

Oct. 27, 1970

I. LUDWIN

3,536,451

SYSTEM FOR CYCLIC PULSED PUMPING AND FLUID INTERACTION

Filed Jan. 21, 1965

4 Sheets-Sheet 1

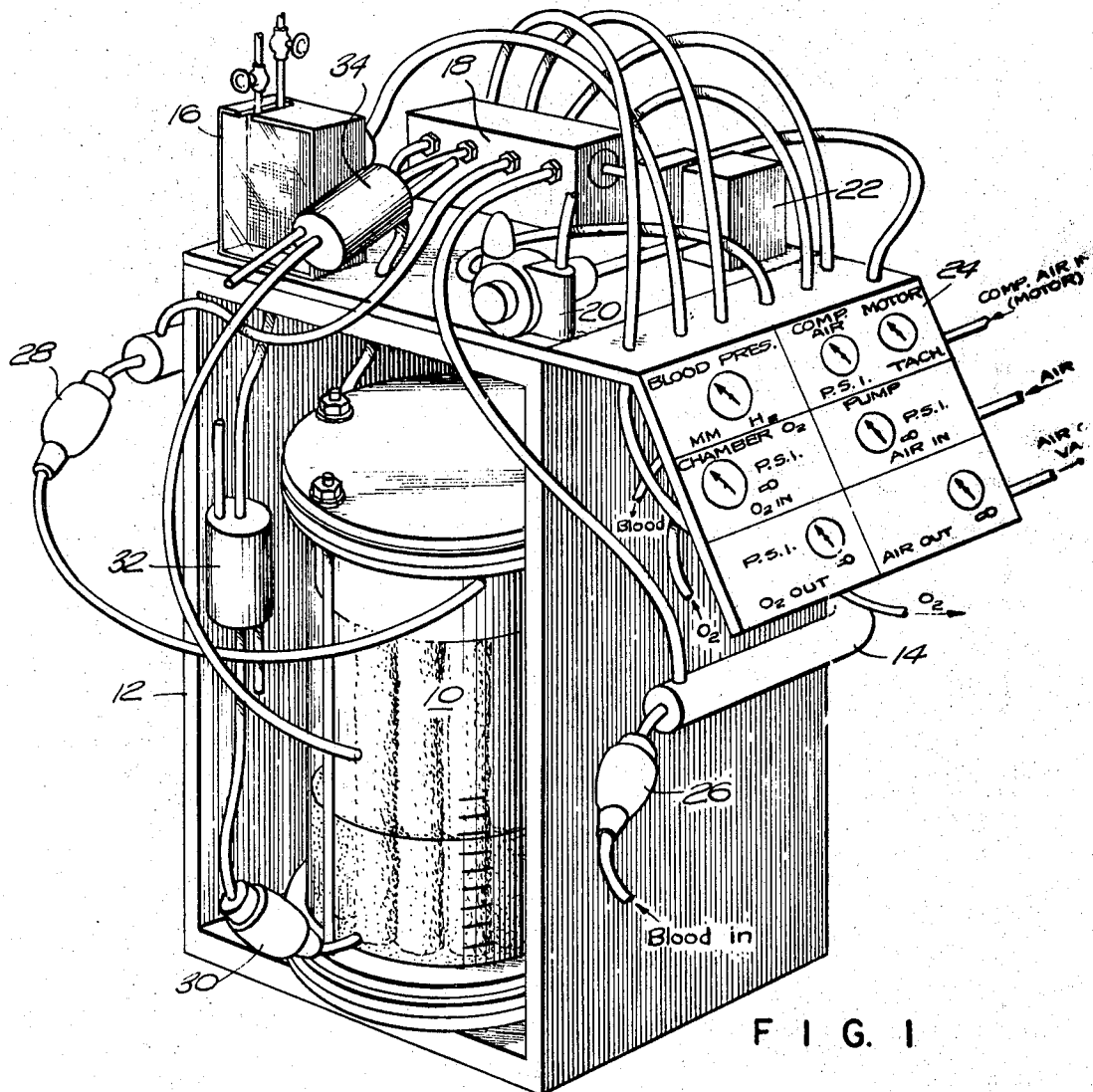


FIG. 1

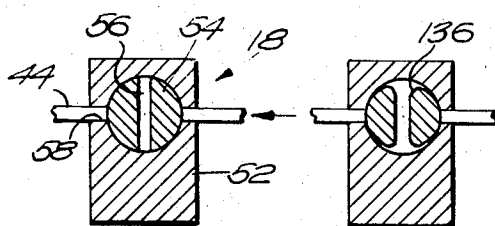


FIG. 8

FIG. 9

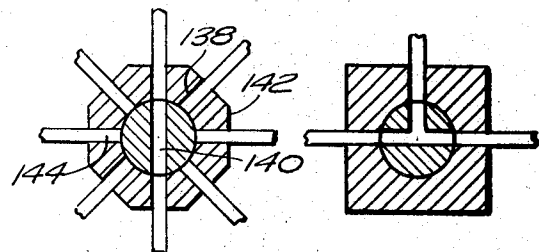


FIG. 10

FIG. 11

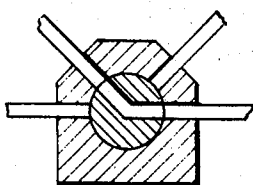


FIG. 12

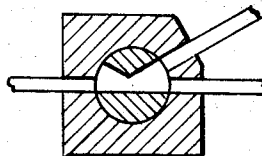


FIG. 13

INVENTOR.
ISADORE LUDWIN
BY
Morse, Altman + Oates
ATTORNEYS

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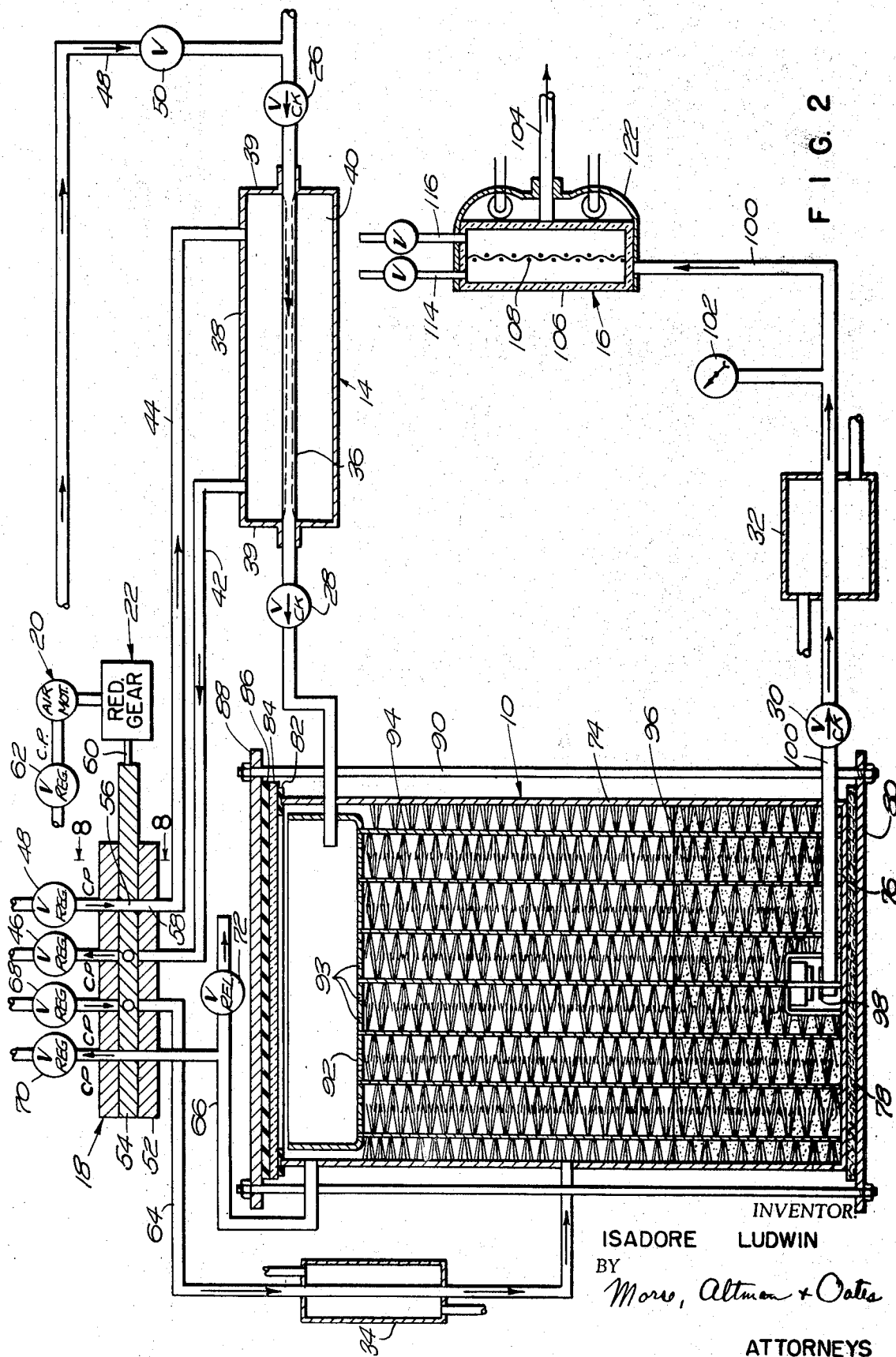
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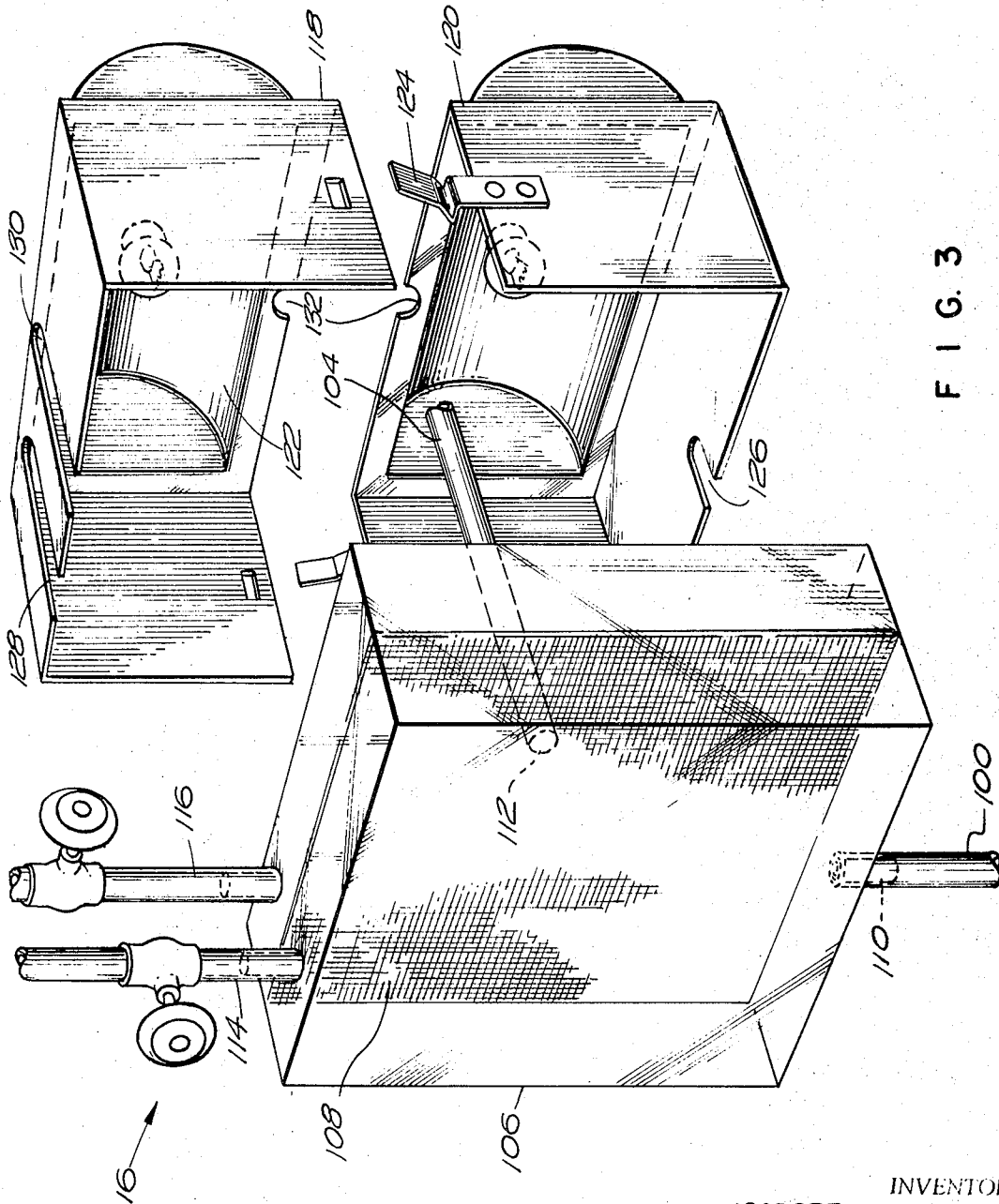


FIG. 3

ISADORE LUDWIN INVENTOR.

BY *Morse, Altman & Oate*

ATTORNEYS

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I. LUDWIN

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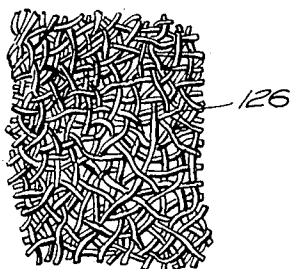


FIG. 4

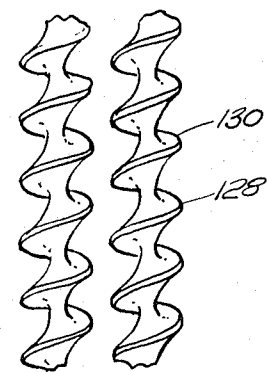


FIG. 5

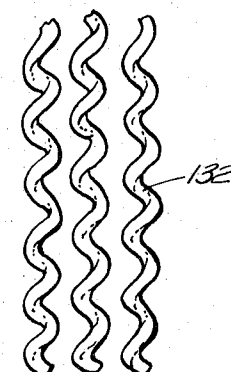


FIG. 6

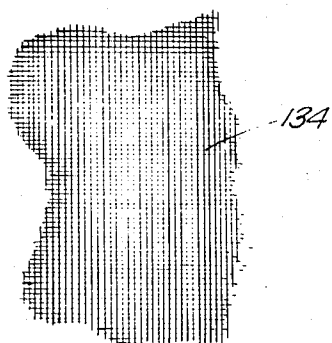


FIG. 7

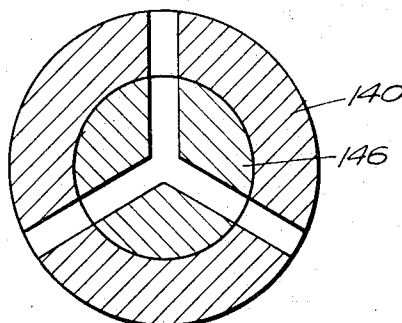


FIG. 14

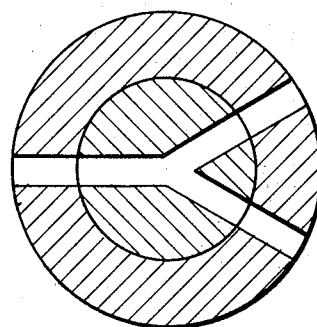


FIG. 15

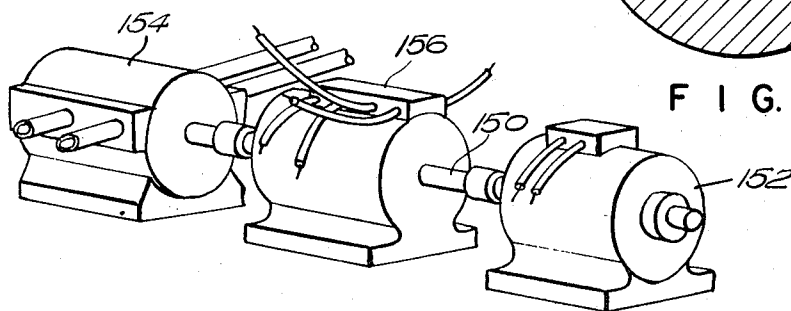


FIG. 16

INVENTOR.

ISADORE LUDWIN

BY

Morse, Altman & Oates

ATTORNEYS

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3,536,451

SYSTEM FOR CYCLIC PULSED PUMPING AND FLUID INTERACTION

Isadore Ludwin, 67 Grove Hill Ave.,
Newton, Mass. 02160

Filed Jan. 21, 1965, Ser. No. 426,771

Int. Cl. A61m 1/03

U.S. Cl. 23—258.5

10 Claims

ABSTRACT OF THE DISCLOSURE

A system is provided for continuously pumping and reacting fluids, which system is particularly suitable as a heart-lung machine wherein blood is pumped, oxygenated and blood relieved of waste CO₂ by pulses of compressed gas. Blood is delivered from the patient into a hyperbaric chamber. The blood enters the top of the chamber and flows down over blood filming surfaces. A gas such as oxygen is introduced to the chamber above the liquid level of the blood collecting at the bottom of the chamber and below the entry point of the blood coming in at the top. Thus the blood and the gas flow in counter-flowing paths for an optimum reaction between the two mediums. The gas in the chamber is pulsated by a control valve unit in such a manner as to pump the blood out of the bottom of the chamber back to the patient, exhaust the gas and CO₂ to ambient and permit additional blood to enter the chamber. The hyperbaric chamber thus serves as both a reaction chamber and as a pump.

This invention relates generally to systems for the treatment of fluids of various types and more particularly is directed towards a closed pressurized system providing an efficient interaction between two fluid mediums typically a gas and a liquid. The invention also includes an hyperbaric chamber providing counterflowing paths for the fluids and characterized by a large surface area along counterflowing paths to optimize the reaction of the fluids, a novel pump for delivering one of the fluids into the chamber and a novel timing valve for controlling the flow of the two mediums into and out of the hyperbaric chamber.

In treating or processing certain fluids, particularly liquids with gases, it is desirable that there be as complete an interaction between the two fluids as possible. For example, in heart-lung machines there should be an efficient interaction between the blood being circulated and the oxygen to insure proper oxygenation before the blood is returned to the patient. Also, an efficient heart-lung machine should be highly reliable, have a minimum number of components, provide full control over various operating parameters and should simulate as far as possible the pumping action of the heart.

Accordingly, it is an object of the present invention to provide an improved system for reacting two or more fluid mediums in a continuous and efficient manner.

Another object of this invention is to provide improvements in pumping devices.

A further object of this invention is to provide improvements in valving devices for controlling the flow of fluid mediums.

A more particular object of this invention is to provide improvements in heart-lung machines and associated components.

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A still further object of this invention is to provide a low-cost, efficient and reliable system for reacting liquids and gases, as for example blood and oxygen for the purpose of oxygenating the blood.

And still another object of this invention is to provide a pumping system for a heart-lung machine, which pumping system closely simulates the pumping action of the heart.

More particularly this invention features a system for reacting fluids, for example oxygen and blood in a heart-lung machine, comprising an hyperbaric chamber defining counterflowing paths for the fluid mediums and providing a high ratio surface area which in cooperation with the pressurized state of the fluids within the chamber optimizes the reaction between the fluids.

The pressure maintained in the hyperbaric chamber not only serves to enhance the liquid-gas reaction but also serves to pump the oxygenated blood and the spent oxygen from the chamber, the blood being pumped back into the patient.

This invention also features a novel pump which, in a preferred embodiment, comprises a resilient tube providing a conduit for one of the fluids, such as blood for example, and extending lengthwise through a relatively rigid tube sealed at both ends to the resilient tube to define an annular chamber between the two tubes. Check valves are disposed in the resilient tube line at either end of the assembly to provide a one-way flow of the blood and by varying the pressure within the annular chamber the blood, for example, may be pumped along the resilient tube in a manner closely resembling the action of the heart.

This invention also features a novel timing valve comprising a valve body having a plurality of spaced ports for the passage of a fluid medium, such as air or oxygen for example, and a cylindrical core having one or more radial passages formed therethrough. The core is mounted within the valve body and the two components are relatively rotatable whereby the core passages cyclically communicate with the ports formed in the valve body to pass a gas or fluid medium along one or more separate conduits according to a predetermined schedule.

However, these and other features of the invention, along with further objects and advantages thereof, will become more readily apparent from the following detailed description of preferred embodiments of the invention, with reference being made to the accompanying drawings, in which:

FIG. 1 is a view in perspective of a heart-lung machine made according to the invention;

FIG. 2 is a schematic diagram of the apparatus illustrated in FIG. 1,

FIG. 3 is an exploded view in perspective of a filter assembly made according to the invention,

FIGS. 4, 5, 6 and 7 are detailed side elevational views of various types of elements having large surface ratios for use within the reaction chamber,

FIG. 8 is a cross-sectional view of the valve taken along the line 8—8 of FIG. 2,

FIGS. 9 through 15 are views similar to FIG. 8 but showing modifications of the valve, and

FIG. 16 is a view in perspective showing a modification of the control system.

Referring now to the drawings and particularly to the FIG. 1, the system as embodied in a heart-lung machine

is generally organized about a combination pump and reaction chamber 10 removably mounted within a housing 12 about which is wound a resilient tube pump 14. Mounted on the top of the housing 12 is an illuminated combination blood filter and bubble trap 16 shown in detail in FIG. 3, and a rotary timing valve assembly 18 which is driven by means of an air motor 20 through a reduction gear assembly 22. A control panel 24 is mounted to the side of the housing to provide operating data and control over the operation of the system. Also operatively associated with the system are check valves 26, 28 and 30 and heat exchangers 32 and 34.

Referring now particularly to the schematic diagram of FIG. 2, the operation of the system will be described. As a heart-lung machine the blood is introduced into the top of the hyperbaric reaction chamber 10 by means of the pump 14. The pump 14 comprises a resilient tube or conduit 36 extending coaxially through and in spaced relation to a rigid tube 38 having annular end walls 39. The end walls of the tube 38 are sealed against the resilient tube 36 by appropriate means and the two tubes define an annular chamber 40 therebetween. In practice, the tube may be made up in various lengths and may follow a variety of configurations. For example, the pump 14 in the FIG. 1 embodiment is U-shaped so as to surround three sides of the housing 12 in a compact fashion. The resilient tube 36 receives blood from the patient and the opposite end leads into the upper portion of the chamber 10. The one-way check valves 26 and 28 are mounted along the resilient conduit one at either end of the rigid tube 38. In place of conventional flow actuated internal check valves, external valving means may be employed. For example, a cyclically actuated clamp may be located at either end of the pump to pinch the resilient tube in the proper timed sequence.

Conduits 42 and 44 connect to opposite ends of the rigid tube 38 and are connected through the timing valve 18 to regulator valves 46 and 48. Typically the conduit 44 is connected to a source of compressed air and the conduit 42 exhausts to the atmosphere on the discharge side of the regulator valve 46. Alternatively, the conduit 42 may be connected to a vacuum pump or the like to provide the desired differential pressure between the two conduits. In practice the pump operates by cyclically varying the pressure within the annular chamber 40 so as to circumferentially cyclically compress and recover, or cyclically distend and recover when used with vacuum, or cyclically distend and compress the resilient tube 36 along that portion within the rigid tube 38.

The timing valve 18 is arranged to first admit compressed air through the line 44 into the chamber 40 so as to first compress the resilient tube as suggested in dotted line in FIG. 2. This will cause the check valve 26 to close and the check valve 28 to open, axially displacing the blood or other fluid contained therein along the tube 36 and into the chamber 10. In the next part of the cycle the compressed air is cut off and the pressure in the chamber 40 is exhausted through the conduit 42 thus permitting the resilient tube 36 to return to its unstressed condition. The recovery of the tube closes check valve 28 and opens check valve 26 drawing in a fresh charge of blood.

The cycle is repeated and the pump delivers a pulsing flow of blood into the reaction chamber. The pumping action simulates the action of the skeletal muscles which compress collapsible veins during contraction. One way valves in the veins insure blood flow towards the heart. The veins fill with blood as the muscles relax.

Each pumping action (compression) and refilling (recovery) of the resilient tube constitutes one cycle of pump operation. The duration of the pumping phase in relation to the recovery phase in each cycle may be changed by appropriate control of the incoming and exhausting gas by means of the timing valve 18. Control of the gas flow resides in the rotary timing valve 18 to be described more fully below. Blood discharge from the resilient tube pump is readily controlled by the pressure differential in the

pump chamber 40 between the incoming and exhausting gases and by the speed at which the pump is cycled.

The operation of the pump is such that it will not interfere with the liquid flow through the resilient tube when the pump is not operating but will prevent back flow. A surge of liquid under high pressure will be carried through the pump without interfering with its operation in any way.

If a portion of pressure differential for operating the pump is achieved by means of a fluctuating vacuum, the pumping action simulates the natural flow of blood into the auricles of the heart which occurs during respiration. In breathing, the volume of the chest is increased in inspiration. This draws air into the lungs. The heart is also affected by the lowered pressure in the thoracic cavity and every inspiration aspirates blood into the heart from the veins. The action of the vacuum line attached to the exhaust side of the pump through the timing valve simulates the aspiration action of breathing upon the auricles of the heart.

If a vacuum source were connected to the chamber 40 through the conduit 42, the resilient tube 36 would expand in the first part of the cycle drawing in blood and, when the vacuum is cut off and the pressure in the chamber returned to an ambient condition the tube would relax to its normal condition pumping out the blood along the tube.

The differential pressure may also be generated by the use of both pressure and vacuum within one pumping cycle.

In addition to the main blood line 36 an accessory line 48 is also provided so that the surgeon may withdraw the blood in an isolated heart chamber for example to introduce it into the unit. A valve 50 is provided for clamping off this line when not in use.

In some instances it might be desirable that the pump 14 also serve as a heat exchanger in order to raise, lower or maintain the blood at a particular temperature level. In such applications the pumping air itself may be cooled or heated prior to entering the pump or heat exchange elements may be wound about the rigid tube 38 as desired.

The rotary timing valve 18 which controls the operation of the pump 14, as well as the hyperbaric reaction chamber 10 in the FIGS. 1 and 2 embodiment comprises an outer valve body 52 having a cylindrical valve member or core 54. The core in this embodiment is formed with four separate passages 56, each formed diametrically through the core which rotates in and out of communication with a plurality of inlet and outlet ports 58 formed in the valve body 52. The passages 56 are oriented at selected predetermined angles with respect to one another according to their particular function and timing relationship. For example the right-hand passage 56, as viewed in FIG. 2, is at a right angle to its immediately adjacent passage since these two passages serve to operate the pump 14 by first introducing pressure to the chamber and then exhausting it. Similarly, the left-hand passages are at right angle to one another for reasons that will presently appear. The core 54 is continuously rotated at a set speed by means of an air motor 20 operating a drive shaft 60 through the reduction gear 22. The regulator valve 62 is provided to maintain a set pressure for the motor 20. The speed of the motor may then be regulated by adjustment of the valve 62.

Connected to the left-hand pair of ports on the timing valve are conduits 64 and 66.

The conduit 64 is connected to a source of compressed oxygen through a regulating valve 68 and the rotary timing valve 18. The conduit passes through the heat exchanger 34 to provide a flow of oxygen into the reaction chamber approximately at its mid-point. The conduit 66 communicates with the upper portion of the reaction chamber and is connected through the timing valve 18 to the regulating valve 70. The conduit 66 is also provided

with a relief valve 72 to prevent the build up of excessive pressure within the chamber.

The reaction chamber 10 is formed from a tubular cylindrical tank or jar 74 of glass, Pyrex or the like, and normally mounted in upright position, as shown in FIG. 1. The bottom of the tank is closed by a glass wall 76 integral with the tank 74. This bottom wall is cushioned by a resilient pad 78 mounted in position by a rigid metal plate 80. The upper end of the tank 74 is closed by an assembly of an annular gasket 82, a glass disk 84 mounted thereon, a resilient rubber pad 86 overlaying the disk and a rigid metal plate 88 mounted over the pad. Tie rods 90, passing through plates 80 and 88, hold the cover assembly in clamping engagement with the tank head.

Inside the upper portion of the tank 74 is a distributor 92 in the form of a relatively shallow foraminous pan. The conduit 36 passes through the wall of the tank 74 into the side of the pan to discharge the incoming blood therein. The incoming blood swirls about the distributor and spreads evenly over the perforated bottom, and flows down through opening 93 toward the bottom of the tank.

The distributor is supported by a series of brush-like devices 34 standing on end and packed into the reaction chamber. The bristles typically are of nylon or other suitable non-wetting material. The purpose of the bristles is to provide flow and surface area for the blood as it descends under the influence of gravity towards the bottom of the chamber, counterflow to the incoming oxygen. The brush-like devices are so close together that the bristles intermesh and the blood flows down over the bristles without forming drops.

The oxygen which enters through the side of the reaction chamber flows up through the bristles while the blood flows down. This counterflowing action together with a high concentration of oxygen, oxygen pressure in the chamber, inflow of fresh oxygen plus the large blood surface area provided by the bristles results in efficient oxygenation of the blood. The oxygenating action may be further increased by cooling the blood so that the oxygen will dissolve more readily into the blood or by providing a taller or wider chamber providing more blood-gas exposure.

Insofar as the counterflowing liquid and gas with large surface area provided optimum heat exchanging conditions, the oxygen may be heated or cooled by the heat exchanger 34 just before being introduced to the chamber. The blood which has been oxygenated collects at the bottom of the tank in a reserve supply. In practice, the blood reserve in the tank is maintained at a level which is below the level of the oxygen and above a float valve 98. It will be understood that a reason for maintaining the blood level below the oxygen level is to prevent frothing of the blood which would occur if the oxygen were to bubble directly into the blood. The function of the valve 98 is to prevent gas bubbles from being pumped back into the patient. The valve 98 is connected to a discharge conduit 100, and the valve inlet is raised about $\frac{3}{4}$ " above the bottom of the reaction chamber. This bottom $\frac{3}{4}$ " of the chamber functions as a sediment trap where solid contaminants are retained below the level of the valve 98 which closes this blood outlet when the level of reserve blood in the chamber falls too low.

The reaction chamber serves not only to oxygenate the blood but also as a pump to return blood to the patient. The pumping action of the reaction chamber depends upon the oxygen pressure during each cycle. Back flow from the chamber into the pump 14 is prevented by the valve 28 which closes after each discharge of blood from the pump into the chamber. The oxygen pressure in the chamber increases and decreases cyclically in response to operation of the timer valve and exerts pressure on the surface of the reserve blood in the lower part of the chamber, forcing some out through the conduit 100. The conduit 100 is of resilient transparent plastic tubing.

A tough resilient material such as that sold under the

trademark "Tygon" may be employed for the conduit 100 as well as the resilient tubing 36. The reason for employing such material is that normally systolic pressure in the aorta causes stretching of the arterial walls and the elastic rebound of the large blood vessels maintains blood flow during diastole. This action is simulated by means of the resilient characteristics of the conduit 100 into which the blood is pumped from the reaction chamber. The tension built up in the conduit by the rapid delivery of blood from the chamber is used to drive the blood forward during the interval between strokes.

The check valve 30 along the conduit 100 is provided to prevent back flow of the arterial blood into the chamber. Chamber pressure is regulated to fluctuate cyclically between predetermined values. The incoming oxygen pressure is controlled by the regulating valve 68 while the oxygen exhaust line is connected to the regulating valve 70 to maintain a desired level of back-pressure within the chamber. Since it is not desirable to drop the arterial pressure to a low level, suitable back pressure is maintained. Thus the chamber pressure should be regulated so that arterial pressure varies from 80 to 120 mm. of Hg or such other values as may be desired during each cycle. In view of the back-pressure maintained in the tank, a somewhat higher operating pressure for the resilient tube pump is required. This difference is relatively small and normally would amount to an increased range of about 2 p.s.i. The relief valve 72 typically is set to lift at 15 p.s.i.

The level of reserve blood in the chamber remains constant when the resilient tube pump 14 and the reaction chamber pump are balanced. When the level of reserve blood starts to rise or fall adjustments may be made to balance the pumping action of the two pumps. Graduated markings are provided on the outside wall of the tank 74 so that the operator may readily gauge the level of the reserve blood.

Balancing of the pumping action of the reaction chamber and the resilient tube pump is accomplished by adjusting the output of oxygenated blood from the chamber at the desired level. When this has been done, gas pressure to the pump 14 is adjusted accordingly until the blood reserve level in the chamber remains constant.

After leaving the reaction chamber, the arterial blood passes through the check valve 30 and then through the heat exchanger 32 for final temperature adjustment. A manometer 102 may also be provided at this point to indicate the pressure of the discharging blood. From the heat exchanger the blood flows into the combination bubble trap and screen filter 16 and then flows through a conduit 104 back to the patient.

The combination bubble trap and screen filter 16 is best shown in FIG. 3 and comprises a shallow transparent box or cartridge 106 transversely divided into front and rear chambers by a fine mesh screen 108. Blood is introduced to the front chamber of the trap on one side of the screen 108 through a nipple 110 to which the conduit 100 is connected. This nipple is mounted on the bottom of the cartridge so that the blood passes up and then through the screen 108, which collects clots and the like into the rear chamber.

The blood then discharges from the trap through the conduit 104. This conduit is connected to the mid face of the back wall of the cartridge by a nipple 112 mounted on the cartridge.

If gas bubbles are present in the trap they will rise to the top of the front or rear chamber where they will be trapped because the outlet 104 is located below the level of any trapped gas. This gas may be bled from the trap through valved lines 114 and 116 connected to the top of the cartridge on either side of the screen. The combination bubble trap and filter is a disposable component detachably mounted to a holder comprising separable halves 118 and 120. These two halves are of box-like construction adapted to accommodate the cartridge and provided with illuminated reflectors 122, which serve

to illuminate the screen **108** for the purpose of detecting the presence of clots on the screen while in use. Should the screen become covered with clots in the course of operation, it would be necessary to change the cartridge before the screen becomes clogged. With the present arrangement, the cartridge may be replaced with substantially no interruption of the blood flow since it is necessary only to detach the conduits **100** and **104** and reconnect them to a fresh cartridge. The cartridge itself is dismounted by releasing spring clips **124** to permit separation of the housing halves and withdrawal. The housing halves are provided with slots **126**, **128**, **130** and **132** to accommodate the various conduits attached to the cartridge.

While the invention has been described with particular reference to the embodiment illustrated in FIGS. 1, 2 and 3, numerous modifications thereto will appear to those skilled in the art. For example, in place of the disposable bristle filaments **94** which provide the large surface area for the counterflowing blood and oxygen, other disposable materials may be used to advantage. For example, in FIG. 4 there is illustrated sections of a material which may be used in place of the bristle elements **94**. The particular material illustrated in FIG. 4 is a synthetic material similar in structure to a loofus sponge comprising a three-dimensional network of open membranes. The material is characterized by a high surface area and is formed from any suitable material such as plastic for example.

In FIG. 5 there is illustrated another element **128** characterized by a high surface volume ratio for use in the reaction chamber. These elements comprise elongated members having helical ramps **130** formed thereabout from one end to the other. In practice, these elements would be placed upright in the chamber and side by side to provide flow paths for the blood and oxygen.

In FIG. 6 there is shown another element which may be used in the reaction chamber. These elements comprise helical members **132** of plastic or the like which may be arranged in the same manner as the elements in FIG. 5.

In FIG. 7 there is shown a mesh material **134** which may be used in the chamber. Preferably this mesh material is fabricated from suitable plastic such as that sold under the trademark "Dacron" for example and arranged in any suitable manner. By way of example the material may be provided in lengths, corrugated transversely and wound into a spiral cylinder for placement in the chamber. The corrugations would thereby define vertical passages for the counterflowing blood and oxygen.

In addition to changes in the reaction chamber various modifications may also be made to the rotary timing valve **18**. In FIG. 8 there is a cross-sectional view of the valve **18** and in this particular embodiment the core passage **56** will line up twice per core rotation with the ports **58** formed in the valve body **52**. This will pass two pulses of compressed air to the pump **14**. In order to increase the period of the pumping stroke the core passage may be enlarged as illustrated at **136** in FIG. 9. This arrangement will increase the period during which the passage and ports will be in communication with one another.

Various other improvements may be made to the timing valve. For example, in FIG. 10 a core **138** is formed with a single passage **140** across its diameter whereas a valve body **142** is provided with a number of evenly spaced radial ports **144** all in the same plane. This arrangement performs functions similar to a number of the FIG. 8 type valve. Some of the ports may be connected to air or oxygen lines for example, and the rotation of the core will result in delivery of gas to opposing ports in timed sequence. Another symmetrical arrangement is shown in FIG. 14 and in this embodiment a core **146** is formed with three evenly spaced radial passages and a valve body **148** is formed with three even-

ly spaced ports which may be connected in various ways to cyclically pass a fluid medium at a rate of three cycles per rotation of the core.

FIGS. 11, 12, 13 and 15 show asymmetrical arrangements with FIG. 11 showing a core having radial passages in the form of a T for cyclical registration with three discharge ports at 90° intervals. FIG. 12 shows another asymmetrical arrangement which is formed with a single passage having radial portions disposed at an obtuse angle and adapted to register first with one pair of obtusely angled ports and then another pair of obtusely angled ports. FIG. 13 shows a core having rather enlarged passages whereby rotation of the core starting from the illustrated position, will communicate the left-hand port with both right-hand ports. Further rotation will cut off all ports and in the next half of the cycle only the parallel ports will communicate near the end of the cycle, first the upper port will be brought into communication and then both of the ports. FIG. 15 shows a core with radial passages two of which are 60° apart while the remaining passage is 150° from either adjacent passage. The valve body is formed with ports similarly positioned. This type of valve is useful in providing even distribution of an entering fluid medium to separate discharge ports or combining two fluids into one discharge.

Referring now to FIG. 16 there is illustrated a modified control mechanism for operating a system such as that described above in timed sequence. In this arrangement a common drive shaft **150** driven by a motor **152** operates a rotary timing valve **154** of the sort shown in FIG. 1 and also operates an electrical distributor **156** which may be connected to solenoid operated valves or the like. This distributor may be provided with a plurality of switches spaced axially apart and operated in timed sequence by a series of axially spaced cams mounted along the shaft **150**. With this arrangement electrical actuating mechanisms may be combined with gas operated components. For example, the valve portion **154** may be employed to supply and exhaust to and from the reaction chamber while the electrical distributor **156** may be employed to actuate an electrical pump or to operate solenoid valves which in turn would supply high pressure air to a flexible tube pump of the sort previously described.

While the system has been described as having particular utility as a heart-lung machine, it will be obvious that it may also be used to advantage for numerous other purposes where it is desired to react two or more fluid mediums. For example the system could be used for such industrial purposes as hydrogenating oils, converting alcohol into vinegar, or making hydrochloric and sulphuric acids for example. Also the various components of the system may be used to advantage for other purposes apart from the system. The pump may be employed to handle a variety of fluid while the rotary timing valve may be employed in numerous flow control applications. Also the rigid housing portion of the pump may be made up in separable sections so that it may be assembled over any selected portion of a resilient conduit to serve as a booster pump. Such a pump would employ the external flow control valving means previously described.

As a heart-lung machine the system is characterized by efficient operation, simplicity in design and construction, low priming volumes, low cost and reliability. Furthermore, the pumping action provided by the system closely resembles the action of the human heart thereby providing natural advantages to the patient.

Other modifications will appear to those skilled in the art. Accordingly, the above description and accompanying drawings should be taken as illustrative of the invention and not in a limiting sense.

Having thus described the invention what I claim and desire to obtain by Letters Patent of the United States is:

1. A system for treating at least two fluid mediums, comprising

- (a) a pressure vessel having a plurality of spaced apart delivery and exhaust ports in the walls thereof and communicating with the interior thereof, said vessel having a common passage therein through which the several mediums delivered and exhausted separately through said ports pass and providing an area wherein said mediums intermingle and mix,
 - (b) first delivery conduit means connected to one of said delivery ports for delivering one of the mediums into said vessel through said one port at a point adjacent the top of the vessel for flow of the medium in said passage,
 - (c) check valve means in said first delivery conduit means to prevent reverse flow of said one medium out of the vessel,
 - (d) second delivery conduit means connected to another of said delivery ports for delivering another of said mediums into said vessel through said other of said ports at another point spaced from and below said one point for flow and contact with said one medium in said passage in a direction opposite to the flow of said one medium,
 - (e) means in said vessel for distribution of said first medium across the said passage to facilitate the mixing of the same thoroughly with said second medium,
 - (f) first and second discharge conduit means connected to different other ports for exhausting said mediums separately from said vessel and permitting pressurization of said vessel for pumping said one medium out of said vessel through said first discharge conduit means, and
 - (g) control valve means connected to said first and second delivery conduit means and said second discharge conduit means for cyclically opening and closing said first and second delivery and second discharge conduit means according to a predetermined schedule to sequentially deliver said first and second mediums into said vessel for intermixture and then pump said mediums separately out of said vessel.
2. A system according to claim 1 wherein said control valve means includes a rotary timing and fluid control valve for one of said fluid mediums, said valve comprising an outer valve body connected to a pressurized source of said one fluid medium and an inner rotatable core, said body being formed with a plurality of valve ports connected to said first and second delivery conduit means and said vessel and said core being formed with at least one passage adapted to periodically register with said valve ports upon rotation of said core to form individual fluid flow paths to said first and second delivery means and said vessel and power means for continuously rotating said core.
3. A system according to claim 1 wherein said distribution means comprises a foraminous distributing member mounted in the upper portion of said vessel to receive said one medium introduced into said vessel, and a plurality of elements characterized by large surface area in relation to volume disposed below said member and defining said common passage in counterflowing directions for said mediums.
4. A system for reacting a gas and a liquid, comprising
- (a) a pressure vessel,
 - (b) means within said vessel providing a common mixing passage for said gas and liquid moving in counterflowing directions within said vessel,
 - (c) first delivery conduit means connected to said vessel passage means for delivering said liquid into an upper portion of said vessel for downward flow along said passage in one direction,
 - (d) check valve means in said first delivery conduit means to prevent reverse flow of said liquid out of the vessel,
 - (e) second delivery conduit means connected to said

- vessel passage means for pressurizing said vessel and for delivering pressurized gas into a lower portion of said vessel for upward flow along said passage in an opposite direction into contact with said liquid, said pressurized gas serving to react with said liquid and pumping said liquid from said vessel,
- (f) means in said vessel for distribution of said liquid across the passage to facilitate the mixing of the same thoroughly with said gas,
 - (g) first and second discharge conduit means connected to different other ports for exhausting said liquid and gas separately from said vessel and permitting pressurization of said vessel through said second delivery conduit means, and
 - (h) control valve means operatively connected to said first and second delivery conduit means and said second discharge means, and means for cyclically actuating said control valve means according to a predetermined schedule to sequentially deliver liquid and gas into said vessel for intermixture and then pump said liquid and gas out of said vessel.
5. A system for oxygenating blood, comprising
- (a) a combination pump and reaction pressure vessel having an upper and lower portion in a common communicating chamber,
 - (b) first delivery conduit means connected to the upper portion of said vessel for delivering blood into the upper portion of said vessel, and including check valve means preventing reverse flow,
 - (c) second delivery conduit means connected to the vessel below said first conduit means for pressurizing said vessel and for delivering gas into said vessel below the point at which the blood enters the vessel, the pressurized gas reacting directly with the blood,
 - (d) first and second discharge conduit means connected to said vessel at its upper and lower portions respectively for permitting pressurization of said vessel and for exhausting said gas and waste products from the upper portion of said vessel and pumping said blood from the lower portion thereof,
 - (e) dispersing means disposed in the upper portion of said vessel for distributing said blood over a substantially horizontal cross-section of said chamber,
 - (f) a member having a large surface area ratio disposed below said dispersing means and providing a common path between the upper and lower portions of said chamber for said blood and said gas moving in counterflowing directions, and
 - (g) control valve means operatively connected to said first and second delivery conduit means, and said first discharge conduit means, and motor means for cyclically actuating said control valve means according to a predetermined schedule to sequentially deliver blood and gas into said chamber and then pump said blood and gas out of said chamber.
6. A chamber according to claim 5 including a float valve connected to said chamber at the blood discharge end thereof for stopping the discharge of said blood below a predetermined level.
7. A chamber according to claim 5 including regulating valve means connected to said second delivery conduit means for controlling said pressure.
8. A chamber according to claim 7 including regulating valve means connected to the first discharge conduit means for controlling the gas exhaust pressure from said chamber.
9. A chamber according to claim 5 including check valve means in said second discharge conduit means for preventing backflow to said chamber.
10. A chamber according to claim 5 wherein said second discharge conduit means includes a length of resilient tubing connected to said chamber at the blood discharge end thereof and adapted to be stressed by said blood when said chamber is discharging said blood and to recover during a non-discharging phase of said

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chamber whereby pumping pressure will be maintained on the blood within said tubing.

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JAMES H. TAYMAN, JR., Primary Examiner

U.S. Cl. X.R.

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