Nov. 14, 1950 S. K. MALEK 2,530,256

THERMOELECTRIC GENERATOR

Filed June 9, 1945 2 Sheets-Sheet 1

Fig. 1.

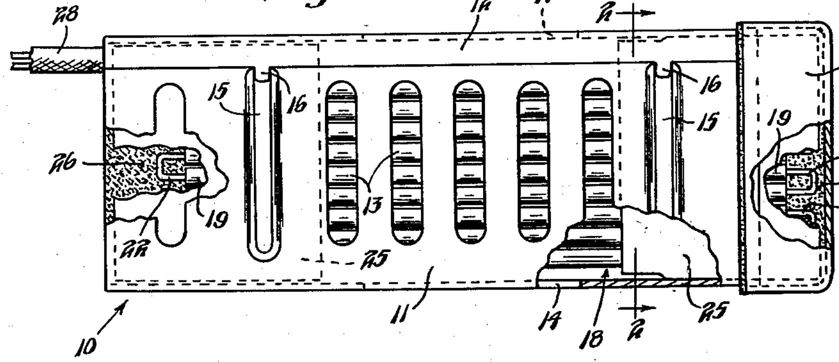

Fig. 2.

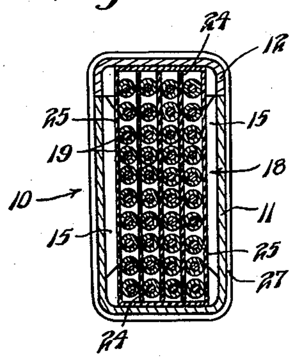

Fig. 3.

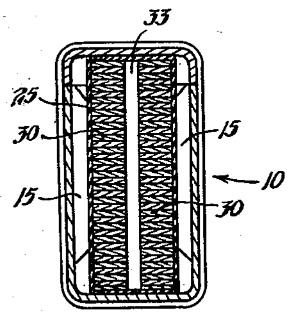

Fig. 4.

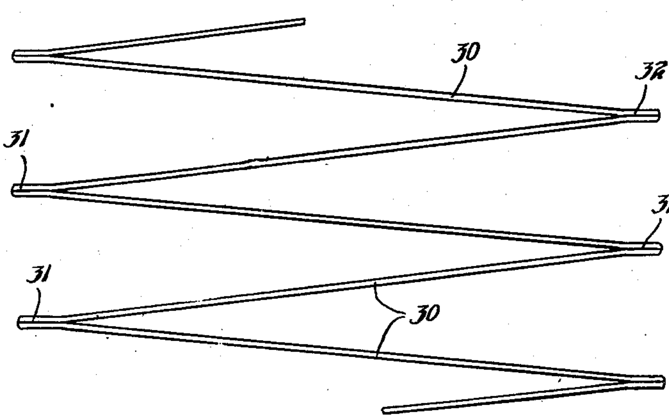

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Fig. 5.

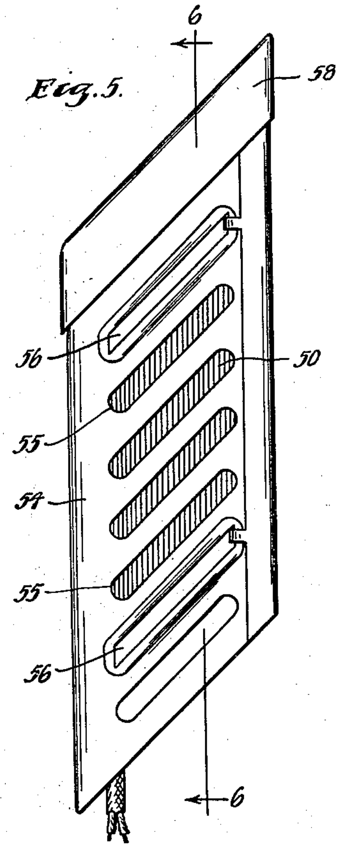


Fig. 6.

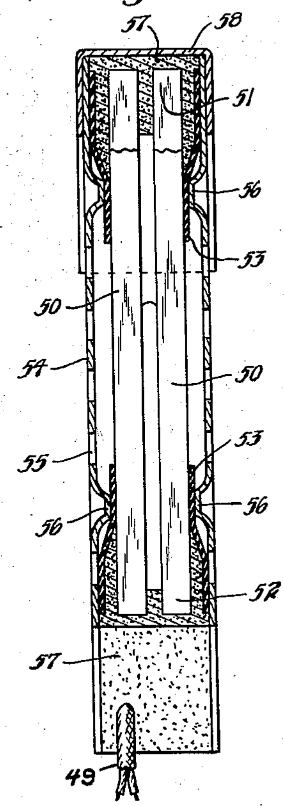
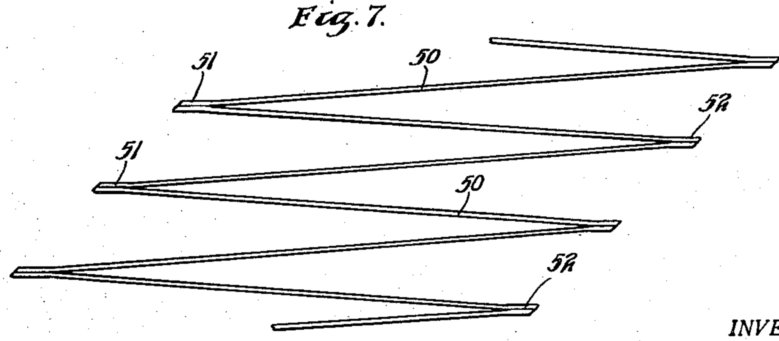


Fig. 7.



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THERMOELECTRIC GENERATOR

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8 Claims. (Cl. 136—4)

This invention relates to improvements in thermoelectric generators and more particularly to the economical construction of a highly efficient thermopile which will give uniform service throughout a prolonged period of use without the necessity of periodically replacing the unit or damaged parts thereof.

It is known in the art that the total output of a thermopile is governed by the number of thermocouples in the unit and the temperature gradient between the hot and cold junctions thereof. In maintaining a high temperature gradient between the junctions, the heated portion tends to deteriorate much more rapidly than the nonheated portion of the thermocouple. An increase in the number of thermocouples, without reducing their size, increases the overall dimensions of the unit, and a reduction in the size of the thermocouple material results in a more rapid deterioration of the hot junction.

In previous constructions, it has been found that the hot junction of the thermocouples oxidizes when subjected to the heat of an open activating flame. The oxidizing of the metal adjacent the hot junction increasingly impairs the efficiency of the device and eventually causes a complete break-down by changing the characteristics of the surface portion of the electrical conducting metal to a nonconductive oxide. Various expedients have been used to overcome this serious objection and to try to increase the effective lift or efficiency period of the thermocouple. Among the expedients tried, the most successful seems to be the practice of covering the portion of the hot junction subjected to the flame with a protective sleeve or cap or suitable material. The protection usually is in the form of a sleeve or cap of heat conducting material which is more or less impervious to oxidation or corrosion. Such protective sleeves or caps have in the past been formed of material such as stainless steel or other suitable material. This practice gave a measure of protection to the wires or strips of the hot junction, but in practice it was found that the coefficient of expansion of the various materials differed considerably. This difference in contraction and expansion soon created an air gap or crack through which gas and air contacted the junction. Oxidation and corrosion of the metal at the junction then followed. Accordingly, the expedient of covering the hot junction with a protective sleeve or cap tended to delay but not prevent breakdown. Even in constructions wherein the hot junctions were protected by a sleeve or cap, it was found necessary to construct the thermocouple, or at least the hot junction portion thereof, of strips or rods having a relatively large cross-sectional area to overcome burning, oxidizing, or damaging which impaired the efficiency of the unit. Consequently, the number of thermocouples per unit of over-all dimension of a thermoelectric generating device of this type is relatively small.

In the present invention, these objectionable features are overcome and means are provided for incorporating a large number of thermocouples in a highly efficient, compact and practically indestructible thermopile unit. Moreover, means are provided for preventing oxidation of the thermocouples by sealing the junctions of the improved thermopile from atmosphere and the products of combustion of the activating flame.

Another object of importance is the means for utilizing the sealing mass for transferring heat between the cover on which the actuating flame impinges and the hot junctions of the device.

Another and still further object of importance and advantage is the provision of means for utilizing the sealing and heat transfer masses for maintaining the thermocouples in two aligned stacks spaced one from another within a casing member. The masses also assist in maintaining the stacks spaced from the walls of the casing member.

A still further object of advantage and importance resides in the provision of means for cooling the intermediate portions of the assembled thermocouples to decrease heat conductance to the cold junctions. Means are also provided for reducing the heat conductance of the covering sheath or casing member.

A further object of advantage and importance is the provision of barrier means for maintaining the sealing and heat transfer masses in the end portions of the sheath.

An additional object of importance is the means for changing the characteristics of the surface portion of the thermocouple members to electrically insulate the assembled members one from another.

Additional objects of importance and advantage will become apparent as the following detailed description progresses, reference being had to the accompanying drawing, wherein

Figure 1 is an elevational view of a thermopile which embodies the invention, portions thereof being broken away;

Figure 2 is a vertical section thereof taken on line 2—2 of Figure 1;

Figure 3 is a sectional view of a slightly modified form of the invention;

Figure 4 is a fragmental portion, slightly enlarged, and expanded, of the thermopile unit shown in Figure 3.

Figure 5 is an elevational view of a further modified form of the invention;

Figure 6 is a vertical section thereof taken on line 6—6 of Figure 5;

Figure 7 is a view of a fragmental portion of the thermopile shown in Figure 5 with the elements spread apart.

The reference numeral 10 indicates generally a sheath or casing member which is preferably constructed of a lower member 11 and an upper member 12. The lower member 11 comprises a channel-shaped member which may be formed of any suitable material, as for instance sheet metal. A plurality of apertures 13 are formed in the sidewalls of the member 11 as is best shown in Figure 1. An additional aperture 14 is formed in the floor of the channel member. An inwardly projecting rib 15 is formed in each sidewall of the member 11 intermediate each end thereof and the apertures 13. The inwardly projecting ribs 15 in addition to reenforcing the member 11 also function as a barrier to maintain the assembled thermocouples in alignment and the masses at the end portions as will hereinafter more fully appear. The upper member of the casing 12 is positioned on the lower member 11 and is secured thereto by tongues 16 pressed into the recesses formed by the inwardly projecting ribs 15 as is best shown in Figure 1. Formed in the upper portion of the member 12 intermediate the end and sides thereof is an aperture 17. The aperture 17 is indicated by dotted lines in Figure 1.

Positioned within the substantially rectangular sheath 10 is a thermopile indicated generally by the reference numeral 18. The thermopile 18 comprises a plurality of thermocouples each consisting of a pair of wire members of dissimilar electrical characteristics, such as Copel and Chromel. Each pair of wires is joined at one end, as by twisting, welding, fusing or the like, to form a hot junction 21 and the opposite ends thereof are joined to the end portions of the next adjacent thermocouples, as is best shown in Figure 1, to provide cold junction 22. The wires are insulated between the junctions by woven glass covers 19.

The thermocouples are arranged in a plurality of aligned files as is best shown in Figure 2, and each file is separated and insulated from the adjacent file by a strip of dielectric material 24. Each end of the thermopile 18 is enclosed in an insulating sheath 25 which functions to maintain the assembled thermocouples in alignment and spaced from the walls of the sheath 10. Each insulating sheath 25 is engaged by inwardly projecting ribs 15 and thus both insulating members and thermocouple units are maintained in spaced relation and parallel to the interior surface of the walls of the sheath 10.

Positioned within each sheath 25 and extending from the inwardly projecting ribs 15 to the end of the sheath is a dielectric mass 26. In practice it has been found that a product marketed under the trade name of Sauereisen #32 cement gives satisfactory results, however, other material having good heat conducting and electrical resistance characteristics may be employed. The dielectric mass 26 which is forced into the insulating sheath 25 to embed and hermetically seal the junctions therein causes the sheath to bulge outwardly and engage the inner surface of the sidewalls of sheath 10. The dielectric mass 26 preferably comprises a cement or mastic material which upon drying and hardening functions to maintain the junctions of the assembled thermocouple in their respective positions. The dielectric material has relatively good heat conducting characteristics so as to provide for thermal convection between the sheath 10 and the junctions of the assembled thermocouples.

Positioned over the hot junction 21 and the surrounding dielectric mass 26 and in frictional engagement with the end portion of sheath 10 is a cap 27. The interior of the cap 27 engages the dielectric mass 26 and provides a good heat conducting path between the cap and hot junctions. The cap 27 may be formed of any suitable flame resistant material such as stainless steel or the like.

Lead wires indicated by the reference numeral 28 are connected to the thermopile and provide means for conveying current generated by the improved thermoelectric generator of this invention to a location of work.

The improved device of this invention may be assembled substantially as follows: wires or strips of metal having dissimilar electrical characteristics are alternately joined to form a thermopile. The thermopile is then arranged in ranks or files with corresponding junctions in alignment and the insulating members 24 positioned between the files. The insulating sheaths 25 are positioned over and project beyond the aligned junctions of the thermopile. The assembled thermopile and insulating members are then positioned within the lower member 11 of the sheath 10 and the upper portion 12 of the sheath 10 is secured in position by depressing one of the tongues 16 thereon into the recess portion of one of the inwardly projecting ribs 15. It is to be noted that the cold junctions 22 and the insulating sheath 25 associated therewith are positioned within the sheath 10 whereas the hot junctions 21 and the insulating sheath 25 associated therewith project beyond the end of sheath 10. The dielectric mass 26 in the form of a relatively stiff cement is now tamped into the open end portions of the insulating sheath 25. The dielectric mass forces the sheath 25 outwardly against the interior surface of sheath 10 as previously stated. However, the mass is prevented from reaching the intermediate portion of sheath 10 by the inwardly projecting ribs 15 which form barriers along substantially the entire surface of the sidewalls of sheath 10. The cap 27 is now positioned over the hot junction end of the unit and is forced thereon to engage the dielectric mass and be secured as by friction, welding or the like to the end portion of the sheath 10. There is thus provided a good heat conducting means, without air space, between the cap and the hot junctions 21.

The improved device of this invention is preferably mounted in horizontal position for operation. Upon an actuating flame being directed against the cap 27 it becomes heated and the heat thereof is conveyed through the dielectric mass to the hot junctions 21. The heating of the cap also causes heating of the sheath 10, and as the sheath 10 warms to a temperature above that of the surrounding air an updraft is created through the apertures 13, 14, and 17 which causes a flow of air over the intermediate portions of the assembled thermocouples. This updraft carries away heat emanating from the intermediate portions of the thermocouples and the sheath 10. Consequently, but a small amount of heat is conveyed from the cap 27 and hot junctions 21 to the cold junction portion of the unit. Moreover, the dielectric mass in which the cold junctions 22 are imbedded tends to dissipate any heat which may reach this portion of the unit. It is to be noted that both the hot and cold junctions of the improved device of this invention are by virtue of being imbedded in dielectric masses hermetically sealed from atmosphere and the products of combustion of the actuating flame. The current generated by the device is conveyed to a point of use by the conductors indicated by the reference numeral 28.

A slightly modified form of construction is shown in Figures 3 and 4 wherein thin ribbon-like strips 30 are employed to build up the thermopile unit. The strips indicated by the reference numeral 30 are relatively thin and if employed in the conventional manner would quickly burn away or be damaged by the actuating flame. However, in the present construction wherein the junctions are sealed from atmosphere it has been found that strips of Chromel and Copel as thin as .008 of an inch may be employed to produce a highly efficient long lived thermopile. These strips are alternately joined, as by spot welding or the like, to provide cold junctions 31 and hot junctions 32 as is best shown in the enlarged view in Fig. 4. The joined strips are subjected to a flame which quickly oxidizes the outer surface thereof to form a nonconducting surface thereon. The joined strips are then arranged in a plurality of files and are compressed and arranged in a sheath 10 as is best shown in Figure 3. In this embodiment, the thermocouples are arranged for the passage of air upwardly through apertures 14 and 17 and the space between the assembled thermocouples when the device is in operation.

In this embodiment, the number of thermocouples in the unit may be greatly increased over the number shown in the other embodiment without increasing the over-all dimensions of the unit. Additionally, in this embodiment the temperature gradient between the hot and cold junctions is substantially the same as in the other embodiment. Consequently, under similar conditions, the E. M. F. generated by the structure shown in this embodiment is greater than the E. M. F. generated by the structure shown in the other embodiment.

The assembly and operation of the embodiment shown in Figures 3 and 4 are substantially the same as in the first described embodiment and need not be repeated here.

A still further modified form of the invention is shown in Figures 5, 6 and 7 wherein the ends of the device are angularly disposed to increase the effective heating and cooling areas thereof without proportionately increasing the overall dimensions of the structure. In this embodiment the thermocouples may be constructed of either the wire or strip material shown in the other embodiment. This embodiment is designed to be installed and operated in a vertical position, but it also functions efficiently when positioned horizontally.

The device of this embodiment comprises a plurality of metallic members 50 joined one to another, as is best shown in Figure 7, to form a thermopile with the hot junctions 51 thereof at one end and the cold junctions 52 at the other end of the assembly. The metallic members are formed of two metals having different thermoelectric characteristics and may be of any desired cross sectional shape. In the construction here shown the members are flat stripped which are assembled alternately in respect to their thermoelectric characteristics. The junctions of the assembled thermopile are aligned diagonally at an angle of approximately 45 degrees with the plane of the body portion as is clearly shown in the drawing to increase the effective heating and cooling areas thereof as compared to a rectangular construction. The surface of the assembled thermopile is oxidized as previously described, to electrically insulate the strips from another. The joined strips are arranged in spaced files which are electrically connected to each other and a conductor 49 connected to the unit provides means for carrying current generated thereby to a point of use.

Positioned on each end of the thermopile and encasing the junctions 51 and 52 thereof is an insulating sheath 53. The sheath 53 may be constructed of mica or other suitable heat impervious dielectric material. A casing member 54 having end portions disposed on a bias corresponds with the ends of the thermopile function to maintain the sheath 53 in position and also provides a protective shield therefor. The casing member 54 is provided with a plurality of apertures 55 in the sides and edges thereof whereby air may contact and flow over the intermediate portions of the thermopile, as in the previously described embodiment. Inwardly extending ribs 56 are also formed in side walls of the casing member 54 to provide abutment means for maintaining the sheath 53 and thermopile in assembly.

The hot junctions 51 and the cold junctions 52 are embedded in dielectric masses 57, as is best shown in Figure 6. The material of the dielectric masses which has good heat conductive characteristics is bonded to the junctions 51 and 52 to seal them from atmosphere and the gases of the combustion chamber in which the device may be positioned. Positioned over the sealed hot junctions and in engagement with the sealing mass is a protective cap 58. The cap 58 is preferably constructed of flame resistant material such as stainless steel or the like and is formed to correspond to and parallel the diagonally aligned hot junctions 51. The diagonal end construction of the improved device provides greater heating and cooling areas for the thermopile and thus tends toward higher efficiency in the unit. The operation of the embodiment shown in Figures 5, 6 and 7 is precisely the same as the operation of the other embodiment previously described.

It will be apparent from the foregoing that herein is provided a compact, highly efficient and long lived unit which may be economically constructed and installed. It will also be apparent to those skilled in the art to which the device appertains that numerous changes in construction and design may be made from the embodiments here shown without departing from the spirit or scope of the invention. Accordingly, the patent granted hereon is not to be limited to the precise structure shown or in any other manner except as may be necessitated by the terminology of the appended claims when given the range of equivalent to which they be entitled.

I claim as my invention:

1. A thermoelectric generator assembly com-

prising in combination a protecting sheath, a thermopile positioned within said sheath with the hot and cold junctions thereof at opposite ends of said sheath, a dielectric mass positioned at each end of said sheath and maintaining said hot and cold junctions in spaced relation and insulated from said sheath, inwardly extending ribs formed in the sidewalls of said sheath for maintaining said dielectric masses in their respective positions and for spacing the thermopile from said sheath, and window openings in the intermediate portion of said sheath for reducing the transfer of heat from the hot junction to the cold junction by exposing the intermediate portion of said thermopile to the atmosphere.

2. A thermoelectric generator assembly comprising in combination a protecting sheath, a thermopile positioned within said sheath with the hot junctions and the cold junctions thereof at opposite ends of said sheath, said thermopile comprising a plurality of strips of metal having different electrical characteristics and joined alternately one to another, the surface of said joined strips being oxidized to insulate them one from another, a dielectric mass positioned in each end portion of said sheath, said dielectric masses being operable to shield said junctions from the atmosphere and providing heat conducting means between said sheath and said junctions, ribs formed on said sheath for maintaining the dielectric masses in their respective positions and for spacing the thermopile from said sheath, and window openings in the intermediate portion of said sheath whereby the intermediate portion of said thermopile is exposed to the atmosphere for cooling thereby.

3. A thermoelectric generator assembly comprising in combination a protecting sheath, a thermopile positioned within said sheath with the hot junctions thereof adjacent one end of said sheath and the cold junctions near the other end, means for sealing said hot and cold junctions from atmosphere and means for exposing the intermediate portion of said thermopile to atmosphere and for reducing the cross-sectional heat conducting area of the sheath.

4. In a thermoelectric generator, a plurality of thermocouples having hot and cold junctions, said thermocouples being electrically connected, means for insulating the elements of said thermocouples one from another, said thermocouples being arranged in a pack, a casing member enclosing said pack, means for sealing the hot junctions of said thermocouples from atmosphere, means sealing said cold junctions from atmosphere, means for maintaining the intermediate portions of the sides of said casing member spaced from the corresponding portions of adjacent thermocouples and for retaining said sealing means around said hot and cold functions and openings in said casing for exposing the intermediate portion of the thermocouples to the atmosphere.

5. In a thermopile construction, a plurality of thermocouples joined one to another, said thermocouples being arranged one upon another in a plurality of stacks with the hot junctions at one end and the cold junctions at the other end of said stacks, a single case enclosing said

stacks, means for sealing the hot and cold junctions of said thermocouples from atmosphere, means for exposing the intermediate portions of said thermocouples to atmosphere, means for maintaining the junction sealing means at opposed ends of said case, and a protective cover positioned over the hot junction end of said case.

6. A thermoelectric generator comprising a plurality of electrically connected thermocouples having substantially parallel elements of dissimilar thermoelectric material, the elements of one material being uniformly shorter in length than the elements of the other material and alternately connected at their ends, whereby an elongated and stepped hot junction end surface is formed at an inclination to the longitudinal axes of said elements.

7. A thermoelectric generator comprising a plurality of electrically connected thermocouples having substantially parallel elements of dissimilar thermoelectric material, the elements of one material being uniformly shorter in length than the elements of the other material and alternately connected at their ends, whereby an elongated hot junction end surface is formed at an inclination to the longitudinal axes of said elements, a protecting cap covering at least the hot junction end of the thermopile and uniformly spaced from the ends of the thermocouple hot junctions, and a heat conducting dielectric material between said thermocouples and said cap.

8. A thermoelectric generator comprising a plurality of superimposed thermocouples having elements of dissimilar thermoelectric material, said elements having oxidized surfaces to serve as insulation therebetween when they are pressed together, the hot junction ends of the elements lying in a plane at an inclination to the side surfaces of at least the adjacent portions of said elements, a centrally apertured sheath around said thermocouples, a cap over said hot junction ends and the adjacent end of said sheath and a heat conducting dielectric material between said hot junction ends and said cap.

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