United States Patent [19]

Chaffee et al.

[11] **3,777,613**

[45] **Dec. 11, 1973**

[54] **GUITAR STRINGS WITH ENLARGED END**

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[22] Filed: **July 24, 1972**

[21] Appl. No.: **274,810**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 160,734, July 8, 1971, abandoned.

[52] **U.S. Cl.** ..... **84/297 S,** 24/114.5, 29/169.5, 29/208 R

[51] **Int. Cl.** **G10d 3/00**

[58] **Field of Search** ..... 84/199, 297 R, 297 S; 24/114.5, 115 A, 123 W; 29/169.5, 208 R

[56] **References Cited**

UNITED STATES PATENTS

2,209,673	7/1940	Bratz	24/114.5
2,535,143	12/1950	Kosmis	84/297 S
3,130,626	4/1964	Martin	84/297 S
3,313,196	4/1967	Mari	84/297 S

FOREIGN PATENTS OR APPLICATIONS

451,488	9/1949	Italy	84/297 S

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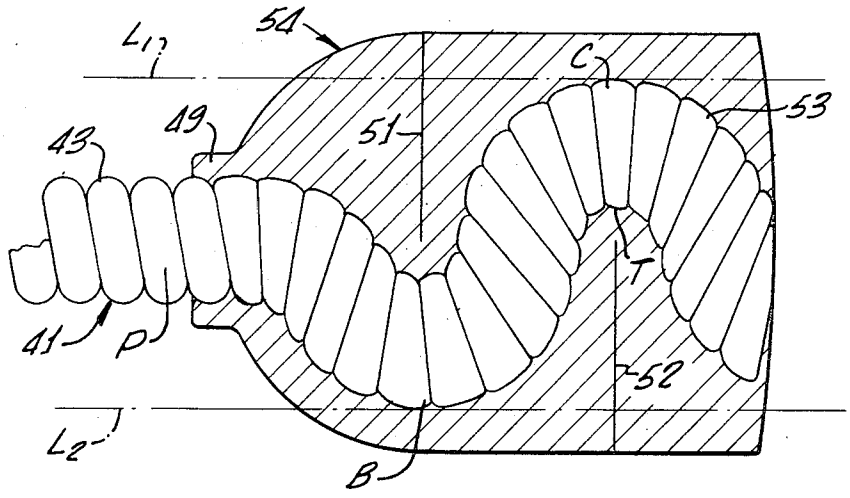
[57] **ABSTRACT**

The article is an S-shaped string end which is embedded in a tightly-folded mass of metal, the metal having axially spaced lateral fold planes on opposite sides of the bent regions of the string.

28 Claims, 23 Drawing Figures



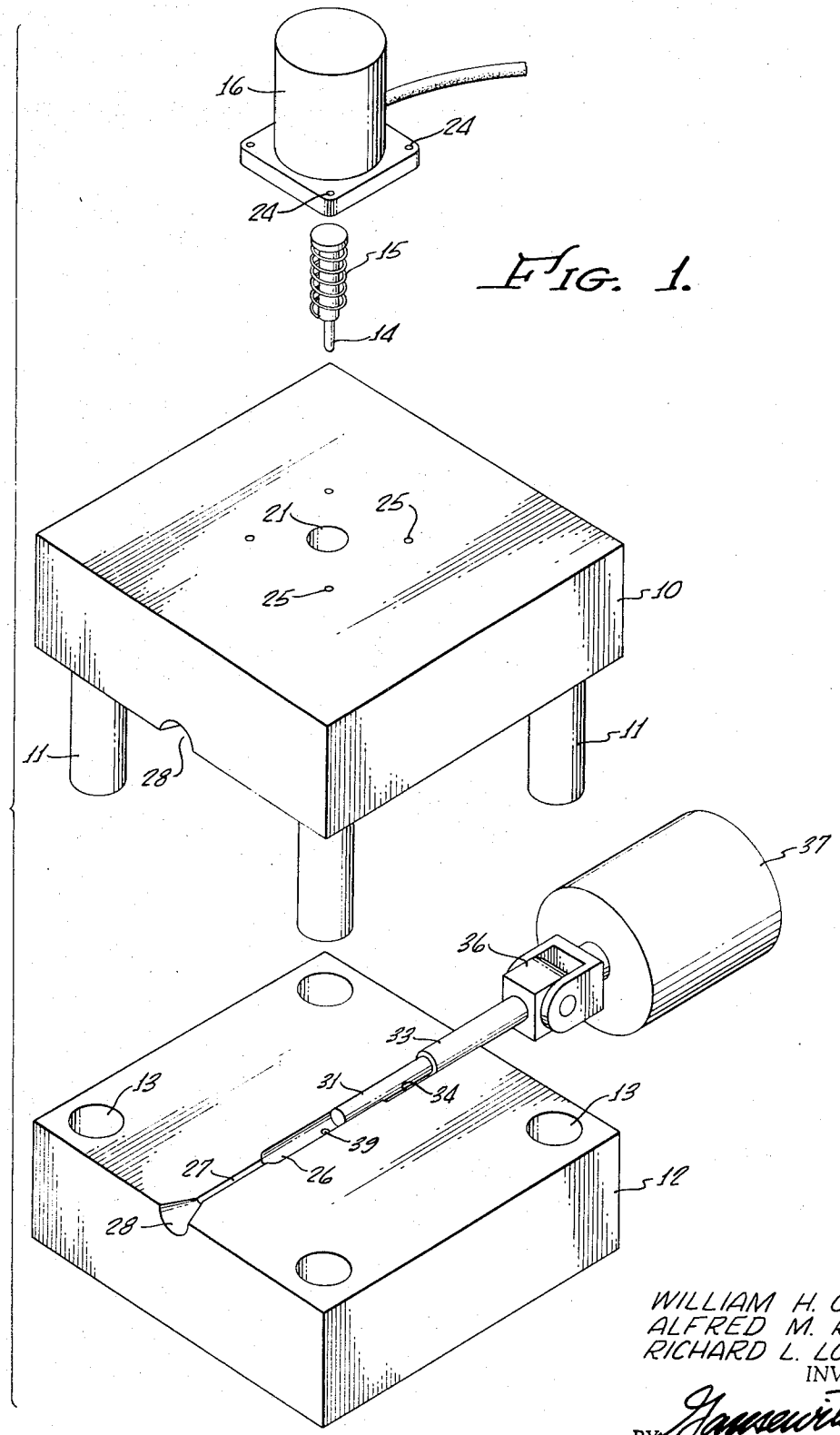


FIG. 1.

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FIG. 2.

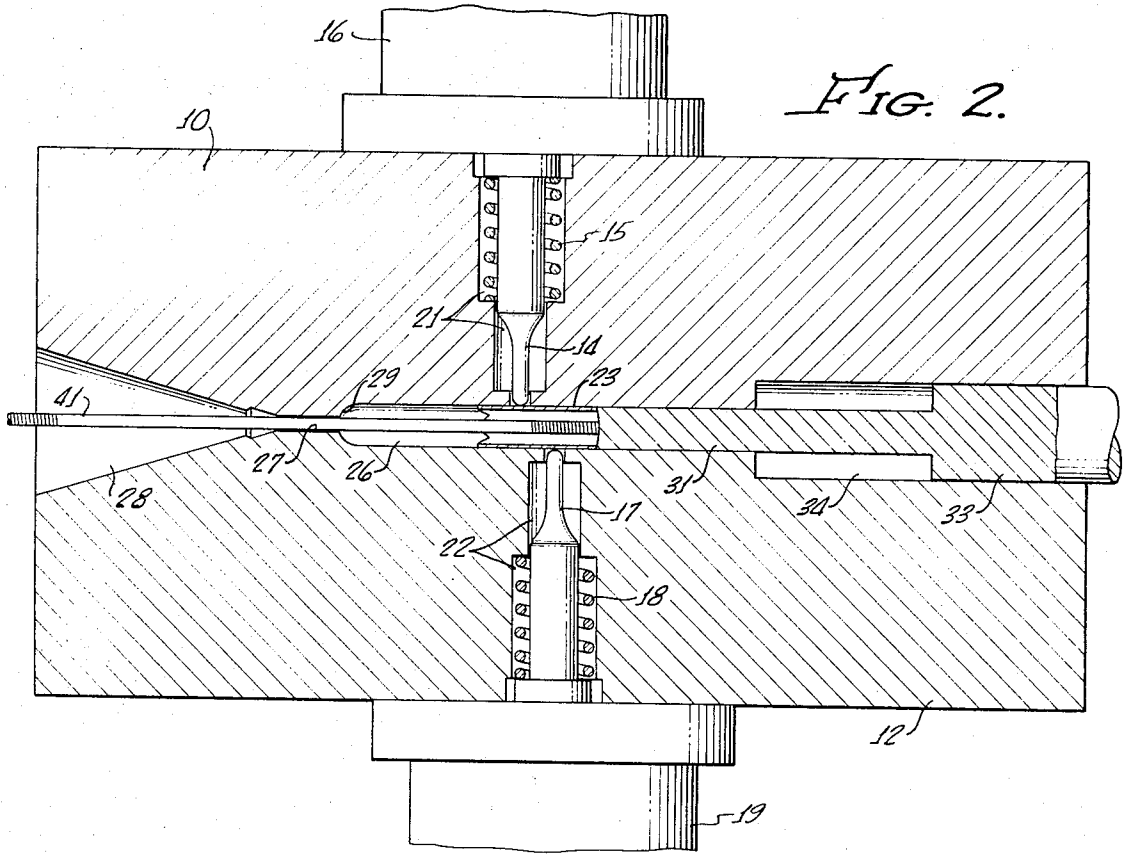
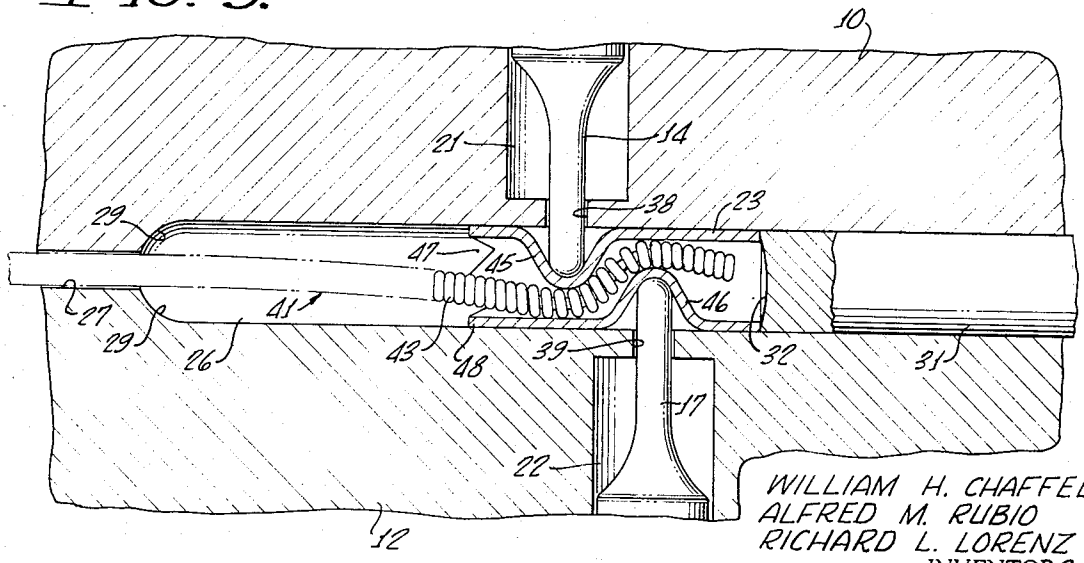


FIG. 3.



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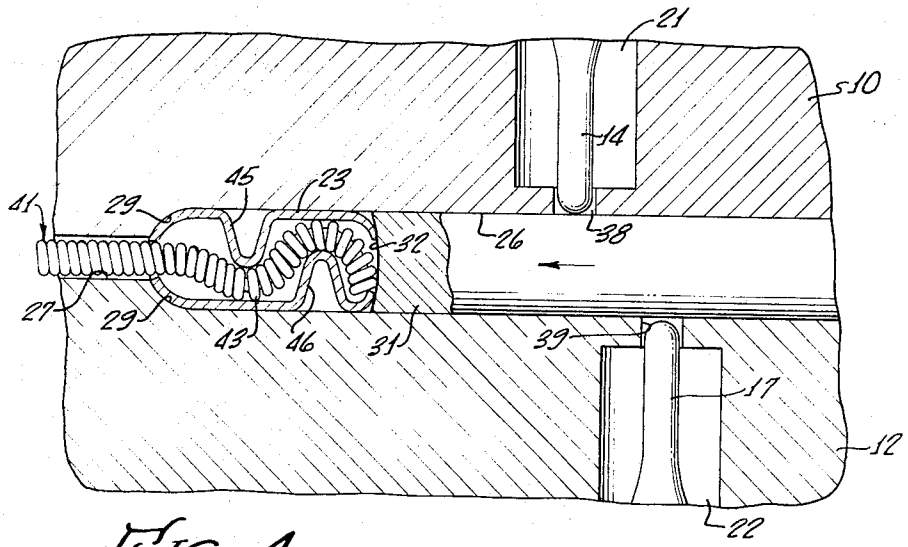

FIG. 4.

FIG. 5.

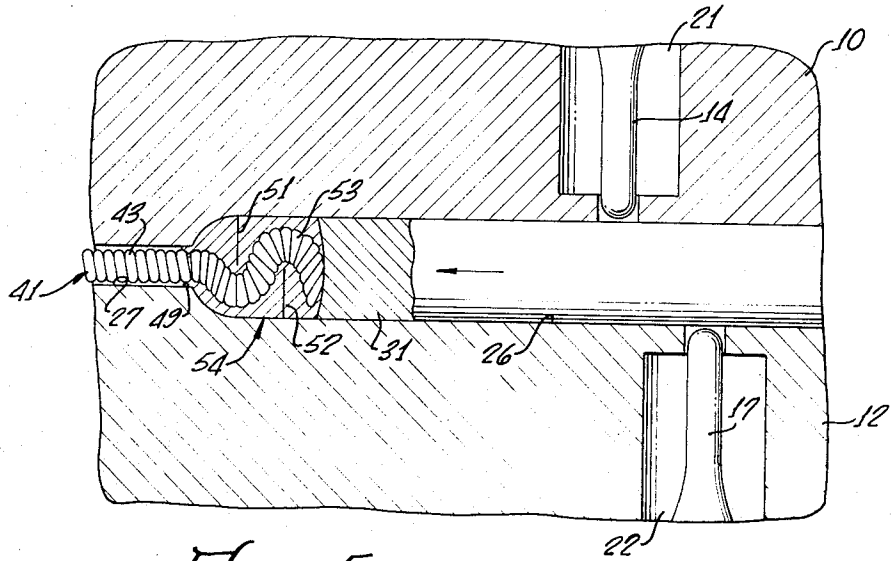

FIG. 5a.

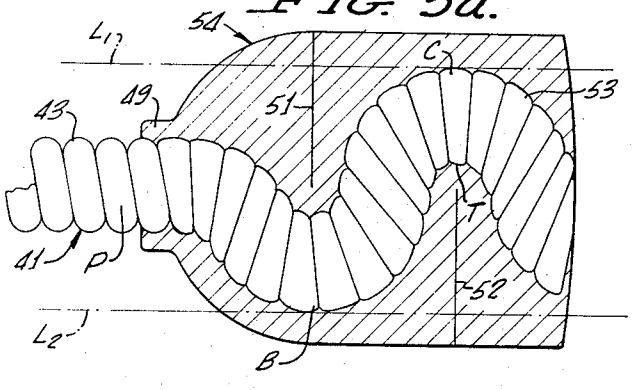

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FIG. 6.

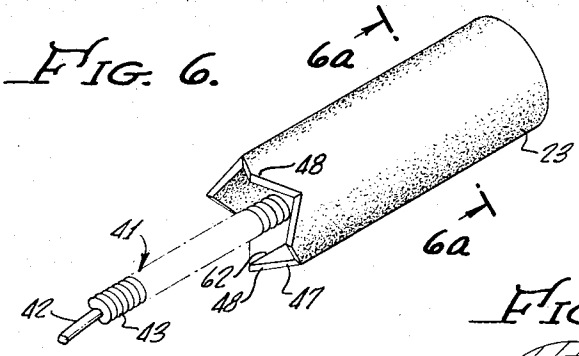


FIG. 6a.

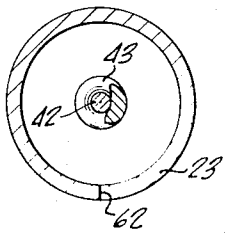
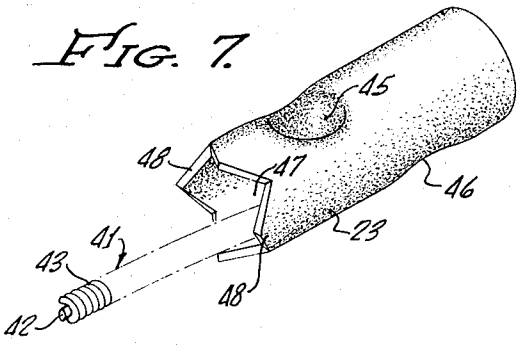


FIG. 7.



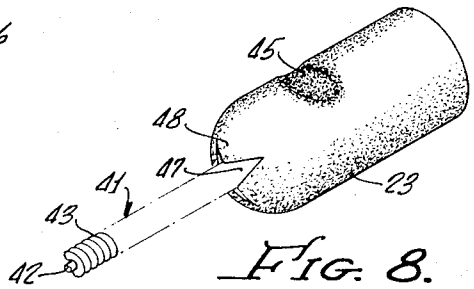
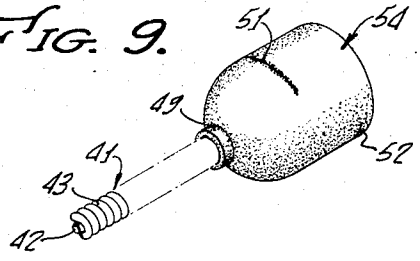


FIG. 8.

FIG. 9.



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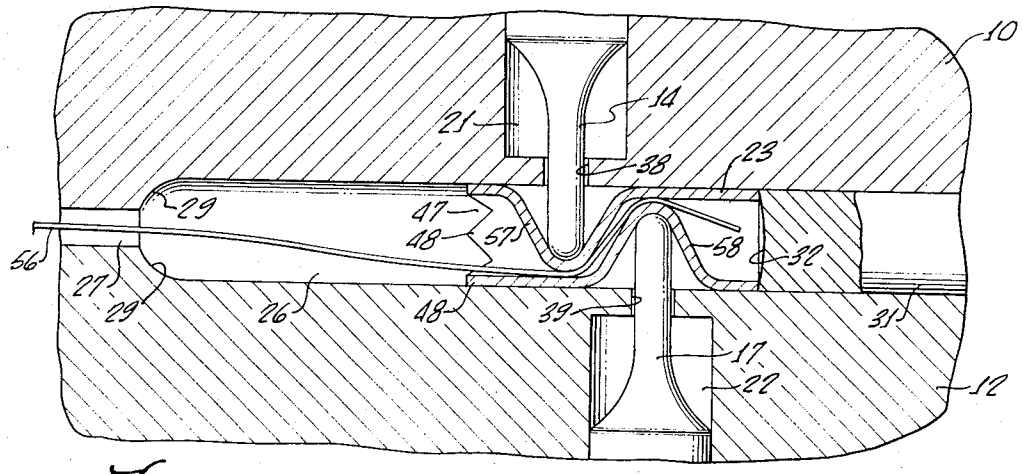

FIG. 10.

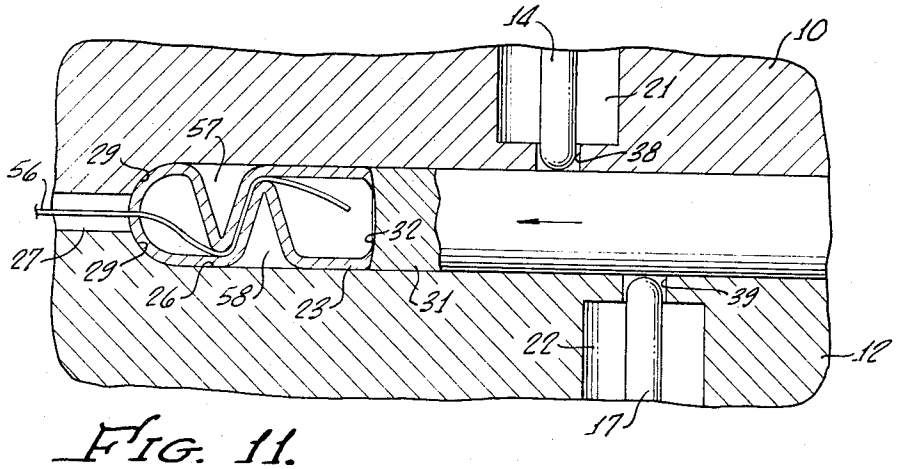

FIG. 11.

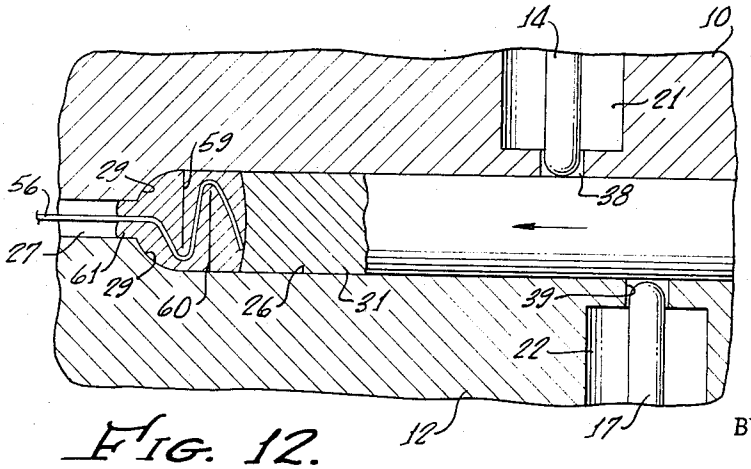

FIG. 12.

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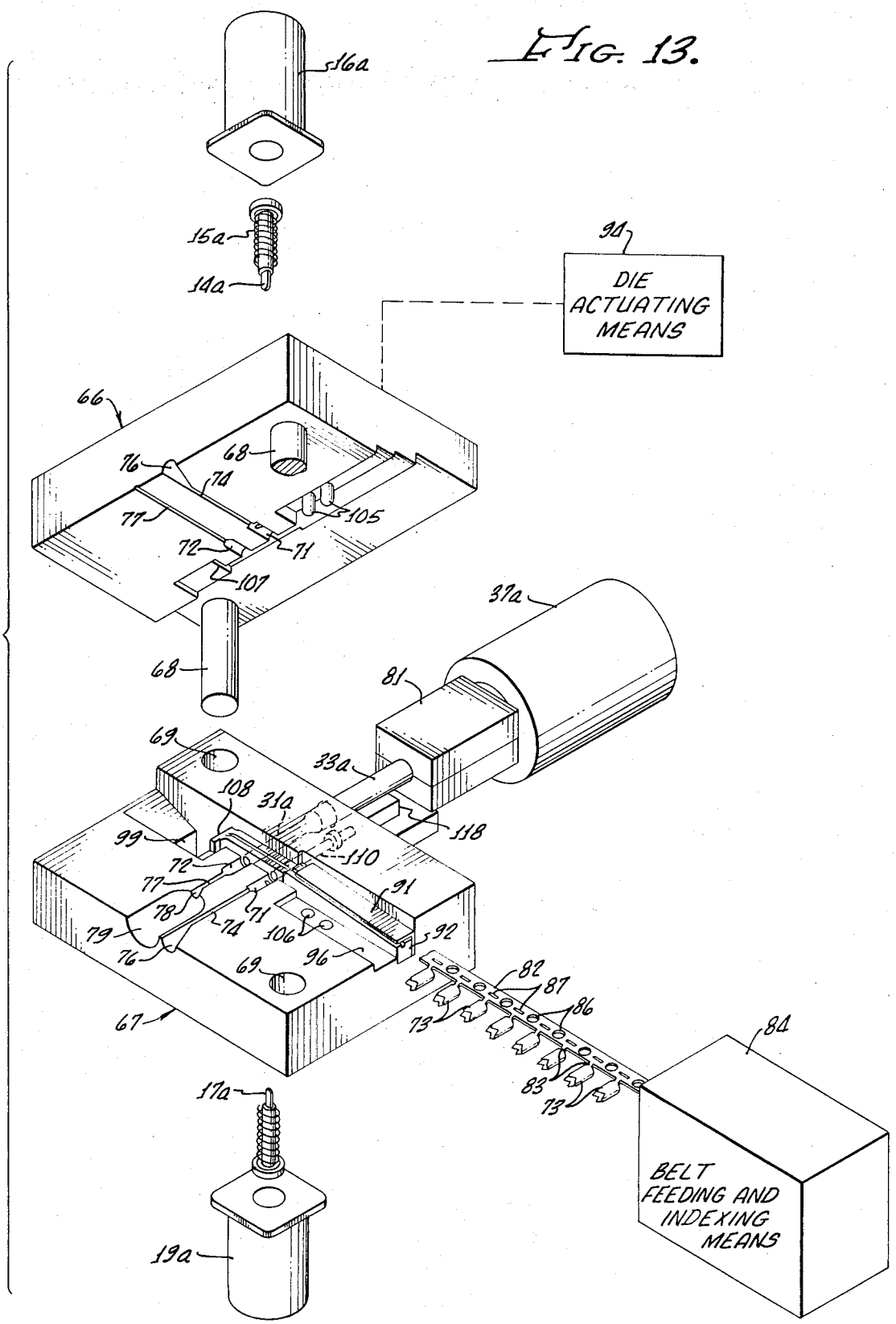
FIG. 13.


16a
15a
14a
90
DIE ACTUATING MEANS
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76
68
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17a
BELT FEEDING AND INDEXING MEANS
19a

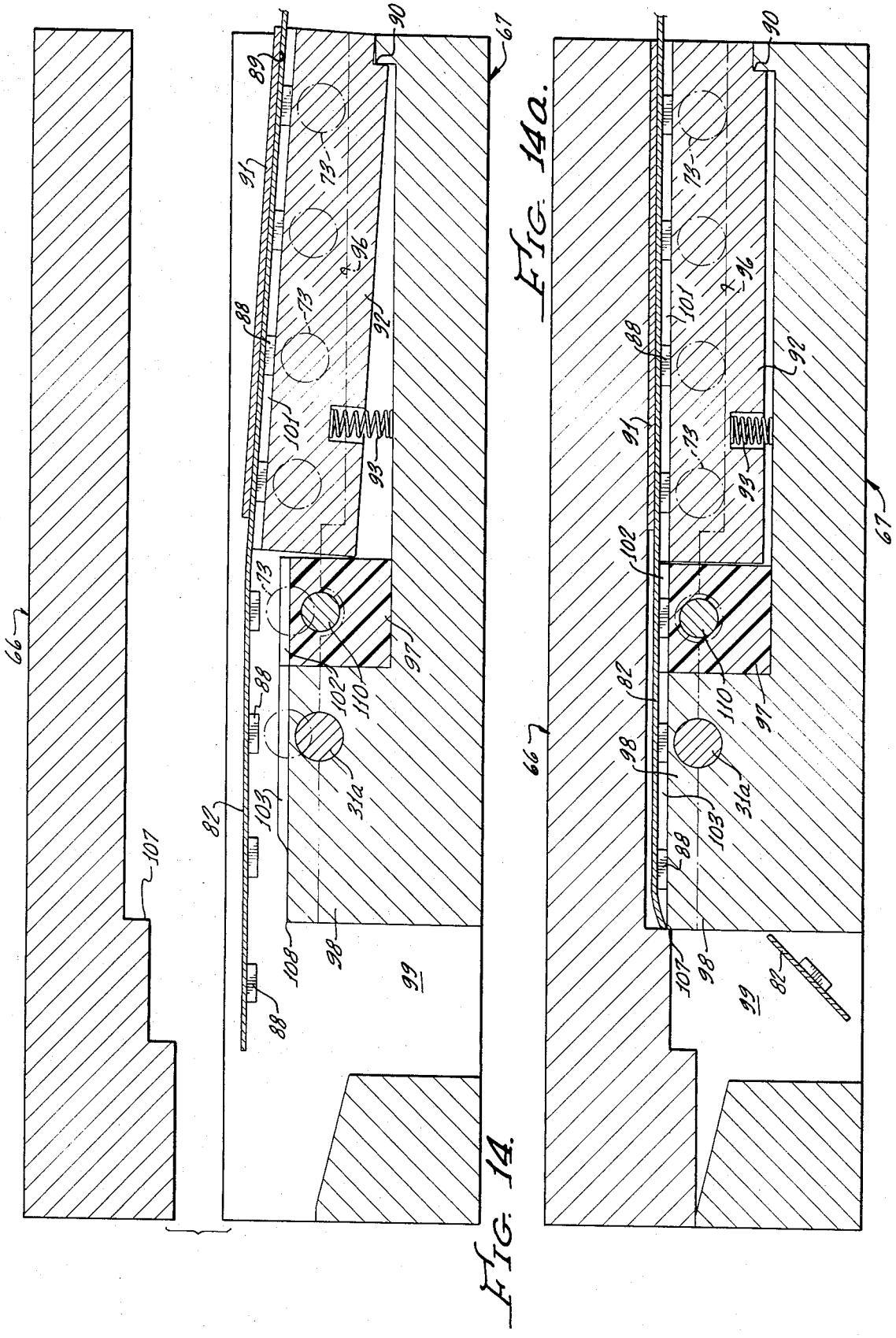
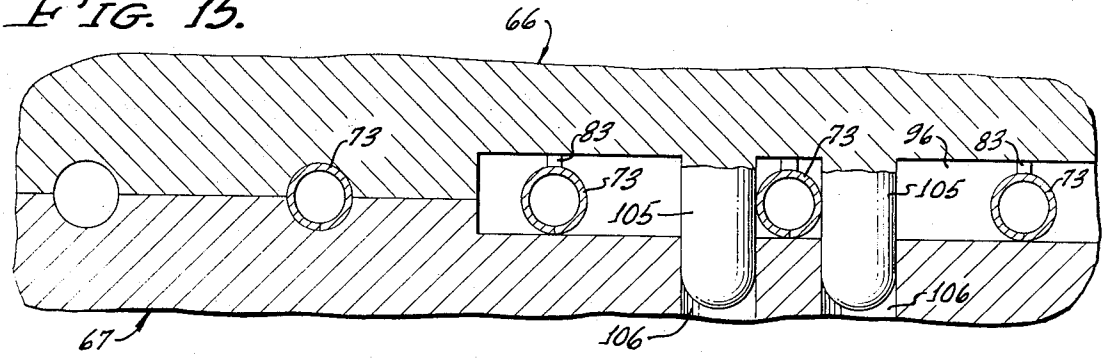


FIG. 14a.

FIG. 14.

FIG. 15.



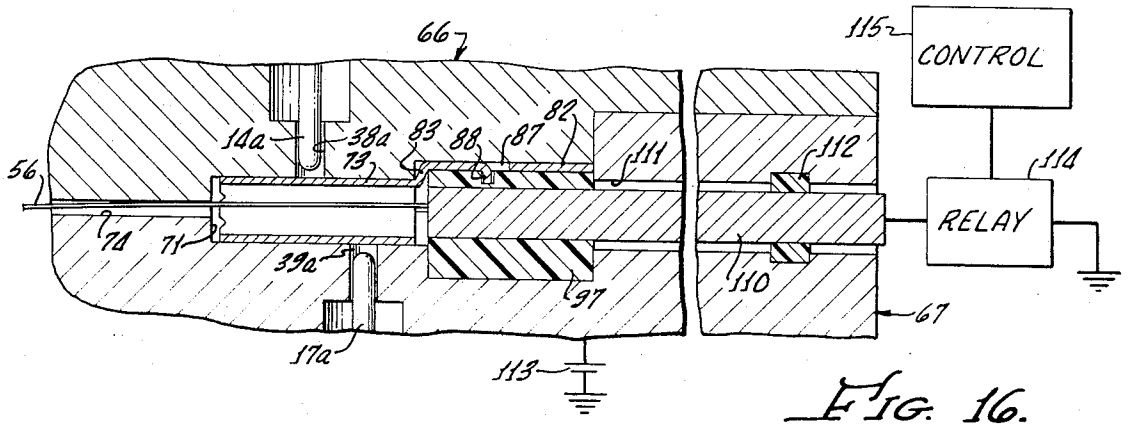


FIG. 16.

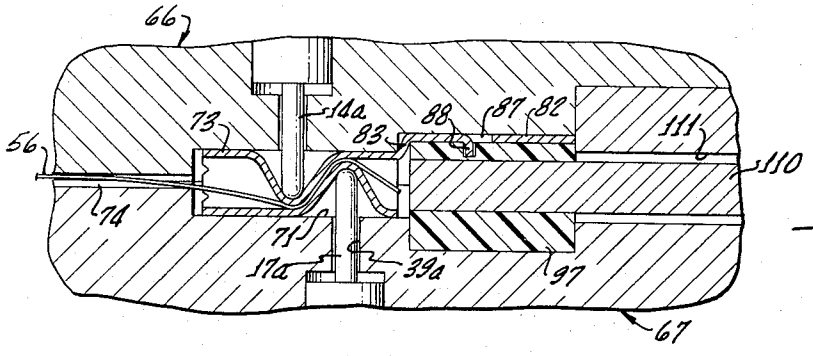
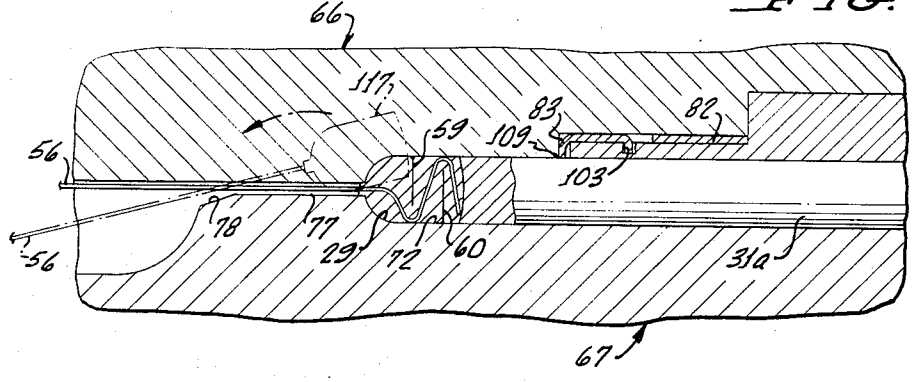


FIG. 17.

FIG. 18.



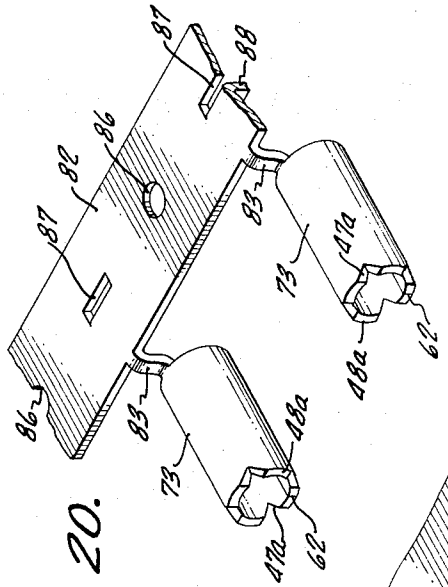


FIG. 20.

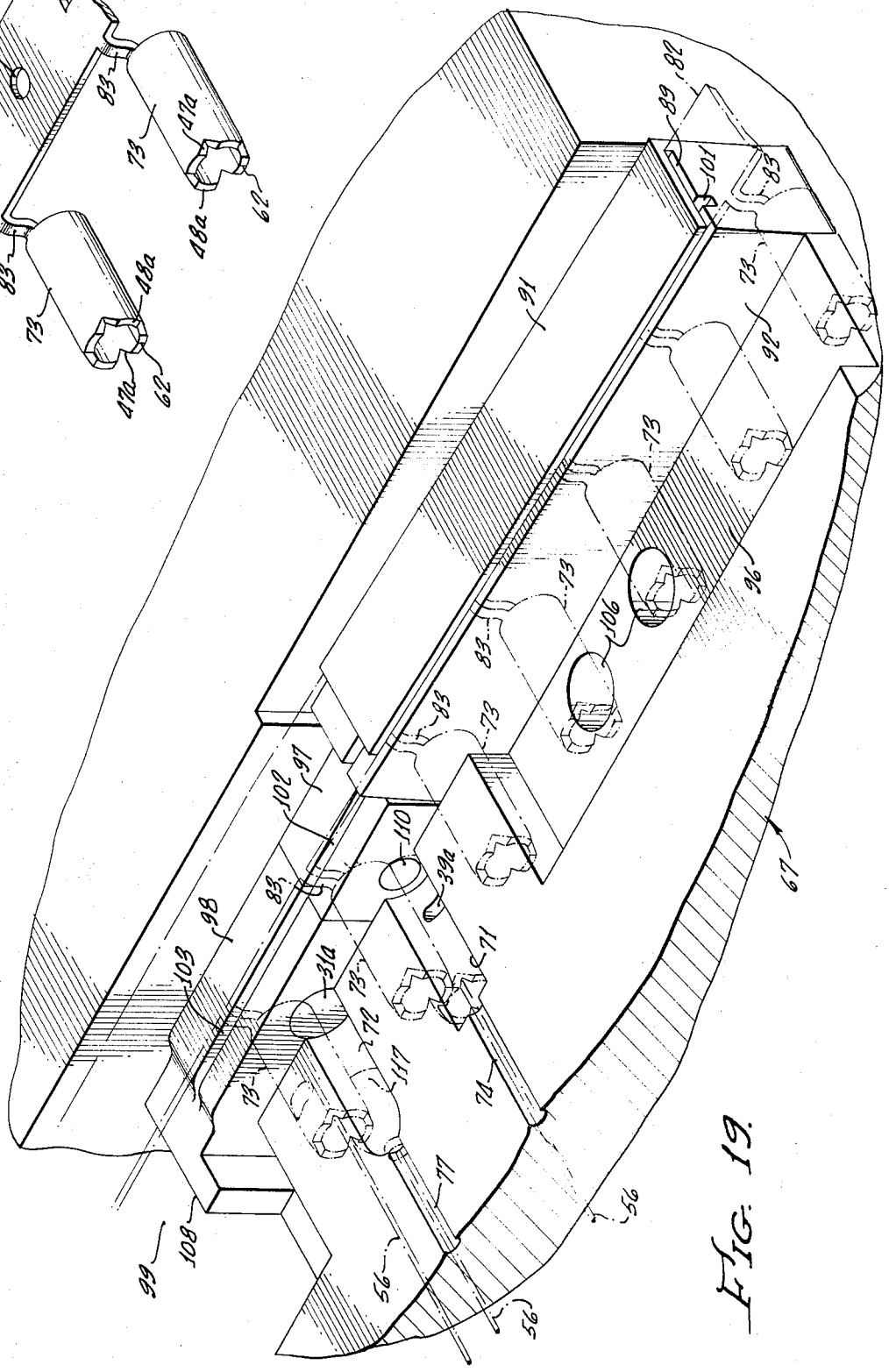


FIG. 19.

GUITAR STRINGS WITH ENLARGED END

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of our co-pending patent application, Ser. No. 160,734, filed July 8, 1971, for a Method of Providing Ball Ends on Guitar Strings, and Article Resulting Therefrom, which is now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to the field of providing enlarged end portions on guitar strings, both wrapped strings and bare or unwrapped strings. The enlarged end portions may for convenience be referred to as "ball ends," but this does not denote sphericity or even roundness.

2. Description of Prior Art

One end of each string of an electric guitar or similar musical instrument is normally provided with an enlarging means which prevents such end from being drawn through a hole in an anchoring means near the tail of the instrument. Thus, the end not enlarged is first threaded through the hole and is then connected to the tuning screw or peg, so that turning of the tuning screw tensions the string.

Conventionally, the enlargement of the one end is effected by manually looping such end around a metal eyelet having an external annular groove therein, and then manually twisting the end upon an adjacent portion of the string in order to lock the eyelet in place. If the string is one which is to be wrapped, the wrapping is thereafter provided on the string.

The procedure indicated in the preceding paragraph is relatively slow and expensive, and also produces the undesired results set forth below. Where the string is one which is to be wrapped, the indicated procedure makes it impractical to effect pre-wrapping of the core wire of the string. Accordingly, the entire process of manufacturing wrapped strings is conventionally a laborious string-by-string operation instead of being a continuous operation whereby a long length of string is machine wrapped and then cut off to length and ball-ended.

Although manufacturing problems relative to conventional methods of manufacturing guitar strings are severe, as outlined above, they are not to be regarded as overshadowing another major disadvantage of the conventional approach. When the string is manually looped around the eyelet and then twisted, the twisting causes cold-working of the string metal and therefore reduces the strength of the string. Because of differences between operators, and differences in the number and tightness of twists, the degree of cold-working varies to a considerable extent from string to string. Accordingly, the tensile strength of the different strings varies throughout a relatively wide range. Since it is not conventional to give a tensile test to each string manufactured, but only to randomly selected strings, it follows that a substantial number of relatively weak strings are sold to customers. This is a severe defect since the problem of string breakage by musicians is an important one, not only because of expense but also because strings may break during television and other performances.

It is therefore highly desirable to provide a guitar string which is either bare or has been pre-wrapped by

automated or other equipment, and which has been ball-ended in such manner as to maintain a relatively high tensile strength. Very importantly, it is highly desirable that the tensile strengths of a large number of ball-ended strings be uniform to within a small number of pounds. It is emphasized that the providing of a high-strength ball end on a wrapped guitar string is particularly difficult, because the soft-metal wrapping tends to act as a lubricant and diminish the anchoring force. The provision of a high-strength ball end on an unwrapped guitar string is also very difficult, because of the small string diameter and because the steel wire is coated with a corrosion-resistant coating of tin or other metal.

SUMMARY OF THE INVENTION

The end of a metal guitar string is provided longitudinally within a metal ferrule or tube, and lateral compressive forces are applied externally to the ferrule to deform the same. Longitudinal compressive forces are then applied to the ferrule while it is confined within a forming chamber. The longitudinal forces are such that the ferrule metal cold flows to substantially fill the forming chamber and to surround and grip the string end for prevention of withdrawal thereof.

The string end is accordingly gripped in a mass of tightly-folded metal, and in a manner causing the string end to be bent. Stated more definitely the article comprises the combination of a guitar string with a ball end, the string portion in the ball end being S-shaped, the ball end having lateral fold planes on opposite sides thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded isometric view schematically illustrating a first embodiment of die and cylinder apparatus for performing the present method, a showing of the lower staking mechanism being omitted;

FIG. **2** is an enlarged longitudinal sectional view schematically representing the dies in closed condition and prior to performance of the staking (lateral deformation) step;

FIG. **3** is a further enlarged view corresponding to the central portion of FIG. **2** but showing the conditions of the elements upon completion of the staking operation;

FIG. **4** is a corresponding view illustrating the commencement of the longitudinal deformation (compression) step;

FIG. **5** illustrates the positions of the parts at the completion of the longitudinal deformation (compression) step;

FIG. **5***a* is an enlarged view showing the ball-end of FIG. **5**;

FIG. **6** is an isometric view showing the string end disposed in the ferrule prior to any deformation;

FIG. **6***a* is a transverse sectional view on line **6***a*—**6***a* of FIG. **6**;

FIG. **7** is a view corresponding to FIG. **6** but showing the parts after completion of the staking step;

FIG. **8** shows the conditions of the parts after the initial portion of the longitudinal compression step;

FIG. **9** illustrates the parts after completion of the longitudinal compression step;

FIGS. **10–12,** inclusive, correspond respectively to FIGS. **3–5,** inclusive, but illustrate the provision of a ball end on a relatively small-diameter bare or unwrapped string;

FIG. 13 is generally similar to FIG. 1, but showing a second embodiment of the apparatus;

FIGS. 14 and 14*a* are enlarged vertical sectional views taken longitudinally of the feed strip (tape or belt) for the ferrules, as viewed in a direction from lower-left to upper-right in FIG. 13, and showing the dies in both open and closed positions;

FIG. 15 is another vertical sectional view, but taken forwardly of the feed strip, and showing the dies in closed condition;

FIG. 16 is an enlarged vertical sectional view taken longitudinally of the staking (lateral deformation) chamber, showing the condition of the parts prior to operation of the staking pins;

FIG. 17 corresponds to FIG. 16 but shows the condition of the parts after operation of the staking pins;

FIG. 18 is an enlarged vertical sectional view taken longitudinally of the longitudinal compression or folding chamber, and illustrating the operation of the ram not only to effect longitudinal compression and thus controlled folding of the ferrule, but also to effect shearing-off of the ferrule from the feed strip;

FIG. 19 is a greatly enlarged isometric view generally corresponding to the lower-central region of FIG. 13; and

FIG. 20 is an enlarged isometric view of a section of the tape having ferrules or tubes thereon.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The words "guitar string" as used herein contemplate not only strings for guitars but also for related musical instruments, such as banjos, mandolins, electric basses, etc.

Referring first to FIGS. 1 and 2, the first embodiment of the apparatus for performing the method may comprise an upper die 10 having downwardly extending guide posts 11 thereon, and a lower die 12 having bores 13 respectively adapted to receive the guide posts 11. An upper stake pin 14 and helical retraction spring 15 are mounted in a bore (and a counterbore) in upper die 10, the stake pin being adapted to be forced downwardly by a hydraulic cylinder 16. A lower stake pin 17 and spring 18 are mounted in a bore (and counterbore) in the lower die 12, and a second hydraulic cylinder 19 is provided to force such lower stake pin upwardly. The bore (and counterbore) for elements 14–15 is numbered 21, whereas the bore (and counterbore) for elements 17–18 is numbered 22. Bore 21 is offset from bore 22 in order that the stake pins 14 and 17 will operate upon opposite sides of a metal ferrule or tube 23 at longitudinally spaced regions therealong.

The cylinders 16 and 19 are connected, respectively, to dies 10 and 12 by suitable means, for example by screws (not shown) adapted to be projected through openings indicated at 24 and 25 in FIG. 1.

The opposed surfaces of upper and lower dies 10 and 12 have formed therein corresponding semicylindrical chambers adapted to form a cylindrical die cavity or forming chamber 26 when the dies are in the closed condition illustrated in various views other than FIG. 1. Cavity 26 communicates coaxially, when the dies are in closed condition, with an elongated wire or string port 27 which, in turn, communicates coaxially with divergent or conical mouth 28 as best shown in FIGS. 1 and 2. It is to be understood that, like the die cavity 26, the port and mouth 27 and 28 are each formed half by upper die 10 and half by lower die 12.

At its end adjacent wire port 27, die cavity 26 is generally hemispherical. The cavity walls at such end thus form rounded cam surfaces 29 (FIG. 3) which converge toward wire port 27. The cavity walls at such end may be termed a closure.

The portion of the die cavity remote from cam surfaces 29 receives coaxially a cylindrical ram 31 having a dished or concave end surface 32. The ram 31 connects coaxially to a piston 33 of larger diameter, such piston being disposed slidably in a piston chamber 34 half of which is defined by upper die 10 and the other half of which is defined by lower die 12. As shown in FIG. 1, piston 33 connects through a pivot connection 36 with the piston portion of a hydraulic cylinder 37 which is suitable supported by means, not shown.

The bores 21 and 22, and associated stake pins 14 and 17, are spaced sufficient distances from cam surfaces 29 that the entire ferrule 23 may be shifted forwardly (to the left) and away from the stake pins during the latter portions of the forming operation. The stake pins are shown as having cylindrical inner end portions the tips of which are hemispherical, such cylindrical portions projecting through upper and lower ports indicated at 38 and 39.

The stake pins are sufficiently close to each other, in a direction longitudinally of the ferrule or tube, that the staking will occur at regions which are respectively spaced from the ends of the ferrule.

The cylindrical inner end portions of the stake pins, which engage ferrule or tube 23, have diameters much smaller than the diameter of the ferrule. However, the diameters of such inner end portions are sufficiently large to assure that the string will be properly gripped and flexed, in response to the staking operation, as set forth below.

Suitable means, not shown, are provided to open and close the dies 10, 12, and to mount the various elements in proper relationship.

DESCRIPTION OF THE METHOD RELATIVE TO A RELATIVELY LARGE-DIAMETER WRAPPED STRING

Referring to FIGS. 1–9, inclusive, the method is illustrated relative to the ball-ending of a pre-wrapped string for a guitar or the like. Relative to FIGS. 10–12, the method is illustrated relative to a small-diameter bare or unwrapped string. It is to be understood that the method may also be performed relative to numerous intermediate and other sizes and types of strings for musical instruments.

The wrapped string is indicated by the reference numeral 41. It comprises a core wire 42 (FIGS. 6–9) of high tensile strength metal such as steel and which is relatively stiff and springy. Around such core 42 is wrapped, in tightly wound helical relationship, a wrap wire 43 of a softer metal such as nickel or bronze. The core may also be double-wrapped, there being two wrap wires instead of one.

The outer diameter of the string 41 (that is to say, of the helical wrap thereon) is slightly smaller than the diameter of the wire (string) port 27 whereby the string will not be a tight fit in such port.

In performing the present method, the inner end of string 41 is disposed longitudinally within the elongated ferrule 23. This may be done by positioning the ferrule

23 in die cavity 26 by first opening and then closing the dies 10, 12. Ferrule 23 is positioned adjacent the inner end 32 of ram 31 (when such ram is in the predetermined retracted position shown in FIGS. 2 and 3), and also adjacent the ports 38–39 for staking pins 14 and 17. The string 41 is then inserted into mouth 28 and through port 27 and through cavity or chamber 26 into the ferrule 23, until the string end engages the dished end 32 of ram 31 as shown in FIG. 2. The inserted string is also shown in FIG. 6.

Ferrule 23 is a tube formed of a relatively hard metal but one which is capable of deformation and cold flow when very high pressures are applied as stated below. The tube has a length much larger than its outer diameter, for example, between two and three times its outer diameter. As indicated above, the tube length is such that the staking takes place at regions spaced inwardly from the extreme ends of the tube.

The outer diameter of the ferrule or tube 23 is only slightly smaller than the diameter of cavity 26, so that the ferrule is a sliding fit in such cavity. The inner diameter of the ferrule is much larger than the outer diameter of the string. Thus, the inner diameter of the ferrule may range from about twice the outer diameter of the string (including any wrapping thereon) to many times the diameter of the string (in the case of small-diameter strings). Because the inner diameter of the tube is thus much larger than the string diameter, the string may assume a generally S-shaped configuration in the tube.

The string end having been disposed longitudinally within ferrule 23, the next step in the method comprises applying lateral compressive or deforming forces to the ferrule in order to deform the same. Because of the offsetting of the staking pins 14 and 17 (longitudinally of the tube or ferrule) as described above, the lateral compressive forces are applied at longitudinally spaced points along the ferrule and on diametrically opposite sides thereof. (In its broader aspects, the present method also comprises inserting the string end after lateral deformation of the ferrule has been at least partially completed.)

Stated more specifically, the upper hydraulic cylinder 16 is employed to force staking pin 14 downwardly, against the bias of spring 15, until the rounded lower end of the staking pin deforms the upper wall of ferrule 23 into pressure contact with the guitar string 41, such string then being gripped or pinched (FIG. 3) between the deformed upper wall of the ferrule and an undeformed portion of the lower wall thereof. Correspondingly, the lower cylinder 19 is employed to force the lower staking pin 17 upwardly to deform the lower wall of the ferrule 23 and cause the same to grip or pinch the adjacent string portion between the deformed lower wall and an undeformed part of the upper wall. Because the described staking is done in a chamber the side walls of which are closely adjacent the ferrule, such staking does not effect collapse or squashing of the entire ferrule.

The result of the staking operation is, as illustrated in FIG. 3, a relationship whereby the string is gripped or pinched at two points and, furthermore, the string regions are laterally offset relative to each other. The inwardly deformed portions of the ferrule wall, and which receive the staking pins 14 and 17, are respectively numbered 45 and 46. The staked ferrule is additionally shown in FIG. 7.

The hydraulic pressure in cylinders 16 and 19 is then released, so that the springs 15 and 18 retract the staking pins 14 and 17 to the retracted positions shown in FIGS. 4 and 5.

As the next step in the method, hydraulic pressure is introduced into cylinder 37 (FIG. 1) to shift piston 33 and ram 31 to the left (toward port 27). This slides ferrule 23 and string 41 to the left until the left end of the ferrule engages the outer regions of cam surfaces 29. Such left end of the ferrule is provided with a plurality (preferably, four) of V-shaped notches 47 which define triangular teeth 48 therebetween as best shown in FIGS. 6 and 7.

Additional leftward shifting of ram 31 by the cylinder 37 causes the teeth 48 to be cammed inwardly along surfaces 29 until the inner ends of the teeth engage the string 41 as shown in FIGS. 4 and 8. This provides an additional gripping action whereby the extreme left end of the ferrule cooperates with the elements 45 and 46 in preventing longitudinal shifting of the string end out of the ferrule during subsequent compression steps. In addition, the teeth 48 minimize the possibility that the left end of the ferrule will shear off the string in response to the compressive forces described below.

Referring again to FIGS. 4 and 8, the condition is illustrated whereby the teeth have not only gripped the string 41 but, also, the elements 45 and 46 have commenced to buckle. Furthermore, the right end of the ferrule has commenced to turn inwardly in response to pressure applied by the dished end 32 of ram 31. Thus, the string end has assumed more of an S-shaped configuration than is llustrated in FIG. 3.

Longitudinal compressive forces are then continued and increased due to further leftward shifting of the ram 31. In accordance with the present method, these forces are very high and effect cold flow of the metal forming ferrule 23 to fill or substantially fill the various gaps or voids around the string end (and thus fill the forming chamber or cavity). The string end is thus effectively seized, locked in and gripped by the metal. The compressive forces are so great that the ferrule metal conforms to the dished end surface of the ram 31 and also conforms to the cam surfaces 29. The S-shaped string configuration of FIG. 4 is tightened to form a tighter (more compact) S as shown in FIG. 5. In addition, a small neck 49 is extruded into the annulus between string 41 and the wall of string or wire port 27, such annulus being small in size for the present large-diameter string.

The inwardly deformed parts 45 and 46 are collapsed to result in longitudinally offset radially extending fold planes 51 and 52, FIGS. 5, 5a and 9, each such plane extending outwardly from one of the bends in the S. The S-shaped string portion which is disposed within the resulting ball end is given the reference numeral 53 in FIGS. 5 and 5a. The finished ball end is denoted 54 in FIGS. 5, 5a and 9.

It is an important advantage of the present method that the tube or ferrule is thus tightly folded in a controlled, predetermined manner which makes possible the mass manufacture of ball-ended strings having substantially uniform high-strength characteristics. Such folding effects bending, or additional bending, of the string end. The staking or lateral deformation step prepares or pre-conditions the tube so that the longitudinal deformation step will achieve predetermined folding thereof. The lateral deformation step is preferably also

such that the string end is pinched and thus retained in the tube. Therefore, the string end is not separated from the tube either during shifting of the ferrule from its lateral deformation station to its longitudinal deformation station, or during the actual performance of the longitudinal deformation and folding step.

Referring, for example, to FIG. 4, it is to be noted that the combined volumes of the tube and of the string end are much less than the volume of the forming chamber or cavity. Therefore, large voids are present in the chamber or cavity, the word "large" being employed in its relative sense instead of its absolute sense because the entire forming chamber or cavity is actually small. Referring next to FIG. 5, the tube is caused to flow until the voids are substantially eliminated, and the forming chamber or cavity is substantially filled with ferrule and string metal. Such flow is effected by moving ram 31 to progressively reduce the size of the forming chamber or cavity.

The hydraulic pressure is preferably applied to cylinder 37 for a time period sufficiently long to insure that there will be no substantial spring back of the metal with consequent loosening of the grip on the S-shaped portion 53 of the string 41 (FIGS. 5 and 5a). As an example, the time required to shift ram 31 from the FIG. 4 position to the FIG. 5 position may be, for example, a little under one second, including the "hold" which occurs before the ram 31 is retracted.

DESCRIPTION OF THE ARTICLE

After completion of the described ball-ending operation, the dies 10 and 12 are opened to permit withdrawal of the resulting article. Such article comprises a string, including a core wire and a wrap wire, which has an S-shaped end portion disposed within a tightly folded and compressed mass of metal, such mass having radial fold planes (51 and 52) adjacent the bends in the S and on opposite sides of the ball end.

To amplify upon the above, and with particlar reference to FIGS. 5 and 5a, the embedded string end portion is shaped generally as a single full cycle of a sine wave. Thus, the embedded string end portion is bent in two places, at B and C in FIG. 5a, each such bend being either the crest or trough of the sine wave (depending upon whether the string end portion is positioned as shown in FIG. 5*a*, or is inverted). One of the fold planes, number 51, is directly opposite the bend B, whereas the other fold plane, number 52, is directly opposite bend C. The inner region of each fold plane 51 and 52 is generally between adjacent portions of the sine wave or "S" (that is to say, the inner portion of plane 51 is in the "trough" above bend B, whereas the inner portion of plane 52 is in the "crest" below bend C).

It is to be noted that each fold plane 51 and 52 is transverse (preferably, generally perpendicular) to the portion of string 41 which is adjacent the mass of folded metal but is not embedded therein. Such adjacent string portion is indicated at P in FIG. 5*a*. It is also to be noted that the fold planes 51 and 52 are substantially parallel to each other, and spaced from each other. The word "plane" is not employed in a precise sense, but only a general sense, since the folds may actually be somewhat irregular.

The portion P, FIG. 5a, lies between two lines L_1 and L_2 which are respectively tangential to bends C and B in the S-shaped embedded string end portion.

Because the mass of tightly folded metal conforms to the shape of the outer (left) end portion of the die cavity or chamber 26, the mass has a cylindrical outer surface generally coaxial wth the string portion P (FIG. 5*a*). Also, one end of the cylindrical mass is generally hemispherical (corresponding to cam surfaces 29), whereas the other end of the cylindrical mass is convex (corresponding to dished end 32 of ram 31). There is a neck 49 around the string at the small portion of the generally hemispherical end.

It is a feature of the present invention that each bend in the guitar string is smooth, not sharp, since a sharp bend in the string may cause a point of weakness.

DESCRIPTION OF THE METHOD AS PERFORMED RELATIVE TO A SMALL-DIAMETER UNWRAPPED STRING

It is a feature of the method that the same apparatus, and the same ferrule 23, may be employed for both wrapped and unwrapped strings, and strings having diameters which vary throughout a substantial range.

Referring to FIGS. 10–12, the method is illustrated as employed in ball-ending a small-diameter unwrapped string 56 formed of music wire, a relatively springy steel. Such music wire is coated with tin or other corrosion-resistant metal. As the first step in the method, the end of the wire is disposed longitudinally within the ferrule 23 as described relative to FIG. 2 of the previous embodiment. Thereafter, hydraulic cylinders 16 and 19 are supplied with hydraulic fluid under pressure to cause radial-inward shifting of staking pins 14 and 17 until such pins move inwardly as far as they can go, namely until spaced portions of string 56 are pinched against opposite wall portions of the ferrule 23 as shown in FIG. 10.

Because of the relatively small diameter of the string 56 in comparison to that of the string 41, and because the staking pins are caused to bottom out, the resulting inwardly deformed portions of the ferrule wall (and which are numbered 57 and 58) are much deeper in FIG. 10 than is shown relative to FIG. 3. The string portions are pinched and gripped by the inward protuberances 57 and 58, whereby the string is prevented from shifting axially relative to the ferrule during the subsequent longitudinal compression step. In addition, and as described relative to the first embodiment, longitudinally spaced portions of the string are laterally offset relative to each other.

The staking pins 14 and 17 are then retracted, following which fluid pressure is applied to cylinder 37 to shift ram 31, ferrule 23 and string 56 to the left. Continued leftward movement of the ram 31 causes the initial longitudinal compression illustrated relative to FIG. 11, whereby the toothed left end of the ferrule is cammed around surfaces 29 to pinch the string 56.

Additional leftward shifting of ram 31 then causes cold flow of the ferrule metal to fill in the voids or gaps, to form the fold planes 59 and 60, and to create the neck 61. Because of the relatively small diameter of the string 56, neck 61 is substantially thicker than that shown in FIG. 5 relative to neck 49. The planes 59 and 60 are deeper in FIG. 12 than in FIGS. 5 and 5*a*, because of the deeper elements 57 and 58 (FIG. 10).

Because the string 56 occupies a much smaller volume within the ferrule than did string 41, the longitudinal compression continues through a longer stroke of ram 31. Thus, the resulting ball end is substantially

shorter in FIG. 12 than is the ball end shown in FIG. 5. In each case, the ram 31 is caused to "bottom out."

The article resulting from the embodiment of FIGS. 10–12 is generally the same as the previously described article, except that the string is smaller in diameter and is not wrapped, adn except that the neck 61 is larger and the body of the ball end is shorter.

SPECIFIC EXAMPLE

The ferrule 23 is formed of sheet metal which is bent into cylindrical shape whereby a longitudinal seam (which need not be soldered or otherwise fused or joined) is provided at 62 (FIG. 6a). Seam 62 is an unfused, longitudinal butt seam. It is a feature of the invention that the lower staking pin may operate on the seamed portion of the ferrule 23.

The diameter of the ferrule 23 is such that it is (as stated above) a sliding fit in the die cavity 26. The outer diameter of the ferrule is 0.156 inch, whereas the inner diameter is 0.114 inch. Thus, the wall thickness of the ferrule is 0.021 inch, which is thin. The length of the ferrule, including teeth 48, is 0.375 inch.

The pressure of the fluid introduced into cylinder 37 is such that a compressive force of 157,000 pounds per square inch is applied to the ferrule in a longitudinal direction in order to compress the same from the FIG. 11 position to the FIG. 12 position (or from the FIG. 4 position to the FIG. 5 position). The pressure of the hydraulic fluid introduced into staking cylinders 16 and 19 is such that the pressure at the inner end of each staking pin is 56,600 pounds per square inch.

The sheet metal forming the ferrule 23 is caused to be relatively hard in order to provide an effective grip on the wire therein, particularly on the small-diameter wires which tend to pull out unless very firmly gripped. An exemplary metal is tin-coated rolled sheet steel, the tin providing resistance to corrosion and rusting. More specifically, the tin-coated rolled steel is tin mill, having a Rockwell hardness (30 T scale) of about sixty-two sixty-eighths, and a Rockwell hardness (B scale) of about sixth sixty-eight seventy-sevenths.

The string size employed with the described ferrule and apparatus may range from about 0.009 inch diameter to about 0.059 inch diameter (including the wrap). It is to be understood, however, that other diameters may be employed with other ferrules and modified apparatus.

The above specific example is given by way of illustration only, and is not to be construed to limit the appended claims other than as specified in such claims. Also, the statement relative to the time (a little under one second) of leftward movement of the ram is given by way of illustration only.

AUTOMATED EQUIPMENT

There has thus been described, in schematic form, a single cavity apparatus for performing the present method and for producing the resulting article. It is to be understood, however, that to achieve high-speed mass production the apparatus may be much more complex. In such more complex apparatus, a large number of ferrules 23 are each connected to a connector strip or belt by means of a suitable tab or ear which is adapted to be sheared off by the ram 31 (or its equivalent) when the ram shifts to the left.

Furthermore, the ferrule 23 may be formed around the string 41 or 56, instead of being first formed and then the string introduced therein. This may be done at a first station, following which staking by means of pins 14, 17 or their equivalents is effected at a second station, following which the longitudinal forming effected by shifting of ram 31 is effected at a third station. Thus, and by analogy to separate progressive dies, the operation may be performed simultaneously (in parallel) on different parts at the different stations, which increases the rate of manufacture. With such a mode of forming, the die cavity 26 need not be as long as that shown in the present drawings since it is not then necessary to shift the ferrule 23 away from the staking pins (staking having been performed at another station).

ADDITIONAL EMBODIMENT OF THE APPARATUS (AND METHOD) FOR BALL-ENDING STRINGS

In the embodiment of the apparatus shown and described relative to FIGS. 1–5 and 10–12, a lateral deformation step is performed when the ferrule is in one location, following which a longitudinal deformation and folding step is performed when the ferrule is in a different location. For example, relative to FIG. 3, the lateral deformation (staking) step is performed at one end of die cavity 26, whereas the longitudinal deformation step is performed at the other end of such cavity as shown in FIGS. 4 and 5. After completion of the lateral deformation step, the ferrule 23 and the string end gripped therein are shifted from the one location to the other. In the embodiment shown in FIGS. 1–5 and 10–12, such shifting of the ferrule 23 and of the string end gripped therein is in a direction longitudinal to the ferrule (namely, along the die cavity 26).

There will next be described, relative to FIGS. 13–20, inclusive, a second or additional apparatus embodiment wherein the ferrule and the string end gripped therein are not shifted longitudinally in the same chamber after completion of the lateral deformation (staking) step, but instead are shifted laterally from one chamber to a completely different chamber after completion of such step. Furthermore, the apparatus and method of FIGS. 13–20 are such that lateral deformation and longitudinal deformation occur simultaneously relative to ferrules in the two chambers or die cavities, thus greatly increasing the rate of production of the ball-ended strings. The embodiment of FIGS. 13–20 also incorporates an automatic means for sensing when the end of the guitar string has been fully inserted into a ferrule, and for initiating the cycle of operation in immediate response to such full insertion. It is thus assured that no ball end will be manufactured wherein the string has been only partially inserted, and it is also assured that the maximum speed of production will be achieved.

Except as specifically stated below, the apparatus, method and article described relative to FIGS. 13–20 are identical to those described relative to FIGS. 1–12.

Referring to FIG. 13, the second embodiment of the apparatus comprises an upper die 66 which mates with a lower die 67, the upper and lower dies being associated with each other by means of posts 68 and bores 69. When dies 66 and 67 are in closed condition, touching or substantially touching each other, they define therebetween first and second laterally spaced die cavities 71 and 72. Both die cavities 71 and 72 are cylindrical, and each is adapted to receive snugly a cylindrical tube or ferrule 73. The outer end of die cavity 72

is rounded or hemispherical as described relative to cam surfaces **29**, FIGS. **3** and **4**.

The first die cavity, number **71**, is adapted to hold ferrule **73** during the lateral compression or staking operation, whereas the second die cavity **72** is adapted to hold the ferrule **73** during the longitudinal compression or folding operation. In order that a string end may be inserted into cavity **71**, such cavity communicates coaxially with an elongated string port **74** the outer end of which is conical to form a mouth **76**. Elements **74** and **76** generally correspond to string port **27** and mouth **28** shown in FIGS. **1** and **2**.

The second die cavity **72**, in which the longitudinal compression or folding occurs, communicates coaxially with a string port **77** the outer end of which connects with a frustoconical intermediate portion **78**. Intermediate portion **78**, in turn, communicates with a large mouth portion **79** formed in the lower die **67** but not necessarily formed in upper die **66**.

Upper and lower staking means are associated, respectively, with the upper and lower dies **66** and **67** and with the first die cavity **71**, in order to effect lateral deformation or compression of the ferrule **73** in such die cavity. The staking means correspond substantially to those described above relative to the first embodiment of the invention, and therefore have been given the same reference numerals except followed by the letter *a* in each instance. The upper and lower stake pins **14***a* and **17***a*, respectively, are therefore positioned and adapted to penetrate die cavity **71** from diametrically opposite sides thereof and at longitudinally spaced points therealong.

The means for effecting longitudinal compression of the tube or ferrule **73** in the second die cavity **72** corresponds generally to that described above relative to FIG. **1**. Thus, a hydraulic clyinder **37***a* (FIG. **13**) is connected by a suitable connector means **81** to a piston **33***a* and thus to a ram **31**a. In contrast to the first embodiment, however, the piston and ram of the present embodiment do not extend between the mated upper and lower dies but instead extend through the lower die only. In all embodiments of the invention, the lower die is preferably maintained stationary at all times, whereas the upper die is moved upwardly and downwardly by suitable actuating means (schematically represented at **94**) in order to open and close the dies.

MEANS FOR FEEDING AND GUIDING THE FERRULES 73

A multiplicity of tubes or ferrules **73** are formed in equallyspaced locations integrally with a feed belt (strip or tape) **82**, as best shown in FIGS. **13** and **20**. Each ferrule **73** is connected at its rear end by an integral tab **83** (FIGS. **15**, **16** and **17**) with the forward edge of belt **82**. Each tab **83** extends downwardly from the forward belt edge to the upper portion of the rear end of each ferrule. The ferrules extend perpendicularly away from the belt edge. The unfused seam of each ferrule, which is best shown at **62** in FIG. **6***a*, is at the lowermost point thereof and lies in a vertical plane which extends through the central portion of the tab **83** for the ferrule. The axis of each ferrule lies parallel to, and spaced below, a horizontal plane containing the feed belt **82**.

The spacing between adjacent ferrules **73** on belt **82** is sufficient to provide adequate metal to permit the ferrules to be formed into cylindrical shape. Furthermore, the distance between adjacent ferrules is such that one ferrule may be disposed in the first die cavity **71** at the same time that a second ferrule is disposed in the second die cavity **72**, so that operations may be performed simultaneously on the ferrules in the two die cavities.

Feed belt or strip **82** is fed longitudinally toward dies **66** and **67** by suitable feeding and indexing means represented diagramatically by the block **84** in FIG. **13**. The feeding and indexing means **84** includes a suitable pawl and ratchet mechanism which feeds belt **82** forwardly, one step, each time the upper die **66** is fully separated from the lower die **67**. The distance of forward feeding, during each step, corresponds to the distance between the die cavities **71** and **72** (which, in turn, is the same as the distance between adjacent ferrules **73** on feed belt **82**).

The feed belt is provided with spaced circular holes **86** adapted to receive actuating portions of the pawl and ratchet mechanism in the feeding and indexing means **84**. In addition, the feed belt **82** is provided with a longitudinal slot **87** adjacent each tab **83**. Each slot **87** results from piercing of belt or strip **82** in order to form a downwardly extending runner or tab element **88** (which runner extends the full length of each slot **87**).

Feed belt **82** fits into a groove **89** (FIGS. **14** and **19**) which is formed beneath the upper and generally horizontal flange **91** of a biasing means **92**. The biasing means **92** is illustrated to comprise an elongated block which is pivotally mounted (at a pivot means **90**, FIGS. **14** and **14***a*) in the lower die **67** and is adapted to pivot vertically between the position shown in FIG. **14** and that shown in FIG. **14***a*. The biasing means or block **92** is spring-pressed toward the upper position (FIG. **14**) by a suitable spring means, such as the one indicated at **93**.

When the upper die **66** is closed downwardly into engagement with lower die **67**, due to operation of the die-actuating means indicated at **94** in FIG. **13**, a lower portion of the die **66** presses downwardly on flange **91** to force biasing means **92** downwardly against the pressure exerted by spring **93**. As soon as the actuating means **94** raises the upper die **66**, the spring **93** is operative to lift the elements **92** and **91** and thus the feed belt **82** to thereby lift ferrules **73** for purposes described below.

During the period when the dies are closed, the ferrules **73** rest in a groove **96** which is formed between the dies, as best shown in FIG. **15**. However, opening of the dies and consequent lifting of belt **82** causes lifting of the ferrules at least partially out of groove **96**, so that the ferrules may be shifted or indexed in response to operation of feed means **84**. Very importantly, the ferrule in staking cavity **71** is also lifted, and therefore may be fed to cavity **72**.

The biasing means or block **92** terminates adjacent an insulator block **97** formed of a suitable electrical insulating material, such block being fixedly mounted in lower die **67** adjacent the rear (inner) end of staking cavity **71** (FIGS. **16** and **17**). Insulator block **97**, in turn, is mounted adjacent a track portion **98** of the lower die **67**, which portion **98** extends from a region rearwardly adjacent the die cavity **72** to a region adjacent a discharge port **99** for scrap belt material. The upper surfaces of insulator block **97** and of track portion **98** are flush with each other and are substantially horizontal, and are also flush with the upper surface of

the main body of biasing block **92** (not flange **91**) when the dies are in closed condition (see FIG. **14***a*).

It is pointed out that the ram **31***a* passes beneath the upper surface of track portion **98** of the lower die. The spacing between the upper region of the ram and the upper surface of track portion **98** is sufficiently small (FIG. **18**) that a ferrule **73** may be disposed in die cavity **72** when the dies are in closed condition.

A suitable track is formed in biasing means **92,** in insulator block **97** and in track portion **98,** in the form of grooves **101–103,** respectively, which are in alignment with each other (FIG. **14***a*) when the dies are closed. The grooves **101–103** serve as track means for the runner or tab elements **88** (FIGS. **14** and **20**) which extend downwardly from feed belt **82,** the relationship being such that belt **82** is thus prevented from moving laterally to any substantial extent. Belt **82** and the ferrules thereon are therefore effectively guided into the dies, and it is assured that closing of the dies will cause two adjacent ferrules **23** to be properly located in the two chambers **71** and **72** as desired.

As indicated above, when the dies **66** and **67** are open the biasing block **92** is spring-biased to the upper position, shown in FIG. **14,** which causes elevation of tape **82** to lift the ferrules **73** substantially out of groove **96** (at least at the inner end of such groove) and also to lift the staked ferrule out of the lower half of die cavity **71.** There is then no resistance or impedance to shifting of the belt **82** due to operation of the feeding means **84.** Such means **84** then feeds the belt outwardly one step, causing the staked ferrule to be disposed above the lower half of the second die cavity (folding cavity) **72.** The ferrule immediately to the rear of the staked ferrule is then disposed above the lower half of first die cavity (staking cavity) **71.**

The die actuating means **94** is then operated to shift the upper die element **66** downwardly, which acts on flange **91** to force the biasing means **92** downwardly to the position of FIG. **14***a*. Furthermore, the tape **82** is forced downwardly into engagement with the upper surfaces of the insulator block **97** and of the track portion **98** of the lower die. The resulting downward shifting of tape **82** and of the ferrules **73** thereon causes the staked ferrule and the one immediately adjacent thereto to fit, respectively, into the cavities **72** and **71.**

It is important that the ferrules **73** be properly oriented relative to tape **82** when the ferrules approach the forming cavities **71** and **72,** in order to insure that the ferrules will properly enter such cavities in response to closing of the dies. To insure this result, the present apparatus incorporates a pair of pins **105** (FIGS. **13** and **15**) which are mounted on the upper die **66** and are adapted to penetrate holes or bores **106** in the lower die. The pins **105** have rounded lower ends, and are adapted to closely straddle one of the ferrules **73** each time the dies close. Because the tape **82** is held in position by flange **91** and by the runners **88** which fit in track groove **101,** it follows that downward movement of the pins **105** into straddling relationship with each ferrule will cause straightening of the ferrule relative to tape **82** in the event that the ferrule was not perfectly perpendicular to a vertical plane containing the axis of such tape. The integral tabs **83** on the steel tape are adapted to retain permanent sets, so the effect of the described straightening continues after the pins **105** are elevated.

It is a feature of the present method and apparatus that each ferrule **73** is sheared off automatically from its associated tab **83** in response to the forcing of ram **31***a* longitudinally into folding chamber **72.** This occurs when the leading face of ram **31a** moves past an edge **109** (FIG. **18**) formed at the inner end of cavity **72.** After the ferrule is thus separated from the feed belt **82,** the belt is merely scrap. To facilitate disposal of such scrap, and to insure that the belt does not interfere with proper orientation of the feeding or other portions of the present ball-ending apparatus, a section of the belt is severed each time the dies **66** and **67** close.

As shown in FIG. **14,** upper die **66** is provided with a shear member or portion **107** which is adapted to cooperate with a sharp edge member **108** on the lower die, the latter being formed at the end of track portion **98** remote from insulator block **97.** Each time the upper die **66** is shifted downwardly by the die-actuating means **94,** the shear member **107** moves closely adjacent edge **108** and severs the porton of the tape **82** which extends past such edge **108.** The severed scrap then falls through discharge port **99** into a suitable receptacle.

DESCRIPTION OF ELECTRICAL SENSING AND CONTROL MEANS

The problem of knowing when the guitar string has been fully inserted (but not excessively inserted) into the ferrule **73** in staking chamber **71** is severe, particularly in the case of relatively small-diameter strings or wires. As mentioned above, these wires may be as small as ten thousandths of an inch in diameter or less. Such small-diameter strings are so flexible that it is difficult or impossible for the operator to manually sense when the wire engages the inner end wall of the staking chamber. The operator may therefore believe that the string has been fully inserted before such is the case. Alternatively, the operator may insert the string excessively far and cause it to bend in various undesired ways after hitting the end wall of the staking chamber.

The present apparatus incorporates an electrical sensing and control means which not only insures that the staking operation (and subsequent operations) will start as soon as the wire end has reached the end of the staking chamber **71,** but is sufficiently fast acting that there is relatively little time for the operator to pass the string inwardly through an excessive distance, thus causing undesired bending of the string end. Also, the operator is prevented from pulling the string outwardly and thus decreasing the anchoring force.

The sensing and control apparatus comprises the above-mentioned insulating block **97** which is mounted at the inner end of the first or staking cavity **71.** Mounted in block **97** coaxially of cavity **71** is a rigid conductor **110,** for example a brass cylinder. The conductor extends through an over-sized bore **111** in lower die **67,** and is held coaxially in such bore and in spaced relationship from the walls thereof by means of an insulator **112** shown in FIG. **16.** Thus, when no string is present, no part of conductor **110** is in electrical contact with the die or other portions of the present apparatus.

The diameter of conductor **110** is at least equal to the diameter of the passage through each ferrule **73.** It follows that when a metal guitar string, such as the unwrapped string shown at **56,** is inserted through string

port 74 and into ferrule 73, the end of the string will engage the end of conductor 110. In extending through the string port 74, the string 56 necessarily engages one of the walls thereof. Therefore, the string comprises an electrical contact means which extends between one of the walls of string port 74 and the end of conductor 110. Contact is therefore made as soon as the string end engages the end of conductor 110, and not before.

A suitable low-voltage power source is connected to the die means, such source having sufficiently low voltage that there is no possible danger to the operator. The source is indicated at 113 in FIG. 16, one side of the source connected to lower die 67 and the other side being grounded. The voltage of the source may be, for example, about 6 to 12 volts. The conductor 110 is connected to one side of a suitable relay 114 (FIG. 16), the other side of the relay being grounded. Therefore, when a string 56 is fully inserted into the ferrule 73 and comes into engagement with conductor 110, a circuit is completed from power source 113 through die 67, thence through the inner end of string 56 to conductor 110, thence through relay 114 to ground, and thence through ground back to the power source 113.

The resulting energization of relay 114 causes the same to effect immediate initiation of operation of a control circuit indicated schematically at 115 in FIG. 16. The control circuit effects immediate operation of cylinders 16*a* and 19*a* (FIG. 13) to actuate the staking pins 14*a* and 17*a* and effect the staking operation, which causes the ferrule to grip and pinch the inner end of string 56. The control circuit also effects operation of ram cylinder 37*a* to cause the ram 31*a* to effect folding and cold flow of the ferrule in chamber 72. Control circuit 115 additionally, after both staking and longitudinal compression functions are completed, effects operation of the die actuating means 94 to raise upper die 66, and also operation of the strip feeding and indexing means 84 to effect feeding of the tape and ferrules as soon as the dies are opened, and to effect closing of die 66 onto die 67 as soon as the feeding has been completed. The entire cycle is thus automatic and is initiated the instant that the end of string 56 engages conductor 110.

SUMMARY OF OPERATION, EMBODIMENT OF FIGS. 13–20

Let it be assumed that the apparatus is in operation, that dies 66–67 are closed, that there is an empty and unstaked ferrule 73 in die cavity 71, and that there is a staked ferrule 73 in die cavity 72. The staked ferrule 73 in cavity 72 grips the inner end of a guitar string or the like (for example, bare string 56), which string extends outwardly through port 77.

The operator then inserts a guitar string or the like into mouth 76 and through string port 74 into the ferrule 73 in cavity 71, until the inner end of the string (such as the bare string 56 shown in FIGS. 16–18) engages conductor 110 and thus initiates the automatic cycle of operation described in detail above. The cycle includes operation of cylinders 16*a* and 19*a* to effect staking in chamber 71, and operation of cylinder 37*a* to effect folding in chamber 72, these operations occurring simultaneously in order to increase greatly the speed of manufacture. Operation of cylinder 37*a* also shears a ferrule 73 off of belt 82, as described relative to FIG. 18.

The upper die 66 is then lifted off the lower, as part of the described automatic cycle of operation, following which the completely ball-ended string drops automatically from the apparatus, as indicated by phantom showings 56–117 in FIG. 18. More specifically, the weight of the protruding long operative section of the string 56 causes a pivoting action about the intermediate mouth portion 78, which is followed by a pivoting action about the outer edge of die 67 at the outer end of large mouth 79, after which the ball-ended string drops out of the apparatus.

It is to be understood that the staking operation which occurs in chamber 71, and the folding operation which occurs in chamber 72, are identical (except that staking and folding take place in separate chambers) to those operations described above relative to FIGS. 10–12 (in the case of bare strings as distinguished from wrapped strings). Where the strings being manufactured are of the wrapped variety, the operations are identical (except that staking and folding take place in separate chambers) to those operations described above relative to FIGS. 3–5.

At the same time that the completely ball-ended string is dropping out of the apparatus after opening of the dies, the indexing and feeding means 84 is operating to shift the feed belt 82 one step forwardly or to the left (which is part of the above-described automatic cycle of operation). Such shifting is possible, despite the fact that the staked ferrule 73 in cavity 71 is still connected to the tape 82, since the biasing means 92 lifts the tape to the FIG. 14 position, and thus causes elevation of the staked ferrule out of the lower portion (half) of cavity 71.

Not only is the staked ferrule lifted out of the lower half of cavity 71, but the associated string end is also lifted out of the lower half of string port 74, this being because the staking operation effects a firm gripping of the string end which is in the staked ferrule. Thus, the shifting of belt 82 by the indexing and feeding means 84 causes the staked ferrule and, additionally, the gripped string end to shift from a position over the lower half of cavity 71 to a position over the lower half of cavity 72 (the latter position being shown in phantom at the upper-left, FIG. 19). The string end is held so firmly by the staked ferrule, and the tape 82 is positioned so precisely by the track means 101–103 and by the runner or tab elements 88, that the string end is, after completion of the feeding step, accurately positioned directly above the lower half of string port 77.

It is pointed out that the positioning of the string above the lower half of port 77 must be precise, or else subsequent closing of the dies will not cause the string to be disposed in the port but, instead, to be damaged by the dies. It is also to be noted that the port 77 must be small in diameter in order to prevent excessive extrusion of metal when cylinder 37a is operated. Port 74, to the staking chamber, is also made small in diameter so that the staking operation will cause the gripped string end portion to lie generally in a vertical plane diametral to ferrule 73 and passing through the unfused seam 62 (FIGS. 6*a* and 20) and also through tab 83. Such precise positioning of the string end in the staked ferrule contributes to the accurate string positioning above the lower half of port 77.

Correct positioning of the string is also aided by the downwardly concave (and downwardly convergent) outer edge at the wide end of mouth 79 (FIG. 1). When

the staked ferrule 73 is in the position shown phantom at the upper-left in FIG. 19, the string 56 flexes downwardly by gravity and engages, and is centered by, such concave edge (which acts as a cam). The string then being aligned between the ferrule and the center of such concave edge, closing of the dies results in precise string positioning in port 77.

As the next part of the automatic cycle of operation, actuating means 94 shifts the upper die 66 downwardly to closed position. Because of the above-stated precise string positioning, the end of string 56 then drops into the lower half of port 77, despite the small port diameter, in response to lowering of the staked ferrule into cavity 72, and in response to downward movement of the upper half of port 77 (in die 66). Closing of the dies also causes the shear member 107 to cooperate with edge 108 in shearing the portion of belt 82 which is disposed over discharge port 99, causes the pins 105 to align a ferrule 73, and fully defines the two die cavities 71 and 72 and the two string ports 74 and 77. The apparatus is then ready for a new cycle of operation, which commences immediately upon insertion of the string 56 into contact with the electrical conductor 110.

There is as indicated relative to the first embodiment, no necessity of providing a stop for the elements 33*a* and 31*a* which are shifted by the cylinder 37*a*. However, in order to insure against breakage of ram 31*a* or associated parts in the event of malfunction, the apparatus may incorporate a stop 118 (FIG. 13) the upper part of which is adapted to be engaged by the vertical end of connector 81. Stop 118 is so positioned that it is normally not engaged during any part of the operational cycle — being instead only engaged, in the event of malfunction, in order to prevent damage to the apparatus.

The ferrules 73 employed in the embodiment of FIGS. 13–20 may be identical to those described in the specific example relative to the first embodiment. However, the teeth at the ferrule ends are truncated as shown clearly in FIG. 20 relative to teeth 48*a*. The teeth being truncated, notches 47*a* of FIG. 20 are less deep than are notches 47 of FIGS. 6 and 7.

In the appended claims, when it is indicated that the forming chamber is caused to be substantially filled with ferrule (and string) metal, the chamber which is referred to is the one present at the end of the forming operation. For example, relative to the embodiments of FIGS. 5, 12 and 18, the forming chamber referred to is the one defiend between the face of the ram (when such face is at its position closest to string port 27 or 77) and the chamber end (the left end, in FIGS. 5, 12 and 18) opposite such face.

In the embodiment of FIGS. 13–20, the tape 82 and ferrules 73 are suitably formed, from sheet metal, at a location different from the location of the llustrated apparatus. It is, however, possible to provide an apparatus wherein the tape 82 and ferrules 73 are formed at additional stations in a single overall machine, which single machine not only forms the tape and ferrules from sheet metal stock, but also incorporates all portions of the apparatus of FIGS. 13–20 and therefore performs all functions of such apparatus. It is also possible, as previously stated, to form the ferrules around the string instead of inserting the string into previously formed ferrules. Furthermore, it is possible to provide apparatus for effecting automatic feeding of the strings into the staking chamber. If desired, in order to regulate the amount of metal in each neck 49 or 61, inserts may be provided in dies 66 and 67 to define ports 77 having different diameters for use with different diameters of strings.

The foregoing detailed description is to be clearly understood as given by way of illustration and example only, the spirit and scope of this invention being limited solely by the appended claims.

We claim:

1. A ball-ended string for a musical instrument, which comprises:
   a string for a musical instrument, one end portion of said string being bent; and
   a mass of tightly folded metal having said bent string end portion embedded therein, said mass having at least one fold plane formed therein.

2. The invention as claimed in claim 1, in which said fold plane extends outwardly from said bent portion of said string in a direction transverse to the portion of said string which is adjacent said mass but is not embedded therein.

3. A ball-ended metal string for a guitar or similar musical instrument, which comprises:
   a metal string for a musical instrument, one end portion of said string being S-shaped; and
   a mass of tightly folded metal having said S-shaped string end portion embedded therein, said mass having two fold planes therein, one of said fold planes extending outwardly from one bend of the S and being between the two regions of the S which are adjacent said one fold plane, the other of said fold planes extending outwardly from the other bend of the S and being between the two regions of the S which are adjacent said other fold plane, said fold planes being substantially parallel to each other.

4. The invention as claimed in claim 3, in which the portion of said string which is adjacent said mass, but not embedded therein, lies between two lines which are parallel to each other and are respectively tangential to the bends of the S.

5. The invention as claimed in claim 3, in which said mass has a cylindrical surface generally coaxial with the portion of said string which is adjacent said mass but not embedded therein.

6. The invention as claimed in claim 5, in which said mass has a convergent wall at one end of said cylindrical surface, said wall being generally hemispherical, said wall being adjacent the end of said mass from which the main body of said metal string projects.

7. The invention as claimed in claim 6, in which said mass has a neck around said string and at the small end of said hemispherical wall.

8. The invention as claimed in claim 5, in which said mass is convex at the end thereof remote from the projecting string.

9. The invention as claimed in claim 3, in which said mass is formed of steel which has cold-flowed closely around the S to seize the same.

10. The invention as claimed in claim 3, in which said mass does not incorporate any substantial voids or gaps.

11. The invention as claimed in claim 3, in which each of said fold planes extends outwardly to the surface of said mass.

12. The invention as claimed in claim 3, in which said fold planes are substantial perpendicular to the portion of said string which is adjacent said mass but is not embedded therein.

13. The invention as claimed in claim 3, in which said metal string comprises a core wire having high tensile strength, and which has helically wrapped thereon a soft metal wrap wire.

14. The invention as claimed in claim 3, in which said metal string is a single-strand music wire made of steel, and having a tin coating thereon.

15. The invention as claimed in claim 1, in which said mass is tightly-folded sheet metal.

16. The invention as claimed in claim 1, in which said mass is tightly-folded thin steel.

17. The invention as claimed in claim 1, in which said mass is tightly-folded metal which is relatively hard but is capable of cold flow when subjected to very high pressures.

18. The invention as claimed in claim 1, in which said mass is tightly-folded rolled sheet steel having a Rockwell hardness (30 T Scale) of about 62/68.

19. The invention as claimed in claim 1, in which said mass is tight-folded metal the wall thickness of which, prior to folding, is about 0.021 inch.

20. The invention as claimed in claim 1, in which said bent string end is smoothly bent, not sharply bent.

21. The invention as claimed in claim 1, in which said ball-ended string is the product of a process comprising mechanically compressing metal in a forming chamber to cause cold flow thereof until said forming chamber is substantially filled, said compressing taking place while said one end portion of said string is disposed in said forming chamber.

22. The invention as claimed in claim 1, in which said ball-ended string is the product of a process comprising providing a metal ferrule around one end portion of said string, applying lateral compressive forces to said ferrule to laterally deform the same, and applying longitudinal compressive forces to said ferrule to longitudinally deform and compress the same and thus form said mass of tightly-folded metal having embedded therein said one string end portion in bent condition.

23. The invention as claimed in claim 22, in which at least said longitudinal compressive forces are applied while said mass is disposed in a forming chamber, and are of sufficient magnitude that the metal cold flows until said forming chamber is substantially filled.

24. The invention as claimed in claim 3, in which said mass is tightly-folded thin steel which is relatively hard but is capable of cold flow when subjected to high mechanical pressures.

25. The invention as claimed in claim 24, in which said thin steel forming said mass is tin mill and has a Rockwell hardness (30 T Scale) of about 62/68, and has a wall thickness, prior to folding, of about 0.021 inch.

26. The invention as claimed in claim 3, in which each bend in said S-shaped string end portion is smooth and not sharp.

27. The invention as claimed in claim 3, in which said ball-ended string is the product of a process comprising mechanically compressing metal in a forming chamber to cause cold flow thereof until said forming chamber is substantially filled, said compressing taking place while said one end portion of said string is disposed in said forming chamber.

28. The invention as claimed in claim 3, in which said ball-ended string is the product of a process comprising providing a metal ferrule around one end portion of said string, applying lateral compressive forces at two longitudinally offset and diametrically opposite points along said ferrule to laterally deform the same, and applying longitudinal compressive forces to said ferrule to longitudinally deform and compress the same, at least said longitudinal compressive forces being applied while said ferrule is disposed in a forming chamber, said longitudinal compressive forces having sufficient magnitude to effect substantial filling of said forming chamber, whereby to form said mass of tightly-folded metal having embedded therein said one string end portion in S-shaped condition.

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