

[54] **FLUIDIC FUEL INJECTION SYSTEM HAVING TRANSIENT ENGINE CONDITION RESPONSIVE MEANS TO CONTROLLABLY EFFECT THE QUANTITY OF FUEL INJECTED**

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[51] Int. Cl. ... **F02d 11/08, F02m 7/06, F02n 37/14**

[58] Field of Search..... **60/39.78; 123/119 R, 123/DIG. 10, 97 B, 139 AW; 261/DIG. 69**

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R27,142	6/1971	Taplin et al.....	60/39.28
3,556,063	1/1971	Tuzson.....	123/DIG. 10
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3,587,543	6/1971	Sulich.....	123/119 R
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Primary Examiner—Wendell E. Burns

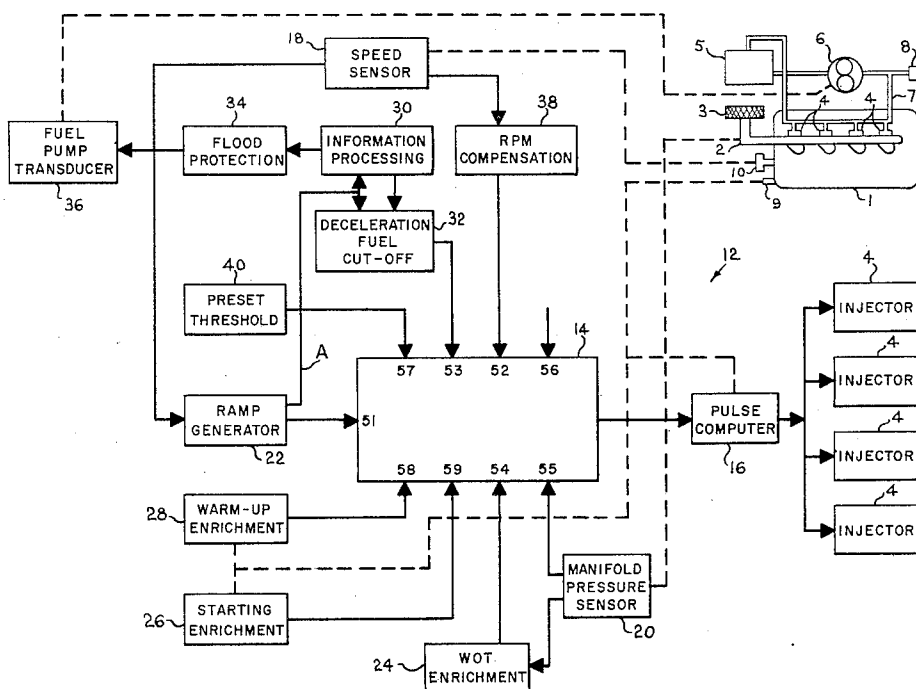
Attorney—Robert A. Benziger et al.

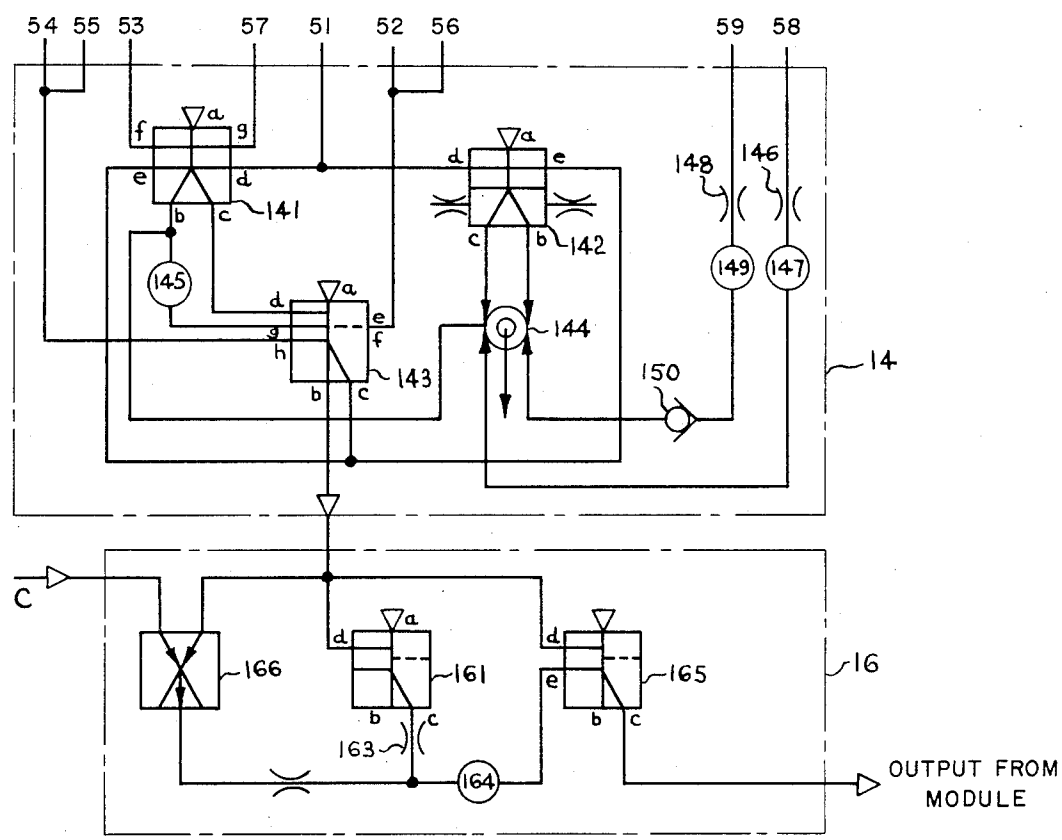
[57] ABSTRACT

A fluidic fuel injection system to provide intermittent

injection of fuel to an internal combustion engine is disclosed herein. The system receives fluid signals from various sensors and circuits to indicate engine operating parameters and processes these signals through a pulse generator and a pulse computer to provide an output fluid pulse to be applied to various injector valve means to control those injector valve means to deliver metered quantities of fuel to the associated engine. The pulse generator means is adapted to receive both pulse (digital) and variable level (analog) signals having varying responsiveness to the associated engine parameter in order to compensate for rapidly changing and slowly changing operating conditions of the engine and to generate a pulse (digital) output signal. The fluidic circuits to which the pulse generator is responsive include speed pulse signal generating means, speed compensation means, starting and warm-up enrichment means as well as timing phase adjustment means. The pulse generator means is primarily responsive to the speed pulse signal and a signal indicative of the engine manifold pressure to generate a basic pulse whose duration may be modified by one or more of the previously mentioned circuits. The pulse computer operates to extend the duration of the pulse produced by the pulse generator to provide additional time for resetting of the pulse generator prior to the generation of the next following pulse. Additionally, means are illustrated for controllably varying the output of the pulse computer in response to an engine operating parameter to provide further control flexibility.

14 Claims, 14 Drawing Figures





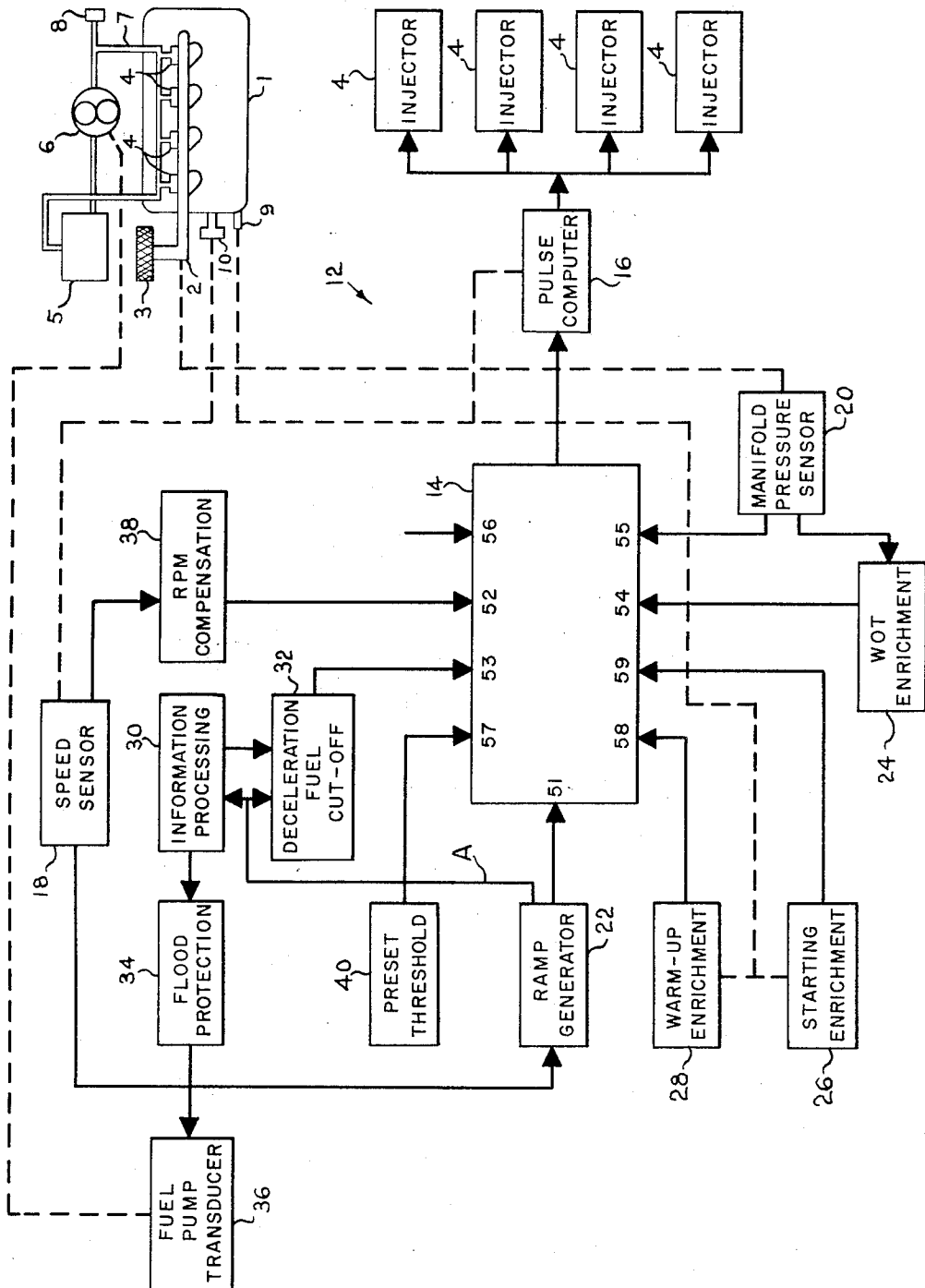
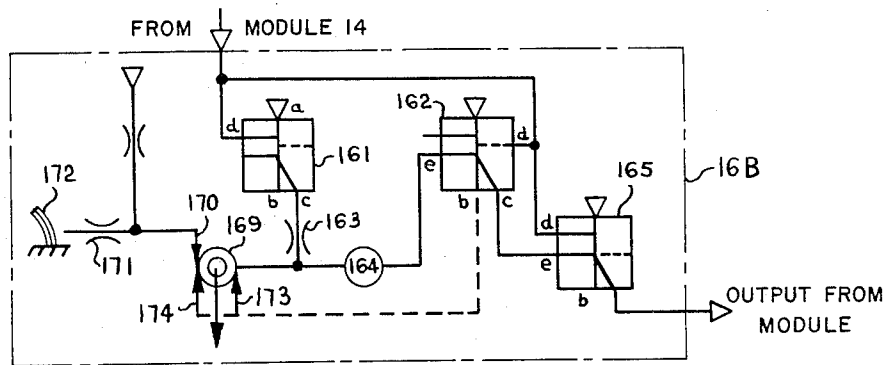
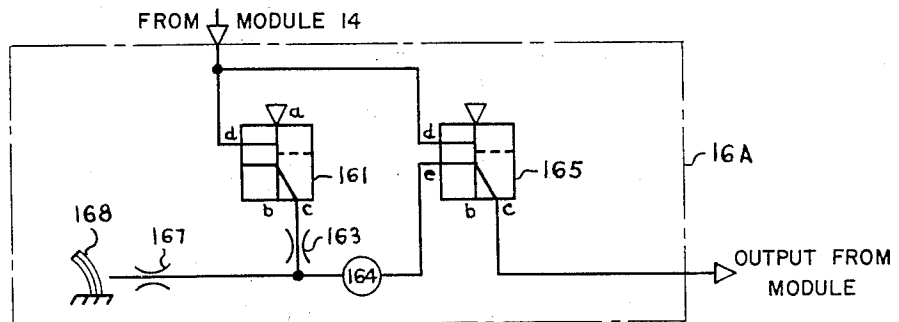
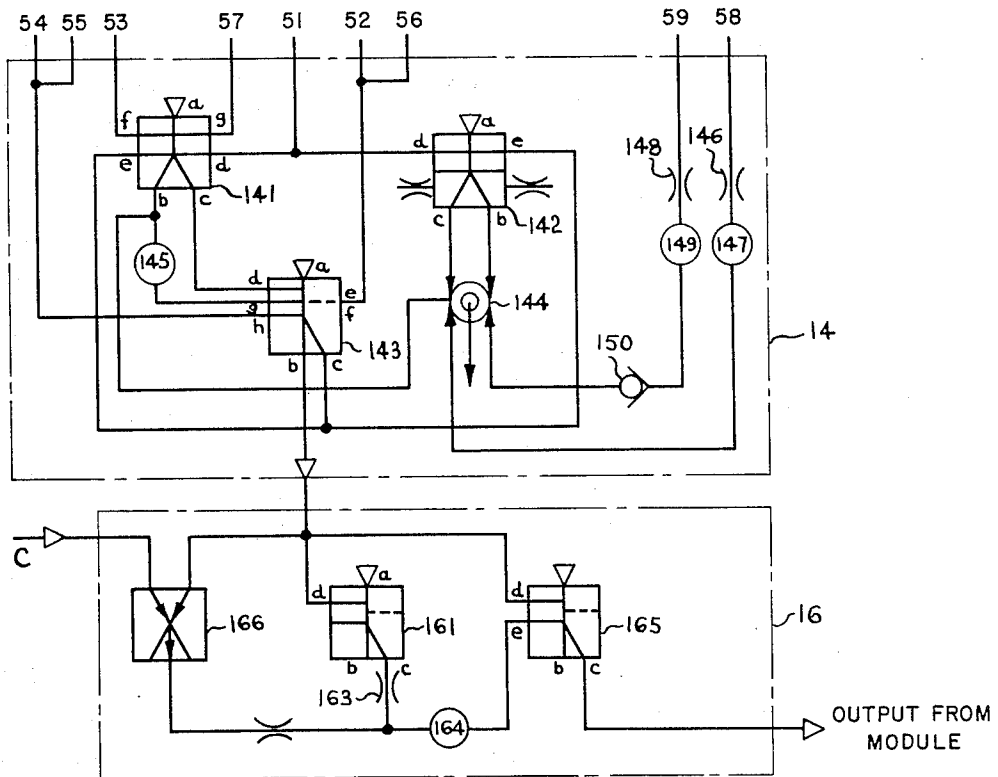


FIGURE 1



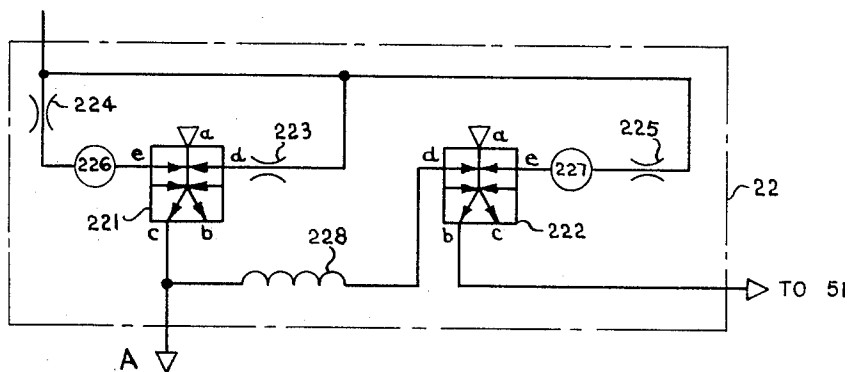


FIGURE 5

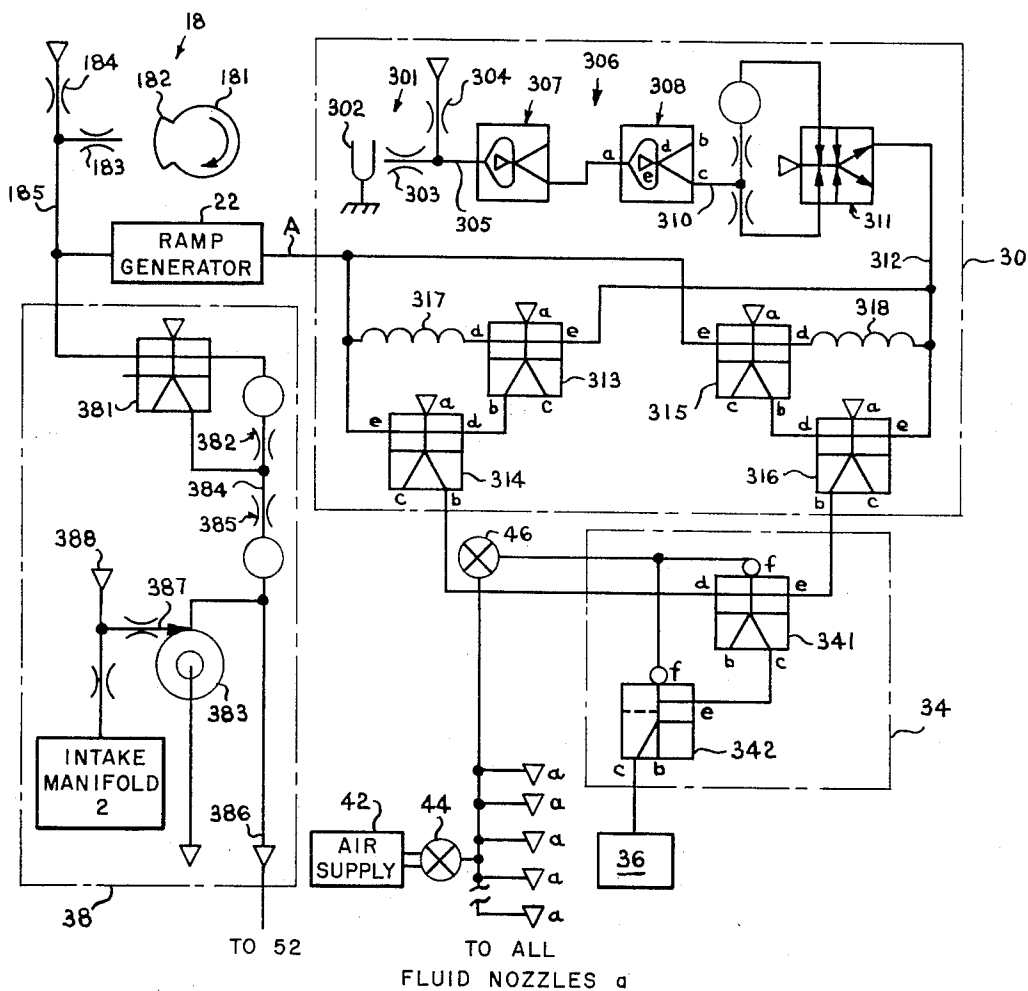


FIGURE 6

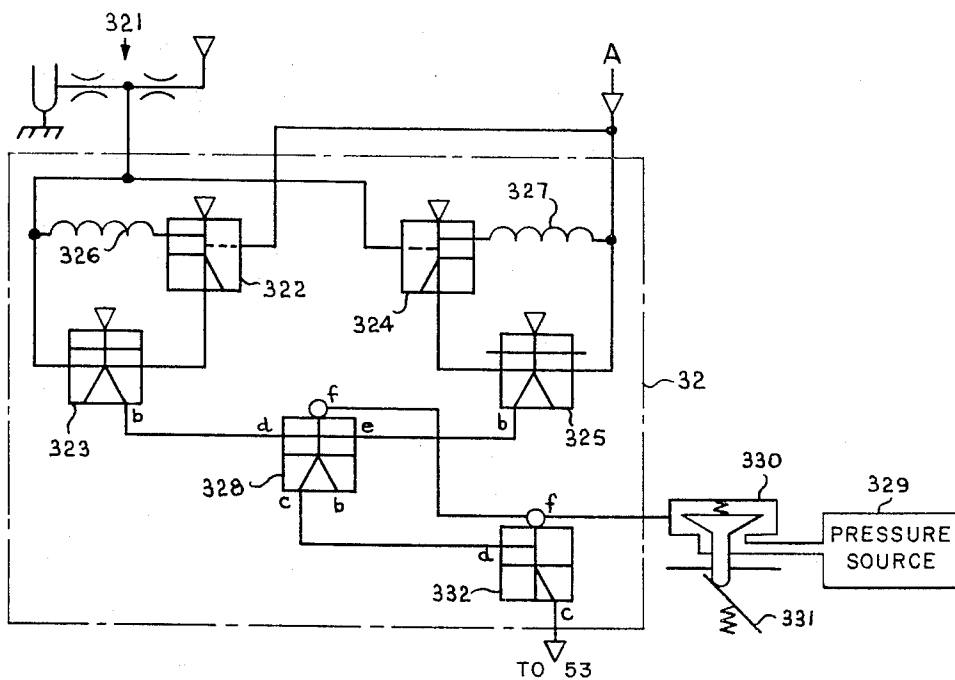


FIGURE 7

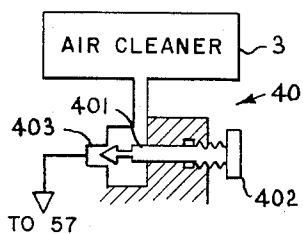


FIGURE 8A

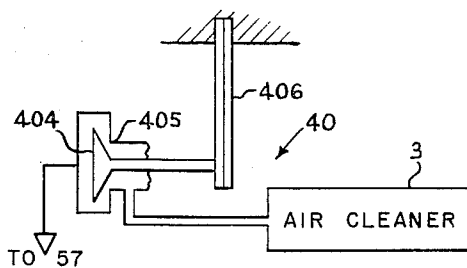


FIGURE 8B

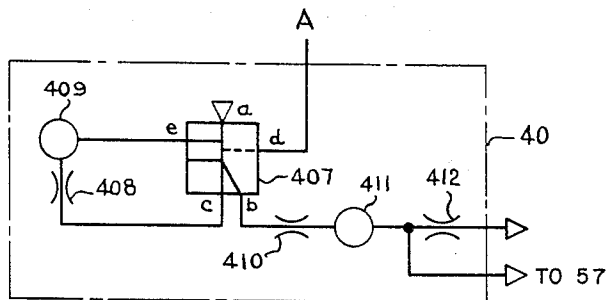


FIGURE 8C

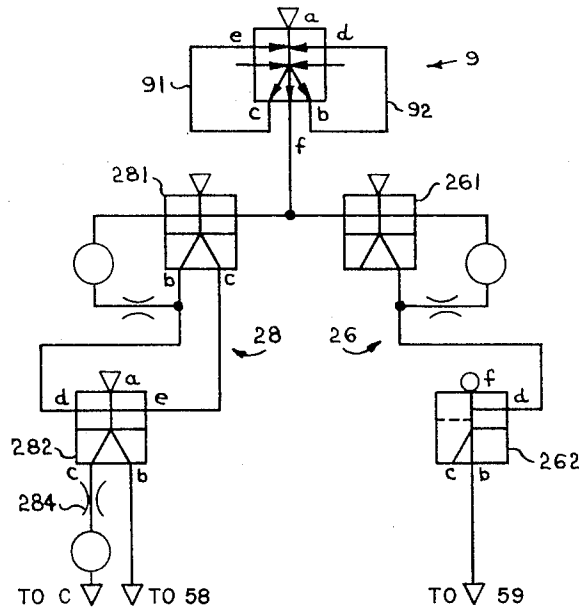


FIGURE 9

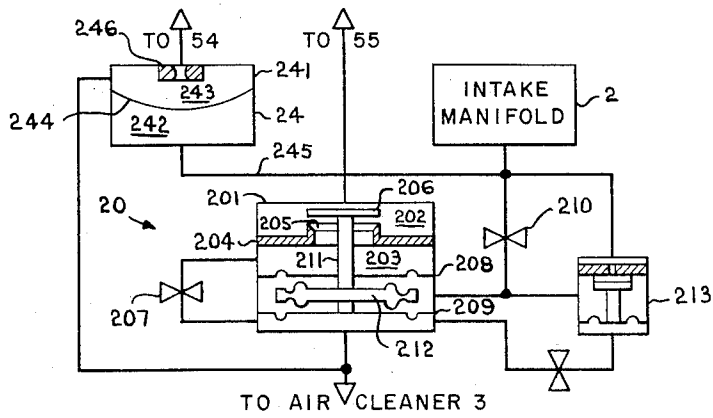


FIGURE 10

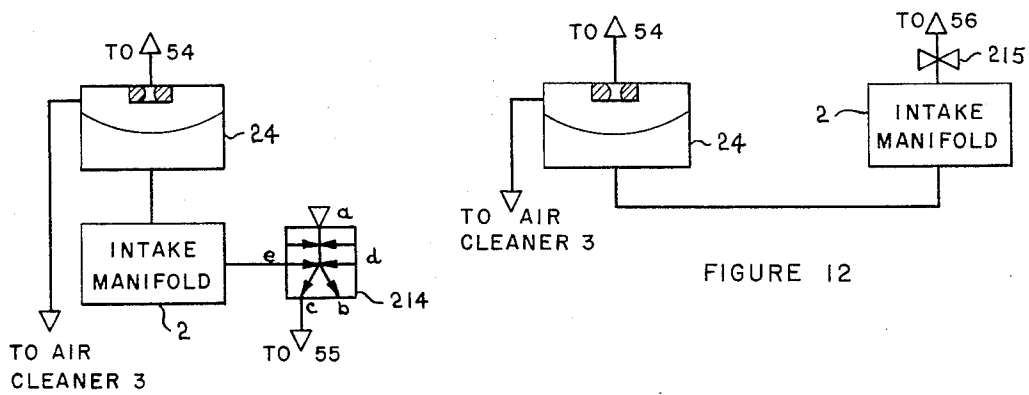


FIGURE 11

FIGURE 12

FLUIDIC FUEL INJECTION SYSTEM HAVING TRANSIENT ENGINE CONDITION RESPONSIVE MEANS TO CONTROLLABLY EFFECT THE QUANTITY OF FUEL INJECTED

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is related to the field of engine fuel control systems generally, and in particular, to that portion of the above-noted field which is devoted to the intermittent provision of fuel to nonturbine internal combustion engines. The present invention is more specifically related to that portion of the above-noted field which is concerned with the fluidic computation and control of precise fuel quantities sufficient to meet then-existing engine operating conditions.

2. Description of the Prior Art

Fluidic fuel delivery systems are relatively well known in the art. U.S. Pat. No. 3,574,346, issued to Janusz S. Sulich and assigned to the assignee hereof, illustrates a relatively complete carburetor having fluidic fuel metering means. Additionally, applicant's prior U.S. Pat. No. Re 27,142 illustrates a rather complete fluidic fuel control system for providing a substantially continuous fuel flow to an engine. While these patents illustrate fluidic fuel control systems which provide metered quantities of fuel in response to specific operating conditions of an engine which may include transient phases, these patents illustrate systems for continuously providing fuel to an engine, and as such they are not well suited to a fuel injection type system operated on an intermittent fuel delivery basis. U.S. Pat. No. 3,587,543 issued to Janusz S. Sulich and assigned to the assignee hereof and U.S. Pat. No. 3,556,063 issued to John J. Tuzson illustrate two fluidic fuel systems for providing intermittent fuel control (or "fuel injection") pulses to an internal combustion engine. However, U.S. Pat. No. 3,556,063, illustrates a system which would be adequate under steady state operation but which would be totally inadequate during various transient modes of operation in view of the fact that the system lacks any means for sensing and utilizing information indicative of a transient condition. It is therefore an object of the present invention to provide a fuel injection system (i.e., a system for providing intermittent fuel control pulses) which is responsive to various transient operating conditions of the associated internal combustion engine and which modulates fuel delivery in accordance to a predetermined scheduling in response to the transient and steady state conditions of the associated engine. U. S. Pat. No. 3,587,543 illustrates a fluidic fuel injection system which broadly satisfies the above-enumerated objective. However, this patent teaches a system which utilizes a summing device in the nature of a pair of vortex amplifiers to establish an opposed variable pressure fluid condition for a pressure-to-mechanical transducer which in turn is used to mechanically vary the phase relationship of a rotary fluid (fuel) manifold relative to a rotating cam which is driven in relation to engine speed. The arrangement as thus described is therefore one in which the injection pulses are initiated by a mechanically rotating cam/fluid ring manifold combination, and the injection command signal is ended by a similar mechanism which is rotating slightly out of phase with respect to the first mechanism and whose manifold ring angular position relative to the cam is variable in response to

the differential pressure generated within a bellows mechanism. While such a device is, of course, suitable, it does not permit the user to realize the full advantage of fluidics, which is primarily the elimination of relatively moving mechanical structure. It is therefore an object of the present invention to provide a fully fluidic fuel injection command generating system which includes transient condition responsive fluidic means to render fully fluidic a comprehensive fuel injection system. It is a still further object of the present invention to provide a fluidic fuel injection system which includes a fluidic (i.e., no moving part) pulse forming mechanism.

The U. S. Pat. No. 3,556,063 illustrates a system which utilizes a pure fluidic pulse former. However, as hereinabove noted, the device does not compensate for transient conditions and is also not capable of accepting inputs in other than digital form. Additionally, it has been determined that for certain high rpm ranges of operation a fluidic pulse former utilized to generate the injection pulses directly does not have sufficient time in the noninjection state to permit relaxation or discharging of any variable time generative means which may be utilized. It is therefore a still further object of the present invention to provide a fully fluidic fuel injection system which includes fluidic means for generating an injection command pulse and fluidic means for lengthening or prolonging that pulse to accomplish the desired fuel injection function. In accordance with the last mentioned objective of the present invention, the applicant has determined that the necessary pulse lengthening at high rpm operation may be a variable function of engine temperature and is most desirable over certain ranges of engine temperature. It is therefore a still further object of the present invention to provide a fluidic means for achieving the pulse lengthening function which means are controllable in response to a variable temperature to provide a pulse lengthening multiplier whose multiplicative coefficient is a controllable variable.

Since the fluid line length involved in transmitting fluid analog signals may constitute a source of unintentional time delays, it is a still further object of the present invention to provide a fluidic fuel control system utilizing both digital and analog techniques to provide a total system compatible with the general cost accuracy and life objectives of fluidics and the specific design objectives of engine manufacturers.

SUMMARY OF THE INVENTION

The present invention contemplates the use of an adjustable fluidic monostable multivibrator as the basic pulse former which has a plurality of control inputs and which provides a pulse signal to a pulse computer for further processing prior to application to the various injector valve means. In addition, a plurality of fluidic circuits are provided to interface between the engine and the monostable multivibrator to provide, as control signals, fluid signals having a variable level, the level being indicative of the sensed engine operating parameter. The pulse computer is characterized in that it comprises an OR gate receiving the basic input pulse as well as a time delay pulse generated in response to the basic pulse such that the OR gate output pulse duration is greater than the basic pulse duration by a factor which depends upon the time delay. In addition, means are illustrated to controllably vary the time delay value

in response to an engine operating condition so that the duration of the output pulse generated by the OR gate is greater than the duration of the basic pulse by a value which represents the time delay factor as controlled in response to the engine variable. The present invention may be characterized by this fluidic two-step injection pulse computing process, wherein the first step comprises an adjustable fluidic monostable multivibrator which receives analog and digital signals to generate a digital output signal for the second step or stage which computes the actual injection command pulse as a function of the output pulse from the first stage and a variable multiplicative factor in such a fashion that each of the two stages has, under the most strenuous operating conditions, a sufficient time for the various fluid chargeable elements to become discharged preparatory to the next pulse computation.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 illustrates the present invention in a block diagram form as applied to a four-cylinder spark ignition internal combustion engine.

FIG. 2 illustrates a fluidic circuit diagram of the pulse generator and pulse computer portions, the first and second stages, of the injection pulse forming portion of the present invention.

FIGS. 3 and 4 illustrate modified fluidic circuits for the pulse computer portion of FIG. 2.

FIG. 5 illustrates a fluidic circuit for generating the primary engine speed pulse input for the pulse forming network of FIG. 2 and according to FIG. 1.

FIG. 6 illustrates the fluidic circuitry to process the speed information to provide for rpm compensation, flooding protection, and fuel pump control according to FIG. 1.

FIG. 7 illustrates the deceleration fuel cutoff circuitry for association with the circuit of FIG. 2 and according to FIG. 1.

FIG. 8 illustrates, in three embodiments denoted as A, B, and C, means for adjusting the triggering level of the pulse former of FIG. 2 to compensate for variations in the phase relationship of the speed signal generated by the circuit of FIG. 5 relative to the engine cranking angle.

FIG. 9 illustrates the fluidic cold starting enrichment and warm-up enrichment circuitry for association with the circuit of FIG. 2 and according to FIG. 1.

FIG. 10 illustrates one form of manifold pressure sensor and wide open throttle signaling means for use with the circuit of FIG. 2 and according to FIG. 1.

FIGS. 11 and 12 illustrate two simplified alternatives to the FIG. 10 embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, the fluidic fuel injection system of the present invention is illustrated in a block diagram form and associated with an internal combustion engine 1. The engine 1 includes an intake manifold 2, having air cleaner 3 mounted thereon, and a plurality of fuel injectors 4 mounted on the manifold 2. The fuel injectors 4 are supplied from fuel reservoir or tank 5 with fuel which is pressurized by pump 6 and supplied through conduit means 7. Fuel pump 6 is illustrated as a constant delivery pump but other forms are well known. A pressure regulator 8 is illustrated in fluid communication with the conduit means 7 in order to

provide a relatively uniform pressure at each of the injector valve means 4. An engine temperature sensor 9 is illustrated herein as associated with the engine 1 and is arranged to communicate a temperature signal to the temperature responsive fluidic circuitry as illustrated by the dashed lines. In addition, an engine speed sensor is illustrated as communicating with the engine pulley 10 to generate a speed signal and the manifold pressure sensor is illustrated as communicating with the intake manifold 2 to generate a signal indicative of the air pressure within the engine intake manifold 2.

The fluidic fuel injection system of the present invention is illustrated in FIG. 1 by the block diagram which is generally denoted as 12. The fluidic fuel injection system 12 is comprised of a fluidic monostable multivibrator circuit 14 which feeds fluidic pulses to the pulse computer 16 which in turn computes an injection pulse for application to the various injector valves 4. For the sake of example, the injector valves may be as illustrated in U.S. commonly assigned Pat. No. 3,665,979—"Gaseous Controlled Fluidic Throttling Valve"—Jerome G. Rivard or Ser. No. 170,162—"Gas Injection Liquid Flow Control Valve"—Clarence E. Vos. In the embodiment illustrated, the pulse computer 16 applies the computed pulse to each of the injectors 4 simultaneously. This permits simultaneous injection of all injector valves 4. It would also be possible to provide a sequential injection system by selective AND gate coupling between one or more injectors 4 and the speed sensor 18. This would provide not only sequential injection in the event that the injectors 4 were individually coupled to the speed sensor through AND gate means, but could also be used to provide for group injection by combining two or more injectors and coupling them to the speed sensor for sequential injection of the various groups.

The monostable multivibrator 14 receives a plurality of inputs which are representative of the various operating conditions of the engine and are tailored to be representative of the preselected performance criteria for the internal combustion engine 1 to which the fuel system of the present invention is coupled. In the fuel system of the present invention, the primary inputs are by means of the speed sensor 18 and the manifold pressure sensor 20. The speed sensor 18 is coupled to ramp generator 22 which feeds an initiating input signal to input terminal 51 of the monostable multivibrator 14. The manifold pressure sensor 20 receives a signal indicative of manifold pressure from the intake manifold 2 and applies this signal, suitably altered in accordance with the performance criteria previously mentioned, to the input terminal 55 of the monostable multivibrator 14. A signal is also communicated to the wide open throttle enrichment means 24 by the manifold pressure sensor 20 to provide a control fluid flow at input terminal 54 of the monostable multivibrator 14. Signals from the temperature sensor 9 are applied to the starting enrichment means 26 and the warm-up enrichment means 28. This temperature signal is operative to provide a selected form of fluid flow from the starting enrichment means 26 at the input terminal 59 of the monostable multivibrator 14 and it is also operative to provide for a selected warm-up enrichment fluid flow from the warm-up enrichment means 28 at input terminal 58 of the monostable multivibrator 14. Ramp generator means 22 also provides information signals for the information processing network 30 and the deceleration fuel cutoff circuitry 32.

ation fuel cutoff network 32. The information processing network 30 provides a control signal indicative of engine speed and engine operational conditions to the flooding protection circuit 34 which, in turn, controls the fuel pump transducer 36. The fuel pump transducer merely operates to convert the fluid signal from the flooding protection circuit 34 into a suitable electrical or mechanical signal for application to the fuel pump 6. Information from the information processing network is also provided to the deceleration fuel cutoff circuit 32 to generate a control fluid flow at input terminal 53 of the monostable multivibrator 14. Speed sensor 18 also provides a signal for application to the rpm compensation circuit 38 which in turn provides a control fluid flow at the input terminal 52 of the monostable multivibrator 14. A preset threshold mechanism 40 provides a control signal for receipt by input terminal 57 of monostable multivibrator 14 to condition the response of monostable multivibrator 14 to the output of ramp generator 22 so as to correspond to a selected phase relationship between the engine speed sensor 18 and the initiation of the fuel injection controlling pulse by the pulse computer 16.

The system as hereinabove described operates as follows. Signals from the speed sensor 18 are applied to ramp generator 22 where they are converted to a ramp signal for application to the monostable multivibrator 14. A fluid signal having a predetermined level is also applied to monostable multivibrator 14 by the preset threshold means 40 and switching takes place when the ramp signal exceeds the preset threshold. The monostable multivibrator 14 will remain in its switched, or unstable, state for a period of time depending upon the signal received at input terminal 55 from the manifold pressure sensor 20. Further control signals may be applied by the warm-up enrichment mechanism 28 and the rpm compensation means 38. In the event of a deceleration, the deceleration fuel cutoff means 32 will apply an inhibiting signal to prevent further pulse generation by the pulse generator means monostable multivibrator 14. In order to prevent engine flooding, the information processing unit 30 and the flooding protection circuit 34 may be arranged to respond to conditions which would otherwise generate engine flooding to modulate or terminate the output of the fuel pump 5. The output of the warm-up enrichment means 28 and the rpm compensation means 38 may be arranged to be fluid signals having a level indicative of the desired compensation or enrichment and may be combined with the signal from manifold pressure sensor 20 to affect the duration of the pulse produced by pulse generator means monostable multivibrator 14. The pulse generated by the pulse generator means monostable multivibrator 14 therefore has a duration which represents the quantity of fuel required by the engine for operation consistent with its predetermined operational requirements. This duration will not, however, necessarily be directly indicative of the requirement and to generate the injection command pulse which is directly indicative of the fuel requirement, computer 16 is arranged to receive the output signal from the monostable multivibrator 14, and also a signal from an engine parameter sensor such as, for instance, engine temperature sensor 9 to generate an output pulse which is directly indicative of the engine fuel requirement. By "representative" is meant that a pulse whose duration when multiplied by a factor which may be one but

which may also be greater than one and which is determined by an engine operating parameter will yield the duration of fuel flow required by the engine to satisfy the predetermined operational characteristics of the engine. By "indicative" is meant a pulse whose duration is equal to the duration of fuel flow required by the engine.

Additionally, the present fluidic circuit includes a cold starting enrichment means 26 which also receives a temperature signal, in this instance from engine temperature sensor 9, and may also be arranged to receive a signal indicative that the engine is in the "start" mode to provide a fluid signal at monostable multivibrator 14 input terminal 59 to provide for the lengthening of the time during which the monostable multivibrator 14 is in an unstable state to provide further quantities of fuel to enrich the air/fuel mixture received by the engine during its starting operation. It will be readily understood that the number and location of temperature sensors may vary from system to system depending on the performance requirements of the associated engine.

While the ramp generator 22 is operative to provide essentially a pulse having a monotonically increasing magnitude, the various other fluidic subcircuits which feed information into the enumerated input terminals of the monostable multivibrator circuit 14 are arranged to provide fluid signals having variable magnitudes which represent the operational conditions of the associated engine. In other words, ramp generator 22 provides a digital input while the various other fluidic circuits provide analog inputs for the monostable multivibrator 14 which responds to these various inputs to provide an output pulse having a duration representative of the fuel injection quantity.

Referring now to FIG. 2, particular fluidic circuits will be described for the pulse generator means monostable multivibrator circuit 14 and the pulse computer 16. It will be appreciated that the specific fluidic circuits and elements described hereinbelow are intended to be illustrative of the present invention and that various modifications and changes in the circuitry will be readily apparent. Departures from specific circuitry to achieve specific goals such as cost reduction, use of commercially available elements, and matching to specific fuel requirements are anticipated and their inclusion herein is intended. It should also be noted that the specific fluidic circuits and elements described hereinbelow are described with reference to a system which utilizes a compressible fluid (for instance air) as the computational fluid and as a consequence, the various recited volumes, restrictions, and bleeds are shown with this computational fluid in mind. The man of ordinary skill in this art will readily recognize that other fluids and other forms of fluid impedance may be substituted. In addition, additional fluid impedances check valves and the like may be inserted as necessary to provide signal tailoring and flow direction control to suit particular requirements.

The pulse generator means monostable multivibrator 14 is comprised of first and second bistable fluidic amplifiers denoted as 141 and 142, monostable fluidic amplifier 143, and fluidic vortex device 144 having a vented output as illustrated. The fluidic amplifiers 141, 142, 143, are comprised of a source of power fluid denoted by the suffix letter *a* and also illustrated by a triangular fluid entry port, a pair of outlet passages denoted by the suffix letters *b* and *c*, and a plurality of

control ports denoted by the suffix letters *d* through *h*, as appropriate. The output passages *b* and *c* of fluidic device 141 are communicated to control ports *d* and *g* of fluidic device 143. Control ports *d* and *g* are control ports arranged to one side of the fluidic device 143 and fluid flow therethrough is operative to bias fluid flow from the main nozzle, *a*, of device 143 to the output passage *c* of device 143 which, in this instance, is illustrated as being a nonpreferred fluid flow outlet passage. In the absence of a biasing control fluid flow, fluid flow from the device 143 would be through the outlet passage, *b*, which is illustrated as being the preferred fluid flow outlet passage. As illustrated, passage *b* is indicated as having a "memory" associated therewith. Monostability in a fluid amplifier may be obtained through geometry of the device, use of the Coanda effect in a selected outlet passage or through self-biasing fluid flow. The use of "memory" in this context is intended to mean any of the possible means of achieving a preferred fluid flow passage condition. Fluid flow in passage *c* of the device 143 is communicated back to the control ports *e* of devices 141 and 142, while fluid flow in passage *b* of device 143 is communicated to the pulse computer 16. A fluid volume, or fluid capacitance, 145 is illustrated intermediate the outlet passage *b* of device 141 and the control nozzle *g* of device 143.

The output passages *b* and *c* of device 142 are arranged to provide for fluid swirl within vortex device 144 and are so arranged that fluid flow from passage *b* of device 142 would generate a clockwise fluid swirl within vortex device 144 while fluid flow from passage *c* of device 142 would generate counterclockwise swirl within vortex device 144. The restricted vent illustrated on the element 142 may be required for impedance matching with the vortex device 144. The outer wall outlet port or passage of vortex amplifier 144 is communicated to the fluid volume 145 intermediate the volume 145 and output passage *b* of fluid amplifier 141. As is known, the presence of swirl within a vortex device is operative to vary the ease with which fluid may flow through the outer wall port or passage of the device.

Input terminal 51 of monostable multivibrator 14 is communicated to control nozzles *d* of fluidic elements 141 and 142. Control nozzle *f* of fluidic element 141 is communicated to input terminal 53 of monostable multivibrator 14, control nozzle *g* of fluidic element 141 is communicated to input terminal 57 of monostable multivibrator 14, control nozzle *e* of fluidic element 143 is communicated to the input terminal 52 of the monostable multivibrator 14, control nozzle *f* is communicated to input terminal 56 of monostable multivibrator 14, control nozzle *h* is communicated to input terminals 54 and 55, in parallel, of the monostable multivibrator 14. For convenience, control nozzles *e* and *f* of device 143 and input terminals 52 and 56 are here illustrated as being common. Input terminals 58 and 59 are communicated to additional control nozzles associated with the vortex device 144. Intermediate input terminal 58 and the nozzle of vortex device 144 with which it is associated is situated a fluid restriction 146 and a fluid volume 147 which are operative to convert a pulse signal input received at input terminal 58 into a fluid level signal for application to the vortex device 144. Intermediate input terminal 59 and the control nozzle of vortex device 144 with which it is associated is situated a fluid restriction 148 a fluid volume 149 and a check

valve 150 which may be required to prevent back flow from variable restrictor vortex device 144. The fluid restriction 148 and the fluid volume 149 are herein operative to convert a pulse signal received at the input terminal 59 to a fluid level signal for application to the vortex device 144.

The monostable multivibrator 14 as hereinabove described operates as follows. A fluid ramp signal is received at input terminal 51 and is communicated to the control nozzle *d* of each of the fluid amplifiers 141 and 142. Application of this signal to the control nozzle *d* of amplifier 142 is operative to cause main fluid flow from the main nozzle *a* to exit from the device through outlet passage *b* and to thereby generate a clockwise swirl within the vortex device 144. The application of the ramp signal to control nozzle *d* of the fluidic element 141 in conjunction with the threshold preset fluid level established at input terminal 57 will be operative to switch fluid flow from the main nozzle *a* to the output passage *b* when a predetermined (pressure) relationship exists between the instantaneous level of the ramp and the level of pressure received at input terminal 57. Fluid flow through outlet passage *b* of fluidic element 141 will be operative to charge the fluid volume 145 at a rate which is a function of the compressibility of the fluid in use and the size of the volume. Fluid flow through the outlet passage *b* of fluidic element 141 will occur only upon termination of fluid flow from outlet passage *c* of element 141 and this will terminate the fluid pressure signal ordinarily received by control nozzle *d* of element 143. In the absence of a fluid signal at either of control nozzles *d* and *g*, fluid flow from the main nozzle *a* of element 143 will be through the preferred outlet passage *b* of element 143 and will appear as a pressure signal to the pulse computer. As fluid flow from outlet passage *b* of element 141 begins to charge the volume 145, the fluid pressure appearing at control nozzle *g* of element 143 will begin to increase. When the level of fluid signal appearing at control nozzle *g* of element 143 reaches a value which may be controlled by the value of the relatively high pressure signals received at input terminals 52 or 56, or relatively low pressure signals received at input terminals 54 and 55, the fluid flow from the main nozzle will be switched from outlet passage *b* to outlet passage *c* which is arranged in a feedback arrangement to provide a fluid pressure signal at the control nozzle *e* of the fluid elements 141 and 142. The presence of a fluid pressure signal in outlet passage *c* of element 143 will signal the termination of the pulse received by the pulse computer 16 and will also cause the fluid elements 141 and 142 to switch so that fluid flow will appear in outlet passages *c* of each of elements 141 and 142. The presence of fluid flow in outlet passage *c* of element 141 will be operative to maintain the bias of fluid element 143 so as to maintain fluid flow through outlet passage *c*. Additionally, the presence of fluid flow in outlet passage *c* of element 142 will oppose the clockwise swirl previously established in vortex device 144 by flow from passage *b* of element 142 and from input terminal 58 so that there will appear a state of no fluid swirl which may be followed by the generation of a weak counterclockwise fluid swirl should engine operating temperature not have been reached. During the time period where there is substantially no swirl within the vortex element 144, the fluid pressure previously accumulated in volume 145 will be rapidly vented into the

vortex device and the volume 145 will be discharged. The appearance of the next ramp signal at input terminal 51 will reinitiate this process to generate an additional pulse for receipt by pulse computer 16. This next succeeding pulse will have a duration which is a function of the pressure signals received at the control nozzles *e*, *f*, and *h* of fluidic element 143, as well as the rate of charge of the fluid volume 145. The input terminals 58 and 59 are arranged to provide additional swirl inducing or inhibiting fluid flows at the vortex device 144 to modulate the swirl rate and to therefore provide a modulating fluid flow which may either add to or subtract from the fluid flow ordinarily entering the fluid volume 145 during charging and pulse forming process.

The pulse computer 16 is comprised of a fluidic device 161 having a main fluid jet or nozzle *a*, a pair of outlet passages *b* and *c*, a control nozzle *d* and a fluidic OR gate 165. Fluidic device 161 is arranged to receive at its control nozzle *d* the fluid pulse generated at outlet passage *b* of fluidic element 143 in the pulse computer 14. Receipt of this pulse is operative to bias fluid flow from the main fluid nozzle *a* of fluidic device 161 to outlet passage *c*, where it is communicated to control nozzle *e* of OR gate fluidic device 165 through a bleed or fluid restriction 163. Intermediate the bleed 163 and the control nozzle *e* of fluidic device 165 is situated a fluid capacitance or volume 164.

The pulse from outlet passage *b* of fluidic device 143 of pulse computer 14 is also applied to one input of the OR gate 165, control nozzle *d* so as to provide an output signal which is substantially in phase with the pulse produced by the pulse generator 14. The pulse produced by pulse generator 14 is also operative to direct fluid flow through the outlet passage *c* of the fluidic element 161 to charge the volume 164. When the volume has reached a critical charge dependent upon fluid compressibility and volume, a pressure pulse will also appear at control nozzle *e* of fluidic device 165 and, in the presence of an output pulse from the pulse generator 14, would not alter or affect operation of the OR gate 165. However, upon termination of the pulse produced by pulse generator 14, fluid flow in the fluid device 161 would switch from the outlet passage *c* to the outlet passage *b* due to the monostable effect of the device discussed hereinabove and the charging of volume 164 would terminate. The accumulated charge in this volume would continue to apply a pressure pulse to the control nozzle *e* of the fluidic element OR gate 165 so as to cause it to generate an injection command pulse for a period of time following the termination of a pulse produced by pulse generator 14. Additionally, AND gate means 166 is illustrated as arranged to receive the pulse signal from pulse generator 14 as well as a signal from an engine operating condition sensor to generate an output signal for additionally effecting the charging of volume 164. AND gate 166 is of the passive type and may be arranged to pass a signal whose magnitude is directly related to the magnitude of the signal received from the associated engine sensor during the receipt of a pulse from pulse generator 14 so as to provide a variable multiplicative factor in the relationship of the pulse computer output pulse and the pulse generator output pulse. In the herein illustrated embodiment, AND gate 166 is arranged to receive a signal indicative of engine temperature, as processed by the circuitry of FIG. 9 to be discussed hereinbelow, through inlet conduit C.

Referring now to FIGS. 3 and 4, two alternative circuit configurations for the pulse computer 16 are illustrated. Each makes use of the pair of fluidic monostable multivibrator devices 161, 162, with the fluid restriction and fluid chargeable volume 163, 164. However, the AND gate mechanism 166 and the associated engine sensor signal are replaced by alternative means of varying the charge accumulated by the volume 164. In FIG. 3, this is illustrated as a nozzle 167 communicating with volume 164 and arranged to direct fluid at a bimetal member 168. By placing the bimetal 168 in an environment temperature is determined to be of significance in the injection pulse computation process, the bimetal 168 can be arranged to vary the rate at which the volume 164 may be charged and discharged by varying the nozzle opening from a fully closed to a fully open position in the known fashion. Thus, for injection pulses which would differ at most only slightly from the pulses generated by the generating means 14, bimetal 168 could be arranged to provide a substantially wide open exit port for nozzle 167 to hold the charging of volume 164 to an absolute minimum and to assist in the discharging of that volume upon termination of the pulse received from pulse generator 14. Conversely, in those situations where the sensed temperature would require a substantial lengthening of the injection pulse as compared to the pulse generated by pulse generator 14, the bimetal 168 could substantially close the exhaust port of nozzle 167 so that the volume 164 could be charged to a maximum amount and the discharge time of that volume could be maintained at a maximum value. In the FIG. 4 embodiment, an additional fluidic monostable multivibrator device 162 has been interposed between fluidic element 161 and OR gate 165. Device 162 is arranged to receive the signal from volume 164 at its control nozzle *e* so that it will bias fluid flow to the nonpreferred outlet passage *c* which is communicated to the control nozzle *e* of OR gate 165. Control nozzle *d* of fluidic element 162 may be in fluid communication with the pulse produced by the pulse generator 14. In this FIG. 4 embodiment, the rate of charge and discharge of the volume 164 is influenced by communicating that volume to the exhaust orifice of a fluid vortex device 169 in which counterclockwise swirl may be induced by control nozzle 170. The nozzle 170 is provided with the energizing fluid in the above-described fashion. A further nozzle 171 is situated intermediate nozzle 170 and the source of fluid supply and is arranged to direct a fluid stream toward a bimetal device 172. The amount of swirl introduced in vortex device 169 by nozzle 170 is therefore inversely related to the amount of closure of nozzle 171 provided by bimetal 172. Bimetal 172 may be situated in a suitable temperature environment so as to provide by its response to that temperature the desired fluid swirl pattern in vortex device 169. Additionally, alternative swirl nozzles 173, 174 are shown communicating with the preferred outlet passage *b* of fluid element 162. Swirl inducing nozzles 173 and 174 are illustrated as being alternative connections which may be used when desired to either oppose or aid the swirl induced by nozzle 170 in suitable instances where the charging and/or discharging of the volume 164 is to be enhanced.

Referring now to FIG. 5, the ramp generator 22 of FIG. 1 is illustrated in a fluidic circuit. The circuit is comprised of first and second fluid amplifying devices

221 and 222, a plurality of fluid bleeds or orifices 223, 224, 225, fluid volumes or capacitances 226, 227, and a fluid delay element 228. The fluidic devices 221, 222, are fluid proportional amplifiers having power nozzles *a*, outlet passages *b* and *c* and control nozzles *d* and *e*. The ramp generator is arranged to receive fluid pulses having a frequency which is indicative of the engine speed and is operative to apply these signals to various of the control nozzles of fluidic elements 221, 222. The fluid restriction 224 and fluid capacitance 226 and the fluid restriction 225 and fluid capacitance 227 are operative to cause the pulse signal received from the speed sensor 18 to appear at the control nozzles *e* of the fluidic elements 221, 222 as a ramp signal, and the application of this signal to the control nozzle *e* of the fluidic amplifier 222 will be operative to cause a corresponding ramp signal to appear in the outlet passage *b* of that amplifier. Fluid restriction 223 on the other hand will be operative to convert a pulse from speed sensor 18 into a prolonged fluid pulse for receipt by control nozzle *d* of fluidic amplifier 221. The combination of the ramp signal at control nozzle *e* and the pulse signal at control nozzle *d* of amplifier 221 will be operative to cause the signal appearing in the outlet passage *c* of the fluidic amplifier 221 to be a relatively sharp pulse which rapidly drops off. This sharp pulse, which may be termed a "spike" pulse, will appear at outlet passage *A* for use in a fluidic circuitry to be described hereinbelow and will also be communicated to the control nozzle *d* of the fluidic amplifier 222 through the fluid delay means 228. This sharp signal upon receipt at control nozzle *d* of amplifier 222, will be operative to terminate the increasing ramp and therefore provide a sharp cutoff characteristic for the ramp signal. This signal will be communicated directly to the input terminal 51 of the pulse generator 14, as illustrated in FIG. 2.

Referring now to FIG. 6, the fluidic circuitry for the processing of the speed information to provide rpm compensation, flooding protection and fuel pump control is illustrated. A representative speed sensor 18 is illustrated as a rotary disc 181 which is driven in response to engine rpm and having a projection therefrom 182 which is arranged to pass in the proximity of a fluid nozzle 183. Fluid nozzle 183 is provided with a source of energizing fluid from the main fluid supply through nozzle 184. The nozzle 183 is operative to eject a fluid stream in the general direction of rotating disk 181 so that the fluid pressure in line 185 is relatively low when the nozzle 183 is not blocked by projection 182 and is concomitantly relatively high whenever the projection 182 passes in front of and therefore partially blocks the nozzle 183. The pressure pulses thus produced in fluid line 185 constitute a speed signal. This speed indicative signal is processed by the ramp generator means 22, as illustrated and described with respect to FIG. 5, and an output pulse signal *A* is generated having a frequency which is proportional to the engine speed. This signal is then available for receipt and use by the information processing circuit 30. The information processing circuit 30 includes a source of reference signal 301 which is comprised of a mechanical oscillator such as tuning fork oscillator 302 arranged to oscillate in the vicinity of a fluid nozzle 303 which is arranged to receive a source of fluid as from the main fluid source through nozzle 304. Such devices are described in my prior U.S. Pat. No. 3,457,938

"Pneumatic Oscillator" issued on July 29, 1969 and assigned to the assignee hereof. A plurality of pressure pulses will appear in fluid conduit 305 having a frequency which is indicative of the resonant frequency of the mechanical oscillator 302. The fluid conduit 305 intercommunicates the nozzle 303 with one form of the known form of frequency divider or binary counter 306. Counter 306 is comprised of a pair of complimentary flip-flops 307, 308 which are arranged to receive the pulses present in fluid conduit 305 and to generate an output signal in conduit 310 having a frequency which is in this instance one fourth of the resonant frequency of the oscillator 302. Of course, other ratios may be used. As is known, a complimentary flip-flop such as that illustrated as 308 has a main fluid nozzle *a*, a pair of outlet passages *b* and *c* and a pair of control nozzles *d* and *e* which are communicated to a common junction by a pair of substantially identical fluid flow conduits having, in the illustrated embodiment, memory means associated with the conduits at the junction. Such a device is operative to receive a fluid signal and to pass it to one of the opposed control nozzles *d*, *e* through its associated fluid conduit. Receipt of this signal will bias main fluid flow so as to cause the fluid flow to exit from the flip-flop through the outlet passage *b*, *c*, which is opposite the control nozzle receiving the fluid pulse. Upon the termination of the fluid pulse, the main fluid flow will continue to exit out of the outlet passage to which it was directed by the fluid pulse. The fluid flow past the associated control nozzle will cause a circulating fluid flow from the nozzle which had received the pulse back through the interconnecting conduit means and out of the other of the control nozzles. Upon the receipt of the next succeeding fluid pulse at the junction, the circulating fluid flow will direct this pulse down the other of the conduits where the memory means will more fixedly establish the signal flow and will therefore cause switching of the fluid flow within the fluidic device. This phenomenon is more completely described as relating to different forms of complimentary flip-flops in U.S. Pat. No. 3,348,773. The pressure pulses appearing in outlet passage *c* of flip-flop 308 will then be processed by the fluidic element and circuitry 311 so as to appear in output conduit 312 as fluid spike pulses. This conversion is described hereinabove with reference to the fluidic element 221 in FIG. 5.

The information processing circuitry is further comprised of two pair of sequenced fluidic bistable elements 313, 314, and 315, 316. As described with reference to fluidic elements throughout this application, each of these bistable devices is comprised of a source of main fluid nozzle *a*, a pair of outlet passages *b*, *c* and a pair of control nozzles *d* and *e*. Nozzle *d* of bistable element 313 is connected to a fluid signal delay means 317 and is adapted to receive the pulse signal *A* from ramp generator means 22. Nozzle *d* of bistable element 315 is arranged to receive a pulse reference signal through conduit 312 and fluid signal delay means 318. The arrangement as illustrated is operative to provide an output signal in outlet passage *b* of fluidic element 314 whenever the frequency of pulses *A* from ramp generator means 22 is greater than the frequency of the reference pulses in conduit 312. Conversely, a signal will be present in outlet passage *b* of fluidic bistable element 316 whenever the frequency of the reference pulses present in fluid conduit 312 is greater than the

frequency of the pulses A from ramp generator means 22.

The output signal generated by the information processing circuit 30 is applied to the flooding protection circuit 34. The flooding protection circuit is comprised of a bistable fluid amplifier device 341 having a main fluid nozzle *f*, a pair of control nozzles *d* and *e*, and a pair of outlet passages *b* and *c*. The control nozzle *d* communicates directly with outlet passage *b* of the fluidic element 314 while control nozzle *e* communicates directly with outlet passage *b* of fluidic element 316. Outlet passage *c* of fluidic element 341 is communicated to the control nozzle *e* of monostable fluidic element 342 which also has a main fluid nozzle *f* and a pair of outlet passages *b* and *c*. The fluidic elements 314, 316, 341 and 342 are interconnected so that fluid flow will be present in outlet passage *c* of fluidic element 341 whenever the frequency of pulses A from ramp generator means 22 exceeds the frequency of the reference pulses present in fluid conductor 312. Control nozzle *e* of the monostable fluidic element 342 is arranged to bias fluid flow from the main fluid nozzle *a* of that element so as to exit from the device through outlet passage *c* which is the nonpreferred outlet passage. This signal can then be applied to the fuel pump transducer 36 so that that element and consequently the fuel pump 6 is energized whenever a fluid signal is present in outlet passage *c*. For all other conditions of the relationship between the signals A received from the ramp generator means 22 and the reference signal frequency present in fluid conduit 312, fluid flow from the monostable device 342 will be through the preferred outlet passage *b* and the fuel pump transducer 36 can therefore be arranged to turn off the fuel pump and terminate fuel delivery for selected conditions of engine operation.

The rpm compensation 38 is comprised of a bistable fluidic element 381 having a feed back loop 382 and a fluid vortex device 383. The bistable device 381 with its feed back loop 382 is operative to provide an output signal in fluid conduit 384 having a signal frequency which directly corresponds to the frequency of closure of fluid nozzle 183 by rotating projection 182 and a pulse shape determined by the characteristics of the feedback loop 382. This pulse signal is then integrated by the integrating means 385 which is comprised of a fluid restriction or bleed and a fluid volume or capacitance. The integrating means is operative to provide in fluid conduit 386 a signal having a fluid pressure level which is directly indicative of the engine speed. Fluid vortex device 383, being used here as a vented variable restriction, is provided with a fluid swirl inducing nozzle 387 which communicates with a source of pressurized fluid 388.

The intake manifold 2 also communicates with the swirl inducing nozzle 387 and is operative to vary the condition of swirl induced in vortex device 383 by the control nozzle 387. The exhaust port of vortex device 383 is vented and the vortex device 383 is operative to modulate the level of signal present in conduit 386 directly in response to the condition of fluid swirl and therefore indirectly to the pressure existing in the intake manifold. The vortex device therefore acts as a variable bleed. This circuit is operative to modulate the signal within fluid conduit 386 over selected regions of intake manifold pressure to provide a modification of the pulse generated by the pulse generator means 14.

This signal is communicated to the input terminal 52 of the pulse generator means 14 where it is used to generate a fluid pressure at control nozzle *e* of fluidic element 143 to controllably affect the switching levels within that device. Thus, the output pulses may be lengthened or shortened in response to variations in engine rpm and manifold pressure. Specific tailoring of the signal within fluid conduit 386 may be accomplished by sizing of the orifices associated with the vortex device 383 and the integrator means 385 for different engine applications.

As also illustrated in FIG. 6, an air supply 42 communicates with each of the main fluid nozzles, *a*, and as otherwise numerically identified, through a valve 44 which may be actuated to be opened by the normal start sequence of the associated engine and to thereafter remain open during subsequent engine operation. Start valve 46 communicates the air supply 42 to main fluid nozzles *f* to energize the fluidic elements having those control nozzles while starting of the associated engine is being attempted (i.e., while the engine is "cranking"). Opening of valve 44 is thereafter operative to apply fluid pressure from the air supply 42 to each of the main fluid nozzles to energize the various fluidic devices and to generate the appropriate vortex device swirl patterns.

Referring now to FIG. 7, the deceleration circuit 32 is illustrated. Circuit 32 is illustrated as being comprised of a source of reference frequency pulses 321, a plurality of bistable fluidic amplifiers 323, and 325, monostable fluidic amplifiers 322 and 324, and a pair of fluid delay means 326, 327. The circuit as thus described is substantially comparable to the reference source 301 and fluidic amplifiers 313, 314, 315, 316, with the fluid delay means 317, 318 is illustrated in FIG. 6. The deceleration circuit 32 is also adapted to receive the fluid pulse signal identified as A and generated by the ramp generator means 22. This circuit is adapted to generate an output signal in outlet passage *b* of element 323 whenever the reference frequency as generated by the generator means 321 exceeds the frequency of the pulses A. Conversely, the circuit is arranged to generate an output signal in outlet passage *b* of fluidic element 325 whenever the frequency of the pulses A exceeds the reference frequency. The outlet passages *b* of fluidic elements 323 and 325 are connected to the control ports *d*, *e*, of further fluidic device 328. This device has its main fluid nozzle, in this case indicated as *f*, connected to a source of pressure fluid 329 through a throttle controlled pressure valve 330 which is arranged to be open whenever the throttle pedal 331 is not depressed. Fluidic device 328 is arranged to exhibit an output signal in outlet passage *c* whenever a control signal is present at control nozzle *e* (which communicates to the outlet passage *b* of the fluid device 325), that is to say, whenever the frequency of pulses A exceeds the reference frequency. Fluidic device 328 operates at this point as an active fluidic AND gate and amplifier element. The amplified signal present in outlet passage *c* of fluidic element 328 is then passed to a control nozzle *d* of fluidic monostable device 332 having its main fluid nozzle *f* also communicating with the source of pressure fluid 329 through the throttle controlled valve 330. The presence of a control fluid signal at control nozzle *d* of monostable device 332 and a flow of fluid from pressure source 329 through open valve 330 to nozzle *f* of monostable

device 332 will cooperate to generate a fluid flow to the nonpreferred outlet passage *c* of monostable device 332 where it will be passed as a fluid signal for application to the input terminal 53 of the pulse generator means 14 as illustrated in FIGS. 1 and 2. The circuit as above described is therefore operative to generate an output signal whenever the speed of the engine, as represented by the pulse frequency *A*, exceeds a pre-established reference speed, which may be a pulse frequency signal generated by any convenient means and is here illustrated as being generated by a device similar to the tuning fork oscillator reference frequency source 301 illustrated and described with reference to FIG. 6. By coupling the fluid flow controlling valve 330 to the throttle pedal as is illustrated in FIG. 7, the fluid outlet signal will be present for application to the input terminal 53 of pulse generator means 14 whenever (a) engine speed is above a pre-established reference and (b) the throttle pedal has been released. These conditions may be arranged to be indicative of a desire for engine deceleration at engine speeds above a pre-established minimum (for example the curb idle speed). The application of the pressure signal to the input terminal 53 of the pulse generator means 14 as illustrated in FIG. 2 may be operative to provide a strong counter-bias for the normally received triggering pulses so as to prevent the triggering signal from initiating the generation of output pulses by the pulse generator means 14 and therefore terminate fuel delivery to the engine by preventing generation of fuel injection pulses.

Referring now to the FIGS. 8A, 8B, and 8C, the preset threshold establishing means 40 is illustrated in three alternative embodiments. The first embodiment, illustrated in FIG. 8A, is comprised of a variable position needle valve 401 which may be adjusted by thumb screw 402 so as to variably control the orifice 403. Orifice 403 intercommunicates input terminal 57 of the pulse generator means 14 with the air cleaner 3 to provide a source of filtered air. Since the interaction regions of the various fluidic devices will be generally operating at a pressure which is lower than the ambient air pressure, the preset threshold adjustment means as illustrated will be operative to provide a fluid flow into the fluidic element interaction region with the flow effect being controlled by the needle valve 401 and orifice 403.

Referring now to FIG. 8B, the preset threshold determining means is comprised of a variable position valve 404, which is cooperative with orifice 405 to provide a variable restriction. The position of valve 404 relative to orifice 405 is variably controlled by bimetal 406. The bimetal and valve structure may be placed in any suitable temperature environment to provide the necessary variation in preset threshold level as a function of temperature in any particular engine configuration. As with the mechanism illustrated in FIG. 8A, the valve structure is operative to vary the intercommunication between the input terminal 57 of the pulse generator means 14 and the engine air cleaner 3. In both the FIG. 8A and FIG. 8B embodiments, the relatively low pressure region of the fluidic element which is connected to input terminal 57 of the pulse generator means 14 has been communicated to the engine air cleaner 3 to guarantee that filtered air will be available. The connection to the air cleaner may, of course, be omitted and the valve 401 or 404 may intercommunicate input

terminal 57 with any other convenient source of filtered air.

Referring now to FIG. 8C, a preset threshold determining mechanism which is responsive to variations in engine speed is illustrated. The system is comprised of a monostable fluidic amplifier 407 having the usual source of main fluid flow *a*, a pair of outlet passage means *b* and *c*, and a pair of opposed control nozzles *d* and *e*. The monostable fluidic amplifier 407 is arranged to receive at its control nozzle *d*, the fluid pulses *A* generated by the ramp generator means 22 such that receipt of a pulse at nozzle *d* will bias main fluid flow from nozzle *a* to the preferred outlet passage *c* where the normally provided memory means of the device will maintain fluid flow until the appearance of a control pulse signal at control nozzle *e*. Integrating means in the form of a fluid bleed or restriction 408 and a fluid volume or capacitance 409 are illustrated as intercommunicating the preferred outlet passage *c* with the control nozzle *e*. This arrangement is operative to provide a switching signal to switch the main fluid flow away from the preferred outlet passage *c* to the nonpreferred outlet passage *b*. As illustrated, this device then comprises a pulse shaper which is responsive to the frequency of engine operation and is operative to provide an output pulse in outlet passage *b* at a frequency which is identical with the actuation frequency, that is the frequency of pulses *A*, and having a preselected output pulse shape as determined by the feedback loop comprising the integration bleed 408 and capacitance 409. A further fluid bleed 410 and fluid capacitance 411 is illustrated being communicated with outlet passage *b* and the fluid bleed 410 and fluid capacitance 411 are arranged in the normal integration fashion. This arrangement is operative to provide a fluid signal downstream from capacitance 411 which has a level representative of the then current engine speed. This signal may then be communicated to input terminal 57 of the pulse generating means 14 to provide a speed responsive variation in the preset threshold signal. Also illustrated for convenience is a further bleed 412 which is operative to act as a signal level reducing mechanism so as to guarantee that the signal received by the input terminal 57 of the pulse generating means 14 is at an appropriate level to accomplish the function intended.

Referring now to FIG. 9, the cold-start enrichment and warm-up enrichment fluidic circuitry 26, 28 are illustrated. Cold-start circuit 26 and warm-up enrichment circuit 28 are both responsive to a fluidic temperature sensor 9. The fluidic temperature sensor 9 is illustrated as being a fluidic oscillator having a pair of feedback loops 91 and 92 which may be exposed to a temperature to be sensed. The frequency of oscillations of a fluidic oscillator is known to be a function of the square root of the temperature being sensed and the main fluid stream from main fluid nozzle *a* will alternately be directed towards outlet passages *b* and *c* in response to the presence of pressure signals at control nozzles *d* and *e* which pressure signals are transmitted from the inlet of the associated outlet passage to the control nozzle at approximately the speed of sound. As the main fluid flow switches from outlet passage *b* to outlet passage *c*, a pressure pulse will appear in outlet passage *f* which is situated intermediate outlet passages *b* and *c*. This pressure pulse will then be applied to selected control nozzles in the first fluidic element of the

fluidic cold-start circuitry 26 and the fluidic warm-up enrichment circuitry 28.

The first element in each of these two fluidic circuits is a pulse shaper identified respectively as 261 and 281. As hereinabove described, the pulse shaper element is responsive to a pressure pulse and operative to generate an output signal in an output passage having a feedback loop associated therewith which signal has a frequency which matches the frequency of the input signal here being generated by the temperature sensor 9 illustrated as the fluidic oscillator and which signal further has a pulse duration which is predetermined and established by the feedback loop. The pulse output signal generated by pulse shaper 261 is applied to control nozzle *d* of monostable fluidic element 262 whose main fluid nozzle *f* is communicated with the primary air supply 42 through start valve 46 as illustrated in FIG. 6. Control nozzle *d* of monostable fluidic element 262 is situated in proximity to the preferred outlet passage *b* of the monostable fluidic element 262 and is therefore operative to direct fluid flow out of the nonpreferred outlet passage *c* whenever a pulse signal is present at the nozzle *d*. The signal present in outlet passage *c* of fluidic element 262 will substantially correspond in frequency and duration to the shaped pulse signal present at the control nozzle *d* of monostable element 262. This signal which corresponds to the temperature sensed by sensor 9 is then inverted by communicating the preferred outlet *b* with the input terminal 59 of the pulse generator means 14 where it is operative to modulate or otherwise vary the swirl circulation generated within vortex device 144 by the occurrence of a normal triggering pulse at input terminal 51. As illustrated, the signal received at input terminal 59 will operate to oppose the swirl induced by the occurrence of a normal triggering pulse received at input terminal 51. Thus for lower temperatures, the inverted signal will increase and the vortex device 144 will operate as a fluid vent thereby delaying the charging up of chargeable volume 145 so as to provide a relatively long time period injection pulse to aid the cold-starting of the associated engine.

The pulse shaping means 281 of the warm-up enrichment circuitry has its outlet passages *b* and *c* communicating with the control nozzles *d* and *e* respectively of bistable fluidic device 282. The main fluid nozzle *a* of bistable device 282 is communicated to the main source of fluid supply 42 as illustrated in FIG. 6. Outlet passage *b* of device 282 communicates with input terminal 58 of the pulse generator means 14. Outlet passage *c* of fluidic element 282 communicates with integrating circuit 284 which is operative to invert and convert the pulse signal received at control nozzle *d* into a variable pressure level signal which may be applied to the fluid conduit identified as C associated with the pulse computer 16. This connection would be used in the pulse computer 16 of FIG. 2 and represents the preferred connection to which the embodiments of FIGS. 3 and 4 were alternatives.

Referring now to FIG. 10, the manifold pressure sensor 20 and wide open throttle enrichment means 24 are illustrated. The wide open throttle enrichment means is illustrated in FIG. 10 as being comprised of a housing 241 which is separated into two chambers 242, 243 by a diaphragm member 244. Chamber 242 is communicated to intake manifold 2 by conduit 245 while chamber 243 is communicated to the input terminal 4 of the

pulse generating means 14 through a nozzle or orifice 246. Diaphragm 244 is arranged so as to sealingly engage orifice 246 whenever the pressure in chamber 243 is less than a predetermined amount above the pressure in chamber 242.

Manifold pressure sensor 20 is comprised of a housing 201 which is divided into a pair of chambers 202 and 203 by wall 204 having orifice 205 located therein. Moveable valve member 206 is arranged to vary the restriction to fluid flow between chambers 203 and 202 provided by orifice 205. Chamber 202 is communicated to the input terminal 55 of the pulse generating means 14 while chamber 203 is communicated through fluid conduits and bleed 207 to a suitable source of fluid pressure which in this case is taken to be the volume of air at substantially atmospheric pressure within the air cleaner so as to provide a source of filtered air. Chamber 203 is further divided by diaphragms or moveable wall members 208 and 209 into three distinct chambers with one of these chambers being communicated to the source of air at substantially atmospheric pressure, the second of these chambers being communicated through orifice 205 to chamber 202 and the last of the three chambers being communicated to the intake manifold through fluid conduits and bleed 210. Valve 206 is coupled to diaphragm 208 by valve stem 211 while constant pressure diaphragm means 212 provides a substantially fixed, relative to the pressure within the diaphragm 212, connection between diaphragms 208 and 209. Diaphragm means 212 is operative to provide an altitude compensation mechanism to vary the orifice opening in response to changes in normal atmospheric pressure or in altitude. Relief valve means 213 are operative to intercommunicate the intake manifold 2 with the intermediate chamber bypassing bleed 210 in those instances where a relatively high manifold pressure suddenly drops, as for instance a transition from wide-open throttle to part-throttle operation and when the response of the manifold pressure sensor 20 would be impeded by the operation of bleed 210.

Referring now to FIG. 11 a simplified, pure fluidic, embodiment of a manifold pressure sensor is illustrated wherein the wide-open throttle enrichment means 24 is substantially as illustrated in FIG. 10 and the manifold pressure sensor 20 of FIG. 10 has been replaced by a fluidic proportional amplifier 214 having a main fluid flow nozzle *a*, a pair of outlet passages *b* and *c* and a pair of control ports *d* and *e*.

In the FIG. 11 embodiment, the fluidic amplifier 214 will be operative to convert a decreasing manifold pressure to an increasing pressure signal for application to the input terminal 55 of the pulse generator means 14.

Referring now to FIG. 12, the pressure within the intake manifold 2 is communicated directly to the input terminal 56 of the pulse generator means 14 through bleed 215 to directly apply the intake manifold pressure as a signal to control nozzle *f* of the fluidic element 143 of the pulse generator means 14. With reference to FIG. 2, it can be seen that the input terminals 55 and 56 are both communicated to control nozzles of the fluidic element 143 but are communicated to oppositely situated control nozzles so that an increasing pressure signal at input terminal 55 would have substantially the same effect on fluidic element 143 as a decreasing pressure signal at input terminal 56. It can also be seen that input terminals 54 and 55 are intercommunicated

within pulse generator means 14 since the wide open throttle enrichment signal derived from the wide open throttle enrichment means 24 is used to modify the normally present manifold pressure signal derived from manifold pressure sensor 20.

I claim:

1. An intake manifold equipped internal combustion engine intermittent injection fluidic fuel control system comprising:

fuel supply means associated with the engine and including at least one fuel injection valve means operative to discharge metered amounts of fuel for consumption by the engine;

speed signal generating means associated with the engine operative to generate a fluidic pulse train signal having a characteristic indicative of engine speed;

pressure sensing means associated with the intake manifold operative to generate a signal having a level proportional to intake manifold pressure;

pulse generator means in fluid communication with said pressure sensing means and said speed signal generating means, said generating means including means responsive to said speed signal operative to generate a signal having a value which increases monotonically with time from the initiation thereof and means operative to compare said pressure signal level of the pressure sensing means with the monotonically varying characteristic of the generated signal of the speed signal generating means thereby providing an output pulse train indicative of the occurrence of a predetermined relationship between said signals, the duration of the output pulses being indicative of the substantially simultaneous engine fuel requirement; and

pulse computer means responsive to the output pulse train of said pulse generator means and operative to generate a second output pulse train to intermittently actuate the injector valve means, the duration of the pulses of the second output pulse train being at least equal to the duration of the pulses generated by the pulse generating means plus a predetermined amount thereby having a pulse length representative of the engine fuel requirement.

2. The system as claimed in claim 1 wherein said pulse generator means is adapted to generate a pulse train output in response to the speed signal generating means pulse train input, the pulses of the output pulse train having a one-to-one correspondence with the pulses of the input pulse train.

3. The system as claimed in claim 1 wherein the pulses of the pulse generator means output pulse train and the pulses of the pulse computer means output pulse train have a one-to-one correspondence.

4. The system as claimed in claim 1 including fluidic deceleration fuel cutoff means operative to generate a signal for receipt by the pulse generator means to inhibit said pulse generator means from producing a pulse train output signal during selected engine decelerations.

5. The system as claimed in claim 4 wherein said deceleration fuel cutoff means comprise:

throttle position sensing means operative to generate a signal indicative of a deceleration condition;

reference signal generating means operative to generate a signal having a predetermined pulse frequency; and

comparison means receiving said throttle position signal, said reference signal and said speed signal operative to generate an output signal whenever the speed signal indicates an engine speed in excess of the speed represented by the reference signal and a deceleration condition exists.

6. The system as claimed in claim 1 wherein said pulse computer means further include control means to selectively vary the predeterminable amount.

7. The system as claimed in claim 6 including further engine temperature responsive means sensing engine temperature operative to generate a fluid signal having a variable characteristic representative of engine temperature and means, including conduit means, operative to apply said signal to said pulse computer means control means to provide the control for selectively varying the predeterminable amount.

8. The system as claimed in claim 1 wherein said speed signal generating means comprise:

primary speed signal generator means responsive to engine speed operative to generate an output pulse train having a pulse frequency representative of engine speed; and

secondary speed signal generator means responsive to said primary generator means signal operative to generate a secondary pulse train signal having pulses occurring in timed one-to-one relationship with the pulses of the primary generator means signal and having a magnitude which monotonically increases from the time of initiation thereof.

9. The system as claimed in claim 8 including further additional generator means intermediate said primary generator means and at least a portion of said secondary generator means responsive to the pulses of said primary generator means pulse train operative to generate short duration fluidic spike pulses and delay means operative to delay, in time, said spike pulses.

10. The system as claimed in claim 9 wherein said secondary generator means comprise a fluidic proportional amplifier having a pair of opposed control nozzles and a pair of outlet passages, one of said pair of opposed control nozzles arranged to receive said primary generator means pulse train and the other of said pair of control nozzles arranged to receive said fluid spike, said fluid spike operative to terminate the secondary generator means pulse train signal.

11. The system as claimed in claim 8 including phase adjustment means in fluid communication with one of said pulse generator means control inputs arranged in opposition to the pulse generator means control input receiving the speed signal pulses, operative to adjustably control the time relationship of the initiation of pulse generator means output pulse relative to the initiation of a primary generator means pulse.

12. The system as claimed in claim 8 including further fluidic speed compensation means arranged to receive said primary generator means signal and a signal from said pressure sensing means indicative of engine operation operative to produce an output signal for receipt by said pulse generator means having a magnitude indicative of the need for enrichment quantities of fuel over selected ranges of engine speed and engine operation.

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13. The system as claimed in claim 1 including further engine temperature responsive means sensing engine temperature operative to generate an output pulse train signal having a frequency which is indicative of sensed temperature and means, including conduit means, for applying said signal to said pulse generator means to selectively control the generated output

pulses produced thereby.

14. The system as claimed in claim 13 wherein said applying means further include pulse averaging means operative to convert said output pulse train signal into an analog signal having a variable pressure level.

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