economical to air condition poultry houses by any means other than spray mists or evaporative coolers.

Summer protective measures for swine are primarily shades with wallows or a water sprinkler. Enclosed swine buildings generally utilize ventilation or evaporative coolers. However, the rapid development of moderately priced refrigerating equipment, better knowledge of the benefits of producing swine at lower than normal summer building temperatures, and the increasing number and sizes of year-round production enterprises have intensified the use of an interest in mechanical air conditioning.

The most commonly used system for cooling feeder pigs and breeding stock is high ventilation rate (50 to 100 cfm per animal) with thermostatically controlled water sprinkling systems[23] set to supply up to ¼ gph per animal when building temperatures exceed 80–85 F. Evaporative coolers are quite common and effective in areas where the average summer wet-bulb temperature is 70 F and below. Mechanical air conditioning is used mostly in farrowing and nursery houses because sprinkling systems wet floors, an undesirable condition for newborn pigs.

Odor control in swine buildings requires that some fresh air be admitted continuously, the ventilation rate being influenced by the frequency of waste removal. Table 3 gives ventilation rates for odor control based on observations of buildings which are cleaned once each day.

Space conditioning with mechanical refrigeration equipment is generally considered by most producers to be more expensive than the benefits warrant. Estimates of cooling loads indicate a range of 0.5 to 0.75 tons per sow and litter and 0.1 to 0.2 tons for each feeder pig. Room air conditioners have been used in farrowing stalls to prevent heat exhaustion when temperatures rise above 90 F. However, large quantities of feed dust and other foreign material commonly found inside swine buildings rapidly clog air passages, and the ammonia in the air may lead to corrosion of heat exchangers.

Zone cooling systems which reduce refrigerating equipment size through eliminating the need to cool the entire shelter have met with more widespread acceptance, particularly for farrowing houses. Two types of zone systems are in use. One type[25] uses insulated ductwork to pipe a small volume of chilled air at low velocity (100–300 fpm) to the snout of the sow. The primary objective is the reduction of the inspired air temperature and moisture content to improve respiratory heat dissipation. System capacities are on the order of 0.1 ton of refrigeration and 10 to 35 cfm of air per sow.

The other type of zone cooling system uses a small, directional, high velocity, low volume blower fitted with a flexible tube for each sow, the blowers pulling cooled air from a common insulated duct. Although the sow is free to inhale the cooled air, the major cooling is accomplished by convection from the skin of the animal. No special effort is made to reduce the dewpoint temperature of the cooled air. Capacities per sow for this system are 0.1 ton of refrigeration and 70 to 80 cfm of air discharging from the nozzle at 2500 to 3000 fpm.

Both zone systems are suitable for year around ventilation as heating equipment can be easily added to warm the cold intake air.

Summer cooling of dairy barns, other than with fans, is not considered economical for most farms at the present time.

DESIGN FACTORS

Load Calculations

Load calculations for winter air conditioning systems should be based on the moisture that needs be removed. Unless the economic situation justifies supplemental heat, the calculated ventilation rate will need be compromised according to the heat available for warming the incoming air. The total moisture load (animal feces, urine, and equipment) should be considered. Figs. 5 through 13 show moisture loads that might be expected with various types of livestock and with various systems of management. Total heat refers to the sum of all sensible and latent heat released within a structure. Generally, the heat and moisture from equipment (lights, motors, and waterers—except for spillage) is of relatively little consequence.

Summer load calculations will need to consider not only the heat from livestock, litter fermentation, and equipment, but also the heat gain of the structure. However, air conditioning may not be needed during the entire day. Tests indicate that no production losses will be experienced with most farm livestock if thermal comfort conditions are exceeded for only part of a day and temperatures during the remainder of the day are sufficiently low to permit recovery.

Table 3 .... Recommended Summer Ventilation Rates for Odor Control in Swine Buildings Cleaned Daily

Size of Pig, lb	Ventilation rate, cfm/animal
12–40	8
50–100	12
100–200	15
Lactating Sow with Litter	40

Insulation

Insulation of livestock buildings aids in maintaining warmth and permits a greater circulation of fresh air than possible in non-insulated animal shelters. With adequate insulation and density of livestock within a shelter, animal heat generally will warm cold make-up air sufficiently to maintain conditions conducive to good production, without adding supplemental heating. Although a portion of animal's feed intake is used for increased metabolism at cold temperatures, the feed saving obtained by supplemental heating rarely pays for the expense of the system in animal shelters. The heat saved by use of insulation permits the removal of the animal's moisture output with ventilation. In addition, condensation on walls and ceilings is reduced in an insulated structure, thus increasing the life of the structure, contributing to cleaner barns (condensation quickly collects the dusts of barns), and reduces the possibility of feed deterioration.

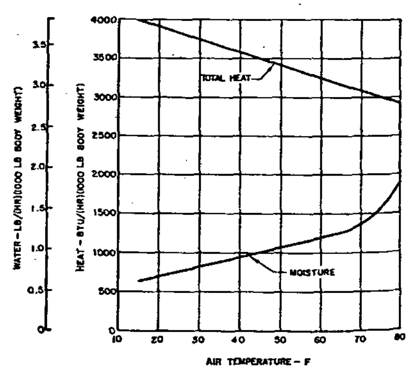
The determination of the economic amount of insulation to be used in animal shelters is complicated by variability in response of animals to temperature, feed costs, weather conditions, and the difficulty of isolating ambient air conditions as an independent parameter of production. To meet these demands, engineering estimates must be based somewhat on judgment, and are, therefore, subject to adjustment according to the experience of the design engineer. For further information on insulation, see Chapter 22 of the 1961 Guide And Data Book.

Internal moisture load for animal shelters exceeds that encountered for human occupancy. In addition to vapor from body surfaces, vapor from body wastes add to the moisture problem. Thus, insulation must have a higher degree of vapor barrier protection than used in offices or dwellings. A good vapor barrier and ventilation above the insulation are essential factors in making roof insulation effective.

A treatise[35] on insulation of poultry laying houses led to the suggested resistivities shown in Table 4. (See Fig. 14 for identification of zones.)

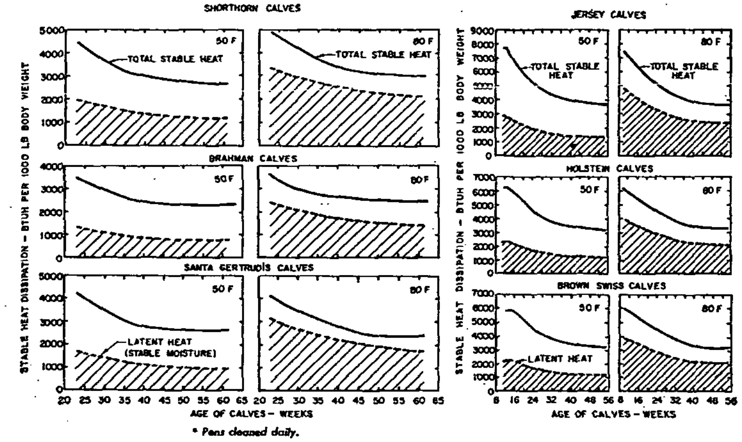
Insulation values for milking rooms are shown in Table 5.

The function and economy of insulation in reducing the peak afternoon hot weather temperatures has not been thoroughly investigated. For regions with high summer heat gain, the side walls are traditionally opened to permit free movement of breezes through the house. Some studies have shown that a well-insulated ($U = 0.06$ for the walls and ceiling) windowless houses with pad and fan evaporative cooling can be controlled enough to give good poultry production in the summer in some parts of the United States. The use of overhead insulation creates a lag in temperature peak between the inside and the outside, reduces roof temperature and consequent radiation to the animal, and reduces the con-



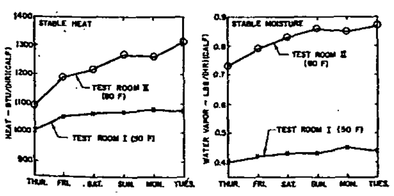
* Data from tests in constant temperature rooms, with 55 to 70 percent relative humidity, and include heat and moisture dissipation from floor and litter.

Fig. 5 .... Stable Heat and Moisture Dissipation Rates with Stanchioned Dairy Cattle*



* Pens cleaned daily.

Fig. 6 .... Stable Heat and Moisture Loads for Beef and Dairy Calves in Pens*,[31,32]



* Pens cleaned every Wednesday. Data were 4 months old beef calves.

Fig. 7 .... Effect of Accumulated Litter on Stable Heat and Moisture Loads*,[31]

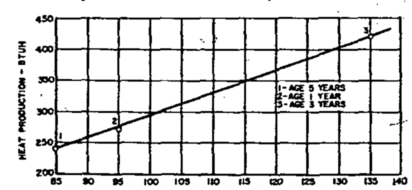


Fig. 8 .... Metabolic Heat Production of Sheep at Approximately 70 F[33]