Aug. 1, 1961 C. F. GREEN 2,994,772

THERMO-RESPONSIVE DETECTING APPARATUS

Filed Nov. 29, 1939

Fig. 1.

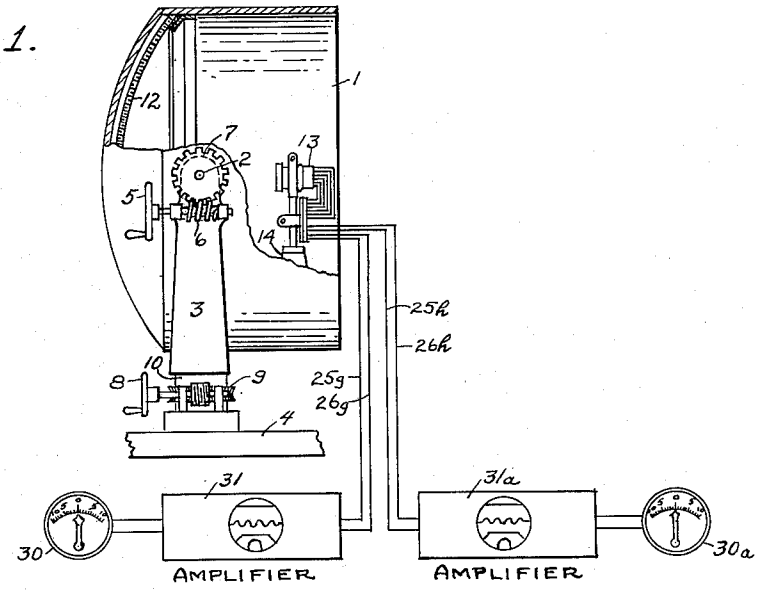


Fig. 2.

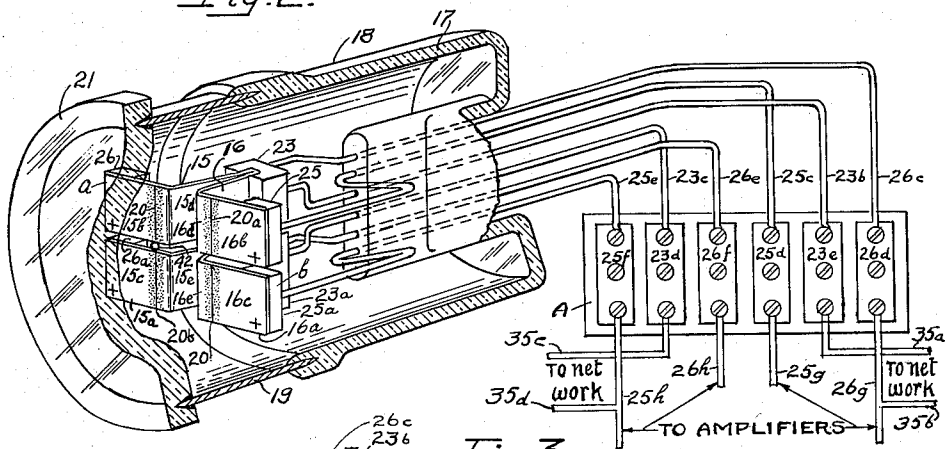
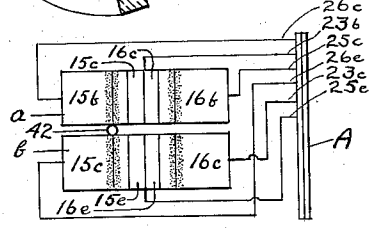


Fig. 3.



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THERMO-RESPONSIVE DETECTING APPARATUS

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Filed Nov. 29, 1939, Ser. No. 306,754
11 Claims. (Cl. 250—83.3)

This invention, which relates to apparatus for detecting objects by means of the radiation received and particularly to apparatus by which invisible objects such as airplanes may be detected by their heat radiation, is a further development of the apparatus described and claimed in my copending application Serial No. 306,753, filed November 29, 1939, and the copending application of Laurens A. Taylor, Serial No. 306,755, filed November 29, 1939, for Detector Apparatus.

One object of this invention is to provide an improved apparatus of the character specified by means of which the orientation of the radiating body in both azimuth and elevation may be accurately determined and easily followed in a program of systematic searching.

Another object of this invention is to provide a detecting apparatus including a double line thermo-couple vacuum tube arranged within the focal region of a reflector system which will enable effective searching for a fast moving unseen target using a rapidly oscillating beam for spotting purposes.

Another object of this invention is to provide a detecting apparatus including a double line thermo-couple vacuum tube arranged within the focal region of the reflector system, which will afford a pick-up angle having a vertical spread of approximately 3° whereby a plane flying horizontally at a given altitude will require several seconds to fly through the beam.

Another object of this invention is to provide a detecting apparatus including a high vacuum thermo-couple tube containing two "line" thermo-couple units arranged one above the other, the units being arranged to automatically compensate for changes in background radiation and to give indications that the center of the beam is on the target.

Another object of this invention is to provide a double line thermo-couple vacuum tube wherein the two compensated units are arranged one above the other, the output of each unit being connected to a separate amplifier-indicator-system, each of which is adapted to be used by an operator during the scanning of each of the apparatus.

With these and other objects in view this invention consists in certain novel details of construction, combination and arrangement of parts to be more particularly hereinafter set forth and claimed.

Referring more particularly to the accompanying drawings in which corresponding parts are indicated by similar reference characters:

FIG. 1 is a sectionized diagrammatic view of a collector-thermo-couple-amplifier-indicator apparatus, illustrating one embodiment of the instant invention;

FIG. 2 is a sectionized perspective view of a thermo-responsive device adapted to be used in connection with the apparatus shown in FIG. 1, and illustrating the arrangement, mounting and connections of the thermo-couple strips within the tube; and

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FIG. 3 is a diagrammatic view of the thermo-line units and their electrical connections with the terminal block.

In the form of thermo-couple vacuum tube described and claimed in my copending application filed November 29, 1939, Serial No. 306,753, the thermo-couple strips are mounted side-by-side and connected in such a manner that their outputs are in bucking relation. This tube while useful for certain purposes has not proved satisfactory for detecting a fast moving body such as an airplane in flight, and this defect led to the development of the line thermo-couple vacuum tube described and claimed in the pending application of Laurens A. Taylor, filed November 29, 1939, Serial No. 306,755, which afforded a greater vertical acceptance angle and permitted faster searching.

The pick-up angle of the "line" thermo-couple tube while constituting quite an improvement over the first mentioned tube, was not satisfactory from the standpoint of angle of vertical spread and rapidity of response and for this reason the double line thermo-couple tube forming the subject matter of the instant application was developed. This tube not only provides a vertical acceptance angle of approximately 3° but likewise enables the operators of the detecting apparatus to determine the location of the target.

In the illustrated embodiment characterizing this invention a drum **1** is pivotally mounted at **2** between the arms of a yoke **3** which is swivally supported on base **4**. This arrangement permits vertical and horizontal oscillation of the drum, as clearly shown in FIG. 1 of the drawings. Suitable means are provided for moving the drum in each of the two planes whereby changes in elevation and azimuth may be affected for the purpose of pointing the drum. While such means may be manually or power operated, the former is illustrated for the sake of simplicity. Thus the hand wheel **5** operates through worm **6** and wormwheel **7** to move the drum in the vertical plane and the handwheel **8** functioning through worm **9** and wormwheel **10**, serves to move the drum in the horizontal plane.

Within the drum is mounted a reflector **12** in the focal region of which is arranged a double line thermo-couple vacuum tube **13**, the tube being suitably supported on the upper end of a standard **14**, as shown in FIG. 1 of the drawings. This double line thermo-couple tube **13** embodies two "line" units *a* and *b* arranged in superimposed relation, each unit being composed of a pair of thermo-couple strips **15—16** and **15***a*—**16***a* the respective strips of each unit being horizontally disposed and arranged in end to end relation with the junction lines **20—20***a* and **20***b*—**20***c*, extending vertically, as clearly shown in FIG. 2 of the drawings.

These "line" units are mounted within and near one end of an evacuated envelope **17**, which comprises a glass portion **18** having a metallic end portion **19** which in the present instance is in the form of a silver sleeve. The end portion **19** is attached at its free end to a window or end plate **21** having a high transmission coefficient for low temperature radiation, such as rock salt. The sleeve has a thin tapered edge at both ends, the glass being fused over the inner end and the outer end of the sleeve is made vacuum tight with the rock salt window by a suitable seal such as silver chloride, as clearly described and claimed in the copending application of August J. Kling, filed

November 29, 1939, Serial No. 306,750, now U.S. Patent No. 2,543,369.

Each of the thermo-couple strips **15**—**16** and **15***a*—**16***a* forming the respective line units *a* and *b* has been made by welding together at their edges, thin plates of electrically dissimilar metals and then rolling down the welded plates until they have obtained the desired thinness, which is of the order of 6 to 10 millionths of an inch. Since the direction of the rolling is transversely of the strip, or in other words in the direction of their junction lines, the welded connection between the two metals is preserved even though the thickness of the resulting strip is reduced to a few millionths of an inch. Very successful results have been obtained by employing for one element of the thermo-couple strips **15** and **16** an alloy composed of nickel 44%, copper 35.5% and iron 0.5%, commonly known as "Copnic," and for the other element of the thermo-couple strips **15** and **16** an alloy composed of nickel 90% and chromium 10%, commonly known as "Chromel."

The thermo-couple strips **15** and **16** of the respective units *a* and *b*, as previously stated are arranged horizontally in an end to end relation with the junction lines **20** extending vertically.

The two thermo-couple strips **15**—**16** and **15***a*—**16***a* of the respective line units *a* and *b* are connected in series and in a reverse manner, that is to say the two outer elements **15***b*—**16***b* and **15***c*—**16***c* of the respective line units *a* and *b* which are of one polarity are attached to supporting bars **25**—**26** and **25***a*—**26***a* respectively, and the inner or intermediate elements **15***d*—**16***d* and **15***e*—**16***e* of the respective line units which are of the opposite polarity are secured to the intermediate bars **23** and **23***a* respectively.

The lengths of the electrically dissimilar metals forming each of the thermo-couple strips, are substantially equal, the exact lengths being such that the rates of heat conduction of the supporting bars, considering the heat conducting properties of the materials, are equal. The intermediate bars **23**—**23***a* are approximately twice the size of the outer bars **25**—**26**, **25***a*—**26***a*, whereby they have approximately twice the heat capacity thereof. Each of the vertically extending junction lines **20**—**20***a*—**20***b*—**20***c* is arranged substantially in the middle of its thermo-couple strip, as clearly shown in FIG. 2 of the drawings.

In order to bring the junction lines **20**—**20***a*—**20***b*—**20***c* of the respective line units *a* and *b* closer together, the inner elements **15***d*—**16***d* and **15***e*—**16***e* are bent backward, as shown in FIG. 2 of the drawings. By thus bringing the two junction lines **20**—**20***a*—**20***b*—**20***c* of the respective units *a* and *b* closer together, are thermo-couple strip of each unit can be made to respond to a background region of radiation, which is closer to the body, whose radiation effects the joining strip of said unit, consequently in so far as background radiation is concerned the output of the thermo-couple strips of the respective units will exactly balance one another.

Assuming that the super-imposed thermo-couple strips **15**—**15***a* are those to be used for detection of a radiating body, while the other junction strips **16**—**16***a* are those to be used for background compensation, then as shown in FIG. 2 of the drawings, the inner bars **23**—**23***a* are connected to the conductors **23***b*—**23***c*, which extend through the stem of the glass envelope **17** to terminals **23***e*—**23***d* of terminal block A. The outer bars **25**—**26** of line unit *a* are connected to conductors **25***c*—**26***c* which extend through the tube of envelope **17** to terminals **25***d*—**26***d* of terminal block A. The remaining bars **25***a*—**26***a* of line unit *b* are connected to conductors **25***a*—**26***e* which extend, as in the case of the other conductors, through the envelope **17** to terminals **25***f*—**26***f* of terminal block A.

Terminals **25***d*—**26***d* are connected via conductors **25***g*—**26***g* to the input side of amplifier **31**, the output side of which is connected through suitable conductors to a milliammeter indicator **30**. The terminals **25***f*—**26***f* of terminal block A are connected via conductors **25***h*—**26***h* to the input side of amplifier **31***a*, the output side of which is connected to a milliammeter indicator **30***a*, as clearly shown in FIG. 2 of the drawings.

To correct for small differences in resistance in thermo-couple construction, which may occur in manufacture due to the variations in materials, thickness of strips and etc., suitable balancing networks (not shown) may be connected via conductors **35***a*—**35***b* and **35***c*—**35***d* between the terminals **23***e*—**26***d* and **23***d*—**25***f* respectively, on terminal block A, as clearly shown in FIG. 2 of the drawings. These resistance elements are introduced to balance the output of the respective line units as the beam of the detector is swung from horizon to zenith in a clear sky, and to thus stabilize the pointers of the indicators, as will be understood without further discussion.

With the components of the instant detecting apparatus arranged as previously stated, its operation is as follows: Assuming that the drum **1** is swung in azimuth, during a search for a radiating body, and that indicator **30** shows a deflection indicating that the image of such body has fallen on the thermo-couple strip **15** of line unit *a* and has reached junction line **20** of this strip. When this occurs the operator will know that the drum is directed on the meridian containing the radiating body and likewise that the image has fallen on the upper thermo-couple strip **15** rather than on the lower thermo-couple strip **15***a*. In order that the operator may determine the exact position of the body in elevation, as well as in azimuth, drum **1** is tilted by manipulation of handwheel **5** to cause the image of the radiating body to move downwardly along junction line **20** of unit *a*.

When the drum **1** has been changed in elevation sufficiently, the image of the body will reach the focal point **42** where it will begin to leave the upper line unit *a* and enter upon the lower line unit *b*. The deflection of the indicator **30** will thereby decrease while the deflection of the instrument **30***a* will increase. By careful manipulation of the elevating control handwheel **5** and if the object is moving in azimuth, by simultaneous manipulation of the handwheel **8** in a suitable manner, the image of the radiating body can be retained exactly on the focal point **42**, in which case both indicators **30** and **30***a* will show approximately equal deflection. The drum under these conditions is pointed directly at the radiating body, whereupon the position of the body in azimuth and elevation may be read from the scales, not shown, with which the drum **1** is provided. Obviously, if the image of the body is first picked up by the lower line unit *b* the elevation of the drum will be changed in the opposite manner until the image reaches the focal point **42**, where it will be held as previously stated.

In conclusion it will seem this invention provides a detection apparatus which not only gives a vertical angle of acceptance greater than that afforded by the detection apparatus described and claimed in the two applications hereinabove referred to, but likewise enables the operator to determine the exact position of the radiating body in azimuth and in elevation.

Having described my invention, what I claim as new and wish to secure by Letters Patent is:

1. In an apparatus for locating distant bodies by thermo-radiation, means for collecting and focusing the heat radiation from a distant body, means within the focal region of collected radiation for translating thermal into electrical energy, said means including means for detecting the position of heat radiating body in azimuth and in elevation, and comprising an evacuated vessel provided with a rock-salt window, a pair of thermo-electric generating units arranged within the vessel one above the other, each unit being composed of a pair of thremo-couple strips disposed in end to end relation and electrically connected in opposition to afford automatic compensation for changes in background radiation, each of

said strips being formed with vertically extending junction lines, the junction lines of one of said units being in alinement with those of the other of said units, and a separate indicator system in an electrical relation with each of said units.

2. In an apparatus for locating distant bodies by thermo-radiation, means for collecting and focusing the heat radiation from a distant body, means within the focal region of the collected radiation for translating thermal into electrical energy, said means including means for detecting the position of the heat radiating body in azimuth and in elevation, and comprising a highly evacuated vessel provided with a window transparent to thermal radiation, a pair of thermo-electric generating units, each of said units including a pair of thermo-couple strips arranged in end to end relation, the strips of the respective units being electrically connected in opposition to afford automatic compensation for changes in background radiation, each of said strips being formed with vertically extending junction lines, the junction lines of one of said units being alined with those of the other of said units, and a separate indicator system in electrical relation with the output of said units.

3. In an apparatus for locating distant bodies by thermo-radiation, means for collecting and focusing the heat radiation from a distant body, means within the focal region of collected radiation for translating thermal into electrical energy, said means including means for detecting the position of the heat radiating body in azimuth and in elevation, and comprising an evacuated vessel provided with a rock-salt window, thermo-responsive means within the vessel immediately to the rear of said window, said means including a pair of thermo-electric generating units situated one above the other, each unit consisting of a pair of thermo-couple strips electrically connected in opposition to afford automatic compensation for changes in background radiation, the width of said strips being such as to afford a wide vertical acceptance angle, each strip having a vertically disposed junction line coextensive with the width of the strip, the junction lines of the upper unit being in alined and spaced relation with respect to the underlying unit, and a separate indicator system in electrical relation with the output of each of said units.

4. In an apparatus for locating distant bodies by thermo-radiation, means for collecting and focusing the heat radiation from a distant body, means within the focal region of the collected radiation for translating thermal into electrical energy, said means including means for detecting the position of the heat radiating body in azimuth and in elevation, and comprising an evacuated vessel provided with a rock-salt window, a pair of thermo-electric generating units situated within the vessel immediately to the rear of said window, each of said units including a pair of thermo-couple strips arranged in end to end relation and electrically connected in opposition to provide a bucking output, each of said thermo-couple strips having a vertically extending junction line coextensive with its width, the junction lines of one of said units being in alinement with those of the other of said units, and each thermo-couple strip being bent rearwardly to position the junction lines of adjoining strips a predetermined distance apart and a separate indicator system in electrical relation with the output of each of said units.

5. In an apparatus for locating distant bodies by thermo-radiation, a reflector system for collecting and focusing heat radiation from a distant body, means within the focal region of the reflector system for translating thermal into electrical energy, said means including means for detecting the position of the heat radiating body in azimuth and in elevation and comprising an evacuated vessel provided with a rock-salt window, a pair of thermo-electric generating units situated one above the other within the vessel and immediately to the rear of said window, each unit being composed of a pair of thermo-couple strips arranged end to end and interconnected at their inner extremities in bucking relation, each strip having a junction line coextensive with its width, the junction lines of one unit being in aligned relation with respect to those of the underlying unit, one pair of aligned junction lines being disposed so that the focal point of the reflector system will be located between the units and at the meeting ends of said aligned junction lines and a separate indicator system in electrical relation with the output of each of said units.

6. In an apparatus for locating distant bodies by thermo-radiation, a reflector system for collecting and focusing heat radiation from a distant body, means within the focal region of the reflector system for translating thermal into electrical energy, said means including means for detecting the position of the heat radiating body in azimuth and in elevation and comprising an evacuated vessel provided with a window transparent to thermal radiation, a pair of thermo-electric generating units situated one above the other within the vessel and immediately to the rear of said window, each unit being composed of a pair of thermo-couple strips situated end to end and interconnected at their inner extremities in bucking relation, each thermo-couple strip having a junction line coextensive with its width, the junction lines of one unit being in aligned relation with respect to those of the underlying unit, one pair of aligned junction lines being disposed so that the focal point of the reflector system will be located between the units and at the meeting ends of said aligned junction lines and a separate indicator system in electrical relation with the output of said units.

7. A thermo-responsive device comprising an evacuated envelope provided with a window transparent to thermal radiation, a pair of thermo-electric generating units within the envelope immediately to the rear of said window, said units being situated one above the other and each unit being composed of a pair of thermo-couple strips arranged end to end and connected in bucking relation, each thermo-couple strip having a vertically disposed junction line coextensive with its width, the junction lines of one of said units being in alined relation with those of the other of said units.

8. A thermo-responsive device comprising an evacuated envelope provided with a window transparent to thermal radiation, a pair of thermo-electric generating units within the envelope immediately to the rear of said window, said units being situated one above the other and each unit being composed of a pair of thermo-couple strips arranged end to end and connected in bucking relation, each thermo-couple strip embodying electrically dissimilar elements united along a vertically extending junction line coextensive with the width of the strip, the junction lines of one of said units being in alined relation with those of the other of said units and having a predetermined spacing.

9. A thermo-responsive device comprising an evacuated envelope provided with a rock-salt window, a pair of thermo-electric generating units within the envelope immediately to the rear of said window, said units being situated one above the other and each unit being composed of a pair of thermo-couple strips arranged end to end and connected in bucking relation, said thermo-couple strips embodying electrically dissimilar inner and outer elements, united along a vertically disposed junction line coextensive with the width of the strip, the inner elements of the adjoining strips being bent backwards to provide a predetermined spacing for the junction lines of each unit and the outer elements of the upper and lower thermo-couple strips being disposed to position said thermal junction lines in alined relation.

10. A thermo-responsive device comprising an evacuated envelope provided with a window transparent to thermal radiation, a pair of thermo-electric generating units within the envelope immediately to the rear of said window, said units being situated one above the other

and each unit being composed of a pair of thermo-couple strips of a predetermined order to thinness and arranged in end-to-end relation and connected in electrical opposition within said envelope, each thermo-couple strip having a vertically-disposed junction line coextensive with its width, the junction lines of one of said units being in aligned relation with those of the other of said units.

11. A thermo-responsive device comprising an evacuated envelope provided with a window transparent to thermal radiation, a pair of thermo-electric generating units within the envelope immediately to the rear of said window, said units being situated one above the other and each unit being composed of a pair of thermo-couple strips 6 to 10 millionths of an inch in thickness and arranged in end-to-end relation and connected in electrical opposition within said envelope, each thermo-couple strip having a vertically-disposed junction line coextensive with its width, the junction lines of one of said units being in aligned relation with those of the other of said units.

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