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[CED 12: Functional Requirements in Buildings]

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CODE OF PRACTICE FOR INDUSTRIAL VENTILATION

(First Revision)

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Indian Standard

CODE OF PRACTICE FOR INDUSTRIAL VENTILATION

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 31 December 1975, after the draft finalized by the Functional Requirements in Buildings Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Due consideration should be given to the ventilation requirements in designing factories and industrial buildings. Provision for ventilation becomes necessary for dilution of inside air to prevent vitiation by causes, such as body odours, to remove contaminants in air released during manufacturing processes and to maintain satisfactory thermal enviroments. The application of ventilation should be considered with other measures to control heat given off during industrial processes. Ventilation by natural means may not be sufficient in certain industries to provide such thermal environments as will assist the maintenance of heat balance of the body and to prevent acute discomfort and injury to the health of the workers. In such cases mechanical ventilation and cooling systems, where necessary, may be employed to achieve satisfactory results. Some principles of industrial ventilation are dealt with in this code in order to give guidance to those concerned in this field. In the preparation of this code, the requirements of the Factories Act and Rules thereunder have been taken into consideration.

0.3 This standard covers ventilation of industrial buildings only and was first published in 1965. The present revision was taken up with a view to incorporate necessary provisions regarding control of heat hazards due to various processes in the industry. Some of the significant changes made are given in **0.3.1**.

0.3.1 In this code certain new definitions have been added. The range of recommended capture velocities and the provisions for orientation of buildings have been included. The design considerations for ventilation, provisions for mechanical ventilation have been modified. The requirements for ventilation of buildings, natural ventilation and positive ventilation have also been modified.

0.4 The current practice in this country regarding the threshold limit values for contaminants (*see* **2.21** and **4.5.1**) is to refer to the latest publication of the American conference of Governmental Industrial Hygienists.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers certain basic requirements regarding safe design, installation, operation, testing and maintenance of ventilating systems with respect to general ventilation and wherever appropriate dilution ventilation for industrial process. This standard also briefly describes measures to reduce the heat hazards due to industrial processes.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Air Change per Hour — The volume of outside air allowed into a room in one hour compared with the volume of the room.

2.2 Axial Flow Fan — A fan having a casing in which the air enters and leaves the impeller in a direction substantially parallel to its axis.

2.3 Capture Velocity — Air velocity at any point in front of the exhaust hood necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the exhaust hood.

2.4 Centrifugal Fan — A fan in which the air leaves the impeller in a direction substantially at right angles to its axis.

2.5 Contaminants — Dusts, fumes, gases, mists, vapours and such other substances present in air are likely to be injurious or offensive to the occupants.

2.6 Dilution Ventilation — Supply of outside air to reduce the air-borne concentration of contaminants in the building.

2.7 Dry Bulb Temperature — The temperature of the air read on a thermometer, placed in such a way as to avoid errors due to radiation.

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*Rules for rounding off numerical values (*revised*).

2.8 Exhaust of Air — Removal of air from a building and its disposal outside by means of mechanical device, such as a fan.

2.9 General Ventilation — Supply of outside air either by positive ventilation or by infiltration into the building.

2.10 Humidification — The process whereby the absolute humidity of the air in a building is maintained at a higher level than that of outside air or at a level higher than that which would prevail naturally.

2.11 Humidity Absolute — The weight of water vapour per unit volume.

2.12 Humidity Relative — The ratio of the actual to the partial pressure of the water vapour at the same temperature.

2.13 Local Exhaust Ventilation — Ventilation effected by exaust of air through an exhaust appliance, such as hood with or without fan located as closely as possible to the point at which contaminants are released so as to capture effectively the contaminants and convey them through ducts to a safe point of discharge.

2.14 Make Up Air — Outside air supplied into a building to replace the air removed.

2.15 Mechanical Ventilation — Supply of outside air either by positive ventilation or by infiltration by reduction of pressure inside due to exhaust of air, or by a combination of positive ventilation and exhaust of air.

2.16 Natural Ventilation — Supply of outside air into a building through window or other openings due to wind outside and convection effects arising from temperature or vapour pressure differences (or both) between inside and outside of the building.

2.17 Positive Ventilation — The supply of outside air by means of a mechanical device, such as a fan.

2.18 Propeller Type Fan — A fan in which the air leaves the impeller in a direction substantially parallel to its axis designed to operate normally under free inlet and outlet conditions.

2.19 Spray-head Systems — A system of atomizing water so as to introduce the moisture directly into a building.

2.20 Temperature Rise — Difference of exit temperature and the temperature of air at the inlet openings.

2.21 Threshold Limit Values (TLV) — Refers to air-borne concentration of contaminant and represent conditions, under which it is believed that nearly all occupants may be repeatedly exposed, day after day, without adverse effect.

2.22 Ventilation — Supply of outside air into, or the removal of inside air from an enclosed space.

2.23 Wet Bulb Temperature — The steady temperature finally given by a thermometer having its bulb covered with gauze or muslin moistened with distilled water and placed in an air stream of not less than 4·5 m/s.

3. ORIENTATION OF BUILDINGS

3.1 Solar Load Factors — In the tropics orientation for minimum solar load during summer should be the main criterion. Wherever appropriate, orientation to avoid the solar heat during summer and to take the desirable heat during winter should be preferred.

3.1.1 Wherever possible suitable sun-breakers have to be provided to cut off the incursion of direct sunlight to prevent heat radiation and to avoid glare.

4. DESIGN CONSIDERATION

4.1 General — Ventilation is required to supply fresh air for respiration, to dilute inside air to prevent vitiation by body odours, to remove any contaminants in air and to provide such thermal environments as will assist in the maintenance of heat balance of the body in order to prevent discomfort and injury to health of the occupants.

4.1.1 *Respiration* — Supply of fresh air to provide oxygen for the human body for elimination of waste products and to maintain carbon dioxide concentration in the air within safe limits rarely calls for special attention as enough outside air for this purpose normally enters the areas of occupancy through crevices and other openings.

4.1.2 *Vitiation by Body Odours* — Where no contaminants are to be removed from air, the amount of fresh air required for dilution of inside air to prevent vitiation by body odours, depends on the air space available per person and the degree of physical activity; the amount of air decreases as the air space per person increases, and it may vary from 20 m^3 to 30 m^3 per person per hour. In rooms occupied by only a small number of person such an air change will automatically be attained in cool weather by normal leakage around windows and other openings and this may easily be secured in warm weather by keeping the openings open.

4.1.2.1 *Recommended values for air changes* — No standards have been laid down under the Factories Act (1948), as regards the amount of fresh air required per worker or the number of air changes per hour. Section 16 relating to overcrowding requires that at least 14 m^3 to 16 m^3 of space shall be provided for every worker and for the purpose of that section no account shall be taken of spaces in a work room which is more than 4·25 m above the floor level.

4.1.2.2 The minimum fresh air required in a work room where there are no contaminants to be removed from air, shall be such as to effect at least three air changes per hour.

4.1.3 *Heat Balance of Body* — Specially in hot weather, when thermal environment inside the room is worsened by heat given off by machinery, occupants and other sources, the prime need for ventilation is to provide such thermal environment as will assist the maintenance of heat balance of the body in order to prevent discomfort and injury to health. Excess of heat from a hot environment has to be offset to maintain normal body temperature (37°C). Heat exchange of the human body with respect to surroundings is determined by temperature and humidity gradient between the skin and surroundings, and therefore depends on air temperature (dry bulb temperature), relative humidity (or wet bulb temperature), radiation from the surroundings and air movement. The volume of outside air to be calculated through the room is, therefore, governed by the physical considerations of controlling the temperature, air distribution or air movement.

4.1.3.1 Proper air movement and fresh air supply will reduce heat stress by dissipating heat from body by evaporation of the sweat particularly when relative humidity is high and the air temperature is below or near body temperature. Air movement and distribution may, however, be achieved by recirculation of the inside and/or outside air.

4.1.3.2 In industrial buildings where workers wearing light clothing are expected to do work of moderate severity with the energy expenditure in the range 235 to 330 kcal/h, the maximum wet bulb temperature shall not exceed 29°C and adequate air movement subject to a minimum of air velocity of 30 m/min shall be provided; and in relation to the dry bulb temperature, the wet bulb temperature of air in the work room as far as practicable, shall not exceed to that given in Table 1.

4.2 Control of Heat — Although it is recognised that ventilation is one of the most effective methods of controlling the thermal conditions in factories, in many situations, the application of ventilation should be preceded by and considered along with some of the following other methods of control. This would facilitate better design of ventilation systems and also reduce their cost.

4.2.1 *Isolation* — Sometimes it is possible to locate heat producing equipment, such as furnaces in such a position as would expose only a small number of workers to hot environments. As far as practicable such sources of heat in factories should be isolated.

4.2.1.1 In situations where relatively few people are exposed to severe heat stress and their activities are confined to limited areas as in the case of rolling mill operators and crane operators, it may be possible to enclose the work areas and supply conditioned air to such enclosures.

TABLE 1 MAXIMUM PERMISSIBLE WET BULB TEMPERATURES FOR GIVEN DRY BULB TEMPERATURE

(*Clauses* 4.1.3.2, 4.3.3 *and* 4.3.4)

Dry Bulb Temperature, °C	Maximum Wet Bulb Temperature, °C
30	29·0
35	28·5
40	28·0
45	27·5
50	27·0

Note 1 — The limits indicated in the table are based on the upper safe limits recommended in the report Thermal Stress on Textile Industry (Report No. 17) issued by the Chief Adviser Factories, Government of India, Ministry of Labour and Employment, New Delhi; these are limits beyond which the industry should not allow the thermal conditions to go for more than one hour continuously. The limits are based on a series of studies conducted on Indian subjects in a psychrometric chamber and on other data on heat casualties in earlier studies conducted in Kolar Gold Fields and elsewhere.

Note 2 — Figures given in the table are not intended to convey that human efficiency at 50°C will remain the same as at 30°C provided appropriate wet bulb temperatures are maintained. Efficiency decreases with rise in the dry bulb temperature for a given wet bulb temperatures attained and efforts should be made to bring down the dry bulb temperatures as well, as much as possible. Long exposures to temperature of 50°C dry bulb/27°C wet bulb may prove dangerous.

Note 3 — Refrigeration or other method of cooling is recommended in all cases where conditions would be worse than those shown in this table.

4.2.2 *Insulation* — A considerable portion of heat in many factories is due to the solar radiation falling on the roof surfaces, which in turn radiate heat inside the factories. In such situations, insulation of the roof or providing a false ceiling or double roofing would be very effective in controlling heat. Some reduction can also be achieved by painting the roof in heat reflective shades.

Hot surfaces of equipments, such as pipes, vessels, etc in the factory should also be insulated to reduce their surface temperature.

4.2.3 *Substitution* — Sometimes, it is possible to substitute a hot process by a method that involves application of localised or more efficiently controlled method of heating. Examples include induction hardening instead of conventional heat treatment, cold rivetting or spot welding instead of hot rivetting, etc.

4.2.4 *Radiant Shielding*—Hot surfaces, such as layers of molten metal emanate radiant heat which can best be controlled by placing a shield having a highly reflecting surface between the source of heat and the worker so that a major portion of the heat falling on the shield is reflected back to the source. Surfaces, such as of tin and aluminium have been used as materials for shields. The efficiency of the shield does not depend on its thickness but on the reflectivity and emissivity of its surface. Care should be taken to see that the shield is not heated up by conduction and for this purpose adequate provision should be made for the free flow upwards of the heated air between the hot surface and the shield by leaving the necessary air space and providing opening at the top and the bottom of the sides.

4.3 Ventilation of Buildings — In the case of an industrial building having a significant internal heat load due to manufacturing processes, the following items may be considered when designing for the maximum possible control of thermal environment:

a) Orientation of the building with respect to the direction of the prevailing winds and of the path of the sun in the sky and to the location of adjoining buildings.

b) Configuration of the building and the manufacturing processes in it.

c) Proper inlets (windows and other openings) and their location with respect to outlet openings.

d) Mechanical ventilation including selection and disposition of fans, inlet grilles and arrangement of ducts.

In the case of industrial buildings wider than 30 m, the ventilation may be augmented by roof ventilation.

4.3.1 The volume of air required shall be calculated by using both the sensible heat or latent heat as the basis. The larger of the two figures obtained should be used in actual practice.

4.3.1.1 Volume of air required for removing sensible heat when the amount of sensible heat given off by different sources namely the sun, the manufacturing processes machinery, occupants and other sources is known and a suitable value for the allowable temperature rise is assumed, the volume of outside air to be provided for removing the sensible heat may be calculated from:

$$Q_1 = \frac{3{\cdot}462 \times K_s}{t}$$

where

Q_1 = quantity of air in m³/h,

K_s = sensible heat gained in kcal/h, and

t = allowable temperature rise in °C.

4.3.1.2 Temperature rise refers mainly to the difference between the air temperatures at the outside and at the inlet openings. As very little data exist on allowable temperature-rise values for supply of outside air in summer months, the values given in Table 2 related to industrial buildings may be used for general guidance.

TABLE 2 ALLOWABLE TEMPERATURE-RISE VALUES

(*Clauses* 4.3.1.2 *and* 4.3.4)

Height of Outlet Openings	Temperature Rise
m	°C
6	3 to 4·5
9	4·5 to 6·5
12	6·5 to 11

Note 1 — The conditions are limited to light or medium heavy manufacturing processes, freedom from radiant heat and inlet openings not more than 3 to 4·5 m above floor level.

Note 2 — At the working zone between floor level and 1·5 m above floor level, the recommended maximum allowable temperature rise for air is 2 to 3°C above the air temperature at the inlet openings.

4.3.1.3 *Volume of air required for removing latent heat* — If the latent heat gained from the manufacturing processes and occupants is also known and a suitable value for the allowable rise in the vapour pressure is assumed:

$$Q_2 = \frac{4\,800 \times k_1}{h}$$

where

Q_2 = quantity of air in m³/h,

k_1 = latent heat gained in k cal/h, and

h = allowable vapour pressure difference in mm of mercury.

Note — In majority of the cases the sensible heat gain will far exceed the latent heat gain so that the amount of outside air to be drawn by ventilating equipment can be calculated in most cases on the basis of the equation given in **4.3.1.1**.

4.3.1.4 Ventilation is also expressed as m³/h/m² of floor area. This relationship fails to evaluate the actual heat relief provided by a ventilation system, but it does give a relationship which is independent of building height. This is a more rational approach because, with the same internal load, the same amount of ventilation air, properly applied to the work zone with adequate velocity, will provide the desired heat relief quite independently of the ceiling height of the space, with few exceptions. Ventilation rates of 30 to 60 $m^3/h/m^2$ have been found to give good results in many plants.

4.3.2 *Natural Ventilation* — The rate of ventilation by natural means through windows or other openings depends on:

a) direction and velocity of wind outside and size and disposition of opening (wind action), and

b) convection effects arising from temperature or vapour pressure difference (or both) between inside and outside the room and the difference of height between the outlet and inlet openings (stack effect).

4.3.2.1 *By wind action*

a) Inlet openings in the building should be well distributed and should be located on the windward side at a low level and outlet openings should be located on the leeward side near the top so that incoming air stream is passed over the occupants. Inlet and outlet openings at high level may only clear the top air without producing air movement at the level of occupancy. When outlets serve as inlets, they shall be located at the same level.

b) Inlet openings should not, as far as possible, be obstructed by adjoining buildings, trees, signboards or other obstructions or by inside partitions in the path of air flow.

c) Greatest flow per unit area of openings is obtained by using inlet and outlet openings of nearly equal areas.

d) Where the stream of wind is quite constant and dependable the openings may be readily arranged to take full advantage of the wind. Where the wind direction is quite variable, the openings shall be arranged so that as far as possible there is approximately equal areas on all sides and the openings be located at the same levels. Thus no matter what the wind direction is, there are always some openings directly exposed to wind pressure and others to air suction and effective movement through buildings is assured.

4.3.2.2 *By stack effect* — Natural ventilation by stack effect occurs when air inside a building is at a different temperature than air outside. Thus in heated buildings or in buildings wherein hot processes are carried on and in ordinary buildings during summer nights and during premonsoon periods, the inside temperature is higher than that of outside, cool outside air will tend to enter through openings at low level and warm air will tend to leave through openings at high level. It would, therefore, be advantageous to provide ventilators as close to ceilings as possible. Ventilators can also be provided in roofs as, for example, cowl, ventipipe, covered roof and ridge vent.

4.3.3 *Mechanical Ventilation, General* — Where adequate air changes specified in recommended values for air changes or for providing thermal environment within the limits specified in Table 1 whichever is higher, cannot be obtained by natural ventilation, mechanical ventilation either by exhaust of air or by positive ventilation or combination of the two shall be provided, and in case of positive ventilation where necessary, air before being brought into the area of occupancy, may be cooled by evaporative cooling or by air-conditioning.

4.3.3.1 *Exhaust of air* — Exhaust fans are provided in walls on one side of the building or in the attic and roofs to draw large volumes of air through the building. These fans are usually of propeller type since they operate against little or no resistance. It is important that windows and other openings near the fans are kept closed as otherwise the fans would draw outside air from these openings and cause what is termed as 'short-circuiting'. Adequate inlet openings shall be provided on opposite side of the building so as to limit inlet velocities. When fans are centrally located on an attic or other unused space and arranged to draw proportionately from several work areas or from exhaust appliances with duct work, these are predominantly centrifugal type or sometimes axial types so as to overcome the resistance from duct work.

4.3.3.2 *Positive ventilation* — Positive ventilation is provided by centrally located supply fans which are usually of centrifugal type having a wide range of capacities and quiet operation. Considerable advantage may be achieved by incorporating the ducts into the building structure and by having the interior surfaces carefully finished to render them smooth and air-tight and treated to prevent the possibility of dust being scoured from the walls by the passing air. Unit ventilators may be provided for individual rooms and may be placed against outside wall near the central line of the room. Both central system and unit ventilators could be equipped to provide, besides the function of ventilating, cooling by evaporative cooling coils. Typical installations are equipped with systems of controls that permits ventilating and cooling effect to be varied, while the fans are operating continuously, in accordance with the room requirements.

4.3.3.3 *Combined systems* — The combined systems with positive ventilation and with exhaust of air have the advantage of providing better control conditions and better distribution of air over the entire area of occupancy particularly in wider buildings. By supplying proper volumes of air at suitable velocities at the required areas through duct work and by extracting the air in the return ducts and recirculating this air after properly mixing it with cool fresh air, completely satisfactory ventilation is obtained. In a combined system it is preferable to provide slight excess of exhaust if there are adjoining occupied spaces and a slight excess of supply if there are no such spaces. Unit exhaustors can also be used to match unit ventilators' exteriors and located along the outside wall.

4.3.4 *Evaporative Cooling* — In regions where high day-time temperatures prevail with reasonably low humidities, evaporative cooling may be employed effectively to lower the temperature of the air to near the wet bulb temperature and produce an air supply cool enough to take care of the indoor sensible heat loads without exceeding the upper safe limits given in Table 1 or the temperature rise values at area of occupancy given in Note 2 in Table 2. By positive ventilation this air may be supplied to produce cooler environments with lower air volume than would be required under **4.3.1.1.** The amount of air required as greater temperature rise than given under Table 2 may be tolerated. Although the relative humidity of supply air will be increased but due to the large sensible heat loads the resultant relative humidity of the air will be sufficiently lowered after mixing with the inside air to produce body cooling.

4.3.4.1 Evaporative cooling with positive ventilation using a central plant consisting of a water spray chamber and a fan to supply outside air into the work room through a distribution duct is far preferable to spray head system which only humidifies the air, the cooling capacity of the air will be very little improved; and none of the air which absorbs the heat given off by machinery, manufacturing processes and occupants, is removed from the building under these conditions.

4.3.4.2 Evaporative cooling is generally used where humidification is necessary to meet the requirements of manufacturing processes in factories, as for instance, in a cotton mill to keep the textile fibres pliable and strong in a rubber factory to prevent static electricity in processes using volatile and inflammable solvents or in printing and lithographic works to maintain accurately the size of the paper and other materials.

4.3.4.3 Where humidification or dehumidification is necessary to meet the requirements of manufacturing processes, the requirements shall be ascertained from the clients. In respect of cotton spinning and weaving factories, attention is drawn to the requirements regarding temperatures and humidities under relevant rules framed by the State Government under Section 15 of the Factories Act (1948).

4.3.5 *Air-Conditioning* — Where the desired temperatures and humidities cannot be obtained by mere ventilation, air conditioning may be resorted to (*see* IS : 659-1964* and IS : 660-1963†).

4.3.5.1 When refrigeration is employed to obtain desired temperature inside a work room it may be necessary to circulate more air than that required for ventilation purposes alone, and in that case, part of the air may be recirculated to save refrigeration.

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*Specification for safety code for air-conditioning (*revised*).

†Specification for safety code for mechanical refrigeration (*revised*).

4.3.5.2 The proportion of recirculated air will depend on the circumstances but the quantity of fresh air taken in shall not be less than that laid down under **4.1.2.1** or that required as make-up air to replace the air exhausted for control of air contaminants (*see* **4.5**) whichever is higher.

4.3.6 Fresh air shall be free from organic matter and deleterious inorganic dust and fume, and should be drawn from areas where the air is not likely to be polluted or vitiated; where necessary, the air should be efficiently filtered.

4.4 Air Distribution — In providing ventilation, proper consideration should be given to size and distribution of windows and other inlet openings in relation to outlet openings arrangement of ducts and selection and disposition of fans and air intake grilles so as to give, with due regard to orientation, prevailing winds, configuration of the building and manufacturing processes carried on, maximum possible control of thermal environments in the work rooms. Air should be distributed evenly without dead air pockets or undue draughts caused by high inlet velocities. When ventilation is provided by infiltration due to exhaust of air, it is important that windows and other openings near the fans are kept closed as otherwise the fans would draw outside air from these openings and cause what is termed 'short circuiting'.

4.4.1 *Air Movement* — The rate of air movement in the vicinity of workers shall be such as to give reasonable comfort without objectionable draughts. In general, velocity of air excess of 60 m/min should be avoided unless the temperatures and humidities are high.

4.4.1.1 Where heavy manual work is performed by workers, a greater degree of air movement may be desirable depending upon the temperature and humidity of air. When the nature of the manufacturing processes demands conditions of temperature and humidity which are above the normal range of comfort, the question of rate of air movement requires critical examination, particularly if the dry bulb temperature is above that of body. If the air is capable of absorbing heat from the body a blast of air up to 300 m/min may be directed at the workers for velocity cooling.

4.5 Ventilation for Control of Air Contaminants

4.5.1 *Local Exhaust Ventilation* — When in a work room by reason of manufacturing processes contaminants are given off, it shall be necessary to provide an efficient local exhaust ventilation of the points at which the contaminants are released to reduce their concentration in the working area below Threshold Limit Values (TLV) (*see* **0.4**). Such points shall, as far as possible, be enclosed, but if it is necessary to have an access while the manufacturing processes are carried on, the exhaust appliance shall confine the contaminants as much as possible and openings for access shall be located, wherever possible, away from the natural path of the contaminants travel.

4.5.1.1 When an exhaust appliance is provided to enclose the point at which contaminants are released, the volume of air required is calculated from the area of openings and the capture velocity sufficient to prevent outward escapement. In other cases, the volume of air required and pattern of air flow in front of the exhaust appliance shall be such that the capture velocities necessary to overcome air currents and convey the contaminants by causing the air recommended capture velocities are listed out in Table 3.

TABLE 3 RANGE OF RECOMMENDED CAPTURE VELOCITIES

Sl No.	Condition of Dispersion of Contaminant	Examples	Capture Velocity
(1)	(2)	(3)	(4)
			m/s
i)	Released with practically no velocity into quiet air	Evaporation from tanks degreasing etc	0·25-0·5
ii)	Released at low velocity into moderately still air	Spray booths; intermittent container filling, low speed conveyor transfers; welding; plating; pickling	0·5-1·0
iii)	Active generation into zone if rapid air motion	Spray painting in shallow booths; barrel filling; conveyor loading; crushers	1·0-2·5
iv)	Released at high initial velocity into zone of very rapid air motion	Grinding: abrasive blasting, tumbling	2·5-10

4.5.1.2 The sizes of the ducts shall be determined considering the volume of air required and duct velocities necessary to convey the contaminants with minimum possible static resistance consistent with the economics of installation and operation. Fan shall be of such type and size as to move the required volume of air and overcome the total resistance of the local exhaust ventilation system including the air cleaning devices.

4.5.2 *Dilution Ventilation* — Dilution ventilation is employed to reduce the concentration of contaminants in the working area below the Threshold Limit Values (TLV) when the contaminants are of low toxicity with TLV above 100 ppm (parts per million by volume) and the quantity of contaminants generated is not high (such as vapours given off by organic solvents of low toxicity). However, dilution ventilation is not as satisfactory for control of air contaminants as is local exhaust ventilation.

4.5.2.1 The exhaust outlets and the air supply inlets shall be so located that air passes through the zone of contamination with the points at which the contaminants are released between the worker and the exhaust outlets. The workers should not stand too close to the zone where contaminants are released.

4.5.2.2 If the rate of vapour generation of rate of liquid evaporation is known, the dilution air requirements is calculated from:

$$\text{Air required in m}^3\text{/kg of evaporation} = \frac{24 \times 10^6 \times k}{\text{molecular weight of liquid} \times TLV}$$

where

k = constant varying from 3 to 10 depending on solvent in question, uniformity of air distribution, dilution of vapours in air, location of exhaust plant and its proximity to evolved vapours, and

TLV = Threshold Limit Value of the solvent

4.5.3 *Make-Up-Air* — Sufficient make-up-air shall be brought into the work room by natural infiltration or by positive ventilation at suitable points in relation to the exhaust points to replace the air exhausted by local exhaust ventilation or by dilution ventilation, and the air may be efficiently filtered or treated, when necessary.

5. INSTALLATION AND OPERATION

5.1 Location — Fans and other equipment may be located in convenient positions considering the intake of fresh air, accessibility for maintenance and noise control.

5.1.1 Where the exhaust of air laden with inflammable dusts, gases or vapours is conveyed through ducts, the electric motor and fan shall be situated outside in such a way that an explosion will not vent into the work room. The fan should be of non-sparking construction and the motor, if not located outside the air stream, should be of flame proof construction.

5.2 Ducts — Where positive ventilation requires ducts for proper air distribution considerable advantage may be achieved by incorporating the ducts into the building structure and by having the interior surfaces carefully finished to render them smooth and air-tight and treated to prevent the possibility of dust being scoured from the walls by the passing air. For removal of corrosive or dust laden contaminants, ducts shall be protected against corrosion and erosion and shall be installed for easy inspection, maintenance, repair and replacement.

5.2.1 Where metal duct work is installed, it shall conform to IS : 655-1963*.

*Specification for metal air ducts (*revised*).

5.3 Noise — Where in a work room owing to the nature of manufacturing processes carried on, noise supression is important, close attention shall be given to the design and installation of motors, fans and ducts to ensure quite operation and to minimize transmission of noise.

5.4 The performance of ventilating equipment, such as fans and filters, over a period of years is considerably influenced by the extent of the initial provision of facilities for its efficient operation and maintenance. The following points shall be borne in mind:

a) Adequate access for inspection, cleaning and repair of component parts;

b) Reasonable space during operation;

c) Location of dampers and other operating controls in such a position as would permit quick and easy operation; and

d) Adequate lighting and ventilation at places where the equipment is to be operated and maintained.

6. TESTING

6.1 All parties concerned shall agree to the objects of test, methods and duration of test, degree of accuracy required and state of ventilating equipment under test. The plant should be run during normal working hours and adjusted properly prior to the test.

6.2 Amount of Air

6.2.1 *Positive Ventilation* — The volume of outside air by positive ventilation shall be measured by appropriate instruments, such as a properly calibrated, 'anemometer', velocity meter and pitot tube. To measure the average velocity of air flow, it is necessary to make a traverse of the instrument over the cross-sectional area of the intake openings or ducts and obtain the average velocity from these results. The volume of air is given by:

$$Q = AV$$

where

Q = volume of air in m³/min,

A = free area of intake openings of ducts in m², and

V = average velocity of air in m/min.

6.2.2 *Exhaust of Air* — The volume of exhaust air shall be measured in the same manner as in the case of positive ventilation by measurement of air velocity and area of exhaust ducts or openings, and multiplying the one with the other.

6.2.3 *Natural Infiltration* — This is difficult to measure as it varies from time to time. The amount of outside air by natural infiltration through doors or windows or through other openings depends on direction and velocity of wind outside and/or convection effects arising from temperature of vapour pressure difference (or both) between inside and outside of the work room.

6.2.3.1 Ventilation due to wind outside is given by the formula:

$$Q = EAV$$

where

Q = volume of air in m³/min;

A = free area of inlet openings in m²;

V = velocity of wind in m/min; and

E = co-efficient which varies from 0·5 to 0·6 when openings face wind, and 0·25 to 0·35 when openings are at an angle.

6.2.3.2 Ventilation due to convection effects arising from temperature difference between inside and outside is given by:

$$Q = 7{\cdot}0\ A\sqrt{h\ (t_r - t_o)}$$

where

Q = volume of air in m/min;

A = free area of inlet openings in m²;

h = vertical distance between inlets and outlets in mm;

t_r = average temperature of indoor air at the outlet, in °C; and

t_o = temperature of outdoor air in °C.

NOTE — The equation is based on 0·65 effectiveness of openings. This should be reduced to 0·50 if conditions are not favourable.

6.2.3.3 When areas of inlet and outlet openings are unequal, '*A*' given in equations under **6.2.3.1** and **6.2.3.2** will be the smaller area and the volume of air will be increased according to the percentage given in Fig. 1.

6.2.3.4 Ventilation by combined effect of wind outside and temperature difference may be evaluated as follows:

a) Calculate the amount of outside air by methods given under **6.2.3.1** and **6.2.3.2**,

b) Express the amount of air due to method **6.2.3.2** as a percentage of the total, and

c) Use Fig. 2 to determine actual flow caused by the combined effect of both.

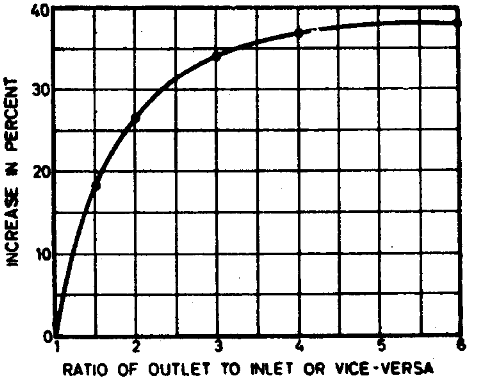

FIG. 1 INCREASE IN FLOW CAUSED BY EXCESS OF ONE OPENING OVER ANOTHER

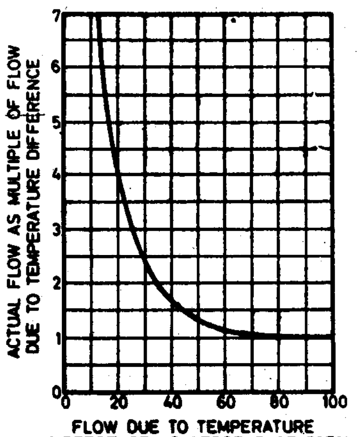

FIG. 2 DETERMINATION OF FLOW CAUSED BY COMBINED FORCES OF WIND AND TEMPERATURE DIFFERENCE

6.2.4 *Combined Effect of Different Methods of Ventilation* — When combination of two or more methods of general ventilation is used, the total rate of ventilation shall be reckoned as the highest of the following three:

a) rate of positive ventilation (*see* **6.2.1**),

b) rate of exhaust air (*see* **6.2.2**), and

c) 1·25 times the rate of natural infiltration (*see* **6.2.3**).

This rule shall be followed until an exact formula is established by research.

6.3 Air Movement — Turbulent air movement at the working zone may be measured either by Kata thermometer (dry silvered type), heated thermo anemometer or properly calibrated thermocouple anemometer. Kata thermometer and heated thermometer give cooling power rather than the velocity of air, and the rate of air movement is found out from the cooling power by reference to a nomogram using the ambient temperature.

6.4 Tolerances — The rate of air flow as measured in the duct or at a grille either by positive ventilation or exhaust of air shall be within 10 percent of the amount required.

6.4.1 Variation of air flow through filters and grilles shall not at any time be more than $\pm$ 20 percent of the mean value.

7. MAINTENANCE

7.1 All ventilating equipment shall be checked periodically and bearings of various moving parts lubricated. The equipment shall also be tested for air delivery. Such tests shall be made at least once in a year.

7.2 The surfaces of any cooling or heating units and air cleaning devices (including filters) shall be inspected at frequent intervals for corrosion and dirt and when corrosion occurs the corroded parts shall be carefully cleaned and protected with anti-corrosion paint or other suitable medium. Cleaning of filters and heat transfer units shall be carried out regularly to promote their efficient use.

8. SAFETY REQUIREMENTS FOR ELECTRICAL EQUIPMENT

8.1 Electrical Equipment — Electrical wiring and installation of electrical equipment shall be in accordance with the requirements of Indian Electricity Act and Rules and shall also conform to IS : 732-1963* and IS : 2274-1963† as applicable.

8.2 Fire Safety — Due consideration shall be given to the fire safety aspects as given in IS : 1646-1961‡.

*Code of practice for electrical wiring installations (system voltage not exceeding 650 volts) (*revised*).

†Code of practice for electrical wiring installations (system voltage exceeding 650 volts).

‡Code of practice for fire safety of buildings (general) electrical installations.

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