Oct. 25, 1960 D. J. CAMERON ET AL 2,957,682

FUEL SYSTEM

Filed May 13, 1957 3 Sheets-Sheet 1

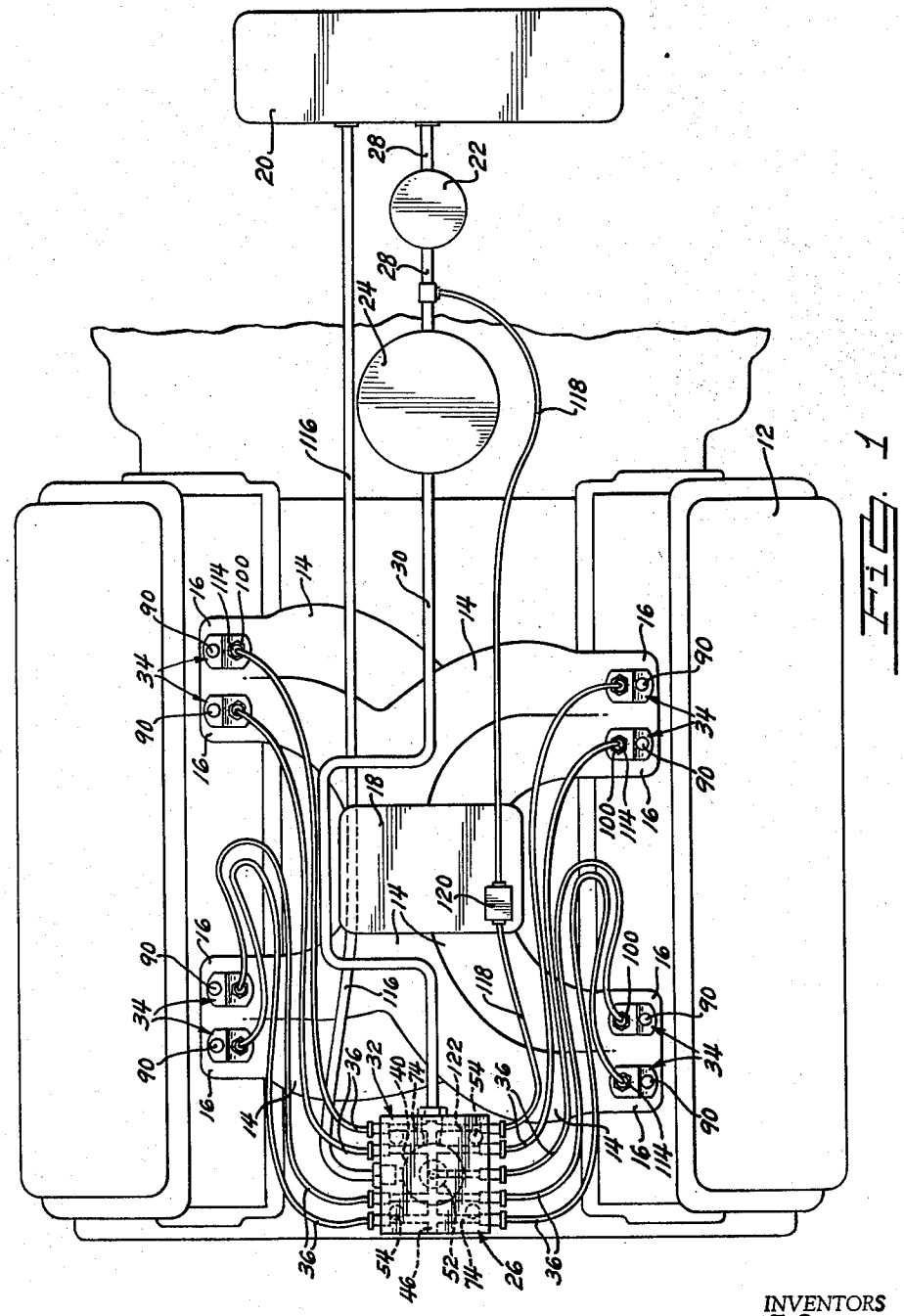


FIG. 1

INVENTORS
DONALD J. CAMERON &
BY ALTON G. DE CLAIRE JR.
Walter Poloroha, Jr.
ATTORNEY

Oct. 25, 1960 D. J. CAMERON ET AL 2,957,682

FUEL SYSTEM

Filed May 13, 1957 3 Sheets-Sheet 2

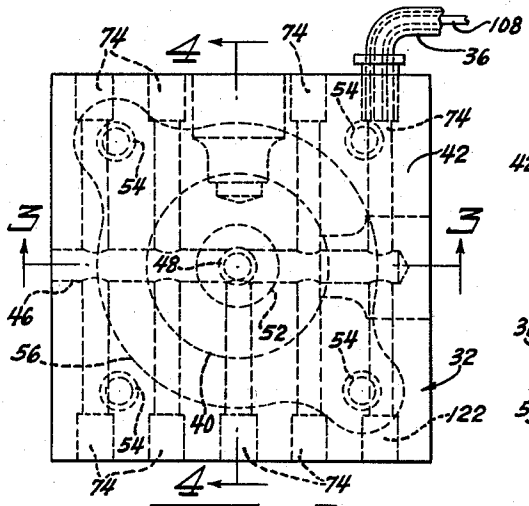


Fig. 2

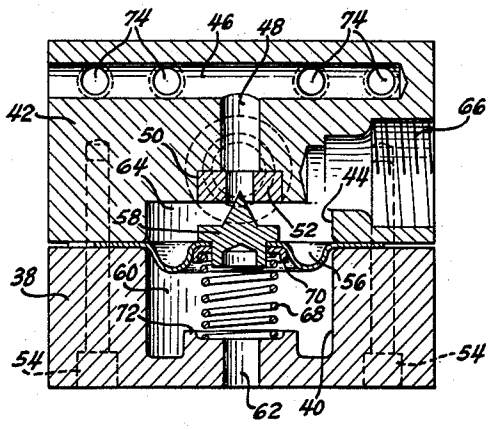


Fig. 3

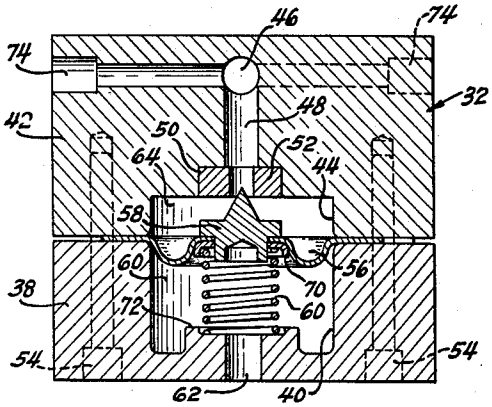


Fig. 4

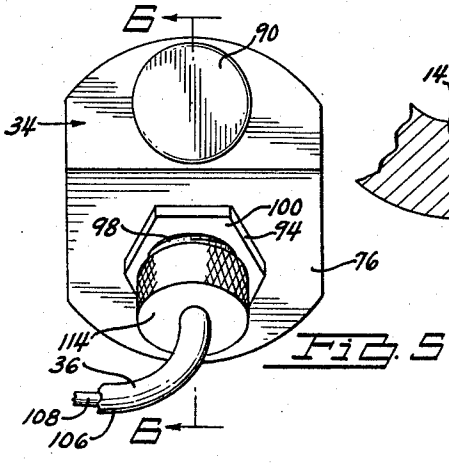


Fig. 5

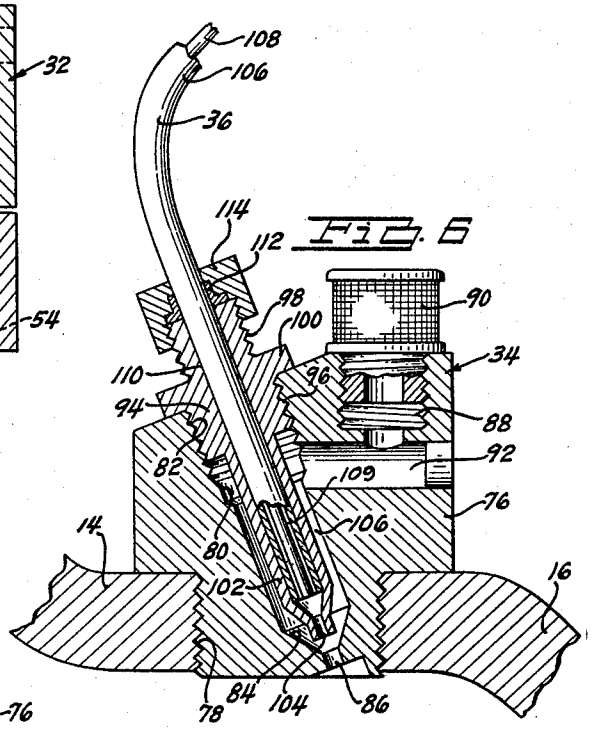


Fig. 6

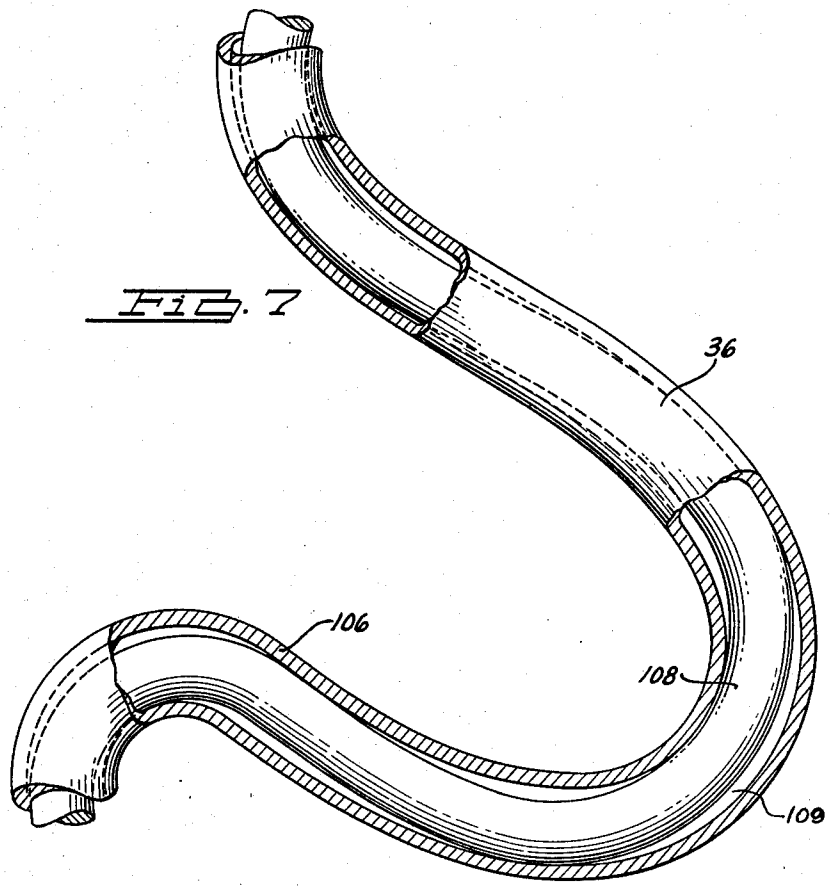
INVENTORS
DONALD J. CAMERON &
BY ALTON G. DE CLAIRE JR.
Walter Patorska, Jr.
ATTORNEY

Oct. 25, 1960 D. J. CAMERON ET AL 2,957,682

FUEL SYSTEM

Filed May 13, 1957 3 Sheets-Sheet 3

Fig. 7



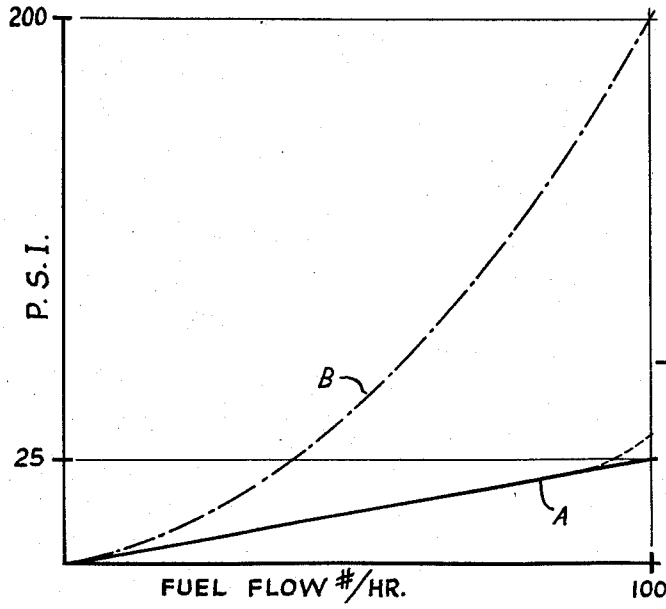


Fig. 8

INVENTORS
DONALD J. CAMERON &
BY ALTON G. DE CLAIRE JR.
Walter Patronaka, Jr.
ATTORNEY

United States Patent Office

2,957,682

Patented Oct. 25, 1960

2,957,682

FUEL SYSTEM

Donald J. Cameron, Roseville, and Alton G. De Claire, Jr., Harper Woods, Mich., assignors to Holley Carburetor Company, Van Dyke, Mich., a corporation of Michigan

Filed May 13, 1957, Ser. No. 658,668

5 Claims. (Cl. 261—23)

This invention relates to fuel systems, and more particularly to laminar flow fuel distribution means for fuel systems adapted for use with internal combustion engines.

Any fuel injection system for internal combustion engines, whether it be of the intermittent or continuous flow type, must be adapted to supply approximately forty to fifty times as much fuel at maximum engine fuel requirements as it does at minimum engine fuel requirements. For example, a given engine may require fuel at a rate ranging from three to one hundred and twenty pounds per hour; in the case of an eight cylinder engine, the rate of fuel supply to each cylinder would, of course, be one-eighth of the total rate.

In the case of turbulent flow systems, assuming a fixed jet is employed, the quantity of fuel flowed varies with the square root of the pressure. Using the above range of flow rates, the ratio of the pressure required to flow 120# per hour to that required to flow 3# per hour is approximately 1600/1; thus if a relatively small jet size is selected so as to flow 120# per hour at a pressure as high as 400 p.s.i., the pressure at 3# per hour will be only 10" of gasoline or about ¼ p.s.i., which is the minimum necessary at idle to overcome the effects of angularity.

It is thus apparent that the use of a fixed-jet, turbulent flow system for the above range of flow rates requires a fuel pump that is capable of delivering fuel over a wide range of pressures and at a very high upper pressure limit. Another reason for this is that if the upper pressure limit is not sufficiently high, the pressure at the lower flow rate will drop off to a value that is insufficient to overcome the fuel vapor pressure at idle speeds, and serious vapor problems will be experienced at or near idle speeds.

While such pumps are available, they are expensive, and any fuel system requiring such a pump suffers a serious cost disadvantage. Furthermore, the small jet sizes required by high pressure turbulent flow systems are easily blocked by dirt particles, varnishes, etc. Also, it is difficult to calibrate such systems so that all of the cylinders are supplied with the same amount of fuel.

It is now proposed to provide a laminar flow system, wherein fuel flow varies directly with the pressure and wherein extremely small jet sizes are not required to maintain minimum flow pressures. Using the above range of flow rates, the ratio of the upper and lower limit pressures in the proposed system is only 40/1, and if the laminar flow restriction employed is such as to provide a low pressure system having a maximum pressure of approximately 25 p.s.i., the pressure at the low flow rate will still be about 24" of gasoline pressure so as to substantially eliminate vapor problems at idle speeds and to completely eliminate angularity problems.

The proposed system will permit the use of a less expensive pump and eliminate the need for small jets

which tend to foul. Even if it is desired to employ a higher pressure pump, the proposed system will provide the desired low range fuel flow rate at pressure sufficient to overcome vapor problems, approximately 10 p.s.i. in the case of pump operating at 400 p.s.i. at the maximum flow rate.

The proposed system comprises a low volume, constant pressure chamber supplied with metered fuel from any desired metering device, a nozzle at each intake port, and a laminar flow conduit from the constant pressure chamber to each nozzle. Each conduit comprises a length of metal tubing having a length of wire inserted therein, with the I.D. of the tubing and the O.D. of the wire being such as to provide a laminar flow path in the diametrical clearance therebetween. The tubing and the wire are commercially available, and the commercial tolerances thereof are such that the flow of fuel to the various intake ports may be easily adjusted or equalized merely by varying the length of wire as compared to the length of tubing or by suitably crimping the tubing. No jets are required at the nozzle, except a relatively large fuel directing jet and an air jet, which provides sufficient restriction to flow of air through an atmospheric air inlet to maintain atmospheric pressure at the fuel directing jet.

The proposed system is thus easily constructed from inexpensive, commercially available materials, and it can be calibrated very easily without expensive reworking. In addition, the conduits have a low volume so that they are filled more rapidly on starting.

These and other objects and advantages of the invention will become more apparent by reference to the following specification and drawings, wherein:

Figure 1 is a diagrammatic top plan view of a fuel system embodying the invention;

Figure 2 is an enlarged top plan view of one of the elements of Figure 1;

Figure 3 is a vertical cross-sectional view taken on the plane of line 3—3 of Figure 2 and looking in the direction of the arrows;

Figure 4 is a vertical cross-sectional view taken on the plane of line 4—4 of Figure 2 and looking in the direction of the arrows;

Figure 5 is an enlarged top plan view of another element shown by Figure 1;

Figure 6 is a vertical cross-sectional view taken on the plane of line 6—6 of Figure 5 and looking in the direction of the arrows;

Figure 7 is an enlarged fragmentary view, partly cut away and in cross-section, illustrating in greater detail the construction of one of the conduits shown by Figure 1;

Figure 8 is a graph comparing fuel flow versus pressure curves for a fixed-jet, turbulent flow system and a fixed-jet, laminar flow system embodying the invention.

Referring to the drawings in greater detail, Figure 1 illustrates a fuel system **10** embodying the invention and fitted on an internal combustion engine **12** having an intake manifold **14** with a plurality of intake ports **16**.

The engine **12** is provided with any suitable combustion air control device **18**, the details of construction of which are not important to the invention except that it may embody a starting fuel system which will be referred to later, and a fuel system **10** including a fuel tank **20**, a fuel pump **22**, a fuel metering device **24**, and a fuel distribution system embodying the invention and generally designated by the numeral **26**. The particular construction of the fuel metering unit **24** is likewise not important to the invention disclosed herein so that the details of construction thereof need not be described, and the pump **22** is that of which the pressure

range and upper pressure limit may be reduced by use of the invention, as described above.

In the system shown by Figure 1, unmetered fuel is supplied by the pump **22** from the tank **20** to the metering unit **24** by means of the conduit **28**, and metered fuel is supplied through the conduit **30** to the header **32**; from the header **32**, metered fuel under a constant pressure is supplied through the individual conduits **36** to the individual inlet ports **16**, each of which is provided with a nozzle assembly **34**.

The header **26** shown in greater detail by Figures 2, 3 and 4 may comprise a lower portion **38** having an annular recess **40** formed therein and an upper portion **42** formed to provide an annular recess **44** and a constant pressure manifold chamber **46** connected with the recess **44** by means of the passage **48** having an enlarged portion **50** adapted to receive an annular valve seat **52**. The upper and lower portions **42** and **38** may be secured together by any suitable means such as bolts **54**, with the flexible diaphragm **56** being held between the upper and lower portions **42** and **38** and serving as a gasket. The diaphragm **56** has secured to the center portion thereof in any suitable manner a valve **58** adapted to engage the valve seat **52**, with the valve **58** preferably being cone-shaped so as to provide a self centering valve assembly.

With the above or any equivalent construction, a lower chamber **60** of which the diaphragm forms one wall is provided; the chamber **60** is vented to atmosphere by means of the passage **62** so as to permit free movement of the diaphragm **56**. The upper chamber **64** on the opposite side of the flexible diaphragm **56** has a metered fuel inlet **66**; when the metered fuel pressure exceeds the force of the spring **68** positioned between the diaphragm cup **70** and the shoulder **72**, the valve **58** is opened and metered fuel may pass into the constant pressure chamber **46** to be distributed to the eight individual fuel outlet passages **74** communicating with the constant pressure manifold chamber **46**.

As shown in detail by Figures 5 and 6, there is provided at each inlet port **16** what may be termed a nozzle assembly **34**, including a body **76** having a portion **78** adapted to be threaded into the wall of the inlet passage **16**. The body **76** may be formed to provide a passage **80** extending in the general direction of the path of the inlet port, with the passage **80** being threaded at its upper portion **82** and terminating at the inlet port end thereof in a conical or reduced diameter portion **84** communicating with the inlet port through a restriction **86**. A second threaded passage **88** may be provided adjacent the threaded portion **82** of passage **80**, and any suitable air filter device **90** may be threaded therein. A third horizontal passage **92** provides communication between the end of threaded passage **88** and the passage **80**, with the outer end of the passage **92** being blocked off. With this or an equivalent construction, manifold vacuum in the inlet port will cause clean air to be drawn through the filter device **90** and eventually through the restriction **86**. The restriction **86** is preferably of such size as to maintain substantially atmospheric pressure, rather than engine intake manifold pressure, at the conical portion **84** of passage **80**.

Referring again to Figures 5 and 6, the nozzle assembly **34** also includes a conduit retaining member **94** having threaded portions **96** and **98** separated by a hexagonal or other nut member **100** and a tubular portion **102** necking down to a relatively large fuel directing jet **104**. The end of the fuel directing jet **104** is spaced from the walls of the conical portion **84** of the passage **80** a sufficient distance so as not to constitute a pressure reducing venturi or restriction which would prevent the objective of maintaining atmospheric pressure at the end of the fuel directing jet **104**.

It is now apparent that the fuel directing jet **104** is not the equivalent of the fixed jet in a high pressure, turbulent flow system; on the contrary, its only purpose is to direct the stream of fuel through the restriction **86**, the size of which is determined by its function of preventing engine manifold vacuum from acting on the fuel at the jet **104**. The member **94** is, of course, threaded into the body **76** so that the tubular portion **102** is positioned co-axially within the passage **80** to provide a clearance **106** through which clean air may pass for the above purpose.

Extending between each of the nozzle asemblies **34** and one of the laterally extending passages **74** in the header **32**, is a laminar flow conduit **36** consisting of suitable lengths of commercially available metal tubing **106** and stainless steel or other wire **108**, with the inner diameter of the tubing and the outer diameter of the wire being such as to provide a diametrical clearance **109** therebetween constituting a laminar flow path or restriction through which metered fuel from the constant pressure chamber may flow to the fuel directing jet **104**, through the restriction **86** and into the intake ports **16**. This construction is shown in greater detail by Figure 7.

It is deemed advisable at this point to derive some of the relationships existing in flow through a cylindrical flow path such as that provided by a plain tube and through an annular flow path provided by applicants' tube with a solid insert. For this purpose, the following symbols will be employed and values assumed:

r=kinematic viscosity for gasoline at about 70° F.$=7.32\times10^{-6}$ ft.^{2}/sec.
l=length of flow path in feet
g=acceleration due to gravity$=32.2$ ft./sec.^{2}
D=diameter of plain tube in ft.

$Q_{max.}$=fuel flow rate for 1 cylinder$=\frac{120}{8}$ #/hr.$=9.26\times10^{-5}$ ft.^{3}/sec.
h=head$=96$ ft.-lb./lb.
Density$=45$#/ft.^{3} (gasoline)
f=friction factor
N_R=Reynolds number (≤2000 for laminar flow)
V_p=velocity of flow through plain tube=ft./sec.
V_1=velocity of flow between sheets=ft./sec.
d=diametrical clearance between tube and insert=ft.
D_m=mean diameter of annular flow path (I.D.$-d$)=ft.
A=area of flow path=ft.^{2}

$$R=\frac{d\pi D_m}{2\pi D_m}=\frac{d}{2}$$

With the exception of the derivation specifically explained, the following basic relationships are known and can be found in most text books relating to fluid mechanics:

Plain tube flow path

$$h=\frac{flV^2}{D^2g} \quad \text{(any flow)} \qquad N_R=\frac{VD}{r}$$

$$f=\frac{64}{N_R} \quad \text{(laminar flow)} \qquad Q=VA$$

Annular flow path

$$h=\frac{flV^2}{d^2g} \qquad f=\frac{64}{N_R} \text{ (laminar flow)} \qquad Q=VD_m\pi d$$

$$N_R=\frac{4VR}{r} \qquad N_R=\frac{4Vd}{2r}=\frac{2Vd}{r}$$

For a plain tube, V is the average velocity across a parabolic front. For two-dimensional flow between plates, the shape of the velocity front is a parabola in one view and a rectangle in the other view. The average velocity for two-dimensional flow is 3/2 that of tube flow. Thus, when the maximum peak velocity is the same, $3/2V_p=V_1$ or $V_p=2/3V_1$, therefore

$$N_R=4/3\frac{V_1d}{r}$$

From the above basic relationships, the following relationships can be derived by simple substitutions, etc.:

Plain tube flow path

(1) $$Q_{max.}=\frac{N_R r \pi D}{4}$$

(2) $$h=\frac{64 N_R l r^2}{2gD^3}$$

It is thus apparent that given a $Q_{max.}$ in Equation 1 will give a particular set value for D, which when used in Equation 2 will give a particular set value for *l*; that is, D appears in both equations and cannot be changed in (2) without affecting $Q_{max.}$ in (1). In other words, to decrease *l* in (2) requires a decrease in D, which requires an increase in N_R in (1); the latter cannot be done without getting into turbulent flow, if N_R was already selected close to 2000 for laminar flow.

Solving the above equations for D and *l*, where the other values are those given in the above list of symbols, gives the following set values: $D=.0081$ ft. and $l=47.5$ ft. This means that to provide the above referred to benefits of a laminar flow system in an engine requiring 120# of fuel per hour, the plain tube conduits to the nozzle must each be approximately .1 inch in diameter and at least 47.5 ft. long. This is obviously not a practical design, since an eight cylinder system would require 380 ft. of conduit. Furthermore, each line has a volume of 4.48 cub. in. (total volume=35.84 cub. in.), which presents a vapor problem and requires a long starting time if the lines should be empty and idle flow rate is 3#/hr.

Annular flow path

(1) $Q_{max.}=3/4 N_R D_M \pi r$

(2) $$h=\frac{64}{2g}\times\frac{9}{16}\times\frac{l r^2 N_R}{d^3} \text{ or } \frac{18 N_R l r^2}{g d^3}$$

It is apparent from Equation 1 above that given Q_{max}, D_m is set for a given N_R; if D_m needs to be increased, however, N_R can be decreased from the critical 2000 value, getting even further from the turbulent flow range. In other words, D_m is flexible to a minimum. In Equation 2, *l* is a function of d^3; therefore, any suitable combination of *l* and *d* can be used and laminar flow will still prevail. Since

$$\frac{l}{d^3}$$

does not appear in Equation 1, any values of

$$\frac{l}{d^3}$$

can be used in Equation 2 without affecting $Q_{max.}$ in Equation 1.

Again, assuming the values given in the list of symbols, actual sets of values of *l* and D_m were found to be as follows, where $d=.008$ inch:

$D_m=.041$ inch (min. since $N_R=2000$) and $l=.474$ ft.
$D_m=.125$ inch ($N_R=516$) and $l=1.74$ ft.

Using the latter combination, each line has a volume of only .0768 cub. in. (total volume=.6144 cub. in.), greatly reducing vapor problems and starting time.

The conduits **36** are made very simply by cutting off a suitable length of tubing **106** and inserting an equal length of wire **108** into the tubing so that the free ends thereof match. The effective laminar flow restriction is dependent upon the diametrical clearance **109** between the wire **108** and the tubing **106** and upon the length of wire in the tubing. It can thus be seen that the clearance **109** and the length of wire may be varied as desired. No particular means is required to retain the wire in the tubing, since it will be retained by friction, particularly when the conduits are bent as shown in Figure 1. One end of each such conduit assembly **36** may then be inserted into the outer end of each of the laterally extending passages **74** and soldered or otherwise secured to the header. The other end of each of the conduit assemblies **36** is merely inserted into the passage **110** extending through the member **94** until the free end of the tubing engages the necked down portion of the tubular portion **102**. A retaining ring **112** may be soldered or otherwise secured to the tubing **106** and a suitable nut **114** may be threaded on the threaded free end **98** of the member **94** to secure the appropriate conduit **36** to its nozzle assembly **34**.

It has been stated above that the air control device **18** may incorporate a starting fuel system. In that event, a conduit **116** for by-passing metered fuel from the chamber **64** to the tank **20** is provided. In addition, a conduit **118** extending from the pump outlet conduit **28**, through any suitable starting fuel device represented generally by the numeral **120** and to the inlet **122** is also provided. In addition, the control device **118** and the starting fuel device **120** are provided with suitable means to by-pass metered fuel back to the tank **20** and to supply starting fuel to chamber **46** on starting and to cut off start fuel and close line **116** when the engine has started.

In the particular embodiment of the invention shown and described above, metered fuel from the metering unit **24** is supplied to the chamber **64** in the header **32**. On starting the engine, the conduit **116** will be open, and metered fuel will be by-passed to the tank **20**, since spring **68** will keep the valve **58** closed. At the same time, starting fuel in the proper amount, as controlled by the start fuel device **120**, will be supplied to the chamber **46**, from which it will be distributed to the inlet ports **16**. As soon as the engine starts, the start fuel will be cut off, the line **116** will be closed and metered fuel pressure will be increased in chamber **64**. When the metered fuel pressure exceeds and force of the spring **68**, the valve **58** will open and metered fuel will enter the constant pressure manifold chamber **46** and be distributed to the separate conduits **16**, as already described.

While a start fuel device **120** is shown and described, it is to be understood that the principal feature of the invention, the laminar flow fuel distribution system, does not necessarily require the use of a start fuel device.

The diametrical clearance **109** between the tubing **106** and the wire **108** of each conduit assembly **36** provides a laminar flow restriction for the fuel so that fuel flow varies directly with pressure instead of as the square root of the pressure, as it would in the case of a fixed-jet, turbulent flow system.

The above is illustrated by Figure 8, wherein the curve A represents Fuel Flow versus Fuel Pressure for a fuel system embodying the invention and curve B illustrates the same for a turbulent flow, fixed-jet system. These curves are intended to be qualitative, rather than quantitative, in nature, since the exact curves would require the specification of actual fixed-jet and restriction dimensions, pump capacities, etc. However, it will be noted generally that the system disclosed herein will supply 100# of total fuel per hour through eight laminar flow restrictions at a maximum pressure of 25# per square inch where each restriction has an area of approximately .0057 sq. in. for the same flow through eight fixed-jets, each having an area of .000056 sq. in., the turbulent flow system will require a maximum pressure of 200# per square inch. At the low flow ranges, however, the pressure in the turbulent system would drop below that of the system embodying the invention and below the minimum required to overcome angularity and vapor formation, unless the small jet size is used.

It is to be observed that the above advantages of the invention are accomplished with a laminar flow restriction having nearly 100 times the area of the fixed jet in an equivalent turbulent flow system. Thus, the laminar flow restrictions are that much less likely to foul.

The laminar flow restrictions of each conduit may be easily calibrated to equalize or vary the flow to each cylinder simply by varying the length of wire or by suitably crimping the tubing in one or more places. This may be done by any mechanic whenever it becomes necessary, such as when one or more conduits are replaced and the fuel flow therethrough must be matched with the other original conduits, etc.

It is also apparent that the conduits are extremely simple in manufacture from inexpensive commercially available materials, the commercial tolerances of which are such that the above described means of calibration is sufficient.

The conduits, particularly where the wire and tube lengths are substantially equal, have a very low volume so that the system is quickly filled with fuel on starting. In addition, the low volume aids in reducing vapor problems.

While but a single modification of the invention is shown and certain dimensions are indicated for purposes of illustration, it is apparent that other modifications thereof may be made and any suitable dimensions may be employed without exceeding the scope of the invention as set forth in the appended claims.

What we claim is:

1. A fuel distribution system for an internal combustion engine, said system comprising a plurality of conduits, each of said conduits comprising a suitable length of tubing having a suitable length of wire inserted therein, said conduits being adapted by reason of the diameterical relation between said tubing and said wire to supply substantially all of the fuel required by said engine by laminar flow of said fuel.

2. In a port injection fuel system for an internal combustion engine having a plurality of intake ports, means wherein fuel flow varies as a linear function of the fuel pressure over substantially the entire range of engine requirements for distributing metered fuel to each of said ports, said means including a laminar flow conduit leading to each of said ports, each of said conduits comprising a length of tubing having a suitable length of solid rod inserted therein, with the diametrical clearance between said tubing and said rod being such as to provide a laminar flow path for said metered fuel.

3. A fuel system for an internal combustion engine requiring fuel at a maximum rate of about 120 #/hr. and having a plurality of intake ports, comprising a fuel tank, a fuel pump rated at 50 p.s.i. or less, fuel metering means and metered fuel distributing means, said fuel distributing means including a nozzle at each of said intake ports, a constant pressure metered fuel chamber posterior to said metering means and a laminar flow conduit between said chamber and each of said nozzles, each of said conduits comprising a length of tubing having a length of wire inserted therein, with the diametrical clearance between said wire and said tubing being such as to provide laminar flow of said metered fuel for all engine fuel requirements.

4. In a fuel system for an internal combustion engine having an intake manifold with a plurality of intake ports, a nozzle for admitting fuel to each of said inlet ports, said nozzle comprising a body having an atmospheric air inlet terminating in a restriction and a hollow member disposed with clearance in said air inlet and terminating in a low restriction fuel directing jet, said fuel directing jet being positioned sufficiently back from said restriction to maintain atmospheric pressure at said fuel directing jet, and a laminar flow fuel conduit leading to said fuel directing jet, said conduit comprising a tube having a wire inserted therein, the relation of the O.D. of said wire and the I.D. of said tube being such that a laminar fuel flow path is provided by the diametrical clearance therebetween for all engine fuel requirements, the relation of the areas of said diametrical clearance and said fuel directing jet being such that the function of said fuel directing jet is primarily to direct the fuel stream through said restriction and not to restrict fuel flow.

5. In a fuel system for an internal combustion engine having an intake manifold with a plurality of intake ports, a nozzle for admitting fuel to each of said inlet ports, said nozzle comprising a body having an atmospheric air inlet terminating in a restriction communicating with said inlet port and of maximum size that will maintain atmospheric pressure in said nozzle, a hollow member disposed with clearance in said air inlet and terminating in a low restriction fuel jet to direct fuel through said restriction, said fuel jet being positioned sufficiently away from said restriction so as not to reduce the pressure at said fuel directing jet below atmospheric pressure, and a fuel conduit leading to said fuel jet, said conduit comprising a tube having a wire inserted therein, the relation of the O.D. of said wire and the I.D. of said tube being such that a laminar fuel flow path is provided by the diametrical clearance therebetween for all engine fuel requirements, the areas of said diametrical clearance on said fuel directing jet being such that the function of said fuel directing jet is primarily to direct the fuel stream and not to restrict fuel flow.

References Cited in the file of this patent

UNITED STATES PATENTS

662,296	Palmer	Nov. 20, 1900
2,406,141	Fredericks	Aug. 20, 1946
2,478,613	Weber	Aug. 9, 1949
2,511,213	Leslie	June 13, 1950