Jan. 27, 1953

F. C. MOCK

2,626,789

CHARGE-FORMING DEVICE

Original Filed Nov. 28, 1944

5 Sheets-Sheet 1

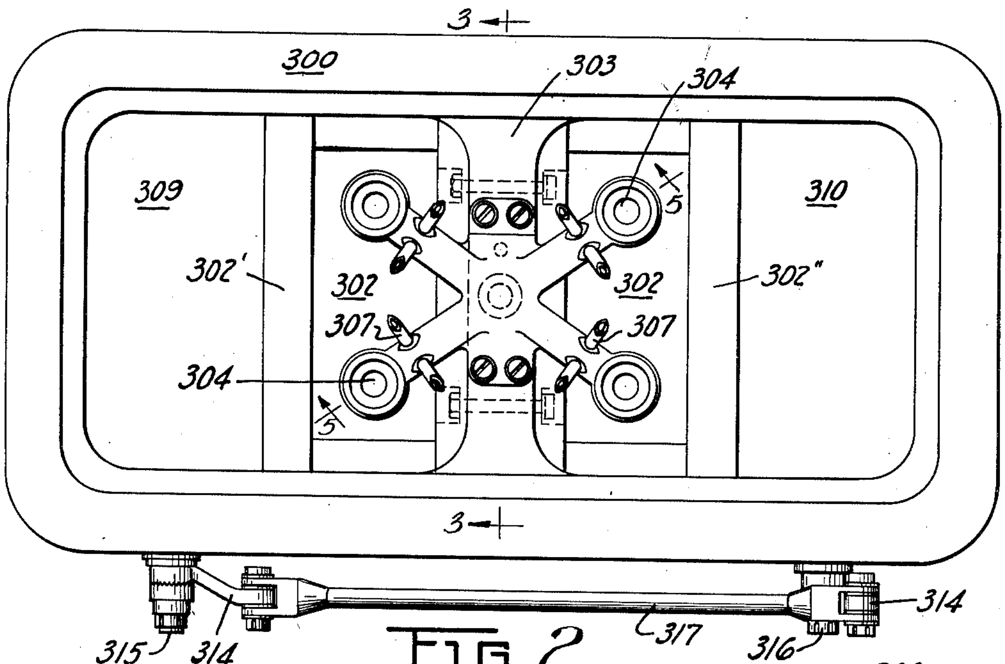

FIG. 2

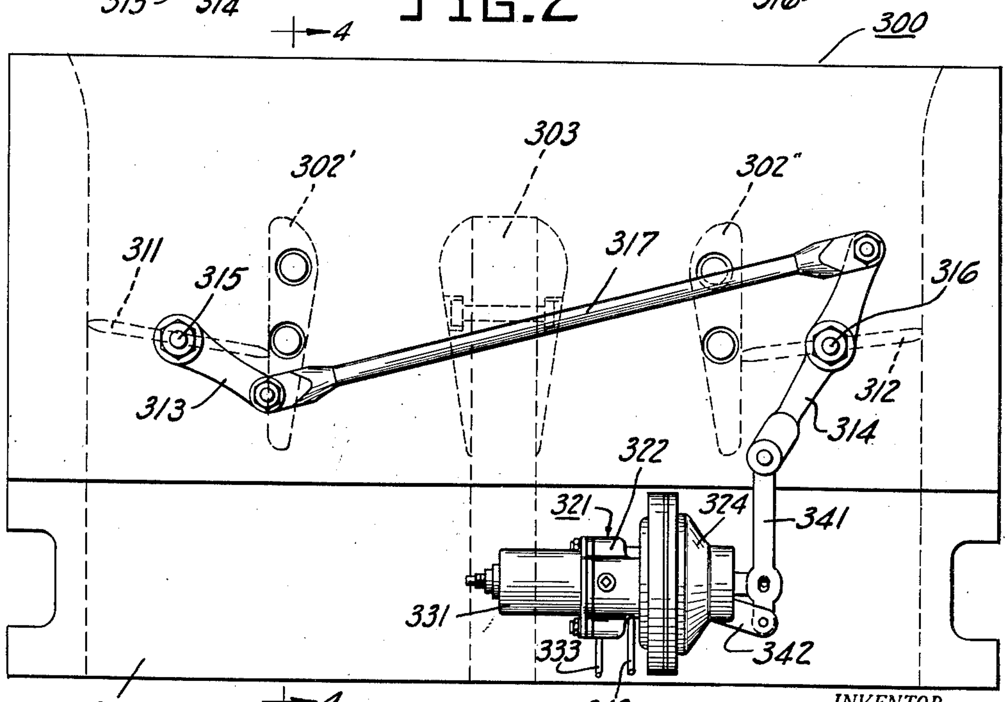

FIG. 1

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CHARGE-FORMING DEVICE

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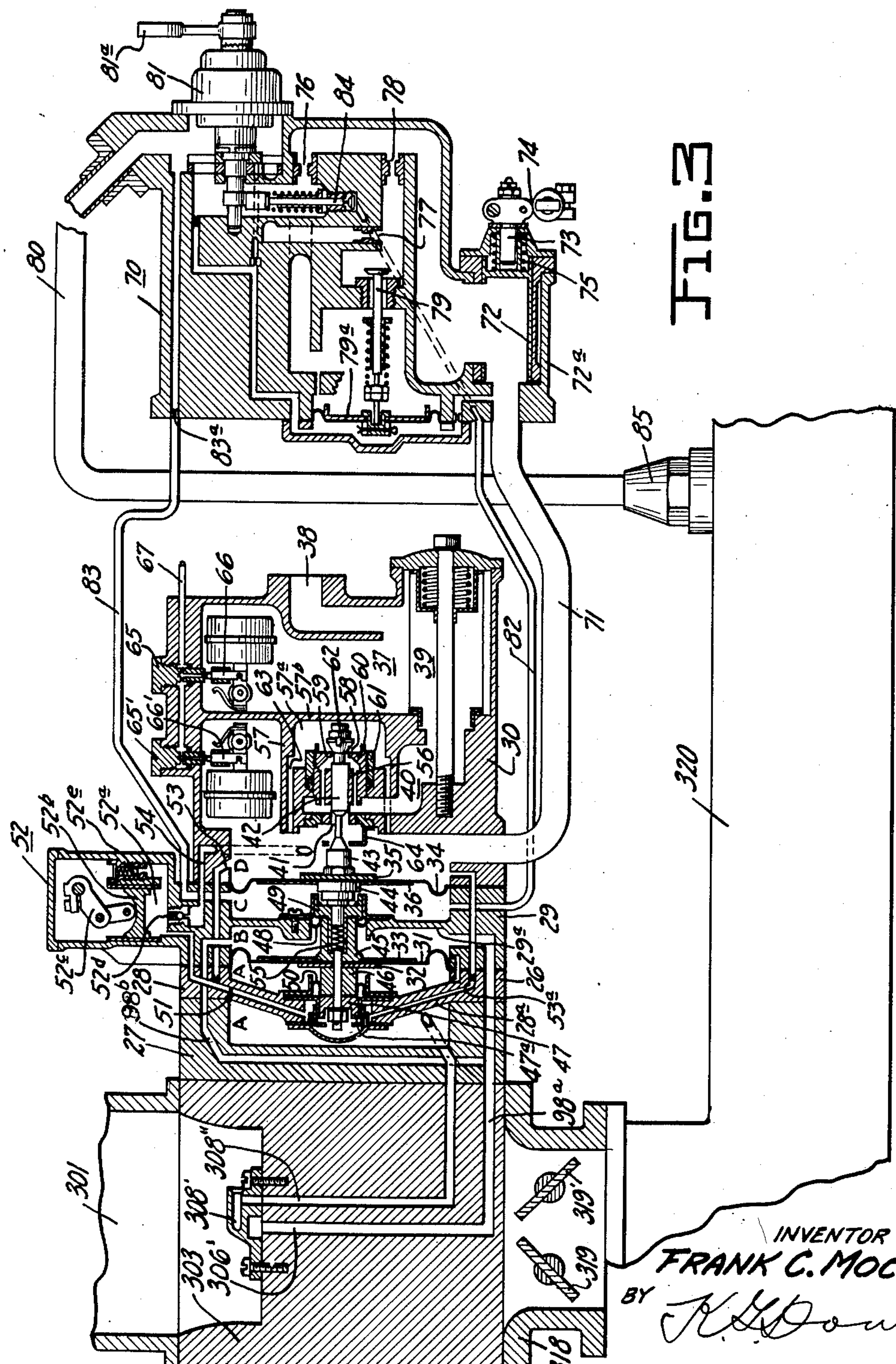

FIG. 3

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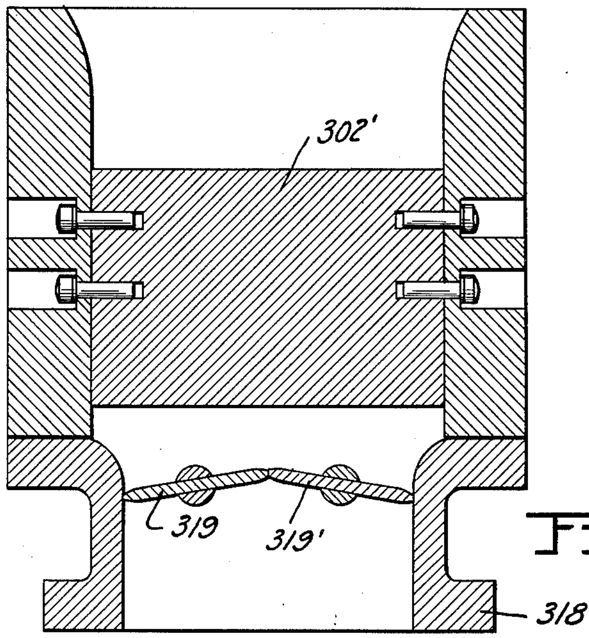

FIG. 4

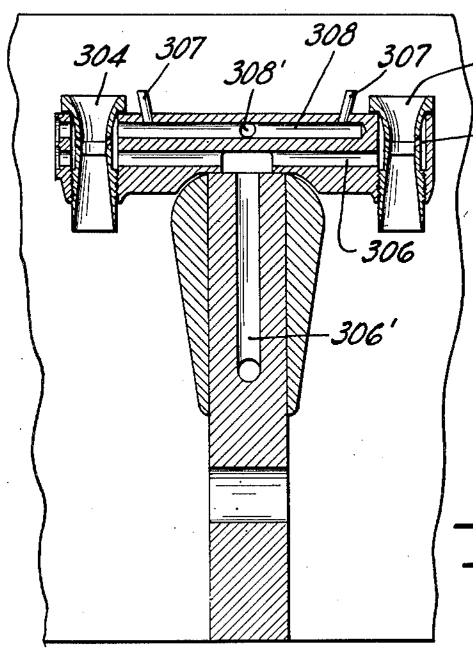

FIG. 5

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CHARGE-FORMING DEVICE

Original Filed Nov. 28, 1944 5 Sheets-Sheet 4

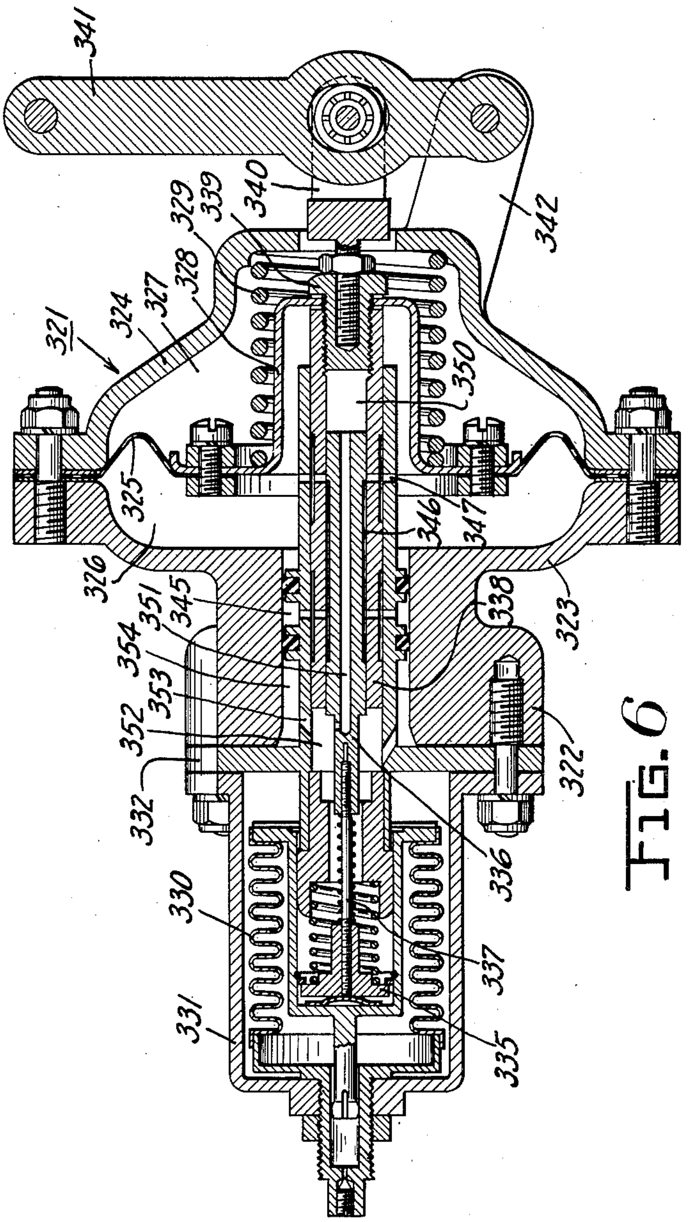

FIG. 6

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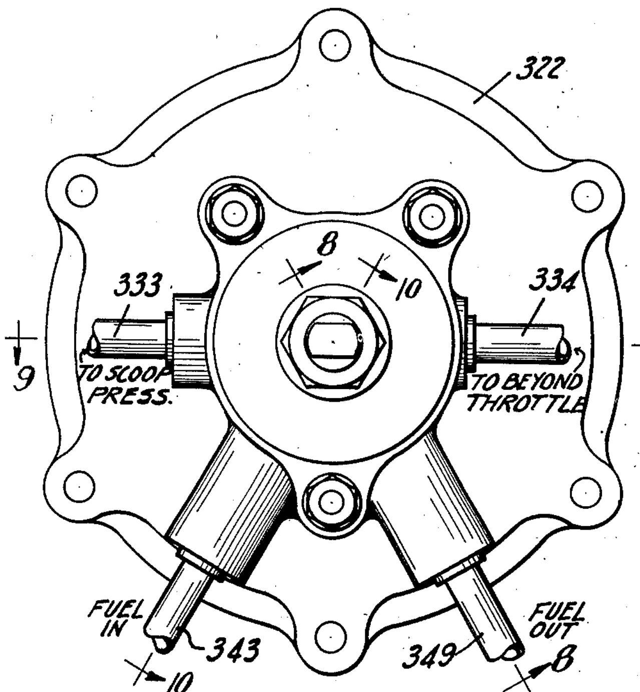

FIG. 7

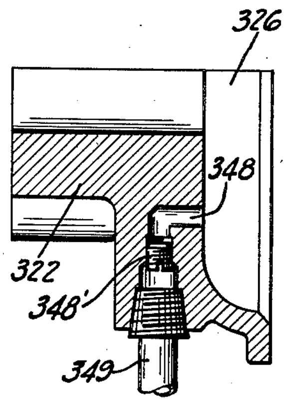

FIG. 8

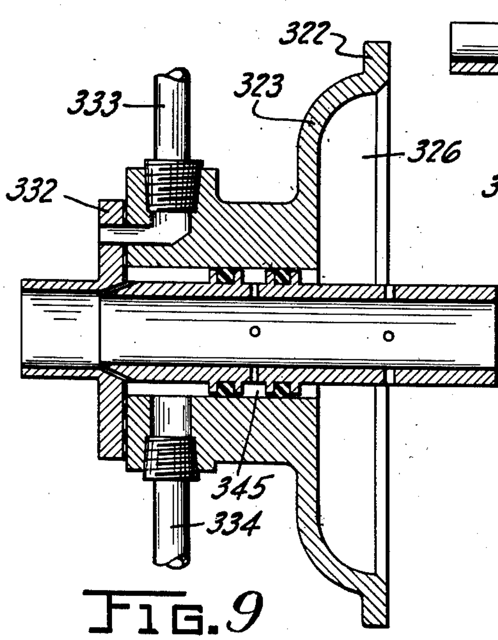

FIG. 9

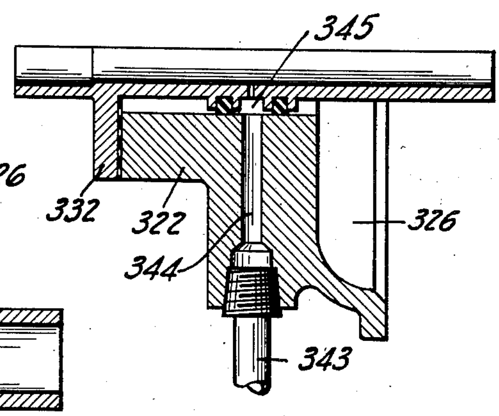

FIG. 10

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Patented Jan. 27, 1953 2,626,789

UNITED STATES PATENT OFFICE

2,626,789

CHARGE-FORMING DEVICE

Frank C. Mock, South Bend, Ind., assignor to Bendix Aviation Corporation, South Bend, Ind., a corporation of Delaware

Original application November 28, 1944, Serial No. 564,287. Divided and this application October 19, 1948, Serial No. 55,401

1 Claim. (Cl. 261—39)

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The instant application constitutes a division of my copending application Serial No. 564,287, filed November 28, 1944 now Patent No. 2,470,098.

This invention relates to charge-forming devices or carburetors for internal combustion engines, and includes among its objects: to provide a carburetor particularly adapted for aircraft engines which will supply fuel to an engine in a predetermined fuel/air ratio over a wide range of air densities and under varying operating conditions; a carburetor wherin Venturi suction may be maintained substantially constant with increasing altitude for any given air flow; a carburetor wherein the loss or pressure drop resulting from air flow through the carburetor at high velocities is reduced to a minimum; a carburetor which will meter fuel accurately irrespective of changes in air density and hence velocity of flow through the air-intake system; to eliminate or modify the effects of so-called "velocity enrichment" in injection carburetors; to provide a carburetor capable of handling wide variations or extremes of intake air density and thereby, among other advantages, adapt it for mounting on the atmospheric side of a two-stage or multiple supercharger system; and otherwise improve the metering or fuel-feeding characteristics of charge-forming devices.

One of the factors which adversely influence accurate metering in injection carburetors for high-altitude aircraft engines is the increase in velocity of the air flowing through the carburetor resulting from a decrease in density as an airplane ascends to high altitudes. In a carburetor of the type with which the present invention is concerned, the fuel valve which admits fuel to the carburetor and hence controls the fuel metering head is regulated by imposing Venturi differential pressure which constitutes a measure of air flow, commonly termed the "air metering force" on an air diaphragm which tends to open the valve and is balanced for a given air flow by the differential between metered and unmetered fuel, or "fuel metering force" imposed on a fuel diaphragm, which tends to close the valve, the air metering force controlling the fuel metering force. A charge is thus delivered to the engine having a predetermined weight or measure of air and a predetermined weight or measure of fuel. The controlling or actuating force on the air diaphragm is obtained by taking a measure of scoop pressure and conducting same to a pressure chamber located at one side of the air diaphragm and applying Venturi suction to a suction chamber located at the other side of said diaphragm. The suction is usually obtained by means of a small or boost venturi located in a position with respect to the main venturi such that the air leaves the boost venturi at a point of maximum pressure drop in the main venturi, thereby materially increasing the pressure drop at the throat of the

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boost venturi. The pressure and suction chambers are connected by one or more calibrated mixture control bleeds which permit a predetermined flow of air through the air diaphragm system; and by regulating this flow of air by means of an altitude aneroid, the air metering force is automatically controlled in accordance with air density and hence mass air flow.

The accuracy of metering with such system of carburetion depends on the air flowing through the carburetor following the laws which govern air flow. Assuming an air venturi of constant area, the depression or suction developed at the throat of the venturi varies as the velocity squared times the density. Thus as altitude is gained, for a given air weight flow, the metering suction and also the resistance to flow (carburetor loss) vary inversely as the air density, the metering pressure head (inches of water) varies inversely as the air density, and the fuel/air ratio varies inversely as the square root of the air density. However, there is a limit to the velocity of flow through the venturi above which the laws governing air flow do not hold true due to so-called "compressibility effects" in the air stream. This limit may, for a given size venturi, be 400 to 450 feet per second and beyond this limit the Venturi differential pressure which governs the air metering force increases at a rate greater than the square of the air velocity, causing enrichment of the fuel charge.

Again, with a fixed venturi there is a loss in power resulting from friction as the velocity increases with decrease in density. If a carburetor loss of say .8 inch of mercury be assumed at ground level, the air charge to the engine will be approximately in the proportion of 29.2/30, but at 30,000 feet altitude where the air density is .37 of that at ground level, the pressure drop through the carburetor will be from 8.9'' Hg to 6.6'' Hg, a loss of approximately 30 per cent of the power.

The ability of a carburetor to handle wide variations of air intake density also adapts it for mounting on the atmospheric side of a two-stage supercharger system and use of the carburetor throttle as the power control irrespective of whether the main or both the main and auxiliary superchargers are active, thereby simplifying the control mechanism, giving added space between the superchargers for an intercooler and at the same time injecting fuel into the main stage supercharger; as contrasted with mounting of the carburetor between stages with the intercooler placed beyond the main stage or engine-driven supercharger where it may condense fuel already vaporized by the supercharger.

The foregoing and other objects and advantages will become apparent in view of the following description taken in conjunction with the drawings, wherein:

Figure 1 is a view in side elevation of a pressure feed carburetor having a fixed venturi and provided with means in accordance with the invention operating automatically to bypass a predermined amount of air past the venturi to compensate for changes in air density;

Figure 2 is a top plan view of Figure 1;

Figure 3 is a sectional view taken on the line 3—3, Figure 2 with the regulator and fuel control units added in sectional diagram;

Figure 4 is a section taken substantially on the line 4—4, Figure 1;

Figure 5 is a fragmentary section taken on the line 5—5, Figure 2;

Figure 6 is a substantial central longitudinal view of a servo motor particularly adapted for controlling the bypass valves of the carburetor;

Figure 7 is an end view of the servo of Figure 6; and

Figures 8, 9, and 10 are sectional views taken respectively on the lines 8—8, 9—9 and 10—10, Figure 7, with the bellows assembly removed.

A carburetor air intake or Venturi body is generally indicated at 300, note Figures 1 and 2; it is rectangular in interior cross-section and adapted for mounting at the discharge end of an air scoop 301, Figure 3, defining an air intake passage for conducting air to an engine, not shown.

Within the body 300 is a main venturi 302 defined by a pair of fixed Venturi walls 302′, 302″ and divided centrally by a partition 303 which supports a plurality of boost venturii 304, four in number in the present instance. Suction is produced in a chamber 305, Figure 5, surrounding the throat of each boost venturi and communicated to chamber B of the regulator 26 of Figure 3 through passages 306, 306′, 98*a* and 98*b*; and impact pressure is received by impact tubes 307 and communicated to chamber A of the said regulator by means of passages 308, 308′ and 308″.

The fuel regulator unit 26 as schematically illustrated in Figure 3 is adapted to be removably mounted to the barrel 300; it consists of a series of castings 27, 28, 29 and 30 detachably connected to one another for convenience in assembly and repair and defining air pressure chamber A, air depression or suction chamber B, metered fuel chamber C, and unmetered fuel chamber D; also a relatively large fuel chamber housing a fuel strainer, vapor separator assembly and fuel valve head assembly. Casting 28 is in the form of a spider ring having a hub portion 28*a*, and casting 29 is provided with a partition wall 29*a*.

Chambers A and B are separated by a flexible diaphragm 31 which is securely anchored at its outer edge between the castings 28 and 29 and is engaged centrally on one side by a rigid plate 32 and on the opposite side by a thin backing plate 33; while chambers C and D are separated by a flexible diaphragm 34 which is securely anchored at its outer edge between the castings 29 and 30 and is engaged centrally on one side by a plate 35 and on the other side by a thin backing plate 36. Chambers B and C are separated by the rigid wall 29*a* and the hub assembly supported thereby.

The casting 30 defines a main fuel chamber 37 to which fuel is supplied under pump pressure through inlet port 38 and thence passes through strainer 39 to valve-inlet chamber 40 and from the latter through valve ports 41 and 58 to chamber D of the regulator. Port 41 is controlled by fuel valve 42 forming part of a valve assembly which is shown and described in detail in the copending application of Frank C. Mock Serial No. 538,153, filed May 31, 1944, now Patent No.

2,500,088. In general, it consists of a plurality of bushings 43, 44, 45, 46, 47 and adjustable stop 47*a*, the fuel diaphragm being clamped at its center between plate 35 and bushing 44 and the air diaphragm between plate 32 and bushing 45. A sealing diaphragm 48 is secured at its outer edge to the wall 29*a* and at its center between bushing 45 and a hollow tie rod and guide bushing 49; and a sealing and balance diaphragm 50 of equal area to diaphragm 48 is secured at its outer edge to hub 28*a* and at its center between bushings 46 and 47. A passage 51 places diaphragm 50 in pressure-communication with piston chamber 52*a* of an accelerator pump generally indicated at 52 and including a piston 52*b* provided with operating linkage 52*c* (which is preferably throttle-actuated), a check valve 52*d* and a pressure-relief valve 52*e*. A balance channel 53 having a restriction therein communicates passage 51 with fuel chamber D, and another channel 53*a*, also having a restriction therein, vents the chamber of diaphragm 50 to said fuel chamber. When the piston 52*b* is actuated by the throttle or other means, on its upstroke fuel is drawn into chamber 52*a* from the fuel chamber through passage 54 past valve 52*d*, and on its downstroke pressure is applied to diaphragm 50 and the fuel valve is opened to correspondingly increase the metering pressure.

An idle spring 55 is located in a chamber defined by the tie rod and guide bushing 49 and functions to maintain a substantially constant metering head when the air metering force acting on diaphragm 31 falls below a certain predetermined value. To permit this spring to so act, the fuel diaphragm 34, fuel valve 42 and bushing 44 are assembled to move in unison as a single unit; and likewise the air diaphragm 31, bushings 45, 46 and 47, guide stem and bushing 49, sealing diaphragms 48 and 50 and associated parts are also assembled to move as a single unit. As long as the air metering force (differential between scoop and Venturi pressures) is above a certain value, or above the idling range, both the air and fuel diaphragms act as a unit on valve 42, but when said force drops below such value, the air diaphragm moves to the left until bushing 47 contacts adjustable stop 47*a*, whereupon the fuel valve is held open by spring 55 sufficiently to produce a metering head consistent with the desired idling mixture. For a more comprehensive description of the operation of the idling system, reference should be had to application Serial No. 538,153 above noted.

The fuel valve assembly and coacting parts are provided with means for neutralizing unbalanced forces or load stresses on the fuel and air diaphragms. Two fuel discharge orifices and valve members therefor are provided which are so constructed and arranged as to oppose one another and balance out or neutralize such unbalanced forces. The head assembly for the fuel valve 42 is supported and guided by a sleeve 56 formed integrally with a housing 57 defining a chamber 57*a*, said housing in turn being formed integrally with a partition wall 57*b*. In addition to the orifice 41, there is fuel-discharge orifice 58 provided by a seat 59 carried by a mounting ring or sleeve 60 adjustably threaded into a hardened steel bushing 61. The right-hand extremity of the fuel valve 42 is provided with a tapered valve member 62 adapted to control the orifice 58. Fuel discharged through orifice 58 flows into chamber 57*a* and thence by way of channels or ducts 63 into chamber D of the regulator. The respective areas of the discharge orifices 41 and 58 and the tapers of the valve members coacting therewith are correlated in a manner such as to balance the fuel valve and parts coacting therewith throughout the range of movement of the valve. Fuel flowing into the chamber 40 is under pump pressure which is always higher than the pressure in chamber D of the regulator, but as the fuel flows through the discharge orifices 41 and 58, there is a suction action which tends to draw their valve members towards closed position, and primarily the balancing is by way of regulating this suction effect so that the force tending to open one valve member is opposed by an equal force tending to close the other valve member, although other factors must be considered, such as pressure differential on opposite sides of the orifices, surface areas exposed to pressure and the flow capacity of the ducts 63.

A baffle 64 serves to diffuse the fuel discharged through orifice 41 and reduce the tendency to form vapor in the system, while the multiple flow channels or ducts 63 act as diffusers for fuel discharged through orifice 58.

The chamber 37 in which fuel is received from the fuel pump (not shown) and unmetered fuel chamber D are provided with vapor-separating systems including vent plugs 65 and 65′ respectively, having vents therein controlled by float valves 66 and 66′ which open the vents when vapor collects sufficiently to lower the fuel level adjacent the float to a point where the float opens the valve. Vapor so vented flows through line or conduit 67 back to the fuel tank (also not shown).

The fuel control unit, generally indicated at 70, receives unmetered fuel from the regulator 26 by means of fuel passage or conduit 71; it contains idle valve 72 rotatably mounted in a casing 72*a* and provided with a stem or shaft 73 and arm 74 having a connection with the throttle linkage (not shown), a spring 75 preventing play in the valve mounting. The valve is shown in open position; it receives the initial flow of fuel from conduit 71 and the fuel passes therethrough to the metering jets, three in number in the present instance, viz: automatic lean jet 76, automatic rich jet 77 and power jet 78. A power enrichment valve 79 is provided and is operated by a diaphragm 79*a* subjected to the differential between unmetered and metered fuel pressure and arranged to open valve 79 when the fuel metering force attains a certain value, the valve 79 constituting the metering element during the early part of the power enrichment range and the jet 78 taking over at higher power flows.

The metering jets are located in flow channels which open into fuel discharge conduit 80 through ports controlled by a manual mixture control valve 81 provided with a handle 81*a*.

Metered fuel pressure is communicated back to C by means of duct or conduit 82, and said latter chamber is relieved of air or vapor by means of duct or conduit 83 discharging into conduit 80 and having a suitable restriction 83*a* therein. A regulator fill valve 84 operated by a cam on the shaft of the valve 81 allows chamber C to fill with fuel when the carburetor has been empty; it is held open in all positions of said valve except idle cut-off. This construction is more particularly shown and described in United States Patent No. 2,361,227.

The conduit 80 conducts metered fuel under

pressure to a discharge nozzle 85 located in air intake conduit 320 and arranged to discharge fuel into the air stream. Nozzle 85 may be set to open under a predetermined pressure, for example, five to fifteen pounds per square inch.

On opposite sides of the main venturi 302, note Figures 1 and 2, are by-pass passages 309 and 310 controlled by valves 311 and 312. These valves are interconnected for movement in unison by means of linkage mechanism comprising arms 313 and 314 secured on shafts 315 and 316 mounting said valves, the said arms being connected by means of a link 317. The arm 314 is adapted for operative connection with a servo motor shown more or less in detail in Figure 6 which will subsequently be described.

Beyond the air intake or Venturi body 300 is a throttle body 318 mounting a pair of coacting throttles 319 and 319′ which extend longitudinally of the throttle body at substantially right angles to the by-pass valves 311 and 312. By arranging the throttles and by-pass valves in the manner illustrated, a marked improvement in air distribution has been obtained over parallel or near parallel arrangements.

In order to obtain accurate compensation for changes in density, the by-pass passages 309 and 310 should be controlled in a manner such that the total by-pass area increases proportionally as the air density decreases with the valves being held stable at all air flows, and the servomotor of Figures 6 to 10, inclusive, has been devised to provide such control and to also coact with a pressure-feed type of carburetor.

The servo-motor is generally indicated at 321 and comprises a central body section 322 which at one extremity is formed with a wall 323 having secured thereto a dished member or cap 324, a diaphragm 325 being clamped between the parts 323 and 324 and defining in conjunction therewith a pressure chamber 326 and a chamber 327. The diaphragm 325 has connected to the central portion thereof a cup-shaped member 328 which projects into the chamber 327 and is encircled by a spring 329.

The body section 322 has mounted thereon a control unit including a bellows 330 responsive to changes in pressure and temperature and therefore density, said bellows being mounted in a housing 331 flanged at its base and secured to the body section 322 with a bushing 332 interposed therebetween. The housing 331 is vented to air scoop pressure by means of pipe or tube 333 and to below-throttle pressure by means of pipe or tube 334, note Figure 7, to thereby obtain a sensitive response to changes in air pressure and temperature in the immediate region of the carburetor.

The bellows is connected at its movable end to a member 335 which in turn is connected to a slidable valve 336 by means of rod 337, the said valve being mounted in a valve sleeve 338 in turn slidable in a bearing sleeve and connected at its lower end to an externally and internally threaded nut 339 which is adjustably connected to a yoke 340 providing a fulcrum for a lever 341, the latter being pivoted at its one end to a relatively stationary bracket 342 and at its opposite end to the arm 314 secured on the shaft 316 of the by-pass valve 312.

The operating fluid is admitted to the servo through pipe 343, inlet duct 344 and annular inlet port 345, the latter communicating with a chamber 346 provided between the valve rod 336 and valve sleeve 338. Fluid from 346 passes by way of discharge port 347 into pressure chamber 326.

Fluid escapes from pressure chamber 326 by way of outlet duct 348 having a restriction or bleed 348' therein and thence by way of pipe 349 to a suitable return, such as the fuel supply tank, not shown.

At the right-hand end of valve rod 336 is a chamber 350 which communicates by way of drilled passage 351 with a chamber 352 at the opposite end of said rod, the latter chamber in turn communicating through port 353 with chamber 354, the latter being in communication with the outlet pipe 334. Any fluid which may leak past relatively moving parts, such as the valve rod 336 and valve sleeve 338, will find an outlet by way of intercommunicating chambers 350, 352 and 354 and thence to the intake of the engine posterior the throttle through pipe 334, or if desired, to the fuel supply tank.

The servo is particularly adapted for use with a carburetor as a self-contained unit or assembly. In practice, fuel under pump pressure has been used as the operating fluid with satisfactory results, the pipe line 343 being connected to the fuel intake anterior the fuel valve where the pressure may be in the neighborhood of seventeen pounds. In the position of the parts as shown in Figure 6, the valve rod 336 is retracted and the pressure in chamber 326 is low. It can be assumed that the bellows 330 is in low altitude position and is just beginning to extend itself in response to a drop in air density. When this happens, valve rod 336 moves to the right and uncovers port 347, bleeding fluid under pressure into chamber 326. The operating pressure in this chamber is proportionate to the area of the inlet port 347 with respect to the outlet port as determined by the size of bleed 348'. As port 347 becomes enlarged due to extension of the bellows 330, the pressure in chamber 326 gradually builds up and moves the diaphragm assembly to the right against the resistance of spring 329, which in turn moves the sleeve 336 to follow-up the movement of valve rod 336 and partially lap the port 347. Upon an increase in density, the bellows 330 tends to collapse, moving valve rod 336 to the left, thereby reducing the pressure in chamber 326, and the spring 329 thereupon urges the diaphragm assembly and the parts connected thereto to the left.

Operation

Under a condition of maximum density, the by-pass valves 311, 312 will be closed, the servo control bellows 330 being in fully retracted or collapsed position maintaining the servo-motor inoperative. At this time, the full air supply to the engine is through the fixed venturi, and the differential pressure acting on the air diaphragm 31 between chambers A and B produces an air metering force which when opposed by the fuel metering force acting on fuel diaphragm 34 maintains the regulator in a state of balance with the fuel valve open sufficiently to allow the required amount of fuel for a given weight of air to flow into the regulator and thence to the metering orifices, subject to variation in accordance with the demands of the engine as determined by the degree of throttle opening.

Should there be a drop in air pressure due, for example, to a gain in altitude, the servo bellows 330 will expand, moving the valve rod 336 to the right and the servo will act to open the by-pass valves 311, 312 sufficiently to permit the increased

volume of air to flow to the engine without materially varying the effective pressure in the main venturi, thereby maintaining the boost suction in chamber B substantially constant for a given mass air flow. Thus the by-pass valves will gradually open as altitude is gained until critical for a given total air-intake is reached and exceeded, at which point the said valves will be fully open. An increase in air density, as by a decrease in altitude, produces the reverse of the foregoing operation, the by-pass valves gradually closing as density increases. In this manner, automatic altitude compensation may be obtained with a high degree of accuracy while at the same time obtaining adequate boost or metering suction at low air flows.

Although the invention has been described in connection with a carburetor wherein the fuel is delivered into an induction passage leading to the engine, it will be obvious that it is equally applicable for use in systems wherein the fuel is introduced directly into the engine cylinders or into the manifold adjacent the intake valves of the engine, or into the induction passage at any desired point, either anterior or posterior to the throttles.

It will be understood that the foregoing and other changes and re-arrangement of parts may be made to suit requirements.

I claim:

A pressure feed carburetor having a main throttle-controlled air-intake passage provided with a fixed main venturi and a boost venturi coacting therewith, a fuel flow passage arranged to discharge into said air-intake passage and having a metering restriction therein, means for supplying fuel under pressure to said fuel passage, a fuel valve for controlling the fuel metering head, means for regulating said valve including an air diaphragm to be subjected to the differential between a measure of air-intake pressure and Venturi suction and a fuel diaphragm to be subjected to the differential between metered and unmetered fuel pressures, an air-intake by-pass passage in parallel with said main venturi for by-passing air flowing in through the main air intake around said latter venturi, a by-pass valve for controlling said by-pass passage, and means responsive to changes in entering air density for controlling said latter valve to maintain the Venturi suction substantially constant for a given mass air flow at varying altitudes, said last-named means comprising a servomotor, a servo valve therefor and a density-responsive aneriod controlling said servo valve.

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