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(72) Inventor FRANK JOHNSTONE

(54) VOLTAGE CONVERTER

(71) We, TRONICAIR INTERNATIONAL LIMITED, a British Company of Acre House, Stirling Road, Kilsyth, Glasgow G65 0PT, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to temperature control apparatus.

According to one aspect of the present invention there is provided a temperature control apparatus comprising: temperature sensing means; an electronic switch which, in operation, is switched by the output of the temperature sensing means, and which, in operation, controls operation of, for example, heating means; and a voltage converter comprising a non-resistive and non-inductive first series path between a first line and a second line including first reactive means, a first unilaterally conductive device and second reactive means, a second series path between the first line and the second line including the first reactive means, the arrangement being such that when an alternating voltage supply is directly connected across the first and second lines, current flows through the first and second series paths maintaining a substantially constant AC voltage across the first reactive means, a substantially constant DC voltage appearing across the second reactive means to power said electronic switch.

The term "unilaterally conductive device" used in the specification and claims is intended to include not only devices such as diodes but also devices such as zener diodes.

The first reactive means may comprise a variable capacitor connected between the first line and a common junction point between the first and second series paths. Alternatively the first reactive means may comprise a plurality of capacitors having different capacitance values and selectively connectable between the first line and a common junction point between the first and second series paths. In the latter case, the apparatus may include a multi-position switch for selectively connecting the capacitors between the first line and said common junction point.

Preferably the apparatus includes a unilaterally conductive voltage limiting device for determining the magnitude of the DC voltage.

According to another aspect of the present invention there is provided temperature control apparatus comprising: temperature sensins means; an electronic switch which, in operation is switched by the output of the temperature sensing means, and which, in operation, controls operation of, for example, heating means; and a voltage converter comprising a non-inductive and non-resistive first series path between a first line and a second line including first reactive means, a first unilaterally conductive device and second reactive means, a second series path between the first line and the second line including the first reactive means and a second unilaterally conductive device, the first unilaterally conductive device permitting current flow from the first line to the second line whilst the second unilaterally conductive device prevents current flow from the first line to the second line, the arrangement being such that when an alternating voltage supply is directly connected across the first and second lines, a substantially constant DC voltage appears across the second reactive means and is applied to power said electronic switch.

In one embodiment the first reactive means comprise a variable capacitor connected between the first line and a common junction point between the first and second unilaterally conductive devices.

The second reactive means may be connected in parallel with a resistive component.

In another embodiment the first reactive means comprises a plurality of capacitors having different capacitance values and selectively connectable between the first line and a common junction point between the first and second unilaterally conductive devices. The temperature control apparatus may include a multi-position switch for selectively connecting the capacitors between the first line and said common junction point.

The second reactive means may be connected in parallel with a unilaterally conductive voltage limiting device. The unilaterally conductive voltage limiting device may be a zener diode.

The temperature control apparatus may include a coil of a reed switch connected in parallel with the second reactive means to be operated by the DC voltage appearing across the second reactive means.

Preferably the second reactive means is an electrolytic capacitor.

The second series path may include a variable resistor to reduce or prevent harmonic distortion of the alternating voltage supply when a load is connected across a second reactive means and to produce a plurality of DC voltages.

Alternatively, the second series path may include a third reactive means connected so that a substantially constant DC voltage appears thereacross when the alternating voltage supply is connected across the first and second lines. A or a further unilaterally conductive voltage limiting device may be connected in parallel with the third reactive means to produce a plurality of DC voltages or summated DC voltages.

Preferably the first and second unilaterally conductive devices together with third and fourth unilaterally conductive devices constitute a diode bridge, the arrangement being such that, in operation, when the alternating current supply is connected across the first and second lines, a substantially constant DC voltage appears across the third and fourth unilaterally conductive devices.

Preferably the unilaterally conductive devices are diodes.

The temperature sensing means may comprise a plurality of temperature sensors connected in parallel. The temperature sensing means may consist of one or more thermistors.

The temperature control apparatus may include mechanical switch means connected to be operated by the output of the electronic switch. The mechanical switch means may be a relay for controlling operation of heating means.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:

Figure 1 is a circuit diagram of one embodiment of a voltage converter of a temperature control apparatus according to the present invention;

Figure 2 is a circuit diagram of a second embodiment of a voltage converter of a temperature control apparatus according to the present invention;

Figure 3 is a circuit diagram of a modification of the voltage converter of Figure 2;

Figure 4 is a circuit diagram of another embodiment of a voltage converter of a temperature control apparatus according to the present invention;

Figure 5 is a circuit diagram of yet another embodiment of a voltage converter of a temperature control apparatus according to the present invention;

Figure 6 illustrates graphically the operation of the voltage converter of Figure 5.

Figure 7 illustrates graphically temperature rise against time for a space for changes in external temperature;

Figure 8 illustrates graphically change in differential relative to changes in the rates of temperature change illustrated in Figure 7;

Figure 9 is a circuit diagram of one embodiment of a temperature control apparatus according to the present invention; and

Figure 10 illustrates a control device for temperature control apparatus according to the present invention.

Throughout the drawings, like parts have been designated by the same reference numerals.

Referring first to Figure 1, there is illustrated one embodiment of a voltage converter of a temperature control apparatus according to the present invention. An alternating current supply is connected to lines L1, L2. Two series paths are formed between the lines L1, L2. The first series path connects the line L1 to the line L2 *via* a variable capacitor C1, a diode D1 and a parallel arrangement consisting of a fixed value electrolytic capacitor C2 and a variable value resistor R1. The second series path connects the line L1 to the line L2 *via* the variable capacitor C1, a diode D2 and a variable resistor R2.

An alternating voltage appears across the variable capacitor C1 but this alternating voltage has a DC component the magnitude and polarity of which is dependant upon the magnitude of the alternating current flowing into the diodes D1, D2. A rectified DC voltage appears across the capacitor C2 and also between terminals P, Q. Adjustment of the resistance value of the variable resistor R2 balances the DC component of the alternating current flowing through the capacitor C1 to reduce or prevent harmonic distortion of the alternating current supply. Thus, in effect, the variable resistor R2 is adjusted to balance a load X1 connected between terminals P, Q. It will be appreciated that an alternating current output of reduced amplitude, compared to the amplitude of the alternating current supply, appears between the terminal P and a terminal R.

Thus a variable amplitude DC voltage appears between the terminals P, Q and a variable amplitude AC voltage appears between the terminals P, R.

Referring now to Figure 2, there is illustrated a second embodiment of a voltage converter of a temperature control apparatus according to the present invention. The voltage converter of Figure 2 is a development of the voltage converter of Figure 1. Whilst in Figure 2 the capacitor C1 is shown as being a fixed value capacitor, it may be a variable capacitor as shown in Figure 1. The resistor R1 of the voltage converter of Figure 1 is replaced by a zener diode Z1 in the voltage converter of Figure 2. The second series path between the lines L1, L2 in the voltage converter of Figure 2 is constituted by the capacitor C1, the diode D2 and a parallel arrangement consisting of a zener diode Z2 and a fixed value electrolytic capacitor C3. The zener diodes Z1, Z2 are a matched pair.

In this embodiment a positive DC voltage appears between the terminals Q, R and a negative DC voltage appears between a terminal R′ and a terminal S. As with the voltage converter of Figure 1, an alternating voltage appears between the terminals QP, R. A DC voltage appears between terminals T, U and this DC voltage has an amplitude which is twice the magnitude of the voltage appearing between terminals R, Q and between terminals R′, S. A terminal V enables the alternating current supply to be taken between the lines L1, L2. The voltage converter of Figure 2 permits outputs to be taken between terminals R′, S terminals T, U and terminals R, Q simultaneously to drive separate circuits (not shown).

The purpose of the zener diodes in the voltage converter of Figure 2 is to provide a balanced load across the capacitor C1 to reduce or prevent harmonic distortion of the alternating current supply when a load X2 connected between the terminals R′, S and the load X1 connected between the terminals R, Q are unbalanced, i.e. are of different power rating. The components in Figure 2 indicated by dotted lines act as throttle devices to prevent surge current in the event that a reactive load is connected between terminals R, Q.

Figure 3 illustrates a modification of the voltage converter of Figure 2. In place of the capacitor C1, two capacitors C4, C5 are provided and are selectively connected to a common junction point between the diodes D1, D2 by a multi-position change-over switch SW1. This arrangement constitutes a variable capacitor since the capacitance value between the line L1 and the common junction point between the diodes D1, D2 may be changed by means of the change-over switch SW1.

In Figure 3, a coil RS1 of a first reed switch, connected in series with a variable trimmer resistor T1, is provided as the load X1 of Figure 2. Similarly, a coil RS2 of a second reed switch, connected in series with a variable trimmer resistor T2, is provided as the load X2. The resistor T1 is adjusted so that the first reed switch will operate when the change-over switch SW1 is connected to the capacitor C5 between the line L2 and the common junction point between the diodes D1, D2. Furthermore, the resistor T2 is adjusted so that the second reed switch will operate when the change-over switch SW1 connects the capacitor C4 between the line L1 and the common junction point between the diodes D1, D2.

Figure 4 illustrates a further embodiment of a voltage converter of a temperature control apparatus according to the present invention. As in the embodiments described above, an alternating current supply is connected between the lines L1, L2. An output is taken between terminals W, X between which is connected a zener diode Z3. Fixed value electrolytic capacitors C6, C7 are connected between the terminals W, X respectively and the line L2. A diode bridge circuit, composed of diodes D3, D4, D5, D6 is connected with the diode D3 between the capacitor C1 and the terminal W, the diode D6 between the line L2 and the terminal W, the diode D5 between the line L2 and the terminal X and the diode D4 between the terminal X and the capacitor C1.

When the line L1 is positive with respect to line L2, current flows *via* the capacitor C1 and the diode D3, the capacitor C6 to the line L2. Current also flows *via* the capacitor C1, the diode D3, a load (not shown) connected between the terminals W, X the diode D5 to the line L2. When the line L2 is positive with respect to line L1, current flows via the diode D6, the load connected between the terminal W, X, the diode D4 and the capacitor C1 to the line L1. At the same time, current flows *via* the capacitor C7, the diode D4 and the capacitor C1 to the line L1.

The capacitor C6 discharges when current is flowing in the diode D6 and the capacitor C7 discharges when current is flowing in the diode D3. The discharge path for the capacitor C6 is *via* the load and the zener diode Z3 connected between the terminals W, X and the diode D5 to the line L2. The discharge path for the capacitor C7 is *via* the diode D6 and the load and the zener diode Z3 connected between the terminals W, X.

The capacitors C6, C7 discharge 180° out of phase with the alternating current supply, thus constituting a smoothing circuit to remove saw-tooth ripple which would be present in a capacitive load connected between the terminals W, X. Thus a stable DC voltage appears across the terminals W, X whilst the voltage between the line L1 and the terminal W and the voltage between the line L1 and the terminal X is fluctuating with the alternating current supply.

Since the capacitors C6, C7 are electrolytic, the charge held across the load connected between the terminals W, X is relatively large and the duplicated push-pull function of the capacitors C6, C7 is lifted or lowered relative to the DC resistance of the diodes D6, D5 respectively.

The voltage converters described above have a considerable power handling capacity and heat dissipation problems, normally associated with variable resistors and transformers, are avoided.

Figure 5 is a circuit diagram of another embodiment of a voltage converter of a temperature control apparatus according to the present invention. The voltage converter of Figure 5 is based upon the voltage converter of Figure 2 but incorporating the modifications of Figures 3 and 4.

In the voltage converter of Figure 5 an alternating current supply is connected between the lines L, L2. An alternating current output appears between the terminals R′, Q, a positive DC voltage appears between the terminals R, P, a negative DC voltage appears between the terminals R′, S as in the voltage converter of Figure 2. Moreover, a DC voltage appears between the terminals W, X as in Figure 4. The capacitors C4, C5 selectively produce a voltage change across the coils RS1, RS2 depending upon the position of the switch SW1. The coil RS1 controls operation of three reed switches RS1—1, RS1—2, RS1—3 and the coil RS2 controls operation of a reed switch RS2—1. The reed switches have a changeover switch action and a normally closed terminal 13 of the reed switch RS1—1 is connected to the line L2 *via* the diode D6. A common terminal 12 of the reed switch RS1—1 is connected to the diode D3, the capacitor C6 and one side of the zener diode Z3. The other side of the zener diode Z3 is connected to a common terminal 14 of the reed switch RS1—2. A normally closed terminal 15 of the reed switch RS1—2 is connected to the anode of the diode D4 and also to a terminal 17 of the reed switch RS1—3 which is connected to terminal 20 of the reed switch RS 2—1.

A normally open terminal 16 of the reed switch RS1—2 is connected to the line L2. A normally closed terminal 18 of the reed switch RS1—3 is connected to the anode of the diode D5, whose cathode is connected to the line L2. A normally open contact 19 of the reed switch RS1—3 is connected *via* the zener diode Z4 to the line L2. A normally closed terminal 21 of the reed switch RS2—1 is connected *via* the electrolytic capacitor C7 to the line L2. A normally open contact 22 of the reed switch RS2—1 is connected to a variable resistor R3 and the variable resistor R3 being directly coupled to line L2.

The resistors T1, T2 are adjusted so that, with the selection by the switch SW1 of the capacitor C5, only the coil RS1 is energised sufficiently to cause the reed switches RS1—1, RS1—2, RS1—3 to engage. The voltage across the coil RS1 and the resistor T1 may be below that of the stabilised voltage of the zener diodes Z1, Z2 but having a holding charge maintained by the capacitor C2. The adjustment of the resistor T2 is opposite to that of the resistor T1 ensuring that only the coil RS1 is engaged. With the coil RS1 energised the diode D6 is disengaged from the terminal P one side of the zener diode Z3 is disconnected from the anode of the diode D4, the capacitor C7 and the anode of the diode D5. The zener diode Z3 is thus connected to the line L2 *via* the terminal 16. The reed switch RS1—3 connects the zener diode Z4 which has a stabilisation voltage equal to that of the zener diode Z3, to the negative side of the capacitor C7, and the anode of the diode D4. Thus current flows from the line L1 via the capacitor C1, the diode D3, the capacitor C6 and the zener diode Z3 to the line L2 providing DC voltage across the capacitor C6 stabilised by the zener diode Z3 when the line L1 is positive with respect to the line L2. When the line L2 is positive with respect to the line L1 current flows *via* the capacitor C7 the zener diode Z4, the diode D4 and the capacitor C1 to the line L1.

The balanced load current flowing into the diodes D3, D4 alternately discharge the capacitor C1 at the alternating frequency of the alternating current supply on lines L1, L2. The capacitor C7, being charged by the reverse cycle, provides a DC output equal to that of the capacitor C6, but where the terminal P is positive with respect to the terminal R′, the terminal S is negative with respect to the terminal R. The voltages appearing across the terminals R, S and the terminals P, R′ are equal and have equal power rating capacities and so can be used to drive two independent circuits (not shown). The DC voltage appearing across the terminals P, S is twice the magnitude of that appearing across the terminals R′, S or the terminals P, R.

When the capacitor C4 is selected by the switch SW1, the voltages across the zener diodes Z1, Z2 reach saturation and the coils RS1, RS2 are both energised. This results in the capacitor C7 being disconnected from the anode of the diode D4 and the resistor R3 being connected between the anode of the diode D3 and the line L2 so providing only one output across the terminals R′, P and isolating the terminals S, R and the terminals P, S.

Selection of the open circuit position of the switch SW1, de-energises both the coils RS1, RS2, allowing current to flow from the line L1 *via* the capacitor C1, the diode D3, the capacitor C6 to the line L2. Moreover current flows from the line L1 *via* the capacitor C1, the diode D3, a load (not shown) connected between the terminals W, X and the diode D5 to the line L2. The diodes D5, D6 provide reverse voltage protection for the capacitors C7, C6 respectively.

Current flow across the diode D3 in Figure 4 and Figure 5 is illustrated by waveform A in Figure 6. The waveform A is influenced by current flowing through the diode D3, the capacitor C6 and the load XL connected between the terminals W, X, the zener diode Z3 and the diode D5. The current flowing in the load is influenced by the current flowing across the diode D3 and also that flowing from the capacitor C7 *via* the diode D6 and the current flowing in the zener diode Z3 from the capacitor C7. The waveform A is influenced by the charging of the capacitor C6, as well as the current flowing through the load connected between the terminals W, X, and zener diode compensation taking place.

Waveform B in Figure 6 compares the voltage amplitude across the capacitor C7 (line V_{C7}) with that across the load connected between the terminals WX (line V_{XL}). The voltage difference is created by the voltage drop across the diode D5, (waveform C) which displays a similar characteristic to that of a saw tooth but is smoother. The voltage appearing across the load connected between the terminals W, X is shown by the waveform D.

A temperature control apparatus according to the present invention may be applied to the field of electronic space temperature measurement. If an electronic amplifier of temperature control apparatus is located in a housing, together with a temperature sensing means, even if the housing has an extremely low thermal capacity, power dissipation from a conventional voltage converter e.g. comprising a transformer and rectifiers for transforming and rectifying the standard alternating current supply (240V) to produce a lower DC voltage to drive the electronic amplifier, will create heat within the housing thus affecting adversely the behaviour of the apparatus. The voltage converters described above, do not have any substantial heat dissipation, and so a temperature control apparatus according to the present invention does not have the disadvantage of conventional temperature control apparatus. As will be appreciated, power dissipation is reduced by using a reactive component, such as a capacitor to attenuate the alternating current supply the reactive component losing its reactive nature when coupled to drive a DC circuit.

Conventional room thermostats whose behaviour produces on/off control for example of space heating, have a detection member whose thermal inertia must be overcome before there can be mechanical displacement of a switching mechanism. This detection member determines two basic control characteristics of the thermostat; firstly, it determines a fundamental response curve to change of ambient temperature and secondly, it determines a basic switching differential of the thermostat. The energy that must be absorbed by the detection member to operate the switching mechanism dictates the switching differential and the mass and thermal conductivity of the detection member determines the response time of the thermostat. The mechanical energy required to operate the switching mechanism is generally proportional to a load current rating of the switching mechanism, and the relationship of mechanical displacement of the detection member to energy is dictated by its mass. The combination of high mass of the detection member with varying rates of change of ambient temperature will produce a controlled switching differential that will increase with increase in rates of change of temperature. Low mass and large displacement detection members produce low energy outputs and therefore the current capable of being switched by the switching mechanism decreases. It is possible that current resistance drop over switch contacts of the switching mechanism will produce self heat within a housing of the thermostat. Self heat will influence the body temperature of the detection member relative to the ambient temperature. As the detection member is responsive to changes in temperature and it has no ability to differentiate self heat heat effects from ambient temperature change, then the control characteristics of the thermostat will be greatly influenced by self heat.

If the temperature change required to activate the switching mechanism causes a large change in the temperature in the space being controlled, it is possible to design an accelerator heater of low power consumption which energises when the switching mechanism is closed, to reduce the temperature difference between the closed and open positions of the switching mechanism. The accelerator heater reduces the temperature difference that the space is subject to and provides a more tolerable change of temperature in terms of comfort which is generally desirable. It should be remembered however that the thermostat is subject to heating load conditions in terms of ambient temperature changes which is reflected by an alteration in the ratio of the time for which the switching mechanism is closed to the time for which is is open. These changes in load condition will reflect a change in the rate of change of temperature in the space the temperature of which is to be controlled, and alter the ratio of space heat and self heat relative to the total heat requirement of the place, and thus sustain a deviation of the control point of the thermostat relative to the control point prior to the change in the heat requirement. Maximum self heat influence will produce the lowest controlled condition, and minimum self heat the highest controlled condition at any fixed control point.

The heat loss from a structure increases with an increase in the temperature difference across the structure and the inverse for a decrease in temperature difference. The response time of the detection member will likewise be faster for a larger temperature difference, and slower for a smaller temperature difference. The response time of the detection member can thus be increased by artificially raising the internal temperature control level of the control housing above that of the required ambient temperature by connecting a low power consumption internal heater across the thermostat live supply to neutral. However, as the heat loss through a wall increases with fall in external temperature, so the heat loss from this internal heater will increase under larger heat load demands producing a shift or deviation of its control point and a reduction in its sensitivity to temperature. These self heat techniques not only change the comfort level between closed and open positions of the switching mechanism but will also produce sustained deviation of the control point due to changes in rates of ambient temperature change and also proportional bands from the control point due to changes in the mark to space ratio of the open to closed times of the switching mechanism. The changes in rates of ambient temperature change will provide a change in the switching differential and therefore a change in the mean temperature of the controlled temperature rise. Any shift therefore in the mean temperature control level relative to the required temperature rise will be critical in the control of energy, as the energy level requirement is directly related to temperature rise.

Figure 7 illustrates graphically temperature rise against time for a space for three changes in external temperature. In each case the temperature rise is obtained by maximum output of a heater, no thermostat being used. Figure 8 indicates graphically change in differential relative to changes of rates of temperature change for the three conditions illustrated in Figure 7. Figure 9 is a circuit diagram of one embodiment of a temperature control apparatus according to the present invention which averts the problems associated with self heat effects and produces stable temperature control avoiding the significant excess energy consumption created by the self heat effects within conventional room thermostats, which cannot be avoided by using conventional electronic control for space temperature control purposes.

It can be seen from Figure 7 that should a constant controlled comfort level be required as indicated at D then the change in external ambient temperature will subject the control to different rates of temperature change as shown by curves A, B, C at points E, F, G. The thermal response of the detection member of a conventional thermostat will therefore lag the ambient temperature relative to the increase in temperature change as shown in Figure 8 by lines A′, B′, C′, and any use of self heat to reduce this lag will result in a sustained deviation of an equal value to that of mean temperature change due to the change of off to on time of the self heat affecting once again the rate of self heat plus ambient heat to operating heat requirement. From Figure 8 it can be seen that, for curve C, a mean control deviation of 2° in 16° is achieved i.e. $12\frac{1}{2}$% excess energy requirement, curve B gives a deviation of mean temperature of 3° in 12° temperature rise, and curve A gives a deviation of 4° in 8° temperature rise. Thus curve B represents a 25% excess energy requirement while curve A represents a 50% excess energy requirement.

To avoid these conditions or alleviate their effects, what is required is a temperature control device dissipating little power or changes of power resulting from changes in its control condition. The temperature control device should have small thermal inertia, a fast time constant, and consistent control differential under varying load conditions, thus providing stable control conditions resulting in significant energy conservations regardless of the fuel being used.

A temperature control apparatus having these properties is illustrated in Figure 9. This temperature control apparatus has a circuit to provide a stabilised DC voltage, this circuit consisting of a capacitor 36, diodes 38, 69 a reservoir capacitor 40, a stabilising diode 41 and a variable resistor 68. The capacitor 36, the diode 38 and the capacitor 40 are connected in series across the alternating current supply on lines A′, B′. A zener diode 41 is connected in parallel with the capacitor 40 to the line B′ of the alternating current supply. The diode 69 and the resistor 68 are connected as shown between a common junction point of the capacitor 36 and the diode 38 to the line B′. The capacitor 36 provides a push-pull AC component which is discriminated by the diodes 38 and 69 and charges the capacitor 40 with a DC voltage whilst its balancing component is dissipated by the resistor 68. The voltage current phase shift provided by the capacitor 36 provides low thermal dissipation of the potential of the alternating current supply when being transformed to its lowest voltage DC level, whilst the dissipation by the variable resistor 68 is of the order of milliwatts. A stabilised DC voltage thus appears across positive and negative rails 42 and 43, connected across the terminals of the zener diode 41. The temperature control device incorporates a resistance bridge of which temperature sensors F and F′, which may be thermistors, form part. The other parts of the resistance bridge are variable resistors 46, 70, fixed value resistors 44, 71, and a zener diode 67. A switching transistor 48 has its emitter connected to the rail 43 via an unilaterial semiconductor diode 52, whose low forward impedence allows the transistor 48 to conduct when the potential applied to its electrodes are correct. The base of the transistor 48 is connected to a common junction 47 and the collector of the transistor 48 to the rail 42 *via* a resistor 50. The base emitter bias of the transistor 48 is such that only the forward impedence of the diode 52 is in circuit when base emitter current flows, thus it follows that the potential at the emitter of the transistor 48 is only slightly above that of the negative rail 43, and the potential at the junction 47 is marginally above the negative rail 43 when its conducting state. This enables the sensitivity of the resistance bridge F F′ 44, 46, 67 to be increased so that the transistor 48 switches as the voltage at junction 47 passes through a well defined predetermined value. The sensor F′ in parallel with the sensor F provides a reduced current for self heat purposes whilst the zener diode 67 is carefully chosen so that, in its non-conducting state, the voltage at the junction 47 is well defined to switch the transistor 48 if the resistor 46 is adjusted for heat demand so increasing the voltage in the line 42 and the junction 47. The effect of self heat current is suppressed by shunting the current flowing from the line 42 to the junction 47 *via* the zener diode 67, thus avoiding self heat effects producing proportional band parameters on the control by averting increased wattage dissipation across sensors F and F′.

The transistor 48, which is a NPN type transistor, has its collector connected to the base of a PNP transistor 54 through a resistor 74. The transistor 54 has its collector biased from the rail 43 *via* a resistor 58 whilst its emitter is biased from the line 42 through a resistor 60. The transistors 48, 54 constitute an amplifying switch, the base voltage at which these transistors conduct being clearly defined and very close to their respective emitters voltages. A further switching transistor 62 has its base connected to the collector of the transistor 54. The emitter of the transistor 62 is connected *via* a low powered relay coil 64 of an output relay RL to the line 42. The collector of the transistor 62 is connected to the rail 43 *via* a resistor 66.

A resistor 63 between the collector of the transistor 54 and the base of the transistor 62 and a resistor 58 produce output coupling essential to the correct operation of both the amplifying switch and the transistor 62. The resistor 74 is used to provide balance current in the inverse switching actions of the transistors 45 and 54 with switching of the transistor 62. Thus the power dissipated across the zener diode 41 is constant during operation of the amplifying switch and the transistor 62. As temperature rise is a function of the square of current, it is critical that the self heat generated within the temperature control device is therefore only marginally above that required for operation of the output relay RL and that the dissipation of power within the temperature control device is not changing relative to the demand condition in the space the temperature of which is to be controlled, and falsely influencing the sensors F and F′.

The temperature control apparatus of Figure 9 utilises only marginally more power than that required by the relay RL and will not produce falsely sensed temperatures.

The temperature control apparatus of Figure 9 operates in the following manner. The resistance of the sensors F, F′, varies as a function of temperature sensed thereby, and therefore alters the voltage developed between the junction 47 and the rail 43. This temperature dependant voltage is utilised to control the amplifying switch constituted by the transistors 48, 54. Through inverse action, the amplifying switch controls the switching transistor 62. Thus the transistors 48, 54 are conductive with current flow in components 52, 58, 50, 60 and 74 and the transistor 62 is conductive with current flow in components 66, 64, 63, 58 and these conditions are balanced in relationship to their inverse action. Such a control will therefore have a small differential, a very small proportional band, low sustained deviation, and stable control, will not be influenced by self heat, or structural temperature losses when wall mounted, and, as a result of its accurate control, produce a considerable energy saving over annual heat loss conditions, when compared with conventional room thermostats or electronic control, and allows the complete unit to be contained within one housing.

Figure 10 illustrates control device for temperature control apperatus according to the present invention having two separate inputs to achieve a common output. A master relay MR1 is fed from a common line L having terminals 1, 1A. Terminals 2, 2A are line switched terminals directly linked to terminals 3, 3A. A signal applied to the terminal 2 passes *via* a capacitor C25 and a diode D40 to a reservoir capacitor C26 thus energising the relay MR1 and connecting a terminal 5 to the line L. Terminals 4, 4A and 6 are connected to a line N. A temperature control apparatus as illustrated in Figure 9, is connected with terminals 1, 2, a heating plant connected to terminals 5, 6 and another temperature control apparatus as illustrated in Figure 9 is connected between terminals 1A, 2A so that two separate controls of the heating plant may be achieved. If the temperature control apparatus connected to the terminals 1, 2 is energised from an off-peak tariff alternating current supply, if the control apparatus connected to the terminals 1A, 2A, is energised by a direct tariff alternating current supply and if the temperature control apparatus connected to the terminals 1, 2 is set to control at a higher temperature than the temperature control apparatus connected to the terminals 1A, 2A, then the control device will operate as follows. The temperature control apparatus connected to the terminals 1A, 2A when demanding heat will connect the line voltage at the terminal 1A to the terminal 2A, the positive half wave of the alternating current supply will pass through a capacitor C25A *via* a diode D40A, be blocked by the diode D40 and charge the capacitor C26 thus energising the relay MR1 and energising the heating plant, the relay MR1 being under cyclic control of the temperature control apparatus connected to the terminals 1A, 2A. With energising of the temperature control apparatus connected to the terminals 1,A, the terminal 2 energises, positive half waves of the alternating current supply passing through the capacitor C25 and the diode D40 and being blocked by the diode D40A and attempting to charge the capacitor C26. Thus both the capacitors C25, C25A will tend to charge with a DC potential. However, the diodes D41, D41A and resistors R21, R21A keep the respective capacitors reactive. With the rise in temperature created by the heating plant, the terminal 2A would de-energise first if the temperature control apparatus connected thereto is set at a lower temperature and the capacitor C26 will remain charged *via* the diode D40 until the temperature set in the temperature control apparatus connected to terminals 1, 2 is reached. cyclic control is then obtained at the set temperature until the off peak tariff alternating current supply period is over. The terminal 2 will de-energise, the capacitor C26 will discharge de-energising the relay MR1, which will not be re-energised until the temperature in the space the temperature of which is to be controlled falls below that of the temperature control apparatus connected to the terminals 1A, 2A.

To obtain equal charge conditions on capacitors C25, C25A and thus produce balanced current conditions from the mains voltage supply, the resistor R21A can be eliminated and the cathode of the diode D41A connected to the cathode of the diode D41. If the charge in the capacitors C25, C25A is unbalanced in any half-wave, they will provide harmonic components on the mains voltage supply and also unequal energy discharges over components in which it is essential to keep the wattage discharge to a minimum to avoid self heat effects.

WHAT WE CLAIM IS:—

1. A temperature control apparatus comprising: temperature sensing means; an electronic switch which, in operation, is switched by the output of the temperature sensing means, and which, in operation, controls operation of, for example, heating means; and a voltage converter comprising a non-resistive and non-inductive first series path between a first line and a second line including first reactive means, a first unilaterally conductive device and second reactive means, a second series path between the first line and the second line including the first reactive means, the arrangement being such that when an alternating voltage supply is directly connected across the first and second lines, current flows through the first and second series paths maintaining a substantially constant AC voltage across the first reactive means, a substantially constant DC voltage appearing across the second reactive means to power said electronic switch.

2. An apparatus as claimed in claim 1 in which the first reactive means comprises a variable capacitor connected between the first line and a common junction point between the first and second series paths.

3. An apparatus as claimed in claim 1 in which the first reactive means comprises a plurality of capacitors having different capacitance values and selectively connectable between the first line and a common junction point between the first and second series paths.

4. An apparatus as claimed in claim 3 including a multi-position switch for selectively connecting the capacitors between the first line and said common junction point.

5. An apparatus as claimed in any of claims 1, 3 and 4 including a unilaterally conductive voltage limiting device for determining the magnitude of the DC voltage.

6. An apparatus as claimed in claim 5 in which the unilaterally conductive voltage limiting device is a zener diode.

7. An apparatus as claimed in any preceding claim including a coil of a reed switch connected in parallel with the second reactive means to be operated by the DC voltage appearing across the second reactive means.

8. A temperature control apparatus comprising: temperature sensing means; an electronic switch which, in operation is switched by the output of the temperature sensing means, and which, in operation, controls operation of, for example, heating means; and a voltage converter comprising a non-inductive and non-resistive first series path between a first line and a second line including first reactive means, a first unilaterally conductive device and second reactive means, a second series path between the first line and the second line including the first reactive means and a second unilaterally conductive device, the first unilaterally conductive device permitting current flow from the first line to the second line whilst the second unilaterally conductive device prevents current flow from the first line to the second line, the arrangement being such that when an alternating voltage supply is directly connected across the first and second lines, a substantially constant DC voltage appears across the second reactive means and is applied to power said electronic switch.

9. An apparatus as claimed in claim 8 in which the first reactive means comprises a variable capacitor connected between the first line and a common junction point between the first and second unilaterally conductive devices.

10. An apparatus as claimed in claims 8 or 9 in which the second reactive means is connected in parallel with a resistive component.

11. An apparatus as claimed in claim 8 in which the first reactive means comprises a plurality of capacitors having different capacitance values and selectively connectable between the first line and a common junction point between the first and second unilaterally conductive devices.

12. An apparatus as claimed in claim 11 including a multi-position switch for selectively connecting the capacitors between the first line and said common junction point.

13. An apparatus as claimed in any of claims 8, 11 and 12 in which the second reactive means is connected in parallel with a unilaterally conductive voltage limiting device.

14. An apparatus as claimed in claim 13 in which the unilaterally conductive voltage limiting device is a zener diode.

15. An apparatus as claimed in any preceding claim including a coil of a reed switch connected in parallel with the second reactive means to be operated by the DC voltage appearing across the second reactive means.

16. An apparatus as claimed in any preceding claim in which the second reactive means is an electrolytic capacitor.

17. An apparatus as claimed in any preceding claim in which the second series path includes a variable resistor to reduce or prevent harmonic distortion of the alternating voltage supply when a load is connected across a second reactive means and to produce a plurality of DC voltages.

18. An apparatus as claimed in any of claims 8 to 16 in which the second series path includes a third reactive means connected so that a substantially constant DC voltage appears thereacross when the alternating voltage supply is connected across the first and second lines.

19. An apparatus as claimed in claim 18 in which a or a further unilaterally conductive voltage limiting device is connected in parallel with the third reactive means to produce a plurality of DC voltages or summated DC voltages.

20. An apparatus as claimed in any preceding claim in which the first and and second unilaterally conductive devices together with third and fourth unilaterally conductive devices constitute a diode bridge, the arrangement being such that, in operation, when the alternating current supply is connected across the first and second lines, a substantially constant DC voltage appears across the third and fourth unilaterally conductive devices.

21. An apparatus as claimed in any preceding claim in which the unilaterally conductive devices are diodes.

22. An apparatus as claimed in any preceding claim in which the temperature sensing means comprises a plurality of temperature sensors connected in parallel.

23. An apparatus as claimed in any preceding claim in which the temperature sensing means consists of one or more thermistors.

24. An apparatus as claimed in any preceding claim including mechanical switch means connected to be operated by the output of the electronic switch.

25. An apparatus as claimed in claim 24 in which the mechanical switch means is a relay for controlling operation of heating means.

26. A temperature control apparatus substantially as herein described with reference to and as shown in the accompanying drawings.

J. MILLER & CO.,
Chartered Patent Agents,
Agents for the Applicants,
Lincoln House,
296—302 High Holborn,
London WC1V 7JH.

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1599757 COMPLETE SPECIFICATION

6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig.1.

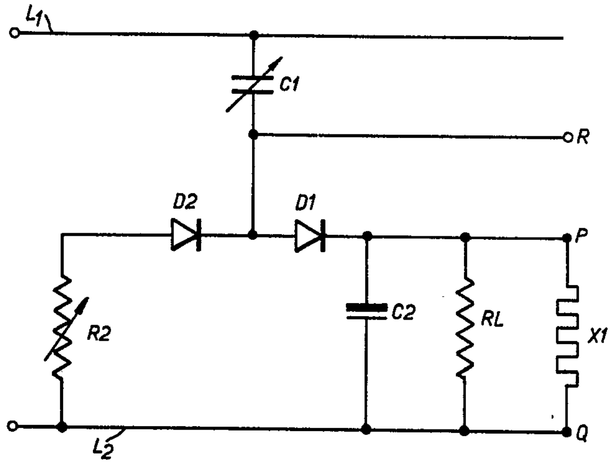


Fig.2.

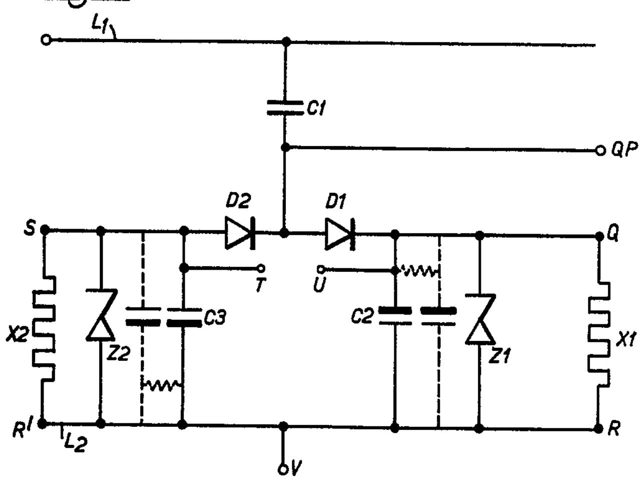
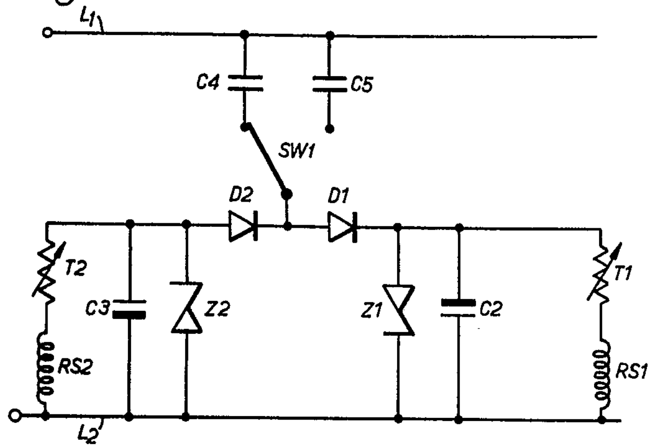


Fig.3.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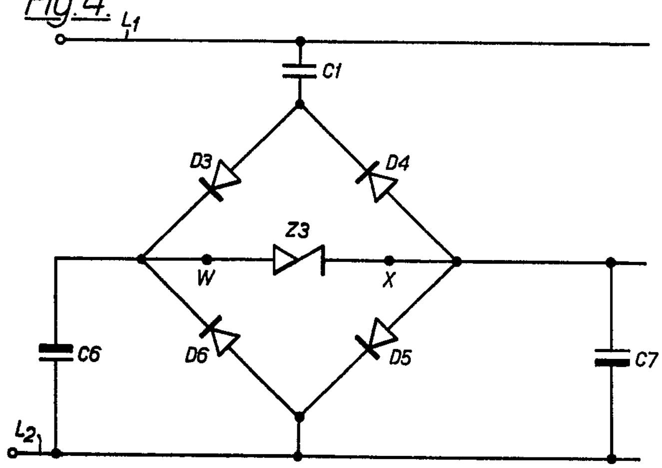
D2
D1
T2
C3
Z2
Z1
C2
T1
RS2
RS1
L2

Fig.4.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D4
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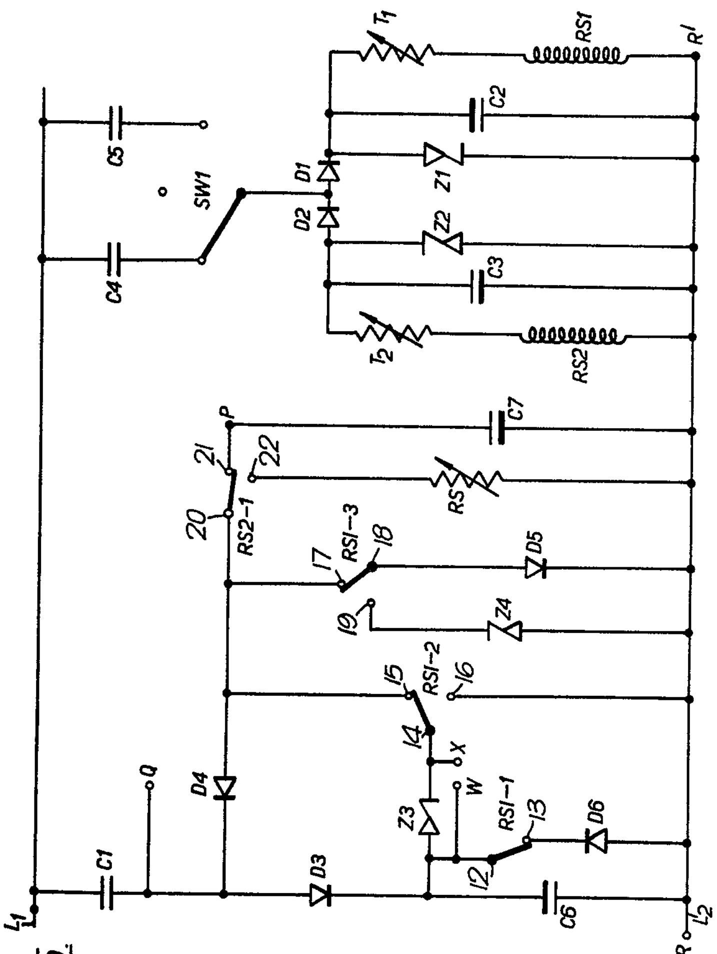
W
X
C6
D6
D5
C7
L2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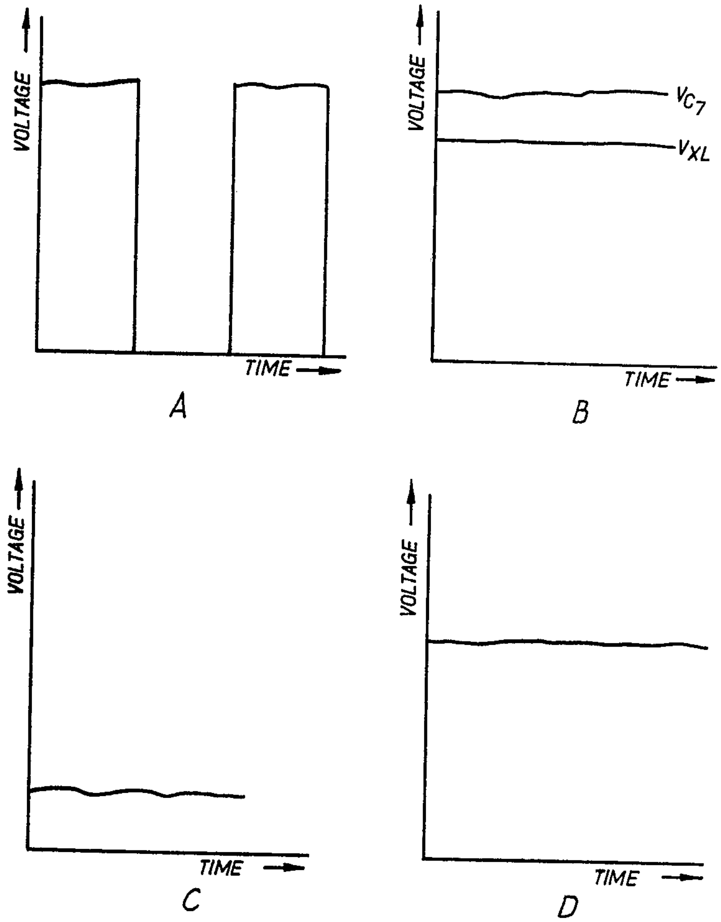
SW1
D1
D2
Z1
Z2
C2
C3
T1
T2
RS1
RS2
R'
P
21
22
20
RS2-1
C7
RS
17
RSI-3
18
D5
19
Z4
15
RSI-2
16
14
X
W
D4
D3
Z3
RSI-1
13
12
D6
C6
R
L2

Fig.5.

Fig.6.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TIME
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VOLTAGE
V_{C7}
V_{XL}
TIME
B
VOLTAGE
TIME
C
VOLTAGE
TIME
D

1599757 COMPLETE SPECIFICATION

6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 5

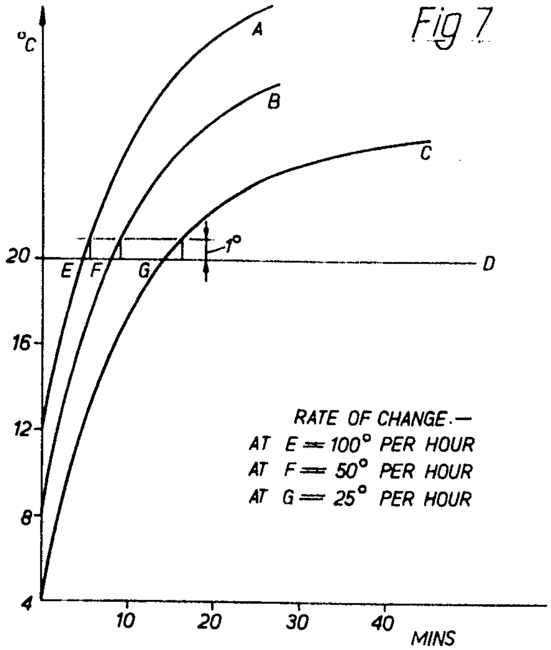


Fig 7

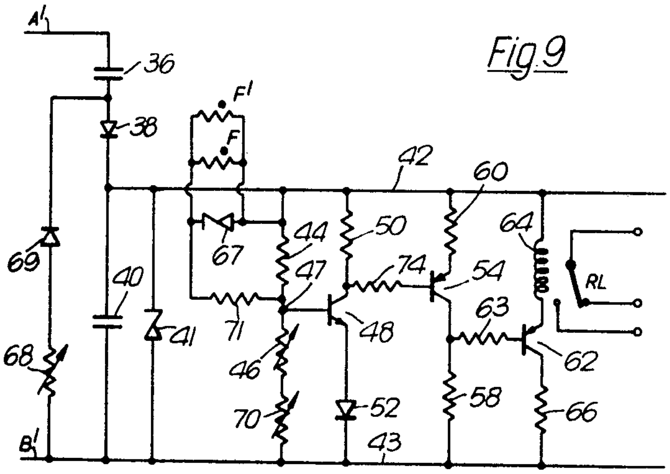
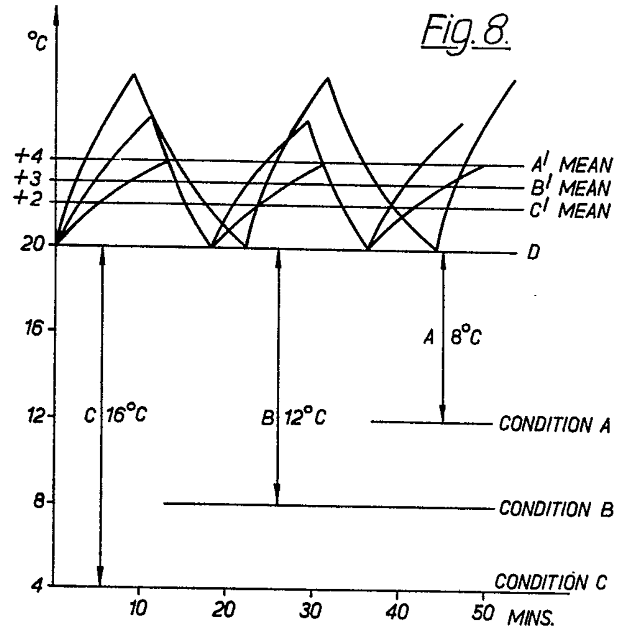


Fig 9

Fig. 8.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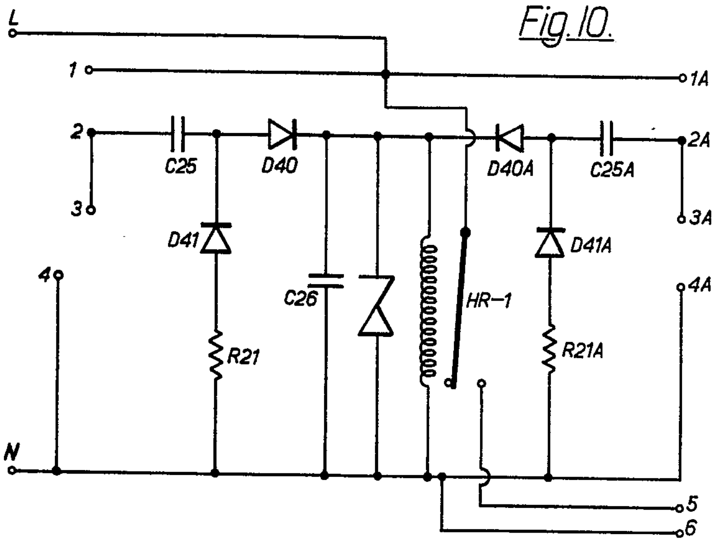
+3
+2
20
16
12
8
4
A' MEAN
B' MEAN
C' MEAN
D
A 8°C
C 16°C
B 12°C
CONDITION A
CONDITION B
CONDITION C
10
20
30
40
50
MINS.

Fig. 10.


L
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3A
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4A
N
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6
C25
D40
D40A
C25A
D41
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C26
HR-1
R21
R21A