United States Patent [19]

Tressel

[11] **3,739,615**

[45] **June 19, 1973**

[54] **METHOD OF MAKING WRINKLE-FREE THIN-WALLED COILED TUBING**

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[22] Filed: **June 1, 1971**

[21] Appl. No.: **148,406**

[52] **U.S. Cl.** **72/57,** 72/142, 72/369, 72/701

[51] **Int. Cl.** **B21d 39/08,** B21f 3/04

[58] **Field of Search** 72/142, 144, 58, 72/61, 57, 369, 466, 701; 29/421, 423

[56] **References Cited**

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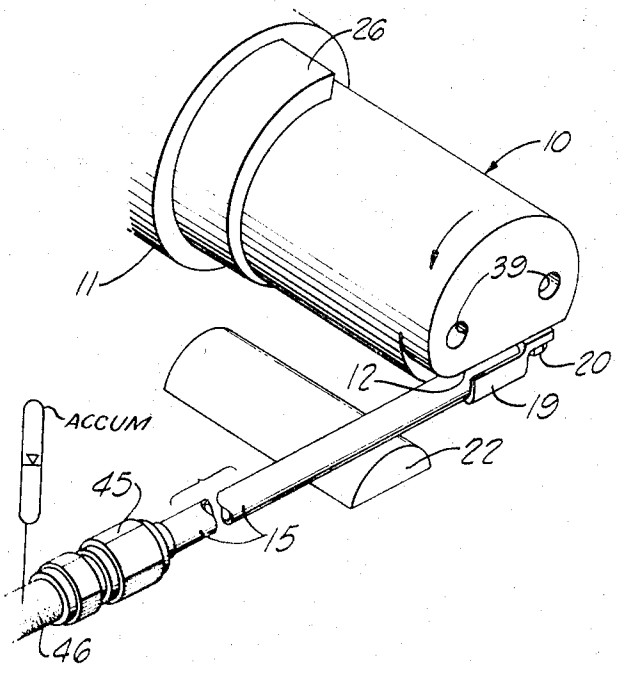
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Primary Examiner—Charles W. Lanham
Assistant Examiner—Robert M. Rogers
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[57] **ABSTRACT**

A method of coiling thin-walled tubing into a small diameter coil free of wrinkles or distortion from end to end thereof. Tubing of the required length is maintained pressurized with liquid to substantially the yield point of the material thereby placing the tube wall in high tensile stress longitudinally and circumferentially and maintaining the tubing straight until it is progressively formed into a coil without the use of clamps, dies or tools other than a rotary mandrel. The method technique permits the formation of multiple layer coils using an inner layer to support the formation of a second layer of convolutions.

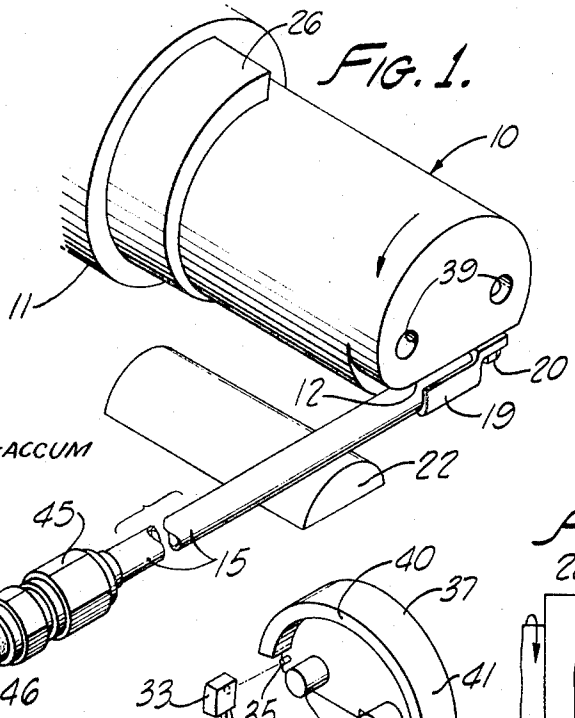
7 Claims, 7 Drawing Figures



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FIG. 1.



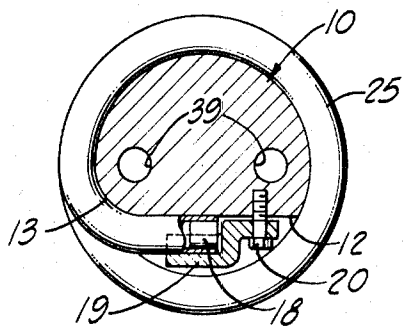


FIG. 3.

FIG. 2.

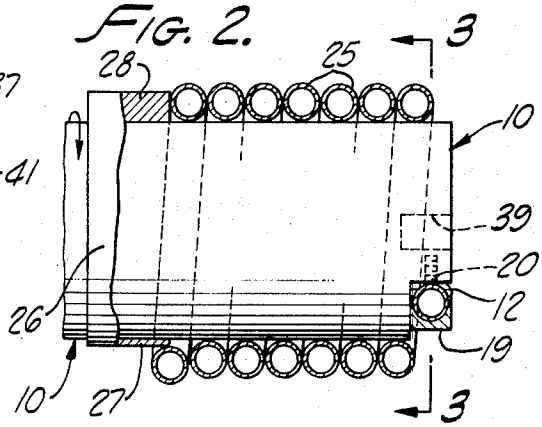


FIG. 7.

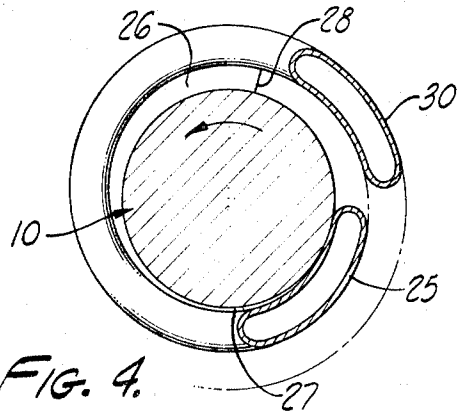


FIG. 4.

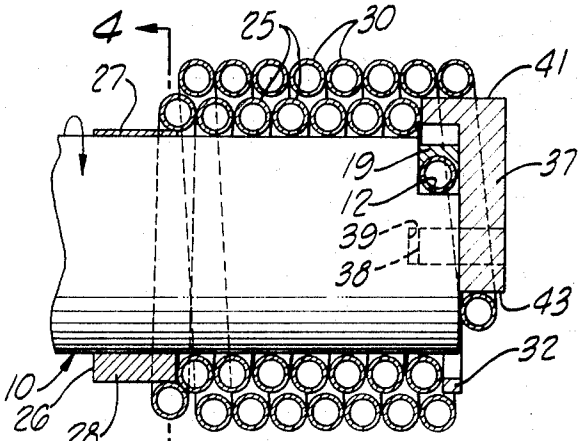


FIG. 5.

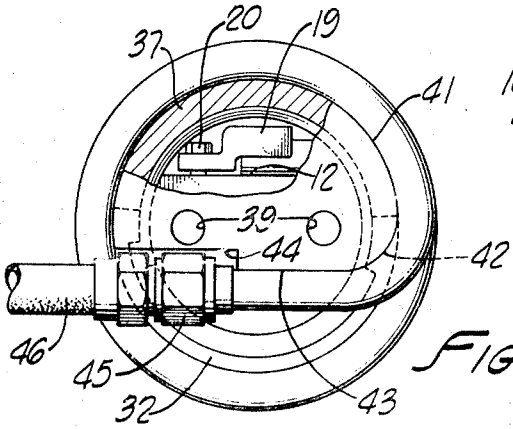


FIG. 6.

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METHOD OF MAKING WRINKLE-FREE THIN-WALLED COILED TUBING

The present invention relates to the formation of high precision coiled tubing and more particularly to an improved high precision technique for coiling thin-walled metal tubing into small diameter coils free of wrinkles and without distorting the tubing out of roundness, and permitting the formation of one or more additional coils using an inner layer to support a surrounding layer of tubing.

Various proposals have been made heretofore for coiling ductile tubing into both single and multiple layer coils. For routine applications the presence of wrinkles and some deformation or flattening of the tubing is of no particular consequence and compensation for resulting losses is readily achieved by employing tubing of somewhat greater size. To minimize wrinkling and deformation resort has been had to internal charges of various characters including fine sand and other materials and these expedients have proven reasonably satisfactory for many applications. However, the use of sand is subject to certain disadvantages and limitations which are unacceptable in meeting highly refined requirements wherein no wrinkling or distortion of the tubing can be tolerated particularly when processing tubing of minimum wall thickness or formed of materials difficult to coil, such as stainless steel. It is found that the slightest damage to the surface of the material leads to deformation of the tubing and the rejection of the part. For example, the slightest scratch or surface damage can weaken the tubing sufficiently to cause malformation of the tubing and an unacceptable coil.

Proposals have also been made heretofore to charge the tubing with pressurized liquid. Such proposals have even included the step of preloading the tubing in tension prior to and during charging with liquid and then closing the valving to make certain that the tube is completely charged with pressurized fluid while the pipe is held in tension. This technique is found satisfactory, cumbersome, and inadequate to meet the requirements of coiling thin-walled stainless steel and other troublesome materials into high precision coils.

The present invention provides a simple, inexpensive and relatively easily practiced technique avoiding the shortcomings of prior practice and is found equally satisfactory for making both single and multi-layer coils meeting the most exacting requirements. Highly pressurized liquid is used to maintain the tubing preloaded in tension both longitudinally and circumferentially thereof to a point closely approaching the yield point of the material. Preferably the inlet end is maintained in continuous communication with the pump and a reservoir or accumulator for the pressurized liquid to assure continuity of the requisite pressure throughout the formation of the coil. The maintenance of substantially the same high pressure assures that unformed portions of the tubing will remain strictly straight right up to the point of coiling and the introduction of additional liquid to compensate for elongation of the tubing. The closed end of the tube is then clamped crosswise of the end of a coiling mandrel having a highly polished surface with the adjacent portion of the pipe resting against a polished and preferably non-metallic fixed anvil as the mandrel is rotated toward the anvil to coil the tubing thereabout in closely spaced convolutions. If a multi-layer coil is desired, then an arcuate shaped

wedge of polished nylon or the like sized to snugly fit the mandrel is placed thereagainst and in position to support the tubing during the transition formation thereof onto the first-formed layer of convolutions. Thereafter, the convolutions of the second layer are formed directly against the underlying convolutions of the first layer. Throughout the coiling operation, the high liquid pressure is maintained constant on the interior of the tubing by a precision pressure regulator or an accumulator. The last convolution may be terminated with its end projecting inwardly crosswise of the end of the two coils by securing a specially shaped form crosswise of the mandrel as will be described in greater detail below.

Accordingly, it is a primary object of the present invention to provide a method and technique for coiling thin-walled tubing into a small diameter coil of one or more convolutions which coil is free of wrinkles or deformation from end to end thereof.

Another object of the invention is an improved technique for coiling tubing having a wall thickness of the order of one thirtieth to one tenth of its diameter into a high precision coil free of wrinkles and flattening from end to end and with both ends of the coil terminating inwardly of the OD of the coil.

Another object of the invention is the provision of an improved high precision method of coiling thin-walled tubing into a multi-layer coil free of distortions and wrinkles and utilizing the first formed layer to support the next layer of the coil.

These and other more specific objects will appear upon reading the following specification and claims and upon considering in connection therewith the attached drawing to which they relate.

Referring now to the drawing in which a preferred embodiment of the invention is illustrated:

FIG. 1 is a perspective view illustrating the tubing anchored to a mandrel fixture in readiness to form the first convolution of the coil,

FIG. 2 is a cross-sectional view lengthwise of the first layer of the coil showing the transition fixture in position to support the tubing enroute to the first convolution of the second layer;

FIG. 3 is a cross-sectional view along line 3—3 on FIG. 2;

FIG. 4 is a cross-sectional view in part taken along line 4—4 on FIG. 5;

FIG. 5 is a longitudinal cross-sectional view after both layers of a two layer coil have been completed;

FIG. 6 is an end elevational view of FIG. 5 with portions broken away and in cross-section; and

FIG. 7 is an exploded perspective view of the two-part support fixture for the last convolution of the second layer.

Referring initially more particularly to FIG. 1, there is shown a suitable mandrel fixture **10** suitable for coiling thin-walled tubing in accordance with the principles of the present invention. It will be understood that this mandrel is supported on the chuck, indicated generally at **11**, of a lathe or other suitable rotary support for the mandrel. The mandrel has a length corresponding generally to the length of the coil to be formed and is machined at its unsupported end to provide a supporting shelf **12** for the closed end of the tubing. This shelf merges smoothly with one end of a carefully machined arcuate surface **13** likewise merging smoothly with the external diameter of the mandrel. All surfaces in con-

tact with the coil are highly polished and may be coated with a non-metallic layer of Teflon, nylon or the like smooth-surfaced material to safeguard against the slightest risk of scratching or abrading the tubing as it is pressed against the mandrel during formation of the coil.

As here shown by way of example, mandrel **10** is 3 inches in diameter and is being used to form a double layer coil of stainless tubing having an OD of 0.500 inches and a wall thickness of 0.017 inches. The yield point of this material is 75,000 psi and the maximum pressure the tubing will withstand during the coiling operation is:

$$P = 2St/d = 2 \times 75{,}000 \times 0.017/\mathbf{0.500} = 5{,}100 \text{ psi}$$

It has been found critically important to maintain the tubing continuously pressurized with liquid to this value throughout the coiling operation. Since the operating pressure is maintained close to the yield, the radially inner half of the tubing yields lengthwise of the tubing along with the greater elongation of the outer half as additional pressurized liquid is supplied to the tubing to compensate for the slight volumetric increase. It is found that wrinkles and distortion inevitably occur unless appropriate means are employed to supply make-up liquid and to maintain the pressure virtually constant during coiling.

One end of the tubing is fitted with a plug **18** braized or otherwise securely anchored in place and the end clamped against shelf **12** of the mandrel by a clamping fitting **19** and clamped by cap screw **20.** Care is taken to support tubing **15** on an anvil **22** of polished preferably non-metallic material. It will be understood that anvil **22** is fixedly supported on the lathe parallel to the axis of mandrel **10** and closely spaced to one side in the manner indicated in FIG. **1.** Mandrel **10** is now rotated toward anvil **22** thereby coiling the tubing upon the mandrel. As here shown, convolutions **25** are in close contact with one another but it will be understood they may be spaced apart by inserting a smooth surface spacer between the coils as they are formed or using other appropriate means well known those skilled in the coiling art. than

If it is desired to form a second layer of convolutions, an arcuate wedge **26** of nylon or material of similar characteristics is placed against the mandrel with one lateral edge lying snugly against the juxtaposed surface of the last convolution. This transition wedge is somewhat greater than 180° in length with its pointed end **27** lying against the mandrel beneath the end of the last tubing convolution. The opposite end **28** of the wedge has a thickness approximately the OD of tubing **15** with the result that, as a lateral force is applied from the left hand side of tubing **15** in FIG. **1,** wedge **26** provides a support ramp for the tubing for its transition to the start of the first turn of the second layer **30** of tubing and resting against the last convolution of the first layer. Thereafter, successive convolutions of the second layer are formed in the same manner as the first but employing the convolutions of the first layer to support and form convolutions of the second layer.

Prior to forming the first convolution of the inner layer the mandrel is preferably fitted with a pair of forming tools best illustrated in FIG. **7.** These include a semi-circular ring **32** formed with enlargements **33,34** at its ends having openings seating over dowel pins **35,35** projecting from the interface of a second forming tool **37.** This second tool likewise has dowels **38** projecting from its inner face designed to seat snugly in bores **39,39** formed in the end face of mandrel **10.**

An arcuate flange **40** projecting inwardly from fitting **37** has an outer surface conforming to the OD of the first layer of tubing convolutions. The outer surface **41** of flange **37** merges with an arc **42** of smaller radius corresponding to arcuate surface **13** (FIG. **3**) of the mandrel itself. Arcuate surface **42** in turn merges with the flat surface **43** (FIG. **6**) notched at **44** to accommodate the coupling **45** connecting the end of tubing **15** to the high strength flexible hose **46.** Although not shown, it will be understood that hose **46** is connected through an accumulator or high precision pressure regulator to an operating high pressure pump. Suitable pressure relief means are employed in accordance with well known procedure to maintain the liquid in supply hose **46** and tubing **15** at the requisite high pressure.

Disassembly of the finished coil is accomplished by first reversing the mandrel to relax the pressure on block **22,** releasing the fluid pressure, and uncoupling hose **46** and coupling **45** from the end of the coil. The end tools **32,37** are then withdrawn axially from the end of the mandrel giving the operator access to cap screw **20** holding the clamping jaw **19** to the starting end of the coil. The finished coil is now ready to be withdrawn from the end of the mandrel and submitted to inspection and final testing.

While the particular method of making wrinkle-free thin-walled coiled tubing herein shown and disclosed in detail is fully capable of attaining the objects and providing the advantages hereinbefore stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the detail of construction or design herein shown other than as defined in the appended claims.

I claim:

1. That method of constructing a multi-layer coil of circular thin-walled tubing having a wall thickness not substantially in excess of one tenth of its OD without forming wrinkles and partial flattening which comprises: closing off one end of the tubing, anchoring the closed end of said tubing to a rotary mandrel having an OD corresponding to the ID of the tubing coil under construction, charging the interior of the tubing with pressurized liquid to substantially the yield point notwithstanding an increase in the volumetric capacity of the tubing as it elongates during coiling on said mandrel, utilizing the highly pressurized liquid charge to hold said tubing straight and in high tension longitudinally and circumferentially thereof, rotating said mandrel while supporting said tubing on a surface spaced from one side of the mandrel until a desired number of convolutions have been formed, and adding pressurized liquid in communication with constant pressure maintaining means to said tubing as it is being coiled to maintain the liquid pressure substantially constant at a value close to the yield point of the tubing notwithstanding an increase in the volumetric capacity thereof as the tubing elongates during coiling about said mandrel.

2. That method defined in claim **1** characterized in the step of anchoring the closed end of said tubing interiorly of the outer surface of mandrel surface and against a surface merging arcuately with the exterior of the mandrel surface.

3. That method defined in claim 1 characterized in the steps of placing a wedge-shaped semi-circular transition member against said mandrel with the pointed end thereof beneath the end of the last convolution of the tubing for use as a ramp to support the tubing while in transition between the last convolution of the first layer of convolutions and the first convolution of a second layer of convolutions, continuing to form a second layer of convolutions directly against said first layer, and releasing the pressure on the liquid in said tubing after completing said second layer and withdrawing the same from said mandrel.

4. The method defined in claim 3 characterized in the step of providing the portion of said mandrel closely beside the first convolution of tubing with an arcuate support for the last convolution of said second layer of tubing which arcuate support includes an arcuate surface of smaller radius than the radius of said second layer and merging tangentially with a straight surface whereby the outer terminal end of said second layer lies inwardly of the OD of said multi layer coil of tubing.

5. The method defined in claim 4 characterized in the step of anchoring the closed end of said tubing interiorly of the mandrel surface and against a surface merging smoothly with the exterior surface of the mandrel whereby both ends of said multi-layer coil of tubing lie inwardly of the OD's of both layers of said coil.

6. The method defined in claim 1 characterized in the step of forming each convolution of said coil in close proximity to the preceding convolution.

7. The method defined in claim 3 characterized in the step of forming each convolution of said first layer of tubing in side by side contact with one another and with the convolutions of said second layer in direct contact with one another and with said first layer of convolutions.

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