Sept. 16, 1947. C. C. RAUSCH 2,427,419

RESUSCITATING APPARATUS

Filed June 30, 1945 3 Sheets-Sheet 1

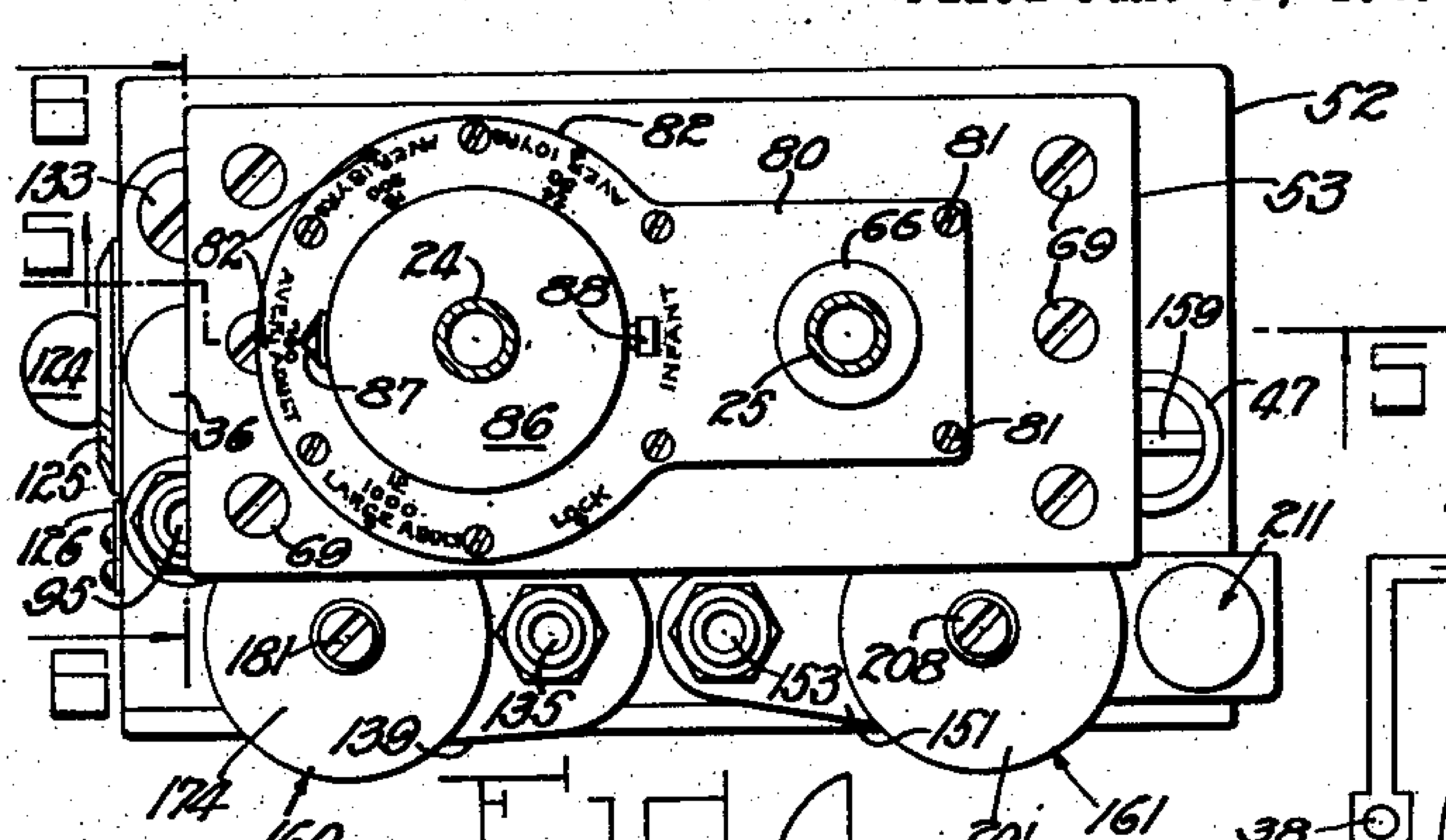

Fig_4

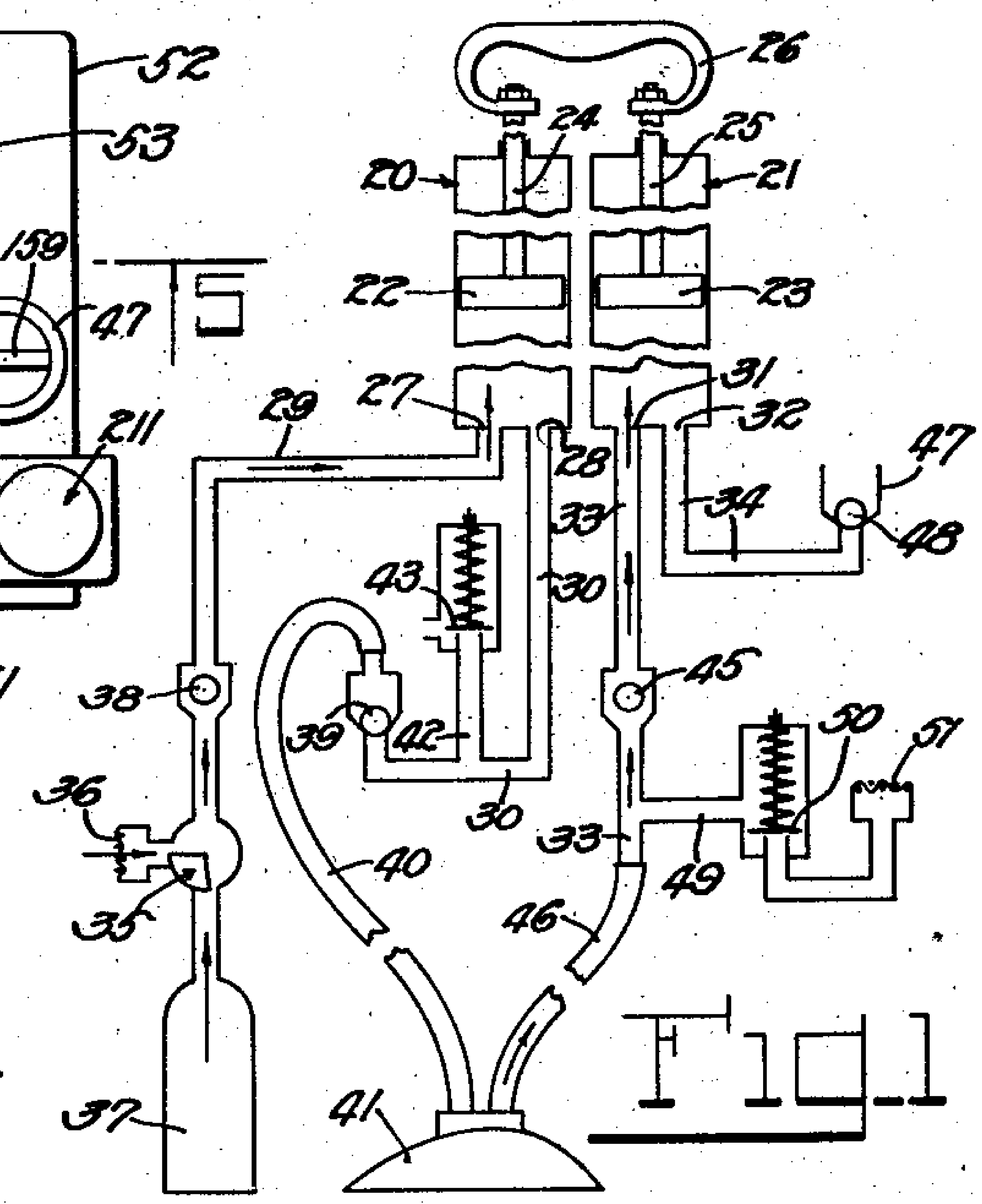

Fig_1

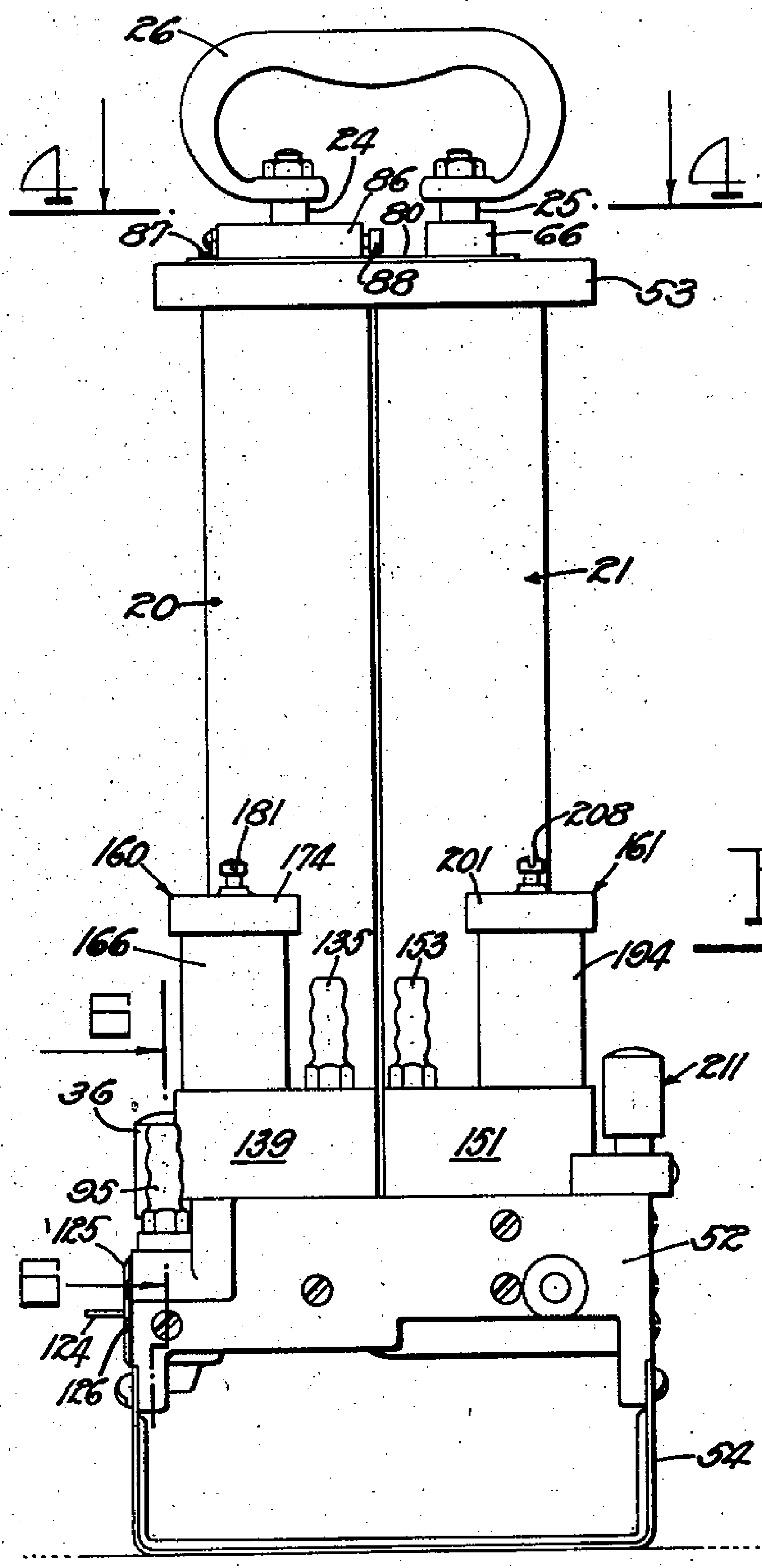

Fig_2

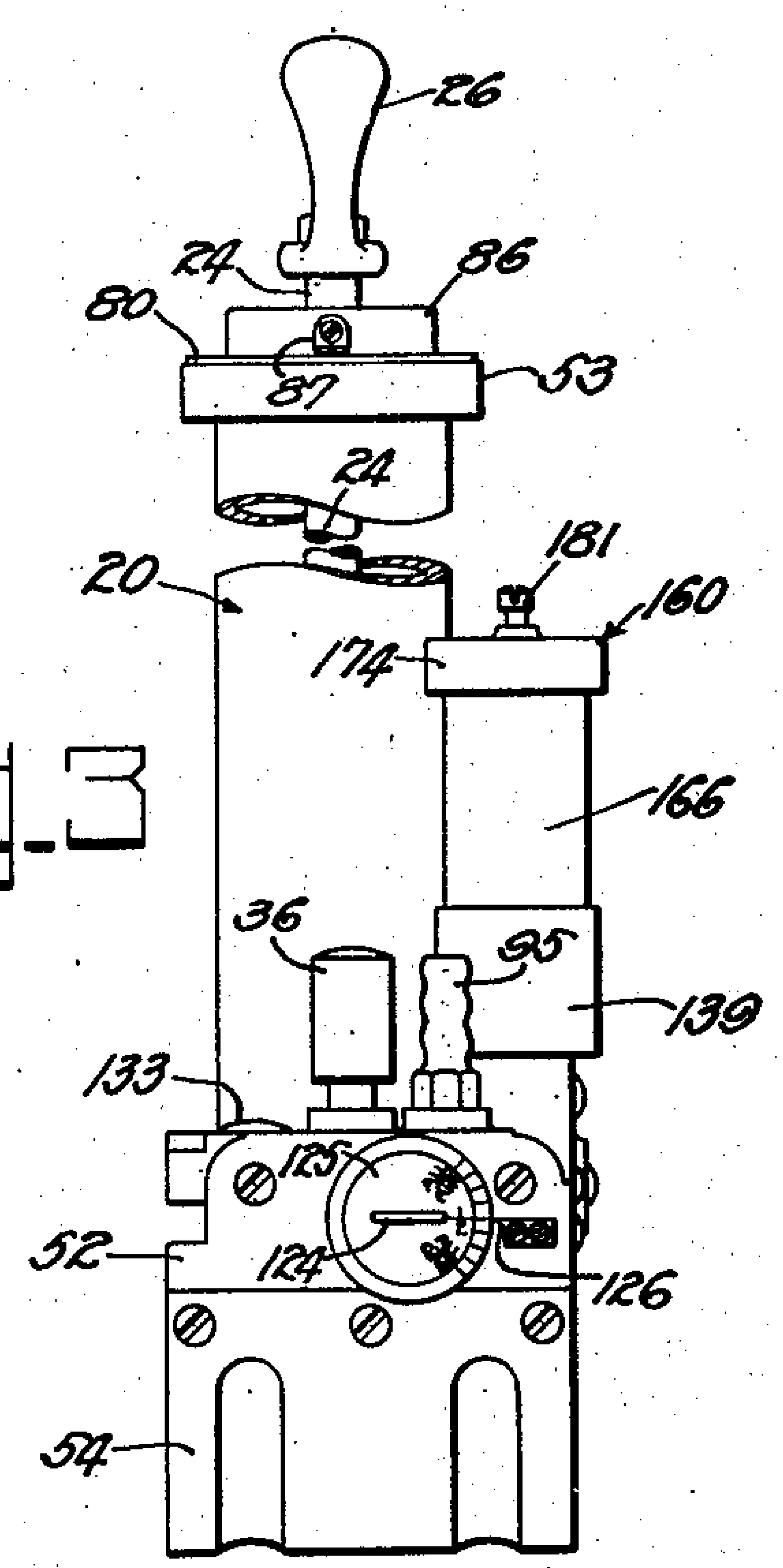

Fig_3

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RESUSCITATING APPARATUS

Filed June 30, 1945 3 Sheets-Sheet 2

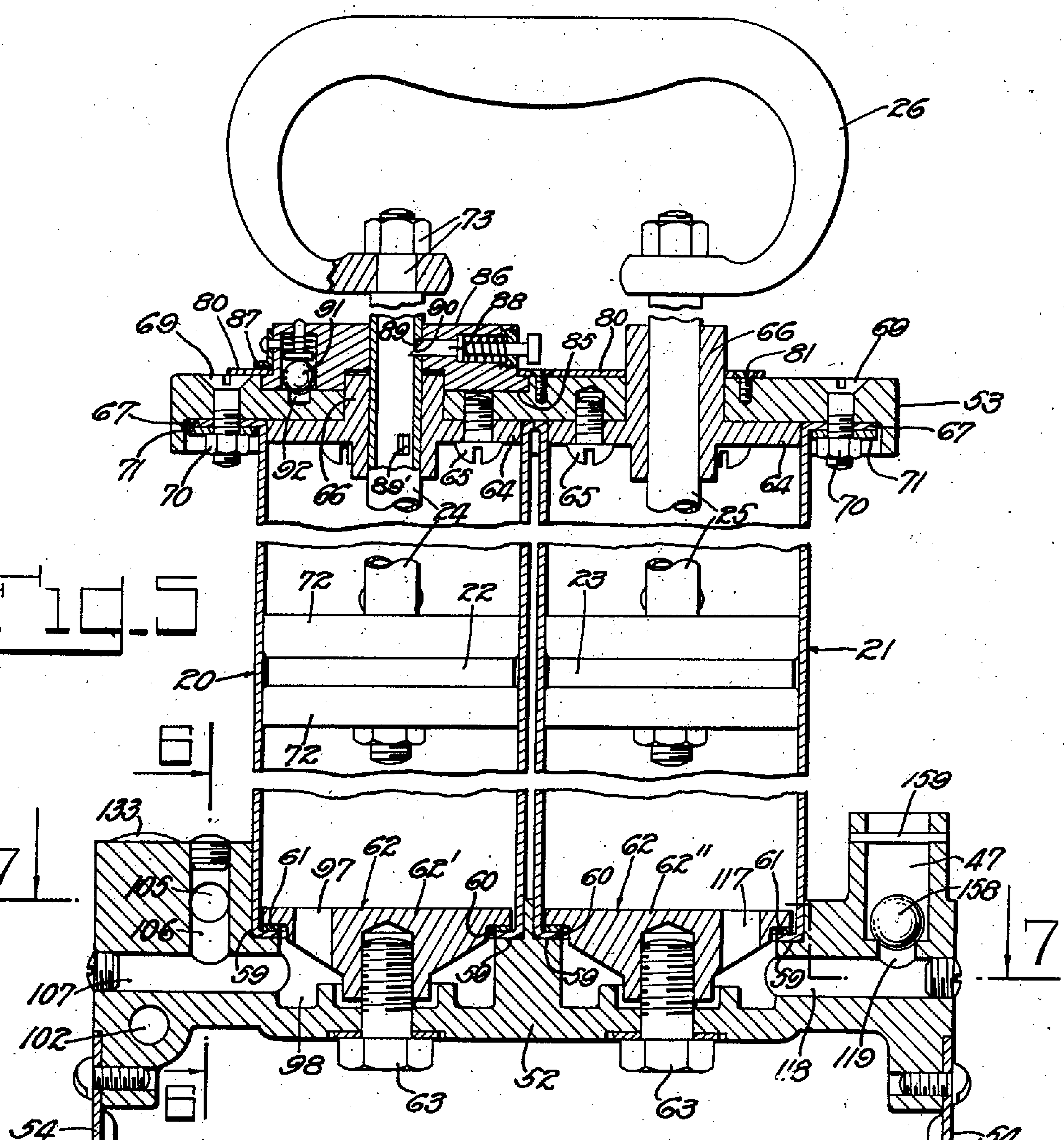

Fig. 5

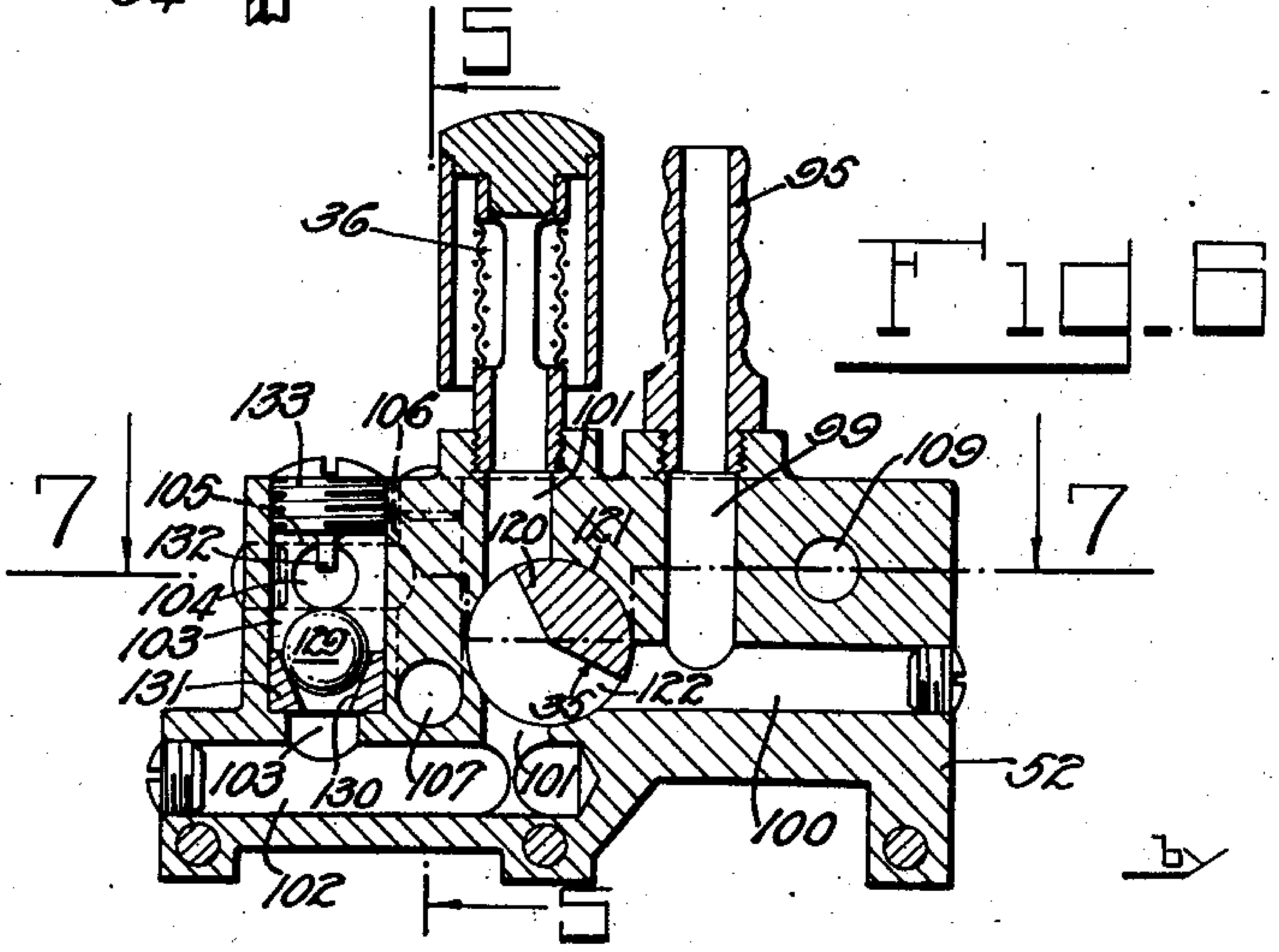

Fig. 6

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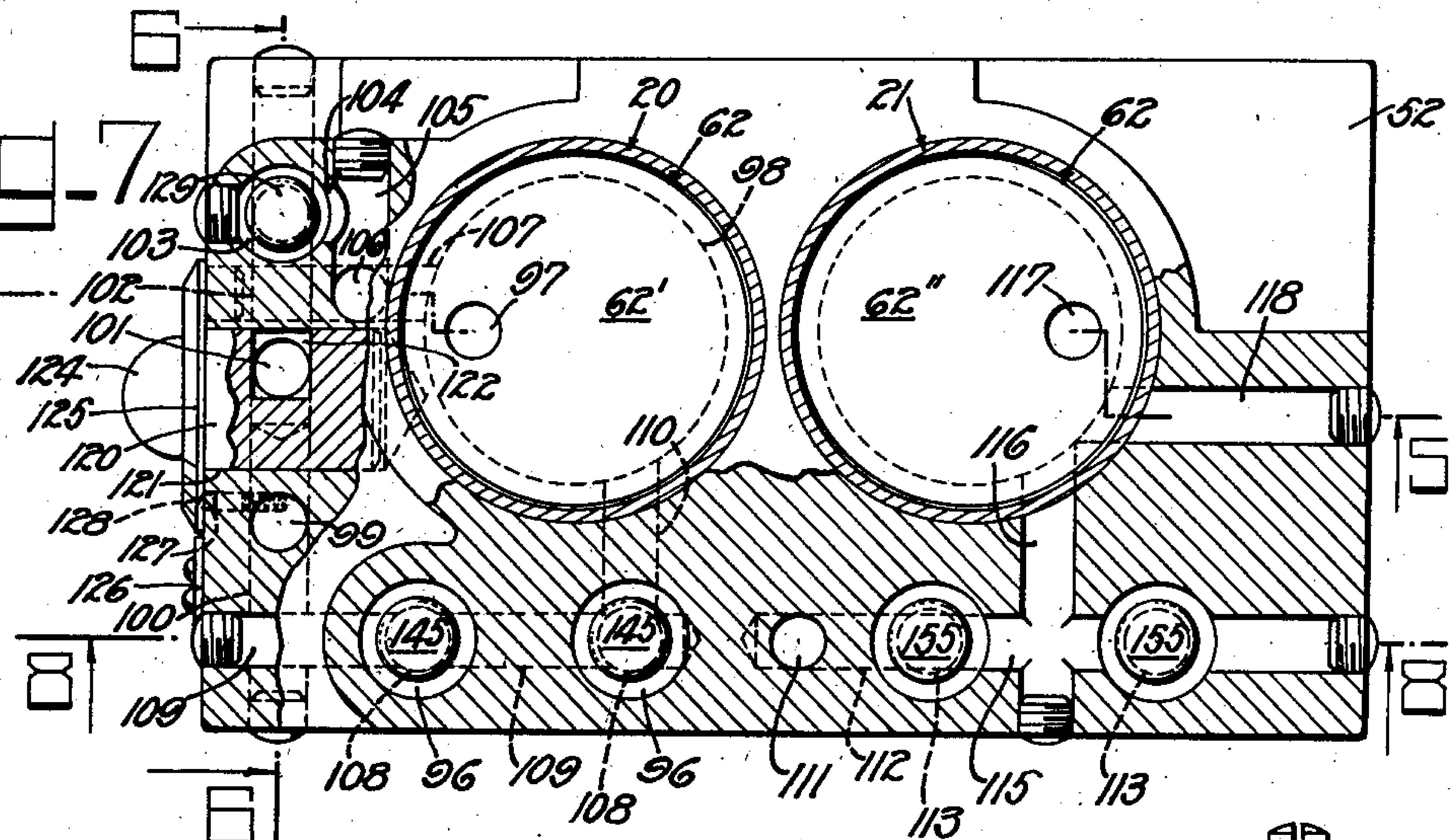
RESUSCITATING APPARATUS

Filed June 30, 1945 3 Sheets-Sheet 3

Fig. 7



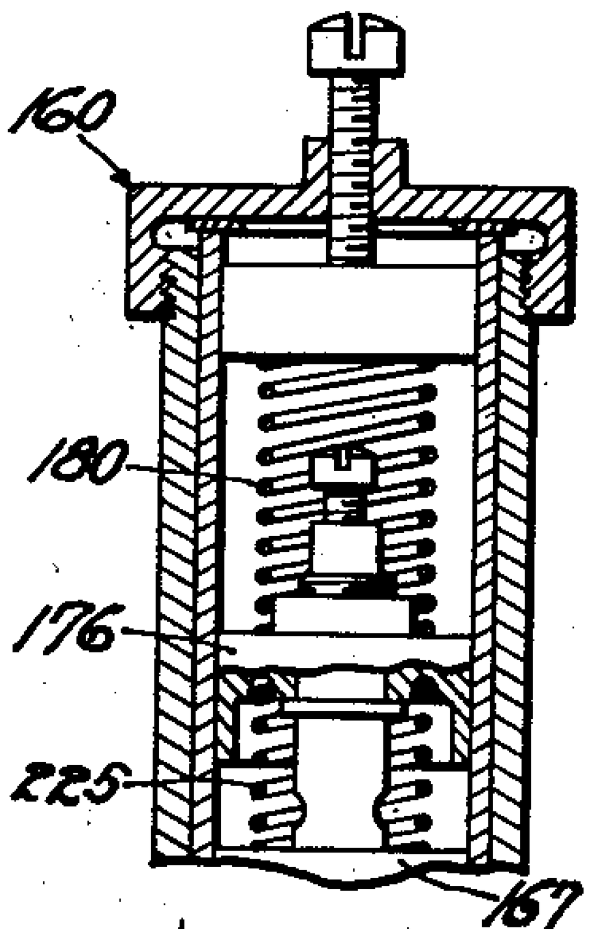


Fig. 9

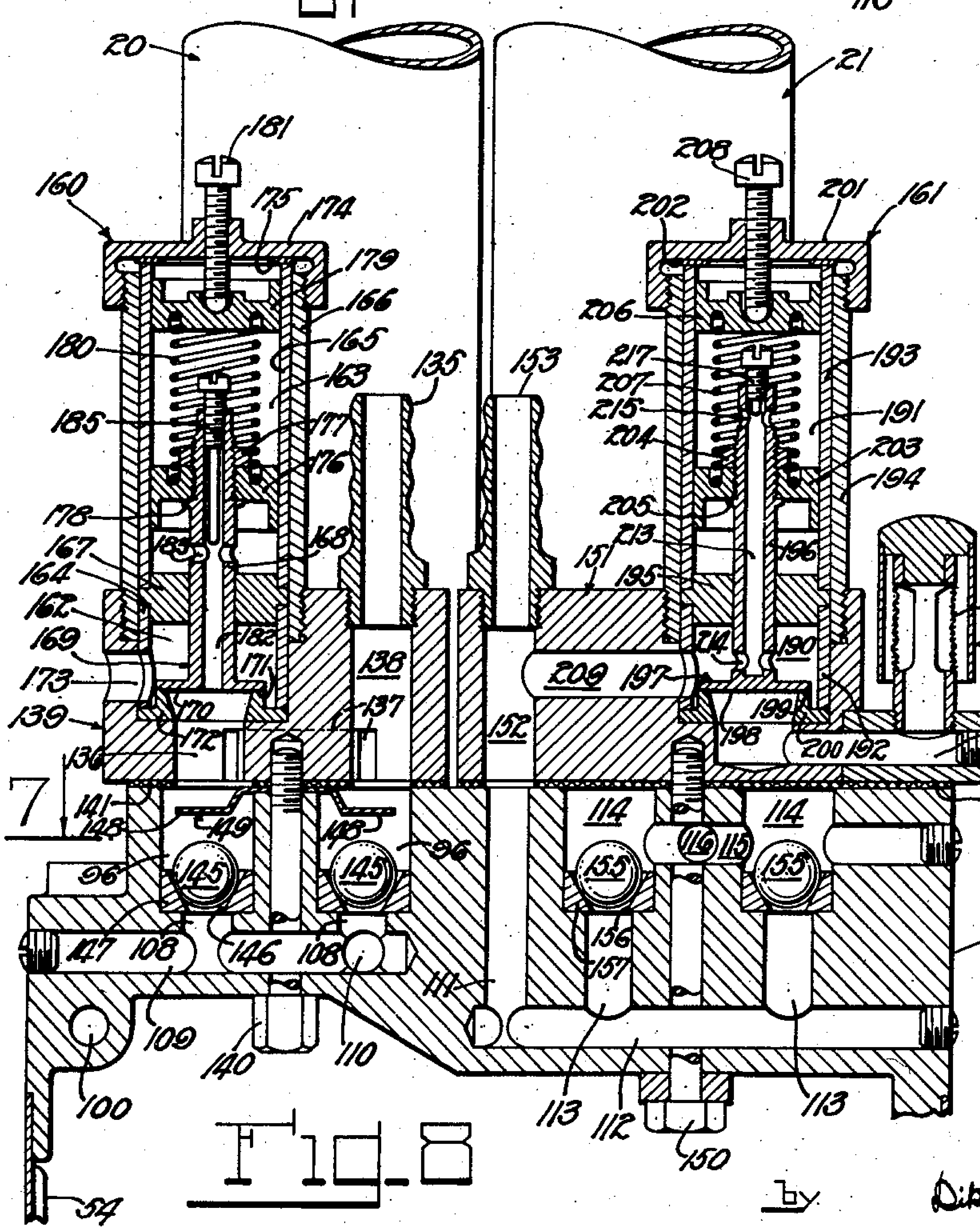


Fig. 8

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UNITED STATES PATENT OFFICE

2,427,419

RESUSCITATING APPARATUS

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Application June 30, 1945, Serial No. 602,584

5 Claims. (Cl. 128—29)

1

This invention relates to resuscitating apparatus for producing artificial respiration in, or assisting in the natural but labored respiration of, persons suffering from asphyxiation, drowning or the like.

Apparatus of this type have heretofore been designed, having for their purpose to force a gas, commonly air and/or oxygen, into a patient's lungs and to exhaust the spent gas therefrom by suction. These prior apparatus have, however, been rejected by the medical profession because their use involved an element of risk to the patient's welfare. The positive and negative pressures to which human lungs are subjected during natural breathing are extremely low, their maximum being, for grown persons, in the neighborhood of +20 millimeters of mercury column on inhalation of fresh air and —10 millimeters of mercury column on exhalation of the spent air. Insubstantially greater pressures, whether positive or negative, are harmful to human lungs, and pressures of 80 and —40 millimeters of mercury column may so damage the lungs as to prove fatal to the patient. While best results in the resuscitation of a person are obtained when the lungs are subjected to the same pressures as during natural respiration, this is not readily accomplished with the prior apparatus because even a slight deviation from their prescribed manual operation for a certain type of patient entails disproportionately large variations in pressures. There also remains the fact that these prior apparatus are a definite menace in the hands of non-skilled persons who in an emergency may be called upon to operate them and through ignorance or well-meant, but excessive, zeal badly harm or even kill the patient. The failure of the prior apparatus to safeguard the patient from harm in consequence of their being improperly operated is due to the inadequacy of their valve mechanisms which, though designed with a view toward keeping the pressures within safe limits under all operating conditions, fail to accomplish this.

It is the primary aim and object of the present invention to provide in a resuscitating apparatus a valve mechanism which automatically and without fail, and regardless of whether the apparatus is operated properly or improperly, controls the pressures well within safe limits so that no harm may ever come to human lungs from this source.

It is also among the objects of the present invention to so devise the valve mechanism that the same, though being unfailingly responsive to

2

pressures well within safe limits, is nevertheless unresponsive to small, harmless pressure fluctuations so as to preserve the volume of gas for delivery to the lungs.

The foregoing and other objects of the invention, together with means whereby the latter may be carried into effect will best be understood from the following description of an illustrative embodiment shown in the accompanying drawings, in which:

Fig. 1 is a diagrammatic view of a resuscitating apparatus;

Fig. 2 is a front elevation of a resuscitating apparatus embodying the present invention;

Fig. 3 is a side elevation of the apparatus, broken away in part;

Fig. 4 is a section taken on the line **4—4** of Fig. 2 and showing most of the apparatus in plan view;

Fig. 5 is a section through the apparatus taken on the line **5—5** of Fig. 4;

Fig. 6 is a section taken on the line **6—6** of Figs. 4 or 5;

Fig. 7 is a section through the apparatus, taken mainly along the line **7—7** of Fig. 8;

Fig. 8 is a section taken on the line **8—8** of Fig. 7;

Fig. 9 is a fragmentary section through a modified part of the apparatus.

Reference is first had to Fig. 1 for a general understanding of the resuscitating apparatus and its operation. The apparatus comprises juxtaposed pressure and suction cylinders **20** and **21** in which are mounted reciprocatory pistons **22** and **23**, respectively, having rods **24** and **25**, respectively, which are connected at their outer ends by a handle **26** for unitary reciprocation of said pistons **22** and **23**. As will appear more fully in the course of the description, the stroke of these pistons may be varied to regulate the volume of gas to be forced into, and exhausted from, a patient's lungs, this regulation being in accordance with the estimated capacity of the lungs determined by the size of the patient. The pressure cylinder **20** is provided at its lower end with an inlet **27** and an outlet **28** with which communicate conduits **29** and **30**, respectively. The lower end of the suction cylinder **21** is likewise provided with an inlet **31** and an outlet **32** with which communicate conduits **33** and **34**, respectively. The conduit **29** is adapted to conduct air or oxygen, or a mixture thereof, to the pressure cylinder **20** during an outward or suction stroke of the piston **22**, there being provided at one end of the conduit **29** a mixing valve **35** with which communicates a screened atmospheric air inlet 36 and an oxygen tank 37, the valve 35 being adjustable to admit into the conduit 29 either gas alone, or any desired mixture thereof. In the conduit 29 is an inlet valve 38 which will open during each suction stroke of the piston 22 to admit the gas to the cylinder 20, and which will be closed at all other times. On each compression stroke of the piston 22, the gas charge in the pressure cylinder 20 is compressed and, when so compressed, opens a discharge valve 39 in the conduit 30 which remains closed during each suction stroke of said piston 22. The compressed gas then passes through an inhalation tube 40 to a mask 41 which may be of any desired design and fits over the patient's face. Provided in a branch 42 of the conduit 30 is a pressure relief valve 43 of such design that it will remain closed within a range of safe pressures in the cylinder 20, and will open under a pressure which might be harmful to the patient.

At the start of an operation of the apparatus, i. e., when the pistons 22 and 23 are initially moved outwardly after placing the mask 41 over a patient's face, a quantity of gas is drawn into the pressure cylinder 20 and a partial vacuum or negative pressure is produced in the suction cylinder 21. The partial vacuum thus produced in the suction cylinder 21 is sufficient to open an inlet valve 45 in the conduit 33 and thereby establish communication, through an exhalation tube 46, between the cylinder 21 and the mask 41 for the purpose of exhausting the patient's lungs of any gas therein. The gas thus drawn into the cylinder 21 is forced from the latter and through the conduit 34 on the next inward stroke of said piston 23. The end of the conduit 34 is preferably enlarged to form a receptacle 47 for a discharge valve 48 which is closed during each suction stroke of the piston 23 to prevent the admission of atmospheric air into the cylinder 21, and which is opened by the pressure produced on each inward stroke of the piston 23 to permit the exhaust of the waste gas from the cylinder 21. A conduit 49, which branches from the conduit 33, contains a suction relief valve 50 and terminates in a screened atmospheric air inlet 51. When the apparatus is properly functioning, i. e., when the negative pressure in the conduit 33 does not exceed a tolerable maximum during any suction stroke of the piston 23, the relief valve 50 will remain closed to prevent the passage of atmospheric air into the conduit 33. However, should the negative pressure in said conduit 33, during any part of a suction stroke of the piston 23, exceed the tolerable maximum, the relief valve 50 will immediately be lifted from its seat and atmospheric air admitted into the conduit 33 to reduce the negative pressure therein below the tolerable maximum. Either one of the relief valves 43 or 50 will open automatically and perform its intended function in consequence of a change in the condition of the patient's lungs or in consequence of improper operation of the apparatus by the operator.

Through numerous experiments conducted with the present apparatus in an endeavor to find the positive and negative pressures best suited to simulated natural respiration, it has been found that positive pressures in the inhalation tube 40 should not exceed 20 millimeters of mercury column, while the negative pressures in the exhalation tube 46 should not exceed 10 millimeters of mercury column.

Referring now to Figs. 2, 3 and 5, the apparatus comprises a base 52 and a head 53 between which the cylinders 20 and 21 are mounted. The base 52 has secured thereto a stirrup 54 for receiving a foot of the operator when the apparatus is operated while standing on the ground or floor. The base 52 is provided with two annular recesses 59 (Fig. 5) for receiving the lower ends of the cylinders 20 and 21 which are preferably turned inwardly to form annular flanges 60. Placed in the lower ends of the cylinders are disk-like clamp members 62 which rest on gaskets 61 that are superposed on the annular flanges 60 of the cylinders. The clamp members 62 are firmly drawn against the gaskets 61, and rigidly secure the cylinders to the base 52, by means of bolts 63 which pass through the base 52 and are threadedly received by said clamp members. Fitted into the upper end of each cylinder is a closure member 64 which is secured to the head 53 by screws 65. The closure members 64 are provided with central hubs 66 which project through the head 53 and provide guide bearings for the piston rods 24 and 25. The upper ends of the cylinders 20 and 21 are turned outwardly to provide flanges 67 on which the head 53 rests. The flanges 67 are drawn into firm engagement with the head 53 by means of screws 69 and nuts 70, the latter also forcing gaskets 71 against said flanges 67 to seal off the upper ends of the cylinders. The pistons 22 and 23 are of identical construction, each including packing disks 72 which are suitably clamped to the pistons. The outer ends of the piston rods 24 and 25 are secured to the common operating handle 26 preferably in the manner shown at 73 in Fig. 5.

Prior to using the apparatus on a particular patient, the volume of gas to be pumped to, and exhausted from, the lungs is first determined by the patient's size and estimated lung capacity. To this end, means are provided to regulate the stroke of the pistons in accordance with the estimated lung capacity of the patient. These means comprise a dial plate 80 (Figs. 4 and 5), secured by screws 81 to the top of the head 53. The dial plate 80 is provided with graduations 82 with which are associated suitable indicia denoting the volumes and the number of strokes per minute of the pistons for different types of patients. The indicia may be impressed or inscribed on the dial plate 80, and may be grouped in accordance with the following table:

	Volume in cc.	Strokes per minute
Infant	75	50
Average child	350	24
Average youth	500	18
Average adult	700	15
Large adult	1,000	12

An additional graduation 82 is preferably provided on the dial plate 80 to designate a "lock" position in which the pistons 22 and 23, are locked in their cylinders in a manner explained hereinafter. Rotatable in an annular recess 85 in the head 53 and retained therein by the dial plate 80, is an index disk 86 (Fig. 5) through which the piston rod 24 extends centrally thereof. The index disk 86 carries a pointer 87 which moves past the graduations 82 when said index disk is turned. The index disk 86 further carries a spring-pressed latch 88 which is adapted to register with any one of several apertures 89 in the piston rod 24 on each suction stroke of the pistons 22 and 23 to limit the stroke to a predetermined length. There are as many apertures 89 in the piston rod 24 as there are graduations 82 on the dial plate 80, and these apertures 89 are spaced longitudinally of, and arranged spirally about, the piston rod 24. In Fig. 5, the latch 88 is shown in registry with the aperture 89 which corresponds to the setting of the index disk 86 for an "Average adult" (Fig. 4). With the index disk 86 thus set, the latch 88 snaps, on the outward or suction stroke of the pistons, into the aperture 89′ to prevent further outward movement of said pistons beyond the cylinder volume for an average adult, i. e., 700 cc. On turning the index disk 86 so that the pointer 87 thereof aligns with the "Lock" graduation 82, the latch 88 will, on the inward stroke of the pistons, register with the aperture 89 (not shown) which is nearest the handle 26, and lock the pistons in their innermost position. Preferably, the pistons 22 and 23 are thus locked in their respective cylinders when the apparatus is not in use. To ready the apparatus for use, the piston rod 24 is released from the latch 88 by withdrawing the latter from the aperture 89 in the former, and the index disk 86 is turned so as to align the pointer 87 with the graduation 82 which is most appropriate for the particular patient on which the apparatus is to be used. Only one other aperture 89′ is shown in the piston rod 24 in Fig. 5, the same being longitudinally spaced and angularly displaced from the nearest aperture 89 thereabove. On turning the index disk 86 to bring the latch 88 into longitudinal alignment with the aperture 89′, for instance, this being the aperture for the longest stroke in the operation of the apparatus, the pointer 87 on the index disk will be opposite the graduation 82 for large adults (Fig. 4) on the dial plate 80. The remaining apertures 89 (not shown) in the piston rod 24 are similarly longitudinally spaced and angularly displaced from each other and from the apertures 89 shown in Fig. 5, so that no two apertures 89 are longitudinally aligned and they are all so coordinated that, on alignment of the latch 88 with either one of these apertures 89, the pointer 87 is adjacent the proper graduation 82 on the dial plate 80. The forward end of the latch 88 is bevelled as at 90 (Fig. 5) so that the same will never interfere with the inward strokes of the piston 23, but will stop the latter on its outward strokes on registering with any one of the apertures 89. To prevent accidental turning of the index disk 86 in any one of its set positions, the same carries a spring-urged ball 91 which is adapted to spring into suitable depressions 92 in the head 53 and yieldingly lock the index disk in these positions.

Provided in the base 52 are suitable passages which connect the pressure cylinder 20 with a nipple 95 and the previously mentioned air inlet 36 (Figs. 3 and 6), as well as with valve chambers 96 in the base 52 (Fig. 8). More particularly, the clamp member 62′ in the pressure cylinder 20 is provided with a passage 97 (Fig. 5) which provides communication between the interior of said cylinder 20 and an annular chamber 98 in the base 52. The nipple 95, which is threaded into the base 52 (Fig. 6) and connected through a suitable hose connection (not shown) with the oxygen bottle 37 (Fig. 1), communicates with the chamber 98 through passages 99 to 107, inclusive (Figs. 6, 7 and 5), while the air inlet 36 is in permanent communication with the passage 101 (Fig. 6). The valve chambers 96 (Fig. 8) communicate with the pressure cylinder 20 through passages 108, 109 and 110 in the base 52 (Figs. 7 and 8) and through the passage 97 in the clamp member 62′ (Fig. 5). The base 52 is provided with further passages which connect the suction cylinder 21 with an inlet duct 111 (Fig. 8) and with the valve receptacle 47 (Fig. 5) previously mentioned in connection with Fig. 1. More particularly, the inlet duct 111 communicates with the suction cylinder 21 through passages 112 and 113, valve chambers 114, and passages 115 and 116 in the base 52 (Figs. 8 and 7), and through a passage 117 in the clamp member 62″ in said cylinder 21 (Fig. 5), while the valve receptacle 47 communicates with the cylinder 21 through passages 118 and 119 in the base 52 and through the passage 117 in the clamp member 62″ (Fig. 5).

The mixing valve 35, previously mentioned in connection with Fig. 1, is contained within the base 52 (Figs. 6 and 7) in a position therein to control the flow to the pressure cylinder 20 of air from the inlet 36 and of oxygen or another suitable gas from the nipple 95. The mixing valve 35 is in the form of a plug 120, rotatable in a bore 121 in the base 52 and provided with a peripheral port 122 (Fig. 6) which is so arranged with respect to the passages 100 and 101 that, as the plug is rotated to reduce the size of either one of these passages, the other passage is proportionately increased, or if the plug is rotated to completely shut off either one of these passages the other passage is completely open. However, in no event may both of the passages 100 and 101 be closed at the same time by the plug 120, there being suitable stop means provided (not shown) which limit the rotation of the plug in this respect. The valve plug 120 is provided on the outside of the base 52 with a handle 124 (Fig. 7) and with a graduated dial 125 (Fig. 3) which is associated with a pointer 126 and by means of which the proper volume of air or mixture of air and oxygen may be regulated. A spring-pressed ball 127 (Fig. 7) in the base 52 is engageable with recesses 128 in the rear face of the dial 125 yieldingly to lock the latter in its set positions. Depending on the setting of the valve plug 120, air or oxygen, or a mixture thereof, passes, during a suction stroke of the pistons, through the port 122 (Fig. 6) into the passage 102 and opens an inlet valve 129 in the passage 103, whereupon the gas may enter the lower end of the pressure cylinder 20 through the passages 104, 105, 106, 107 and 97 (Figs. 5 and 6). The inlet valve 129 is in the present instance in the form of a ball which normally rests on a conical seat 130 in an insert 131 in the passage 103, and is limited in its lift by a stop 132 on a screw plug 133. This valve serves to prevent air or gas being forced back into the passage 100 on the down stroke of the suction piston 20.

The valve chambers 96 in the base 52 (Fig. 8) communicate with a nipple 135 through passages 136, 137 and 138 in a casing 139 which is secured to the top of the base 52 by bolts 140, there being a gasket 141 interposed between said casing 139 and base 52. The nipple 135, which is screw-threaded into the passage 138, communicates with the face mask 41 through the inhalation tube 40 (Fig. 1).

On the inward or compression stroke of the pistons, the gas previously drawn into the pressure cylinder 20 is forced from the same through the passages 97 (Fig. 5), 110, 109 and 108 (Figs. 7 and 8), and opens inlet valves 145 in the valve chambers 96, whereupon the gas passes to the face mask 41 through the passages 136, 137 and 138, thence through the nipple 135 and the inhalation tube 40. The inlet valves 145 are in the present instance in the form of balls (Fig. 8) which normally rest on conical seats 146 provided by inserts 147 in the valve chambers 96. The lift of these valves 145 is limited by the ends 148 of a spring clip 149.

Also secured to the top of the base 52 by bolts 150 is another casing 151 (Fig. 8), having a passage 152 which provides communication between the inlet duct 111 in the base 52 and a nipple 153 which communicates with the face mask 41 through the exhalation tube 46 (Fig. 1). A gasket 154 is interposed between the casing 151 and base 52. Air or any other gaseous content of the patient's lungs is, on each outward or suction stroke of the pistons, drawn through the face mask 41 and exhalation tube 46 (Fig. 1) to the nipple 153 (Fig. 8), thence through the passages 152, 111, 112 and 113 and, after opening inlet valves 155 in the valve chambers 114, through the passages 115, 116 and 117 (Figs. 8, 7 and 5) to the interior of the suction cylinder 21. The inlet valves 155 are in the present instance in the form of balls which normally rest on conical seats 156 provided by inserts 157 in the valve chambers 114.

On the inward stroke of the pistons, air or any other gaseous content of the patient's lungs, previously drawn into the suction cylinder 21, is forced from the latter through the passages 117, 118 and 119, and opens the outlet valve 158 to escape into the atmosphere. The outlet valve 158 is preferably ball-shaped and is restricted in its lift by a pin 159.

Provisions are made to prevent in the cylinders 20 and 21 the creation of excessive positive and negative pressures, respectively, which might be harmful to the patient. To this end, positive and negative pressure relief valve units 160 and 161 (Figs. 2 and 8) are provided on the casings 139 and 151, respectively. The relief valve unit 160 provides a valve chamber 162 and an auxiliary cylinder 163, the former being formed by a sleeve 164 in the casing 139 and the latter by a cylindrical liner 165 in a tubular member 166 which is screwed with its bottom end into the casing 139. Interposed between, and separating, the valve chamber 162 and auxiliary cylinder 163 is a plug 167 which serves as a guide for the stem 168 of a relief valve 169 the face 170 of which normally rests on a seat 171, provided by an insert 172 in the valve chamber 162. The valve chamber 162 is vented through an opening 173. The upper end of the tubular member 166 threadedly receives a cap 174 by means of which the liner 165, plug 167, sleeve 164 and insert 172 are retained in end-to-end engagement and firmly secured to the casing 139. A gasket 175 is preferably interposed between the liner 165 and cap 174. Slidable in the cylinder 163 is a plunger 176 which is retained by a nut 177 on an annular shoulder 178 of the valve stem 168 and, hence, is movable with the valve 169. Interposed between the plunger 176 and a plug 179 in the cylinder 163 is a preloaded compression spring 180 which yieldingly urges the valve 169 against its seat 171. The plug 179 is slidable in the cylinder 163, and the compression of the spring 180 may be regulated by a set screw 181 in the cap 174. The valve stem 168 is centrally recessed as at 182 and has a transverse passage 183 to provide communication between the passage 136 and the lower side of the cylinder 163.

Should, during any part of an inward or compression stroke of the pistons 22 and 23, the pressure of the gas in the passages 136, 137 and 138, with which the inhalation tube 40 communicates through the nipple 135, exceed what is considered a "safe" pressure limit of 20 mm. of mercury column, for instance, the excessive pressure acts on the face 170 of the relief valve 169 and also on the plunger 176 in the cylinder 163 and lifts said valve to provide communication between the passage 136 and the vented valve chamber 162 until the pressure drops to the "safe" limit. While the pressure in the passages 136, 137 and 138 will soon drop when the relief valve 169 opens, due to the relatively large escape area between the valve seat 171 and the open valve 169, the excessively compressed gas in the cylinder 163 does not as quickly escape through the relatively narrow passage 182, 183 in the valve stem 168, wherefore the cylinder 163 acts also as a dash pot for the relief valve 169 on its closure. The dash pot effect upon the relief valve 169 may even be enhanced and regulated by restricting the cross-sectional area of the recess 182 in the valve stem 168 in advance of the transverse passage 183 therein by means of an adjustable needle valve 185.

The relief valve unit 161 comprises a valve chamber 190 and an auxiliary cylinder 191, the former being formed by a sleeve 192 in the casing 151 and the latter by a cylindrical liner 193 in a tubular member 194 which is screwed with its bottom end into the casing 151. Interposed between, and separating, the valve chamber 190 and cylinder 191 is a plug 195 which serves as a guide for the stem 196 of a relief valve 197, the face 198 of which normally rests on a seat 199, provided by an insert 200 in the valve chamber 190. Threaded over the top end of the tubular member 194 is a cap 201 which retains the liner 193, plug 195, sleeve 192 and insert 200 in end-to-end engagement and firmly secures them to the casing 151. A gasket 202 is preferably interposed between the liner 193 and cap 201. Slidable in the cylinder 191 is a plunger 203 which is retained by a nut 204 on an annular shoulder 205 of the valve stem 196 and, hence, is movable together with the relief valve 197. Interposed between the plunger 203 and a plug 206 in the cylinder 191 is a pre-loaded compression spring 207 which yieldingly urges the valve 197 against its seat 199. The plug 206 is slidable in the cylinder 191 and is adjustable therein by a set screw 208 to regulate the compression of the spring 207. The valve chamber 190 communicates through a passage 209 with the passage 152 which, as previously explained, forms a part of the communication between the face mask 41 and the intake side of the suction cylinder 21. The face 198 of the seated relief valve 197 is vented through a passage 210 and an air inlet 211 which is preferably screened at 212 to prevent the entry of dust and other atmospheric impurities. The valve stem 196 is provided with a central recess 213 and spaced transverse passages 214 and 215 which provide communication between the valve chamber 190 and the upper part of the cylinder 191.

Should, during any part of an outward or suction stroke of the pistons 22 and 23, the negative pressure in the passage 152, which communicates with the exhalation tube 46 through the nipple 153, exceed what is considered a "safe" negative pressure of 10 mm. of mercury column, for instance, the excessive negative pressure acts on the relief valve 197 as well as on the plunger 203 and lifts said relief valve from its seat, thereby establishing communication between the vent passage 210 and the communication line between the face mask 41 and the intake side of the suction cylinder 21 until the negative pressure in said communication line drops to the safe limit. While the negative pressure or partial vacuum in the passage 152 will soon be reduced when the relief valve 197 opens, due to the relatively large area between the valve seat 199 and the open valve 197 through which atmospheric air may enter, atmospheric air will not as quickly pass into the cylinder 191 through the relatively narrow passage 213, 214, 215 in the valve stem 196 and reduce the negative pressure in the cylinder 191, wherefore the latter acts also as a dash pot for the relief valve 197 on its closure. The dash pot effect upon the relief valve 197 may even be enhanced and regulated by restricting the cross-sectional area of the recess 213 in the valve stem 196 in advance of the transverse passage 215 therein by means of an adjustable needle valve 217.

The plunger 176 in the auxiliary cylinder 163 exposes to the pressures in the inhalation line of the apparatus a considerably larger area than the relief valve 169, with the result that the latter is as sensitive to gas pressure as a much larger valve, yet, when open, does not permit the escape of nearly as much gas as the larger valve. Hence, the provision of the plunger 176 in the auxiliary cylinder 163 not only renders the relief valve 169 far more sensitive to gas pressure than its actual size would permit, but also permits the design of said relief valve in such small dimensions that the amount of gas delivered to a patient's lungs is still adequate even when the relief valve is open in consequence of improper operation of the apparatus. Actual tests have shown that the relief valve 169 opens unfailingly at a maximum pressure in the inhalation line of the apparatus of approximately 20 mm. of mercury column and that the pressure in said line hardly increases beyond this maximum even when the piston 22 is stroked with unreasonable vigor. This maximum pressure at which the relief valve 169 opens and which is hardly exceeded in the inhalation line under any circumstances, is quite harmless to human lungs, wherefore the apparatus may safely be used by an unskilled operator, if an emergency demands this. The small dimensions of the relief valve 169 also make for a condensed construction of the relief valve mechanism. Furthermore, the restricted passage 182, 183 through the valve stem 168 delays the pressure build-up in the auxiliary cylinder 163 sufficiently so that harmless and often unavoidable momentary fluctuations of pressure near the maximum in the inhalation line do not force the relief valve 169 open, thus avoiding any surging of the relief valve between its closed and open positions. The explained delay in the pressure build-up in the auxiliary cylinder 163 has the effect that even on a very rapid increase of the pressure in the inhalation line to and beyond the maximum the area of the relief plunger 176 exposed to the pressure is only gradually subjected to the increasing pressure, with the result that the relief valve 169 is gradually lifted from its seat to an extent solely determined by the pressure on one side of the valve and the compression of the spring 180 on the other side of the valve. On the other hand, the explained dash-pot effect of the auxiliary cylinder 163 upon the relief valve 169 on its closure causes the latter to close gradually and become seated lightly and quietly, thus causing hardly any wear to the relief valve over a long period of use. The explained cushioned performance of the relief valve 169 is also inducive to gradual, rather than abrupt, changes in the pressure in the inhalation line at those times when said valve performs, thus making for an even flow of gas to the patient's lungs under all circumstances.

Like advantages are secured by providing the auxiliary cylinder 191 and the plunger 203 in the negative pressure relief valve unit 161. Actual tests have shown that the relief valve 197 opens unfailingly at a maximum negative pressure in the exhalation line of approximately 10 mm. of mercury column, and that the negative pressure in this line hardly increases beyond this maximum even when the piston 23 is stroked with unreasonable vigor. A negative pressure of 10 mm. of mercury column is quite harmless to human lungs, wherefore the apparatus is safe even in the hands of an unskilled operator. Surging of the relief valve 197 between its closed and open positions in consequence of harmless momentary fluctuations of the negative pressure in the exhalation line is avoided due to the delayed negative pressure build-up in the auxiliary cylinder 191 through the restricted passage 213, 214, 215 in the valve stem 196. The delayed negative pressure build-up in the auxiliary cylinder 191, and the explained dash pot effect of the latter upon the relief valve 197 on its closure, render the performance of the latter valve as cushioned as that of the positive relief valve 169, with the result that the relief valve 197 is hardly worn over a long period of use and the flow of the spent air or liquid from the patient's lungs is fairly even under all circumstances.

While the relief valves 169 and 197 are comparatively small in size and accordingly light in weight, their weight is supplemented by that of their respective plungers 176 and 203. This increase in the weight of the relief valves is advantageous inasmuch as a heavier, spring-closed valve will, when subjected to excess pressure, not suddenly surge wide open and fluctuate, but will open more gradually and be more steady when open, than a lighter valve.

Part of the force required to open either relief valve 169 or 197 may be supplied by a compression spring which acts counter to the spring that holds the valve closed. Thus, a compression spring 225 is shown in Fig. 9 which is interposed between the plug 167 and the relief plunger 176 of the positive pressure relief valve unit 160, said spring acting counter to the compression spring 180. With this modification, the force of the valve closing spring 180 has to be increased to compensate for the counter force from the valve-lifting spring 225.

I claim:

1. In a resuscitator having sucking and blowing cylinders, pistons and valves therefor, and conduits connecting the cylinders with the patient, the combination of, a vented chamber for each of said conduits, a valve in each chamber normally yieldingly closed to shut off said chamber from the connected conduit and opened by excess pressure in the latter, a cylinder having a sealed end into which said valve extends, and a plunger slidable in said cylinder and mounted on said valve, the latter having a passage providing permanent communication between said conduit and sealed cylinder end.

2. In a resuscitator having sucking and blowing cylinders, pistons and valves therefor, and

conduits connecting the cylinders with the patient, the combination of, a vented chamber for each of said conduits, a valve in each chamber to shut off the latter from the connected conduit when closed, a cylinder having a sealed end into which said valve extends, a plunger slidable in said cylinder and mounted on said valve, and a compression spring in said cylinder bearing with one end against said plunger to close said valve, the latter having a passage providing permanent communication between said conduit and sealed cylinder end.

3. Pressure relief valve mechanism as set forth in claim 2, further including another but weaker compression spring in said cylinder also bearing against said plunger and tending to open said valve.

4. In a resuscitator, having two pumps each having an inlet and an outlet, a face mask, and inhalation and exhalation conduits connecting said mask with the outlet of one pump and the inlet of the other pump, respectively, the combination of vented chambers open to said conduits, respectively, a valve in each chamber normally yieldingly closed to shut off said chamber from its respective conduit and opened by excessive pressure in the latter, two cylinders each having a sealed end into which a valve extends, and a plunger in each cylinder mounted on the valve extending thereinto, each valve having a passage providing permanent communication between the sealed end of its respective cylinder and the corresponding conduit.

5. In a resuscitator, having a pump having an inlet and an outlet, and a conduit connecting

said inlet with a patient, the combination of a vented chamber open at one side to said conduit, a valve in said chamber having a stem and being normally yieldingly closed to shut off said chamber from said conduit and opened by excessive negative pressure in the latter, a cylinder at another side of said chamber into which said valve stem extends, the cylinder end most remote from said chamber being sealed, and a plunger slidable in said cylinder and mounted on said valve stem, said valve having a passage providing permanent communication between said conduit and sealed cylinder end.

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