Europäisches Patentamt
European Patent Office
Office européen des brevets

(19) (11) Publication number: 0 034 936
A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 81300737.4

(22) Date of filing: 23.02.81

(51) Int. Cl.[3]: F 02 M 17/38
F 02 M 7/12, F 02 M 7/24
F 02 M 23/04

(30) Priority: 26.02.80 CA 346476

(43) Date of publication of application:
02.09.81 Bulletin 81/35

(84) Designated Contracting States:
DE SE

(71) Applicant: CTS Corporation
905 North West Boulevard
Elkhart Indiana 46514(US)

(72) Inventor: Lloyd, Charles F.
231 Elmhurst Drive
Rexdale Ontario(CA)

(72) Inventor: Zalewski, Z. Leo
R.R. 8
Brampton Ontario(CA)

(72) Inventor: Brendle, Paul C.
3501 Glen Erin Drive Apt. 1112
Mississauga Ontario L5L 2E9(CA)

(74) Representative: Amann, Hannes Gerhart
H.G. Amann and Company 27 Hillersdon Avenue
London, SW13 0EG(GB)

(54) Method and apparatus for controlling fluid flow at an orifice.

(57) Control apparatus, typically for carburettors, which comprises an actuator device (20) having a permanent magnet armature and a pair of coils surrounding the permanent magnet, and a microprocessor (18) responsive to certain parameter-sensed variables including pressure (12), temperature (14), throttle conditions (16) and oxygen content (10) in order that these variously sensed parameters can be communicated to the microprocessor wherein there is transduced by algorithm either a digital signal or an analog signal. The digital or analog signal is then fed to the actuator device in the form of a demand signal for current flow to the armature coils. The coils upon energisation mechanically displace the armature to effect mechanical transducing of the electrical signal to control an actuator rod effecting orifice control. The armature thus effectively controls the orifice size, which in turn determines fuel/air ratio for an internal combustion engine, in conjunction with a carburettor function. Fuel-air control creates operating conditions which in turn are re-sensed by the sensors, the sensors in turn repeating their operation so that there is provided a closed loop servo system either by digital or analog signals.

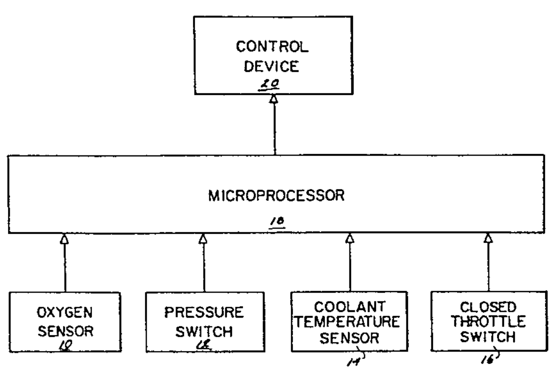

FIG. I

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Specification

Method and Apparatus for Controlling Fluid Flow at an Orifice

This invention relates to method and apparatus for controlling fluid flow at an orifice, more especially in relation to carburettors.

Prior art devices for fluid flow control at an orifice include various solenoid operated members. Upon electrical energisation of the solenoid to control the position of an armature, the armature in turn controls an actuator rod with an orifice-controlling end portion. In the known art, the orifice control provides an effective input control regulating the amount of volatilizable fuel which is metered to a carburettor, with the aim of controlling fuel flow in relation to carburettor function so that the fuel is most efficiently burned. There is in the prior art the intent to continuously monitor the schedule of fuel flow by means of various sensors which are responsive to key operating parameters such as ambient pressure, ambient temperature, oxygen in the exhaust flow, throttle position etc., all of which are relevant factors in the determination of a proper air-fuel ratio.

Typically, these parameters as determined by the sensors are communicated to a microprocessor of conventional design. The microprocessor in turn has a system of logic and algorithm whereby the inputs from the sensors are transduced into an electrical signal. The electrical signal is either a digital signal with a binary type wave output or an analog signal in which the amplitude of the signal is related to and effects a control function in accordance with the degree of amplitude of the output signal. However, it has been beyond the art to produce a simple device which can transduce the described electrical signal output of the microprocessor to a mechanical translation of an armature to produce a precise displacement of the armature and its associated orifice-modifying means, thereby to secure proper control of the orifice. It is the orifice control which in turn determines optimum air-fuel ratio reflective of operating conditions determined by the sensor inputs as aforedescribed. The difficulty is that the described known system, while sound in principle, is nevertheless beyond the state of the art to achieve either because the system has internal lag, or is not achievable with components and combinations of components which are within effective economic cost range. For example, components which are theoretically capable of achieving the foregoing results are either too expensive and must be custom constructed, or do not lend themselves to large scale manufacture and a capability of proper functioning within the range of the expected stack-up of tolerances and overall operating conditions encountered in conventional internal combustion engines.

It is an object of the present invention to provide a method of and apparatus for control of fluid flow at an orifice which provides a solution to the above-described problem.

Thus, the invention in one aspect provides a control device consisting of a relatively few number of components consisting essentially of an armature made up of a permanent magnet with north and south pole pieces responsive to two spaced electromagnetic coils which closely surround the poles throughout the range of their movement. The armature drives an orifice-controlling member which is displaceable and is selectively positionable by the armature to control the metering of fuel to a carburettor and thereby controls air-fuel ratio.

Surrounding the electromagnetic coils and armature is a magnetically permeable sleeve. In conjunction with the actuator rod and armature is one or a pair of springs which are adjustable in spring tension and can effectively determine the critical operating characteristics of the armature.

It is an important feature of the present invention that the described armature-coil arrangement is virtually instantaneously and linearly responsive to transduced electrical signals derived from critical sensor elements which continuously monitor the temperature, pressure, throttle conditions and oxygen content. These sensors are continuously in communication with a microprocessor which develops a corresponding signal of either digital or analog characteristics, such signal being continuously received and transduced into mechanical movement by the development of current within the coils of the electromagnet of a magnitude appropriate to the incoming microprocessor signal (of either digital or analog wave form) and the armature thereafter displaces or positions the orifice-controlling member in relation to the orifice. Thus, there is an effective monitoring, virtually instantaneous and linear in property, so that response is continuously made to conditions as determined by the sensors and the fuel-air mixture thereby continuously monitored and provided in whatever proportionality is necessary to maintain optimum conditions as determined by the sensors. The system as a whole has closed loop self servo control maintaining a preferred operating system logic.

Thus, in another aspect, the invention provides an effective servo system in which sensor elements continuously monitor operating condition, testing for deviations from ideal engine operating conditions best calculated for optimum efficiency and pollution-free operation. The armature includes an orifice-controlling adjustable spring force which is adjustably in opposition to the armature movement, and will determine the correct metering orifice size and hence the correct conditions of air-fuel ratio communicated through the carburettor to the engine and the engine operating performance is then continuously checked by the sensors that are available for feedback to the armature so that the orifice size is continuously monitored and maintained at optimum conditions.

It is an important feature of the present invention that unique and precise spring adjustments are available in relation to the armature so that the mechanical displacement of the armature can be exactly adjusted to obtain the correct orifice size adjustment.

Thus, in general, the present invention provides a unique and effective combination of fuel-metering control in relation to sensors and microprocessors to secure continuous relatively pollution-free and efficient engine operation and does so by means of individually adjustable armatures which are spring adjusted by mechanical adjustment means, in which the spring rate and spring response can be independently adjustable.

Further features of the present invention will become apparent from a consideration of the following description which makes reference to the accompanying drawings wherein some embodiments of the invention are described by way of example.

In the accompanying drawings:-

Figure 1 is a schematic block diagram of a microprocessor controlled catalytic converter system wherein the present invention is utilised;

Figure 2 is a diagram of a carburettor showing the various carburettor functions interrelated to the control apparatus of the present invention;

Figures 3, 4, 5, 6 and 7 are longitudinal section views schematically illustrating respective embodiments of actuator devices utilised in the present invention;

Figure 8 is an isolated, enlarged, detail view illustrating an adjustable spring means in an actuator device, whereby both the spring rate and spring response is variable to adjust the device for a given set of operating conditions;

Figure 9 is an illustration of a digital wave form which the microprocessor communites to the control apparatus, this being typically a binary wave form which can be pulsed at regular intervals;

Figure 9(a) illustrates a digital, binary, pulsating wave form in which the actuator device for the control apparatus is bipolar energised, i.e. coils are energised first in one polarity and then in the opposite polarity to effect positive drive of the armature in either of opposite directions;

Figure 9(a) also illustrates a digital, binary, pulsating wave form in which the actuator device for the control apparatus is bipolar energised, i.e. the coils are energised first in one polarity and then in the opposite polarity to effect positive analog control of the armature in a direction represented by the average value of the wave form;

Figure 10 illustrates an alternative wave form for analog control of the coils wherein the armature is operated in an analog mode; and

Figure 11 is a block diagram of the complete control apparatus illustrating the sensors, microprocessor, actuator device, carburettor, and the closed loop nature of the entire system.

Referring now to Figure 1, a plurality of spaced sensors are designated generally by reference numerals 10, 12, 14 and 16. The sensors will be disposed at various locations on a vehicle and are particularly adapted to provide continuous measurements of operating parameters to a microprocessor 18 of conventional configuration. The microprocessor is not a part of the present invention, per se, but a typical microprocessor is available for purposes of the present invention in the form of an electronic control module which contains the necessary program and system of algorithm.

The sensors, which are of conventional design, are intended to provide such parameters as oxygen content in the exhaust, and are designated generally as oxygen sensor 10, pressure sensor 12, cooling temperature sensor 14, closed throttle sensor 16, and if required an ambient pressure sensor which is not shown. These sensors continuously provide monitored information to the microprocessor which in turn communicates an algorithm signal to a remote actuator or control device 20.

Referring now to Figure 2, an actuator device now referenced 22 is associated with and operates the fuel-metering rod 23 of a carburettor, having an end 24 movable in relation to a fixed fuel-metering orifice 26 defined by a throat section 28 of a Venturi. In addition, the control mechanism 22 displaces an armature bracket 30 one end 34 of which is positioned to bear against a lean mixture stop 36. The opposite side of the bracket is positioned to bear against a rich mixture stop 38. The two stops 36 and 38 are threaded for micrometric adjustments relative to respective co-acting supports 40, 42.

The armature bracket 30 also operates an idle bleed air valve 43 through a spool valve 44 having a valve rod 46 which has rod end 48 in contact with bracket end 35, so that movement of armature bracket 30 controls both the effective cross sectional area of the fuel-metering orifice 26 and the idle bleed air valve 43.

Referring next to the various embodiments of the actuator device illustrated in Figures 3-7, these various devices will be explained in detail commencing with Figure 3.

In the device 19 illustrated in Figure 3, an armature 50 operates downwardly to displace a connector means 52, thereby determining the operative position for the fuel-metering rod 23 and valve rod 46 of Figure 2. When means 52 is displaced, this is against the bias of a spring 54.

The armature 50 operates in a digital mode and is responsive to a binary energising input signal such as that shown in Figure 9, i.e. the armature is either energised to be pulled to a fully-down position or when unenergised it is moved by the spring 54 to an up position. The technique of control is that in one mode, i.e. energised or "on" mode, the device determines a lean mixture, and in an unenergised or "off" mode with the spring 54 displacing the connector means 52 upwardly, the engine being controlled operates in a rich mixture mode. The overall control operation consists in integrating the number of "on" and "off" positions so that the integration of the totality of the "on" and "off" modes will result in an appropriate air-fuel ratio. Referring again to Figure 3, the armature 50 which displaces the connector means 52 does so responsive to energisation by two spaced sets of coils 56 and 58, which are wound on a bobbin 60.

The armature 50 consists of a permanent magnet 62 having two pole pieces 64 and 66, the characteristics of which make the armature linearly displaceable under a constant force responsive to the generation of current within the coils. It is an important characteristic of the invention that a digital signal in the form of binary signals effects a rapid acceleration of the armature, displacing it on a time basis almost instantaneously in a downward movement against the biassing spring 54, and immediately upon de-energisation of the coils the electromagnet will be virtually instantaneously linearly displaced in the opposite direction by means of the compressed biassing spring 54. Thus, the above described armature-coil arrangement is susceptible to a signal of digital form (see Figure 9) derived from the sensors and microprocessor also previously referred to. Surrounding the coils is a magnetically permeable casing 68 which serves to contain the coils 56, 58, and the bobbin 60 provides a stop 70 limiting downward movement of the armature 50 when it is energised. The upward movement of the armature effected by the spring 54 displaces the connector means 52 upwardly until it engages a rich mixture stop 38 micrometrically adjusted relative to the support 42 as illustrated in Figure 2. The microprocessor 18 (Figure 1) supplies a signal to the coils 56, 58, causing them to be energised to an "on" mode, thereby drawing the armature 50 downwardly against the resistance of the spring 54 as before described.

It is a characteristic of the digital wave pattern of Figure 9 that there is an almost vertical inclination of the signal from zero to one. The same applies at the terminal part of the duty cycle. Typically, the cycle is adjusted so that it is effective from 15 to 85% of the time, i.e. the actuator device is in an "on" mode between 15 to 85% of the duty cycle, the total time duration of which is typically about 100 milliseconds, with the signal varying from zero to plus 12 volts.

Typically, the microprocessor may be one which is fully exemplified within the context of the C-4, Computer Control Catalytic Converter system described in the "Citation" Shop Manual ST365-80, pages 8A-64, 65 and 66, a publication by General Motors, Chevrolet Division.

The apparatus as described in relation to the actuator device of Figure 3, is alternatively usable with a binary digital signal having a wave characteristic such as that illustrated in Figure 9(a), wherein the binary signal wave varies from plus one to minus one. In this instance, the coils are energised in either one of opposite directions of current flow, and the spring 54 and another oppositely compressible spring (not shown) are utilised to achieve a "neutral" position for the armature. The latter is then either energised positively in an up direction or positively in a down direction against the coacting and oppositely compressible springs which in the absence of energisation of the coils cause the armature to be spring displaced to a neutral position corresponding to an average amplitude of zero of the wave. Thus, when the wave is positive, i.e. at plus one, the coils are energised with current flow in one direction to effect a downward force of the armature 50 against the resistance of the spring 54, and when the wave goes negative, i.e. to minus one during the duty cycle of approximately 100 milliseconds, the current direction is reversed to cause an upward force of the armature 50 against the resistance of the oppositely compressible spring (not shown). The resultant net position of the armature 50 and the connector means 52 will be determined according to the time average of the magnetic forces and the spring characteristics.

Referring to Figure 4, there is again illustrated an actuator device having an armature 50 with pole pieces 64 and 66, one at each of the opposite ends of the permanent magnet 62, and a pair of coils 56, 58. The coils are again wound on a bobbin 60 disposed within casing 68. These members have substantially the same characteristics as described for the embodiment in Figure 3. However, in this embodiment, an elongated rod 72 of armature 50 has at an end 74 thereof an orifice controlling metering pin 78 which effectively defines the operative cross-sectional area of an air-metering orifice 80 adapted to control the amount of idle bleed air in a somewhat different manner than that illustrated in Figure 2. At the lower end of the armature 50 is an elongated rod 81 having a metering pin 82 controlling the effective cross-sectional area of a fuel metering orifice 84 again in a somewhat different manner than that illustrated in Figure 2.

In this embodiment, there is located a coil spring 86 bearing at one end against an annular boss 88 in an elongated sleeve 90 and at the opposite end bearing against the pole piece 64, thereby urging the armature 50 upwardly in an orifice opening direction in relation to fuel-metering and in an orifice closing direction in relation to air control. Thus, when the armature is not energised, the mixture tends to be a rich mixture, meaning that there is a higher ratio of fuel to air than during the null position or off position of the armature. When the sensors induce the microprocessor to develop a positive signal and the wave progresses from a zero to a "one" amplitude to commence a duty cycle (Figure 9), the coils 56, 58 receive a current which causes the armature 50 to be displaced downwardly against the resistance of the spring 86. Thus, referring to Figures 9 and 4, whenever a binary digital signal is developed commencing from zero to one and as long as the duty cycle exists for the period 0 to 100 milliseconds, the armature 50 will be displaced downwardly in an "on" position causing the metering pin 82 to move into the orifice 84 to reduce its effective cross-section and thereby reduce the amount of fuel. In relation to a greater amount of air, when the armature 50 moves downwardly the metering pin 78 is displaced outwardly from the orifice 80 increasing its effective cross section so that the fuel-air ratio produced represents a much leaner mixture.

This monitoring and control of the fuel-air ratio is effected by the movements of a throttle valve being sensed by sensors in a close-looped servo system, which sensors in turn actuate the microprocessor, the micro-processor in turn developing the duty cycle as illustrated in Figure 9 and the binary signal then being used as the operating parameter for the armature 50. In this way, the engine operating conditions are continuously sensed, which includes the monitoring of oxygen flow in the exhaust system, the sensing of temperature, pressure and throttle condition, and responsively to those conditions through the microprocessor there is a corresponding positioning of the fuel and air control members in the throttle valve to adjust the engine to the appropriate operating conditions relative to the information sensed by the sensors.

Referring next to the embodiment illustrated in Figure 5, there is shown an actuating device which operates on an "analog" principle, i.e. in this embodiment the device is intended to provide not merely an on-off operation but a continuous monitoring of orifice size micrometrically. There is an ability to control the effective cross-sectional area of the orifices not merely on a statistical on-off basis with the averaging principle utilised for achievement of the correct air-fuel ratio, but instead the positioning of the metering pins relative to the orifices is measured continuously and is adjusted by means of an analog signal in the manner which will next be described.

In this embodiment, there is an armature 50 having two pole pieces 64, 66 which are displaced by means of closely surrounding circumposed coils 56, 58, respectively. The coils are wound on a bobbin 60. There is a closely surrounding casing 68 which is magnetically permeable as before described. At the one end of the armature there is an elongated rod 72 and a metering pin 78 which controls the effective cross-sectional area of the air metering orifice 80 thereby to determine one portion of the air-fuel ratio. At the bottom part of the armature is an elongated rod 81 with a metering pin 82 that controls the effective cross-sectional area of the fuel-metering orifice 84. Thus, the position of the metering pin 82 relative to the orifice 84 determines the quantity of fuel that is delivered through the carburettor to the engine.

The movement of the armature 50 is also controlled by means of two spaced springs 86 and 86a. Spring 86 is compressed between an adjustable nut 92 which is threadedly received on the threaded outer surface of the elongated rod 81 and bears at the other end against a seat 98 of the bobbin 60. The second spring 86a is compressed between a fixed seat 100 and an adjustable nut 102 which is also threadedly received on the threaded outer surface of the elongated rod 81. By adjusting nuts 92 and 102, the characteristics of the device can be controlled. It should be noted that the springs 86, 86a according to their adjustment by the associated nuts 92 and 102 determine the neutral position of the armature, i.e. the position which the metering pins assume relative to the metering orifices when there is a condition of no signal or when there is a zero time-averaged value of current in the coils 56 and 58.

In this embodiment, unlike the prior embodiments, the sensors act through the microprocessor in the manner before described but the algorithm of the microprocessor develops either a binary output signal as illustrated in Figure 9(a), or an analog signal such as illustrated in Figure 10, thereby effecting a metering of the effective cross-sectional areas of the air-metering orifice 80 and fuel-metering orifice 84 by the metering pins 78 and 82, respectively, to achieve the appropriate air-fuel ratio in accordance with the parameters of oxygen content, pressure, temperature, throttle position etc., these all being parameters sensed by the sensors for processing through the microprocessor in a closed-loop servo system. The described embodiment is responsive to a continuous sensing by the sensors and positions the metering pins relative to the air and fuel orifices thereby determining the operating characteristics of the engine, which develops outputs again continuously sensed by the sensors so that there is a closed-loop feedback system: first by the output parameters sensed by the sensors and then the positioning of the fuel-air ratio metering pins that in turn determine the output characteristics of the engine.

Referring next to the embodiment shown in Figure 6, the armature, bobbin, coil and casing are virtually the same as before described. There is a slightly different configuration of the metering pin 82, which has the form of constant cross-sectional area metering pin 82a in Figure 6, and likewise metering pin 78 is replaced by a constant cross-sectional area metering pin 78a. The characteristics of the device in Figure 6 can be varied by means of a spring 104 compressed between a fixed seat 101 on the bobbin 60 and a single adjustable nut 106 threadably received on an elongated rod 81 and a spring 105 compressed between the nut 106 and a shoulder 107 in an elongated sleeve 90. Adjustment of the nut 106 determines the neutral position of the armature 50.

The "gain" is a variation in the response of the device to an energising signal and may be varied by the original adjustment of the device but remains relatively fixed thereafter. In operation, the current magnitude in the coils effects a particular positioning of the metering pins 78a, 82a by micrometric adjustments in accordance with the time-average value of the digital signal of Figure 9(a) or the amplitude of the analog signal (Figure 10).

Referring next to the embodiments shown in Figures 7 and 8, there is illustrated a further embodiment of the invention wherein the actuator device is again responsive to a time-average value of the digital signal of Figure 9(a) or the analog signal of Figure 10 for micrometric adjustment of the air and fuel orifices by co-acting metering means. The metering of the orifices is accomplished by the device generally described previously in relation to Figures 2 and 3, but there is a variation in the response of the device by means of a particular placement of springs. Because of the slight differences in construction, the entirety of the device will be described. Again, as in the previous embodiments, the armature 50 consists of a permanent magnet 62 with two opposite pole pieces 64, 66 secured to end portions of the magnet. Surrounding the armature is the bobbin 60 supporting two coils 56, 58 which upon energisation effect a mechanical displacement of the armature. The amount of the current for energising the coils is in accordance with the characteristics of a variable signal developed by the microprocessor, the character of the signal and its duration being developed by the algorithm of the microprocessor. Just as in the previous embodiments, a magnetically permeable casing 68 surrounds the coils and assists in directing the magnetic flux during energisation of the coils. At one end of the armature is a displaceable driveplate 52a. A fixed bridge 108 includes a nut 110 which is adjustable relative to the bridge. The nut 110 is rotated in order to displace longitudinally a coil spring 112 one end of which is threadably received by the nut and the other end of which is screwed into and secured in the pole piece 66. Therefore, by rotating the nut 110 it is possible to control the spring position and thus determine the null or neutral position of the armature 50 and the driveplate 52a at the time when no current is developed in the coils.

Another adjustment is provided by an internal screw 114 that screws within the inner diameter of the coil spring 112, and is received through an interior opening of the nut 110 and within the coil spring 112 so that as it is turned downwardly it determines the effective number of spring coils that are operative under compression or expansion at any given armature position. The "gain" is thus controlled once the spring has been positioned by rotation of the nut 110. By adjustment of the nut 110 and screw 114, it is possible to determine the neutral or null position and response characteristics of the armature to a given signal developed from the microprocessor.

The effective length of the spring 112 together with its spring rate are the two adjustment characteristics which enable the user to vary the static position and response of the device to a given input signal. These two adjustments are relatively easy to obtain and can be carried out not only initially to calibrate the apparatus but also are available throughout the operation of the apparatus to optimise its operation for certain operating conditions.

With regard to operation of the complete control apparatus, and first making reference to Figures 1-3, 9 and 11, the actuator device is calibrated initially to be responsive to the signals from a microprocessor 18 on a continuous basis, the microprocessor output signal being related to the conditions of operations as determined by the sensors 10, 12, 14 and 16. This also is shown schematically in Figure 11 in which the sensors are shown as having inputs to the microprocessor 18. The output is in the form of digital binary signal supplied continuously to the air-fuel ratio actuator designated generally by reference numeral 20. The signal, which is utilised for the device in Figure 3, is a binary signal having a wave form as shown in Figure 9, i.e. a recurring pulse signal having a duty cycle of approximately 15 to 85 percent. When the microprocessor pulses, the plus one pulse is communicated to the spaced coils 56 and 58 as a current which effects displacement of the armature 50 consisting of the permanent magnet 62 of two pole pieces 64 and 66. Actuation of the armature 50 causes displacement of the connector means 52 in a downward direction indicated by the arrow 21 in Figure 3 and produces a selective positioning of the valve rod 46 and the fuel-metering rod 23 illustrated in Figure 2. These two control members thereby determine the amount of fuel which is effectively metered through orifice 26 and the amount of idle bleed air controlled by the spool valve 44. This determines the air-fuel ratio which is carburetted and then communicated to the cylinders of an internal combustion engine (not shown). The output of the engine is then again sensed directly or indirectly by the sensors 10, 12, 14 and 16 illustrated in Figures 1 and 11, thereby defining a closed-loop feedback system following the flow path in Figure 11. When the signal as shown in Figure 9 ends its on or binary 1 interval, the amplitude returns to zero thus de-energising the coils 56 and 58 of the device 19 (Figure 3) and the spring 54 then restores the means 52 to its neutral or null position thereby repositioning the idle bleed air spool valve 44 and the fuel-metering rod 23, and once again changing the amount of metered fuel and metered air and thus affecting the air-fuel ratio once again.

It is contemplated as part of the present invention, in relation to the actuator device of Figure 3 for example, that the wave pattern can be varied as to the duty cycle and time interval, i.e. any portion of the wave from zero to 100 percent can be utilised. It is also an important feature of the invention that there is nearly an instantaneous response corresponding to a signal from zero to one. However, the response time of such a signal and the task of attempting mechanically to transduce that signal into the nearly instantaneous positioning of valves has proved quite difficult in the art; a characteristic of the invention is that it does have such an almost instantaneous response. Thus, the required current magnitude for full energisation of the coils in the device is almost instantaneously achieved because of the constructional features of the combination armature, bobbin and casing. The response of the armature to coil energisation for mechanical transducing, i.e. positioning of the metering rod 23 and valve 44 relative to the metering orifice 26 and idle bleed air valve 43, is that immediately upon build up of current in the coil there is an instantaneous force developed on the armature, and the armature is of such size and magnetic coupling qualities with the field that it develops an almost instantaneous displacement and thereby a very highly responsive positioning of the valve and metering rod.

Resulting from this, it is another major feature of the present invention that, by electronic adjustment of the duty cycle in any of the preferred manners well within the state of the art, an almost instantaneous adjustment of the air-fuel ratio can be achieved. The actuator device of Figure 3, for example, utilises a binary signal and is constructed on the principle that there is either a rich or lean mixture at any one time instant. However, the averaging of these time instants over a larger period of time will produce the overall desired air-fuel ratio. This corresponds to the well-known principle of "averaging" to achieve the desired operating condition.

Referring next to the operation of the analog type of device wherein the energising coils associated with the actuator are responsive either to an analog signal or to a suitable digital signal, reference is made to the device shown in Figure 5, in conjunction with Figures 1, 2, 10 and 11.

The microprocessor 18 responsive to the sensors 10, 12, 14 and 16 provides a signal output, the amplitude of the signal producing a corresponding current generation in the coils of the actuator 20. For example, the microprocessor 18, which can produce either a digital or analog output, produces in one instance an analog signal which yields a value of current within the coils as determined by the magnitude of the signal. Similarly, the position of the metering pins 78 and 82 within the air and fuel metering orifices 80 and 84 is effected almost instantaneously since one of the characteristics of the actuator is the development of virtually instantaneous response because of the force developed by the armature 50 responsive to the developed current within the coils 56, 58. Thus, movement of the metering pins to appropriate positions occurs almost instantaneously within a time frame directly related to the instant signal amplitude (Figure 10) and instantaneous current generation within the coils (Figure 5). It is for this reason that the device, as described, can be responsive to either signals which are of a digital (binary) or analog characteristic. Some devices of the art are not compatible with a selectively determined signal of either analog or digital characteristics.

The actuator devices shown in Figures 6 and 7 are virtually the same functionally as the analog device illustrated and described in detail for Figure 5. Therefore, the operation of the devices 6 and 7 will not be repeated in detail since they follow essentially the same as the already described species of Figure 5. However, the device of Figure 7 embodies certain unique mechanical adjustments by which its response is more closely and selectively correlated to the electronic output signal of either Figure 9(a) or Figure 10.

The adjustment in this case is determined by a two-fold spring adjustment, the one consisting of a nut 110 which is rotatable relative to its support, namely fixed bridge 108, such movement being effective to advance the coil spring 112 through the central opening of the nut 110 and thereby longitudinally position the attached armature 50 to a preferred position relative to the coils 56, 58. Additionally, such an advancing movement of the coil spring 112 determines the effective number of coils that position the armature 50 when the coils are de-energised. There is an internal screw 114 which can advance below the nut 110 and internally of the spring 112, the screw having the same pitch at its outer surface as the inner spring circumference, whereby the screw adjusts the number of effective spring coils and thereby the response to a given signal input. The first described adjustment is also effective for determining the neutral position or null position of the armature 50 including the pole pieces 64, 66 relative to the coils 56, 58. As previously mentioned, it is important that during operation of the actuator device the pole pieces at all times be within the circumscribed area of the coils so that the response in movement of the armature by the coils is at all times linear and unaffected by the degree of movement of the armature. A degree of adjustment of response is obtainable by virtue of the nut 110 and coil spring 112 advancing or retracting the armature 50 whereby the neutral or start position of the armature relative to the coils 56, 58 is preferably determined. The limit of movement of the actuator is in one direction fixed by engagement of a portion of the drive plate with the nut 110, and is limited in the opposite direction by the engagement of the pole piece 64 with the stop 70 of the bobbin 60.

Although the present invention has been illustrated and described in connection with certain example embodiments, it will be understood that these are by no means restrictive as to the scope of the invention which is defined in the claims appended hereto.

Claims

1. A method of remotely controlling the effective cross section of an orifice associated with fuel/air supply to an internal combustion engine, comprising the steps of continuously sensing physical data in the form of gas analysis, throttle operation, pressure and/or temperature data, and continuously supplying such information to a microprocessor to effect a transduced electrical signal, characterised by the steps of communicating such transduced electrical signal to a pair of electrical coils, and mechanically transducing the energisation of said coils through a permanent magnet member to displace an armature and operatively connected control means to control said orifice, the controlled orifice in turn determining the physical data fed back from the sensors thereby to define a closed loop control network, and continuously opposing the displacement of the armature by said coils by resilient means having a predetermined rate.

2. A method in accordance with claim 1, wherein the transduced electrical signal communicated from said microprocessor to said coils is in the form of a digital or an analog transduced signal, characterised by the further step of providing a variable duty cycle means for controlling

the transduced electrical signal communicated to the pair of electrical coils.

3. A method in accordance with claim 1 or claim 2, characterised in that communicating the transduced electrical signal to a pair of electrical coils produces a substantially instantaneous mechanical displacement of the armature, and the response of the armature is operatively controlled by varying the predetermined rate of the resilient means opposing the displacement of said armature.

4. A method in accordance with claim 3, characterised in that the mechanical response of the armature to the transduced electrical signal at any one predetermined armature position is adjusted by varying the response rate of the resilient means at the predetermined armature position, thereby varying the gain of the response.

5. Apparatus for controlling fluid flow more especially to enable the method of claim 1, comprising means forming a metering orifice; and a member for controlling the effective orifice size by movement into and out of the region of the orifice to control its open cross-sectional area; characterised by an actuator device comprising an armature comprising a longitudinally movable permanent magnet with north

and south pole end portions, a coil surrounding each pole portion and having lateral dimensions which encompass circumferentially each pole portion throughout its effective range of longitudinal movement, and resilient biassing means determing a predetermined neutral position of said armature; remotely disposed sensors for measuring operating conditions controlled by said effective orifice size, means for energising said coils responsively to a digital or analog signal developed from signals derived from said sensors, and feedback means to said orifice controlling member to control the movement and position of said orifice controlling member in accordance with the digital or analog signal.

6. Control apparatus in accordance with claim 5, characterised in that the actuator device further comprises a surrounding sleeve and a control rod operatively secured to said armature and extending within said sleeve, the resilient biassing means comprising a resilient spring one end developing biassing effort against a portion of the armature and the other end received by a fixed internal portion of the sleeve, whereby the armature and orifice controlling member driven by the control rod are biassed in an orifice opening direction.

7. Control apparatus in accordance with claim 5, characterised in that the actuator device further comprises a control rod secured to said armature, a sleeve operatively surrounding said control rod, and two independently operable adjustor nuts on a threaded portion of said control rod, the resilient biassing means comprising respective spring means individually controlled by each adjustor nut, one of said spring means operatively bearing against a fixed portion of said device and biassing one of the adjusting nuts and the control rod and armature in one direction, the other of the spring means being operatively fixed and opposing said one spring means in cooperation with said second adjusting nut, each of said adjusting nuts being individually movable to control the compression of its respective spring means whereby the neutral position of said armature and control rod and thereby said orifice-controlling member is determined at the condition of zero energisation of said coils.

8. Control apparatus in accordance with claim 5, characterised in that said actuator device further comprises a threaded member operatively secured to said armature, and an adjustable nut received on said threaded member, the resilient biassing means comprising two opposed spring means each bearing at one end against

a fixed portion of the device and at the other end against the adjustable nut whereby the opposed springs determine the neutral position of said armature when the coils are unenergised.

9. Control apparatus in accordance with claim 5, characterised in that the resilient biassing means comprises a spring secured at one end to the armature and the other end received by an adjustable nut, the actuator device also including a screw disposed within the spring and adjustable nut whereby adjustment of the nut and screw varies the neutral position of the armature and the spring response.

10. Control apparatus in accordance with anv of claims 5 to 10, characterised in that the sensor signals are fed to a microprocessor adapted to develop binary digital signals fed to the coil windings to actuate the armature for predetermined time intervals of 1,0 or of 1, -1.

11. Control apparatus in accordance with any of claims 5 to 10, characterised in that the sensor signals are fed to a microprocessor adapted to develop an analog current fed to the coil windings to effect a consequent magnetic energisation having an analog equivalent to the current flow within said coils, thereby effectively to position the orifice-controlling member in micrometric

amounts related to the information from said sensors.

12. Control apparatus in accordance with any of claims 6 to 10, wherein the sensor signals are fed to a microprocessor adapted to develop binary digital signals fed to the coil windings to actuate the armature for predetermined time intervals of 1, -1.

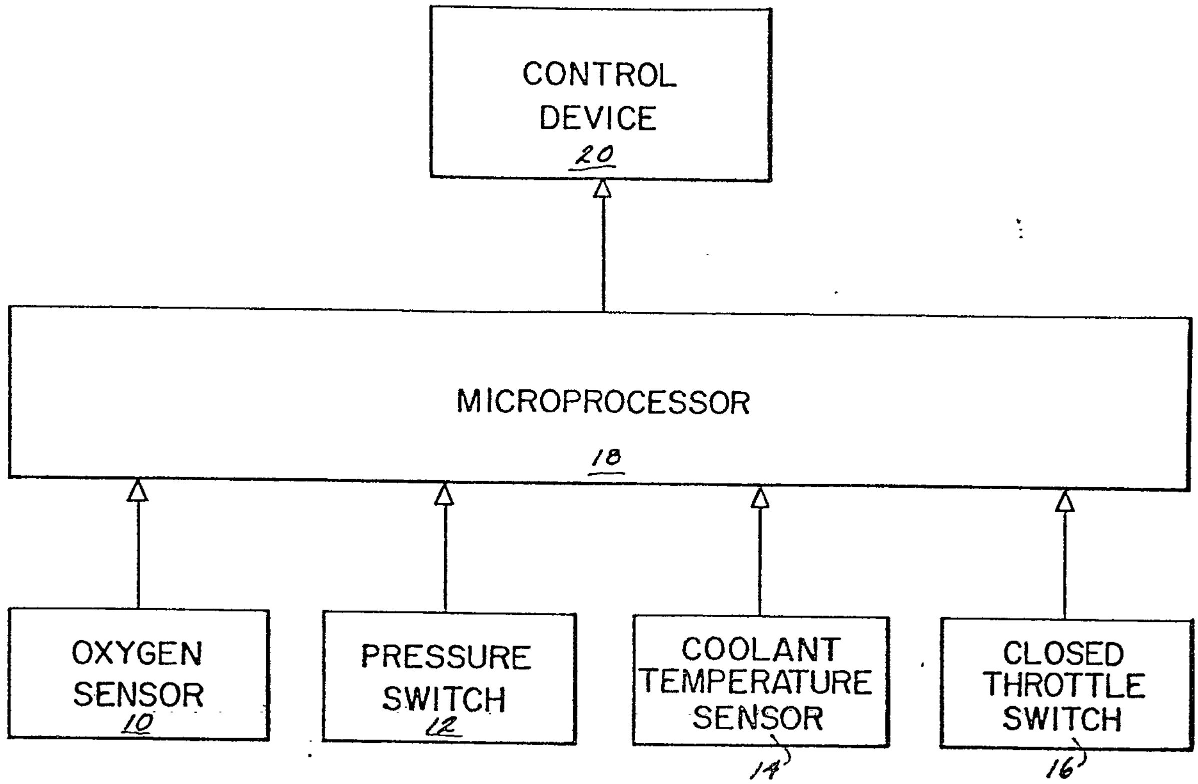
CONTROL DEVICE
20
MICROPROCESSOR
18
OXYGEN SENSOR
10
PRESSURE SWITCH
12
COOLANT TEMPERATURE SENSOR
14
CLOSED THROTTLE SWITCH
16

FIG. 1

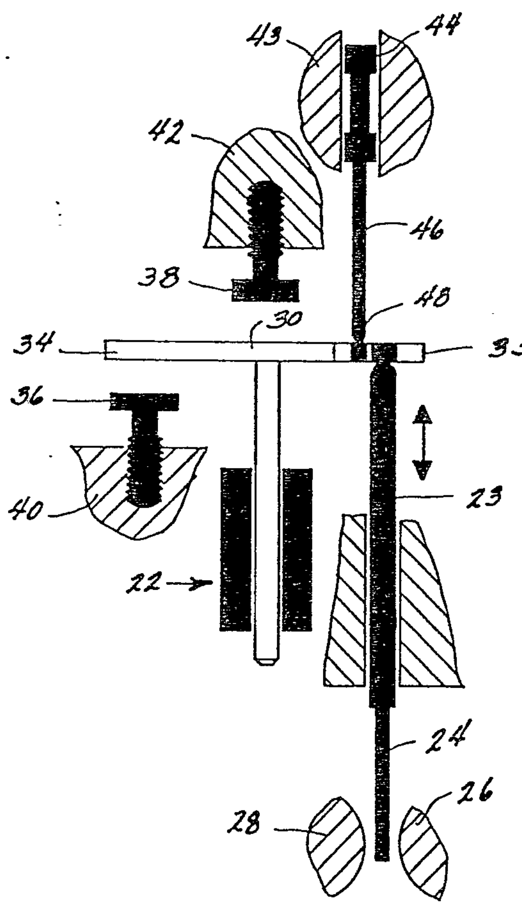
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FIG. 2

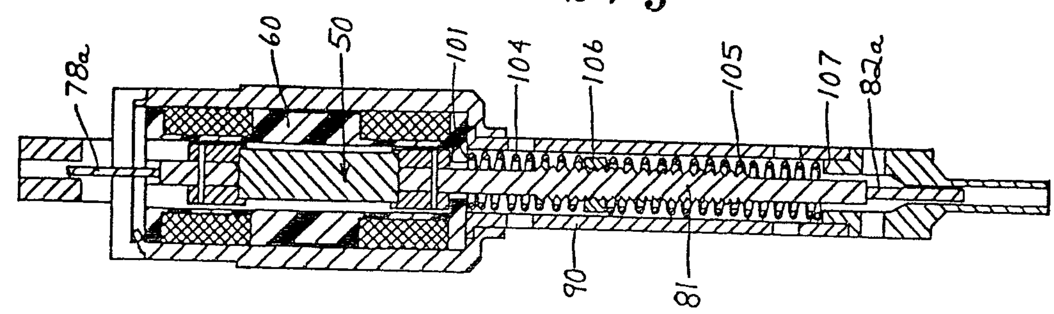


FIG. 6

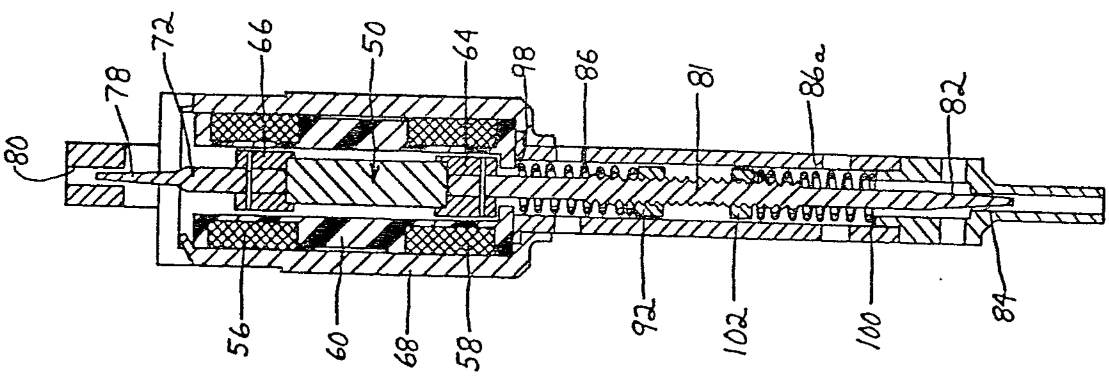


FIG. 5

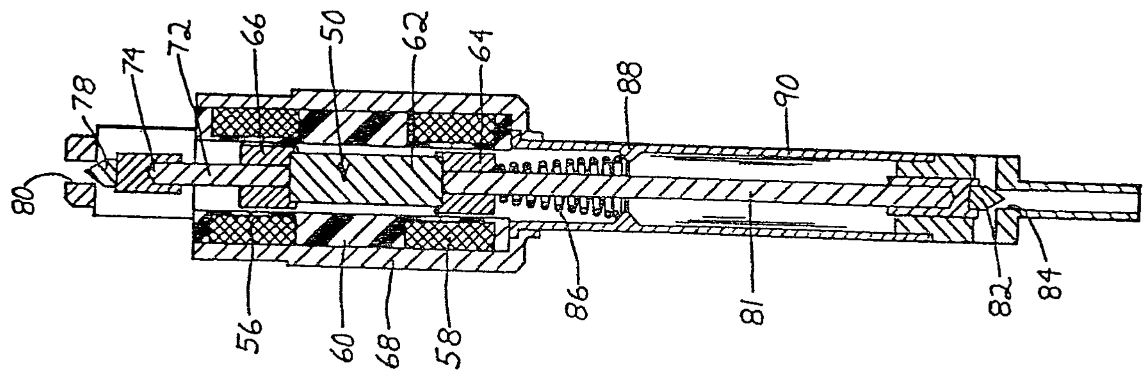


FIG. 4

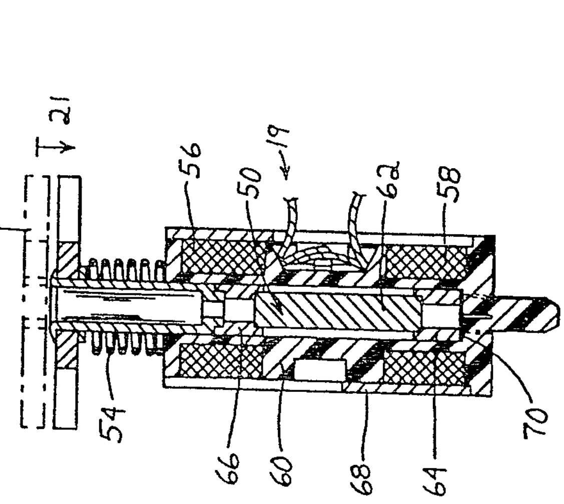
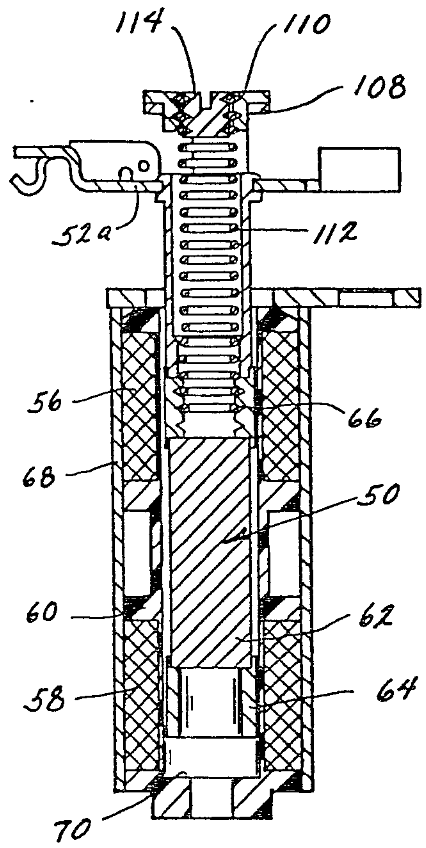


FIG. 3


114
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112
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62
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64
70

FIG. 7

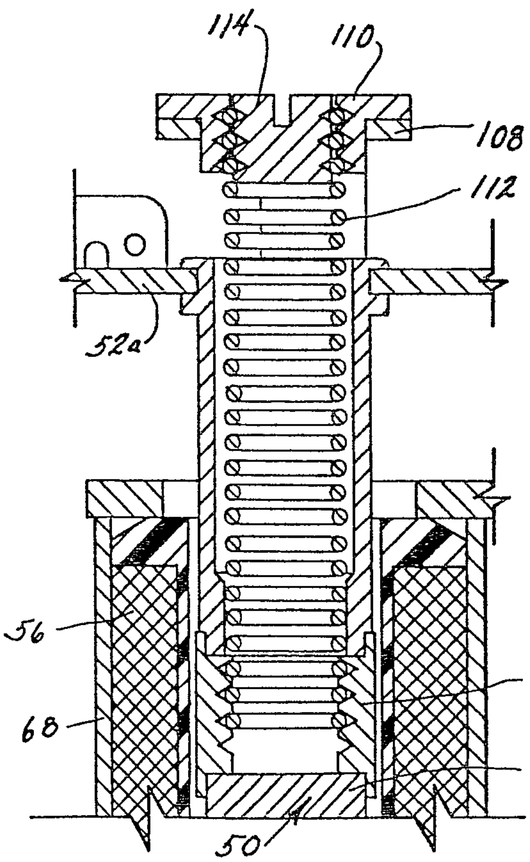
114
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FIG. 8

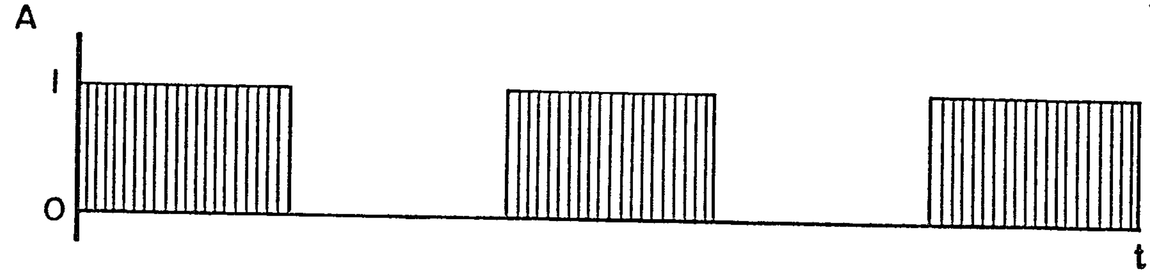

FIG. 9

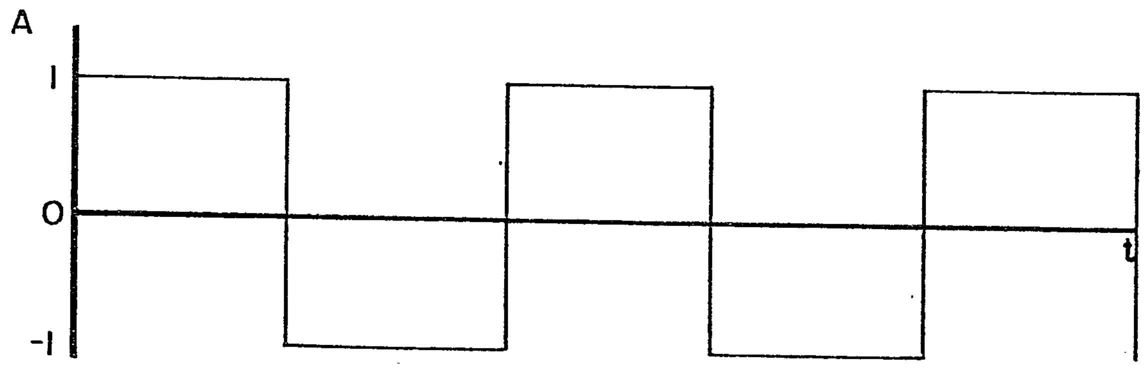

FIG. 9A

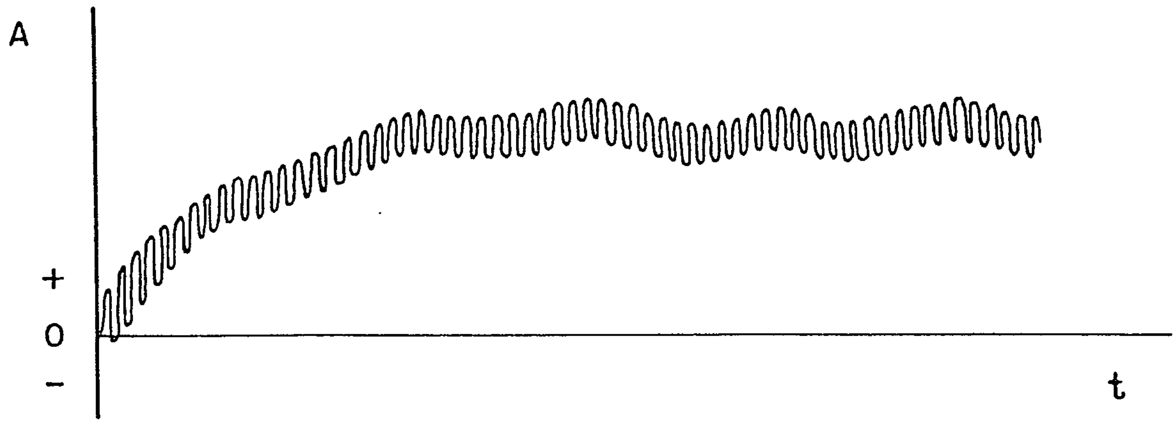
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FIG. 10

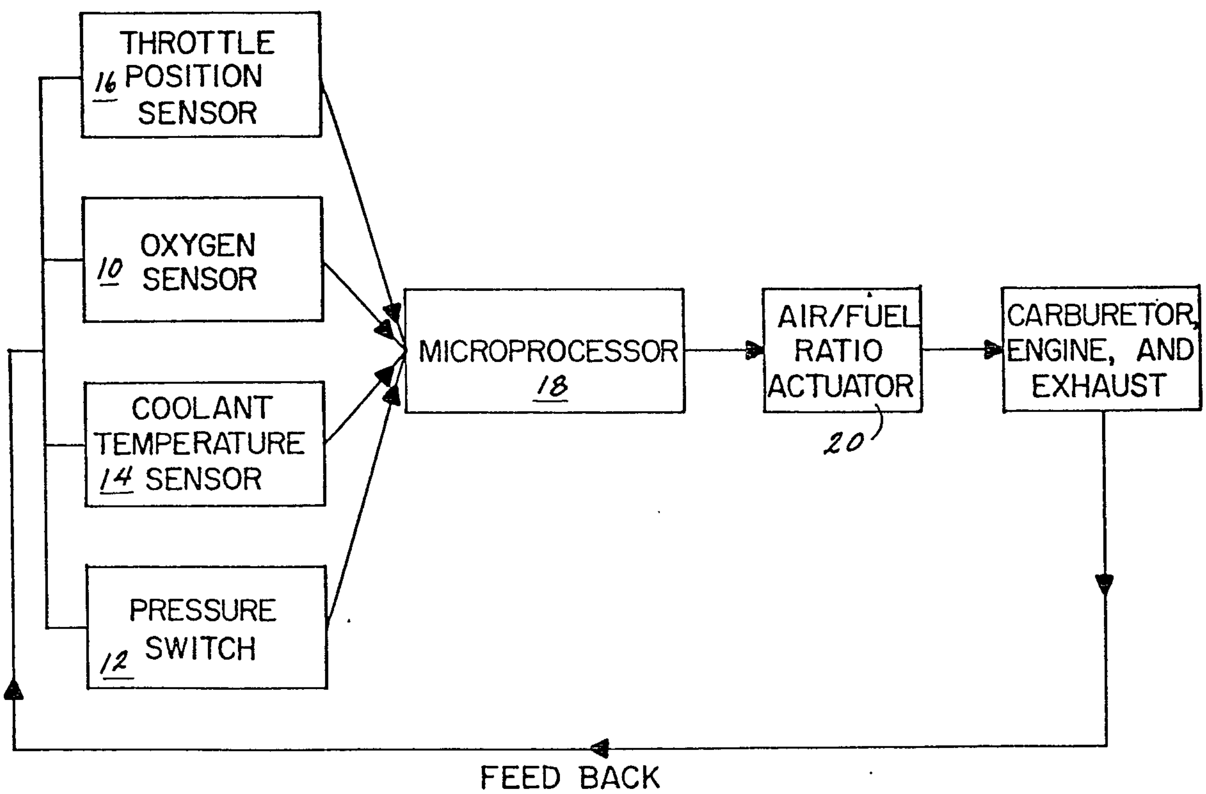
THROTTLE POSITION SENSOR
16
OXYGEN SENSOR
10
COOLANT TEMPERATURE SENSOR
14
PRESSURE SWITCH
12
MICROPROCESSOR
18
AIR/FUEL RATIO ACTUATOR
20
CARBURETOR, ENGINE, AND EXHAUST
FEED BACK

FIG. 11

0034936

European Patent Office

EUROPEAN SEARCH REPORT

Application number
EP 81 30 0737.4

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
P	DE - A1 - 3 017 467 (NISSAN MOTOR CO.) * claims 2, 6; page 10, line 20 to page 12, line 5; fig. 1 * --	1,2
	Patents Abstracts of Japan, Vol. 1, No. 105, 16 September 1977 page 3071M78 & JP - A - 53- 70225 --	1
P	DE - A1 - 2 942 837 (NISSAN MOTOR CO.) * claims 1, 2; fig. 1 * --	1,2
	DE - A1 - 2 813 752 (HITACHI) * claims; page 27, lines 26 to page 29; fig. 1, 2, 3, 8 * --	2,3
A	EP - A1 - 0 006 770 (STE INDUSTRIELLE DE BREVETS ET D'ETUDES) * claim 1; page 6, line 13 to line 26; fig. 1 * --	
A	AUTOMOBILTECHNISCHE ZEITSCHRIFT, Vol. 80, No.9, September 1978, Stuttgart, G. HÄRTEL "Vergaser mit elektronischem Regeleingriff" page 400 --	
A	US - A - 4 129 105 (NIPPONDENSO CO.) * whole document * -- ./..	

CLASSIFICATION OF THE APPLICATION (Int. Cl.³)

F 02 M 17/38
F 02 M 7/12
F 02 M 7/24
F 02 M 23/04

TECHNICAL FIELDS SEARCHED (Int. Cl.³)

F 02 M 7/00
F 02 M 9/00
F 02 M 17/38
F 02 M 19/00
F 02 M 23/00

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
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T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	18-05-1981	CANNICI

EPO Form 1503.1 06.78

European Patent Office

EUROPEAN SEARCH REPORT

Application number
EP 81 30 0737.4

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.³)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	US - A - 4 132 199 (HITACHI LTD.) * whole document * ----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.³)