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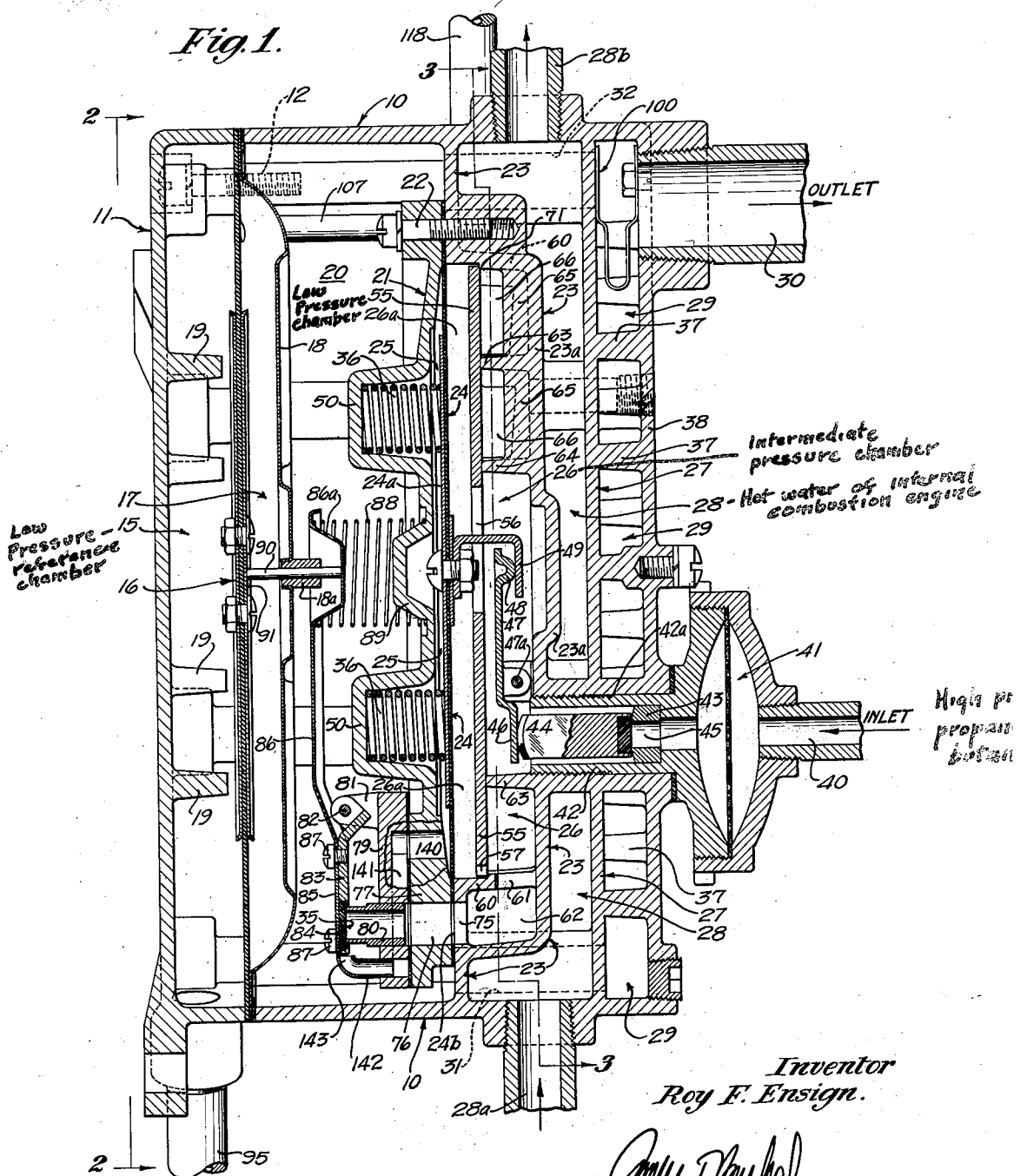
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2,248,222

LIQUID GAS CONVERTER AND REGULATOR

Filed May 27, 1938

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

Fig. 2.

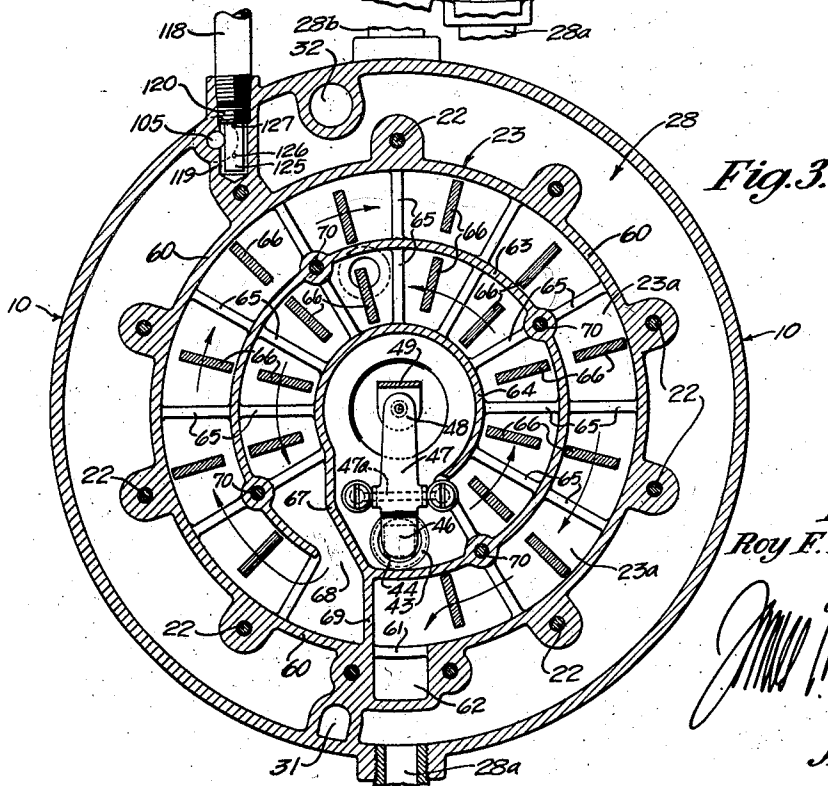
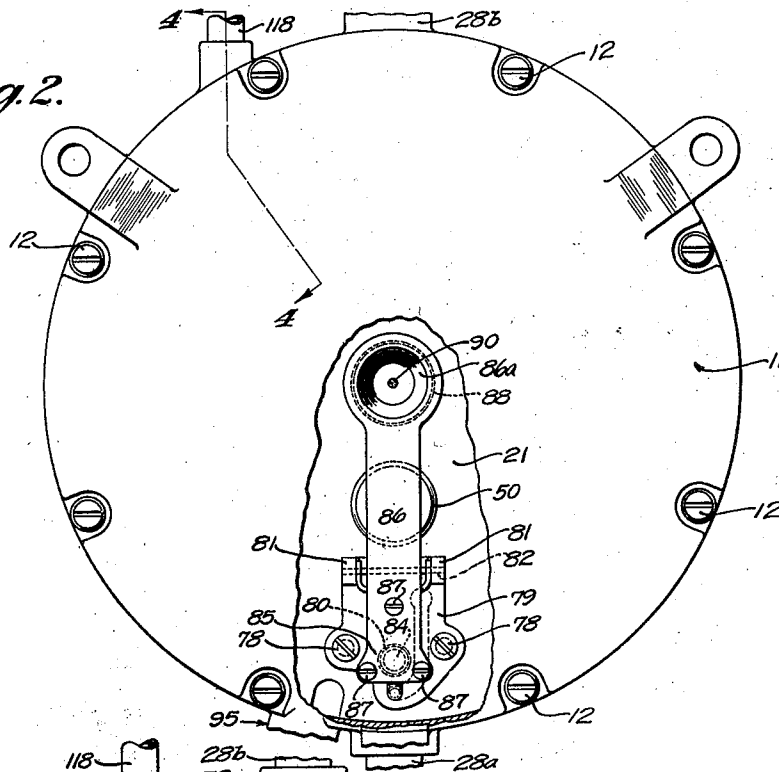


Fig. 3.

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3 Sheets-Sheet 3

Fig. 5.

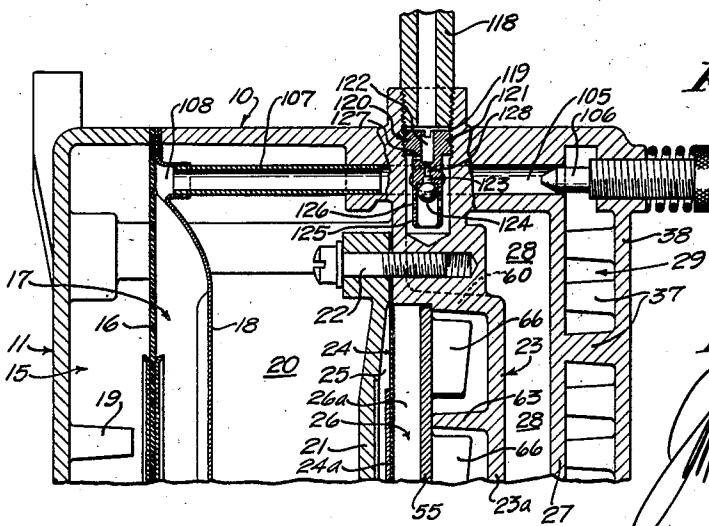
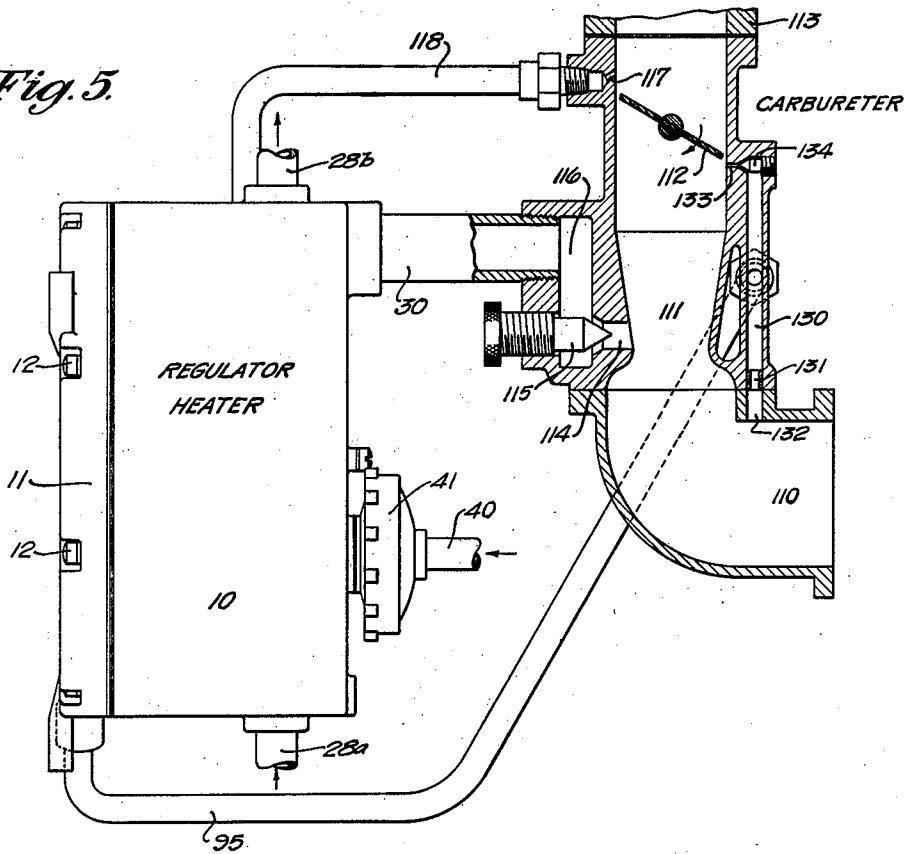


Fig. 4.

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LIQUID GAS CONVERTER AND REGULATOR

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Application May 27, 1938, Serial No. 210,441

16 Claims. (Cl. 257-2)

This invention has to do with devices designed for regulating the pressure of fluid initially derived from a high pressure source. The invention is generally applicable to any situation wherein it is desired to utilize pressure fluid and feed it at a uniform regulated and relatively low pressure. However, the typical inventive embodiment hereinafter described has been designed specifically for feeding an internal combustion engine or its carburetor, with fuel gas; and the invention will therefore be explained in detail with reference to combination or use with a gas engine carburetor, but without implied limitation except in such specific particulars as may be hereinafter stated in the following claims.

Of late years it has become more or less common to use, for engine fuel purposes, certain highly volatile fuels, such as propane and butane hydrocarbons. At normal atmospheric pressure butane vaporizes at about 32° F., propane at about minus 50° F. The vapor pressure of propane at common atmospheric temperatures may run as high as 175 lbs. per sq. in. or more; the vapor pressures of butane at common atmospheric temperatures are less than that of propane, running down to zero pressure at about 32° F. The fuels now commercially supplied may be either substantially pure propane or butane, or more commonly a mixture. Accordingly, in order to be successful in operation, devices of the character of this invention should be able to handle fluids whose initial pressure varies quite widely, and nevertheless to deliver the fluid at the predetermined desired low pressure within very small limits of variation and at wide variations in operating speeds.

Another problem encountered in the handling of such fuels is that of supplying a substantially dry gas at the predetermined low pressure. Especially when atmospheric temperatures are relatively low, and especially with fuels largely characterized by butane, the expanded low pressure gas is likely to be very wet, or even in large proportion not to be vaporized at all. It is consequently one of the problems inherent in devices of the nature here under consideration to provide an effective and efficient means of heating the expanded fluids to insure substantially dry vaporization.

The more particular objects and corresponding accomplishments of the present invention will be the best gathered from the following detailed description of a preferred embodiment; but I may state initially that a general object of the

invention is the provision of pressure regulating and controlling means, of such nature and having such controls, that the pressures at which the fuel is delivered may be maintained within very small variations from a predetermined figure, over wide ranges of all the operating conditions, and under very accurate control by the operating conditions of the engine. It is also an object to provide an effective means for heating and vaporizing the fluids concurrently with their pressure reduction; and in that connection it is a further object to provide such means of control and sequences of heating that the vaporization of liquid within any of the pressure stages will not materially affect the final outlet pressures. And it is a further object to provide a device of high operating capacity in small and compact size and in a unitary structure.

The general nature of the invention itself, its objects and accomplishments, will be best understood from the following detailed description of the embodiment which at present I prefer, and illustrated in the accompanying drawings, in which

Fig. 1 is a vertical longitudinal central section showing the preferred form of my invention; Fig. 2 is an end elevation, partially broken away, at reduced scale and taken as indicated by line 2-2 on Fig. 1;

Fig. 3 is a cross section taken as indicated by line 3-3 on Fig. 1, also at reduced scale;

Fig. 4 is a detailed section taken as indicated by line 4-4 on Fig. 2, at the scale of Fig. 1; and

Fig. 5 is a diagram illustrating the interconnections between the device and a typical gas carburetor.

As shown in the drawings, the device here illustrated has a substantially cylindric housing, which is preferably formed mainly in one integral cast portion 10, and a relatively smaller portion 11 which is secured to portion 10 as by the screws shown at 12. Within this housing there are formed the following described main chambers, which preferably bear the spacial relationships to each other that are illustrated in the drawings, and described hereinafter; although as will be apparent from the following description these relationships may be varied. As shown specifically in the drawings, referring now most particularly to Fig. 1 and progressing from left to right, the chamber 15 is enclosed by the body portion 11 and the low pressure diaphragm 16. The chamber 15 may be aptly characterized as the low pressure reference chamber. At the right hand side of low pressure

diaphragm 16 there is a low pressure diaphragm chamber 17, enclosed between diaphragm 16 and a wall 18 which is here shown as being made of pressed sheet metal with its peripheral edges clamped, along with the peripheral edge of diaphragm 16, between the two housing portions 10 and 11. Diaphragm 16, as will hereinafter appear, moves under pressure toward the left in Fig. 1, and housing portion 11 is provided with stop lugs 19 to limit such movement.

The main chamber next to the right of wall 18 is the low pressure chamber 20, whose walls are formed mainly by wall 18, the peripheral walls of main housing portion 10, and an interior transverse wall 21, the detailed nature of which will be hereinafter pointed out.

The interior wall 21 is secured, as by screws 22 to another, and preferably integral, interior transverse wall of main housing 10 and designated generally by the numeral 23. The intermediate pressure diaphragm 24 is peripherally clamped between walls 21 and 23; and the walls and diaphragm form an intermediate reference pressure chamber 25 at the left of diaphragm 24, and an intermediate pressure chamber to the right of diaphragm 24 and generally indicated by the reference numeral 26.

Between the wall 23 and the wall 27 next to the right in Fig. 1, there is formed the heat medium chamber 28, with inlet at 28a and outlet at 28b. Hot water from the engine cooling system may conveniently be used. Immediately to the right of wall 27 is a final low pressure chamber 29 from which the gas outlet 30 leads at the top. This final low pressure chamber 29 is interconnected with low pressure chamber 20 by the passages 31 and 32 (hereinafter described) so that in some respects the chambers 29 and 20 together form a low pressure chamber. The low pressure chamber, thus formed, is preferably divided into the two chambers 20 and 29, in this specific and illustrative embodiment of the invention, for particular reasons of design and construction as will hereinafter appear, and in order to place the low pressure chamber or a portion of it, immediately next a heat transfer wall of the heat medium chamber 28, while the opposite head transfer wall of that heat medium chamber also forms a wall of the intermediate pressure chamber 26. It is one of the features of this invention that the heat medium chamber is thus located directly between the intermediate pressure chamber and the low pressure chamber, for efficient transfer of heat to the fluids in both those chambers. While the heat chamber thus might be arranged directly between the intermediate pressure chamber 26 and the low pressure chamber 20, the preferred form of structure, in which the low pressure regulating valve 35, the intermediate reference pressure chamber 25, and the diaphragm loading springs 36, are all placed in or formed by wall 21, make it desirable that the low pressure chamber 20 have, in effect an extension in the low pressure chamber 29 which becomes a low pressure heating chamber or passage. This low pressure heating chamber 29 is shown in the drawings as being equipped with a plurality of heat conducting studs or ribs 37 for the efficient conduction of heat from wall 27 to the fluids in chamber 29, and to the exterior end wall 38 and thence to the fluids.

The initial high pressure inlet is at 40, to a strainer structure 41 that need not be described in detail, but which involves an inlet nipple 42

screw-threaded into, and reaching from the exterior of the housing through, a cored passage 42a which reaches from the exterior housing wall 38 to the intermediate pressure chamber 26. Nipple 42 carries a suitable valve seat 43 upon which the valve plunger 44 operates, moving toward the right in Fig. 1 to close the valve passage 45 in the seat. Valve 44 is pressed on to its seat by the operation of the end 46 of valve lever 47 pivoted at 47a to the wall 23. Valve lever 47 lies within the intermediate pressure chamber 26, and its other end 48 is acted upon by a stirrup 49 attached to diaphragm 24; the whole arrangement being such that when diaphragm 24 moves to the left, by reason of pressure in chamber 26, the valve 44 will be moved to the right and seated.

Springs 36, housed in recessed portions 50 of the wall structure 21, bear on a plate 24a which is attached to diaphragm 24, and tend to move diaphragm 24 toward the right and therefore to allow valve 44 to open under the inlet pressure. The force exerted by springs 36 on diaphragm 24 and the pressure in chamber 25 mainly determine the pressure which is to be carried in the intermediate pressure chamber 26. For instance, it may be desired to carry an intermediate pressure in chamber 26 of about 5 lbs. per sq. in. above atmosphere. In the particular embodiment here described, the pressures in chamber 25 are usually about atmospheric. Springs 36 will thus be chosen to exert on diaphragm 24 a total pressure amounting to about 5 lbs. per effective sq. in. of the diaphragm. The forces then acting on the diaphragm are the spring forces, the substantially atmospheric pressure in 25, and the intermediate pressure in chamber 26. The only other force which acts on the system is the high pressure acting on valve 44. In the proportions shown (and it may be remarked that Fig. 1 of the drawings shows a regulator in full size and of a capacity for feeding an engine of 100 H. P. or more) the effective area of diaphragm 24 may be taken as about 5" diameter and that of valve 44 about 1/4" diameter. The relative areas are about 1 to 400. Variation of the initial inlet pressure by as much as 100 lbs. will vary the intermediate pressure in chamber 25 by about only 1/4 lb. per sq. in. The immediate foregoing, of course, relates to the static condition of the system; flow of fluid through the system at any large velocity will cause some variation in the pressure obtaining in chamber 26, and this will be spoken of later. When the fluid pressure is reduced at valve 44 the accompanying expansion of the fluid causes a corresponding drop in temperature, unless the fluid is concurrently heated. Heating of the fluid, at the intermediate pressure, is accomplished by heat conduction directly through the wall 23, the fins and ribs attached to that wall, and plate 55 which lies in contact with the fins in the chamber 26. The plate 55 more or less divides the chamber 26 into two sub-chambers, one of which, 26a, lies between plate 55 and diaphragm 24. The plate has an opening 56 at its center through which stirrup 49 reaches, and has a notched opening 57 at its lower edge for free passage of liquid which may accumulate in the bottom of the chamber. Altogether, the plate 55 does not interfere with pressure equilibrium between the part of the chamber to the left of the plate and that to the right; but at the same time it serves to maintain a relatively quiet and relatively non-circulating body of

fluid in the sub-chamber 26a directly at the face of diaphragm 24.

The other part of chamber 26, between plate 55 and the wall structure 23, is provided with a system of fins and ribs for efficient heat conduction, and these are best shown in Figs. 1 and 3. As will be understood from inspection of these two figures the wall structure 23 includes a dish-shaped portion having a circular peripheral wall 60, which is unbroken except for the outlet opening 61 which leads from the lower part of chamber 26 at the right of plate 55 into an outlet chamber or passage 62, from which the fluids flow as hereinafter described in more detail to the low pressure regulator valve 35. The dish-shaped portion of wall structure 23, together with the diaphragm 24, encloses the chamber 26; and, as shown in Fig. 1, this dish-shaped portion projects into the heat chamber 28 and thereby increases the heat transfer area presented to the heating medium in that chamber. Within this dish-shaped wall structure, the wall 23 has a plurality of circular fins 63 and 64 whose height is such that plate 55 rests directly against their edges; and a plurality of radial ribs 65 of height approximately half the distance between plate 55 and the wall 23a, which latter forms what might be called the bottom of the dish-shaped portion of wall structure 23. Plate 55 is also provided with a plurality of radial ribs or lugs 66 which are not of sufficient dimension to touch the wall 23a; the ribs 65 and 66 thus offering an enlarged heat transfer surface without too materially interfering with circulation of the fluids through the chamber. Fluid enters the chamber at the valve 44 through nipple 43 and thence its main flow is in the direction indicated by the arrows in Fig. 3. The inner circular fin 64 is not completely circular but is broken at its bottom where the valve lever 47a passes through the opening thus formed (see Fig. 3) and the central opening 56 in plate 55 allows the fluids free access to the subchamber 26a next the diaphragm 24. But the main circulation of the fluid does not travel along the path just stated, being rather through the spaces between the circular fins in the direction indicated in Fig. 3. Having traveled through almost a complete circle from valve 46 between the two circular fins 63 and 64 the fluid then encounters the wall 67 which, as shown in Fig. 3, interconnects inner circular fin 64 with outer circular fin 63, and passes through the opening 68 which is formed by a break in the outer circular fin 63 near its bottom. Here an interconnecting wall 69, between outer circular fin 63 and the outer circular wall 60, forces the fluid to travel in a reverse circular direction, as indicated by the arrows, between the outer circular fin and the outer wall 60, to reach the discharge opening 61, which leads to the low pressure regulator valve 35.

Plate 55 is held in place by screws which are not shown in Fig. 1, but whose position is indicated in Fig. 3 at 70, the plate being thus held in good heat conducting contact with the fins 63 and 64, and also with the shoulder 71 of the circular wall 60. To allow free escape of liquid from the bottom of sub-chamber 26a to outlet 61, the loose fitting of plate 55 may suffice, but the notch 57 is shown for that purpose. However, the notch or any equivalent opening at the bottom of plate 55 should preferably not be large enough to set up any substantial circulation of fluids in sub-chamber 26a; only large

enough to prevent liquid from progressively accumulating in sub-chamber 26a.

The wall structure 60—23a and the fins and ribs, and also plate 55, are constructed of a good heat conducting material; as are also the wall 27, studs 37 and wall 38. The other walls and parts of the structure need not necessarily be of heat conducting material; but they are, in the particular design here shown. The result is that the fluids are more or less heated throughout the whole apparatus, but are particularly heated in the chambers 26 and 29.

Thus, the fluids, whether vapor or liquid, or a mixture, are heated as they pass through the intermediate pressure chamber 26, and then pass from that chamber through the outlet opening 61 into passage 62 formed in the lower part of the wall structure 23. Here they pass through the opening 75 in that wall structure, through a hole 24b in diaphragm 24 and thence through an opening 76 in a thickened part 77 of the wall structure 21. Attached to this wall part 77 by screws 78 (see Fig. 2) is a small casting 79 which carries the valve seat nipple 80 and also has pivot lugs 81 to carry pivot pin 82 for the pivoted valve arm 83. The outer swinging end of valve arm 83 has in it a recess or opening which carries the valve gasket 84 that seats on the end of valve seat nipple 80. The back side of the gasket opening in arm 83 is closed by, and the gasket is backed up by, the portion 85 of a valve lever 86 which is conveniently made of sheet metal and attached to valve arm 83 by screws 87. This valve lever is ribbed or flanged, as indicated in Fig. 1, to stiffen it, and at its end has a circular embossed portion 86a which forms a centering boss for the coiled compression spring 88 which is confined between the end of lever 86 and the wall structure 21, being centered on that wall structure by the boss 89. Bearing against the end of lever 83 is a longitudinally movable pin 90, whose other end contacts a plate 91 attached to the low pressure diaphragm 16. Pin 90 passes through a guide bearing 18a set in the wall 18. It is preferably made to fit that guide bearing with a snug sliding fit, but it is not necessary that the passage of pin 90 through the wall 18 be fitted fluid-tightly, as a small or minor leakage at that point is of no material consequence. As pointed out hereinafter, the operating pressures obtaining in chambers 17 and 20 may be in most instances very nearly the same, because chamber 17 is connected with the composite low pressure chamber of which 20 forms a part. In the specifically preferred operation of this device, the operating pressures obtained in chamber 17 are preferably somewhat different from those which may obtain in chamber 20, but the differences are not large enough to induce any materially important flow of fluid through the guide bearing 18a if it leaks a little.

Generally speaking, the fluid pressure maintained in low pressure chamber 20 will depend upon the forces acting on low pressure diaphragm 16 and on low pressure regulating valve 35. Seeing that the final outlet pressure from chamber 20 is desired to be maintained with reference to atmospheric pressure (and also in this particular case quite close to it) the reference pressure chamber 15 at the left side of low pressure diaphragm 16 is connected by the pipe or tube 95 either to atmosphere or to a modified atmospheric pressure. The right hand side of diaphragm 16 is acted upon by the pressure in

chamber 17, which pressure, until we consider certain particulars and modifications, may be taken to be substantially the pressure in the low pressure chamber 20. The reference pressure tends to press the diaphragm toward the right and thus to open the low pressure regulating valve 35. Pressure in chamber 17, and spring 88, tend to move the diaphragm toward the left and close valve 35. Thus, in general, the pressure exerted by spring 88, per effective square inch of diaphragm 16, will determine the difference between the pressures in chambers 15 and 17 at which the diaphragm will act to close valve 35, or in other words, will determine the sub-atmospheric pressure per square inch which will normally be maintained by the action of the diaphragm and valve in the chambers 20 and 17. Applied to use on an internal combustion engine carbureter, the low pressure end of this regulator will be set to deliver normally at a slight sub-atmospheric pressure, say $\frac{1}{4}$ to $\frac{1}{2}$ inch of water, below atmosphere. Assuming that the pressure at valve 35 varies by as much as one-fourth lb. per sq. in., the effective area ratio between diaphragm 16 and the valve area at 35 (about 500 to 1) will maintain pressure variations in chamber 20 and chamber 17 within about $\frac{1}{2000}$ of a lb. per sq. in.

It will of course be understood that, in the foregoing, I am describing a specific arrangement designed particularly to produce a sub-atmospheric delivery pressure. The invention, however, is not at all necessarily limited to operating in that manner, and can operate to produce any delivery pressure having any desired relation to the reference forces, which again may be any suitable forces. For instance, if spring 88 be attached to produce on diaphragm 16 a pull to the right, the resultant delivery pressure will be above atmosphere. In the drawings such an arrangement may easily be visualized by supposing spring 88 to be a tension spring secured to lever 86, with the lever and pin 90 and diaphragm 16 connected together.

Even larger variations of pressure in intermediate chamber 26 will not seriously affect the pressures in 20; and therein lies one of the reasons for heating the fluids in the intermediate pressure chamber as well as in the final low pressure chamber. In normal operating conditions most of the liquid may be vaporized in chamber 26. If a fairly large amount of liquid should be present in that chamber when the engine demands were suddenly reduced, vaporization might raise the pressure in 26 considerably. But, because that vapor is produced at a point where it is subject to the control of the low pressure regulator before reaching the low pressure chamber, any such increase in pressure will cause only a very slight increase in the final delivery pressure.

From the low pressure chamber 20 the fluids then pass through the cored openings 31 and 32, through the wall structures 23 and 27 and the intermediate heat chamber 28, to the final low pressure heating chamber 29. One of these openings, 31, is located near the bottom of the structure, so that any liquid tending to accumulate in chamber 20 will pass through that opening into the lower portion of the final low pressure chamber 29. That liquid, and the vapors from it, must then necessarily pass through the whole vertical extent of the final heating chamber 29 in order to reach the outlet 30; and thereby it is insured that any liquid, whether in solid liquid

form or in the form of suspended mist, will become thoroughly and dryly vaporized by the time it reaches outlet 30.

On the other hand, it is not desirable to pass dry vapors through the final heating chamber 29, both because it is unnecessary to waste heat in further heating those dry vapors, and because the enforced passage of an unnecessarily large volume of fluids through a final heating chamber of a size and heat transfer capacity best and most efficiently suited to heat and vaporize a smaller amount of fluid would set up velocities resulting in an undesirably large difference in pressure between low pressure chamber 20 and the final outlet at 30. Consequently the dry vapor passage 32 is provided to intercommunicate chambers 20 and 29 near their tops. Furthermore, the passage 32 is made relatively large while the passage 31 is relatively somewhat restricted, for purposes which will appear. And a light spring flap valve 100 is applied to the outlet end of passage 32, not necessarily tightly fitting, and adapted to be opened by a slight difference of pressure between passage 32 and outlet 30. The pressure difference necessary to open the valve 100 is related to the pressure difference necessary to draw fluids through the final heating chamber 29. The spring pressure of the valve is preferably so determined that the following actions take place. At low operating ranges, when the fluid velocities through the device are relatively small the pressure differences not then being sufficient to open valve 100, all of the fluid, including both dry vapor and liquid, will be drawn through the lower passage 31 and the final heating chamber 29. At higher ranges of operation, engendering a greater pressure difference between passage 32 and outlet 30, valve 100 will be opened so that the dry vapors from chamber 20 will pass directly to the outlet through passage 32, while all the liquid which falls to the bottom of chamber 20 will be drawn through the lower passage 31 and thence through the final heating chamber.

From what has been said it will be understood that there will always be some pressure difference between chamber 20 and the final outlet 30. At low ranges of operation this pressure difference may be so slight as to be negligible, in an apparatus of any given size. And thus, if the apparatus and its passages be made large enough in proportion to the amount of fluid passing through it, it might be quite practicable to expose the right hand side of diaphragm 17 directly to the pressure in chamber 20 (that is, to do away with the supporting wall 18) but, among its other objects, one object of the present invention is to make the apparatus as a whole compact and small and of high performance capacity. Consequently, it is preferred to take cognizance of the difference in pressure between chamber 20 and outlet 30, to segregate the chamber 17 next diaphragm 16, and to apply to chamber 17 as near as possible the pressure actually existing at the outlet under all the varying conditions of operation. Another reason, later appearing, for separating chambers 17 and 20, is to facilitate application of the engine or carbureter controls.

Fig. 4 shows in detail the connections made for the purpose just stated. A cored or drilled passage 105 connects with the outer end of chamber 29 at a point reasonably close to outlet 30 and to passage 32, which is also close to outlet 30 (see Figs. 3 and 4). This passage 105 is controlled by an adjustable needle valve 106 which, how-

ever, is preferably of such size with relation to passage 105 that the passage can never negligently be entirely closed. The purpose of regulation at this point will appear. Passage 105 is cored across the heat medium chamber 28 and is extended across chamber 20 by the inserted tube 107 which is at its end connected into a nipples opening 108 in the wall 18 near its periphery. With valve 106 wide open the intercommunicating passage thus provides for free and open equalization of pressure between chamber 17 and substantially the outlet 30. If it be desired at all times to govern the pressure in chamber 17 by the pressure at the outlet, it would only be necessary to provide the intercommunicating passage 105 or 107. But in many instances and particularly in feeding the carbureter of an internal combustion engine it is desirable to vary the pressure in diaphragm chamber 17 and thereby to controllably vary the outlet pressure which feeds the carbureter. Suitable provisions are accordingly made.

Fig. 5 shows the operating relationships between my regulator heater and a typical simple form of gas carbureter. In this figure the regulator heater is shown in elevation and so labeled and the carbureter is labeled. The simple form of carbureter here shown has an air intake 110, a Venturi passage 111 and throttle 112, the passage through the carbureter connecting with the engine manifold 113. At a point of high velocity in the Venturi passage the gas port 114 communicates therewith, regulable by valve 115, and a gas passage 116 communicates the outlet pipe 30 of the regulator with the valve 115 and port 114. Above the throttle (between the throttle and the engine) there is a small port 117 which is connected by tube 118 to the parts of the regulator now to be described. As shown in Fig. 4 the tube 118 is threaded into a bore 119, and also in this bore under the end of tube 118 there is an apertured plug 120. This plug has an upper head 121 threaded tightly into the bore. A longitudinal passage 122 leads through the plug to a downwardly facing valve seat 123, and a ball valve 124 is adapted to close the passage by seating upwardly on that seat. The ball is confined within a tubular extension 125 of the plug, the lower end of the extension being formed, as by crimping, to prevent the ball dropping out of its end. There are apertures at 126 through the tubular wall of this extension above its lower end, to provide fluid passages from passage 122 to the exterior of the plug extension when the ball is in its lowermost position. The lower extension portion of the plug is smaller than the bore 119, and that bore at a point below the plug head 121 communicates with the passage 105. This communication, by intersection of the two bores 105 and 119, is best shown in Fig. 3.

Immediately under the head 121 the plug has a small calibrated orifice 127 which communicates the plug bore 122 with the lower part of bore 119. The lower part of the plug passage 122, at or near the valve seat 123, is also suitably calibrated at 128. The orifice at 127 will ordinarily be smaller than the orifice at 128.

Assuming that the engine fed by the carbureter is being turned over for starting with the throttle only partially open, the manifold depression existing inside the throttle valve is then fairly high. That depression, communicated via tube 118 to the plug 120 may (but not necessarily) have the effect of drawing the ball 124 upward onto its seat; but, even if the ball is thus raised, the time

interval necessary to lower the pressure in the manifold and raise the ball is sufficient, with the suction acting through both the orifices 127 and 128, to reduce the pressure in chamber 17 to something below atmosphere, so that the regulator and carbureter are made ready to go into almost instant action. It may be, as hereinafter pointed out, that the ball valve will only be seated by the higher depressions attendant idling operation; but even if the ball is seated by the starting suction, the described action will take place.

When the regulator is standing idle, fuel will normally be present in the intermediate pressure chamber 26 at the predetermined pressure, say 5 lb. per sq. in. But the pressure existing in the low pressure chamber 20, 29, and also in the diaphragm chamber 17, will be atmospheric pressure, because that is the pressure which then exists at the outlet 30. Consequently, whenever standing idle, the low pressure control valve 35 will be closed, as will also the intermediate pressure control valve 44. On starting the engine the depression existing in the venturi 111 is communicated to the regulator outlet 30. This depression may not be very great because the throttle may not be very wide open and the engine speed is low. Consequently it is helpful to the starting operation that the pressure in diaphragm chamber 17 be quickly reduced, and momentarily reduced even to a point lower than what it would otherwise be in normal operation; because by that reduction of pressure in chamber 17 the low pressure control valve 35 is opened quickly and allows the low pressure chamber 20 and 29 to be filled with fuel at pressures somewhat higher than would otherwise be the case. The operation thus results in the carbureter being momentarily fed with fuel at a somewhat high pressure, thus facilitating engine starting.

As soon as the engine has started, then the function of ports just described is to regulate and control the outlet or delivery pressure of the regulator in accordance with varying conditions of engine operation. If the engine is idling, a relatively high depression again exists above the throttle. This relatively high depression is sufficient to raise or keep the ball valve 124 on its seat and is therefore communicated to the passage 105 and 107 and chamber 17 only through the small calibrated orifice 127. The general effect of the communication of that depression to chamber 17 is, of course, to lower the pressure in chamber 17 and to operate the diaphragm to open the low pressure valve 35 and thus increase the delivery pressure of the regulator. But, due to the communication 105, 107 between the regulator outlet and chamber 17, the pressure in diaphragm chamber 17 tends always normally to be the pressure existing at the regulator outlet. Adjustment of the valve 106 adjusts the relation between the size of orifice 127 and the effective size of the communication passage 105, and thus adjusts and regulates the amount of outlet pressure variation which will be effected by any given depression existing at the carbureter port 117. In practice valve 106 will be regulated so that, in idling operation, the pressure in diaphragm chamber 17 will be modified (lowered) sufficiently to make the regulator deliver fuel at a pressure sufficiently higher than its normal, sub-atmospheric, delivery pressure to give the carbureter sufficient fuel to make the slightly rich mixture desired for idling. The outlet pressure of the regulator during idling operation may thus be

close to or even somewhat above atmospheric in order to insure proper operation at idling, when the velocity depression existing in venturi 111 may be so slight that the carbureter would not draw in any gas at all if the regulator outlet pressure were sub-atmospheric in any substantial amount.

With the engine operating in its medium power ranges and speeds, with the throttle somewhat open, the depression at port 117 falls, and the modifying influence of that depression upon diaphragm chamber 17 and the regulator outlet pressure becomes correspondingly less. The adjustment of valve 106 may be such that, at medium operating ranges, the depression effect from port 117 is more or less negligible. But, speaking in a general way, during any operation of the engine, there is always some depression existing at port 117 and consequently the regulator always delivers fuel at a pressure somewhat above that which it would normally deliver (the sub-atmospheric pressure for which it is set) if it were not for the modifying influence under consideration.

These modifying influences may be so predetermined and adjusted so as to amount to substantially nothing more than an idling control. The ball valve 124 may be made of such size and weight, compared with the size of calibrated orifice 128, that the ball will be maintained upward on its seat during all the varying phases of engine operation; thus making the small calibrated orifice 127 the only communication of manifold depression with the regulator for modifying purposes during all conditions of engine operation. If that be the case, then the modifying effect of the manifold depression may be more or less negligible, or at least comparatively slight, except at idling.

On the other hand, the ball valve may be made of such relative size and weight that, when the manifold depression falls to some predetermined figure, the ball will fall from its seat and open the larger calibrated orifice 128; so that, at that predetermined, and any lower, manifold depression, the modifying influence will be increased because of the increased effective size of the orifices through which the depression influence is exerted. Thus, for instance, by proper calibration of the parts, the ball may fall off its seat at some predetermined condition of engine operation, such as the relatively full load low speed condition when the manifold depression is relatively low; and, by operating thus, the effective modification of the regulator outlet pressure will be increased to feed fuel at a relatively high pressure during the periods of heavy load operation of the engine.

The reference pressure operating upon diaphragm 16 is normally atmospheric. But, because of the fact that the air pressure in the air intake passages and in the venturi of a carbureter may vary substantially at different speeds of operation, particularly if the carbureter be provided with an air cleaner, the reference pressure in chamber 15 is preferably modified by the pressure actually existent in the carbureter intake passage. Thus, the balance tube 95 is connected to the carbureter passage 130 which, via a calibrated bushing 131 communicates with a passage 132 which picks up the static pressure in the carbureter air intake. The reference pressure in diaphragm reference chamber 15 is consequently at all times the actual air pressure under which the carbureter is operating; and, accordingly, the pressure delivered at 30 are pressures having

reference to the actual atmospheric pressure under which the carbureter is operating.

For purposes of economy in operation, the reference pressure in chamber 15 may be further modified by communication of depression to the carbureter passage 130 via a small port 133 controllable by an adjustable valve 134, and which port communicates with the main carbureter passage at a point just under the throttle when closed; the typical relative positions being shown in Fig. 5. As the throttle opens, in the direction indicated by the arrow in Fig. 5, and opens past the idling position and into positions which the throttle assumes during the medium operating ranges of the engine, port 133 is uncovered, so to speak, to the depression existing in the manifold above the throttle. That depression, proportionately communicated to the balance tube 95 by the controlled orifice 133, tends to lower the reference pressure in chamber 15 and consequently tends, all other conditions being the same, to close the low pressure control valve 35 and to reduce the outlet pressure of the fuel delivered to the carbureter. Thus, a comparatively lean mixture is provided for the medium operating ranges of the engine. But when the throttle is wide open and the engine operating under heavy load, the depression then being very slight, this economizer action is negligible or practically non-existent.

One more feature of the device is especially designed for the maintenance of high operating capacity in a device of a given size. Certain features that have effectiveness to that end have already been explained; particularly the feature of controlling the low pressure regulating diaphragm 16 by the pressure actually extended at the outlet. That arrangement has the general effect of keeping actual pressure in chamber 20 at the control valve 35 sufficiently high to maintain the desired or predetermined pressure at the outlet, regardless of the flow velocities and consequent frictional losses of pressure in the device.

Of course, the operation of low pressure control valve 35 to allow faster flow from intermediate pressure chamber 26, whereby to build up the pressure in chamber 20, has the immediate effect of lowering the intermediate pressure in chamber 26, with a resultant wider opening of the initial pressure control valve 44 to keep up the pressure in chamber 26. But, obviously, the opening of initial valve 44 must depend upon a fall of pressure in chamber 26, however slight that might be for operation of the device involving reasonably low velocities. However, at higher velocities the fall in pressure may be considerable. Means are provided for automatically keeping up the intermediate pressure in chamber 26 as the velocities increase.

In my explanation of the structure and operation of the device so far, it has been assumed that, say, atmospheric pressure, or some other fixed pressure is present in the reference pressure chamber 25, between the diaphragm 24 and the wall structure 21. Whatever the pressure there may be, its operation on diaphragm 24, if unopposed, would tend to open the initial control valve 44. Consequently any increase in pressure in chamber 25 will tend to open valve 44 and tend to raise the pressure in intermediate pressure chamber 26, in order to reach equilibrium conditions.

As shown in the drawings, the reference pressure chamber 25 for diaphragm 24 is connected to the low pressure chamber 20 via an opening

140 through wall structure 21, a cored passage 141 in the casting 79, and a tube 142 mounted in that casting. The passage just described will, except for the modification now set out, place a reference pressure upon diaphragm 24 that will be equal to the pressure at any time existent in low pressure chamber 20.

Thus, if pressure in chamber 20 is relatively raised for the purpose of providing a higher pressure of final delivery, or raised to keep the final delivery pressure constant at higher operating velocities, the reference pressure against diaphragm 24 will be correspondingly raised, and the intermediate pressure in chamber 26 also correspondingly raised, thus better to suit the instant conditions of operation. But further, to at least keep the pressure in chamber 26 up to normal, and preferably to effectively raise it at the higher velocities of operation, the tube 142 is provided with a bend 143, forming a Pitot tube which picks up the velocity head of the radially outflowing stream of fluid which escapes under that gasket of valve 35. The action of communicating tube 142 is therefore not only to communicate reference pressure chamber 25 with the low pressure chamber 20, to make those two pressures vary together, but also to add to the pressure in chamber 25 the velocity head of the flow of gas between chamber 26 and chamber 20. The sum total result of these two actions is that, within the ultimate capacity of the device, pressures in chambers 26 are kept up, or even increased, as flow velocities through the device increases.

I claim:

1. A unitary pressure regulator and heater for vaporizable fluids, comprising a structure having an external peripheral wall and a plurality of internal and substantially parallel transverse dividing walls defining two spaced pressure fluid chambers and a single heating medium chamber between them and separated from each of them by only a single heat conductive wall, all of said chambers being of relatively large dimensions in the transverse directions of said dividing walls and of relatively small dimensions perpendicular thereto; said structure including an inlet for high pressure fluid and an outlet for fluid at low pressure, automatic pressure regulating means acting to admit pressure fluid from the high pressure inlet to one of said fluid chambers and maintain the fluid therein at an intermediate pressure, and automatic pressure regulating means acting to admit fluid from said intermediate pressure chamber to the other fluid chamber and maintain the fluid therein at a low pressure, said low pressure outlet communicating with said low pressure chamber.

2. A unitary pressure regulator and heater for vaporizable fluids, comprising a structure having an external peripheral wall and a plurality of spaced internal transverse dividing walls defining two spaced pressure fluid chambers and a single heating medium chamber between them and separated from each of them by only a single heat conductive wall, one of said pressure fluid chambers being a low pressure chamber and the other being an intermediate pressure chamber, and said transverse walls also forming another low pressure fluid chamber immediately adjacent that side of the intermediate pressure chamber which is opposite the heating medium chamber, the two low pressure chambers being interconnected, a high pressure inlet, and a low pressure outlet communicating with

the first mentioned low pressure chamber; automatic pressure regulating means acting to admit pressure fluid from the high pressure inlet to the intermediate pressure chamber and maintain the fluid therein at an intermediate pressure, and automatic pressure regulating means acting to admit fluid from said intermediate pressure chamber to the second mentioned low pressure chamber and maintain the fluid therein at a low pressure.

3. A unitary pressure regulator and heater for vaporizable fluids, comprising a structure having walls forming a heat medium chamber, a low pressure fluid chamber and an intermediate pressure fluid chamber each in immediate heat conductive relation to the heat medium chamber, and another low pressure fluid chamber out of direct conductive relation to the heat medium chamber and communicating with the first mentioned low pressure chamber, a high pressure inlet, and a low pressure outlet communicating with the first mentioned low pressure chamber; automatic pressure regulating means acting to admit pressure fluid from the high pressure inlet to the intermediate pressure chamber and maintain the fluid therein at an intermediate pressure; and automatic pressure regulating means acting to admit fluid from said intermediate pressure chamber to the second mentioned low pressure chamber and maintain the fluid therein at a low pressure, said means including a pressure controlling valve and a valve actuating diaphragm, and means, independent of the second mentioned low pressure chamber and the intercommunication between the two low pressure chambers, for applying to said diaphragm the pressure existing in the first mentioned low pressure chamber at the low pressure outlet.

4. A unitary pressure regulator and heater for vaporizable fluids, comprising a structure having an external peripheral wall and a plurality of spaced internal transverse dividing walls defining a heating medium chamber, a low pressure fluid chamber immediately adjacent one side of the heat medium chamber and in heat conductive relation thereto, an intermediate pressure responsive diaphragm which, together with the transverse walls of the structure, forms at one face of the diaphragm an intermediate pressure chamber lying at the other side of the heat medium chamber and in heat conductive relation thereto, the structure having also a transverse wall which encloses a reference pressure chamber at the opposite face of said diaphragm, another transverse wall which, together with the reference chamber wall, defines a second low pressure fluid chamber, a low pressure responsive diaphragm which together with the last mentioned transverse wall defines a low pressure diaphragm chamber, walls extending through the first mentioned low pressure chamber and the heat medium chamber and forming a high pressure inlet passage connecting to the intermediate pressure chamber, a pressure controlling valve controlling said passage and actuated by the intermediate pressure diaphragm, a passage connecting the intermediate pressure chamber with the second mentioned low pressure chamber, a low pressure controlling valve controlling said last mentioned passage and actuated by the low pressure diaphragm, a passage connecting the low pressure chamber with the intermediate diaphragm reference chamber, walls extending through the heating medium chamber and forming an intercommunicating passage between the two low

pressure chambers, a low pressure outlet passage communicating with the first mentioned low pressure chamber, and means forming a passage connecting the low pressure diaphragm chamber with the first mentioned low pressure chamber near the outlet passage.

5. In a pressure regulator and heater, two separated chambers, means for heating fluid while passing through one only of said chambers, a source of fluid under pressure, pressure regulating means acting to admit fluid from the source to the other chamber and to maintain therein a regulated fluid pressure, an outlet communicating with the upper part of the first mentioned chamber, and two passages intercommunicating the two chambers respectively at their upper and lower portions, the upper one of said passages being larger than the lower, and a valve controlling the upper passage and opening when the pressure in the upper part of the first mentioned chamber is less than that in the upper part of the other chamber.

6. In a pressure regulator and heater, two separated chambers, means for heating fluid while passing through one only of said chambers, a source of fluid under pressure, pressure regulating means acting to admit fluid from the source to the other chamber and to maintain therein a regulated fluid pressure, an outlet communicating with the upper part of the first mentioned chamber, and two passages intercommunicating the two chambers respectively at their upper and lower portions, one of said passages being larger than the other.

7. In a pressure regulator and heater, two separated chambers, means for heating fluid while passing through one of said chambers, a source of fluid under pressure, pressure regulating means acting to admit fluid from the source to the other chamber and to maintain therein a regulated fluid pressure, a passage intercommunicating the two chambers, an outlet communicating with the heated chamber, said pressure regulating means including a diaphragm, and means independent of the second mentioned chamber and the inter-chamber communication, communicating directly to said diaphragm the pressure existing at the outlet.

8. In a two-stage fluid pressure regulator, having a source of high pressure fluid, regulator means including an actuating diaphragm, for reducing the high fluid pressure to an intermediate pressure, a low pressure chamber, a second pressure regulator means taking fluid at the intermediate pressure and admitting it to the low pressure chamber; the combination of means for applying to the diaphragm of the first mentioned regulator a reference pressure made up of the fluid pressure in the low pressure chamber plus a part of the velocity head of the fluid flowing into that chamber under control of the second mentioned regulator.

9. In a two-stage fluid pressure regulator, having a source of high pressure fluid, regulator means, including an actuating diaphragm, for reducing the high fluid pressure to an intermediate pressure, a low pressure chamber with a low pressure outlet, a second pressure regulator, including an actuating diaphragm, acting to take fluid at the intermediate pressure and admit it to the low pressure chamber; the combination of means for applying to the diaphragm of the second mentioned regulator the low pressure existing at the outlet, and means for applying to the diaphragm of the first mentioned regulator a

reference pressure made up of the fluid pressure in the low pressure chamber plus a part of the velocity head of the fluid flowing into that chamber under control of the second mentioned regulator.

10. In a two stage fluid pressure regulator, having a source of fuel at high pressure, regulator means, including an actuating diaphragm, for reducing the high fluid pressure to an intermediate pressure, a low pressure chamber with a low pressure outlet, a second pressure regulator, including an actuating diaphragm, acting to take fluid at the intermediate pressure and admit it to the low pressure chamber, the combination of means for applying to the diaphragm of the second mentioned regulator the low pressure maintained by that regulator means, means for modifying the pressure applied to said diaphragm by restricted application thereto of a sub-atmosphere pressure, and means for applying to the diaphragm of the first mentioned regulator a reference pressure made up of the fluid pressure in the low pressure chamber plus a part of the velocity head of the fluid flowing into that chamber under control of the second mentioned regulator.

11. In a two stage fluid pressure regulator, having a source of fuel at high pressure, regulator means, including an actuating diaphragm, for reducing the high fluid pressure to an intermediate pressure, a low pressure chamber with a low pressure outlet, a second pressure regulator, including an actuating diaphragm, acting to take fluid at the intermediate pressure and admit it to the low pressure chamber; the combination of means for applying to the diaphragm of the second mentioned regulator the low pressure maintained by that regulator means, means for modifying the pressure applied to said diaphragm by restricted application thereto of a sub-atmospheric pressure, said last mentioned means embodying a passage leading to the said diaphragm and including orifice communication of predetermined size, and a valve acting to partially close said orifice communication when the sub-atmospheric pressure falls below a predetermined amount.

12. In a fluid pressure regulator, having a source of fuel at high pressure, regulator means, including an actuating diaphragm, for reducing the high fluid pressure to a low pressure, a low pressure chamber with a low pressure outlet; the combination of means for applying to said regulator diaphragm the low pressure maintained by that regulator means, means for modifying the pressure applied to said diaphragm by restricted application thereto of a sub-atmospheric pressure, said last mentioned means embodying a passage leading to the said diaphragm and including orifice communication of predetermined size, and a valve acting to partially close said orifice communication when the sub-atmospheric pressure falls below a predetermined amount.

13. In a pressure regulator and heater, two separated chambers, means for heating fluid while passing through one of said chambers, a source of fluid under pressure, pressure regulating means acting to admit fluid from the source to the other chamber and to maintain therein a regulated fluid pressure, a passage intercommunicating the two chambers, an outlet communicating with the heated chamber, said pressure regulating means including a diaphragm, and means independent of the second mentioned

chamber and the intercommunication between the two chambers, communicating to said diaphragm the pressure existing at the outlet, said means including structure forming a diaphragm chamber at one face of the diaphragm separated from the second mentioned chamber.

14. In a two-stage fluid pressure regulator, having a source of high fluid pressure, regulator means including an actuating diaphragm for reducing the high fluid pressure to an intermediate pressure, a low pressure chamber, a second pressure regulator including a controlling valve taking fluid at the intermediate pressure and admitting it to the low pressure chamber; the combination of a passage leading from the low pressure chamber to one face of the diaphragm of the first mentioned regulator, said passage including a velocity head pick-up exposed to the velocity of fluid flow through the valve of the second mentioned regulator.

15. In a two-stage fluid pressure regulator, having a source of high fluid pressure, regulator means including an actuating diaphragm, for reducing the high fluid pressure to an intermediate pressure, a low pressure chamber, a second pressure regulator means taking fluid at the intermediate pressure and admitting it to the low pressure chamber; the combination of means applying to that side of the diaphragm of the intermediate pressure regulator, where pressure on the diaphragm tends to open the intermediate pressure regulating valve, a pressure dependent in part on the velocity head of the fluid

flowing into the low pressure chamber under control of the second mentioned regulator, whereby increased flow into the low pressure chamber attendant a pressure drop in that chamber causes increase in the intermediate pressure.

16. A unitary pressure regulator and heater for vaporizable fluids, comprising a structure having an external peripheral wall and a plurality of internal and substantially parallel transverse dividing walls defining two spaced pressure fluid chambers and a single heating medium chamber between them and separated from each of them by only a single heat conductive wall, all of said chambers being of relatively large dimensions in the transverse directions of said dividing walls and of relatively small dimensions perpendicular thereto, and said heat conductive walls having spaced heat conductive projections which project across each of the two fluid pressure chambers; said structure including an inlet for high pressure fluid and an outlet for fluid at low pressure, automatic pressure regulating means acting to admit pressure fluid from the high pressure inlet to one of said fluid chambers and maintain the fluid therein at an intermediate pressure, and automatic pressure regulating means acting to admit fluid from said intermediate pressure chamber to the other fluid chamber and maintain the fluid therein at a low pressure, said low pressure outlet communicating with said low pressure chamber.

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