2. Inlet openings should not be obstructed by buildings, trees, sign boards, etc., outside, nor by partitions inside.

3. Greatest flow per square foot of total opening is obtained by using inlet and outlet openings of nearly equal areas.

4. In the design of window ventilated buildings, where the direction of the wind is quite constant and dependable, the orientation of the building, together with amount and grouping of ventilation openings, can be readily arranged to take full advantage of the force of the wind. Where the wind's direction is quite variable, the openings should be arranged in sidewalls and monitors so that, as far as possible, there will be approximately equal areas on all sides. Thus, no matter what the wind's direction, there will always be some openings directly exposed to the pressure force, and others to a suction force, and effective movement through the building will be assured.

5. Direct short circuits between openings on two sides at a high level may clear the air at that level without producing any appreciable ventilation at the level of occupancy.

6. In order that temperature difference may produce a motive force, there must be vertical distance between openings. That is, if there are a number of openings available in a building, but all are at the same level, there will be no motive head produced by temperature difference, no matter how great that difference might be.

7. In order that the force of temperature difference may operate to maximum advantage, the vertical distance between inlet and outlet openings should be as great as possible. Openings in the vicinity of the neutral zone are less effective for ventilation.

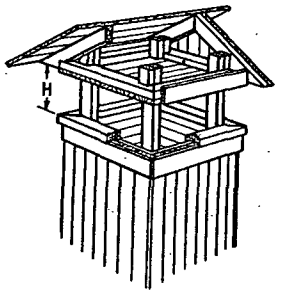

FIG. 5. RECOMMENDED TYPE OF COVER FOR WOODEN OUTLET FLUE

The opening H should equal one-half the least dimension of the flue. Heavy insulation of the level deck is essential.

8. In the use of monitors, windows on the windward side should usually be kept closed, since, if they are open, the inflow tendency of the wind counteracts the outflow tendency of temperature difference. Openings on the leeward side of the monitor result in cooperation of wind and temperature difference.

9. In an industrial building where furnaces that give off heat and fumes are to be installed, it is better to locate them in the end of the building exposed to the prevailing wind. The strong suction effect of the wind at the roof near the windward end will then cooperate with temperature difference, to provide for the most active and satisfactory removal of the heat and gas-laden air.

10. In case it is impossible to locate furnaces in the windward end, that part of the building in which they are to be located should be built higher than the rest, so that the wind, in splashing therefrom, will create a suction. The additional height also increases the effect of temperature difference to cooperate with the wind.

11. The intensity of suction, or the vacuum produced by the jump of the wind, is greatest just back of the building face. The area of suction does not vary with the wind velocity, but the flow due to suction is directly proportional to wind velocity.

12. Openings much larger than the calculated areas are sometimes desirable, especially when an increase in occupancy may occur, or when extremely hot days may be anticipated. In the former case, free openings should be located at the level of occupancy for psychological reasons.

13. In single story industrial buildings, particularly those covering large areas, natural ventilation must be accomplished by taking air in and out of the roof openings. Openings in the pressure zones can be used for inflow, and openings in the suction zone, or openings in zones of less pressure, can be used for outflow. The ventilation is accomplished by the manipulation of openings to get air flow through the zones to be ventilated.

VENTILATION OF ANIMAL SHELTERS[10]

Animal shelters require ventilation to remove moisture, odors and, in the case of dairy stables, excess heat.

Outlets. Outlet flues for natural draft systems should be round or approximately square. A thermal resistance ($1/U$) of not less than two is required in their side walls. They should extend at least two feet above the highest part of the roof. Only one outlet is recommended for each room or pen. The use of several outlet flues may result in excessive up-drafts in some flues, and down-drafts in others.

If flues have roofs or covers, these should be high enough to provide unobstructed openings on all sides, equal in height to one-half the least dimension of the flue, Fig. 5. A level, heavily insulated ceiling under the flue roof, and over the entire area of the flue, is important.

Inlets. Inlets should direct the incoming air vertically upward so as to avoid drafts on the animals, and to insure immediate mixing of incoming air with the room air. A reasonably uniform distribution around the stable or pen is desirable. Inlet flues, that deliver air close to the side walls, stimulate convection currents, which is desirable. When so placed, they also tend to bathe the side walls with cool air, thus reducing temperature difference between the inside and outside of the wall.

From the standpoint of air movement, insulation of inlet flues is not important. Condensation is, however, likely to occur on them, unless the thermal resistance of their walls is at least two.

Controls or throttling devices in inlet flues are seldom required. If used, they are best applied to the inlets and limited to the side of the building facing prevailing winter winds. They should be so made that an opening, at least one inch wide by the width of the flue, will always remain open.

Amounts of heat and water produced by livestock vary not only with the different kinds of animals, but also with age, weight, feed consumption and production. These facts, and the vagaries of the weather, make exact calculations impossible. The following practical recommendations are based on numerous, carefully checked observations.

It is desirable to keep the relative humidity of livestock shelters below 85 percent. Temperatures may be as indicated in the discussion for each kind of animal.

Dairy Stables

The most usually accepted temperatures for dairy stables, where cows are confined in stanchions or tie stalls, are from 45 to 55 F. These temperatures are readily maintained in winter weather by the body heat of the herd in well constructed, well stocked and well ventilated stables. Stable volume in excess of 600 cu ft, and exposed wall area in excess of 130 sq ft per 1000 lb animal weight are, in general, undesirable.

Side walls should have an overall thermal resistance of from 2 to 5, depending on the temperature zone and wind exposure. Thermal resistance of the ceiling should be 50 percent greater than that of the side walls. In stables of this size and so insulated, a ventilation rate of 3200 to 3800 cu ft per (hr) (1000 lb of animal) usually insures good conditions.