

Aug. 26, 1941.

P. L. DULANEY

2,253,771

APPARATUS FOR FABRICATING THERMOELECTRIC GENERATORS

Filed Aug. 2, 1940

5 Sheets-Sheet 1

FIG. 1

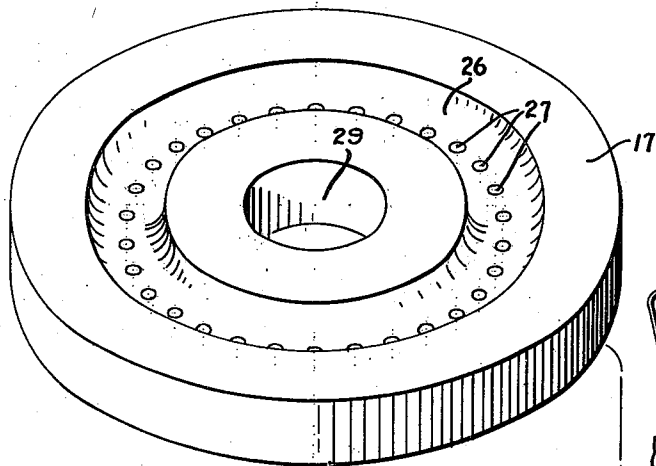


FIG. 2

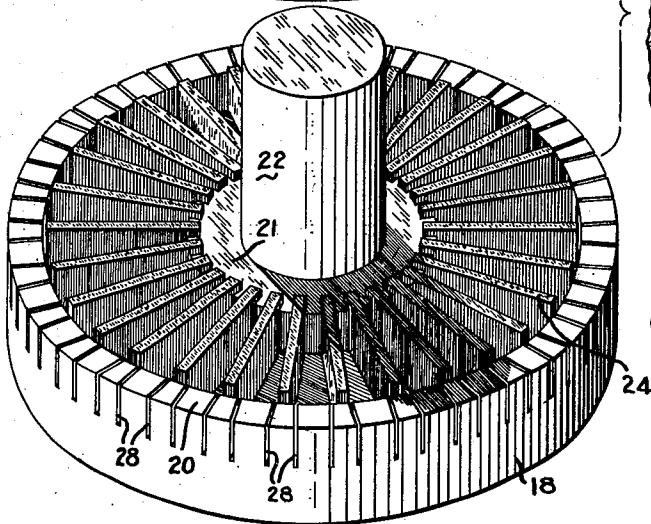
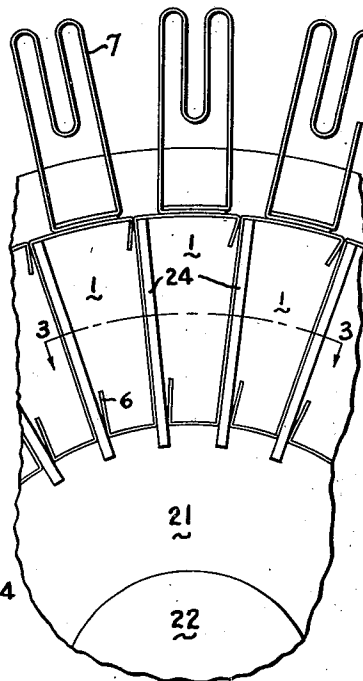


FIG. 3

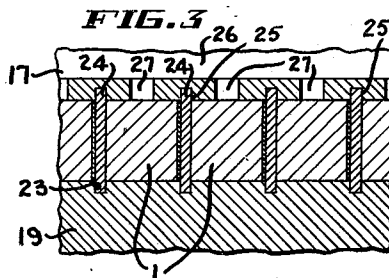
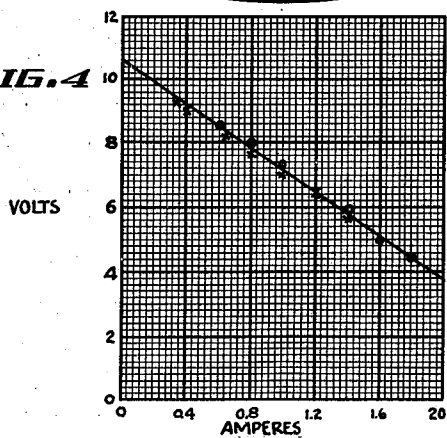


FIG. 4



INVENTOR  
PAUL L. DULANEY

By *Taulmin & Taulmin*  
ATTORNEYS

**Aug. 26, 1941.**

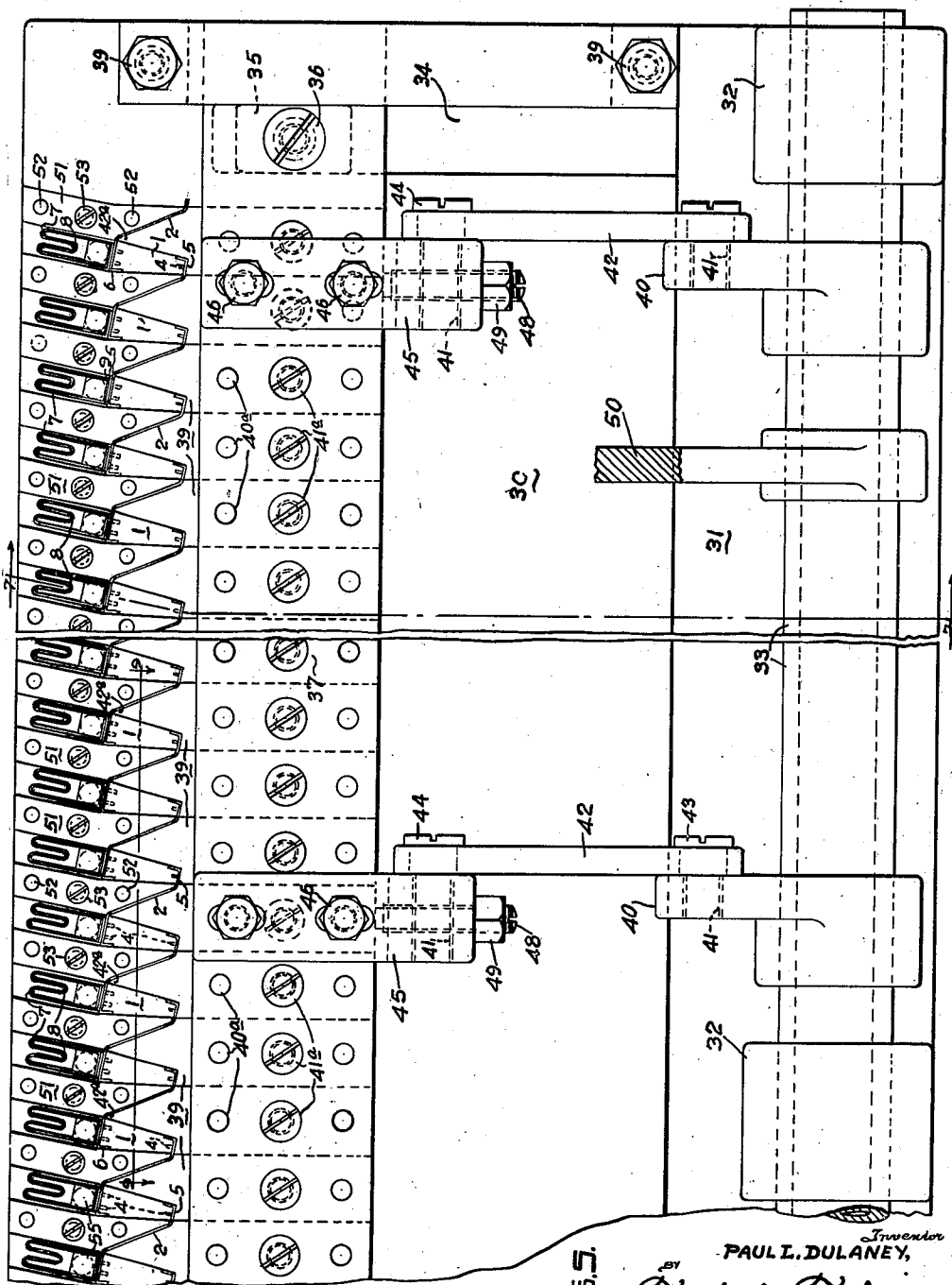
**P. L. DULANEY**

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# APPARATUS FOR FABRICATING THERMOELECTRIC GENERATORS

Filed Aug. 2, 1940

5 Sheets-Sheet 2



**PAUL L. DULANEY,**

*Inventor*

BY Paul L. Dulaney  
Attorneys

Aug. 26, 1941.

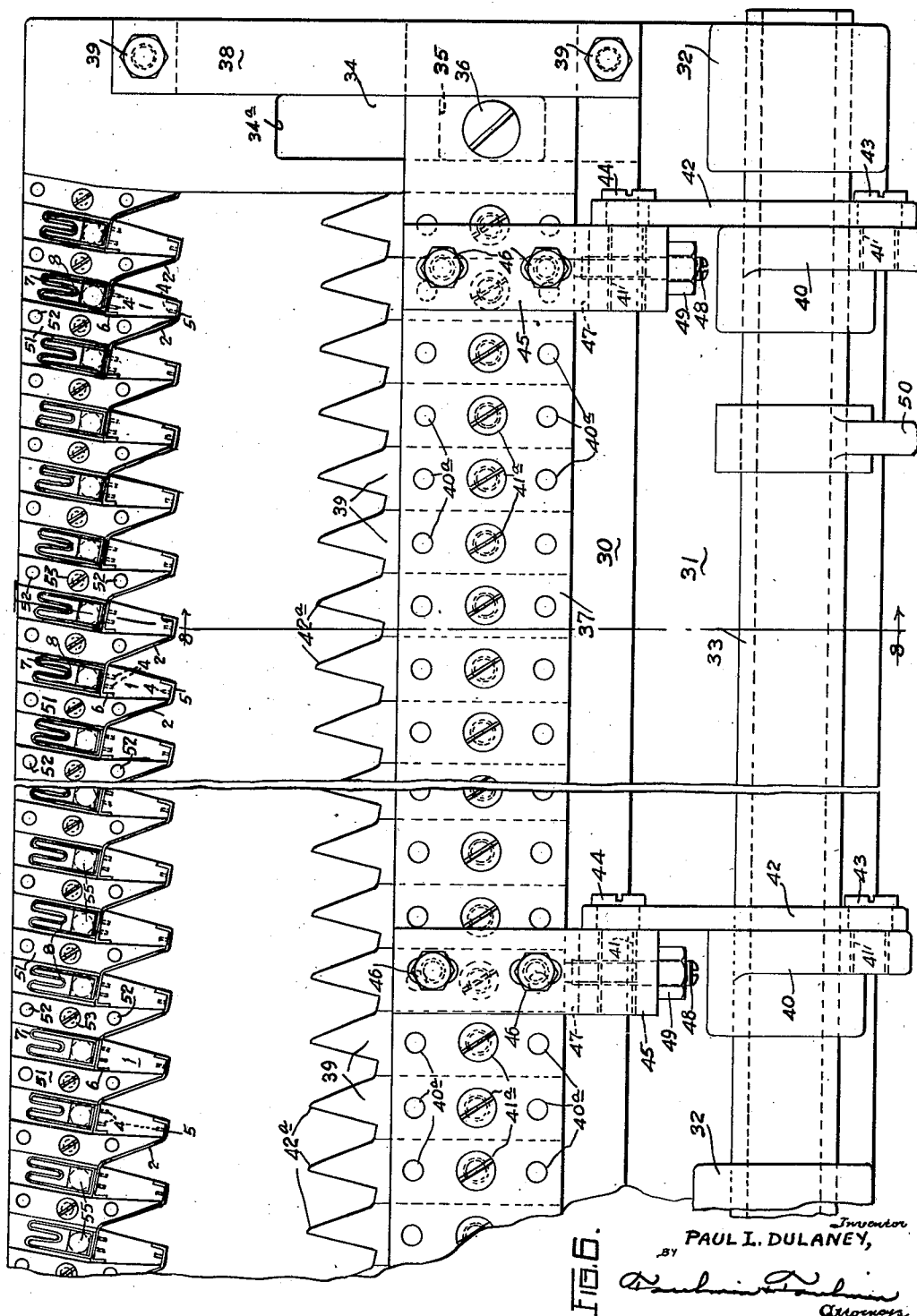
P. L. DULANEY

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APPARATUS FOR FABRICATING THERMOELECTRIC GENERATORS

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Aug. 26, 1941.

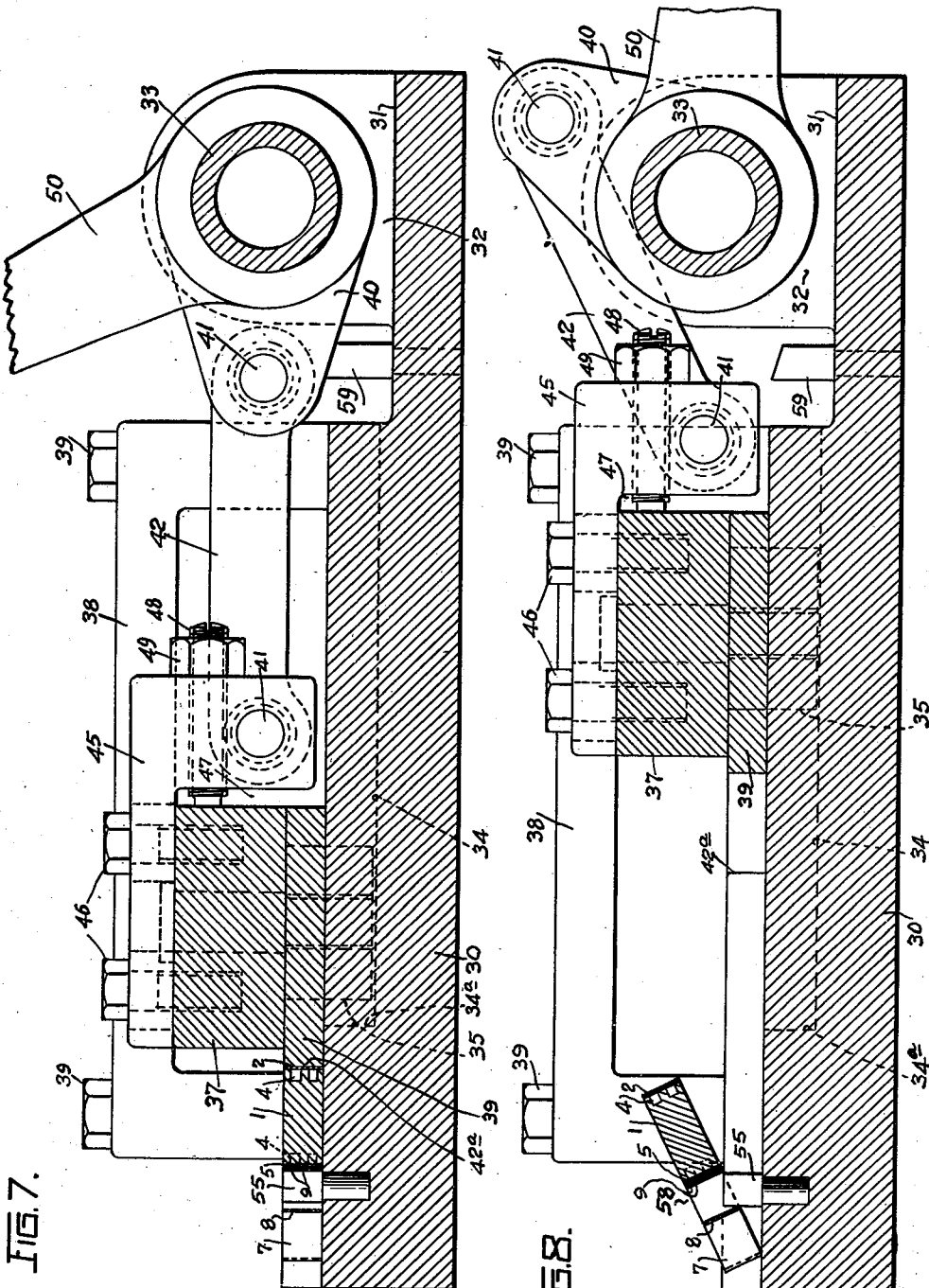
P. L. DULANEY

2,253,771

APPARATUS FOR FABRICATING THERMOELECTRIC GENERATORS

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PAUL L. DULANEY, Inventor  
*Paul L. Dulaney*  
Attorney

Aug. 26, 1941.

P. L. DULANEY

2,253,771

APPARATUS FOR FABRICATING THERMOELECTRIC GENERATORS

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FIG. 9.

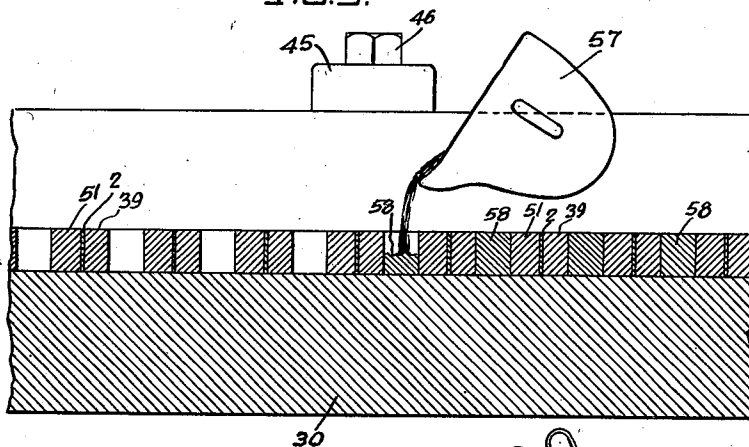


FIG. 11.

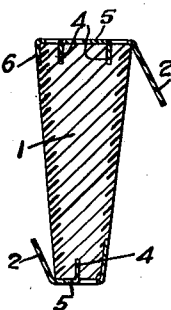


FIG. 10.

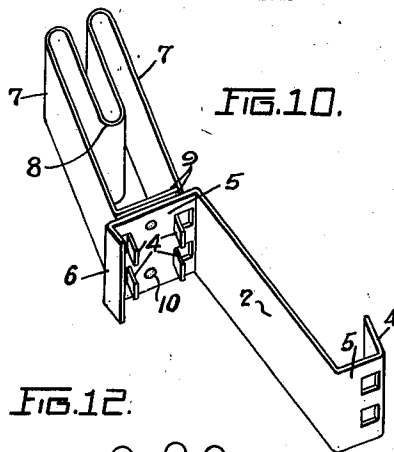


FIG. 12.

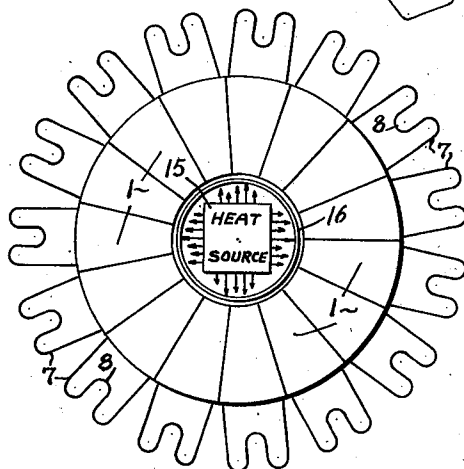
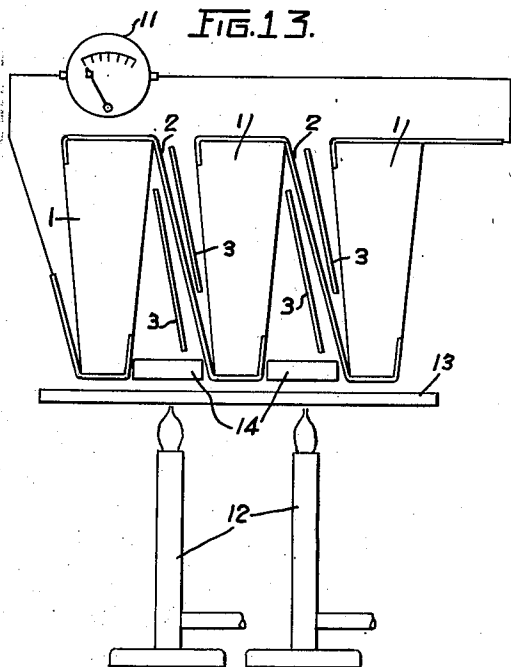


FIG. 13.



Inventor  
PAUL L. DULANEY,

*Paul L. Dulaney*  
Attorneys

## UNITED STATES PATENT OFFICE

2,253,771

## APPARATUS FOR FABRICATING THERMO-ELECTRIC GENERATORS

Paul L. Dulaney, Cincinnati, Ohio, assignor to  
The Huenefeld Co., Cincinnati, Ohio, a corporation of Ohio

Application August 2, 1940, Serial No. 349,995

5 Claims. (Cl. 22-116)

The present invention relates to thermo-electric generators and more particularly to generators of thermoelectromotive force which employ thermoelectric alloys.

The Wiegand application Serial No. 288,408, filed August 4, 1939, entitled "Thermoelectric generators" discloses an improved thermoelectric generator composed of a large number of thermoelectric units connected in series. These units are constituted of an alloy of antimony and zinc together with connecting strips of a metal known on the market as "copel." It was pointed out in the application that, when each unit is subjected to temperature gradients of suitable magnitude, thermoelectric energy of practical amount is produced within the unit.

In practice, a number of these units are connected in series with the hot junctions presented to a source of indirect heat and the current is taken from a face of the first and last units of the series. While it is apparent that each unit could be separately cast from the alloy and electrically connected together in any suitable manner, such a procedure is necessarily very slow, tedious and expensive.

The primary object of the invention is to provide a quick and inexpensive method of making thermoelectric generators, particularly of that type which comprises a number of units all electrically connected in series or series-parallel.

Another object is to provide an improved method and apparatus for simultaneously fabricating a plurality of units composed of thermoelectric material and electrically connected together; to provide an improved mould in which the units may be cast as a group together with the electrical connectors, all shaped to their final configuration.

These objects are attained, in brief, by providing two types of moulds. In one type, the units are cast as segments taking a cylindrical form. In the other type, the segments are cast in a rectilinear form which can be thereafter constrained to a cylindrical shape if desired. Provision is made in each type of mould for holding the conductors in place during the casting operation and the moulds can be readily broken to remove the generator without disturbing the conductors.

The invention will be better understood when reference is made to the following description and the accompanying drawings, in which—

Figure 1 is a perspective view of a circular form of mould for casting the thermoelectric

units and conductors which constitute the improved thermoelectric generator.

Figure 2 is a fragmentary plan view, somewhat enlarged, of the lower half of the mould shown in Figure 1.

Figure 3 is a sectional view taken along line 3-3 in Figure 2 and looking in the direction of the arrows.

Figure 4 is a diagrammatic view showing the electrical output of a number of thermoelectric units connected in series with their hot junctions heated by readily attainable temperatures.

Figure 5 is a plan view of a modified form of mould in which the units are cast in a rectilinear arrangement rather than in a circular configuration. This figure shows the mould in its closed position with the thermoelectric units left in the mould.

Figure 6 is a view somewhat similar to Figure 5 but with the mould in open position, ready to remove the units.

Figure 7 is a sectional view taken along line 7-7 in Figure 5 and looking in the direction of the arrows.

Figure 8 is a sectional view taken along line 8-8 in Figure 6 and looking in the direction of the arrows.

Figure 9 is a sectional view taken along line 9-9 in Figure 5 and showing the step of pouring the mould.

Figure 10 is a perspective view of an electrical conductor for connecting adjacent thermoelectric units in series in combination with a heat-radiating fin.

Figure 11 is a cross sectional view of the improved thermoelectric unit with the electrical conductors secured to opposite ends of the unit.

Figure 12 is a diagrammatic view illustrating the manner in which the hot junction of an improved thermoelectric generator of the circular form may be conveniently heated from an internal heat source.

Figure 13 is a diagrammatic view showing the manner of heating the improved thermoelectric generator where the units are arranged rectilinearly.

Referring more particularly to Figure 11, numeral 1 designates a thermoelectric unit or member which has the property of developing a considerable E. M. F. across two opposite faces when the constituents of the unit are of the character and are made in a manner to be described hereinafter. These units preferably have a wedge-shaped form and are cast as a block of uniform thickness. A number of the units are

assembled together, either rectilinearly, as shown in Figure 13, or in a circular formation, as shown in Figure 12, with the smaller width portions extending in the same direction.

In the case of a circular form, the units, when assembled, may define a cylinder of closed configuration and have a thickness determined by the thickness of the unit or block. The sides of each segmental block are electrically insulated from one another, except for a conductor 2 which makes contact with the outer surface of the block and the inner surface of the next adjacent block, as can be seen more clearly in Figure 13. The segmental blocks or units are insulated from one another by means of strips 3 of mica or other insulating material, which are interposed between the conducting strips 2 and the converging sides of the block.

The strips 2 are secured to the blocks 1 in any suitable manner, but, as will be explained in connection with the moulding operation, are preferably cast in place by means of projecting tabs 4 which are shown more clearly in Figures 10 and 11. The strips also have a length sufficient to provide a flat portion 5 at each end, which abuts the opposite end faces of each block and, in addition, there is a leg 6 bent at an angle with respect to the portion 5. The leg 6 is also preferably cast in the block.

The lower end portion of the block, as seen in Figure 11, will be termed the "hot junction end" and the upper portion the "cold junction end." In order to maintain the cold junction end at a relatively low temperature, this end is provided with a heat-radiating device, preferably in the form of a copper strip or fin 7, as shown in Figure 10. This strip is preferably bent in the middle, as indicated at 8, and secured in any suitable manner to the upper flat surface of the metal strip 2. In practice, the copper strip is sufficiently long to provide a pair of overlapping ends, as indicated at 9, these ends being spot-welded together and to the portion 5 of the strip 2, as indicated at 10 in Figure 10.

The alloy is preferably constituted of antimony and zinc, with the antimony in the proportion of 67% to 55%, and the zinc in the proportion of 33% to 45%. I have obtained particularly good results when employing an alloy of 66% antimony and 34% zinc. The alloy is mixed with 5-10 ounces of dechlorinated salt per hundred pounds of antimony and a trace of arsenic.

As stated hereinbefore, the strips 2 may comprise any metal having a melting point higher than that of the alloy, but it is preferred that copel be used for this purpose, since this metal does not corrode under high temperatures. Copel is procurable on the market in strip form and contains nickel and copper. The segmental blocks may have any convenient size and shape, but particularly good results have been obtained when the narrow width of the segment is approximately  $\frac{3}{8}$ " and the wider width is approximately  $\frac{3}{4}$ " and the segment has a length of approximately  $1\frac{1}{8}$ " and a thickness of approximately  $\frac{5}{8}$ ".

It was pointed out in the application referred to hereinbefore that when 150 units of this particular size are assembled together, either in a rectilinear or circular formation and connected in series by the strips 2 and the hot junctions heated to a temperature of approximately 800° F. with the cold junctions cooled to approximately 200° F., an electromotive force of not less than

eleven volts was generated between the two end terminals. This is exemplified in Figure 13 by the reading of the voltmeter 11 connected across the end terminals of a three-unit assemblage. These results are graphically indicated on the chart shown in Figure 4. When a current of one ampere was drawn, the voltage dropped to seven volts, and at two amperes the voltage was four volts, giving an output of between seven and eight watts.

However, it will be understood that these values are to be considered in a purely exemplary or typical sense because considerably greater voltage and current are available when employing higher temperature gradients or using larger size units. It will be realized that these voltage and current values find considerable use in the electrical art, as for example, charging storage batteries, or for supplying heater or filament current of commercial radio sets or for operating other electrical devices.

It has been found that the optimum results by way of thermoelectric energy of constant character are obtained by subjecting the hot junctions to radiant energy in the form of indirect heat. This heat may be obtained from any suitable source and, as a typical example, I have shown the hot junctions of each unit as being heated by Bunsen burners 12 positioned under a plate 13 of refractory metal and adapted to radiate heat to the units 1 (Figure 13). Heat baffles or barriers 14 are preferably positioned between the units to prevent the heat from striking the converging sides of each unit. However, it will be understood that, in practice, these units, when assembled, may lie close to one another, thus eliminating the necessity for the baffles.

In Figure 12 there is shown a heat source generically indicated by the rectangle 15 which may comprise an oil burner for heating a cylindrical metal plate 16 which radiates heat to the hot junctions of the units 1.

It is apparent that the practical application of the improved thermoelectric unit requires a number of such units to be connected in series or in series-parallel and it is desirable to form or otherwise fabricate all of the units constituting a group simultaneously, including the electrical connections.

Figures 1, 2 and 3 illustrate an improved mould for fabricating a thermoelectric generator of the circular type. As shown in Figure 1, the mould is constituted of an upper or pouring plate member 17 and a lower or mould member 18. The latter is preferably constituted of a circular metal plate 19 which is provided with an annular outer rim 20 and an annular inner rim 21. These rims have a depth somewhat greater than the thickness of the blocks 1. The inner rim 20 is provided with an opening for receiving an up-standing circular rod 22 for positioning the pouring plate with respect to the mould. The bottom plate 19 is provided with a plurality of radially extending grooves indicated at 23 (Figure 3), which loosely receive a number of metal partitions 24. The latter fit at their inner ends into vertical grooves formed in the inner rim 21, but at their outer edges there is a small gap for reasons stated hereinafter. The partitions 24 have a width or depth greater than the height of the rims so that a portion thereof projects upwardly from the upper surface of each rim. These projecting portions are received in a number of

slots 25 cut radially in the under-surface of the pouring plate 17. On the side of the member 17 opposite from the grooves, there is an annular groove 26, preferably of an arcuate shape and entering this groove there are a number of openings 27, as many as there are spaces between the partitions 24 and so arranged as to fall between the partitions when the portions of the mould are assembled together. The rim 20 of the lower mould member is provided with a number of vertically extending slots 28, two per space between the partitions 24.

It will be understood that the partitions 24 are readily removable from their grooves after the upper member 17 has been lifted from the lower member 18. There are as many of these partitions and, therefore, spaces therebetween as there are a number of units to be cast and connected together simultaneously. Obviously, the distance between partitions at the inner and outer rims corresponds to the desired wide and narrow widths of the segmental blocks.

Assuming that the partitions have all been placed in their respective grooves the next thing is to insert the connecting strips and cooling fins. As stated hereinbefore, in connection with Figure 10, the strip 2 is provided at each end with the inwardly extending tabs 4 and also with the bent legs 6. The fin 7 is spot-welded or in any other manner secured to the upper flat portion of the strip. The opposite portions of the fins 7 are pressed downwardly into each pair of slots 28 (Figure 1) and the strip 2 is given a position such that the lower end of the strip (as seen in Figure 10) presses against the vertical surface of the rim 21. This position of the strip causes the upper edge of the flat portion 5 of the strip to bear against the inner surface of the outer rim 20. The long portion of the strip 2 bears against the sides of the partitions 24 and the legs 6 are bent at such an angle as to extend slightly into the space between the partitions.

The hole 29 in the pouring plate 17 is then brought into alignment with the rod 22, and the plate pressed downwardly until the upper edges of the partitions 24 fit themselves into the slots of the plate. This will bring the openings 27 midway across each space between the partitions, as can be seen in Figure 3. If the member 17 is sufficiently heavy, no clamp is necessary. The mould is, therefore, ready for the pouring of the metal.

In the preparation of the alloy, the antimony should first be tested in its raw state by a flame to determine whether any arsenic is present. A trace of arsenic is needed in the fusing of the metal, its action being that of a flux to assist the formation of many minute crystals during the melting of the antimony. If there is no arsenic in the metal, a small amount is added in the next step which is to melt the antimony. This is done at approximately 1350 degrees F., at which temperature the metal is light red in color. There is then added another flux which breaks up the antimony into the finest possible condition and drives off any gas that is present in the molten mass. Suitable fluxes for this purpose are ordinary salt, magnesium, beryllium and vanadium. Before salt is added, it must be heat treated for a couple of hours at a temperature of 800° F. to 900° F. to dechlorinate the salt. After this treatment, the salt is dark brown in color and is added to the antimony in a proportion of five to ten ounces per hundred pounds of antimony.

Zinc is added with the temperature remaining at 1350° F. and its addition should be accompanied by extreme vigilance to prevent appreciable lowering of the temperature or too rapid a mixing of the metals. The final step in the process is the pouring of the mixture into the mould through the openings 27, the metal being maintained preferably at a temperature of approximately 1350° F. during this step.

The molten metal will fill up all of the spaces between the partitions 24, encompassing the tabs 4 and the legs 6 of the strip 2, thus securely holding the strip and the heat radiating fin to the unit. It has been found that, when the block 1 has the dimensions set forth hereinbefore, satisfactory results are obtained by way of securing the strip 2 to the block at the tabs as to provide the latter with a dimension of approximately  $\frac{1}{8}$ " wide, i. e., as measured in the vertical direction, and  $\frac{3}{8}$ " long as measured in the horizontal direction. As the size of the unit 1 is increased, the length and width of the tabs should be increased accordingly.

After the alloy has solidified, the member 17 is raised. The partitions 24 may be individually removed from the slots by grasping their upper edges which project above the alloy. It has been found that no difficulty is encountered in removing the partitions, since the latter have served to conduct heat rapidly away from the surface of the alloy, giving it a surface chill which facilitates the separation of the partitions from the alloy. The exterior chilled surface of the unit has been indicated in Figure 11 by the heavier cross-hatched lines.

The thermoelectric units and their inter-connecting conductors may then be removed as a group from the space between the rims 20, 21 and the sprues formed by the metal rising through the openings 27 may be chiseled or otherwise removed.

It is apparent that the units, upon removal from the mould, will retain their cylindrical form, each unit being spaced from the adjacent unit by a gap equivalent to the thickness of the partitions 24. The next step is to sever one of the metal strips at the middle, in which case the halves of the strip, which are connected respectively to the narrow end of one unit and the wide end of the adjacent unit may be employed as the end terminals for the entire group. The mica strips 3 are next inserted between each of the strips 2 and the converging sides of the units, as indicated in Figure 13. The group of units may then be pressed together, as indicated in Figure 12, and held in this position in any suitable manner, for example, by means of an insulated plate (not shown) extending over the upper and lower flat surfaces of the units and clamped together.

In Figures 5 to 9 inclusive, I have shown a modified form of mould in which the thermoelectric units are cast in a rectilinear formation, rather than in a circular formation as was explained in connection with Figure 1. It will be understood that the rectilinear units may be either bent to a circular configuration as a whole thus giving the same effect as if moulded in a circular mould or they may be left in their original rectilinear arrangement and operated in this manner.

As in the case of the circular mould referred to hereinbefore, the rectilinear mould is also composed of two parts which are held together during the moulding operation and thereafter

separated to remove the thermoelectric generator. The mould is constituted in part of a base plate 30 of heavy thickness as indicated in Figures 7 and 8, this thickness being cut down to a thickness indicated at 31 at one end. The plate preferably is made of cast iron with the upper surface of the thicker portion machined smooth. The thinner portion 31 is provided with a plurality of upstanding lugs 32, the number of which depend on the length of the mould, i. e. the number of thermoelectric units being simultaneously moulded, and equidistantly spaced along the length of the plate 30. The lugs 32 serve as bearing members for a hollow shaft 33 which extends over the entire length of the mould.

The base plate 30 is provided at each end with a transversely extending groove or slot 34 which are preferably cast during the fabrication of the plate 30 and are thereafter machined to proper dimension. The forward edge of the slot 34 is indicated at 34a (Figures 7 and 8) and it will be noted that this slot extends to the right from this edge, as far as the portion 31 of reduced thickness. The dimensions of the slot 34 are such as slidably to receive a guide block 35. To this block there is secured by means of screws 36 a fairly wide supporting plate 37 which extends the entire length of the mould. Thus the slots 34 serve to guide the support plate 37 over a path transversely of the plate 30 for a distance determined by the length of the slot 34.

In order to prevent the guide blocks 35 from leaving the slots 34, I provide a bridge member 38 at each end of the base plate 30, the height of the inner surface of the bridge member being such as snugly to fit over the upper surface of the support plate 37, as is shown more clearly in Figures 7 and 8. These bridge members are secured to the base plate by means of bolts 39. From the immediate foregoing description, it will be clear that the support plate is restrained from movement in the horizontal direction by the guide blocks 35 which slide in the slot 34 and is restrained from movement in the vertical direction by the under surface of the bridge members 38.

As will be explained presently, the support plate 37 carries the movable part of the mould and its function is to move this part into engagement with the stationary part of the mould after which the mould is broken by withdrawing the movable part to give access to the molded member. This movable part of the mould is constituted of a plurality of fairly narrow plates indicated at 39, these plates having a rectangular configuration along three sides and a tooth or serrated configuration at one end as shown in Figure 6. The plates 39 are individually secured to the support plate 37, preferably by a pair of metal dowel pins indicated at 40a and a centrally positioned screw indicated at 41a.

It will be noted from Figures 5 and 6 that the serrated edge indicated at 42a defines the contour, in part, of two sides of the thermoelectric units 1, and also defines the direction that the strip 2 takes when connected between two adjacent thermoelectric units. These positional relationships can best be seen in Figure 5 where the serrated edge 42a is in the closed mould position. In order to assure accuracy in the spacing of the serrations 42a and their configuration, it is desirable that the plates 39 be individually machined to proper dimension.

For moving the plates 39 toward and away from the stationary portion of the mould which

will be described presently, I provide a well-known toggle mechanism. As seen more clearly in Figures 7 and 8 the shaft 33 is provided with two or more suitably positioned cranks 40 which terminate at their ends opposite from the shaft 33 in the openings 41 which serve as bearings for one end of a number of draw links or levers 42. The draw links 42 may be rotatably secured to the cranks 40, if desired, by means of the screw headed studs 43. The opposite end of each draw link 42 is rotatably mounted by means of a stud 44 on the lower or depending portion of an L-shaped block 45. The upper or horizontal leg of this block is secured to the support plate 37, referred to hereinbefore, by means of a pair of bolts 46.

As can be seen more clearly in Figures 7 and 8 there is a space indicated at 47 left between the inner surface of the vertical portion of the block 45 and the adjacent surface of the support plate 37. The purpose of this space is to provide adjustment between the plate 37 and the block 45. This adjustment is brought about by means of a horizontally positioned screw 48 which bears against the surface of the support plate 37 and is threaded into the block 45. This screw carries a lock nut 49. The openings in the block 45 which receive the upper end of the shanks of the bolts 46 are preferably of slotted configuration so that upon loosening of the bolts 46, and loosening the lock nut 49, the screw 48 can be rotated to change the length of the space 47. Thus the position of the support plate 37 with respect to the block 45 can be adjusted. The need for this adjustment will be explained when the operation of the mould is described.

It is apparent that as the crank 40 is rotated upwardly, the draw link 42 is moved to the right from the position as shown in Figure 7 to the position shown in Figure 8, causing the block 45 and the support plate 37 carried thereby to also move to the right. It has already been pointed out that the support plate 37 is connected at each end to the guide blocks 35 which slidably move in the slots 34. In order to rotate the crank 40, I may secure to the shaft 33 a hand lever 50 which serves to rotate the shaft in the bearings 32 and thus to cause a simultaneous reciprocation of all of the draw links 42 depending upon the movement of the lever 50. By comparing Figures 7 and 8, it will be noted that the lever 50 has been moved through approximately 120° during which time the block 45 and the support plate 37 have been moved from their innermost position to their outermost position.

The stationary portion of the mould is constituted of a plurality of toothlike plates 51 which are secured to the upper surface of the base plate 30 in any suitable manner. As seen in Figures 5 and 6 these plates do not abut one another but there is a space left therebetween for loosely receiving the copper fin 7 of each thermoelectric unit. In order to assure accuracy with which the plates 51 register with the serrations 42a of the movable portion of the mould the plates 51 should preferably be machined to dimension and securely held on the base plate, preferably by means of a pair of dowel pins 52 and a screw 53. It will be noted that the parallel sides of the plates 51 are cantled to the right in parallel alignment as this has been found desirable from the standpoint of breaking the mould as easily as possible.

In order to properly position the metal part

of each thermoelectric unit preparatory to the moulding operation, I may provide a number of upstanding square headed dowel pins 55 which are snugly received in openings spaced along the upper edge of the base plate. These openings are positioned in the space between the plates 51 as can be seen in Figures 5 and 6.

For simultaneously moulding a large number of thermoelectric units in the improved rectilinear mould, all of said units being electrically connected together, the first step is to properly position the metal parts which are shown in Figure 10. It has been explained that these metal parts comprise the copper fin 7 welded or otherwise secured as at 10 to a strip of copel 2. The square heads on the dowel pins 55 are so oriented that the two opposite sides of the heads are parallel to each space between the plates 51. The width of these square heads is such as snugly to fit within the lower portion of the copper fin 7 consequently, in positioning the metal parts of each thermoelectric unit, it is only necessary to place the lower end of the fin 7 around three sides of each square headed dowel pin. Since the strip 2 is rigidly secured to the fin 7, the dowel pin will also orient the strip throughout its entire length.

Assuming that the movable portion of the mould is in its open position as shown in Figures 6 and 8, it is then necessary to move the lever 50 counterclockwise causing the guide blocks 35 to move in slots 34, thus moving the support plate 37 and the plates 39 secured thereto into the upper or closed mould position (as seen in Figure 5). The support plate 37 is moved upwardly, as far as possible or until the inclined surfaces of the serrations 42 contact with any portion of the strips 2.

If desired, the movable portion of the mould may be placed in a semi-closed condition, in fact so close to the stationary portion of the mould as to leave only slightly open slots between the two halves of the mould when the metal parts 2, 7 are placed in position. In practice, this has been found to be the preferred way rather than placing the metal parts in position while the mould is fully opened.

It is apparent that when the mould is closed in the manner described and assuming that the plates 39 and 51 have end portions of proper shape and dimension, a wedgelike space will be left between the stationary and movable portions of the mould into which tabs 4 project.

The next step is to pour the mould, and this has been shown diagrammatically in Figure 9, by the use of the ladle 57. The alloy is prepared in the ladle as was explained in connection with the circular mould and the spaces left between the stationary and movable elements of the mould are filled with the alloy. This has been indicated in Figure 9 by the reference character 58 which figure also shows one of the spaces being partially filled.

After allowing the units to cool, the mould is broken by moving the handle 50 to the right and causing the support plate 37 to be retracted as explained hereinbefore. Inasmuch as the tabs 4 are securely embedded in the alloy, the metal portions 2, 7 are rigidly secured to the unit as is indicated in Figure 11. The unit and associated parts are then preferably removed from the stationary portion of the mould by tilting them, the narrow side up, far enough to free the copper fins from the square heads of the dowel pins and

then lifted out in a complete strip from end to end of the mould. This operation has been generically indicated in Figure 8 by the reference character 58.

It is apparent that the adjustments accorded by the screw 48 (Figure 7) enables the moulder to accurately determine the exact length of the units 1 because in moving the lever 50 from one extreme position to the other, the distance through which the plates 39 are moved can be regulated or controlled by the proper determination of the space 47 which in turn is controlled by the longitudinal position of the screw 48. Adjustments of the latter also serve to provide the proper registry between the plates 39 and 51 by which the diagonally extending portions of the strips 2 are rigidly held in position during the moulding operation. In order to assure proper adjustment by the screw 48, it is obvious that the crank 40 must never reach dead center when the mould is in its completely closed condition because a slight forward movement of the crank, perhaps due to wear, might inadvertently cause a retraction of the plates 39. Thus a stop pin 59 is provided on the base 30 immediately below the crank 40 as seen in Figures 7 and 8 to limit the travel of the crank.

The final result of the molding operation is the fabrication of a large number of thermoelectric units in rectilinear alignment, as many as there are spaces between the movable and stationary portions of the mould, all electrically connected together by means of the copel strips. This rectilinear formation can be changed to a circular arrangement by simply pressing the units together so that the inclined sides of each unit will abut the adjacent unit but spaced therefrom in order to prevent short circuiting, by an insulating strip indicated at 3 in Figure 13.

Comparing the rectilinear mould shown in Figures 5 to 9 with the circular mould shown in Figures 1 and 3, it will be noted that the rectilinear mould has no cover or pouring plate equivalent to element 17, but the units are all separately poured. Consequently there are no sprues formed when the rectilinear mould is employed although it will be understood that if desired a pouring plate similar to element 17 may be provided for the rectilinear mould and clamped or otherwise secured in place during the pouring of the metal.

From the foregoing, it is evident that I have broadly described a practical method of fabricating a thermoelectric generator comprising any number of units which are electrically connected together as they leave the mould. By casting a large number of units in a single mould, uniformity of the thermoelectric properties of the individual units is assured since the size and contents of the units are the same.

It is further apparent that while I have described the moulding operation as pertaining to a series connection between units, I may, if desired, arrange the copel strips within each mould to provide a parallel connection in order to increase the current output without increasing the electromotive force.

It will be understood that I desire to comprehend within my invention such modifications as come within the scope of the claims and the invention.

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

1. Apparatus for fabricating a thermoelectric generator, said apparatus comprising a mould including an outer annular rim and an inner annular rim, radial partitions extending between the said rims and connected to at least one of said rims and spaced from one another to leave wedge-shaped openings for receiving a thermoelectric alloy, said partitions being so arranged with respect to said cylinders as to accommodate an electrical conductor, one end of which projects into one end of one of said openings and the other end of the conductor projects into the opposite end of the adjacent opening, whereby the ends of the conductor are cast into adjacent blocks of alloy and the blocks are connected in series to constitute a thermoelectric generator.

2. Apparatus for fabricating a thermoelectric generator, said apparatus comprising a pair of cylinders in concentric relation to form a mould, radial partitions extending between the cylinders and spaced from one another to leave wedge-shaped openings, said partitions being arranged with respect to said cylinders as to accommodate electrical conductors, the corresponding ends of which project into similar ends of said openings, and the other end of each conductor projects into the corresponding opposite end of each adjacent opening, and means for simultaneously filling said openings with molten thermoelectric alloy to form solidified blocks of alloy with the ends of each conductor cast into adjacent blocks, whereby the blocks are connected in series to constitute a thermoelectric generator of circular configuration.

3. Apparatus for fabricating a thermoelectric generator, said apparatus comprising a pair of cylinders in concentric relation to form a mould, radial partitions extending between the cylinders and spaced from one another to leave wedge-shaped openings, said partitions being arranged with respect to said cylinders as to accommodate electrical conductors, the corresponding ends of which project into similar ends of said openings, and the other end of each conductor projects into the corresponding opposite end of each adjacent opening, and means for simultaneously filling said openings with molten thermoelectric alloy to form solidified blocks of alloy with the ends of each conductor cast into adjacent blocks, whereby the blocks are connected in series to constitute a thermoelectric generator of circular configuration, said means comprising a plate disposed over said cylinders and provided with metal-pouring apertures di-

rectly above each of said wedge-shaped openings.

4. Apparatus for fabricating a thermoelectric generator, said apparatus comprising a pair of cylinders in concentric relation to form a mould, radial partitions extending between the cylinders and spaced from one another to leave wedge-shaped openings, said partitions being so arranged with respect to said cylinders as to accommodate electrical conductors, the corresponding ends of which project into similar ends of said openings and the other end of each conductor projects into the corresponding opposite end of each adjacent opening, one of said cylinders having an annular outer rim, said rim being slotted to receive a heat-radiating fin, said fin being secured at one end to said conductor, and means for simultaneously filling said openings with molten thermoelectric alloy to form solidified blocks of alloy with the ends of each conductor cast into adjacent blocks whereby the conductors and the heat-radiating fins are secured thereto and the blocks are connected in series to constitute a thermoelectric generator of circular configuration.

5. Apparatus for fabricating a thermoelectric generator, said apparatus comprising a two-part mould constituting a pouring plate and a mould portion, the mould portion being formed of a pair of cylinders in concentric relation, detachable partitions extending between the cylinders and spaced from one another to leave wedge-shaped openings, said partitions being so arranged with respect to said cylinders as to accommodate an electrical conductor, one end of which projects into one end of one of said openings and the other end of the conductor projects into the opposite end of the adjacent opening, the pouring plate portion of the mould being constituted of a cylindrical plate which fits over the mould portion and is provided with grooves to receive the upper edges of the partitions, said plate being also provided with a plurality of apertures positioned over each of the wedge-shaped openings in the mould portion when the mould is closed, said apertures being adapted to receive a thermoelectric alloy in molten form which fills the wedge-shaped openings and solidifies about the ends of said conductors whereby the solidified blocks of alloy are connected in series to constitute a thermoelectric generator of circular configuration.

PAUL L. DULANEY.