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METHOD OF CURVING TUBING SECTIONS

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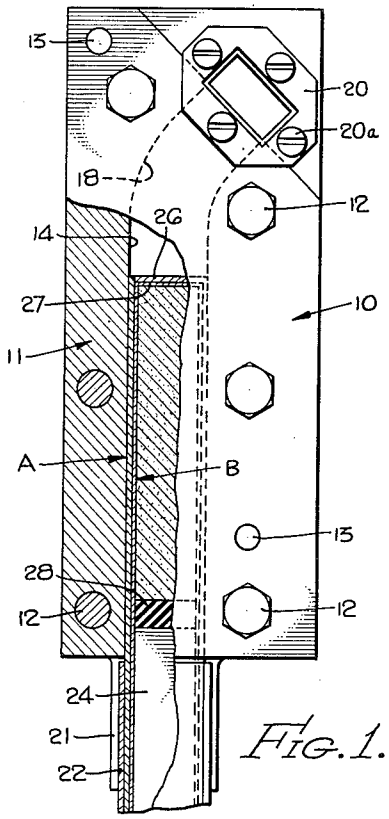


FIG. 1.

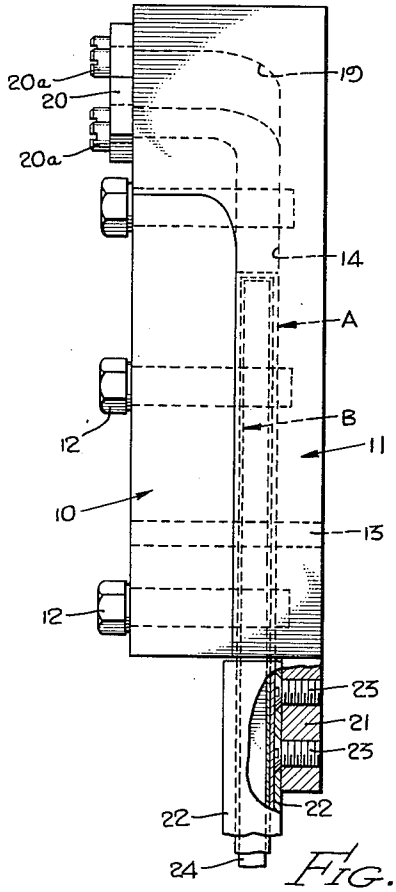


FIG. 2.

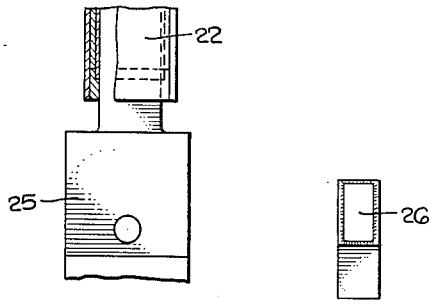


FIG. 3.

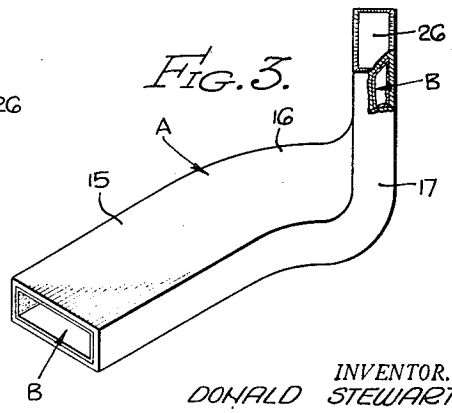
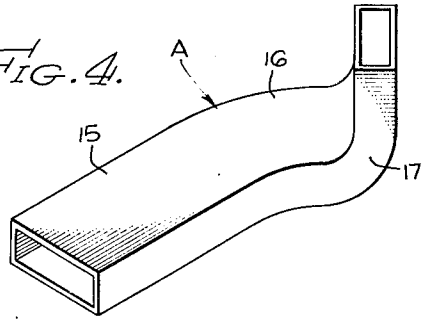


FIG. 4.



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METHOD OF CURVING TUBING SECTIONS

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4 Claims. (Cl. 29—157)

This invention relates to a method of forming curves in tubing and is particularly concerned with forming curves in rectangular tubing to produce curved waveguide sections for use in radar equipment.

The present invention will be explained in the following specification with particular reference to the formation of curves in rectangular magnesium alloy tubing, but it is distinctly pointed out that the invention is not intended to be limited to the formation of curves in tubing of any particular material or tubing of any particular shape unless set forth in the claims, and the concepts of the present invention find wide application in the formation of curves in many types of tubing.

In airborne radar equipment, weight is an important factor and, therefore, it is advantageous that the waveguide be constructed from the lightest possible metal, and magnesium alloy has been generally acceptable as the appropriate waveguide material for such equipment.

Attempts have been made to form simple and compound curves in rectangular tubing, but such attempts have been found to be complicated and relatively expensive. For instance, some prior methods have been followed to successfully form curves in tubing, but during the various steps of the method, the interior of the tubing is roughened, thereby requiring expensive additional operations to smooth the interior to enable the proper transmission of radio frequency energy. Other prior methods necessitate the use of a lubricant, such as graphite, during the various steps of the method. These lubricants must be removed to enable the interior of the tubing to be plated, and the removal operations have been expensive and not always successful.

A primary object of the present invention is to provide a method for forming a curve in a section of tubing without incurring the disadvantages above set out, and so as to preserve the finish of the interior of the section of tubing, and which method is simple, inexpensive and practical.

More particularly, an object of the present invention is to provide a method of forming a curve in a section of tubing comprising sealing one end of a section of tubing, inserting a sleeve of dissimilar metal into the section, partly filling the section with a granular material, forcing the section of tubing through a curved die recess by the application of a force against the granular material to curve the section of tubing and sleeve, removing the granular material from the sleeve and dissolving the sleeve to leave the curved section of tubing.

Various other objects of the present invention will be apparent from the following description taken in connection with the accompanying drawings wherein:

Fig. 1 is a top plan view, partly broken away, of one form of apparatus by which the method of the present invention can be carried out.

Fig. 2 is a fragmentary side elevation of the apparatus disclosed in Fig. 1.

Fig. 3 is a perspective view of a curved section of tubing having therewithin the curved sleeve and illustrating the assembly in the condition after removal from the apparatus.

Fig. 4 is a view similar to Fig. 3 but showing the section of tubing after the removal of the sleeve and showing the sealed end of the tubing being removed.

The method of the present invention when utilized for forming a curve in a section of magnesium alloy tubing comprises the steps of sealing one end of the section of tubing, providing an aluminum sleeve having external

cross sectional dimensions slightly less than the internal dimensions of the section of tubing and a wall thickness less than that of the section of tubing, sealing one end of the aluminum sleeve, inserting the aluminum sleeve, sealed-end-first, into the section of tubing, partially filling the aluminum sleeve with a granular material, such as sand, heating the filled assembly, forcing the assembly through a curved die recess by the application of a force against the sand to thereby curve the section of tubing and sleeve, removing the sand from the sleeve, and dissolving the sleeve to leave the curved section of tubing. The invention more broadly considered includes the concept of providing a chemically dissimilar metallic sleeve within the section of tubing which is to be bent so that after the assembly has been curved, the dissimilar sleeve can be dissolved by subjection thereof to the effects of a suitable reagent or acid which will attack only the sleeve and leave the section of tubing unattacked.

The method of the present invention can be conveniently carried out by an apparatus such as disclosed in the accompanying drawings. In general terms, the apparatus may be defined as comprising a die member provided with an accurately formed recess therein conforming with the external configuration of the section of tubing which is to have a curve formed therein. In conjunction with the die there is provided a ram, which can be hydraulically, mechanically or otherwise driven, to be inserted into the sleeve and against the granular material therein and by which the section of tubing may be forced through the die recess in accordance with the method set forth herein.

Referring now more particularly to the drawings, it will be seen that for the formation of a tube having the compound curves such as illustrated in Figs. 3 and 4, the die consists of an upper die block **10** and a lower die block **11**, which are secured together by means such as suitable bolts indicated at **12** and aligned by locating dowel pins shown at **13**. Die block **11** has a transversely rectangular die recess **14** formed therein, which die recess has a configuration conforming to the external configuration of the section of tubing to be inserted into the die. Die block **10** performs the function of a cover plate for the die recess formed in die block **11**.

For convenience, the section of magnesium alloy tubing has been designated by the letter A in both straight and curved condition, and the aluminum sleeve has been designated by the letter B in both its straight and curved condition. In its curved condition, the section of tubing A includes a straight rectangular body portion **15** transversely curved in a horizontal plane as indicated at **16** and also transversely curved in a vertical plane as indicated at **17**. For forming a section of tubing with the compound curve thus indicated, the recess **14** of the die is formed with a curvature in a horizontal plane as indicated at **18** in Fig. 1, and as indicated in Fig. 2, the recess **14** is formed with an upwardly extending curvature **19** to produce the vertical portion **17** at the end of the finished section of tubing.

Die blocks **10** and **11** are also secured together by a plate **20** attahced to the die blocks by screws **20***a*, plate **20** serving to insure that the vertical portions of the die blocks will not separate when a tubing assembly is forced through the die.

The die recess **14** is fully open at both ends, and a tubing assembly is inserted into the lower end of the die as the parts are depicted in Figs. 1 and 2. At the lower end of the lower die block **11**, as the parts are depicted in Fig. 1, there is provided an outwardly projecting integrally formed platform **21**, to which is secured a ram guide **22** by means of screws **23**. The ram guide **22** is rectangular in internal cross section and conforms to the external configuration of the section of tubing A, the ram fitting into the sleeve B so that the ram is indirectly supported by the ram guide **22** during movement of the ram.

The ram closely conforms in external configuration to the internal configuration of the sleeve B. Ram **24** is provided with a suitable enlargement **25** by which it may be directly or indirectly connected to any desired driving means such as a piston which may be hydraulically or mechanically driven.

The method of the present invention will be explained with reference to a section of magnesium alloy tubing but as heretofore pointed out, this example of how the concept of the present invention has been practically applied is not intended to limit the invention, but only illustrates a practical application of the concept of the present invention. A section of tubing A of magnesium alloy having an internal configuration conforming substantially to the configuration of the finished curved section of tubing is provided. The section of tubing is cut to a length somewhat longer than the final usable length. The forward end of the tube is closed or sealed, such as by means of a welded end plate **26**. An aluminum sleeve, having a slip fit within the section of tubing A and being sealed at **27**, is inserted sealed-end-first into the magnesium alloy section of tubing A. It is preferable that the wall thickness of the aluminum sleeve be as thin as possible to allow it to readily expand to engage the interior of the magnesium alloy section of tubing A during the process of forcing the tubing assembly through the die and also to decrease the time necessary to dissolve the aluminum sleeve after the tubing assembly has been curved. It is also important that sleeve B be not only of a dissimilar material or metal but that it have sufficiently similar working characteristics to those of the tubing so that the section of tubing and sleeve deform similarly under the conditions of treatment of these materials.

The tubing assembly is then partially filled with a granular material, preferably sand, and thereafter heated. Magnesium alloy is both cold-short and hot-short, and therefore a step of the present invention necessarily includes heating the tubing assembly to a temperature of between approximately 350 degrees to 800 degrees Fahrenheit. By way of example, with the particular size tubing which is presently being used, a temperature between 700 and 750 degrees Fahrenheit has been found to be quite successful. Such temperatures may be achieved by inserting the tubing assembly within a heating oven or heated in any other suitable way such as electrical heating means built into the die. After the heating step, the ram **24** is inserted into the aluminum sleeve and into engagement with the sand. A driving member is then placed into engagement with the enlarged end **25** of the ram **24** and with the die firmly held, the ram is forced against the sand thereby forcing the tubing assembly through the die recess and out the end of the die recess to a limited extent. After the sealed end of the tubing assembly protrudes from the die recess a short distance, the pressure on the ram is terminated. The die is then parted and the curved tubing assembly removed.

It has been discovered that in carrying out the method of the present invention, the external surfaces of the tube blank should be lubricated. A suitable lubricant for this purpose has been found to be graphite, although, of course, this invention is not intended to be limited to a graphite lubricant since any other suitable lubricant having the equivalent properties of graphite could be used.

In the preferred series of steps of the method of the present invention, the last increment of sand inserted into the sleeve B is mixed with a binder and tamped into place preferably by the use of the ram **24**. When the tubing assembly is heated, this mixture is baked and serves the purpose of retaining the sand filler within the tubing assembly during the manipulation of the parts prior to the insertion of the ram within the tubing. The last increment therefore is in the shaft of a plug and has been given the reference numeral **28** in Fig. 1. As soon as pressure is applied to the ram, the plug breaks up and thereafter for all practical purposes is merely a part of the sand filler within the tubing.

The particular granular material which is inserted into the aluminum sleeve B is extremely important. The particular filler used, sand, has certain properties which allow the forming of curves in sections of tubing while maintaining the internal dimensions of the tubing. The sand within the aluminum sleeve bites into the internal walls of the sleeve expanding the sleeve outwardly into frictional engagement with the internal walls of the section of tubing and therefore distributing the applied force along the section of tubing A. Therefore, there is very little force imposed on the sealing plates **26** and **27**. Actually, the sealing plates **26** and **27** cannot stand any considerable force and therefore if a granular material were used which did not bite into the walls of the tubing to distribute the force as above stated, the plates **26** and **27** would be ruptured immediately upon the application of force to the granular material.

Another important objection to the transmission of any substantial force to the forward end of a tubing assembly is that such force would stretch the tubing so that the internal dimensions of the section of tubing would not be maintained during the formation of the curves in the tubing. Since the force on the ram is distributed along the tubing assembly, there is no stretching of the tubing assembly and consequently the internal dimensions of the section of tubing A are maintained even though rather complex curves are formed in the tubing. The sand additionally serves to prevent internal collapse of the walls of the tubing. The sand is prevented from flowing out the forward end of the sleeve and section of tubing A by means of the end plates **26** and **27**, this being the major function of these plates.

As an example of the kind of sand which has been used successfully in forming curves in magnesium alloy tubing, a commercial grade of Mesh 30, so-called round sand, has been satisfactorily employed. It is also contemplated that a small quantity of graphite lubricant or the like can be added to the sand filler if it is discovered that a sand has too high a bite characteristic. By the addition of a graphite lubricant or equivalent, the bite characteristic of the sand can be somewhat lessened. On the other hand, if the bite characteristic of the sand is not sufficient, it is contemplated that a suitable granular material having more angular particle shaped characteristics than sand can be added to the sand to increase the bite quality of the sand. By a proper selection of sand, the required flow qualities desired can in many instances be obtained without resorting to the above expedients, since it is well known to artisans and tradesmen dealing with commercial sand products that sand varies widely in its flow characteristics, especially as resulting from variations in its sharpness.

After the tubing assembly has been removed from the die, the aluminum sleeve B is dissolved by the use of a suitable chemical reagent, such as caustic soda or hydrofluoric acid. Such chemical reagent does not attack the magnesium alloy, the magnesium alloy being chemically dissimilar metal, but does completely remove and dissolve the aluminum sleeve therefore leaving a clean, smooth interior surface on the section of tubing A. Obviously, there is no lubricant coating on the interior of the section of tubing A and therefore the section of tubing is ready for use.

The forward sealed end of tubing A is removed and scrapped. It has been found in practice that the forward end of the section of tubing A is not quite properly formed and therefore is removed.

The above specific description of the methods of the present invention has been given with reference to forming curves in a section of tubing of magnesium alloy. It is obvious that the concepts of the present invention are broader than the above specifically described application of the method, since it is obvious that the section of tubing could be of aluminum and the sleeve could be of magnesium alloy. Under these conditions, the magnesium alloy sleeve could be removed by subjecting the sleeve to the effects of nitric acid. Furthermore, the concepts of the present invention can be applied to form curves in sections of tubing wherever the sleeve and section of tubing have chemically dissimilar characteristics such as to enable the sleeve to be removed by subjecting it to a chemical reagent without affecting the section of tubing. Furthermore, the specific step of heating the tubing assembly will not be required with metals which are not cold short or hot short.

Although the invention has been described with reference to forming a curve in a section of tubing having a rectangular cross section, it is obvious that curves may be similarly formed in tubing sections having other cross sectional shapes, such as circular, elliptical, etc.

It will, of course, be understood that the apparatus here shown is merely illustrative of the various types of die-ram arrangements and other arrangements which may be used in carrying out the method of the present invention, and it will be understood that various changes, modifications and the full use of equivalents may be resorted to in the practice of the invention without departing from the spirit or scope of the appended claims.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. The method of forming a curve in a section of magnesium alloy tubing, comprising sealing one end of the section of tubing, providing an aluminum sleeve having external cross sectional dimensions slightly less than the internal cross sectional dimensions of the section of tubing and a wall thickness substantially less than the section of tubing, sealing one end of the aluminum sleeve, inserting the aluminum sleeve sealed-end-first into the section of tubing, partially filling the aluminum sleeve with sand, heating the filled assembly, lubricating the outer surface of the section of tubing, forcing the assembly through a curved die recess by the application of a force against the sand to thereby curve the section of tubing and sleeve, removing the sand from the sleeve, and dissolving the sleeve to leave the curved section of tubing.

2. The method of forming a curve in a section of magnesium alloy tubing, comprising sealing one end of the section of tubing, providing an aluminum sleeve having external cross sectional dimensions slightly less than the internal cross sectional dimensions of the section of tubing, sealing one end of the aluminum sleeve, inserting the aluminum sleeve sealed-end-first into the section of tubing, partially filling the aluminum sleeve with sand, heating the filled assembly, lubricating the outer surface of the section of tubing, forcing the assembly through a curved die recess by the application of a force against the sand to thereby curve the section of tubing and sleeve, removing the sand from the sleeve, and dissolving the sleeve to leave the curved section of tubing.

3. The method of forming a curve in a section of tubing, comprising sealing one end of the section of tubing,

providing a sleeve of dissimilar metal and sealing one end of the sleeve, inserting the sleeve sealed-end-first into the section of tubing, partially filling the sleeve with sand, forcing the assembly through a curved die recess by the application of a force against the sand to curve the section of tubing and sleeve, removing the sand from the sleeve, and dissolving the sleeve to leave the curved section of tubing.

4. The method of forming a curve in a section of tubing, comprising sealing one end of the section of tubing, providing a sleeve of dissimilar metal and sealing one end of the sleeve, inserting the sleeve sealed-end-first into the section of tubing, partially filling the sleeve with sand, lubricating the outer surface of the section of tubing, forcing the assembly through a curved die recess by the application of a force against the sand to curve the section of tubing and sleeve, removing the sand from the sleeve, and dissolving the sleeve to leave the curved section of tubing.

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