July 7, 1953 H. C. WATERMAN ET AL 2,644,300

ELECTRICAL FUEL FEEDING SYSTEM

Filed June 10, 1946 3 Sheets-Sheet 1

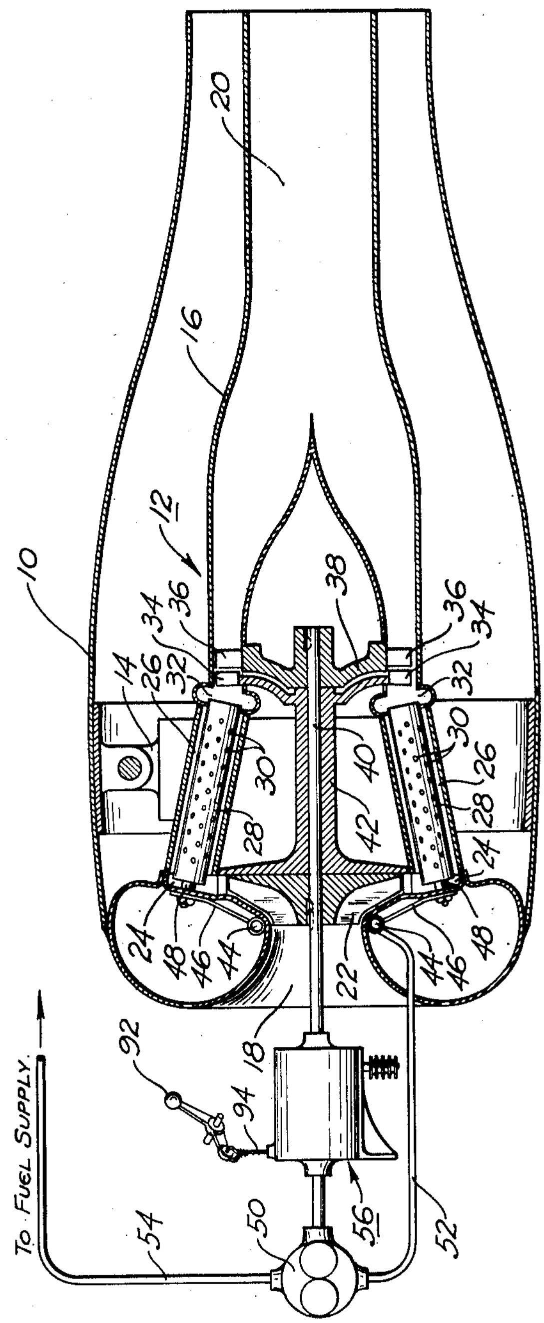

Fig.1.

INVENTORS.
FRANK V. KUZMITZ.
HERBERT C. WATERMAN.
BY Cecil J. Arens
ATTORNEY

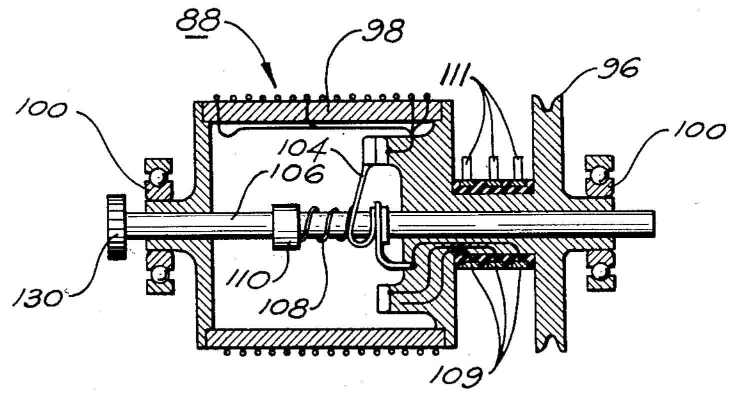

Fig. 4.

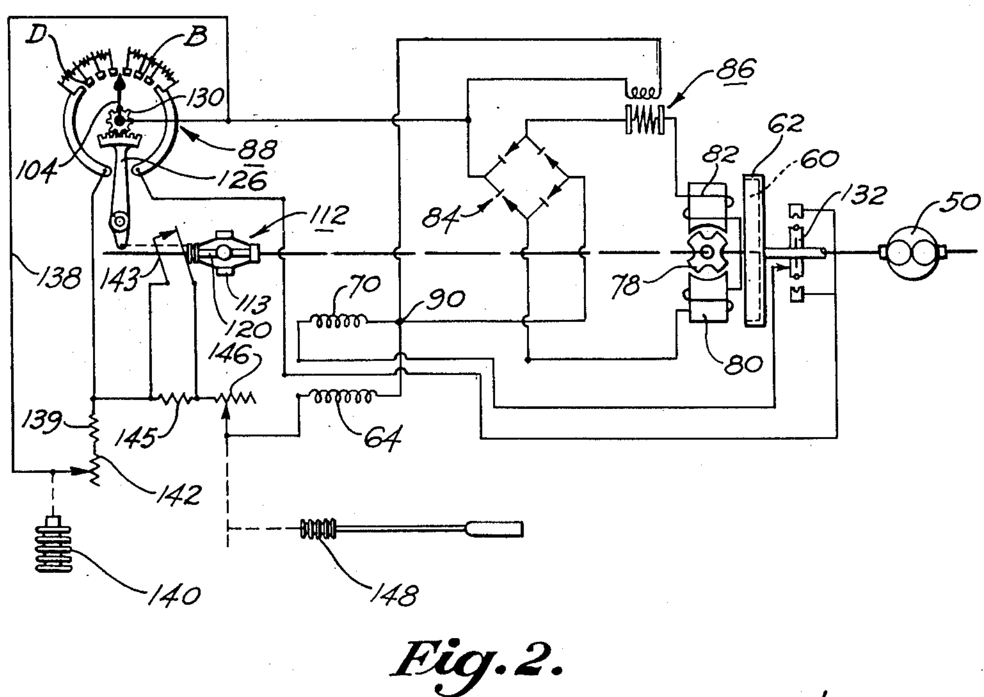

Fig. 2.

INVENTORS.
FRANK V. KUZMITZ
HERBERT C. WATERMAN.
BY Cecil F. Arens
ATTORNEY

ELECTRICAL FUEL FEEDING SYSTEM

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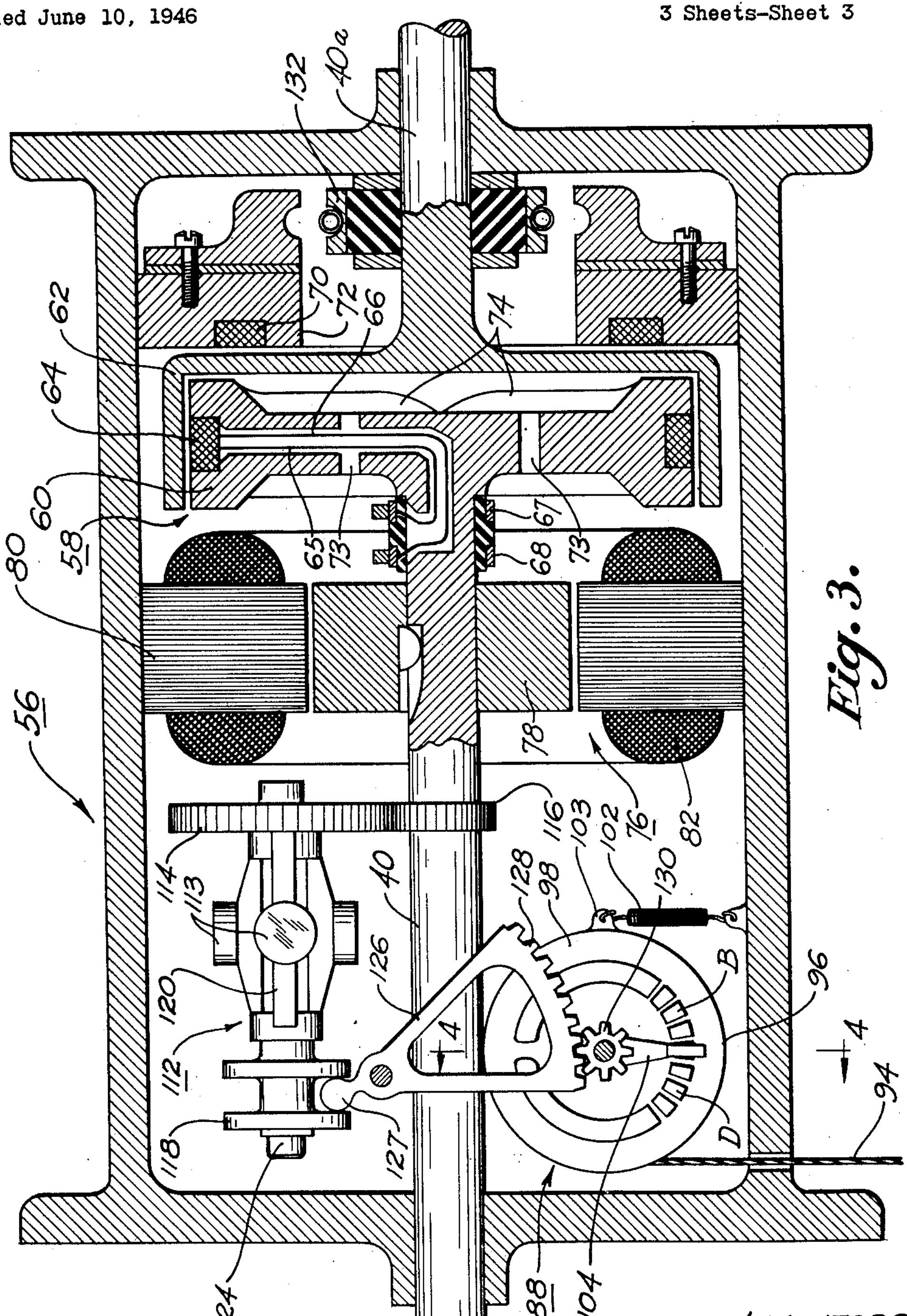

Fig. 3.

INVENTORS.
FRANK V. KUZMITZ.
HERBERT C. WATERMAN.
BY. Cecil J. Arens
ATTORNEY

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UNITED STATES PATENT OFFICE

2,644,300

ELECTRICAL FUEL FEEDING SYSTEM

Herbert C. Waterman, Chicago, Ill., and Frank V. Kuzmitz, South Bend, Ind., assignors to Bendix Aviation Corporation, South Bend, Ind., a corporation of Delaware

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11 Claims. (Cl. 60—39.28)

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This invention relates generally to a fuel control device or system for engines, and while not limited thereto, it is particularly adapted for gas turbine engines.

The fuel control device of the present invention utilizes a self-contained, self-energized unit which in conjunction with a fuel pump and the engine to be supplied with fuel forms a complete system.

It is an object of the invention to provide an improved electrical fuel control device for an engine which will automatically maintain the engine with which it is associated at a predetermined speed in accordance with a given setting of a power control member or throttle lever.

It is a further object of the invention to provide an electrical fuel control device responsive to engine speed for automatically varying the fuel supply to the engine.

It is another important object of the invention to provide an electrically operated fuel control device incorporating overspeed and overtemperature protection for the engine or burner system with which it may be associated.

Another important object of the invention resides in the provision of an electrically operated fuel control device for a power plant or engine, wherein the speed of the engine is reflected as a voltage which controls the excitation to a mechanism for varying the fuel supply to the engine.

A further important object of the invention resides in the provision of an electrically operated fuel control device for a power plant or engine incorporating an automatic adjustment for varying the idling speed in proportion to altitude.

The above and other objects and features of the invention will be apparent from the following description of the apparatus taken in connection with the accompanying drawings which form a part of this specification, and in which:

Figure 1 is a diagrammatic representation of a fuel system of the invention associated with a jet engine;

Figure 2 is a schematic embodiment of the fuel control system illustrating the circuit diagram in detail;

Figure 3 is a diagrammatic view partly in section of the device of the invention; and

Figure 4 is a diagrammatic view partly in section of one form of potentiometer used in the circuit and is taken on line 4—4 of Figure 3.

Referring now to Figure 1, reference numeral **10** designates a nacelle in which is located a jet

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engine **12** supported by brackets **14**. The engine comprises an outer casing **16** flared or turned inwardly at its front end to define an air inlet **18** and contoured at its rear end to define a reaction tube **20**. Disposed within the casing **16** is a rotary air compressor **22**, which forces air into an annular header **24** which is in communication with a plurality of peripherally spaced cylinder-like generator or burner chambers **26** which house burners **28** having air inlet passages **30** in the walls thereof. The burners **28** discharge into a collector ring **32** arranged to convey the hot air and products of combustion past a set of stationary blades **34** and against blades **36** integral with a turbine rotor **38**. The rotor **38** and air compressor **22** are mounted on a common shaft **40** rotatably supported in a bearing **42**. Air entering the inlet **18** is picked up by the compressor, which acts to direct the air into the annular header **24**, burner chamber **26** and thence through the air inlet passages **30** into the burners **28** where combustion takes place. The expanded air and products of combustion are first directed against the blades **36** of the turbine rotor **38** to drive the compressor and then discharged to atmosphere through the reaction tube **20** to effect propulsion of the plane.

The engine is equipped with a manifold **44** having branch conduits **46** connected to nozzles **48** which discharge fuel into the burners **28**. A gear pump **50** is drivably connected to the engine through shafts **40** and **40a**, and is interposed between conduits **52** and **54** to receive fuel from a fuel supply reservoir, not shown, and put the fuel under pressure for supplying the same to the engine.

To control the pump speed, which in turn regulates the rate of flow of fuel to the engine, a control mechanism **56** is interposed between the engine **12** and pump **50**. As best shown in Figure 3, the means for controlling the pump is in the form of a control mechanism comprising a magnetic clutch, or an eddy current clutch **58** having a driving member or rotor **60** integral with the engine shaft **40**, and a driven member or wheel **62** integral with the shaft **40a** to drive the gear pump **50**. The rotor **60**, which is made of a material possessing magnetic properties, is provided with a driving coil **64** having leads **65** and **66** connected to slip rings **67** and **68** respectively. The driven member or wheel **62** is likewise made of a material possessing magnetic properties. A braking coil **70** carried by a stationary magnetic element **72** will cause the driven member **62** to be retarded or arrested when the coil is excited, in a manner hereinafter described. The rotor 60 has openings 73 therethrough, and blades 74 integral therewith, for circulating air between the members 60 and 62 of the magnetic clutch or coupling to cool the wheel.

The source of current for exciting coils 64 and 70 is obtained from a permanent magnet rotor type alternator 76 the output voltage of which has a magnitude and frequency proportional to the speed of the engine shaft to which the permanent magnet 78 is keyed, see Figures 2 and 3. A laminated stator 80 of the alternator, has coils 82 thereon which are connected to a full wave dry disc type rectifier 84 to convert the A. C. taken from the alternator to a D. C. supply. Although a selenium rectifier is shown in the drawings it is understood that any of the dry disc type rectifiers will perform equally satisfactorily. A voltage regulator 86 of the carbon pile type is located in circuit between the alternator and the rectifier to thereby hold the voltage of the D. C. supply reasonably constant.

For varying the excitation of the coils 64 and 70 a potentiometer 88 is connected to the rectified supply or selenium rectifier 84, as shown, and to one terminal of each of coils 64 and 70. The other terminal of each of the coils being connected to a common point 90 which in turn is connected to the selenium rectifier 84 and to the voltage regulator 86. The potentiometer is so constructed that when throttle 92 is advanced, cable 94 which encircles pulley 96 will rotate the resistor assembly or element 98 in a counter-clockwise direction, as viewed in Figure 3. The direction of rotation of the resistor assembly would be opposite in Figure 2 because of the schematic arrangement. The element 98 is carried in bearings 100 (see Figure 4). A spring 102 has one end fixed to the control casing and has its other end engaging a lug 103 of element 98 to return the element to the position shown in Figure 2 when the throttle is released or moved to idle position. A wiper arm 104 is held in a neutral position during idling speeds of the engine and is operatively connected to shaft 40 to respond to engine speeds above idling to cause the arm to move to a position corresponding to the throttle setting, to provide in conjunction with element 98, a servo-device which automatically adjusts the fuel pump delivery to a given throttle setting. As best shown in Figure 4, the wiper arm 104 is carried by a shaft 106 supported in the element or resistor assembly 98. The wiper arm is constructed to slide on either contacts D of the driving coil or on contacts B of the braking coil dependent upon throttle positioning. A coil spring 108 has one end fixed to the shaft 106 by collar 110 and its free end engaging the wiper arm to permit the shaft to rotate with respect to the wiper arm after the latter has rotated to a position where it has engaged limit stops, not shown. This construction permits a small amount of movement between the wiper arm and shaft to thereby prevent destruction of the parts in the event of overspeed of the shaft 40. The connections from the potentiometer to the selenium rectifier and the coils 64 and 70 are made through slip rings and brushes 109 and 111. Each position of the wiper arm is representative of a predetermined engine speed. Attention is called to the fact that excitation of the coils 64 and 70 may be from an outside source if desired and need not come from an alternator coupled with the engine as herein described. It is important only that the current through the

coils be varied in accordance with engine fuel requirements.

In order to position the wiper arm in accordance with engine speed to thereby provide the desired coupling intensity for a given throttle setting to drive the pump, a velocity sensitive device 112 is interposed between the arm and the engine shaft 40. The velocity sensitive device comprises a set of centrifugally operated weights 113, and a gear 114 meshing with a gear 116 fixed to shaft 40 to drive the device. A collar 118 of the velocity sensitive device is connected to arms 120 to which the balls 113 are fixed. The centrifugal force of the balls acting through the arms 120 shift the collar 118 along shaft 124 to thereby rotate the wiper arm 104. A gear sector 126 is formed at 127 to be engaged by the collar 118 and includes a gear 128 which meshes with a pinion 130 secured to shaft 106.

When the throttle is moved from wide open to closed position the fuel pump output to the engine must not be completely cut-off. That is, an engine idling speed is preselected and the pump output must always be sufficient to meet the engine fuel requirements at that speed. This means that if the braking coil could be energized at any time regardless of the speed of the pump shaft $40a$, it would be possible to cut-off entirely the fuel supply or pump output to the engine. This, of course, is highly objectionable since it would necessitate a complicated starting apparatus to again use the engine. To prevent energizing the braking coil when the engine is at or below idle speed a centrifugally actuated switch 132, which responds to the speed of shaft $40a$, is disposed in the braking coil circuit. The switch is closed to permit excitation of the braking coil in response to shaft speeds above a maximum idle speed of the engine but open in response to shaft speeds below maximum idle speed of the engine to prevent excitation of the braking coil at this time, to thereby insure a continuous supply of fuel to the engine although the throttle be moved from full open to closed position, as shown in Figure 2.

A wire 138 shunts the potentiometer 88 so that current will flow through the driving coil 64 when the wiper arm 104 is in its neutral position, shown in Figure 2. With the wiper arm in this position the throttle is closed but enough current is by-passed through the connection or wire 138 and resistor 139 to excite the driving coil to drive the pump at a speed adequate to supply fuel for idling of the engine. Since the idling speed is a function of altitude and increases with higher altitudes, means for varying the idling speed of the engine is required. This means includes an altitude sensitive device, or pressure and temperature sensitive device 140 and a variable resistor 142. The variable resistor 142 responds to the pressure sensitive device and is disposed in the connection 138 in series with the resistor 139 and the driving coil to cause the value of the resistance in the circuit to vary inversely with altitude.

To provide overspeed protection means, a normally closed switch 143 shunts a resistor 145 in circuit with the driving coil. The construction and arrangement of the switch is such that it is opened by the velocity sensitive device when the engine exceeds a predetermined speed to thereby connect the resistor 145 in series with the driving coil to increase the resistance in series therewith. The resistor is of such a value that it limits the driving coil excitation and consequently fuel delivery to a value known to be safe.

To prevent overheating of the engine, overtemperature means is provided and includes a variable resistor 146 which is actuated by a temperature sensitive device 148 having an operative connection with a temperature bulb or the like located where it will be subjected to engine temperatures, as for example in the thermal relation with one or more of the burner chambers 26.

Operation of the system is as follows:

Assuming at the outset a condition of idling, at which time the potentiometer wiper arm 104 and resistor assembly 98 will be in the position in Figure 2. Advancing the throttle 92 pulls on the control cable 94 which rotates the resistor assembly 98 clockwise as viewed in Figure 2 to a position where the wiper arm 104 touches one of the contacts D to remove some or all of the resistance in series with the driving coil 64 of the magnetic clutch, depending on the amount of throttle movement. As hereinbefore pointed out the driving coil 64 is carried by the rotor 60 which is engine driven. When the excitation of the driving coil is increased as a result of throttle advancement, the slip between the wheel 62, which is integral with shaft 40*a*, and the rotor 60 is decreased. That is, since the pump must deliver more fuel to the engine the torque requirement of the pump has increased and to satisfy this demand for an increase in fuel delivery the excitation or coupling intensity must be increased. This increases the speed of the eddy current wheel thereby increasing the pump speed and hence, the fuel output to the engine. As the additional fuel causes the engine to approach the desired speed the velocity sensitive device 112 comes into action to move the wiper arm 104 in such a direction as to increase the resistance in series with the driving coil to thereby provide a follow-up or servo mechanism. This action continues until a balance is obtained where the driving coil is just sufficiently excited to maintain the pump at a speed where the proper amount of fuel is delivered to the engine to preserve the preselected speed in accordance with the given throttle setting. Frequently, due to lags in the system the engine will tend to run faster than the desired speed, in which case the velocity sensitive device will continue to act to cut in resistance in series with the driving coil, thereby causing less excitation of the driving coil and consequently more slip between the rotor and the wheel so as to reduce fuel delivery to the engine. At times when this speed overshoot is large enough the velocity sensitive device will cause the wiper arm 104 of the potentiometer to move over onto the contacts B exciting the braking coil 70. Excitation of the braking coil acts as a brake on the eddy current wheel to slow the fuel pump. As soon as an equilibrium condition is reached the wiper arm will ride steadily on one of the contacts B of the potentiometer or hunt between two other contacts.

Retarding the throttle 92 slacks the cable 94 to permit the spring 102 to rotate the resistor assembly 98 counter-clockwise as viewed in Figure 2 so that the wiper arm slides on the contacts B thereby energizing the braking coil to cause a reduction in speed of the fuel pump. (It will be remembered that prior to retarding the throttle the wiper arm 104 was rotated clockwise or to the right of the positions shown in Figure 2, since the arm had assumed a position on one of the contacts D of the driving coil.) As the engine slows down the velocity sensitive device causes the wiper arm to rotate counter-clockwise, tending to follow up the movement of the resistor assembly, to cut in more resistance in series with the braking coil until eventually opening the braking coil circuit, at which time the wiper arm will rotate to engage one of the contacts D to seek an equilibrium position for the new preselected speed.

It is to be understood that the control may be used in conjunction with other types of feul regulating devices such, for example, as a fuel metering valve assembly to regulate the flow of fuel into an internal combustion engine or the like.

Having thus described the various features of the invention, what we claim as new and desire to secure by Letters Patent is:

1. The combination with an engine of the type utilizing liquid fuel, of fuel supply means communicating with the engine, an engine throttle, a pump associated with said fuel supply means and constructed and arranged for delivering fuel to the engine, a magnetic clutch having one member drivably connected to the engine and a second member drivably connected to the pump, said one member constructed and arranged to be magnetically coupled with said second member, a magnetic brake for said second member, and means for controlling said magnetic brake and the intensity of the magnetic coupling including a servo device having two cooperating relatively movable members one of which is moved in response to throttle setting and the other of which is moved in response to change in engine speed to automatically regulate the fuel to the engine for a given throttle setting.

2. For use with an engine having a fuel system with a throttle therefor and a pump in the system for pumping fuel to the engine at a rate dependent upon the throttle position, means for controlling said pump comprising magnetic means interposed between the engine and pump to drive the latter at a variable speed to regulate the fuel output to the engine in accordance with a given throttle position, a velocity sensitive device responsive to engine speed, said first named means also including an electric circuit, an engine driven alternator in the circuit for supplying energy thereto, and a follow up mechanism including a potentiometer in the circuit having two members movable with respect to each other, one of which responds to throttle movement and the other of which responds to the velocity sensitive device.

3. For use with an engine having a fuel system with a throttle therefor and a pump in the system for pumping fuel to the engine at a rate dependent upon the throttle position, means for controlling said pump comprising magnetic means interposed between the engine and pump to drive the latter at a variable speed, a velocity sensitive device responsive to engine speed, said first named means also including an electric circuit, and a follow up mechanism including a potentiometer in the circuit having two members movable with respect to each other, one of which responds to throttle movement and the other of which responds to the velocity sensitive device so that with a given throttle setting the velocity sensitive device will tend to automatically control the magnetic means.

4. For use with an engine having a fuel system with a throttle therefor and a pump in the system for pumping fuel to the engine at a rate dependent upon throttle position, means for controlling said pump comprising magnetic means

interposed between the engine and pump to drive the latter at a variable speed, a velocity sensitive device responsive to engine speed, said first named means also including an electric circuit, a servo mechanism for maintaining the engine at a speed corresponding to the throttle position including a potentiometer in the circuit, said potentiometer constructed and arranged to respond to throttle movement and to the velocity sensitive device, and an idling adjustment for the engine comprising a shunt in the circuit around the potentiometer, said shunt being operable to energize the magnetic means to insure limited fuel delivery to the engine at a time when the throttle is in closed position.

5. For use with an engine having a fuel system with a throttle therefor and a pump in the system for pumping fuel to the engine at a rate dependent upon throttle position, means for controlling said pump comprising magnetic means interposed between the engine and pump to drive the latter at a variable speed to regulate the fuel output to the engine in accordance with a given throttle position, a velocity sensitive device responsive to engine speed, said first named means also including an electric circuit, a servo mechanism for maintaining the engine at a speed corresponding to the throttle position including a potentiometer in the circuit, said potentiometer constructed and arranged to respond to throttle movement and to the velocity sensitive device, an idling adjustment for the engine comprising a shunt around the potentiometer, said shunt constructed and arranged to energize the magnetic means to insure fuel delivery to the engine at a time when the potentiometer is in a position to not pass current, and an altitude sensitive device in the shunt for varying the idling speed in accordance with the engine altitude.

6. For use with an engine having a fuel system with a throttle therefor and a pump in the system for pumping fuel to the engine at a rate dependent upon the throttle position, means for controlling said pump comprising a magnetic clutch with a field of variable intensity drivably connecting the pump to the engine, a velocity sensitive device responsive to engine speed, an electric circuit, a follow up mechanism including a potentiometer in the circuit having two members movable with respect to each other, one of which responds to throttle movement and the other of which responds to the velocity sensitive device so that with a given throttle setting the velocity sensitive device will tend to automatically control the magnetic clutch, and an overspeed device in the circuit operatively connected to the velocity sensitive device to control the intensity of the field at engine speeds above a predetermined limit.

7. For use with an engine having a fuel system with a throttle therefor and a pump in the system for pumping fuel to the engine at a rate dependent upon the throttle position, means for controlling said pump comprising a magnetic clutch with a field of variable intensity drivably connecting the pump to the engine, a velocity sensitive device responsive to engine speed, an electric circuit, a follow up mechanism including a potentiometer in the circuit having two members movable with respect to each other, one of which responds to throttle movement and the other of which responds to the velocity sensitive device so that with a given throttle setting the velocity sensitive device will tend to automatically control the magnetic clutch and

an overtemperature mechanism in the circuit sensitive to engine temperatures above a preselected value to control the intensity of the field.

8. For use with an engine utilizing a gas turbine and a burner or generator to which air is supplied under pressure, a fuel system including a throttle and a pump for pumping fuel to the engine at a rate dependent upon throttle position, a magnetic clutch having a field of variable intensity and two members relatively movable, one of said members being drivably connected to the engine and the other member drivably connected to the pump, a magnetic brake for said other member, a velocity sensitive device responsive to engine speed, a potentiometer having two relatively movable elements constructed and arranged so that one of the elements responds to throttle movement and the other to the velocity sensitive device, means connecting the potentiometer to said one member to thereby vary the magnetic intensity thereof, and means connecting the potentiometer to said magnetic brake to thereby vary the magnetic intensity thereof.

9. For use with an engine having a fuel system with a throttle therefor and variable fuel delivery means in the system for supplying fuel to the engine at a rate dependent upon the throttle position, means for controlling said delivery means comprisiing magnetic means interposed between the engine and delivery means to drive the latter at a variable speed to regulate the fuel output to the engine in accordance with a given throttle position, a velocity sensitive device responsive to engine speed, said control means including an electric circuit, an engine driven alternator in the circuit for supplying energy thereto, and a potentiometer in the circuit constructed and arranged to respond to throttle movement and to the velocity sensitive device.

10. For use with an engine having a throttle and a fuel system with a variable delivery device therein for supplying fuel to the engine, a magnetic coupling having driving and driven members and provided with a field of variable intensity linking said members, one of which members is connected to the engine and the other of which is connected to the variable delivery device, a device responsive to engine speed, and electrical means including an electrical follow up control capable of varying the magnetic intensity of said field, said control being connected to said throttle for establishing a predetermined engine speed setting and to said engine speed responsive device for automatically maintaining the speed setting established.

11. For use with an engine having a throttle and a fuel system with a variable delivery device therein for supplying fuel to the engine, a magnetic coupling provided with a field of variable intensity interposed between the engine and variable delivery device, a device responsive to engine speed, and electrical means including an electrical follow up control capable of controlling the magnetic intensity of said field, said control being connected to said throttle and settable thereby for preselecting engine speed, and said control also being connected to said engine speed responsive device for maintaining the preselected speed.

HERBERT C. WATERMAN.
F. V. KUZMITZ.

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