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ELECTRIC REGULATION

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Fig. 1.

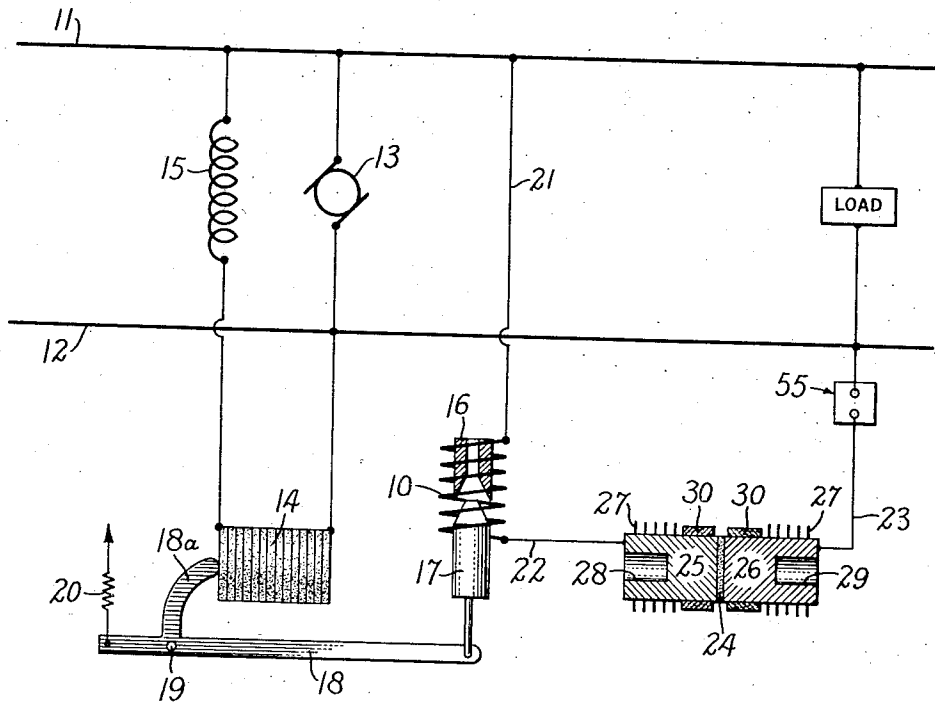


Fig. 2.

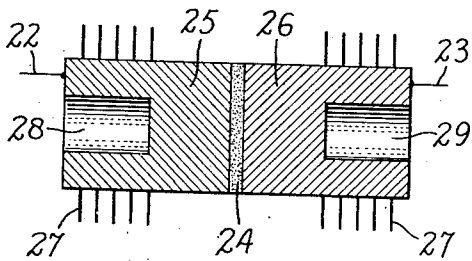
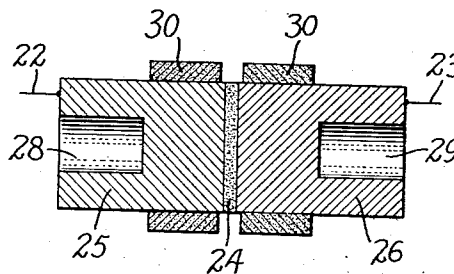


Fig. 3.



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ELECTRIC REGULATION

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Original application January 21, 1935, Serial No. 2,707, now Patent No. 2,067,604, dated January 12, 1937. Divided and this application December 17, 1936, Serial No. 116,285

3 Claims. (Cl. 171-229)

This invention relates to electric regulation.

One of the objects of this invention is to provide a simple, practical and inexpensive regulating system and apparatus that will be of efficient and reliable action and capable of precision and accuracy of regulation throughout the peculiarly varying conditions of practical use, particularly variations in temperature. Another object is to provide a system and apparatus for the regulation of electrical circuits that will be of wide adaptability and use in successfully coping with the heretofore unsurmounted difficulties caused by changes in temperature. Another object is to provide an electromagnetic control apparatus for a system or electrical apparatus that will maintain dependably and efficiently the desired or intended standard of operation or control thereof in spite of changes in resistance of the electromagnetic winding due to temperature changes, and to provide such a control system or apparatus capable of a wide range of use in the electrical arts. Another object is to provide a system or apparatus of the above mentioned character in which the efficiency is vastly improved, energy consumption diminished, and genuine precision of action achieved. Another object is to provide a system or apparatus of the above mentioned character that will be of simple and inexpensive construction, capable of ready and convenient installation, and compact and rugged in construction. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combination of elements, and arrangements of parts as will be exemplified in the structure to be hereinafter described and the scope of the application of which will be indicated in the following claims.

This application is a division of my copending application, Serial Number 2,707, filed January 21, 1935, patented January 12, 1937, No. 2,067,604.

In the accompanying drawing, in which are shown several of the various possible embodiments of certain mechanical features of my invention,

Figure 1 is a diagrammatic representation of one form of regulating apparatus and system, part of the former being shown in cross-section;

Figure 2 is a vertical sectional view of the resistance unit with the heat insulation removed; and

Figure 3 is a vertical sectional view of the resistance unit with the heat transfer fins removed.

Similar reference characters refer to similar parts throughout the several views in the drawing.

As conducive to a clearer understanding of certain features of my invention it might at this point be noted that in the electrical arts, particularly in the field of, for example, regulation of electric circuits for constancy of voltage, reliance has to be placed upon an electromagnetic winding in the form of a coil or helix, an electromagnet with an armature controlled thereby, or a solenoid winding with a core controlled thereby; in such an electromagnetic winding, of which examples have just been noted purely by way of illustration, the conductor, usually copper wire, of which the winding is made, is subject to variations in temperature due to electrical heat losses in the resistance of the conductor itself. The electrical energy dissipated in the form of heat in the conductor is proportional to the product of the square of the current by the resistance of the conductor itself. With change in temperature, the resistance of the conductor and hence of the winding also changes. The temperature, and hence the resistance, of the conductor making up the winding is thus subject to relatively great changes, being further affected by such variables and factors as the temperature of the atmosphere, the temperature of the apparatus with which the winding may be closely associated physically, the rate of heat dissipation by the winding, the length of the periods of energization of the winding as compared with the length of the periods when the winding is de-energized, and other factors.

If therefore the winding is intended to control, through its magnetic induced flux, any related apparatus, mechanisms, circuits, or the like, the production of a critical value of flux must be dependent upon achievement of a fixed or critical value of current through the coil, but due to the variability of the resistance of the winding as above pointed out, the voltage necessary to achieve this given value of current from the winding will necessarily vary with the variations in the resistance.

Let it be assumed, for example, that the winding is to achieve, with related means, constancy of voltage in an electrical circuit; if the winding and its related parts are so constructed as to regulate for constancy of current (to produce the above mentioned flux), the voltage necessary to maintain this constancy of current through the winding varies with the change in resistance of the conductor of the winding, assuming that the

winding is bridged directly across the circuit the voltage of which is to be maintained constant. The result is that very substantial departures from the desired value of voltage are caused by the change in the resistance of the winding.

It has heretofore been proposed to counteract these effects by placing in series with the winding a relatively large external resistance of zero temperature coefficient of resistance and such an arrangement has become wide practice; the theory of such practice is that, by thus greatly increasing the total resistance of the winding circuit, the change in resistance that takes place within the winding itself becomes a small enough factor relative to the total circuit resistance to tolerate the nevertheless inescapable fact of change in voltage of regulation. However, such an arrangement does not remedy the difficulty and is moreover of limited scope of application, not to mention its wastefulness of material and electrical energy or low efficiency. Where the energy requirements of the winding or controlling coil are relatively large, the applicability of this prior practice fails unless many disadvantages can still be tolerated.

For example, let it be assumed that the control winding has to be constructed so large that its energy requirement is 100 watts; if the change in resistance of such a winding causes a 15% voltage variation and if it is desired to reduce that variation to a maximum of 5%, it is necessary to have connected in series with the winding an external resistance which is twice that of the winding, the external resistance requiring therefore that an additional 200 watts must be dissipated therein. If the range of change of temperature of the control winding is still greater, with the corresponding change in resistance, then even larger values of external resistance must be used to reduce the ultimate voltage variation. These instances illustrate some of the distinct disadvantages of such prior practice which, in no case, it will be seen, achieve an entire absence of voltage variation. If the winding therefore is employed for regulation of voltage, constancy of voltage cannot be and is not achieved.

One of the dominant aims of this invention is to do away with such disadvantages as have just been noted above and to provide a system and apparatus in which genuine control or regulation may be dependably and inexpensively achieved, and maintained throughout the widely varying conditions of practical use.

Referring now to Figure 1 of the drawing, I have there diagrammatically shown an electromagnetic winding 10 of the general character above mentioned; by way of illustration and to clarify a ready understanding of my invention, I have shown the winding 10 as the control or regulating winding in a system or apparatus for achieving constancy of voltage across the circuit 11—12, winding 10 being connected, as more clearly hereinafter described, to be responsive to that function (voltage, in this instance) of the electrical energy in the circuit 11—12 which it is desired to maintain constant.

In so far as certain features of my invention are concerned, the winding 10 may control, affect, or actuate or coact with any desired or suitable parts or apparatus which are, by the winding 10, made to effect a correction of departures from the selected value of the function of the electrical energy that it is desired to maintain constant. For example, the winding 10 may be in the form of a relay for controlling a resistance

which in turn is made to affect the voltage across the circuit 11—12; thus for example, a generator 13 (either alternating current or direct current) may be the source of supply of electrical energy to the circuit 11—12 and the resistance, illustratively in the form of a carbon pile 14, may, under the control of the winding 10, affect the excitation of the field winding 15 of the generator 13, thus to control the voltage of the output of the electrical source 13.

By way of further illustration, the winding 10 may form part of a solenoid having a fixed core 16 and a coating movable core 17, these two parts being suitably shaped, as by tapering them as is indicated in Figure 1, so that, with respect to the mechanical resistance opposing movement of the movable core 17, the winding 10, at a given or intended energization, will hold the core 17 in whatever position it is moved throughout its range of movement. Movable core 17 may be connected to a bell crank lever 18 pivoted at 19, and having its one arm 18a operating upon the free or unanchored end of the carbon pile 14. A spring 20 opposes the pulling effort of the solenoid.

Disregarding resistance changes in the winding 10, increase in voltage across the circuit 11—12 increases the energization of the winding 10 beyond the value corresponding to the voltage desired to be maintained constant across the circuit 11—12, whereupon the pressure on the carbon pile 14 is lessened, its resistance increased, and the resultant decrease in the excitation of the generator 13 restores the voltage to normal. Should the voltage decrease, a reverse action takes place in that the corresponding decreased energization of the winding 10 disturbs the mechanical equilibrium theretofore existing and permits the spring 20 to swing the lever 18 in clockwise direction, thus increasing the pressure on the carbon pile 14 and correspondingly increasing the excitation of the generator 13 to restore its voltage to normal.

As pointed out above, where the winding 10 is to respond to changes in voltage, it is bridged across the circuit the voltage of which is to be affected. Accordingly one terminal of winding 10 is connected by conductor 21 to one side, conductor 11, of the circuit 11—12; the other terminal of winding 10 is connected by conductors 22 and 23 to the other side, conductor 12, of this circuit, but through a temperature-change compensating device generally indicated at R.

The device R includes a member 24 having a negative temperature coefficient of resistance and has thermally related to it means giving the part 24 a thermal capacity which is high compared to the thermal capacity of the part 24 itself. The winding 10 may be constructed in any suitable manner; whatever its physical construction, it embodies necessarily the mass of conductor (usually copper) of which it is wound together with such possible related parts as an iron core, parts either of solid dielectric material or of metal between which or upon which the conductor is wound, and like parts, giving the winding an ultimate mass having a certain area of exposed surface or surfaces which can and do function as heat-radiating or heat-dissipating surfaces. Depending upon such factors as these, varying they do with the design, purpose, power or physical dimensions of the winding, the winding is found to have a thermal capacity which is, relatively speaking, large, and it is found that the winding has a corresponding characteristic of

rate of rise of temperature beginning with the flow therethrough of its rated energizing current and hence also a corresponding characteristic of rate of decrease of temperature when the energizing current is cut off. The relatively large ratio of thermal capacity of the coil to cooling surface area of the coil makes this rate of change of temperature relatively low.

The device R (Figure 1) embodying a relatively small part 24 (inherently of small thermal capacity) has thermally related to it one or more members, illustratively two in number as shown at 25 and 26 in Figure 1, of a material like cast iron, steel, brass, or other suitable metal or material, in sufficient volume or mass to give the device R, with respect to the latter's heat-radiating surfaces, a high thermal capacity, and moreover a ratio of thermal capacity to heat-radiating surface of device R that is equal to or commensurate with the ratio of the thermal capacity of the winding 10 to the heat-radiating surface of the winding 10.

By way of illustration the part 24, having a negative temperature coefficient of resistance and made of any suitable material having such a coefficient, such as carbon, carbon compositions, psilomelane, galena, silicon-carbide, zincite, graphite, certain alloys (such as bronze made up of 88% of copper and 12% of tin with a small quantity of phosphorous), may be in the form of a disk interposed between the ends of the parts 25 and 26 which are made up in the form of preferably cylinders made, for example, of cast iron.

Parts 25 and 26 are provided with removable heat-radiating fins 27 and are recessed at 28 and 29. They are also provided with removable wrappers of heat-resisting and heat-insulating material 30. By removing the fins and leaving all, or part, of the insulating material in place, heat-radiation is cut down. By removing the insulating material and leaving all, or part, of the fins in place, heat-radiation is increased. By leaving a suitable number of fins and a suitable amount of insulation in place, it is possible to duplicate the heat characteristics of electrical units, such as solenoid with an iron core, which characteristics cannot easily be duplicated without the use of both fins and insulating material. Thus, the fins and the insulating material act together to form a control means, whereby it is possible to control the heat characteristics of the unit to make them correspond to the corresponding characteristics of an electrical unit.

The members 25—26 may or may not be included in the circuit of the winding 10 though it is more convenient to include them in that they may thus also serve as the contactors with the disk-like resistance element 24; the cross-section of metal in the members 25—26 is sufficiently large virtually in any case so as not materially to affect the resistance of the circuit or to be materially affected by I^2R losses therein. In any event the resistor 24, of negative temperature coefficient and of small mass and hence of small thermal capacity is in the circuit of the winding 10 and has its thermal capacity greatly increased by being thermally related to a relatively large mass such as the metal members 25—26. As the resistor 24 heats up, due to the flow of current therethrough, heat flows from the resistor 24 to the mass 25—26, the total mass of the device R being given such an external or other exposed heat-dissipating surface that the rate at which the temperature of the entire mass of the device R changes with flow of current through the

resistor 24 substantially matches or equals the rate of change of temperature of the winding 10. Depending upon the relative temperature coefficients of resistance and upon the relative ohmic resistances of the winding 10 and the resistor 24, the mass of the part or parts 25—26 and the heat-dissipating surfaces thereof may be changed or determined to control the rise or fall of temperature of the resistor 24 with continued flow of current or cessation thereof respectively so that the increment of change of resistance in winding 10 in one direction is exactly counterbalanced by an equal increment of change in resistance in the resistor 24 in the opposite direction.

With this arrangement exact or precise regulation at the intended voltage may be accomplished. This regulation is effective over a wide range of temperature and voltage and over a long period of time. Due to the fact that parts 25 and 26 absorb and dissipate heat along the same curves as does coil 10 and its associated parts, the respective temperatures of resistor 24 and coil 10 will be substantially identical at all times; there will be no lag of one temperature with respect to another regardless of the rapidity of fluctuation of the line voltage and the temperature of the surrounding atmosphere.

As pointed out above, in obtaining this result it is at times necessary to provide fins which perform the function of carrying heat away rapidly, and act in the manner that flanges upon an iron core might act. With such fins in place it might be necessary to add a suitable amount of heat-insulating material 30, to correspond to the heat-insulating material associated with coil 10. In a like manner, recesses 28 and 29, or any other deformation, might be provided to correspond with recesses or other deformations in core 10. It is understood that these various means may be used either separately or together, but that by providing a choice of these three means, a complete control of heat characteristics of the resistance unit is provided.

Figure 2 shows the resistance unit of Figure 1 with all of the heat-insulating material removed so as to give maximum effective heat-radiating surface; and Figure 3 shows the same unit with the fins removed but with the heat-insulating material in place so as to give minimum effective heat-radiating surface. This illustrates the wide range of operating characteristics which may be obtained from a single resistance unit, although it is understood that additional fins might be provided in Figure 2 and additional insulating material might be provided in Figure 3.

I have above mentioned, by way of illustration, certain specific examples of materials which may be employed in my system and apparatus and which have a suitable negative temperature coefficient of resistance. Now in accordance with certain other features of my invention, I may employ for the material of the resistance medium, such as the resistor 24, material having the characteristic of changing its ohmic resistance with change in voltage applied to the resistance material itself.

Such materials which substantially depart from Ohm's law in that the current flowing in the circuit is not necessarily proportional to the voltage impressed are known as non-linear impedances, and may take the form of inductances with iron cores, thermionic vacuum tube conductors, gaseous discharge devices such as neon lamp or helium glow lamps, certain electrolytic conductors and many other devices. Some de-

vices are pure resistance devices and follow Ohm's law for direct current, such as an iron-cored inductance, while on alternating current, the impedance of the device or its resistance to current flow, is dependent upon the impressed voltage and other factors, such as the frequency of alternating voltage. Other materials have a practically instantaneous response to voltage variations, so that the characteristics do not depend upon its immediately previous history, and therefore at any given instant the amount of current flowing through the material depends only upon the voltage impressed at that instant and not upon the current flowing the previous instant.

A material may be selected so that as the voltage impressed on the material increases, the current may increase at a greater rate than would be the case if current were always proportional to the voltage impressed. Thus, in a pure resistance with a linear impedance characteristic, the current will be proportional to the impressed voltage.

With a non-linear impedance material used for the resistance unit, the current may not be proportional to the voltage, as the current increases much more rapidly than voltage. Thus, if in a regulating system a definite current change must be made in the current of energization of winding 10 (Figure 1) in order to overcome mechanical friction and magnetic hysteresis to achieve a desired change, the change in voltage for a pure linear impedance will require the same percent variation in regulated voltage to achieve the required current change as is the magnitude of the current change in percent of total current flowing in winding 10. However, if a non-linear impedance material is used as the resistance element in the coil circuit of winding 10, then it is readily apparent that a small voltage variation will result in a relatively large change in current in winding 10 in its attendant non-linear resistance unit. Therefore, to obtain a required current change in winding 10, the change in regulated voltage will be much less if a material is used having a non-linear impedance characteristic rather than a linear impedance.

In alternating current circuits, such an effect is obtainable very readily by placing an iron-cored inductance in series with the winding 10, so proportioning the core in the inductance coils that the iron is near or beyond its saturation value at the voltage at which the system is to regulate.

In both alternating and direct current circuits, materials which have a practically instantaneous response to voltage variations are of advantage due to their independence of the frequency of the system voltage, whether alternating or direct current.

One such material is commercially known as "Thyrite", U. S. Patent No. 1,822,742 and is obtainable from the General Electric Company at Schenectady, N. Y.; this material, described in the "General Electric Review" of February, 1930, has mechanical characteristics somewhat similar to those of dry-process porcelain and has the characteristic that its conductivity varied with the potential. For example, the ohmic resistance is equal to a constant (which depends upon the physical dimensions of the material to be employed) divided by the current to the exponential α , as set forth in the above-mentioned publication. To illustrate the action of this material, it

might be noted that its above-mentioned properties are of such a character that doubling the voltage results in a flow of current therethrough the magnitude of which is on the order of twelve times the magnitude of the current flowing before the voltage was doubled. Thus, the resistor 24 may be in the form of a disk of "Thyrite", illustratively a disk or annulus of about three inches in diameter and about one-eighth of an inch in thickness. This material, moreover, also has a negative temperature coefficient of resistance in that its resistance decreases with increase in temperature.

In addition to the advantages resulting from the use of a resistor with a negative temperature coefficient of resistance, a resistor made up of this material such as "Thyrite" achieves many marked advantages. Illustratively let it be assumed that the winding 10 has the following characteristics, namely, a resistance on the order of 100 ohms, an operating voltage on the order of 50 volts, and an operating current or a critical current of energization of 0.5 ampere; let it be assumed, also, that, in accordance with the past practice as hereinabove earlier mentioned, there is included in the circuit of this winding an external resistor of 200 ohms, so that at 0.5 ampere, the voltage drop across the resistance is 100 volts. A variation of 3% in the current of energization due perhaps to any condition of electro-mechanical unbalance in a regulating or relay system, would result in a variation of 1.5 volts across the winding and of 3.0 volts across the resistance making a total voltage variation to which the system and apparatus is subjected of 4.5 volts.

If, however, instead of using such a resistance in accordance with prior practice, I use a resistor of "Thyrite" in circuit with the above-assumed winding such that the above-mentioned 3% voltage variation (increase in voltage drop across the winding 10 due to the increase in current of energization) is effective, due to the above-described characteristic of the material, to produce a voltage drop across the resistance of only 0.25 volt, then the total voltage variation of the system instead of being 4.5 volts, becomes the sum of 1.5 volts and 0.25 volt and hence 1.75 volts, resulting in a total voltage variation of only about 1.2% of the total voltage of 150 volts of the circuits 11-12. Thus the performance of the system and apparatus is vastly improved with respect to the voltage sensitivity of the system including winding 10 and resistor R, a relatively small voltage variation resulting in a large chance in current of energization.

The resistance material having the above-mentioned novel characteristics I may employ in various ways; for example, I may embody it in the form in which the resistors shown, relating it to appropriate masses of appropriate thermal capacities and heat-radiating surfaces or I may let these resistances take other forms, relying upon the negative resistance coefficients of temperature and include in the circuit of the corresponding resistor device R and winding 10 an additional resistor made up of a non-linear impedance characteristic; in Figure 1 I have diagrammatically indicated at 55 how the resistor of this material may be thus included in the system and apparatus. In such case I am enabled to reduce the size and thermal capacity of the resistor R due to the coating effect of the resistor 55. In such case also I may dispense in the resistor device R with a resistor having a nega-

tive temperature coefficient of resistance and use a resistance of zero temperature coefficient, retaining only the non-linear impedance characteristics of resistance, although commonly a resistance material of non-linear impedance characteristic has also a negative temperature coefficient of resistance.

Thus it will be seen that there has been provided in this invention an apparatus in which the objects above-mentioned, together with many thoroughly practical advantages, are successfully achieved. It will thus be seen that the invention is of a thoroughly practical character, and is in action dependably precise, and is, moreover, well adapted to meet the varying conditions met with in practice.

As many possible embodiments may be made of the above invention and as many changes might be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth, or shown in the accompanying drawing, is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a system of electric regulation within an electric circuit wherein a translating device, having certain predetermined internal and external physical characteristics and having certain predetermined thermal capacity and certain predetermined heat radiating surface, has the characteristic that its impedance changes with changes in operating temperature, a compensating impedance unit having internal and external physical characteristics and thermal capacity and heat radiating surface similar to the corresponding characteristics of the translating device, and having an impedance which varies as the temperature changes in a manner to compensate for changes in the impedance of the translating device, said compensating unit having a main body

and a plurality of fin-like elements extending therefrom.

2. In a system of electric regulation within an electric circuit wherein a translating device, having certain predetermined internal and external physical characteristics and having certain predetermined thermal capacity and certain predetermined heat radiating surface, has the characteristic that its impedance changes with changes in operating temperature, a compensating impedance unit having internal and external physical characteristics and thermal capacity and heat radiating surface similar to the corresponding characteristics of the translating device, and having an impedance which varies as the temperature changes in a manner to compensate for changes in the impedance of the translating device, said compensating unit having a main body with an opening therein to increase the rate of dissipation of heat and with insulating material thereon to retard the dissipation of heat.

3. In a system of electric regulation within an electric circuit wherein a translating device, having certain predetermined internal and external physical characteristics and having certain predetermined thermal capacity and certain predetermined heat radiating surface, has the characteristic that its impedance changes with changes in operating temperature, a compensating impedance unit having internal and external physical characteristics and thermal capacity and heat radiating surface similar to the corresponding characteristics of the translating device, and having an impedance which varies as the temperature changes in a manner to compensate for changes in the impedance of the translating device, said compensating unit having a main body with an opening therein and a plurality of fin-like elements extending therefrom and with insulating material thereon.

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