The invention relates to a system for maintaining a fully dephased relationship between the two sides of a siamezed free piston gasifier unit or between two separate gasifiers. It is particularly desirable to maintain substantially a 180 degree phase relationship in a siamezed machine of the inward compression type since the pumping work of the compressors is then reduced by having the scavenging ports of one gasifier side open during the delivery cycle of the other gasifier side. The magnitude of the inlet and exhaust pulsations is reduced and the frequency is doubled for both types of engines. It also permits a more equal loading of each of the gasifiers.

The invention is embodied in a system utilizing a valve operated by oscillating bounce pressures in the gasifiers in such a manner as to transfer bounce air from the bounce chamber system of one gasifier unit to the other in a siamezed free piston gasifier, or between the bounce chamber systems of two entirely separate gasifiers.

In the drawings:
FIGURE 1 is a schematic presentation of a free piston engine system having two gasifiers and illustrating a dephaser system embodying the invention;
FIGURE 2 is a pressure and valve displacement vs. time curve in the system of FIGURE 1 when one of the gasifiers is leading its position by 60 degrees;
FIGURE 3 is a schematic illustration similar to FIGURE 1 and showing a modification of the dephaser system; and
FIGURE 4 is a pressure and valve displacement vs. time curve illustrating the system condition of the system of FIGURE 3 when one of the gasifiers is leading its position by 60 degrees.

The schematic illustrations in FIGURES 1 and 3 have been considerably simplified and do not purport to illustrate details of gasifiers not relevant to the invention. FIGURE 1 illustrates two separate gasifiers while FIGURE 3 illustrates a pair of siamezed gasifiers. It is understood that either of the dephaser systems shown in these figures may be used with either arrangement.

Referring more particularly to FIGURE 1, the gasifiers 10 and 12 have engine cases 14 and 16 defining case chambers 18 and 20, compressor chambers 22, 24, 26 and 28, bounce chambers 30, 32, 34 and 36, and combustion chambers 40 and 42. Bounce chamber balance lines 44 and 44, respectively, connect bounce chambers 30 and 32, 34 and 36. Piston assemblies 22, 24, 26, 28, and 29 are received in the cases 14 and 16 and define walls of the respective bounce, compressor and combustion chambers. Each piston assembly includes a firing piston section 54 and a compressor piston section 56. As is common in the art, the firing piston sections 54 are reciprocally received in the case cylinder liners 58 forming the side walls of the combustion chambers, and the compressor piston sections 56 separate the intake and the compressor chambers. The gasifiers illustrated are of the inward compression type and appropriate compressor chamber intake and exhaust valves 60 and 62 are provided. Details of the exhaust and scavenging ports in the cylinder liners are omitted since they form no part of the invention. Any suitable construction of this nature may be utilized. Other operative portions of the gasifiers have also been omitted for simplicity.

The similar portions of the gasifiers of FIGURE 3 are illustrated diagrammatically as being of the siamezed type, however, wherein the case chambers 18 and 20 are formed as a common chamber or connected by a conduit 64 of sufficiently large dimension to insure unrestricted flow between the case chambers.

The dephaser system of FIGURE 1 includes a valve body 66 having a spool type valve 68 reciprocally received therein. The valve 68 may be constructed in a generally tubular manner with an intermediate wall 70 separating the opposite end chambers 72 and 74. The valve is also provided with several lands which are utilized for control purposes. Land 76, in cooperation with valve body 66, defines a bounce pressure-receiving chamber 78 surrounding the bounce pressure-receiving chamber 72. The effective area of land 76 defining the annular wall of the chamber 78 is substantially equal to the effective valve area of valve end chamber 72. Another land 80 is spaced from land 76 and cooperates therewith to define an annular mean bounce pressure chamber 82 which is connected through unrestricted opening 84 with the valve end chamber 74. Land 86 on one end of the valve defines a portion of the valve wall area of chamber 74. Land 88 is positioned intermediate lands 80 and 86 and defines bounce pressure balancing chambers 90 and 92. Valve body 66 is provided with bounce pressure balance ports 94 and 96 respectively connecting with bounce pressure balance chambers 90 and 92. Chambers 90 and 92 are connected and disconnected by the positioning of land 88 as valve 68 reciprocates in valve body 66. The limits of movement of valve 68 are defined by shoulders 97 and 98 on the valve body which engage the rear stop land 99 and one side of land 86. A throttling orifice 102 is provided through land 76 to restrictively connect chambers 78 and 82, and another throttling orifice 104 is provided through wall 70 to restrictively connect chambers 72 and 74. The bounce chambers of gasifier 10 are connected through conduit 104 to chamber 72 and conduit 106 to port 96. The bounce chambers of gasifier 12 are connected through conduit 105 with chamber 78 while conduit 110 connects them to port 94.

Curve 112 of FIGURE 2 represents the bounce pressure in gasifier 10 as the gasifier goes through an entire cycle. The cycle time is plotted in percentages of time per cycle. Curve 114 represents the bounce pressure in gasifier 12. The pressure represented by curve 112 is conducted through conduit 104 to valve chamber 72 and the pressure represented by curve 114 is conducted to valve chamber 78 by conduit 106. The throttling orifices 100 and 102 supply mean bounce pressure to chamber 74. This pressure is illustrated by the straight line 116. The summation of the instantaneous pressures in valve chambers 72 and 78 provides the basis for curve 118. This particular curve results because the situation plotted presumes the gasifiers to be out of phase by 120 degrees or 33 percent time. In this instance, gasifier 12 follows gasifier 10 by 120 degrees, or may be considered to be leading its proper position by 60 degrees. It is also noted that the pressure values represented by curve 118 are obtained because the pressure-time relation for the bounce pressure in a gasifier is not a sine wave.

In order for the dephaser valve system to operate as closely to the ideal position as possible, it is preferable that the bounce chamber conduits 104 and 106 be of a minimum length. Similarly, it is preferable to have the bounce chamber balance transfer lines 42 and 44 closely coupled to the ports 94 and 96 by conduits 110 and 106, respectively. The valve 68 must be constrained to move less than 90 degrees about its axis so that it will function as a force mass system. This is accomplished by utilizing a valve mass of a proper value for the pressures and areas involved. The valve 68 is assumed to be at rest.
in the rear position illustrated wherein rear stop 99 engages shoulder 97 on valve body 66. This position is equivalent to time 1 on the pressure diagram. It is noted that, at this time, the mean pressure represented by curve 116 exerts more force on the valve through its action against wall 70 and land 86 than the sum of the bounce pressures represented by curves 112 and 114. At time 2, the forces are equal and the valve begins to move toward the front position. The front position is obtained when land 86 engages the valve body shoulder 98 providing a forward stop. The mass of the valve is so chosen that it will not arrive at the forward stop until 90 degrees after valve movement is begun, as shown on the valve motion curve 120. This inertial delay insures that air will be transferred from the bounce chamber of the gasifier which is running too fast, in this instance gasifier 12, through chambers 90 and 92, ports 94 and 96 and conduits 106 and 110, to the bounce chamber of the gasifier which is running too slow, in this instance gasifier 10. A decrease in air contained in the bounce chamber of gasifier 12 will tend to slow the piston assembly of that gasifier and will increase the angle by which the gasifier 12 follows gasifier 10. This is aided by the fact that the transferred air is introduced into the bounce chamber system of gasifier 10, consequently tending to increase its speed.

At time 3, the forces acting on valve 68 again reverse and the valve begins to move toward the rear stop 97 and engages that stop 90 degrees later. This valve motion is indicated by curve 120. A small amount of air will be transferred in the wrong direction but the net air flow will be in the proper sense. This process will continue until a 180 degree phase relationship is achieved. At this time, equal quantities of air will be transferred from one gasifier bounce chamber to the other gasifier bounce chamber alternately and the phase relationship will be maintained.

The system will accomplish exactly 180 degrees phase operation at only one speed. However, this speed may be chosen so that it is in the middle of the gasifier speed range and, since gasifiers tend to run at substantially constant speeds as compared to engines such as those normally used in automobiles, for example, a satisfactory speed range can be accommodated.

The modified system shown in FIGURES 3 and 4 includes gasifier valve body 166 in which air interchangeably received. Valve 168 is formed as a hollow spool-type valve with an intermediate wall 170 separating the opposite end chambers 172 and 174. Wall 170 has a smaller outer diameter center section than the remaining portion of the valve and provides a groove 178 between the lands 176 and 180. Valve body 166 has a pair of annular spaced recesses 198 and 192 formed therein with their adjacent edges being spaced apart the same distance as the width of groove 178. Groove 178 is, therefore, closed to both of these chambers when the valve is in the middle position. Ports 194 and 196 are provided through the valve body wall so that they respectively connect with chambers 192 and 190. Port 184 is provided in the valve body intermediate chambers 190 and 192. Bounce pressure is conducted from gasifier 10 to chamber 172 through conduit 204. Bounce pressure from gasifier 12 is conducted to chamber 174 through conduit 208. Conduit 206 connects with port 196 and conduit 210 connects with port 194. Conduit 212 leads to a pressure storage and transfer tank 214 and is connected with port 184. As in the modification of FIGURE 1, it is preferred that the bounce chamber connections be closely coupled. The areas acted upon by bounce pressures in chambers 172 and 174 are equal. The tank 214 may be connected with the transfer lines 206 and 210 for either gasifier bounce chamber system depending upon the position of valve 168.

The situation illustrated in FIGURE 4 is the same as that for FIGURE 2 wherein the gasifiers are out of phase by 120 degrees. This means that gasifier 12 follows gasifier 10 by 120 degrees and may be considered to be leading its proper position by 60 degrees. Valve 165 is constrained to move only a short distance. The actual distance is determined by the pressures, areas and valve mass utilized. The left end of the diagram of FIGURE 4 corresponds to the valve position when the valve is at the end of its travel toward chamber 172 and conduit 204. At time 1, the bounce pressures are equal and thereafter the pressure in chamber 172 rises above the pressure in chamber 174. This is illustrated by dash-curves 216 for the bounce pressure of gasifier 10 and 218 for the bounce pressure of gasifier 12. The increase of pressure in chamber 172 causes valve 165 to move toward conduit 209 and chamber 174 and opens the groove 178 to the chamber 192, thereby connecting the bounce chamber of gasifier 12 through conduit 210, port 194, chamber 192, grooves 176, port 184 and conduit 212 to the tank 214. At the beginning of engine operation tank 214 will become pressure charged by bounce pressures as valve 168 alternately connects the tank with the gasifier bounce chamber systems. The pressure in the tank will, therefore, follow the bounce pressure of gasifier 12 until time 2 is reached.

At time 2 another pressure reversals occur and valve 165 moves back to the end of the valve body containing chamber 172 and to which conduit 204 is connected. Because of the lack of symmetry of the bounce pressure diagrams of the gasifiers, some air will be transferred from gasifier 12 to gasifier 10. Some energy transfer also occurs since the air, which was compressed in tank 214 to the bounce pressure of gasifier 12, is expanded in the bounce chamber system of gasifier 10. This action will tend to slow down gasifier 12 and speed up gasifier 10 and tend to restore the desired 180 degree phase relationship. When the 180 degree position is reached, an equal amount of air and energy will be transferred in each direction.

In this modification it is desirable to have the mass of valve 165 to be as small as reasonably possible so as to enable the quickest possible opening times to be obtained. For this reason, valve motion curve 220 of FIGURE 4 shows a relatively flat portion of the cycle for the valve movement from one end of the valve body to the other. The volume of tank 214 is dependent upon the size of the gasifiers, the pressures at which they operate and other factors. The pressure occurring in tank 214 throughout the cycle is illustrated by the heavy curve 222 in FIGURE 4.

The device will operate over a sufficient speed range and is preferably designed to provide exactly 180 degree phase operation at the center of the expected speed range. The gasifiers will then tend to run at substantially 180 degree phase relation since gasifiers tend to run at more constant speeds than many other types of engines.

I claim:

1. In a free piston engine assembly comprising a pair of gasifiers each having a bounce chamber, a gasifier dephaser comprising a valve body having a slide receiving therein for reciprocable movement, a first chamber having a valve wall area on one end of said valve, a second chamber having a valve wall area defined by a land on said valve and equal in area to said first chamber valve wall area and on the same pressure side of said valve, a third chamber having a valve wall area on the other end of said valve and having an
area equal to said first and second valve wall areas combined and on the opposite valve pressure side therefrom, a first throttle orifice interconnecting said first and third chambers and a second throttle orifice interconnecting said second and third chambers, a fourth chamber having a pair of ports and a valve land for connecting and disconnecting said ports upon movement of said valve, one of said gasifier bounce chambers being connected with said first chamber and one of said ports, and the other of said gasifier bounce chambers being connected with said second chamber and the other of said ports.

2. A free piston engine gasifier dephaser system for a pair of free piston gasifiers each having a bounce chamber system, said dephaser system comprising a valve body and a valve reciprocally moveable therein, first and second equal valve area bounce chamber system pressure chambers each connected with one of said gasifier bounce chamber systems and coupled in cumulative series, a mean bounce chamber pressure chamber coupled in equal valve area opposed relation to said first and second chambers, and a bounce chamber system interconnection chamber having a pair of ports respectively connected with said pair of gasifier bounce chamber systems, said ports being connectable and disconnectable with each other by reciprocating movement of said valve whereby a higher bounce chamber system pressure from one gasifier is transferable through said ports to the bounce chamber system of the gasifier having lower pressure to maintain said gasifiers in substantially 180 degree phase relation.

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