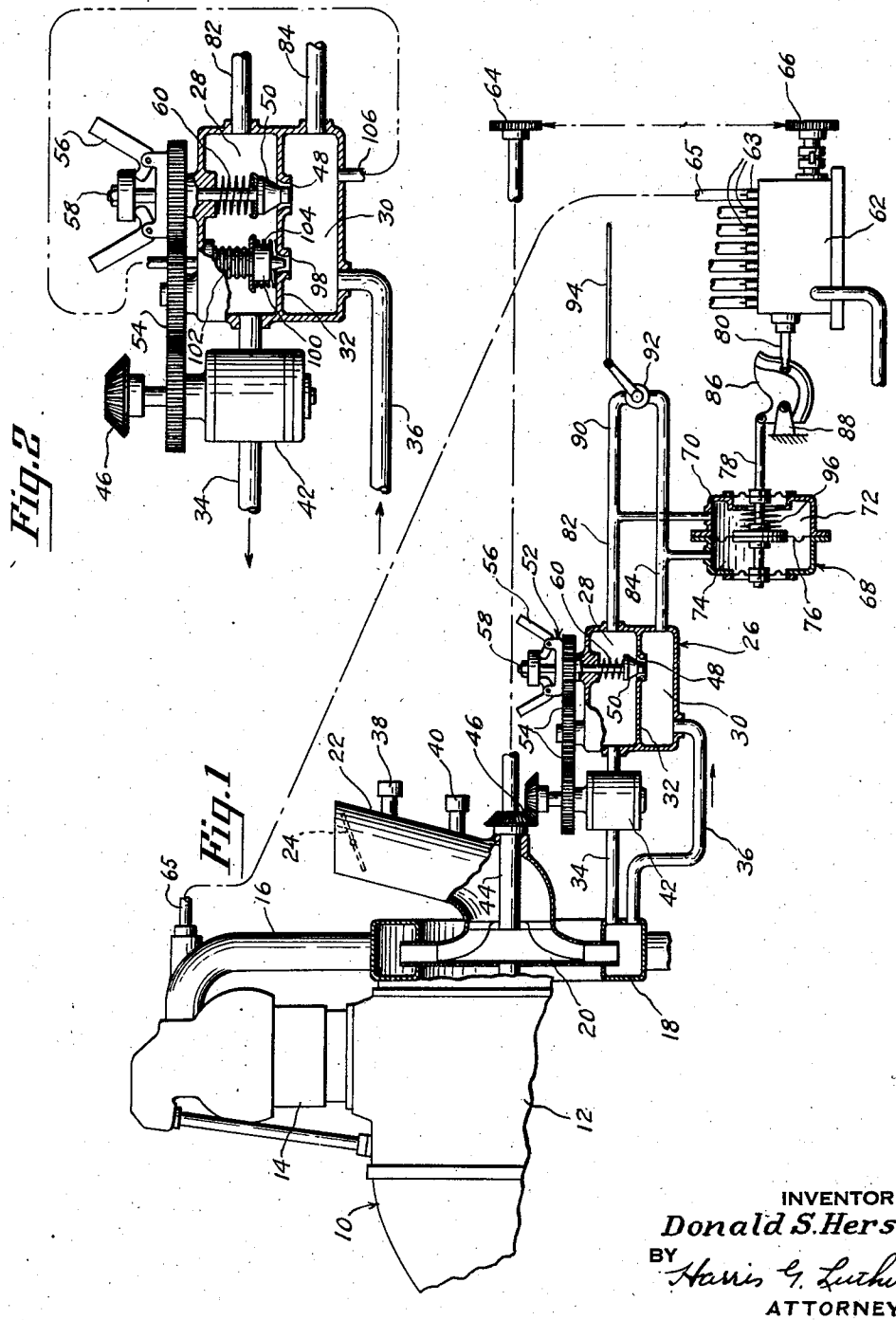
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CHARGE FORMING APPARATUS

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INVENTOR
Donald S. Hersey
BY Harris G. Luther
ATTORNEY

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CHARGE FORMING APPARATUS

Donald S. Hersey, West Hartford, Conn., assignor to United Aircraft Corporation, East Hartford, Conn., a corporation of Delaware

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This invention relates to improvements in engine fuel supplying and controlling apparatus and has particular reference to an improved apparatus for controlling the displacement of an engine fuel injection pump to proportion the amount of fuel supplied to the engine to the mass rate flow of engine intake air.

An object of the invention resides in the provision of an improved fuel pump control which will accurately proportion the amount of fuel supplied to the engine to the weight of intake air supplied to the engine, per unit of time.

A further object resides in the provision of compensating means for adjusting the fuel supply to changes in the volumetric efficiency of the engine over the operating speed range of the engine.

Other objects and advantages will be more particularly pointed out hereinafter or will become apparent as the description proceeds.

In the accompanying drawing, in which like reference numerals are used to designate similar parts throughout, there is illustrated a suitable mechanical embodiment for the purpose of disclosing the invention. The drawing, however, is for the purpose of illustration only and is not to be taken as limiting or restricting the invention since it will be apparent to those skilled in the art that various changes in the illustrated embodiment may be resorted to without in any way exceeding the scope of the invention.

In the drawing,

Fig. 1 is a diagrammatic view of an engine fuel control apparatus constructed according to the invention certain parts being broken away and shown in section to better illustrate the construction thereof, and

Fig. 2 is a sectional view on an enlarged scale of a somewhat modified form of a portion of the device illustrated in Fig. 1.

Referring to the drawing in detail, the numeral 10 generally indicates an internal-combustion engine such as a radial air-cooled engine ordinarily employed for the propulsion of aircraft. The invention, however, is not limited to any particular type of internal-combustion engine, the type of engine shown being merely for the purpose of illustration. The engine 10 may have a crankcase 12 upon which are mounted a plurality of cylinders, one of which is indicated at 14, connected by suitable intake pipes, one of which is indicated at 16, with the diffuser chamber portion 18 of a supercharger including an engine driven impeller 20 and an air intake duct 22 leading to the impeller entrance and provided with a throttle 24. A casing, generally indicated at 26, including two chambers 28 and 30 separated by a transverse partition 32, is connected to some portion of the engine air intake system, such as the diffuser chamber 18, by fluid conduits 34 and 36. That the casing may be connected with some other portion of the supercharger system, such as the air intake duct 22, is indicated by the blanked off connections 38 and 40.

The conduit 34 is connected with the chamber 28 and the conduit 36 is connected with the chamber 30 and one of these conduits, for example the conduit 34, is intercepted by a constant displacement fluid measuring device 42 which may operate as a pump driven from the engine by suitable means, such as the shaft 44 and gear connection 46. The measuring device or pump 42 will serve to move a predetermined volumetric quantity of air through the casing 26 for each speed of the engine 10.

The transverse partition 32 between the chambers 28 and 30 is provided with an orifice 48 the area of which is controlled by a movable tapered plug 50 actuated by a governor, generally indicated at 52, driven through a suitable gear connection 54 from the drive for the pump 42 and including centrifugally actuated flyballs 56 acting on the valve stem 58 in a direction resiliently opposed by the coiled compression spring 60.

With this arrangement the pressure necessary to force the air through the orifice 48 will necessitate a pressure differential between the chambers 28 and 30 which pressure differential is a direct measurement of the density of the air flowing through the orifice at any particular engine speed. Since the tapered plug 50 compensates the area of the orifice for all speeds of the engine driven pump 42 the pressure differential between the chambers 28 and 30 will at all times constitute an indication of the density of the engine intake air. Additional compensation for changes in the volumetric efficiency of the engine with changes in speed may be provided by changing the shape of the tapered plug.

Fuel is supplied to the engine by means of a suitable fuel injection pump, which may be a commercial type of pump, generally indicated at 62, driven by the engine through suitable means, such as an extension of the shaft 44 and the driving elements 64 or 66. The pump illustrated is a known form of fuel injection pump having separate pump cylinders, as indicated at 63, for the various engine cylinders, each pump cylinder being connected to a respective engine cylinder by a suitable tubular connection as indicated at

65. The displacement of the pump can be adjusted by suitable stroke varying means, including the shaft 80, connected with the cylinders 63. If no compensation were provided this pump would always supply to the engine a quantity of fuel directly proportional to the speed of the engine. This arrangement would be entirely satisfactory if the power developed by the engine were always directly proportional to engine speed. However, since operation of the throttle 24, and other well known features, introduce conditions under which the engine power does not vary with engine speed, it becomes necessary to provide means for adjusting the pump so that the fuel supplied to the engine will be in proportion to the weight per unit of time of intake air supplied to the engine rather than proportional to engine speed. If the volumetric efficiency of the engine were constant for all operating speeds the mass rate flow of engine intake air would always be the product of engine speed, engine displacement, and the density of the intake air and a device, such as that indicated at 26, responsive to variations in the density of the engine intake air would be entirely adequate to adjust the pump to regulate the amount of fuel supplied to the mass rate flow of engine intake air. This could be accomplished by connecting with the casing 26 a pneumatic device, generally indicated at 68, comprising a hollow casing 70 separated into two chambers 72 and 74 by a flexible transverse diaphragm 76 to which is connected a rod 78 operatively connected with the stroke changing element 80 of the injection pump 62 the two chambers 72 and 74 being connected with the chambers 28 and 30 by respective conduits 82 and 84. A pivoted cam member 86 is interposed between the shaft 78 and the element 80 and supported by a fixed member 88 and rotated about this fixed pivotal mounting 88 by the shaft 78, and has a sliding connection with the element 80. The contour of this cam can be shaped to provide an economizer action to richen the fuel-air mixture whenever the pressure differential between the chambers 28 and 30 exceeds a predetermined value or is in the higher portion of the range of pressure differences of the density responsive device as when the engine is operating at a high mean effective pressure.

In most types of internal-combustion engines it is also desirable to provide a manual mixture control. In the illustrated arrangement this can be accomplished by providing a bleed line 90 between the conduits 82 and 84 and intercepting this bleed line with a valve 92 operated by a suitable device, such as the link 94, which may be connected with an independent manually operable device.

In the form of the invention shown in Fig. 2 the arrangement is substantially the same as that illustrated in Fig. 1 and described above except that a modified form of economizer is utilized. This economizer comprises a second orifice 98 in the partition 32 controlled by a tapered plug 100 which is moved by a flexible bellows or "Sylphon" 102 balanced by a compression spring 104. The exterior of the bellows 102 is exposed in the chamber 28 and the interior is connected through a conduit 106 with the chamber 30.

The economizer action shown in Fig. 2 may be substantially as follows:

There will be an increase in engine manifold density at high engine speeds and throttle opening positions, particularly where the device 26 is connected with the supercharger diffuser 18, and this increase in manifold density will cause an increase in the pressure of the air in the chamber 30 with respect to the pressure in chamber 28 of the device 26, assuming the airflow to be in the direction of the arrows shown on Fig. 2. This increase in pressure in the chamber 30 will be transmitted through the conduit 106 to the interior of the bellows 102 and when the consequent pressure difference between the chambers 30 and 28 exceeds a predetermined value or reaches the upper range of the pressure differences created in said chambers by operation of said engine, the pressure difference acting on the two sides of the bellows will move the tapered plug 100 to further restrict the orifice 98 to thereby increase the pressure differential between the chambers 28 and 30 which will imply a somewhat higher air density than is actually present in the engine intake system. This indicated increase in air density will act through the conduits 82 and 84 on the pneumatic device 68 to somewhat increase the capacity of the fuel injection pump 62 to supply a somewhat richer fuel mixture to the engine for high power engine operation.

While a suitable mechanical embodiment has been hereinabove described and illustrated in the accompanying drawing for the purpose of disclosing the invention, it is to be understood that the invention is not limited to the particular embodiment so described and illustrated but that such changes in the size, shape and arrangement of the various parts may be resorted to as come within the scope of the subjoined claims.

Reference is made to my copending applications Serial Nos. 311,153 (filed December 27, 1939), and 370,160 (filed December 14, 1940), which show and claim subject matter shown but not claimed in this application.

Having now described the invention so that others skilled in the art may clearly understand the same, what it is desired to secure by Letters Patent is as follows:

1. Charge forming apparatus for an internal combustion engine having an air intake system and a variable capacity fuel supply means having a driving connection with said engine comprising, engine driven means for continuously forcing a sample of intake air through a restricted orifice and creating a pressure drop across said orifice, speed responsive engine driven means for varying the restriction of said orifice in accordance with variations in engine speed, means actuated by the pressure drop across said orifice to regulate the output capacity of said fuel supply means in accordance with variations in said pressure drop, and economizer means biasing the adjustment of said fuel supply means toward a richer fuel-air mixture when the pressure drop across said restriction exceeds a predetermined value.

2. Charge forming apparatus for an internal combustion engine having an air intake system and an engine driven fuel supply means the output capacity per operating cycle of which is adjustable comprising, a pneumatic shunt circuit having a restriction therein connected at both ends to said air intake system, an engine-driven pump having a constant volumetric capacity for each operating cycle interposed in said conduit for continuously forcing a measured volume of intake air therethrough, speed responsive means operatively connected with said engine for varying the magnitude of said restriction in direct proportion to variations in engine speed, a pneumatic device connected with said shunt circuit

and with said fuel supply means and actuated by variations in the pressure drop across said restriction to vary the output capacity of said fuel supply means in direct proportion to variations in said pressure drop, and economizer means biasing the adjustment of said fuel supply means by said pneumatic means toward a richer fuel-air mixture when the air density in said air intake system exceeds a predetermined value.

3. In combination with an engine having a restricted passage through which intake air is forced, means for maintaining the flow rate through the restricted passage so that the pressure differential across the restriction varies in accordance with changes in intake air density, an engine driven variable volume pump for injecting fuel into said intake air, a pressure actuated device operated by said pressure differential and operatively connected with said pump for adjusting said pump by changing the volume per revolution capacity thereof in accordance with changes in intake air density, and economizer means biasing the adjustment of said fuel supply pump toward a richer air-fuel ratio when the density of the air in said air intake system exceeds a predetermined value.

4. In combination with an engine having a restricted passage through which intake air is forced, means for maintaining the flow rate through the restricted passage so that the pressure differential across the restriction varies in accordance with changes in intake air density and engine volumetric efficiency, means for injecting fuel into said intake air, means for measuring the quantity of fuel injected, means actuated by said pressure differential for adjusting said measuring means to maintain the correct proportion of fuel to air for different intake air densities and for changes in engine volumetric efficiency, and economizer means biasing the adjustment of said fuel injecting means toward a richer air-fuel ratio when the density of the air in said air intake system exceeds a predetermined value.

5. In combination with an engine having a restricted passage through which intake air is forced, mechanism for maintaining a predetermined ratio of orifice size and airflow to provide a pressure drop across said restricted passage proportional to intake air density and a speed induced engine variable, such as volumetric efficiency, including means responsive to changes in engine speed for varying the free area of said restricted passage, means for injecting fuel into said intake air, means for measuring the quantity of fuel injected, means actuated by said pressure differential for adjusting said measuring means to maintain the correct proportion of fuel to air for different intake air densities and different engine speeds, and economizer means comprising means independently operated to vary the restriction to flow of air from one side of said restricted passage to the other in proportion to variations in the air density in said air intake system to provide a richer fuel-air mixture for said engine when the density of the air in said air intake is high exceeds a predetermined value.

6. Charge forming apparatus for an internal combustion engine having an air intake system and an engine driven fuel supply means the output capacity per operating cycle of which is adjustable, comprising a pneumatic shunt circuit having a restriction therein connected at both ends to said air intake system, an engine driven pump having a constant volumetric capacity for each operating cycle interposed in said pneumatic shunt circuit for continuously forcing a measured volume of intake air therethrough, speed responsive means for varying the magnitude of said restriction in direct proportion to variations in engine speed, and a pneumatic device connected with said shunt circuit and with said fuel supply means and actuated by variations in the pressure drop across said restriction to adjust the output of said fuel supply means by varying the output capacity thereof in direct proportion to variations in said pressure drop, and economizer means actuated by the pressure drop across said restriction to bias the adjustment of said fuel supply means toward a richer fuel-air mixture when the pressure drop across said restriction exceeds a predetermined value.

7. Charge forming apparatus for an internal combustion engine having an air intake system and an engine driven fuel supply means the output capacity per operating cycle of which is adjustable, comprising a pneumatic shunt circuit having a restriction therein connected at both ends to said air intake system, an engine driven pump having a constant volumetric capacity per operating cycle interposed in said circuit for continuously forcing a measured volume of intake air therethrough, speed responsive means for varying the magnitude of said restriction in direct proportion to variations in engine speed, a pneumatic device connected with said shunt circuit and with said fuel supply means and actuated by variations in the pressure drop across said restriction to vary the output capacity of said fuel supply means in direct proportion of variations in said pressure drop, and means biasing the adjustment of said fuel supply means by said pneumatic means toward a richer fuel-air mixture ratio when the air density in said air intake system is high exceeds a predetermined value.

8. The arrangement as set forth in claim 6 including economizer means comprising a cam actuated by said pneumatic device and located in the connection between said pneumatic device and the capacity varying control of said fuel supply means.

9. The arrangement as set forth in claim 6 including economizer means comprising means operative in response to air pressure in said intake system above a predetermined value to vary the magnitude of the restriction in said pneumatic shunt circuit.

10. Charge forming apparatus for an internal combustion engine having an air intake system and a fuel supply means comprising, an intake air sampling device including a casing comprising two chambers connected independently with said air intake system and separated by a transverse partition having an orifice therethrough, a positive displacement engine driven pump interposed in the connection between one of said chambers and said air intake system to maintain a circulation of engine intake air through said chambers and said orifice, speed responsive means effective by varying said orifice to maintain the pressure drop across said orifice substantially unaffected by variations in engine speed, a pneumatic device connected with said chambers and with said fuel supply means and actuated by changes in the pressure differential between said chambers to vary the output capacity of said fuel supply means in accordance with variations in the density of the engine intake air, and economizer means comprising a second orifice in the partition between

said chambers, and means operative to vary the area of said second orifice in inverse proportion to variations in the air pressure in said intake system.

11. Charge forming apparatus for an internal combustion engine having an air intake system and fuel supply means comprising, an intake air sampling device including a casing comprising two chambers connected independently with said air intake system and separated by a transverse partition having an orifice therethrough, a positive displacement engine driven pump interposed in the connection between one of said chambers and said air intake system to maintain a circulation of engine intake air through said chambers and said orifice, means for maintaining a predetermined ratio of orifice size and airflow to provide a pressure drop proportional to the density of intake air, a pneumatic device connected with said chambers and with said fuel supply means and actuated by changes in the pressure differential between said chambers to vary the output capacity of said fuel supply means in accordance with variations in the density of the engine intake air, and economizer means comprising a second orifice in the partition between said chambers, and means operative to vary the area of said second orifice in inverse proportion to variations in the air density in said air intake system, said area varying means comprising, an expansible bellows disposed in one of said chambers and internally connected with the other of said chambers and a valve member movable by said bellows relative to said orifice.

12. In an engine charge forming apparatus, an engine driven adjustable displacement fuel pump, an air sampling device for continuously passing a sample quantity of engine intake air through a restriction and having means operative to maintain a predetermined ratio between the volumetric flow rate of the sample air and the size of the restriction to provide across said restriction a pressure head proportional to the density of said intake air, means actuated by said pressure head and operatively connected with said fuel pump for varying the quantity of fuel delivered per cycle by said pump in accordance with variations in intake air density to maintain a substantially constant proportion between the weight of intake air and the weight of fuel delivered to said engine in the same time interval, and economizer means actuated by said pressure differential in the higher portion of its range of values to modify the operation of said fuel pump to increase the proportion of fuel in the engine charge.

13. In an engine charge forming apparatus, an engine driven adjustable displacement fuel pump, means for continuously passing a sample quantity of engine intake air through a restriction, means operative to maintain a predetermined ratio between the volumetric flow rate of the sample air and the size of the restriction to provide across said restriction a pressure head proportional to the density of said intake air, means actuated by said pressure head and operatively connected with said fuel pump for varying the quantity of fuel delivered by said pump per cycle in accordance with variations in intake air density to maintain a substantially constant proportion between the weight of intake air and the weight of fuel delivered to said engine in the same time interval, and economizer means operatively connected with the fuel pump and actuated by said pressure differential in the higher portion of its range of values to modify the operation of said fuel pump to increase the proportion of fuel in the engine charge.

14. In an engine charge forming apparatus, an engine driven adjustable displacement fuel pump, means for continuously passing a sample quantity of engine intake air through a restriction, means operative to maintain a predetermined ratio between the volumetric flow rate of the sample air and the size of the restriction to provide across said restriction a pressure head proportional to the density of said intake air, means actuated by said pressure head and operatively connected with said fuel pump for varying the quantity of fuel delivered by said pump in accordance with variations in intake air density to maintain a substantially constant proportion between the weight of intake air and the weight of fuel delivered to said engine in the same time interval, and economizer means actuated by said pressure differential in the higher portion of its range of values to modify the operation of said fuel pump to increase the proportion of fuel in the engine charge, said economizer means comprising a cam mounted on a fixed pivot, a connection between said cam and said pressure head actuated means to turn said cam about said fixed pivot, and a connection between said cam and said fuel pump for varying the displacement of said fuel pump in accordance with variations in said pressure head, said connection including a cam track shaped to provide an increase in the proportion of fuel in said engine charge when said pressure head is above a predetermined value.

15. In a charge forming apparatus for an internal-combustion engine provided with a supercharger for engine intake air, an engine driven adjustable displacement fuel pump, engine driven means connected with the outlet of said supercharger for continuously passing a sample quantity of air from said supercharger outlet through a restriction, means for varying the area of said restriction in accordance with variations in the speed of operation of said sampling means to provide across said restriction a pressure head proportional to the density of said intake air, and means actuated by said pressure head and operatively connected with said fuel pump for varying the quantity of fuel delivered by said pump in accordance with variations in intake air density to maintain a substantially constant proportion between the weight of intake air and the weight of fuel delivered to said engine in the same time interval.

16. In an engine charge forming apparatus, an engine driven adjustable displacement fuel pump, engine driven means for continuously passing a sample quantity of engine intake air through a restriction, means for varying the area of said restriction in accordance with variations in the speed of operation of said sampling means to provide across said restriction a pressure head proportional to the density of said intake air, means actuated by said pressure head and operatively connected with said fuel pump for varying the quantity of fuel delivered by said pump in accordance with variations in intake air density to maintain a substantially constant proportion between the weight of intake air and the weight of fuel delivered to said engine in the same time interval, economizer means actuated by said pressure differential in the higher portion of its range of values to modify the operation of said fuel pump to increase the proportion of fuel in the engine charge, and a manually operable mixture control comprising, a pneumatic shunt connec-

tion by passing said restriction, and a manually operable valve in said shunt connection for modifying the pressure head across said restriction by providing an adjusted bleed passage through said shunt connection.

17. In a charge forming apparatus for a multi-cylinder internal-combustion engine, an engine driven adjustable displacement fuel injection pump having a separate connection with each engine cylinder for injecting metered quantities of fuel into said cylinders at properly timed intervals, an air sampling device for continuously passing a sample quantity of engine intake air through a restriction and having means operative to maintain a predetermined ratio between the volumetric flow rate of the sample air and the size of said restriction to maintain across said restriction a pressure head proportional to the density of the intake air, and means actuated by said pressure head and operatively connected with said fuel pump to vary the displacement of said pump in accordance with variations in intake air density whereby said pump will inject into said engine cylinders fuel charges proportioned to the weight of the intake air charges drawn into said cylinders and timed in accordance with the operating speed of said engine.

18. In a charge forming apparatus for a multi-cylinder internal-combustion engine, an engine driven adjustable displacement fuel injection pump having a separate connection with each engine cylinder for injecting metered quantities of fuel into said cylinders at properly timed intervals, engine driven means for continuously passing a sample quantity of engine intake air through a restriction, engine driven speed responsive means for varying the area of said restriction in accordance with variations in engine speed to maintain across said restriction a pressure head proportional to the density of the intake air, and means actuated by said pressure head and operatively connected with said fuel pump to vary the displacement of said pump in accordance with variations in intake air density whereby said pump will inject into said engine cylinders fuel charges proportioned to the weight of the intake air charges drawn into said cylinders and timed in accordance with the operating speed of said engine.

DONALD S. HERSEY.