

[54] COIL FORMING APPARATUS METHOD
AND GALVO-MOTOR PRODUCT

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[58] Field of Search 324/154, 155;
336/222, 225

[56] References Cited

UNITED STATES PATENTS

470,340	3/1892	Weston	324/155
1,695,422	12/1928	Grisdale et al.	324/155 X
985,420	2/1911	Keller	324/154 R X

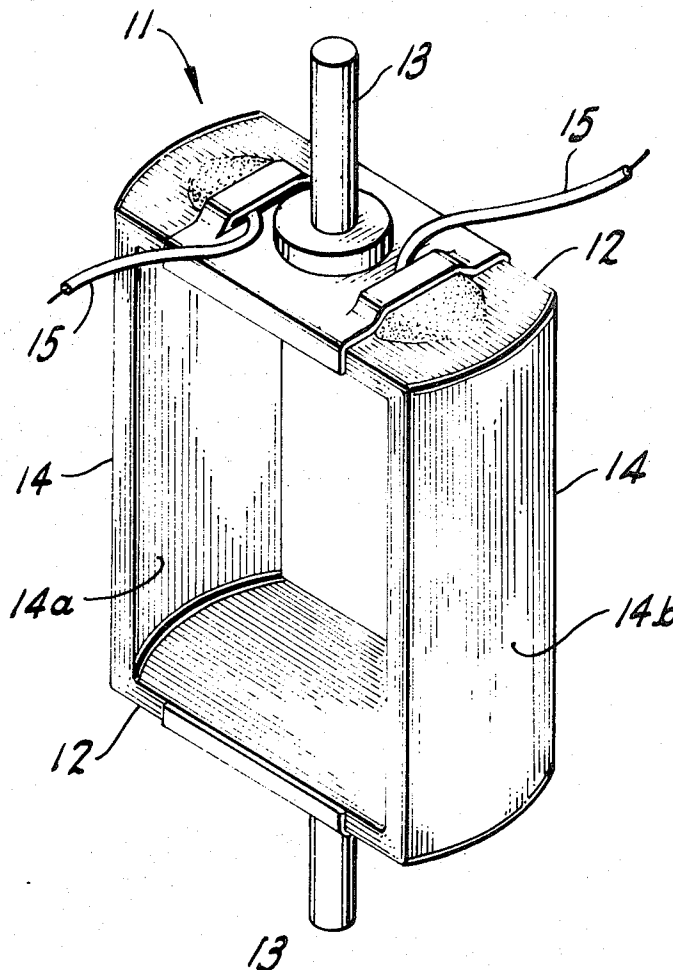
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[57] ABSTRACT

A contour molded galvo-motor coil together with the forming apparatus and the specific method of manufacture. A low inertia coil is formed which also allows a smaller air gap in the magnetic circuit of the galvo-motor. The associated improvement in galvo-motor efficiency results from the inverse square relationship between flux density and length of air gap. The formed coil is shaped as a section of a thin walled circular cylinder and impregnated with a compound during winding which when cured provides a rigid unitized coil structure. The low mass resulting from the absence of the conventional coil form and the high rigidity afforded by the coil shape and impregnation compound eliminate torsional deformation during operation and provide a galvo-motor having high efficiency and accuracy.

3 Claims, 6 Drawing Figures



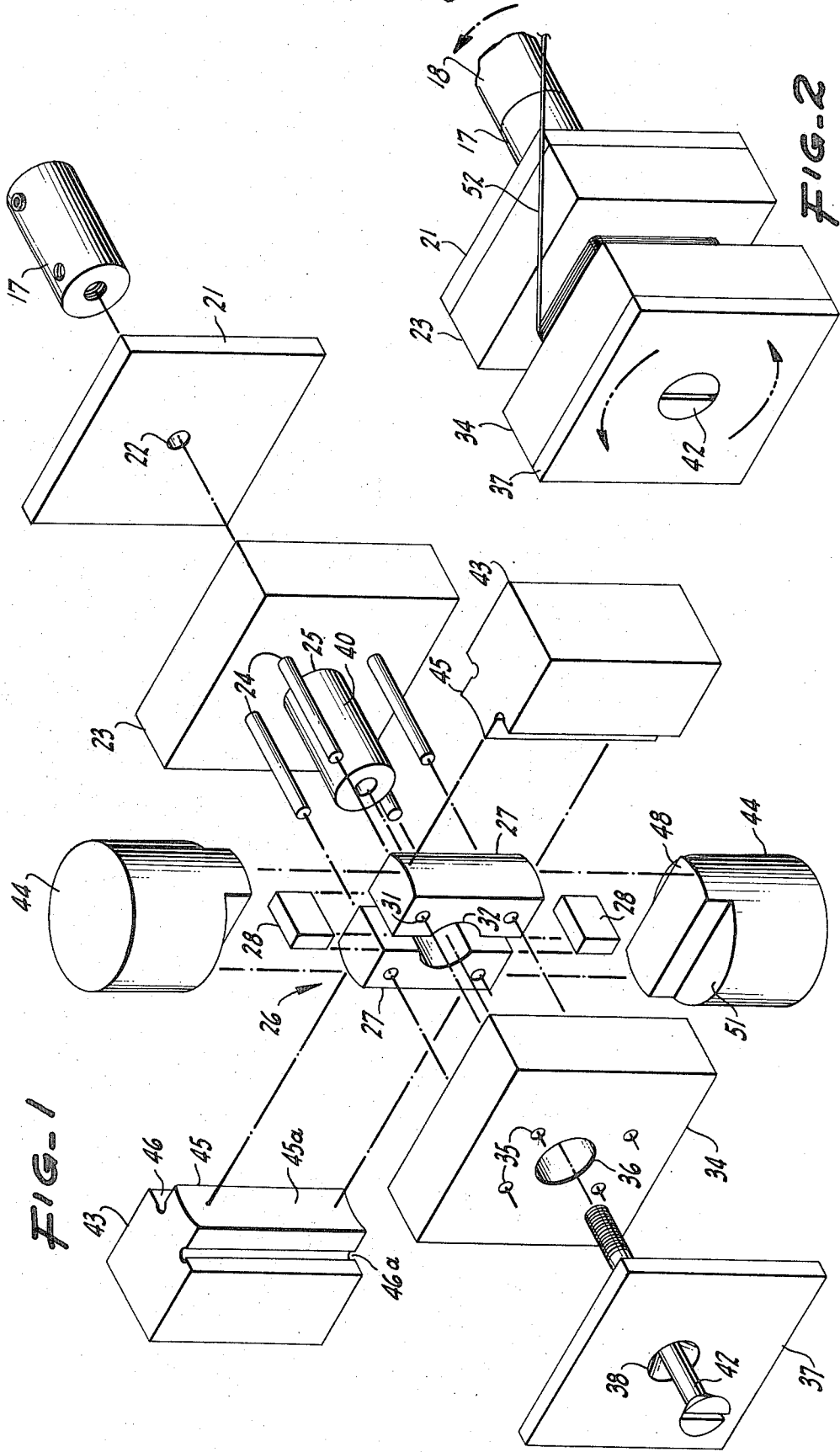


FIG. 3

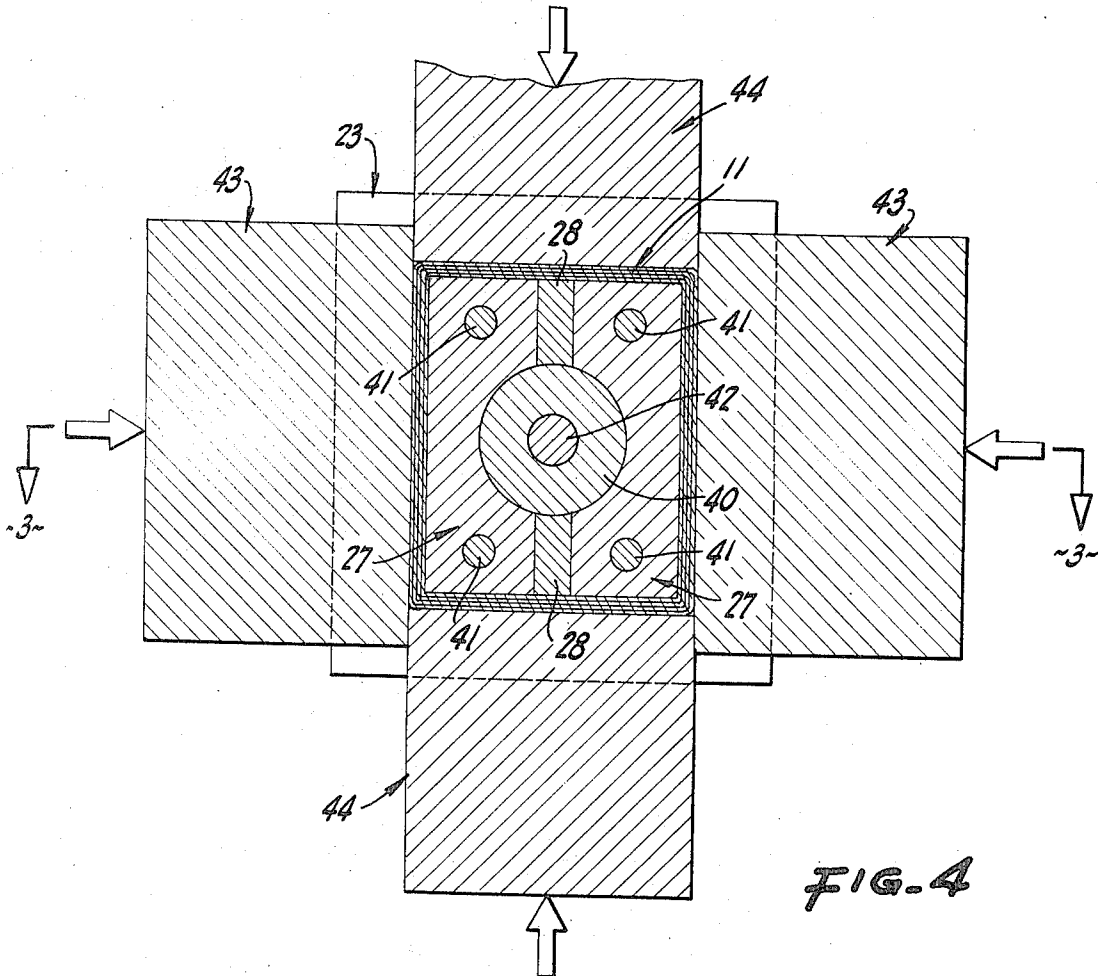
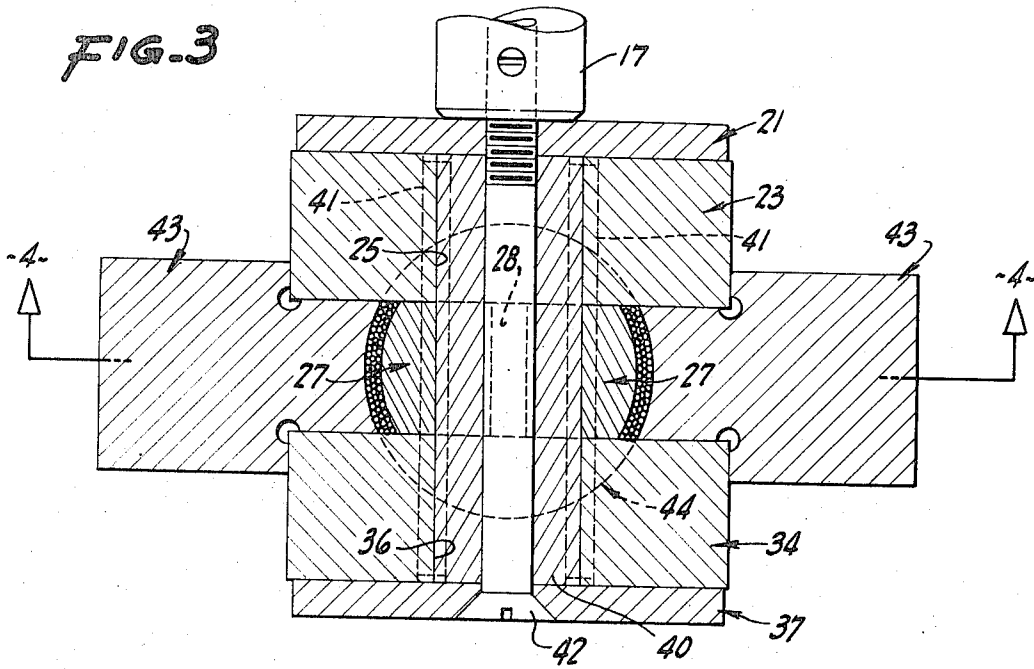


FIG. 4

FIG. 5

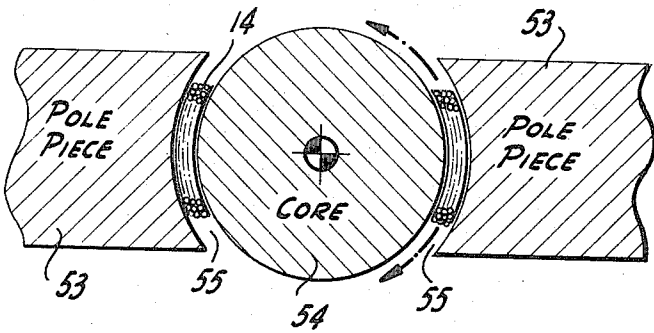
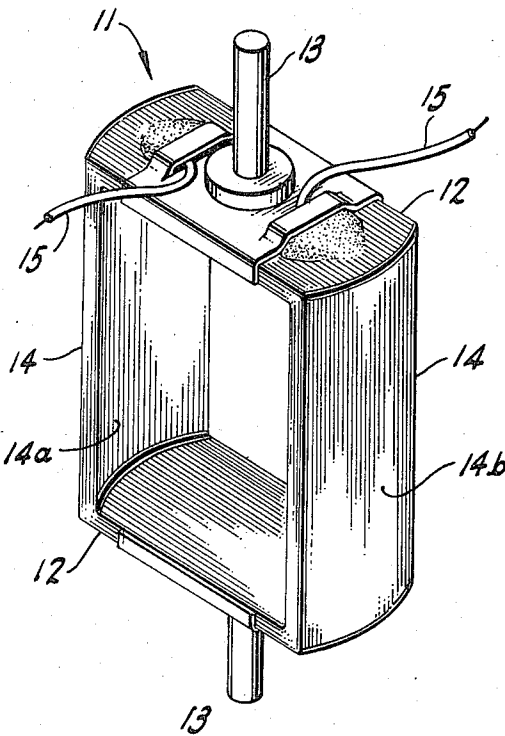


FIG. 6

COIL FORMING APPARATUS METHOD AND GALVO-MOTOR PRODUCT

THE BACKGROUND OF THE INVENTION

This invention relates to galvo-motor coils and to method and apparatus for manufacturing the same in a particular form.

In the past such coils have been manufactured using non-magnetic metal channels as coil forms onto which electrical conducting wire was wound. The channel became the structural support for the wound coil and therefore was an integral part of the coil itself. When an electric current flowed through the coil causing it to move within the magnetic field of the galvomotor, the coil was required to work against the added inertia of the channel. Furthermore, the magnetic gap between the core and pole pieces of the galvo motor had to be sufficiently wide to allow space for the channel, rectangular in cross section, to move freely through a rotational path. The wire wound channel also produced unpredictable coil thicknesses from one coil to the next. To accommodate the tolerance in coil thickness the magnetic gap was further extended. Uniformity in performance from one galvomotor to the next was therefore achieved through a sacrifice of magnetic efficiency.

To resist torsional deformity about the coil axis of rotation a metal channel was required to be of a minimum thickness. This thickness requirement not only increased the length of the magnetic gap leading to inefficiency, but also reduced the frequency response of the galvo-motor for a given size magnet and given amount of electrical power consumed due to the greater resulting mass of the coil. Greater power consumption at times required an increase in the size of the coil wire used, resulting in further addition of coil mass. This also lowered the potential frequency response characteristics of the galvo-motor coil of the lowest possible mass and the highest torsional rigidity providing at the same time maximum efficiency due to its geometric configuration.

SUMMARY AND OBJECTS OF THE INVENTION

The contour molded coil of the present invention as produced by utilizing special forming apparatus described herein provides a low-mass, ideally shaped galvo-motor coil with a high torsional rigidity. The structural strength is derived from the cured impregnation compound and the thin walled circularly cylindrical shape molded into the sides. The coil sides are maintained at a uniform thickness from coil to coil by the exact spacing designed into the coil winding forms and the curving mold forms, which together make up a unitary wiring assembly or jig. The coil end turns are properly shaped to receive pivots mounted on the center line of the cylinder of which the coil sides are wall sections.

The impregnation compound is applied to the electrical conductor as it is wound onto the coil form and will be present in excess amount prior to the assembly of the coil side forms and end turn forms. The final forming assembly allows escape of excess impregnation compound as the side and end mold forms are forced by pressure into their final positions. Curing of the impregnation compound within the coil in its final formed configuration takes place in the forming apparatus assembly. Those members of the forming apparatus which are in contact with the coil and subsequently

with the impregnation compound are made of a material which resists adhesion of the compound to their surfaces. At the completion of the cure cycle, the forming apparatus assembly may be disassembled readily without injury to the formed coil and without requiring cleaning of the forming apparatus prior to its next use.

The method involved in forming the coil on the coil form includes wetting the electrical conductor with the impregnation compound prior to presenting it to the coil form to be rotated on a winding machine. The process includes bringing out both ends of each strand of conductor laid down on the coil form during the winding process for subsequent electrical connection. The application of the exterior forming members involves pressing them into place and thereby exuding excess impregnation material and attaining the desired coil shape in the uncured condition. Curing takes place in accordance with the characteristics of the compound applied to the conductor during the winding steps.

In general it is an object of the present invention to provide a coil forming apparatus, method, and galvo-motor product which will overcome the above limitations and disadvantages.

It is a further object of the present invention to provide a contour molded coil and galvo-motor with low mass, high torsional rigidity, and a geometric configuration which optimizes galvo motor efficiency.

Another object of the invention is to provide a galvo-motor coil with a higher potential for accurate operation as a component of a recording apparatus.

Another object of the invention is to provide a contour molded coil and galvo-motor which will allow higher frequency response characteristics in strip chart recorders.

Another object of the invention is to provide a contour molded coil and galvanometer pen motor with greater operational efficiency due to decreased magnetic air gap and coil mass.

Another object of the invention is to provide a forming apparatus for a galvo-motor coil which will faithfully reproduce mechanical and electrical characteristics for a large number of coils.

Another object of the invention is to provide a method and apparatus for a forming galvo-motor coil upon which the coil is initially wound, finally formed and cured without the necessity for in-process removal and the consequent possibility of coil deformation or damage.

Another object of the invention is to provide a method of manufacture for a contour molded galvo-motor coil of relatively few simple steps which minimizes the possibility of variation in mechanical and electrical characteristics of the coil.

A BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded view of the coil forming apparatus including the final forming components.

FIG. 2 is an isometric view of the apparatus for winding and initial forming of a coil.

FIG. 3 is a side elevational view of the final forming assembly taken along the line 3—3 of FIG. 4.

FIG. 4 is an end elevational view of the final forming assembly taken along the line 4—4 of FIG. 3.

FIG. 5 is an isometric view of a finished contour molded coil.

FIG. 6 is a diagrammatic view of the contour molded coil in position in a galvo-motor circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The contour molded coil of the present invention generally consists of a single continuous strand of electrical conductor wound as a coil as shown in FIG. 5. The coil is generally formed with top and bottom end turns 12 which in this configuration are flat. Pivots 13 are mounted on the end turns which provide an axis of rotation for the coil. Coil sides 14 complete the loop described by the coil and in section are shaped like a section of wall of a thin walled circular cylinder. There is a first inside radius of curvature 14a and a second outside radius of curvature 14b on the circular cylindrical shell-like sides of the coil which are substantially identical for both the right and left sides. End connections 15 are brought out from the body of the coil 11 for each continuous strand of insulated electrical conductor.

Referring now to FIGS. 1 through 4, the apparatus for winding and initial formings 16 is shown in detail and includes a collet 17 having a threaded axial hole 18 at one end and adapted at the other end to mount on a winding machine driving shaft 19. Abutting the collet 17 is a first pressure plate 21 of a rigid material such as metal and having a centrally located clearance hole 22 aligned with the cylindrical axis of the collet 17.

Abutting the first pressure plate 21 is a first planar coil width form 23 which is fabricated of a suitable material such as teflon which resists adhesion by the impregnation compound. The first coil width form 23 has a rectangular array of holes 24 in this embodiment centrally located about a larger hole 25 with its center aligned with the clearance hole 22 in the first pressure plate 21.

A split coil form 26 is comprised of two identically shaped coil form halves 27 and two spacers 28 which are also of a suitable material to which the impregnation compound will not adhere. The coil form halves 27 have two holes 31 each of the same diameter as the holes 24 in the first coil width form 23, and a radius 32 centered on one of the long sides with the same radius as the hole 25 in the coil width form 23. The other long side of the coil form half 27 has the convex face 33 of a right circular cylinder with its center on the vertical axis of symmetry of the split coil form assembly 26 as depicted in FIG. 1. The spacers 28 are placed between the coil form halves 27 so as to clear the radii 32 thus presenting a rectangular array of four holes 31 and a center aperture bounded by the radii 32 substantially similar to the array in the first coil width form 23. The split coil form assembly 26 is mounted adjacent to the first coil width form 23.

A second planar coil width form 23 of a material resisting adhesion by the impregnation compound has an array of four holes 35 and a larger centrally located hole 36 substantially in the same array as holes 24 and 25 on the first coil width form 23. The second coil width form 34 abuts the split coil form assembly 26.

A second metallic pressure plate 37 has a centrally located hole 38 aligned with the centrally located hole 22 in the first pressure plate 21. The second pressure plate 37 contacts the side of the second coil width form 34 which is opposite the side contacting the split coil form assembly 26.

A hollow metallic cylindrical locating pin 40 is inserted in the centrally located holes 25 and 36 in the first and second coil width forms 23 and 34 and

through the aperture formed by the radii 32 in the split coil form assembly 26 to provide linear alignment between the last names parts 23, 26, and 34. Solid metallic cylindrical locating pins 41 are inserted through the matching arrays of holes 24, 31, and 35 to provide rotational alignment between the first and second coil width forms 23 and 34 and the split coil form assembly 26. A threaded shaft 42 is inserted through the hole 38 in the second pressure plate 37, through the axial hole in the hollow cylindrical locating pin 40, through the centrally located clearance hole 22 in the first pressure plate 21, and into the threaded hole 18 in the collet 17, thus securing the component parts of the winding and initial forming assembly 16 together.

Final forming members are placed on the winding and initial forming assembly 16 after the coil has been wound thereon to shape the external surfaces of the coil 11. These components consist of a right and a left coil side form 43 which are substantially identical in shape, and a top and a bottom end turn block 44 which are also substantially identical in shape. Both of the coil side forms and the end turn blocks are fabricated of some material resisting adhesion by the impregnation compound such as teflon. The coil side forms 43 have a land 45 extending from one side with a concave face 45 of a right circular cylinder with its center on the cylindrical axis of the cylindrical section forming the split coil form 26 when it is assembled as hereinafter described. The height of the land 45 as measured from a shoulder 46 on the coil side forms 43 is designed to provide the desired thickness of the coil sides when the shoulder 46 is seated against the sides of the first and second coil width forms 23 and 34. Relief 46a is provided at the junction of the shoulders 46 and the sides of the lands 45 to allow the shoulders 46 to seat firmly without obstruction.

The end turn blocks 44 also have lands 48 on one end which have a flat face. There are shoulders 51 from which the height of the lands 48 are measured and which when seated against the two remaining sides of the first and second width forms 23 and 34 provide the desired thickness of the coil top and bottom end turns 12.

The method involved in the invention disclosed herein includes applying uncured impregnation compound such as a suitable epoxy cement to an electrical conductor strand 52 and subsequently winding it on the coil form assembly 26 which is mounted in the winding and initial forming assembly 16. Following the winding of the conductor 52 the right and left coil side forms 43 are pressed into the winding and initial forming assembly 16 from the sides locating the convex surfaces 33 of the split coil form assembly 26 until the shoulders 46 seat firmly on the side of the first and second coil width forms 23 and 34. The top and bottom end turn block 44 are then pressed into the sides of the winding and initial forming assembly 16 from the sides locating the flat ends of the split coil form assembly 26 until the shoulders 51 seat firmly against the remaining sides of the first and second coil width forms 23 and 34. During the process of inserting the coil side forms 43 and the end turn blocks 44 excess impregnation compound will be exuded from the assembly. Subsequent to the removal of the excess impregnation compound the entire assembly is subjected to the curing cycle recommended for the impregnation compound used.

Upon completion of the cure cycle the coil side form 43 and the end turn block 44 are removed and the threaded shaft 42 is also removed. The first and second pressure plates 37 and 21 are separated as are the first and second coil width forms 23 and 34, the hollow locating pin 40, and the four solid locating pins 41. These two spacers 28 are pushed out from the side of the split coil form assembly 26 allowing that two form coil halves 27 to collapse toward the center of the coil 11 carried thereon so that they may be removed.

As shown in FIG. 5 the finished coil form has pivots 13 which define the axis of rotation of the coil and which are attached to the top and bottom end turns 12. The axis of rotation described by the center line through the pivots 13 must be substantially the same as the mean radius of curvature of the circular cylindrical sections forming the coil sides 14. Cured impregnation compound fills the spaces between the turns of conducting wire in the finished coil 11 and presents a smooth surface on the final formed and cured coil assembly 11. The impregnation compound also provides rigidity which is further enhanced by the cylindrical section shape of the coil side 14 and affords resistance to torsional distortion due to motion of the coil mass which in service may reach rotational frequencies well over 100 Hz.

The contour molded coil 11 is used in conjunction with galvanometer motors which in turn are used to drive low inertia devices such as a strip chart recorder pen or a mirror in a recorder using radiant energy as a means of creating a record. As best seen in FIG. 6 a magnetic circuit is constructed consisting of pole pieces 53, a magnetic core 54, air gaps 55 between the pole pieces 53 and the core 54, and a magnetic return path between the pole pieces (not shown). The flux density in the magnetic circuit is inversely proportional to the reluctance of the circuit and the reluctance in turn rises as the width of the air gap 55 increases. The absence of a coil form, because of the rigidity of the contour molded coil 11, and the cylindrical shell section shape of the coil sides 14 allow the air gap 55 to be decreased while still affording freedom of motion within the air gap 55 for the coil sides 14 as they move about the axis of rotation on the pivots 13.

It can be seen that the contour molded coil represents a significant improvement in coil fabrication technology. The electrical conductor becomes an integral part of the entire structure. It is precision molded into a physical configuration which allows minimum air gap in the galvo-motor. The cylindrical section imparted to the contour of the coil by the mold enhances coil rigidity and coupled with the low mass of the coil due to the absence of the conventional coil form, provides unusual resistance to torsional deformation during high frequency applications. The three essential design criteria of low coil mass, high coil rigidity, and optimum

coil shape are achieved without conflict or compromise.

I claim:

1. A galvanometer coil constructed for use without a coil form consisting solely of at least one continuous strand of insulated electrical conductor, formed into a loop consisting of a plurality of turns of said strand of conductor with the ends thereof available for electrical connection, said loop having first and second sides adapted to be moved through a magnetic gap and third and fourth return end sides generally perpendicular to said first and second sides serving to interconnect said first and second sides, a pair of pivots mounted on said third and fourth sides to define an axis of rotation of said loop, said first and second sides of said loop being constructed in the form of corresponding opposite sections of a circular cylindrical shell of uniform thickness with a radius of curvature center on said pivot axis, and uncured impregnation compound applied to said insulated electrical conductor immediately prior to formation of said loop and subsequently cured to form said loop into a unitary self supporting structure, whereby torsional deformation about the axis of rotation of said loop due to inertial resistance of the mass thereof is reduced to very low values by the low mass of said loop structure and the strength provided by the cylindrical shell structure of the sides thereof.

2. In a galvo-motor, a magnetic circuit, means forming a pair of pole pieces of magnetic material in said magnetic circuit having circular cylindrical concave faces positioned so that the radii of curvature of the concave faces have a common center line, a contour molded coil of electrical conductor having coil sides in the shape of corresponding opposite sections of a circular cylindrical shell of uniform thickness disposed on a radius of curvature centered on said common center line but shorter than that of the concave faces on the pole pieces and positioned adjacent to the pole pieces, coil ends connecting said coil sides forming a generally rectangular coil, pivots mounted on said coil ends on the common center line, whereby said coil is free to rotate about the common center line past said pole piece faces.

3. A galvo-motor as in claim 1 further including a core of magnetic conductive material with convex faces describing the surface of a circular cylinder having a radius of curvature with a center on said common center line but shorter than the radius of curvature of said contour molded coil sides, said convex faces positioned opposite the concave faces of the pole pieces, whereby a narrow circular cylindrical gap is formed between the pole pieces and the core in which said contour molded coil is disposed substantially filling said gap and free to rotate therein.

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