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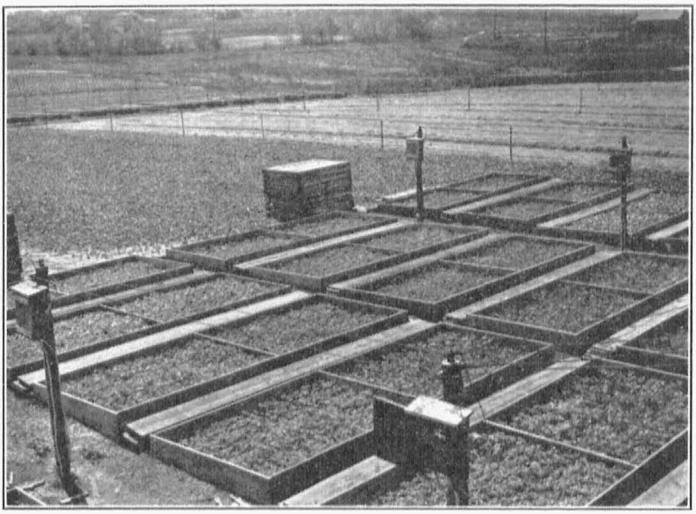
Electric Hotbeds



COLUMBIA, MISSOURI

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Electric Hotbeds

Ralph R. Parks

Hotbeds are used by gardeners, florists, and farmers for starting plants which are to be used early in the growing season. In the process of preparing these plants for field planting, they are transplanted to other hotbeds or to "cold frames" as they develop and require more space. A relatively warm bed, 65 to 85 degrees Fahrenheit, is required to germinate most seeds and grow them to transplanting size. This can be done under optimum conditions in from one to two weeks, depending on the nature of the crop. After that time, the plants are allowed to grow more slowly, so that they will develop their root systems and form into sturdy, tough stock that will stand the temperatures and high winds encountered in early field planting.

Heat caused by the chemical action taking place in fresh manure has been universally used in operating hotbeds. The heat from a ten to fifteen-inch layer of manure is usually enough to start a bed of plants and then protect them over a period of two months, providing the weather is not too severe after the first surge of heat from the manure has been dissipated. With the motorization of farms as well as urban industries, securing manure for hotbeds becomes an increasingly serious problem. Hot water and steam systems of heating have been used, but the investment required in these systems is a serious disadvantage. Usually a gardener prefers to build a plant house rather than equip hotbeds with steam or hot water heat.

Electricity offers a solution to the hotbed heating problem. It also makes possible a closer control over soil temperatures and light conditions in plant houses and greenhouses than is now possible.

EUROPEAN GARDENERS USE ELECTRIC HOTBEDS

Harold Edholm, a European experimenter, reports* that hotbeds used in Sweden, Norway, and other European countries, are heated with soil immersion cable placed either directly in the soil or in tile, laid in the soil to facilitate soil ventilation. In some instances, these tile have vertical outlets every 32 feet to allow heating of the air with the heater cables. In other cases a separate cable is laid in the hotbed air to heat it directly. Edholm also reports that bottom insulation of hotbeds is desirable to reduce heat losses to the sub-soil. He suggests

*A paper read to the Royal Academy of Agriculture, Sweden, May 15, 1927.

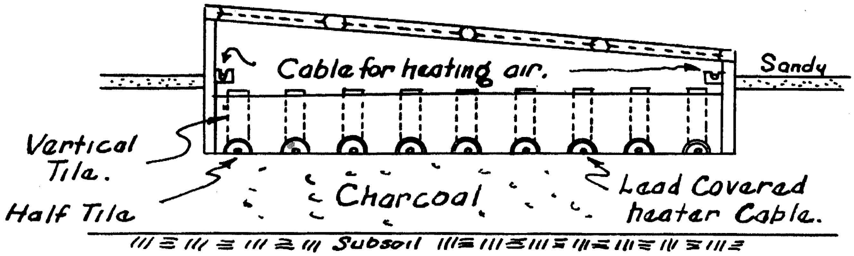


Fig. 1.—Electric Hotbed Used in Europe.

charcoal for this insulation. The charcoal, besides furnishing insulation, releases carbon dioxide for plant food.

G. Jacobsen,* an experimenter from Aker, Norway, reports that the small amount of heat sent downward from immersion heater units is not lost, but on the contrary serves to limit temperature fluctuations in the bed. He also suggests that capillary water is more valuable to plant growth than the saving that might be made in using insulation. Where material such as charcoal is used, the cost of insulation is apt to be more than the value of the energy sent to the sub-soil of the bed.

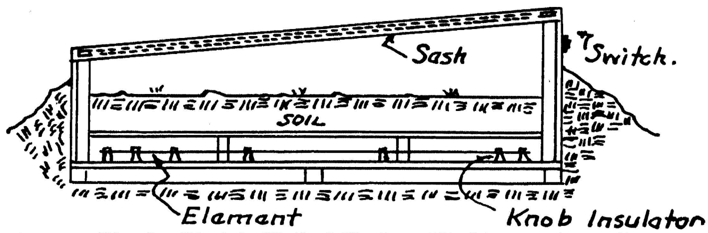


Fig. 2.—Electric Hotbed Used at Washington State College.

OVEN-TYPE HEATING SYSTEMS

Harry L. Garver, in State College of Washington Bulletin 219, describes the use of coiled resistance wire in an oven-like compartment over which the hotbed is suspended on burlap or fine mesh wire. If sufficient heater wire is used this system allows a very uniform spread of heat through the soil above. The cost of constructing this type of bed is its greatest deterrent to more popular use by gardeners.

Maurice W. Nixon, at Cornell University, reported** work similar to Garver's. One of the features of his work was the use of an out-

*A very interesting paper on Electric Soil Heating read at the International Horticultural Congress at London, August, 1930, in which was described a system of heating very similar to that being followed in Missouri.

**This report was made to the Empire State Gas and Electric Association in August, 1930.

side thermostat to regulate the operation of the hotbed heaters by the temperature of the outside air.

General Electric Company Laboratories at Schenectady also report work done with the oven-type of hotbed heater and present a very elaborate plan of construction in their Bulletin GEA1319. No cost figures are presented with the plan, but one gardener reports a cost of $75 for one that he built for his garden.

IMMERSION HEATER CABLES

The first electric hotbed built and tried at the Missouri College of Agriculture was of the oven-heater type patterned after the plan presented by Garver. It gave very satisfactory results during the early season of 1929 so it was suggested to a few possible cooperators in St. Louis county that they try that type of unit along with their manure beds. The plan met with such disfavor because of its high first cost and possible short life that it was considered necessary to build special heater units of the immersion type before any scheme of electric hotbed heating would be popularly accepted. Accordingly, pipe units were assembled. These units were built of ¾ inch galvanized water pipe, the inside of which was lined with porcelain wiring tubes. Resistance wire coiled on 3/16 inch rod was then stretched through these tubes and the ends secured to copper conductors with small brass bolts. The bottom sketch in Figure 10 shows the arrangement of the pipe heaters in a 6x12 bed.

This scheme of heating worked so well that special orders for flexible heater cable were placed with manufacturers the following season. This cable will be on the market by the spring of 1932. It is made of a single strand of resistance wire insulated with asbestos and protected with a lead sheath. It is subject to mechanical injury and must be removed from the bed before spades or other sharp tools are used to dig up the soil at the depth it is placed. However, with its wire core it can be subjected to pull without injury, so it is easily removed from the bed. The top sketch of Figure 10 shows the arrangement of a 48-foot length of this cable in a 6x12 bed. The cable is designed to give a heating capacity of 10 to 12 watts per foot of length. In placing it in the bed, the gardener simply lays his frame out on a smooth surface, with a slope to the south where possible. The cable is then laid in the bottom of the frame and 6 inches of hotbed soil is put into the frame over the cable.

One objection that might be raised to the use of immersion cables for soil heating is that if they are spaced too far apart or if the soil is too thin over them, they will cause an uneven plant growth

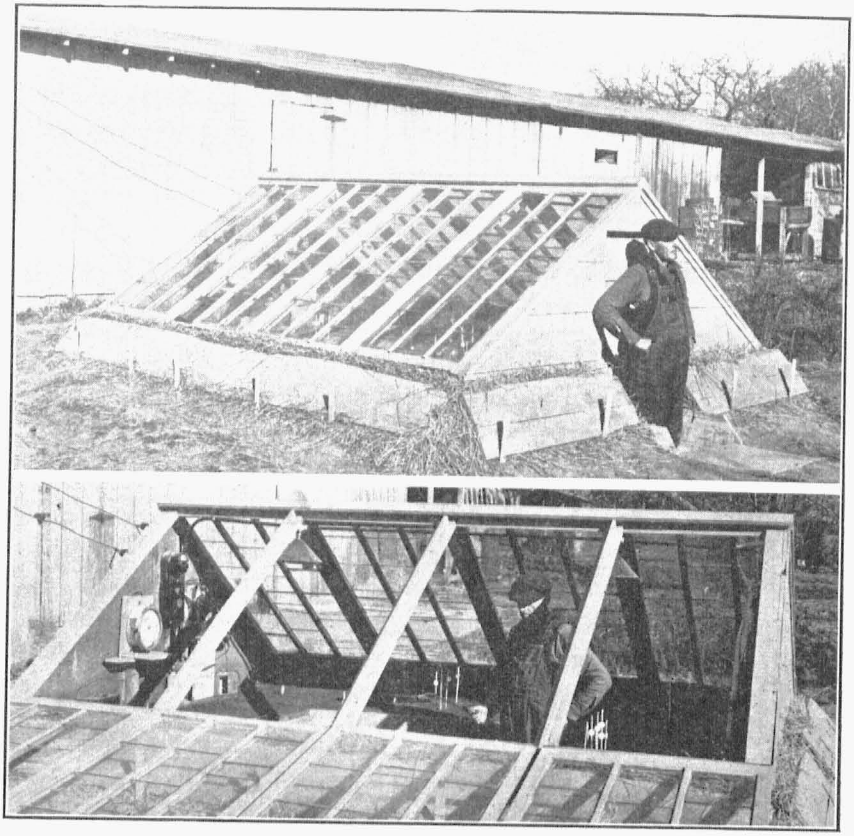


Fig. 3.—An Electric Plant House.

in the bed due to the difference in soil temperature directly over and between the cables at the soil surface. This point has been carefully checked through observations of plant growth in cable heated beds during the past three seasons and through temperature variations as they occurred in experimental beds near the University Greenhouse during the season of 1931. Figure 4 shows the temperature variations as they occurred in soil where the cable was placed 6 inches deep and 18 inches apart. The temperature in the soil 3 inches deep and directly over the cable was 8 to 10 degrees higher than midway between them. At a depth of 1½ inches below the surface this difference was only 4 to 5 degrees. Surface temperatures were not enough different to cause uneven growth of plants in the bed.

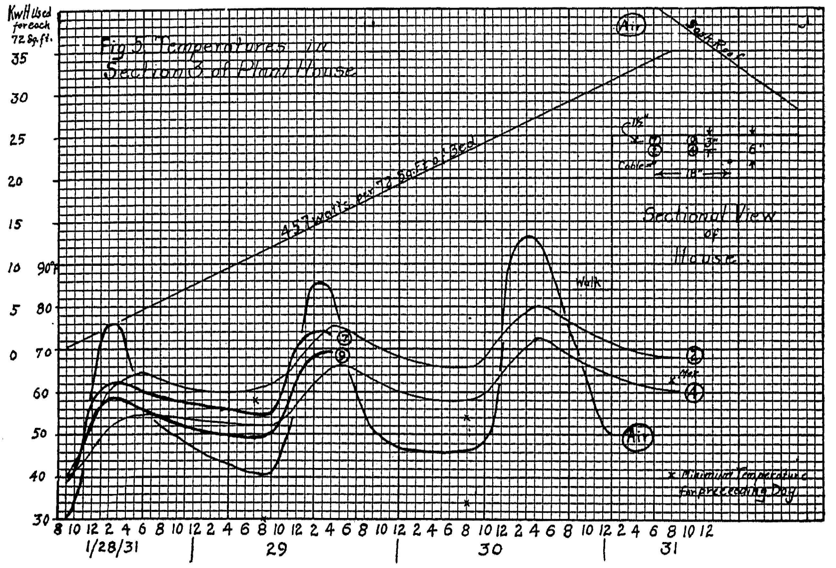


Fig. 4.—Temperatures in Section 3 of Plant House.

ADVANTAGES OF ELECTRIC HEAT

Even with intensive motorization around large trucking centers, manure for heat is yet available, since it can be freighted and hauled from outlying districts. However, with improved systems of hotbed management, electricity offers a better solution of the heating problem than any other form of heat,—if the cost can be made at all competitive.

The advantages of electric hotbeds over manure hotbeds are:

1. Electric heating apparatus can be quickly and easily installed, while it takes quite a lot of time and labor to make manure beds.
2. Electric hotbeds can be turned on or off depending on the outside weather conditions, while the heating process of manure under a bed is practically continuous.
3. A pure heat can be obtained in any part of the electric hotbed soil or air. Manure heat is steamy and carries with it gases that are harmful, in large quantities, to plant growth.
4. The flexibility in the operation of electric hotbeds allows the gardener more certainty in when his plants will be available for field planting because they can be forced with heat, possibly light, or can be retarded by keeping the heat from them.

5. These advantages improve the working conditions of the gardener, reduce operating costs, and make plant raising more interesting.

ELECTRIC HOTBEDS SHOULD BE WELL INSULATED

Heat energy is used in hotbeds to maintain temperature conditions under which plants can develop at a normal rate for future field planting. Practically all of the energy used in securing these temperature conditions is eventually lost to the outside air by heat leakage. This leakage takes place principally through the top of the bed from five in the evening to eight in the morning, and amounts to perhaps 350 watts with a 40 degree temperature difference between the outside and inside of a hotbed.*

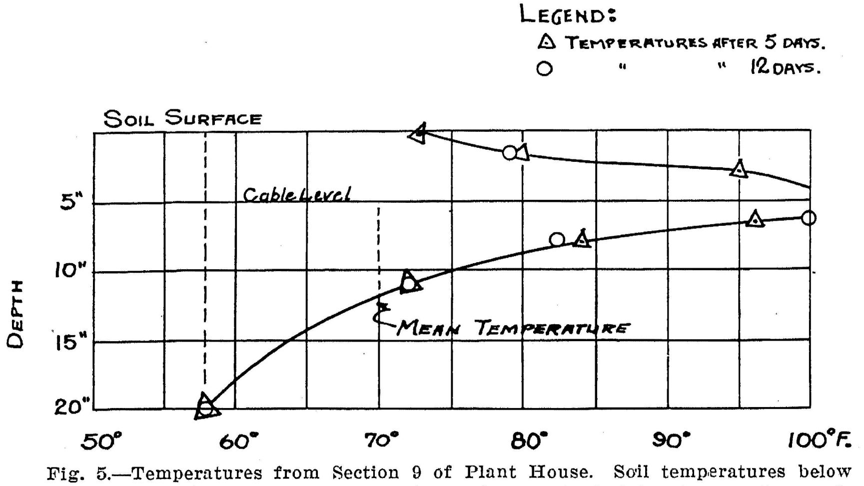


Fig. 5.—Temperatures from Section 9 of Plant House. Soil temperatures below immersion heater cables tend to become fixed after the hotbed has become "warmed-up."

Insulation of the sides of a hotbed is also important. If the frame is set above ground, it has just half as much surface exposed to the outside as does the top of the bed. Many gardeners protect the sides by placing the beds two to three feet apart and filling the alley with straw. However, if the straw is to be a good insulator, it must

*Handbooks give the heat conductivity values of glass and cypress, as 1.06 and 0.67 B. t. u. per hour per square foot per degree of temperature, respectively. In adding the effect of these two materials (adding reciprocals) we find that the heat conductivity value, if the two were in solid sheets, is 0.41. Then the watt input required to hold a temperature of say 70 degrees Fahrenheit in a 6x12 hotbed when the outside temperature is 30 degrees (considering only top loss) is: $\frac{0.41 \times 72 \times 40}{3.415}$ or 347 watts. Had the covering been only glass by itself it would have required $\frac{1.06 \times 374}{0.41}$ or 895 watts to maintain 70 degrees temperature. Thus the importance of top insulation in maintaining optimum hotbed temperatures can be seen.

be kept dry. For that reason, board walks should be laid over the straw to drain water from between the beds.

Bottom insulation has been a point for much discussion. There has not been enough work done on the subject to enable one to make definite conclusions; however, the few trials which have been made to date seem to indicate that there are as many advantages in leaving off bottom insulation as there are disadvantages from loss of heat to the sub-soil of the bed. Let us assume, for simplicity, that the entire soil mass below the heater cables is heated to temperatures comparable to those shown in Figure 5. If all the soil in the bed from a level one inch below the heater cable is needed and usable for plant progagation, and any heat below that level is wasted energy as far as the plants are concerned, the total waste in the case of a 6x12 bed is approximately 9 kilowatt-hours, or 27 cents with energy costing 3 cents a KwH.*

ELECTRIC HOTBEDS DIFFER IN OPERATION

A common mistake that a gardener makes in attempting to properly operate electric beds is to ventilate his beds too much at the expense of his electricity bill. Manure beds require quite a lot of ventilation to get rid of the steam and ammonia fumes coming from the manure, but there is no such disadvantage to electric bed operation. If a gardener is careful to water electric beds (when needed) in the early part of the day, so that the surface of the bed will have an opportunity to dry before the cool night temperatures strike it and condense moisture around the plant, there should be very little need for ventilation except to keep down excessive temperatures under a bright sun.

Electric operation suggests the possibility of automatic heat control. No doubt thermostat equipment can be adapted and has been used with some success on electric hotbeds. The fact remains that temperatures change so slowly in the electric beds, as they now are equipped, that it is doubtful if automatic control will have any advan-

*Measuring the area in Figure 5 between the curve and the 58 degree line below the 6 inch top layer of soil and dividing the amount by the height of the left side of the area, we find that the mean temperature of the mass is 70 degrees or a temperature rise of 12 degrees has been effected by the heater.

The moisture content of the soil 8 inches deep in Section 9 of the Plant House where this trial was conducted was found to be 20 percent. Assuming it to be good garden soil, it has a specific heat of approximately 0.25. Under laboratory check one cubic foot of the soil was found to weigh 74 pounds; or for our problem a block of the material 1 foot square and 14 inches deep weighed 91 pounds. Then:

20% (moisture) x91x1.00 (specific heat) equals 18.2
80% (dry soil) x91x0.25 (specific heat) equals 18.2
or 36.4 B.t.u.

are required to raise 91 pounds of the soil 1 degree Fahrenheit. And: 36.4x12 (de-

And: $\frac{\text{26 4x12 (degrees rise)}}{\text{3415 B. t. u. in a KwH.}}$ equals 0.128 KwH per square foot in heating the lower part of the bed. In case of a 6x12 bed it amounts to 9.2 kilowatt-hours or 28 cents with energy costing 3 cents per KwH.

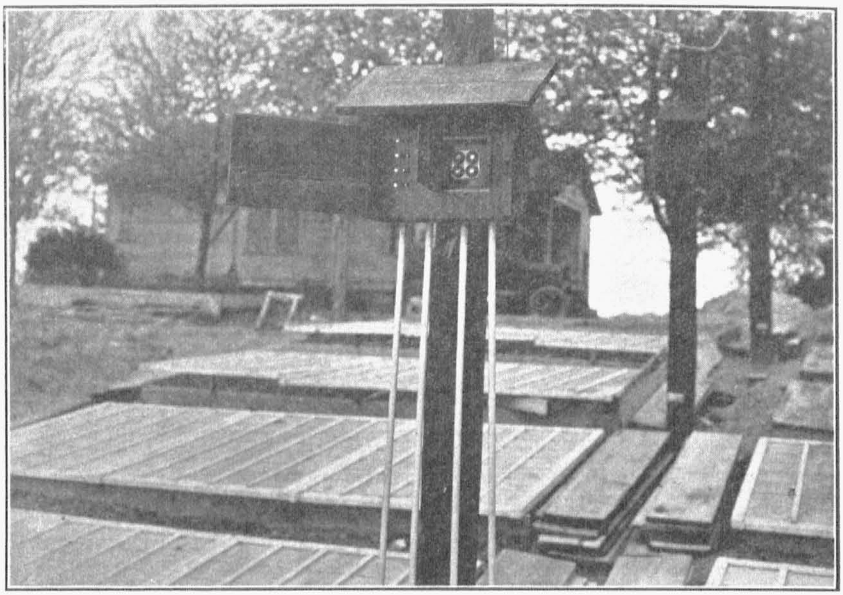


Fig. 6.—A distribution cabinet contains one switch and fuse for each of four hotbeds. A 3-wire 110-220 volt system is used in supplying 110 volts to each hotbed heater cable.

tages over manual control where the gardener watches his beds as closely as he now does. If automatic control is put on the heating apparatus it should also be placed on the mechanical ventilating apparatus, because the latter is more important from the standpoint of optimum temperatures. Another suggestion which has been made is that there be two or more heats for different weather conditions. The practical gardener says that if he must make a greater investment in his heating apparatus, which he must to get multi-heat possibilities, then the advantage must offset that additional cost. Again, the temperature change in electric hotbeds as they are now equipped with low wattage heaters, and the slowness with which they cool when the heat is turned off, makes it doubtful if multi-heat units have any advantage over manual control and the operators estimate of future temperature needs in the beds.

Heaters for both the air and the soil in an electric bed might be practical in cool climates where sudden changes are apt to injure hotbed plants; however, weather conditions do not change fast enough ordinarily to keep the gardener from anticipating changes and preparing for them by using extra covering over his beds.

MUST ADAPT TO LARGE-SCALE OPERATION

The commercial gardener starts his manure hotbeds about the first of each year in order to have sturdy plants ready for field planting about the first of April. During probably two-thirds of this time little or no heat is needed except that from the sun. Authorities state that the heat from a cubic yard of fresh manure is equivalent to 88 kilowatt-hours. If a 6x12 bed is filled with 14 inches of manure, the heat equivalent in kilowatt-hours would be 264. However, much of this heat is not usable because it is being liberated continuously and is accompanied by steam and some gases that must be turned loose to the outside air at intervals. At best a 14-inch layer of manure will heat a hotbed continuously for two or three weeks. From that time on the temperature is reduced considerably. In St. Louis county, where most of the hotbed experiments to date have been made, a car load of manure costs $50 on the railroad siding. By the time that manure is hauled and placed in the beds it has cost the gardener $6 to $8 for a 6x12 bed.

If electricity is to replace manure in hotbed heating, it must meet the above mentioned conditions. Being supplied with pure heat, electric hotbeds require less ventilation, consequently less heat, than manure beds. Too, electricity can be saved during warm days and favorable weather by the turning of a switch, while the heat dissipation in the manure bed must continue. Low first cost is another condition that should be met by electric hotbeds. If the first cost cannot be made low, the operating costs and yearly depreciation should be comparable with that of manure beds.

ELECTRIC HOTBEDS PLEASE PRACTICAL GARDENERS

Three cooperators used experimental electric hotbeds of the pipe immersion heater type in St. Louis county during the late season of 1929. During the following season these same three, plus four additional ones, used heater cable in experimental beds. During the season of 1931, 15 gardeners in St. Louis county cooperated on the project. One of these used twenty-four 6x16 beds; he had cooperated the year before using one bed. Another operated twelve 6x12 beds; he had cooperated both years before. Besides the electric hotbeds in St. Louis county, one cooperator furnished records on a bed in Jackson county, another furnished records from Cole county, and a third furnished records from Greene county. All are well pleased with their results.

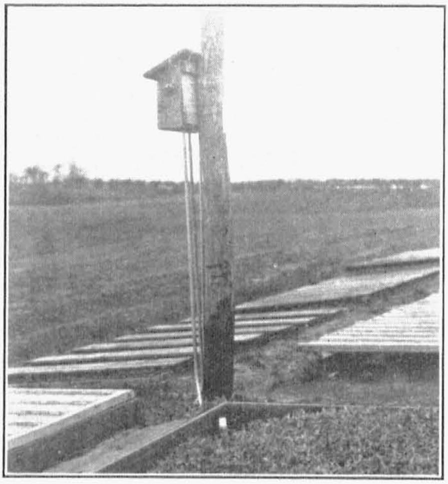


Fig. 7.—Rigid conduit is used to protect the connections to the bed. In each bed a connector cap is used for connecting the cable to the power source.

Hotbed operation has not been the only application for this system of soil heating. Three cooperators in St. Louis county and three in Jackson county report favorable results from soil heating in greenhouses and plant-houses. Where air temperatures are normally held low in greenhouses, florists find that they can materially hurry the rooting of cuttings by furnishing extra heat to the benches. During the early season plant-house operators find that the ground soil heats very slowly even with relatively high air temperatures, so electric heater cables are used to boost the soil temperature in comparison with that of the air to germinate seeds and give the plants a start.

WIRING NOT COMPLICATED NOR EXPENSIVE

The safety, economy, and convenience in the wiring of any appliance is always debatable because of the many ideas presented and the many fittings in the market to be used. The system described in Figure 9 on page 14 has been thoroughly tried and is recommended by thoroughly competent rural service men. Any short cut from this system, such as using rubber covered wire in place of conduit, will prove to be more expensive over a period of time and will add hazards to the operation of the electric units.

The Cable.—A slip connection in the beds is provided so that the operator can easily remove the heater cable before changing the

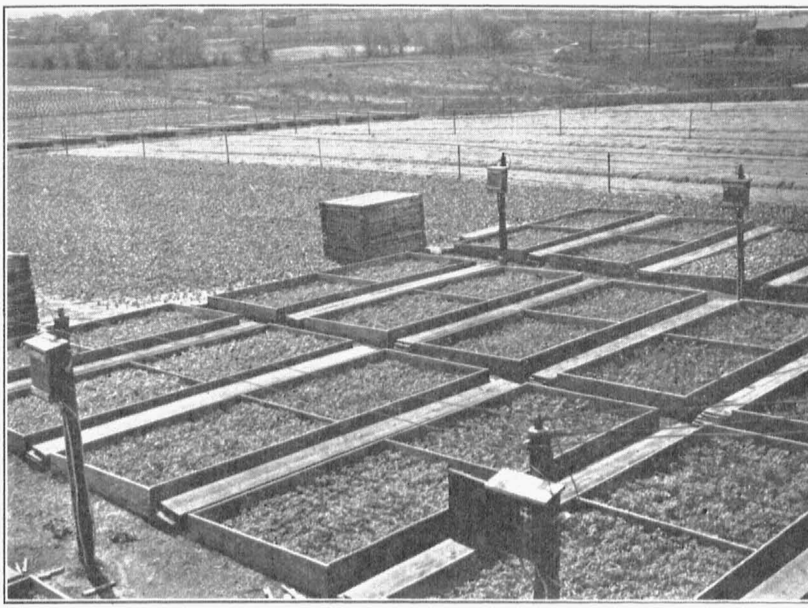
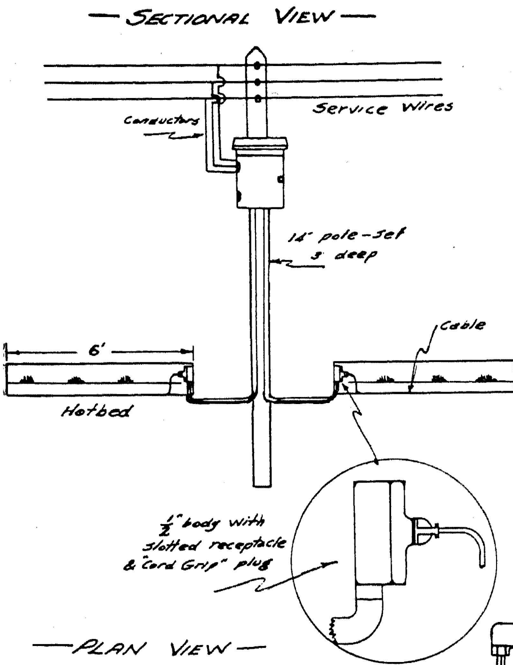


Fig. 8.—A group of electric hotbeds in St. Louis county. Each cabinet controls the heat to four hotbeds.

soil in the frames each season. If it were left in, sharp tools might cut the lead sheath. The flexible cable is adaptible to any shape of forcing structure. Where beds are used as long as the cable length, the far end connections can be made to a common neutral* return, or the end of each resistance wire can be grounded to the lead sheath with a suitable clamp, and sealed to exclude moisture. Then connections are made, at the starting end, from the lead sheath of each cable to the neutral wire of the system, the resistance wire being connected to one of the phase wires.

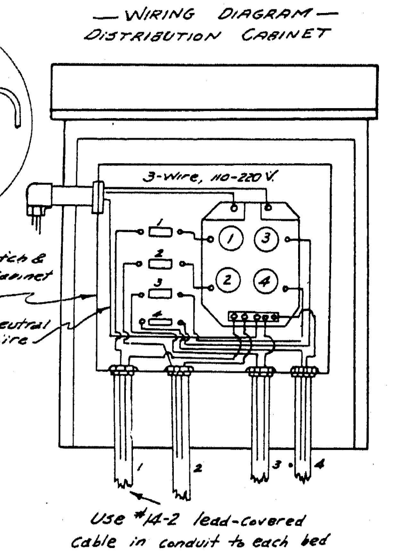
Repairing a ruptured lead sheath cable is relatively a simple process. The unit should first be laid out on the ground and put into operation so that the heat will dry out the insulation. Then a piece of lead is taken from a short section of other cable, wrapped around the ruptured piece, and soldered in place. This cable, designed for low operating temperatures, should not be expected to give satisfaction at capacities above 20 watts per foot in moist soil and 10 watts per foot in the air.

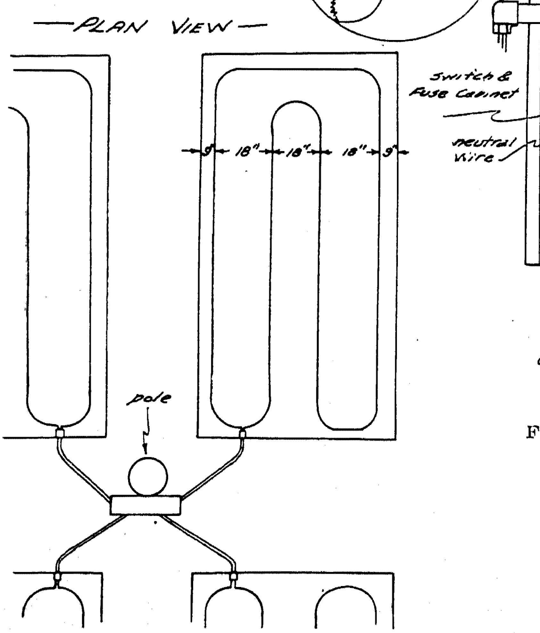
*In a 110-220 volt, 3 wire system, the two outer wires are called the phase wires and have a potential difference of 220 volts. The center wire comes from a point midway between the two phase wire connections in the secondary coil of the transformer. It is called the neutral wire and usually is a "grounded neutral" because there is a connection running between it and a water pipe or iron stake driven in the ground so there will be no potential difference between it and the ground. This is a safety measure taken to prevent high voltages from coming on the secondary system.



List of Materials

1-4 circuit, switch and fuse cabinet
3- single insulator brackets
1-14'-4" top pole
1- cypress wood box for cabinet
4- 10 Amp. toggle switches—S. P.
4- 15 Amp. plug fuses
1- ½"x10" galvanized nipple
1- ½" entrance fitting
4- ½"x10' galvanized conduit
46'- No. 14-2 cond. lead covered cable
4- ½" E bodies and—
4- Slotted receptacles for same
4- Cord grip connector caps
5- ½" bushings
5- ½" locknuts





For 6'x12' beds, use 48' of No. 22 Nichrome lead-covered cable in each. For 6'x16' beds, use 64' of No. 16 Nichrome lead-covered cable in each. Fasten the ends into the cord grip caps.

Fig. 9.—Plan of wiring a group of four hotbeds for electric heat. Also list of materials..

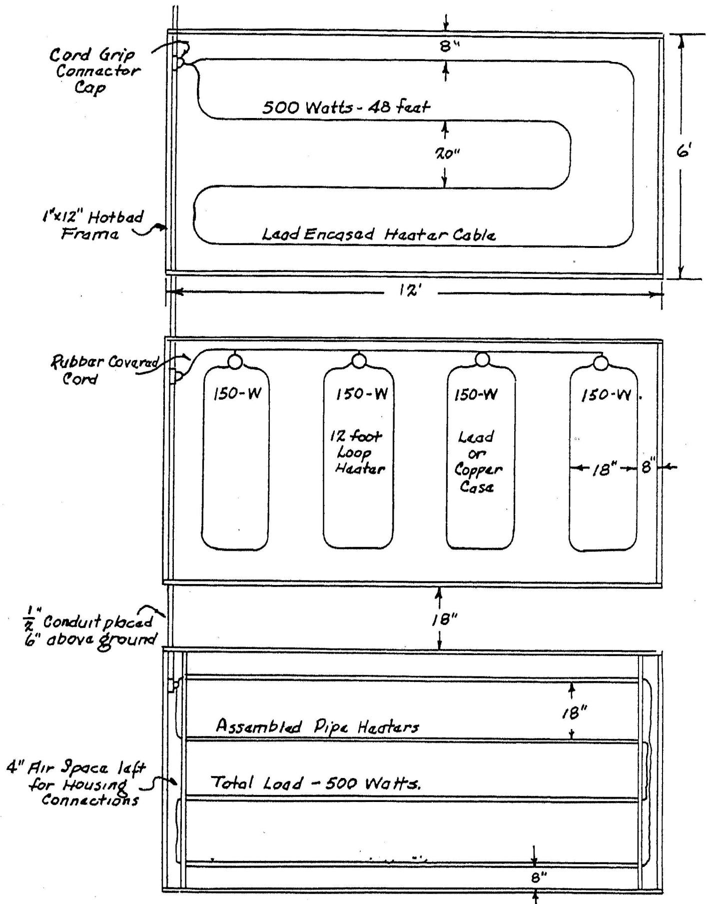


Fig. 10.—Sketch of three types of electric hotbed heaters used during 1930 spring season.

Connections to the Cabinet.—Individual connections are specified for each hotbed to simplify the unit as much as possible, and standardize on the materials. Cord grip connector caps are used to insure protection of the operator from live parts, and to prevent possible shorts from the lead sheath touching live parts. A moisture proof receptacle should be used inside the hotbed frame because of condensation and possible water from operation of the beds. In such underground wiring, lead covered conductors are always specified inside of conduit to provide moisture protection as well as mechanical protection to the wires.

The Cabinet.—It is believed that until a better system of automatic control can be worked out, switching equipment for individual beds should be provided in a convenient place near the bed. Individual fuses should also be provided so that difficulty with any one bed can be quickly located without interfering with the operation of the rest.

Service Wires.—The standard service connections to farmsteads are 3-wire 110-220 volt. That is the service that should be run to a group of four or more beds. The advantage of such a system is that when the load is properly balanced the energy is coming from a 220-volt source, and therefore has less loss in transmission than if it came from a straight 110-volt source. Consequently, smaller wires can be used for the same load.

SUMMARY

1. Ordinarily, it is economical to substitute electricity for manure in hotbeds when the cost of trucking and labor in handling the manure is considered.
2. Operating costs on electric hotbeds vary with the season, crop grown, insulation, and method of handling. In general 100 to 250 kilowatt-hours are sufficient to heat a 6x12 hotbed for one season.
3. Under conditions in Missouri, immersion heater cables will perform essentially the same as oven-type heaters and will cost considerably less.
4. A 6x12 hotbed frame can be "electrified" for about $5.00. It is safe and easy to operate.