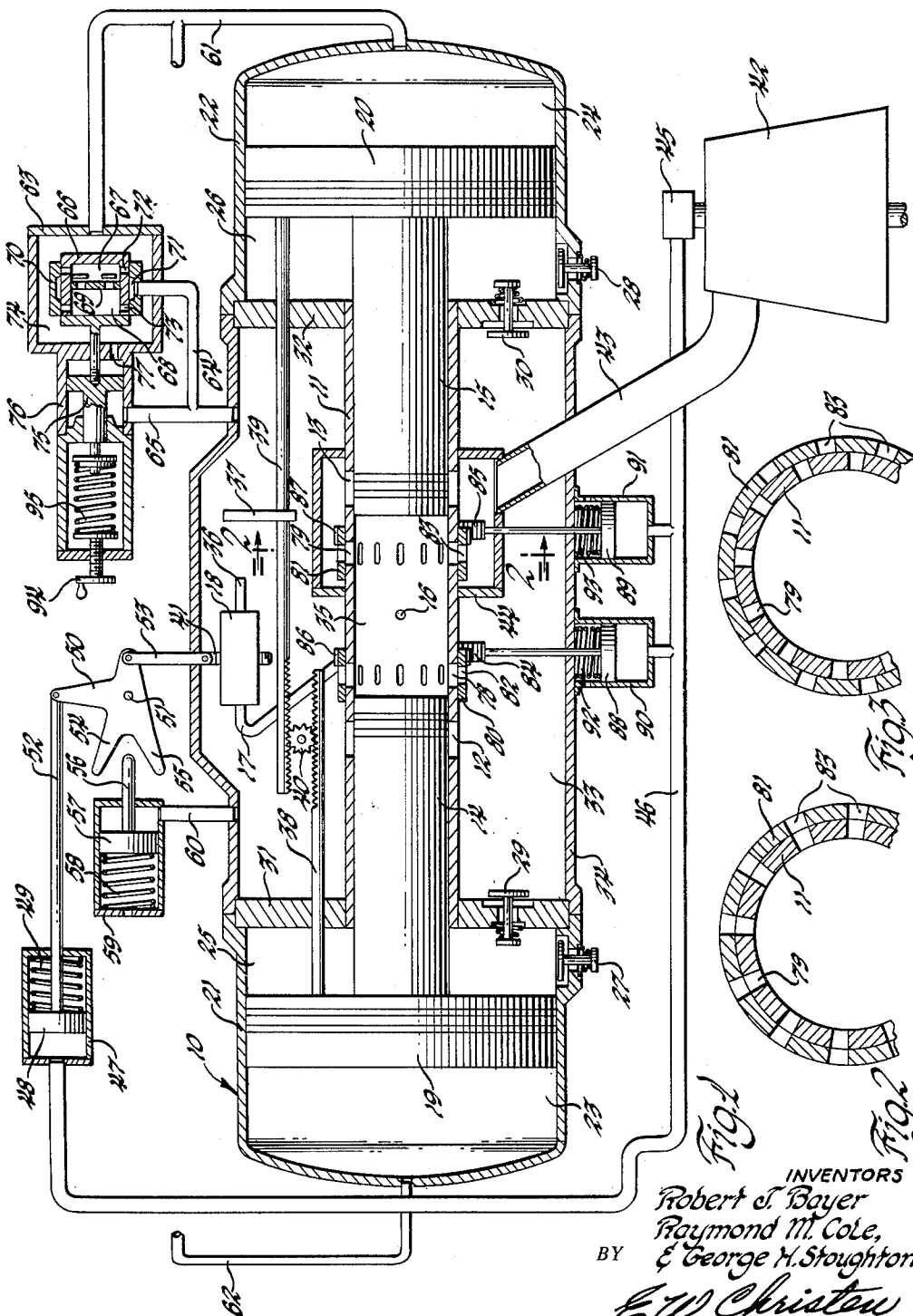


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 A FREE PISTON ENGINE DURING LOW LOAD CONDITIONS
 OF AN ASSOCIATED RECEIVER MACHINE
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APPARATUS FOR AUTOMATICALLY REDUCING THE STROKE OF A FREE PISTON ENGINE DURING LOW LOAD CONDITIONS OF AN ASSOCIATED RECEIVER MACHINE

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2 Claims. (Cl. 69-13)

This invention relates to free piston engines and, more particularly, to a means for improving the efficiency of such engines at low load or idle condition.

The invention is shown as applied to a free piston diesel cycle gasifier which supplies combustion gases under pressure to drive a turbine or other suitable receiver machine. It is known that the delivery from a gasifier can be regulated as to pressure and quantity to the requirements of the receiver machine over the ordinary load range thereof by regulating the amount of fuel which is supplied to the gasifier combustion chamber. It is also known that the minimum delivery of the gasifier is determined by the compression ignition point and that this minimum delivery will exceed the capacity of the receiver machine when the diesel intake and exhaust ports are arranged to provide good efficiency under medium and full load conditions. Because of this it has been common practice to feed only a portion of the gasifier's exhaust to the receiver machine at low load and idle and to allow the remainder to blow off to atmosphere with a consequent loss of efficiency.

The object of this invention is to reduce and even obviate the surplus delivery of the gasifier that occurs with light loading or idle running of the receiver machine.

The delivery of the gasifier is reduced at low load and idle conditions by incorporating an auxiliary set of intake and exhaust ports in the diesel cylinder between the main intake and exhaust ports and to open the auxiliary ports under such low load and idle conditions. The minimum stroke of the gasifier can thus be shortened at such conditions as it need only be long enough to uncover the auxiliary ports and the compression ignition point can be maintained without affecting the longer strokes which will occur at normal or full loads when the auxiliary ports are closed. The reduction in stroke at low gasifier exhaust pressures reduces the delivery to the receiver machine and thus obviates the need to blow off gasifier exhaust at light loads. To obtain efficient operation of the gasifier at higher loads, it is necessary that the auxiliary ports be closed; otherwise, the expansion ratio and stroke would be reduced when they should be increased.

In the drawings:

FIGURE 1 is a diagrammatic longitudinal section of a free piston gasifier in accordance with the invention and shown as feeding a turbine to produce shaft power.

FIGURE 2 is a partial section of the gasifier taken along the plane indicated by the line 2-2 of FIGURE 1 and illustrating the auxiliary exhaust ports in light load position, and

FIGURE 3 is a partial section similar to FIGURE 2 and illustrating the auxiliary exhaust ports in heavy load position.

Referring to the drawings the gasifier 10 operates on the two stroke diesel principle and comprises a central diesel cylinder 11 having main inlet ports 12 and main exhaust ports 13 with a pair of opposed diesel pistons 14 and 15 serving to uncover such ports in the conventional manner as the pistons approach their outer dead points. The inner and outer dead points of the pistons 14 and 15 are variable in accordance with various operating conditions.

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The diesel cylinder 11 also has a fuel injector 16 centrally disposed therein and connected by conduit 17 to an injection pump 18.

The diesel pistons 14 and 15 have compressor pistons 19 and 20 secured thereto which operate in compressor cylinders 21 and 22 to form cushion chambers 23 and 24 and compressor chambers 25 and 26. The compressor chambers 25 and 26 have intake valves 27 and 28 through which the air to be compressed is drawn and delivery valves 29 and 30 which are fitted in separating walls 31 and 32 to deliver compressed air to an accumulator or scavenge chamber 33 which is formed by the walls, the diesel cylinder 11 and an engine case 34. The compressed air in the scavenge chamber 33 serves to supply and scavenge the diesel cylinder combustion chamber 35 through the intake ports 12 in the usual manner under heavy load conditions.

The cushion chambers 23 and 24 store the energy of the free pistons during their outward strokes under the influence of the combustion of the fuel in the diesel cylinder 11 and return the energy to the pistons for the inward strokes thereof which effect compression in the compressor chambers 25 and 26, delivery of compressed air to the scavenge chamber 33 and the compression of the diesel cylinder combustion chamber 35 after the pistons have closed the ports 12 and 13.

The injection pump 18 has a pump plunger 36 which is operated from a lever 37 secured to one of the synchronizing rods 38 and 39 of the free piston assemblies. The synchronizing rods 38 and 39 are fixed to the compressor pistons 19 and 20 and have a rack and pinion connection with each other at 40 to maintain the piston assemblies in synchronization. The lever 37 operates the pump 18 as the pistons approach their inner dead points to cause fuel injection and the quantity of fuel injected is regulated in the conventional manner by a rack 41 which causes the piston of the pump to rotate about its axis. The quantity of fuel injected per cycle of piston movement is greater as the rack 41 is moved downwardly in the drawing.

The movements of the rack 41 are effected automatically in dependence upon the load demand of the receiver machine which comprises a gas turbine 42, the inlet of which is connected by a pipe 43 to an exhaust collector 44 that receives the diesel cylinder discharge by way of the exhaust ports 13 as the pistons approach their outer dead point. In order to obtain automatic control of the rack 41, a governor 45 is provided to variably pressurize a liquid in a pipe 46 which connects to a cylinder 47 to operate a piston 48 against a spring 49 and move a bell crank 50 about its pivot 51 through push rod 52, the bell crank 50 being connected to the rack 41 by a link 53. The governor 45 is so arranged that with an increase in load on the turbine the pressure in the conduit 46 will increase and the rack 41 will be moved increasingly downward to increase the amount of fuel injected.

The amount of fuel injected into the gasifier is held within maximum and minimum limits which are variable in dependence on the working pressure of the gasifier, i.e., the pressure in the scavenge chamber 33 or exhaust conduit 43, and the rack 41, accordingly, has its movements regulated within such limits by cams 54 and 55 which are formed on the bell crank 50 to engage a movable stop 56 and to set the limits. The stop 56 is carried by a piston 57 which engages a spring 58 in a cylinder 59. A conduit 60 places the cylinder 59 in communication with the scavenge chamber 33 so that one face of the piston 57 is acted upon by the pressure in the scavenge air chamber in opposition to the spring 58. The position of the movable stop 56 thus varies in dependence upon the working pressure of the gasifier and the engagement

of the stop with the cam 54 thus sets the minimum values of fuel injection in dependence on working pressure and the maximum values of fuel injection are likewise thus set by the engagement of the stop with the cam 55. During normal operation the stop 56 does not engage the cams 54 or 55 and the position of the fuel rack 41 is directly dependent on the control pressure from the governor 45.

The cushion chambers 23 and 24 are connected by conduits 61 and 62 so that their pressure fluctuations will be in balance and are also connected to a conventional stabilizer 63 which has conduit connections 64 and 65 to the scavenge air chamber 33. The stabilizer controls the mass of air in the cushion chambers in dependence on the gasifier's working pressure which is variable in accordance with the load. The stabilizer 63 consists of a slide valve 66 formed into two internal chambers 67 and 68 which communicate with each other by a check valve 69. The slide valve 66 reciprocates in a valve chest 70 so that the chambers 67 or 68 can communicate with the valve chest chamber 71 by way of apertures 72 or 73. The valve chest chamber 71 is connected to the working pressure of the engine case by way of the conduit 64. The stabilizer 63 forms a compartment 74 about the valve 66 and valve chest 70 and this compartment is supplied with cushion chamber pressure by the conduit 61. When the slide valve 66 is moved to the left, air can flow from the cushion chambers to the scavenge air box by way of the conduit 61, chamber 74, aperture 73, check valve 69, aperture 72, chamber 71 and conduit 64 as long as the cushion chamber pressure exceeds the scavenge pressure. When the slide valve 66 is moved to the right, air can flow from the scavenge air chamber to the cushion chamber by way of the conduit 64, chamber 71, aperture 73, check valve 69, aperture 72, chamber 74 and conduit 61 as long as the scavenge air pressure exceeds the cushion chamber pressure.

The scavenge air chamber pressure remains fairly uniform at any given load and rises with load increases. The cushion chamber pressure varies in accordance with the position of the piston assemblies and drops below the scavenge pressure when the assemblies approach inner dead point and rises above scavenge pressure when they approach outer dead point. It is thus possible to vary the mean pressure of the cushion chambers in accordance with the working pressure of the gasifier by transferring air between the scavenge air chamber and cushion chamber through the stabilizer. The slide valve 66 is shifted to accomplish this air transfer by a stepped piston 75 which is disposed inside a cylinder 76. A restrictor orifice 77 provides a means for supplying the mean pressure of the cushion chambers to the larger face of the stepped piston 75 in opposition to the working pressure of the gasifier which is supplied to the smaller face by the conduit 65. The dimensioning of the stepped piston 75 affords a means of controlling the variations of the final compression in the diesel cylinder 11. The stabilizer 63 has the usual adjustable wheel 94 which raises the final compression pressure in the diesel cylinder so that the engine can be started when cold. The wheel 94 acts on a spring 95 which in turn acts on the differential piston 75 so that the final compression pressure may be raised during engine warm up.

When the turbine 42 operates in a zone extending from medium load to maximum load, regulation of the power plant can be afforded exclusively by direct control of the fuel rack 41 from the governor 45, for the gasifier delivery can be adapted to the receiver machine requirements in this range by varying the length of stroke of the free piston assemblies. With the arrangement thus far described and without benefit of the subject invention, it is not possible to further vary the length of stroke of the free piston assemblies to reduce the gasifier delivery for idle and low load conditions. Under these conditions the gasifier delivery pressure need only be in the neighborhood of one atmosphere. In this load region the mini-

mum delivery from the gasifier is set by the minimum outer dead points of the free piston assemblies which are determined by the position of the diesel intake and exhaust ports 12 and 13. The minimum outer dead points of the free pistons occur when the ports 12 and 13 are opened by the pistons in an amount just enough to supply and scavenge the diesel cylinder. The gasifier delivery at such time is greater than the turbine can accommodate at low and idle loads if the main intake and exhaust ports 12 and 13 are located for maximum efficiency at medium and full operating loads.

Heretofore, after shortening the piston stroke as much as possible, it has been common to allow the surplus gasifier exhaust to escape to atmosphere at low loads and idle by way of a blow off valve located in the exhaust conduit 43 and ahead of the turbine inlet. It is apparent that such blow off represents an efficiency loss at low load and idle conditions which should be obviated.

In order to reduce the losses resulting from gas escaping during the idle running and low loads, the invention provides a means for reducing the piston stroke at such conditions. The diesel cylinder 11 is provided with a set of auxiliary intake and exhaust ports 78 and 79 which are located inboard of the main ports 12 and 13. A pair of ring valves 80 and 81 are rotatably mounted on the diesel cylinder 11 and are provided with ports 82 and 83 which can be brought into and out of registry with the ports 78 and 79, as may be seen in FIGURES 2 and 3. The auxiliary intake and exhaust ports 78 and 79 are closed by the ring valves 80 and 81 when the turbine is at medium or high load condition and are opened during idle or low load condition. The opening and closing of the auxiliary intake and exhaust ports is accomplished automatically by gear racks 84 and 85 which engage gear teeth 86 and 87 formed on the periphery of the ring valves 80 and 81. The gear racks 84 and 85 connect to pistons 88 and 89 in cylinders 90 and 91 which communicate with the fluid pressure of the governor 45. As the turbine load decreases to low load and idle condition, the governor control pressure decreases and the springs 92 and 93 act on the pistons 88 and 89 against the reduced pressure to open the auxiliary ports 78 and 79. The control pressure rises at high loads and moves the ring valves 80 and 81 to closed position.

The auxiliary ports 78 and 79 afford a means for reducing the piston stroke at low load conditions and thus the gasifier delivery so that the gasifier blow off is not required. The piston stroke is shortened as the pistons need only move outward sufficiently to register with the auxiliary ports. The invention thus provides reduced outer dead points for the piston assemblies at low or idle load condition.

We claim:

1. An internal combustion free piston power plant comprising a diesel cylinder having main intake and exhaust ports and auxiliary intake and exhaust ports spaced therefrom, a compressor cylinder, a cushion cylinder, a piston assembly reciprocal in said cylinders and having a variable stroke, a scavenge chamber arranged to receive compressed air from said compressor cylinder and to feed said air to said diesel cylinder through said intake ports, fuel injection means for said diesel cylinder, a receiver machine subject to variable loads and arranged to receive exhaust gas from said diesel cylinder through said exhaust ports, separate intake and exhaust valves for closing said auxiliary intake and exhaust ports at high load conditions of said receiver machine and for opening said auxiliary ports at low load conditions, and governor means responsive to said various load conditions for automatically operating said valves for said auxiliary ports, said ports being so located that the piston assembly uncovers the auxiliary ports prior to the main ports on the power stroke to reduce piston displacement and exhaust gas delivery at low load conditions.

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2. Apparatus in accordance with claim 1 wherein said intake and exhaust valves each comprises a ring movably mounted on the outer periphery of the diesel cylinder and having ports therethrough adapted to be brought into and out of registry with the respective auxiliary intake and exhaust ports of said diesel cylinder on movement of said ring.

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