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2,898,524

WINDINGS FOR ELECTROMAGNETS

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FIG. 1.

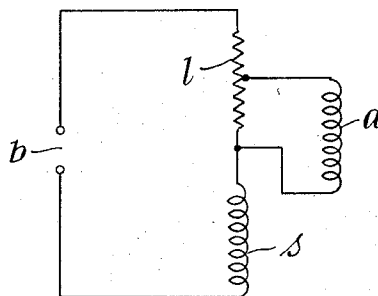
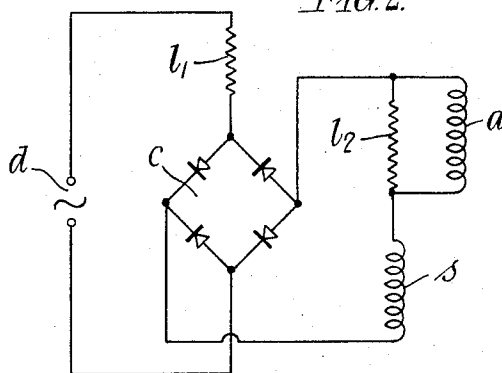


FIG. 2.



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WINDINGS FOR ELECTROMAGNETS

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4 Claims. (Cl. 317—123)

This invention concerns exciting windings for electromagnets, particularly such for automatic regulators, relays and the like, and has for its object to provide by simple means effective compensation for variation of the resistance of such windings with variation of temperature.

According to the invention, an electromagnet is provided, in addition to a main winding having a substantial coefficient of resistance connected in series with a ballast resistor substantially insensible to temperature variation, with an auxiliary winding which is connected in parallel with a part of the said resistance and which is arranged so that its magneto-motive force opposes that of the main winding, variations of winding temperature within the working range producing substantially equal, but effectively opposite, variations of the magneto-motive force of the respective windings.

Two ways of carrying the invention into effect will now be described by way of example and with reference to the accompanying drawing, in which:

Figure 1 is a circuit diagram for one arrangement in accordance with the invention, and

Figure 2 a circuit diagram for a second such arrangement.

In the arrangement illustrated in Figure 1, a main winding s and an auxiliary winding a are wound upon the magnet so that their magneto-motive forces are opposed, the effective magneto-motive force being a net force equal to the force of the main winding s less that of the auxiliary winding a . The windings may be of different materials, but are preferably both of copper, as any advantage obtainable by using, for the auxiliary winding, some other material with a different temperature coefficient of resistance will in practice generally be more than offset by the disadvantage of high resistivity. The main winding s is connected in series with a temperature-insensitive ballast resistor l across a source b of supply of current. The auxiliary winding a is connected in parallel with a part of the ballast resistance l .

With this arrangement, windings designed to satisfy the following approximate relation can be made to achieve full temperature compensation at $t^\circ \text{C.}$, assuming a normal temperature of 20°C. :

$$\frac{AT_{at}}{AT_{st}} \approx \frac{R_{s20}}{R_1 + R_{st}} \left[\frac{\alpha_s}{\alpha_a} + \alpha_s(t - 20) \right]$$

wherein R indicates resistance, α indicates temperature co-efficient of resistance, AT indicates ampere turns,

the suffixes in each case indicating a respective component and/or temperature condition. As already indicated α_s and α_a are preferably equal or substantially so.

If the windings require to be excited by direct current and the source of supply is alternating current, full-wave bridge rectifiers may be connected in circuit with the respective windings. However, with the circuit shown in Figure 2, an advantageous arrangement requiring only one rectifier can be adopted. In this arrangement, the

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auxiliary winding a is connected in parallel with one part l_2 of the ballast resistor and the said part l_2 is connected in series with the main winding s across one diagonal of a bridge rectifier c . The other part l_1 of the ballast resistance is connected through the other diagonal of the bridge c across the source d of alternating current.

Normally, the value of the ballast resistance in the above arrangements will be set at a fixed value. If desired, however, provision may be made for adjusting its value or the proportion of the part across which the auxiliary winding is connected. For example, in the arrangement of Figure 1, provision may be made for adjusting the intermediate tapping point in the resistance l .

It is an advantage of the above-described arrangements that the use of inconveniently fine-gauge wire for the auxiliary winding a can generally be avoided.

Arrangements such as have been described give a net magneto-motive force whose variation over the working range is small. The relation between the net magneto-motive force and temperature is, however, not a straight-line relation. The characteristic is a comparatively flat topped curve with a more rapid rise and fall towards the ends of the temperature range. In practice, a portion of the characteristic appropriate for the particular requirements will be selected for the working range and/or the characteristic will be adjusted to a shape appropriate for the said requirements. These conditions can be influenced by the relative values chosen for the parts of the ballast resistor and by the value of the ballast resistance in relation to the resistance of the main winding. Alternatively, a semi-conductor with a variable negative temperature coefficient of resistance may be connected either in series with or across either of the two windings.

If the same compensation is required for variation of winding temperature due to self heating as for that due to ambient changes, it may be advantageous to interleave the main and auxiliary windings. On the other hand, if desired, compensation for the two effects may be made unequal by arranging for unequal temperature rises in the windings due to self heating.

Such arrangements can be advantageously applied to electro-magnetic regulators, for example to the carbon-pile regulator described in the specification of my Patent application No. 399,794, now Patent No. 2,828,395. In such cases, the said arrangements have certain advantages over compensating arrangements utilising, for example, a bimetal element acting on the control spring of the regulator: For one thing, the compensation is independent of the setting of the control spring. Moreover, as the net magneto-motive force is substantially unaffected by temperature, undesirable effects due to changes in the force/deflection characteristic of the magnet system are obviated: For instance, a change in the cut-in voltage with temperature is avoided. Transitory errors due to sudden changes of ambient temperature can also be avoided, as the thermal time constants of the two windings can be made similar. This is of particular benefit in applications used on aircraft. Finally, it is of advantage that the temperature characteristic can be adjusted, merely by selecting or setting resistors separate from the magnet, without appreciably affecting the net magnetomotive force.

However, the invention is applicable with similar advantages to magnet windings of apparatus other than regulators, for instance relays, saturable chokes, motor and generator fields and, generally, to any winding whose magneto-motive force requires to be temperature-compensated.

I claim:

1. An electromagnet comprising, a ballast resistor substantially insensitive to temperature variation, a main winding having a substantial temperature coefficient of

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resistance and connected in series with said ballast resistor, an auxiliary winding having a substantial temperature coefficient of resistance, connected in parallel with a part only of the said ballast resistor and which is arranged so that its magneto-motive force opposes that of said main winding, variations of winding temperature within the working range producing substantially equal, but effectively opposite, variations of the magneto-motive force of the respective windings.

2. An electromagnet as claimed in claim 1, wherein the main winding and the part of the ballast resistor across which the auxiliary winding is connected are connected in series across one diagonal of a bridge rectifier, the other diagonal of the said rectifier being connected across a source of supply of alternating current through the other part of the ballast resistor.

3. An electromagnet as claimed in claim 1, wherein full wave rectifiers are connected in circuit with respective windings for rectifying current supplied to the said windings from an alternating current source.

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4. An electromagnet carbon-pile regulator having a temperature-compensated electromagnet comprising, a ballast resistor substantially insensitive to temperature variation, a main winding having a substantial temperature coefficient of resistance and connected in series with said ballast resistor, an auxiliary winding connected in parallel with a part only of the said resistor and which is arranged so that its magneto-motive force opposes that of the main winding, variations of winding temperature within the working range producing substantially equal, but effectively opposite, variations of the magneto-motive force of the respective windings.

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