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A. DREYER

2,115,419

PRODUCTION OF HIGHLY ELASTIC FLEXIBLE TUBES OR DIAPHRAGMS

Filed July 21, 1937

FIG. 1.



FIG. 2.

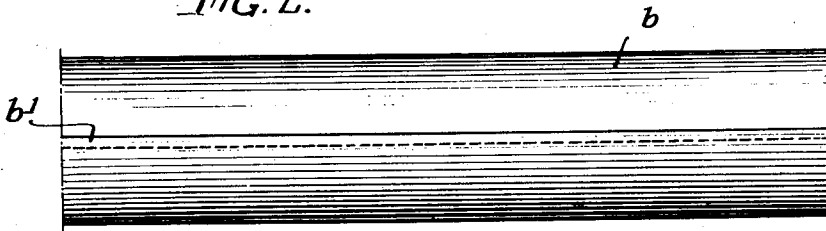


FIG. 3A.

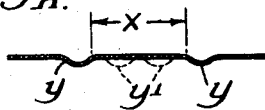


FIG. 6.

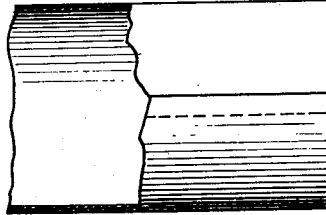


FIG. 3.

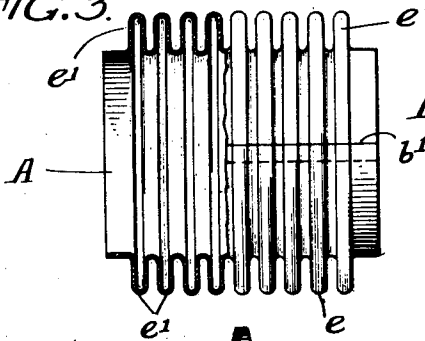


FIG. 7.

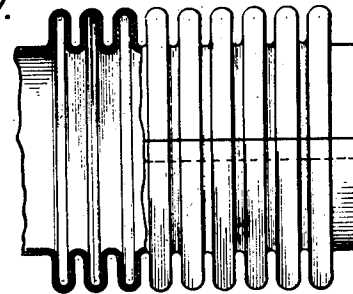


FIG. 4.

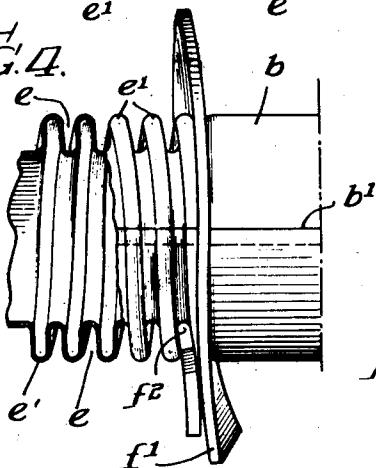
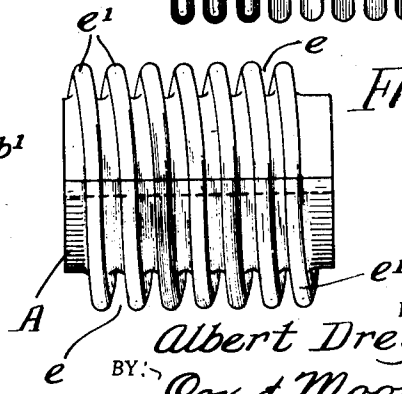


FIG. 5.



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UNITED STATES PATENT OFFICE

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PRODUCTION OF HIGHLY ELASTIC FLEXIBLE TUBES OR DIAPHRAGMS

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Application July 21, 1937, Serial No. 154,839
In Germany June 19, 1936

7 Claims. (Cl. 29—162)

This invention provides a method for producing highly elastic flexible tubes (so-called diaphragms) in the form of tubings either with juxtaposed parallel annular channels and ridges, or with helical grooves, characterized in that a strip of exceedingly thin (about 0.1 mm.) readily weldable metal (such as iron, rustless steel, Monel metal) is first bent transversely in relation to its length and thus shaped as a slotted tube, whereupon the edges of the slot are lapped and electrically welded, and the tube is then corrugated to render it easily flexible.

So-called flexible tubes, also termed diaphragms, were hitherto made of tombac, brass, or similar alloys, seamless drawn tubes of very thin material (0.03 to 0.3 mm. wall thickness) being used.

Quite apart from the fact that the production of such thin, seamless, drawn tubes of tombac, brass and similar alloys, with the accurate gauging required for the special purpose in view, is in itself very difficult, and the cost of such tubing is accordingly very high, there is a progressively increasing demand for flexible tubes for purposes (such as containing ammonia in thermostats in refrigerators) for which tombac, brass and similar alloys are out of the question since diaphragms of such materials would be completely destroyed, in a few days, under the conditions encountered. The same applies to the case of mercury fillings, with which the aforesaid alloys form an amalgam. Again, in the case of high temperatures, the known flexible tubes prove unsuitable, inasmuch as, owing to fatigue they lose their elasticity at about 300° C. Further, in operations employing acetylene, the risk of explosion arises through the decomposition of the (dissolved) gas, if flexible tubes of tombac or other alloys high in copper be employed.

These facts led to experiments for ascertaining whether tombac and brass tubing could be replaced by seamless, drawn, iron tubing in the production of flexible tubes. However, the work undertaken in this connection led to the result that the manufacture of such tubing from such exceedingly thin metal is a source of still greater difficulties. Though it was found that iron tubing could be produced, in which the thickness of the material was approximately true to gauge, it transpired that the structure of such tubing was stressed to such a degree, in the drawing operation, that most of the tubings failed to stand the further working up into flexible tubes. A discard of 50-70% had to be allowed for, and, moreover, the few usable flexible tubes obtained

could not be expected to last very long, the material already exhibiting inadequate extensibility. Microscopic examination of the seamless, drawn iron tubings showed clearly that the structure of the material had suffered considerably—which is, naturally, the case, to a higher degree, in the finished flexible tubes.

These and other difficulties are removed, according to the invention, by proceeding in the following manner:—

A strip of extremely thin (about 0.1 mm.) sheet metal suitable for welding (such as iron, non-corrosive steel or Monel metal) is first bent, in known manner, transversely to its longitudinal direction and thus formed into a slotted tube, then the slot is closed by lapping and electrically welded by the resistance-welding method, and thereafter the tube is rendered easily flexible, by corrugating the wall.

The application of electrical resistance welding is essential. In view of the extreme thinness required of the metal in such flexible tubes or diaphragms, electrical arc welding, or butt welding, is out of the question. Whereas, earlier experiments in the manufacture of metal hose have shown that strip of the usual gauge for that purpose could not be satisfactorily welded electrically, but only by the autogenous method, it is found, on the contrary, in the present instance of the far thinner metal of the flexible tubes in question, that the electrical resistance welding of the lapped joint is advantageous. This is attributable to the circumstance that, in the case of thicker sheet metal, the electrical resistance process does not heat the metal sufficiently, so that, instead of the essential interfusion of the material, the edges are merely cemented together. In certain circumstances this may suffice for many purposes, but not for the production of metal tubes in which the quality of the welded seam is expected to fulfill very stringent requirements. On the other hand, it is found that, in the case of such very thin sheet metal as is in question for the production of the present flexible metal tubes, the electrical resistance method thoroughly heats the metal and, given sufficient pressure of the electrode rollers on the seam, actually causes the material to unite by fusion, in such a manner that the lapped portion is only very slightly thicker than the rest of the tube wall. Now, this circumstance is of the highest importance in the manufacture of the flexible tubes, namely, that the seam is not substantially thicker than the rest of the tube wall; and this is the more

so in proportion as the sheet metal employed is of finer gauge. Consequently, whereas, for example when material about 0.5 mm. thick is employed (as is customary for the manufacture of metal hose) the welded seam can hardly be reduced at the overlap to less than 0.8 mm., even by very heavy rolling pressure in welding, and is therefore about $\frac{1}{3}$ mm. thicker than the rest of the tube wall, the material, in the case of sheet metal only 0.15 mm. thick, fuses together in such a manner that the welded seam is not much thicker than 0.2 mm.—that is to say, is only about $\frac{1}{100}$ mm. thicker than the remainder of the tube wall. This exceeding tenuity of the welded seam then no longer forms any impediment to the production of satisfactory flexible tubes.

Typical embodiments of flexible tubes produced in accordance with the new method are illustrated in the accompanying drawing to which reference will now be made.

In the drawing:

Fig. 1 is a plan view illustrating the method of forming the metal ribbon into tubular form.

Fig. 2 is a view on an enlarged scale showing the tube after it has been formed and welded longitudinally.

Fig. 3 is a view illustrating the tube after it has been corrugated annularly.

Fig. 3—A also illustrates the method for producing the annular corrugations.

Fig. 4 is a view illustrating a method for helically corrugating the tube.

Fig. 5 shows the completed helically corrugated tube.

Fig. 6 illustrates a tube composed of a plurality of nested metal cylinders, and

Fig. 7 shows the construction of Fig. 6 after it has been corrugated.

According to Fig. 1 the metal ribbon *b*, run off from a reel *a*, is first transformed into a slotted tube *c* by bending it round, in a suitable apparatus, transversely to its longitudinal direction. Then follows the electric welding of the slot, the edges being lapped as shown in Fig. 2, in which *b* denotes the tube and *b'* the welded seam. The tube is next rendered easily flexible by corrugating so as to form complete annular channels and ridges, or a helical groove.

The corrugating of the tube with complete annular corrugations is represented, by way of example, in Fig. 3, the tube wall being shaped, by known means, in the following manner:—in the first place, shallow grooves *y* are formed, as illustrated in Fig. 3—A, by rolling, so as to leave, between each two of said grooves *y*, a cylindrical portion *x*, the length of which corresponds approximately to the span of two such grooves *y*, as indicated at *y'*, whereupon the cylindrical portions are transformed, by upsetting the tube in the longitudinal direction, into ridges *e'*, to which correspond the grooves *e*. By dividing the resulting corrugated hose into separate pieces, the desired flexible tubes *A* are obtained, both ends of which can then be shaped in the form of cylindrical rims for attachment to a pipe.

When the production of flexible bodies from separate pieces of sheet metal is in question, their length will depend on the number of corrugations required in each case, and both ends of the flexible tube must be left plain.

For the production of helically grooved flexible tubes, it is specially advantageous to proceed as represented in Fig. 4. The helical groove, to which corresponds the ridge *e'*, is formed by the

action of a tool which presses the groove, as a single screw thread, to the desired depth in the tube wall. In the figure such tool is shown, by way of example, in the form of a helically shaped plate *f*, which may be designed, at *f'*, for the application of the rotational force, the other end *f''* being pressed into the groove *e* while the tube *b* is moved in the longitudinal direction. The helically shaped plate and the method of corrugating a tubing thereby is not claimed herein, but is described and claimed in a copending application of James Fentress and Albert Dreyer, Serial No. 47,366, filed October 30, 1935. After subdividing the corrugated hose thus produced, the flexible tube or diaphragm *A* (Fig. 5) is obtained.

By nesting several thin sheet metal cylinders, as shown in Fig. 6, and then working them up conjointly into a flexible tube, as illustrated in Fig. 7, tubes having a high degree of elasticity can be produced for standing higher pressures. Experience shows that such tubes composed of a plurality of thin walls flex more readily and have a far longer working life than tubes of the same total thickness of metal in a single wall. Thus, a flexible tube composed of three 0.1 mm. tubings rolled conjointly, is more flexible than one composed of a single tubing 0.3 mm. thick. This is attributable to the circumstance that the corrugations of the individual layers are able to describe a relative slip in bending and straightening. This feature also enables flexible bodies to be produced, which may be composed of different materials in accordance with the requirements to be fulfilled in each case.

The electrical resistance welding allows not only the employment, as material, of pure iron, but also of alloys which would be difficult to weld by the autogenous method, as well as alloys which, owing to the very difficult working treatment, are not obtainable at all in the form of seamless drawn tubing. Practically all alloys having a higher resistance than copper are suitable for electrical resistance welding. Thus, as already mentioned, tubings composed of Monel metal have been found suitable, and also those of nickel-copper alloys, German silver alloys, and rustless varieties of iron, thereby remedying a further great deficiency, inasmuch as flexible tubes of these materials have hitherto been unobtainable in commerce.

According to the invention, that is, by employing electrically welded lapped tubings, it is also possible to produce flexible tubes composed, on the outside, of a different material from that on the inside. For example, the interior of the flexible tube may consist of Monel metal, with an intermediate sheathing of Siemens-Martin iron, and an external sheath of Monel metal.

By employing a sufficient number of thin sheet-metal cylinders fitting into one another as closely as possible and also being conjointly rolled before being worked up into a flexible tube, so that the several layers lie firmly one against another, flexible tubes to stand elevated pressures can be produced, thereby enabling the flexible tube to be utilized, as a so-called compensator, for axial insertion in a conduit, in contrast to the compensators hitherto used which exhibit the defect, inter alia, of having, in most cases, to be inserted at an angle in the conduit, this often necessitating the provision of very expensive shafts and causing considerable frictional losses in the conduit, through bends and curves. Such known compensators (especially in the case of corru-

gated, or even smooth expansion bends) also require a relatively high force to set them in operation.

Various changes may be made in the invention as above set forth for purposes of illustration without departing from the spirit thereof. The invention is accordingly not to be limited to the specific embodiments and method steps hereinbefore described, but only as indicated in the following claims.

The invention is hereby claimed as follows:—

1. The method of making flexible metal tubing which comprises forming a strip of readily weldable metal of a thickness of approximately .1 mm. into cylindrical form with lapped edges, welding said lapped edges together by the electrical resistance method in such a manner that the thickness of the metal at the seam is approximately the same as that of the rest of the tube wall, interfitting the cylinder thus formed with a similarly formed cylinder of slightly different size so that one cylinder nests within the other, and thereafter corrugating the cylindrical tubing thus formed to render it flexible.

2. The method of making flexible metal tubing which comprises forming a strip of readily weldable metal of a thickness of approximately .1 mm. into cylindrical form with lapped edges, welding said lapped edges together by the electrical resistance method in such a manner that the thickness of the metal at the seam is approximately the same as that of the rest of the tube wall, interfitting the cylinder thus formed with a similarly formed cylinder of slightly different size so that one cylinder nests within the other, conjointly rolling the cylindrical tubing thus formed to bring the nesting cylindrical walls into firm engagement, and thereafter corrugating the cylindrical tubing to render it flexible.

3. The method of making flexible metal tubing which comprises forming a strip of readily weldable metal of a thickness of approximately .1 mm. into cylindrical form with lapped edges, welding said lapped edges together by the electrical resistance method in such a manner that the thickness of the metal at the seam is approximately the same as that of the rest of the tube wall, interfitting the cylinder thus formed with a plurality of similarly formed cylinders, each of said cylinders being of slightly different size so that the cylinders nest within each other, and thereafter corrugating the cylindrical tubing thus formed to render it flexible.

4. The method of making flexible metal tubing which comprises forming a strip of readily weldable metal of a thickness of approximately .1 mm.

into cylindrical form with lapped edges, welding said lapped edges together by the electrical resistance method in such a manner that the thickness of the metal at the seam is approximately the same as that of the rest of the tube wall, interfitting the cylinder thus formed with a similarly formed cylinder of slightly different size and of different metal so that one cylinder nests within the other, and thereafter corrugating the cylindrical tubing thus formed to render it flexible.

5. The method of making flexible metal tubing which comprises forming a strip of readily weldable metal of a thickness of approximately .1 mm. into cylindrical form with lapped edges, welding said lapped edges together by the electrical resistance method in such a manner that the thickness of the metal at the seam is approximately the same as that of the rest of the tube wall, interfitting the cylinder thus formed with a similarly formed cylinder of slightly different size so that one cylinder nests within the other, and thereafter helically corrugating the cylindrical tubing thus formed to render it flexible.

6. The method of making flexible metal tubing which comprises forming a strip of readily weldable metal of a thickness of approximately .1 mm. into cylindrical form with lapped edges, welding said lapped edges together by the electrical resistance method in such a manner that the thickness of the metal at the seam is approximately the same as that of the rest of the tube wall, interfitting the cylinder thus formed with a similarly formed cylinder of slightly different size so that one cylinder nests within the other, and thereafter annularly corrugating the cylindrical tubing thus formed by annularly channeling the tubing at spaced intervals and by compressing the tubing longitudinally to form ridges between said channels whereby to render the tubing flexible.

7. The method of making flexible metal tubing which comprises forming a strip of rustless steel of a thickness of approximately .1 mm. into cylindrical form with lapped edges, welding said lapped edges together by the electrical resistance method in such a manner that the thickness of the metal at the seam is approximately the same as that of the rest of the tube wall, interfitting the cylinder thus formed with a cylinder of slightly different size so that one cylinder nests within the other, and thereafter deeply corrugating the cylindrical tubing thus formed to render it flexible.

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