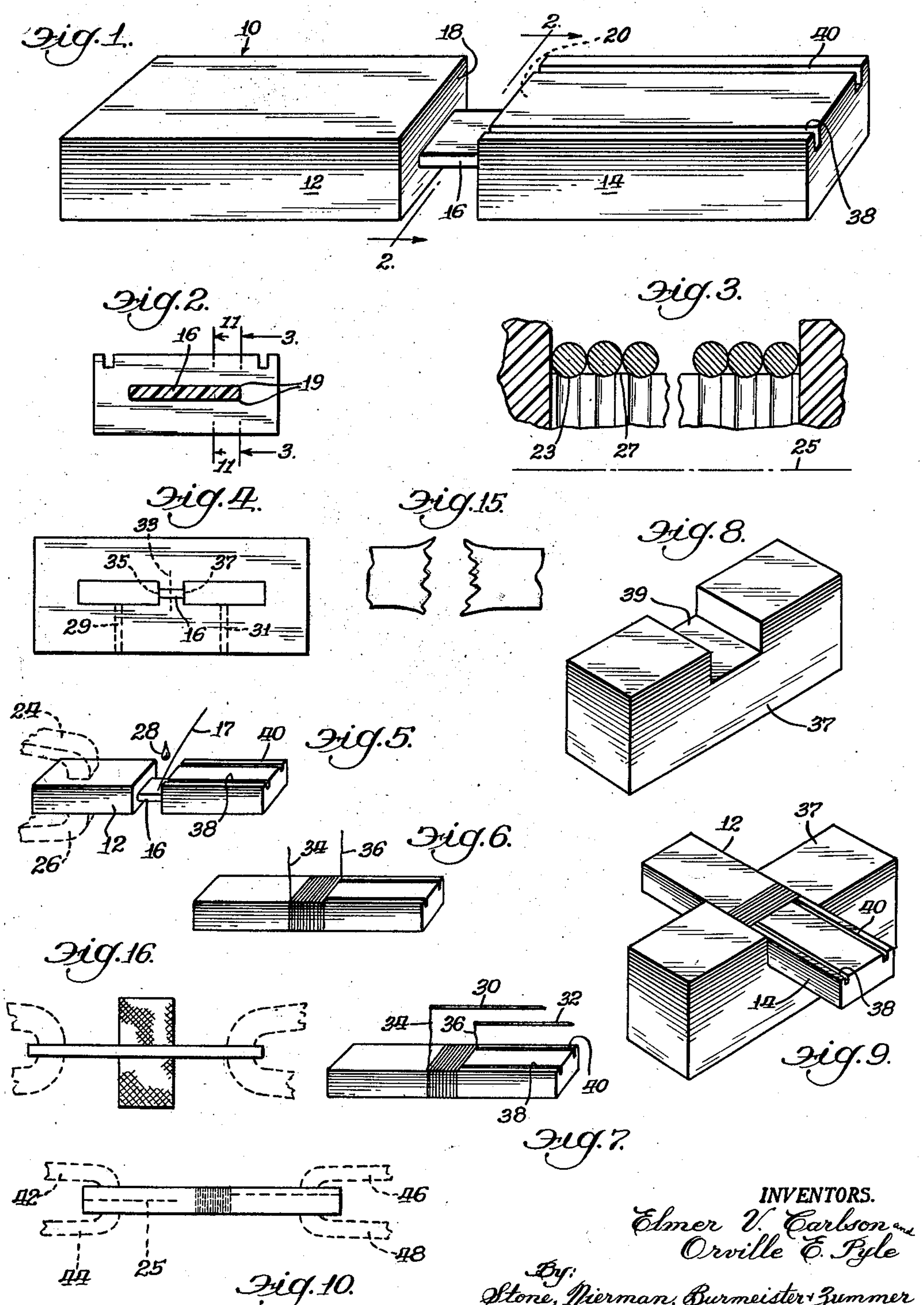
May 11, 1965 E. V. CARLSON ETAL 3,182,384

METHOD OF MAKING SELF-SUPPORTING COILS AND MANDREL THEREFOR

Filed Dec. 27, 1960 2 Sheets-Sheet 1



INVENTORS.
Elmer V. Carlson and
Orville E. Pyle
By: Stone, Nierman, Burmeister & Zummer
Attys.

METHOD OF MAKING SELF-SUPPORTING COILS AND MANDREL THEREFOR

Filed Dec. 27, 1960 2 Sheets-Sheet 2

Fig. 11.

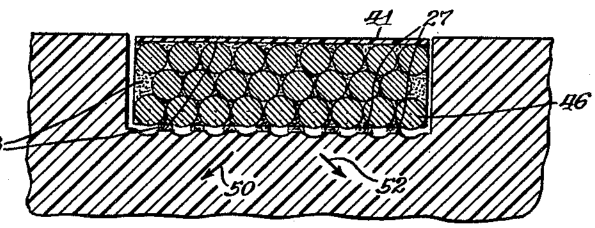


Fig. 12.

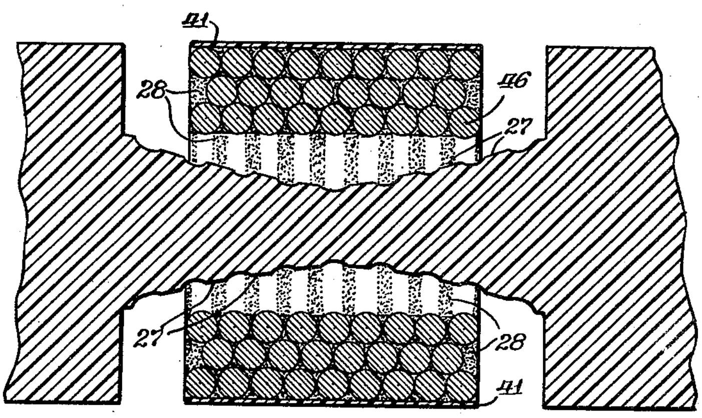


Fig. 13.

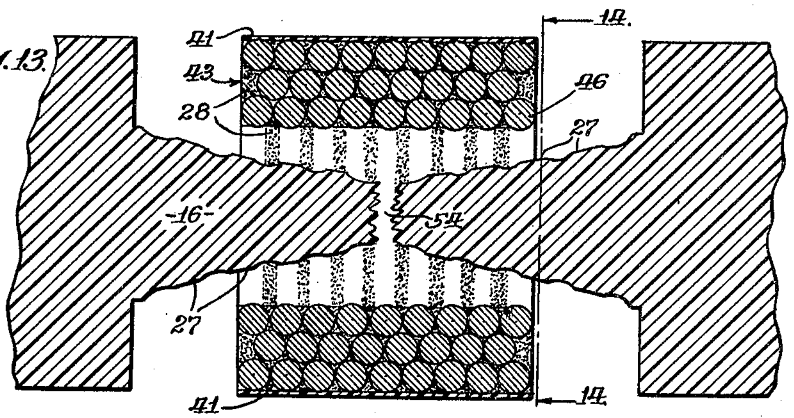
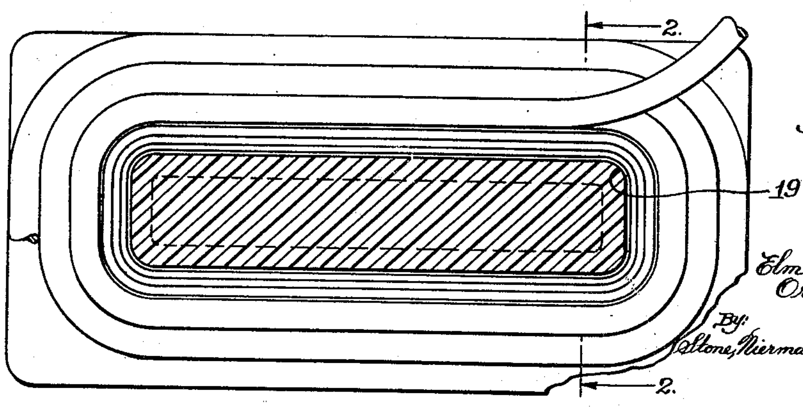


Fig. 14.



INVENTORS.
Elmer V. Carlson &
Orville E. Pyle
By: Stone, Nierman, Burmeister + Zummer
Attys.

United States Patent Office
3,182,384
Patented May 11, 1965

3,182,384
METHOD OF MAKING SELF-SUPPORTING COILS AND MANDREL THEREFOR
Elmer V. Carlson, Prospect Heights, and Orville E. Pyle, Des Plaines, Ill., assignors to Industrial Research Products, Inc., Franklin Park, Ill., a corporation of Delaware
Filed Dec. 27, 1960, Ser. No. 78,743
7 Claims. (Cl. 29—155.57)

This invention relates to a method of making self-supporting coils of wire, and is particularly adaptable to making such coils of fine wire, 40-gauge or finer, having a core hole or tunnel of substantially constant cross section where at least one dimension is a thirty-second of an inch or less. Specifically, the invention relates to an expendable mandrel which may by stretching, be contracted, and broken, after the winding operation and thus removed from the coil without damaging the innermost wire windings. The invention also includes a method of making the mandrel and a method of forming the exterior of the coil.

A self-supporting coil is one wherein a set adhesive holds the windings in a desired coil shape. Such a coil is wound on a coil form carrying adhesive or with adhesive applied to the wire during winding. After the adhesive has set, the coil form is removed. A self-supporting coil occupies less volume than the same coil on a bobbin so that when space in a transducer is at a premium, self-supporting coils may be used.

This invention is particularly useful when the mandrel must have a thickness of .020 inch or less. The maintenance of re-usable mandrels is expensive and time consuming and the use of meltable or dissolvable mandrels involve difficulties and risks in handling and procedures with fine wires and small core holes.

The general object of this invention is to remove a solid mandrel of substantially uniform cross section from a coil tunnel without damaging the winding adjacent to the tunnel. Specifically, applicants seek to contract a solid mandrel from the wire turns forming the tunnel wall of the self-supporting coil, and then remove the mandrel of reduced cross section axially without damaging the windings that form the tunnel wall of the coil.

Applicants' first specific object is to select for the mandrel a material having hardness and plastic flow characteristics at room temperatures such that it has sufficient structural strength to support coil winding, and upon stretching, it will flow and the mandrel surfaces will contract toward its axis sufficiently to clear the coil tunnel by at least a few diameters of the wire being wound, before it breaks. A feature of this invention is a mandrel made of a thermoplastic having certain hardness, stiffness and elongation characteristics.

Applicants' second specific object is to break the mandrel near the axial center of the coil. If the mandrel can be broken at the center of the coil, the mandrel parts will each carry a short end which can more easily be withdrawn from the coil than one long end. Where a mandrel will break in its stretched length depends upon the nature of the material.

A feature of this invention is the forming at opposite ends of the mandrel of gripping blocks which act as retaining walls of a coil as it is wound. The mandrel, therefore, is a form of bobbin. When the two gripping blocks are pulled apart, the force is transferred to the mandrel in such a manner that the stress is not excessive at the gripping points or at the ends of the mandrel. The stress within the mandrel section is nearly uniform. An advantage of the use of the blocks formed integrally with the mandrel resides in the fact that the blocks themselves

do not stretch and hence care need not be exercised in exactly positioning the gripping jaws of the stretching machine on the blocks so that they will be equidistant from the center of the coil. A feature of this method for fabricating the coil forms is that blocks attached to the ends of the mandrel can be accurately located within the winding machine on successive coils by providing for accurate mechanical location of one or both of these blocks.

A second feature carrying out this object is the forming of the mandrel in an injection mold wherein the material is introduced from both ends of the mandrel so that the material flows or meets at or near the center of the mandrel. Apparently, at the point where the same material comes together, the strength is less than in the rest of the mandrel and this aids in causing the mandrel to separate near its midpoint.

Another specific object of this invention is to select a material for the mandrel which will flow toward the axis of a mandrel having a rectangular or lozenge cross section, that is, a material possessing plastic flow in all directions.

Another specific object of this invention is to select for a mandrel a material whose ends do not snap laterally of the mandrel axis or produce splayed, jagged fangs upon breaking.

These and such other objects as may appear are attained in the embodiment of the invention described in connection with drawings wherein:

FIGURE 1 is a perspective view of the applicants' coil form carrying end blocks joined by a mandrel;

FIGURE 2 is a view in cross section of the coil form taken on the line 2—2 of FIGURE 1;

FIGURE 3 is a partial view taken on the line 3—3 of either FIGURE 2 or FIGURE 14 and greatly enlarged;

FIGURE 4 is a schematic plan view of one-half of an injection mold for making the mandrel;

FIGURE 5 is a schematic perspective view illustrating the coil winding step;

FIGURE 6 illustrates the finished coil in the mandrel;

FIGURE 7 illustrates attaching the lead wires preparatory to banding with a shroud to obtain a selected shape and desired dimensions;

FIGURE 8 is a perspective view of a jig for holding the coil form during the enshrouding step;

FIGURE 9 illustrates the wire-wound coil form positioned in the guideway of the jig of FIGURE 8;

FIGURE 10 is a schematic illustration of the jig and coil form positioned in a drawing or pulling machine;

FIGURES 11, 12 and 13 are views taken on the line 11—11 of FIGURE 2; the relationship of the mandrel to the coil immediately after stretching commences is shown in FIGURE 11; immediately before the mandrel separates, in FIGURE 12; and immediately after separation, in FIGURE 13;

FIGURE 14 is a view taken on the line 14—14 of FIGURE 13, with, however, the adhesive and enshrouding materials removed;

FIGURE 15 is a schematic illustration of an undesirable type of mandrel rupture; and,

FIGURE 16 is a schematic view illustrating the points on opposite ends of a mandrel of constant cross section at which the pulling jaws should be engaged.

THE PROCESS

Referring to FIGURE 1, applicants' expendable coil form **10** consists of two blocks **12** and **14** connected by a land **16** having whatever cross section is required for the tunnel of a coil to be wound. The land **16** is the mandrel and the whole constitutes a form of bobbin. The blocks **12** and **14** are shown rectangular, but since, as will appear, their shape is to define the perimetric cross section of the coil and also to facilitate holding by clamps, their shape may be varied. The mandrel itself has a constant cross section. The walls 18 and 20 lie in parallel planes at right angles to the axis of the mandrel.

Referring to FIGURE 2, the edges 19 of the mandrel may be given a substantial radius in order to minimize a wire's seating itself in the material as suggested in FIGURE 3, see also FIGURE 14. The tension on the wire may be high during winding and the inside windings which ultimately form the tunnel of the coil may embed themselves to form grooves 23 and arises 27. In order to attain the object of this invention, it is necessary to avoid abrading the inner windings 21 by the arises 27 during movement of the mandrel surface toward the axis 25. The shallower the grooves 23 between the arises 27, the less contraction of the mandrel is required to leave the wires undisturbed.

Applicants form the coil from 10 by injection molding. Referring to FIGURE 4, which schematically shows a plan view of the face of one-half of the mold, two material gates 29 and 31 are positioned either side of the mid-line 33 of the cavity of the mandrel 16 so that the material, for example, polyethylene, from the two gates 29 and 31 will meet approximately at the line 33 and there form a transverse strata of fused polyethylene of slightly less tensile strength than that in the balance of the mandrel 16. Moreover, the tensile strength of the polyethylene at the planes of joinder 35 and 37 to the blocks respectively will be approximately equal to that of the block and the mandrel so that separation at these planes during the pulling step is unlikely.

Referring to FIGURE 5, the block 12 of the coil form 10 is positioned between jaws 24 and 26 of a winding machine. A tailstock of a winding machine may be used where the mandrel 16 is so elastic that it would flex and interfere with winding if it were held only by the block 12. The operator applies an adhesive suggested by the droplet 28 to the mandrel core 16, or the adhesive may be applied to the wire as fed to the mandrel. This adhesive has the property of not adhering to the material of the mandrel. Next, the end of a wire 17 is wrapped around the mandrel core 16 and the winding proceeds until the coil is formed as indicated in FIGURE 6. Assuming that the coil is to have the perimetric configuration of a cross section of the block 12, the coil form may be pressed between flat surfaces to bring the entire coil within the planes of the side walls of the blocks 12 and 14. Also, excessive adhesive may be removed. If desired, referring to FIGURE 7, comparatively heavy wire leads 30 and 32 may be soldered to the respective coil leads 34 and 36 and seated in channels 38 and 40 originally formed in the block 14. Preferably there is a slight clearance between the perimeter of the coil and the planes of the surfaces of the blocks 12 and 14. Alternatively the grooves 38 and 40 may be holes passing axially through the block 14 and/or 12 and closely fitting to the lead wires such as 30 and 32 so as to restrict the flow of adhesive or imbedment along these wires.

Thereupon, the coil form and coil is mounted in a jig 37, see FIGURE 8. This jig is either treated or coated so as to be non-adherent to the adhesive used on the coil, and/or the imbedment compound shrouding the coil, or is made from a material inherently having this property, such as that used for the mandrel. It is a block having an open-sided, transverse slot or guideway 39 whose width is such as to receive tightly the width of the coil form 10, and whose depth equals the thickness of the blocks 12 and 14. The width of the jig 37 exceeds the length of the mandrel core 16. The coil may either be coated with a quantity of an imbedment compound 41, or a quantity of the imbedment compound may be placed in the slot 39 and thereafter the mandrel assembly pressed into the slot, see FIGURE 9. Alternatively, the coil assembly may be placed within the slot and the imbedment compound flowed into the pocket thus formed. The imbedment compound which may be, but is not necessarily, the same as the adhesive 28 used on the coil is allowed to set or cure to form a shroud around the coil protecting the wire and providing surfaces accurately located with respect to the mandrel 16.

Alternatively, the block 37 may be modified so as to take the form of two blocks which fit around the mandrel, thus permitting accurate control of all exterior surfaces of the coil.

The next step is taken subsequent to the setting or curing of the adhesive on the coil and the imbedment compound and consists of stripping the jig block from the coil. This leaves the coil with shaped exterior surfaces on the mandrel 16 disposed between the blocks 12 and 14.

The portions 12 and 14 are clamped by means suitable for applying tension between these members such as between a pair of jaws 42 and 44, and a second pair of jaws 46 and 48, FIGURE 10. These pairs of jaws are pulled apart along the axis 25 of the mandrel separating the blocks 12 and 14, and in the process stretching the mandrel 16. As the mandrel portion 16 is stretched, it contracts from all sides, pulling away from the wire windings in the tunnel, as illustrated in exaggerated form in FIGURE 11. The direction of the flow of the mandrel material is believed to be along the lines of the arrows 50 and 52 in FIGURE 11. As the pulling continues, the mandrel core 16 separates at 54, see FIGURE 13. When this occurs, the clearance between the walls of the mandrel core 16 and the inside tunnel walls of the coil is such that the two ends are drawn out without damaging any of the windings of the coil tunnel.

The rate of pulling may be substantially constant, although some materials may perform better if the pull is started at a high rate and then continued at a lower rate.

THE MATERIAL OF THE MANDREL

The mandrel must be made of a material whose surface will contract toward the mandrel's axis when the mandrel is stretched along its axis. The contraction must be sufficient so that all walls of the contracted mandrel will clear the coil tunnel winding by a distance such that upon withdrawal of the mandrel, the coil tunnel windings will not be abraded. The key quality is contraction of all surfaces toward the axis of stretch before the rupture occurs. The material of the coil form must possess sufficient ductility or plastic flow. This implies that the strain at the ultimate stress must exceed the strain at the yield point by a substantial amount. In this circumstance, as the coil form is separated, the material in the mandrel 16 is stretched and in so doing flows toward its axis and its cross section is reduced. The behavior of the material under this condition must be ductile rather than elastic, or at least behave as if it is ductile rather than elastic for a sufficient period to permit the removal of the coil from the mandrel section. This does not preclude the use of materials possessing a plastic memory which after a period of time may resume a shape close to that it possessed prior to the stretching operation.

The material of the mandrel must have at least four other qualities. Firstly, it must have a modulus of elasticity sufficiently great to impart rigidity to the coil form. A broad range of decreasing rigidities may be employed with decreasing convenience. It is most convenient during the winding process the coil form be supported at only one end. This means that the material must be stiff enough so that the tension applied to the wire during winding does not seriously deflect the mandrel off of the axis of rotation or twist the mandrel about the axis of rotation. It must also restrain the free end of the coil form against centrifugal forces which may develop from small unbalances. A lower modulus of elasticity may be used if both ends of the coil assembly are supported while one end is driven, and a still lower modulus may be used if the driving force is applied to both ends of the coil form. The material must be sufficiently stiff to resist excessive imbedding of the wire in the surface of the mandrel. The modulus also must be sufficiently high to prevent expanding the mandrel assembly axially due to the forces generated by the wire against the surfaces **18** and **20**.

Secondly, the material of the coil form must have a sufficiently high yield point to resist distortion during the winding operation. As in the case of the elastic modulus, the yield point can be reduced progressively as one employs more complicated means for supporting the coil form, that is, a high yield point material will permit the mandrel to be supported only at one end. A material with a lower yield point may be driven only at one end while being supported at both ends. A still weaker material may be used if the coil form is supported and driven at both ends.

Thirdly, the material of the mandrel should preferably resist chemical attack and adhesion by the adhesive used to bind the coil. This can conveniently be one of many plastic materials which inherently can possess this property but does not preclude the use of a material on which a surface coating or treatment is applied to induce this property.

Fourthly, the material must be readily fabricable. An extremely convenient way of producing such coil form is by injection molding of thermoplastic materials. However, it is not impossible and in some instances may be quite practical to fabricate the coil form by other means, such as casting or machining.

One material which has been found to fulfill the foregoing requirements is polyethylene. For a particular coil, where the mandrel portion was .085 inch long in the axial direction, and had a rectangular cross section .020″ x .118″, materials having stiffnesses of 95,000 to 175,000 pounds per square inch, a tensile strength in the range of 3,300 to 5,000 pounds per square inch, and an elongation ranging between 12% and 300%, performed adequately as coil forms for this process. A wide variety of plastic materials are available which can be formulated to possess the characteristics enumerated above and suitable for this process. Others among these are acetal, acrylic, chlorinated polyether, nylon, polypropylene, styrene, polycarbonate, polychlorotrifluoroethylene, fluorocarbon, and vinyl.

Specific materials which have been used for this purpose are:

Material 1

[Manufacturer: W. R. Grace & Co.]

Trade Name and Grade	Grex 50-090C	50-120C.
Type of Material	Polyethylene	
Stiffness	95,000	95,000.
Yield Point	3,900	3,900.
Elongation	50%	50%.

Material 2

[Manufacturer: Phillips Chemical Co.]

Trade Name and Grade	Marlex 6050	5065.
Type of Material	Polyethylene	
Stiffness	150,000	115,000.
Yield Point	4,400	3,800.
Elongation	12%	20%.

Material 3

[Manufacturer: Celanese Corp. of America]

Trade name and grade	Fortiflex A-500.
Type of material	Polyethylene.
Stiffness	140,000.
Yield point	3,300.
Elongation	13%.

Material 4

[Manufacturer: Hercules Powder Co.]

Trade name and grade	Pro Fax.
Type of material	Polypropylene.
Stiffness	175,000.
Yield point	5,000.
Elongation	220%.

Material 5

[Manufacturer: Allied Chemical Corp.]

Trade name and grade	AC-150.
Type of material	Polyethylene.
Stiffness	115,000.
Yield point	3,400.
Elongation	300%.

METHOD OF MAKING THE MANDREL

Applicants' preferred method of making the mandrel is by flowing the material into a mold from gates equally spaced from the mid-point **23** of the mandrel **16**, FIGURE 4.

Usable mandrels can be made by casting or machining.

ADHESIVES

The adhesive which is used to bind the turns of wire in the coil together to form a rigid piece capable of holding its form after the mandrel has been removed requires two distinctive characteristics. First, it must bind the turns together without destroying the insulation coating on the wire and thereby causing short circuits within the coil or attack the coil form. Second, it must adhere to the wire but must not adhere to the mandrel material. The same material which is used for binding the wire may be used as an imbedment filler to give the exterior of the coil the desired geometric shape or this imbedment material may be a second material which also does not adhere to the mandrel material or the material of the fixture. The adhesives (cements, release agents, etc.) used are materials having a low fusion temperature which is well recognized in the art.

BREAKING THE MANDREL INSIDE COIL

Applicants obtain best results where the mandrel core separates at the mid-point of the coil. This separation occurs where the total amount of material in the cross section of the core is the least. When a bar of almost any material is stretched, the greatest amount of contraction toward the axis of the material is at the midpoint between the two clamps applying the force. It follows that the pulling forces should be applied at points equidistant from that point of the mandrel at the center point of the core tunnel. Referring to FIGURE 16, where a mandrel is shown of constant cross section, with C the center point of the coil tunnel, the mandrel should be gripped at points such as A and B which are equidistant from C.

Referring now to FIGURE 10, where the clamps engage the blocks **12** and **14**, the pulling force on the mandrel core itself, referring now to FIGURE 1, is at the point of juncture with the mandrel with the face **18** of the block **12**, and the face **20** of the block **14**. This means that when applicants start to pull the blocks **12** and **14** apart, the force is applied immediately adjacent the two ends of the coil, which is highly desirable. Under the forces used, the blocks **12** and **14** are stressed far below the yield point and thus do not stretch, and hence it is immaterial whether the jaws **40**, **42** and **44** are spaced from the center point of the mandrel core **16**.

The structure of the mandrel **16** assists in properly breaking in the center. Referring to FIGURE 4, one-half of an injection mold is shown in plan view with gates **29** and **31**. The plastic under equal pressures meets along the center line **74**, and apparently the line of joinder is a little weaker.

The invention is useful wherever a solid core of constant cross section is to be removed from a body erected therein without frictional engagement with the body's tunnel wall. The method is practiced at room temperatures and is clear.

Having described applicants' invention, what applicants claim is:

1. The method of making a self-supporting coil whose tunnel has a substantially uniform cross section which comprises the steps of making a mandrel of a material possessing plastic flow characteristics at room temperature and having formed integrally therewith an enlarged

block at each end, the wall of each block facing the mandrel constituting the retaining wall of a coil to be wound thereon, of winding wire in the presence of an adhesive on the mandrel between the retaining walls, and of pulling the two blocks in opposite directions after the adhesive has set until the mandrel breaks.

2. The method of making a self-supporting coil which comprises the steps of forming a mandrel of a plastic material having plastic flow characteristics at room temperatures, of winding wire on the central portion of the mandrel in the presence of a material having a comparatively low fusion temperature to form a coil with the mandrel projecting from each end, and then of pulling the mandrel apart by a force acting axially of the coil for a time and with a force sufficient to contract the walls of the mandrel away from the coil tunnel wall to provide an annular clearance throughout the length of the coil tunnel, and then removing the mandrel.

3. The method of claim 2 wherein the final step of removing the mandrel consists in continuing to pull its opposite ends until the mandrel separates.

4. The method of claim 2 wherein the plastic material is a thermoplastic polymer.

5. The method of claim 2 wherein the plastic material is of the group consisting of polyolefins, polytetrafluoroethylene and vinyl polymers.

6. The method of claim 2 wherein the plastic material is polyethylene.

7. The method of claim 2 wherein the plastic material is polypropylene.

References Cited by the Examiner

UNITED STATES PATENTS

1,933,444	10/33	Moreira	29—427
2,199,879	5/40	Deroche	29—427
2,683,572	7/54	Morin	224—118
2,861,755	11/58	Hauser	242—118
2,944,338	7/60	Craig	29—423
2,970,373	2/61	Kohl	29—423
2,988,804	6/61	Tibbets	29—423 XR

CHARLES W. LANHAM, *Primary Examiner.*

WHITMORE A. WILTZ, WILLIAM J. STEPHENSON, *Examiners.*