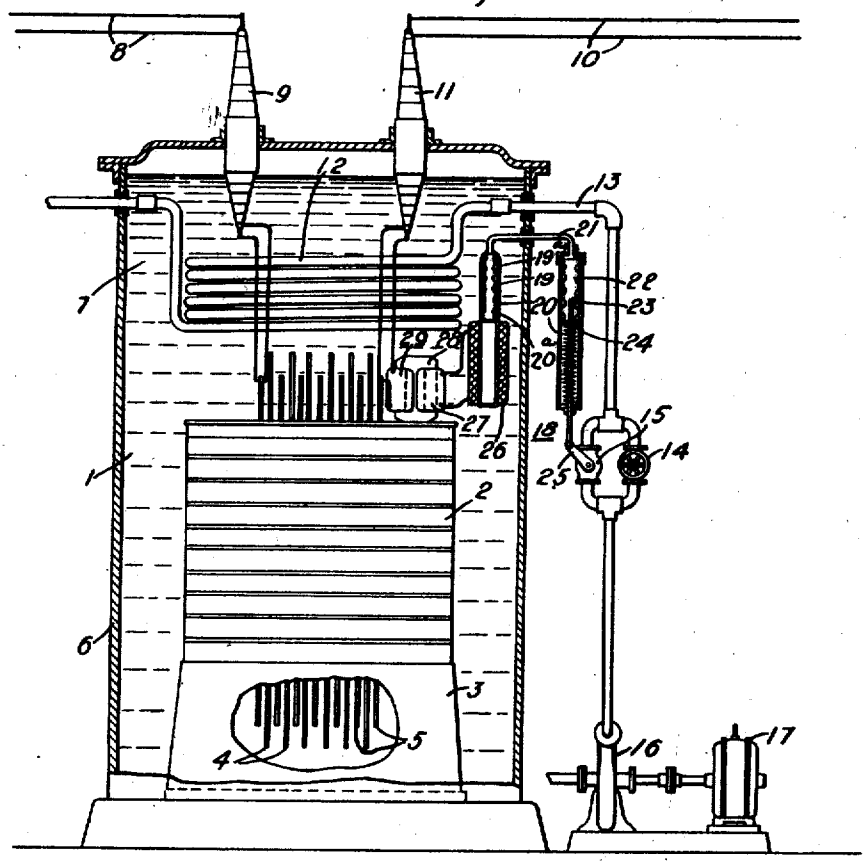
Sept. 11, 1923. 1,467,843

W. M. DANN ET AL

PROTECTIVE SYSTEM

Original Filed Sept. 10, 1915

Fig. 1.



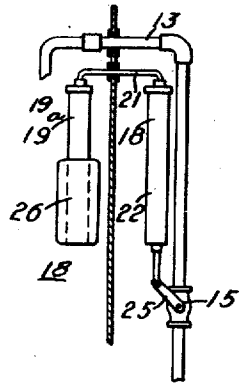




Fig. 2.

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# UNITED STATES PATENT OFFICE.

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## PROTECTIVE SYSTEM.

Original application filed September 10, 1915, Serial No. 50,112. Divided and this application filed November 11, 1918. Serial No. 331,493. Renewed October 17, 1919.

*To all whom it may concern:*

Be it known that we, WALTER M. DANN, a citizen of the United States, and a resident of Wilkinsburg, in the county of Allegheny and State of Pennsylvania, and CHARLES LE G. FORTESCUE, a subject of the King of England, and a resident of Pittsburg, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in Protective Systems, of which the following is a specification, this being a division of application, Serial No. 50,112, filed Sept. 10, 1915.

Our invention relates to protective systems having special relation to systems which may be employed in connection with electrical apparatus to safeguard it from excessive temperatures arising from the flow therethrough of abnormally high currents on overloads, and it has for its object to provide protective systems of the character designated which shall be instrumental in conserving, when not needed, the cooling means which are employed to neutralize the heating effect of the aforesaid heavy currents.

More particularly, our invention relates to cooling means for electrical transformers and is particularly adapted for employment with transformers which are immersed in an insulating fluid containing coils of pipe through which cooling fluid is adapted to flow.

In transformers of the character designated, the present practice is to allow water to pass through the cooling coil in such quantities that the highest permissable temperature which the insulating fluid may reach, on account of heavy currents flowing through the transformer windings, is not exceeded. Such a system is of undoubted benefit where the transformer works on a steady load and the temperature fluctuations within the transformer tank are of a minimum amount. However, when large power transformers, cooled in the above-mentioned manner, are utilized in railway systems or in other systems where the power demands fluctuate over an extremely large range, it is essential that the cooling means—in this instance, the amount of water flowing through the pipe coil—shall be so governed that only such amount of water shall pass through the coil as is required by the temperature of the insulating fluid.

In many installations, it is found that a saving of approximately 50% in the amount of water used may be effected by means of our invention, as compared with the usual practice.

It is obvious, in large transformers, some of which have a water rate of 9½ gallons per minute, it is almost imperative that means shall be provided to save as much water as possible, and this is especially true where the water must be paid for by the gallon, as is the case in many localities.

Moreover, a number of the protective systems now in use in connection with transformers contemplate the opening of the load circuits of the transformer when a certain predetermined load current is exceeded. After the load circuits have been interrupted, many of the devices of the character designated will allow the transformer to cool and thereafter place them again in service by closure of the circuit-interrupting means. Obviously, this method is open to many objections, the chief of which is the fact that the load circuit of the transformer is opened whenever the predetermined conditions are exceeded. It would be a great saving if it were possible to keep the transformer in continuous service, even under the heavy-overload conditions and to so arrange the protective apparatus that an additional response of the cooling means would be had under the influence of the heavy-load currents.

One object of our invention, therefore, is to arrange a protective system which is responsive to both the excessive currents flowing in the load circuits and to the temperature of the surrounding fluid in which the electrical device is positioned. So far as we are aware, the idea of arranging a protective system, in this case a cooling system, in such manner that it will be influenced by both of the above elements, is novel and, therefore, such a system might well be employed with electrical apparatus which is used without insulating fluid but is surrounded by air since, as will hereinafter appear, a system constructed in accordance with our invention could easily be adapted to operate to supply cooling fluid directly to the electrical

device itself as, for instance, a system wherein the cooling air supplied to an electrical apparatus is dependent upon both the load current and the temperature of the medium surrounding the apparatus.

Moreover, as will hereinafter appear from the detailed description of our apparatus, the means which we have provided as responsive to both the load and the temperature conditions of an electrical device are constructed in such manner that the temperature of any portion of the electrical apparatus may be accurately reproduced in miniature, and, therefore, even if an electrical device develops abnormally hot spots when supplied with heavy currents, provision may be made to cool such hot spots by so constructing the thermal responsive means that the conditions existing at the predetermined hot spots are accurately reproduced in the device which is instrumental in controlling the amount of the cooling means.

For a better understanding of the nature and scope of our invention, reference may be had to the following description and the accompanying drawing in which Fig. 1 is a view, partially diagrammatic, partially in elevation and partially in section, of a transformer embodying a form of our invention, and Fig. 2 is a view showing a modified form of a portion of the apparatus shown in Fig. 1.

Referring to Fig. 1, a transformer 1 comprising a core member 2, a bottom end frame 3 and spaced pancake coils 4 and 5, is disposed in a containing case 6. A body of insulating fluid 7, such as oil, is contained in the case 6 and completely immerses the transformer 1. High-tension leads 8 project through a pair of outlet bushings 9 and low-tension leads 10 project through a pair of outlet bushings 11. A cooling coil 12, disposed above the transformer 1 and submerged in the body of insulating fluid 7, is supplied with a cooling fluid through an inlet pipe 13 which, in turn, is supplied through a hand valve 14 and an automatically-actuated valve 15 that are inserted in the supply line intermediate the inlet pipe 13 and a feed pump 16. A motor 17 is shown directly coupled to the feed pump 16 in order to provide for a continuous circulation of the cooling fluid through the cooling coil 12. By opening the hand valve 14, the cooling coil 12 is supplied with a constant flow of cooling liquid which, for ordinary operating conditions, is adequate for cooling the transformer winding. However, when the transformer is subjected to excessive overloads or frequent peak loads which may cause hot spots of dangerously high temperatures to be developed in the transformer, it is essential to increase the flow of the cooling fluid through the cooling coil 12 in order to adequately protect the transformer. To this end, we have provided the auxiliary by-pass valve 15, the operation of which is automatically effected by means of a temperature regulator 18, which, in turn, is influenced by the temperature conditions obtaining in the hottest portion of the transformer 1.

The regulator 18 comprises a thermostatic element 19 and a controller element 20. The thermostatic element comprises a tubular receptacle $19^a$ containing a body of heavy hydro-carbon oil and an expansible and contractible corrugated metal tube $20^a$. The controller element 20 comprises a tubular member 22, the upper end of which is connected to the upper end of the tubular receptacle $19^a$ by a tube 21 of small diameter. An expansible and contractible corrugated metal tube 23, capable of being compressed when an increase of temperature causes the liquid contained in the tubular receptacle $19^a$ to expand, is contained within the tubular member 22. It will be noted that the tubular receptacle $19^a$, the tube 21 and the tubular member 22 constitute a hermetically-closed chamber. When the temperature of the body of liquid contained in the tubular receptacle $19^a$ increases, the pressure thus developed is transmitted to the tubular member 22 to effect compression of the corrugated tube 23. As a result, a piston 24 in the member 22 is actuated to operate an arm 25 which, in turn, actuates the by-pass valve 15. Under normal conditions, the design of the structure is such that the by-pass valve 15 is kept closed.

The tubular receptacle $19^a$ of the thermostatic element 19 is embraced by a heating coil 26 which is connected in circuit with the secondary winding 27 of a series transformer 28, the primary winding 29 thereof being connected in circuit with the secondary leads 10 of the transformer. The heating coil 26 is covered by a suitable heat-insulating material or lagging 30. It follows that the current flowing through the heating coil 26 is proportional to the load-current traversing the windings of the transformer.

Those familiar with the design of transformers may accurately determine the temperature obtaining in any selected portion or the portion of a transformer in which the highest temperature will develop as a result of the unequal cooling facilities afforded the various portions thereof. The data required for determining the temperatures of these selected portions, and particularly the hot spots in a transformer, comprise the weight of the copper employed, the watts to be dissipated per pound of copper, the exposed surfaces of the transformer coils, etc. From this data, the thermal capacity of the transformer may be determined and also the heat gradient through the windings to the body of cooling liquid or oil 7. As a consequence thereof,

the temperatures of the hottest portions of the transformer winding, under all conditions of load, may be accurately calculated. Therefore, by reproducing, in miniature, the temperature conditions obtaining in the hottest portion of a transformer and utilizing them to actuate the temperature regulator 18, the cooling of the transformer may be regulated in accordance with the instantaneous value of the temperature of the hottest portion of the winding, under all conditions of load. To accomplish this, the heating coil 26, in combination with the thermostatic element 19, is so designed as to have the same heat emissivity as the transformer 1 which, as above mentioned, may be calculated from the data available to the designing engineers. The characteristics of the heating coil 26 must be such that the percentage of copper per unit of volume is same as that of the transformer windings, the heat dissipated per unit volume by the coil 26, under given load conditions, must be the same as that of the transformer windings, and the emissivity of the oil must likewise correspond to that of the transformer windings. Since these various factors may be predetermined with substantial accuracy, as above mentioned, and made adjustable within certain limits by means of taps on the heating coil 26 and the lagging thereof, the temperature conditions obtaining in the hottest portion of the transformer may be thus reproduced and utilized to influence the action of the thermostatic element 19 of the temperature regulator 18.

While the valve 15 shown in Fig. 1 operates to supplement the flow of cooling fluid passing through the valve 14, it is possible to insert the valve 15 in the supply mains so as to regulate the entire flow of the cooling fluid admitted to the cooling coil 12. This embodiment is shown in Fig. 2 in which the temperature regulator 18 operates the arm 25 of the valve 15 that constitutes the only regulating device for controlling the flow of the cooling fluid passing through the inlet pipe 13. The remaining structure shown in Fig. 2 is similar in all respects to that shown in Fig. 1, and the operation of the temperature regulator 18 is likewise controlled by the heating coil 26, as explained in connection with Fig. 1.

Although we have shown and described our invention as applied to a specific structure, such as a power transformer, it is evident that it may be applied to many other types of apparatus and, therefore, since we consider the idea of arranging a thermal responsive device to be influenced both by the load current of the electrical device and by the temperature of the surrounding medium of said device to be entirely novel, we desire that the very broadest interpretation be placed upon the appended claims and that due consideration be given to the fact that various modifications therein may be made by those skilled in the art without involving a departure from the spirit and scope of our invention.

We claim as our invention:

1. The combination with an electrical device, and means for delivering a cooling medium thereto, of means influenced both by the load current of said device and by the temperature thereof for governing the delivery rate of the cooling medium.

2. The combination with an electrical device, and means for delivering a cooling medium thereto, of means influenced both by the load current of said device and by the temperature thereof for automatically governing the delivery rate of the cooling medium and additional means for manually varying the delivery rate of the cooling medium.

3. The combination with an electrical device, a container therefor, fluid in said container in which said device is placed, and means for delivering a cooling medium thereto, of means responsive to the load current of said device and to the temperature of said fluid for governing the delivery rate of said cooling medium.

4. The combination with an electrical device, a container therefor, fluid in said container in which said device is placed, and means immersed in said container, through which a cooling medium is passed, of means influenced both by the load current of said electrical device and by the temperature of said fluid for varying the amount of cooling fluid passing through said means.

5. The combination with an electrical device, a container therefor, fluid in said container in which said device is placed, and means immersed in said container, through which a cooling medium is passed, of means for regulating the rate of flow of the cooling medium comprising a current coil energized in proportion to the load current of said device and immersed in said fluid, whereby it is affected jointly by the load current and the temperature of the fluid.

6. The combination with an electrical device immersed in an insulating fluid, and a cooling coil for said insulating fluid, of means comprising a current coil energized in proportion to the load current of said electrical device and immersed in said insulating fluid, means whereby the cooling fluid passing through said cooling coil may be varied to any desired degree, and actuating means associating said first means and said cooling-coil supply means, whereby the amount of said cooling fluid passing through said cooling coil is automatically varied in accordance with the load current of said device and in accordance with the temperature of said insulating fluid.

7. The combination with an electrical ap-

paratus, of means influenced by the load current of said apparatus and by the temperature thereof comprising heat-storage and heat-insulating materials, the ratio of the heat-storage capacity of said means to the heat-insulating material thereof being the same as that of the heat-storage material to the heat-insulating material of the electrical apparatus.

8. In combination with an electrical apparatus comprising heat-insulating material, a protective device comprising a current-carrying means traversed by a current proportional to the current of said electrical apparatus and heat-insulating means, the temperature of said protective device being influenced by that of said material and the ratio of the material of the current-carrying means of said device to the heat-insulating material thereof being the same as the ratio of the corresponding portions of the electrical apparatus.

9. In combination with an electrical apparatus embodying current-carrying material and heat-insulating material, a protective device comprising a current-carrying coil and heat-insulating material associated therewith, the temprature of said device being influenced by that of said heat-insulating material, the percentage of current-carrying material per unit volume of the coil being the same as that of the current-carrying material of said electrical apparatus, and the heat dissipated per unit volume of the coil being the same as the heat dissipated per unit volume of the current-carrying material of said electrical apparatus.

10. In combination with an electrical apparatus, protective means therefor comprising a coil adapted to carry a current proportional to the current of said electrical apparatus and lagging material associated with said coil, the ratio of the heat-storage capacity of said coil to the lagging material thereof being the same as the ratio of the corresponding factors of the electrical apparatus to each other, and the protective means being disposed in a medium which has the same temperature as that in which the electrical apparatus is located.

11. The combination with an electrical apparatus that is subjected to variable loads and heating conditions incident thereto, of a temperature-responsive device associated with said apparatus and influenced by the same cooling medium, said device comprising a current-carrying element that is heated in accordance with the current traversing said electrical apparatus and is surrounded by heat-insulating material, the relative proportions of heat-insulating material and heat-generating material comprising the current-carrying element being so adjusted that the temperature characteristic of said device substantially corresponds, in time and form, to the temperature characteristic of said apparatus, irrespective of the variable load conditions that may be imposed thereupon.

12. The combination with an electrical apparatus subjected to the flow of a cooling medium and to variable loads and heat-storage conditions incident thereto, of a protective device associated with said apparatus and positioned to be influenced by the same cooling medium possessing corresponding temperature conditions, said device comprising a current-carrying coil that is heated in accordance with the current traversing said electrical apparatus and lagging material, the relative proportions of the heat-storage material of said device and the lagging material thereof being so adjusted that the temperature characteristic of said device substantially corresponds, in time and form, to the temperature characteristic of said apparatus, irrespective of the variable loads imposed thereupon.

13. The combination with an electrical apparatus subjected to the flow of a cooling medium and to fluctuating loads, of a thermal protective device associated with said apparatus and influenced by a cooling medium having a temperature which substantially corresponds to the temperature of the cooling medium for said apparatus, said device comprising a current-carrying coil traversed by a current that is proportional to the fluctuating loads imposed upon said apparatus, and heat-insulating material, the ratio of the heat-storage capacity of said device to the heat-insulating material thereof being the same as that of the heat-storage capacity to the heat-insulating material of the electrical apparatus, thereby imparting to said device a temperature characteristic which substantially coincides, in time and form, to the temperature characteristic of said apparatus, irrespective of the fluctuating loads imposed upon said apparatus and the time of their duration.

In testimony whereof, we have hereunto subscribed our names this 8th day of Nov., 1918.

WALTER M. DANN.
CHARLES LE G. FORTESCUE.