Nov. 3, 1936. A. G. WORTHING ET AL 2,059,835

DESTRUCTION OF LIVING ORGANISMS

Filed Jan. 29, 1936 3 Sheets-Sheet 1

Fig. 1.

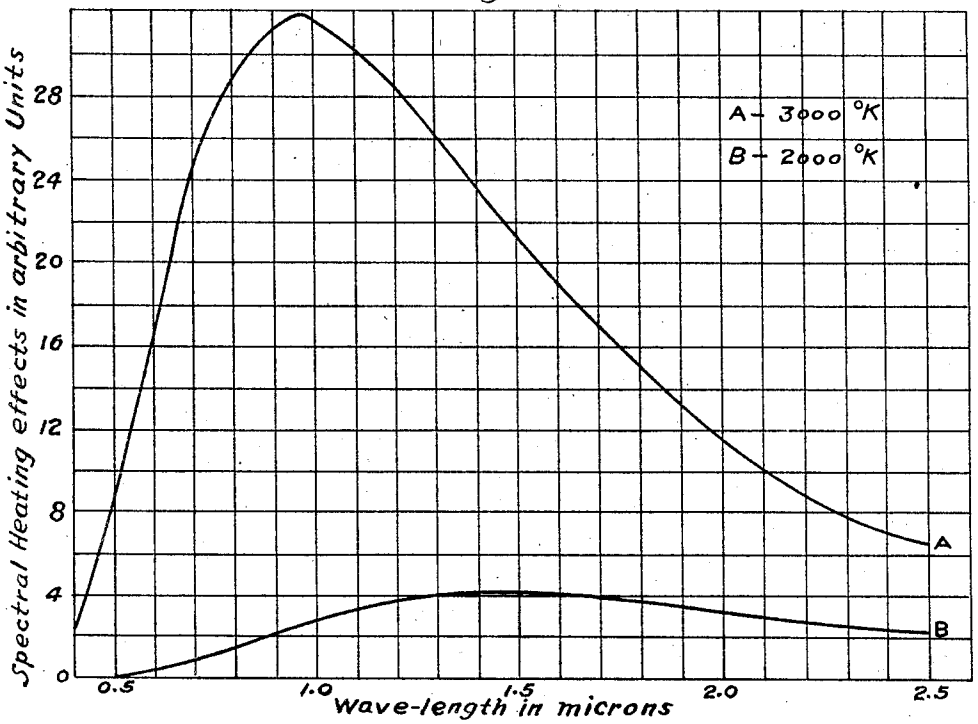
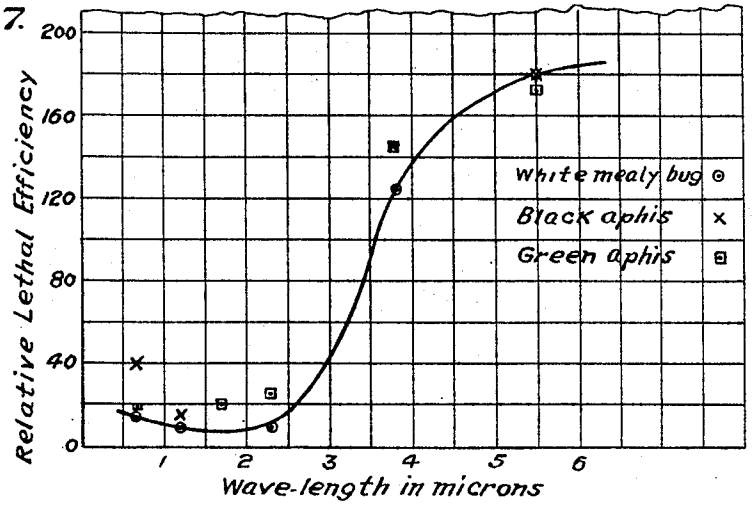


Fig. 7.



INVENTORS

Archie G. Worthing

Ralph S. Emley

by Clarence P. Byrnes

Their atty.

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DESTRUCTION OF LIVING ORGANISMS

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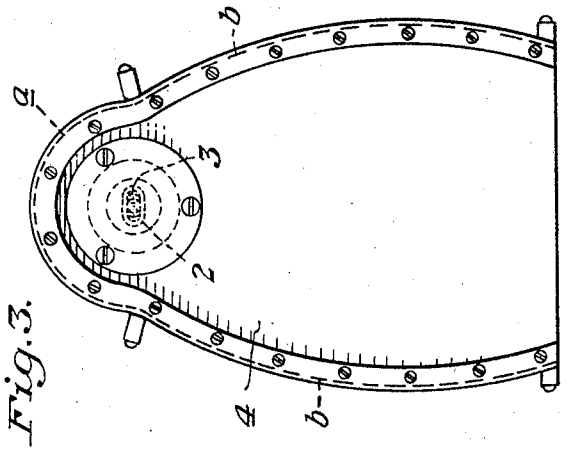


Fig. 3.

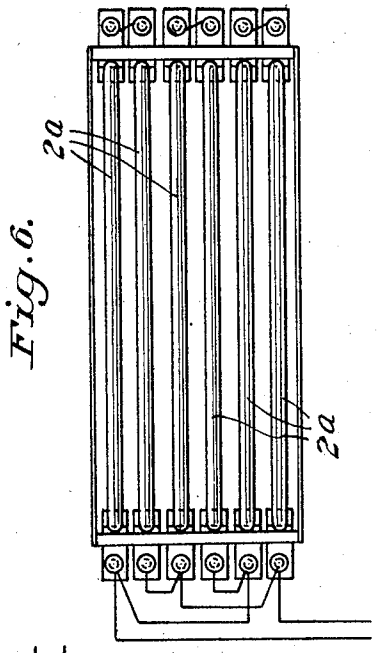


Fig. 6.

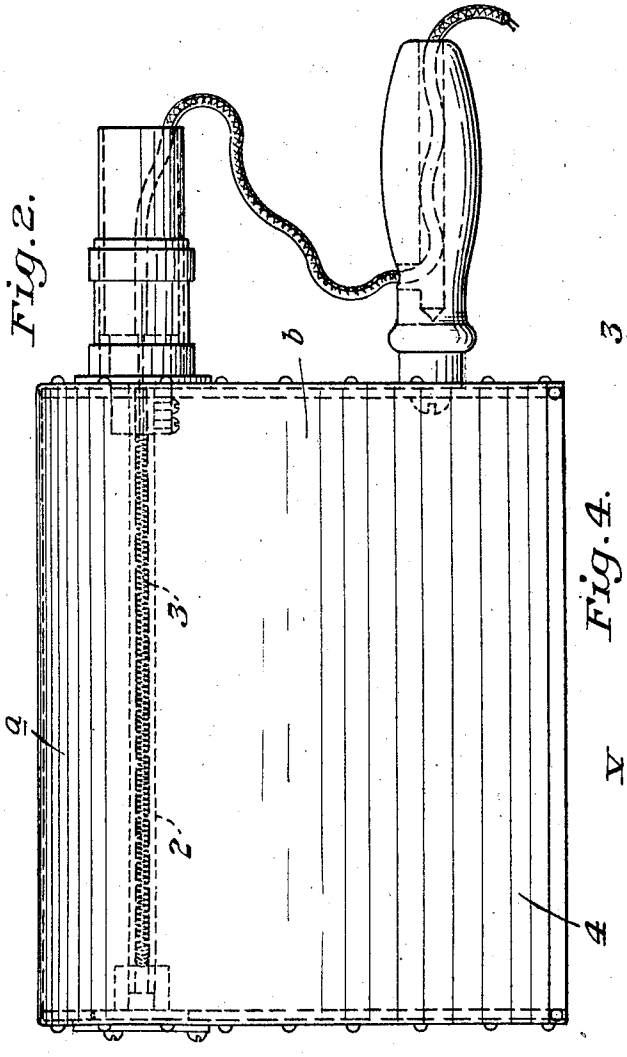


Fig. 2.

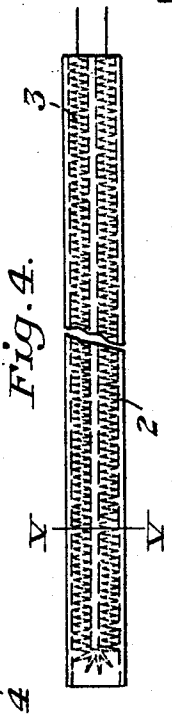


Fig. 4.

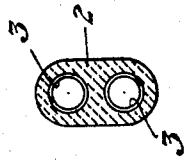


Fig. 5.

INVENTORS

Archie G. Worthing

Ralph S. Ewbank

By Clarence P. Byrnes

Their Atty

Nov. 3, 1936. A. G. WORTHING ET AL 2,059,835

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Fig. 8.

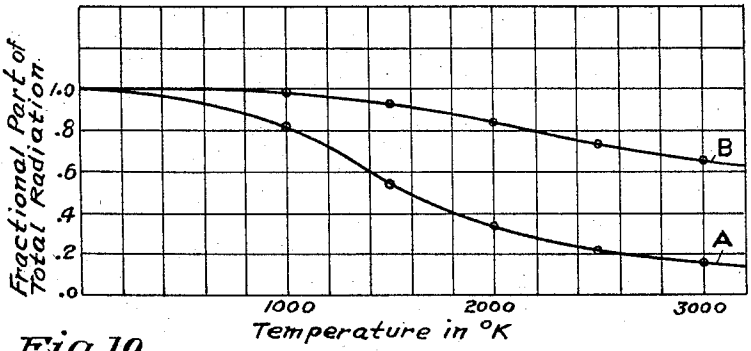


Fig. 10.

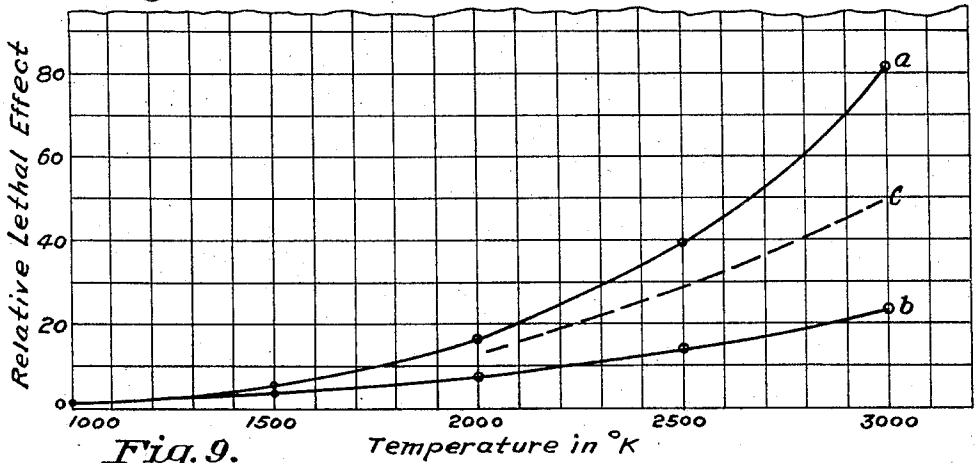
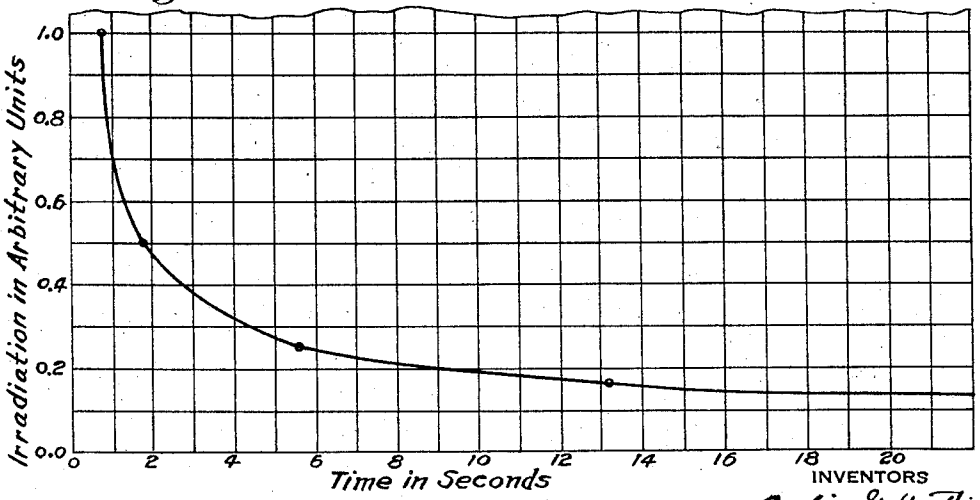


Fig. 9.



INVENTORS

Arthur G. Worthing

Ralph S. Eubert

by Clarence P. Byrnes

their atty.

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UNITED STATES PATENT OFFICE

2,059,835

DESTRUCTION OF LIVING ORGANISMS

Archie G. Worthing, Pittsburgh, and
Ralph S. Euler, Sewickley, Pa.

Application January 29, 1936, Serial No. 61,364

5 Claims. (Cl. 21—2)

Our invention relates to the killing of insects or vermin, or other small organisms by radiant energy absorbed by them.

In the drawings—

Figure 1 is a graph showing spectral energy curves for a black body at 2000° K. and 3000° K.;

Figure 2 is a front elevation of a sweeping field unit for killing insects by radiant energy;

Figure 3 is an end elevation of Figure 2;

Figure 4 is a front elevation of a preferred form of radiator;

Figure 5 is a cross section on line V—V of Figure 4;

Figure 6 is a front elevation of a group unit which may be used with or without a housing or reflector;

Figure 7 is a graph illustrating the lethal efficiency for various radiation bands when the radiant energy is applied to mealy bugs;

Figure 8 is a graph showing computed curves for black body radiation, which are to be discussed later;

Figure 9 is a curve showing the relation between irradiation and time of killing; and

Figure 10 is a graph showing computed lethal effects for black body radiation.

Swiss Patent 127,472 of October 1, 1928, disclose an electric radiating body having a parabolic reflector of circular cross section and a front protective guard. When the radiating element or body, shown as consisting of electric resistance bars mounted axially in the reflector, is raised to a temperature of about 200° to 300° C., and the device is moved over bedding, for example, bedbugs or other vermin are destroyed. That patent also states that heating bodies with different heating effects may be used such, for example, as those which are capable of developing a glowing heat up to 1500° C.

Our invention is based upon a number of discoveries which we have made, some of which are as follows:

(*a*) The lethal efficiency of radiant energy impinging on many if not all small insects, bugs, vermin, etc., is the greatest in what we term the "far infra-red" region of the spectrum. By the "far infra-red" region, we mean that portion of the infra-red region extending from about 2.6μ onward in the direction of longer wave lengths; i. e., from about 26,000 Angstrom units onward for a reasonable distance toward the longer wave lengths. Hence, in a device for the extermination of small insects, bugs, vermin, etc., the radiator should be such as to produce a beam of radiant energy, of which an especially large or predominant amount is within said "far infra-red" region.

(*b*) The lethal efficiency of radiant energy depends upon the irradiation. By the term irradiation, we mean the rate at which radiant energy impinges upon a surface per unit of area. The dependency of lethal efficiency upon irradiation is such, within practical limits, that doubling an irradiation of itself results in more than a doubling of the lethal effects produceable. Hence, a device for the extermination of small insects, bugs, vermin, etc., by radiant energy, should be such as to yield high intensities of irradiation.

(*c*) There is apparently a progressive increase in lethal efficiency as we proceed into the far infra-red region, at least for a reasonable distance, as regards lethal results upon the black aphid, the green aphid and the mealy bug. That is, the longer the wave length within a reasonable distance in this region, the greater the lethal efficiency.

(*d*) There is a decided superiority in lethal efficiency for a given irradiation associated with reduced temperatures, such for example as 1000° K. (Kelvin) in preference to 3000° K.; although this fact is affected by the second discovery, cited above. As stated, the lethal efficiency depends upon the irradiation factor, which factor (other things being the same) rises with increasing temperature. Consequently, the irradiation factor and the value of lower temperatures are somewhat opposed to each other and apparently, for the most desired results, a mean should be adopted which utilizes both factors as far as possible; and this mean will probably depend somewhat upon the particular insect or vermin to be attacked.

In other words, we have discovered that, for the destruction by means of radiation, of small insects such as aphids and mealy bugs, "far infra-red" radiation is most desirable, and that its best results are obtained with relatively low temperatures and with certain radiators of the non-metallic type. On the other hand, a high irradiation such as occurs with increased temperatures and approach to black body conditions is desirable. Hence, in attacking certain forms of life, the advantages and disadvantages should be considered and the most satisfactory condition adopted.

With black bodies, the rate of radiant energy emission varies as the fourth power of the temperature. We are here using the term "black body" as a source of radiation whose spectral heating effects for a given area and temperature

of the source cannot be exceeded by that from any other incandescent source; and, as is common technically, we also use the black body as the standard with which other sources are compared. In accord with the above, the area under the 3000° K. spectral energy curve of Figure 1 of the drawings is

$$\left(\frac{3}{2}\right)^4$$

times the corresponding area under the 2000° K. curve. Also the wave length at which maximum heating effect for complete absorption of the radiant energy occurs, shifts toward the shorter wave lengths with increase in temperature, so that the wave length for the maximum for the 3000° K. curve is just two-thirds of that for the 2000° K. curve.

The spectral energy curves of bodies other than black bodies, for a given temperature, show deficiencies of heating effects at all wave lengths in comparison with black bodies, in accord with their spectral emissivities (relative spectral heating effects in comparison with those from a black body at the same temperature). The deficiency in the case of unoxidized metallic bodies for such cases is generally much greater in the far infra-red than in the visible and the near infra-red. In using the terms "far infra-red" and "near infra-red", we again state that the division line which we arbitrarily set between these portions is at about 2.6μ. Similarly, certain non-metallic bodies such as quartz, if sufficiently thin, are especially deficient compared to a black body throughout the visible and near infra-red ranges of wave length.

We may here state that a metallic body such as tungsten, as a radiator, favors the emission of radiant energy within the visible and near infra-red regions; while quartz favors the far infra-red range. On the other hand, certain other substances such as carbon, carborundum and oxidized iron and steel possess rather high spectral emissivities throughout the range of wave lengths generally of interest in our work. They also withstand the desired temperatures.

It is well known that when an incandescent source, such as a tungsten filament, is operated at a temperature of 2500° K. or higher in a bulb of ordinary glass or thin quartz, most of the radiant energy from the tungsten is located within the visible and near infra-red regions and is transmitted by the glass or quartz. At the same time, the radiant energy located in the far infra-red region is largely absorbed by the glass or quartz. Of the energy thus absorbed, a slight amount is re-radiated, while the remainder is carried away by convection in the atmosphere surrounding the glass or quartz enclosure or guard. That which is radiated by the glass or quartz, however, will generally not be included in the beam.

Taking into consideration the above and other factors of discovery found in a long and careful investigation of the lethal effects of these rays, we have devised a radiator system or systems which are designed to give efficient killing at relatively small expense. The general basis for the radiator system is (1) the sweeping field unit. We mean by this a unit containing a source, the whole of which has been so designed as to concentrate the radiation from the source into a beam whose section, particularly in the region of the maximum produceable irradiations shall be elongated laterally in at least one direction with the contained radiation so distributed that all portions of a surface to be treated may be readily swept more or less equally by the beam, as it moves over that surface. Generally, the concentration of the radiation in the beam will not be uniform. Instead, one finds a rather narrow strip running centrally the long direction of the beam section throughout which the concentration is roughly constant and of the maximum magnitude for the section. On each side of the maximum, the concentration of radiation falls off to indefinite edges. The manner of falling off is much the same whatever the starting points in the central maximum strip. In certain types of units, however, the concentration of the radiation in the plane where it is likely to be used is roughly the same throughout the elongated sweeping field.

For example, the section of the beam near the section of greatest concentration may be of rectangular shape with the highest concentration located along its longitudinal axis or median line, so that as the field at an appropriate distance is swept by the radiator or the stream of material to be treated passes in front of the radiator all parts will be irradiated by radiant energy which rises to its highest effect at the median line, this median line being of substantially uniform efficiency from near one end of the rectangle side of the beam to near the other end (side of the beam). Such a radiator in a unit is shown at 2 in Figures 2 and 3 and by itself in Figures 4 and 5. In such case, the radiator consists of a generally straight elongated electrical insulator or of a generally straight elongated insulated metallic sleeve with an oxidized surface, with longitudinal hole or holes to receive an energy source such as an electrical resistor which may consist of a coil 3 of nichrome or similar resistor wire. The insulator may, of course, be other than straight, is preferably opaque to radiations of all wave lengths, and preferably possesses high spectral emissivities in the far infra-red as above defined. Such electrical insulators or refractories are now commonly made by laboratory supply companies from earthy refractory materials.

Such a radiator may be used with or without a reflector. The radiator, while generally opaque to the far infra-red, may or may not be opaque to the visible or the near infra-red, but should possess high spectral emissivity in the far infra-red. Such a refractory tube or hollow body of refractory material may be covered with a thin layer of a material having a higher spectral emissivity than the material coated. For example, the refractory radiator may be coated with a thin layer of carborundum or of powdered silica. Instead of a hollow body of refractory material, coated or not, we may use an insulated steel sleeve with an oxidized outer surface. Such a sleeve with an iron oxide surface has high emissivities in the far infra-red region and may even be preferable to the refractory sleeve with carborundum coating, because of temperature and strength considerations. In such case the sleeve would be insulated from the electrically alive conductor when it is heated by such an internal electrical conductor.

We prefer generally to employ a reflector which concentrates the radiant energy into a wide beam with its greatest concentration along a central longitudinal line. Such a reflector is shown at 4 in Figures 2 and 3, consisting of an elongated tubular housing whose cross section consists of a semi-circle *a* and two portions *b*, *b*

of an ellipse, one of whose foci coincides with the center of the semi-circle.

This housing should have a highly polished interior mirror-like surface, with a cross section preferably part of a parabola or an ellipse, or part of an ellipse and part of a circle, or part of a parabola and part of a circle, preferably with plane ends. This housing, which is preferably of metal, such as aluminum having a polished interior, should contain a longitudinal radiating unit of opaque material having a high spectral emissivity in the far infra-red region, which unit receives its energy from an electrically heated wire or resistor extending through it. The emitter should, at each cross section of the mirror or reflector, extend through or near the focus of the parabola or a focus of the ellipse, or a focus of the ellipse or the parabola and the center of the semi-circle of the cylindrical mirror housing.

The refractory material or metallic sleeve with oxidized surface is not electrically alive and it protects the electrical resistor heater from contact during use. We thus obtain an elongated sweeping field unit in which the radiant energy within the region which we have found most desirable, is collected into a beam giving a substantially even or uniform effect as the device is swept over a field, or as the field passes before the device; so that in each case the desired far infra-red radiant energy kills the insect or vermin life. In this manner we also make the device relatively safe for the user and obtain a relatively high efficiency in accord with our discoveries as to the high lethal efficiency in the infra-red range beyond about 2.6μ.

Figure 6 illustrates a form of a sweeping field unit having electrically alive radiators 2*a* which yield an area in close juxtaposition to the actual radiators, which may be irradiated rather uniformly and to a relatively high intensity. As with the other form already described, the actual radiators need not be electrically alive. In the latter case, though equally safe electrically, it is not as safe as the former for many uses because of nearness of the material being irradiated to the actual high temperature sources. We do not claim herein the lamp or radiator disclosed herein nor the method of operating it, both of which we prefer, as the same will be claimed in divisional case Serial No. 95,224, filed August 10, 1936.

Figure 7 illustrates tests on white mealy bugs showing the relative lethal efficiency of the radiation for various radiation bands which are conveniently selected. As here used, the lethal efficiencies for the various bands are inversely proportional to the required wattages per unit irradiated area for the same killing time for the insects. It will be noted that the near infra-red radiant energy is much less efficient than that of the far infra-red beyond 2.6μ. In fact, for both mealy bugs and black and green aphids, there is evidence of a progressive increase in lethal efficiency as we progress into the far infra-red, at least for a reasonable distance.

Apparently the far infra-red for these cases is about ten times as efficient as the visible and the near infra-red, and hence we can compute the relative lethal effects of the far infra-red compared to those of the near infra-red and visible for a source whose spectral energy curve is known.

The curves of Figure 8 based upon the spectral energy curves for a black body at various temperatures (see Figure 1), are computed curves showing interesting characteristics. Curve A shows, as a function of temperature, the fractional part of the radiation that may be classed as far infra-red, while curve B illustrates the fractional part of the lethal effects which may be associated with the far infra-red, on the assumption (approximately verified) that the far infra-red has ten times the lethal efficiency of the remainder of the radiation. From these curves, it will be noted that, at 1000° K., in the far infra-red, where only 82% of the radiant energy is found, 98% of the lethal effects are produced. It is also surprising to note that while only 15% of the radiant energy is found in the far infra-red at 3000° K., yet 65% of the lethal effects are associated with that region at that temperature, as per the latter curve. Of course, Figure 8 does not apply to other than black body sources. However, if the emission relation between a black body and any body in question is known, the effects thereof can be calculated similarly.

In Figure 9, we show a graph illustrating the relation between time of killing exposed aphids (in seconds), and the irradiation in arbitrary units.

The two opposite tendencies, with regard to lethal efficiencies above mentioned, which occur when the temperature of the radiator (assumed to be a black body) is increased are shown in the curves of Figure 10. Curve *a* shows the variation in lethal effects for a particular black body that would be obtained were the radiation of all wave lengths equally efficient. The ordinates for this curve are strictly proportional to the total heating effects. In accord with what has been said, the lethal effect at 3000° K. would be just 2^4, or sixteen times that at 1500° K. Curve *b* similarly shows the variation in lethal effects for the same black body radiator that would be obtained were the far infra-red just ten times as efficient (approximately verified) as is the near infra-red and the visible, and there were no dependency of lethal effects on the intensity of the irradiation. On this basis one expects at 3000° K. lethal effects which are but slightly more than one-fourth those expected were the near infra-red and visible as efficient as is the far infra-red; while at 1000° K. there is no practical difference. These two curves are consistent with curves A and B of Figure 8. In the dashed curve *c* of Figure 10, an attempt is made to show the gain in lethal effects which results from the increase in efficiency which comes with an increase in the irradiation. Just how this curve should be drawn is very much a matter of speculation. It definitely indicates, however, an advantage for the high temperature radiation and a probable need of adjustment of the two factors for the attainment of a most economical source.

The advantages of our invention will be apparent since a simple, relatively inexpensive and easily applied method and apparatus are provided for destroying insects, vermin, etc., particularly of the small type. Our special type of sweeping field lamp and source of radiant energy may be used where any range of rays within the spectrum is used; although, of course, we prefer to use it in combination with a radiator which concentrates most of the radiant energy in the far infra-red region. Likewise, a radiator which concentrates the energy in or about the far infra-red region may be used with or without my special radiator and/or reflector. Likewise, the type of radiator may be changed, as well as the type of reflector. The radiator should be at or adjacent the focus of the elongated reflector, and the reflector should project the rays in a beam with as

much concentration of the radiation as possible. The sweeping field radiator device may be moved by hand or by suitable connections, or material such as wheat, may be passed in a thin stream in front of the device while stationary. The device may, of course, be carried on a vehicle as, for example, if it is applied to the killing of boll weevils in a cotton field. The radiator is preferably exposed to the air and has no protective screen, such as glass or similar material in front of it, other than perhaps a very open metal screen, since much of the far infra-red energy would be lost in that case.

Many other changes may be made in our apparatus and method without departing from our invention. By the words heating effects in this specification we mean the maximum heating effects of radiation; such as is obtained by directing the radiation upon the ideal black body.

We claim:

1. The method of destroying small organisms by irradiation, which consists of generating infra-red radiation consisting substantially of wave lengths from 26000 Angstrom units toward the longer wave lengths in the infra-red region, and collecting and directing said radiation against said organisms for a sufficient time to cause ultimate death thereof.

2. The method of destroying small organisms by irradiation, which consists of generating infra-red radiation consisting substantially of wave lengths from 26000 Angstrom units toward the longer wave lengths in the infra-red region, and reflecting and concentrating said radiation against said organisms for a sufficient time to cause ultimate death thereof.

3. The method of destroying small organisms by irradiation, which consists of generating infra-red radiation consisting substantially of wave lengths from 26000 Angstrom units toward the longer wave lengths in the infra-red region, and collecting and directing said radiation against said organisms for a sufficient time to cause ultimate death thereof, while causing relative movement between the small organisms and said radiation.

4. In the method of destroying small organisms, the steps consisting of generating a laterally elongated beam of infra-red radiation consisting substantially of wave lengths from 26000 Angstrom units toward the longer wave lengths, and causing a relative sweeping movement between the organisms and said beam.

5. In the method of destroying small organisms, the steps consisting of generating a laterally elongated beam of infra-red radiation of substantially uniform intensity laterally and substantially of wave lengths from 26000 Angstrom units toward the longer wave lengths in the infra-red region, and causing a relative sweeping movement between the organisms and said beam.

ARCHIE G. WORTHING.
RALPH S. EULER.