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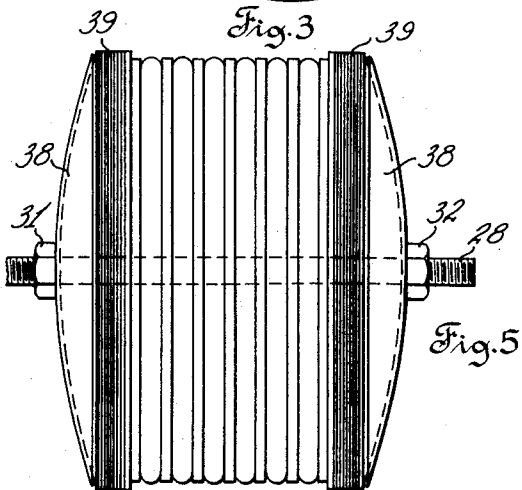
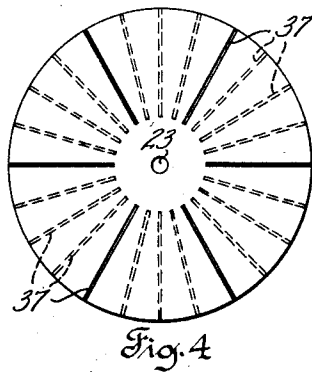
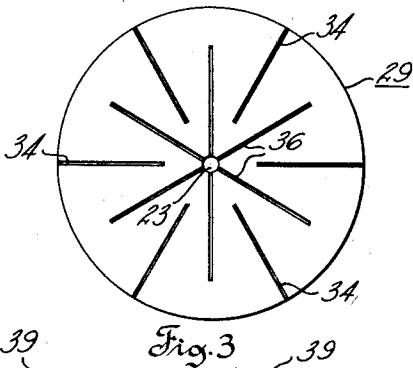
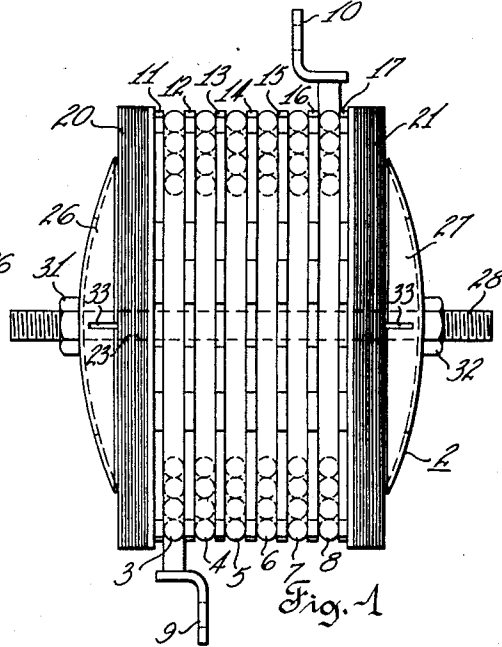
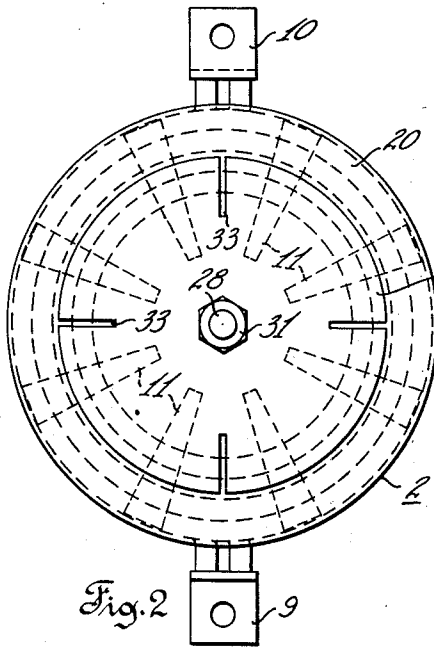
C. E. MERCIER

2,907,965

REACTOR WITH END SHIELDING HAVING DISK LAMINATIONS

Filed Aug. 24, 1956

2 Sheets-Sheet 1



Inventor
Carl E. Mercier
By *Warren F. B. Ford*
Attorney

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REACTOR WITH END SHIELDING HAVING DISK LAMINATIONS

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2 Sheets-Sheet 2

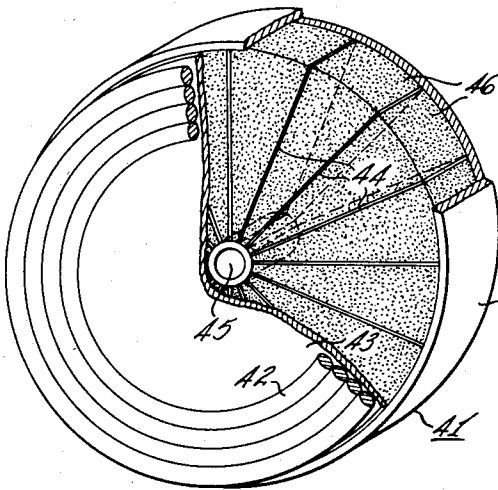


Fig. 6

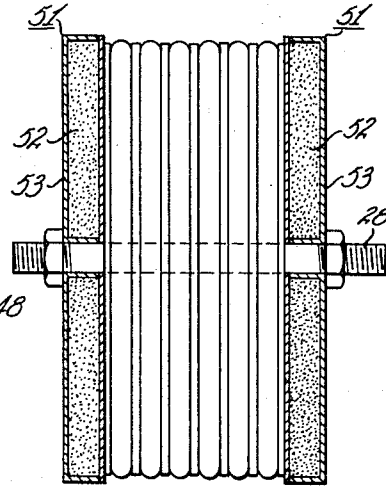


Fig. 7

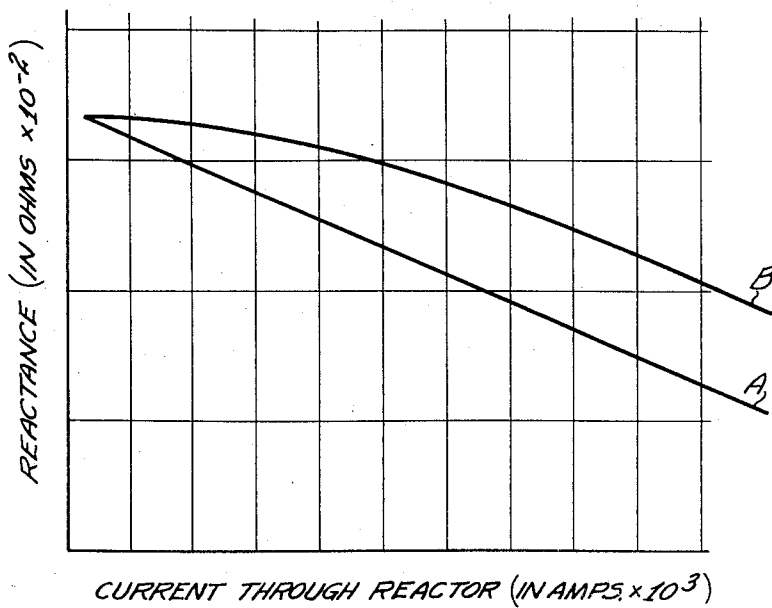


Fig. 8

Inventor
Carl E. Mercier
By Warren F. B. Fidelity
Attorney

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REACTOR WITH END SHIELDING HAVING DISK LAMINATIONS

Carl E. Mercier, West Allis, Wis., assignor to Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

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4 Claims. (Cl. 336—84)

This invention relates to electric induction apparatus and more particularly to end shielded current limiting reactors.

In low voltage industrial power systems, circuit breakers are utilized for interrupting the circuits under predetermined operating conditions. Such circuits may have large capacities, and quite often such circuits can deliver momentary currents beyond the capacity of the circuit breakers associated with the system. Where the short circuit currents delivered may exceed the current interrupting capacity of the circuit breakers associated with the circuit, either larger capacity breakers (which are expensive and require more space) are substituted or current limiting reactors are used in series with the breakers to limit the short circuit currents to a value within the interrupting capacity of the breakers.

Current limiting reactors usually consist of turns of heavy copper having an air core. These reactors must be either mounted in nonmagnetic cabinets or provided with magnetic end shielding to limit the stray flux produced during normal operation and during prolonged overloads or heavy short circuit currents, thereby limiting localized heating of the cabinet walls or magnetic stresses which may cause physical damage to the cabinet structure. End shielding also tends to decrease the leakage flux.

Heretofore, magnetic shields for current limiting reactors have lacked one or more of the characteristics desirable in such shields. They either failed to provide sufficient shielding to protect associated components, with the result that the unrestrained magnetic field produced arcing, excessive heating and excessive forces in the metal enclosing cabinet, or they were mechanically too weak to withstand pressure and impact usually encountered when the shields served as end clamps for holding the coil turns together, or they provided too much reluctance to satisfactorily direct flux in the desired or chosen path, or they were too difficult or expensive to manufacture.

In accordance with one aspect of the present invention, a new and improved current limiting reactor is provided in which eddy currents are limited and stray flux is controlled. The reactor comprises the combination of interconnected layers of conductive windings, spacer members of insulating material disposed between the layers of conductive windings, a plurality of slotted metallic disk laminations on the opposite ends of the conductive windings, metal end shields disposed beyond the opposite ends of the disk laminations, each of the end shields comprising a substantially dish shaped metallic shield slotted in such a manner as to limit the circulation of eddy currents in the shield, and means for maintaining the protective end shields in cooperative relationship with the stacks of conductive windings and the disk laminations.

It is, therefore, one object of the present invention to provide a new and improved reactor for limiting the amount of current in a given circuit during abnormal conditions.

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Another object of this invention is to provide a new and improved reactor having metallic disk laminations and metallic end shields of particular geometrical configurations which control the flux path through the reactor.

A further object of this invention is to provide a new and improved current limiting reactor in which metallic disk laminations with a plurality of slots or apertures increase the path length of the eddy currents induced therein.

A still further object of this invention is to provide a new and improved current limiting reactor in which slotted metallic disk laminations and slotted metallic end shields limit the circulation of eddy currents and confine the circulation of stray flux.

Other objects and advantages of the invention will become apparent from the following description when read in connection with the accompanying drawings, in which:

Fig. 1 is an elevational view of a reactor embodying features of the present invention;

Fig. 2 is an end plan view of the reactor shown in Fig. 1;

Fig. 3 is an end view of the stack of disk laminations shown in Fig. 1 illustrating one lamination slot arrangement;

Fig. 4 is an end view of a stack of disk laminations showing a modification of the slot arrangement shown in Fig. 3;

Fig. 5 is an elevational view of a reactor illustrating a modification of the end bells shown in Fig. 1;

Fig. 6 is an isometric view partly in cross section of a reactor end shield with parts broken away to show a group of radially arranged rectangular laminations;

Fig. 7 is an elevational view partly in section of a further modification of the reactor shown in Figs. 1 through 6 and embodying features of this invention; and

Fig. 8 is a current reactance graph of the characteristics of the type of reactors disclosed.

Referring to the accompanying drawings wherein like reference characters refer to like parts throughout, Fig. 1 illustrates a current limiting reactor of the type adaptable for mounting in metal clad switchgear in low voltage industrial power systems, which can be installed in the main feeder bus or in branch circuits to protect a breaker or a group of breakers. The current limiting reactor 2 comprises a plurality of layers 3, 4, 5, 6, 7 and 8 of heavy copper conductors, the layers being interconnected so as to give a continuous winding, and the ends of the windings having terminals 9 and 10.

To provide for ventilating and insulating the layers 3, 4, 5, 6, 7 and 8 from one another, a plurality of spacer members 11, 12, 13, 14, 15, 16 and 17 are associated with these layers. As is more clearly illustrated in Fig. 2, the spacers 11 disposed about the upper surface of layer 3 of the conductors are evenly spaced from each other, eight such spacers 11 preferably being disposed on one side of the layer 3. The spacers on the opposite sides of and between the other layers forming the reactor 2 are similarly disposed so that effective air spaces or ventilating channels are provided between the different layers. As is well known in the art, porcelain or some other suitable insulator such as a fibrous material impregnated with a resinous binder may be used for these radial spacers separating each coil layer.

In forming the layers 3, 4, 5, 6, 7 and 8 of the conductive windings, the different layers are progressively connected so as to provide a continuous circuit throughout the assembled layers. Suitable transpositions in the windings may be utilized if so desired.

The invention may be used as a single phase reactor, or in groups as a multiphase reactor. One single phase reactor may be used in each phase of the circuit, a typical

mounting arrangement being three reactors mounted together for a three phase circuit.

In accordance with the invention claimed, two groups of metallic disk laminations 20 and 21 are provided on opposite ends of the assembled layers of conductive windings in the current limiting reactor 2. These groups of laminated disks are substantially identical in construction and are usually large enough to cover the ends of the conductive windings of the reactor. The function of the disk laminations is to provide the desired flux path around the reactor, to provide as short a flux path as possible and to decrease the reluctance of the flux path so that for equal values of current through a coil a higher reactance is obtained than would be possible without these laminations.

The disk laminations 20 and 21 are preferably made of a magnetic material such as steel. The number of laminations may be increased or decreased according to the size and structure of the reactor and the nature of the flux path desired. Each lamination is provided with a stud-receiving aperture 23 in its radial center. A non-magnetic stud 28 extends through the length of the reactor and cooperates with a nut at each end of the reactor to hold the windings, disk laminations and end bells together. The disk laminations may be individually insulated with high temperature varnish before stacking and clamping.

Some or all of the disk laminations may be perforated with a plurality of spaced slots extending inwardly about the periphery of the laminations. These slots may be of any radial length, ordinarily the longer the slot the more effective its function in reducing circulating eddy currents and controlling stray flux patterns. The number of slots will be determined by the size of the current being controlled and the length of the slots. Slots in the disk laminations tend to increase the path length of the current induced in the laminations, and thereby to increase the resistance of the laminations to the eddy current tending to flow through these laminations. Decreasing the current flowing in these laminations decreases the counter-electromotive force and permits leakage flux to shift from an elliptical path which bypasses one stack of laminations, to a path axially through the coil, radially through the disk laminations and end bell, through the air to the disk laminations and end bell on the other end, and radially through these disk laminations to the axis of the coil. Further modifications of the slotted construction for disk laminations are illustrated in Figs. 3 and 4.

In stacking the slotted disk laminations, the slots may be aligned so as to provide a uniform slot pattern throughout the stack of disk laminations, as illustrated in Fig. 3, or they may be stacked with the slots staggered circumferentially either uniformly or nonuniformly, as illustrated in Fig. 4. As shown in Fig. 3, the laminations of each of the groups may be stacked so that corresponding slots in adjacent laminations of each group form common slots through the group.

If disk lamination slots are staggered, the laminations must be electrically insulated from each other. Therefore, because of the cost of insulation and because of the uncertainties involved, a preferred embodiment of the present invention utilizes vertically aligned slots. If the laminations are stacked so that the slots in adjacent laminations are aligned, the oxide on the surfaces of these laminations may provide the necessary insulation.

The slot patterns in the magnetic disk laminations limit and control circulating eddy currents, and the laminations provide a low reluctance path for the flux during and after periods of short circuit current flow.

Dish shaped metallic end bells, caps or shields 26 and 27 are disposed one outside each of the two stacks of disk laminations 20 and 21, with their outer edges bearing thereon. These end shields have a dual function, mechanical and electromagnetic. Mechanically, they clamp the coil turns together by cooperating with the

center stud. When constructed of a magnetic material, they assist the disk laminations in guiding flux in a desirable path. These end shields are constructed similarly to each other, being approximately a convex section of a sphere. They may be either of a size to substantially cover the disk laminations, as illustrated in Fig. 5, or of a size to only partially cover the disk laminations, as illustrated in Fig. 1. Since one function of these end shields is to clamp the coil turns together, end shields which have an outer diameter nearly equal to the mean diameter of the reactor coils distribute the clamping force fairly evenly between the various coil turns. Holes are provided at the center of end shields 26 and 27 to allow the stud 28 to extend through and cooperate with nuts 31 and 32 to hold the entire assembly together.

End shields 26 and 27 may be provided with a plurality of slots 33 spaced about the periphery thereof and extending inwardly therefrom. The slots in the end shield limit and control the circulation of eddy currents, and the shield provides a low reluctance path for the flux. High circulating currents set up in the end shield induce a flux opposed to the main leakage flux. This flux is somewhat reduced by slotting the end shields. Therefore, the radial length and number of these end shield slots will be determined by the amount of shielding desired and the degree of reactance drooping characteristic desired, as shown in Fig. 8.

These end shields may be hollow or solid. Since eddy current circulation increases with the thickness of the metal, short circuit reactance would be lower when utilizing a solid rather than a hollow end shield, and the reactor would therefore be less effective.

Fig. 3 illustrates a modification of the slot pattern of the laminated disk stacks 20 and 21. In the modification shown, each lamination comprises a plurality of inwardly extending spaced radial slots 34 disposed about its periphery and a plurality of slots 36 outwardly extending radially from the center of the lamination. The group of disk laminations 29 is shown uniformly stacked, so that the slots are vertically aligned throughout each stack. However, these laminations may be so stacked that the slots of one lamination are angularly displaced or staggered with regard to the slots in adjacent laminations.

In Fig. 4 another modification of the slotted construction of the metallic disk laminations is shown. A plurality of inwardly extending spaced radial slots 37 is shown about the periphery of each disk lamination, with the disk laminations stacked so that the slots are vertically staggered. This arrangement may come about by random stacking with no effort spent to line up the slots, which makes for a more economical assembly.

In Fig. 5, dish shaped metal end shields 38 are disposed outside of, and substantially cover, the stacks of disk laminations 39. These disk laminations and end shields are shown without slots thereby providing a shorter path length for the current induced in the disks and end shields, and consequently providing a lower current reactance than does a structure such as that shown in Fig. 1 with slotted disk laminations and/or slotted end shields.

Fig. 6 illustrates a further modification of the invention wherein a partitioned unit 41 comprising a housing 43, magnetic rectangular dividers 44 and filler material 46, replace the combination of the disk laminations and end shield at each end of the winding shown in Figs. 1, 2 and 5. Part of the layer of winding 42 nearest the unit 41 and part of the housing 43 of unit 41 are broken away to reveal the spaced rectangular dividers 44 and the filler material 46. The dividers 44 are plane surface members made of a magnetic material such as iron or steel, are disposed each on a flat plane, and extend radially relative to a common point 45, on their edges, to form a plurality of complementary pie shaped sections disposed side by side.

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These dividers should preferably be dipped in, or otherwise coated with, a high temperature varnish. The dividers 44 may be secured with a nonmagnetic filler material 46, such as high temperature casting resin, non-metallic spacers, or sand. The housing 43 for the unit may be metallic or nonmetallic, or may be metallic except for an outer nonmagnetic cover 48. A pair of units 41 perform substantially the same function as the combination of stacks of disk laminations and end shields shown in Figs. 1, 2 and 5. That is they increase the reactance of the reactor during periods of short circuit and limit the stray end flux that would otherwise cause excessive heating of the nearby metallic parts and of the cubicle housing.

Fig. 7 shows a further modification of the invention in which a pair of end caps, each comprising a hollow cylindrical member 51 similar in outer design to those shown in Fig. 6, replace the combination of disk laminations and end shields at each end of the winding shown in Figs. 1, 2 and 5. In this design, the members 51 may be formed of metallic or nonmetallic material filled with a magnetic material such as, for example, grains of iron powder 52. The covers 53 of member 51 may be nonmetallic, with the remainder of the member formed of a metallic material.

Fig. 8 is a graphic comparison of two characteristic curves, current to reactance, illustrating the effect of the presence of radial slots in the stacks of disk laminations. Curve A is for a reactor of the type shown in Figs. 1 and 2 but employing unslotted disks, and curve B is for the same reactor with four equidistantly spaced radial slots in each stack of disk laminations. As noted from Fig. 8, the ohmic reactance of the reactor with radial slots in the disk laminations is higher at high currents because of the greater length of the eddy current path, and the gain in reactance is more pronounced when most needed during periods of high current flow or short circuit conditions.

Although only a few embodiments of the present invention have been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims.

What is claimed is:

1. In a reactor, the combination comprising a stack of interconnected layers of electrically conductive windings, spacer members of electric insulating material disposed between said layers of conductive windings, a plurality of magnetic disk laminations arranged in groups, one group being disposed at each of the opposite ends of said stack with the laminations of each group being arranged substantially parallel to the layers of said stack, said groups comprising laminations each having spaced radially extending slots, end caps disposed one adjacent each of said groups on opposite ends of said stack, each of said end caps comprising metallic material, and means for maintaining said end caps in cooperative relation with said stack of conductive windings and said groups of disk laminations.

2. In a reactor, the combination comprising a stack of interconnected layers of electrically conductive windings, spacer members of electric insulating material dis-

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posed between said layers of conductive windings, a plurality of magnetic disk laminations arranged in groups with each lamination having equidistantly spaced radially extending slots, one group being disposed at each of the opposite ends of said stack with the laminations of each group being arranged substantially parallel to the layers of said stack, said laminations of each of said groups being stacked so that corresponding slots in adjacent laminations of each of said groups form common slots, end caps disposed one adjacent each of said groups on opposite ends of said stack, each of said end caps comprising metallic material and forming a shield, and means for maintaining said end caps in cooperative relation with said stack of conductive windings and said groups of disk laminations.

3. In a reactor, the combination comprising a stack of interconnected layers of electrically conductive windings, spacer members of electric insulating material disposed between said layers of conductive windings, a plurality of magnetic disk laminations arranged in groups with each lamination having spaced radially extending slots, one group of said plurality of groups being disposed at each of the opposite ends of said stack with the laminations of each group being arranged substantially parallel to the layers of said stack, said laminations of each of said groups being stacked so that corresponding slots in adjacent laminations of each of said groups are staggered, means arranged between adjacent laminations of each of said groups for electrically insulating said laminations from each other, end caps disposed one adjacent each of said groups on opposite ends of said stack, each of said end caps comprising metallic material forming a shield, and means for maintaining said end caps in cooperative relation with said stack of conductive windings and said groups of disk laminations.

4. In a reactor, the combination comprising a stack of interconnected layers of electrically conductive windings, spacer members of electric insulating material disposed between said layers of conductive windings, a plurality of magnetic disk laminations arranged in groups, one group being disposed at each of the opposite ends of said stack with the laminations of each group being arranged substantially parallel to the layers of said stack, said groups comprising laminations each having spaced radially extending slots, slotted end caps disposed one adjacent each of said groups on opposite ends of said stack, each of said end caps comprising metallic material, and means for maintaining said end caps in cooperative relation with said stack of conductive windings and said groups of disk laminations.

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