Nov. 5, 1940. A. L. WARD 2,220,561

MAGNET FOR LIFTING ANNULAR OBJECTS

Filed May 15, 1937

FIG. 1.

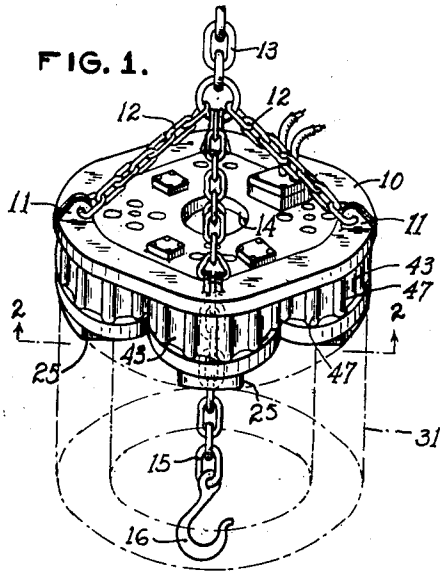


FIG. 2.

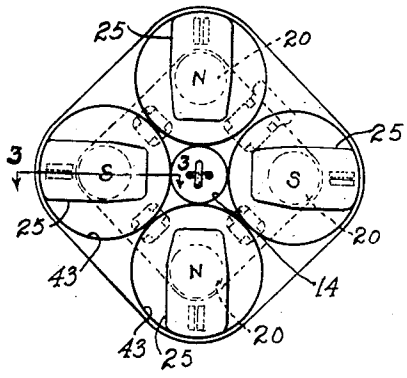


FIG. 4.

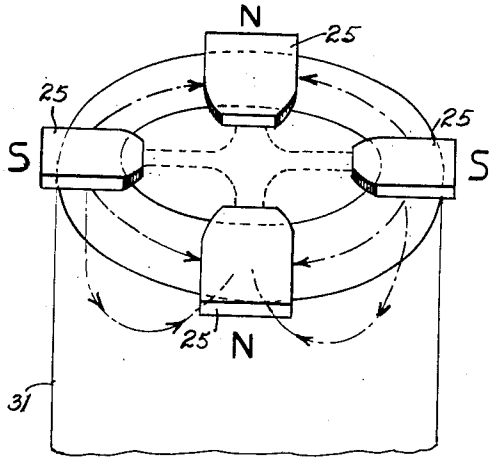


FIG. 3.

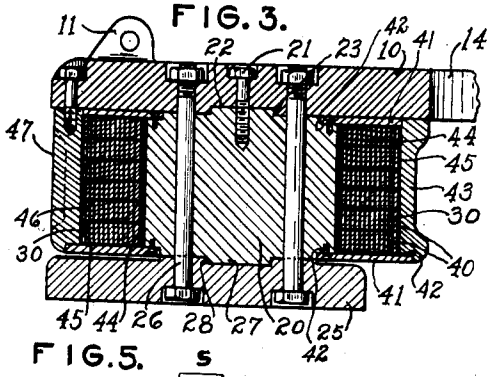


FIG. 5.

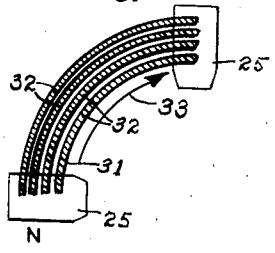


FIG. 6.

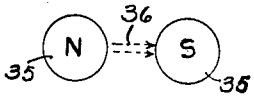
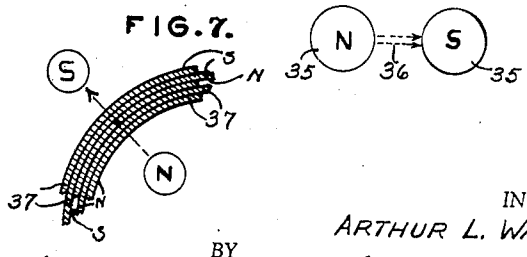


FIG. 7.



PRIOR ART

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MAGNET FOR LIFTING ANNULAR OBJECTS

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5 Claims. (Cl. 294—65.5)

This invention relates to lifting magnets and more particularly to lifting magnets for lifting annular pieces of magnetic material such as coiled strip steel and the like.

Electromagnets have been used extensively for many years for lifting magnetic material such as scrap iron, steel billets and various finished shapes made of ferrous metal. Generally the commercial type of magnets now used are of the circular type, such as disclosed in U. S. Letters Patent No. 1,325,914, issued Dec. 23, 1919, to Lewis D. Rowell. In general the circular type of magnet consists of a hollow inverted bowl-like yoke or body of cast iron or steel having a peripheral flange and a central boss which defines with the flange an annular channel, the flange portion providing one pole piece of the magnet and the central boss providing the other pole. The resultant annular channel accommodates a single winding coaxial with the flange and boss, the coil being retained therein and the lifting face of the magnet closed by a suitable covering which is preferably of a non-magnetic material. This type of magnet is suitable for general uses such as lifting scrap iron, steel billets and sheets, pigs, and other materials and has adequate contact area and is efficient for such general purposes.

Lifting magnets have been developed for lifting special shapes of ferrous metal, the modifications being made in the magnets to provide as large a contact area with the shape to be lifted as is consistent with economy in manufacture and shop practices. For instance, elongated magnets have been designed for lifting bars, rails and pipes.

Limitations in the types of magnets above described have led to the development of magnets having a better flux distribution. One example of such developments is disclosed in United States Letters Patent No. 1,316,672, to John P. Bethke, and comprises a multi-polar, circular magnet having a generally annular pole piece which also forms the magnet body and has a plurality of circumferentially spaced depressions which are symmetrically disposed about the axis of the annular piece and each of which opens in one face of the annular pole piece. Poles, each of which is provided with a separate winding, are located in these depressions, respectively, and each of these poles is spaced from the side walls of its associated depression. Each of these coil bearing poles is connected to the body member at the base of its associated depression. The annular pole piece is of magnetic material and has a peripheral flange portion and a central portion and thus provides return paths for flux from the coil bearing poles. In such a magnet, flux from the coil bearing poles divides and passes to the outer annular flange portion and to the central portion of the annular pole piece, and passes also through the portions of the annular pole piece which lie between the depressions. Thus the flux follows paths which are preponderantly radial with respect to the annular pole piece or body member. This type of magnet is used, among other things, for lifting coils of strip steel or iron by engagement of the magnet with the end of the coil of strip metal and is suitable for strips and coils of limited size.

With the improvements in cold reduction mills in the steel industry, the width of the strip rolled and the size of the resultant coils has gradually increased until coils have become so large that they cannot be handled efficiently by magnets of the types above described. Due to these changes in the width of strip and size of coils, the proportions of contact area at the ends of the coils available for engagement with the magnet is so greatly reduced relative to the weight of the coils that the coils either cannot be lifted by the prior magnets, or, if lifted, the coils creep and cannot be held upright and in a central position with respect to the lifting magnet. If not held centrally, the coils of strip tend to tilt and, when deposited by the magnet, strike on edge with resultant damage and bending of the strip stock.

Cold reduced steel strip, however, must be handled carefully so as not to damage the edges of the strip or deface the surface. One of the principal reasons for the failure of the first described prior magnets to operate effectively in connection with coils of cold reduced steel or coils of other ferrous material is because the magnetic flux produced thereby flows generally radially between the inner or central pole and the outer peripheral pole.

In the case of the distributed circumferentially spaced, intermediate poles, the flux likewise flows radially between each distributed pole and the peripheral pole and the central pole, the strongest pull being adjacent the distributed poles with varying degrees of pull at the zones therebetween.

Since the coils of strip steel necessarily are wound in the form of an annulus of metal having a wide central opening or inner diameter, the prior magnets, if centrally placed on the end thereof, are positioned with the central pole in alignment with the central opening of the coil

and not sufficiently close to any of the metal of the coil to assist appreciably in the resultant attraction. If the magnets were to lift the coil in this position, telescoping of the coil might result, the outer turns of the coil being held by the outer pole of the magnet while the inner turns, being in the region of low flux density between the poles, might drop away. Further, because of the high reluctance path under the central pole, to lift coils of strip with this type of magnet requires a much greater number of ampere turns than would be required in a solid load of the same weight.

Again, due to the fact that the magnetic flux seeks the path of lowest reluctance, coils which are lifted by such a magnet with the central pole over the central opening of the coil, tend to creep across the face of the magnet when being carried by a crane. More specifically, this is because the magnet cannot be set in absolute coaxial relation with the coil and the mass of the coil will be nearer to the central pole at one portion than at another and the coil will tend to creep due to the greater attraction and pull on the coil where this closer mass has reduced the reluctance and caused a concentration of flux.

Another reason why coils of strip steel are difficult to lift by prior magnets is that very often the edges of the coil convolutions are not in the same plane but may be offset axially of the coil as much as one or two inches from each other. Consequently, when the magnets, such as above described, are lowered on the coil and the flux passed radially between the peripheral and central pole pieces, the flux passes through the convolutions of the coil perpendicularly to the faces thereof. This tends to magnetize the convolutions so that opposite faces of each convolution are of different polarity and adjacent faces of adjacent convolutions are of opposite polarity. Consequently, the convolutions are mutually attractive and tend to pack together under the influence of the flux with resultant frictional resistance to movement of the convolutions relative to each other endwise of the coil. This mutual attraction of the convolutions makes it difficult, if not impossible, for the prior magnets to move the convolutions axially of the coil so that the edges at the end engaged by the magnet are drawn into a common plane. Consequently the area of metal contact with the face of the magnet is very small. This condition usually results at one or the other sides of the coil, wherever the convolutions happen to be the closer together initially and the resultant reduced area of metal contact between the coil and magnet renders the magnets very inefficient and unsatisfactory for this purpose.

Attempts have been made to solve this problem by using a standard magnet with the central pole so placed that it touches one side of the annulus, but such attempts have resulted in unbalanced loads and tilting of the coils and an increase in flux leakage.

The use of oversize magnets for this purpose is not satisfactory due to disproportionate cost and weight and to the fact that they conceal the coil hanging therebeneath so that when the coils are to be placed accurately in position, for example on an annealing base, the operator cannot see the position of the coil. If the coil happens to be off center or tilted, the operator cannot properly position it.

Another attempt to solve the problems presented was to provide an elongated central pole piece designed to bridge across the central opening of the coil, but such attempts result in unequal flux distribution and, in order to correct this disadvantage, necessitate the use of too much iron in the pole piece with the accompanying disproportionate increase in weight.

A still further development was the provision of two standard magnets connected by steel bars, the center pole of each magnet being adapted to center upon the metal portion of the annulus so that the greater amount of flux of each magnet would pass from the center pole through the coiled strip to the inner and outer edges of the coil and thence to the outer peripheral pole. It was found, however, that if the coils were loosely wound, the air gap between the convolutions of the coiled strip greatly reduced the efficiency of the structure and limited the loads the same as in the case of the single magnet in the Bethke Patent No. 1,316,672.

With the above discussion of the prior art at hand, the problems presented, and the solutions thereof provided by the present invention can be more readily appreciated.

A principal object of the present invention, therefore, is to provide a lifting magnet which will readily lift coils of strip steel of ferrous metal efficiently.

A correlative object is to provide a magnet for this purpose which is simple in design, compact, durable, economical to manufacture and repair, and which is sufficiently small relative to the size of coils to be lifted that the crane operator can readily see the coil and accurately place it in the desired positions.

Another object is to provide a magnet which will maintain the coil in a centered and balanced position.

Another object is to provide a lifting magnet having a ring shaped flux distribution in which the lines of force extend generally around the central axis rather than radially thereof so that greater efficiency is provided in lifting annular shapes.

A correlative and equally important object is to provide a magnet in which the flux distribution is such that adjacent areas of the convolutions of the coil are mutually repellent so that, as the energized magnet is lowered onto the coil, the convolutions are rendered relatively free to travel axially of the coil with respect to each other and thereby dispose the edges of the convolutions in a single plane and provide large contact area for contact with the magnet.

Another object is to provide a magnet for the purposes described having a body which has a central opening and arrangement of pole pieces such that the ordinary hook hoist can be disposed through the opening and used from the magnet hoist chain while the magnet is mounted on the chain.

Other objects and advantages will become apparent from the following specification wherein reference is made to the drawing, in which:

Fig. 1 is a perspective view of a magnet embodying the principles of the present invention and showing its application to a coil of strip steel;

Fig. 2 is a bottom plan view of the magnet illustrated in Fig. 1;

Fig. 3 is an enlarged fragmentary sectional view of the magnet taken on a plane indicated by the line 3—3 in Fig. 2;

Fig. 4 is a diagrammatic perspective view showing the coil to be lifted, the location of the pole

pieces of the magnet with respect thereto, and the flux distribution;

Fig. 5 is a diagrammatic illustration of the flux distribution and operating effect with respect to the coil convolutions between two adjacent poles of the magnet;

Fig. 6 is a diagrammatic illustration of a modification of the present invention; and

Fig. 7 is a comparative illustration of the flux distribution and operating effects between adjacent poles of a magnet of the prior art.

A preferred embodiment of the present magnet comprises a substantially square or annular yoke or body member **10** which may be cast steel or other flux conducting material and which, at its upper face, is provided with a plurality of chain or cable connecting lugs **11**, symmetrically arranged with respect to the axis of the yoke **10**. The yoke is supported by radial chains **12** which are connected to a common hoist chain **13** which extends axially of the yoke or body **10**. The yoke is provided with a central opening **14** through which extends an extension **15** of the chain **13**, the extension being provided with a suitable hoist hook **16** which depends below the bottom plane of the magnet so that it may be used without dismounting the magnet from the chain.

Mounted on the underside of the yoke **10** are a plurality of cylindrical magnetic cores **20**, the cores being arranged in radially spaced relation to the axis of the yoke and symmetrically disposed thereabout and also spaced circumferentially of the yoke with respect to each other. The core pieces **20** are preferably of cast steel and may be attached to the yoke by suitable bolts **21**, threaded into the core, cylindrical bosses **22** being provided on the upper ends of the cores and fitting into complementary holes **23** in the underside of the yoke so as to strengthen the structure against side thrusts and to maintain the cores accurately in position.

Mounted on the cores, respectively, are cast steel pole pieces **25** which are preferably secured to the associated cores by suitable bolts **26** as illustrated. On the under faces of each of the cores is provided a central boss **27** which fits into a complementary hole **28** on the associated pole piece so as to hold the pole piece in fixed position against any lateral thrusts. Wound about each core piece **20** is an energizing winding **30** which will be more fully described hereinafter, but which may be of any desired construction.

As better illustrated in Fig. 4, the pole pieces **25** are so placed and shaped that, when the magnet is lowered upon the annular shaped load to be lifted, such, for example, as a coil **31** of strip steel, the pole pieces engage the end of the annulus at uniformly distributed circumferentially spaced end areas. An even number of pole pieces is preferably used, each pole piece being energized by an individual winding. The windings preferably are so connected electrically that adjacent pole pieces are concurrently energized at opposite polarity as illustrated in Figs. 2 and 4. Thus, circumferentially of the associated annular load or coil of strip, the poles are alternate in polarity with respect to each other. Consequently, when the magnet is disposed in the position illustrated in Figs. 1 and 4 on the end of the coil of strip metal, the flux will flow from the north poles generally along the convolutions **32** of the coil to the south poles in a direction substantially parallel to the convolutions, as illustrated in Fig. 5.

Since the flux does not pass perpendicular to the surface of the convolutions and thus across the air gaps therebetween and since the yoke or body **10** completes the magnetic circuit for all poles, the only air gaps are those immediately under each pole. There is, therefore, only one air gap for each winding with resultant high efficiency. Again, the only leakage paths are from pole to pole and as shown by the dotted lines of Fig. 4 and these paths must pass through the central opening of the coil of strip. Consequently, as to the leakage paths, the reluctance is so great that nearly all of the flux is constrained to pass through the annular load itself.

This direction of the flux path through the load is an important feature of the invention. Referring to Fig. 5, two adjacent poles are shown with portions of the convolutions **32** of the coil **31** extending from one pole to the other. Assuming the flow of flux is from the north to the south poles, as indicated by the arrow **33** in Fig. 5, it is apparent that the portions of each convolution between adjacent poles will have its opposite faces of the same polarity at all portions along its length. Furthermore, it is apparent that both faces of all convolutions are correspondingly of the same polarity between the same circumferential limits so that the convolutions are mutually repellent. As a result, when the magnet is lowered onto the coil and energized, all of the convolutions tend to spread apart from each other, especially at the portion of the coil at which they are initially the closest together. This greatly reduces the frictional resistance between the convolutions so that the weight of the magnet and the pull thereof is sufficient to cause the convolutions to move relative to each other axially of the coil of metal and thus dispose their upper edges in the common plane with a resultant large contact area with the magnet.

As mentioned, coils of steel are very often wound loosely and gaps between the convolutions are sometimes as much as one half of an inch at one side or the other. Multiplying this by the number of convolutions, which is often ten or fifteen, a total air gap of several inches results. The high reluctance of such a path greatly reduces the lifting power of prior magnets. With the present magnet, however, since the flux passes in a direction parallel to the length of the convolutions it does not encounter the air gaps between the convolutions and consequently a much greater lifting force can be obtained in relation to the number of ampere turns.

Referring again to Fig. 4, the pole pieces are shown as of alternate polarity and from a theoretical standpoint such arrangement should provide the best lift. Actual tests have demonstrated that with a magnet arranged as herein described, even if pole pieces at one side of the yoke or body **10** are of the same polarity and pole pieces are arranged at the opposite side of the annular yoke **10** of the opposite polarity with respect to the first mentioned pole pieces, the flux is concentrated necessarily into paths positioned diametrically opposite to each other, instead of paths defining a ring, but such separate paths likewise extend substantially parallel to the convolutions. Such an arrangement of poles is illustrated in Fig. 6, wherein the two separate paths of flux from the pole pieces **35** are indicated by the arrows **36**.

The advantages of these flux distributions are readily apparent from a brief consideration of Fig. 7, wherein the flux flow radially of the magnet or transversely of the convolutions as in

prior structures is illustrated. In such an instance, the opposite faces of each convolution **37** are of opposite polarity and the adjacent faces of adjacent convolutions are of opposite polarity. Consequently the convolutions are mutually attractive and tend to draw together at that side of the coil at which they happen to be the closest when initially energized by the magnet. This prevents or reduces the movement of the convolutions axially of the coil so that the upper edges cannot be drawn readily into a common plane and further increases the air gap between the adjacent convolutions at the opposite side of the coil with resultant flux concentration at the side of reduced air gap and a resultant unbalancing of the load.

The pole pieces are preferably of a greater dimension radially of the body or yoke member than the thickness of the annulus so that, as illustrated in Fig. 4, the entire width of the poles at any point of contact with the annulus of the strip metal is greater than the width of the annulus radially.

The windings **30** of the individual poles may be of any desired construction, but preferably are similar to the type described in United States Letters Patent to Lewis B. Rowell, No. 1,325,914. Each of the windings comprises a plurality of sections **40** accommodated between upper and lower protecting plates **41** which are fitted upon suitable ledges **42** formed about the periphery of each of the cores **20** and about enclosing casing **43**, the plates being held in place by suitable screws, as illustrated. Suitable insulation is placed between the core and winding as indicated at **44** and between the winding and casing as indicated at **45**. Each section **40** of the winding comprises a flat strip of conductive material wound flatwise into a spiral with insulating tape interposed between the convolutions. The sections are placed in coaxial relation, one on top of the other, with suitable strips of insulating material **46** therebetween. Each layer of winding is connected at one end to an end of the adjoining section so as to form one continuous winding.

Each of the coil casings **43** comprises a hollow cylinder of cast brass or other non-magnetic material so as to maintain a high reluctance path between the yoke and each pole piece and concentrate the flux through the metal part of the annular load. Each coil casing **43** is machined to fit tightly against the periphery of the protecting plates **41** and suitable ribs **47** are formed on the outer surface thereof to strengthen the casing and assist in dissipating heat generated by the winding. The windings are preferably connected in series although other connections may be used.

In order to provide ready access to the terminals of the windings and to prevent moisture from entering the casings, the connections between the coils are preferably made within the usual terminal boxes, the terminal box being rendered moisture proof and water tight by filling with suitable insulating compound, all in a well known manner.

Because of the preferred arrangement of pole pieces and windings above described, the central opening **14** of the magnet may be much larger than has heretofore been possible, and consequently a hoist hook of proper size for the loads to be carried by the crane may be passed therethrough.

It is apparent from the foregoing description that a magnet embodying the principles above described is particularly effective for lifting coiled strip steel or ferrous material and that the structure requires but few parts, is extremely simple, compact, and durable and comparatively small in size in relation to the coils which may be lifted thereby.

Having thus described my invention, I claim:

1. An electromagnet for lifting annular coils of strip metal endwise and comprising a body member having a central axis, a plurality of positive magnetic pole pieces and a plurality of negative magnetic pole pieces carried by said body member, all of said pole pieces being spaced from the central portion of the body member and all being spaced apart from one another circumferentially, and the face of each pole piece lying wholly within a sector defined by radii through the axis of the body member and which is different from and spaced from the sectors in which the other pole pieces lie.

2. An electromagnet for lifting annular coils of strip metal endwise and comprising a body member, a plurality of positive magnetic pole pieces and a plurality of negative magnetic pole pieces carried by said body member, all of said pole pieces being spaced from the central portion of the plane of the contact face of the magnet which portion is peripherally defined by the combined entire inner ends of all of the pole pieces, and all being spaced apart from one another circumferentially, and each pole piece lying wholly within overall limits, circumferentially of the magnet, which are spaced circumferentially from the overall limits, circumferentially of the other pole pieces.

3. A magnet for lifting annular coils of strip metal endwise comprising a magnet frame having a central axis and having a plurality of downwardly projecting pole pieces, all of said pole pieces being spaced from the central portion of the magnet frame and all being spaced apart from one another circumferentially, separate annular magnet windings surrounding each pole piece respectively, said windings being so wound and interconnected with respect to each other as to cause some of said pole pieces to be of one polarity and the remaining pole pieces to be of the opposite polarity, each of said pole pieces having at its lower extremity a pole face, said pole faces being of such extent radially with respect to the axis of said magnet frame as to be capable of engaging substantially all of the turns of the coiled strip metal at a plurality of end areas of the coiled strip, each of which end areas lies wholly within a sector defined by radii through the center of the coil and which is spaced from the sectors of the other areas, and each pole face being spaced from the central axis of the magnet frame and lying wholly within a sector defined by radii through the axis of the magnet frame and which is spaced from the sectors of the other pole faces.

4. A magnet for lifting annular coils of strip metal endwise comprising a magnet frame having a central axis and having a plurality of downwardly projecting pole pieces, all of said pole pieces being spaced from the central portion of the magnet frame and all being spaced apart from one another circumferentially, separate annular magnet windings surrounding each pole piece respectively, said windings being so wound and interconnected with respect to each other as to cause some of said pole pieces to be of positive polarity and the remaining pole pieces to be of negative polarity, separate non-magnetic metallic cases surrounding each wind-

ing respectively, each of said pole pieces having at its lower extremity a pole face, said pole face being of such extent radially with respect to the axis of said body member as to be capable of engaging substantially all of the turns of the coiled strip metal at a plurality of end areas of the coiled strip metal, each of which end areas lies wholly within a sector defined by radii through the center of the coil and which is spaced from the sectors of the other areas, each pole face being spaced from the central axis of the magnet frame and lying wholly within a sector defined by radii through the axis of the magnet frame and which is spaced from the sectors of the other pole faces, and said non-magnetic cases substantially preventing any leakage flux from passing from the pole faces to the magnet frame.

5. An electromagnet for lifting annular coils of strip metal endwise and comprising a body member having a central axis, a plurality of magnetic pole pieces carried by said body member, said pole pieces being spaced from the central portion of the body member, and being spaced apart from one another circumferentially with respect to said axis, electrical energizing means for causing circumferentially adjacent pole pieces to be of opposite polarity with respect to each other, the circumferentially adjacent surfaces of adjacent pole pieces being positioned relative to each other so that, combined with the said spacing and the said energization of the pole pieces, there are more low reluctance flux paths extending generally circumferentially with respect to said axis than extending generally radially with respect to said axis, and attaching means on the body member adapted for attachment to a hoist for suspending the electromagnet.

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