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D. A. BELL
INDUCTANCE DEVICE
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Fig. 1

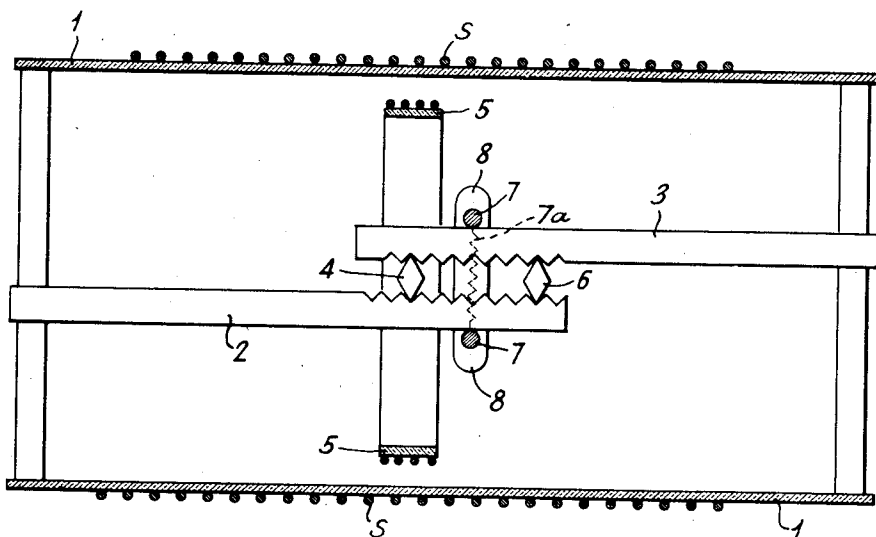


Fig. 2

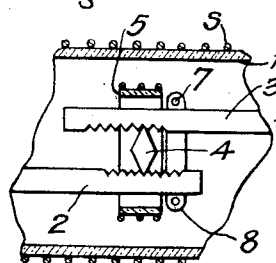
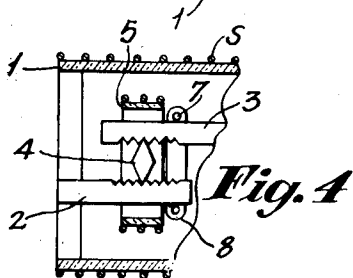
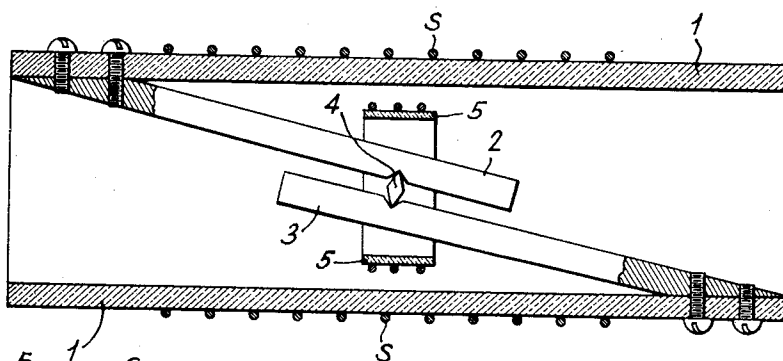


Fig. 3

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INDUCTANCE DEVICE

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9 Claims. (Cl. 171-242)

This invention relates to inductance devices and more particularly to temperature compensated inductance devices of the kind wherein zero temperature coefficient of inductance variation or some predetermined desired temperature coefficient of inductance variation is obtained by utilizing changes in the dimensions of a main coil structure to produce changes in the position relative thereto of a short circuited coil or eddy current member positioned in the magnetic field of said main coil.

The main object of the present invention is to provide improved inductance devices of the kind referred to wherein the means for translating dimensional changes in the main coil structure into positional changes of the short circuited coil or eddy current member shall be sufficiently free from friction to be smoothly and sensitively responsive and wherein the time lag in response shall be extremely small. As will be seen later, reduction of time lag is obtained by reason of the adoption of constructions wherein thermal expansion effects in the mechanism which translates dimensional changes in the main coil structure into changes in the relative position of the short circuited coil or eddy current member are substantially avoided.

According to this invention an inductance device of the kind referred to comprises a main inductance coil structure, a short circuited coil or eddy current conductor in the field of said main coil, a pair of members made of a material of substantially zero coefficient of temperature expansion and attached to different points upon the main coil structure so as to move relatively to one another in opposite directions as a result of changes in the dimensions of said main structure due to temperature changes, and means operated by said relative movement for rotating the short circuited coil or eddy current conductor.

The invention is illustrated in the accompanying drawing, in which:

Fig. 1 shows a longitudinal section of an inductance coil of this invention;

Fig. 2 shows a longitudinal section of another embodiment of this invention;

Fig. 3 shows a partial section of an embodiment of this invention wherein the temperature compensating members have threads of different pitch; and

Fig. 4 shows a partial longitudinal section of an embodiment of this invention with the compensating elements mounted at one end of the coil.

Referring first to Fig. 1, the main inductance

coil structure is in the form of a solenoid S wound upon a cylindrical former 1 of insulating material. Carried from opposite ends of said former and inside the same are two members 2 and 3 made of a material of substantially zero temperature coefficient of expansion, e. g., the nickel steel alloy known under the registered trade name "Invar", said members being in the form of rods and overlapping one another at their ends. Each member is cut or otherwise formed with rack teeth as shown where it overlaps the other so that the rack teeth on the two members face one another at about the middle of the main coil former. Thus, if the coil former expands, the rack teeth will move in opposite directions outwardly, while if the coil former contracts, they will move in opposite directions inwardly. Since the members 2, 3 are of "Invar", they will not introduce any appreciable expansion or contraction and the displacement of the rack teeth relative to one another will be dependent practically only on the longitudinal expansion and contraction of the former 1. Spanning the space between the two racks is a double knife edged member 4, one knife edge engaging a tooth in one rack and the other an opposite tooth in the other rack. This double knife edge member 4 is upon a shaft which constitutes a diametrical support for a small, helical, short circuited coil 5 positioned within the main coil. A similar, parallel, double knife edge member 6 is provided between the two racks at some other point in their lengths and a member 8 carrying a pair of spring loaded rollers 7 (the springs are shown by the dash lines as 7A) is fitted over the two rack formed members so that the said rollers 7 engage the backs of said members and thus hold them in firm contact with the two double knife edge devices 4, 6. This construction is very nearly frictionless, and almost entirely free from backlash, besides being very simple. Upon expansion or contraction of the main coil former 1 the short circuited coil 5 will be rotated an extent depending upon the amount of expansion or contraction, the arrangement being such that at some predetermined mean or datum temperature the short circuited coil is in some predetermined position relative to the main coil, e. g., coaxial therewith.

It will be seen that with the above arrangement, it is possible by suitable design to obtain substantially zero coefficient of temperature variation for the whole inductance device or alternatively some predetermined desired law of temperature-inductance variation can be obtained.

The variation of inductance will depend upon the diameter and number of turns of the coil 5, the coefficient of thermal expansion of the former 1 and the mechanical magnification which is determined by the ratio of the distance between the knife edges of member 4 and the length of the former 1. For small displacements of coil 5 from the coaxial position the mutual inductance between coils S and 5 is proportional to the cosine of the angle of displacement and therefore final adjustment may be obtained by adjusting the angular position of the coil 5 at datum temperature. Such provision for adjustment may be made in various different ways. For example as shown by Fig. 3, one rack formed member may be formed with rack teeth of slightly different pitch from that upon the other rack formed member, the two pitches being different after the manner of the well known type of vernier coupling commonly employed for fine adjustment of the angular setting of two shafts. With such a vernier arrangement of the teeth, a desired adjustment of the setting at datum temperature can readily be made, for the angular position of the short circuited coil 5 relative to the main coil S (at datum temperature) can obviously be varied by moving the double knife edge device 4 by which said coil is rotated along the racks, i. e., by choosing the appropriate position of the said double knife edged device along the dissimilar racks. Alternatively, as shown by Fig. 4, instead of using a vernier rack arrangement and mounting a short circuited coil centrally within the main coil, similar racks may be employed and the said racks be so arranged that the short circuited coil 5 is carried near one end of the main coil S instead of, as shown in Fig. 1, more or less centrally (longitudinally). With this arrangement the short circuited coil will (at datum temperature) be more or less within the field of the main coil in dependence upon the position relative to the lengths of the racks of the double knife edged device 4 by which said coil is rotated and by varying this position any desired initial setting within a given range may be obtained.

Fig. 2 shows a somewhat simplified construction. Here, the "Invar" or similar members 2, 3 are inclined relatively to the axis of the former 1 so that they can be carried directly from the ends of the said former. Only one member 4 is used and the rack teeth of Fig. 1 are replaced by a pair of V grooves, as shown. The second knife edge member 6 and the parts 7 and 8 of Fig. 1 are dispensed with, the natural elasticity of the members 2, 3 being relied upon to maintain firm contact between the knife edges and the V grooves.

All of the structures illustrated are nearly frictionless and it will be noted that, practically speaking, the former 1 is the only expansible member in the compensating mechanism, so that difficulties and time lag effects due to temperature changes occurring at different rates in different parts of the apparatus are avoided. Theoretically, the actual value of the coefficient of thermal expansion of the coil former 1 is of no importance (so long, of course, as it has an appreciable value of coefficient) but, in practice, the coil S will probably be a copper conductor and it is important that the conductor of the coil S and the former 1 move together. Such simultaneous movement can be assured by using, for example, a former 1 consisting of a tube of

ceramic material with the coil S in the form of a helix of thin copper burnt on. Where, however, the coil is in the form of copper or other conductive wire wound on a former of insulating material, close contact between wire and former depends on the elasticity of the conductor. For obvious reasons, it is not desirable to have the wire so tight as to stress it beyond about half its breaking stress and this should be borne in mind when deciding upon the material of the former 1. Take the case of copper with a breaking stress of between 2.8 and 3.1×10^9 dynes per sq. cm. and a Young's modulus of about 12.5×10^{11} dynes per sq. cm. Since the maximum stress is not to exceed about half the breaking stress, this means a maximum permissible stress of about 1.5×10^9 dynes per sq. cm., which corresponds to a maximum permissible extension of 1.2×10^{-3} . If the operating temperature range is to be (say) 40°C . and this extension is not to be exceeded, then obviously the difference between the coefficient of thermal expansion of the former and that of copper must not exceed

$$\frac{1}{40} (1.2 \times 10^{-3}) = 30 \times 10^{-6}$$

What is claimed is:

1. An inductance device of the kind referred to comprising a main inductance coil structure, a short circuited coil in the field of said main coil, a pair of members made of a material of substantially zero coefficient of temperature expansion and attached to different points upon the main coil structure so as to move relatively to one another in opposite directions as a result of changes in the dimensions of said main structure due to temperature changes, and means operated by said relative movement for rotating the short circuited coil.

2. An inductance device of the kind referred to comprising a main inductance coil structure consisting of an inductance winding in intimate thermal contact with a former of expansible material, a pair of members made of a material of substantially zero temperature coefficient of thermal expansion carried one from each end of said former, said members having their free ends overlapping, a short circuited coil in the field of the main coil, and a rotatable member engaged between the overlapping ends of said pair of members so as to be rotated thereby as a result of coil former expansion or contraction, said rotatable member serving to rotate the short circuited coil.

3. A device as claimed in claim 1 wherein the short circuited coil has a shaft by which it may be rotated and on which is a double knife edge member which is positioned between and engaged by opposing rack teeth formed on overlapping ends of the members of substantially zero temperature coefficient.

4. A device as claimed in claim 1 wherein the short circuited coil has a shaft by which it may be rotated and on which is a double knife edge member which is positioned between and engaged by opposing V grooves formed on overlapping ends of the members of substantially zero temperature coefficient.

5. A device as claimed in claim 1 wherein the short circuited coil is supported near one end of the main coil so that it will at datum temperature be more or less within the field of the main coil, the arrangement being such that the extent to which said short circuited coil is within the field of the main coil at datum temperature may be adjusted.

6. An inductance device comprising a main inductance coil structure, a short-circuited coil in the field of said main coil, a pair of members made of material of substantially zero coefficient of temperature expansion and attached to different points on the main coil structure so as to move relatively to one another in opposite directions as a result of changes in the dimensions of the main structure due to temperature changes, said members having rack teeth, the pitch of which are different from each other, a knife-edged member supporting said short-circuited coil and supported by said member having rack teeth, whereby the angular position of the short-circuited coil at datum temperature may be adjusted by moving said knife edged member between the different pairs of teeth.

7. An inductance device of the kind referred to comprising a main inductance coil structure, a short circuited coil in the field of said main coil, a pair of members made of a material of substantially zero coefficient of temperature expansion and attached to different points upon the main coil structure so as to move relatively to one another in opposite directions as a result of changes in the dimensions of said main structure due to temperature changes, and means operated by said relative movement for rotating the short circuited coil, said means comprising a knife edged member retained between said pair of members by spring-like tension means.

8. A temperature compensated inductance wherein a zero temperature coefficient of induc-

tance variation is obtained at a desired predetermined temperature comprising an inductance coil structure, a conducting member located in the magnetic field of said inductance coil structure to cause a loss in said magnetic field due to eddy currents, a pair of members made of a material of substantially zero coefficient of temperature expansion and attached to different points on said coil structure so as to move relative to one another in opposite directions as a result of changes in the dimensions of said coil structure due to temperature changes, and means operated by said relative movement for rotating the conducting member within the magnetic field of said inductance coil.

9. A temperature compensated inductance wherein a zero temperature coefficient of inductance variation is obtained at a desired predetermined temperature comprising an inductance coil having a conductor wound on an insulating tube of ceramic material, a conducting member located in the magnetic field of said inductance coil to cause a loss in said magnetic field due to eddy currents, a pair of nickel steel alloy members of substantially zero coefficient of temperature expansion and attached to different points on said coil structure so as to move relative to one another in opposite directions as a result of changes in the dimensions of said coil structure due to temperature changes, and means operated by said relative movement for rotating the conducting member within the magnetic field of said inductance coil.

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