It is desirable to utilize alcohol in conjunction with diesel fuel in a diesel engine. Herein, a mixer (24) includes a chamber (28) and an elongated flow path (30) having first (32) and second (34) end portions (32, 34). A plurality of restricted orifices (36) connect the flow path (30) with the chamber (28) at a plurality of positions along the length of the flow path (30). The mixer (24) is positioned and adapted to receive diesel fuel in a first end portion (32) of the flow path (30) and alcohol in the second end portion (34) of the flow path (30). Desired quantities of diesel fuel and alcohol are measured out into the flow path (30). Thereafter, they flow through the restricted orifices (36) under pressure and are thoroughly mixed and emulsified in the chamber (28). Uniformity of diesel fuel-alcohol flow is thereby attained during steady state operating conditions. Control of the diesel-alcohol mixing ratio and of total fuel flow are also described, both as functions of engine operating conditions.
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Description
Dual Fuel Mixer-Emulsifier

Technical Field
This invention relates generally to a mixer-emulsifier for intermixing two dissimilar fluids and more particularly to a mixer-emulsifier for providing a diesel-alcohol fuel mixture to a diesel engine.

Background Art
Petroleum based fuels such as diesel fuel are being rapidly depleted. This makes it desirable to burn fuels obtained from other sources. Useful fuels include alcohols, made from coal, natural gas or renewable plant matter, synthetic fuels made from coal or oil shale, and perhaps liquified petroleum gas. These fuels, particularly synthetic fuels made with minimal processing and alcohol, tend to have very low cetane numbers and are thus difficult to burn in a diesel engine cycle. They can be burned, however, if mixed with a diesel fuel in percentages up to, for example, about 50%. It is also, at times, desirable to add a nonfuel fluid, such as water, along with diesel fuel. This can reduce nitrogen oxide emissions by as much as 50%.

While some synthetic fuels mix well with diesel fuels, others, such as alcohol, can only be kept in solution with diesel fuel if the fuels are both impractically free of water. Water, of course, will not mix with diesel fuels at all. Thus, it is generally required to provide separate fuel tanks for the alcohol (or water) and the
diesel fuel and to mix these liquids within the injection system. Since alcohol and diesel fuels are not miscible when even small amounts of water are present, and since water is not miscible with diesel fuels, it would be desirable if the alcohol or water could be emulsified with the diesel fuel in, or as they enter into, the injection system, prior to injection into the combustion chamber.

It should also be recognized that such fuels as alcohol cannot be readily moved through a conventional diesel fuel pump system, since alcohol has relatively low lubricity and would tend to cause close fitting parts within the fuel pump to wear very fast or possibly even to seize.

The prior art has primarily used carburetion or dual injectors to blend or mix dissimilar fuels within the combustion system. Cost is considerably increased when a second injection system is added to an engine. Further, it may be difficult to add the second set of injectors because of space limitations. Hence, retrofitting of existing engines is, at best, difficult, and at worst, impossible.

A further problem which exists when utilizing a mixture of diesel fuel and alcohol is that it is very undesirable to use a low cetane fuel such as alcohol at start-up or at idle conditions of the engine. The amount of alcohol that can be tolerated by a diesel engine varies from a very small amount during starting and idle conditions to a much larger amount at the higher loads on the engine. Thus, control of the amount of alcohol, as a function of engine speed and/or
load, is desirable.

Still further, when differing mixtures of diesel fuel and alcohol are utilized in an engine, the amount of energy of the mixture, per unit volume, varies. Thus, control of the total volume of fuel to be injected, as a function of engine speed and/or load, is also desirable.

The present invention is directed to overcoming one or more of the problems as set forth above.

Disclosure of the Invention

In accordance with one aspect of the present invention, an improvement is provided in a fluid flow system which has first pressurizing means for periodically developing (a) a first pressure for pumping and (b) a transfer pressure for not pumping a first fluid to flow out of an outlet and towards a fluid injector. The improvement comprises a mixer having a chamber communicating with the fluid injector, an extending flow path having first and second end portions and being separated from the chamber and a plurality of restricted orifices connecting the flow path with the chamber at a plurality of positions along the length of the flow path. The pump outlet is communicated with the first end portion of the flow path. Second pressurizing means serves for periodically motivating a second fluid to flow at a second pressure into the second end portion of the flow path in response to the first pressurizing means being at the transfer pressure.
Utilizing a mixer as described above, very thorough mixing of two dissimilar and substantially immiscible fuels, such as alcohol and diesel fuel, can be accomplished. Further, this mixing can be accomplished with little or no modification to the fuel pump system of a conventional diesel engine. The alcohol does not come in contact with the moving parts of the fuel pump. As a result, the low lubricity of the alcohol does not create a problem. Controlled portions of the diesel fuel and alcohol (or other second fluid) are introduced into the flow path, assuring a uniform fuel mixture during each stroke of the fuel pump. When operating in accordance with the preferred embodiment of the present invention, the amount of alcohol used can be made a function of engine speed, intake manifold pressure, or exhaust manifold temperature. Substantially no alcohol is used during start-up or idle operations, and increased amounts of alcohol can be used as the engine is run at higher loads and/or speeds. The timing and relative volumes of the diesel fuel and alcohol pumped can also be controlled as a function of intake manifold pressure or exhaust manifold temperature to provide automatic diesel-to-alcohol ratio adjustment for the different volumetric energy contents of diesel fuel and alcohol.

**Brief Description Of The Drawings**

Figure 1 illustrates, schematically, a system in accordance with an embodiment of the present invention, as connected to deliver a mixture of two fluids; Figure 2 illustrates, in section, a
portion of the system of Figure 1 and including a mixer in accordance with an embodiment of the present invention;

Figure 3 illustrates, in partial view in section, an embodiment of a fuel pump as shown schematically in Figure 1;

Figure 4 illustrates, in section, an alternate mixer to that shown in Figure 2; and

Figure 5 illustrates, in section, an alternate check valve assembly to that shown in Figure 2.

Best Mode For Carrying Out The Invention

A fluid flow system 10 is seen generally in Figure 1. The system 10 includes a first fuel pressurizing means 12 such as the conventional fuel pump 14 seen in Figures 1 and 3. The fuel pump 14 receives a first fluid from a pump 15 and periodically develops a first pressure for pumping the first fluid from a chamber 16 and via a conduit 18, and allows pressure to fall to a transfer pressure, slightly above the pressure of a fuel tank 20. At the transfer pressure fluid is not pumped from the chamber 16. The first fluid motivated by the fuel pump 14 is eventually delivered to a conventional nozzle or fuel injector 22.

In accordance with the present invention, a mixer 24, serves to mix the first fluid with a second fluid and to emulsify the mixture. The mixer 24 is positioned to receive the flow from the conduit 18 and to deliver that flow, along with the second fluid, to a conduit 26 which leads to the fuel injector 22.
Adverting now to Figure 2, the structure of the mixer 24 is shown in detail. The mixer 24 includes an inlet passage 27 and a chamber 28 which communicates fluid with the conduit 26 and to the fuel injector 22. The mixer 24 further includes an elongated flow path 30 having a first end portion 32 and a second end portion 34 and being separated from the chamber 28. A plurality of spaced apart restricted orifices 36 connect the flow path 30 with the chamber 28 at spaced intervals along the length of the flow path 30. The elongated flow path 30 is generally of a helical configuration.

Means 38 are provided for communicating fluid from chamber 16 through conduit 18 of the fuel pump 14 with the first end portion 32 of the flow path 30. In the particular embodiment illustrated, the means 38 includes the conduit 18 and the passage 27.

In the embodiment as shown in detail in Figure 2, the mixer 24 includes a body 42 (usually cylindrical) which fits tightly within a bore 44 in a housing 45. The body 42 has an external surface 46, and the flow path 30 is a generally spiral or helical undercut 48 in the external surface 46. The chamber 28 is located within the body 42, and is generally centrally located therein and generally cylindrical in shape. The restricted orifices 36 are in the form of radial passages in the body 42 leading from the undercut 48 to the chamber 28.

Second pressurizing means 50 serves for periodically motivating a second fluid, generally alcohol, to flow at a second pressure into the mixer 24 via the second end portion 34 of the flow
path 30 in response to the pressure of the first pressurizing means 12 falling to the lower transient pressure. The second pressurizing means 50 may include, for example, a tank 52 connected by a conduit 54 to a pump 56 which motivates the fluid to flow through a conduit 58. The pump 56 will generally not be of the jerk type variety, but will instead provide a relatively constant second pressure in the conduit 58. The second pressure can be adjusted in a manner which is explained below.

Referring again to Figure 2, the conduit 58 connects to valve means 60, in the embodiment illustrated a conventional spring loaded check valve 61, which allows flow of the second fluid towards the second end portion 34 of the flow path 30 in response to the second pressure exceeding the transient pressure by at least a selected amount. The valve means 60 also prevents such flow in response to the second pressure not exceeding the transfer pressure by at least the selected amount and serves for preventing reverse flow. The strength of a spring 62 of the check valve 61 determines the selected amount by which the second pressure must exceed the transient pressure for flow to take place towards the flow path 30.

Adverting to Figure 1, it will be seen that in the preferred embodiment of the invention the fuel injector 22 injects a fluid, either the first fluid or an emulsified mixture of the first and second fluids, into a cylinder 63 of an engine 64, which has an inlet manifold 65 and an exhaust manifold 66.
Pressure control means 68 are provided for controlling the second pressure and flow of the second fluid to the mixer 24 in response to operating conditions of the engine 64. As is seen in Figure 1, a relief valve 70 is provided in the conduit 58 which receives pressurized fluid from the fluid pump 56. The relief valve 70 is connected to reduce excess pressure, over that desired in the conduit 58, by returning fluid to the tank 52.

A pressure control relief valve 72 is provided in series with the relief valve 70. Pressure from the inlet manifold 65 is applied through a conduit 74 to one side of a bellows 76 and serves as a biasing force to hold the pressure control relief valve 72 in its closed position. When sufficient pressure is built up downstream of the relief valve 70 (which is set at a relatively low value, generally just enough to overcome the fuel transfer pressure), the bellows 76 is flexed leftwardly allowing fluid flow past the relief valve 70 and the pressure control relief valve 72 to the tank 52.

As an alternative, the pressure in the conduit 74 can be supplied by the expansion of a suitable fluid such as mercury which is in thermal contact with the exhaust manifold 66, as via a conduit 77, shown in phantom. As the exhaust manifold heats up, the expanding liquid forces the bellows 76 rightwardly, thus increasing the effective pressure acting through pressure control relief valve 72. As a result, a larger volume of alcohol, at a greater pressure, flows through conduit 58 and enters the mixer 24. As the
gas temperature in the manifold 66 is lowered, the bellows 76 is less strongly biased rightwardly in Figure 1, and a greater quantity of the alcohol is recycled past the relief valve 70 to the tank 52. With increased pressure in the conduit 58, an increased volume of the alcohol flows into the mixer 24 in any given period of time. Thus, the pressure control means 68 can be made to increase the second pressure in response to increased inlet manifold pressure and to decrease the second pressure in response to decreased inlet manifold pressure. Alternatively, the pressure control means 68 can be made to increase the second pressure in response to increased exhaust manifold temperature and to decrease the second pressure in response to decreased exhaust manifold temperature.

It should be noted that flow control means 78 are preferably included for controlling the amount of the second fluid which enters the second end portion 34 of the flow path 30, in response to the amount by which the second pressure exceeds the transfer pressure. In the embodiment illustrated, the flow control means 78 is in the form of a restricted passage 80 which receives the flow from the check valve means 61 and delivers it to the second end portion 34 of the flow path 30. Generally, the restricted passage 80 will be selected whereby the amount of second fluid flowing therethrough will be a function of the square root of the pressure of the second fluid passing through the check valve means 60.
Referring now to Figure 3, the structure of the fuel pump 14 is shown. It will be seen that the fuel pump 14 includes an inlet 81 and return means 82, in the embodiment illustrated a return passage leading from the fuel pump 14 via a conduit 83, to the fuel tank 20. In this manner, when the second fluid is being flowed into the second end portion 34 of the flow path 30, the first fluid can at the same time be flowed backwardly through the return passage 82 to the fuel tank 20.

Diesel-alcohol mixtures generally have a different energy content, per unit volume, than does diesel fuel alone. Hence, it is desirable to provide means 88 to control the volumetric output of the pump 14, in response to engine operating conditions. This control can be made responsive to, for example, inlet manifold pressure or exhaust manifold temperature. This provides compensation for a lower heating value per unit volume of alcohol compared with diesel fuel. A rack 90, which adjusts the timing of the fuel pump 14 and the volume of fuel pumped by the fuel pump 14, can be moved in response to engine operating conditions. For example, as the rack 90 is moved linearly this can serve to rotate the plunger 92 of the fuel pump 14, which may be one of a plurality of such fuel pumps. Rotation of the plunger 92 could then control, through operation of a scroll 94, the beginning, duration and ending of each pumping stroke of the fuel pump 14. The adjustment of the rack can be controlled by suitable conventional electrical or mechanical rack adjusting means, as indicated schematically at 95.
in Figure 1.

**Embodiment of Figure 4**

Figure 4 illustrates, with primed numbers representing like parts to those in Figure 2, an alternate embodiment mixer 24'. In particular, in the embodiment of Figure 4 the mixer 24' includes a body 42' fitting within a bore 44' (in place of the body 42 and bore 44 of Figure 2) in a housing 45'.

The difference between the embodiment of Figure 4 and that of Figure 2 is that the restricted orifices 36' of the Figure 4 embodiment are of a structure sufficient to impinge the first and second fluids with one another within the chamber 28' as these fluids exit the orifices 36'. The point or points of impingement of the first and second fluids within the chamber 28' may be selected to be on a center axis 96 of the chamber 28', or may be elsewhere within the chamber 28'.

**Embodiment of Figure 5**

The embodiment of Figure 5 shows an alternate valve means 60' which can serve to replace the valve means 60 shown in Figure 2. The advantage of the embodiment of Figure 5 is that it does not require a spring. This can be important in operations wherein each of a number of cylinders are independently supplied with fuel by an apparatus generally as shown in Figure 2. In such a situation, it is important that each of the cylinders receive an equal amount of fuel. If the spring constants of the various springs of the valve means 60 are not precisely equal, different
amounts of fuel may be supplied to different cylinders. In the embodiment of Figure 5, there is no spring, thus eliminating the problem. Basically, a disc check 97, having one or more cross grooves 98, serves as the valve means 60'. The alcohol flowing from conduit 58', lifts the disc check 97 and moves it against the face of a valving chamber 100. However, flow can still proceed around the disc check 97 through the grooves 98 and through the restricted passage 80'. When pressure is built up in the restricted passage 80' due to the pressurization caused by the fuel pump 14, the disc check 97 is moved downwardly and seals against a lapped surface 102. The various conduits 58' are manifolded, one to another, thereby assuring that equal pressure and flow occurs in each of the conduits 58', and therefore equal proportions of alcohol are provided to each of the cylinders 63 of the multicylinder engine 64.

Industrial Applicability

The improvement of the invention is particularly useful for emulsifying diesel fuel and a second fuel, such as alcohol, before the resulting mixture enters the diesel engine 64.

In operation, the fuel pump 14 operates in a conventional manner providing fluid periodically at a first (high) pressure and allowing the pressure to fall to a transient (low) pressure, corresponding, generally, to the pressure in the fuel return passage 82 and tank 20. When the fuel pump 14 is supplying the first pressure, diesel fuel is forced through the passage 40 and into the first end portion 32 of the flow path 30.
The diesel fuel also is forced to flow through the restricted orifices 36 and into the chamber 28. From the chamber 28 the fuel is forced to flow, due to the pressure developed by the fuel pump 14, through the conduit 26 and to the fuel injector 22.

When the pressure developed by the fuel pump 14 drops to the transient pressure (i.e., when the fuel pump is not pressurizing the diesel fuel in the conduit 18), pressure in the conduit 58 is sufficient to cause alcohol to flow through the valve means 60, through the restricted passage 80, and into the second end portion 34 of the flow path 30. This pressure is generally not sufficient to cause any flow to proceed through the conduit 26 and to the fuel injector 22. The restricted nature of the orifices 36 helps to assure the flow of the alcohol into the second end portion 34 of the flow path 30 causing a reverse flow of diesel fuel out of the first end portion 32 of the fuel path 30 and backwardly through the passage 40 and eventually into the return means 82 of the fuel pump 14. As a result, a portion of the fuel path 30, namely the first end portion 32, is filled with diesel fuel while another portion, namely the second end portion 34, is filled with alcohol. Thereafter, as the fuel pump 14 increases pressure to the first pressure, the diesel fuel and alcohol in the flow path 30 are forced to flow through the restricted orifices 36, into the chamber 28, through the conduit 26 and to the fluid injector 22. It is, thus, clear that under steady state conditions a substantially constant and selected ratio of diesel fuel to alcohol is supplied for each stroke of the
fuel pump 14.

The apparatus described above can be readily retrofitted to existing engines since the components are relatively small as well as being inexpensive. Alcohol is not introduced into the fuel pump 14, whereby the low lubricity of alcohol does not prove to be a problem. A thorough and uniform mixture of alcohol and diesel fuel is assured, since this mixture is distributed into the elongated flow path 30 and then thoroughly mixed in the chamber 28. In accordance with a preferred embodiment of the invention, the amount of alcohol can be metered depending upon engine conditions. Similarly, the total amount of fuel propelled by each stroke of the fuel pump 14 can be metered in accordance with engine operating conditions. The metering is generally adjusted so that alcohol is not present at start-up or during idle operations. On the other hand, when the engine is under a heavy load, a relatively large amount of alcohol can be supplied to the diesel engine.

Other aspects, objectives, and advantages of this invention can be obtained from a study of the drawings, the disclosure, and the appended claims.
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Claims

1. In a fluid flow system (10) having an outlet (16) and first pressurizing means (12) for alternately developing (a) a first pressure for pumping and (b) a transfer pressure insufficient for pumping a first fluid to flow out of said outlet (16) and towards a fluid injector (22), the improvement comprising:

   a mixer (24,24') having a chamber (28,28') communicating with said fluid injector (22), an extending flow path (30,30') having first (32,32') and second (34,34') end portions (32,32',34,34') and being separated from said chamber (28,28'), and a plurality of restricted orifices (36,36') connecting said flow path (30,30') with said chamber (28,28') at plurality of spaced apart positions along said flow path (30,30');

   means (38) for communicating said outlet (16) with said first end portion (32,32') of said flow path (30,30'); and

   second pressurizing means (50) for pumping a second fluid at a second pressure into said second end portion (34,34') of said flow path (30,30') in response to said first pressurizing means (12) being at said transfer pressure.

2. The system (10) as set forth in claim 1, wherein said mixer (24,24') includes a body (42,42') having an external surface (46,46'), said chamber (28,28') is located within said body (42,42') and said flow path (30,30') is a generally spiral undercut (48,48') in said external surface (46,46').
3. The system (10) as set forth in claim 1, wherein said second pressurizing means (50) includes:
   a reservoir (52) of said second fluid;
   means (56) for pumping said second fluid at said second pressure into said second end portion (34,34') of said flow path (30,30'); and
   valve means (60,60') allowing flow of said second fluid towards said second end portion (34,34') of said flow path (30,30') in response to said second pressure exceeding said transfer pressure by at least a selected amount, preventing such flow in response to said second pressure not exceeding said transfer pressure by at least said selected amount, and preventing reverse flow.

4. The system (10) as set forth in claim 3, wherein said fluid injector (22) injects said first fluid into a cylinder (63) of an engine (64) having an inlet manifold (65) and an exhaust manifold (66), and further including:
   pressure control means (68) for controlling said second pressure in response to engine operating conditions.

5. The system (10) as set forth in claim 4, wherein said pressure control means (68) increases said second pressure in response to increased inlet manifold pressure and decreases said second pressure in response to decreased inlet manifold pressure.
6. The system (10) as set forth in claim 4, wherein said pressure control means (68) increases said second pressure in response to increased exhaust manifold temperature and decreases said second pressure in response to decreased exhaust manifold temperature.

7. The system (10) as set forth in claim 1, wherein said orifices (36') are of a structure sufficient to impinge said first and second fluids with one another in said chamber (28').

8. The system (10) as set forth in claim 1, further including:
   flow control means (78) for controlling the amount of said second fluid entering said second end portion (34,34') in response to the amount by which said second pressure exceeds said transfer pressure.

9. The system (10) as set forth in claim 1, further including:
   return means (82) for returning a portion of said first fluid to said first pressurizing means (12) in response to said second fluid entering said second end portion (34,34') of said flow path (30,30').
10. The system (10) as set forth in claim 1, further including:
means (88) for controlling said first pressurizing means (12) in response to engine operating conditions.

11. A mixer-emulsifier (24,24') connectable to a fuel pressurizing system (10) for an internal combustion engine (64), said system (10) having a first fuel pressurizing source (12) and a second fuel pressurizing source (56) connected via the mixer-emulsifier (24,24') to a fuel injector (22) the mixer-emulsifier (24,24') comprising:
a housing (45,45') having a bore (44,44'), a first fluid inlet (18) connected to the first fluid pressure source (14), a second fluid inlet (58) connected to the second fluid pressure source (56) and an outlet conduit (26,26') connected to the fuel injector (22); and
a mixer body (42,42') positioned in the housing bore (44,44') and having an extending fluid flow path (30,30') having a first end portion (32,32'), and a second end portion (34,34'), a mixing chamber (28,28') connected to the outlet conduit (26,26') and a plurality of passages (36,36') connecting spaced apart positions along the flow path (30,30') to the mixing chamber (28,28'), said first end portion (32,32') being connected to the first fluid inlet (18) and said second end portion (34,34') being connected to the second fluid inlet (58).
12. The mixer-emulsifier (24') as set forth in claim 11, wherein said orifices (36') are of a structure sufficient to impinge fluids from said first (12) and second (56) fluid pressurizing sources with one another in said chamber (28').

13. The mixer-emulsifier (24,24') as set forth in claim 11, wherein said engine (64) has an inlet manifold (65) and an exhaust manifold (66), and further including:

pressure control means (68) for controlling a pressure supplied by said second fluid pressure source (56) in response to engine operating conditions.

14. The mixer-emulsifier (24,24') as set forth in claim 13, wherein said pressure control means (68) increases said second pressure in response to increased inlet manifold pressure and decreases said second pressure in response to decreased inlet manifold pressure.

15. The mixer-emulsifier (24,24') as set forth in claim 13, wherein said pressure control means (68) increases said second pressure in response to increased exhaust manifold temperature and decreases said second pressure in response to decreased exhaust manifold temperature.
### I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) 3

According to International Patent Classification (IPC) or to both National Classification and IPC

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* Special categories of cited documents: 16
  * "A" document defining the general state of the art
  * "E" earlier document but published on or after the international filing date
  * "L" document cited for special reason other than those referred to in the other categories
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  * "T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention
  * "X" document of particular relevance

### IV. CERTIFICATION

Date of the Actual Completion of the International Search 4

23 March 1982

Date of Mailing of this International Search Report 4

22 APR 1982

International Searching Authority 4

U.S.

Signature of Authorized Officer 26

[Signature]

E. ROLLINS CROSS