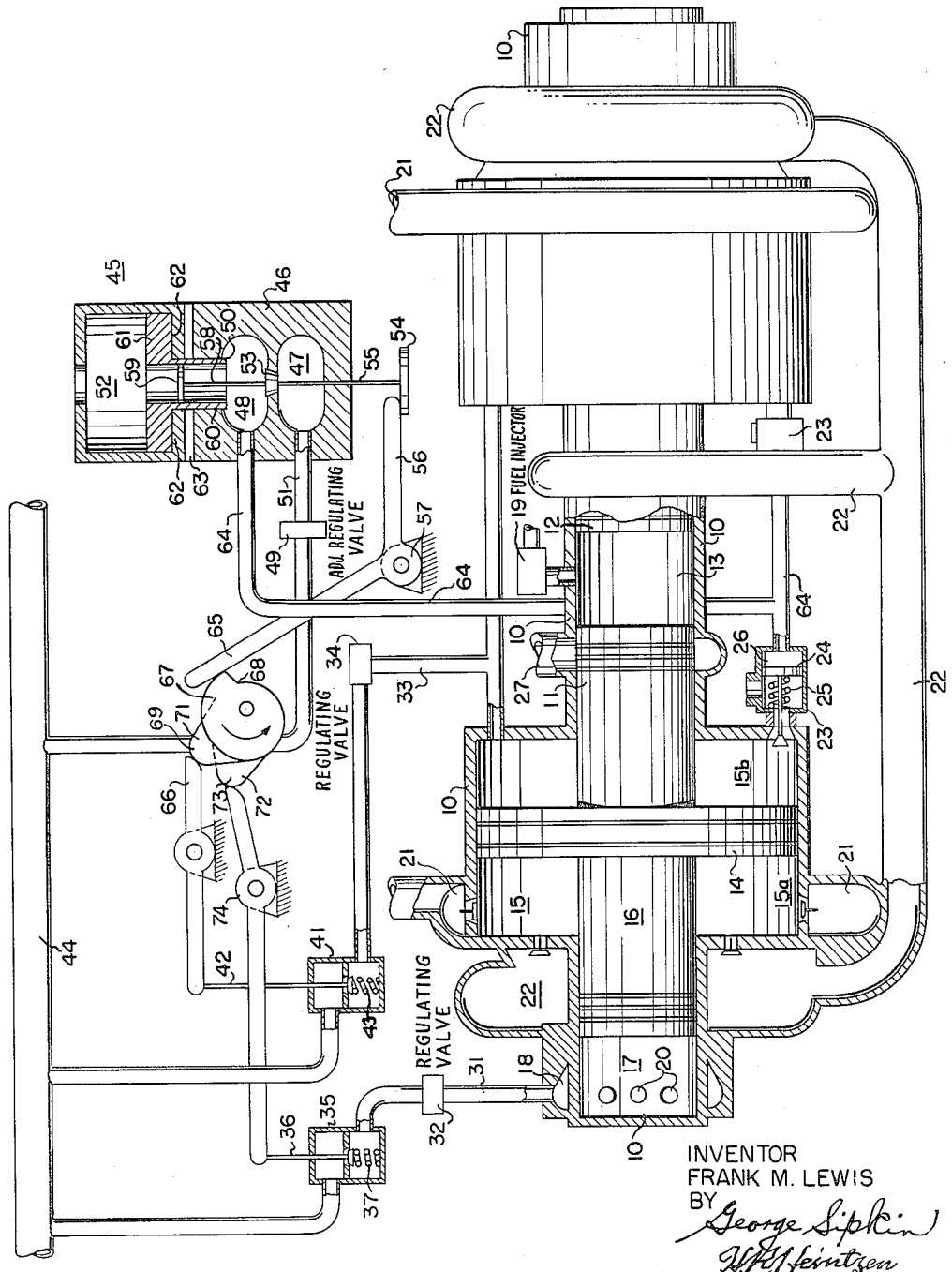
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STARTER FOR FREE PISTON GAS GENERATOR

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STARTER FOR FREE PISTON GAS GENERATOR

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This invention relates to a starter for a free piston gas generator and more particularly to a starter for a free piston gas generator of the internal combustion type.

Starters for free piston gas generators of the internal combustion type must properly orient the free engine pistons and must force the engine pistons through a compression stroke to compress air in the power cylinder to the pressure and temperature required to ignite the fuel injected therein. The starter must also provide reliable starting with varying initial conditions of temperature, pressure and orientation of the free pistons and must be simple to operate so that the gas generators may be started by unskilled personnel.

It is an object of this invention to provide a novel and improved starter for a free piston gas generator of the internal combustion type.

Another object of this invention is to provide a novel and improved starter for a free piston gas generator of the internal combustion type, which starter is reliable and efficient in its operation and simple in its control.

Other objects and advantages of the invention will hereinafter become more fully apparent from the following description of the annexed drawing, which illustrates a preferred embodiment, and wherein:

The single figure of the drawing is an elevational view, partially in section, of a free piston gas generator of the internal combustion type incorporating the starter of this invention, the starter and controls therefor being shown exaggerated in size for clarity.

Description

Referring now to the drawing, the reference numeral **10** designates the housing of a free piston gas generator of the internal combustion type, similar to the one described in the patent to F. M. Lewis, et al., 2,600,251, entitled Starter for Free Piston Engine, and which comprises a central power cylinder **13**, a pair of larger combination cylinders **15** which are at opposite ends of the power cylinder **13** and coaxial therewith, and a pair of direct bounce cylinders **17** which are coaxial with the power and combination cylinders **13** and **15** and are located at the outer extremities of the housing **10**. A pair of opposed engine pistons **11** and **12** are positioned in the power cylinder **13** to reciprocate therein, and each piston **11** or **12** comprises one piston of a group of pistons termed a piston unit. Each of the piston units further comprises a combination piston **14** which reciprocates in the combination cylinder **15**, and a direct bounce piston **16** which reciprocates in the direct bounce cylinder **17**. The pistons of each piston unit are directly connected together to form a unitarily operating structure. Only one set of cylinders comprising cylinders **13**, **15** and **17**, and one piston unit comprising pistons **11**, **14** and **16** have been shown in detail. Since both sets and units are identical, the auxiliary equipment to be described in connection with one unit will be understood to have a counter-part for the other unit.

Adjacent the outer ends of the housing **10** are auxiliary

air chambers **18** to which compressed air is supplied for starting. The auxiliary air chambers **18** communicate with the direct bounce cylinders **17** through ports **20** which are so positioned that they are covered by the direct bounce pistons **16** in their outermost positions. The pistons **16** have a sufficiently loose fit in the outer ends of the direct bounce cylinders **17** so that when the ports **20** are covered thereby, air under pressure in the auxiliary air chambers **18** is permitted to leak around the ends of the pistons **16** and to enter the direct bounce cylinders **17** in the free spaces provided between the ends of the cylinders **17** and those of the pistons **16**. Compressed air is admitted into each auxilary air chamber **18** through a pipe **31** and a pressure regulating valve **32**, and the flow of air through the pipe **31** is controlled by a valve **35** which comprises a valve stem **36** and a compression spring **37**. Compressed air is supplied to the valve **35** from a compressed air source (not shown) through a supply line **44**.

The combination pistons **14** divide each of the combination cylinders **15** into two chambers, a compressor chamber **15***a* and a reverse bounce chamber **15***b*. Air is supplied through a pipe **21** to the compressor chambers **15***a* which are connected together and to the power cylinder **13** by a conduit **22** through which air compressed in the chambers **15***a* is supplied to the cylinder **13**, and high pressure combustion products are exhausted from the power cylinder **13** through an exhaust conduit **27** which is connected to the engine (not shown) to be driven by these gases. A fuel injector **19** injects fuel into the power cylinder **13** at the proper time by means not shown. Compressed air for starting may be supplied to the reverse bounce chambers **15***b* from the supply line **44**, through a pipe **33** and a regulating valve **34**, and is controlled by a valve **41** which comprises a valve stem **42** and a compression spring **43**. The reverse bounce chambers **15***b* may be vented to the atmosphere on starting by dump reciprocating valves **23** which comprise valve pistons **24** positioned in valve cylinders **26**, and which are biased toward the closed position by springs **25** bearing against the pistons **24**. Compressed air to move the pistons **24** against the action of the springs **25** and open the valves **23** may be supplied to the cylinders **26** by a pipe **64**, from the supply line **44** through a starting unit **45**.

The starting unit **45** comprises a generally cylindrical housing **46** containing a lower compartment **47** communicating with an upper compartment **48** through a valve **53**. A small diameter cylinder **50** opens directly into the top of the upper compartment **48** and serves to connect the upper compartment **48** with a large diameter cylinder **52** in the top portion of the housing **45** forming a shoulder **62** therein. The cylinders **50** and **52** are oriented with their longitudinal axes vertical and are coaxial.

A heavy mass **61** is positioned within the large diameter cylinder **52** to move vertically therein and has a downward extending tubular extension **60** which fits closely within the small diameter cylinder **50**. The heavy mass **61** rests upon the shoulder **62** when it is in its downward position. The housing **46** is pierced by ports **63** therethrough in the top portion of the small diameter cylinder **50** just below the shoulder **62**, and the ports **63** are covered by the tubular extension **60** when it is in its downward position, and uncovered when it is in its upward position. A stationary disk or piston **59** is positioned in the tubular extension **60** and is secured to the valve **53** in housing **46** by a rod **58**, thus reducing the effective piston area of the lower end of the extension **60**. A pipe **51** which includes a pressure regulating valve **49** connects the interior of the lower compartment **47** with the supply line **44**. The pressure regulating valves **32**, **34**, and **49** are well known in the art and are not described in detail

here. The pressure regulating valve 49 restricts the rate of flow of air into the housing 46 to an amount less than the amount that can escape through the ports 63 when they are uncovered. A pipe 64 connects the upper compartment 48 with the cylinders of the reciprocating valves 23.

One arm 56 of a pivoted bell crank 57 bears against an extension 54 of a valve stem 55 of the valve 53 to maintain that valve normally closed. The bell crank 57 comprises a second arm 65 which bears against a cam 67 having a sharp step 68. A second cam 69, operatively connected to the cam 67 to rotate therewith, has a projecting portion or nose 71 arranged to bear against one end of a lever 66, and the other end of the lever 66 abuts the top end of the valve stem 42 to control the operation of the valve 41. A third cam 72, operatively connected to the cams 67 and 69 to rotate therewith, has a projecting portion or nose 73 arranged to bear against one end of a second lever 74, and the other end of the lever 74 abuts the top end of the valve stem 36 to control the operation of the valve 35.

Operation

The gas generator is started by first rotating the cams 67, 69, and 72 until the nose 71 on the cam 69 bears against and rotates the lever 66 to open the valve 41 and admit compressed air from the supply line 44 into the reverse bounce chamber 15*b*. The pressure of the air admitted to the reverse bounce chamber 15*b* acts on the piston 14 to move the pistons 11, 14 and 16 in the direction of their outward strokes. The piston unit comprising the piston 12 is moved in a similar manner and its operation will not be further described. Air is forced from the chamber 15*a* into the power cylinder 13 through the conduit 22 by the movement of the pistons 14.

The cams 67, 69 and 72 are then rotated until the nose 73 of the cam 72 causes the lever 74 to rotate, opening the valve 35 and admitting compressed air to the auxiliary air chamber 18. The pressure regulating valves 32 and 34 are so adjusted that the pressure of the air in the auxiliary air chamber 18 exerts a slightly lesser force against the piston 16 than the air in the reverse bounce chamber 15*b* exerts against the piston 14.

After the piston unit has been moved to the end of its outward stroke by the air in the chamber 15*b* and the air under pressure in the auxiliary air chamber 18 and in the reverse bounce chamber 15*b* has become stabilized, the cams 67, 69 and 72 are rotated farther or until the end of the bell crank 57 clears the end of the sharp step 68 in the cam 67 removing the impediment to the rotation of the bell crank 57. By this time, the noses 71 and 73 have moved past the levers 66 and 74 and have allowed the valves 35 and 41 to close under the action of the springs 37 and 43 respectively. The pressure of the air in the lower compartment 47 of the starting unit 45 then forces the valve 53 open, causing the bell crank 57 to rotate and the end of the arm 65 to fall into the step 68. The compressed air supplied to the housing 46 through the pipe 51 expands throughout the housing 46, exerting an upward force on the lower end of the tubular extension 60 and moving the heavy mass 61 upwardly. The mass 61 moves upwardly under the action of the pressure of the air in the upper compartment 48 and in the small diameter cylinder 50 but is retarded in its movement by its own mass which must be accelerated from rest.

Compressed air is conducted from the upper compartment 48, through the pipe 64 to the valve cylinder 26 of the dump valve 23, forcing open the dump valve 23 against the action of the spring 25, and allowing the air in the reverse bounce chamber 15*b* to vent to the atmosphere. The air in the auxiliary air chamber 18 must leak around the circumferential clearance of the bounce piston 16 at the outward position to which it was moved by the air under pressure in the reverse bounce chamber 15*b*, before it can get behind the piston 16 and do work. While this relatively slow process is taking place, the air pressure in the reverse bounce chamber 15*b* drops to substantially atmospheric pressure, and the piston units 11, 14 and 16 is then forced in the direction of a compression stroke by the air under pressure in the direct bounce cylinder 17 and the auxiliary air chamber 18.

The dump valve 23 must remain open during the compression stroke of the engine piston 11 and during the early portion of the succeeding outward stroke so that air may be drawn into the reverse bounce chamber 15*b* to provide a cushion for the pistons 11, 14 and 16 on subsequent compression strokes. To maintain the dump valve 23 open during this time, the air pressure in the housing 46 must be maintained sufficiently high to keep open the valve 23 against the action of the spring 25. The pressure of the air in the housing 46 remains high until the ports 63 are uncovered by the tubular extension 60, at which time the air exhausts through the ports 63 to the atmosphere and the air pressure in the housing 46 and in the cylinder 26 drops allowing the spring 25 to close the dump valve 23. The inertia of the mass 61 to which the extension 60 is secured retards the upward movement of the extension 60 for a finite period of time.

Details of construction

For a tubular extension 60 of a fixed size and forming a piston of fixed area at its lower end, the speed with which the mass 61 will rise under the influence of the air under pressure in the upper compartment 48 and in the cylinder 50 is determined by the pressure of the air in the housing 46 and by the weight of the mass 61. Since the weight of the mass 61 is rather difficult to vary once the starting unit 45 has been constructed, the pressure of the air entering the housing 46 from the supply line 44 is controlled to control the rate of rise of the mass 61 and the extension 60. The pressure regulating valve 49 is made adjustable, and, for proper operation of the starter, is adjusted until the pressure of the air entering the housing 46 from the pipe 51 is sufficient to force the mass 61 upward to the point where the ports 63 are uncovered by the extension 60 in the time required for the engine piston 11 to complete its compression stroke and that much of its return outward stroke as is necessary to draw sufficient air into the reverse bounce chamber 15*b* to form a cushion for the piston unit on its subsequent compression strokes. In this manner, changes may be made in the time of travel of the weight 61 to compensate for variations in starting conditions of the equipment and operation.

In order for the air under pressure to exhaust rapidly from the housing 46 even though air continues to enter through the pipe 51, the aggregate cross-sectional area of the ports 63 must be greater than the cross-sectional area of the pipe 51, the valve 53 or the opening in the pressure regulating valve 49. This necessitates a comparatively large diameter cylinder 50 and, since the extension 60 must fit closely in the cylinder 50, it must also be of large diameter. To decrease the effective piston area at the lower end of the extension 60, the extension is made tubular by boring or other means, and the stationary piston 59 is positioned therein.

The cams 67, 69 and 72 are mounted upon one shaft to be rotated together, and for the proper operation of the equipment, it is preferred that the cams 67, 69 and 72 be angularly displaced around the shaft to effect the proper sequence of operations.

The starter of this invention is simple in its construction and operation, yet reliable. It is capable of the precision timing necessary to start free piston gas generators of the internal combustion type, but is easily operated by unskilled operators. The starter will start a free piston gas generator regardless of the initial positions of the pistons and is adjustable to provide for varying conditions of pressure, temperature and equipment.

Obviously many modifications and variations of the

present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A starter for an internal combustion engine of the free piston type having a pneumatic direct bounce chamber, the compression of air in which tends to move the engine piston in the direction of its compression stroke, and a pneumatic reverse bounce chamber, the compression of air in which tends to move the engine piston in the direction of its outward stroke, said starter comprising means for injecting air under pressure into said reverse bounce chamber and then into said direct bounce chamber, the air injected into said reverse bounce chamber exerting a greater force than the air injected into said direct bounce chamber to move the engine piston through its outward stroke, an exhaust valve for exhausting said compressed air from said reverse bounce chamber into the atmosphere, means for biasing said exhaust valve to the closed position, mechanism responsive to air pressure for opening said exhaust valve, and timing means for supplying said last named air pressure to said mechanism for a predetermined period of time, said timing means comprising an actuating chamber communicating with said mechanism, a conduit for admitting air under pressure to said actuating chamber and to said mechanism to open said exhaust valve, a vertical cylinder having exhaust ports in the upper end thereof, and a weighted piston in said cylinder covering said ports and adapted to be moved upwardly therein for a fixed distance without uncovering said ports and for an additional distance upwardly for uncovering said ports by the air pressure in said actuating chamber, said ports being of sufficient size to reduce the pressure of the air in said actuating chamber and said mechanism to below the pressure at which said mechanism maintains said exhaust valve in the open position.

2. The starter defined in claim 1 wherein said exhaust valve comprises a reciprocating valve having a stem connected thereto, and said mechanism comprises a cylinder, a piston in said cylinder and adapted to reciprocate therein, said piston being connected to said valve stem to move said reciprocating valve and resilient means in said cylinder bearing against said valve piston for biasing said reciprocating valve to the closed position whereby the admission of compressed air to said valve cylinder through said conduit moves the piston against the action of said spring to open said valve.

3. The starter defined in claim 2 wherein said weighted piston has an axial bore therethrough, and further including a stationary member closely positioned in said bore, whereby the effective piston area of said weighted piston is reduced.

4. A timing device comprising a housing providing a vertical timing cylinder, exhaust ports in the housing communicating with the cylinder, a weighted piston within said cylinder adapted for vertical movement and normally covering said ports, an air chamber within said housing and below the cylinder, a partition in the housing separating the air chamber and the cylinder and having an aperture of less cross sectional area than the aggregate cross sectional area of said exhauts ports, a fluid pressure responsive valve for said aperture, means for supplying air under pressure to the air chamber, releasable holding means for said valve for controlling the flow of air under pressure from the air chamber to the cylinder to force the weighted piston upwardly to uncover the ports, connections for said timing cylinder to receive air under pressure therefrom for an interval of time equal to the time between the opening of said valve and the exhaustion of said air under pressure through the ports to the atmosphere and for releasing said holding means, and means connected to said means for introducing air under pressure into the air chamber to control the pressure of the air so introduced whereby the time of rise of said weighted piston may be regulated.

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