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(54) THERMOELECTRIC GENERATOR

(54) GENERATEUR THERMO-ELECTRIQUE

(57) Abstract:

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BE IT KNOWN that HOWARD J. FINDLEY, a citizen of the United States and a resident of Shaker Heights, Ohio, U. S. A., Engineer, having made an invention entitled

THERMOELECTRIC GENERATOR

the following is a full, clear and exact disclosure of the nature of the said invention and of the best mode of realizing the advantages thereof.

This invention relates to thermoelectric generators and provides an improved construction for devices of this kind which affords a compact arrangement for the thermocouples and permits a wide temperature differential to be maintained between the "hot" and "cold" junctions. The improved construction also provides a heating chamber of novel form by utilizing a series of refractory electrically insulating rings which support the thermocouples and form therewith an assembly unit. The invention also provides a novel form of thermocouple and contemplates the use of mechanical means for causing a flow of cooling medium over certain of the junctions of the thermocouples.

In the accompanying sheets of drawings showing one embodiment of the thermoelectric generator,

Fig. 1 is an elevational view, with portions broken away, showing a thermoelectric generator embodying my invention;

Fig. 2 is a transverse sectional view taken through the device on line 2--2 of Fig. 1;

Fig. 3 is a partial elevational view of the thermopile showing the electrical connections for the groups of the thermocouples;

Fig. 4 is a partial longitudinal sectional view on an enlarged scale, taken as indicated by line 4--4 of Fig. 2;

Fig. 5 is a perspective view showing one of the insulating refractory rings of the thermopile in detached relation;

Fig. 6 is a transverse sectional view taken through one of the refractory rings as indicated by line 6--6 of Fig. 5;

Figs. 7 and 8 are partial transverse sectional views showing details of construction and taken respectively on lines 7--7 and 8--8 of Fig. 1;

Fig. 9 is a partial perspective view showing another form of refractory ring;

Fig. 10 is a transverse sectional view thereof taken on line 10-10 of Fig. 9;

Figs. 11 and 12 are diagrammatic side and end views, respectively, of the thermopile showing a series-parallel hook-up for the thermocouples; and

Figs. 13 and 14 are similar diagrammatic side and end views of the thermopile showing another series-parallel hook-up for the thermocouples.

The embodiment of the thermoelectric generator shown in the accompanying drawings comprises in general a thermopile 10, a fuel burning means 11 for supplying heating medium to one portion of the thermopile and a mechanical means 12 for supplying cooling medium to another portion of the thermopile.

As shown in the drawings, the thermopile 10 comprises an elongated assembly unit made up of a plurality of thermocouple groups or rings 13 and a plurality of electrically-insulating refractory rings 14. The thermocouple groups 13 are in axially spaced substantially parallel relation and each group comprises

an annular series of substantially radially extending circumferentially spaced thermocouples 15. The rings 14 are arranged in an elongated series in contiguous substantially coaxial relation and form a substantially cylindrical gas-tight wall 16 defining or enclosing an elongated heating or combustion chamber 17.

The thermoelectric generator is preferably, though not necessarily, provided with an outer housing 18 in which the thermopile 10 is disposed. As shown in this instance the housing 18 may be an elongated structure of cylindrical or other desired shape and formed of sheet metal or other suitable material. The thermopile 10 is arranged in the housing so that the wall 16 formed by the refractory rings 14 extends coaxially with the wall of the housing but is spaced therefrom to provide therebetween an annular cooling chamber 19. The thermopile 10 is provided at one end thereof with a spider member 21 and at its other end with a hollow fluid-conducting member or exhaust fitting 22.

The spider member 21 may comprise a sheet metal ring having a peripheral flange 23 engaging the wall of the housing 18, and a shouldered annular recess 24 into which one end of the wall 16 extends. Between the peripheral flange 23 and the shouldered recess 24, the spider may have a plurality of openings 25 forming a portion of the cooling chamber 19. The spider is provided centrally thereof with an opening through which the fuel burning means 11 communicates with the heating chamber 17.

The exhaust fitting 22 may be in the form of a metal body having heat-radiating fins 27 externally thereof and also having a fluid-conducting passage 28 extending therethrough. The fitting 22 may have a shouldered annular recess 29 surrounding

the passage 28 and into which the opposite or outer end of the wall 16 extends. The exhaust fitting 22 is mounted in the housing 18 by means of lugs 30 formed on certain of the fins 27 and screws 31 extending through the wall of the housing into threaded openings provided in such lugs. The spider member 21 is connected with the exhaust fitting 22 by a plurality of elongated screws or rods 32 whose threaded outer ends extend through ears 33 which are formed integral with certain of the fins of the exhaust fitting. From the construction of the thermopile 10, as just described, it will be seen that the inner end of this unit is supported by the spider 21 and its outer end is supported by the exhaust fitting 22 and that the refractory rings 14 are held in clamped relation by the rods 32. The thermopile may be supported at an intermediate point by a second spider 34.

As shown in Fig. 2 the thermocouples 15 each comprise a pair of elements 36 and 37 formed of dissimilar metals such as iron and constantan or any other suitable combination of metals. The elements 36 and 37 may be ribbon-like pieces of metal whose inner ends extend into overlapping relation and are welded or otherwise connected together to form thermocouple junctions 38 which are referred to as "hot" junctions. The outer ends of the elements 36 and 37 also extend into overlapping relation and are welded or otherwise connected to form "cold" thermocouple junctions 39. It will be seen from Fig. 2 that the junctions 38 and 39 are arranged alternately or in staggered relation so as to result in all of the thermocouple elements 36 and 37 of one of the groups 13 being connected in series relation with each other. In each of the groups 13 one end of the series of thermocouples is connected with a lead or terminal 40 and the other end of the series is

connected with an adjacent lead or terminal 41. The adjacent groups 13 are connected in series with each other by means of short connectors 42 arranged in staggered relation as shown in Fig. 3. Suitable lead wires 43 and 44 may be connected with the end groups 13a and 13b of the thermopile 10.

As shown in Figs. 1 and 2 the thermocouples 15 extend substantially radially of the device and have their hot junctions disposed in the heating chamber 17 and their cold junctions 39 disposed in the cooling chamber or air passage 19. The elements 36 and 37 of the thermocouples extend through the wall 16 formed by the refractory rings 14. In addition to forming the wall of the heating chamber, the refractory rings 14 also support the thermocouples 15 in spaced relation and electrically insulate the adjacent thermocouples from each other.

The rings 14 may be made of any heat resisting and electrically-insulating material which will have sufficient strength to support and retain the thermocouples 15 in the desired arrangement. Preference is made to the use of rings formed of molded refractory ceramic material, and to enable the rings to hold the thermocouples in the desired arrangement the rings are provided with radiating grooves 46 extending across their end faces and which are of a width to snugly receive the ribbon-like elements 36 and 37. The portions of the ring remaining between adjacent grooves 46 form axial teeth or projections 47 which extend between each pair of adjacent elements 36 and 37. The grooves 46 are of a depth approximately equal to one-half of the width of the elements 36 and 37, and when the rings 14 are assembled in contiguous substantially coaxial relation, the grooves of one ring register with the grooves of the adjacent ring and cooperate therewith to form radial passages extending

across the rings and in which the elements 36 and 37 are accommodated. It will be noted that when the grooves of adjacent rings are in the above-explained registering or complemental relation, the radial slots formed thereby have a desired depth or length axially of the thermopile and that they hold the thermocouples with the ribbon-like material thereof disposed edgewise to the flow of fluid through the combustion chamber 17 and the cooling passage 19.

As seen in Figs. 1 and 4, the rings 14 have interfitting engagement with each other which may be obtained by constructing the rings so that each ring has a concave end face 49 and a convex end face 50 as shown in Fig. 6. When the rings are assembled the convex face of each ring has interfitting engagement with the concave face of the adjacent ring. This interfitting engagement facilitates the operation of assembling the rings in coaxial alignment with each other and assists in holding or retaining the rings in such alignment. As shown in Figs. 4 to 6 inclusive, the end faces of the rings also have annular grooves 51 formed therein which cut across the transversely extending grooves and teeth 46 and 47, and when the rings are in assembled relation the grooves 51 of each ring register with the corresponding grooves of the adjacent rings. Suitable refractory cement 52 is applied to the rings during the building of the thermopile 10 and serves to unite the rings into a substantially solid tube or sleeve and to also form a gas-tight seal between the rings and around the thermocouple elements 36 and 37. The cement 52 substantially fills the grooves 51 and forms annular keys 53 therein which assist in holding the rings in proper axial alignment.

From the foregoing detailed description it will be seen that the thermopile 10 can be conveniently constructed as a preassembled unit and then placed in the housing 18. When the thermopile has been assembled into the housing it will also be

seen that one end thereof is anchored to the housing, in this instance the outer end, as by means of the screws 31 engaging the lugs 30 of the exhaust fitting 22. The spider 25 at the opposite end of the thermopile is slidable in the housing 18 so as to accommodate the expansion and contraction which occurs in the thermopile as the result of the heating and cooling thereof.

For supplying heating medium to the chamber 17 containing the hot junctions 38, there is provided the above mentioned fuel burning means 11 which is located at the inner end of the thermopile 10. This fuel burning means may include a tapered burner tube 55 which communicates with the heating chamber 17 by extending snugly into the central opening of the spider member 21. The fuel burning means 11 also includes a suitable burner 56 extending axially of the tube 55 and from which gas or liquid fuel is projected and burned. The flame and heated combustion gases are projected into the heating chamber 17 into direct contact with the junctions 38 and after passing through the chamber 17 are discharged through the passage 28 of the exhaust fitting 22. Since the series of refractory rings 14 form a substantially gas-tight wall for the chamber 17, it will be seen that the flame and combustion gases are confined so that they must pass through this chamber into the exhaust fitting 22.

It is desirable to maintain a wide temperature differential between the hot and cold thermocouple junctions 38 and 39 and this is accomplished by supplying cooling medium to the junctions 39. For this purpose there is provided the above mentioned mechanical means 12 for propelling cooling medium through the passage 19 in which the junctions 39 are disposed. This propelling means may comprise a suitable propeller fan 57 and an electric motor 58 with which the fan is connected. The fan is located at a suitable point in the housing 18, in this instance just outwardly of the exhaust fitting 22, and operates to draw cool air into the housing through the openings 59 to cause such air to flow over the exhaust fitting 22 and through the passage 19 in

contact with the junctions 39 and the radiating portions of the elements 36 and 37 which project outwardly from the wall 16 of the heating chamber 17.

In accomplishing its function of cooling the junctions 39, the air picks up heat from the exhaust fitting 22 and the radiating elements 36 and 37 of the thermocouples and when such heated air is discharged from the housing it can be used as a space heating medium or can be directed against any object desired to be heated. Likewise, the heated combustion gases which are discharged through the exhaust fitting 22 can be used as a heating medium. Electric current for operating the motor 58 is obtained from the thermopile 10 although this motor can be operated from some other source of current if desired. Likewise, the electric current generated by the thermopile 10 can be used for other purposes than driving the fan motor 58.

For bringing the flame and combustion gases in more direct contact with the thermocouples 38, it may be desirable to provide a flame spreader or deflector 60 in the heating chamber 17. The spreader 60 comprises a tubular member extending axially of the heating chamber and may be suitably supported as by having its outer end connected with the exhaust fitting 22. The spreader may have a closed tapered end 61 adjacent the fuel burning means 11 and its opposite end may extend through the exhaust fitting 22 and may have an open funnel-shaped portion 62 located in front of the fan 57 so that air from the latter will be directed into the spreader. At one or more points therealong, the spreader may have hooded aspirated openings 63 through which the air supplied by the fan will be discharged or drawn during the operation of the device. The air thus supplied through the spreader

60 may serve as supplemental air for combustion and other purposes. The spreader 60 can be omitted if desired.

It has been found desirable to construct the thermocouples 15 with a metallic coating 65 thereon which considerably increases the heat and electrical conductivity of the thermocouples. This metallic coating may be of nickel or chromium or may be a coating formed by successive layers of these metals. The metallic coating is preferably applied to the thermocouples after the junctions 38 and 39 have been formed and extends over the junctions as a continuous coating which protects the junctions from corrosion and deterioration, particularly the junctions 38 which are subjected to the direct action of the flame and combustion gases. The metallic coating 65 can be applied to the thermocouples in any suitable way such as by dipping the thermocouples or the thermocouple groups 13 in a heated bath of metal or by subjecting the thermocouples or thermocouple groups to an electroplating action.

In Figs. 9 and 10 there is shown another form of refractory ceramic ring 67 which can be used instead of the rings 14 in forming the wall 16. The end faces of the ring 67 are transversely grooved similarly to the ends of the ring 14. On one end of the ring 67 the intervening teeth 68 are shouldered as indicated at 69 and the other end face has an annular groove or recess 70 therein. The teeth 71 lying outside of the groove 70 are somewhat higher than the teeth 72 which lie inwardly of the groove 70. When a plurality of the rings 67 are arranged coaxially in a group or stack the tops of the teeth 68 extend into the recessed end of the adjacent ring with the annular shoulder 69 engaging just inside the teeth 71. Suitable refractory cement is also used

between the rings 67 in the same manner and for the same purpose as with the rings 14.

During the operation of the thermoelectric generator a continuous stream of burning fuel and combustion gases is directed by the burner 56 through the chamber 17 into the exhaust fitting 22. The flame and combustion gases heat the junctions 38 while the junctions 39 are being cooled by the air delivered by the fan 57. Electric current is generated in the junctions 38 and 39 and since the thermocouples are connected in series the voltages add up and an electromotive force of substantial value is made available at the leads 43 and 44.

Instead of connecting all of the thermocouples in series there can be used a series-parallel relation for the thermocouples which is more satisfactory in certain cases, particularly where different sections of the thermopile are heated to different temperatures. In the diagrammatic views of Figs. 11 and 12 there is shown a series-parallel arrangement wherein the thermocouple rings 75 of the thermopile 76 are each divided into three sectors 77. Each such sector comprises a plurality of radially extending individual thermocouples 78 connected in series. The sectors of the thermocouple rings are arranged to lie in axially extending rows, as shown in Fig. 11, and the sectors of each row are connected in series by the connectors 78. The positive leads 79 at one end of the axial rows are connected together and the negative leads 80 at the other end of the axial rows are connected together to give a parallel hook-up for the three rows of sectors.

In the diagrammatic views of Figs. 13 and 14 there is shown another series-parallel hookup in which the thermocouple rings 82 of the thermopile 83 are in three groups 84, 85 and 86. The individual radially extending thermocouples 87 of each ring

are connected in series and the rings of each group are also connected in series by the connectors 88. Each of the groups 84, 85 and 86 has a positive lead 89 at one end and a negative lead 90 at its other end and these leads are connected to give a parallel hookup for the groups of thermocouple rings.

From the foregoing description and accompanying drawings it will now be readily understood that there is provided a thermoelectric generator of a new and improved construction and which is compact in design and efficient in operation.

Having regard to the foregoing disclosure, the patent to which this specification forms part confers, subject to the conditions prescribed in the Patent Act, 1935, the exclusive right, privilege and liberty of making, constructing, using and vending to others to be used, the invention as defined in claims submitted by the patentee as follows:

1. In a thermoelectric generator, a heating chamber comprising a series of substantially coaxially disposed contiguous refractory rings having grooves extending generally radially thereacross, and a plurality of thermocouples extending into the heating chamber through said grooves, said thermocouples being made of ribbon-like material and being held by said grooves so that the ribbon-like material is disposed in edgewise relation to the longitudinal axis of said heating chamber.

2. In a thermoelectric generator, a heating chamber comprising a series of substantially coaxially disposed contiguous refractory rings having grooves extending generally radially thereacross, a plurality of thermocouples extending into the heating chamber through said grooves, and refractory cement forming a substantially gas-tight seal between said rings and around said thermocouples.

3. In a thermoelectric generator, a heating chamber comprising a series of substantially coaxially disposed contiguous refractory rings having radiating grooves extending thereacross, and a plurality of thermocouples extending into the heating chamber through said grooves, said thermocouples being in substantially parallel axially spaced groups and each group comprising a series of substantially radially extending thermocouples held in circumferentially spaced relation by their engagement in said grooves, said thermocouples being made of ribbon-like material and being held by said grooves so that the ribbon-like material is disposed in edgewise relation to the longitudinal axis of said heating chamber.

4. In a thermoelectric generator, a heating chamber comprising a series of substantially coaxially disposed contiguous refractory rings in interfitting engagement with each other and having grooves extending generally radially thereacross a housing extending longitudinally around said heating chamber and spaced from the wall thereof to form a passage for cooling fluid and a plurality of thermocouples disposed in said grooves and extending therefrom into the heating chamber and said cooling passage, said thermocouples being made of ribbon-like material and being held by said grooves so that the ribbon-like material is disposed in edgewise relation to the longitudinal axis of said heating chamber and cooling passage.

5. In a thermoelectric generator, a heating chamber comprising a series of substantially coaxially disposed contiguous refractory rings having grooves extending thereacross, said rings being disposed so that the grooves of one ring register substantially with the grooves of the adjacent ring to form passages, and a plurality of thermocouples extending into the heating chamber through said passages.

6. In a thermoelectric generator, a tubular heating chamber comprising a series of contiguous refractory rings having interfitting engagement with each other, said rings having substantially radial grooves extending thereacross and the rings being disposed so that the grooves of one ring register substantially with the grooves of the adjacent ring to form passages, and a plurality of thermocouples supported by said heating chamber and extending thereinto through said passages.

7. In a thermoelectric generator, a pair of spaced outer and inner substantially coaxial tubular members defining a heating chamber and a cooling chamber, the inner member having a wall formed by a series of refractory ceramic rings held in substantially coaxial relation and having radiating grooves extending thereacross, a plurality of thermocouples extending through said wall and having junctions disposed in said heating and cooling chambers, said thermocouples being in substantially parallel axially spaced groups and each group comprising a series of substantially radially extending circumferentially spaced thermocouples lying in said radiating grooves, means for causing a flow of combustion gases through said heating chamber in direct contact with the thermocouple junctions therein, and mechanical means operable to propel cooling air through said cooling chamber in direct contact with the thermocouple junctions therein.

8. In a thermoelectric generator, a pair of spaced outer and inner substantially coaxial tubular members defining a heating chamber and a cooling chamber, the inner member having a wall formed by a series of refractory ceramic rings held in substanially coaxial relation and having radiating grooves extending thereacross, said outer member constituting a housing for the generator, a plurality of thermocouples extending through said wall and having junctions disposed in said heating and cooling chambers, said thermocouples being in substantially parallel axially spaced groups and each group comprising a series of substantially radially extending circumferentially spaced thermocouples lying in said radiation grooves, means for causing a flow of heated combustion gases through said heating chamber in direct contact with the thermocouple junctions therein, and electrically driven mechanical means contained in said housing and operable by electric current from said thermocouples for propelling cooling air through said cooling chamber in direct contact with the thermocouple junctions therein.

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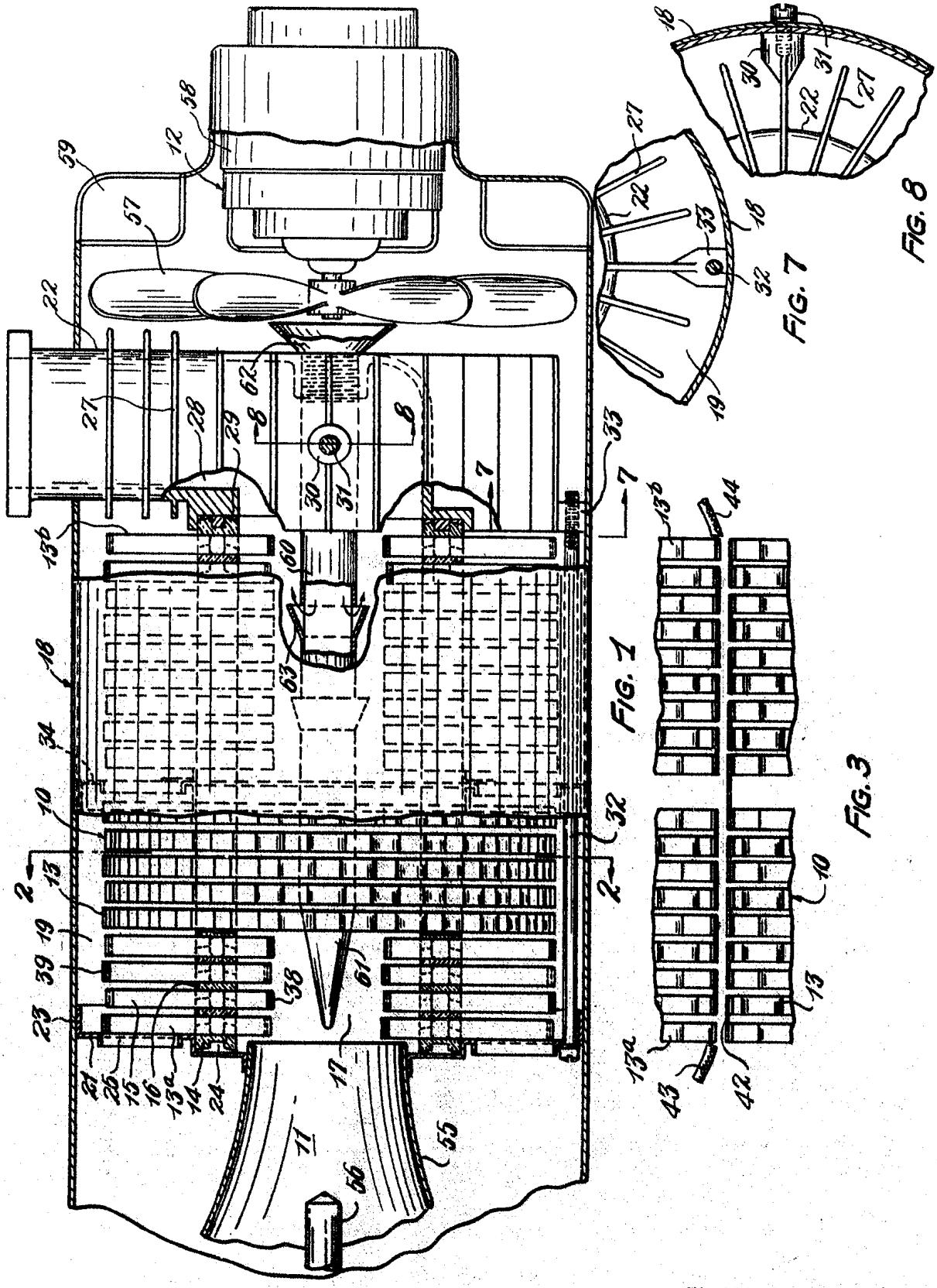

FIG. 1



FIG. 8



FIG. 7



FIG. 3

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*Certified to be the drawings referred to in the specification hereunto annexed.*

Ottawa, Ontario, Canada, May 17, 1943.

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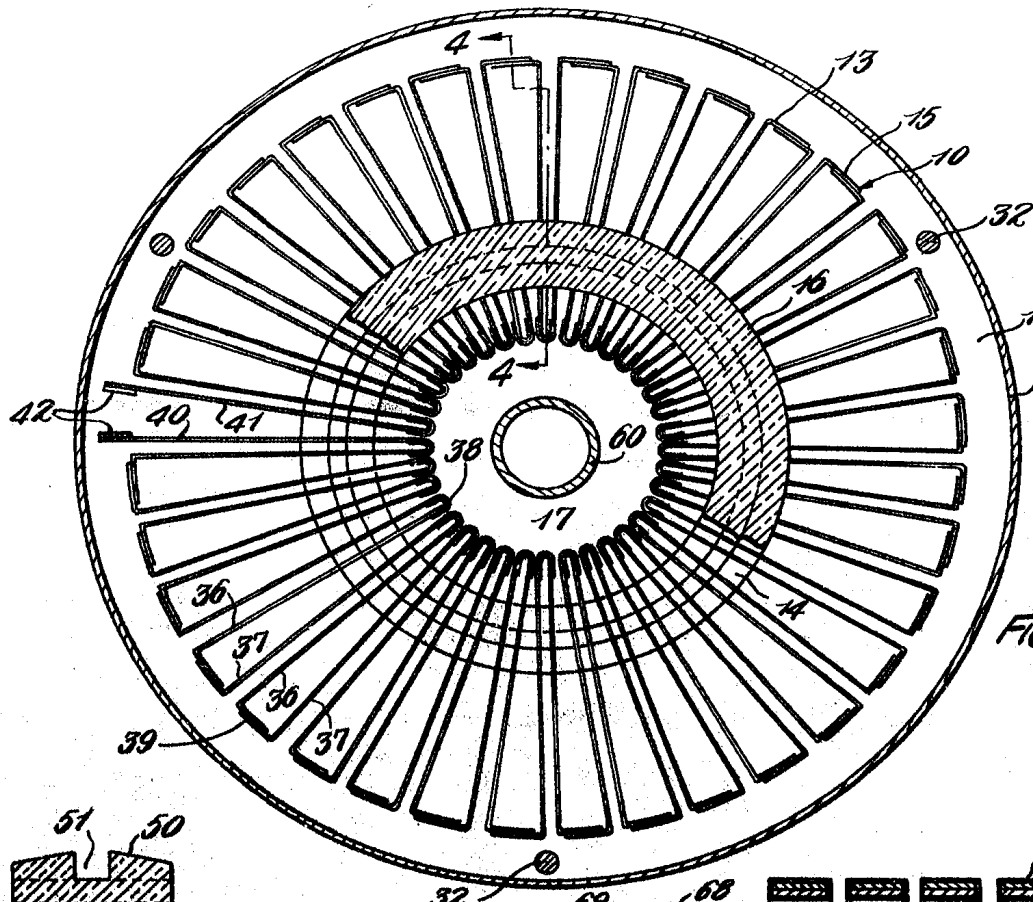


FIG. 2




FIG. 6

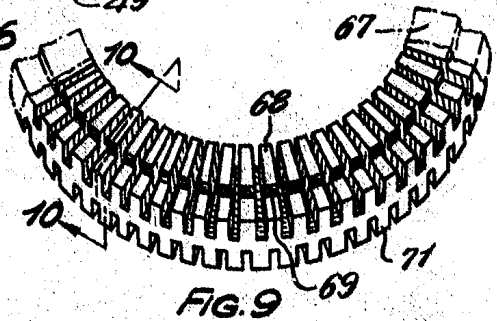


FIG. 9

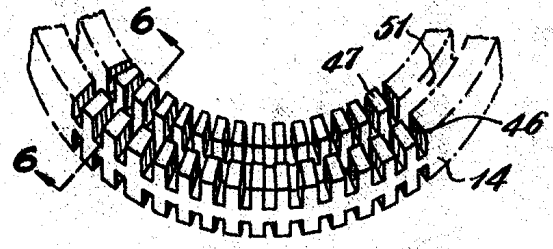


FIG. 5

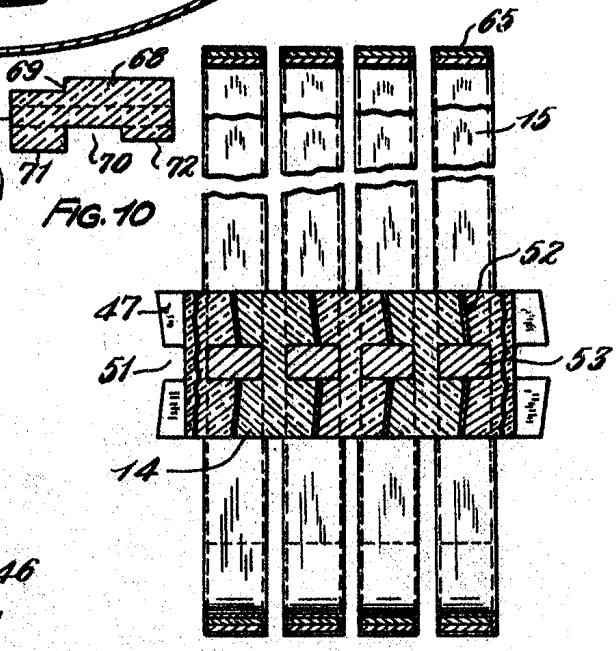


FIG. 10




FIG. 4

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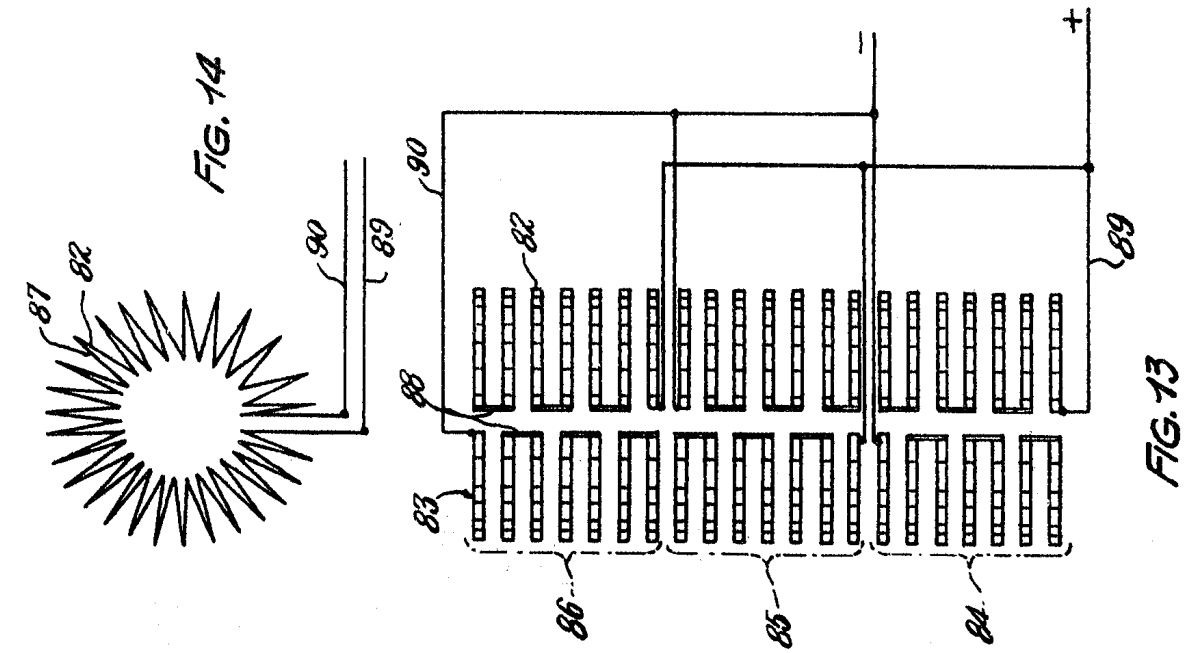


FIG. 14

FIG. 13

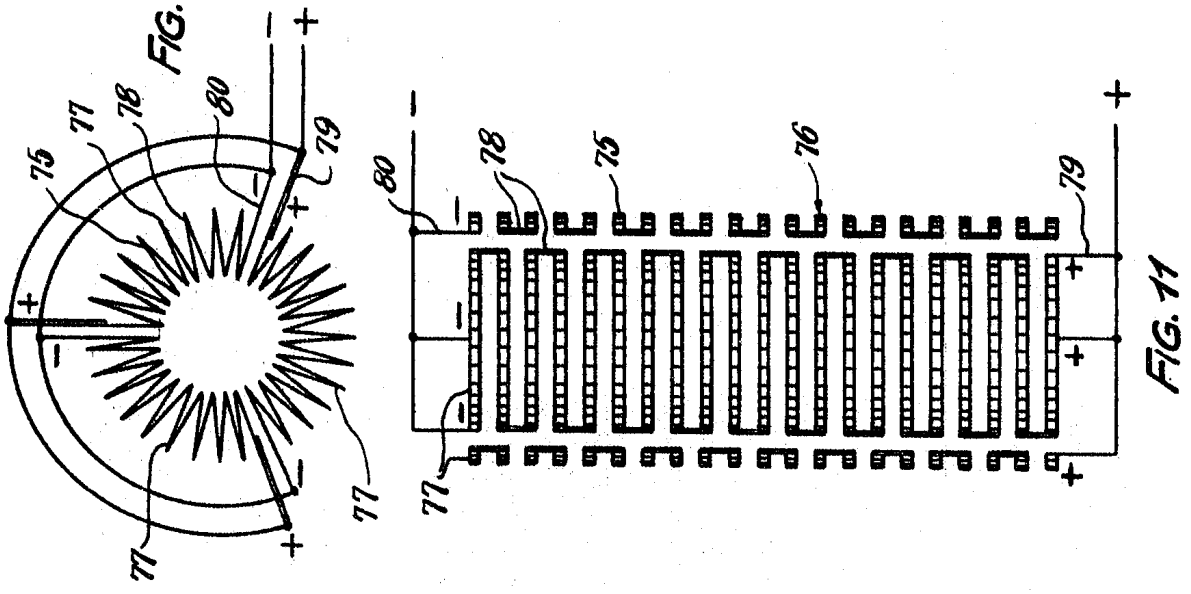


FIG. 12

FIG. 11

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