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ART OF FORMING AND DISTRIBUTING CHARGES FOR INTERNAL COMBUSTION ENGINES

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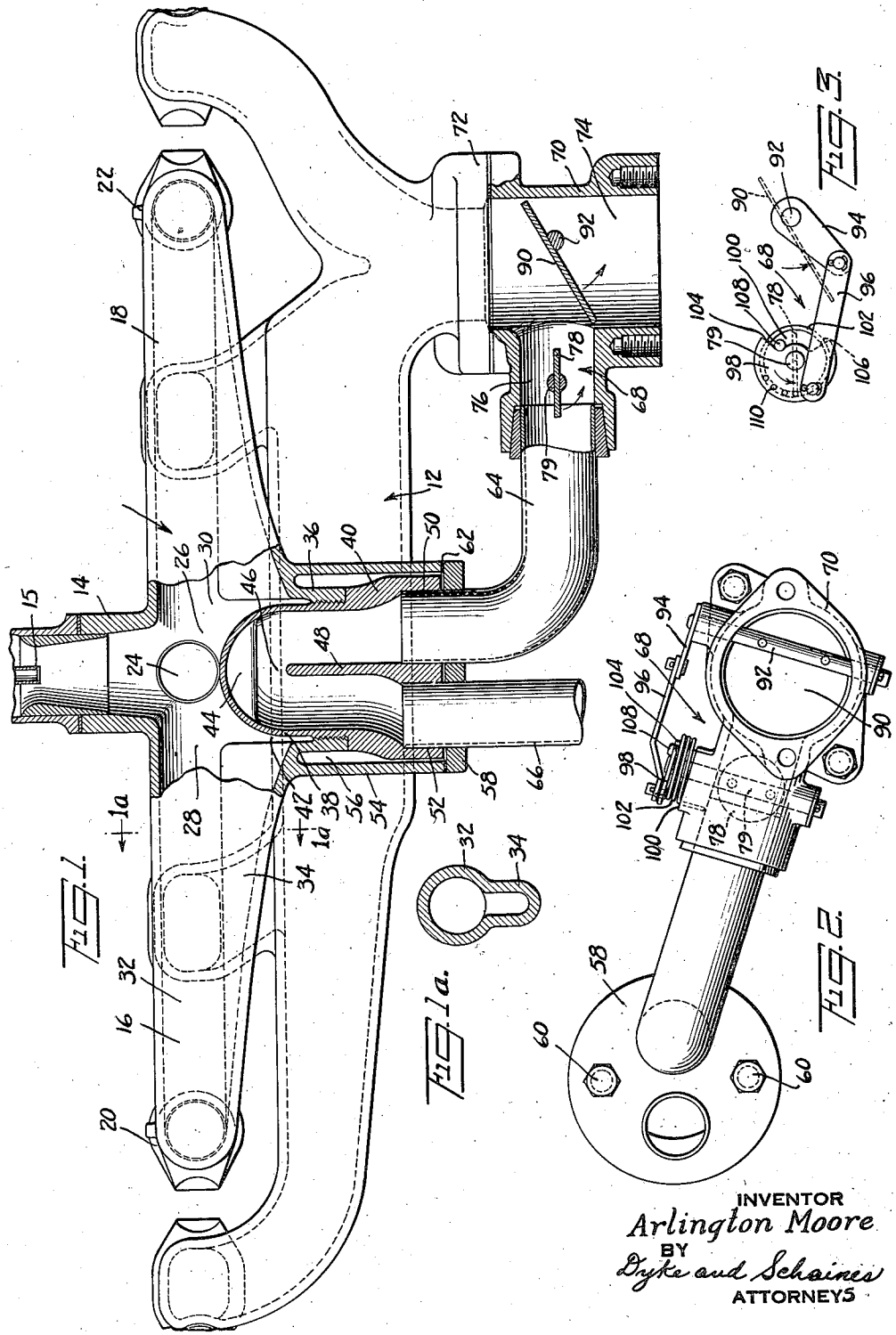


FIG. 1.

FIG. 1a.

FIG. 2.

FIG. 3.

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ART OF FORMING AND DISTRIBUTING CHARGES FOR INTERNAL COMBUSTION ENGINES

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Application December 10, 1932, Serial No. 646,687

4 Claims. (Cl. 123—122)

My invention relates to means for and methods of homogenizing the charge materials and distributing the same in such condition to the cylinders of an internal combustion engine.

The present invention constitutes an improvement upon the inventions shown, described and claimed in my copending applications Serial No. 513,804, filed February 6, 1931, Serial No. 514,105 filed February 7, 1931 and Serial No. 530,518, filed April 16, 1931, now patents numbered 1,981,876, 1,990,662 and 1,953,888, respectively.

With constructions such as disclosed in said applications I am able to vaporize the fuel component enroute to the engine cylinders, to maintain adequate charge velocities for the stable entrainment of the fuel component without sacrifice of volumetric efficiency, to provide adequate facilities for drainage of the branches during initial operation and for vaporization of the fuel thus drained, to concentrate the hot exhaust gases on the central portion of the intake conduit contiguous to the point of subdivision or deflection of the charge stream into the branches for causing vaporization of fuel particles discharged through or thrown out of the charge stream at said point enroute to the engine cylinders, and to render the thermal efficiency of said central heated portion substantially such as to cause fuel vaporization at a rate to prevent accumulation of fuel in said heated portion and thermal decomposition of fuel to form tarry products liable to impair the thermal efficiency of said portion.

The present invention has for its object to provide a construction of the character specified in which the heating means thereof is effective to thoroughly vaporize the fuel component to obtain uniform distribution to the cylinders and good combustion.

Another object of the invention is to provide a construction of the character specified which insures adequate vaporization of the fuel component at fractional loads productive of economy operation, and at full load operation productive of power operation.

Another object of the invention is to provide a construction of the character specified in which the heating means thereof is effective in subjecting the unvaporized fuel particles of the charge to spheroidal vaporization substantially throughout the range of operation of the engine for producing stable vaporization of the fuel component without unduly heating the charge as a whole.

Another object of the invention is to provide a structure of the character specified in which the heating means thereof is effective in causing the delivery of a cool, dense, homogeneous charge to the cylinders so as to obtain maximum engine torque and horse power with high economy.

Another object of the invention is to provide a structure of the character specified in which the heating means thereof is automatically controlled to supply the heat at the point of transfer thereof to the charge without excessive heating of the charge.

Another object of the invention is to provide a structure of the character specified in which the heating means thereof is controlled in response to the kinetic action of the exhaust gas stream.

Another object of the invention is to provide a novel method of effecting fuel vaporization.

Other objects will in part be obvious and in part be pointed out hereinafter.

In the accompanying drawing:

Figure 1 is an elevation, with parts in section, of one form of apparatus constructed according to and embodying my said invention;

Figure 1*a* is a section thereof on the line 1*a*, 1*a* of Fig. 1;

Figure 2 is a bottom plan of means for passing the hot exhaust gases into heating relation to the intake manifold; and

Figure 3 is an elevation of mechanism for controlling the passage of exhaust gases.

The fuel vaporizing and charge distributing construction embodying my said invention is adapted for use with carbureters or fuel supplying devices of various types, such as with the carbureter disclosed in my copending application Serial No. 525,992, filed March 28, 1931, and while the manifold is particularly adapted for distributing charge mixtures containing fuel of high volatility, such as gasoline, charge mixtures containing fuel of low volatility may be effectively distributed thereby in homogeneous admixture with the air.

When three port manifolds, such as herein shown as an example of one embodiment of the invention, are employed, there is a tendency for the charge to be distributed to the ports unequally. This condition is aggravated because the incoming charge picks up condensed fuel from the intake manifold walls, and particularly in the longer branches where the tendency to condense is greater. The condensation or loading up of fuel in the intake manifold normally takes place during periods of low speed operation. The accumulated or condensed fuel swept into the engine cylinders, especially when the throttle is opened for acceleration, causes waste of fuel,

lubricating oil dilution, non-uniform distribution with temporary over-richness of the mixture in certain of the cylinders, and other detrimental effects, resulting especially in roughness of engine operation.

In my invention I rely upon the suitable application of heat to the intake conduit whereby the fuel component of the charge is completely vaporized, and the maintenance of this condition is preferably supplemented or helped by providing branches of progressive decreasing cross-section such as disclosed as a feature of the intake manifolds of said Patents No. 1,981,876 and No. 1,990,662 and of my application Serial No. 234,417, now Patent No. 1,901,763, thereby promoting uniform distribution to the intake ports with resulting smooth, powerful and economical engine operation.

As in said applications first above mentioned the heating in the present invention is applied through an exhaust gas heated dome-shaped member of high thermal conductivity located in alignment with the central neck at the juncture of the intake branches, and in a recess disposed out of the path of the charge mixture into the branches so that the air is not heated. In the embodiment of the invention disclosed, adapted particularly for gasoline or like highly volatile fuels, this dome shaped member constitutes the sole means of supplying heat to the fuel component, the intake manifold neck and branches being preferably air cooled, and devoid of contact with heated surfaces. It is my purpose to subject the fuel particles projected or impelled from the charge stream upon deflection thereof into the branches against the dome to temperatures higher than the end point of the fuel to produce spheroidal vaporization of the fuel, and to obtain the resulting advantages accruing therefrom as hereinafter more fully described. For example, the end points for gasolines of various gravities range from about 300° F. to 524° F., and the spheroidal points in the same order range from 350° F. to 620° F. The exhaust gas temperatures vary under various conditions of engine operation from about 300° to 400° F. to about 1400° to 1500° F., the low temperatures occurring at engine idling and the highest temperatures occurring at full load high speed. The exhaust gas temperatures vary directly with ignition retardation, the extent of variation depending on the load and speed of the engine. The exhaust gas temperatures also vary directly with the engine speed and with the percent of engine load. The exhaust gas temperature also varies directly with the fuel flow rate, and is less with mixture ratios slightly richer than the high power ratio. From the foregoing, it is apparent that the exhaust gas temperatures actually available in an engine are adequate, except at low speeds-light load to substantially produce spheroidal vaporization of fuel throughout the range of engine operation, provided that the heat available can be adequately transferred to the fuel. At engine idling and very light loads, the high depression and very little fuel used produces excellent atomization and entrainment.

The completeness of fuel vaporization depends on the B. t. u.'s of heat which can be transferred to the fuel for causing such vaporization, upon the rate of heat transfer from the exhaust gas to the fuel, and upon the extent of surface available for transferring such heat. The time required to vaporize the fuel is also appreciable, especially when it is necessary to approach complete saturation of the air as in carburetion, and the vapor pressures tend to oppose such vaporization. Since the charge mixture is drawn through the manifold at a high velocity, the time allowed for fuel vaporization in the manifold is short. By my invention I am able to transfer adequate heat to the fuel for obtaining a homogeneous charge within the time available for vaporizing the fuel, the vaporization being such as to enable the charge to enter the cylinders without condensation of fuel, even though the manifold branches through which the charge travels are relatively cool.

In the present invention I effect maximum rate of transfer of heat from the exhaust gas to the fuel by provision of a heated dome composed of a material of high heat conductivity, such as a copper alloy having a thermal conductivity of about .92 as compared to that of iron which is about .16. By shaping the heated surface like a dome, adequate heated surface is provided disposed in fully exposed relation to the projected fuel particles, without being in exposed relation to the air component of the charge. I am thus able to provide ample heated surface without undue extension thereof in a horizontal plane. The provision of a dome-shaped heating surface, having a relatively large vertical component, particularly in a down draft manifold as shown, enables the fuel particles to roll or gravitate over the surface while being subjected to the heating effects thereof, and hence more readily vaporized without danger of collecting in puddles which under the intense heating available might cause the fuel to form tarry products instead of vaporizing.

The effectiveness of my improved manifold may be enhanced by use of a carbureter such as shown and described in my application Ser. No. 525,992, now Patent No. 2,056,615. With such carbureter the fuel may be properly metered to maintain the mixture-ratio desired, for economy and power operation, and the fuel is discharged in a finely divided state directly into the region of reduced pressure, which facilitates vaporization, and through an unimpeded path directly against the copper dome. It is also desirable to automatically control the ignition timing, as for example by means shown and described in my application Ser. No. 490,632 filed October 23, 1930. With proper control of the ignition and fuel metering supplemented by fuel atomization, the exhaust gas temperatures obtained may be rendered more uniform and most effective in promoting fuel vaporization at all stages of engine operation.

With my arrangement, adequate exhaust gas temperatures are always available, even at low speeds, for causing spheroidal vaporization of the fuel without unduly heating the air or unduly cooling the heated surface by contact with the air. The transfer of heat through the radiating medium of high conductivity is rapid and any change in exhaust gas temperature is instantly effective on the fuel without undue lag. For example, upon acceleration after a period of idling, when the exhaust temperature is low and the intake pressure is practically atmospheric pressure, the dome quickly heats up to adequately vaporize the additional fuel required at such stage of operation.

At fractional loads, the heat available because of the high rate of transfer, while sufficient for producing spheroidal vaporization of

the fuel, insuring economy in the use of fuel and good distribution to the several cylinders, is not so excessive as to require reduction, whereas under load conditions and at high speeds, when the exhaust gas temperatures are far in excess of the spheroidal temperatures required to vaporize the fuel preferably used, I make provision for controlling the heat available at the dome, during such last named conditions, so as not, by unduly heating the air, to impair the volumetric efficiency, and hence the power of the engine, and at full load, while insuring spheroidal vaporization, I am able in the present invention to supply cool dense charges to the cylinders productive of maximum power.

Referring to the drawing, the intake manifold 10 (the form illustrated being of the downdraft type) is shown separated from the exhaust manifold 12 which is of usual construction. The charge mixture passes into the manifold through the central neck portion or descender 14, the fuel, as one example, being shown delivered directly into the neck 14 from nozzle 15. From neck 14 the charge enters into the branches 16 and 18 and out through the elbow outlets 20 and 22, the central cylinder being supplied by the short passage or branch 24.

The intake manifold 10 illustrated as one example, is for a six cylinder engine having intake ports in sets of pairs in the cylinder block. With cylinder blocks designed for receiving only two intake manifold branches, the branch 24 is omitted. With the form shown, neck 14 leads downwardly to connect with the manifold at substantially the middle thereof and immediately above the entrances to its branches, and at this point a distributing chamber 26 is provided from which the mixture is supplied to the manifold branches 16 and 18.

The branches 16 and 18 have entrances 28 and 30 thereto from the chamber 26 of enlarged areas as compared to the area of the openings 20, 22 and 24, and their cross-sectional area gradually decreases towards the end portions 20 and 22 to cause an increase in the velocity of the fuel charge as the same approaches the elbows, and in this way the charge mixture can be delivered to the straight-in passages 20 and 22. The cross-sectional area of said branches 16 and 18 at the elbows 20 and 22 is substantially the same as the cross-sectional area of the entrance to passage 24.

The branches 16 and 18 each preferably comprises a semi-cylindrical upper portion 32 of substantially uniform cross-section from the inner end thereof to the elbow thereof, and preferably horizontal, and a lower reduced channel portion 34 at the base thereof merging into the upper portion 32 and likewise extending from the inner end of the branch into the elbow thereof and gradually decreasing in cross-sectional area and depth towards each elbow, the upper portion 32 forming the major part of the branch and the lower portion 34 the lesser part. The portions 34 jointly with the upper portions 32 form passages providing the relatively large entrances 28 and 30 and gradually decreasing in cross-sectional area to said elbows 20 and 22, this structure being disclosed and claimed in my said Patents No. 1,901,763 and No. 1,990,662.

By progressively enlarging the general contour of the branch at the bottom, the branch is made to incline downwardly towards the center of the manifold at a substantial angle for drainage purposes. At the same time the branch passage as a whole varies in cross section at a rate determined solely by variations in cross section of the relatively smaller lower portion 34, the rate of variation in cross section of the branch passage as a whole being less than the rate of variation in cross-section of the lower portion 34. The lower portions 34 therefore provide sufficient inclination for drainage and effect relatively slight progressive restriction of the branches to cause acceleration ratio proportional to distance traveled by the charge materials to effect uniform delivery through all ports.

The intake conduit 10 at the juncture of the branches opposite the neck 14 is provided with a downwardly extending annular wall portion 36 opening into the intake manifold at the upper end thereof. The portion 36 receives a hollow dome-shaped member 38 threaded therein and extending below and overlapping the lower edges of the portion 36 as indicated at 40. The dome 38 is disposed with the convex upper portion thereof opposite the neck 14 in spaced relation to the inner ends of the channel portions 34 and forms with the upper end of the portion 36 an annular chamber or space 42 about the dome, the upper end of the dome 38 preferably lying entirely below the horizontal plane through the manifold at the juncture of the parts 32 and 34. The troughs 34 drain into said chamber 42. The dome 38 is preferably composed of a copper alloy which has a thermal conductivity five or six times greater than that of iron employed in the usual "hot spots". The convex upper portion of the dome 38 comprises a relatively thin wall having ribs 44 on the inner side thereof for increasing the heat absorption while the lower portion 40 thereof has thicker walls.

The interior 46 of the dome 38 is exposed to the hot exhaust gases and includes provision for insuring a positive circulation of the gases therethrough. This means in the present embodiment of the invention comprises a deflector or baffle 48 integral with the dome 38 and bisecting the chamber 46, the baffle 48 terminating short of the top of the dome 38. The baffle 48 forms a return bend passage in the dome having an entrance opening 50 and an outlet opening 52.

The depending portions 36 and 40 are surrounded by an annular wall 54 depending from and integral with the lower portion of the manifold 10, and disposed in spaced relation to the portions 36 and 40 to form a dead air space 56 therebetween serving to insulate the dome 38 laterally against heat radiation to atmosphere and to concentrate heat transfer at the convex end of the dome 38. The lower ends of the dome 38 and wall 54 are closed by a plate 58 secured in position by bolts 60, a gasket 62 being disposed between the lower edge of the part 54 and the plate 58 to seal the juncture therebetween. The plate 58 is provided with openings registering with the openings 50 and 52 at the lower end of the dome 38. The hot exhaust gases are conducted as hereinafter more fully described from the exhaust manifold 12 to the dome 38 through a pipe 64 passing through plate 58 and secured in opening 50. The exhaust gases thus circulated through the dome are vented directly to atmosphere through a pipe 66 passing through plate 58 and secured in opening 52. A positive circulation of exhaust gases through the dome 38 is thus insured, keeping the dome heated to a maximum.

The passage of the exhaust gases to the dome 38 is preferably controlled automatically to pre-

vent overheating when the exhaust gas temperatures are high, the means for effecting this control being indicated generally at 68. While any of the usual devices may be employed for controlling the passage of the exhaust gases through the dome 38, in the present embodiment of the invention, the means employed depends for operation on the pressure and flow characteristics of the exhaust gas. For this purpose a casting 70 is secured to the discharge outlet 72 of the exhaust manifold 12. The casting 70 has a passage 74 therethrough registering with the outlet 72 and from which the exhaust gases are conducted through the muffler to atmosphere. The casting 70 is provided with a lateral outlet 76 in which the entrance end of the pipe 64 is secured. The passage of the exhaust gases through the pipe 64 is controlled by a valve 78, preferably of the butterfly type, having a central pivot 79, and preferably loosely fitting and thus providing clearance when in closed position to allow a limited flow of exhaust gas to the dome. The flow of exhaust gas through passage 74 to the muffler is controlled by an exhaust gas pressure and flow responsive member 90 therein, preferably comprising a butterfly valve having the pivot 92 thereof offset relative to its diameter, the pressure responsive means 90 controlling the position of the valve 78 as hereinafter described. In closed position the valve 90 is disposed at an inclination having the lower edge thereof below the entrance to the passage 76 and serving to deflect the exhaust gases into said passage 76. In this position of the valve 90 clearance is provided so as not to entirely restrict flow of exhaust gas to the muffler.

For moving valve 78, the valve 90 is provided with a crank 94 secured to the pivot 92, and connected by a link 96 to a crank plate 98 secured to the pivot 79 of valve 78, the connections being disposed at the outside of the casting 70. The plate 98 is disposed in spaced relation to the outer end of the boss 100, and the opening movement of the valve 90 is resisted by a coil spring 102 disposed between the plate 98 and boss 100 and anchored at the ends thereto. The plate 98 has a cut away portion providing abutments 104 and 106 coacting with a stop 108 projecting from the boss 100. In the position of the parts shown the spring 102 urges the abutment 104 into engagement with the stop 108 and the opening movement of valve 90 is limited by engagement of the abutment 106 with said stop. The plate 98 is provided with a series of holes 110 for adjustably receiving the end of the spring 102 anchored to the plate 98 so as to adjust the spring tension in accordance with the requirements.

In operation, especially when gaseous injection, such as from nozzle 15, is employed for blasting the fuel into and through the air stream in neck 14, the fuel is very thoroughly pulverized, and, because of its resulting great surface exposure to the air, absorbs heat therefrom very rapidly. Rapidity of heat absorption is of utmost importance because of the extremely short interval of time available and which is longest with the slow charge travel during engine idling and shortest with the high speed charge travel encountered at full power operation. The heat of the charge is thus reduced so as to favor having high density charge productive of good volumetric efficiency, and the fuel is in large part put into such condition—gasified and/or vaporized and/or in fogged or like highly divided state—that it is suspended in and carried along with the air stream without condensation or deposition on the conduit walls as the air stream branches or changes direction on its way to the engine cylinders.

The stream of blasted fuel, or fuel carried by the air from an ordinary carbureter, usually contains some fuel portions or droplets heavy enough to continue their substantially straight line travel without material deflection with the moving air. Unless given a liberal application of heat, this fuel portion would wet and load up the walls of the intake manifold.

By changing the direction of the intake manifold passage in the neighborhood where the blasted or inertia impelled heavier fuel particles strike the conduit walls, I can carry the lighter fuel particles thoroughly suspended in the air stream towards the engine cylinders with the air stream, and by applying heat of the exhaust gases to the dome 38 against which the fuel particles strike, I am enabled to secure a selective application of heat to vaporize and suspend these particles without undesirably heating the air of the charge.

The illustrated mode of securing such effect is by directing the fuel blast or fuel charge mixture downwardly in the intake manifold neck 14, which at the bottom branches to each side, and by providing the heated convex dome 38 in line with the discharge end of the neck 14, which dome is struck by and supplies vaporizing heat to the fuel particles impinging thereon, the dome having a greater horizontal projection than the cross-section of the neck 14 to insure impact of all the projected fuel particles on the dome.

Inasmuch as the exhaust gas is positively circulated through the dome 38 under an appreciable pressure differential because of the direct venting of the bypassed exhaust gas to atmosphere, the dome may be subjected to the maximum heat available. By disposing the convex dome 38 in the path of the downwardly projected fuel, the impact of the fuel particles thereon cause the particles to be reflected therefrom or to be deflected without tending to coalesce or accumulate thereon, as such particles would be likely to do if the surface were flat, an extended downwardly curving surface being provided along which the fuel particles may gravitate until vaporized, thereby enhancing vaporization or fuel nebulizing without the accumulation of liquid fuel in the bottom of the crucible or chamber 42. The vaporizing effect is also assisted by the provision of a downdraft manifold in which the fuel particles are caused to gravitate in the direction of air flow onto the dome 38. During this operation the inner side of the wall 36 is maintained by conduction sufficiently hot to assist in vaporizing any fuel particles deflected thereon from the dome.

By my invention the heat available for fuel atomization, the heating being applied entirely through the externally insulated dome 38, is sufficient to subject the fuel particles impinging thereon to spheroidal temperatures producing spheroidal vaporization substantially throughout the range of engine operation, and that such spheroidal action occurs is evidenced because the fuel does not form tarry or other precipitates on the dome 38 and in the crucible 42, and the vapor produced is substantially dry, not being readily condensed subsequently by contact with the cool walls of the intake manifold.

The heating capacity of the dome 38 depends on the area of the surface thereof and on the

flow of exhaust gas through the interior thereof. The diameter of the dome **38** is preferably made greater than the diameter of the passage **14** in alignment with said dome so that the flaring stream of projected fuel particles passing from the neck **14** is sure to all contact with said dome to cause vaporization. Further, although the dome **38** has sufficient surface area to supply the required heat for vaporizing all the fuel, the surface thereof is disposed largely out of the path of the air passing to the cylinders, the dome including a substantial vertical component which is more effective in promoting vaporization without exposing the air to the heating effects thereof.

The structure of the intake manifold because of the provision of the tapered channel portions **34** and because of the slightly flaring neck portion **14** facilitates the deflection of the main portion of the charge into the branches, the same skirting the dome **38** without the air thereof being appreciably heated. The channels **34** opening at their inner ends into the crucible **42** also provide passages for the return of the vaporized fuel from the crucible **42** into the main charge stream.

The heating being applied at the dome **38** only, and the structure of the manifold being as above described, substantially complete vaporization of the fuel component is accomplished without heating the air so as to appreciably reduce the volumetric efficiency, and this result is enhanced when supplemented by the automatic control of the passage of the exhaust to the dome **38**, as hereinafter described.

The exhaust gas pressure and velocity of the exhaust gas stream vary directly with the speed and percent of engine load, (which is a direct function of exhaust gas temperature). Hence as the exhaust gas pressure, or velocity increases beyond a certain value, the valve **90** starts to open under the pressure exerted by the exhaust gas stream, closing the valve **78**, the flow of exhaust gas through passage **64** gradually decreasing to a minimum at full load when maximum power is desired. By adjustment of heat resistant spring **102** the pressure at which the valve **90** starts to open may be controlled.

At engine idling and road torque loads, the highly conductive dome **38** supplies heat at a rate sufficient to insure spheroidal vaporization. At these stages of operation the valve **78** is open to supply maximum exhaust gas to the dome **38**. By discharge of the fuel through nozzle **15** in an atomized state and into the region of pressure reduction vaporization is accomplished at lower temperatures. At these stages of engine operation, uniform distribution of the charge to the cylinders and economy in operation are obtained. Under heavy load conditions of operation, particularly at high speeds, while the fuel flow rate is greater and the intake pressure reduction less, the exhaust gas temperatures available are in excess of those required to effect spheroidal vaporization. At this stage power is required in engine operation, and the quantity of exhaust gas flowing through the dome **38** is reduced by valve **78** so that adequate fuel vaporization is obtained without unduly heating the air, thereby maintaining a volumetric efficiency productive of maximum power at full load operation.

By my invention, when the exhaust gas temperatures are low, adequate fuel vaporization is obtained by the provision of positive circulation of a maximum quantity of exhaust gas through the dome, and by the provision of means for rapidly transferring the heat to the fuel because of the high thermal conductivity of the dome **38**. When power is required, the exhaust gas temperatures then being high, the valve **78** closes off to reduce the quantity of exhaust gas passing to the dome **38**, complete vaporization being obtained, while maintaining the charge in a cool dense condition.

To maintain the homogeneous suspension of the fuel in the air so attained, I keep the sectional area of the intake manifold, and, therefore, of the moving charge stream as low as practicable without unduly restricting charge flow through the manifold, thus keeping the charge moving rapidly and avoiding any slowing up or expansion of the charge material on its way to the engine cylinders, which would be productive of condensation, and I also preferably maintain the charge velocity during such travel, as by progressive reduction of the cross-sectional area of the manifold branches from the common neck portion thereof to the engine cylinders. The grooves **34** also tend to retard spiral movement of the charge. The intake branches are air insulated from the exhaust manifold, no heating being applied to the charge in the branches.

Using my manifold the charge is thoroughly homogenized because of the efficient vaporizing and spheroidizing action of the dome **38**, and this is accomplished without undue heating of the air. This results in better distribution of the charge to the cylinders and in maximum power and economy.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. A charge forming and distributing manifold comprising an exhaust gas heated, dome-shaped member in alignment with the entrance to the manifold, said member having an insulating jacket disposed about the same.

2. A charge forming and distributing manifold comprising a hollow member disposed in alignment with the entrance to the manifold and having provision for circulating exhaust gas therethrough, said manifold having a portion surrounding said member in spaced relation thereto and forming therewith dead air space serving to insulate the member against heat radiation to the atmosphere.

3. A charge forming and distributing manifold comprising a hollow portion projecting into the manifold from the outside adjacent to the point of deflection of the charge, said portion being heat insulated at the outside of the manifold, and having provision for circulating exhaust gas through the interior thereof.

4. A charge forming and distributing manifold comprising a hollow, dome-shaped member disposed in a recess in the manifold opposite to the entrance thereof, said member being composed of a metal of high thermal conductivity, and being insulated at the outside of the manifold, and means for circulating exhaust gas through said member.

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