wall coils, one pipe over the other; pipes pocketed under plant benches or in narrow walks against the sides of solid beds are less efficient than those in the open, but greenhouse heating engineers must deal with averages and the co-efficient 2 has been found to be safe.

Only the glass and other exposed surfaces reduced to the equivalent of glass are considered in the calculation. The factors or divisors for glass surfaces are derived from the following formula:

$$R = \frac{(T - t) \times G}{(150 - T) \times 2}$$

where

T = temperature desired, fahr.;
t = temperature out of doors (0 deg. fahr.);
150 = temperature of water in radiating surface, fahr.;
G = glass and glass equivalent surface;
2 = co-efficient of transmission;
R = radiating surface.

From the above formula the divisors in the table following are derived:

Table 2. Factors for Glass Surfaces

For 70 to 75 deg. divide sq. ft. of glass and equivalent by 2.0
For 65 to 70 deg. divide sq. ft. of glass and equivalent by 2.28
For 60 to 65 deg. divide sq. ft. of glass and equivalent by 2.62
For 55 to 60 deg. divide sq. ft. of glass and equivalent by 3.0
For 50 to 55 deg. divide sq. ft. of glass and equivalent by 3.46
For 45 to 50 deg. divide sq. ft. of glass and equivalent by 4.0
For 40 to 45 deg. divide sq. ft. of glass and equivalent by 4.67
For 35 to 40 deg. divide sq. ft. of glass and equivalent by 5.5

It will be noted that the temperatures given in the table are not 75 deg., 70 deg., 65 deg., etc., but 70-75 deg., 65-70 deg., 60-65 deg., etc. Greenhouses are so very sensitive to wind and so very unamenable to exact calculation that the initiated greenhouse man allows himself 5 deg. as leeway or as a factor of safety, and when he intends to heat to 60 deg. he specifies 55-60 deg.

Greenhouses do not respond exactly to figures in various ways: The same amount of glass may in two different houses enclose vastly different volumes; the air loss between the laps, though probably never calculated, may be quite different per square foot of glass in two houses of the same size, design and construction, on account of the difference in workmanship or of glass quality, or of both. The humid atmosphere of greenhouses—and for some purposes the atmosphere is much more humid than for others, as for instance, for rose growing—at some temperatures causes the laps to seal with condensation, checking, or stopping the air loss through the laps. At lower temperatures these laps are sealed with ice and at still lower temperatures the inside surface of the glass is entirely frosted over so that its conductivity is changed. It may be much more difficult to heat a greenhouse at 15-20 deg. above zero, or even at 25 deg. above zero, with the wind blowing, than at zero or below, because the low temperature house may be sealed with ice, as stated.

A greenhouse that is not stocked, i.e., in which the crop is not planted and therefore not watered, and which does not carry the normal humidity is much more difficult to heat than a live house, one in operation. And so, the same formula will not work out exactly for outside temperatures below zero because of the varying heat loss. In some parts where the minimum outside temperature is above zero, or where the minimum of zero is rarely reached and then for short periods only, as in some Southern states, while it is true that the same amount of heat is required to offset the low outside temperature, the duration of the cold spell is so very short that it is unnecessary to pipe the houses or to provide boilers as large as the same house or houses would require further North so that the judgment and experience of the heating engineer is vital.

RATIO OF AIR CONTENT TO GLASS SURFACE

The ratio of air content of the greenhouses to the glass surfaces increases with the width, so the number of changes of air through laps of glass, however many they may be, are less per hour with a wide house than with a narrow one, and the experienced heating man knows this and judiciously omits a line or two of pipe in very wide houses, after having divided the glass surface by the proper divisor.

Fig. 1 shows in section two conventional, even span, adjacent greenhouses of the ridge and furrow, or saw-tooth type, converted by extending the roof lines until they bisect each other, into one even span house; and the sketch also shows at once that above the eaves line the cubic contents contained by the same amount of glass in the large house is just twice the quantity contained above the eaves lines in the two small ones, and, obviously, it requires less heat units to heat the one large house than it does the two small houses, although the glass surfaces are the same. But how much less heat? Who can say? Glass laid by eye measurement, and glass of varying quality are inconstants. How may the air loss be determined?

A table compiled for purposes of comparing the cubic contents and the glass surfaces in the roofs of the houses in widths of 20 to 80 ft. with the same roof pitch shows that the air content above the eaves line in the 20 ft. houses bears the following relation to the glass in the roof.

Glass : Contents :: 1 : 2.34

whereas in 80 ft. houses, with the same roof pitch:

Glass : Contents :: 1 : 9.8

KINDS OF PIPE

Greenhouse radiation is almost always made up of pipe surface—horizontal pipe placed on the side walls, on the sides of solid beds and under raised benches, sometimes on the columns supporting the roof.

For hot water heating in private greenhouses, 3½ in. cast iron pipe, in 9 ft. lengths, is best; this pipe is provided with a hub and a spigot; it