July 31, 1951 A. H. CANADA 2,562,696

THERMOPILE CONSTRUCTION

Filed Oct. 29, 1947

Fig. 1.

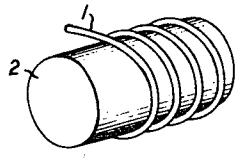



Fig. 2.

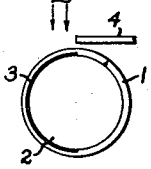



Fig. 3.

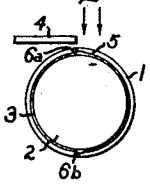



Fig. 4.

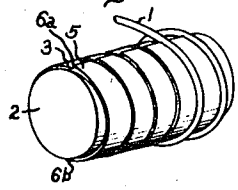



Fig. 5.

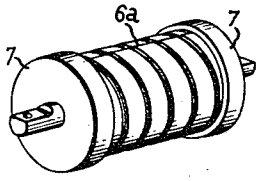



Fig. 6.

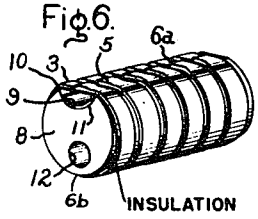



Fig. 7.

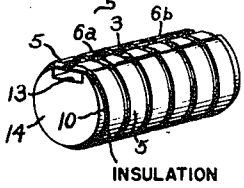



Fig. 8.

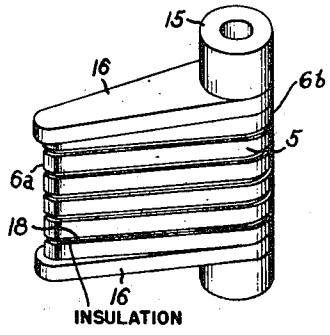



Fig. 9.

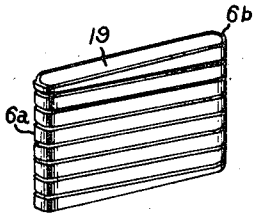



Fig. 8a.

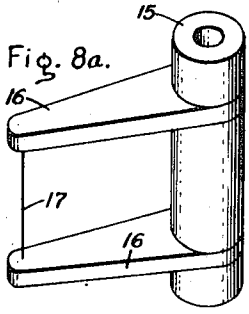



Fig. 10.

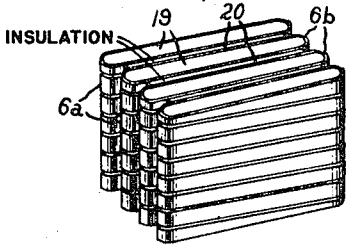
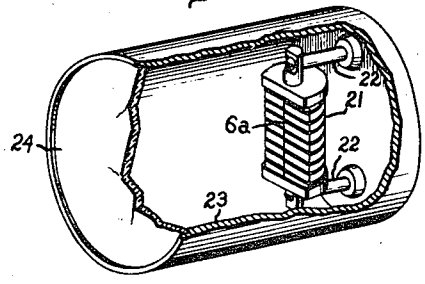



Fig. 11




Inventor:
Alfred H. Canada,
by Pinnell & Mack
His Attorney.

Patented July 31, 1951

2,562,696

# UNITED STATES PATENT OFFICE

2,562,696

## THERMOPILE CONSTRUCTION

Alfred H. Canada, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

Application October 29, 1947, Serial No. 782,791

4 Claims. (Cl. 136—4)

1

My invention relates to an improved process for making thermopiles by the vacuum evaporation of thermoelectrically dissimilar metals on to an electrically non-conducting surface, and to an improved thermopile made thereby.

An object of my invention is to provide an improved process for making thermopiles permitting easier construction of thermopiles having a large number of thermoelectric junctions. Another object of my invention is to provide an improved thermopile of increased sensitivity. A further object of my invention is to provide a thermopile having an improved frequency response.

The features of my invention which are believed to be novel and patentable will be pointed out in the claims appended hereto. For a better understanding of my invention, reference is made in the following description to the accompanying drawing in which Figs. 1 through 4 are views illustrating steps in my improved process for making thermopiles; Fig. 5 is a perspective view of the completed thermopile; Figs. 6 through 8 and Fig. 9 are perspective views showing other novel forms of my thermopile; Fig 8*a* is a perspective view of the supporting structure of the thermopile shown in Fig. 8; Fig. 10 is a perspective view showing a method of combining thermopiles of the form shown in Fig. 9; and Fig. 11 is a perspective view showing a thermopile mounted in an evacuated case, a part of the case being shown cut away for better illustration. Similar reference characters refer to similar parts throughout the drawing.

Referring now to Figs. 1 through 4 of the drawing, illustrating my process for making thermoplies, I wind a masking strip 1, preferably having a circular cross-section as shown, in the form of a spiral or helix about an electrically insulating lateral surface of a support 2, as shown in Fig. 1. Masking strip 1 may be a small wire, or a quartz, silk, or other fiber, and in a simple form of my thermopile support 2 may be a short glass rod. A space is left between adjacent convolutions of the masking strip so that a continuous spiral strip of the insulating surface remains exposed. Next, a metal, such as bismuth, is evaporated in a vacuum and deposited as a film or thin coating 3 between the convolutions of the masking strip upon the exposed or unmasked insulating surface on one side of support 2 as shown in Fig. 2, a solid longitudinal mask 4 being used to restrict the deposit to the desired side. Means is provided whereby support 2 may be rotated sufficiently to

2

obtain a deposit of uniform thickness over the desired area. A very thin coating of metal may be so deposited; the thickness of such a coating can be accurately controlled and varied to suit the needs of a particular application. Typical thickness range from 1000 to 10,000 angstrom units. Throughout the drawing the thickness of the coatings shown is exaggerated for better illustration. Mask 4 is now moved to shield the deposited coating of metal, as shown in Fig. 3, and another metal, such as antimony, thermoelectrically dissimilar to the first metal, is evaporated in a vacuum and deposited as a film or thin coating 5 upon the exposed insulating surface on the other side of the support. These two coatings are made to overlap slightly so that a plurality of junctions 6 of the two metals is formed upon the insulating surface, one set of junctions 6*a* where the two metals overlap along the front of the support and one set of junctions 6*b* where the two metals overlap along the back of the support. Hereinafter, junctions 6*a* are arbitrarily assumed to be the measurement or "hot" junctions of the thermopile, and junctions 6*b* the reference or "cold" junctions. Such choice is arbitrary since the two sets are physically identical. Mask 4 may now be removed. A thin coat of blacking, such as gold "black," may be applied over one or both sets of junctions to make them more responsive to radiant energy, if such is desired. Masking strip 1 preferably is now unwound and removed, as shown in Fig. 4, leaving the metallic coatings 3 and 5 in the form of a helix or spiral strip extending around the support, and comprising a plurality of thermoelectric junctions. The completed thermopile is shown in Fig. 5. Metal-end caps 7 serve both as electric terminals and as supports for mounting the thermopile.

It is notable that the edges of my metallic coatings are very smooth and regular. Although the masking strip may be a wire whose diameter is large compared to the thickness of the deposited coatings, excellent masking is obtained. Using this method, small sensitive thermopiles can be made which have an unusually large number of "hot" junctions, 200 or more per inch of length of rod 2, a lesser number of junctions being shown in the drawings merely to better illustrate the details of construction. This large number of "hot" junctions is an important advantage since the responsivity of a thermopile is directly proportional to the number of such junctions. Another advantage arises from the thinness of my metallic coatings, which gives

them a low thermal capacity and also decreases the amount of heat carried away from the junctions by conduction through the metal. When support 2 is a solid glass rod, as shown in Figs. 1 through 5, the low thermal capacity of the metallic junctions relative to the rate of heat loss to the glass rod provides a thermopile having an exceptionally high frequency response, for example, above 200 cycles per second. Thus when a cathode ray oscillograph or similar device is used to record the output voltage of my thermopile, a record may be made of variations as rapid as 200 cycles per second in infra-red light or other radiant energy focused on the thermopile junctions. Still another advantage of my thermopile arises in that its nominal resistance is high, being about 300,000 ohms for a pile having 100 "hot" junctions. Thus, the output signal may be efficiently detected by a circuit having a high input impedance, such as a conventional electronic amplifier, since the thermopile impedance matches such input impedance sufficiently well for efficient energy transfer. The simplicity of my process provides manufacturing economy over more tedious methods of making many-junction thermopiles previously used.

Added sensitivity for my thermopile may be obtained by using a support of the type shown in Fig. 6. A supporting member, which may be a glass rod 8, has a longitudinal groove 9 along one side thereof. A thin sheet 10 of thermally and electrically insulating material, such as collodion or a lacquer film extends about the rod as shown, a portion of the sheet being stretched across groove 9 and thus held away from direct contact with the rod. Upon this sheet the metallic coatings 3 and 5 are applied in the manner hereinbefore described. The "hot" junctions 6*a* of the thermopile are located upon that portion of insulating sheet 10 which is stretched across groove 9, as shown, so that the thermal capacity of the entire structure in the region of such junctions is very low, and the loss of heat by conduction away from the junctions is minimized. Further sensitivity may be obtained by shaping groove 9 as a semi-cylinder with its axis along the line of "hot" junctions. Prior to the application of insulating sheet 10, a reflecting coating 11, such as a thin deposit of silver, may be applied to the surface of groove 9. This will form a reflecting surface behind the "hot" junctions which will reflect back on to the junctions energy they lose from their rear faces by radiation.

Since the temperature measured by a thermopile is the difference in temperature between its "hot" and "cold" junctions, a means for controlling the "cold" junction temperature may be desirable. For this purpose, a hollow passage 12, as shown in Fig. 6, may be provided through the supporting member and located near or adjacent to "cold" junctions 6*b*. A liquid whose temperature can be controlled may be circulated through this passage to keep the "cold" junctions of the thermopile at a constant temperature, thus increasing the accuracy of the instrument. Alternatively, for other purposes, the "hot" and "cold" junctions of the thermopile may be made exactly alike, the support being symmetrical as to such junctions. Then each set of junctions may be adapted to measure radiant energy received from a different source, the thermopile output being proportional to the difference in energy received from each source, thus providing a differential or "balancing" system using only one thermopile.



This may be accomplished by placing the "hot" and the "cold" junctions respectively on opposite sides of an axially symmetrical support, as in Fig. 5, or the form shown in Fig. 7 may be employed. In the latter form, a section of insulating sheet 10 is stretched across a groove 13 in the supporting member 14, which may be of glass or other material, and both "hot" junctions 6*a* and "cold" junctions 6*b* are placed upon this section, forming two parallel lines of thermoelectric junctions as shown in Fig. 7. This form is the more sensitive as its thermal capacity and thermal conductivity are smaller in the region of its junctions.

Fig. 8 shows another form of thermopile embodying the same principles as that shown in Fig. 6. Fig. 8*a* shows the supporting structure for the Fig. 8 thermopile. Referring now to Figs. 8 and 8*a*, the supporting structure comprises a hollow cylinder or tube 15, and two supports 16 which hold a quartz fiber or thread 17, as shown in Fig. 8*a*. Tube 15 and supports 16 may be of glass or other material. A thin sheet 18 of thermally and electrically insulating material, such as collodion or a lacquer film, is stretched around tube 15 and fibre 17, as shown in Fig. 8. Quartz fiber 17 supports a portion of insulating sheet 18 and holds it away from direct contact with the heavier supporting member parts 15 and 16. The "hot" junctions 6*a* are located upon the insulating sheet adjacent the quartz fiber, at which point heat losses through conduction are very low. The "cold" junctions 6*b* are located adjacent the tube 15; through which a liquid may be circulated to maintain a constant temperature.

In the form of thermopile shown in Fig. 9, the support is a thin glass plate 19 which may be about 0.003 inch thick. It is evident that the plate may be of other materials than glass, or that a "plate" could be formed by stretching a thin sheet of insulating material around threads or other supporting members. The "hot" junctions 6*a* in this form are located along the front edge of the plate, the cold junctions 5*b* along the back edge. A number of such plates may be placed side by side, separated from one another by thin sheets 20 of electrically insulating material, such as collodion or a lacquer film, as shown in Fig. 10 or supported slightly apart or otherwise electrically insulated one from another, to provide a heat-sensitive area of any desired size. If, in such an arrangement, the two metal coatings of each plate overlap at the front edges of the plates to form an area of junctions 6*a*, but do not overlap at the back edges, leaving a small gap in each turn of the spiral metallic coating in place of junctions 6*b*, an electrical image will be formed upon the mosaic of metallic endings thus formed which will reproduce the thermal image which may be focused on the front edges of the plates. This electrical image may be scanned by means of electronic scanning devices known to those skilled in the art to provide a system for viewing infra-red or heat images. Such an arrangement is made possible by the large number of "hot" junctions and the high frequency response obtainable using my method of making thermopiles.

Any of the forms of thermopile which I have described can be made even more sensitive by mounting the thermopile inside an evacuated tube or container to prevent the loss of heat by conduction to the surrounding atmosphere. One way of doing this is shown in Fig. 11. A thermo-

pile 21, which may be any form of my thermopile, is held by supports 22 within a tube or container 23, said tube being evacuated and sealed after the thermopile is mounted therein. A window 24 of heat-transparent material permits radiant energy to enter the tube and impinge upon the "hot" junctions 6a of the thermopile. Supports 22 may be electrically conducting and extend through the back face of the tube to the outside thereof, and the output voltage of the thermopile may thus be transmitted by said supports to terminals outside tube 23.

In accordance with the patent statutes, I have described the principle of my invention and the apparatus which I now consider to be the best embodiment thereof, but I wish it to be understood that the apparatus shown is only illustrative and that the invention may be carried out by other means.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A thermopile comprising a supporting member, a thin sheet of electrically insulating material extending laterally around said member, a portion of such sheet being held away from thermal contact with the supporting member by the configuration of said member, and a plurality of metallic films deposited upon said sheet and combining to form a many-turn spiral strip about said member, said films being of two kinds, one kind being of a metal thermoelectrically dissimilar to the other, the two kinds being deposited respectively upon different portions of said sheet so that each turn of the spiral strip comprises sections of each kind of film, said two kinds of films overlapping slightly at each junction thereof so that a plurality of thermoelectric junctions is formed along said spiral strip, at least one set of such thermoelectric junctions being located on a portion of said thin sheet which is held away from thermal contact with said supporting member, whereby transfer of heat from such junctions to the supporting member is minimized.

2. A thermopile comprising a supporting member, a hollow passage through such member adapted to contain a flow of liquid, a thin sheet of electrically insulating material extending laterally around said member, a portion of such sheet being held away from direct contact with the supporting member by the configuration of said member, and a thin coating of evaporated metal deposited upon the outer surface of said thin sheet in the form of a spiral strip having a plurality of turns extending laterally about said member, that portion of the coating which is on one side of said member being of one metal and that portion of the coating which is on the other side of said member being of a thermoelectrically dissimilar metal, there being a slight overlap at each junction of the two metals so that two sets of thermoelectric junctions are formed along said spiral strip, one set of such junctions being located on a portion of said thin sheet which is held away from direct contact with the supporting member, the other set of such junctions being located on a portion of said thin sheet which is in contact with the supporting member and near the hollow passage therethrough.



3. A thermopile comprising a support provided with a semi-cylindrical groove, said groove having a heat-reflecting inner surface, a thin sheet of thermally and electrically insulating material extending about the support and stretched across the groove, two metallic coatings deposited upon the outer surface of said sheet combining to form a many-turn helix about the support, said two coatings respectively being of two thermoelectrically dissimilar metals, said two coatings respectively being deposited upon opposite sides of said support and overlapping slightly at the front and rear boundaries of such two opposite sides, one of said boundaries lying along the axis of the semi-cylindrical groove so that a plurality of thermoelectric junctions is formed substantially along said axis.

4. A thermopile comprising a cylindrical support, a thread, means to support the thread parallel to the axis of such cylindrical support, a thin sheet of electrically insulating material extending about the cylindrical support and the thread so as to form a continuous insulating surface, two metallic coatings deposited upon such surface combining to form a many-turn spiral strip thereabout, said coatings respectively being of two thermoelectrically dissimilar metals, said two coatings respectively being deposited upon opposite sides of said surface and overlapping slightly at the boundaries of such two opposite sides, so that a plurality of thermoelectric junctions is formed along said spiral strip.

ALFRED H. CANADA.


## REFERENCES CITED

The following references are of record in the file of this patent:

### UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 1,638,943 | Little | Aug. 16, 1927 |
| 2,106,768 | Southworth | Feb. 1, 1938 |
| 2,306,272 | Levy | Dec. 22, 1942 |
| 2,381,819 | Graves | Aug. 7, 1945 |

### FOREIGN PATENTS

| Number | Country | Date |
|---|---|---|
| 12,288 | Great Britain | of 1885 |
| 864,964 | France | Feb. 10, 1941 |

### OTHER REFERENCES

Kersten et al.: Rev. Sc. Insts., vol. 3 (1932), pp. 194–5.

Jones, R. V.: J. Sc. Insts., vol. 14 (1937), pp. 85–6.

Gier et al.: Temperature, Am. Inst. Physics (1941), p. 1286.

Strong: Procedures in Experimental Physics (1942), pages 315, 329, 330.

Office of Scientific Research and Development Report, PB 19778, March 31, 1943.

Roess et al.: Rev. Sc. Insts., vol. 16, July 1945, pages 164–171.