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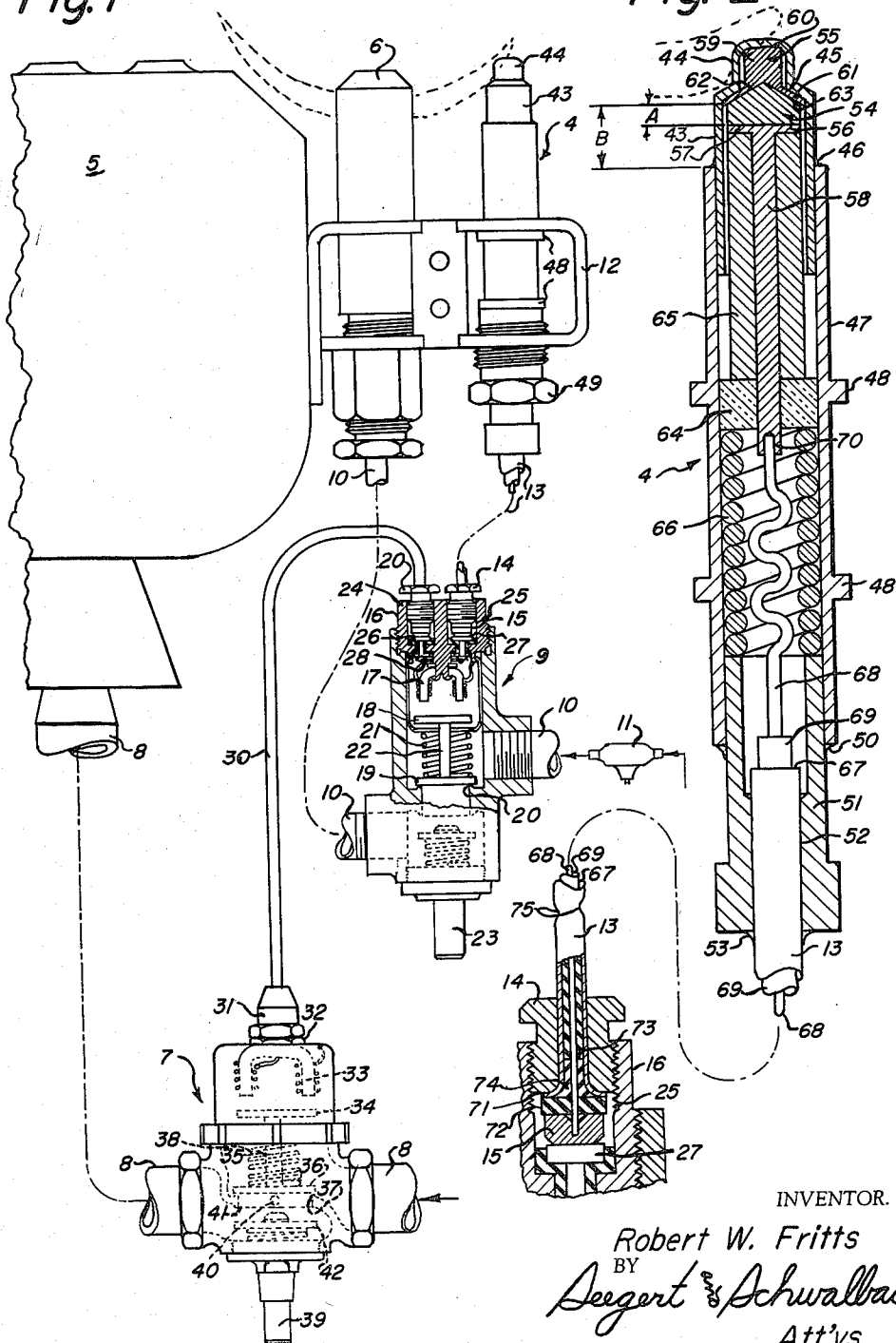
2,961,474

THERMOELECTRIC GENERATOR

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Fig. 1

Fig. 2



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THERMOELECTRIC GENERATOR

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5 Claims. (Cl. 136—4)

This invention relates to improvements in thermoelectric generators. Thermoelectric generators have long been utilized as the source of electrical energy for self-powered control systems, one such use finding widespread application being in safety shut-off systems for control of the flow of gaseous fuel to the main and pilot burners of gaseous fuel burning apparatus. In systems of this type the thermoelectric generator is heated by the pilot burner flame, and the electrical energy generated is utilized to energize and hold open one or more manually resettable safety shut-off valves. On outage of the pilot burner, the thermoelectric generator gradually cools, and the output thereof diminishes, eventually reaching a reduced level insufficient to hold the safety shut-off valve open, whereupon said valve "drops-out" to closed position and remains in said position until subsequently reset.

The time interval between extinction of the pilot burner flame and closure of the safety shut-off valve is termed the "drop-out" time of the system. The usual drop-out time of conventional systems found in domestic applications is on the order of 40 to 45 seconds. While this drop-out interval is considered safe in domestic systems in which the rate of fuel flow is moderate, such a time interval would be extremely dangerous in, for example, industrial applications wherein large volumes of gaseous fuel are consumed per unit time. Substantially reduced drop-out time is required, therefore, in high capacity systems, and attainment of satisfactory drop-out characteristics for such applications has heretofore been possible only by resort to complicated and expensive equipment.

A general object of the present invention is to provide and improved thermoelectric generator the operation of which is characterized by a rapid rate of decay in its output voltage following termination of the application of heat thereto.

Another object of the invention is to provide an improved thermoelectrical generator of the class described which for the first time makes safe the use of inexpensive self-powered safety shut-off systems for the control of relatively large capacity systems heretofore requiring expensive control apparatus.

A further object of the invention is to provide an improved thermoelectric generator of the aforementioned character which is interchangeable with the thermocouple of standard construction embodied in domestic self-powered fuel control systems, said improved generator affording such a system substantially reduced drop-out time characteristics. Use of the improved thermoelectric generator has particular appeal in connection with, for example, safety shut off of fuel flow to the oven burner of a residential gas range, the reduction in the amount of escaping gas during the drop-out time not only increasing the safety of the system, but also reducing the physical discomfort resulting from breathing of the escaping gas.

A more specific object of the invention is to provide

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an improved thermoelectric generator of the class described utilizing a thermoelement of semi-metallic material having high thermoelectric power, said generator being constructed in a manner to afford maximum life expectancy.

Still another object of the invention is to provide an improved thermoelectric generator as aforescribed which is relatively simple and inexpensive in construction and is well-adapted to mass production fabrication.

The invention is capable of receiving a variety of mechanical expressions, one of which is shown on the accompanying drawing, but it is to be expressly understood that the drawing is for the purposes of illustration only, and is not to be construed as a definition of the limits or scope of the invention, reference being had to the appended claims for that purpose. In the drawing, wherein like characters of reference are employed to designate the same parts in each of the figures:

Figure 1 is a fragmentary elevational view, partly in section, of a self-powered safety shut-off gaseous fuel control system having the improved thermoelectric generator embodied therein as the pilot burner flame sensitive source of power; and

Figure 2 is an enlarged axial sectional view of one form of thermoelectric generator constructed in accordance with the principles of the present invention, the lead for said generator being shown fragmentarily and partly in section.

The safety shut-off fuel control system illustrated in Figure 1 of the drawing controls the flow of gaseous fuel to a main burner 5 and a coacting pilot burner 6. The main burner 5 may be of a size to consume a relatively large volume of gaseous fuel per unit time, and the fuel flow thereto is under the control of an electromagnetic manually resettable safety shut-off type valve 7 interposed in the fuel supply pipe 8 leading from a source (not shown) of gaseous fuel under pressure. Fuel flow to the pilot burner 6 is under the control of an electromagnetic manually resettable safety shut-off type valve 9 interposed in the fuel supply line 10 connecting the pilot burner to a suitable source (not shown) of fuel under pressure, for example, through a pressure regulator shown diagrammatically at 11.

Supported, for example, on the main burner 5, is a mounting bracket 12 affording mounting means for the pilot burner 6 as well as for a thermoelectric generator 4 of novel construction to be described in detail hereinafter. The generator 4 is provided with a coaxial type lead 13 having a connector nut 14 and terminal 15.

The safety shut-off valve 9 comprises a mounting nut 16 for an electromagnet and valve assembly comprising an electromagnet 17, a coacting armature 18, and a valve member 19 biased toward an annular valve seat 20 by a spring 21. A stem 22 connects the valve member 19 with the armature 18, so that the bias of the spring 21 also biases the armature 18 toward its retracted position shown. Manual reset means 23 is provided to reset the valve member 19 to open position and to simultaneously reset the armature 18 into engagement with the pole faces of electromagnet 17. The mounting nut 16 is formed with a pair of internally threaded recesses 24 and 25 having terminal tips 26 and 27 insulatably mounted therein respectively. One end of the energizing coil for the electromagnet 17 is connected in circuit with the terminal tip 26, and other end of said coil is grounded to the mounting nut 16 as shown. The terminal tips 26 and 27 are connected in circuit with each other by means of a conductor 28.

The socket 24 of the mounting nut 16 is adapted to receive the connector nut 20 of a coaxial type lead 30, the opposite end of which is provided with connector means 31 for threaded engagement with cooperating con-

necter means 32 on the valve 7. The valve 7 is provided with an electromagnet 33 and a cooperating armature 34 which is connected by means of a stem 35 to a valve member 36. The valve member 36 is biased toward an annular valve seat 37 by means of a spring 38, which, through the stem 35, also biases the armature 34 toward retracted position with respect to the electromagnet 33. Manual reset means 39 is provided for resetting the valve member 36 to open position, and simultaneously resetting the armature 34 to attracted position with respect to the electromagnet 33. The connector means 31 and 32 afford electrical connection of the internal conductor of the lead 30 with one end of the energizing winding of the electromagnet 33 and of the outer conductor of said lead with the grounded other end of said winding. It will be observed that in the electrical circuit so far described, the energizing windings of the electromagnets 17 and 33 are connected in parallel circuit relation with the thermoelectric generator 4.

Where it is desired to utilize a single fuel control valve for controlling both main and pilot burner fuel, the valve 9 may be omitted, in which case the fuel supply conduit 10 for the pilot burner is connected to a pilot fuel tap 40 interposed between the valve seat 37 and a spaced annular seat 41, and the generator lead is connected directly to the valve 7. Where such an arrangement is used, flow interruption is afforded by the use of a flow interrupter disc 42 cooperable with the valve seat 41 and forming part of the reset means 39, said disc being operable to interrupt fuel flow to the main burner 5 during resetting of the valve 7, while permitting fuel flow to the pilot burner 6 during such resetting, all as is well known in the art. The valve 7, particularly in large capacity systems, may also take the form of the valve shown and described in the copending application for patent of Donley S. Collins, Serial No. 639,908, filed February 13, 1957, and assigned to the assignee of the present application.

Referring more particularly to Figure 2 of the drawing, the thermoelectric generator 4 takes the form of a thermocouple comprising a first thermoelement 43 in the form of a tubular cup-shaped sheath member of stainless steel having a reduced diameter outer end portion 44 providing an internal annular shoulder 45. The sheath member 43 is coaxially fixed, as by silver soldering or brazing at 46, within an end portion of a tubular sheath member or extension sleeve 47, the latter being formed with suitable external shoulder means 48 for coaction with the mounting bracket 12 and mounting nut 49 shown in Figure 1. Fixed, as by silver soldering or brazing at 50, is a tubular sheath member or bushing 51 disposed coaxially within the opposite end of the sleeve 47, said bushing and sleeve being preferably formed of brass. The bushing 51 is provided with a portion of reduced internal diameter 52 in which one end of the coaxial lead 13 is snugly received, said lead being sealed therein, as by silver soldering or brazing at 53.

Coaxially disposed within the sheath member 43 is a second thermoelement 54 in the form of a cylindrical ingot of semi-metallic material to be described in detail hereinafter. The thermoelement 54 is provided with contact electrodes 55 and 56 for effecting electrical connection therewith, the electrode 56 preferably having a fused or bonded electrical connection with said thermoelement at 57, and having an elongated stem portion 58 extending coaxially within the sheath member 43 and sleeve 47 as shown. The contact electrode 55 has a stem portion 59 extending coaxially within the reduced diameter portion 44 of sheath member 43 and is joined at its outer end to the outer end of said reduced diameter portion, as by welding at 60. The contact electrode 55 also has an enlarged head portion 61 seated against the annular shoulder 45 and preferably formed with a concave conical surface 62 for receiving the adjacent complementary convex conical end surface 63 formed on the thermoelement

54. The contact electrodes 55 and 56 are preferably formed of material which will not react with the semi-metallic thermoelement 54. Suitable materials from which the contact electrodes may be made are iron, molybdenum, and alloys of iron and molybdenum, each of said materials preferably having only the normal minute amounts of residual impurity therein.

A bushing 64 of thermal and electrical insulating material has a sliding fit within the bore of the sleeve 47, and the end portion of the contact electrode stem 58 extends through said bushing and is thereby maintained centered within the sleeve 47 and sheath 43. A metallic bushing 65 has a snug coaxial fit on the contact electrode stem 58 and is interposed between the head portion thereof and the insulating bushing 64 as shown. Extending coaxially within the sleeve 47 and interposed between the insulating bushing 64 and bushing 51 is an elongated helical compression spring, preferably of heat resistant stainless steel, which acts through the insulating bushing 64, metal sleeve 65 and contact electrode 56 to place the thermoelement 54 under axial compression between the electrodes 55 and 56. The coaction of the conical surfaces 62 and 63 on the electrode 55 and thermoelement 54, respectively, maintains the thermoelement 54 and the adjacent portions of the contact electrode 56 and sleeve 65 centered within the sheath 43. The pressure contact between the surfaces 62 and 63 affords a low resistance electrical connection between the thermoelement and contact electrode 55 which functions as a "hot" thermojunction in the operation of the generator 4. The bond 57 between the thermoelement 54 and the electrode 56 and the fused connection 46 between the sheath 43 and sleeve 47 both afford "cold" thermojunctions in the operation of said generator.

It will be observed that there is a relatively small mass of metal adjacent and in good heat conducting contact with the "hot" junction aforementioned, i.e., the reduced diameter portion of the sheath 43 and the contact electrode 55. On the other hand, there is a relatively massive metallic assembly in good heat conducting contact with the "cold" thermojunction aforementioned, i.e., the contact electrode 56 with its elongated stem 58 and the metallic sleeve 65. It will also be observed that the aforementioned relatively large metallic mass is maintained by the insulating bushing 64 out of heat conducting contact with the sheath 43 and sleeve 47, so that heat transfer between said mass and said sheath and sleeve can take place only by radiation or through gaseous fill referred to hereinafter.

It will also be observed that the relatively short length of the thermoelement 54 affords a relatively small contact separation indicated in Figure 2 by the letter A. This short contact separation permits substantial heat transfer through the thermoelement 54 in spite of relatively low thermal conductivity characteristics of the semi-metallic material from which it is made. In the preferred embodiment of the invention, the aforementioned contact separation is preferably not greater than the diameter of the cylindrical thermoelement 54. It will be noted that the sheath member 43 has a relatively thin-walled portion indicated by the letter B in Figure 2 thermally connecting the outer end portion of said sheath with a thicker-walled, and hence more conductive, portion of the enclosing structure. In order to afford substantial heat transfer from the outer end portion of the sheath member 43 to said more conductive enclosure portion, for example, to the sleeve 47, the length of the thin-walled sheath portion B is kept relatively short. In the preferred embodiment of the invention the dimension B is preferably not greater than the outer diameter thereof.

The coaxial type thermoelectric generator lead 13 comprises a tubular outer conductor 67 and a coaxial inner conductor 68 insulated therefrom by an insulating sleeve 69 preferably made of non-hygroscopic material. The inner conductor 68 is connected in circuit with the stem

58 of the contact electrode 56, as by a brazed or welded connection at 70, and the portion of the conductor 68 extending within the compression spring 66 may be formed with a serpentine shape as shown to provide extensibility for a purpose to be hereinafter described. The end of the lead 13 remote from the generator 4, in addition to carrying the connector nut 14, has the outer tubular lead conductor 67 radially outwardly flared, as at 71, for engagement by the end of said nut. The inner lead conductor 68 has a low resistance electrical connection with the terminal tip 15, and a relatively rigid insulating spacer 72 surrounds the inner lead conductor and is interposed between the tip 15 and the flange 71 to insulate said tip from said flange while at the same time maintaining a predetermined minimum spacing therebetween. The spacer 72 may be of glass melamine or other suitable material.

The insulation 69 between the inner and outer lead conductors 68 and 67 terminates short of the flange 71, as at 73. Surrounding the inner lead conductor 68 within the outer lead conductor 67 and between the insulating washer 72 and the end portion 73 of the insulation 69, is an insulating seal 74 of pliable material, for example, silicon rubber, which directly contacts both the inner and outer lead conductors. Prior to the connection of the lead 13 to the generator 4, and after the terminal tip 15 is fixed to the end of the inner conductor 68 following placement of the seal 74 and insulating spacer 72 on the conductor 68, an axial pull is exerted on the inner conductor to draw the spacer 72 and tip 15 toward the flange 71 and thereby force the material of the pliable seal 74 into the adjacent end of the outer conductor 67 and into sealing engagement with both the inner conductor 68 and said outer conductor. While the inner conductor is thus under tension, the outer conductor is crimped, as at 75, to frictionally clamp the inner conductor 68 through the insulation 69. This clamping engagement maintains the portion of the inner conductor between the crimped portion 75 and the tip 15 under continuous tension so that the seal 74 is continuously pressed by the spacer 72 to maintain a continuous hermetic seal between the conductors 67 and 68.

By virtue of the seal 74 and the aforedescribed sealing connections at 53, 50 and 46, an hermetically sealed sheath or envelope is provided which encloses the thermoelement 54 and contact electrodes 55 and 56, said sheath comprising the outer tubular conductor 67, tubular sheath members 51 and 47, and sheath member 43. This envelope or enclosure means preferably contains a reducing fill, for example methane or other suitable hydrocarbon gas affording, when heated, hydrogen which tends to reduce oxidation within said enclosure means.

The thermoelement 54 is preferably made of semi-metallic material having high thermoelectric power, for example, an alloy further described in Patent No. 2,811,570 of Sebastian Karrer, said alloy comprising lead and at least one member of the group tellurium, selenium and sulphur. For example, the thermoelement 54 of lead-selenium-tellurium composition could include a selenium-tellurium constituent in which the selenium is but a trace. In this case such constituent should constitute 35% to 38.05% by weight of the composition, the balance (61.95% to 65% by weight) being lead. At the other extreme, where the selenium-tellurium constituent consists almost entirely of selenium with but a trace of tellurium, such constituent should comprise 25% to 27.55% by weight of the final composition, the remainder (from 72.45% to 75% by weight) being lead. Between these two extremes, the selenium-tellurium constituent varies linearly with the ratio of selenium to tellurium (expressed in atomic percent) in the selenium-tellurium constituent.

The thermoelement 54 may also be formed with an alloy of lead, selenium and sulphur. For example, a thermoelement 54 of the lead-selenium-sulphur composition could consist of a selenium-sulphur constituent in

which the sulphur is but a trace. In this case, such constituent should constitute from 25% to 27.55% by weight of the composition, the balance (from 75% to 72.45% by weight) being lead. At the other extreme, where the selenium-sulphur constituent consists almost entirely of sulphur with but a trace of selenium, such constituent should comprise from 12.8% to 13.37% by weight of the final composition, the remainder (from 87.2% to 86.63% by weight) being lead. Between these two extremes, the selenium-sulphur constituent varies linearly with the ratio of selenium to sulphur (expressed in atomic percent) in the selenium-sulphur constituent.

With regard to the aforementioned compositions, it will be observed that in each case there is an excess of lead over and above the amount thereof necessary for satisfying the stoichiometric proportions of the compound formed in the second constituent or constituents, i.e., the tellurium, selenium or sulphur. For example, the composition consisting substantially of lead and selenium can contain up to 10.4% lead by weight of the total composition over and above the 72.41% by weight lead stoichiometrically necessary for combination with selenium.

The electrical characteristics of the aforementioned semi-metallic alloys, desirable, for example, in thermoelectric generator elements, can be markedly and advantageously altered in a reproducible manner by the addition thereto of controlled amounts of matter other than the constituents of the base composition. Such additions may also be denominated "beneficial impurities," as distinguished from undesirable impurities. For convenience, these additions are hereinafter designated "promoters," since they tend to enhance the electrical characteristics desired for the particular application of the base compositions.

The above-described base compositions exhibit negative thermoelectric power and negative conductivity. By the addition of certain "promoters" such negative properties may be enhanced, while the polarity of the electrical properties of the base composition may be reversed by the addition of certain other promoters to provide a semi-metallic composition having positive electrical characteristics. Patent No. 2,811,571, of Robert W. Fritts and Sebastian Karrer, gives a complete description of the beneficial impurities, including both departures from perfect stoichiometry and promoters, which have been found to be effective for improvement of electrical properties of the semi-metallic thermoelectric generator elements when added to the aforementioned base compositions in minor amounts, for example, up to a maximum of 6.9% by weight of beneficial impurity including 3.9% excess lead and 3.0% promoter.

The proportions and ranges of the various constituents aforementioned, and particularly the minimum limits of lead constituent in the base compositions, must be regarded as critical if the composition is to have the desired electrical and physical properties. If the lead content is significantly less than the minimum amount indicated for any particular selenium-tellurium or selenium-sulphur proportion, the polarity of the Seebeck E.M.F. changes, and the desired electrical and mechanical properties will not be reproducible. On the other hand, if the lead content of any composition appreciably exceeds the aforementioned maximum limits, the resulting composition is too metallic in nature to afford satisfactory energy conversion efficiencies. Not only are the proportions and ranges of the aforedescribed compositions to be considered critical but so also is the purity. More specifically, the limit of tolerable metallic impurity in non-promoted final compositions has been found to be on the order of 0.01%, and the composition must be substantially oxygen free, if the mechanical and electrical properties desired are to be obtained and are to be reproducible. In the case of promoted compositions, however, the limit of tolerable impurity is 0.001%.

The fuel control system shown in Figure 1 is placed in operation by manually resetting the safety shut-off valve 9 to permit fuel flow to the pilot burner 6. Ignition of the fuel at the pilot burner 6 causes impingement of the pilot burner flame upon the reduced diameter portion 44 of the sheath member 43 of the generator 4, whereupon said generator, upon heating of the "hot" junction at the surfaces 62-63, generates electrical energy sufficient to energize the windings of the electromagnets 17 and 33 of valves 9 and 7 respectively. Energization of the electromagnet 17 causes the latter to retain the armature 18 in attracted position and the valve 19 in open position after release of the reset means 23, permitting continuous fuel flow to the pilot burner 6. The pressure regulator 11 insures that the supply of fuel to the pilot burner 6 is maintained at relatively constant pressure, so that uniform heating of the generator 4 results. After energization of the electromagnet 33, the valve 7 may be reset, the armature 34 being retained in attracted position and the valve 36 in open position by said electromagnet following release of the reset means 39, to afford continuous fuel flow to the burner 5.

During application of heat to the outer end portion of the sheath 43 substantial quantities of heat flow through the thermoelement 54 into the relatively massive metallic assembly afforded by the contact electrode 56, its stem 58 and the metallic sleeve 65, and as a result, said assembly acquires a relatively large heat content. In contrast to this, the relatively small mass of the contact electrode 55 and the reduced diameter portion 44 of the sheath 43 acquires only a relatively small heat content even though its operating temperature is substantially higher than that of said assembly. While the substantial heat flow through the thermoelement 54 results in a temperature differential between the "hot" and "cold" thermojunctions thereof which is less than that found in the operation of conventional thermoelectric generators, and those having longer thermoelements, the high thermoelectric power of the semi-metallic thermoelement material nevertheless affords an output which is greater than that afforded by conventional metallic thermocouples, for example, those utilizing stainless steel and copel thermoelements.

During the operation of the generator 4, prolonged exposure to heat may tend to cause a certain amount of sublimation and resultant shortening of the semi-metallic thermoelement 54. Deleterious results from any such action are prevented, however, by the elongated helical spring 66 which, in exerting a compressive stress of approximately 15 lbs. upon the thermoelement 54, maintains the low resistance contact between the surfaces 62-63 and affords take-up of any length reduction in the thermoelement 54. The elongated nature of the helical spring 66 provides for a relatively large amount of such take-up and thereby insures prolonged life expectancy for the generator 4.

Upon extinguishment of the flame at the pilot burner 6, the outer end portion of the generator 4 cools rapidly to quickly reduce the differential in temperature between the "hot" thermojunction 62-63 and the "cold" thermojunction 57 with a simultaneous rapid drop-off in the output of the generator to the "drop-out" value effecting closure of the valves 7 and 9 and termination of all fuel flow to the main and pilot burners. As illustrative of the rapid action of systems embodying improved thermoelectric generator 4, safety shut off of the fuel in one such system was effected within four seconds of extinguishment of the pilot burner flame. This compares with a time interval of forty seconds required in systems having as their source of power standard metallic thermocouples, for example, those having stainless steel and copel thermoelements.

The aforementioned rapid response of the improved thermoelectric generator 4 to extinguishment of the pilot burner flame is attributable to structural features effect-

ing a rapid reduction in the reduced operating temperature differential between the "hot" and "cold" thermojunctions of the generator. On outage of the pilot burner flame, heat is radiated from the hot relatively small mass outer end of the generator 4, the maximum amount of such radiative cooling being afforded by the mounting of said generator in a relatively open environment to provide the maximum solid angle through which heat can radiate from the aforementioned generator end portion. Heat is also conducted away from the relatively small mass outer end portion of the generator 4 through the sheath member 43 to the cooler sleeve 47, as well as from the contact electrode 55 through the thermoelement 54 and into the cooler relatively massive metallic assembly afforded by the contact electrode 56, and the sleeve 65. The last-mentioned massive metallic assembly is prevented from cooling rapidly during the rapid cooling of the outer end portion of the generator, not only because of the large heat content thereof made possible by its large mass, but also because of the fact that said assembly is held out of direct contact with the cooler portions of the sheath member 43 and sleeve 47 by the insulating bushing 64 and therefore heat cannot be conducted therefrom to said members. Thus, the differential between the "hot" and "cold" thermojunctions of the thermoelement 54 is rapidly reduced from its operating value to effect a corresponding drop-off in the electrical output of the generator 4 as a result of the aforementioned rapid cooling of the "hot" junction and simultaneous maintenance of the temperature of the "cold" thermojunction of the thermoelement 54 near its operating value.

The improved thermoelectric generator 4, because of the simplicity of its construction can be fabricated by mass production techniques from relatively inexpensive components. It is sturdy in construction and, if desired, can be made interchangeable with presently installed conventional metallic thermocouples to impart rapid drop-out characteristics to the systems into which they are introduced.

What is claimed as the invention is:

1. A thermoelectric generator comprising a cup-shaped metallic outer thermoelement, a tubular member of metal different from that of said outer thermoelement coaxially joined at one end to the open end of said cup-shaped thermoelement to form therewith a sheath and affording at said juncture an outer cold thermojunction, a semi-metallic inner thermoelement coaxially disposed within said cup-shaped thermoelement, means forming a hot thermojunction between the closed end of said cup-shaped thermoelement and the adjacent end of said inner thermoelement, and metallic heat storing and thermojunction means forming an inner cold thermojunction with the opposite end of said semimetallic inner thermoelement and extending axially in spaced relation within said outer thermoelement and tubular member, said heat storing and thermojunction means having a cross-sectional area of a size to occupy the major portion of the cross-sectional area of the hollow interior of the portion of the sheath in which it is disposed and having a length substantially greater than the axial distance between said hot thermojunction and said outer cold thermojunction.

2. A thermoelectric generator comprising a cup-shaped metallic outer thermoelement, a tubular member of metal different from that of said outer thermoelement coaxially joined at one end to the open end of said cup-shaped thermoelement to form therewith a sheath and affording at said juncture an outer cold thermojunction, a cylindrical semimetallic inner thermoelement coaxially disposed within said cup-shaped thermoelement and having an axial length not substantially greater than its diameter, means forming a hot thermojunction between the closed end of said cup-shaped thermoelement and the adjacent end of said inner thermoelement, and metallic heat storing and thermojunction means forming an inner cold

thermojunction with the opposite end of said semimetallic inner thermoelement and extending axially in spaced relation within said outer thermoelement and tubular member, said heat storing and thermojunction means having a cross-sectional area of a size to occupy the major portion of the cross-sectional area of the hollow interior of the portion of the sheath in which it is disposed and having a length substantially greater than the axial distance between said hot thermojunction and said outer cold thermojunction.

3. A thermoelectric generator comprising a cup-shaped metallic outer thermoelement, a tubular member of metal different from that of said outer thermoelement coaxially joined at one end to the open end of said cup-shaped thermoelement to form therewith a sheath and affording at said juncture an outer cold thermojunction, a semimetallic inner thermoelement coaxially disposed within said cup-shaped thermoelement, means forming a hot thermojunction between the closed end of said cup-shaped thermoelement and the adjacent end of said inner thermoelement, the axial distance between said hot thermojunction and said outer cold thermojunction being not substantially greater than the outer diameter of said outer thermoelement, and metallic heat storing and thermojunction means forming an inner cold thermojunction with the opposite end of said semimetallic inner thermoelement and extending axially in spaced relation within said outer thermoelement and tubular member, said heat storing and thermojunction means having a cross-sectional area of a size to occupy the major portion of the cross-sectional area of the hollow interior of the portion of the sheath in which it is disposed and having a length substantially greater than the axial distance between said hot thermojunction and said outer cold thermojunction.

4. A thermoelectric generator comprising a relatively thin-walled cup-shaped metallic outer thermoelement, a thicker-walled tubular member of metal different from that of said outer thermoelement and having greater thermal conductivity than said thermoelement coaxially joined at one end to the open end of said cup-shaped thermoelement to form therewith a sheath and affording at said juncture an outer cold thermojunction, a semimetallic inner thermoelement coaxially disposed within said cup-shaped thermoelement, means forming a hot thermojunction between the closed end of said cup-shaped thermoelement and the adjacent end of said inner thermoelement, and metallic heat storing and thermojunction means forming an inner cold thermojunction with the opposite end of said semimetallic inner thermoelement and extending axially in spaced relation within said outer thermoelement and tubular member, said heat storing and thermojunction means being insulatably supported within said sheath and having a cross-sectional

area of a size to occupy the major portion of the cross-sectional area of the hollow interior of the portion of the sheath in which it is disposed and having a length substantially greater than the axial distance between said hot thermojunction and said outer cold thermojunction.

5. A thermoelectric generator comprising a relatively thin-walled cup-shaped metallic outer thermoelement, a thicker-walled tubular member of metal different from that of said outer thermoelement and having greater thermal conductivity than said thermoelement coaxially joined at one end to the open end of said cup-shaped thermoelement to form therewith a sheath and affording at said juncture an outer cold thermojunction, a cylindrical semimetallic inner thermoelement coaxially disposed within said cup-shaped thermoelement and having an axial length not substantially greater than its diameter, means forming a hot thermojunction between the closed end of said cup-shaped thermoelement and the adjacent end of said inner thermoelement, the axial distance between said hot thermojunction and said outer cold thermojunction being not substantially greater than the outer diameter of said outer thermoelement, and metallic heat storing and thermojunction means forming an inner cold thermojunction with the opposite end of said semimetallic inner thermoelement and extending axially in spaced relation within said outer thermoelement and tubular member, said heat storing and thermojunction means being insulatably supported within said sheath and having a cross-sectional area of a size to occupy the major portion of the cross-sectional area of the hollow interior of the portion of the sheath in which it is disposed and having a length substantially greater than the axial distance between said hot thermojunction and said outer cold thermojunction.

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