United States Patent

[11] **3,579,810**

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[45] Patented **May 25, 1971**
[73] Assignee **The United States of America as represented by the Secretary of the Army**

[54] **METHOD OF MAKING CAPILLARY ASSEMBLIES FOR OXYGENATORS AND THE LIKE**
8 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **29/527.1,** 23/2585, 264/277
[51] **Int. Cl.** **B23p 17/00,** B23p 25/00
[50] **Field of Search** 29/527.1; 23/258.5; 264/277, 317

[56] **References Cited**
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2,449,606	9/1948	Kraft	264/277
2,972,349	2/1961	DeWall	23/258.5
2,976,583	3/1961	McCarthy	29/527.1X
3,446,361	5/1969	Douty	264/277X

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ABSTRACT: An inexpensive and rapid method of assembling capillary units and the like is disclosed. Commercially available capillary tubing is first wound around two end pins spaced apart a predetermined distance slightly greater than the length of the capillary strands in the completed unit. Each end pin is then dipped into an epoxy potting compound and caused to harden. The hardened ends are thereafter cut in appropriate places so as to expose the capillary tubes. A suitable outer housing, having appropriate conduits for the transfer of blood and oxygen to the unit, may then be provided to the assembled capillaries.

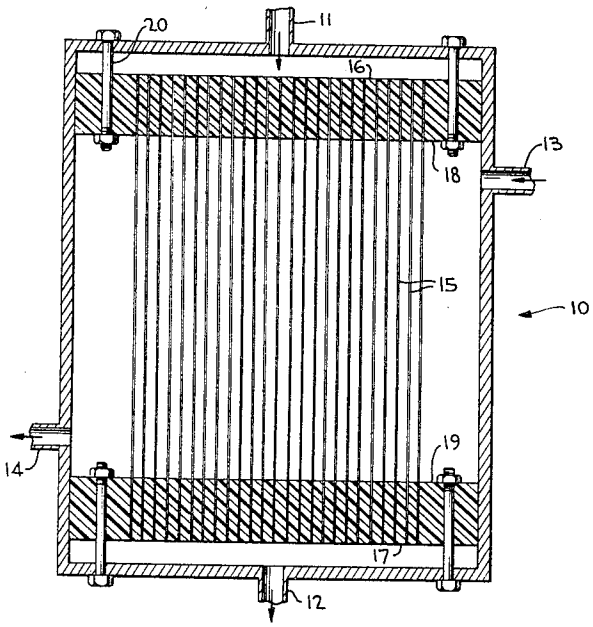

FIG. 1

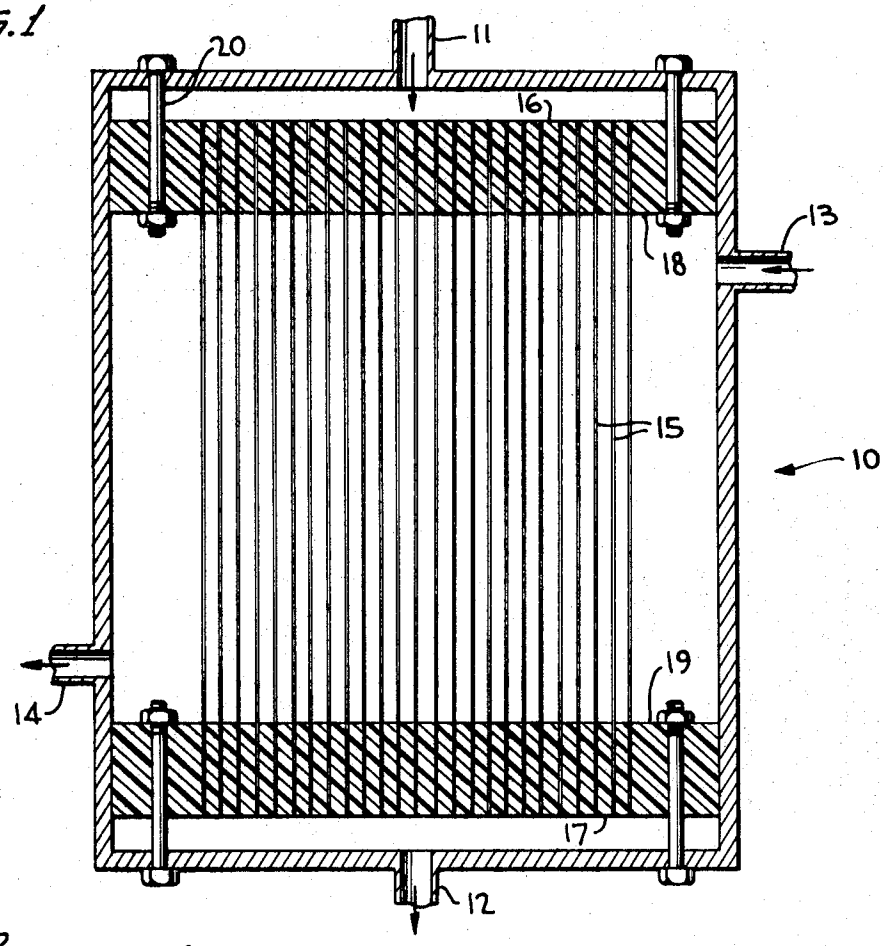

FIG. 2

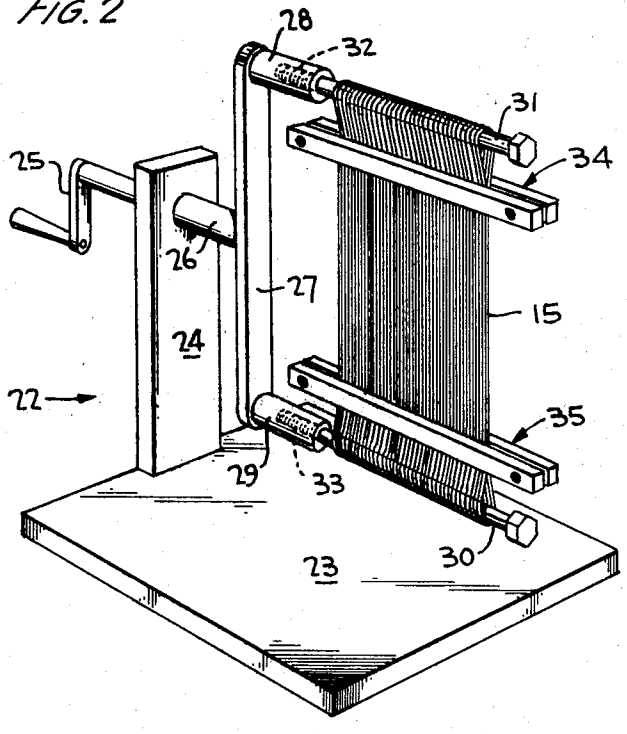

FIG. 6

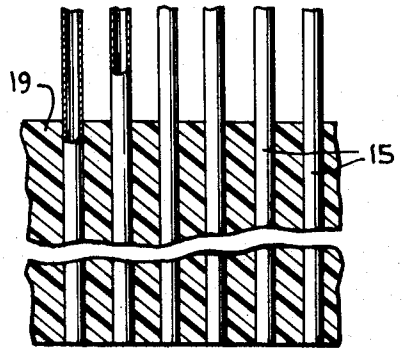

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FIG. 3

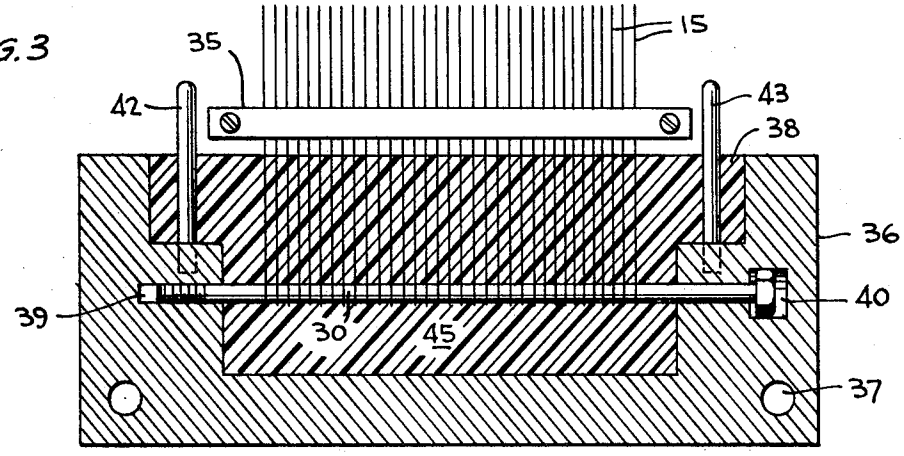


FIG. 4

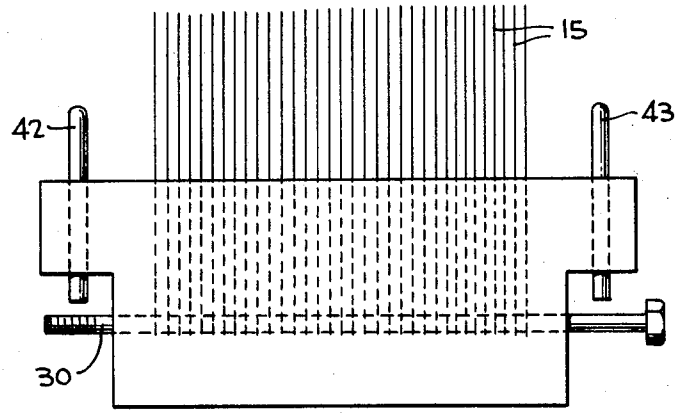
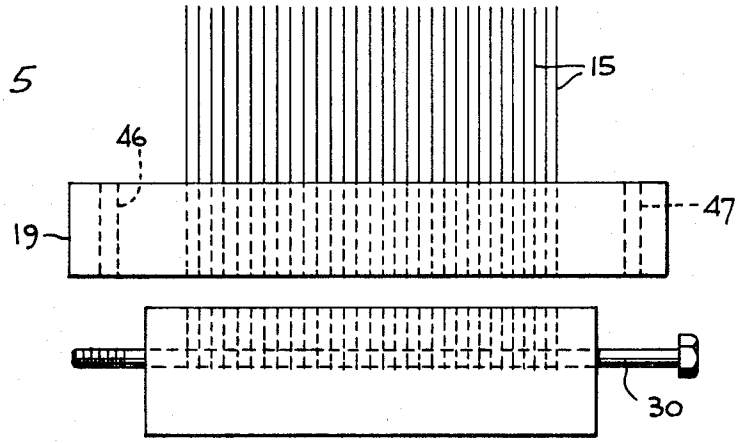


FIG. 5



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METHOD OF MAKING CAPILLARY ASSEMBLIES FOR OXYGENATORS AND THE LIKE

RIGHTS OF GOVERNMENT

BACKGROUND OF THE INVENTION

This invention relates to a capillary assembly unit and, in particular, to a method of forming the two ends of such a unit.

A typical capillary unit used as an oxygenator is disclosed by De Wall in U.S. Pat. No. 2,972,349, issued Feb. 21, 1961. Generally such a unit comprises a rectangular box having a plurality of thin capillary tubes connected between the two end walls of the unit. Blood is transmitted from one end wall to the other through the capillary tubes while oxygen is transmitted into the rectangular box and caused to completely surround the blood-containing capillary tubes. Oxygenation of the blood occurs in a well-known manner as described in the De Wall patent. The materials of which the capillary tubes are formed must be permeable to the transmission of both oxygen and carbon dioxide while being impermeable to blood. A silicone rubber known as Silastic is commonly used for this purpose, although other plastic materials have been known to be useful.

Because of the numerous capillaries required to make up a typical capillary unit, ordinarily between 500 and 2,000 capillaries, the manufacture of such units is a tedious task. Previously such units have been manufactured by drilling or otherwise forming thousands of tiny holes of the appropriate diameter in the end walls of the unit, and then individually inserting the capillary tubes, each cut to its appropriate length, into each of the holes. Obviously this method of manufacture requires many hours of tedious labor, and the cost of manufacturing such units increases significantly with the number of man-hours required.

It is, therefore, a primary object of this invention to provide an inexpensive, rapid, and reliable method of manufacturing capillary units.

A further object of this invention is to eliminate the need for preforming capillary holes in each of the two end walls of the unit.

Still another object of the invention is to eliminate the need for individually inserting each of the capillary tubes into each preformed capillary hole.

A further object of the invention is to eliminate the need for individually measuring and cutting each capillary tube to its required length.

These and other objects of the invention will become more apparent from the following description of the invention.

SUMMARY OF THE INVENTION

Briefly, in accordance with this invention, a capillary unit is made by first winding many turns of commercially available Silastic tubing onto a winding unit. The winding unit comprises a pair of guide pins which are spaced-apart a predetermined distance to provide for the desired length of tubing. After a sufficient number of strands have been wound on the winding unit, the capillary tubes, together with the two guide pins, are removed from the winding unit and each end is inserted into the cavity of a mold. The mold is filled with Silastic or epoxy potting compound so as to completely surround the tubing together with the guide pin. The potting compound is caused to harden and is then removed from the mold and cut in the appropriate place so as to expose the ends of each of the capillary tubes. This operation is repeated at both ends of the tubing.

Thereafter, only the sidewalls as well as the appropriate means for providing the gas and blood inputs need to be put in place for a completed oxygenator unit.

BRIEF DESCRIPTION OF THE DRAWINGS

The specific nature of the invention as well as other objects, aspects, uses, and advantages thereof will clearly appear from the following description and from the accompanying drawings, in which:

FIG. 1 is a front cross-sectional view of a completed oxygenator unit made in accordance with this invention.

FIG. 2 is a perspective view of the winding unit used in accordance with the teachings of this invention.

FIG. 3 is a front cross-sectional view of the mold used to manufacture the two ends of the oxygenator unit in accordance with this invention.

FIGS. 4 and 5 are cross-sectional views of one end of the oxygenator unit after it has been removed from its mold.

FIG. 6 is an enlarged cross-sectional view of one end of the oxygenator unit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, FIG. 1 shows oxygenator unit **10** having blood inlet means **11** and blood outlet means **12**, as well as oxygen inlet means **13** and carbon dioxide outlet means **14**. Blood entering inlet means **11** is forced into capillary tubes **15** by means of open ends **16**. The blood travels through capillary tubes **15**, exiting at open ends **17**, and leaves the oxygenator unit by means of outlet conduit **12**. Oxygen gas is transmitted through inlet conduit **13** and completely surrounds blood-containing capillary tubes **15**. Because the capillary tubes are permeable to gases, blood in the capillary tubes is oxygenated and carbon dioxide given off. The carbon dioxide leaves the oxygenator unit by means of outlet conduit **14**. Capillary tubes **15** are held in place at both ends by means of epoxy resin blocks **18** and **19**, which are secured to the outer walls of oxygenator unit **10** by means of bolts **20**. An enlarged fragmentary view of capillary tubes **15** is shown in FIG. **6**.

FIG. 2 shows the first step involved in manufacturing an oxygenator unit in accordance with this invention. Because capillary tubing is commercially available in long continuous rolls, advantage is taken of this fact by continuously winding the tubing many times around a winding unit such as that shown in FIG. **2**. The winding unit comprises a base **23** which supports a vertical column **24** having thereon a horizontal rotatable shaft **26**. Shaft **26** is rotated by means of handle **25** and supports an arm **27** securely mounted at right angles to shaft **26**. At the two extreme ends of arm **27** are securely mounted two short horizontal bars **28** and **29**. Bars **28** and **29** are adjustable along the length of arm **27** so as to provide a desired length of tubing. Connected to bars **28** and **29** by means of threaded screws **32** and **33** are a pair of pins **31** and **30**. Capillary tubing is wound around pins **31** and **30** as many times as necessary, usually several hundred or more loops, in order to obtain the desired number of capillary tubes necessary for the oxygenator unit. After the winding process, tubing **15** is tied at one or two places by clamps **34** and **35**. Pins **30** and **31** are then removed from the winding unit and each end is sequentially dipped into epoxy potting compound as will be further described with respect to FIG. **3**.

FIG. 3 is a front cross-sectional view of a mold **36** having therein a cavity **38**. Mold **36** is securely held together by means of bolts or screws which fit into holes **37**. By removing the securing means in holes **37** the mold can be opened up so as to insert end pin **30** into appropriate slots **39** and **40**. After pin **30** together with capillary winding **15** is inserted and secured into slots **39** and **40**, cavity **38** is filled with epoxy potting compound **45**. Any known commercially available potting compound may be used. Typically GE–RTV 615 has been used satisfactorily in this invention. While the compound is still in its liquid condition, rods **42** and **43** are inserted into appropriate places in mold **36** for a purpose which will be hereinafter described.

In order to shorten the curing and hardening time of the epoxy compound, mold **36** is placed on a hot plate and cured for about 1½hours at approximately 250° F.

After the epoxy compound has sufficiently hardened, it may be removed from mold **36** and will appear as shown in FIG. **4**. The bottom portion of the hardened mold is then cut off with a sharp instrument and discarded as shown in FIG. **5**, leaving only the top portion which will constitute end block **19** of oxygenator unit **10**. Rods **42** and **43** as shown in FIG. **4** can be easily be removed, thereby leaving preformed holes **46** and **47** for receiving bolts **20** as shown in FIG. **1**.

It should be apparent that the entire process an be performed rapidly and efficiently by unskilled operators. The process is also readily adaptable to assembly line techniques.

Example

An oxygenator unit was constructed in accordance with this invention by providing 500 windings of Silastic tubing around the winding unit, and dipping each end of the tubing into the cavity of a molding unit such as shown in FIG. **3**. The unit was filled with about 165 mg. of Silastic resin GE–RTV 615, and cured at 250° F, for about 1½hours.

It will be appreciated that the embodiment described herein is only exemplary, as many modifications could be made within the spirit and scope of this invention. For example, the winding unit need not be as shown and, in fact, may be replaced by two guide pins securely held in some appropriate place at a predetermined spaced-apart distance. The winding unit need not be rotatable as it would be a simple matter to wind capillary tubing around the ends of two stationary guide pins. Oxygenator unit **10** also need not be as shown, for it may, if desired, be constructed completely of plastic material in a single unitary structure. The method can be used to assemble capillary units other than oxygenators. For example, extracorporeal circulation systems for assisting the functions of the heart, kidney and lungs may be assembled in accordance with this invention.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described, for obvious modification will occur to persons skilled in the art.

I claim:

1. A method of assembling a capillary unit comprising:

a. winding a continuous strand of capillary tubing around two pins spaced-apart a predetermined distance;

b. maintaining each pin in a potting compound;

c. causing the potting compound to harden;

d. cutting the hardened potting compound so as to expose a plurality of open ended capillary tubes while at the same time providing a rigid portion holding said ends in fixed relation to each other; and

e. providing conduit means for transferring appropriate fluids to the capillary unit.

2. The method of claim **1** wherein the pins are spaced-apart a distance slightly greater than the desired length of capillary tubing in the completed capillary unit.

3. The method of claim **2** wherein the pins are located on a winding unit having means to rotate the pins and means to adjust the distance between the pins.

4. The method of claim **3** wherein the pins are detachable from the winding unit.

5. The method of claim **1** wherein the potting compound comprises a resinous epoxy material capable of being hardened.

6. The method of claim **1** wherein the step of hardening the potting compound includes the step of applying heat to the compound.

7. The method of claim **1** further comprising the steps of placing each pin into a mold having a cavity therein and pouring the potting compound into the cavity.

8. The method of claim **7** further comprising the steps of inserting a predetermined number of rods into the potting compound prior to hardening so as to provide preformed holes in said rigid portion to be used for securing each end of the capillary unit to an external housing.