

[54] **SPLIT ENGINE OPERATION**

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[58] Field of Search **123/198 F, 127, 97 B**

[56] **References Cited**

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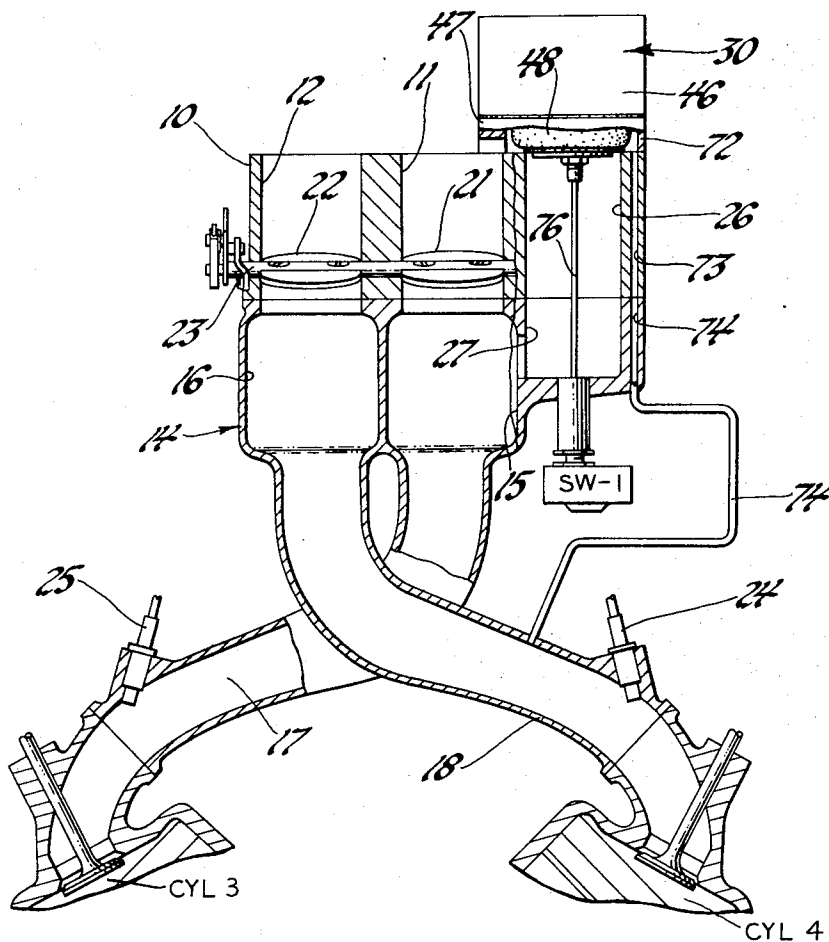
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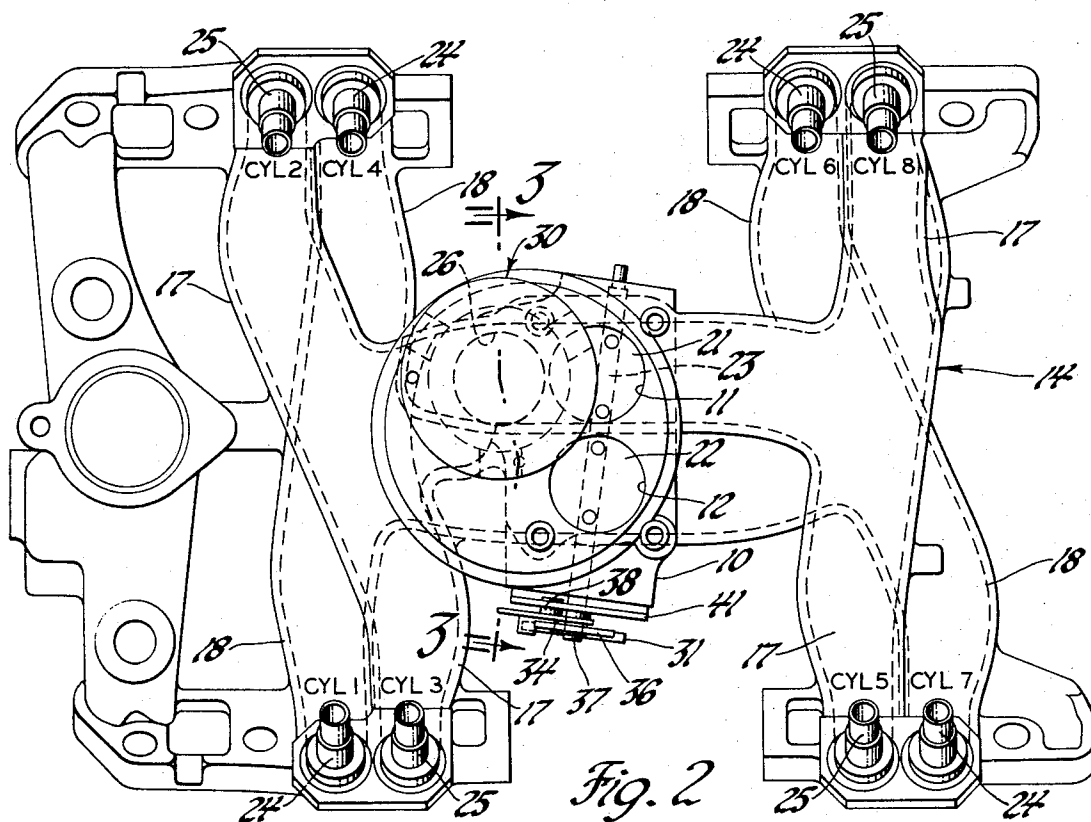
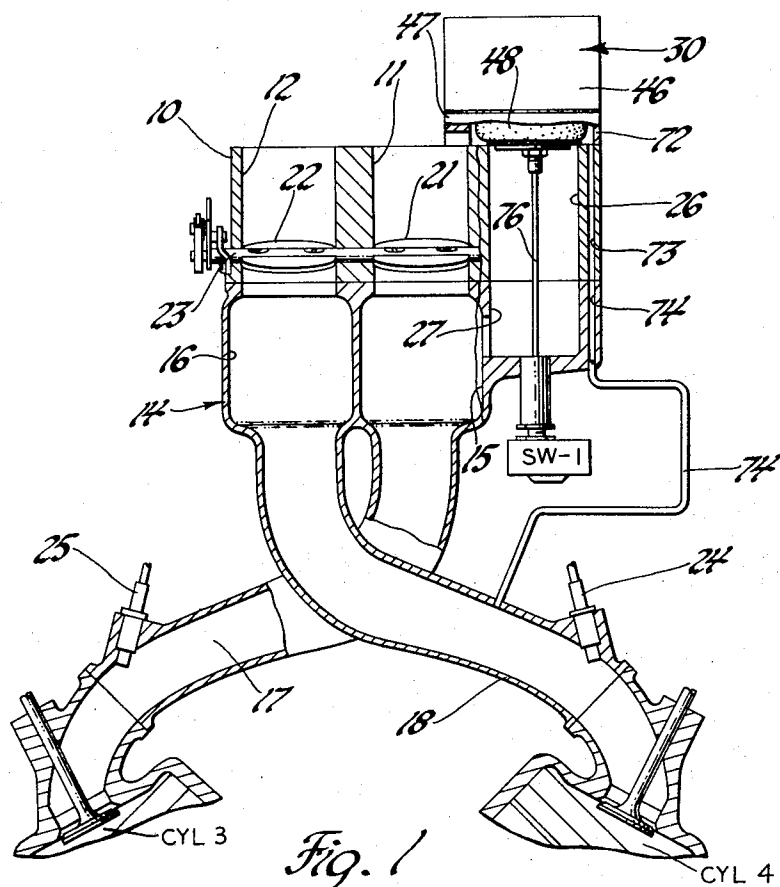
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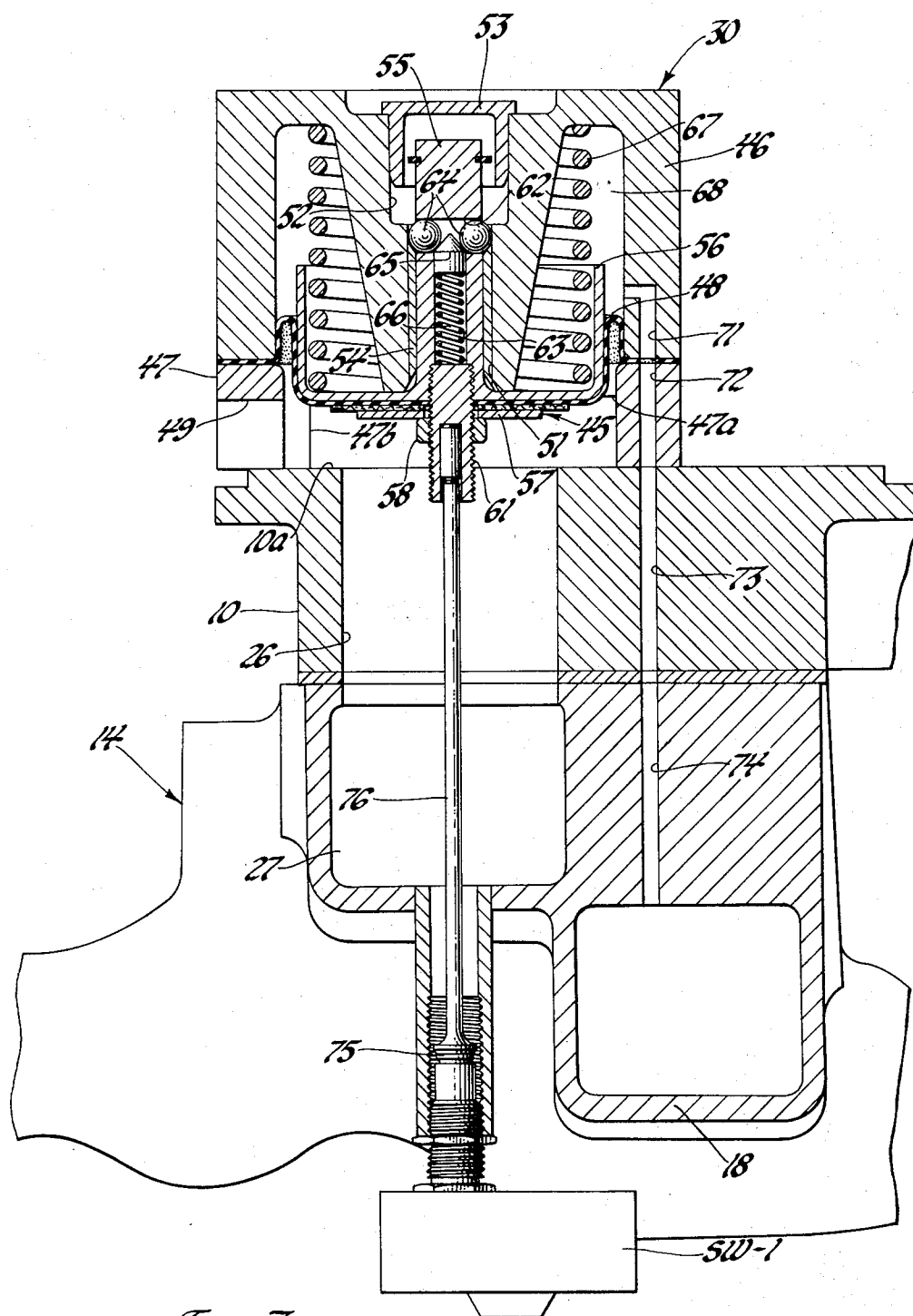
ABSTRACT

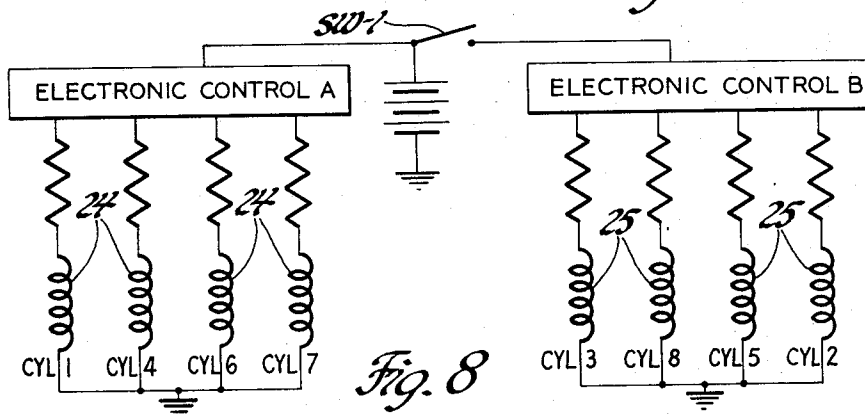
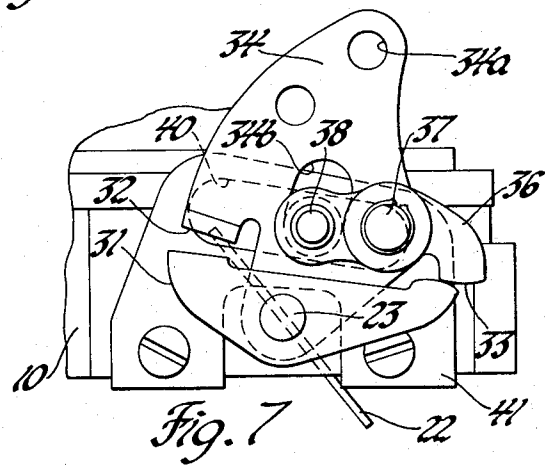
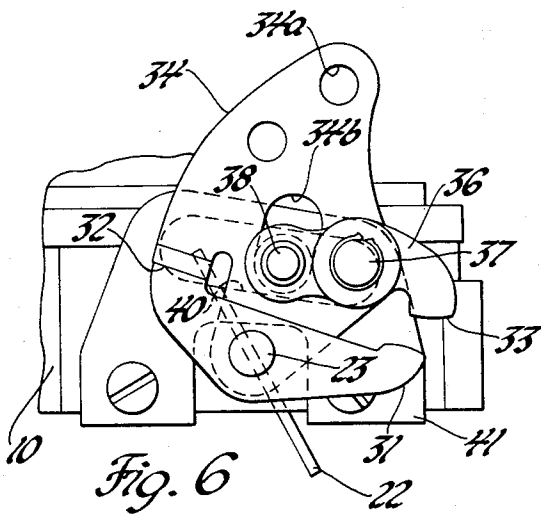
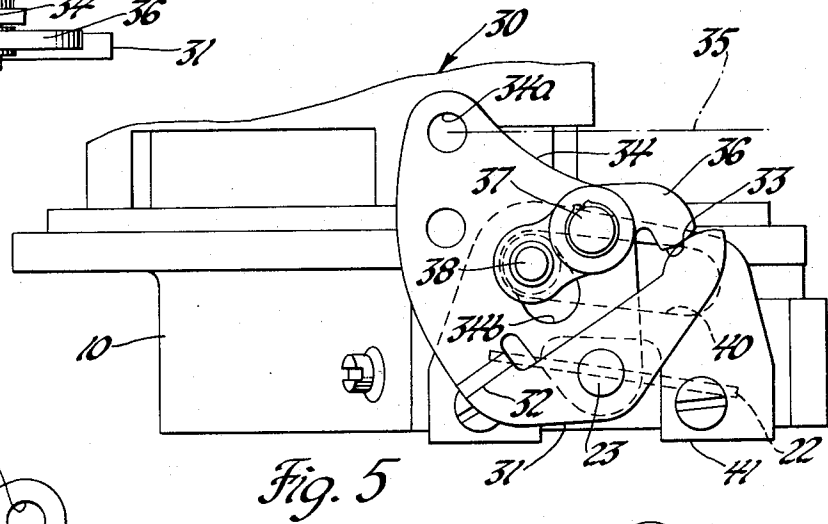
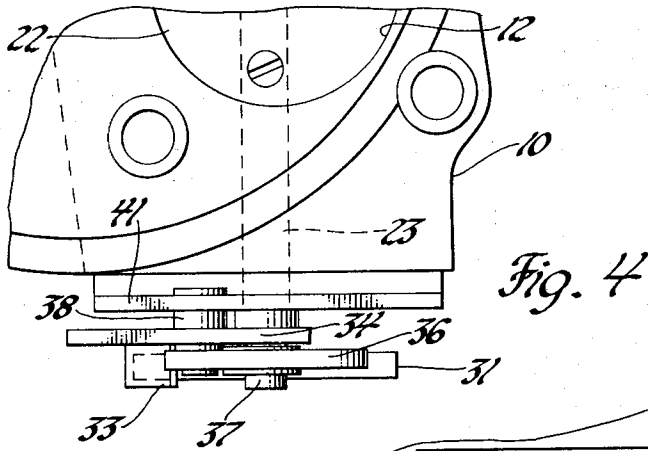
Split engine operation of an internal combustion engine having an electronic fuel injection system is effected automatically from four to eight and back to four cylinder operation in compliance with the engine load by a charge forming device having individual throttle valve controlled induction passages supplying air through a divided header type intake manifold to four of the engine cylinders, a throttle valve positioning device controlling throttle valve opening as a function of four cylinder or eight cylinder engine operation. Manifold vacuum is used to sense the engine mode shift point and causes a spoiler valve to open to provide wide open throttle operation of the unloaded cylinders and also to interrupt the triggering impulses to the fuel injection nozzle of the unloaded cylinders.

7 Claims, 8 Drawing Figures









SPLIT ENGINE OPERATION

This invention relates to an internal combustion engine control system and, in particular, to a charge forming device to effect split engine operation whereby the engine will operate on less than all of its cylinders under normal or light load conditions but in which full engine operation is effected when the engine load exceeds a predetermined value.

A split engine and its basic operation has previously been disclosed in U.S. Pat. No. 2,954,022 issued Sept. 27, 1960 to Stanley H. Mick. As explained in the afore-noted patent, it has been found that considerable economies can be realized when it is possible to resort to split engine operation, for example being able to operate an eight cylinder engine on four cylinders under moderate load conditions. The economy is effected by the fact that individual cylinder efficiency is increased when the individual cylinder load is increased during split engine operation in contrast to reduced cylinder loads as occurs with full engine operation during light or moderate load conditions.

It is an inherent characteristic of an internal combustion engine to be most efficient under high load conditions. This is attributable to the quantity of air fed to the cylinders. Maximum air is supplied to the cylinders when the throttle is open, indicative of high load, therefore, more air may be compressed in turn increasing the compression ratio. Since engine efficiency increases with compression pressure and compression pressure increases with cylinder load, the desirability of split or part cylinder engine operation as a means for maintaining high cylinder loads becomes apparent. However, previous systems to effect such split engine operation have been overly complicated.

Accordingly, it is the primary object of this invention to provide a split engine operating system with a simple charge forming device adapted to automatically shift engine operation between four to eight cylinder operation as a function of engine load.

Another object of this invention is to provide a split engine operation system in which manifold vacuum is used to sense the engine operation mode shift point to effect opening of a spoiler valve to provide wide open throttle operation of the unloaded cylinders of the engine and to interrupt the triggering impulses to the fuel injection nozzle of the unloaded cylinders.

These and other objects of the invention are attained by means of a charge forming device having separate throttle controlled induction systems for each half of the cylinders of an engine with a throttle blade angle positioning device to correct throttle blade positioning when the engine shifts between a split engine operation and full engine operation, a manifold pressure responsive spoiler valve arrangement being used to supply air to the unloaded cylinders of the engine during split engine operation.

For a better understanding of the invention, as well as other objects and further features thereof, reference is had to the following detailed description of the invention to be read in connection with the accompanying drawings, wherein:

FIG. 1 is a schematic illustration of a portion of an internal combustion engine showing the induction system with the split engine operation control system in accordance with the invention used to effect automatic

split engine operation, the spoiler valve of this system being shown in the closed position;

FIG. 2 is a top view of the engine charge forming system;

FIG. 3 is an enlarged sectional view taken along line 3—3 of FIG. 2 showing the spoiler valve in open position;

FIG. 4 is a top enlarged view of a portion of the throttle assembly of FIG. 2;

FIGS. 5, 6 and 7 are enlarged side views of the throttle blade angle positioning system showing the position of the elements of this system with the throttle valves closed prior to engine operation, the position of these elements at one-half throttle position during four cylinder mode of operation and, at one-half throttle position during eight cylinder mode of operation, respectively; and,

FIG. 8 is a schematic illustration of a portion of the electronic fuel injection control circuit of the engine.

The invention is described and illustrated with reference to an eight cylinder internal combustion engine, although it is apparent that the invention could be applied to engines having any number of cylinders in excess of one.

It is apparent that alternate firing cylinders should be selected for active or inactive cylinders. In other words, for an eight cylinder engine having a normal firing order of, for example, 1-8-4-3-6-5-7-2-, the active cylinder group can then be, for example, cylinders 1-4-6-7-. Separate air intake passages, throttles, and intake manifold passages are provided for the active and inactive cylinders of the engine.

Referring now to the drawings and specifically to FIGS. 1 and 2, a throttle body 10, having a pair of through bores forming induction passages 11 and 12 therein, is mounted on an intake manifold 14 of the divided header type in which individual air intake passages 15 and 16 are adapted to supply air to each of four of the engine cylinders through individual cylinder intake runner passages 17 and 18, respectively. Throttle valves 21 and 22 are disposed in the induction passages 11 and 12, respectively, and are fixed to a throttle shaft 23 for actuation in a manner to be described.

In the arrangement shown, a group of cylinders and associated air intakes are always "active" whereas the remaining cylinders are normally "inactive" with the latter being activated only after the engine load exceeds a predetermined value. In the embodiment illustrated, induction passage 12, throttle valve 22, intake passage 16 and the four associated cylinder intake runner passages 18 are the active part of the system whereas induction passage 11, throttle valve 21, intake passage 15 and the four associated cylinder intake runner passages 17 constitute the normally inactive part of the system.

Fuel is adapted to be supplied to the cylinders of the engine through fuel injection nozzles 24 and 25, part of a conventional so-called electronic fuel injection system, not shown, since it does not, per se, constitute a part of the present invention. In this electronic circuitry, provision is made for the fuel shut-off to four cylinders, that is the inactive cylinders, and this is accomplished by merely breaking the triggering circuit leading to these four fuel injection nozzles 25 through a control switch in a manner to be described.

During operation of the engine at a four cylinder operation mode, the four unloaded or inactive cylinders

must in effect run with wide open throttle. In accordance with the invention, this is effected by providing an air spoiler port or passage 26 in the throttle body 10 placed in communication via an intake bore 27 in the intake manifold with the intake passage 15 therein, the flow of air therethrough being controlled by a spoiler valve device, generally designated 30, which is actuated in response to intake manifold pressure to the active cylinders of the engine.

As seen most clearly in FIG. 4, the throttle shaft 23 is suitably journaled in the throttle body 10 whereby the throttle shaft extends through the induction passages 11 and 12 with one end of this shaft extending out from the throttle body. The throttle valves 21 and 22, in the form of blades, are fixed to the throttle shaft in offset relation to the center line of the throttle shaft, with the throttle valve 21 offset to the left and the throttle valve 22 offset to the right of the throttle shaft center line, with reference to FIG. 4, the offset of the throttle valve 21 being greater than that of throttle valve 22. With this arrangement during eight cylinder mode of engine operation, induction air passing through both of the induction passages 11 and 12 will cause overbalancing of these throttle valves tending to close them. During four cylinder mode of engine operation, induction air will pass through the spoiler port 26 to the unloaded cylinders and through the induction passage 12 to the loaded cylinders. This will effect overbalancing of the throttle valve 22 in induction passage 12, tending to open this throttle valve.

To maintain the same engine output torque at mode change from four cylinder to eight and back to four cylinder operation for a given throttle setting, the throttle valve blade angles must be corrected automatically. However, the difference between the four cylinder operation throttle valve blade angle and eight cylinder operation throttle valve blade angle is not a constant value. Accordingly, in order to automatically control the varying angular difference in the two blade positions between four cylinder and eight cylinder blade angles, a throttle blade angle positioning device is provided as part of the throttle valve linkage system to control throttle valve opening.

As best seen in FIGS. 4, 5, 6 and 7, the throttle blade angle positioning device includes a throttle shaft lever 31 fixed intermediate its ends to the outboard end of the throttle shaft 23 for rotation therewith. The rotational position of this throttle shaft lever depending on whether the engine is operating on four cylinders or on eight cylinders is effected either by engagement with a fixed stop 32 or by engagement with a movable stop 33. The fixed stop 32 is formed as an integral part of a throttle lever 34 pivotally supported on the throttle shaft inboard of the throttle shaft lever, the throttle lever being provided with an aperture 34A to receive a throttle control link 35 for operation in a conventional manner through an accelerator pedal arrangement, not shown.

The throttle lever 34 also pivotally supports a differentiator lever 36, one arm of which forms the movable stop 33. As shown, the differentiator lever 36 is pivotally supported intermediate its ends on a pivot pin 37 fixed to the throttle lever 34 and is provided on the opposite arm from the movable stop 33 thereon with a cam follower 38 which extends through an elongated slot 34b in the throttle lever 34 into engagement with the cam slot 40 in a cam plate 41 fixed inboard of the

throttle lever to the throttle body 10. To effect engine operation, with reference to FIG. 5, the throttle lever is rotated from the position shown, at closed throttle, in a counterclockwise direction to open the throttle valves to a full throttle position. In the embodiment illustrated, the cam slot 40 is shaped to effect counterclockwise rotation of the differentiator lever as the throttle lever is rotated clockwise from the closed throttle toward full throttle position to vary the effective position of the movable stop as desired.

In order to more clearly understand the operation of the above described throttle blade angle positioning device, the sequence of operation at mode change with the throttle at one-half open throttle position will be described. Assuming that the engine is in a four cylinder mode of operation, the throttle lever 34 having been moved clockwise to effect one-half throttle open setting, the induction air passing through the induction passage 12 produces an opening force on the offset throttle valve 22 rotating the throttle shaft 23 clockwise so as to position the shaft lever 31 in contact with the fixed stop 32 of the throttle lever 34, as seen in FIG. 6, to limit the opening of the throttle valve to this throttle setting. With the throttle lever 34 in the same position, but with the engine then switched over to an eight cylinder mode of operation, the induction air will now pass through both induction passages to produce a closing force, because of the fact that the throttle valves are offset on opposite sides of the throttle shaft to effect rotation of the throttle shaft 23 and shaft lever 31 in a counterclockwise direction from the position shown in FIG. 6 to the position shown in FIG. 7 until the shaft lever 31 comes into contact with the movable stop 33 on the differentiator lever.

It is apparent from the above description that for any angular position of the throttle lever in four cylinder operation, the differentiator lever through the cam arrangement described, will be rotated, as desired, to position the movable stop 33 to produce the correct throttle shaft angle when the shift to eight cylinder mode of operation is made. It will also be apparent at this time that when the engine is running in the eight cylinder mode of operation, with the induction air passing through both induction passages, throttle blade equilibrium cannot be achieved and operation of the throttle valves is then directly controlled by engagement of the movable stop 33 with the shaft lever 31 through operation of the throttle lever 34. With the arrangement described to control throttle valve blade angle, at mode shift, the engine output torque will not change and the shift of the valve blade angle will be effected automatically and with no hesitation.

To effect the wide open throttle condition needed by the unloaded cylinders during four cylinder operation and to provide the proper environment for automatic throttle blade positioning as previously described, the spoiler valve 30 is used to control the flow of air through the spoiler port 26 and is actuated by a differential pressure actuated motor responsive to engine manifold pressure in the active cylinders.

As best seen in FIG. 3, the spoiler valve is provided with a valve element 45 movable from a position seated against the upper surface 10a of the throttle body closing off the spoiler port 26 to a second or unseated position unblocking the passage of air through the spoiler port. As shown, the spoiler valve assembly is formed by an upper piston housing 46 and a lower support hous-

ing 47 with a roll diaphragm 48 sandwiched therebetween. The support housing 47 having a central aperture 47a therethrough is similar to a trivet in that it is provided with three spaced apart legs 47b by means of which it is secured to the throttle body in a suitable manner thereby providing arcuate openings 49 in the side thereof for the ingress of air to the spoiler port 26.

The piston housing is provided with a stepped through bore formed by a lower bore 51 of reduced diameter and an upper enlarged bore 52, the latter being then closed at one end by plug 53. A bushing 54 is positioned within the bore 51 to slidably receive the stem 55 of a cup-shaped piston 56. The piston 56 is positioned on one side of the roll diaphragm with the valve 45 and a retainer washer 57 positioned on the opposite side of the diaphragm and are secured together by means of a nut 58 threaded on a screw fastener 61 threaded into the central threaded bore of the piston stem. The stem 55 of the piston 56 is provided with a radial through bore 62 intersecting the axial bore 63 and of a size to receive a pair of detent balls 64 which are urged radially outward by means of a tapered piston detent 65 biased into engagement with the balls 64 by a spring 66 within the bore, one end of the spring abutting against the screw fastener and the other end against the detent 65. The piston 56 and roll diaphragm 48 are normally biased in a direction so that the valve 45 is seated against the throttle body by means of a piston spring 67.

The piston 56 and diaphragm 48 form with the piston housing 46 a chamber 68 which is in communication with the engine intake manifold pressure of the four active cylinders by means of a passage 71 extending from the chamber 68 in the piston housing 46, a passage 72 extending through one of the legs of the support housing 47, a passage 73 in the throttle body 10 and a passage 74 in the intake manifold extending to an intake runner passage 18.

Operation of the spoiler valve 30 is also used to control the operation of the fuel injection nozzles 25. As shown, a normally opened electrical switch SW-1 is secured to the intake manifold with its actuator in position to be engaged by one end of a rod fixed for movement with the piston as by being secured at its other end to the screw fastener 61. With this arrangement when the piston is up in the position shown in FIG. 3 with the spoiler valve open, the upward movement of the piston to this position pulls the rod out of engagement with the actuator of the switch so that the switch is open, as shown in FIG. 3, whereas when the piston is moved downward, the rod engages the actuator of the switch SW-1 to close this switch. As shown schematically in FIG. 8, the switch SW-1 is connected to the electronic control circuit for the actuation of the fuel injectors, the electronic control A controlling the triggering impulses to fuel injectors 24 and the electronic control B controlling the triggering impulses to fuel injectors 25. With this arrangement, when the spoiler valve is actuated to unseat valve 45 the switch SW-1 is opened, interrupting the triggering impulses to the fuel injectors for the inactive cylinders with the triggering circuit being reinstated when the valve 45 is again closed.

As can be seen in FIG. 2, the spoiler valve 30 is positioned to overlie a portion of the induction passage 11 so that when the valve 45 of the spoiler valve is unseated, air induction will occur through the openings in

the spoiler valve support housing 47 through spoiler port 26 rather than through the induction passage 11 to the inactive cylinders.

As previously described, the chamber 68 in the spoiler valve 30 is subjected to the intake manifold pressure to the active cylinders. With the engine operating during an eight cylinder mode of operation under load, the spoiler valve piston assembly is in a position, down from that shown in FIG. 3, with the valve 45 seated against the upper surface 10a of the throttle body to cover and block air passage through the spoiler port 26. During this mode of operation, the piston spring 67 biases and holds the valve element 45 tightly against its seat on the upper surface of the throttle body.

However, if during this eight cylinder mode of operation the engine load is reduced, the manifold depression increases. When the depression in the manifold has risen to, for example, sixteen inches of mercury, the larger area of the diaphragm and piston assembly exposed to this vacuum pressure within the chamber 68, as compared to the area of this assembly exposed to vacuum pressure through the spoiler port 26, creates a force great enough to retract the diaphragm and piston assembly against the combined force of the piston spring 67 and the suction at the spoiler port 26 tending to hold the valve 45 seated to unseat the valve 45 from the upper surface of the throttle body crisply. The surface of the diaphragm 48 on the side on which the valve 45 is mounted is then exposed to the higher pressure air prior to its induction into the spoiler port 26 so that the diaphragm and piston assembly can rapidly move upward to the position shown in FIG. 3, whereat the detent balls 64 as they clear the upper end of the bushing 54 can move radially outward to engage the detent stops formed by the upper end of this bushing. The high negative pressure in the chamber 68 plus the mechanical detent provided by the detent balls 64 will then hold the piston and diaphragm assembly in the retracted position. As the piston and diaphragm move up, the rod 76 will move out of engagement with the actuator 75 of the switch SW-1 to open the circuit leading to the fuel injectors 25 of the now inactive cylinders.

The engine is now operating in a four cylinder mode of operation. The diaphragm 48 and piston 56 will then remain retracted until the load on the engine, while operating in this four cylinder mode of operation, increases until the manifold pressure to the active cylinders recedes to a predetermined pressure, for example, to 2 inches of mercury. When this occurs, the force of the piston spring 67 will be sufficient to overcome the differential pressure forces acting on the diaphragm and piston assembly and the force of the detent mechanism to now move the diaphragm and piston assembly downward from the position shown in FIG. 3 to seat the valve 45 to block the passage of induction air through the spoiler port 26. As this occurs, the rod 76 is also moved downward to engage the actuator 75 of the switch SW-1 to bring the fuel injection nozzles 25 back into service so that the engine is again operating in an eight cylinder mode of operation.

What is claimed is:

1. A charge forming device for split engine operation of an internal combustion engine having an N number of cylinders supplied by separate fuel injectors, said system comprising, a first air induction system having a first intake passage to N/2 of the cylinders, a second

air induction system including a second intake passage and an air spoiler port to the remaining N/2 cylinders, a throttle shaft journaled to extend through said first and second intake passages, a first throttle valve and a second throttle valve oppositely offset mounted on said throttle shaft for respectively controlling the flow of air through said first intake passage and said second intake passage, an automatic throttle blade angle positioning means connected to said throttle shaft for effecting a throttle valve position angle correction when the engine shifts from between an N/2 cylinder and an N cylinder mode of operation and, a manifold pressure responsive spoiler valve means, responsive to manifold pressure in said first air induction passage downstream of said first throttle valve, positioned to control the flow of air through said spoiler port for shifting the operation of the engine between N/2 cylinder operation and N cylinder operation.

2. A charge forming device for an internal combustion engine having an N number of cylinders supplied by separate fuel injectors comprising, a first induction system having a first intake passage to N/2 of the cylinders, a second air induction system including a second intake passage and an air spoiler port passage to the remaining N/2 cylinders, a throttle shaft journaled in position to extend through said first intake passage and said second intake passage, a first throttle valve and a second throttle valve mounted on said throttle shaft for respectively controlling the flow of air through said first intake passage and said second intake passage, throttle valve angle positioning means operatively connected to said throttle shaft for automatically positioning said first throttle valve and said second throttle valve when the engine shifts between an N/2 cylinder mode of operation and an N cylinder mode of operation, a pressure responsive spoiler valve means, responsive to manifold pressure in said first air induction passage downstream of said first throttle valve, positioned to control the flow of air through said spoiler port passage and, means actuated by said pressure responsive spoiler valve means to control the operation of the fuel injectors to said remaining N cylinders.

3. A charge forming device according to claim 2 wherein said throttle valve angle positioning means includes a lever fixed to said throttle shaft and a throttle

lever means pivotally supported relative to said throttle shaft and having a fixed stop thereon positioned for engagement with said lever and a movable stop positioned for engagement with said lever.

4. A charge forming device according to claim 3 wherein said throttle lever means includes a throttle lever pivotally supported relative to said throttle shaft and having said fixed stop thereon, a differentiator lever pivotally mounted on said throttle lever and forming said movable stop, a fixed cam means and, a cam follower mounted on said differentiator lever for engagement with said cam means to effect pivotal movement of said differentiator lever on said throttle lever upon pivotal movement of said throttle lever.

5. A charge forming device according to claim 2 wherein said pressure responsive spoiler valve means includes a valve means movable from a first position blocking the flow of air through said spoiler port passage to a second position unblocking said spoiler port passage, spring means operatively connected to said valve means to normally bias said valve means to said first position, and manifold pressure responsive actuator means operatively connected to said valve means to effect movement of said valve means from said first position to said second position.

6. A charge forming device according to claim 5 wherein said pressure responsive spoiler valve means includes a housing and wherein said manifold pressure responsive actuator means includes a diaphragm and piston assembly mounted in said housing and forming therewith a chamber, means connecting said chamber to said first air induction passage downstream of said first throttle valve and, spring biased detent means associated with said diaphragm and piston assembly and with said housing to releasably retain said valve means in said second position.

7. A charge forming device according to claim 5 wherein said means actuated by said pressure responsive spoiler valve means is operatively connected to said valve means for interrupting the operation of the fuel injectors to said remaining N/2 cylinders when said valve means is moved from said first position to said second position.

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