CHAPTER 2
VENTILATION SYSTEM DESIGN

1. NEED OF VENTILATION

- To provide a continuous supply of oxygen necessary for human existence.
- To remove contaminants such as:
  - Carbon dioxide
  - Water vapour
  - Heat and smells from cooking
  - Gases and vapours from industrial processes
  - Odor

2. VENTILATION DESIGN PRINCIPLES

When considering ventilation design the following approach could be adopted before sizing begins and the following questions should be considered:

1. What areas need ventilation?

   The contaminants should be listed for these areas.

2. What type of system should be used, supply, extract or balanced?

3. Are there any alternative systems to consider?

4. Is air conditioning necessary in the building?

- If air conditioning is necessary then should it be incorporated into the ventilation system?

Ventilation Design (Continued)

5. Where should the fan(s) shallbe installed?
6. What type of fan(s) and plant should be used?
7. Is a separate heating system necessary?
8. What type of control system should be used?
9. What type of air distribution system should be used, upward or downward?
10. Have I considered what will happen in the event of a fire in the building?
11. Have I considered the noise from fans?e

Sizing Procedure

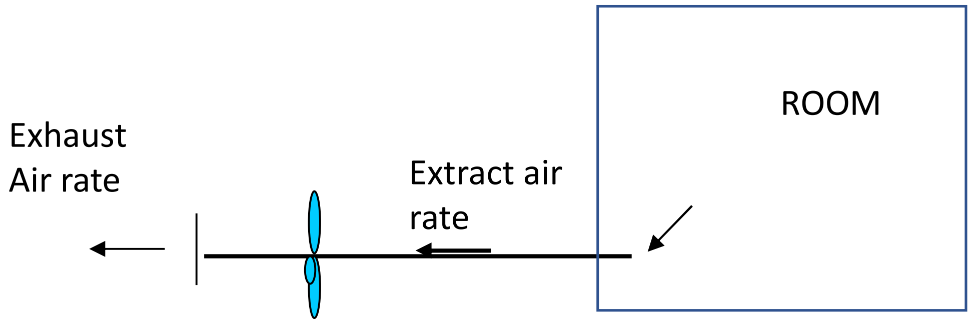
1. Calculate Ventilation rates.
2. Decide on number of fans and grilles/diffusers.
3. Draw scale layout drawing:
   - Position fan(s).
   - Lay out ductwork.
   - Lay out grilles and diffusers.
   - Indicate flow rates on drawing.
4. Size ductwork
5. Size fan
6. Size grilles and diffusers.

Design Criteria

To design a ventilation system, the engineer has to meet two basic requirements by selecting the type of ventilation system and ventilation rate:

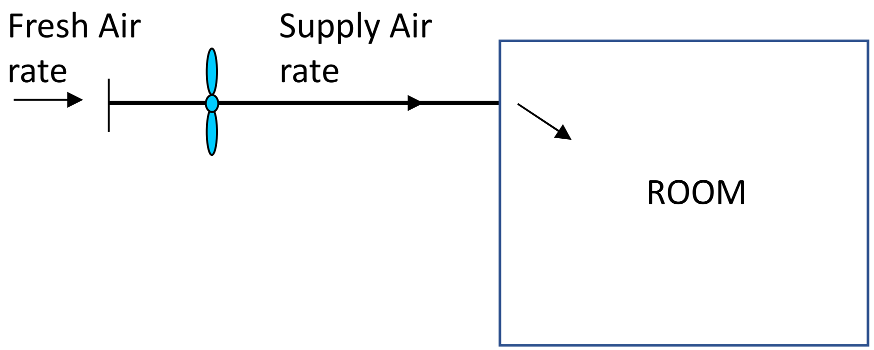
- To change the air in the room sufficiently so that smells, fumes and contaminants are removed.
- To supply fresh air for the occupants.

a) Extraction System



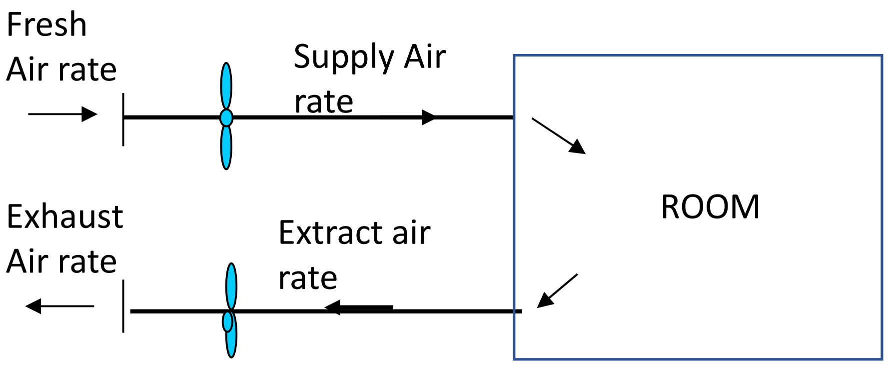
- Pressure in the room is below surrounding
- Fresh air is drawn into the room through openings

b) Supply System



- Pressure in the room is above surrounding
- Used air is exhausted from the room through openings

c) Balanced Ventilation with no Recirculation



- Pressure in the room can pressurized by making supply greater than exhaust
- Fresh air is drawn and Used air exhausted from the room by fan

Ventilation Rate Calculation

Ventilation rate (m^3/h)=Air Change Rate (/h) x Room Volume (m^3)

Air Change Rate (/h) comes from Standards

Ventilation rate (m^3/s) = Ventilation rate (m^3/h) / 3600

Fresh Air Ventilation Rates

Fresh Air Rate (m^3/s) = Fresh Air rate per person ($l/s/p$) x number of occupants s

Recommended outdoor air supply rates fas per ES

Type of building/Occupancy	Minimum outdoor air supply air-change/h
Office	6
Restaurant, canteens	10
Shops	6
Workshop, factories	6
Classrooms	8
(i)Car parks	6
(ii)Toilets, bathrooms	10
(iii)Lobbies, concourse, corridors, staircases and exits	4
Kitchens (commercial, institutional and industrial)	(iv)20-60

3. SYSTEM LAYOUT

Sin lay-ot of ventilation systems thefollowing guide has to be observed

- fans are often better than one since its makes the ventilation system more flexible.
- Also the air to be supplied or removed may be in different areas of a room or building where individual fans can be more effective.
- The number of grilles or diffusers may depend on the ceiling layout, lighting layout and amount to air to be transferred.
- Sometimes it is necessary to complete a preliminary grille size to decide on the final number in a room.

System Layout (continued)

- Accurate, scaled plan drawings are necessary for installation, fabrication, estimating and commissioning a ventilation scheme.
- Sometimes elevations, sections and details are also necessary especially in complicated installations.
- Drawings should show:
  1. Flow rates of air.
  2. Ductwork to scale with sizes indicated.
  3. Air flow direction
  4. Items of plant
- Other details such as;, support details, fan specification, grille and diffuser details, louvre details, plant details, insulation, ductwork specification may be given on a drawing or in a specification document.

Layout

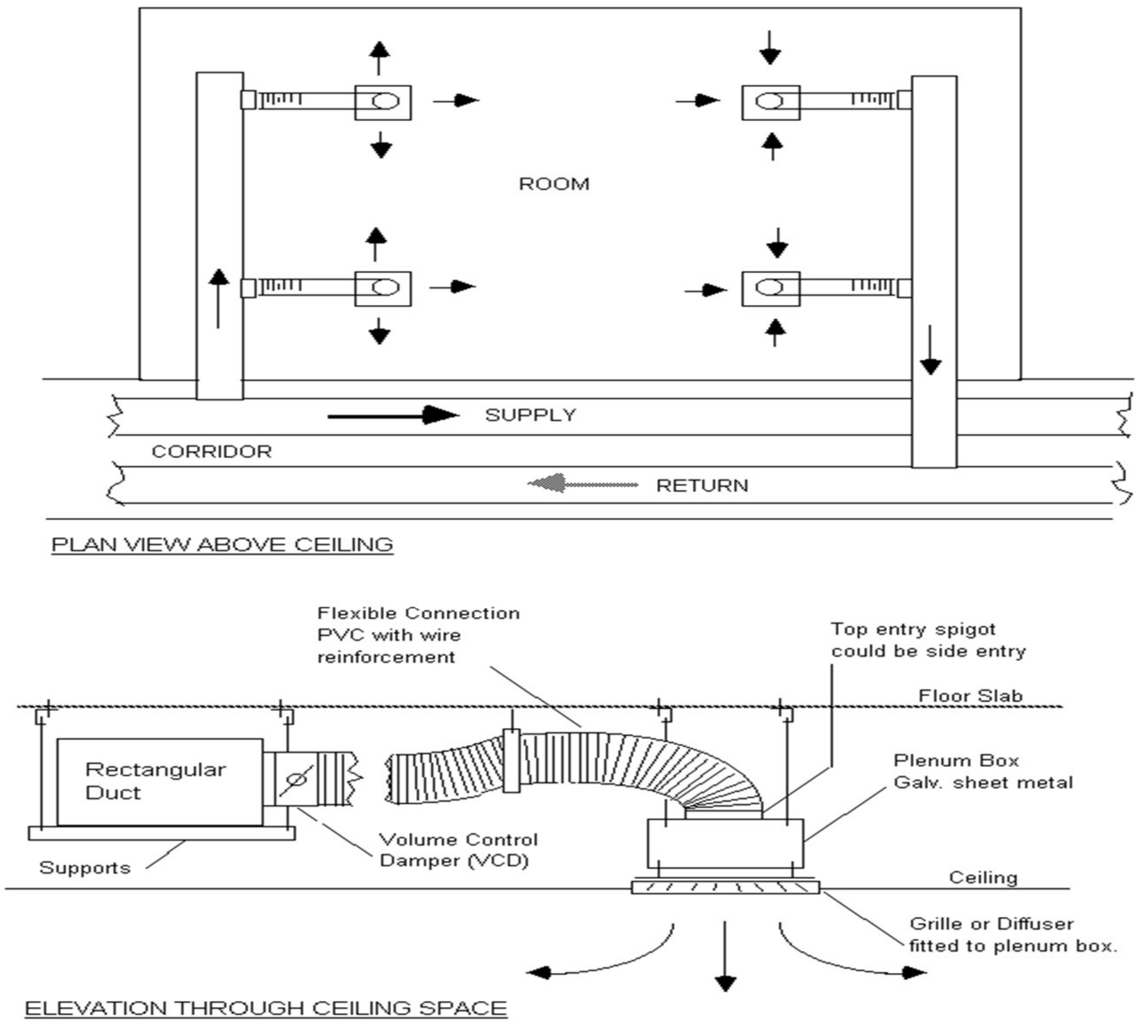


FIG. 1 TYPICAL VENTILATION SYSTEM LAYOUT (SUPPLY & RETURN WITH GRILLES)

4. AIR DISTRIBUTION

- Air distribution in a large hall poses some difficulties which must be addressed.
- The object of good air distribution is to allow air to be supplied to all parts of the room to avoid draughts
- This means that all the areas in a room should have the benefit of cool air if required or warm air if required. Also all occupants should have a supply of fresh air.
- In an air conditioning system cool air may be supplied at high level and allowed to drop to low level to be extracted.

6. CONTROL OF VENTILATION SYSTEMS IN THE EVENT OF A FIRE

It is important in large buildings to control a ventilation system in the event of a fire. Smoke from a fire can spread quickly through a building and this spread of smoke can be assisted by the ductwork system if incorrectly designed. Some of the strategies to prevent spread of smoke are as follows;

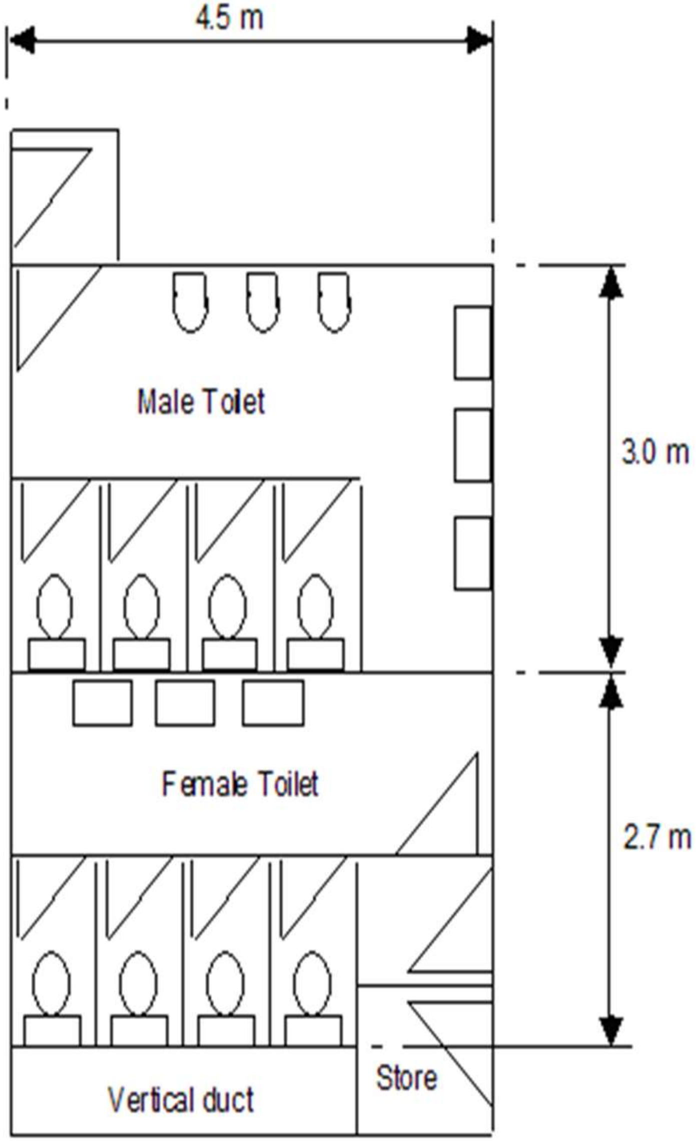
- Switch off all fans automatically when a fire alarm control panel is activated.
- Provide ductwork fire dampers between fire zones and provide a system of automatic closure of dampers.
- Fire stop all holes around ductwork.
- Provide smoke roof vents.
- Provide pressurising fans.
- Providing smoke extract fans.

7. TOILET VENTILATION DESIGN

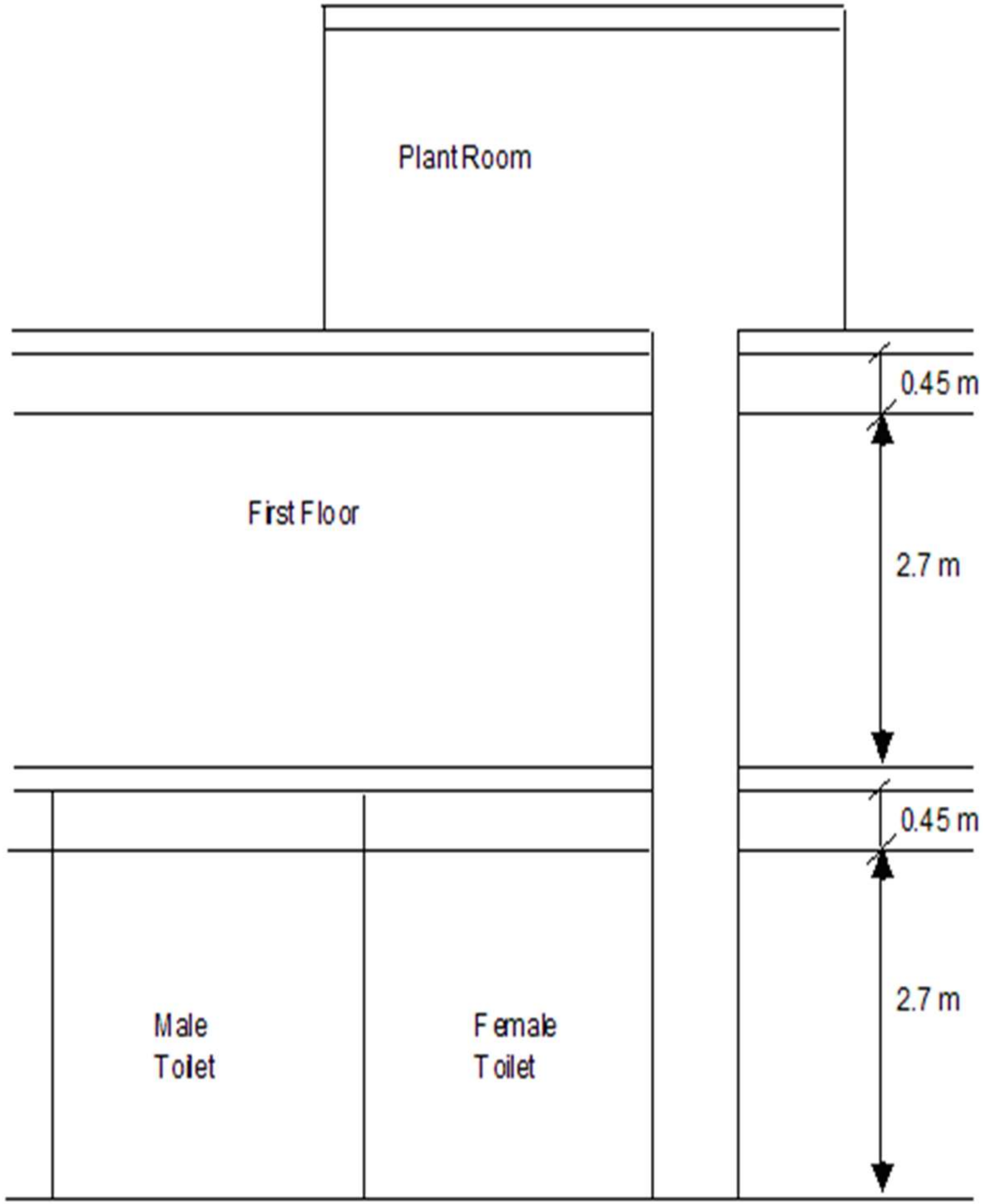
- The volume of the Male Toilet is: 4.5 x 3.0 x 2.7 m = 36.45 m^3
- The ventilation rate in m^3/h is:
- **Ventilation Rate (m^3/h) = Room volume (m^3) x air change rate (ac/h)**

- **Ventilation Rate (m^3/h) =** 36.45 m^3 x 10 AC/h

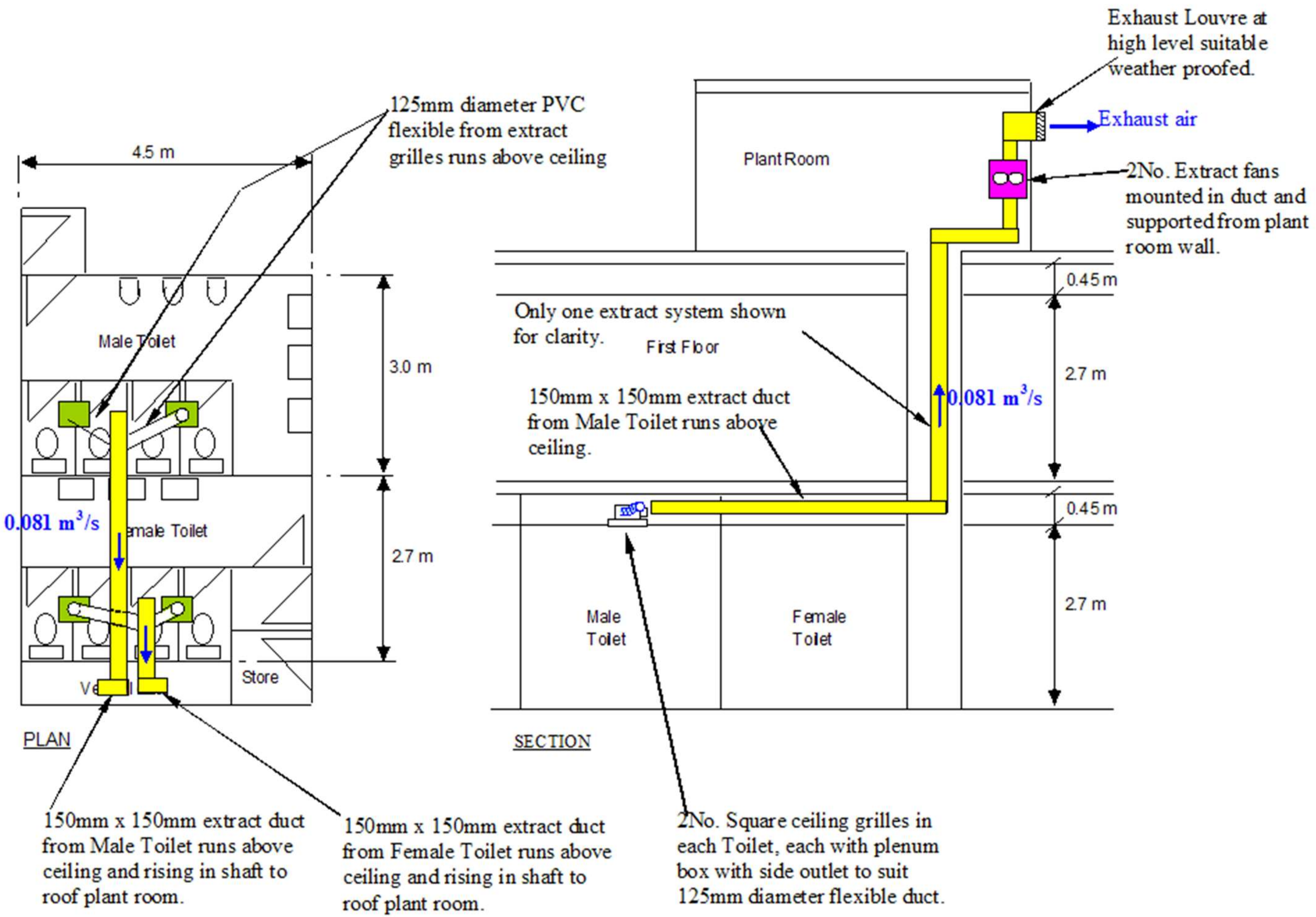
- = 365 m^3/h. Divide by 3600
-
- The ventilation rate is = 0.1 m^3/s.
-
- A simple method of duct sizing would be:
- Duct area = volume flow rate / air velocity.



PLAN



SECTION


Exhaust Louvre at high level suitable weather proofed.
125mm diameter PVC flexible from extract grilles runs above ceiling
4.5 m
Plant Room
Exhaust air
2No. Extract fans mounted in duct and supported from plant room wall.
0.45 m
Male Toilet
3.0 m
Only one extract system shown for clarity.
First Floor
2.7 m
150mm x 150mm extract duct from Male Toilet runs above ceiling.
0.081 m³/s
0.081 m³/s
Female Toilet
2.7 m
0.45 m
Male Toilet
Female Toilet
2.7 m
Store
PLAN
SECTION
150mm x 150mm extract duct from Male Toilet runs above ceiling and rising in shaft to roof plant room.
150mm x 150mm extract duct from Female Toilet runs above ceiling and rising in shaft to roof plant room.
2No. Square ceiling grilles in each Toilet, each with plenum box with side outlet to suit 125mm diameter flexible duct.

TOILET VENTILATION DESIGN(CONT.)

- An appropriate maximum air velocity for a toilet is 4 m/s
- Therefore duct area = 0.1 / 4 = 0.025 m^2.
- If a square duct is used then the duct size is: $(0.025)^{0.5}$ =0.160 m x 0.160 m
- The nearest standard size is 0.175 m x 0.175 m or,

  175mm x 175mm.

TOILET VENTILATION DESIGN (cont)

Ethiopian building code specifies 10 air change for toilette ventilation

7persons can use the male toilet

- Ventilation Rate (= 36.457*10)=3645m3/h

- Ventilation Rate (lps) =100lps

TOILET VENTILATION DESIGN (cont)

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7. ALLOWABLE DUCT VELOCITIES

To avoid noise air velocities shall be limited to

Building	Air Velocity (m/s)	
	Main Duct	Branch
Auditoria	4	3
Hotel bedroom, Conference hall	5	3
Private office, Library, Hospital ward	6	4
General office, Restaurant, Dept. store	7.5	5
Cafeteria, Supermarket, Machine room	9	6
Factory, Workshop	10-12	7.5

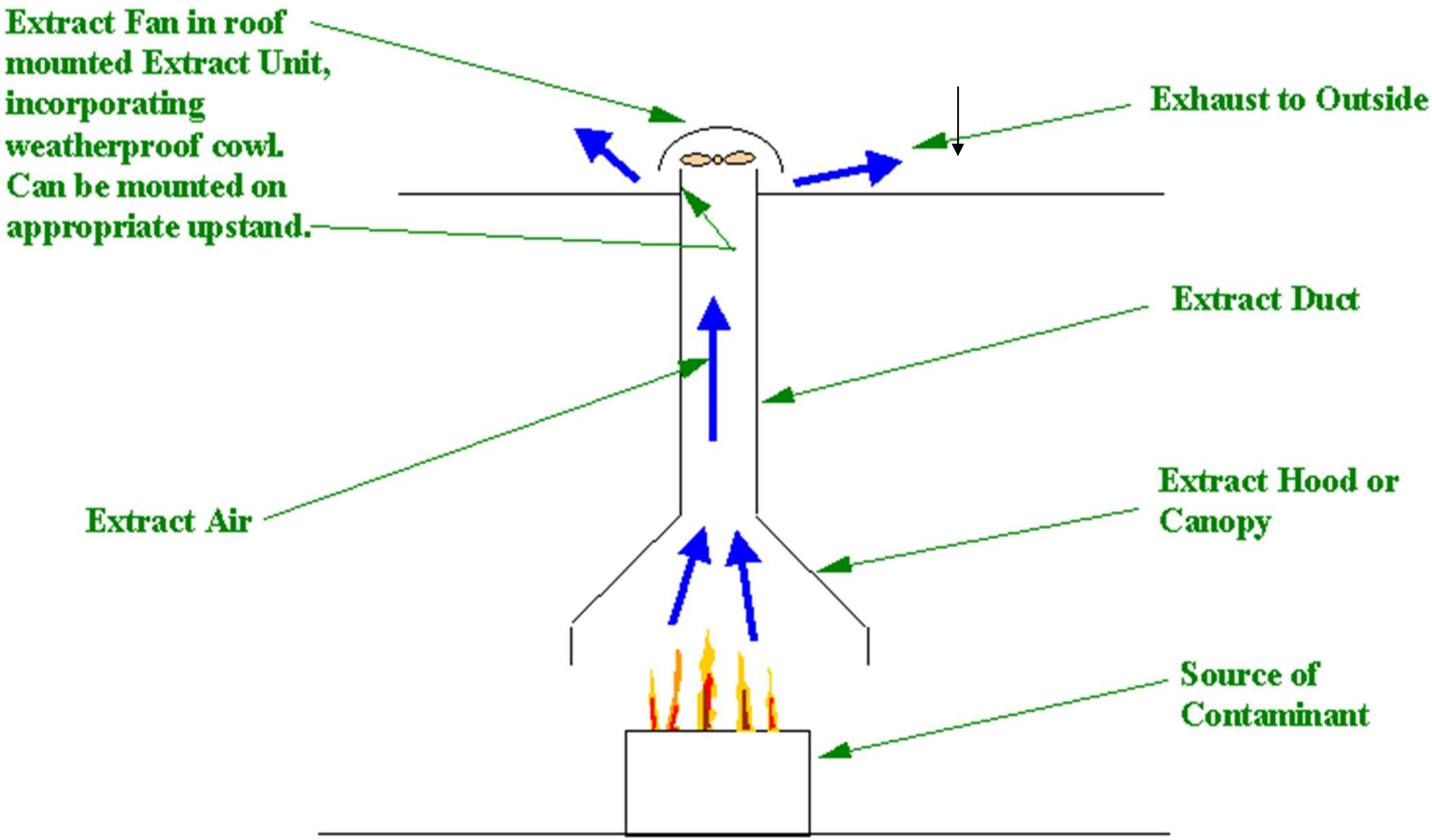
8. KITCHEN VENTILATION SYSTEM (Kitchen Hood)

- Hot air rises up! An exhaust fan in the ceiling could easily remove the heat produced by cooking equipment. But mix in smoke, volatile organic compounds, grease particles and vapor from cooking, a means to capture and contain the effluent is needed to avoid health and fire hazards. While an exhaust hood serves that purpose, the key question is always: what is the appropriate exhaust rate?
- The answer always depends on the type (and use) of the cooking equipment under the hood, the style and geometry of the hood itself, and how the makeup air (conditioned or otherwise) is introduced into the kitchen.

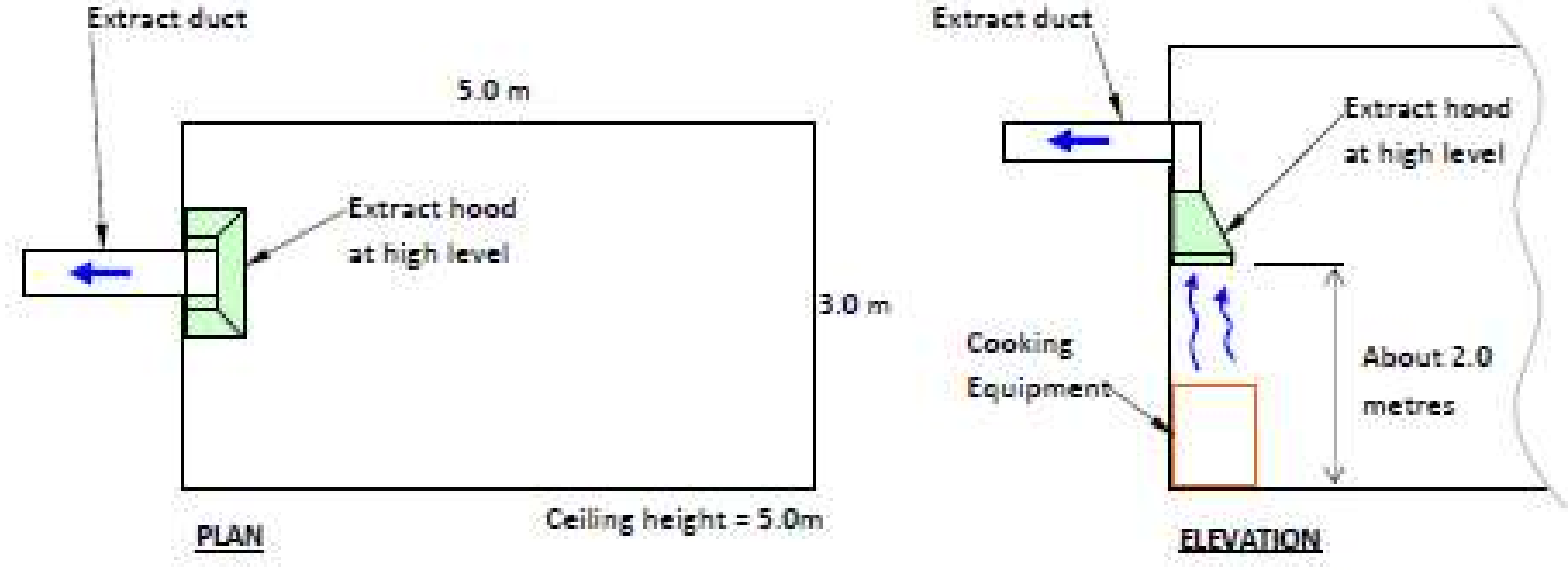
Kitchen Hood

Mechanically ventilated kitchens shall be designed for a ventilation rate of not less than 20 air-changes per hour. When kitchen hoods are in operation, the exhaust air through the hoods can be considered as contributing to the exhaust requirement for ventilation.
Sufficient make-up air (upto 80 % of exhaust) shall be provided and negative pressure in the kitchen area shall be maintained when the kitchen hood is in operation.

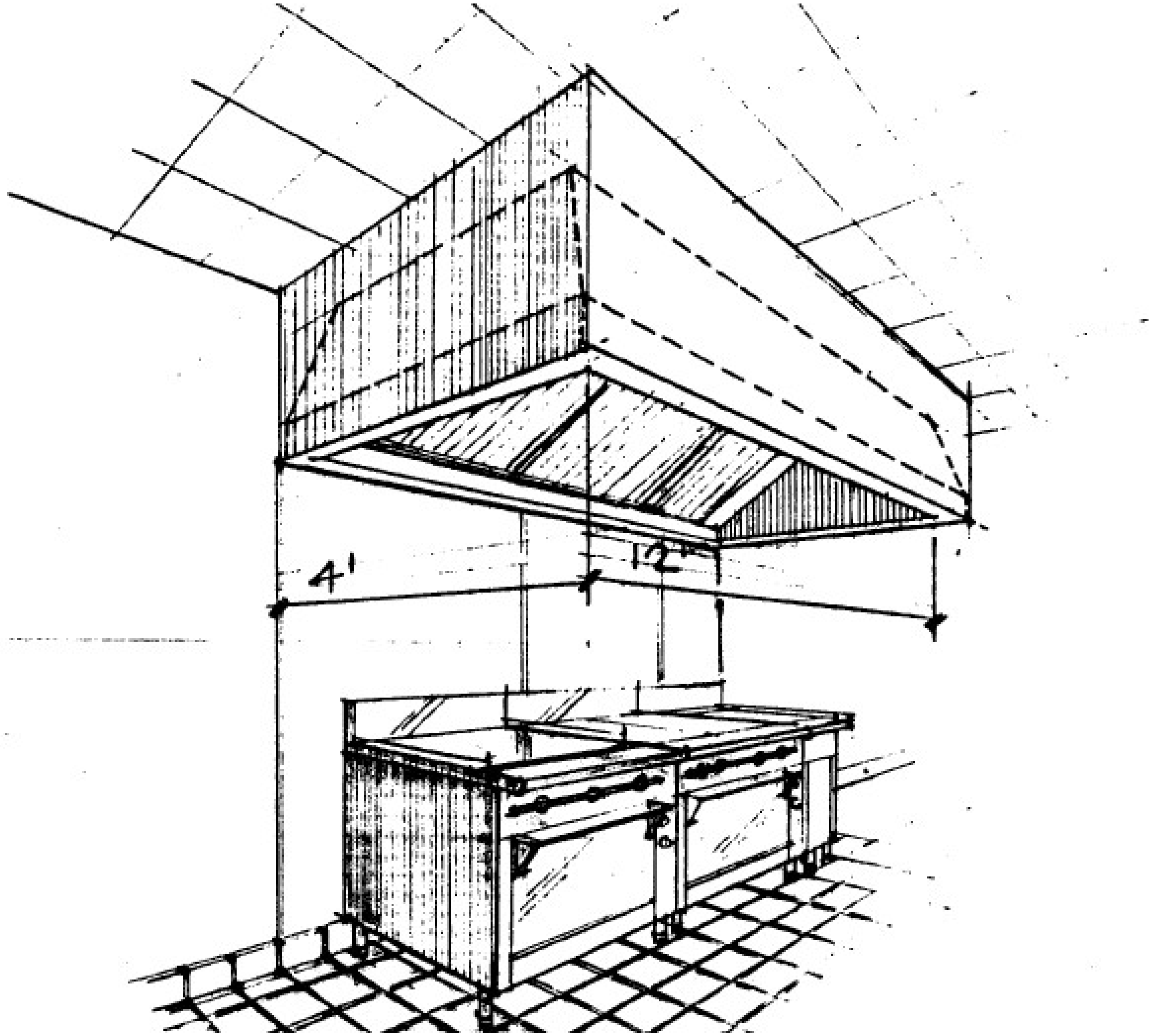
Kitchen Hood



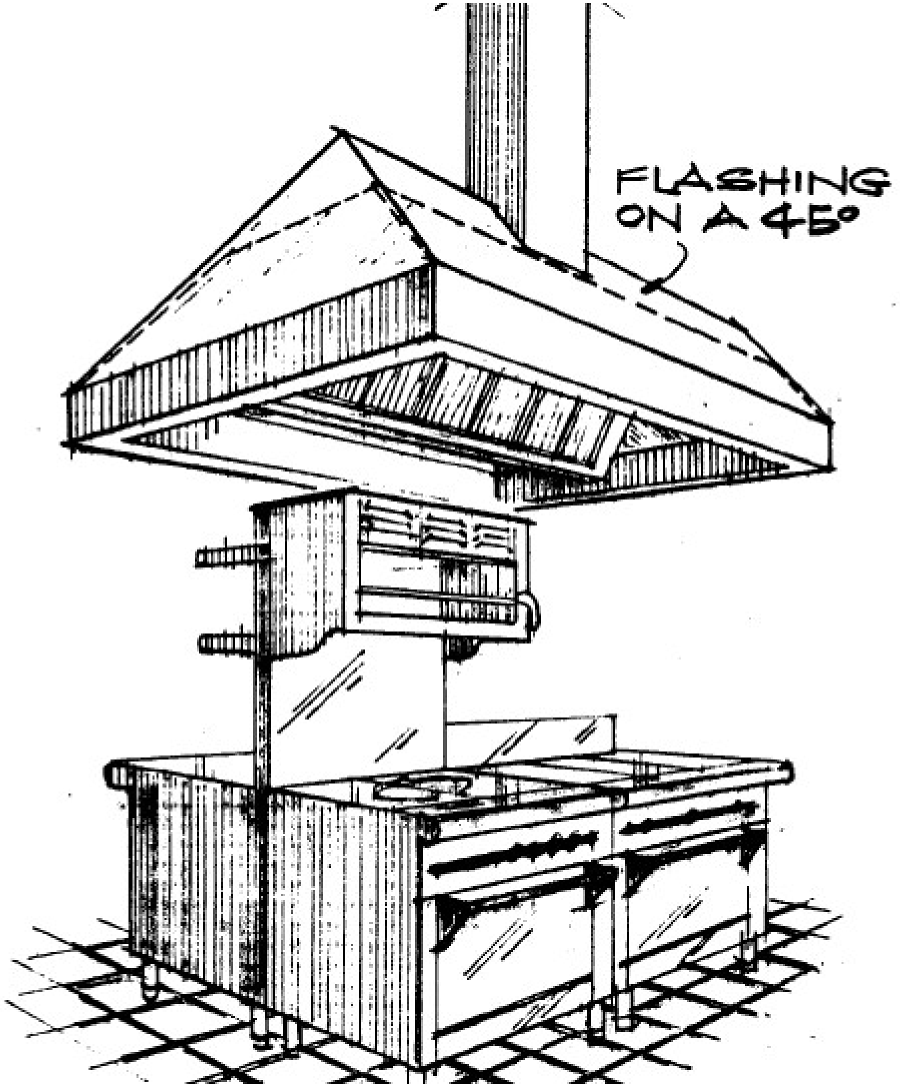
Canopy Kitchen Hood



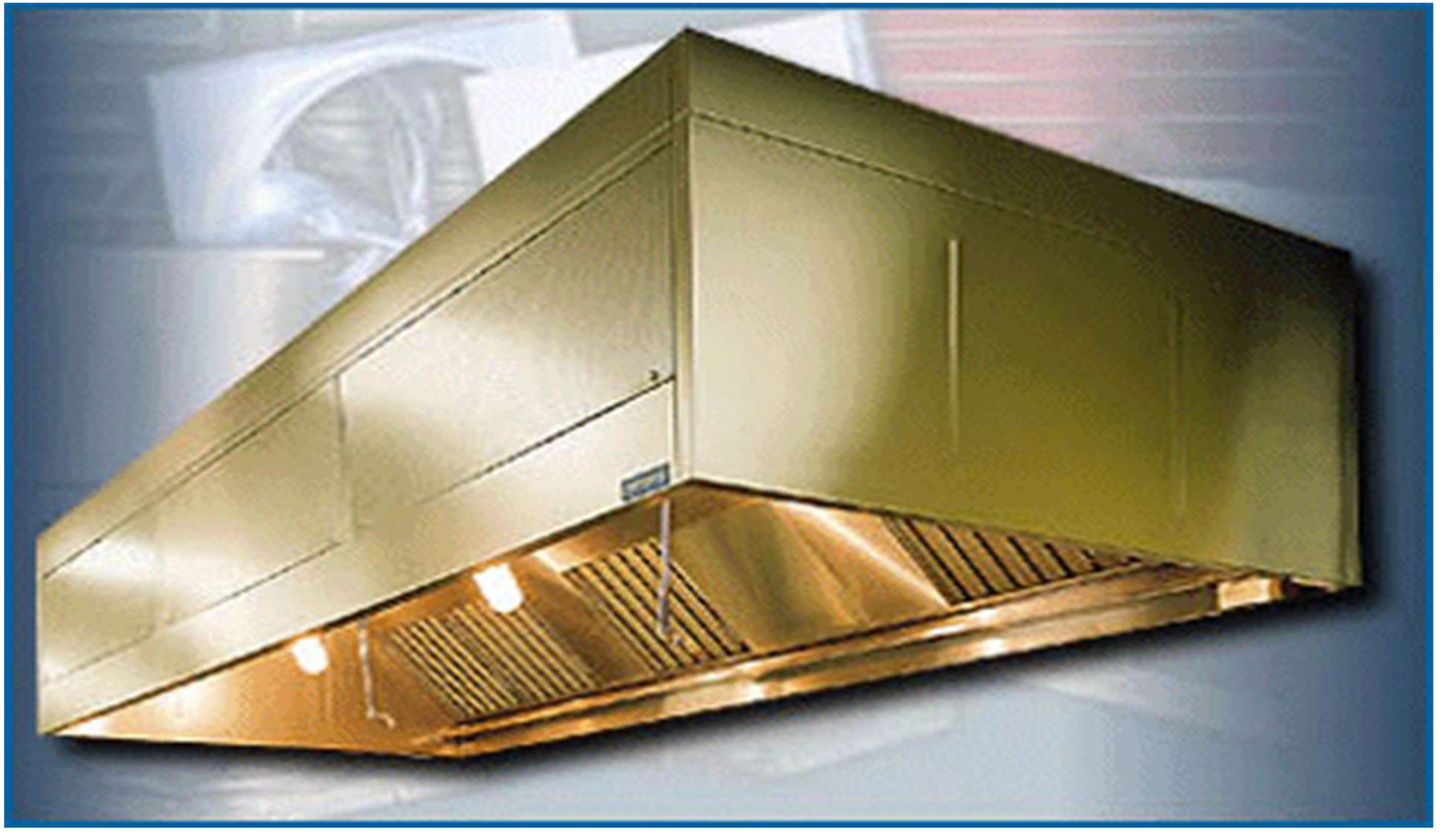
Canopy Kitchen Hood



Island Kitchen Hood



Kitchen Hood Detail



Kitchen Hood Requirements

- Washable grease filters with standby units shall be located within the hood as close to the major heat source as practical.
- Mechanical exhaust system for the cooking area of a kitchen in a hotel, restaurant, coffee house or the lime shall be independent of those serving other parts of the building.
- Kitchen-exhaust hoods shall be installed above appliances of heating capacity greater than 8 kW and likely to generate grease vapor (e.g. ranges, fryers, barbecues). Where grease is present, kitchen hoods incorporating grease filters shall be used.
- Kitchen exhaust hoods shall be manufactured from rigid impervious hard-faced and non-combustible materials, such as mild steel, stainless steel or aluminum.
- Duct thickness shall be 1.2 mm in case of steel

Kitchen Hood Ventilation Requirements as per ES

(For appliances requiring a kitchen exhaust hood, the exhaust flow rate Q[m^3/s] shall not be less than that given in the following formula, if it is an “island” hood:

$$Q = 1.4V * 2(L + W)H * F$$

- Where:
- V = Capture velocity which shall not be less than 0.30 m/s for commercial type kitchens
- L = Length of cooking surface, m
- W = width of cooking surface, m
- H = Distance of hood to emitting surface, m
- F = 1.0 for heavy duty high temperature, grease burning, deep-fat frying cooking with equipment such as works, broilers, char-broilers normally associated with solid or gas fuel burning equipment
- F = 0.7 for light duty, medium and low temperature cooking with equipment such as ovens, steamers, ranges, griddles and fryers.

9. CAR PARK VENILATON

It is required to ventilate the car parking areas in a building in order to remove carbon monoxide and other combustion products from the areas. Parks are plced often in the basement of the building

- Except where natural ventilation is available by window area equal or greater15 % of carpark area, a mechanical ventilation system incorporating a supply part and an exhaust part, and capable of providing six air changes per hour is required for car parking areas in a building.
- The mechanical ventilation system in commercial car parks may be operated at a lower rate at times of low occupancy subject to the condition that the carbon monoxide concentration is maintained below the permitted level of approximately 25 ppm averaged over an hour period incorporating aCO sensor that turns the fan off and on.

CAR PARK VENTILATON

- The supply air shall be drawn directly from the exterior and its intake shall not be less than 5m from any exhaust discharge openings. Outlets for the supply air shall be adequately distributed over the car park area.
- Ist Basement car parks needs only extraction system
- 2nd and below basement need extraction and fresh air supply system
- The system is designed 6 AC./h for ventilation 10 AC/h for smoke exhaust in the event of fire. Hence a two speed fan is used for exhaust system. The exhaust fan will operate at lower speed

Car Park Ventilaton Design Alternative

- Ducted System

Fresh air supply and exhaust ducts placed alternatively in the cr park with supply and exhsut grills placed evenly in the cr park. The supply and exhaust will be connected to exhaust and supply fans at the end or outside the building

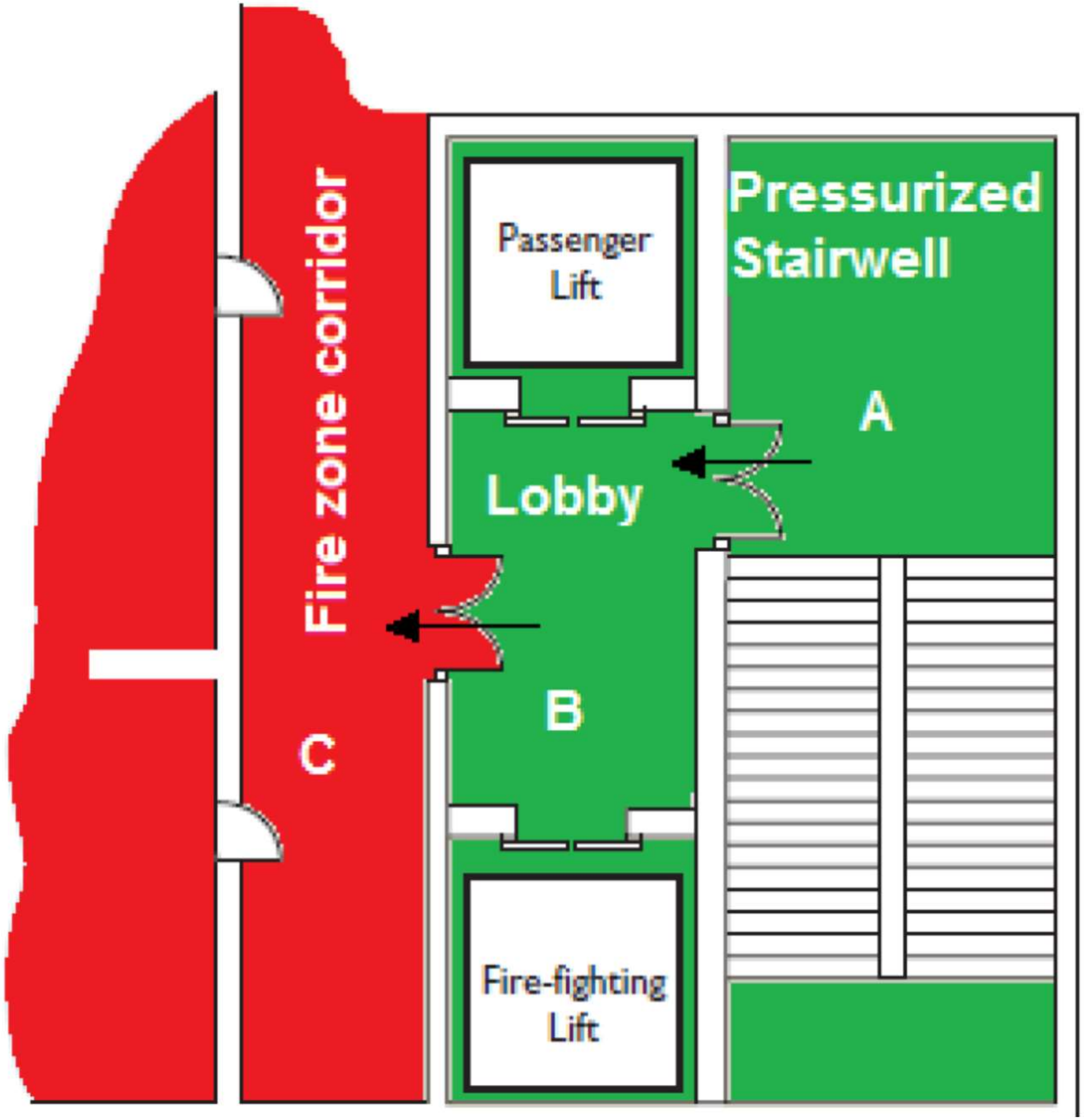
- Ductless System

Jet fans placed evenly in the building from supply side to exhsut side. They push the air from supply side to exhaust side. The supply and exhaust duct ends at two opposite of the building will be connected to exhaust and supply fans at the end or outside the building

STAIR CASE PRESSURIZATION

- In a high-rise building, the stairs typically represent the sole means of egress during a fire. It is imperative for the exit stairs to be free of smoke and to incorporate design features that improve the speed of occupant egress. Most building codes require the fire stairwells in a high-rise building to be pressurized to keep smoke out.
- The International Building Code (IBC) allows three active smoke control methods to contain smoke among which is. Pressurization Method (IBC Section 909.6)
- Pressurization systems use mechanical fans to produce a positive pressure on the stairwells. The two key pressurization principles are maintaining:
- 1. A pressure difference across a barrier
- 2. Average velocity of sufficient magnitude.

How is smoke is prevented by pressurized air from entering in the stair well

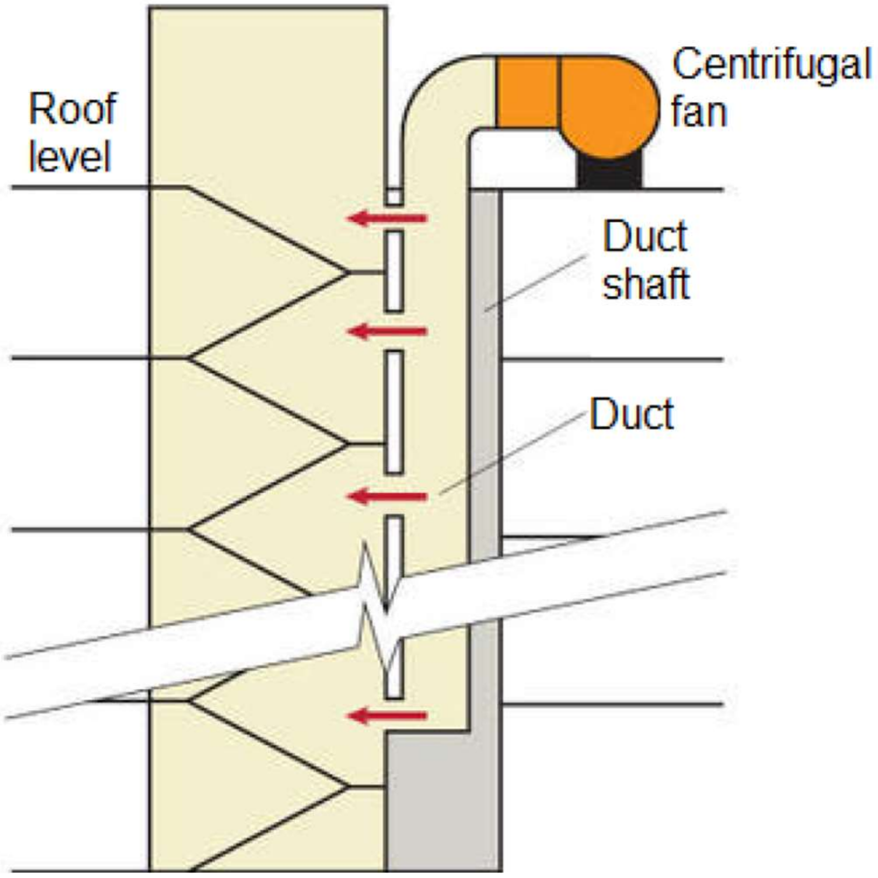


STAIR CASE PRESSURIZATION

- Consider an example of a stairwell “A” maintained at a positive pressure relative to lift lobby “B” which is at a higher pressure relative to the fire zone corridor space “C”. Each of the three zones A, B and C are separated by the partition barriers and the doors. The lobby and stairwell (marked green) can be classified as escape routes, refuge area and tenable environment. These invariably repeat themselves at the same position at each floor level for at least a number of successive floors.

Air flows from the higher pressure area to the lower pressure area. By pressurizing Zone A. migration of smoke from zone C to A through B is prevented.

How is smoke is prevented by pressurized air from entering in the stair well



STAIR CASE PRESSURIZATION

The Staircase Pressurisation calculation is based on the following design criteria:

a) Airflow velocity of not less than 1 m/s through doors when all 3 doors are open (1 main exit door + 2 consecutive floors).

b) Minimum Pressure Differential between staircase & adjacent accommodation space is 50 Pa when all doors are closed. there is no pressure differential requirement when doors are in open conditions.

c) Maximum Force required to open any door at the door handle shall not exceed 110 N.

To determine the air flow required to maintain a specified pressure differential, the following equation is used:

Q = 0.827 A (ΔP)1/2

Q = Air Flow rate (m3/s).

A = Flow area or leakage area (m2).(leakage area of total doors in the stairwell)

ΔP = Pressure difference (Pa).