G R E E N - H O U S E   C O N S T R U C T I O N

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GREENHOUSE CONSTRUCTION.

Outline.

Different forms of greenhouse.

Location and arrangement.

Greenhouse walls.

Construction of the roof.

Painting of the greenhouse.

Greenhouse heating.

Hot water heaters.

Pipes and piping.

G R E E N H O U S E   C O N S T R U C T I O N.

While the various glass structures are generally distinguished according to their use, as Rose houses, Palm houses, Store houses, Graperies, etc., for our present purpose, it will be well to first consider them from the builder's standpoint, as lean-to, span roof, etc. These names have been applied from the various shapes that may be given to the houses. While any of these forms may be used for all purposes, each one of them is particularly adapted to the growth of certain plants; and as they each have their special advantages and disadvantages, they should all be considered. However, as the space is too limited for the treatment of all the various forms, I will consider simply the construction of an even span house.

When erected in connection with some other building, the aspect and slope cannot always be regulated; but, when possible, greenhouses for this purpose should be on the south slope, so that no ray of light or heat will be cut off, either from the east or west. If against some other structure, it should be built north and south, with its north end next the other building.

When locating a detached house, a level spot is not objectionable, if good drainage can be secured; but if it can be located at the top of a south and westerly slope, it is all the better, as there the sun is available for extra hours at both ends of the day. If the spot chosen is not level, it should be graded, if possible. A slope of two or three inches to sixty feet is not objectionable, for it will serve to carry off the drain from the gutters;

and in a group of houses, while it is preferable that each house should be practically level, if the land selected cannot be readily graded so as to bring the house on the same level, there would be no serious objection to having the houses ranged one above the other, in regular tiers.

A thorough drainage, especially of the boiler room, should be the first desideratum in locating a house. In arranging a group of houses, the width and height of the different structures, and the shape of the roof will also have much to do with the exact location of them. If they are not arranged in ridge and furrow style, it will be necessary to leave a space of from twelve to twenty feet between the courses. They should be as near to one another as possible to save land, and for convenience and economy in operating, as well as in heating.

By convenient arrangement, the work in the greenhouse may be much lessoned. The potting and work rooms should be centrally located, and made convenient in every way for the work. In commercial houses, where orders must be filled upon short notice, the packing room should be situated so as to facilitate all speed and at the same time economical. In retail establishments, the customer's convenience must be looked too, and at the same time everything must be arranged neatly and conveniently for the customer. Among the furniture for such a room, it should be fitted up with counter, glass show cases, refrigerator, etc.

Greenhouse walls may be constructed of various materials, as wood, brick, stone, or grout, or any combination of these materials. Here, where stone is to be had so readily and cheaply, it undoubtedly will make the cheapest and most durable wall. Therefore, I choose it in the construction that I propose. One of the chief objections to the stone walls for their construction is that stone is a good conductor of heat; but this objection may be overcome by making the walls hollow, or by placing the house so low that the grade on the outside will come up to the sill plate. The other forms of walls are good, but when durability is considered, they are more expensive.

In putting in a masonary wall, the excavation for the foundation should be at least three feet below the proposed outside grade, and of a width to allow of from fifteen to eighteen inches footing course. This course should occupy the trench up to the level of the inside of the house, and may, with advantage extend to the sill plate, which is often from eighteen to twentyfour inches or more above the interior of the house.

The wall plates may be placed level, on top of the wall, or at the same angle as the roof. As a rule, two inch lumber is heavy enough. Whichever method is chosen, the wall should be finished off at the same angle, and the plate securely fastened in place. (For gutter, see drawing).

The construction of the roof is the next subject to be considered. The portion of the house which receives most attention is the strips that support the glass. There are a dozen or more different forms of sash bars and as many different ways of glazing, and yet the old wooden sash bar is still prefered by most commercial florists; for the sash bars found in some of the large modern constructions, both in size and shape, are identical with those of thirty years ago. Although the glazing is supposed to be so tight that no water can pass through into the house, there will more or less condensed moisture gather on the under side of the glass; and to prevent drip as much as possible, it will be found good to have them with a drip gutter on each side of the bar; although some florists prefer them with out the gutters.

Ordinary white pine makes a good sash bar, and if kept well painted, will be found quite durable. The southern cypress is, however, generally preferred. It is straight grained, rather more durable than white pine under the best of care, and much more so if they should be neglected. Cypress is also stronger and stiffer than the white pine, and for this reason, the sash bars can be made somewhat smaller, which is an advantage, as they do not catch so many of the sun's rays. For lapped glass, when drip gutters are wanted, a good form is shown in Fig. one; while, if drip gutters are not wanted, Fig. two shows a good form.

When glass from fourteen to sixteen inches wide is used, the weight or size of sash bar will depend on the distance between the purlins. The rabbet for the glass should be about five sixteenths of an inch wide, and one half inch deep. Vertical sash bars for the ends should be about one and one eight by one and seven eights inches. The rabbet may be of the same size as for the roof sash bars. In fact, the same bars may be used to no great disadvantage. For butted glass, whether used with or without glazing strip, either of the above mentioned forms (Fig. 1 and 2) may be used. The pattern shown in Figs. 3,4, and 5 are, however, preferable for this kind of glazing. The sash bars there shown are practically alike, III

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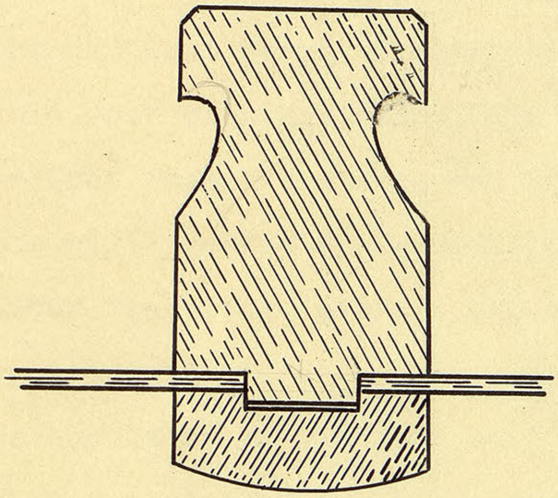

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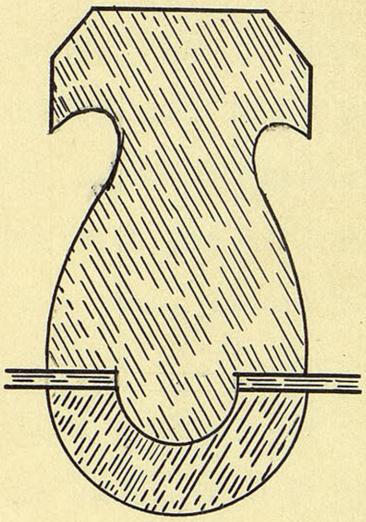

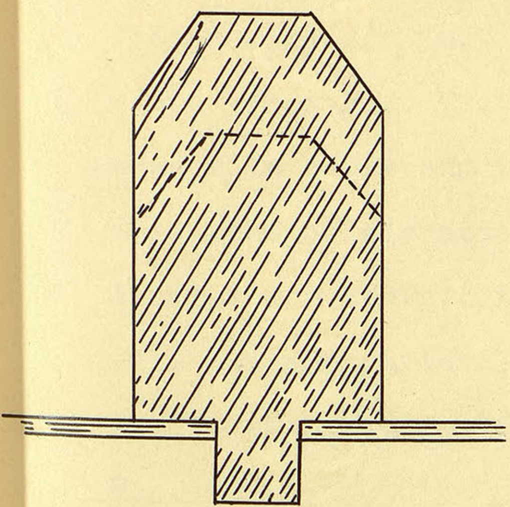

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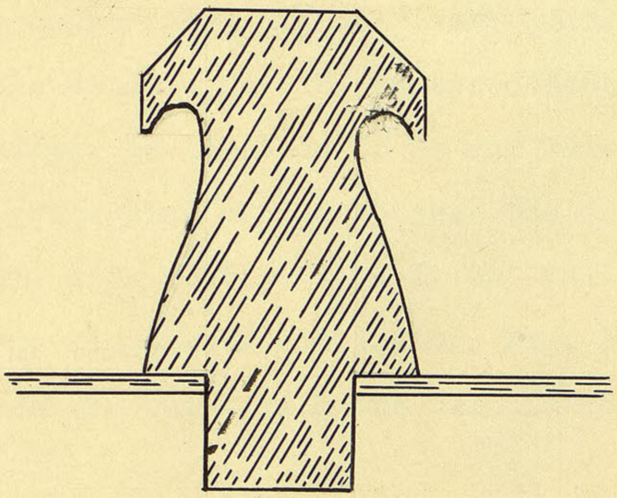


II

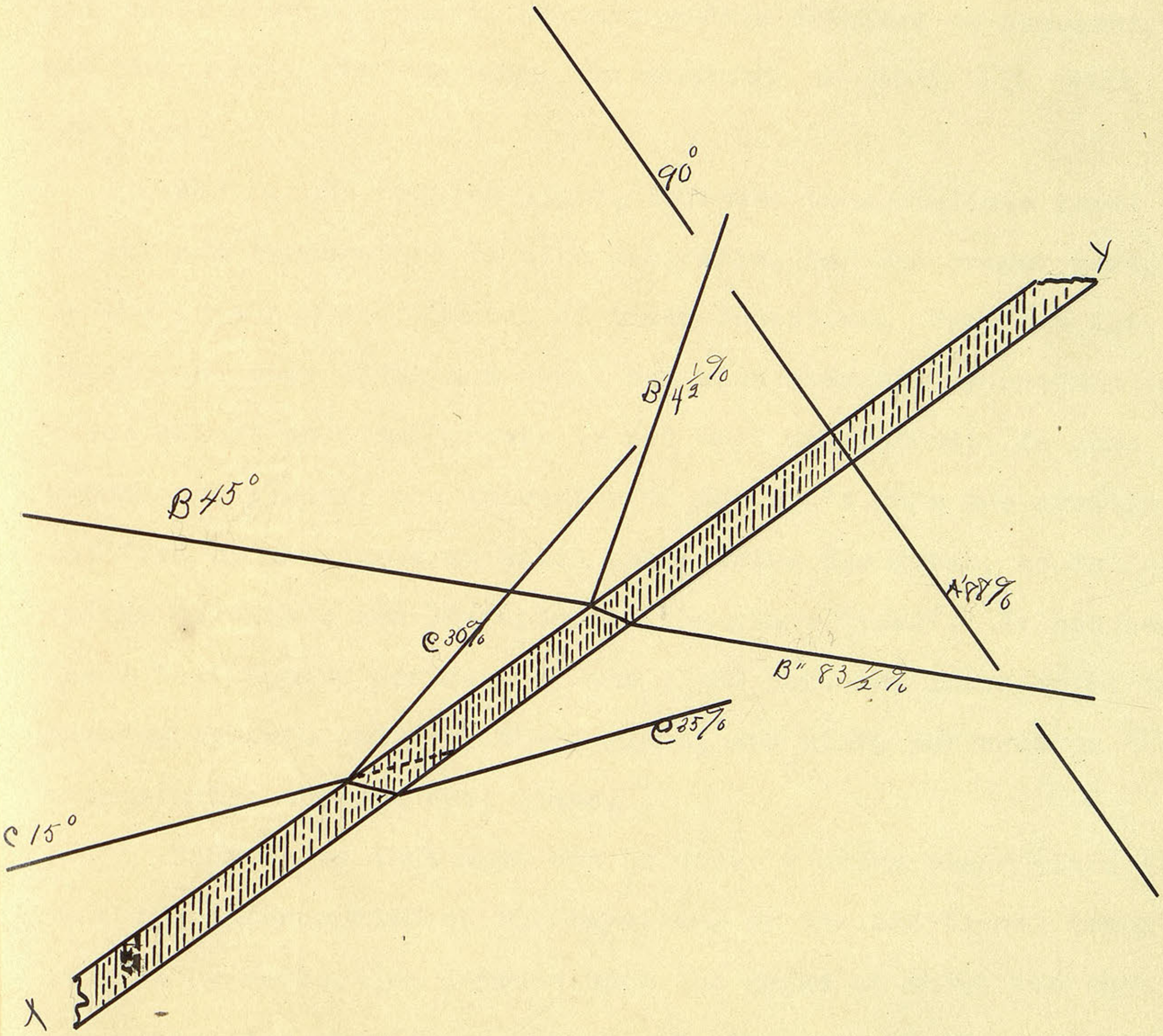
and the chief difference lies in the cap. In Fig. 6, is shown a a form of sash bar with out a drip gutter, for use with butted glass.

One of the simplest forms of construction for ventilation is to cover the whole roof with sash bars, and then cut off every seventh eighth, one four feet from the ridge, and insert a grooved header to support it. This will provide for a ventelating sash two to three feet wide, and four feet long, every eight or ten feet, according to the size of glass used.

The ridge should be of two inch stuff, from four to six inches deep, according to the size of the house and the sash bars. If the ventilators are continuous, it should have a groove on each side to admit the glass. If they are not continuous, only one groove is needed. The arrangement of the ridge is shown in Fig. 7. A little finish will add much to the appearance, and cost very little more.

From Fig. 7 and 8, the details for the construction of an even span house can be obtained, in addition to an end view and side view of elevation and grand plan of the house. The following details are shown: side wall with gutter, Fig. 1; end wall with sill and end rafters, Fig. 2; ridge with ventilator, Fig. 3, and double gutter when two houses are built with one wall in common Fig. 4.

In constructing the roof, the sash bars and end rafters should be cut at such an angle as will make a tight joint with the ridge above and the plate below, and then firmly nailed in place. If the plates are placed at the same angle as the roof, the lower end of the sash bars should be let into them about one half inch, as the glass is generally of scant width; if the sash bars are placed


90°
Y
B' 4½%
B 45°
A 78%
C 30%
B" 83½%
C 35%
C 15°
X

the exact distance apart, measuring from shoulder to shoulder, as the glass is supposed to measure; a good fit will be obtained.

All plants require light, in order to assimilate their food; an optimum temperature is also desirable, for the proper performance by the organs of the plants, of their functions. From the sun, we obtain not only light and heat but also chemical or actinic rays, whose effect on plant growth is not well understood. In case of greenhouse plants, the intensity of the sun's rays are greatly modified by the angle at which they strike the glass, as well as by the thickness and character of the glass itself. It has been found that twelve per cent of the light rays are intercepted in passing through ordinary sheet glass, and sixty per cent in their transmission through opal glass.

This shows that much can be done by using clear glass to prevent the interception of the rays; and as the additional amount that is lost by reflection depends upon the angle at which the rays strike the glass, the careful adjustment of the slope of the roof should not be neglected.

When rays of light fall upon sheets of glass at a right angle, they pass through without being turned from their course, and there is no loss except from absorption, which will amount to about twelve per cent. When they meet the glass at an oblique angle, a portion of the rays are reflected, and the remainder, less those lost by absorption, pass through the glass, and leave it in the same direction they had before entering.

Fig. 9, illustrates the effect of a pane of glass, x,y, upon rays of light, falling upon it at various angles, A, having 90 degrees, B, 45 and C 15. A passes directly through and emerges with 88% of its original intensity. B, in meeting the glass has 4 1/2% of its rays reflected to B'; the balance, on entering the glass, are reflected or bent from their course, and on leaving the glas, with 83 1-2% of their intensity, are reflected or bent back to their original direction at B". The effect upon the rays at C, which meet the glass at an angle of 15 degrees, is not unlike that on B, except that 30% of the rays are reflected at C; while only 8% emerge at C" the refraction, if anything, especially in the case of very oblique rays, is a benefit. The absorption increases with the thickness of the glass, and it is evident that there would be more loss, were it obliged to take the course 1-3, than there is in its refracted course 1-2.

The following is a table showing the amount of light lost by reflection at different angles of incidence.

Angle	of	ray	60 deg.	---------------------	light	lost	2.7%
"	"	"	50 "	---------------------	"	"	3.4%
"	"	"	40 "	---------------------	"	"	5.7%
"	"	"	30 "	---------------------	"	"	11.2%
"	"	"	20 "	---------------------	"	"	22.2%
"	"	"	15 "	---------------------	"	"	30.0%
"	"	"	10 "	---------------------	"	"	41.2%
"	"	"	5 "	---------------------	"	"	54.3%

During the short days of winter, when the sun is only above the horizon for less than 10 hours, as many of the rays should be trapped as possible, especially previous to 10 oclock A. M., and after 2 P. M. At the winter solstice, when the sun is farthest to the south, it rises about 25 degrees above the horizon at noon, and the slope of the roof should be such that the amount of light reflected while the sun is between the horizon and the above altitude should be the least possible.

The angle that the roof makes with the horizontal should never be less 30 or 35 degrees, and still better results in trapping the rays of light will be obtained if the roof has a slope to the south of 60 degrees, or more. The heat and actinic rays, in their passage through the glass, are subject to much the same laws of reflection and absorption as those of light, and in the case of absorption, the effect produced by semi-opaque glass is even greater. In determining the proper pitch for the roof of a greenhouse, in addition to considering the requirements for the transmission of the sun's rays in their full intensity at the season when they are most needed, various practical considerations should be taken into account, among which would be the height of the side walls, the width of the house, the height of the roof above the plants, and the effect upon heating of the houses as well as upon the drip from the glass.

It will at once be seen that it is not desirable to have a roof so steep as to greatly increase the glass area, and consequently, enlarge the consumption of fuel; while, if it is understood that that plants grow best where conparatively near the glass it will be seen to be otherwise, except in "short span houses to the south" to have the roof at a very sharp incline, as it will bring the plants at the center of the house at a considerable distance below the glass.

The use to which the house is to be put should also be taken into account, as; if it is to be used only for wintering over plants no growth being desired, it will be economy, both in construction and heating, to have the roof as level as possible, and good results will be obtained at a pitch of 26 degrees as in a greater one. On the other hand, for crops that requirean abundance of light for their quick development, the slope should not be less than 30 degrees, and if it can be secured without interfering in any way with the usefulness of the house in other respects, 38 would be better.

The glass that is now used most is known as sheet glass, either single or double strength. The latter costs somewhat more than the single strength, but it is less likely to burn the plants, and as it will stand a much harder blow, the breakage from hail storms and accidents will be much less, so that it will be cheaper in the end. In selecting greenhouse glass, two points in particular should be borne in mind, first, glass should be of good size; second, it should be even in thickness, flat,and free from imperfections that cause sun burning.

Glass is graded first, second, third, etc. The quality growing poorer as the number enlarges. The imperfections in glass is melted, the impurities settle to the bottom, leaving the glass on top quite clear. From this the "firsts" or "bests" are made by less expensive workmen than the "firsts", and not only are they likely to contain imperfections, but they are less even in thickness.

In the past, "seconds" of French or Belgean sheet glass have been commonly used, and are still prefered by most builders; but American natural glass is now being extensively used and it is said that the "firsts" are fully as good as the French "seconds" while the American "seconds" make a very satisfactory roof. The grade known as "A" quality, American glass, is suitable for almost any purpose, while "B" quality will answer for many classes of houses. The natural gas glass is thought by some to fully equal the same grades of European glass.

The size of the panes of glass has increased, until to day we find in use some twenty and even twenty-four inches wide. While this extreme large glass makes a very light house, well suited for growing roses and lettuce, it is generaly thought that a smaller size is preferable. For widths above eighteen inches the price rapidly increases, and this extra cost will be an important question, both at the time of the erection and in case of breakage. When glasses are to be butted, square panes are preferable, as it is likely to have straight edges at least one way. So when all is considered, from fourteen to eighteen inch glass is preferable to smaller, as well as larger sizes of glass. Unless there is a decided change, the above widths, in lengths of from twenty to twenty-four inches are the ones most likely to be used.

While double straight glass cost somewhat more than the single, the greatly reduced loss in case of hail storm, and the fact that the breakage by frost and other causes is less with the double strength than with the single strength, makes it preferable. It is generally believed that when in good condition, the danger from hail storms is only from one third to one half as great.

In setting glass, two points in particular must be held in view. First: It is desirable to have the roof as near air tight and water tight as possible. Second: The glass must be held firmly in place. The usual manner in which glass is laid is to lapp it with the upper pane extending about one eight of an inch over the one below it. For curvilinear roofs this is practically a necessity; and when glass is straight and even and well laid, it makes a good roof. Nearly all panes are more or less curved, and if two panes not equal are placed together, there is likely to be a crack either at the corner or in the center of the panes. Care should therefore be taken to assort the glass, and if the curves are of different angles, it is well to select those of one angle for one row and the others for other rows.

For glazing on wooden sash bar, if the glass is to be lapped, asterals should be selected with one half inch rabbets, which receive a line of putty sufficient to fill the shoulder. The best grade of putty should be used, and this should be mixed with the pure white lead, at the rate of one part of lead to five parts of putty. If a larger portion of lead is used, it will make the work of cleaning the bars a very difficult one in case of breakage, while if the bars are kept properly painted, the mixture as above will hold for many years.

The putty should be worked rather soft, using linseed oil if necessary, and it will be found that it will stick to the wood best, if it is used as soft as it can be used without sticking to the hands when they are well coated with whiting.

Having applied the putty to a number of sash bars the glass may be laid on and carefully pressed into place, squeezing out all all surplus putty until the upper end of the pane rests on the bar and the lower upon the pane below, with a lap not exceeding one eighth of an inch. Care should be taken to have the curve of the glass up, if drip gutters are to be used, and down if not. The surplus putty both inside and outside is then scraped off, pains being taken to fill all cracks that may be left. With the old method of putting the putty on top of the glass, it was found that in a year or two that the water worked the putty and peeled it off, leaving a crack at the side of the pane as well as underneath. This both allowed the heat to escape and the water to enter, besides allowing the glass to slip down and blow off if other fastenings became loosened.

For the purpose of holding the glass in place there are more than a dozen kinds of brads and points. One of the best and cheapest seems to be the ordinary five eighths inch wire brads. This is stiff enough to hold the glass firmly in place and have such a hold upon the wood that if properly driven in there will be no danger of its loosening and allowing the glass pane to slip down. Another advantage of this brad is that it is unconspicuous and therefore not unsightly and it offers little obstruction to the brush when the sash bars are painted.

In order to preserve the wood from decay and the iron work from rusting, the materials should be covered with some substance that will render the wood-work water-proof, and prevent the oxidation of the iron. There are on the market many patent paints that may be suitable for certain purposes, but very few of them will prove suitable for greenhouse painting. If pure white lead and linseed oil with a small amount of Japan are used, the result will be as satisfactory as can be obtained from any mixed paint. If the house is to be painted white, a little black should be added to take off the glare. However, some other light color may be preferred to white, and a pleasing one can be made by adding yellow and a small amount of green, producing a very light shade of green. With dark trimings upon the house this will give a pleasing effect. While it is desirable to use pleasing tints for painting greenhouses, preservation of the timber is the main object to be sought.

The priming coat should be given before the house is erected. As soon as the parts come from the mill, the joints should be made as far as practicable, and then should be given a good priming coat. In putting up the house, too much pains cannot be taken in coating every joint with pure white lead paint. As soon as the frame work is up, a second coat should be given it. Our best greenhouse builders use two coats of paint for commercial, and three for private establishments. If only two coats are to be given, every crack and nail hole should be filled with putty before the second coat is applied, but if a third coat is to be given, the puttying should be delayed until the second coat is dry. When three coats are to be given, it will be easiest to apply the last coat to the interior of the house before the glass is set, although it would serve to hold the putty in place under the glass, if it were applied after the glazing is completed. Whatever the number of coats, the last one to the exterior should not be given until the glass has been set, as then any crack that may remain at the side of the panes can be filled, and the roof will be made water tight. The putty would also become softened, and would work out were it not painted. In drawing the sash on the exterior, the paint should be rather thicker than is used in ordinary painting, and it is an excellent idea if it is drawn out upon the glass for, perhaps one sexteenth of an inch. In this way the paint will serve as a cement to hold the panes in place, should the other fastenings become displaced.

In our climate, most of the plants grown in greenhouses require artificial geat to be maintained from six to nine months of the year, in order that natural conditions may be secured for them. While some plants are not injured by exposure to 32 degrees, and thrive best at 45 deg. to 50 deg., the so called "store" plants should have 70 deg., or more, and to secure these temperatures in in greenhouses, various methods are used. The crudest method is by decomposing vegetable materials, and allowing the heat to radiate into the air. Second: The Polimase system, which consists in passing cool air over a hot iron surface, and directing it into the house. Third: By burning wood or coal in a furnace, and directing the gaseous products of combustion through the house in a brick or tile, horizontal chimney, known as a flue. Fourth: This differs only in the method of conveying the heat, as in this, it is taken up by water and carried where ever needed in the form of steam, or by the circulating water itself.

No matter what method is used, we should look to several points in making our choice. First: The cost and durability. Second: The economy of fuel and attendance. Third, the efficiency; both as concerns the amount and regularity, of heat supplied.

Aside from durability, and compactness of construction, the following points in the makeup of the heater should be considered: First: The amount and arrangement of the direct (fire) surface, and its proper adjustment to the grate area. Second: The arrangement of the water sections, or tubes, and the circulation of the water in the heater. Third: Ease of cleaning the flues, and the arrangements for shaking, dumping, removing the ashes, regulating the draft, etc. Fourth: The character of the points, with regards to the ease with which leaks can be repaired and breaks mended.

Many heaters are quite intricate in their construction, and the different parts are fastened with screw joints, or, as is more common, the joints are packed and the parts are drawn together with bolts. Everything else being equal, the fewer joints there are, the less chance there will be of braks, and in selecting a heater this should be considered, as well as the character and location of the joints. Some of the sectional heaters are so constructed that, if one section is broken in any way, it can be used without it until it can be mended or a new one procured. In case the section has to be replaced by another, the arrangement should be such that the change can be readily made.

Some advantages of wrought iron pipes over cast iron pipes may be briefly stated as follows: The lengths of pipe are from two to nearly four times as long, and can be screwed together instead of having to pack the numerous joints; there is less chance of leaky joints or of cracked pipes; although the cast iron four inch pipe has only twice the radiating surface, it is necessary to prove four times the amount of water for circulation that the two inch contains; on account of the size and weight of the four inch pipe, it is necessary to have them low down under the benches, but little above the level of the heater, while the small wrought iron pipes can be carried in the very angle of the ridge if desired, and thus a far more rapid circulation can be maintained than with large pipe; the large pipe carrying a large amount of water and giving a slow circulation, is at a much lower temperature, particularly on the returns, and a smaller radiating surface will suffice when small pipe is used; so that a two inch wrought iron pipe may be counted equivalent in heating capacity to a four inch cast iron pipe. It has been claimed that large piping is safer to use, as it will hold the heat longer. This is undoubtedly true, if the fire is allowed to go out; but, with a well arranged system, a regular even temperature can be maintained with small pipes from 10 to 12 hours, on mild winter nights, and from seven to eight hours on severe nights which is as long as one can risk the large pipes without attention.

The size of pipe best suited for coils. Considered as radiating surface only, one inch pipe would be preferable, but, except for very short runs, since the friction increases as the size of the pipe decreases, a larger size should generally be used. 1 1-4 inch can be used to advantage in coils not over forty feet long, and if the height is sufficient, the length, 1 1-2 inch pipe will be intirely satisfactory; two inch pipe will work well up to one hundred and fifty feet; but it is better in all houses over one hundred feet long, to use two or more short coils of 1 1-2 inch pipe. In this way, by having proper flow and return pipes connected with the coils, houses three hundred feet long can be heated with hot water.

In determining the size for the feed pipes, the length of the house and the height that the coils will have should be considered, as well as the number of square feet of radiation to be supplied.

For houses of average length and width, the average height of the coils six feet above the bottom of the heater.

2	inch	pipe	will supply	200 - 300	square	feet	of	radiation
3	"	"	"	600 - 800	"	"	"	"
3 1/2	"	"	"	800 -1000	"	"	"	"

In most parts of the country it is reckoned that,

1	sq.	foot	of	pipe	will	heat	to 40	deg. -	4 1/2	square	feet	of glass
1	"	"	"	"	"	"	50	" -	4	"	"	" "
1	"	"	"	"	"	"	55	" -	3 1/2	"	"	" "
1	"	"	"	"	"	"	60	" -	3	"	"	" "
1	"	"	"	"	"	"	65	" -	2 1/2	"	"	" "
1	"	"	"	"	"	"	70	" -	2	"	"	" "

While a slightly higher estimate would be safe, it is economy to have an abundant radiation, especially for tropical houses.

In estimating the surface of wrought iron pipe,

1	inch	pipe	is	reckoned at	.344	sq.	feet	per linear	foot,
1 1/4	"	"	"	"	.434	"	"	"	" "
1 1/2	"	"	"	"	.497	"	"	"	" "
2	"	"	"	"	.621	"	"	"	" "

With these tables to work from, it will be quite easy to figure the amount of pipe needed for any given house.