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FLUID MIXING DEVICE

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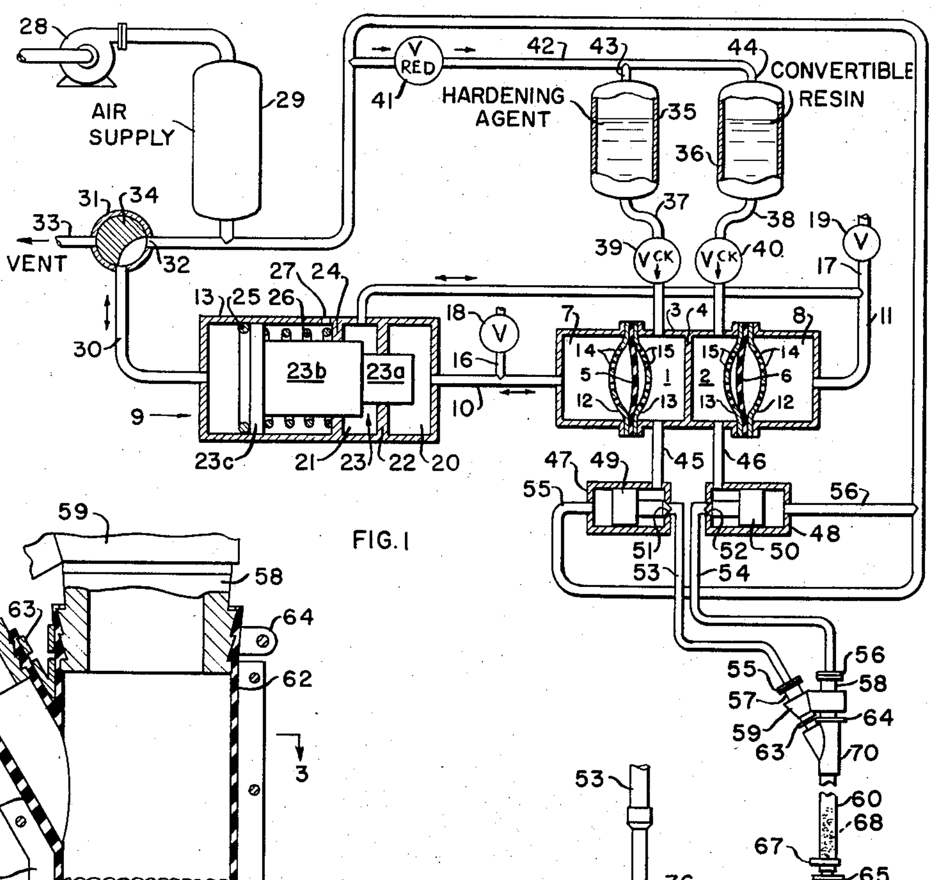

FIG. 1

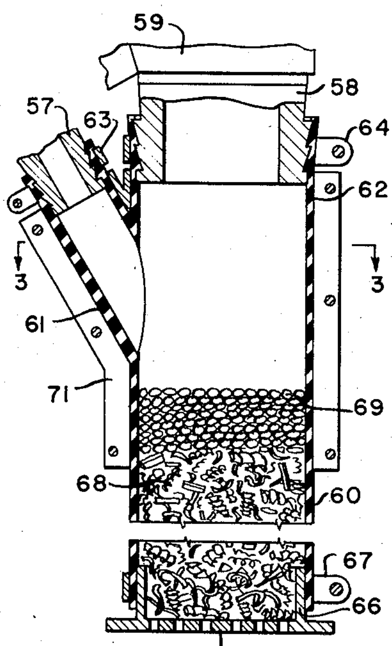

FIG. 2

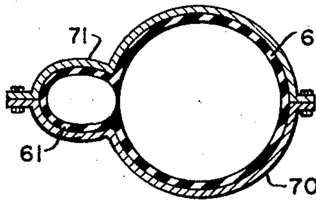

FIG. 3

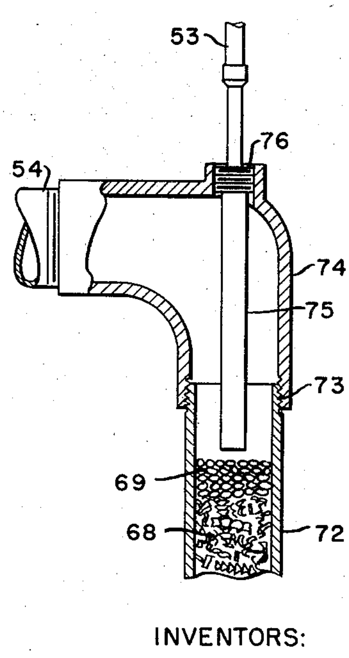

FIG. 4

INVENTORS:
ROBERT E. TABER
DONALD R. HAWKINSON

BY: Oswald H. Milmore

THEIR ATTORNEY

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FLUID MIXING DEVICE

Robert E. Taber, Berkeley, and Donald R. Hawkinson, Kensington, Calif., assignors to Shell Development Company, New York, N.Y., a corporation of Delaware

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The invention relates to the continuous blending of streams of fluent materials including a liquid, and is particularly although not exclusively adapted for mixing a convertible resin with a hardening agent to form a mixture having a high degree of homogeneity. The invention is concerned both with apparatus for supplying such streams in desired proportion and a mixing unit wherein such streams are commingled. In distinction to batch mixing, mixing of such streams is herein called continuous mixing although the streams may flow intermittently or with pulsations. Although the invention will be described as applied to the mixing of two liquid streams, it does not exclude the simultaneous mixing of additional materials which may or may not be liquid.

A convertible resin is one which is a liquid or is plasticizable when alone but which sets up into a hard, essentially infusible mass under certain conditions, as when it is mixed with a hardening agent. A hardening agent is a curing agent or a catalyst which, when mixed with a convertible resin, causes the latter to set into such a hard mass. This hardening occurs soon after the resin and hardening agent are brought together and the mixture remains fluent for periods of time that vary with the nature and temperature of the materials as well as the concentration of the hardening agent; such periods may be only several seconds up to several hours.

Apparatus for mixing convertible resins with hardening agents have heretofore been designed to commingle the ingredients just prior to discharge so as to avoid the necessity of having to clean extensive portions of the mixer, an operation which is necessary when the mixer is shut down to avoid the setting up of the remaining mixture. This has resulted in imperfect mixing and in poor results, since the properties of the hardened mass are dependent upon a high degree of homogeneity. Moreover, the inconvenience of cleaning out the mixer has made it necessary to employ materials that set up so slowly that there is no danger of setting up in the mixer during short periods of shutdown. Cleaning the mixer with solvents is impracticable in certain cases, e.g., when resins are applied to highways where solvents are not always available and the disposal of the spent solvent is a problem. Finally, the use of solvents involves considerable cost and significant hazards.

It is also important in many instances to have the fluids, viz., convertible resin and hardening agent, mixed in the proper proportions. Since they must be supplied to the mixing unit under pressure when the latter is of the tortuous flow or similar type which does not have power-driven movable mixing elements, feed pumps must be used. Such feed pumps have, however, presented practical difficulties, among which are the difficulties of sealing the piston to the cylinder while maintaining running clearances in the case of piston pumps, slippage in the case of rotary pumps such as gear pumps, and of inducing flow through the pump intakes, especially when dealing with viscous liquids. These circumstances have made it difficult to supply the liquid streams to the mixing unit under pressure at an accurate, predetermined flow ratio.

It is an object of this invention to provide a mixer which will produce a product having a high degree of homogeneity and yet is so inexpensive that those parts wherein setting up of the resin is apt to occur can be discarded, whereby the necessity of cleaning the mixer to remove hardened material is obviated. Ancillary thereto, it is an object to provide a mixer wherein the commingling of resin and hardening agent in any of the permanent parts of the apparatus is prevented.

A further object is to produce a mixing apparatus having an improved feed system wherein the ingredients are supplied to the mixer under pressure in correct proportions.

In summary, according to the invention, the mixing apparatus includes a plurality of separate conduits through which the fluent materials are supplied under pressure, and a disposable mixing unit that includes an elongated tube having one or more inlets at one end connected by coupling means to said conduits, for the separate admission of said fluent materials, an outlet at the other end, and contacting material, such as steel lathe turnings, confined within the tube between the inlet and outlet ends and providing small flow passages. It was found that a high degree of homogeneity can be attained in such a mixing unit with the usual combinations of convertible resins and hardening agents, which often are of such nature as to require prolonged mixing in a conventional powered mixer, with but a modest expenditure of energy. This energy is supplied to the mixing tube as pressure and is measured by the pressure drop through the mixing tube. This drop will vary with the viscosity and nature of the materials, and is, typically, from 5 to 30 lbs. per sq. in.

The mixing unit is so economical that it may be discarded upon shut-down of the mixing apparatus by simply uncoupling it from the aforesaid conduits. This makes it unnecessary to wash out the mixing unit.

The mixing tube may be of rigid or non-rigid material, depending on circumstances, and is elongated, i.e., it has a length to diameter ratio of at least three. A particularly inexpensive and useful construction is to form the tube of plastic material having sufficient strength to withstand the internal pressure at the inlet, or encased by a metallic reinforcing sheath at least near the inlet end, where the highest pressures prevail, to protect it against rupture. It is useful to employ a transparent plastic, such as polyvinyl chloride, sold commercially under the trade name "Tygon," because the extent of the mixing can be observed. Thus, one of the materials being mixed normally has a color or color intensity different from that of the other, or may be dyed to effect a visible contrast, and incomplete mixing can be detected by observing striations in the tube. Moreover, it is in many instances desirable to use a tube that is elastic, e.g., when used in conjunction with a feeding device that produces pulsed flow, such as that described herein; in this case the tube is dilated in rhythm with the pulsations and discharges a stream wherein the pulsations are smoothed out. The mixing unit is, however, also useful with other types of feeders, wherein steady flow occurs.

The contacting material advantageously contains plates that have uneven, e.g., curved, surfaces, the area of each particle being preferably above a specified value so that tortuous, repeatedly and irregularly intercommunicating flow channels are produced. Moreover, the packing material should have sufficient rigidity to retain its shape when subjected to the pressure of the fluids admitted to the tube.

The feeder for producing proportional flow rates of the liquids to be mixed may comprise a pair of expansible pump chambers the movable walls of which are flexible diaphragms driven by separate bodies of hydraulic fluid which are displaced in proportional volumes by positive displacement pumps having a common drive, such as a common stepped piston, the liquids being supplied to the respective pump chambers through non-return valves under sufficient pressure to cause flow of liquids into the chambers and to expand the pump chambers during the intake part of the cycle. These pump chambers discharge into delivery conduits that have back-pressure check valves set to open only upon the occurrence in the delivery conduits of predetermined pressures in excess of the liquid supply pressures, so that continuous flow of the liquids through the pump chambers is prevented. These check valves also prevent any return flow of liquid through the conduits, whereby the undesired commingling of the liquids in these conduits or valves and the consequent hardening of these therein are prevented.

The invention will be further described with reference to the accompanying drawing forming a part of this specification and showing one preferred embodiment thereof, wherein:

Figure 1 is a diagrammatic view of the mixing apparatus, parts being shown in section;

Figure 2 is a vertical sectional view of the mixing unit, on an enlarged scale;

Figure 3 is a sectional view taken on the line 3—3 of Figure 2; and

Figure 4 is a vertical sectional view of the upper part of a modified form of mixing tube.

Referring to Figures 1–3 of the drawings in detail, the proportional feeding device includes a pair of expansible pump chambers 1 and 2 bounded by a cylindrical housing 3 having a medial rigid wall 4 and by flexible diaphragms 5 and 6, respectively. The sides of these diaphragms remote from the pump chambers are acted upon by hydraulic fluid in fluid chambers 7 and 8 supplied from a suitable mechanically or pneumatically driven proportional displacement device, such as the device 9, by pipes 10 and 11. Movement of the diaphragms is limited by pairs of dished plates 12, 13, having holes 14 and 15. Make-up fluid may be supplied via pipes 16 and 17 through normally closed valves 18 and 19.

The proportional displacement device includes displacement chambers 20 and 21 which are connected to pipes 10 and 11, respectively, and separated by a partition wall 22 through which the smaller cylindrical portion 23*a* of a stepped piston 23 extends with a close sliding fit. The chamber 21 is bounded at one side by a second transverse wall 24 through which the larger cylindrical portion 23*b* of the cylinder extends with a close sliding fit. The head 23*c* of the piston is sealed to the inner wall of the casing 9 by a seal ring 25. The piston is urged to retraced position by a coiled compression spring 26 acting between the head 23*c* and the partition 24, the space containing this spring being vented through a port 27. The piston 23 is driven pneumatically by air supplied by a compressor 28 through an air supply reservoir 29, pipe 30 and a three-way valve 31 which includes a high-pressure air inlet 32, a vent 33 and the connection to the aforesaid pipe 30. The valve contains a rotary plug 34 which may be driven continuously or intermittently by suitable means not shown. When the rotary plug 34 is positioned as shown air enters the housing 9 to move the piston toward the right, thereby displacing hydraulic fluid from the chambers 20 and 21 into the chambers 7 and 8, respectively, in volumetric ratio determined by the areas of the cylindrical portions 23*a* and 23*b* to move the diaphragms 5 and 6 to contract the pump chambers 1 and 2. It will be noted that this ratio is unaffected by the length of the piston stroke. When the plug 34 is turned 90° clockwise from the position shown the pipe 30 is connected to the vent 33, permitting air to be discharged while the piston is moved toward the left by the spring 26; hydraulic fluid then flows from the chambers 7 and 8 through the pipes 10 and 11 into the displacement chambers 20 and 21, respectively, while the diaphragms move to expand the pump chambers 1 and 2. It is evident that these pump chambers are contracted and expanded in amounts equal to the volumes of hydraulic fluid flowing through the pipes 10 and 11.

The liquids to be mixed are stored in tanks 35 and 36 and conveyed by feed ducts 37 and 38 through check valves 39 and 40 to the pump chambers 1 and 2. These liquids may, for example, be a hardening agent and a convertible resin, respectively. By way of example, the resin may be an epoxy type resin, such as a liquid glycidyl polyether of 2,2-bis(4-hydroxy phenyl) propane having the consistency of molasses and the hardening agent may be tri(2 ethyl hexoate) of tris(dimethyl amino methyl) phenol. These materials are maintained under suitable pressure by admitting air to the upper parts of the reservoirs from the pressurized air reservoir 29 through a pressure-reducing valve 41, manifold pipe 42 and branch pipes 43 and 44. It is evident that the air pressure is thereby made effective to flow the somewhat viscous liquids into the pump chambers. Also, in view of this pressure, which is transmitted through the diaphragms 5 and 6 to the hydraulic fluid, the latter tends to move the stepped piston 23 toward the left when the valve cock 34 is turned to the venting position thereof, so that the spring 26 may in certain cases be omitted. Finally, the pressurizing of the liquids makes it necessary to provide some form of back-pressure element in the pump discharge or delivery pipes 45 and 46 if accurate metering is to be achieved. Thus, these pipes may be connected to the sides of back-pressure check-valves 47 and 48, each having a slidable piston 49 or 50 carrying a needle which controls an axial discharge port 51 or 52 leading to a discharge conduit 53 or 54. Any suitable means may be employed for urging the pistons to their forward positions, wherein they close the ports 51 and 52, as shown. In the embodiment illustrated, this means includes air pipes 55 and 56, which are connected to the pressurized air reservoir 29 and admit high-pressure air against the rear faces of the pistons. Inasmuch as the forces exerted against the front ends of the pistons 49 and 50 by the liquids pressures in the pipes 45 and 46 can never exceed the forces exerted on the rear ends of the pistons by the air pressure in the pipes 55 and 56 when the cock 34 is in venting position, it is evident that the back-pressure valves 47 and 48 prevent the liquids from flowing into the conduits 53 and 54 merely by the pressure within the reservoirs 35 and 36. Moreover, these valves cannot be opened by such liquid pressures as are developed in the conduits 53 and 54 by the operation of the feeder, so that these valves function also as check valves.

The conduits 53 and 54 are connected by couplings 55 and 56 to coupling nipples 57 and 58, which are held together by a bracket 59. The disposable mixing unit, according to the invention, includes a tube 60, preferably made of transparent, elastic plastic material such as that marketed under the trade name "Tygon." This tube has a plurality of separate inlets 61 and 62 at the upper end thereof which are coupled to the nipples 57 and 58 by means of clamp bands 63 and 64. The lower end of the tube has an outlet opening within which is fitted any suitable element for retaining contacting material within the tube. This retaining means may be in the form of a perforated plate 65 having an integral tubular part 66 which extends into the lower end of the tube and is held frictionally by a clamping band 67. The interior of the tube contains rigid contacting material in the form of discrete bodies **68** which are packed to provide a multitude of small flow passages. These bodies, which advantageously extend over a length of the tube equal to at least several times the diameter thereof, are preferably in the form of thin lamellae or small curved plates of irregular shapes, as described hereinafter, and normally have rough, extended surfaces. Initial distribution of the liquids over the cross sectional area of the tube may be effected with somewhat lower pressure drop by providing a short section of smoother contacting material, such as glass helices, beads or rings **69** near the top.

Improved results are attained by using as the principal contacting material **68** thin small curved plates having uneven or irregular, e.g., curved, surfaces, to provide tortuous, irregularly intercommunicating flow passages, the plates being of sufficient sizes to provide flow passages which have appreciable lengths between their points of communication with other flow passages. Such a material is especially desirable for homogenizing fluids such as convertible resins and certain hardening agents which are difficult to mix. With small, compact (i.e., non-lamellar) bodies, such as glass helices, beads or rings, the liquids flow around the bodies and the divided streams re-unite soon and with such regularity that less effective mixing of the liquids occurs. Metal chips, e.g., from shaping or lathe turning operations, can be used. Steel lathe turnings having thicknesses from about 0.01 to 0.02 in., shown in the drawing, were found to be well suited; in this instance each plate is curled, sometimes through several convolutions, either spirally or helix-like. Such turnings have rough surfaces as well as sharp, rough or burred edges. By way of a specific example, a suitable mixing unit had a packed section with a diameter of one-half inch and a length of five to fifteen inches, of which the lower 75 to 90% contained steel lathe turnings **68**, produced by taking a 0.015 in. cut. The turnings had, on average, a total surface area (including both sides) of 0.11 sq. in. per piece and the pieces were shaped so that 146 were packed in each cubic inch of the packed section while displacing 17% of the volume, the remaining 83% being flow channels. In general, for homogenizing liquids of the above-mentioned nature it is preferred to use plates having uneven, preferably curved surface areas of at least 0.03 sq. inch. per plate and outlines to displace between 10 and 25% of the gross volume when packed in the tube. They should be of material having sufficient strength and rigidity to maintain their shape when pressed against the plate **65** by the pressure of the admitted liquids. Thus, it was found that aluminum lathe turnings of the thickness and shape indicated above were rapidly compacted and gave poor results.

The tube **60** may be optionally provided with a reinforcing sheath including complementary metal sections **70** and **71** encasing the upper parts of the tube and bolted together.

In operation the cock **34** is initially positioned to vent the pipe **30**. Liquid from the reservoirs **35** and **36** thereupon flow through the check valves **39** and **40** into the pump chambers **1** and **2**, thereby moving the diaphragms **5** and **6** to enlarge these chambers and displace hydraulic fluid from the chambers **7** and **8** through pipes **10** and **11** into the displacement chambers **20** and **21** respectively; the piston **23** is thereby moved to the left, aided by the spring **26**. The back-pressure valves **47** and **48** prevent the liquids from flowing into the conduits **53** and **54** at this time. The cock **34** is next turned to the position shown, whereby high-pressure air flows through the pipe **30** to move the piston **23** to the right; this displaces hydraulic fluid in a fixed proportion which is determined by the sizes of the stepped portions **23***a* and **23***b* into the chambers **7** and **8**, thereby moving the diaphragms **5** and **6** to contract the chambers and causing correspondingly proportioned quantities of the liquids to be discharged through the pipes **45** and **46**. During the last-mentioned flow the check valves **39** and **40** are closed and the pressures within the delivery pipes **45** and **46** are sufficient to displace the pistons **49** and **50** against the air pressure in the pipes **55** and **56**. The liquids, therefore, flow through the conduits **53** and **54** and the coupling nipples **57** and **58** into the mixing tube **60**. The contacting materials **68** and **69** cause the liquids to be dispersed and mixed intimately to produce a homogeneous mixture which is discharged through the perforations in the plate **65**. It may be noted that the latter openings may constitute the final outlet of the mixing apparatus; however, a supplementary nozzle or spreading device may be added. When the desired amount of liquids has been discharged the cock **34** may be moved to neutral position, wherein the pipe **30** is isolated; the piston **23** thereupon stops. To discharge a quantity of the liquids in excess of that expelled by one stroke of the piston **23**, the cock **34** is moved alternately between the position shown and venting position. Whenever it is moved to venting position, additional liquids enter the pump chambers through the check valves **39** and **40** in amounts proportional to the areas of the stepped portions **23***a* and **23***b* of the piston. It is evident that the rates of liquid flow are always in a predetermined proportion, regardless of the lengths of the strokes of the piston **23**. Whenever the cock **34** is brought to the position shown liquid is expelled from the pump chambers as is described above. The flow of liquids in the conduits **53** and **54** will be of a pulsing character; these pulsations are, however, smoothed out to a certain extent by alternate dilations of the elastic tube **60**. Moreover, since this tube is transparent the effectiveness of the mixing can be observed.

The ratio between the liquids can be rapidly altered by replacing the piston **23** by another wherein the ratio of the cross sectional areas of the parts **23***a* and **23***b* is different; the partition wall **22** and/or **24** must also be replaced.

Should the flow of the resin mixture be interrupted for a period long enough to permit the resin to set up into a hardened mass within the tube **60**, it is simply removed from the coupling nipples **57** and **58** by loosening the clamp bands **63** and **64**, discarded, and replaced by a new unit.

It should be noted that the valves **47** and **48**, by their check valves' functions, prevent the flow of either liquid into the part of the conduit system provided for the other liquid, whereby setting up of the resin in any of the permanent parts of the system is avoided.

The mixer is especially suitable whenever short setting time resins are mixed, such as in supplying resin for potting, for highway strip painting or highway patch application where facilities for cleaning a mixer are not conveniently available, but may be used also for mixing other substances.

Referring to Figure 4, the mixing unit comprises a disposable metal tube **72** containing contacting material **68**, **69**, as described above. The coupling means is a threaded connection at **73** to an elbow pipe **74** which is connected to the supply conduit **54** from the proportioning pump. A smaller pipe **75**, connected to the supply conduit **53**, extends through the upper wall of the pipe **74** and is supported thereon by a threaded fitting **76**. The low end of the pipe **75** extends centrally into the tube **72** to deliver liquid to a level below the top of the latter. The bottom of the tube **72** may be provided with a perforated plate as shown in Figure 2. The operation of this embodiment is as was described above with the difference that both liquids enter through the same inlet opening. Since the liquids enter separately and are first commingled some distance below the top of the tube **72**, there is no danger of setting up a hard mass in the pipe

74 or 75, which are permanent parts of the mixing apparatus.

We claim as our invention:

1. A mixing unit for forming a homogeneous mixture of liquids comprising a tube having an inlet for the admission of said liquids under pressure, an outlet for the discharge of the resulting mixture, and contacting material in the form of small, curved plates having uneven surfaces packed within said tube between said inlet and outlet throughout a distance equal to several times the diameter of the tube, said plates being shaped to leave flow channels through the bulk thereof and having rigidity sufficient to maintain their shapes against substantial compaction when liquid is forced through the flow channels with a pressure drop of over 30 lbs. per sq. in.

2. A mixing unit according to claim 1 wherein each of said plates has a total surface area of at least 0.03 sq. in., said bodies having outlines to displace from about 10 to 25% of the gross volume thereof.

3. A mixing unit according to claim 1 wherein said plates are steel lathe turnings having rough surfaces.

4. A disposable mixing unit for forming a homogeneous mixture of a convertible resin with a hardening agent comprising a tube having inlet means adapted to be coupled detachably to conduit means providing separate passage for the separate admission of the resin and hardening agent, an outlet for the resulting homogeneous mixture, and steel lathe turnings packed within said tube between the said inlet means and the outlet throughout a distance equal to at least several times the diameter of the tube, said lathe turnings having the shapes of small curved plates to leave flow channels therethrough.

5. A disposable mixing unit for forming a homogeneous mixture of a convertible resin with a hardening agent comprising a tube of plastic material having inlet means adapted to be coupled detachably to conduit means providing separate passages for the separate admission of the resin and hardening agent, an outlet for the resulting homogeneous mixture, a perforated retaining member near said outlet, and contacting material composed of small, curved plates packed within said tube between said retaining member and said inlet means throughout a distance equal to several times the diameter of the tube and providing small, repeatedly intercommunicating flow passages, said plates being shaped to leave flow channels through the bulk thereof and having rigidity sufficient to maintain their shapes against compaction when liquid is forced through the flow channels with a pressure drop of over 30 lbs. per sq. in.

6. Apparatus for continuously producing a homogeneous mixture of a convertible resin with a hardening agent which comprises: separate sources of said resin and hardening agent; means including separate conduits for feeding said resin and hardening agent separately and under pressure at controlled flow rates from said sources; a disposable mixing tube having at least one inlet opening near one end and an outlet for the resulting mixture at the other end and containing randomly packed contacting material providing small, tortuous flow passages confined within said tube between said inlet means and outlet, said contacting material comprising small curved plates having rigidity sufficient to resist compaction and thereby maintain the shapes of said tortuous flow passages when said resin and hardening agent are forced through the mixing tube with a pressure drop in excess of 30 lbs. per sq. in.; and coupling means for connecting said tube detachably to said conduits for the separate admission of said resin and hardening agent under pressure.

7. Apparatus according to claim 6 wherein said mixing tube has a wall of plastic material and is encased at least near said inlet end thereof by a rigid metallic reinforcing sheath.

8. Apparatus according to claim 6 wherein said mixing tube has a wall of transparent material which makes observation of the mixing possible.

9. Apparatus according to claim 6 wherein said separate conduits include check valves between the feeding means and the mixing tube for preventing the back flow of either the resin or hardening agent into the conduit supplying the other material, thereby preventing commingling of resin and hardening agent before entering the mixing tube.

10. Apparatus for continuously producing a homogeneous mixture of convertible resin with a hardening agent which comprises: separate sources of said resin and hardening agent; means including pumps having expansible chambers with reciprocating walls and separate conduits for feeding said resin and hardening agent with pulsations separately and under pressure at controlled flow rates from said sources; a disposable mixing tube having a wall of elastic material, at least one inlet opening near one end and an outlet at the other end and containing contacting material which provides small, tortuous flow passages, said material comprising small curved plates having rigidity sufficient to resist compaction and thereby maintain the shapes of said tortuous flow passages when said resin and hardening agent are forced through the mixing tube with a pressure drop in excess of 30 lbs. per sq. in.; and coupling means for connecting said tube detachably to said conduits for the admission of said resin and hardening agent under pressure.

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