June 20, 1961 R. W. FRITTS 2,989,281

OPERATOR FOR VALVES OR THE LIKE

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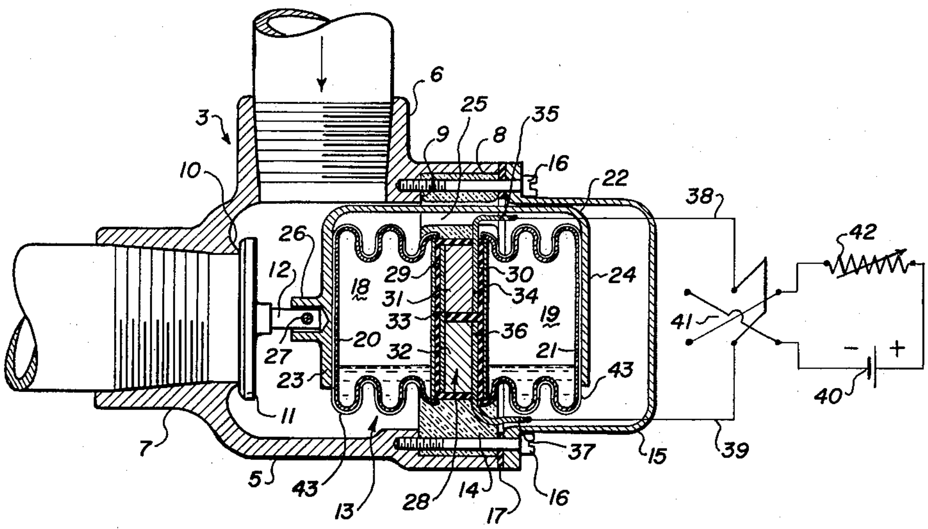

Fig. 1

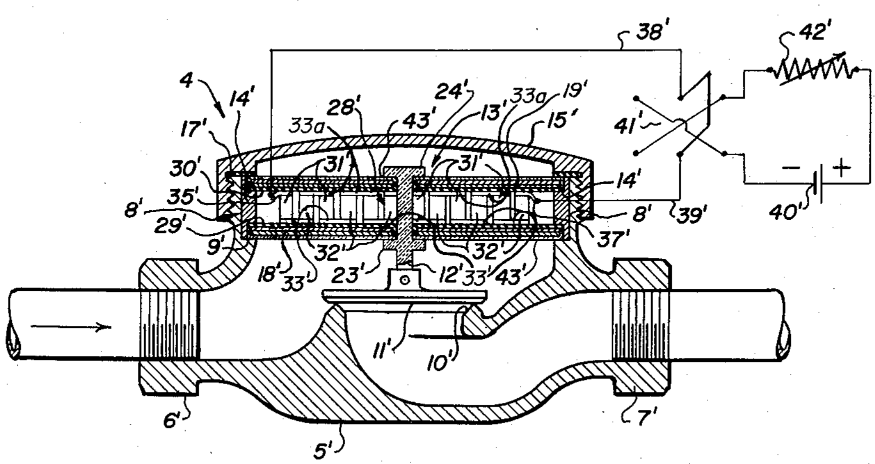

Fig. 2

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OPERATOR FOR VALVES OR THE LIKE

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7 Claims. (Cl. 251—11)

In certain control systems actuation of control members, for example, fuel control valves actuated to open position against the pressure of the fuel controlled, requires the expenditure of a substantial amount of work. In self-powered systems, for example those in which the power available for effecting valve actuation is derived solely from a thermoelectric generator, the limited power available places a very substantial limitation upon the work which can be performed by conventional electromagnetic operators in response to energization thereby, for example, in opening a valve as aforementioned. In conventional electromagnetically operated valves, the operator comprises an armature having retracted and attracted positions with respect to an electromagnet, said armature having a force transmitting connection with a valve member for effecting opening movement of the latter directly upon attractive movement of the armature, which movement occurs substantially instantaneously with energization of said operator.

It is a general object of the present invention to provide an improved electroresponsive operator for valves or the like which is capable of performing substantially increased amounts of work in response to energization by small values of electrical energy, said operator functioning to integrate small increments of work over a time interval sufficient to produce an increased total work value sufficient, for example, to actuate a larger capacity valve.

Another object of the invention is to provide an improved operator for valves or the like which is reversible in accordance with the plurality of the energizing current and which is well-adapted for use in on-off as well as modulating type controls.

More particularly, it is an object of the invention to provide an improved operator of the aforementioned character utilizing the operating principles of thermal motors and employing in a novel manner thermoelectric heat pump means having thermoelement means of semimetallic material.

A more specific object of the invention is to provide an improved operator of the class described utilizing dual temperature responsive actuating means, one of said means having a movable portion movable in a given direction in response to an increase in temperature, and the other having a movable portion movable in the same given direction in response to a drop in temperature, the thermoelectric heat pump means being operatively associated with both of said temperature responsive means in a manner to be operable when energized by current of one polarity to transfer heat energy from the second temperature responsive means to the first temperature responsive means, thereby increasing the temperature of the first temperature responsive means and decreasing the temperature of the second temperature responsive means to effect simultaneous movement of the movable portions of both of said means in the same direction, there being a force transmitting connection between said movable portions and a member to be actuated, for actuation of said member with movement of said movable portions. Reversal of the polarity of the energizing current effects reverse operation of the heat pump means and thereby reverse actuation of said member.

Another specific object of the invention is to provide an improved operator of the character described which,

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though temperature responsive in its operation, is substantially unaffected by changes in ambient temperature.

Another object of the invention is to provide an improved operator of the class described which is characterized by highly efficient operation, simplicity of construction and economy of manufacture.

Other and further objects of the invention will become apparent as the description proceeds. The invention is capable of receiving a variety of mechanical expressions, two of which are shown on the accompanying drawings, but it is to be expressly understood that the drawings are for the purposes of illustration only, and are 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 reference characters are employed to designate the same parts in both of the figures:

FIGURE 1 is an axial sectional view of an electroresponsive valve having embodied therein one form of operator constructed in accordance with the principles of the present invention; and

FIGURE 2 is an axial sectional view of an electroresponsive valve having embodied therein another form of operator constructed in accordance with the invention.

Referring more particularly to FIGURE 1 of the drawings, the valve **3** illustrated therein takes the form of a gaseous fuel control valve which comprises a valve body **5** having a fuel inlet connection **6** and a fuel outlet connection **7**, and having an open end counterbored at **8** to provide an annular internal shoulder **9**. The body **5** is formed with an annular valve seat **10** surrounding the outlet opening, and a valve member **11** cooperates with the valve seat **10** to control the flow of gaseous fuel, through the body **5**. The valve member **11** is provided with a stem **12** by means of which it is carried by an electroresponsive operator indicated generally by the numeral **13**.

The operator **13** comprises a circular supporting member **14** disposed within the counterbore **8**, and a cover **15** closes the outer end of the valve body opening. Screws **16** holding the cover **15** and supporting member **14** in place with respect to the body **5** and affording clamping of a gasket **17** between said body **5** and cover **15** to afford a seal therebetween. The supporting member **14** may be made of heat insulating moldable material and rigidly supports, as by having molded therein, adjacent end wall portions of a pair of expansible and contractible enclosures **18** and **19** which may take the form of bellows having generally parallel movable outer end wall portions **20** and **21** respectively. Bellows **18** and **19** may each contain a temperature responsive expansible and contractible volatile fluid fill having a liquid phase preferably of sufficient volume so that said phase at all times remains in a single body in contact with the inner end walls of said bellows. A movable force transmitting member in the form of a generally U-shaped bracket **22** having arms **23** and **24** extends without contact through a suitable opening **25** in the support member **14** and has its arms **23** and **24** compressively engaging the outer end wall portions **20** and **21** of the bellows **18** and **19**, preferably through a thermal insulating layer **43** as shown, to thereby maintain said end wall portions in fixed spacial relationship. The arm **23** carries a socket **26** in which the valve stem **12** is secured as by a pin **27**.

Electroresponsive means in the form of thermoelectric heat pump **28** is provided for the purpose of effecting expansion of one of the bellows **18** and **19** and simultaneous contraction of the other of said bellows to afford, through the member **22** and valve stem **12**, actuation of the valve member **11**. The heat pump **28** may be molded into the member **14** along with the end wall portions of the bellows 18 and 19 and is interposed between said end walls, being separated therefrom by thin layers 29 and 30 of material having good electrical insulating and heat conducting properties. The heat pump 28 may comprise a pair of spaced generally semi-circular thermoelements 31 and 32 conforming to the shape of the bellows end walls and electrically joined on one face by a circular thermojunction member 33 of metal having good thermal and electrically conductive properties. Electrically joined to the opposite face of the thermoelement 31 is a generally semi-circular thermo-junction member 34 having a terminal portion 35 extending externally of the supporting member 14 as shown, and similarly joined to the other face of the thermoelement 32 is a generally semi-circular thermojunction member 36 having a terminal portion 37 projecting externally of the support member 14 as shown. The thermojunction members 34 and 36 may be made of the same material as the thermojunction member 33. The terminals 35 and 37 of the heat pump 28 are connected by means of conductors 38 and 39, respectively, to a source 40 of direct current indicated schematically as a battery, the schematic symbol, however, is intended to indicate any suitable direct current source, for example a thermoelectric generator. The connections of the conductors 38 and 39 with the source 40 may include a double-pole double-throw polarity reversing switch 41, and, if desired, current varying means in the form of a variable resistance 42, which may be temperature responsive.

The function of the heat pump 28 is to pump heat from one of the bellows 18 and 19 to the other, and for this purpose it is desirable that the thermoelements 31 and 32 be of any suitable material which exhibits a high Peltier coefficient, low thermal conductivity and low electrical resistivity. More specifically, the thermoelements 31 and 32 may be of the materials described in the copending application of Robert W. Fritts and Sebastian Karrer, Serial No. 512,436, filed June 6, 1956, now Patent No. 2,896,005. Such materials are semi-metallic alloys or compositions which may be characterized as binary metallic compounds of slightly imperfect composition, i.e., containing beneficial impurities constituting departures from perfect stoichiometry by reason of an excess of one of the metals over the other and/or containing added beneficial impurity substances denominated hereinafter "promoters." Such semi-metallic compositions have semi-conductor-like conductivity (both electrical and thermal as aforementioned). Semi-metallic alloys or compositions also include mixtures of such binary metallic compounds, which may be denominated ternary metallic alloys or compositions. Certain of these alloys or compositions exhibit negative and certain exhibit positive electrical characteristics.

It is preferred that one of the thermoelements, for example, thermoelement 31, exhibit positive electrical characteristics and the other thermoelement, for example thermoelement 32, exhibit negative electrical characteristics. The reason for this is that current flow through an element which exhibits positive electrical characteristics causes heat to be pumped in the direction of current flow therethrough, whereas curent flow through a thermoelement which exhibits negative electrical characteristics causes heat to be pumped in the direction opposite to the direction of current flow therethrough. Thus, if current flows through the heat pump 28 from the terminal 37 to the terminal 35, heat will be pumped from the bellows 18 to the bellows 19 through both of the thermoelements 31 and 32, thereby effecting expansion of the bellows 19 and simultaneous contraction of the bellows 18 with opening movement of the valve member 11. Conversely, if the polarity of the energizing current is reversed, for example, by manipulation of the reversing switch 41, current flow through the heat pump 28 from the terminal 35 to the terminal 37 causes heat to be pumped from the bellows 19 to the bellows 18 through both of the thermoelements 31 and 32, producing simultaneous expansion of the bellows 18 and contraction of the bellows 19 and effecting closing movement of the valve member 11.

A negative thermoelement may, for example, be formed of an alloy comprising lead and at least one member of the group tellurium, selenium and sulphur. For example, a negative thermoelement of lead-selenium-tellurium composition could include a tellurium-selenium constituent in which the selenium is but a trace. In this case, such constituent should constitute from 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 tellurium-selenium constituent consists almost entirely of selenium with but a trace of tellurium, such constituent should comprise from 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.

A negative thermoelement may also be formed of an alloy of lead, selenium and sulphur. For example, a thermoelement of 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 (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, a 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% lead stoichiometrically necessary for combination with selenium.

The electrical characteristics of the aforementioned semi-metallic alloys, desirable, for example, in thermoelements for heat pump application, 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 compositions 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.

As has previously been observed, all of the aforementioned base compositions exhibit negative Peltier E.M.F. 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 compositions may be reversed by the addition of certain other "promoters" to provide a semi-metallic composition having positive electrical characteristics, i.e., positive conductivity and Peltier E.M.F.

The aforementioned copending application 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 the electrical properties of semi-metallic thermoelements for heat pump applications 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 for promoted compounds and a maximum of 10.4% by weight of beneficial impurity for unpromoted compositions.

The proportions and ranges of the various constituents aforementioned and particularly the minimum limits of lead constituent in the compositions, must be regarded as critical if the composition is to have the electrical properties desired in thermoelectric heat pump elements. If the lead content is significantly less than the minimum amount indicated for any particular selenium-tellurium or selenium-sulphur proportion, the desirable values of Peltier E.M.F. and resistivity will not be afforded, and the significant electrical and mechanical properties will not be reproducible. On the other hand, if the lead content for any composition appreciably exceeds the aforementioned maximum limit, the resulting compositions is too metallic in nature to afford satisfactory electrical characteristics for the purposes of the present invention.

A positive thermoelement may also be formed of an alloy of lead and tellurium in which there is an excess of tellurium over and above the amount thereof necessary for satisfying the stoichiometric proportions of the compound lead-telluride. Such alloy or composition should consist essentially of lead and tellurium in which the lead is present in the range of 58.0% to 61.8% by weight and the balance in the range of 42.0% to 38.2% by weight tellurium. It will be observed that in this case there is an excess of tellurium over and above the amount thereof necessary for satisfying the stoichiometric proportions.

As has been previously observed, the tellurium rich base lead-tellurium compositions exhibit positive Peltier E.M.F. and positive conductivity. The electrical characteristics of this compound, desirable, for example in thermoelements for heat pump applications, can be markedly and advantageously altered in a reproducible manner by addition thereto of controlled amounts of matter other than the constituents of such base composition. Such matter may also be denominated "beneficial impurities" as distinguished from undesirable impurities, and for convenience, such additions are also designated "promoters," since they tend to enhance the electrical characteristics desired for the particular application of the base composition.

The aforementioned copending application 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 semi-metallic thermoelements for heat pump applications when added to the aforementioned tellurium rich base lead-tellurium compositions. For example, up to a maximum of 5.5% by weight of beneficial impurities including 4.9% excess tellurium and 0.60% promoter for promoted compounds and a maximum of 6.7% by weight of beneficial impurities for unpromoted compositions.

The proportions and ranges of the constituents of the tellurium rich compositions aforementioned and particularly the minimum limits of tellurium in the compositions, must be regarded as critical if the composition is to have the electrical properties desired in thermoelectric heat pump elements. If the tellurium content is significantly less than the minimum amount indicated, the desired values of Peltier E.M.F. and resistivity will not be afforded and the significant electrical and mechanical properties will not be reproducible. On the other hand, if the tellurium content appreciably exceeds the aforementioned maximum limits, the resulting compositions will not afford satisfactory electrical characteristics for the purposes of the present invention.

Not only are the proportions and ranges of the compositions aforedescribed considered to be critical, but so also is the purity. More specifically, the limit of tolerable metallic impurity in the final composition 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 maintained and are to be reproducible. In the case of promoted compositions, however, the limit of tolerable impurity is 0.001%.

It will be observed that the bracket **22**, in addition to affording a means for transmitting movement of the bellows end walls to the valve member **11**, also affords means compensating for the effect of changes in ambient temperature on the bellows **18** and **19**, since any tendency of ambient temperature changes to expand or contract one bellows has an equal effect on the other bellows and the resultant forces are balanced out through the bracket **22**. The external heat insulating layer **43** further nullifies the effect of ambient temperature on the bellows **18** and **19**, and contributes to the efficiency of the device by preventing thermal short-circuiting through the bracket **22**.

In operation of the form of the invention illustrated in FIGURE 1, when the switch **41** is disposed as shown and no current is flowing through the heat pump **28**, the valve member **11** is disposed in closed position. To effect opening movement of the valve member **11**, the switch **41** is thrown toward the left, as viewed in FIGURE 1, to cause current to flow through the heat pump **28** from the terminal **37** to the terminal **35**. As aforementioned, this causes heat to be pumped from the bellows **18** to the bellows **19**, increasing the vapor pressure within the bellows **19** and decreasing said pressure in the bellows **18** to cause expansion of bellows **19** and contraction of bellows **18** and corresponding opening movement of the valve member **11**. The valve member **11** opens an amount roughly proportional to the amount of current flowing through the heat pump **28**, and where modulation of the flow of the fluid controlled is desired, the amount of current flowing through the heat pump **28** can be varied in accordance with temperature changes by the use of the temperature responsive variable resistance **42**. Where modulation is not desired, however, the variable resistance **42** or **42'** may be omitted, in which case the current from the source **40** flowing through the heat pump **28** effects full opening of the valve member **11** upon the aforementioned actuation of the switch **41**.

If, now, the switch **41** is returned to the position shown in FIGURE 1, current will cease to flow through the heat pump **28**, and the valve member **11** will close slowly as temperatures of the bellows **18** and **19** equalize to cause the latter to return to the position shown in FIGURE 1. If, instead of being returned to its open-circuit position shown in FIGURE 1, the switch **41** is thrown to the right to effect reversal of the polarity of the current flowing from the source **40** through the heat pump **28**, the heat pump **28** immediately pumps heat from the bellows **19** to the bellows **18** as aforedescribed, to effect expansion of the bellows **18**, contraction of the bellows **19** and rapid closure of the valve member **11**. Where desired, the switch **41** or **41'** may take the form of a thermostat, thus affording control of the operation of the valve **11** in accordance with the ambient temperature at such thermostat.

The operator **13** is highly efficient, not only because of the high efficiency of the heat pump **28** in pumping large amounts of heat per unit of electrical energy expended, but also because of the novel structural arrangement whereby the effectiveness of the heat pump **28** is substantially doubled by taking advantage of both the heat absorbing function and the heat emitting function thereof to extract heat from one bellows and add heat to the other. The reversibility of operation of heat pump **28** in accordance with the polarity of the energizing current makes a further major contribution to the adaptability of the operator **13** as valve actuating means, affording said operator positive valve actuating force in either of two opposite directions depending upon the polarity of the energizing current.

Referring now to FIGURE 2, the valve 4 shown therein embodies an operator **13'** also exemplifying the invention and having a form somewhat different from that of the operator **13** shown in FIGURE 1. In FIGURE 2 the parts indicated by primed reference characters correspond to parts in FIGURE 1 indicated by the same reference characters unprimed.

The illustrated operator **13'** comprises a pair of centrally apertured bimetal members **18'** and **19'** which may take the form of spaced generally parallel strips having their end portions disposed in diametrically opposed axial grooves **8'** formed within the open end of the valve body **5'** as shown. The end portions of the members **18'** and **19'** are held in spaced relation by spacing members **14'** disposed within the grooves **8'** and having portions interposed between the members **18'** and **19'** as shown. The adjacent surfaces of the bimetal members **18'** and **19'** are respectively provided with relatively thin layers **29'** and **30'** of material having good electrically insulating and heat conducting qualities. The opposite surfaces of the members **18'** and **19'** and the edge surfaces thereof are provided with the layer of heat insulating material **43'** as shown. The valve stem **12'** is preferably of material of low thermal conductivity and is provided with annular flanges **23'** and **24'** respectively engaging the layer **43'** overlying the member **18'** and the layer **43'** overlying the member **19'** as shown.

The orientation of the bimetal members **18'** and **19'** is such that the central portion of the member **18'** tends to deform upwardly when said member is cooled, and the central portion of the member **19'** tends to deform upwardly when the latter is heated.

A heat pump **28'** is interposed between the bimetal members **18'** and **19'** in good heat conductive contact therewith by engagement with the layers **29'** and **30'**. The heat pump **28'** comprises a plurality of serially connected thermoelements **31'** and **32'** of relatively smaller size than but of preferably the same material as the thermoelements **31** and **32** of FIGURE 1, said thermoelements being joined by thermojunction members **33'** adjacent the bimetal member **18'** and ***33a*** adjacent the bimetal member **19'**. The thermojunction members **33'** and ***33a*** may be of the same material as the thermojunction members **33**, **34**, and **36** of FIGURE 1. The thermoelements **31'** are of one conductivity type, for example positive, and the thermoelements **32'** are of the opposite conductivity type, for example, negative, and in the serial relationship, the positive and negative thermoelements are alternately related as shown.

In the operation of the form of the invention shown in FIGURE 2, when the switch **41'** is in the position shown and no current is flowing through the heat pump **28'**, the valve member **11'** is closed. When the switch **41'** is thrown toward the left to cause current flow from the source **40'** through the heat pump **28'** from terminal **37'** to terminal **35'**, heat is pumped by each of the thermoelements **31'** and **32'** from the bimetal member **18'** to the bimetal member **19'**, thereby cooling the member **18'** and heating the member **19'**. In response to this action, the central portions of the members **18'** and **19'** simultaneously deform upwardly, and acting through the stem **12'**, open the valve member **11'**. If the switch **41'** is now returned to the position shown in FIGURE 2 to terminate current through the heat pump **28'**, the bimetal members **18'** and **19'** will slowly return to their positions shown in FIGURE 2 as the temperature is equalized, thereby effecting corresponding slow closing movement of the valve member **11'**. On the other hand, if the switch **41'** is flipped from its left-hand position to its right-hand position, the current flow through the heat pump **28'** is reversed, and the action of said heat pump is likewise immediately reversed to cause each of the thermoelements **31'** and **32'** to pump heat from the bimetal member **19'** to the bimetal member **18'**, thereby causing rapid return of said bimetal members to their position shown in FIGURE 2 and corresponding rapid closing movement of the valve member **11'**.

Adjustment of the amount of opening of the valve member **11'** can be effected by adjusting the amount of current flowing through the heat pump **28'** by means of the variable resistance **42'**. Where modulation is desired, the variable resistance **42'** may be temperature responsive to afford variation in the current flow through the heat pump **28'** and thereby variation in the opening of the valve member **11'** in accordance with the temperature. Where snap action is required of the operator **13'**, the bimetal members **18'** and **19'** may be of the pre-stressed type to afford such action. The reason for use in the operator **13'** of a plurality of relatively small-sized heat pump thermoelements **31'** and **32'** is to afford physical flexibility of the heat pump **28'** permitting the latter to conform to the shape of the bimetal elements **18'** and **19'** as the same deform in response to the pumping of heat by said heat pump.

The low thermal conductivity of the valve stem **12'** prevents heat conduction therealong between the bimetal members **18'** and **19'**, and together with the thermal insulating layers **43'** helps maintain any differential in temperature between the members **18'** and **19'** established by the heat pump **28'**. It will also be noted that the operator **13'** is substantially immune to changes in ambient temperature, not only by virtue of the opposite orientation of the bimetal members **18'** and **19'**, but also because of the fact that the bimetal members **18'** and **19'** are effectively clamped between the heat pump **28'**, and the flanges **23'** and **24'** of the valve stem **12'**.

While electroresponsive operators **13** and **13'** constructed in accordance with the principles of the present invention are shown as being used as valve actuating means, it is obvious that their use is not limited to such applications, and that where desired various changes and modifications may be made in said operators without departing from the spirit of the invention. All of such changes are contemplated as may come within the scope of the appended claims.

What is claimed as the invention is:

1. In an operator for valves or the like, first and second temperature responsive actuating means each having a portion movable in response to changes in temperature, and a thermoelectric heat pump comprising thermoelement means having oppositely facing opposite end surfaces, and thermojunction members joined to said end surfaces to form heat absorbing and heat emitting thermojunctions respectively at the opposite ends of said thermoelement means, said thermoelement means affording substantially straight line current flow path means between the heat absorbing and heat emitting thermojunction members joined thereto, said heat pump being interposed physically between said first and second actuating means with said heat absorbing thermojunctions in juxtaposition and heat transfer relation with said first actuating means and said heat emitting thermojunctions in juxtaposition and heat transfer relation with said second actuating means, said heat pump tending when energized to transfer heat energy from said first actuating means to said second actuating means to effect simultaneous thermoelectric cooling of said first and thermoelectric heating of said second actuating means and to thereby effect simultaneous movement of said movable portions of both of said actuating means.

2. In an operator for valves or the like, first and second temperature responsive actuating means comprising first and second bimetallic members respectively each having a portion movable in response to changes in temperature, and a thermoelectric heat pump comprising thermoelement means having oppositely facing opposite end surfaces, and thermojunction members joined to said end surfaces to form heat absorbing and heat emitting thermo-

junctions respectively at the opposite ends of said thermoelement means, said thermoelement means affording substantially straight line current flow path means between the heat absorbing and heat emitting thermojunction members joined thereto, said heat pump being interposed physically between said first and second bimetallic members with said heat absorbing thermojunctions in juxtaposition and heat transfer relation with said first bimetallic member and said heat emitting thermojunctions in juxtaposition and heat transfer relation with said second bimetallic member, said heat pump tending when energized to transfer heat energy from said first bimetallic member to said second bimetallic member to effect simultaneous thermoelectric cooling of said first and thermoelectric heating of said second bimetallic member and to thereby effect simultaneous movement of said movable portions of both of said bimetallic members.

3. In an operator for valves or the like, first and second temperature responsive actuating means comprising first and second temperature responsive expansible and contractible enclosures each having a portion movable in response to changes in temperature, and a thermoelectric heat pump comprising thermoelement means having oppositely facing opposite end surfaces, and thermojunction members joined to said end surfaces to form heat absorbing and heat emitting thermojunctions respectively at the opposite ends of said thermoelement means, said thermoelement means affording substantially straight line current flow path means between the heat absorbing and heat emitting thermojunction members joined thereto, said heat pump being interposed physically between said first and second enclosures with said heat absorbing thermojunctions in juxtaposition and heat transfer relation with said first enclosure and said heat emitting thermojunctions in juxtaposition and heat transfer relation with said second enclosure, said heat pump tending when energized to transfer heat energy from said first enclosure to said second enclosure to effect simultaneous thermoelectric cooling of said first and thermoelectric heating of said second enclosure and to thereby effect simultaneous movement of said movable portions of both of said enclosures.

4. An operator for valves or the like comprising first temperature responsive actuating means having a portion movable in one direction in response to a decrease in temperature and in the opposite direction in response to an increase in temperature, second temperature responsive actuating means having a portion movable in said one direction in response to an increase in temperature and in said opposite direction in response to a decrease in temperature, a thermoelectric heat pump comprising a plurality of generally parallel thermoelements having oppositely facing opposite end surfaces, and thermojunction members joined to said end surfaces to form heat absorbing and heat emitting thermojunctions respectively at corresponding opposite ends of said thermoelements, said thermoelements each affording a substantially straight line current flow path therethrough between the heat absorbing and heat emitting thermojunction members joined thereto, said heat pump being interposed physically between said first and second actuating means with said heat absorbing thermojunctions in juxtaposition and heat transfer relation with said first actuating means and said heat emitting thermojunctions in juxtaposition and heat transfer relation with said second actuating means, said heat pump tending when energized to transfer heat energy from said first actuating means to said second actuating means to effect simultaneous thermoelectric cooling of said first actuating means to below the ambient temperature and thermoelectric heating of said second actuating means to above the ambient temperature and to thereby effect simultaneous movement of said movable portions of both of said actuating means in said one direction, a member to be actuated, and means having spaced portions engaging the movable portions of said first and second actuating means affording an actuating connection between both of said actuating means and said member for effecting actuation of the latter responsive to said simultaneous movement of said movable portions.

5. An operator for valves or the like comprising first temperature responsive actuating means comprising a first temperature responsive expansible and contractible enclosure having a portion movable in one direction in response to a decrease in temperature and in the opposite direction in response to an increase in temperature, second temperature responsive actuating means comprising a second temperature responsive expansible and contractible enclosure having a portion movable in said one direction in response to an increase in temperature and in said opposite direction in response to a decrease in temperature, a thermoelectric heat pump comprising a plurality of generally parallel thermoelements having oppositely facing opposite end surfaces, and thermojunction members joined to said end surfaces to form heat absorbing and heat emitting thermojunctions respectively at corresponding opposite ends of said thermoelements, said thermoelements each affording a substantially straight line current flow path therethrough between the heat absorbing and heat emitting thermojunction members joined thereto, said heat pump being interposed physically between said first and second enclosures with said heat absorbing thermojunctions in juxtaposition and heat transfer relation with said first enclosure and said heat emitting thermojunctions in juxtaposition and heat transfer relation with said second enclosure, said heat pump tending when energized to transfer heat energy from said first enclosure to said second enclosure to effect simultaneous thermoelectric cooling of said first enclosure to below the ambient temperature and thermoelectric heating of said second enclosure to above the ambient temperature and to thereby effect simultaneous movement of said movable portions of both of said enclosures in said one direction, a member to be actuated, and means having spaced portions engaging the movable portions of said first and second enclosures affording an actuating connection between both of said enclosures and said member for effecting actuation of the latter responsive to said simultaneous movement of said movable portions.

6. In a valve having a valve member movable in opening and closing directions, an operator for said valve member comprising first and second temperature responsive actuating means each having a portion movable in response to changes in temperature, a thermoelectric heat pump comprising thermoelement means having oppositely facing opposite end surfaces, and thermojunction members joined to said end surfaces to form heat absorbing and heat emitting thermojunctions respectively at the opposite ends of said thermoelement means, said thermoelement means affording substantially straight line current flow path means between the heat absorbing and heat emitting thermojunction members joined thereto, said heat pump being interposed physically between said first and second actuating means with said heat absorbing thermojunctions in juxtaposition and heat transfer relation with said first actuating means and said heat emitting thermojunctions in juxtaposition and heat transfer relation with said second actuating means, said heat pump tending when energized by current of one polarity to transfer heat energy from said first actuating means to said second actuating means to effect simultaneous thermoelectric cooling of said first and thermoelectric heating of said second actuating means and to thereby effect simultaneous movement of said movable portions of both of said actuating means in one sense, said heat pump also tending when energized by current of the opposite polarity to transfer heat energy in the opposite direction to effect simultaneous movement of said movable portions in an opposite sense, and means affording an actuating connection between said movable portions and said valve member to effect opening movement of said valve mem-

ber with movement of said movable portions in said one sense and closing movement of said valve member with movement of said movable portions in said opposite sense.

7. In a valve having a valve member movable in opening and closing directions, an operator for said valve member comprising first temperature responsive actuating means comprising a first temperature responsive expansible and contractible enclosure having a portion movable in one direction in response to a decrease in temperature and in the opposite direction in response to an increase in temperature, second temperature responsive actuating means comprising a second temperature responsive expansible and contractible enclosure having a portion movable in said one direction in response to an increase in temperature and in said opposite direction in response to a decrease in temperature, a thermoelectric heat pump comprising a plurality of generally parallel thermoelements having oppositely facing opposite end surfaces, and thermojunction members joined to said end surfaces to form heat absorbing and heat emitting thermojunctions respectively at corresponding opposite ends of said thermoelements, said thermoelements each affording a substantially straight line current flow path therethrough between the heat absorbing and heat emitting thermojunction members joined thereto, said heat pump being interposed physically between said first and second enclosures with said heat absorbing thermojunctions in juxtaposition and heat transfer relation with said first enclosure and said heat emitting thermojunctions in juxtaposition and heat transfer relation with said second enclosure, said heat pump tending when energized by current of one polarity to transfer heat energy from said first enclosure to said second enclosure to effect simultaneous thermoelectric cooling of said first enclosure to below the ambient temperature and thermoelectric heating of said second enclosure to above the ambient temperature and to thereby effect simultaneous movement of said movable portions of both of said enclosures in said one direction, said heat pump also tending when energized by current of the opposite polarity to transfer heat energy in the opposite direction to effect simultaneous movement of said movable portions of both of said enclosures in said opposite direction, and means having spaced portions engaging the movable portions of both of said enclosures affording an actuating connection between said movable portions and said valve member to effect opening movement of said valve member with movement of said movable portions in said one direction and closing movement of said valve member with movement of said movable portions in said opposite direction.

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