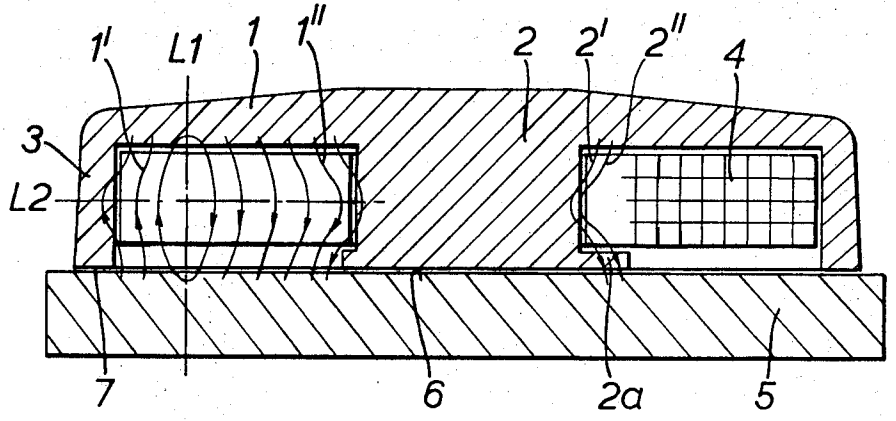
July 21, 1970 L. FRITZ 3,521,209

ELECTROMAGNETIC LOAD LIFTING DEVICE

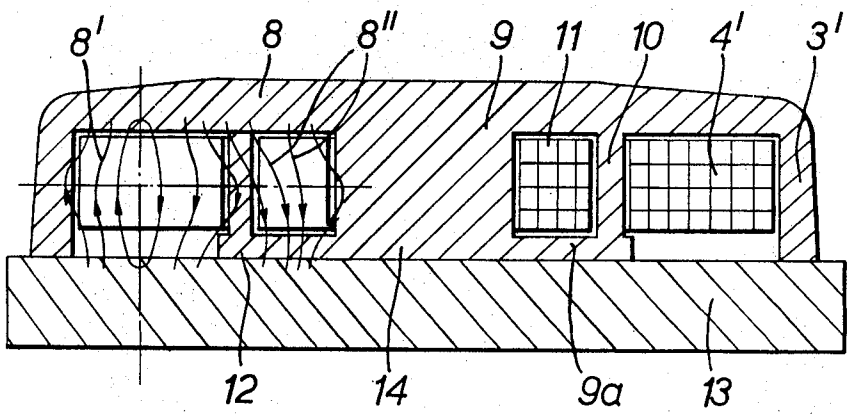
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FIG. 1.



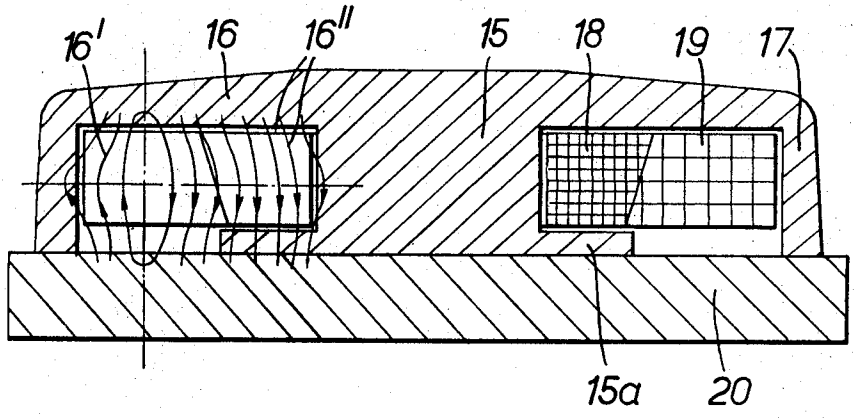
PRIOR ART

FIG. 2.



PRIOR ART

FIG. 3.



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ELECTROMAGNETIC LOAD LIFTING DEVICE

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FIG.4.

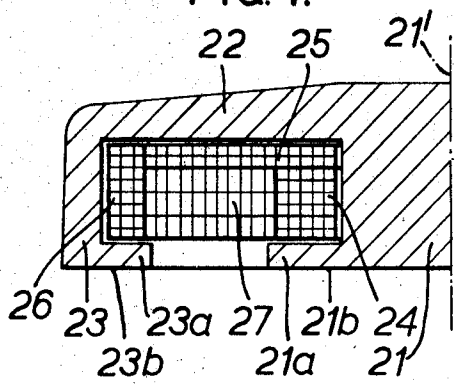


FIG.5.

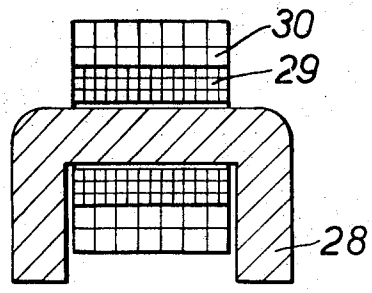


FIG.6.

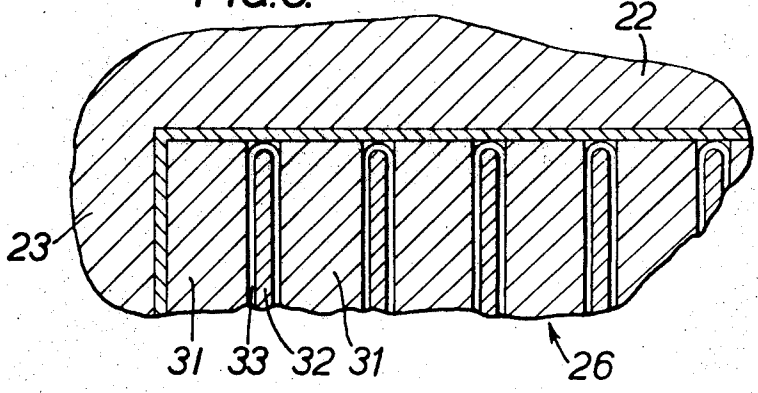
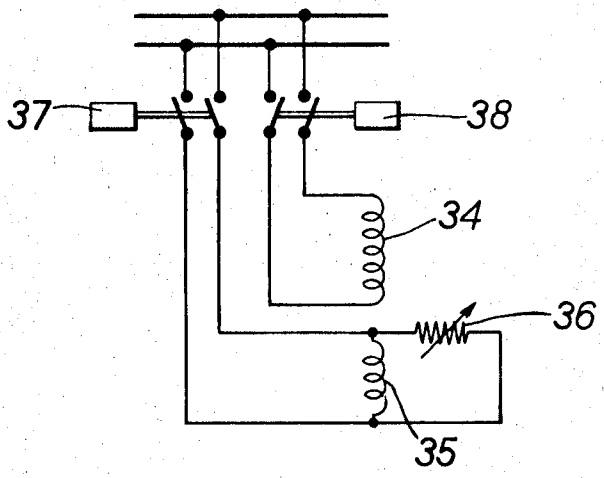


FIG.7.



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ELECTROMAGNETIC LOAD LIFTING DEVICE

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Int. Cl. H01f 7/20
U.S. Cl. 335—291 8 Claims

ABSTRACT OF THE DISCLOSURE

A load lifting electromagnet having a ferromagnetic housing and an excitation coil which is formed at least partially by a coil made of ferromagnetic material. The magnetically conductive coil is so arranged relative to the housing, that the magnetic cross section of the housing is increased, apart from the inherent excitation action of the magnetically conductive coil.

This invention relates to electromagnets, in particular to DC-energized electromagnets for lifting loads, especially of greater weight.

Conventional load lifting electromagnets generally comprise a ferromagnetic housing and a coil of excitation for generating a magnetic field associated with the housing. The housing includes pole pieces terminating in pole faces through which the lines of force of the magnetic field pass and by means of which the load is attracted. However, only those components of the lines of force, that extend in a normal direction with regard to the active pole faces, are capable of exerting a pulling force on the load. Tangential components remain without any effect upon the load. Therefore, in electromagnets for load lifting purposes, the ratio of normal components to tangential components of the lines of force should be as great as possible. In practice, in known electromagnets of the type here in question, the ratio of useful normal components to tangential and stray components is comparatively low.

Similarly, in prior art electromagnets, the ratio of active surface area basically available to the passage of flux to the total area of the magnet facing the load to be lifted is comparatively low, so that as a consequence, the efficiency of prior art magnets is comparatively low, i.e. a relatively great amount of ampere turns as well as a ferromagnetic housing of relatively large size are necessary in order to provide a magnet capable of lifting a certain load. One of the main reasons for such an unsatisfactory efficiency is that a certain cross section of the ferromagnetic housing must be reserved for the coil of excitation, which cross section as a result is not available as a path for the lines of force.

Further details explaining the difficulties experienced with such prior art electromagnets will be set forth hereinbelow in connection with the description of preferred embodiments of this invention.

It is an object of this invention to provide an electromagnet having an efficiency materially greater than is true with prior art electromagnets of corresponding construction, that is an electromagnet having the same overall size and being provided with the same number of ampere turns as a prior art electromagnet, but yielding a substantially greater pulling force than such a prior art electromagnet.

It is a further object of this invention to provide an electromagnet having low magnetic losses in the magnetic path of its housing.

It is another object of this invention to provide an electromagnet being protected automatically against

damages from overvoltages as produced, for instance, when the supply of electric energy to the magnet is suddenly interrupted.

Accordingly, the invention provides an electromagnet for lifting ferromagnetic loads, including a ferromagnetic housing and a coil of excitation associated therewith. The coil of excitation consists at least partially of a coil made of ferromagnetic material, which partial coil as a consequence may act as a coil of excitation generating a magnetic field and simultaneously may serve as a path for the lines of magnetic force so to augment the cross section available for the lines of magnetic force passing through the ferromagnetic housing. In view thereof, the ferromagnetic partial coil or coils are arranged in the immediate vicinity of those portions of the housing through which the lines of magnetic force extend. However, care is taken that in all circumstances bridging of pole pieces or pole faces, respectively, of opposite magnetic polarity is avoided. The partial coil may also, due to its intensive magnetic coupling with the remainder of the excitation coil, act as an attenuating coil capable of protecting the coil of excitation, if it is shorted before the disconnection of the remaining nonferromagnetic portion of the coil of excitation.

Further details and advantages of this invention will become apparent from the following description of preferred embodiments of this invention in connection with the accompanying drawings, wherein:

FIG. 1 is a radial sectional view through a pot-shaped conventional electromagnet;

FIG. 2 is a radial sectional view through another pot-shaped prior art electromagnet somewhat similar to the electromagnet of FIG. 1, having, however, an improved arrangement of the coils of excitation and a somewhat more suitable configuration of its housing resulting in a better efficiency than this is possible with the magnet of FIG. 1;

FIG. 3 is a radial sectional view of a pot-shaped load lifting electromagnet basically having a structure similar to that of FIGS. 1 and 2, respectively, but which otherwise is constructed in compliance with this invention;

FIG. 4 shows a radial sectional view through one half of a pot-shaped electromagnet as illustrated in FIG. 3, but having a somewhat modified coil according to a further embodiment of this invention;

FIG. 5 is a schematical longitudinal sectional view of a U-shaped load lifting electromagnet having a coil of excitation designed in accordance with the principles of this invention;

FIG. 6 illustrates on an enlarged scale a fractional view of FIG. 4 representing a preferred practical embodiment of a partial coil as employed in accordance with this invention; and

FIG. 7 shows diagrammatically a preferred embodiment of this invention for the electrical connection of the coil of excitation and the partial coil, respectively, with each other and to the mains or a similar source of electric DC-energy.

Referring now to the drawings, FIGS. 1 and 2 represent embodiments of the prior art and will be briefly described in order to set forth more clearly the problems encountered in connection with load lifting electromagnets of the type here in question and the principle underlying this invention.

The electromagnet of FIG. 1 generally is of pot-like configuration. A circular disk-like bridge or yoke member 1 is provided with a substantially cylindrical center pole portion 2 and, at its periphery, terminates into an annular circumferential outer pole portion 3 substantially concentrical with the central pole portion 2. An annular coil of excitation 4 is located within the recess

defined between pole pieces 2 and 3. When coil 4 is energized, a load 5 will be attracted by means of pole faces 6, 7 of the pole pieces 2, 3. At its lower end, the center pole piece 2 may have a portion of enlarged diameter, as indicated in FIG. 1, so that a shoulder is formed protruding beyond the coil of excitation. The diameter of this shoulder may be of smaller size as illustrated in the left half of FIG. 1, or of larger size as indicated with reference numeral 2*a* in the right portion of FIG. 1.

A number of lines of force 1', 1'' representative of the lines of force formed with this type of electromagnet are schematically illustrated in the left portion of FIG. 1. The lower portion of a line L1 indicates the area in which the normal components of magnetic induction are at a minimum and of zero amplitude. The intersection of line L1 and a further line L2 may be considered the center of the magnetic lines of force. The points, at which lines L1 and L2 intersect yoke member 1 and outer pole piece 3, respectively, indicate critical cross sections of the magnetic path susceptible to magnetic saturation. As apparent from the drawings, a considerable amount of the lines of force does not pass through the ferromagnetic housing, but through the recess between pole pieces 2 and 3, respectively, receiving coil 4. Accordingly, substantial magnetic losses take place within this nonferromagnetic area. Moreover, the normal components of the lines of magnetic force extending in the area between pole pieces 2 and 3 are of comparatively low amplitude, having a magnetic induction of between 0 and 1 kilogauss, and consequently may not exert a major effect on load 5. Only the magnetic force lines leaving or entering, respectively, the pole faces 6 and 7 comprise great normal components, the magnetic induction of these components being between 10 and 20 kilogauss.

In a well dimensioned circular load lifting magnet of the kind referred to in connection with FIG. 1, the percentage of surface area covered by the active surfaces 6, 7 rarely amounts to more than 35% of the total area of the surface facing the load, the annular area included between the pole pieces 2 and 3 accordingly amounting to 65% of the total area. However, the pulling forces exerted on the load by this comparatively large area merely amounts to at most 10% of the total force by which load 5 is attracted.

Accordingly, if an appreciable increase in pulling force and consequently a higher efficiency of the electromagnet are to be accomplished, it will be necesary to amplify the percentage of normal components in the area between pole pieces 2 and 3.

Further, it would be desirable to enlarge the cross sections of the ferromagnetic housing, particularly in the region corresponding to the intersection of line L1 with pole piece 3 and line L2 with yoke member 1, in which regions the ferromagnetic housing is subject to saturation increasing the magnetical losses which in turn cause a reduction of magnetic induction available in the surface area of the magnet. However, such an enlargement of the critical cross sections referred to is not possible without suffering from other disadvantages, as either the overall volume of the entire magnet would have to be increased or the cross section of the coil of excitation would have to be reduced.

As pointed out above, attempts have been made to improve the magnetic behavior of electromagnets by providing protrusions as the shoulder 2*a* of FIG. 1. The progress achieved by such a measure, however, is actually negligible. As indicated by the two lines of force 2' and 2'', the flux in this area, in spite of the presence of shoulder 2*a*, must still pass through a comparatively large nonmagnetic space causing high magnetic losses, and the normal components of the magnetic induction decrease very rapidly over the radial width of shoulder 2*a*, toward the outer edge thereof.

In order to overcome such disadvantages, and to increase the portion of normal components in the area between the active pole faces 6, 7, a structure according to FIG. 2 has already been suggested, this structure having, in a manner similar as in FIG. 1, a yoke member 8, an outer annular pole piece 3' and a center pole piece 9. A part of the coil of excitation is arranged as an auxiliary coil 11 within the center pole portion 9, an annular auxiliary pole piece 10 extending between a main coil of excitation 4' and the auxiliary coil 11. Both coils 4' and 11 are so related to each other, that the magnetic polarity of a pole face 12 of the auxiliary pole piece 10, on the one hand, and of a pole face 14 of the center pole piece 9, on the other hand, are the same, so that both pole pieces 9 and 10 may be bridged by a pole plate 9*a*, without causing a magnetic short circuit. The lines of magnetic force in this prior art enbodiment extend in the manner illustrated in the left half of FIG. 2. As evident therefrom, the amount of normal components is enlarged and the distance between the center pole piece 9 and the outer pole piece 3' is reduced, but the fact remains that the magnetic force lines passing through the area filled by the auxiliary coil 11 must traverse a nonferromagnetic space. Consequently, the ratio of normal components of the magnetic induction to the total induction is improved in comparison with the structure of FIG. 1, but the total cross section of ferromagnetic material available for the magnetic flux lines is substantially the same as in FIG. 1, so that considerable magnetic losses are still suffered, the problem of saturation of the magnetic cross section likewise not being overcome. The normal components of the induction at the pole face 12 are substantially constant over the radial width of pole face 12—in contrast to the normal components of the protrusion 2*a* which decrease toward the edge of protrusion 2*a*—but their value is only 55% of that prevailing in pole face 14.

In connection with FIGS. 3 and 4, it will now be explained how the drawbacks of the before described prior art magnets of FIG. 1 or 2, respectively, largely may be over come. The ferromagnetic housing of the magnet of FIG. 3 has a center pole piece 15 terminating in a circular yoke member 16, which in turn terminates in an outer annular pole piece 17 corresponding to the pole pieces 3 and 3' of FIGS. 1 and 2, respectively. In contrast to the embodiments of FIGS. 1 and 2, which both are provided with conventional coils, the coil of excitation provided between central pole piece 15 and peripheral pole piece 17 in this case is composed of a coil component constituted by first coil 19 of conventional structure and being made of nonferromagnetic material, such as aluminum or copper wire. However, the coil component 19 does not constitute the entire coil of excitation, but in addition, a second coil component 18 is provided, that is made of wire, tape or another suitable strip-like material having ferromagnetic properties, such as steel or iron, cobalt, nickel, iron due to its relatively good electric conductivity and due to its comparatively low price being a preferred material. In the embodiment of FIG. 3, the forromagnetic coil 18 concentrically surrounds center pole piece 15. A pole plate 15*a* is attached to the lower end of pole piece 15, that has about the same outer diameter as ferromagnetic coil 18 so that the lower surface of ferromagnetic coil 18 is covered by the plate 15*a*. The nonferromagnetic coil 19 concentrically surrounds the magnetic coil 18.

When coils 18 and 19 are energized so that a magnetic field is generated, load 20 may be attracted and within the area extending between center pole piece 15 and peripheral pole piece 17, the field lines extend in a manner as indicated schematically with lines 16', 16'' . . . As evident, the distance between pole pieces 15 and 17 substantially is the same as in FIG. 2, that is, it is considerably smaller than the corresponding distance of FIG. 1. However, in contrast to the embodiment of FIG. 2, the lines of magnetic force 16'' do not have to

travel through a nonmagnetic area as this is true with flux lines 8'' of FIG. 2, but due to the location of coil **18** adjacent to pole piece **15** will find an additional ferromagnetic path constituted by the ferromagnetic coil **18**. Therefore, in this preferred embodiment of the invention, the percentage of normal components of the magnetic induction in pole plate **15***a* is much greater than in pole plate **9***a* and pole face **12** and is essentially constant over the radial width of pole plate **15***a*, so that the efficiency of the electromagnet of this invention is materially increased.

The outer surface of ferromagnetic coil **18** adjacent to the nonferromagnetic coil **19** may be of tapering configuration, so that the diameter of coil **18** gradually grows from pole plate **15***a* toward yoke **16**. This configuration would compensate for the stray flux prevailing in the vicinity of the corner formed by center pole piece **15** and by yoke member **16**. The ferromagnetic housing itself may be made of cast steel or another suitable material as usual in the field of load lifting electromagnets.

FIG. 4 represents a sectional view of the left half of another preferred embodiment of this invention generally similar to the embodiment of FIG. 3, the ferromagnetic housing of FIG. 4 comprising a cylindrical center pole piece **21** and an annular outer pole piece **23**, both pole pieces being bridged by the common preferably circular yoke member **22**. Pole pieces **21** and **23** at their lower ends in this case both terminate in pole plates **21***a* and **23***a*, protruding toward each other beyond the outer diameter of pole piece **21** and the inner diameter of pole piece **23**, respectively. In this embodiment, three different ferromagnetic coils **24**, **25**, and **26** are provided, each of these ferromagnetic coils extending adjacent to and parallel with a ferromagnetic flux conducting portion of the ferromagnetic housing thereby supplementing and augmenting the cross section of the ferromagnetic housing without, however, appreciably reducing the ampere turns and, likewise, without bridging the magnetic pole pieces **21**, **23** which would of course result in a magnetic short circuit. The outer diameter of ferromagnetic coil **24** corresponds substantially to the outer diameter of pole plate **21***a* and, similarly, the inner diameter of ferromagnetic coil **26** is only slightly less than the inner diameter of pole plate **23***a*. The upper ferromagnetic coil **26** has an inner diameter corresponding to the outer diameter of pole piece **21** and an outer diameter corresponding approximately to the inner diameter of pole plate **23***a*. Coil **26** extends over the entire height of the recess receiving the coil of excitation while the height of coil **24** and **25** together corresponds to the entire height of the recess. The remainder of the coil of excitation, that is coil **27**, in a conventional manner is made of aluminum or copper wire or the like. The effect achieved by this arrangement of the coil of excitation is principally the same as in FIG. 3, that is, active magnetic pole faces of comparatively large size are obtained and the normal components emanating from pole faces **21***b* or **23***b* are considerably increased in amplitude and density. Consequently, the embodiment of FIG. 4 provides for a very high ratio of pulling force to ampere turns.

FIG. 5 illustrates another embodiment of this invention having a U-shaped core **28** whose yoke portion is first surrounded by a ferromagnetic coil **29** and, in addition thereto, with a nonferromagnetic coil **30** enclosing the ferromagnetic coil **29**, so that the magnetic cross section of the yoke section is increased and that stray flux, which as is known in electromagnets having U-shaped cores is comparatively pronounced in the yoke region, may be reduced. In spite of this enlargement of the magnetic cross section, no reduction takes place with regard to the space between the two lateral legs of core **28** for receiving the coil of excitation.

FIG. 6 shows a particularly advantageous possibility of forming the ferromagnetic coil as used for example in connection with the embodiment of FIG. 4. A strip or tape of electrically conductive, ferromagnetic material is wound in layers **31** about an axis corresponding with the center line **21'** of FIG. 4. Together with the strip of ferromagnetic material, there is wound a second layer **32**, **33** for electrically insulating adjacent layers **31** of the ferromagnetic coil from each other. The insulating layer may be purely electrically insulating material. In lieu thereof, the insulating layer may likewise consist of two different layers **32**, **33**. In this instance, layer **32** may be made of a nonferromagnetic, but electrically conductive material whereas the other layer **33** surrounding layer **32** may possess the required electrically insulating properties. For example, layer **32** may be constituted by aluminum foil having a thickness of about 20μ, whereas the isolating layer **33** may be an electrolytically applied oxide-insulation having a thickness of about 5μ. This kind of oxide-insulation is very heat resistant and likewise is resistant to electric voltages to a degree sufficient to insulate adjacent layers **31** as well as layers **31** and **32** from each other, respectively. If layer **32** is made of an electrically conductive material, its windings may be connected in parallel with the windings of layer **31** so to enhance the total conductivity of the ferromagnetic coil **26**.

The ferromagnetic coil separated from the coil **27** may yield the additional advantage of protecting the coil of excitation from destruction due to overvoltages. Such overvoltages may take place when the electric current fed through the excitation coil is suddenly interrupted so that voltage peaks of considerable amplitude are produced. Specific devices may be associated with the coils of excitation of electromagnets for protecting the excitation coils from the deteriorating effect of overvoltages, but these protecting devices remain ineffective as soon as the feeding cable will break. With the invention, the ferromagnetic coil may be bridged without the interconnection of the feeding cable by a device whose resistivity is a function of the voltage across the ferromagnetic coil, this resistance dropping in response to a rise in voltage across the coil.

In FIG. 7, such a circuit is shown. Coil **34** is representative of the nonferromagnetic component of the coil of excitation, and coil **35** is representative of the ferromagnetic coil. In operation, both coils are connected to a suitable source of direct current through electrical switches **37** and **38**, respectively. Coil **35** is bridged by a device **36** having a resistance which is great if the potential difference between the two terminals of coil **35** is at its nominal value, but drops considerably in response to an increase of the aforementioned potential difference. This voltage response device may be constituted by a varistor or any other arrangement having similar characteristics.

In this arrangement, switch **37** may be actuated and overvoltages arising at the terminals of coil **35** as a result of the interrupted current flow will then be attenuated by the voltage responsive device. If subsequently switch **38** is opened, current flow through coil **34** will be interrupted which normally likewise may lead to overvoltages. Ferromagnetic coil **35**, which remains bridged by device **36** and which because of its good magnetic conductivity is very closely magnetically coupled with coil **34**, will then act as an attenuating coil with regard to coil **34**.

It will be understood, that various modifications of the embodiments described will be possible without departing from the scope of this invention. In particular, it should be noted in this conjunction, that the concept of this invention may be applied in an analogous manner to other kinds of electromagnets not especially designed for the purpose of lifting loads.

What is claimed is:

1. A DC-electromagnet, particularly for lifting loads or the like, having a ferromagntic housing with pole pieces of opposite polarity and at least one coil of excitation associated with said housing for generating lines of magnetic force, said coil of excitation being composed of one coil-section made of electrically conductive and ferromagnetic material and a remaining coil-section made of

electrically conductive, but non-magnetic material, said one coil-section extending contiguously along portions of said housing conducting said lines of magnetic force and confining an intermediate space between said pole pieces of opposite polarity preventing bridging of said pole pieces, thereby increasing the effective magnetic cross-sections of said portions conducting said lines of magnetic force, and said remaining coil-section being located within said intermediate space.

2. An electromagnet according to claim 1, wherein said portions of said housing conducting lines of magnetic force and contiguous to said one coil-section terminate in pole plates extending across the lateral width of said one coil-section.

3. An electromagnet according to claim 1 wherein said one coil-section at least partially is made of strip of ferromagnetic material wound into the form of said coil, the individual turns of said strip being electrically insulated from each other by at least one additional insulating layer composed of an inner layer of electrically conductive material and an outer layer having insulating properties, said outer layer enclosing said inner layer at least at opposite sides adjacent said ferromagnetic material.

4. An electromagnet according to claim 3, wherein said inner layer is made of aluminum foil, whereas said outer insulating layer is constituted by an electrolytically applied oxide-insulation.

5. An electromagnet according to claim 4, wherein said inner layer of said additional layer forms an additional electrical coil electrically connected in parallel with said one coil-section.

6. An electromagnet according to claim 1, wherein said one coil-section is bridged by a voltage responsive device.

7. An electromagnet according to claim 1, wherein said ferromagnetic housing has a center pole and a peripheral

outer pole piece substantially concentrical with said central pole piece said central pole piece terminating in a pole plate having an outer diameter enlarged with regard to the outer diameter of the center pole piece, said annular peripheral pole piece terminating at its lower end in a pale plate having a smaller inner diameter than said outer peripheral pole piece, said coil of excitation comprising a first ferromagnetic coil surrounding said center pole piece and having an outer diameter slightly less than that of the pole plate associated with said center pole piece, a second ferromagnetic coil extending along the inner surface of the outer annular pole piece and having an inner diameter slightly less than the pole plate associated with said outer pole piece, and a third ferromagnetic coil extending along the inner surface of the yoke member and having an inner diameter substantially equal to the outer diameter of the center pole piece and an outer diameter substantially equal to the inner diameter of said second ferromagnetic coil.

8. An electromagnet according to claim 1, wherein said ferromagnetic housing is U-shaped and has two lateral legs bridged by a yoke member, said yoke member being surrounded by said ferromagnetic coil and said ferromagnetic coil being surrounded by said coil of nonferromagnetic material.

References Cited

UNITED STATES PATENTS

2,548,179	4/1951	Underwood	336—177 XR
2,716,736	8/1955	Rex	336—177 XR
2,761,094	8/1956	Frampton	335—291

GEORGE HARRIS, Primary Examiner

U.S. Cl. X.R.

335—299; 336—177