

[54] METHOD OF MAKING SPIRAL TUBE
MIXING DEVICE[75] Inventors: **John K. Thorne**, Decatur, Ala.; **Jay E. Sobel**, Highland Park, Ill.[73] Assignee: **Universal Oil Products Company**,
Des Plaines, Ill.[22] Filed: **Sept. 25, 1974**[21] Appl. No.: **509,154****Related U.S. Application Data**[62] Division of Ser. No. 402,871, Oct. 2, 1973, Pat. No.
3,866,886.[52] U.S. Cl. **29/455; 29/456; 29/516;**
29/520; 72/77[51] Int. Cl.²..... **B21D 39/00; B23P 11/00**[58] Field of Search 29/456, 516, 455, 520;
72/77; 259/4; 62/513; 260/683.48;
23/269; 165/156[56] **References Cited****UNITED STATES PATENTS**

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2,137,044	11/1938	Dawson	29/456 X
2,157,252	5/1939	Visser et al.	29/516 UX
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3,128,821	4/1964	Andersen.....	72/77
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FOREIGN PATENTS OR APPLICATIONS

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Primary Examiner—Charlie T. Moon*Attorney, Agent, or Firm*—James R. Hoatson, Jr.;
Barry L. Clark; William H. Page, II[57] **ABSTRACT**

High speed, very uniform mixing of two fluids is achieved by a mixing device formed from a pair of tubular members. The inner tube, which may be formed of sintered stainless steel powder, is porous along its entire length, but plugged at one end so that a first fluid under pressure within it will be forced radially outwardly through the pores. The outer tube is spirally corrugated and positioned in concentric relation with the porous tube. The inner surfaces of the corrugations contact the porous tube and cause a second fluid flowing from one end to the other of the corrugated tube to flow along the spiral path of the corrugations. Since the spiral corrugations cause the second fluid to flow very rapidly over the outer surface of the porous tube, the second fluid will continually strip or shear away the fluid exiting through the pores and thus promote extremely rapid and thorough mixing of the first fluid into the second fluid to form a mixed fluid or a reaction product, depending on the nature of the fluids in the two tubes. The tubes are placed in intimate contact with each other by an improved forming method wherein the outer tube is corrugated in two steps while in contact with the inner tube.

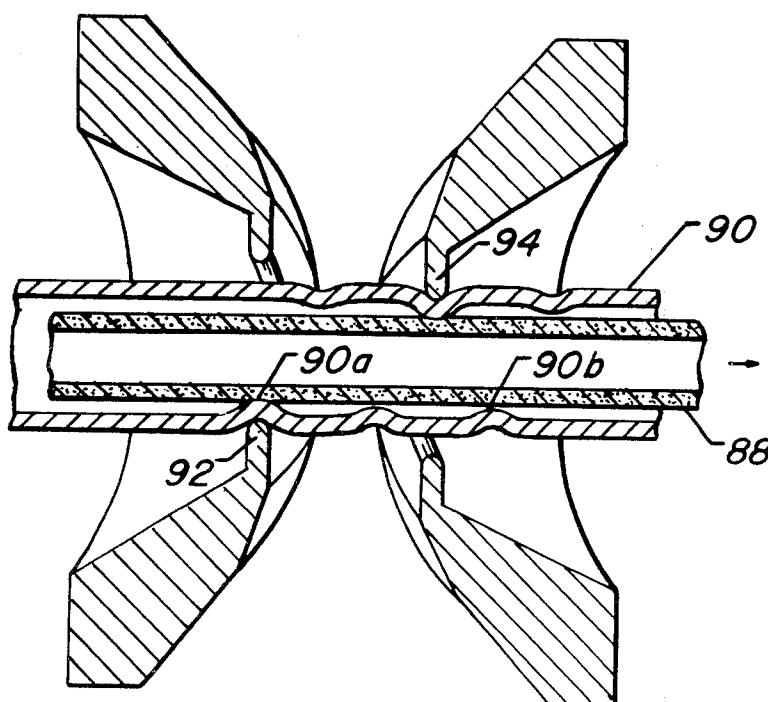
5 Claims, 5 Drawing Figures

Figure 1

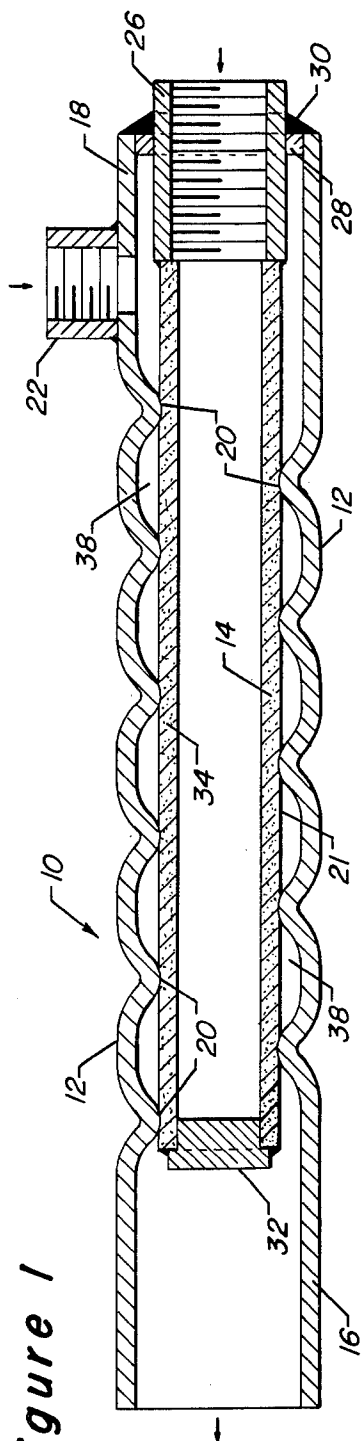
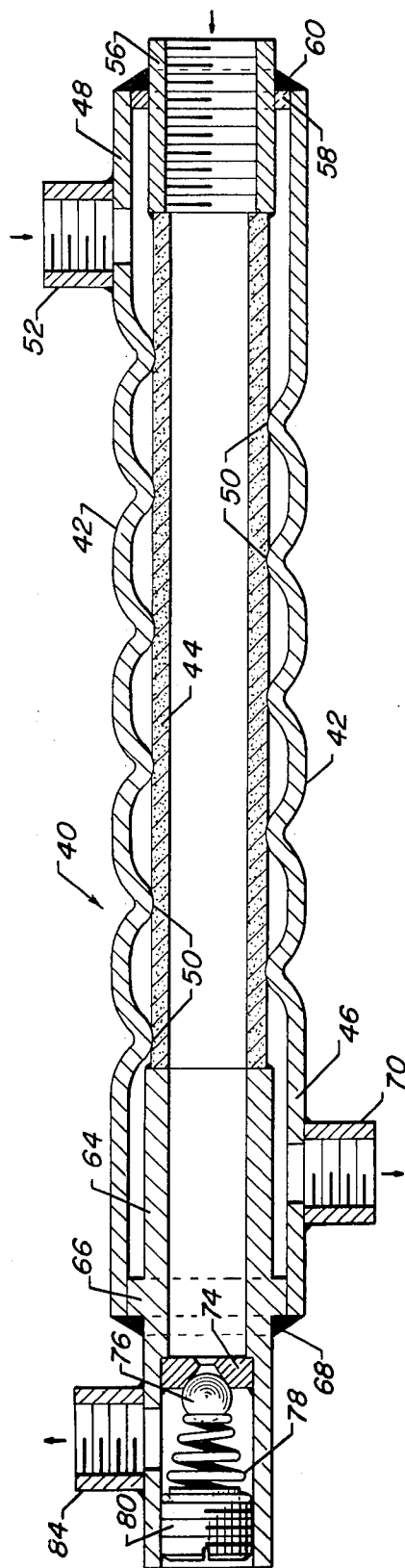


Figure 2



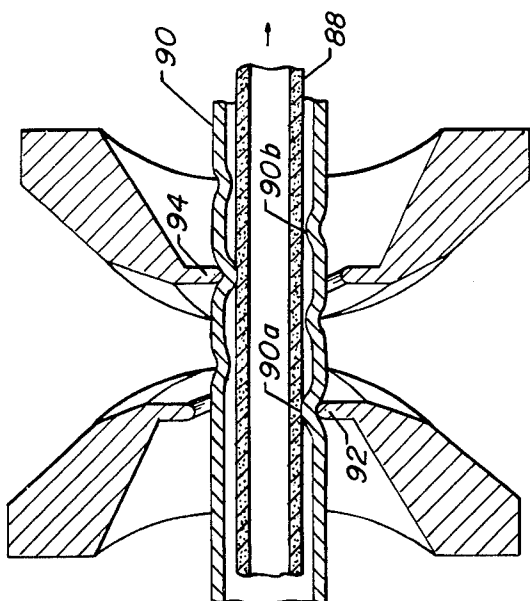


Figure 3

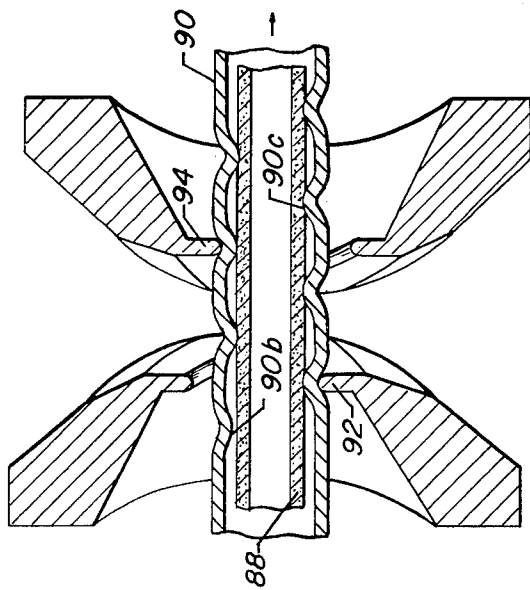


Figure 4

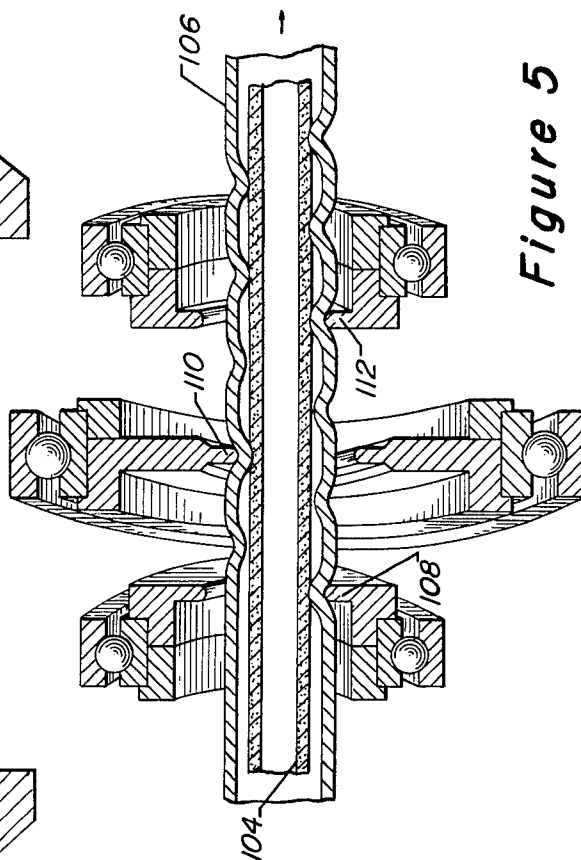


Figure 5

METHOD OF MAKING SPIRAL TUBE MIXING DEVICE

This is a division of application Ser. No. 402,871, filed Oct. 2, 1973, now Pat. No. 3,866,886.

BACKGROUND OF THE INVENTION

The invention relates to the field of fluid mixing devices. Examples of prior art fluid mixers can be found in U.S. Pat. Nos. 2,951,061; 3,240,337; 3,435,092; 3,438,720; 3,554,228; and 3,677,714 where fluid is passed through openings or small pores in one member into contact with a fluid in another member. In each of these prior art devices the mixing is somewhat slow and non-uniform. Other prior art devices, as exemplified by U.S. Pat. Nos. 2,908,486; 3,158,192; 3,270,806; 3,498,370; 3,545,063; 3,566,615; and 3,709,665 teach that heat transfer to or from a single fluid or between different fluids can be enhanced by lengthening the contact path by causing at least one of the fluids to follow a spiral or other tortuous path. These latter devices do not provide for any mixing of fluids.

Although many of the prior art mixers provide fairly uniform mixing, there are certain mixing applications wherein it is desirable that the dispersion of one fluid into another be extremely rapid and that the distribution of the fluids be uniform. Such an application might be in an alkylation reactor such as disclosed in U.S. Pat. Nos. 2,951,061; 3,435,092 and 3,607,970 where an olefin-isoparaffin hydrocarbon stream is combined with a liquid acid stream.

SUMMARY OF THE INVENTION

It is among the objects of this invention to provide a mixing or reacting device for fluids which will promote extremely rapid and uniform dispersion of one fluid into another, will prevent localized feed concentration buildups, will provide plug flow and prevent back mixing, and will be very compact.

These and other objects are achieved by the mixing apparatus of the present invention in which a porous metal tube formed of a sintered metal powder, such as stainless steel, is closed or restricted at one end and mounted within a surrounding spirally corrugated tube. A first fluid is introduced into the inner porous tube under sufficient pressure to cause it to move radially outwardly through the pores in the tube wall. A second fluid, which is introduced into the corrugated tube at a lower pressure, is forced to flow around the spiral path defined by the inner walls of the corrugations and the outer wall of the porous tube which the corrugations engage. Since the second fluid continually wipes the surface of the porous tube, any fluid exiting from the pores in the porous tube will be sheared off and will instantly and uniformly be dispersed in the second fluid or will react with it to form a reaction product. In a modification of the mixing apparatus, one end of the porous tube is provided with a back pressure means, such as a spring loaded check valve, which permits a portion of the flow in the inner tube to be recycled or transported to another location.

The apparatus provides the most efficient mixing when the corrugations on the outer tube are in intimate contact with the porous tube so that the fluid flowing between the tube walls will be forced to follow a helical path. It has been found, however, that it is impossible to telescope together a porous tube and a corrugated tube when the outer wall of the porous tube and the

inner wall of the outer tube are of the same diameter or even within several thousandths of an inch of each other without the metals seizing. The springback characteristics of stainless steel during cold working have been found to prevent a smooth outer tube from being corrugated into intimate contact with a porous tube in the normal operation of a two die corrugating machine similar to that disclosed in Andersen Pat. No. 3,128,821. We have found, however, that by making two passes of concentric porous and smooth tubes through such a pair of dies, and without changing the positions of the dies relative to each other, it is possible to both form the corrugations in the outer tube and force them into intimate contact with the porous tube so that the corrugations on the outer tube will have a smaller internal diameter than the outer diameter of the porous inner tube immediately adjacent the spiral line of contact between the inner and outer tubes. Rather than make separate passes through a single pair of dies, it is also possible to achieve intimate contact by passing the composite tube assembly through successive pairs of dies or through a single set of three or more corrugating dies such as that disclosed in Kelstrom Pat. No. 2,583,189.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side sectional view of the improved mixing device;

FIG. 2 is a side sectional view similar to FIG. 1 but showing a modification;

FIG. 3 is a side sectional view showing a pair of corrugating dies corrugating the outer wall of the tube composite which forms the mixing device;

FIG. 4 is a view identical to FIG. 3 except that the tube composite is shown undergoing a second pass through the corrugating dies; and

FIG. 5 is a view similar to FIG. 3 but showing a modified form of corrugating device.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, the improved mixing device indicated generally at 10 includes a non-porous outer tube member 12 and a porous inner tube member 14. Each of the tubes 12, 14 is preferably formed of stainless steel with the porous inner tube being formed by a sintering technique using metal powder. The tube 12 has a non-corrugated exit end 16 and a non-corrugated entrance end 18. The portion of the tube 12 which is intermediate the non-corrugated end portions 16, 18 includes corrugations which are defined by a spiral ridge 20 which engages, and preferably, is slightly embedded within the outer surface 21 of the porous tube 14. An inlet fitting 22 welded to the side of outer tube 12 at end 18 thereof is internally threaded to facilitate its connection to a source of fluid (not shown) to be passed through the tube 12.

The porous inner tube 14 has an internally threaded, non-porous inlet fitting 26 welded to it. A spacing ring 28 fills the annular space between the tubes 12, 14 and is welded to each of the tubes by a weld bead 30. Alternatively, a flange could be formed on the fitting 26 which would serve the same purpose as ring 28. Flow of fluid through the inner end of the porous tube 14 is prevented by plug member 32 which is welded to the tube. When the device 10 is in use, plug 32 blocks flow through the porous tube 14 so that the pressure of a

first fluid passing into the tube causes the fluid to flow through the myriad tiny openings in the wall 34 of the tube. As the first fluid reaches the outer surface 21 of the porous tube it is instantly sheared from said surface by a second fluid flowing along the surface as it passes through spiral channel 38 on its way from inlet fitting 22 to exit opening 16. Where the first and second fluids flowing through the inner and outer tubes are of a nature such as to produce an exothermic reaction upon contact with each other, the disclosed mixing device is especially efficient since mixing is extremely rapid and the respective fluids well dispersed. In addition, the extended outer surface of tube 12 produced by the corrugations enhances the ability of the device to dissipate excess heat as it is produced. An example of such a reaction would be the feeding of a hydrocarbon stream such as olefin-isoparaffin into the porous tube 14 and the outward radial dispersion of said stream into a hydrofluoric acid stream passing through spiral channel 38.

FIG. 2 shows a modification 40 of the mixing device 10 shown in FIG. 1. The mixing device 40 includes a non-porous outer tube 42, a porous inner tube 44, non-corrugated end portions 46, 48, a spiral corrugated ridge 50, a threaded fluid inlet fitting 52, a non-porous inlet fitting 56 for the porous tube 44, and an annular spacing ring 58 attached to the outer tube 42 and the fitting 56 by a weld bead 60. The mixing device 40 differs from the device 10 of FIG. 1 in that flow through the porous tube 44 is not completely prevented at the end of the tube opposite its entrance end. Rather, a back pressure means comprising an end fitting 64 is provided. The fitting 64 includes a flange 66 welded to the outer tube 42 at 68. Since the weld 68 and flange 66 effectively block the exit end of tube 42 a side mounted, internally threaded fluid outlet member 70 is provided. The fitting 64 further includes a valve seat 74, and a ball valve member 76 biased against the seat 74 by a spring 78. Fluid passing by the valve member 76 exits through a threaded outlet fitting 84. By means of a screw type adjustment member 80 threaded in the end of fitting 64 the amount of back pressure exerted by the ball 76 on the fluid within the porous tube 44 can be closely controlled. This back pressure adjustment feature is useful where it is desired to permit a portion of the fluid within the porous tube to pass through the mixing device without being mixed and either carried to another location or returned to the fluid source. The valve assembly also permits the pressure, and thus the flow rate, of the fluid passing through the walls of the porous tube to be controlled independently of variations in the inlet pressure from the fluid source, as long as the inlet pressure is in excess of that required.

FIGS. 3 and 4 illustrate a preferred method for assembling a porous inner tube and a non-porous outer tube to each other. Referring to FIG. 3, a porous inner tube 88 is shown after it has been positioned within a smooth outer tube 90. The tube composite is fed from left to right through a pair of dies 92, 94 which may be of the type disclosed in Andersen Pat. No. 3,128,821. As the left die 92 engages the tube 90 it forms a groove and a corresponding ridge 90a which is forced into contact with the outer surface of porous inner tube 88. Since the material of the tube 90 is preferably stainless

steel, one must contend with a property known as "spring back" which causes the groove and ridge formed by die 92 at 90a to spring away from the inner tube 88 as shown at 90b as the groove and ridge advance relative to the die. In FIG. 4, the corrugated composite formed by the dies of FIG. 3 is shown being passed back through the same dies 92, 94. This second pass provides a second cold working operation which causes the ridges 90b to assume a final position in contact with the inner tube 88 as shown at 90c. In each die set, the major deformation is done by the initial die. In order to keep the ends of the tubes uncorrugated the dies are moved radially into the tubes only where corrugations are desired. Preferably, the dies force the ridges about 0.002 - 0.004 inch into the surface of the porous tube 88.

FIG. 5 shows an alternative method of assembling the outer and inner tubes to each other which utilizes a triple ring corrugating device of the type shown in Kelstrom Pat. No. 3,583,189. A porous tube 104 and a smooth non-corrugated outer tube 106 are fed from left to right through left die 108, center die 110 and right die 112. The additional cold working of the tube material which takes place due to the right hand die 112 causes the ridge, which is formed as shown at 106a by die 108, and which springs away after forming as shown at 106b, to be moved permanently into contact with the porous tube 104 as shown at 106c.

The details of the mounting structures for the various dies shown in FIGS. 3 - 5 have not been shown since they are explained in great detail in the aforementioned U.S. Pat. Nos. 3,128,821 and 3,583,189, the content of which is incorporated herein by reference.

We claim as our invention:

1. A method of forming a mixing device comprising the steps of: positioning a cylindrical porous tube inside a cylindrical, non-porous outer tube, said outer tube having an inner diameter which is larger than the outer diameter of the inner tube; corrugating the outer tube to form a spiral groove by means of a pair of dies engaged with opposite outer side portions of the tube, said dies being axially spaced from each other; and additionally corrugating said tube by contacting said groove with at least one die to deepen said groove and force the ridges which define it into intimate contact with said porous inner tube.

2. A method in accordance with claim 1 wherein said step of additionally corrugating said tube forces said ridges into said porous tube so that the inner diameter of the corrugations is less than the outer diameter of the porous tube immediately adjacent the spiral line of contact between said inner and outer tubes.

3. A method in accordance with claim 1 wherein said additional corrugating step is performed by a third die member positioned downstream of said pair of dies.

4. A method in accordance with claim 1 wherein said additional corrugating step is performed by a second pass of the tubes between said pair of dies.

5. A method in accordance with claim 4 wherein the radial distance between each of said pair of dies and the axis of the tubes is not altered before making said second pass.

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