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Single Stack Ventilating System for Kitchens of Multistorey Houses

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Single Stack Ventilating System for Kitchens of Multistorey Houses

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SYNOPSIS

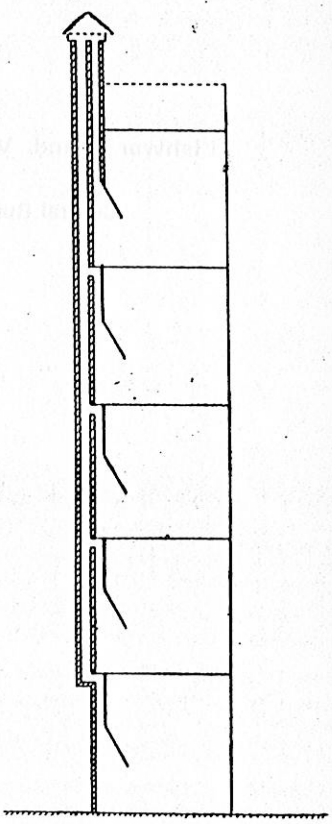
Design and functioning of a single stack system for extraction of smoke from kitchens of multistorey houses have been described. The system consists of a common flue running along the height of the building. Chimneys from kitchens at different floors terminate into the common flue. An optimisation of the design showed that a separate chimney should be provided for the kitchen on the topmost floor, and the rest of the kitchens be ventilated through the common flue projected about 2 m above the roof of the building. The cross-sectional area of the flue should have its circular equivalent of diameter 23.8, 25.78 and 28.71 cm. for a system serving two, three and four storeys respectively. General relationships have also been derived between the dimensions of the flue and the number of kitchens connected to it. These formulae can be used for computing the size of flue of any given number of storeys.

Introduction

A survey of ventilation systems conducted in kitchens of various categories of houses brought out[1] the necessity of providing chimneys in kitchens where reliance is placed on natural ventilation for the removal of smoke, fumes and other undesired products of cooking processes. Based on earlier investigations[2], an efficient, simple and economical design of chimney has been evolved for single storey houses. The satisfactory performance and usefulness of chimneys with optimised design has also been established by installing them in houses where cowdung and firewood are used as fuel. Provision of such a chimney for each kitchen of multistorey building can no doubt serve the purpose, but the arrangement is expensive and cccupies large spaces inside kitchens of the upper floors. Investigations were, therefore, undertaken to evolve a simple and economical design of chimney for multistorey buildings. Details of such a system and its design considerations are the subject matter of this paper.

Proposed arrangement :

A schematic view of the proposed system is shown in Fig. 1. It consists of a common flue running along the height of the building. Kitchens on different floors are provided with separate chimneys each consisting of a quarter conical hood with radius at the base equal to 0.65m and angle of apex 60°. A 0.21 m diameter pipe is mounted on the hood and connected at the other end to the common flue. Smoke and fumes from different kitchens emanating through these chimneys enter the common flue for onward discharge to the outside atmosphere.



FIG·1·SCHEMATIC VIEW OF SINGLE STACK VENTILATING SYSTEM FOR MULTISTOREY HOUSES

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Functional requirements

The system, apart from being simple and economical needs to be functionally efficient. The latter aspect requires (i) total extraction of smoke and fumes when the chimney at one or different floors are in use and (ii) prevention of downward (reverse) flow of smoke through the chimneys of upper floors when chimneys at lower floors are in use. Therefore, dimensions of the flue are determined with this aim in view.

Principle of operation and theoretical considerations in design :

The air in the vicinity of cooking platform being lighter than the outside air rises up and fills the chimney of the individual kitchen and also the common flue. The difference in the weights of the column of gases inside the chimney and column of same height of cooler outside air provides the necessary pressure-head for the movement of gases through the chimney. Part of this head is utilised in overcoming the resistance of the chimney and the rest provides kinetic energy to the flue gases. The energy equation for the system may, therefore, be written as

$$\Delta P = \Delta P_R + \tfrac{1}{2} l_i V^2 \qquad \ldots\ldots(1)$$

where ΔP = theoretical pressure head.

ΔP_R = Loss in pressure head due to the resistance of the system.

l_i = Density of gases inside the chimney.

V = Velocity of gases inside the chimney.

Theoretical Pressure Head

Since the magnitude of pressure head, (ΔP) depends upon the height of column of hot gases, it will, obviously, be minimum when the chimney of topmost floor is in operation. Therefore, a system based on this minimum head would also function efficiently when greater head is available due to the operation of kitchens at lower floors. Now assuming the height of the common flue above the top most floor as H, and height of chimney inside the kitchen—as 2M, the theoretical head is given by

$$\Delta P = (H+2)\,(l_o - l_i)\,g$$

where l_o = Density of outside air.

g = Accleration due to gravity.

Measurements carried out in several houses as also in an experimental chimney installed at a mock-up building showed that the temperature of gases inside the chimney are generally around 10°C higher than the outside air temperature. Accordingly, the theoretical pressure head is given by

$$\Delta P = 0.326\,(H+2)\,l_i \qquad \ldots\ldots(2)$$

Resistance of the system

The loss in pressure-head due to resistance of the system is the sum of the losses occuring at the inlet of the hood, through the straight parts of the chimney. and due to changes in the direction of flow of gases at the junction of the individual chimneys and the common flue. Following standard method[3] of duct design, the total resistance is obtained by adding these losses. For the topmost kitchen, the resistance

$$\Delta P_r = 0.5\,\tfrac{1}{2} l_i v^2 + \frac{0.028 \times 2}{0.21}\cdot\tfrac{1}{2} l_i v^2 + 1.6\tfrac{1}{2} l_i v^2 + \frac{0.028H}{D}\cdot\tfrac{1}{2} l_i V^2 \qquad \ldots\ldots(3)$$

Hence the equation (1) reduces to

$$0.326(H+2)\,l_i = \tfrac{1}{2} l_i V^2 + \frac{0.028H}{D}\cdot\tfrac{1}{2} l_i V^2 + \left(2.1 + \frac{0.028 \times 2}{0.21}\right)\tfrac{1}{2} l_i v^2 \qquad \ldots\ldots(4)$$

Where v = Velocity of gases in the portion of chimney inside the kitchen.

V = Velocity of gases in the common flue.

D = Diameter of the common flue.

When the chimney at the topmost floor is in use the head available due to the hot gases in the common flue would cause extraction of air from the kitchens located at lower floors as well. By applying Shaw's theory[4] of electrical analogy to air current, it can be shown that in connecting two, three and four chimneys to a single stack, the total flow of gases through the common flue would be respectively 1.5, 1.66 & 1.74 times the flow of a single kitchen chimney.

Now taking desired rate of extraction[5] from each kitchen as 0.036 m³/sec, and putting the corresponding value of v and V in equation (4), the following relationships are obtained between the dimensions of common flue for two, three and four storey houses :—

$$0.652 = 0.004374\,D^{-4} + 0.0001225\,HD^{-5} + 1.067 \qquad \ldots\ldots(5)$$

$$0.652H = 0.005357\,D^{-4} + 0.00015\,HD^{-5} + 1.067 \qquad \ldots\ldots(6)$$

and

$$0.652H = 0.005885\,D^{-4} + 0.0001648\,HD^{-5} + 1.067 \qquad \ldots\ldots(7)$$

Based on these equations, the heights of the flue (H) have been computed for various values of its diameter. The data, as is plotted in Fig. 2 make it easy to determine the appropriate height of the chimney of a given value of its diameter. When all the chimneys are in simultaneous operation, the common flue will be filled with hot gases along its entire

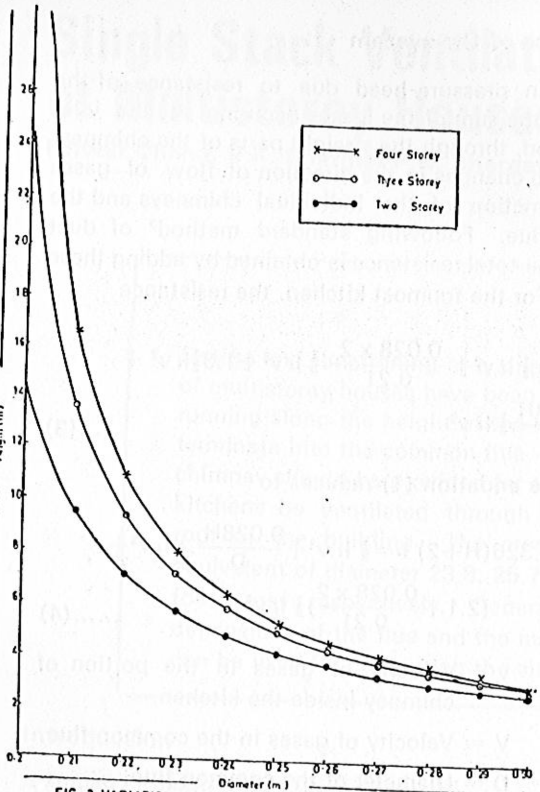

FIG-2-VARIATION OF HEIGHT WITH DIAMETER OF THE FLUE

height. Obviously, the theoretical head will be maximum for the bottom most kitchen and minimum for the top most. Now, assuming the resistance of the straight part of the common flue between two kitchen junctions as R, the resistance of the kitchen chimney from hood to the common flue will be approximately 3 R. Then the total resistance of the system for a given number of storeys(n)—as calculated by using Shaw's theory of electrical analogy of air currents, works out to $R\,(1+3.42\,e^{-0.27n})$. Now, assuming the neutral zone of the system at the junction of the top most chimney, the rate of flow of gases at the outlet of the system will be equal to

$$\frac{A\sqrt{H\,(t_i-t_o)}}{R(1+3.42e^{-0.27n})}$$

and the rate of extraction through the chimney on the ground floor will be $\frac{a\sqrt{3n-1}}{(n+3)\,R}$. Thus, application of the equation of continuity leads to the following relationship between the height and diameter of the common flue.

$$A = 0.0346\,\frac{n}{n+3}\,\sqrt{\frac{(3n-1)}{H}}\left(1+3.42\,e^{-0.27n}\right) \quad ......(8)$$

Based on the above equations, a few typical values of D for chimney heights equal to 4, 5 and 6m. are given in Table 1 also. A flue with these dimensions has all the side openings below the neutral zone. This ensures that no reverse flow of smoke occurs in the chimney of upper floors when a chimney at lower floor is in use.

TABLE 1

Diameters of the flue for various chimney heights.

Number of Storeys	H=4 m	H=5 m	H=6 m.
2	24.42	23.06	22.04
3	27.17	25.78	24.64
4	30.39	28.71	27.45

Optimised design of the common flue

The data plotted in Fig. 2 indicate that the required height of the flue increases with the decrease in the diameter of the flue and quite tall chimneys are required when diameter is kept small. As an example, for a diameter equal to 0.21 m. the required heights are about 9.5 m, 13.5 m and 16.5 m for double, triple, and four storey houses. Such large heights of flue can not be accepted because of aesthetic and economic considerations. Therefore, it is desirable to provide a separate chimney for the topmost kitchen and connect the remaining chimneys to the common flue. With such a system, a part of the height of the common flue (above its topmost side junction with the kitchen), will run along the wall of topmost kitchen and rest will be projected above the roof of the building. Assuming normal height of each floor as 3 m, height

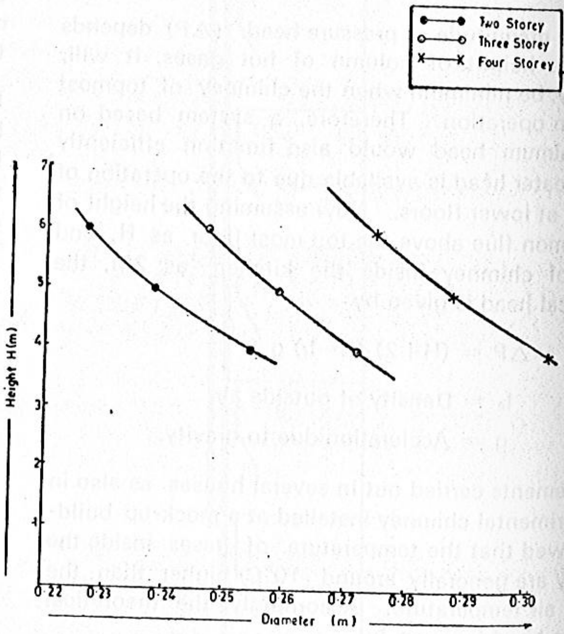

FIG-3-DIMENSIONS OF THE FLUE

of parapet wall 1m, and a further projection of chimney as 1m, the permissible value of H comes out to be about 5 m. However, due to variations in height of parapet wall, the value of H may vary from 4 to 6m. Corresponding to these heights, the required diameter of flue were determined from equation (8) and also from Fig. 2. Out of the two values of diameter so obtained for each of the heights, the higher was chosen for the design of the system so that conditions of total extraction of smoke as also of prevention of reverse flow are satisfied. The relevant design data are shown in Fig. 3. When the flue is rectangular, its dimensions, a and b are so chosen that the desired equivalent diameter satisfies the following relationship

$$D = 1.3\ (a\ b)^{5/8}\ (a+b)^{-1/4}$$

Field trial of the systems :

The trial of the system with proposed design was carried out on an experimental chimney installed on a mock up building. The chimney consists of a common flue with 23 x 23 cm^2 in cross section and about 13.75 m in height. The bottom of the flue was kept closed and a protecting cap was mounted at the top to prevent entry of rain. Chimneys similar to these recommended for single storey houses were mounted at the four floors of the mock up building. These chimneys were connected to the common flue at 0.3, 2.8, 5.3 and 7.8 m above the bottom. Kitchens about 1.85 x 1.75 m^2 in size were made at various floors by putting temporary enclosures having chimney in one of the corners. Chullahs with normal design in common use were made under the hoods and smoke similar to that produced in normal cooking conditions was generated by burning cowdung cakes. Observations were taken on several days under different conditions of temperature and wind. It was found that spillage of smoke occurs from the chimney of topmost floor while total extraction of smoke takes place from the other chimneys. It is attributable to the fact that the height of common flue above the topmost chimney junction is 6 m corresponding to which the chimney diameter should have been 26.1 cm. while the chimney in question has an equivalent diameter of 24.98 cm. Trials were also made by closing the topmost chimney so that system represented the coupling of three chimneys with H = 8.5 m. The system was found to work satisfactorily. It was also observed that when the height of chimney is reduced by about 3.5m, and the height of common flue above the topmost junction of chimney is kept about 5 m, total extraction of smoke takes place in all the kitchens. These dimensions of the flue agrees well with the recommended dimensions and have provided an experimental verification of the design evolved.

Concluding remarks and discussion

An optimum design of kitchen chimney has been worked out for multistorey houses. It is recommended that a separate chimney should be provided for the kitchens located at the topmost floor. Chimneys of kitchens on the rest of the floors should be connected to a common flue running along the height of the building and projecting about 2 m above the roof. The dimensions of common rectangular flue should be so chosen that their circular equivalents are 23.8, 25.78 and 28.71 cm. for a system connecting two, three and four chimneys respectively. Relationships have also been derived between the dimensions of the common flue and the number of chimneys connected to it. The relationships have also been verified experimentally and can be made use of for computing the size of flue for any given number of storeys.

Acknowledgement

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