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Knapp et al.

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[54] **FUEL INJECTION APPARATUS**

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[73] Assignee: **Robert Bosch GmbH,** Stuttgart, Germany

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.** **F02m 39/00,** F02b 33/00

[58] **Field of Search** ..... 123/32 EA, 32 AE, 123/119 R, 139 AS

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[57] **ABSTRACT**

In a fuel injection apparatus which delivers metered fuel to fuel injection valves, there is provided, downstream of each differential pressure valve which ensures a constant pressure drop across each fuel metering valve and upstream of the associated fuel injection valve, a chopper valve which, in the low rpm range effects an intermittent fuel injection into the intake tube of the internal combustion engine to prevent uncombusted gas mixture from entering the exhaust system in said rpm range.

9 Claims, 7 Drawing Figures

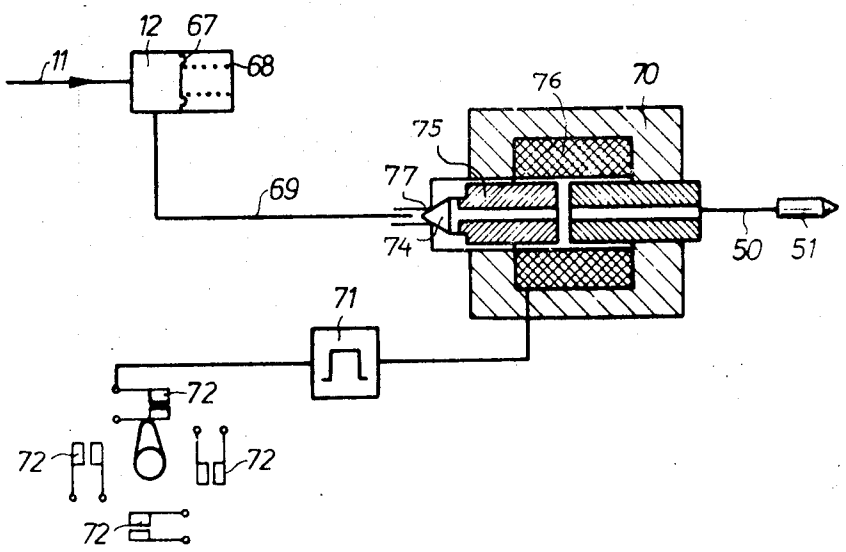


Fig. 1

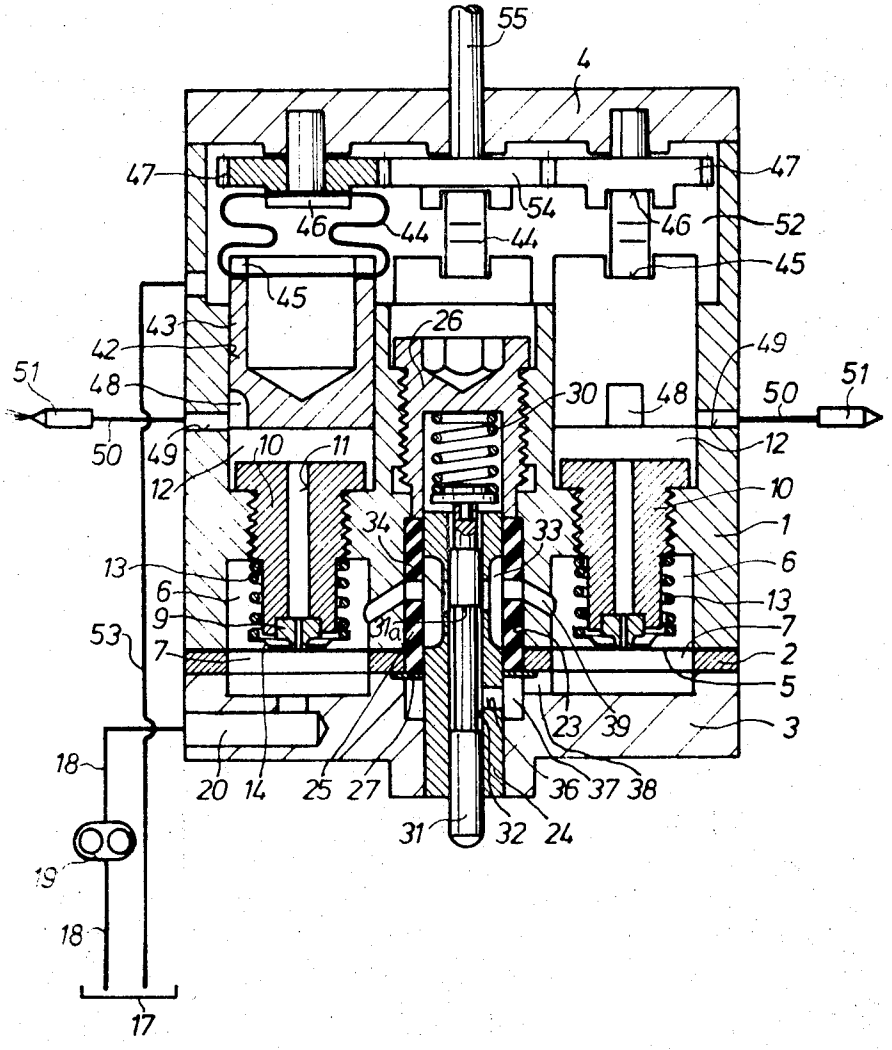

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Fig. 2

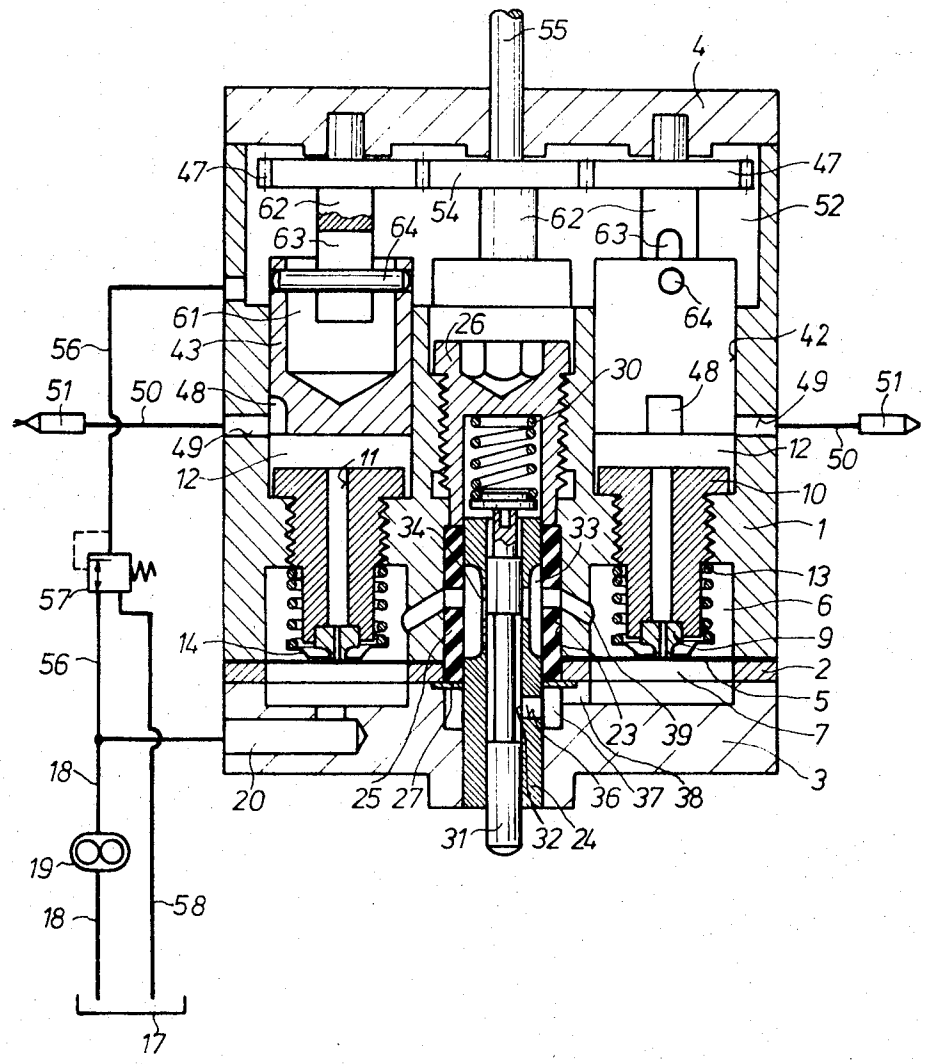

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Fig. 3

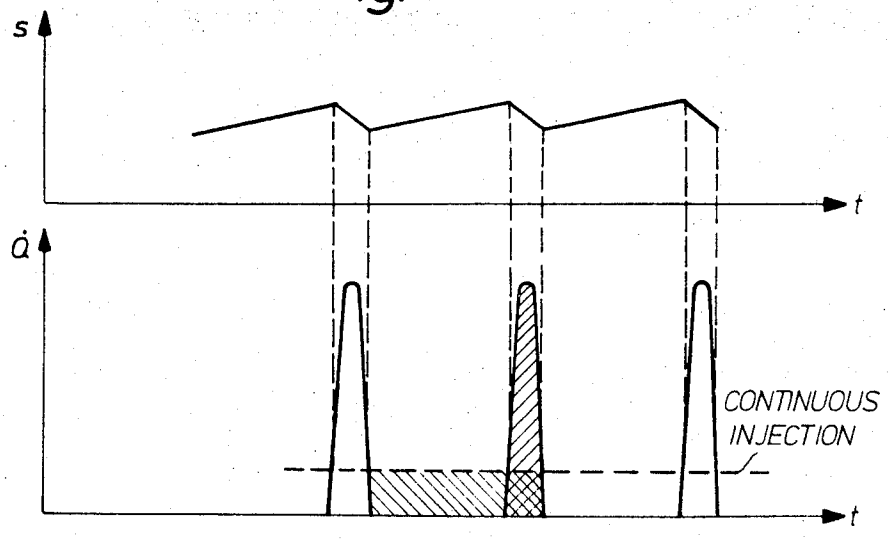


Fig. 4

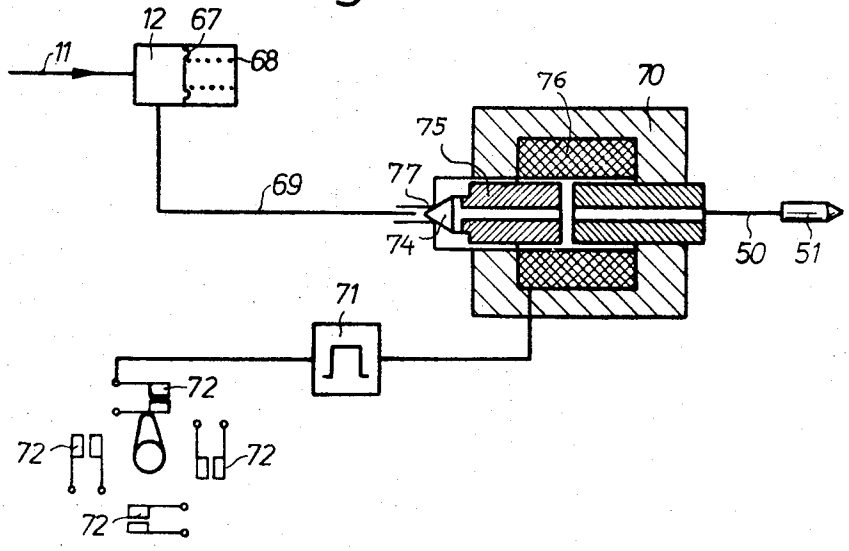


Fig. 5a

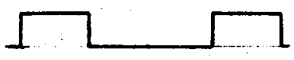
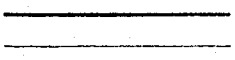


Fig. 5b



Fig. 5c



FUEL INJECTION APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to a fuel injection apparatus particularly for multi-cylinder, spark plug-ignited internal combustion engines and is of the type that includes a distributor device and metering valves. The setting of the latter may be simultaneously and arbitrarily varied to determine the fuel quantities supplied to the fuel injection valves. At each metering valve there prevails a pressure drop which is substantially constant, i.e., independent from the magnitude of the flow passage section of the fuel metering valves. For this purpose, with each fuel metering valve there is associated a differential pressure valve the flow passage section of which is variable by a yielding member exposed at its one side to the fuel pressure downstream of the metering valve and at its other side to the fuel pressure upstream of the same metering valve.

In fuel injection apparatus of the aforenoted type, the fuel injected into the suction or air intake tube of the internal combustion engine can be adapted very accurately to the momentary operational conditions. The setting magnitude which is a function of the operational conditions, effects at the metering valve a change of the metering flow passage section. A uniformly accurate fuel metering corresponding to the momentary flow passage section of the fuel metering valve is achieved by maintaining the aforenoted constant pressure drop, so that the metering of the fuel is independent from the pressures upstream and downstream of the metering valve.

In fuel injection apparatus of the aforenoted type distributor devices with metering valves have been used, the control plunger of which, by means of its axial displacement, opens a control slot to a greater or lesser extent. In this apparatus, the differential pressure valve is formed as a flat valve seat valve, the movable part of which is constituted by a membrane as disclosed, for example, in German published application DOS No. 1,803,066. It has been found that in internal combustion engines in which there is a large valving overlap, the continuous injection in the range of low rpm's and large load leads to a significant increase of non-combusted carbon hydrates in the exhaust gas. The gas replacement in the cylinders of the internal combustion engine is tuned for high rpm's; thus, in low rpm's because of the simultaneously open intake and exhaust valves, there occurs an exchange of the air-fuel mixture at the intake side with the exhaust gas at the exhaust side. The undesirable result of this phenomenon is that uncombusted mixture is introduced into the exhaust system. In case of low loads and particularly in idling rpm's this undesired effect is reduced, since the closed butterfly valve in the air intake tube hinders the aforenoted gas exchange.

OBJECT AND SUMMARY OF THE INVENTION

It is an object of the invention to provide an improved fuel injection apparatus in which the above-noted disadvantages are eliminated.

Briefly stated, according to the invention, the improved fuel injection apparatus is provided with means which, during the suction stroke of the engine, cause an intermittent injection of the metered fuel quantities at low rpm's. Said means ensure that with an increasing rpm the injection becomes automatically continuous.

The invention will be better understood as well as further objects and advantages become more apparent from the ensuing detailed specification of several exemplary embodiments taken in conjunction with the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a longitudinal sectional view of a fuel injection apparatus incorporating one embodiment of the invention;

FIG. 2 is a longitudinal sectional view of a fuel injection apparatus incorporating another embodiment of the invention;

FIG. 3 illustrates in diagrams the traveling path of an accumulator piston and the injected fuel quantities, both as a function of time in the low rpm range;

FIG. 4 is a schematic representation of still another embodiment of the invention and

FIGS. *5a–5c* are diagrams illustrating different scanning ratios of a vibrator component forming part of the embodiment according to FIG. **4.**

DESCRIPTION OF THE EMBODIMENTS

Turning now to FIG. **1,** there is shown a fuel injection apparatus which has a housing **1,** an intermediate plate **2,** a base plate **3** and a top closure **4.** Between the housing **1** and the intermediate plate **2** there is clamped a metallic membrane **5** which extends through a plurality of cavities distributed evenly about the axis of the housing **1.** Each cavity is formed by aligned bores in parts **1, 2, 3** and each is divided by the traversing membrane part into a chamber **6** and a chamber **7.** Each cavity **6, 7** with the associated membrane part (which constitutes a moving valve member) forms part of a differential pressure valve. The embodiment described here is a distributor device for a four-cylinder engine and thus has four differential pressure valves. In each of these valves the membrane **5** forms a flat seat valve with a stationarily held valve seat **9** which is coplanar with the clamping plane of the membrane. The valve seat **9** is held in a valve seat carrier **10** which is screwed into the housing **1** and which has an axial bore **11** through which fuel may flow into an accumulator chamber **12.** A coil spring **13,** with the interposition of a spring seat disc **14,** biases the membrane **5** open, so that all the differential pressure valves are open when not in operation.

Those portions of each chamber **7** that are defined by the base plate **3** are interconnected in such a manner by means of an annular channel (not shown) that liquid may flow from the first chamber **7** through the second and third chambers **7** to the fourth chamber **7,** but cannot directly flow from the first chamber **7** to the fourth chamber **7.** From a fuel tank **17** there extends a conduit **18** through a continuously delivering fuel pump **19** and a bore **20** to the aforenoted first chamber **7.** From the last or fourth chamber **7** there extends a return conduit containing a pressure maintaining valve (neither shown) back to the fuel tank **17.**

In an axial bore **23** of the distributor mechanism there is disposed a guide sleeve **24** which is secured against axial shift and rotation by means of an elastic sealing sleeve **25.** The latter, which may be of rubber, is axialy compressed by means of a cooperation between a plug **26** threadedly held in the housing **1** and a plate **27** supported between the base plate **3** and the intermediate plate **2.**

In the guide sleeve 24 there is disposed a control plunger 31 which is provided with an annular groove 32 and which is axially displaceable against the force of a spring 30. In the guide sleeve 24 there are provided longitudinal, axially parallel grooves 33 which are connected with the axial bore of the guide sleeve 24 by means of axially parallel control slots 34. Dependent upon the position of the control plunger 31, the upper edge 31*a* bounding the annular groove 32 opens a greater or lesser portion of the control slots 34. In the guide sleeve 24 there is further provided a radial port 36 which provides a continuous communication between the annular groove 32 and an annular channel 37 which is bounded by the intermediate plate 2, the sealing sleeve 25 and the bearing sleeve 24 and which is arranged in the base plate 3. From the annular channel 37 there lead radial extending channels 38 (one shown) to the aforedescribed annular channel that interconnects the individual chambers 7. Each longitudinal groove 33 of the guide sleeve 24 is connected through an associated channel 39 with a chamber 6 of the differential pressure valves. Thus, with each differential pressure valve there is associated a longitudinal groove 33 with its control slot 34.

The above-described distributor device operates as follows:

The fuel flows from the fuel tank 17 through the conduit 18, the continuously operating fuel delivery pump 19 and the bore 20 into the first chamber 7 and therefrom through the aforenoted, not shown annular channel to the other chambers 7 of the other differential pressure valves. Through the channels 38 the fuel is admitted into the annular channel 37 and therefrom it flows through the radial port 36 into the annular groove 32 of the control plunger 31. From the annular groove 32 the fuel flows through the control slots 34 in a metered manner into the longitudinal grooves 33 and therefrom, through the channels 39 into the chambers 6 of the differential pressure valves.

The stiffness of the membrane 5 and the strength of the springs 13 are so designed that in case of a change of the predetermined pressure drop between the two chambers 6 and 7 of a differential pressure valve, the flow passage section between the membrane and the valve seat 9 changes until the aforenoted predetermined pressure drop is reestablished.

After the fuel has flown through the differential pressure valves, it is admitted through the bores 11 into accumulator chambers 12, one associated with each differential pressure valve. The volume of each accumulator chamber 12 is variable by means of an accumulator piston 43 axially displaceable in a cylinder 42 against the return force of a soft leaf spring 44. It is seen that with each differential pressure valve there is associated an individual assembly formed of components 12, 42, 43, 44. Each leaf spring 44 nests in a cutout 45 of the accumulator piston 43 and in a cutout 46 of a spur gear 47. All spur gears 47 mesh with a center spur gear 54 keyed to a shaft 55 which rotates with the same rpm as the engine cam shaft. Each accumulator piston 43 has at its periphery an axially extending groove 48 which is continuously open towards the associated accumulator chamber 12. As it will be described hereinafter, in the proper position of the accumulator piston 43 and the groove 48 fuel is admitted from the accumulator chamber 12 through an outlet port 49 into a conduit 50 leading to a fuel injection valve 51. The fuel leaking between any cylinder 42 and the associated accumulator piston 43 may flow in a depressurized manner from a chamber 52 through a conduit 53 into the fuel tank 17.

The operation of the aforedescribed device will now be set forth in connection with one metering valve.

The fuel metered at the metering valve 32, 34 is admitted through the differential pressure valve 5, 9 into the accumulator chamber 12. There, by virtue of its pressure, it displaces the accumulator piston 43 in an axial direction against the force of the leaf spring 44 which functions as a low-friction coupling between the accumulator piston 43 and the gearing 47, 54. At low rpm's the continuously metered fuel is chopped by the aforedescribed device, since fuel is admitted from the accumulator chamber 12 into outlet port 49 only if the groove 48 of the accumulator piston 43 is in registry with the outlet port 49. At higher rpm's the accumulator piston 43, by virtue of the increasing mass effects and the greater metered fuel quantities, sets itself in such a manner that dependent upon the volume flow rate, continuously maintains open a certain flow passage section at the upstream end of the outlet port 49. It may be observed from the position of the accumulator pistons 43 in FIG. 1 that the chopping effect is fully effective there, since the accumulator pistons are situated low enough to cover and uncover the associated outlet port 49 as they are rotated by virtue of the assembly 44, 47, 54, 55. If, by virtue of the forces generated during higher rpm's, the accumulator pistons 43 are shifted upwardly to a sufficient extent, the ports 49 will be in continuous communication with the respective accumulator chamber 12, since pistons 43 then rotate out of range of the associated outlet port 49. It is also seen that if the accumulator pistons 43 assume a position between the two above-mentioned positions, then, as they rotate, full communication and partial communication between outlet port 49 and accumulator chamber 12 will alternate and there will thus be no complete blocking of the injection when port 49 and groove 48 are out of registry. In the last-named case there is a chopping effect, but it is only partially effective. The length and width of the groove 48 are adapted to the operational characteristics of the internal combustion engine.

By means of chopping the continuously metered fuel quantities with the aforedescribed device, the injection of the fuel into the intake tube of the engine during its suction strokes may be effected in such a manner that an exchange between the air-fuel mixture and the exhaust gas at low rpm's is effectively prevented. Thus, for low rpm's and large loads there is achieved a substantially smaller fuel consumption. Since the sequence of replacement of exhaust gas with fresh mixture is tuned for high rpm's, an exchange of the two types of gases does not take place in such rpm range. Thus, for such rpm's the chopped, intermittently effected injection automatically changes over to a continuous injection.

The fuel injection apparatus illustrated in FIG. 2 differs from the embodiment described in connection with FIG. 1 in that the return force for the accumulator piston 43 is supplied not by a spring 44, but by the fuel itself. For this purpose, from the conduit 18 there extends a conduit 56 containing a pressure regulating valve 57 which maintains a constant pressure in the chamber 52 and from which there leads a return conduit 58 to the fuel tank 17. Each accumulator piston 43

has an axial bore **61** which communicates with the chamber **52** and into which extends a coupling member **62.** A slot **63** of the latter cooperates with a radial pin **64** supported in the accumulator piston **43.** Each coupling part **62** is rigidly connected with the associated gear **47** which meshes with the gear **54** rotated by the shaft **55** with the same rpm as the engine cam shaft.

The use of fuel as the pressure liquid to supply a return force for the pistons **43** permits to maintain an accurately constant return force to which the accumulator pistons are exposed in any of their axial positions.

The course of the accumulator effect with respect to time *t* is illustrated in FIG. **3** for low rpm's in terms of the piston stroke *s* (upper diagram) and the injected fuel quantities Q (lower diagram). At the moment of registry between the groove **48** of the accumulator piston **43** and the outlet port **49,** injection takes place into the intake tube of the engine. At the same time, the accumulator volume and the piston stroke decrease until the moment when communication between the groove **48** and the outlet port **49** is interrupted by virtue of the rotation of the accumulator piston. The fuel quantity injected with this process directly during the suction stroke of the internal combustion engine corresponds to the fuel quantity which would be normally injected in this period when a continuous injection takes place. The dashed horizontal line in the lower diagram indicates the continuous level of injection when the piston **43** only partly blocks the outlet port **49** when the latter is out of registry with the groove **48.**

Turning now to the embodiment illustrated schematically in FIG. **4,** there is shown an accumulator membrane **67** which, as a yielding member, closes the accumulator chamber **12** and is biased by a coil spring **68.** Fuel is admitted to each accumulator chamber **12** along a passage **11** similarly to the embodiments of FIGS. **1** and **2.** The accumulator chamber **12** is connected by means of a conduit **69** with a chopping valve **70** of very simple structure. For example, it may include a movable valve member **74** forming an integral part of an armature **75** surrounded by a stationary solenoid **76.** When the latter is energized, the valve member **74** is pressed against a stationary valve seat **77.** The chopping valve **70** is controlled by a monostable multivibrator **71** which thus electromagnetically opens it to permit fuel flow in the conduit **50** to the fuel injection valve **51.** The triggering of pulses is effected by contacts **72** incorporated in the ignition distributor (not shown) of the internal combustion engine. The advantage of a membrane as an accumulator member is that it has a very small mass.

The operation of the device described in connection with FIG. **4** will now be explained.

The fuel metered in the distributor device (of the type as discussed in connection with FIGS. **1** and **2**) is admitted from the accumulator chamber **12** through the conduit **69** at higher rpm's into the conduit **50** and the fuel injection valve **51** without interruption by the chopper valve **70.** In the range of lower rpm's the chopper valve **70** is controlled by the monostable multivibrator **71** which is formed of the power transistor proper and a weaker transistor. The triggering of the vibrator **71** occurs through the contacts **72** built into the ignition distributor (not shown). The monostable multi-vibrator **71** may thus be flipped in an rpm-synchronous manner from its stable condition into its unstable condition. The pulse period of the monostable multi-vibrator is designed in such a manner that at low rpm's there appears a scanning condition as shown in FIG. **5***a*, whereas at intermediate rpm's the injection begins to be continuous by the crowding of the pulses as shown in FIG. **5***b* and at high rpm's the injection becomes entirely continuous (FIG. **5***c*).

Similarly to the previously described mechanical solution, the injection occurs at low rpm's in the intake tube during the suction stroke of the internal combustion engine. The transition from an intermittent injection to a continuous injection is based on the phenomenon that the delay of response of the chopper valve **70** is slower than the pulse frequency.

It has been found that the exhaust gas values at low rpm's in the range of lower loads are better than when the injection is effected in a continuous manner. By electric circuit means as described it is a simple matter to maintain the electric chopper valves **70** continuously open dependent upon the vacuum or the position of the butterfly valve. In this manner there is obtained an additional favorable matching of the fuel injection with the engine characteristics of the internal combustion engine, while in the range of low rpm's and large output there occurs an intermittent injection, whereas in the range of low load and high rpm's the injection is continuous. When the vehicle coasts in gear, the electronic control further permits a simple interruption of the fuel admission by discontinuing the transmission of electric pulses.

What is claimed is:

1. In a fuel injection apparatus associated with a multi-cylinder internal combustion engine, said apparatus being of the type that includes (a) fuel metering valves equalling the number of cylinders in said engine, (b) means for simultaneously controlling said fuel metering valves, (c) a separate differential pressure valve joining each fuel metering valve downstream thereof for ensuring a constant pressure drop across each fuel metering valve independently from the flow passage section thereof and (d) a separate fuel injection valve downstream of each differential pressure valve for receiving metered fuel therefrom, the improvement comprising:

A. chopper valve means disposed between each said differential pressure valve and its associated fuel injection valve to effect an intermittent delivery of accumulated fuel downstream from each differential pressure valve to its associated fuel injection valve and

B. rpm-responsive means operatively connected to said chopper valve means for rendering the latter effective at lower rpm's to provide for intermittent delivery of fuel and rendering it ineffective at higher rpm's to provide for continuous delivery of fuel.

2. An improvement as defined in claim **1,** including

A. a separate accumulator chamber in communication with each differential pressure valve and disposed downstream thereof and

B. an accumulator member movably disposed in each accumulator chamber to determine the volume of the latter.

3. An improvement as defined in claim **2,** wherein said accumulator member is formed as an accumulator piston slidable in said accumulator chamber, said improvement further includes

A. means exerting a return force on said accumulator piston against the force generated by the pressure of fuel in said accumulator chamber and

B. means for rotating said accumulator piston with the rpm of said engine.

4. An improvement as defined in claim **3,** wherein said means for rotating said accumulator piston includes

A. a gearing and

B. a soft leaf spring for drivingly coupling said gearing to said accumulator piston, said soft leaf spring also constitutes said means exerting a return force.

5. An improvement as defined in claim **3,** including means for admitting fuel under pressure to said accumulator piston for opposing the force of the fuel in said accumulator chamber; said last-named means, together with the associated fuel under pressure constitutes said means exerting a return force.

6. An improvement as defined in claim **3,** wherein said accumulator piston has on its lateral face an axially parallel groove in communication with said accumulator chamber, said groove, during rotation of said accumulator piston, is adapted to be in and out of registry with an outlet port connecting said accumulator chamber with the associated fuel injection valve.

7. An improvement as defined in claim **2,** wherein said accumulator member is constituted by a membrane, said improvement further includes

A. an electromagnetic valve disposed downstream of said accumulator chamber and upstream of the associated fuel injection valve, said electromagnetic valve constitutes said chopper valve means and

B. a monostable multi-vibrator operatively connected to said electromagnetic valve and constituting said rpm-responsive means.

8. An improvement as defined in claim **7,** including means for flipping said monostable multi-vibrator from its stable condition into its unstable condition synchronously with the engine rpm.

9. An improvement as defined in claim **7,** including

A. contacts incorporated in the ignition distributor of the engine, said contacts being connected with said monostable multi-vibrator and

B. means for periodically opening and closing said contacts to trigger said monostable multi-vibrator.

* * * * *