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 per cent. 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 per cent 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.

The following recommendations do not apply to so-called pen stables or loafing barns in which there is a thick manure and bedding pack on the floor, and in which doors are normally kept open.

Outlets. One flue will serve a stable 200 ft long. In stables over 120 ft long the flue should be about midway between the ends or, if the stable is L-shaped, near the angle. In shorter stables it may be at any convenient location.

The exhaust point in the stable should be not more than 18 in. above the floor. This permits removal of only the coolest air, and prevents rapid fluctuations in stable temperature.

A basic rule for finding the cross-section of the outlet flue is:

$$A_o = \frac{176\ N}{\sqrt{h}} \qquad (6)$$

where

A_o = area of the outlet flue, square inches.
N = weight of animal population, thousands of pounds.
h = vertical distance from top of inlet flues to top of outlet flue, feet.

For large flues the flue area obtained from the basic formula may well be reduced according to the chart, Fig. 6, because of a decrease in friction.

Example 2. Assume a stable in which the vertical height from the top of the inlets to the top of the outlet flue is 32.5 ft, and in which 38 cows averaging 1300 lb will be housed.

Solution. From Equation 6

$$A_o = \frac{176 \times (38 \times 1.300)}{\sqrt{32.5}} = 1525 \text{ sq in.}$$

From Fig. 6 the factor to be applied to this area is 94.5 per cent. Therefore, the area of flue required is $1525 \times 0.945 = 1441$ sq in.

Inlets. Inlet flues, each approximately 60 sq in. in area, have given good results. One such flue should be provided for each 3500 lb animal weight. They should deliver air from points 12 to 18 in. below the ceiling.

Sheep Barns

Shelters used for breeding and feeding stock usually have enough openings so that no special provision for ventilation is required. Barns for winter lambing flocks, however, require ventilation systems. Fermentation in

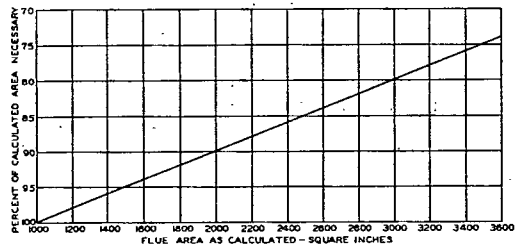

FIG. 6. MODIFICATION OF FLUE AREA FOR OUTLETS EXCEEDING 1000 SQ IN.

the floor pack of manure produces heat, vapor and odor. These must be added to the ventilation load regularly produced by the animals.

Outlets. In practice, results obtained by the basic formula, Equation 7, when modified by the use of the chart, Fig. 6 have given good results:

$$A_o = \frac{4A_f}{\sqrt{h}} \qquad (7)$$

where

A_o = area of the outlet, square inches.
A_f = floor area, square feet.
h = vertical height from top of inlet openings to top of outlet flue, feet.

The bottom of the outlet flue should be 15 to 24 in. above the surface of of the manure pack.

Inlets. Provide one inlet, 60 sq in. in area, for each 150 sq ft of floor area. Inlets should be well distributed around the side walls and designed to deliver air near the ceiling (see section on Dairy Stables).