May 15, 1962 R. L. CARMON ET AL 3,034,570

FLUID CENTRIFUGE

Filed Sept. 25, 1958 3 Sheets-Sheet 1

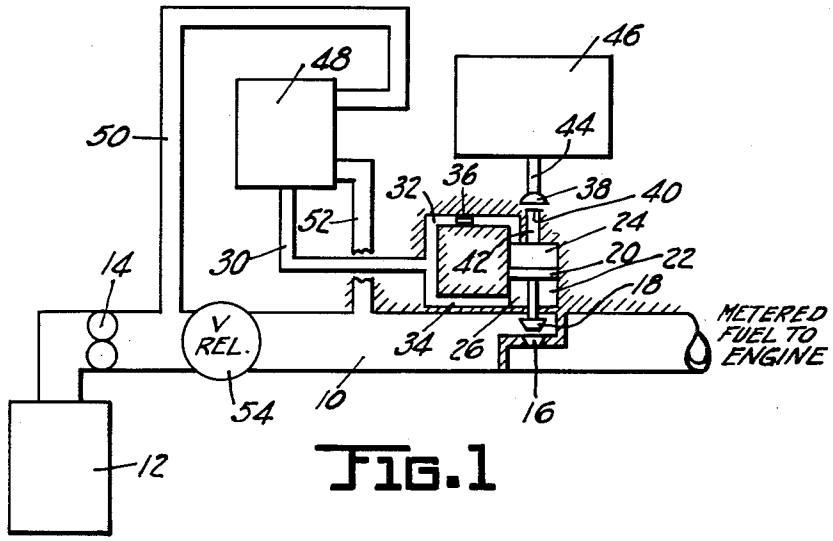


FIG. 1

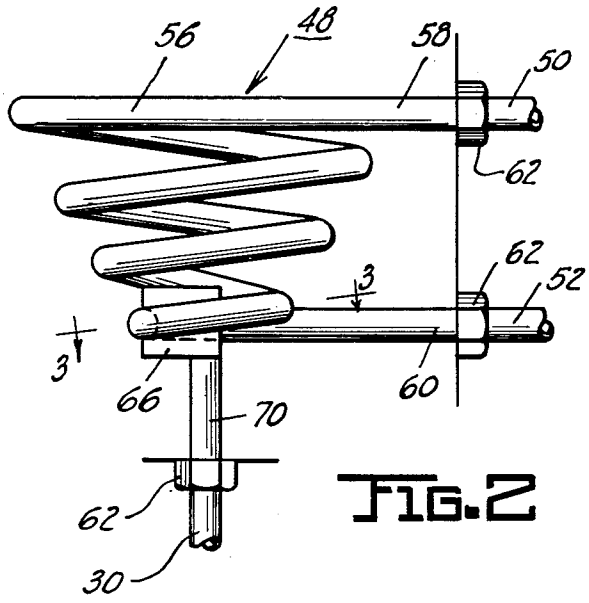


FIG. 2

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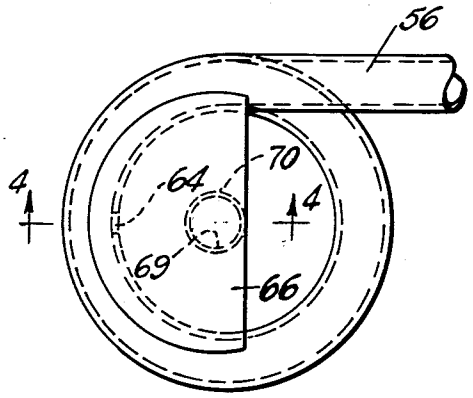


FIG. 3

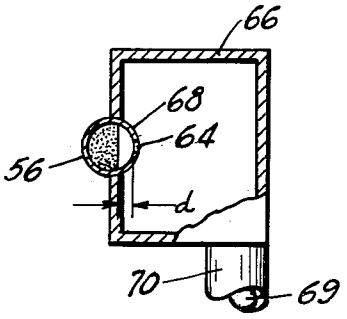


FIG. 4

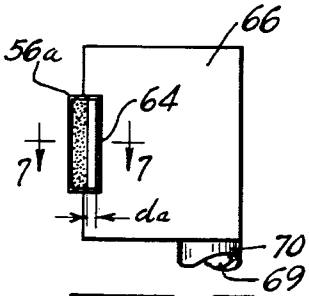


FIG. 5

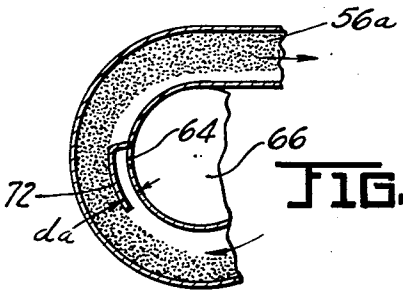


FIG. 7

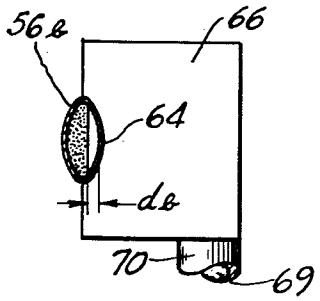


FIG. 6

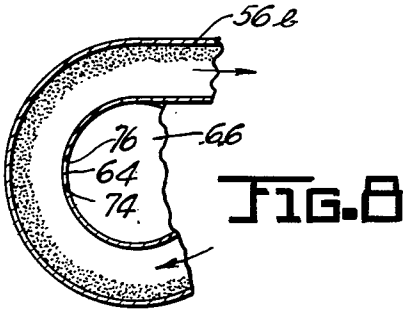


FIG. 8

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FLUID CENTRIFUGE

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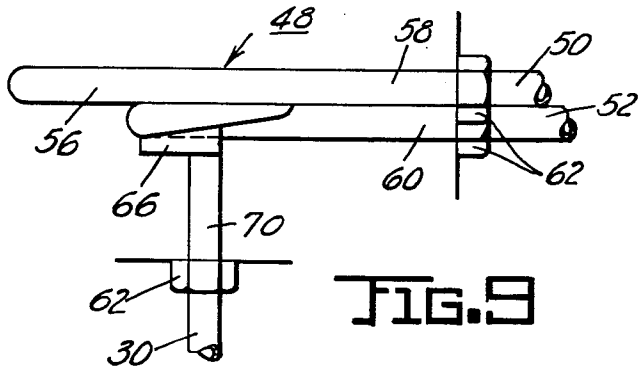


FIG. 9

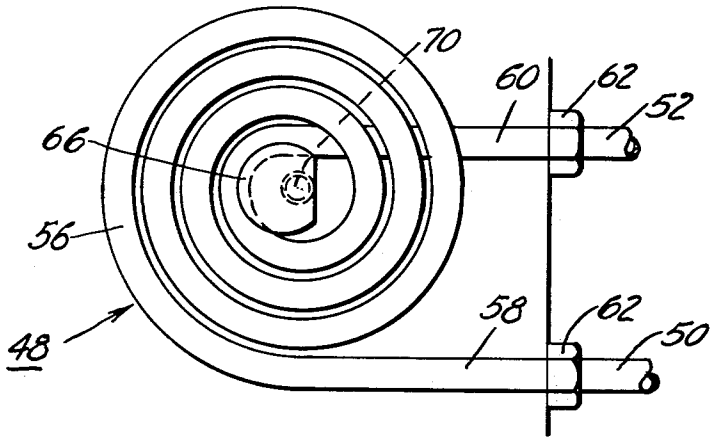


FIG. 10

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FLUID CENTRIFUGE

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13 Claims. (Cl. 158—36.4)

This invention relates generally to apparatus for removing particles of foreign material from a fluid and particularly to a fluid centrifuge.

In many hydraulically operated servo systems it is desirable to provide a source of pressurized fluid which is maintained free of particles of foreign material such that plugging of valve orifices, excessive wear of precision mechanical surfaces, and sticking of sliding members is eliminated. One such servo system may be found in almost any conventional jet engine fuel control system and, preferably, it is with such a fuel control system that the present invention is designed for use.

Heretofore, the particles of foreign matter have been removed from the pressurized fluid by means of relatively fine mesh filter screens which are subject to clogging due to the gradual accumulation of particles of matter on the external surface of the filter screen. This requires frequent removal and cleaning or replacing of the filter screen if the efficiency of the filter is not to be impaired. It is, therefore, an object of this invention to provide a fluid centrifuge for removing particles of foreign matter from a fluid.

It is an object of this invention to provide a fluid centrifuge which is simple in construction, easy and economical to make and efficient in operation.

Another object of this invention is to provide a lightweight and compact fluid centrifuge.

It is a further object of this invention to provide means for removing foreign particles of matter from a fluid which functions indefinitely without the need for periodic cleaning.

Another important object of this invention is to provide a fluid centrifuge which requires no moving parts for its operation.

Additional objects and advantages of the present invention will be apparent to those skilled in the art from the following description and accompanying drawings, wherein:

FIGURE 1 is a schematic representation of a fuel system embodying the present invention;

FIGURE 2 is a schematic representation of the fluid centrifuge embodying the present invention;

FIGURE 3 is a sectional view taken on line 3—3 of FIGURE 2;

FIGURE 4 is a sectional view taken on line 4—4 of FIGURE 3;

FIGURES 5 and 6 are views similar to FIGURE 4, showing modifications of the pipe 56;

FIGURE 7 represents a sectional view taken on line 7—7 of FIGURE 5;

FIGURE 8 represents a view similar to FIGURE 7, showing a modification of the port 64;

FIGURE 9 is a schematic representation of a modified form of the present invention; and

FIGURE 10 is a plan view of the modified form shown in FIGURE 9.

Referring to the drawings, numeral 10 indicates a fuel conduit which receives fuel from a fuel tank 12 and discharges fuel to a combustion engine, not shown. An engine driven fuel pump 14 is provided to pressurize the fuel in the fuel conduit 10. A variable area orifice 16 disposed in conduit 10 serves to control the flow of fuel through conduit 10. The effective flow area of the orifice 16 is controlled by a valve 18 connected to a servo piston 20 which slides in a chamber 22. The servo piston 20 divides the chamber 22 into two variable volume chambers, 24 and 26, which are connected to a servo supply passage 30 via passages 32 and 34, respectively. A restriction 36 is secured in passage 32. The pressure drop across the servo piston 20 and thus the position of the piston is controlled by a flapper valve 38 which coacts with a valve seat 40 at the outlet end of a passage 42 connected between the chamber 24 and a suitable source of drain pressure P_o, not shown. The flapper valve 38 is connected to one end of a rod 44, the opposite end of which is connected to control apparatus 46. The control apparatus 46 is responsive to one or more variable conditions of engine operation such as speed, temperature and the like and produces an output signal by means of which the rod 44 and thus flapper valve 38 are actuated as a function of the variable conditions of engine operation. The control apparatus 46 is conventional in operation and does not form any part of the present invention.

A fluid centrifuge 48 is arranged to receive fuel under pressure from conduit 10 via an inlet passage 50 and discharge a portion of the fuel received to servo supply passage 30. The remaining portion of the fuel received is discharged to conduit 10 via an outlet passage 52. A pressure relief valve 54 of any known convenient type is disposed in conduit 10 between inlet passage 50 and outlet passage 52. The pressure relief valve 54 is responsive to the pressure drop across the fluid centrifuge 48 and functions to direct the total output of pump 14 to the fluid centrifuge 48 until said pressure drop reaches a predetermined value at which time the valve 52 opens to allow the excess fuel to flow therethrough to valve 18.

Referring to FIGURE 2, wherein the fluid centrifuge 48 is shown schematically in greater detail, numeral 56 designates a pipe having an inlet end 58 and an outlet end 60 connected to inlet passage 50 and outlet passage 52, respectively, via suitable pipe couplings 62. The pipe 56 is spirally coiled about a central axis and in its preferred configuration forms a helical flow path which decreases in diameter in the general direction of fuel flow from inlet passage 50 to outlet passage 52. The pipe 56 is of uniform cross-sectional flow area throughout its length. At the smallest diameter of the spiral, the inner wall of the pipe 56 is provided with one or more openings or ports 64 radially formed therein (see FIGURE 3) which open into the interior of a semi-round receptacle 66. The receptacle 66 has an opening 68 circumferentially formed in the wall thereof which encircles the opening or port 64. The receptacle 66 and pipe 56 are fixedly secured together by any suitable means such as a weld which provides a fluid seal. Centrifuged fuel collects in the receptacle 66 in a manner to be explained and is extracted therefrom via an outlet port 69 formed in the end wall of the receptacle 66 thereafter flowing to the servo supply passage 30 via a passage 70 connected between the outlet port 69 and the supply passage 30.

Fuel flowing through the pipe 56 is acted upon by centrifugal force which causes particles of foreign matter carried by the fuel to move outwardly in the pipe away from the axis of the spiral. The centrifugal force which

acts on any given particle of foreign matter varies in accordance with the relationship

$$F_c = m\frac{v^2}{r}$$

where F_c represents the centrifugal force, m the mass of a given particle of matter, v the linear or tangential velocity of the given particle of matter at a given point in the flow stream, and r the radial distance from the central axis of the spiral to the center of gravity of the particle of matter. Since the pipe **56** has a uniform cross-sectional flow area throughout its length the linear or tangential velocity v of a given particle of matter remains substantially constant throughout its travel through the pipe **56**, assuming a constant pressure drop at all times across the centrifuge **48**, as will be appreciated by those familiar with the fundamentals governing the flow of incompressible fluids through pipes. For a given particle of foreign matter the mass m is constant. Therefore, it is readily seen that the centrifugal force F_c acting on a particle of foreign matter having a given mass m varies as a function of the radial distance r only. Thus, the centrifugal force which varies as an inverse function of the radial distance r progressively increases as the diameter of the spiral decreases and reaches a maximum value in the region of the opening or port **64**. It will be realized that, by virtue of their different densities and settling rates, particles of lint, sand and metals which ordinarily make up the bulk of contaminants in a fuel supply will respond to the centrifugal effect to varying degrees.

Referring to FIGURE 4 which represents a cross section of pipe **56** taken on line **4—4** of FIGURE 3, the cross-sectional area of the pipe **56** is divided into two portions. The innermost one-third portion represents fuel from which the particles of matter have been displaced and the remaining two-thirds represents fuel to which the particles of foreign matter have been displaced. The symbol d represents the maximum distance along a radial line that a particle of foreign matter must be displaced during its travel through pipe **56** to escape the innermost one-third portion of the flow path. The length of the pipe **56** is dependent upon the particle of matter having the least density and corresponding lowest settling rate and the distance d through which it is to be displaced, and must be long enough to meet the time requirement imposed by these variables. FIGURES 5 and 6 represent rectangular and elliptical versions of pipe **56** which are designated by numerals **56***a* and **56***b*, respectively. The pipes **56***a* and **56***b* have rectangular and elliptical flow areas, respectively, each of which are divided into two areas equivalent to the corresponding two areas of the circular pipe **56** shown in FIGURE 4. It will be noted that while the area remains the same in all cases d_a and d_b is less in the rectangular and elliptical versions of pipe **56** as compared to the distance d in the circular version such that a shorter pipe may be used.

In the region of port **64**, it is desirable to minimize the effects of turbulent flow which may cause some of the centrifuged particles of matter to re-enter the inner portion of the flow path and be carried out of the port **64**. FIGURES 7 and 8 illustrate alternate means which may be provided in the pipe **56**, **56***a* or **56***b* to avoid this problem. Referring to FIGURE 7, numeral **72** designates a thin plate connected at its top and bottom edges to the pipe **56***a* and connected at one end to the inner wall of the pipe **56***a* adjacent the downstream edge of the port **64**. The plate **72** extends upstream of the port **64** and is spaced from the inner wall of pipe **56***a* in accordance with the distance d_a indicated in FIGURE 5. The plate **72** acts as a flow divider and provides an effective barrier between contaminated fuel and uncontaminated fuel in the region of port **64**.

Referring to FIGURE 8, turbulent flow in the region of port **64** may also be reduced by providing port **64** with curved edges which tend to divert fuel through port **64** from the main flow path at a relatively small angle. As shown in FIGURE 8, the upstream edge **74** of port **64** is curved inwardly with respect to the axis of the pipe **56***a* and the downstream edge **76** of port **64** is curved outwardly with respect to the axis of the pipe **56***a*.

A predetermined minimum pressure drop is maintained across the centrifuge **48** in order to force fuel through pipe **56** at a rate whereby the required linear velocity is developed to effect separation of the particles of foreign matter from the fuel in the aforementioned manner. The predetermined minimum pressure drop also serves to maintain an adequate supply of fuel to meet the fuel flow requirements of the servo system at all times. To this end, the pressure relief valve **54** operates to maintain the predetermined minimum pressure drop across the centrifuge **48** regardless of the output of pump **14** which during normal operation is considerably in excess of that required for proper centrifuge action.

During operation of the system, contaminated fuel flows from the pump **14** through passage **50** into pipe **56**. As the fuel flows through pipe **56** centrifugal force acts upon the particles of foreign matter causing the particles to move toward the outermost portion of the spiral flow path in the order of their densities, the most dense responding relatively fast and the least dense responding relatively slow. As the centrifugal force increases in accordance with the decreasing diameter of the spiral flow path, the particles will be cause to settle out progressively faster such that the centrifuged particles are concentrated in the outermost two-thirds portion of the flow path by the time the opening or port **64** is reached. The particles of foreign matter are carried by the fuel past the opening or port **64** through passage **52** to conduit **10**. Clean fuel is extracted from the innermost one-third portion of the flow path via the opening or port **64** which empties into the receptacle **66** which in turn supplies the servo system with fuel as required.

It will be understood that the pipe **56** is not restricted to being coiled in the helical pattern shown in FIGURE 2 but may be spirally coiled in one plane, as illustrated in FIGURES 9 and 10, without reducing the effectiveness of the centrifuging action. Various other modifications of the preferred embodiment may be made by those skilled in the art within the scope of the invention as defined in the appended claims.

We claim:

1. Apparatus for separating contaminants from a pressurized fluid, comprising a receptacle for uncontaminated fluid; an outlet passage for contaminated fluid; a conduit communicating said pressurized fluid with said outlet passage; said conduit being coiled about an axis and having an outlet port formed in the radially innermost wall thereof, said outlet port communicating with said receptacle, said fluid being forced through said conduit at a rate whereby centrifugal force causes said contaminants to collect in a portion of the fluid flowing through said conduit leaving the remaining portion relatively free of contaminants, the latter named portion being ejected through said outlet port to said receptacle and the former named portion together with said contaminants being discharged to said outlet passage.

2. Apparatus as claimed in claim 1 wherein said conduit is a pipe having a circular cross-sectional flow area.

3. Apparatus as claimed in claim 1 wherein said conduit is a pipe having a rectangular cross-sectional flow area.

4. Apparatus as claimed in claim 1 wherein said conduit is a pipe having an elliptical cross-sectional flow area.

5. Apparatus for separating contaminants from a pressurized fluid comprising a receptacle for uncontaminated fluid; an outlet passage for contaminated fluid; a conduit communicating said pressurized fluid with said outlet passage, said conduit being coiled about an axis and having an outlet port formed in the wall of said conduit and communicating with said receptacle, said outlet port being

upstream from said outlet passage and radially disposed in the wall of said conduit toward said axis, said fluid being forced through said coiled conduit at a rate whereby centrifugal force causes said contaminants to move outwardly in said conduit relative to said axis leaving a portion of the fuel flowing through said conduit relatively free of contaminants, said uncontaminated fuel flowing through said outlet port to said receptacle and the remaining portion of the fuel together with said contaminants flowing through said conduit to said outlet passage.

6. Apparatus for separating contaminants from a pressurized fluid comprising a receptacle for uncontaminated fluid; an outlet passage for contaminated fluid; a conduit communicating said pressurized fluid with said outlet passage, said conduit forming a spiral flow path which decreases in diameter in the direction of fuel flow with respect to an axis; an outlet port disposed in the wall of said conduit toward said axis; said fluid being forced under pressure through said conduit at a rate whereby centrifugal force causes the contaminants to move outwardly in said conduit relative to said axis leaving a portion of the fuel flowing through said conduit relatively free of contaminants, said uncontaminated fuel being ejected from said conduit through said outlet port to said receptacle and the remaining portion of the fuel in said conduit together with said contaminants being ejected through said conduit to said outlet passage.

7. Apparatus for separating contaminants from a pressurized fluid, comprising a receptacle for uncontaminated fluid; an outlet passage for contaminated fluid; a conduit communicating said pressurized fluid with said outlet passage, said conduit being coiled about an axis so as to form a decreasing diameter helical flow path; an outlet port radially disposed in the wall of said conduit toward said axis; said fluid being forced under pressure through said conduit at a rate whereby centrifugal force causes the contaminants to move outwardly in said conduit relative to said axis leaving a portion of the fuel flowing through said conduit relatively free of contaminants, said uncontaminated fuel being ejected from said conduit through said outlet port to said receptacle and the remaining portion of the fuel in said conduit together with said contaminants being ejected through said conduit to said outlet passage.

8. In a fuel control system for a combustion engine having a burner, the combination of a source of fuel under pressure; a fuel conduit for delivering fuel from said source to said burner; valve means in said fuel conduit for controlling fuel flow therethrough; fuel operated servo means operatively connected to said valve means for controlling the position thereof; means responsive to a variable condition of engine operation for controlling said servo means; and means for removing foreign particles of matter from the fuel supplied to said servo means including a fuel conduit spirally coiled about an axis, said spiral conduit having an inlet connected to receive fuel from said source of fuel and an outlet connected to discharge fuel to said first named fuel conduit upstream from said valve means, means including a valve member in flow controlling relationship with said first named fuel conduit for generating a pressure drop between said inlet and outlet connections; an outlet port disposed in the wall of said spiral conduit toward said axis upstream from said outlet and communicating with said servo means, said fuel being forced through said spiral conduit at a rate whereby centrifugal force causes the foreign particles of matter to move outwardly in said spiral conduit relative to said axis leaving a portion of the fuel in said spiral conduit substantially free of contaminants, said uncontaminated fuel being ejected from said conduit through said spiral outlet port and the remaining portion of the fuel in said spiral conduit together with said foreign particles of matter being ejected through said outlet to said first named fuel conduit.

9. In a fuel control system for a combustion engine having a burner, the combination of means for supplying fuel under pressure in excess of engine fuel requirement; a fuel conduit for delivering fuel from said means to said burner; valve means in said fuel conduit for controlling fuel flow therethrough; control means responsive to a variable engine operating condition for controlling the operation of said servo means; pressure responsive valve means disposed in said fuel conduit in series flow relationship with said valve means; and means for removing particles of foreign matter from the fuel supplied to said servo means including a fuel conduit spirally coiled about an axis, said spiral conduit having an inlet connected to said first named fuel conduit upstream from said pressure responsive valve and an outlet connected to said first named fuel conduit downstream from said pressure responsive valve; and a plurality of spaced outlet ports disposed in the wall of said spiral conduit toward said axis upstream from said outlet and communicating with said servo means, said fuel being forced through said spiral conduit at a rate whereby centrifugal force causes the particles of foreign matter to move outwardly in said spiral conduit relative to said axis leaving a portion of the fuel in said spiral conduit substantially free of said particles of foreign matter, said portion of the fuel being ejected from said spiral conduit through said plurality of outlet ports and the remaining portion of the fuel in said spiral conduit together with said particles of foreign matter being ejected through said outlet to said first named fuel conduit, said pressure responsive valve means being operative to maintain the pressure drop across said last named means above a predetermined minimum value.

10. In a fuel control system for a combustion engine having a burner, the combination of a source of fuel under pressure; a fuel conduit for delivering fuel from said source to said burner; valve means in said conduit for controlling flow therethrough; fuel operated servo means operatively connected to said valve means for controlling the position thereof; means responsive to a variable condition of engine operation for controlling said servo means; and means for removing foreign particles of matter from the fuel supplied to said servo means including a fuel conduit coiled about an axis, said coiled fuel conduit having an inlet connected to receive fuel from said source of fuel and an outlet connected to discharge fuel to said fuel conduit, an outlet port disposed in the wall of said conduit toward said axis upstream from said outlet and communicating with said servo means, said fuel being forced through said conduit at a rate whereby centrifugal force causes the foreign particles of matter to move outwardly in said conduit relative to said axis leaving a portion of the fuel in said conduit substantially free of contaminants, said uncontaminated fuel being ejected from said conduit through said outlet port and the remaining portion of the fuel in said conduit together with said particles of foreign matter being ejected through said outlet to said fuel conduit.

11. In a fuel control system as claimed in claim 10 wherein said means for removing foreign particles of matter further includes valve means operatively connected to said coiled fuel conduit for controlling the flow of fuel therethrough to maintain the pressure drop thereacross above a predetermined minimum value.

12. In a fuel control system for a combustion engine having a burner, the combination of a source of fuel under pressure; a fuel conduit for delivering fuel from said source to said burner; valve means in said conduit for controlling fuel flow therethrough; fuel operated servo means operatively connected to said valve means for controlling the position thereof; means responsive to a variable condition of engine operation for controlling said servo means; and centrifuge means including means defining a spiral flow path operatively connected to said fuel conduit and said servo means for removing foreign particles of matter from a portion of the fuel flowing from said source, said portion of the fuel flow being de-

livered to said fuel operated servo means and the remaining portion of the fuel flow from said source together with said foreign particles of matter being delivered to said fuel conduit.

13. Apparatus as claimed in claim 6 wherein said conduit is coiled spirally with substantially all of the coils in one plane.

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