

PATENT SPECIFICATION

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(54) ADJUSTABLE ROTARY VALVE TIMING APPARATUS FOR AN INTERNAL COMBUSTION ENGINE

(71) We, DANA CORPORATION, a corporation organized and existing under the laws of the State of Virginia, United States of America, of 4500 Dorr Street, Toledo, Ohio 43615, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a rotary valve system for internal combustion engines, the system being capable of varying timing.

The basic structure and many advantages of rotary intake and exhaust valves for internal combustion engines are well known. The principle advantages are in the areas of maintenance and dependability, cost, ease of assembly, and engine size and weight.

In a typical internal combustion engine, engine efficiency is compromised by the provision of fixed valve timing and duration. This is true of conventional camshaft engines and also typical rotary valve systems. The valve opening specification for a given engine is chosen for average engine load and speed conditions expected. A compromise thus results in that the engine is rendered much less efficient at differing engine conditions than would be the case if optimum valve settings could be employed for such differing conditions. Typically, valve overlap is too great at low engine r.p.m., and not sufficient at high r.p.m. and high power output, due to well known variations in the effects of charge momentum under varying conditions.

Various apparatus have been suggested for providing adjustable valve timing in connection with rotary valves. One such arrangement involves the use of blocking devices which may be added to or subtracted from the port opening leading

into the valve rotor from either the intake of the exhaust manifold. Depending on the positioning of the blocking devices, the port may be modified to advance, retard, and/or modify the duration of the valve-open period. Of course this modification can only be made when the rotary valve assembly is dismantled.

Another suggested adjustable valve timing apparatus involves the use of an adjustable sleeve in the rotor housing in the position of the manifold side port. The sleeve, which includes an opening serving as the port, is circumferentially movable with respect to the valve rotor, so that the position of valve opening and closing can be varied and valve timing is accordingly adjusted. The timing can actually be adjusted during operation of the engine, in response to changing conditions, thereby somewhat broadening the optimum efficiency ranges of the engine in which the system is incorporated. However, besides presenting maintenance problems due to the complexity of the apparatus at the manifold side housing port, this type adjustable valve timing does not provide for adjustment of the duration of valve opening. Thus under conditions when it would be desirable to have a certain degree of valve overlap around top dead centre piston position, and another degree of valve overlap around bottom dead centre, these specific requirements cannot be met and engine efficiency is reduced.

In accordance with the invention, an adjustable valve timing apparatus for an internal combustion engine having at least one combustion chamber, comprises a valve housing defining a housing port which is arranged, in use, to be in open communication with the combustion chamber, the housing port having leading and trailing edges, a generally cylindrical driven valve rotor within the valve housing,

at least one open passageway through the rotor and defining opposed open rotor ports for registry with the housing port upon rotation of the valve rotor, each of the rotor ports having leading and trailing edges for moving over the leading and trailing edges respectively of the housing port to provide initial valve opening and final valve closing respectively, at least a portion of one of the leading and trailing edges of at least one of the ports being inclined with respect to the axial direction and means adjacent to the housing for shifting the relative axial positions of the housing and the rotor during rotation of the rotor to adjust valve timing.

The adjustable valve timing apparatus thus includes valve rotors which are axially movable in their housings during operation of the engine. The ports in either the housing, the rotor itself, or both include leading and trailing edges which are inclined with respect to the axis of the rotor. These edges in conjunction with axial movement of the rotor provide for variation in valve opening timing, valve closing timing and preferably also duration of valve opening. Relative axial movement between the ports of the housing and of the rotor shifts the rotor position at which initial opening of the valve occurs, as well as rotor position at which completion of valve closing occurs. Valve duration may be varied along with timing, so that for a given valve timing, there is a corresponding valve duration which would be desirable for selected timing.

In a preferred construction, the cooperating ports of both the rotor and the housing have inclined leading and trailing edges, each port generally assuming the shape of a triangle oppositely oriented with respect to the axial direction. The leading edges of both ports are parallel, when in registry, and the trailing edges of both are parallel, when in registry, providing for abrupt and complete opening and closing of the valve, rather than a gradual decrease in area of the valve during opening or closing.

For adjustment of the axial position of the valve rotor during operation of the engine, an actuator system may be connected to a rotor corresponding to a bank of firing cylinders. The actuator system takes into account both engine speed and engine power output requirements, the latter typically being determined by vacuum measurement, in selecting and setting the optimum valve timing and duration for the sensed condition. Both intake and exhaust valve rotors can be controlled as to timing and duration by axial movement effected by the actuator system. The actuator system may employ various forms of known sensing and

control apparatus, and the specific components of such apparatus do not form a part of the invention.

The adjustable rotary valve system may be advantageously employed in almost any type of internal combustion engine, including stratified charge engines, engines operating on a two-stroke cycle and diesel engines. Any such engine realizes better fuel economy by the application of the present invention, due to the use of the optimum combustion cycle for each engine condition. Undesirable engine emissions are also greatly reduced by the adjustable valve system, particularly at low engine r.p.m. and idle in a typical internal combustion engine. An additional benefit of the system is reduced engine noise. Particularly at engine idle, where the present system retards valve timing, reduces valve opening area and provides minimum valve opening duration, unlike standard cam engines, combustion noise is significantly diminished.

An engine with two alternative examples of valve timing apparatus in accordance with the invention is illustrated in the accompanying drawings, in which:—

Figure 1 is an elevational cross sectional view showing a portion of the internal combustion engine including the rotary valve system;

Figure 2 is an enlarged sectional view showing a valve rotor and rotor housing, with the valve in the open position;

Figures 3 and 4 and 5, are schematic representations showing the adjustable valve assembly in a position of maximum advance, the figures demonstrating the progression of the rotor port across the housing port;

Figure 6 is a graphic representation of the advanced timing condition;

Figures 7, 8 and 9 are further schematic representations demonstrating the progression of the rotor port across the housing port when the valve timing is in its maximum retarded position;

Figure 10 is a graphic representation similar to that of Figure 6 but illustrating the maximum retarded condition;

Figure 11 is a view showing an alternative rotor port configuration;

Figures 12, 13 and 14 are views similar to Figures 3, 4 and 5, at maximum valve timing advance, but showing the alternative rotor port configuration of Figure 11 and a corresponding housing port configuration;

Figures 15, 16 and 17 are views similar to Figures 12, 13 and 14 but with valve timing at maximum retarded position;

Figures 18 and 19 are graphic representations showing valve overlap of intake and exhaust valves at maximum

advance and at maximum retard, respectively; and,

Figure 20 is a schematic representation of a valve timing adjustment actuator system which shifts the position of the valve rotor during operation of the engine.

In the drawings, Figure 1 shows in cross section a portion of an internal combustion engine 10 including rotary valves 11 and 12 for intake and exhaust, respectively. The valves 11 and 12 include valve housings 13 and 14, each having first and second openings 16 and 17. The first openings 16 are aligned with and in communication with conduits 18 and 19 connected to the intake manifold and the exhaust manifold (neither shown), respectively, while the openings 17 are in communication with a combustion chamber 15 as shown. As will be seen below, one of the ports 16 or 17 on each valve 11 and 12, preferably the port 17, has leading and trailing edges which are angled with respect to the axis of the cylindrical housings 13 or 14. Rotatable and axially movable within the stationary housings 13 and 14 are valve rotors 21 and 22. Each rotor may be designed to rotate in either direction, but it will be assumed in this preferred embodiment that both rotors 21 and 22 rotate clockwise as viewed in Figure 1.

The rotary valve assemblies 11 and 12 may include side seals 20, end seals (not shown) and bearings (not shown).

Each of the valve rotors 21 and 22 includes a generally diametric through passageway 23 defining similarly shaped rotor ports 24 at either end of the passageway. In Figure 1 the intake rotor 21 is shown with a leading edge 24a of one of its ports 24 in alignment with a leading edge 17a of the housing port 17. The opposite intake rotor port 24 has already reached the housing port 16, since at this end of the housing the point at which the ports of the rotor and the housing meet is not critical. In this preferred embodiment, these manifold side ports are sized and positioned to be open whenever the combustion side ports are open, so that valved timing and duration is controlled solely by the interaction between the combustion side housing port 16 and the rotor port 24. It is to be understood that the timing and duration could be controlled at the manifold side ports as well. Thus, in Figure 1 the intake valve 11 is at the point of initial opening. Similarly, on the other side of the combustion chamber 15, the exhaust valve 12 is just about to close. This corresponds to the fact that even at the maximum retarded position of the adjustable valve system, there is preferably a slight overlap between intake opening and exhaust closing. As shown in Figure 1, a crankshaft

25 and a piston 26 associated with the intake and exhaust valves 11 and 12 are approximately at top dead centre position. The actual piston position is slightly below (prior to) top dead centre, since both valves are slightly open at top dead centre in accordance with the valve overlap.

Figure 2 shows one of the intake and exhaust rotary valve assemblies 11 and 12 in an enlarged cross sectional view. Although the discussion below applies to either valve, the valve shown in Figure 2 may be assumed to be the intake valve 11, and the discussion focuses on the intake valve. The rotor port 24 and rotor housing port 17 are shown such that the timing and duration of the valve assembly 11 are at the maximum retarded position.

Figures 3 to 5 and Figures 7 to 9 diagrammatically indicate various relative positions of the housing port 17 and the rotor port 24 as the rotor port progresses to the right in the figures. The valve rotor, which is axially movable in the housing as discussed above, is represented in the maximum advance position in Figures 3 to 5 and in the maximum retarded position in Figures 7 through 9.

Figures 6 and 10 graphically show the crankshaft angles through which the valve 11 is open at maximum timing advance and maximum timing retard, respectively. The upper vertical radial lines 31 represent top dead centre piston position, so that the vertical radial lines 32 represent bottom dead centre piston position, so that the difference between the two positions is 180° of the crankshaft, with a total of 360° of the crankshaft depicted. At maximum advance, the valve may open in the neighborhood of 30 crankshaft degrees prior to top dead centre, and remain open through approximately 60 crankshaft degrees beyond bottom dead centre. As Figure 10 indicates, valve opening and closing are only a few degrees before and after top dead centre and bottom dead centre, respectively, when valve timing is in the maximum retarded position. It should be noted that one full revolution of the crankshaft corresponds to only one-quarter revolution of the intake and exhaust valves 11 and 12 for the four-stroke cycle engine 10 depicted in Figure 1. In a half revolution of the valve rotor 21 of the intake valve 11, for example, the engine has completed an entire cycle, since the rotor 21 has returned to a similar position, the two opposed ports 24 of the rotor 21 being identical.

The rotor housing port 17 of Figures 3 to 5 and Figures 7 to 9 includes a first generally rectangular portion 33 having leading and trailing edges 33a and 33b parallel to the axis 36 of the rotor, and a second portion 34 having angled leading

and trailing edges 34a and 34b. Both these edges angle outwardly from the rectangular portion 33, with the leading edge 34a angling gently and the trailing edge 34b angling more sharply as will be further described below. This puts the trailing edge of the port area 34 more remote from the main rectangular area 33 than is the leading edge 34a. As explained below, this corresponds to the fact that when valve timing is "advanced" (the term as used herein implies earlier valve opening and later valve closing), the delay in valve closing beyond bottom dead centre is greater than the lead in valve opening before top dead centre. This concept, illustrating in Figure 6, is well known in the art as advantageous under conditions requiring valve timing advance and has in fact been reflected in the design of conventional camshafts.

Figures 3, 4 and 5 demonstrate the progression of the rotor port 24 from the point of initial valve opening to the point of final valve closure, at the maximum advanced setting. Figure 6 shows the valve-open crankshaft angle represented by this setting. As can be seen by the Figures, the initial portion of valve opening occurs gradually along the leading edge 34a of the port 16, with the open area increasing from a small triangle to a larger triangle at the point where the leading edge 24a of the rotor port meets the leading edge 33a of the rectangular portion 33 of the housing port 17. Similarly, when the valve is closing, the open area is a diminishing triangle due to the interaction of the angled trailing edges 24b and 34b, so that the valve closes gradually.

Figures 7, 8 and 9 illustrate the progression of the rotor port 24 across the housing port 17 from the point of valve opening to the point of valve closing, with the valve timing at its maximum retarded setting. The rotor port 24 is axially shifted to the maximum extent possible from its position shown in Figures 3, 4 and 5. As Figure 7 illustrates, when compared with Figure 3 above, the point of valve opening is now farther along in the travel of the rotor and thus later in time. Similarly, Figures 9 and 5 show that the point of valve closure is considerably earlier in time. As Figure 10 demonstrates, valve opening and closing now occur close to top dead centre and bottom dead centre crank shaft positions, respectively, resulting in a considerably shorter valve-open duration. Figures 7, 8 and 9 also show that valve opening and closing is now more abrupt, since only the rectangular area 33 of the housing port 17 is involved. The maximum valve opening area is also considerably reduced, as seen by a comparison of

Figures 8 and 4. This is desirable in that, as will be seen below, valve timing positions toward maximum retard correspond to low engine load and r.p.m. conditions wherein the size of the valve opening can and should be small, because of low fuel requirements.

It can easily be seen from Figures 3 to 5 and Figures 7 to 9 that axial positions of the rotor port 24 intermediate the maximum position shown in the two groups of Figures will result in intermediate settings of valve timing and duration, because of the inclination of the leading and trailing edges 34a and 34b of the housing port 17.

Figures 11 to 17 relate to a second and preferred embodiment of the adjustable rotary valve timing apparatus. These Figures depict a rotor 21' having a through passageway defining ports 24' of a generally triangular shape. The ports 24' each include a leading edge 24a' which is inclined at a small angle to the axis 36 of the rotor. A trailing edge 24b' of each port is inclined at a greater angle to the axis 36.

As shown in Figures 12 through 17, the modified apparatus includes a generally triangular shaped housing port 17' complementary to the rotor port 24'. Leading edges 17a' and 24a' of the housing port and the rotor port, respectively, are parallel, as are trailing edges 17b' and 24b'. Figures 12 through 14 show the progression of the rotor port 24' across the housing port 17', from the point of opening to the point of closure of the valve, with the valve timing set at maximum advance position. Figures 15 through 17 show the corresponding progression when the valve rotor 21' has been shifted to its maximum retard position. The views thus show the same progression as that of Figures 3 to 5 and Figures 7 to 9, and the graphical representations of Figures 6 and 10 apply also to Figures 12 to 14 and Figures 15 to 17, respectively.

As is demonstrated by the drawings, the axial shifting of the relative positions of the triangular ports 24' and 17' varies the timing of the opening and closing of the valve similarly to the ports discussed above. Similarly, a smaller valve opening area is produced at maximum retard, as shown in Figure 16. In fact, the ports 17 and 24 and the ports 17' and 24' are designed to produce the same effect on valve timing and duration, the effect being illustrated in Figures 6 and 10.

The triangular ports are preferred because they provide for an abrupt and uniform opening and closing of the valve. This is because, as discussed above, the leading edges of the cooperating ports are parallel and the trailing edges are also parallel. Thus, the valve opens along a line which runs the entire length of the resulting

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5 valve opening area, as shown in Figures 12 and 15, rather than gradually as with the first embodiment discussed above. The shape of the resulting opening is roughly that of a shifting parallelogram, except that the ports may have rounded corners as illustrated.

10 The shape of the triangular openings of the lower housing port 17' and the rotor ports 24' of the preferred embodiment is determined by the several factors which affect engine design. Thus, projected engine load fuel requirements and engine speed will affect the port design.

15 If, for example, the projected engine demand requires a range of intake valve timing which is variable from a minimum retarded condition (opening at a point near top dead centre at the beginning of the piston intake stroke) to one of maximum advance (opening before the piston reaches top dead centre), the slope of the leading edges 17a' and 24a' of the ports 17' and 24' must be relatively steep, away from a centreline C' of these ports.

20 Thus, the greater the angle between the centreline C' and the leading edges 17a' and 24a', the more the timing of the valve can be "advanced" (to open sooner) upon maximum shifting of the intake rotor 21 in its housing 13 as explained above. Similarly, the greater the angle between the trailing edges 24b' and 17b', the longer duration of valve opening can be imparted upon maximum shifting of the rotor 21'. The same is true with respect to timing the exhaust port.

25 Likewise, any intermediate timing to be afforded either the intake or exhaust ports 24' are determined by the angular relationship between the centreline C' and the points along the leading and trailing edges which first respectively "open" the valve and then "close" the valve depending on the amount of axial shifting of the rotor 21 or 22. The shape of the ports illustrated in Figures 3 to 5 and 7 to 10 is similarly determined.

30 Figures 18 and 19 are diagrams illustrating valve overlap. Figure 18 shows valve overlap at maximum advance, while Figure 19 shows overlap at maximum retard, for both types of valve ports described above. Upper and lower vertical radial lines 38 and 39 represent top dead centre and bottom dead centre piston positions, respectively, as indicated. Outer arcs 41a and 41r represent the crankshaft angles through which the intake valve is open, while inner arcs 42a and 42r represent the crankshaft angles through which the exhaust valve is open. As in Figures 6 and 7 discussed above, the direction of the crankshaft travel is assumed to be clockwise in these diagrams,

70 which are representative of a standard format well known in the internal combustion engine art for depicting valve overlap. The overlap of the intake and exhaust arcs at the top of the diagrams, in the vicinity of top dead centre piston position, represent actual periods when the intake and exhaust valves of a firing cylinder are both open. However, the apparent overlap around bottom dead center piston position does not represent a period when both valves are open. Two full revolutions of the crankshaft comprise a cycle in a four-stroke cycle engine, so that while the bottom dead centre position for the intake arcs 41a and 41r represents bottom dead centre at the end of the intake stroke, bottom dead centre position for the exhaust arcs 42a and 42r represents the beginning of the exhaust stroke, which does not immediately follow the intake stroke but is 360° later. As Figures 18 and 19 indicate, the intake and exhaust arcs may be symmetrical, i.e., intake opening may precede top dead centre by the same angle that exhaust closing follows top dead centre, and likewise for intake closing and exhaust opening with respect to bottom dead centre.

75 Figure 20 schematically indicates a valve timing actuator system 45 which may be employed in connection with the adjustable valve timing and duration system. The valve housing 13 with its port 17 is indicated, with the port 24 of the axially movable rotor 21 shown at maximum advance and maximum retard positions, as indicated by the diagrams 46 and 47, respectively. At the end of the rotor 21 may be a pulley 48 with a timing belt 49 driven in timed relationship with the engine 10, connecting with a second pulley 50 extending from a shaft 51 of an actuator control 52. The actuator control is capable of shifting the pulley 50 axially to any position between the two positions indicated in Figure 20. Such movement of the pulley 50, while it and the rotor pulley 48 are rotating, will move the pulley 48 and rotor 21 along with the actuator pulley 50. However, a rigid connecting link 56 having a bearing connections 57 and 58 to the actuator shaft 51 and to a shaft 59 extending from the rotor 21 may be provided for positive control of the rotor 21.

80 As shown in Figure 1, the timing belt 49 may extend from the actuator pulley 50 around both the intake rotor pulley 48 and an exhaust rotor pulley 53, so that intake and exhaust timing are both controlled by the actuator control 52. Rigid connecting links (not shown) such as the link 56 may extend from the actuator shaft to both rotors. The timing belt and pulleys are shown for illustrative purposes only; any

suitable drive means and any suitable axial shifting mechanism may be used, and they may be either integral or separate.

5 The internal mechanism of the actuator control 52 may comprise any suitable and well known actuator apparatus. The actuator is rotationally driven by the crankshaft, since the speeds of the actuator and of the valve rotor 21 must always be proportional to that of the crankshaft. Connection may be by spline (not shown), so that the actuator can receive and deliver rotary motion while its shaft 51 is shifted axially. The shifting mechanism may be driven by pneumatic, hydraulic, electric or purely mechanical apparatus.

10 The actuator control 52 is governed in its shifting function by a processor 54 which senses both engine speed and manifold vacuum (to determine power output) and sends the appropriate signal to the actuator control 52. The exemplary chart 55 shown associated with the processor 54 illustrates how the processor utilizes engine speed and manifold vacuum data to determine the proper signal to be sent to the actuator control 52. The scales and values on the chart are only examples and will vary with different engines. The horizontal scale on the chart represents manifold vacuum in inches of mercury, while the vertical scale represents the extent of valve timing advance. The family of oblique lines represents engine r.p.m. as indicated. Valve timing may be varied between the line indicating maximum retard to the uppermost line indicating maximum advance. Note that all engine speed lines are dashed below the maximum retard line, since no further retardation occurs. The entire 500 r.p.m. line lies below maximum retard.

15 If, for example, engine load produces a manifold vacuum of 10 inches of mercury and engine speed is 3000 r.p.m., the processor 54 would select a timing setting approximately corresponding to the middle setting graphically indicated at the right of the chart 55. As the chart indicates, at the highest values of manifold vacuum (minimum engine load), valve timing is at maximum retard, regardless of engine speed. Similarly, at minimum engine speed, the timing is at maximum retard, regardless of engine loading.

20 The processor 54 which governs the actuator control 52 according to engine speed and load and the formula graphically illustrated by the chart 55 may utilize any of a variety of types of apparatus capable of receiving a plurality of variables, processing the variables according to a predetermined formula, and sending a variable signal to a controller in accordance with the formula.

65 It should be understood that various

aspects of the preferred embodiments described above may be altered or re-arranged without affecting the operation of the adjustable valve timing system. The shaped ports can be located in the rotor itself rather than in the housing, in the case of the embodiment of Figures 3 to 9 described above. In the embodiment of Figures 12 to 17, of course, the shaped ports are located in both the housing and the rotor. In the case of either embodiment, the shaped ports of the rotor housing can be located at the manifold side of the housing rather than at the combustion side. These shaped ports can also be provided at both locations in the housing.

70 The adjustable valve timing and duration apparatus can also be employed in diesel engines. Although fuel is injected into the combustion cylinders of such an engine, the air which enters the combustion chambers through valves can be routed through adjustable rotary valves as with the fuel-air charge discussed above. Similarly, the exhaust valves can be adjustable rotary valves. The operation of the diesel is subject to the same considerations discussed above, including factors related to variations in charge (air) velocity and momentum, so that dynamic adjustment of the valve timing and duration of both the intake and exhaust valves can result in the elimination of timing compromise and a corresponding increase in engine efficiency.

80 The apparatus of the invention can also be used in connection with two-stroke cycle engines, wherein dynamic adjustment of timing and duration has the same advantageous effects.

WHAT WE CLAIM IS:—

1. An adjustable valve timing apparatus for an internal combustion engine having at least one combustion chamber, the apparatus comprising a valve housing defining a housing port which is arranged, in use, to be in open communication with the combustion chamber, the housing port having leading and trailing edges, a generally cylindrical driven valve rotor within the valve housing, at least one open passageway through the rotor and defining opposed, open rotor ports for registry with the housing port upon rotation of the valve rotor, each of the rotor ports having leading and trailing edges for moving over the leading and trailing edges respectively of the housing port to provide initial valve opening and final valve closing respectively, at least a portion of one of the leading and trailing edges of at least one of the ports being inclined with respect to the axial direction, and means adjacent to the housing for shifting the relative axial

positions of the housing and the rotor during rotation of the rotor to adjust valve timing.

5 2. An apparatus according to Claim 1, wherein at least a portion of each of the leading and trailing edges of the housing port is inclined with respect to the axial direction.

10 3. An apparatus according to Claim 1 or Claim 2, wherein at least a portion of each of the leading and trailing edges of the rotor ports is inclined with respect to the axial direction.

15 4. An apparatus according to Claims 2 and 3, wherein the inclinations of the leading edges of each rotor port and the leading edge of the housing port are similar to one another when the leading edges are in registry and the inclination of the trailing edge of each rotor port and the trailing edge of the housing port are similar to one another when the trailing edges are in registry.

25 5. An apparatus according to Claim 4, wherein the leading and trailing edges of the housing port are inclined to define opposite sides of a first triangle and the leading and trailing edges of each rotor port define opposite sides of a second triangle

30 which is similar to the first triangle and which is inversely oriented in the axial direction with respect to the first triangle whereby the leading edges are parallel when the leading edges are in registry and the trailing edges are parallel when the trailing edges are in registry.

35 6. An apparatus according to any one of the preceding Claims, wherein the means for shifting the relative axial positions of the rotor and housing includes drive belt means for shifting the rotor within the housing which is arranged to be stationary with respect to the combustion chamber.

40 7. An apparatus according to Claim 1, substantially as described with reference to either one of the examples illustrated in the accompanying drawings.

45 8. An internal combustion engine having at least one combustion chamber provided with a valve timing apparatus according to 50 any one of the preceding Claims.

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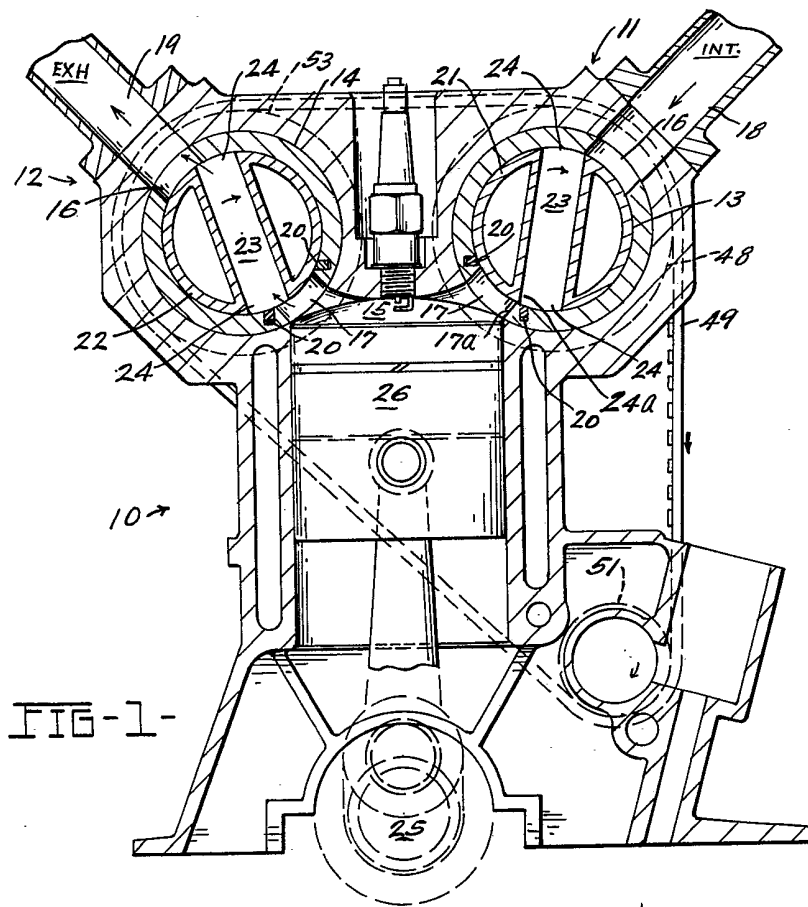


FIG-1-

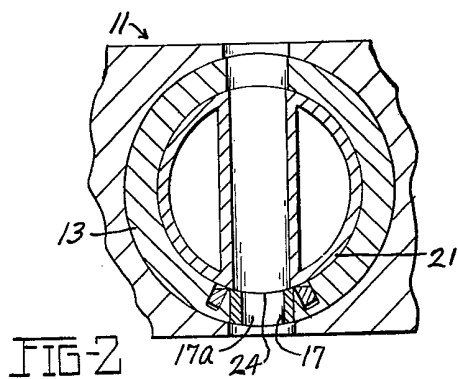


FIG-2

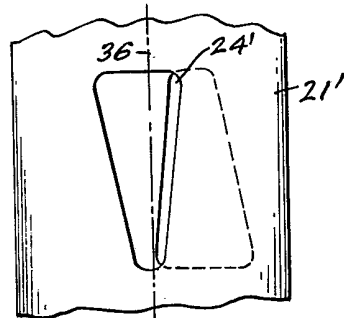


FIG-11-

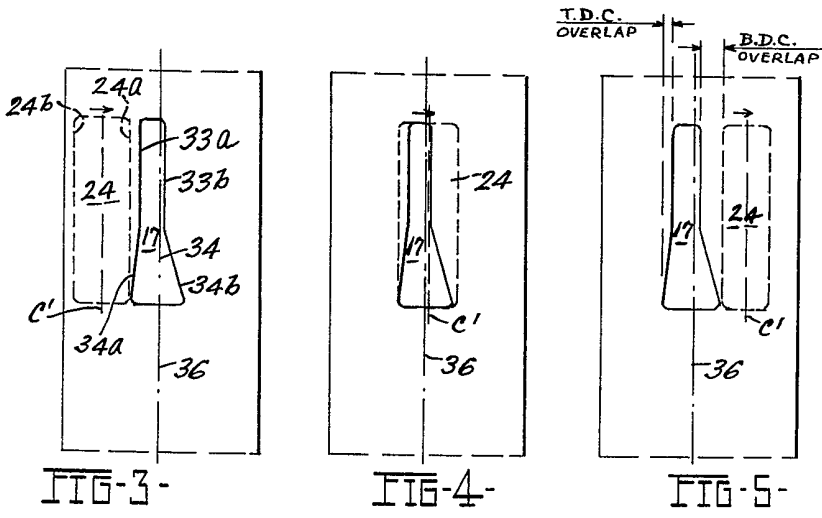


FIG-3-

FIG-4-

FIG-5-

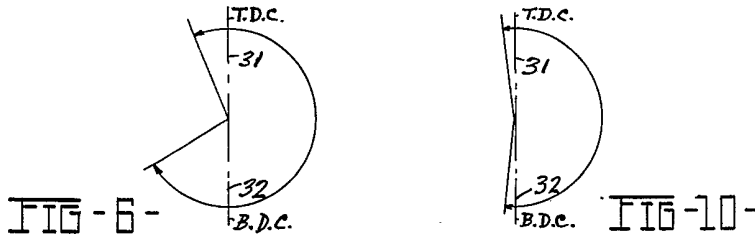


FIG-6-

FIG-10-

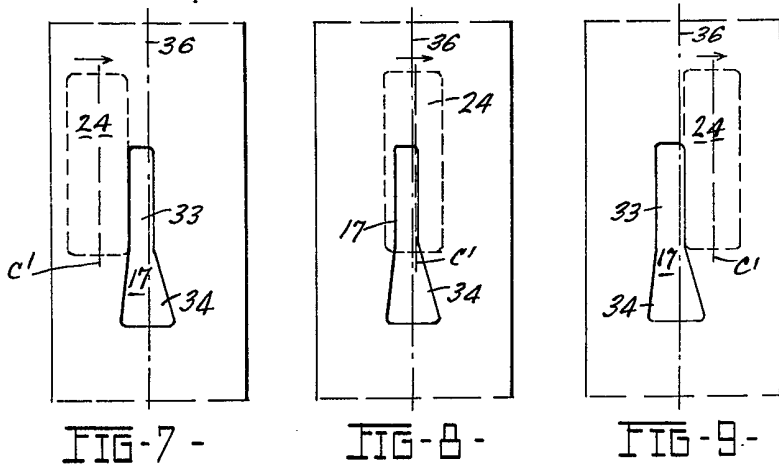


FIG-7-

FIG-8-

FIG-9-

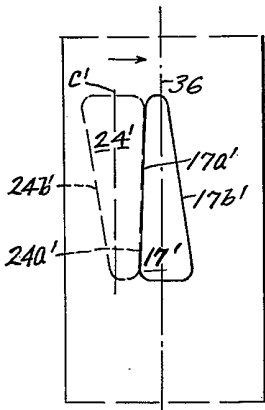


FIG-12-

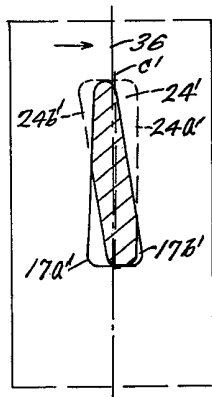


FIG-13-

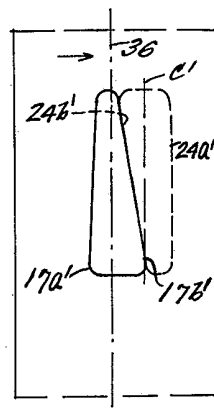


FIG-14-

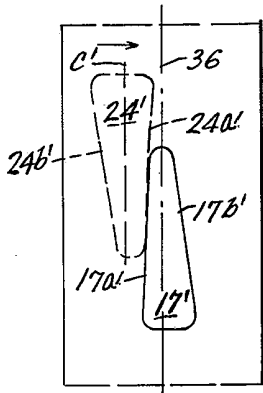


FIG-15-

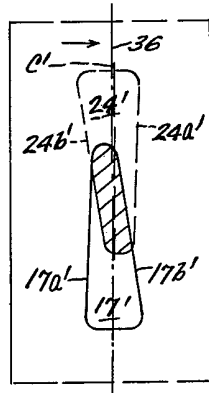


FIG-16-

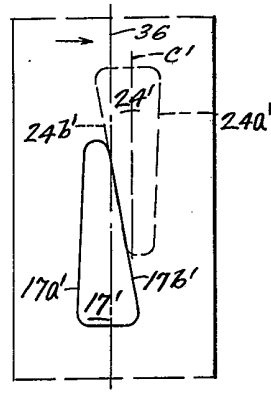


FIG-17-

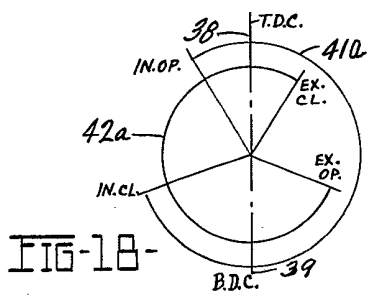


FIG-18-

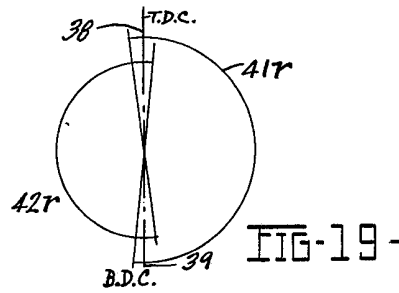


FIG-19-

