors may be sued to control ventilation
Enclosed parking garage				150	75	
Auto repair rooms				150	75	
Hotels,Motels,Resorts,Dormitories						ndependent of roomsize
				cfm / room	L / s.roo	
Bedrooms				30	15	
Living rooms				30	15	
Baths				35	18	Installed capacity for intermittent use
Lobbies	30	15	8			Seealsofoodbeveragese merchandising,barberad beauty shops, garages
Conference room	50	20	10			
Assembly rooms	120	15	8			
Dormitory sleeping areas	20	15	8			
Offices						Someofficeequipmentay requite local exhaust.
Office space	7	25	13			
Reception areas	60	15	8			
Telecommunication centers and data entry areas	60	20	10			Supplementarysmokera equipment may be required.
Conference rooms	50	25	13			
Public Spaces						
				cfm / ft^2	L / s.m	
Corridors and utilities				0.05	0.25	
Public restrooms, cfm/ wc or urinal		50	25			Mechanicalexhaustwito recirculationisrecommeded
Locker and dressing rooms				0.5	2.5	

(to be continued)

TABLE 8A (continued)

Application	Estimated Maximum** Occupancy P/1000 ft² or 100m²	Outdoor Air Requirements cfm/ person	L/s person	cfm/ft²	L/s.m²	Comments
Smoking lounge	70	60	30			Normallysuppliedbytraai Localmechanicalexhau with Norecirculationrecommd
Elevators				100	50	Normally supplied by transfer ai
Retail Stores, Sales Floors, and Show Room Floors						
Basement and street	30			0.30	1.50	
Upper floors	20			0.20	1.00	
Storage rooms	15			0.15	0.75	
Dressing rooms				0.20	1.00	
Malls and arcades	20			0.20	1.00	
Shipping and receiving	10			0.15	0.75	
Warehouses	5			0.05	0.25	
Smoking lounge	70	60	30			Normally supplied by transfe air, local mechanical exhaust: exhaust with no recirculationrecommended.
Specially Shops	25	15	8			
Barber	25	25	13			
Beauty	20	15	8			
Health Centers	8	15	8			
Florists						
				0.30	1.50	
Clothiers, furniture	8	15	8			
Hardware, drugs, fabric	8	15	8	1.00	5.00	
Supermarkets						Ventilation to optimize plant growth may dictate requirement
Pet shops						
Sports and Amusement						Wheninternal combustion engines are operatedfor maintenance of playing surfaces increased ventilation rates may be required.
Spectator areas	150	15	8			
Game rooms	70	25	13			
cc arenas (playing areas)						
Swimming pools (pool and deck area)				1.00	5.00	Higher values may be required for humidity control Special ventilation will be neede to eliminate special stage effects (e.g., dry ice vapors, mists, etc.)
Theaters	60	20	10			
Ticket booths	150	20	10			
Lobbies	150	15	8			
Auditorium	70	15	8			Ventilation within vehicles may require special consideration
Stages, studios						
Transportation	100	15	8			
Waiting rooms	100	15	8			
Plat forms	150	15	8			
Vehicles						
Workrooms	10	15	8			Spaces maintained at low temperatures (-10°F to + 50°F or -23°C to + 10°C) are not covered by these requirements unless the occup- ancy is continuous. Ventilationfromadjoining spaces is permiss- ible. When the occupancy is intermittent, infiltration will normally exceed the ventilation requirement.
Meat processing						

(to be continued)

TABLE 8A (continued)

Application	Estimated Maximum** Occupancy P/1000 ft^2 or 100m^2	Outdoor Air Requirements cfm/ person	L/s person	cfm/ft^2	L/s.m^2	Comments
Photo studios	10	5	8			
Darkrooms	10			0.50	2.50	
Pharmacy	20	15	8			
Bank vaults	5	15	8			
Duplicating, printing				0.50	2.50	
undesirable						Installed equipment must incorporate positive exhaust and control (as required) of contaminants (toxic or otherwise).
2.2 INSTITUTIONAL FACILITIES						
Education						
Classroom	50	15	8			
Laboratories	30	20	10			Special contaminant control systems may be required for processes or functions including laboratory animal occupancy.
Training shop	30	20	10			
Music rooms	50	15	8			
Libraries	20	15	8			
Locker rooms				0.50	2.50	
Corridors				0.10	0.50	
Auditoriums	150	15	8			
Hospitals, Nursing and Convalescent Homes						
Patient rooms	10	25	13			Special requirements or codes and pressure relationships may determine minimum ventilation rates and filter efficiency. Proce-duresgenerating contaminants may require. Air Shall not be recirculatated Into other speaes
Medical procedure	20	15	8			
Operating rooms	20	30	15			
Recovery and ICU	20	15	8			
Autopsy rooms				0.50	2.50 .	
Physical Therapy	20	15	8			
Correctional Facilities Cell	20	20	10			
Dining halls	100	15	8			
Guard stations	40	15	8			

*** Table 8A prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to control CO_2 and other conlaminants with an adequate margin of safety and to account for health variations among people, varied activity levels, a moderate amount of smoking.**

**** Net occupiable space.**

(to be continued)

TABLE 8B[a] - OUTDOOR REQUIREMENTS FOR VENTILATION OF RESIDENTIALFACILITIES (PRIVATE DWELLINGS, SINGLE, MULTIPLE)

Applications	Outdoor Requirements	Comments
Living areas	0.35 air changes per hour not less than 15 cfm (7.5 L/s) per person	For calculating the air changes per hour, the volume of the living spaces shall include all areas within the conditioned space. The ventilation is normally satisfied by infiltration and natural ventilation. Dwellings with tight enclosures may require supplemental ventilation supply for fuel-burning appliances, including fireplaces and mechanically exhausted appliances. Occupant loading shall be based on the number of bed rooms as follows: First bedroom, two persons: each additional bedroom, one person. Where occupant loadings are known, the shall be used.
Kitchensb	100 cfm (50 L/s) intermittent or 25 cfm (12 L/s) continuous or openable windows	Installed mechanical exhaust capacity[c]. Climatic conditions may affect of the ventilation system.
Baths. Toiletsb	50 cfm (25 L/s) intermittent or 20 cfm (10 L/s) continuous or openable windows	Installed mechanical exhaust capacity[c].
Garages003A		Normally satisfied by infiltration or natural ventilation
Separate for each dwelling unit	100 cfm (50 L/s) per car	
Common for several units	1.5 cfm/ft^2 (7.5 L/s m^2)	See "enclosed parking garages", Table 8A of this standard.

a) In using this table the outdoor air is assumed to be acceptable.

b) Climatic conditions may affect choice of ventilation option chosen.

c) The air exhausted from kitchens, bath, and toilet rooms may utilize air supplied through adjacent living areas to compensate for the air exhausted. The air supplier shall meet the requirements of exhaust systems.

PART II

EQUIPMENT & SYSTEMS

11. AIR MOVEMENT UNITS (FANS)

11.1 Types of Fans

The types of fans as classified by the AMCA Standard 99-0066-83 are as follows:

a) Axial Fans: which is furthur divided into:

- Propeller fan
- Tube axial fan (fan without guide vanes)
- Vane axial fan (with inlet or discharge guide vanes or both). The vane axial fan comes with
  - Fixed pitch
  - Adjustable pitch
  - Variable pitch

b) Centrifugal Fans: which is furthur divided into:

- Tubular centrifugal fan
- Centrifugal fan with different Impellers such as:
  - air foil
  - backward inclined
  - forward inclined
  - radial

c)Mixed Flow Fans (impeller contained either in a cylindrical or volute casing).

d) Specific Fan Units: can be any one of the following type:

- Air handling unit
- Steam or hot water unit heater
- Power roof or wall ventilator
- Utility set
- Centrifugal ceiling or wall exhauster
- Air curtain unit
- Make-up air unit.

11.2 Classifications

The following shall be the total static pressure classifications (total static pressure includes the internal static pressure losses). for operating limits of centrifugal fans:

Class A: Total static pressure of 7.62 milibar (0 inch to 3 inches maximum of water gage).

Class B: Total static pressure of 7.62 to 14 milibar (3 inches to 5.5 inches maximum of water gage)

Class C: Total static pressure over 14 milibar and upto 31 milibar(5.5 inches of water gage and upto 12.25 inches water gage).

11.3 Fan Appurtenances

The fan appurtenances shall be considered as the accessories added to a fan for purposes of control, isolation, safety, static pressure regain, wear, etc. Common fan appurtenances include inlet boxes, inlet box dampers, variable inlet vanes, outlet dampers, vibration isolation bases, inlet screens, belt guards, evases or diffusers, sound attenuators, wear protection, turning gears, etc.

11.4 Volume Control

The air volume delivered by fan can be controlled by any one of the following:

a) Variable speed motor control or variable frequency drive

b) Outlet damper control

c) Variable inlet vane control

e) Fan drive change

11.5 Safety Requirements

11.5.1 Fan applications depending on hazarduous area classification may involve the handling of potentially explosive or flammable particles, fumes or vapors. Such applications shall require careful consideration of all system components to insure the safe handling of such gas streams. (This Standard deals only with the fan unit installed in that system mentioned in this Clause).

11.5.2 The use of this Standard in no way implies a guarantee of safety for any level of spark resistance. "Spark resistant construction also does not protect against ignition of explosive gases caused by catastrophic failure or from any airstream material that may be present in a system".

Notes:

1) Bearings, drive components or electrical devices shall not be placed in the air or gas stream unless they are constructed or enclosed in such a manner that failure of that component cannot ignite the surrounding gas stream.

2) All fan parts shall be electrically grounded.

3) For this Standard, nonferrous material shall be any material with less than 5% iron or any other material with demonstrated ability to be spark resistant.

11.6 Fan Selection Method

11.6.1 The selection of a fan for (air conditioning or) ventilation applications involves choosing the most inexpensive combination of size, arrangement, type and class of construction to meet the required duty, while providing stable operation at an acceptable sound level and efficiency.

11.6.2 Outlet velocity should not be used as a selection criterion as regards sound output. The best sound characteristics are normally achieved at maximum static efficiency, and in the case of high pressure fans this generally occurs at outlet velocities higher than those commonly used in low pressure systems used with the plenum.

11.6.3 The following selection factors should also be taken into consideration;

a) Air volume required:

b) system resistance or static pressure: (system pressure loss = fan static pressure + fan velocity pressure);

c) entering air conditions-dry-bulb temperature and moisture content; air density; state of air, e.g. containing dirt or abrasive particles, corrosive fumes, or inflammable gases;

sometimes surrounding air conditions and their effect on motor, drive, etc., must be considered;

d) barometric pressure/altitude at plant location; in other words air density;

e)type of application or service (e.g. comfort, industrial, quietness);

f) type of system and possible changes in system characteristic (e.g. dirty filters, variable volume units);

g) space available for fan and drive and permissible weights;

h) fan arrangement, position of inlet(s) and outlet(s), and direction of discharge;

i) fan connections-type and size, type of motor power available;

j)type of drive and arrangement, requirements for drive adjustment, speed control or standby duty;

k) fan accessories such as access doors, drive guards, variable inlet guide vanes or outlet dampers, vibration isolators, flexible connections;

l) special design features, such as split casings for ease of assembly (large centrifugals), special paints or protective finishes, blade wear plates. Scroll liners, insulation clips, ‘all-weather’ covers over drive and motor for outside location;

m) acceptable noise level;

n) width of fan (single or double).

Notes:

a) When installed in a system, fan inlet and discharge connections should conform to good practice to minimize air turbulence, and ensure even air flow at low pressure drop.

b) Fans should be effectively isolated to prevent noise and vibration transmission through the ductwork system, or to adjacent spaces. This includes anti-vibration mounting under the supports or bases, including the motor and drive. Inlet and outlet ductwork connections should be of the flexible type. The electrical connection to the motor should have a flexible loop in it.

c) All points shall be required to have lubrication carried out strictly in accordance with the manufacturer’s instruction. Reference is made to IPS-C-AR-110.

11.7 Fan Ratings

11.7.1 General

11.7.1.1 It is not practical to test a fan at every speed at which it may be applied. Nor is it possible to simulate every inlet density which may be encountered.

11.7.1.2 The performance of a complete series of geometrically similar fans can be calculated from the performance of smaller fans in the series using the appropriate equations.

11.7.1.3 Because of the relationship between the volume flow rate and pressure for any given fan, each set of equations for changes in speed, size or density, applies only to the same "point of rating" and all the equations in the set must be used to define the converted condition. A "point of rating" is the specified fan operating point on its characterestic curve.

11.8 Fan Equation

The prime importance of fan equation derived from the fan laws, applied to the understanding of HVAC system when fanoperating with air at constant density, are as follows:

1) In US Units:

a) $$\frac{cfm_2}{cfm_1} = \frac{rpm_2}{rpm_1}$$

b) $$\frac{p_2}{p_1} = ' \frac{rpm_2}{rpm_1}^{\mu_2}$$

c) $$\frac{bhp_2}{bhp_1} = ' \frac{rpm_2}{rpm_1}^{\mu}$$

d) $$(d_2/d_1)^{\frac{1}{2}} = [rpm1/rpm2]$$

e) $$\frac{rpm(fan)}{rpm(motor)} = \frac{pitcldiammotopulley}{pitcidlamfanpulley}$$

Where:

cfm **=** Cubic feet per minute

rpm **=** Revolutions per minute

P **=** Static or total pressure (in. w.g.)

bhp **=** Brake horsepower

d **=** Density (lb/cu ft)

Note:

Above items represent the following:

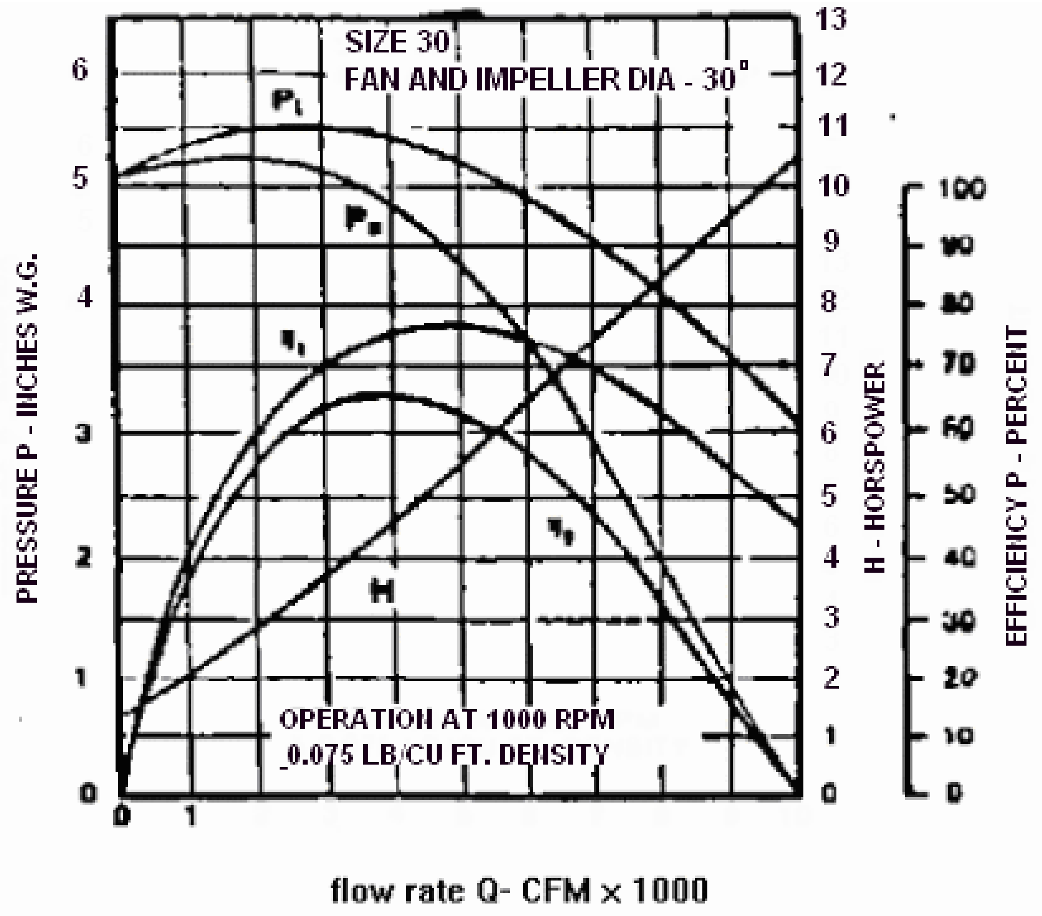
- in item (a) flow rate varies as fan speed.

- in item (b) pressure varies as square of fan speed.

- in item (c) power varies as cube of fan speed.

11.9 Fan Performance Curves

11.9.1 A fan performance curve illustrated below and extracted from AMCA Publication 201-90 is a graphical presentation of the performance of a fan. It covers from entire range from free delivery (no obstruction to flow) to no delivery (an air tight system) with no air flowing. Gas density, fan size, and speed (N) are usually constant for the entire curve and must be stated.



FAN PERFORMANCE CURVE

11.9.2 One, or more, of the following characterestics may be plotted against volume flow rate (Q).

Static pressure	P_s
Total pressure	P_t
Power	H
Fan Static efficiency	η_S
Fan total efficiency	η_t

Notes:

1) For performance curves reflecting general characterestics of variety of fan types where parameters such as diameter and speed are not defined, reference is made to AMCA Fan Application Manual.

2) The class standard of a centrifugal fan defines the capability of a fan to operate safely at every point of rating on a minimum

performance limit for that class, (AMCA Standard 99-2408).

3) Individual manufacturer's capacity curve shall be reviewed for actual fan performance.

11.10 Explosion-Proof Fans

11.10.1 The explosion proof fans and blowers shall meet the requirements of NEC Articles 500-503 under Class 1, Group C and D or Class 2 Groups E, F and G under Divisions 1 and 2.

11.10.2 The pressurization system shall provide intermittently high make-up air volumes necessary for compliance with NFPA 496 and similar industrial codes.

11.10.3 The unit shall be provided with corrosion resistant housing, industrial grade built in dust or carbon filters or deep bed filters for very corrosive atmospheres, detectors for smoke hydrocarbon or specific gas with alarm and automatic shutdown.

11.10.4 The control panel NEMA 7 enclosure or equivalent shall preferably be remote with pressure read-out, pressure loss alarms and purge controls.

12. AIR BALANCING DEVICES (DAMPERS AND LOUVRES)

12.1 Dampers

12.1.1 General

A damper is a primary element in a duct system and used for controlling air flow rates by introducing a resistance to airflow in the system.

12.1.2 Functional categories

Functional categories of dampers in an HVAC&R system are divided into following types:

12.1.2.1 Volume control dampers

Used, when necessary to regulate flow at a specific location in a duct system. These dampers which may be single blade, parallel blade or opposed blade type, and are divided into:

a) Manual Balancing Dampers

b) Isolating Dampers

c) Modulating Dampers

d) Backdraft Dampers

e) Fan Inlet Dampers

d) Fan Outlet Dampers

12.1.2.2 Temperature control dampers

Pairs of temperature control dampers are used when it is necessary to control temperature at a specific location in a duct system. These damper pairs are commonly single blade parallel blade, or opposed blade type linked together, or controlled together, in a face and bypass or mixing arrangement through pneumatic or electric actuators. These dampers are divided into:

a) Fresh-Air Mixing Dampers

b) Multizone Dampers

12.1.2.3 Pressure control dampers

Used when control pressure at a specific location in a duct system is necessary. These dampers are normally single blade, parallel blade or opposed blade type and are suitable for pneumatic, electric or manual actuators. These are divided into:

a) Modulating Dampers

b) Backdraft Dampers

c) Pressure Relief Dampers

12.1.2.4 Fire and smoke dampers

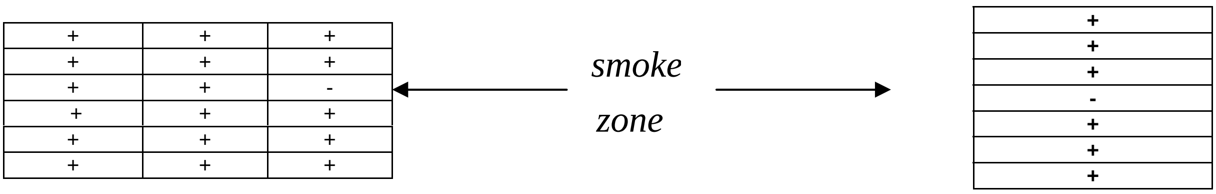
12.1.2.4.1 Smoke control systems

12.1.2.4.1.1 Any fire generates smoke which will, unless managed positively, spread throughout the building. Natural buoyancy, wind, stack effect and pressures generated by the fire will promote the spread of smoke through stairwells, elevator shafts, ductwork, chases, and gaps in construction.

12.1.2.4.1.2 Smoke control systems create air pressure differentials using the building HVAC system, dampers and smoke partitions. These pressure differences can effectively contain the smoke in a localized area and often direct the flow of smoke along a desired exhaust path. The aim of smoke control is to establish smoke-free zones and exit routes for safe evacuation of building occupants. Smoke-free areas also allow firefighters to locate the fire more quickly and to depend less on cumbersome oxygen breathing apparatus.

12.1.2.4.1.3 Buildings can be zoned for smoke control in several ways. Often an entire floor is a smoke zone. However, it is also possible for several zones to be established on each floor. The illustration below shows two buildings zoned for smoke control. The smoke control system must be flexible enough to contain the smoke originating in one

zone by positively pressurizing(+) adjacent zones and creating a relative negative pressure (-) in the smoke origin zone.



12.1.2.4.2 Damper operational requirements

Before smoke control was developed, fan systems were shut down during fires, and fire dampers were closed by the heat. No use was made of air pressures to contain and control smoke. The requirement that fire dampers must close as the heat reaches a certain level is now in question. With latest smoke management techniques, combination fire smoke dampers may need to function at temperatures beyond these ratings. Simple closure at 100°C (212°F) or below is no longer the absolute requirement. The following combination fire smoke damper control options are recommended:

a) Fire Temperature Closure at 74°C to 100°C (165°F. 212°F)

b) Fire Temperature Closure at 138°C to 140°C (280°F. 285°F)

c) Positive Override of Fire Temperature Closure

d) Temperature Limited Override of Fire Temperature Closure

12.1.2.4.3UL 555 Standard for safety fire dampers & ceiling dampers

12.1.2.4.3.1 Fire dampers shall be licensed to carry the UL label only after extensive testing as prescribed by UL 555 Classified Fire Dampers and ceiling dampers must pass tests to demonstrate:

- Operational reliability
- Corrosion resistance
- Resistance to fire for 1 or 3 hour duration
- Resistance to fouling and contamination
- Structural strength and resistance to structural deterioration.

12.1.2.4.3.2 Fire resistance ratings of 1 hours and 3 hours are available under UL 555. Walls and partitions with fire ratings less than 3 hours shall be properly protected with 1 hour dampers. The three hour dampers shall be used in walls and partitions with fire ratings of 3 hours or more (these requirements have been established by NFC Standard 90A).

12.1.2.4.3.3 UL 555 requires each fire damper to display a UL label which shows the damper's rating (1 or 3 hours). To provide building code required protection, fire dampers must also be properly installed. On all such installations manufacturer's instructions must accompany dampers.

12.1.2.4.4 UL 555 S Standard for safety-leakage rated dampers, for use in smoke control systems

12.1.2.4.4.1 Smoke Dampers have been tested and rated as required by UL 555 S. This relatively new standard and while it does not include the fire resistance and related structural strength testing involved in UL 555, it does require more extensive operational reliability testing. Similar corrosion and fouling resistance testing is also required.

12.1.2.4.4.2 In addition UL 555 S evaluates the damper's ability to close and restrict the passage of smoke by testing for leakage when the damper is closed. Smoke dampers shall be motor operated dampers with one of the following functions:

a) Close during a fire/smoke emergency to seal off an opening through a smoke barrier to prevent the spread of smoke.

b) Close or open during a fire/smoke emergency to allow the building HVAC System to function as an Engineered Smoke Control System and prevent the spread of smoke by pressurizing zones surrounding the fire area with clean air.

12.1.2.4.4.3 UL 555 S establishes a number of leakage categories to allow HVAC and fire protection system design engineers to specify dampers with leakage characteristics appropriate to the application requirements.

Leakage Class I - Ultra-low leakage (less than 4 cfm/ft^2 at 1" WG or 8 cfm/ft^2 at 4" WG).

Class II - Very low leakage.

Class III - Low leakage (less than 40 cfm/ft^2 at 1" WG or 80 cfm/ft^2 at 4" WG).

Class IV - Standard leakage.

Notes:

1) UL 555 S Classified Smoke Dampers must display a UL label showing the leakage classification.

2) The UL 555 S classified smoke and combination fire/smoke dampers are at temperature upto 121°C (250°F) for operation with electric or pneumatic actuators. These dampers can be equipped with fusible link rated at 74°C (165°F).

12.1.3 Damper Designs

12.1.3.1 Frames

Damper frames are generally categorised as: U-Channel, hat channel, flat and flanged frames. For ease of installation they are fabricated about 6 mm (inch) smaller than the clear opening. Flanged frame dampers are generally fabricated to mate a damper flange with a duct flange.

12.1.3.2 Blades

12.1.3.2.1 Damper blades slats that generally rotate inside the damper frame anywhere from the fully open to the fully closed position or to any other desired percentage of blade opening. Blades are generally categorized as flat, triple V or air foil type.

12.1.3.2.2 Blades may vary in width to accommodate all damper sizes and its mode of rotation may be parallel or opposed.

12.1.3.3 Blade axles

These are mechanically fastened welded or rivetted to both ends of the blade. They are shafts that extends from the blade through the frame.

12.1.3.4 Blade stops

These are metal strips generally spot welded or rivetted in place.

12.1.3.5 Bearing

12.1.3.5.1 Bearings are categorized as "sleeve" (bushing) or "ball" bearings. They are normally pressed into a frame member and may sometimes be formed in the frame member.

12.1.3.5.2 Selection of bearing shall be based on the ambient conditions where the damper will be installed and type of application.

12.1.3.5.3 On vertical bladed dampers with vertical axles, thrust washers or thrust bearings are recommended to prevent the blade ends rubbing on the frame or seals.

12.1.3.6 Linkage

The linkage shall be designed to prevent independent action of any blade in a mechanism mounted on the blade face or concealed within the damper frame, which provides parallel or opposed blade rotation depending on the blade linkage method.

12.1.3.7 Side (end or jamb) seal

These are strips of material normally positioned between the damper frame and the blade end. They are used to prevent the undesirable leakage of air between the damper’s blades and its frame.

12.1.3.8 Mullion

Is a division between multiple section dampers. These add stiffness as it is constructed of two jambs fastened together with or without reinforcement.

12.1.3.9 Drive blade

The drive blade is the blade designed to accept the operating force which is transmitted to all the other blades through interconnecting linkage.

12.1.4 System Effects

They are conditions that cannot be measured directly, but the conditions effects will influence the final performance of the damper. They vary directly as the velocity pressure when duct velocities are over 10 m/s (2000 fpm).

12.1.5 Damper Selection

The proper selection of a damper shall be specific towards the damper application to meet functional, environmental and system effects. Planned considerations shall be provided towards system pressures, leakage rates, temperature ranges, environmental effects life cycle requirements, cycle time and maintenance needs.

Notes:

1) Damper finishes shall be coated to resist rough weather conditions and chemical reagents. For specific and industrial application and requirements, renowned, damper manufacturer's shall be consulted .

2) For description of damper construction and materials, reference is made to IPS-M-AR-225.

12.2 Louvres

12.2.1 General

12.2.1.1 Louvres is a device comprising multiple blades which when mounted in an opening, permits the flow of air but inhibits the entrance of other elements.

- Fixed louvres are those in which the blades do not move.
- Adjustable louvres are those in which the blades may be operated either manually or by mechanical means.

12.2.1.2 Louvres may be installed in exterior walls visible to the public. It may be produced in maximum single section sizes as dictated by shipping, handling or finishing limitations.

12.2.2 Louvre design

12.2.2.1 Frames

Louvre frames can generally be classified as channel type or flange type fabricated smaller than the clear opening for ease of installation.

12.2.2.2 Basic fixed blades

These blades shall be plain or with center baffle positioned at various angles within the frame.

12.2.2.3 Drainable fixed blades

These blades shall be set from 30 to 45 angles with a gutter or rain trough at the lower edge.

12.2.2.4 Adjustable blades

These blades shall be capable to rotate within the louvre frame any where from the full open to full closed position.

12.2.2.5 Sightproof louvre

The sightproof louvres may be installed with vertical or horizontal blades with Y, Z and V blades being the most common shapes. These louvres shall be used for ventilation, weather protection, prevention of vandalism or insertion of foreign objects.

12.2.2.6 Acoustical louvre

These louvres shall be able to permit ventilation and decrease the transmission of sound by its special construction. Due to the task it requires to perform, pressure drop and free area may be sacrificed.

12.2.2.7 Sand louvre

These louvres shall be used in areas which are subjected to sand storms and should be designed to trap some of the particulate within the body of the louvre.

12.2.2.8 Sun screens/sun canopies

These louvres shall be attached to buildings to deflect direct sunlight. Special considerations shall be given to the structural support when a cantilever design is used.

12.2.2.9 Equipment screen

These louvres may be used to screen HVAC electrical or mechanical equipment from view. Blade design may vary to meet specific free areas, degree of vision barrier requirements or to match adjacent walls.

12.2.3 Louvre free area

12.2.3.1 The free area represents the minimum area through which the air can pass and varies with its size. The free area is the calculated louvre free area divided by the louvre gross area multiplied by 100.

12.2.3.2 The louvre free area percentage selected must be considered in relation to the:

- Air performance-pressure drop;
- water penetration requirements;
- air leakage;
- sound transmission loss.

12.2.4 System effects

System effects influences the final performance of the louvre and can be categorized as inlet conditions, outlet conditions, screens and wind velocities.

12.2.5 Louvre selection

12.2.5.1 Permiting airflow into or out of structure, a correctly sized and fabricated louvres shall be expected to function the following:

a) Look aesthetically attractive and complement the surrounding architecture.

b) Inhibit undesirable elements from entering the structure.

c) Offer low air resistance so that fan power is conserved for the rest of the system.

d) Minimize energy losses into or out of the structure.

12.2.5.2 The following formula shall be used to size a louvre for a given airflow and a recommended free area velocity. Each louvre shall have its free area velocity value based on tests performed in accordance with AMCA Standard 500.

Free Area (m^2) $\approx \dfrac{Design\ Fiow (M^3/s)}{\mathrm{Re}\,commended\ Velocity\ (M/S)}$

Notes:

1) A louvre size shall normally specify width (first) followed by height. The free areas are listed in manufacturer's tables.

2) For construction of louvre construction and materials, reference is made to IPS-M-AR-225.

13. AIR CLEANING DEVICES (FILTERS)

13.1 General

Air cleaning devices remove contaminants from an air or gas stream. Degree of removal required, quantity and characteristic of the contaminant to be removed and conditions of the air or gas stream will have a bearing on the unit selected for any given application. According to ACGIH, air cleaning device are divided into two basic groups:

a) Air filters

b) Dust collectors

13.2 Air Filters

13.2.1 Classification

13.2.1.1 Air filters shall be designed to remove dust concentrations found in outside air employed in HVAC systems where dust holding should not exceed 2 mg (upto 0.2 mg) per cubic meter of air (four grains per thousand cubic feet of air).

13.2.1.2 Filter con be classified into general categories:

- pre-filters

- final filters

13.2.1.3 For datas on minimum recommended level of air cleaning performance for pre-filters and final filters reference is made to Attachment 4.

13.2.1.4 The rating of air filter represent the following three operating characterisitics that distinguish the various type of air filters (or air cleaners):

a) Arrestance and efficiency

b) Air flow resistance

c) Life or dust-holding capacity

13.2.1.4.1 Arrestance and efficiency

a) The primary consideration in filter selection is the air cleanliness required in the space being served. This dictates the Arrestance/ Efficiency requirement of the filter. To determine the effectiveness of a filter to clean the air, the commonly used standard is the ASHRAE 52-76/EUROVENT 4/5 and BS 6540 test method. This test method defines two values:

1) Arrestance is the ability of a filter to retain large and heavy particles. This value is based on the weight percentage of dust particles retained by the filter. Arrestance is used for primary filters and prefilters.

2) Efficiency is the effectiveness of the filter in removing small and light particles, mainly carbon. This value is determined by the dust spot (discoloration) tests. Efficiency is used for medium and high efficiency filters.

b) For filters with the highest efficiency such as HEPA, ULPA, different test methods are used such as "Sodium Flame" (Eurovent 4/4 and BS 3928) and DOP tests. These methods use test aerosols to determine the efficiency for small particles, typically 0.3 µm diameter.

Notes:

1) There is no direct relation between above test methods.

2) Arrestance and efficiency increases during the life of a filter. All values in manufacturer’s catalogs are average values over the lifetime of the filter.

3) It is strongly recommended not to use filters beyond their specifications and not to exceed the recommended final resistance.

4) DOP= DIOCTYL PHTHALATE

(OILY, HIGH BOILING POINT LIQUID)

13.2.1.4.2 Air flow resistance

a) Resistance to air flow reflects the energy required to force the air through the filter.

b) Resistance values shown in manufacturer’s catalog are for a clean filter at its rated air volume and a recommended final resistance, at which time the filter should either be reconditioned or replaced.

c) Where a system is required to deliver the specified minimum air volume, that portion of the system resistance assigned to the air filter shall be equal to its final operating resistance.

d) Where a constant air volume is desired, it will be necessary to maintain a uniform system resistance by means of dampers or by choosing a constant resistance filter such as electrostatic filter.

13.2.1.4.3 Dust-holding capacity

It defines the amount of a particular type of dust that an air cleaner can hold when operated at a specified air flow rate to some maximum resistance value, or before its arrestance is reduced as a result of the collected dust.

13.2.2 Selection procedures

Filter selection shall be based on the level of clean air required in the occupied areas and the concentration of particulates in the incoming and recirculated air.

When selecting a filter the following procedures shall be considered:

a) The air flow rate for which the filter is designed.

b) The face velocity, which is the average velocity of air (m/s) entering the effective face area of the filter.

c) Resistance; that is difference between static pressure upstream and downstream specified for "clean" and "dirty" conditions when operated at the standard rating.

d) Efficiency; which is generally provided in manufacturer’s catalog, is a measure of the ability of the filter to remove dust from the air and can be calculated from the following formula:

$$N=100\frac{(C_1C_2)}{(C_1)}$$

Where:

N = filter efficiency

C1 = upstream concentration

C2 = downstream concentration

e) Dust holding capacity represents the mass of dust that a filter can retain airflow during a rise in pressure drop from its initial clean resistance to some arbitrary maximum value, usually twice the value of pressure drop when clean.

f) Resistance to fire hazard factor.

13.2.3 Filter types

13.2.3.1 Dust filters

Used as prefilter in areas with severe dust or sand storms, and industrial environments with high concentrations of dry, granular contaminants. These filters may be incorporated with dust louvres operating on principals of inertial separation.

13.2.3.2 Automatic viscous filters

These are self-cleaning multi-duty filters particularly suitable for areas with high dust concentration or as a pre-filter in multi-stage pre-filteration systems.

13.2.3.3 Roll filters

These are automatic renewable media air filter, available in both horizontal and vertical mode. The glass fiber filtering media is automatically fed into the air stream and re-rolled after it has accumulated its dust load. The glass fiber curtain moves intermitantly at pre-determined levels depending upon dust load.

13.2.3.4 Panel (cartridge) filters

13.2.3.4.1 These high efficiency filters are heavy duty low resistance used as primary or prefilters, permanent or disposable type.

13.2.3.4.2 The permanent metal filter shall consist of strips of galvanized woven screen (pleated) can be cleaned in hot water with a detergent. They are used dry for the collection of grease in kitchens or treated with an oil coating to collect dirt by the viscous impingement principle.

13.2.3.4.3 The disposal panel type may consist of fibreglass media, giving primary protection to the conditioned space or used for protecting more expensive secondary filters.

13.2.3.5 *HEPA/ULPA filters

These are Absolute filters designed to remove airborne biological contaminants in hospital critical areas and pharmaceutical processing industries as well as to meet exacting requirements of laboratories, precision manufacturing and microelectronics industries. They are also used when the cleanest air is required such as operating theatres and clean rooms. The filters can have efficiencies upto 99.90% capable to remove down to 0.1 µm of airborne contaminants.

*** HEPA = High Efficiency Particulate Air (Arrestor)**

ULPA = Ultra-Low Penetration Air Filter

13.2.3.6 Bag/bacteria filters

These are medium and high efficiency filter particularly suitable for difficult operating conditions such as variable air volumes, repeated fan shut down, high humidity or intermittant exposure to water.

13.2.3.7 Grease filters

13.2.3.7.1 Used on residential and commercial kitchens, grease filters protect exhaust equipment. When filters are not used in the kitchen, exhaust system grease will collect on the blower wheel and motor with the tendency to deteriorate the insulation on wires.

13.2.3.7.2 Frequently, flash fires originating from cooking operations spread from the store to grease deposits in the exhaust system. Because of the chimney effect created in vertical duct work, in non-filtered kitchen exhaust system, a very intense rapidly spreading fire can engulf the entire system.

13.2.3.7.3 The build-up of extensive grease deposits in out of sight inaccessible locations with efficient grease filters shall be limited to less than 10% .

13.2.3.7.4 Mandatory incorporation of efficient grease filters would create minimum cleaning of grease deposits from the hood’s collection device thus promote and improve safety, sanitation and health standards. Properly designed and selected grease filters shall be able to establish itself on overall effectiveness of any kitchen exhaust system.

13.2.3.8 Paint booth filters

Used on special application of paint shop or similar, for maximum continuous operating temperature upto 100°C (212°F) shall effectively remove all types of paint overspray. It shall protect fan, exhaust ducts, and motors in paint spraying operations, and ensure that clean air is exhausted to the atmosphere. These filters have fire retardent synthetic media complying to DIN 53438, classification F1/K1.

13.2.3.9 Electrostatic air filters (precipitators)

These are based on electronic precipitation, applied both in general ventilating and air conditioning system for capturing dust and fumes at source for cleaning and recirculation. They are used to collect fine dust as well as smoke from air by electrical attraction. This is accomplished by imposing an electrostatic charge of definite polarity on the dust particle through ionization and collecting the charged particles on metal plates of opposite polarity

13.2.3.10 Activated carbon filters

13.2.3.10.1 It is used to effectively remove undesirable gasses and vapors from an airstream. They posess a high affinity in odor control encountered at airports, petrol stations, large car parks, large kitchens, conference rooms and hospitals.

13.2.3.10.2 Each filter housing shall preferably be inclusive of:

- Pre-filter section to hold panel type pre-filter.
- Final filter panels for full flow high velocity carbon filter type.

13.2.3.10.3 The activated carbon filter shall be contained preferably in removable cells constructed of high heat medium impact polystyrene plastic to withstand corrosion. The cells shall contain internal separators to minimize settling of the carbon and shall be capable of being refilled.

13.2.3.11 Lint filter

Used particularly in textiles mills to remove ink mist and paperfly in printing rooms, or to collect miscellaneous fibrous material, thus also reducing static electricity.

13.2.4 Filters with control fan systems

The following recommendations shall be applied to filters installed with central fan systems:

1) Duct connections to and from the filter shall change size or shape gradually to assure even air distribution over the entire filter area.

2) Sufficient space shall be provided in front of or behind the filter, or both, depending on its type, to make it accessible for inspection and service a distance of 40 to 80 cms will be required, depending on the filter chosen.

3) Access doors of convenient size shall be provided to the filter service areas.

4) All doors on the clean air side shall be gasketed to prevent infiltration of unclean air. All connections and seams of the sheet-metal ducts on the clean-air side should be as airtight as possible. Any filter bank must be caulked to prevent bypass of unfiltered air. This is most important when high efficiency filters are used.

5) Electric lights shall be installed in the chamber in front of and behind the air filter.

6) Filters installed close to an air inlet shall be protected from the weather by suitable louvers, in front of which a large mesh wire screen should be provided.

7) Filters, other than electronic air cleaners, shall have permanent indicators to give a warning when the filter resistance reaches too high a value or is exhausted, as with automatic roll media filters.

8) Electronic air cleaners shall have an indicator or alarm system to indicate when high voltage is off or shorted out.

13.2.5 Selection requirements

Failure of air filter installations to give satisfactory results, in most cases, may be traced to faulty installation or improper maintenance or both. The recommended requirements of a satisfactory and efficiently operating air filter installations are as follows:

1) The filter must be of ample size for the amount of air and dust load it is expected to handle. An overload of 10 to 15 percent is regarded as the maximum allowable. When air volume is subject to future increase, a larger filter should be installed.

2) The filter must be suited to the operating conditions, such as degree of air cleanliness required, amount of dust in the entering air, type of duty, allowable pressure drop, operating temperatures, and maintenance facilities.

3) The filter type shall be the most economical for the specific application. The initial cost of the installation should be balanced against efficiency and depreciation as well as expense and convenience of maintenance.

Note:

Economic consideration shall not take into account the initial cost, as a relatively high initial cost may allow for longer life and lower operating costs.

13.3 Dust Collectors

13.3.1 General

Dust collectors are designed for heavier loads from industrial processes, where the air or gas to be cleaned originates in local exhaust systems or process stacks gas effluents. Loading varies from 0.1 to 20 grains or more per cubic foot, making concentrations in dust collectors 100 to 20,000 times greater than that for which air filters are designed.

13.3.2 Selection factors

The dust collectors come in numerous designs utilizing a number of principles and featuring wide variation in effectiveness, first cost, operating and maintenance cost, space, arrangements and materials or construction. Factors influencing equipment selection shall include:

- concentration and particle size of contaminant
- degree of collection required
- characterestics of air or gas stream
- characterestics of contaminants
- method of disposal

13.3.3 Types

13.3.3.1 Electrostatic precipitators

13.3.3.1.1 These high voltage units (low voltage are used for air filteration) are the predominant collector in the high efficiency, high cost group.

13.3.3.1.2 The principle of collection relies on the ability to impart a negative charge to particles in the gas stream causing them to move and adhere to the grounded or positively charged collector plates.

13.3.3.1.3 Most of these units shall be designed for horizontal air flow with velocities of 0.5 to 3 m/s (100 to 600 fpm).

13.3.3.1.4 These units are extensively used in high temperature gas cleaning from equipment such as blast furnaces, open hearth furnaces and central station pulverized fuel boilers.

13.3.4 Fabric collectors

13.3.4.1 These are high efficiency, medium cost collectors, passing air or gas through a fabric at low velocity. The usual fabric is a specially woven cotton, although wool, paper, glass cloth and synthetic fabrics may also be used.

13.3.4.2 Maximum recommended temperature for cotton fabric shall be 82°C (180°F), for wool 93°C (200°F). The synthetic fabrics may be used upto 135°C (275°F) and glasscloth upto 288°C (550°F).

13.3.4.3 Rate of flow through the media varies with collector type, application and dust concentration. Selections shall be limited within 12.7 milibar (5" wg) pressure drop.

13.3.5 Wet collectors

Wet-type of collectors shall have the ability to handle high temperature and moisture-laden gases, eliminating a secondary dust problem in disposal of collected material. In wet collectors the efficiency depends on the energy input per volume of air only and is independent of operating principle.

Notes:

1) For other types of dust collectors reference is made to industrial ventilation published by American Conference of Governmental Industrial Hygienists (ACGIH).

2) Another type of air cleaning device not sourced by ACGIH is through air purification system used for reducing static electricityand eliminating air contaminants of smoke, bacteria particulate, chemical fumes etc. through the method of bi-polar ionization and air scrubber.

14. AIR DISTRIBUTION SYSTEM (DUCTING & AIR OUTLETS)

In the HVAC trade, the air distribution system are accomplished by following means:

- Ductwork
- Air diffusing unit

14.1 Ductwork

14.1.1 The following recommended factor shall be considered in manufacturing ducts:

a) satisfactory air tightness of completed duct ;

b) vibration-free operation;

c) even flow of air without undue pressure loss in system;

d) structural soundness to serve the purpose of conducting the hvac air within the system with a minimum of turbulence, and at levels where comfort will not be reduced within the areas to be ventilated.

14.1.2 Based on the position of the joint or fastening lock the following three basic ways of making a duct shall be considered:

i) The two-piece duct with two corner locks diagonally opposite each other.

ii) The one-piece wrapper with a single corner lock.

iii) The two-piece center lock method-large pieced section, where two locks are placed at the centers of opposite flat sides.

14.1.3 For sheet metal fabrication, the following three method of operations shall apply:

1) Preparing metal in the flat-that is cutting metal to the required size and notching it to a pattern.

2) Forming metal-forming a type of lock seam, cross breaking or bending, or shaping metal to a radius.

3) Final assembly which is final seaming and completion of the sheet metal product.

14.1.4 The fabrication procedures executed in Iran shall be in accordance with SMACNA regulations, using proper ake-offs, duct turning vanes, splitter dampers, smooth transitions long radius elbows as required. The acceptable ethod of duct sizing shall be through any one of the following:

- velocity method (constant and reduction type)
- equal friction method
- static regain method

Notes:

1) The T-method of duct sizing is a 3-step procedure by determining the optional life cost of an HVAC duct system coveringcondensing, selection and expansion which are consequently performed. This method is not recommended for Iran.

2) For additional information on ducting, reference is made to IPS-E-AR-120.

14.1.5 Duct design method

The design of the duct system must take into account the space available, allowable noise levels, duct leakage, thermal and noise insulation, effect of air contaminants on duct materials, fire and smoke control and pressure losses due to friction and turbulence.

14.1.5.1 High velocity method

14.1.5.1.1 The maximum velocity for high velocity method ducting method shall be considered over 12.5 m/s (2500 fpm) and maximum 3" total static pressure. As duct velocity increases, so does duct friction and total pressure.

14.1.5.1.2 Duct construction method shall not differ materially from that of conventional velocity system, but duct fabrication shall be of higher quality. sizing methods used follow the same basic procedures as those for conventional velocity systems, but the low friction methods combined with static regain usually will provide the best results.

14.1.5.1.3 Rectangular ducts require less head room but heavier gage materials than round ducts. In round ducts it is not necessary to increase gage for pressure and velocities less than 5" WG (water gage) and/or 25 m/s (5000 fpm). Round ducts come in fabricated versions in relatively long lengths, with elbows one gage heavier.

14.1.5.2 Low velocity method

14.1.5.2.1 The low velocity method are recommended for ventilation system as they enjoy the following advantage:

- consumption of lower fan energy
- cheaper in first price
- no limitation on space are encountered

14.1.5.2.2 Air distribution through fibreglass ductboard, unplasticised PVC or other suitable options for low velocity ducting shall be applied per engineer’s discretion and availability of material. For maximum duct velocities for low velocity systems reference is made to Attachment 5.

14.2 Air Diffusing Unit

14.2.1 General

14.2.1.1 Diffusion is distribution of air within a space by an outlet discharging supply air in various directions and planes. The function of an air diffusing unit is to introduce treated air into conditioned space.

14.2.1.2 The object of air diffusion is to create the proper combination of temperature, humidity, and air motion in the occupied zone of the conditioned room. To obtain comfort conditions within this zone, standard limits shall be established as an acceptable effective draft temperature .

14.2.2 Types

The following are the recommended types of air diffusing unit classified by their construction features:

a) Grilles and Registers

Generally rectangular, they can be single or double deflection, with adjustable or fixed horizontal/vertical bars, with or without key-operated opposed blade dampers.

b) Ceiling Diffusers

They can be flush-fixed or step-down, rectangular or circular, various air pattern with opposed blade damper. The T-Bar diffusers can be fixed pattern. The perforated types are used in clean rooms and surgical suite.

c) Linear/slot Diffusers

These are suitable for sidewall, sill, ceiling or floor installation, comes in various size and quantity of slots, different bar styles with volume control damper and adjustable air pattern.

d) Plenum/light Troffers

These are designed as plenum channel diffuser and dual side diffusers used with luminaires. They can be used integrated with air handling ceiling systems in single or multi slot, one-way or multi-way air pattern.

14.2.3 Construction

14.2.3.1 The units shall be suitable for heavy-duty application and constructed of either steel, plain or extruded aluminum, baked enamelled finish. The units must be protected by gaskets and designed for acceptable NC ratings.

14.2.3.2 The air balancing accesories such as opposed blade dampers shall be constructed of steel, while the control grid and air turning devices shall preferably be constructed of aluminum.

Note:

All air diffusing units shall be installed with adequately sized moth-proof wooden frame.

14.2.4 Noise criteria

14.2.4.1 While considering the air outlet velocity, drop, rise, spread and throw of the air outlet, top priority shall be provided to the acceptable NC limitation. For recommended outlet velocity and air changes per hour that adresses an acceptable NC rating reference is made to Attachment 6.

14.2.5 Location and selection

14.2.5.1 Design of the air distribution and air diffusion system is influenced by:

- building application
- building and room size
- building construction type
- building interior design
- sources of heat gain or loss
- outlet performance and design
- NC limitations.

14.2.5.2 The location of supply outlets shall be provided on following areas:

-to neutralize any connection currents set up by a concentrated load
- far from the return and exhaust grilles
- below the lighting load

Notes:

1) For selection the most suitable and correctly sized air distributions unit reference is made to manufacturer's catalogs.

2) For more on air diffusion and air diffusing equipment refer to chapters 2 and 32 of ASHRAE 1989 Fundamentals and Equipment Volume.

PART III

APPLICATION GUIDELINES

15. APPLICATION GUIDELINES

15.1 General

The system in which a fan is installed shall be of good quality. This means that the duct system should deliver the air to the fan in a smooth non-turbulent condition so the fan can do its job most effectively. The ductwork away from the fan should provide an unobstructed, low-resistance exit for air leaving the fan.

15.2 AMCA Seal

15.2.1 It is recommended that all fans purchased must bear the AMCA or similar approved international body seal. The seal shows that the equipment's aerodynamic performance has been varified by an independent and objective test and the published certified performance ratings based on the verification test(s) have been calculated properly.

15.2.2 Certified performance shall be based upon one or more of fan test setups described in ANSI/AMCA standard 210-85. These setup represent the types of installations actually used in the real world (site). The resulting aerodynamic performance ratings are therefore definitely achievable in a real world situation.

15.3 Control Rooms

15.3.1 Control rooms are generally air conditioned through the use of all air systems. For durability of instruments and required inside conditions, an effective condition of pressurization shall be employed to maintain a minimum static pressure of 50 pa (5 mm WG) for continuous operation.

15.3.2 Pollutant free non-contaminated air shall be introduced at a minimum of six air changes per hour from accessible locations per AMCA and/or similar European authorities' recommendations.

15.3.3 Balanced pressure relief dampers shall be non-reversible type and employed to vent-off excess air.

15.3.4 All control rooms shall be supported by a back-up emergency power supply appropriate for year-round operation.

15.3.5 A pressure switch sensing room pressure shall incorporate visual and audible arrangements raising an alarm at pressure drop of 25 pa (2.5 mm WG). This switch shall be protected with a time delay relay, adjustable between 5 and 30 seconds allowing response for corrections.

15.3.6 A suitable U-tube mercury filled manometer shall be located in a strategic area of the room in order to correctly measure the inside and outside pressure difference.

15.3.7 In order to provide protection against ingress of liquid, hazardous location and mechanical damage of motors, starters and drives associated with the ventilating and purging equipment, shall be of a configuration suitable for Division 1 area.

15.3.8 To maintain the rigid conditions of IAQ, the enclosed control room shall be leak-proof fully air tight.

15.4 Battery Rooms

15.4.1 Pollutant free non-contaminated air shall be introduced at a rate of fifteen air changes per hour from accessible locations per recommendations of AMCA, or authoritative International bodies.

15.4.2 A mechanical ventilation system shall be provided through centrifugal fans with heavy duty PVC casing and wheel with directly coupled single phase electric motor and speed adjustable between 800 to 1500 RPM.

15.4.3 The exhaust air ducts and exhaust air louvres shall be heavy duty PVC or of hot dip galvanized construction.

15.4.4 The air intake and exhaust shall be installed on the doors, walls, ceiling, etc. preferably diagonally opposite each other.

15.5 Electrical Substations

15.5.1 An effective condition of pressurization shall be employed to provide a continuous minimum static pressure of 50 pa (5 mm WG).

15.5.2 Pollutant free non-contaminated air shall be introduced at a rate of 20 air changes per hour from accessible locations per recommendations of AMCA, or authoritative International bodies.

15.5.3 A hot dip galvanized rain and sand proof external air intake unit shall be provided. The ventilating fan with v-belt or direct drive transmission suitable for 800 to 1450 RPM shall be used. The anti-friction bearing shall be sealed type to operate trouble-free for approximately 30,000 hours. The vibration damper supports under the frame shall be treated with epoxy paint. Pressure louvres and other accessories shall be adequately furnished.

15.6 Kitchens

15.6.1 General

A kitchen ventilation system will function if air requirements are by controlled means. The following four basic air flow pattern are recommended to be established:

a) Air flow between the kitchen and surrounding areas: It is essential that the kitchen operate under a negative pressure in order to prevent the escape of kitchen air into adjacent areas, including dining rooms. Adjacent rooms shall be supplied with positive air make-up to prevent outside air, hot or cold, from infiltrating into these areas. This combined with the negative pressure in the kitchen will maintain the correct flow of air between the adjacent rooms and the kitchen.

b) Air flow within the kitchen: As a rule of thumb the amount of fresh air make-up shall be 75% of the total air being exhausted. This shall be delivered across the room from the ventilator and diffused to all areas of the kitchen by blower action.

c) Air pattern over the cooking equipment and into the ventilator: The blanket of air passing across the cooking surface, must be of sufficient volume and velocity to prevent the contaminated air from the cooking source from escaping into kitchen space.

d) Air flow through ventilator, transition and ductwork: A transition of engineered size must be provided as an integral part of the ventilator, to maintain adequate air flow in both the ductwork and ventilator. These are direct results of blower size and system static pressure.

15.6.2 Commercial kitchens

15.6.2.1 Design criteria

15.6.2.1.1 For proper commercial kitchen design and equipment application, the following factors must be determined:

1) How ventilation air is supplied to the kitchen and how much is required.

2) The fuel source for cooking and its relationship to the ventilation and exhaust needed.

3) Combustion product discharge through the exhaust system.

4) Kitchen make-up air introduction and its use as exhaust.

5) Convective air currents, their production by cooking equipment, and their effect on ventilation and exhaust effectiveness.

6) The need for ventilation and exhaust in relation to the type of cooking process being performed.

7) Kitchen volume, equipment layout, and building design and their role in ventilation and exhaust system design and effectiveness.

8) Filters used with cooking equipment and their resistance to airflow.

9) The manner in which heat, grease, or vapor production associated with cooking processes is classified.

10) Ventilation and exhaust being matched to the type of cooking equipment, food being prepared, and specific hood design.

11) The need for new methods and guidelines for the calculation of ventilation and exhaust requirements based on equipment and the cooking process.

Note:

Based on cooking processes, above design criteria shall be used in determining if a hood and exhaust system are needed for each process.

15.6.2.2 Exhaust system

15.6.2.2.1 The commercial cooking exhaust system design strongly

recommends elimination of prescriptive requirements and replacements by more systems engineering guidance with regulatory acceptance based on effective operation.

15.6.2.2.2 The classification of exhaust rate can be based on various prescriptive standards such as:

- cooking source
- geometry of the hood
- geometry of equipment
- floor area of the kitchen

15.6.2.2.3 The exhaust system shall be such to remove smoke and grease-laden vapors that would pose a life safety problem if unventilated or allowed to be recirculated through the HVAC system. Recommended extract rates for kitchen appliances shall be based on datas mentioned in Table 9.

TABLE 9 - NOMINAL EXTRACT RATES FOR KITCHEN APPLIANCES

EQUIPMENT	AIR EXTRACTION RATES LITRE/S (CFM)	
	PER UNIT	PER m^2 NET AREA OF APPLIANCE
ROASTING AND GRILLING RANGES		
(UNITTYPE)APPROXIMATELY		
1 m SQUARE:	300(636)	300(636)
PASTRY OVENS	300(636)	300(636)
FISH FRYERS GRILLES STEAK	450(934)	600(1270)
GRILLES	250-300(530-636)	450(954)
SALAMANDERS (SPECIAL GRILLES)	450(954)	900(1900)
	450(954)	900(1900)
STEAMINGANDVAPOR PRODUCING:		
BOILING PANS (140-180 LITRE)	300(636)	600(1270)
STEAMERS	300(636)	600(1270)
SINKS (STERILIZING)	250(530)	600(1270)
BAIN-MARIE	200(424)	300(636)
TEA SETS	150-250(318-530)	300(636)

15.6.3 Master kitchen exhausts

15.6.3.1 Master kitchen exhaust systems, including fan, main riser and main ductwork, when connecting multiple exhaust hoods in multiple tenant spaces shall be designed and installed before individual tenants have completed their own (kitchen layout) design.

15.6.3.2 Master exhaust system shall represent over five tenant space to maximize flexibility of the design.

15.6.3.3 Since correlation among exhaust requirements, tenant size and type of food service are unpredictable, based on overage for a group of tenants ranging from 40 to 110m^2 and serving everything from yogurt to kebabs, consider onem^3/hr per m^2 when sizing the main exhaust duct.

15.6.3.4 With five or eight tenant on a system, it is recommended to locate the exhaust riser at one end of the main duct run, rather than in the middle.

15.6.3.5 All ductwork shall be grease and water tight sized at 9 m/s (1800 fpm) that is at 7.5 to 11 m/s (1500 minimum and 2200 fpm) maximum velocity, conforming to National Fire Protection Association (NFPA) bulletin No. 96.

15.6.3.7 In order to prevent excessive pressure drop in the main ductwork and fittings, the number of elbows and transitions shall be minimized by using long radius elbows.

15.6.3.8 Each tenant shall be required to install fire extinguishing system to protect cooking surface hood and ductwork connection to the main duct. Fire protection shall be coordinated by using fire protection at every hood and coordinating extinguishing systems.

Note:

The designer shall review individual tenant designs to ensure that the tenants comply with design criteria.

15.6.4 Kitchen hood

15.6.4.1 General

The purpose of the hood is to capture, as nearly as possible, all the heat, smoke, odors, grease and grease vapors produced in the cooking process and to contain them until the fan can exhaust them.

15.6.4.2 Types of hoods

Hoods may be classified into two basic types:

1) Ventilator or back shelf hood; designed to be as close as possible to the cooking surface, 45 to 60 cm above it.

2) Canopy type hood, which are more widely used, shall have following variations:

a) Canopy-island hood (4-sides exposed), suitable for airflow rate of 762 L/s (150 cfm/ft^2).

b) Canopy-wall hood (3-sides exposed), suitable for airflow rate of 508 L/s (100 cfm/ft^2).

c) Canopy-corner wall hood (2-sides exposed)

d) Canopy-slot type hood (also called double cavity hood).

15.6.4.3 Design procedures

The following recommended simple steps shall be considered for design procedure of a grease filter equipped kitchen exhaust system. (Hood selection procedures are not covered in this Standard):

a) Dimensions of the hoods (including face area).

b) Volume of air to be exhausted.

c) Number of filters required. (The filters shall be able to remove particles of grease which result from splattering or when the vapor cools and condenses).

d) Diameter of the duct from the hood to the point of discharge

e) Resistance against which the blower must exhaust the calculated volume of air. (Contaminated air must be removed from the cooking surface and cooler air must be introduced to cool grease vapors coming off the cooking surface).

f) To maintain the designed velocity, adequate supply of make-up air shall be provided at 1 m/s to 1.5 m/s (200 to 300 fpm) to minimize draft within cooking area.

g) The design must comply with the codes that are in effect.

h) The installation and operating cost must be kept within reason.

15.6.4.4 Duct construction

The recommended considerations to be noted in kitchen exhaust duct construction shall be as follows:

1) The fabricated rectangular ducts shall be as nearly square as possible.

2) The duct should be constructed of 1.20 mm (18 gage) or heavier steel (see NFPA #96).

3) A minimum of 45 cm (18 inches) clearance should be provided from unprotected combustible construction. (Refer to NFPA #96, Appendix B, for clearance from protected construction).

4) All seams and joints shall have a liquid tight continuous external weld.

5) Exhaust ducts from kitchen hoods must be independent and not connected with any other ventilating system.

6) An opening shall be provided at each duct direction change for inspection and cleaning.

7) Vertical risers should be located outside the building and adequately supported by the exterior building wall. When risers must be located within the building, they should be enclosed in a continuous enclosure (see NFPA #96). A base residue trap should be provided on all risers.

8) Exhaust ducts should not pass through fire walls or fire partitions.

15.6.4.5 Filters for kitchen hood

Filter selection and installation shall be based on following requirements:

1) Size of filters shall be selected and number of filters determined from manufacturer’s data.

2) Filters shall be shielded from direct radiant heat.

3) Filters shall be installed 45° to 60° to horizontal at following mounting height: (minimum distance to lowest edge of filter).

a) No exposed cooking flame at 76 cms (30 inches).

b) Charcoal and similar fires at 137 cms (54 inches).

c) Other exposed fires at 107 cms (42 inches)

15.7 Laboratories

Ventilation and exhaust system for laboratories shall depend on type, size, nature of activities and other crucial factors. To meet OSHA requirements laboratories shall be pre-engineered in an environmental enclosures for designated work areas.

Note:

1. Consulting engineers and manufacturers in this field shall be consulted for proper design and adequate ventilation requirements for various type of laboratories.

2. OSHA= Occupational Safety and Health Administration.

15.8 Hospitals

15.8.1 The two principal problems encountered in designing a ventilation system for a hospital are the prevention of cross-infection between wards and keeping the risk of sepsis occurring to a minimum. Sepsis occur when certain bacteria enter a wound.

15.8.2 To prevent airborne bacteria entering a wound, the quality, quantity and the pattern of air movement shall be given careful consideration.

15.8.3 With positive pressure ventilation the average bacterial concentration is reduced to about a quarter of that present with an extract ventilation system.

15.8.4 The regulation of air movement through the entire operation ward (theatre suite) which depends on the functional relation between the rooms, demands the following requirements:

a) the operating suite should be independent of the general traffic and air movement in the rest of the hospital;

b) the rooms of the suite should be so arranged that there is a continuous progression from the entrance, through zones that increasingly approach sterility, to the operating and sterilizing rooms;

c) persons working within the suite should be able to move from one ’clean’ area to another without having to pass through unprotected or traffic areas; thus, the surgeon, after he has changed into his operating suit, should be able to move to the scrub room without passing through the entrance lobby;

d) it should be possible to remove dirty materials from the suite without passing through clean areas;

e) the directions of air flow within the suite should always be from the cleaner to less-clean areas;

f) the heating and ventilating systems should ensure safe and comfortable climatic conditions for the patient, surgeons and other staff.

15.8.5 The highest degree of air purity is a critical requirement in such hospital facilities as operating rooms, delivery rooms and newborn infant care wards.

15.8.6 Because internal organs of the body are exposed to room air during surgical operations the following stringest controls on air contamination shall be applied.

a) restriction of air movement between various departments and control of air movement within certain departments, to reduce the risk of airborne cross infection;

b) a specific need for the ventilation and filteration equipment to dilute and/or remove particulate or gaseous contamination and airborne micro-organisms;

c) close tolerances in differing temperatures and humidities may be required for various areas;

d) the design should allow for accurate control of environmental conditions.

15.8.7 Hospital laboratories handling infectious diseases or viruses, and sanitary accommodation adjacent to wards, shall be maintained at negative pressure in order to prevent exfilteration of air borne contaminants.

15.8.8 In the event of extreme cases the contaminated air shall be first passed through HEPA filters before being exhausted to atmosphere.

Note:

For proper filteration of hospital ward, guidance of suitable manufacturers are strongly recommended.

15.9 Lavatories

15.9.1 Ventilation rates

15.9.1.1 Using mechanical ventilation, a minimum extract rate of 8 air changes per hour or 20 litre/s per WC pan or washhand basin, whichever is greater, is satisfactory to meet the statutory requirements. In the case of public lavatory facilities, it is good practice to increase the extract rate to within the range 10 to 15 air changes per hour. Mechanical ventilation can be operated intermittently on individual systems provided it continuous to run for at least 15 or 20 minutes after usage of space.

15.9.1.2 For sanitary rooms with direct access to outdoor air, natural ventilation requirements are specified as at least one opening with an area of at least 1/20th of the floor area of the room or 0.1 m2, whichever is greater.

15.9.2 Air replacement in ventilated lobbies

15.9.2.1 Replacement air for lavatories in public buildings can be supplied by using common or separate toilet and lobby supply plants, or made up by an air supply totally via the lobby.

The air shall pass into the lavatory preferably through a louvred door or with a no-vision door grille. The replacement air shall be introduced at, or close to the comfort temperature, at a velocity not exceeding 1.5 m/s (300 fpm).

15.9.2.2 The practice of extracting slightly more air than is supplied shall be adopted, thus preventing egress of odors from the toilet area.

15.9.3 Stand-by facilities

Twin fans and/or motors may be required for WC extract systems. Where centrifugal fans are installed, changeover dampers will be required, designed so that the air pressure within the system assists in holding them in position. Automatic changeover facilities may be required in addition to the above.

15.10 Parking Garages

15.10.1 Free air flow across above-ground car parks is to be encouraged, and for natural ventilation, openings in outside walls should have an aggregate area equal to at least 5% of the floor area at each level, and at least half of that area should be in opposite sides.

15.10.2 According to building type between 6 and 10 air changes per hour are recommended, for mechanical ventilation. Extract points should be adequately placed to eliminate pockets of stale air where dangerous fumes could collect. Extract should be from both high and low level, with special attention given to low points and drains. An automatic CO detection system should be used to initiate increased ventilation and raise an alarm when the CO concentration rises above 100 ppm.

15.10.3 Where many vehicle engines are likely to be running simultaneously, e.g. at car park entrances and exits and in vehicle repair centers, it is important to relate the ventilation rate to the rate of pollution generation in the exhaust gases. Generally, carbon monoxide is the most critical pollutant although some of the other exhaust gas constituents, e.g. oxides of nitrogen and hydrocarbons, may need to be taken into account or at least checked. Table 10 gives some indication of the composition of vehicle exhaust from correctly tuned diesel, petrol and liquid petroleum gas (LPG) engines. Concentration several times higher may result from badly tuned or cold running engines.

TABLE 10 - MAIN CONTAMINANTS IN VEHICLE EXHAUST

ENGINE	CARBON MONOXIDE/PPM	OXIDES OF NITROGEN/PPM	HYDROCARBONS/ PPM	ALDEHYDES/PPM
PETROL	20000-50000	600-4000	10000	40
DIESEL	200-4000	200-2000	300	20
LPG	10000-20000	700-800	600	---

15.10.4 In the absence of more specific information, an approximate assessment of the degree of pollution in a confined space can be made assuming the rate of exhaust discharge as 1.2 litre/s per brake horse power.

15.10.5 It is recommended that ventilation rate be designed to maintain a CO level of 50 mg/kg (ppm), with peak levels not to exceed 125 mg/kg (ppm). The American Conference of Governmental Industrial Hygienists recommends a threshold limit value of 50 mg/kg (ppm) for an eight-hour exposure, and EPA has determined that, at or near sea level, a CO concentration of 125 mg/kg (ppm) for less than one hour would be safe. For installations above 1.067m (3,500 ft), far more stringent limits shall be required.

15.10.6 Equation below may be used to determine the necessary ventilation rate. In the case of stationary vehicles, ventilation and energy needs can be substantially reduced by the direct extraction of their exhaust fumes. Specially designed systems are available for this purpose.

$$Q=q\frac{(l \quad C_e)}{C_e \quad C_O)}$$

Where:

- ***Q* =** flow rate of outdoor air litre/s
- ***q* =** release rate of contaminant within the space litre/s
- **C_e**= limiting contaminant concentration within space litre/litre
- **C_o=** concentration of the contaminant in the outdoor air litre/litre

15.11 Industrial Applications

15.11.1 General

15.11.1.1 Control of the industrial environment is necessary for maintaining the efficiency health and safety of workers, for heat control, and for control of gases, vapors, dusts and fumes.

15.11.1.2 Government regulations must be observed with regard to ventilation rates and other requirements for hazardous trades.

15.11.2 Recommended procedure

15.11.2.1 On industrial applications where sensible heat release is less (such as the warm-moist type like in laundries, textile mills, etc.), adequate air movement and necessary engineering shall be provided to limit the high moisture content of the air and reduce heat loss.

15.11.2.2 Industrial exhaust system shall be designed to collect and capture the above contaminants through the provision of a local hood with distribution ducts to convey these contaminants to air cleaning or particle capturing devices.

15.11.2.3 For wood working operations, fuel burning and exhaust gas producing operations, cutting and abrading processes, for welding, burning and soldering, and for chemical operations, an extensive exhaust system shall be designed and provided for absolute control of contaminants.

15.11.2.4 In drying systems, provisions shall be arranged to remove water, or other liquids, from solids, liquids and gases, by the application of thermal methods.

15.11.2.5 Drying process in solids shall be preceded by mechanical separation methods such as filteration, settling, centrifuging etc, thus reduce drying costs. Depending on the continuous rate of drying a solid may initially dry for a ’constant rate period’ followed by a ’falling rate period’.

Note:

Determination of correct temperature and drying time for various thicknesses and types of materials is fundamental to the proper solution of drying problems. Slow drying rates may

be required to avoid shrinkage, cracking and distortion; too rapid drying may harden the exterior of the material and retard subsequent flow of moisture.

15.11.4 Explosion venting

15.11.4.1 Provisions shall be made in dust collection equipment to reduce the risk of property damage and personnel injury where explosive mixtures of dust are anticipated. These collectors' housing shall be capable to contain the considerable pressure rise that results from a vented explosion.

15.11.4.2 For datas on probable maximum pressure that may build up during explosive venting reference is made to NFPA 68-1978.

15.11.5 Exhaust hood

15.11.5.1 The most effective method of preventing a contaminant from entering the breathing zone of a worker is to capture and exhaust them through local hoods. For air volume flow rate equations for hoods and canopies reference is made to Attachment 7 and for industrial hood design data to Attachment 8.

15.11.5.2 As recommended by ACGIH the following selection principles of exhaust hood shall be considered:

a) Location: The hood shall be placed as close to the sources of contaminant as possible.

b) Enclosure: In order to control less air, the operation shall remain enclosed as much as possible.

c) Direction of air flow: The hood shall be located such that the contaminants are removed away from the breathing zone of the occupant or worker.

d) Shape: The hood shall be located and shaped in such a way, that the original velocity will be able to throw away the contaminant into the hood opening.

15.12 Environmental

15.12.1 General

A range of environmental and architectural requirements designed to protect and improve standards of hygiene and safety at work, in line with current awareness and legislation are recommended for the design engineer's awareness and considerations, conforming to BS 5295.

15.12.2 Sound and noise conditioning

15.12.2.1 Speech noise generated in open plan areas disturbs and distracts the office staff attempting to concentrate on their work. Lack of privacy often leads to irritation of mind and causes low work output. Installation of partitions and other acoustic treatments are not feasible.

15.12.2.2 Sound attenuators shall be developed and furnished to provide simple and economic means of improving the acoustic environment in open plan areas and cellular offices. This approach provides salient features to speech privacy spectrum.

15.12.3 Dissection and fume extraction

15.12.3.1 This system shall be conducted in specific areas where there is an awareness of danger from preservative fumes given off by both human and animal organs during pathological and histological dissection and staining.

15.12.3.2 The health and safety authority recommends that the concentration level for formaldehyde should be no more than 2 ppm within a short-term exposure limit of ten minutes. Fumes from xylene and other noxious chemicals should also be given equal considerations.

15.12.4 Incineration

Hygenic disposal of hospital and laboratory waste together with industrial and commercial substances shall be considered and designed to meet the projects special requirements. Proper treatment shall be provided to its exhaust through appropriately designed chimneys.

Note:
For additional information on incinerators reference is made to IPS-G-ME-253.

15.12.5 Fumingation and sterilizing
It shall be provided with units incorporated with gassing, sterilant sprays or ultra-violet system specifically designed for medical pharmaceutical museum and library premises and/or chambers. Design work shall be coordinated with close assistance of an expert.

ATTACHMENTS

(The Attachments are not part of this standard but is included for information purposes only.)

ATTACHMENT 1

ENGLISH TO METRIC CONVERSION CHART FOR BASIC FAN ENGINEERING TERMS

TERMS	ENGLISH UNIT	CONVERSION FACTOR (4)	METRIC UNIT (1)
Volume flow	CFM	0.000472	Cubicmeters/second(m^3/S)
Pressure	Static pressure-inches	0.24836	Kilopascals (kPa)
Power	Brake horsepower	0.74570	Brake kilowatts (bkw)
Tip speed	Feet/minute (fpm)	0.00508	Meters/second (m/s)
Speed (2)	Revolutions/minute(rpm)	0 .01667	Revolutions/second (rps)
Velocity	Feet/minute (fpm)	0.00508	Meters/second (m/s)
Density	Pounds/cu. ft. (lbs./ft ^{3})	16.018	Kilogram/cu.meter(kg/m3)
Temperature(3)	Degrees fahrenheit(°F)	(°F-32) 1.8	Degrees celsius (°C)
Heat	Btu/hour	0.29310	Joules/second (J/s)
Weight	Pounds	0.45359	Kilograms (kg)
Area	Square feet (ft.^{2})	0.0929	Square meter (m^2)
Volume	Cubic foot (ft^3)	0.02832	Cubic meter (m^3)
Dimensions (Linear)	Inches	25.40	Millimeters (mm)
Torque	lbs.-force-inches	0.11298	Newton-meter (n-m)
Moment of inertia	lbs.-ft.^{2}	0.042140	Kilogrammeterssquared(kgm^2)
Stress	lbs./in.^{2}	6.889	Kilopascals (kpa)

Notes:

1) The choice of the appropriate multiple or sub multiple of an SI unit is governed by convenience. The multiple chose for a particular application should be the one which will lead to numerical values within a practical range (i.e. kilopascal for pressure, kilowatts for power, megapascal for stress, and liters/second for volume flow.)

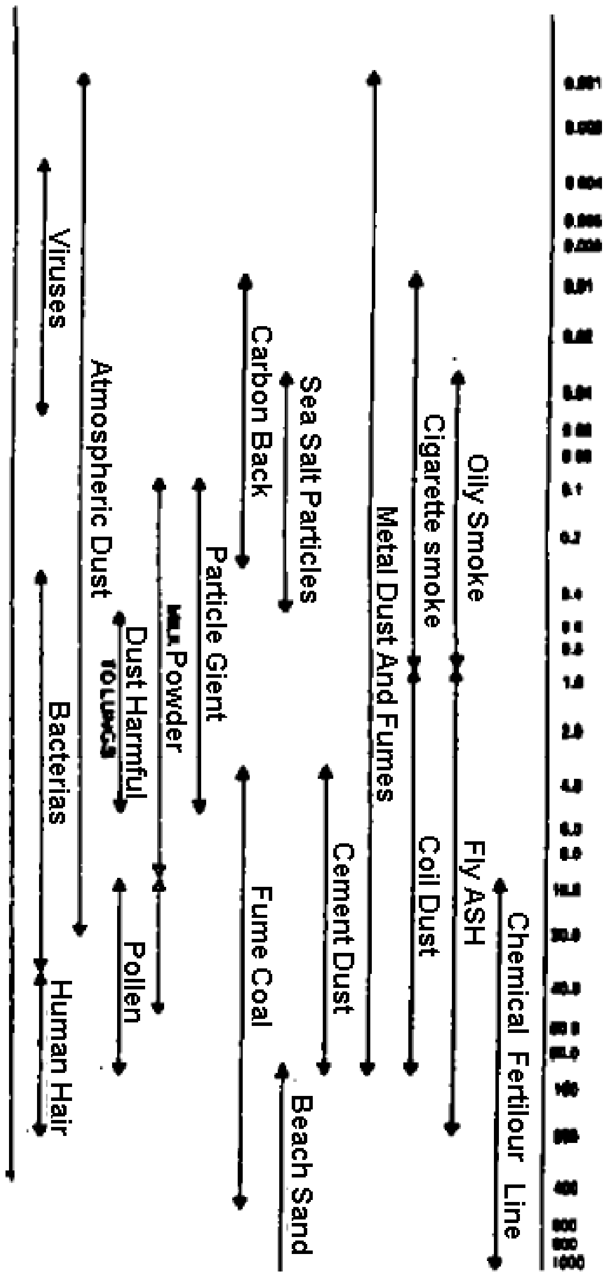
2) The second is the SI base unit of time. Although outside SI, the minute has been recognized as necessary to retain for use because of its practical importance.

3) The kelvin is the SI base unit of thermodynamic temperature and is preferred for most scientific and technological purposes. The degree celsius (°C) is acceptable for practical applications.

4) Multiply "Customary" unit by this factor to obtain AMCA Standard, except for kelvin temperature.

ATTACHMENT 2

IDENTIFICATION AND SIZE OF PARTICLES IN ATMOSPHERE



Note:

A micron is 1/25400 th of an inch. Particles smaller than 10 microns are normally not visible to the naked eye. A figure of 0.001 mm (one micron) divide by 25.4 equals 0.000039 inch.

ATTACHMENT 3
RECOMMENDATION INDOOR DESIGN NC RANGES

1. Private residences	**25 to 30**
2. Apartments	**25 to 30**
3. Hotels/ motels	
a. Individrooms or suites	**30 to 35**
b. Meeting/banquet rooms	**25 to 30**
c. Halls, corridors, lobbies	**35 to 40**
d. Service/support areas	**40 to 45**
4. Offices	
a. Executive	**25 to 30**
b. Conference rooms	**25 to 30**
c. Private	**30 to 35**
d. Open-plan areas	**35 to 40**
e. Computer equipment rooms	**40 to 45**
f. Public circulation	**40 to 45**
5. Hospitals and clinics	
a. Private rooms	**25 to 30**
b. Wards	**30 to 35**
c. Operating rooms	**35 to 40**
d. Corridors	**35 to 40**
e. Public areas	**35 to 40**
6. Churches	**25 to 30**[b]
7. Schools	
a. lecture and classrooms	**25 to 30**
b. Open-plan classrooms	**30 to 35**[b]
8. Libraries	**30 to 40**
9. Concert halls	**b**
10. Legitimate theaters	**b**
11. Recording studios	**b**
12. Movie theaters	**30 to 35**
13. Laboratories with fume hoods	**c**

a) Design goals can be increased by 5 dB when dictated by budget constraints or when nose intrusion from other sources represents a limiting condition.

b) An acoustical expert should be consulted for guidance on these critical spaces.

c) See section on "Laboratory Fume Hood Exhaust" in 1987 ASHRAE Handbook: Systems and Applications.

ATTACHMENT 4

MINIMUM RECOMMENDED FILTER PERFORMANCE

CONDITIONS	PREFILTER	FINAL FILTER
NORMAL DIRT LOADING CONDITIONS	80-85% ARRESTANCE	60-65% EFFICIENCY
GENERALOCCUPIED AREAS (OFFICES, GENERAL VENTILATION AREAS, ETC.)	80-85% ARRESTANCE	60-65% EFFICIENCY
HEAVY DIRT LOADING CONDITIONS (SENSITIVE AREAS)	25-30% EFFICIENCY 25-30% EFFICIENCY	80-85% EFFICIENCY 90-95% EFFICIENCY

ATTACHMENT 5

RECOMMENDED MAXIMUM DUCT VELOCITIES FOR LOW VELOCITY SYSTEMS

APPLICATION	VELOCITY IN m/s	(MAIN DUCTS)* (fpm)
RESIDENCES	3	(600)
APARTMENTS HOTEL BEDROOMS HOSPITAL BEDROOMS	5	(1000)
PRIVATE OFFICES DIRECTORS ROOMS LIBRARIES	6	(1200)
THEATRES AUDITORIUMS	4	(800)
GENERAL OFFICES HIGH CLASS RESTAURANTS HIGH CLASS STORES BANKS	7.6	(1500)
AVERAGE STORES CAFETERIAS	9.1	(1800)
INDUSTRIAL	12.7	(2500)

* Noise generation is the controlling factor.

ATTACHMENT 6

RECOMMENDED AIR OUTLET VELOCITIES (FOR GRILLES, DIFFUSERS ETC.)

APPLICATION	TERMINAL VELOCITY m/s	(FPM)
BROADCAST STUDIOS	1.5-2.5	(300-500)
RESIDENCES	2.5-3.8	(500-750)
APARTMENTS	" "	(500-750)
MOSQUES	" "	(500-750)
HOTEL BEDROOMS	" "	(500-750)
THEATERS		
PRIVATE OFFICES,	" "	(500-750)
(ACOUSTICALLY TREATED)	2.5-4	(500-800)
PRIVATE OFFICES,	5	(1000)
CINEMA	5-6.3	(1000-1250)
GENERAL OFFICES	7.62	(1500)
DEPT. STORES, UPPER FLOORS	10	(2000)
DEPT. STORES, GROUND FLOOR		

RECOMMENDED AIR CHANGES PER HOUR

BANKS & COMPUTER ROOMS	3-5
RESTAURANTS	12-15
TOILET/BATHROOMS/BATTERY ROOM	12-15
LABORATORIES	8-12
DRY CLEANERS/LAUNDERETTES	24-40
WORK CANTEEN/CONTROL ROOM	6-10
HOSPITALS/CLINICS	6-10
SWIMMING POOLS	25-30
CONFERENCE ROOMS	10-12
OFFICES	8-10
DOMESTIC KITCHENS	12-18
LIVING ROOMS	5-8
RETAIL SHOPS	4-6
SUPERMARKETS	8-10
DARK ROOM/X-RAY	10-15
CLASSROOMS	2-4

Note:

To determine the fan capacity, find the space volume in m^3 and multiply it by above air changes to obtain fan extraction capacity. The fan shall be capable to ventilate the occupied space.

ATTACHMENT 7
AIR VOLUME FLOW RATE EQUATIONS FOR HOODS AND CANOPIES

TYPE OF HOOD	AIR VOLUME FORMULA	NOTES
CANOPY (SEE NOTE BELOW)	COLD SOURCE Q= 1.4 PDv	IF D EXCEEDS O.3 B USE EQUATION FOR HOT SOURCE. CANOPY SHOULD OVERHANG TANK BY 0.4 ON EACH SIDE.
	HOT SOURCE, EXPOSED HORIZONTAL SURFACE $Q=0.038\ A_S\ \sqrt{hD} +0.5\ (A\ \ A_S)$	Q IS PROGRESSIVELY UNDER-ESTIMATED AS D INCREASE ABOVE 1m CANOPY SHOULD OVERHANG TANK BY 0.4 ON EACH SIDE
	HOT SOURCE, EXPOSED SIDES AND TOP $Q=0.038A_S \sqrt{\frac{hA_tD}{A_S}} +0.5(A\ \ A_S)$	Q IS PROGRESSIVELY UNDER-ESTIMATED AS D INCREASE ABOVE 1 m. CANOPY SHOULD OVERHANG TANK BY O.4 ON EACH SIDE
PLAIN SLOT	$Q = L_Y (4 \not\subset \sqrt{\frac{X}{W}} + W$ oR $Q = 3.7L_V X$	ASPECT RATIO R SHOULD BE NOT LESS THAN 10 , (0.2 OR LESS)
FLANGED SLOT A=WL (sq.ft)	$Q=0.75\ L_V\ (4 \not\subset \sqrt{\frac{X}{W}} + W$ OR $Q=v\ (10X^2+d)$	ASPECT RATIO R SHOULD BE NOT LESS THAN 10. IF X IS LESS THAN 0.75 W USE EQUATION FOR PLAIN SLOT. (0.2 OR LESS)
PLAIN OPENING A=WL (sq.ft)	$Q = V\ (10\ \sqrt{RX^2} + A\ )$ OR $Q = V\ (10\ x^2 + D\ )$	ASPECT RATIO R NOT TO EXCEED 5. MAY BE USED FOR GREATER ASPECT RATIOS WITH LOSS OF ACCURACY.
FLANGED OPENING	$Q=0.75v(10\ \sqrt{R}\ X^2+A)$ OR $Q = 0.75\ V\ (10\ X^2+A)$	ASPECT RATIO R NOT TO EXCEED 5. MAY BE USED FOR GREATER ASPECT RATIOS WITH LOSS OF ACCURACY. IF X IS LESS THAN 0.75 W USE EQUATION FOR PLAIN OPENING.

SYMBOLS:

A = area of hood/opening m^2
As = horizontal surface area of source m^2
At = total exposed heated surface area of source m^2
B = breadth of source m
D = height above source m
L = length of hood/opening m
P = perimeter of source (work) m
Q = volume flow rate m^3/s
R = aspect ratio (L/W)
W = width of hood/ opening m
X = distance from source m
h = rate of convective heat transfer W/m^2
v = control (capture) velocity m/s

Note:

Where material is or workers must bend over sources, use of canopies are not recommended.

ATTACHMENT 8

INDUSTRIAL HOOD DESIGN DATA (RANGE OF CONTROL VELOCITIES FOR HOODS)

CONDITION OF DISPERSION OF CONTAMINANT	EXAMPLES	CONTROL VELOCITY m/s (fpm)
RELEASEDWITH PRACTICALLYNO VELOCITY INTO QUIET AIR	EVAPORATION FROM TANKS; DEGREASING, ETC.	0.25-0.5 (50-100 fpm)
RELEASEDATLOWVELOCITY INTO MODERATELY STILL AIR	SPRAY BOOTHS; INTERMITTENT CONTAINER FILLING; LOW SPEED CONVEYOR TRANSFERS; WELDING; PLATING.	0.5-1.0 (100-200 fpm)
ACTIVE GENERATION INTO ZONE OF RAPID AIR MOTION	SPRAY PAINTING IN SHALLOW BOOTHS; CONVEYOR LOADING	1.0-2.5 (200-500 fpm)
RELEASED AT HIGH INITIAL VELOCITY INTO ZONE OF VERY RAPID AIR MOTION	GRINDING; ABRASIVE BLASTING, TUMBLING	2.5-10 (500-2000 fpm)

Note:

The higher values apply if: small hoods handling low volumes are used; hoods are subject to draughts; airborne contaminant is hazardous.

APPENDICES

APPENDIX A

SOUND POWER CALCULATIONS

1- The design procedure for calculating sound power levels are based on datas from independent testing facilities.

2- The eight octave bands of the audible frequency spectrum for the sound power levels shall be based on following procedures:

a) Inlet or Outlet Sound Powers

Step 1: The base sound power levels shall proceed as shown below;

OctaveBand	1	2	3	4	5	6	7	8
CenterFrequency	63	125	250	500	1000	2000	4000	8000
BasePowerLevel\(dB)	30	33	42	44	41	38	34	25

Step 2: The volume/pressure correction factor shall be added to each octave band.

Step 3: The efficiency correction shall be added to each octave band as follows:

i) Determine the maximum total efficiency (TE) from manufacturer's table.

ii) Determine the duty total efficiency

$$TE=100\left(\frac{CFM \times SP}{6362 \times BHP}\right)$$

iii) The dB addition to each octave band is calculated as;

$$dB=60\log_{10}\left(\frac{MaxTE}{TE}\right)$$

Or:

Determine the efficiency ratio $\frac{\left(MaxTE\right)}{TE}$ and the Table below shall be used to find the dB add:

EfficiencyRatio	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**1.8**
dB Add	0	2	5	7	9	11	12	14	15

EfficiencyRatio	**1.9**	**2.0**	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	**2.6**	**2.7**
dB Add	17	18	19	21	22	23	24	25	25

Step 4: Based on site altitude add the RPM correction from the table below:

OctaveBand	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Fan Speed:								
3500 RPM	-3	-3	-10	-1	+2	+4	+4	+10
1700 RPM	0	0	0	0	0	0	0	0
1170 RPM	+2	+4	+ 1	0	-3	-2	- 8	- 6
870 RPM	+3	+5	+ 2	-2	-4	-4	-11	- 8
690 RPM	+4	+6	+ 3	-3	-5	-6	-13	-10

Step 5: Where applicable, add the blade correction shown below. This applies where selections

have half the standard number of blades on the rotor.

OctaveBand	1	2	3	4	5	6	7	8
dB Add	+2	+10	+5	+3	+3	0	+2	+3

Step 6: With sound trap fans, add the correction for 'S' construction

S Fan Correction (dB)

OctaveBand	1	2	3	4	5	6	7	8
dB Add	0	-3	-7	-10	-10	-7	-7	-1

b) Radiated Sound Power

Step 7: To determine the radiated noise, add the appropriate corrections to the inlet/outlet noise.

OctaveBand	1	2	3	4	5	6	7	8
w/Osoundtrap	-10	-12	-17	-18	-23	-24	-27	-27
W/S trap	-8	-16	-17	-22	-30	-31	-35	-30

3-The following illustrates the summary for the above calculation method. Inserted figures are examples to indicate how to arrive to these results.

OctaveBand	1	2	3	4	5	6	7	8
CenterFrequency	63	125	250	500	1000	2000	4000	8000
Step 1	30	33	42	44	41	38	34	25
Step 2	+57	+57	+57	+57	+57	+57	+57	+57
Step 3	+1	+1	+1	+1	+1	+1	+1	+1
Step 4	0	0	0	0	0	0	0	0
Step 5	0	0	0	0	0	0	0	0
Step 6	0	-3	-7	-10	-10	-7	-7	-1
TotalInlet/OutletPowerLevel	88	88	93	92	89	85	85	82
Step 7	-8	-16	-17	-22	-30	-32	-35	-30
Total Radiated Power level	80	72	76	70	59	50	50	52