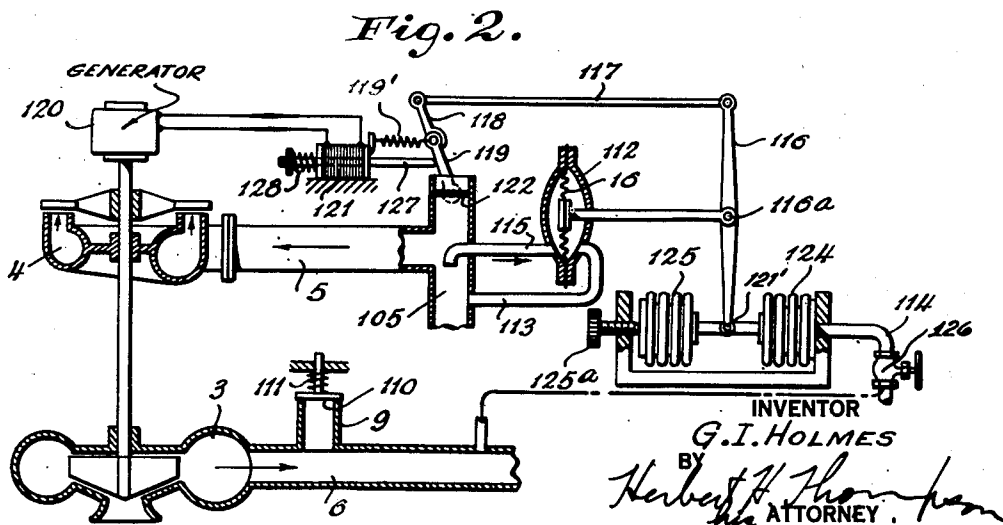
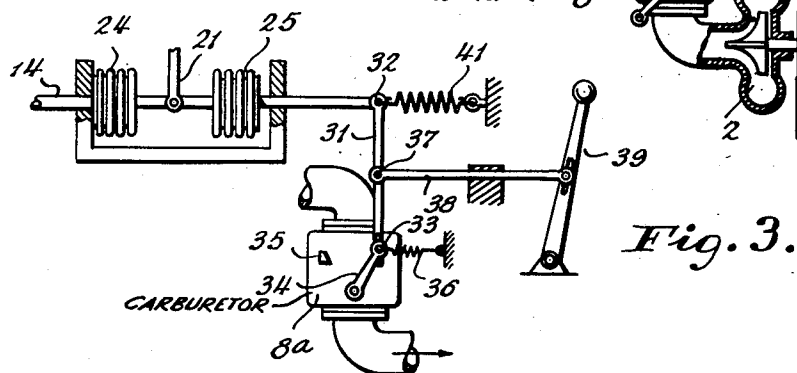
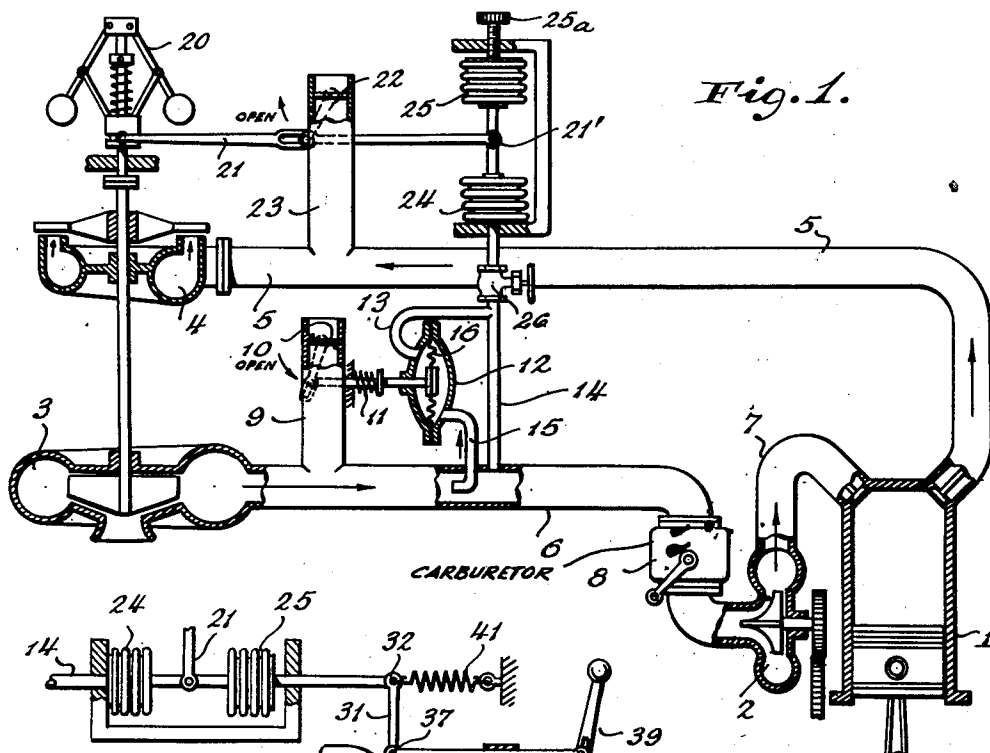


July 10, 1951

51 **G. I. HOLMES** 2
TURBO-SUPERCHARGER SYSTEM HAVING CONTROLLED INLET
AND EXHAUST WASTE GATE
Filed Feb. 12, 1944

2,559,623



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2,559,623

TURBO-SUPERCHARGER SYSTEM HAVING
CONTROLLED INLET AND EXHAUST
WASTE GATESGifford I. Holmes, Garden City, N. Y., assignor
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Application February 12, 1944, Serial No. 522,053

3 Claims. (Cl. 230-115)

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My invention relates to blower chargers and supercharger systems for supplying gaseous or vaporized fuel to prime movers.

It is an object of the invention to provide an improved blower-charger system for a prime mover, and especially to provide an improved power plant for aircraft.

An object is to provide an improved system for charging an internal combustion engine with an exhaust-driven blower charger.

Another object is to provide methods and apparatus for preventing the stalling of aircraft engines at high altitudes at partially closed throttle.

Another object is to provide methods and apparatus to prevent over-heating and reduced engine efficiency of supercharged aircraft engines at relatively low altitudes.

Another object is to provide arrangements for overcoming the phenomena known as "pumping" or pressure pulsations in a turbo-blower for internal combustion engines.

A further object is to provide arrangements for maintaining airflow from an exhaust-driven blower.

Still another object is to provide an arrangement for bleeding sufficient air to maintain reasonably uniform blower output pressure.

Another object is to provide arrangements for avoiding engine detonation caused by pulsation in intake pressure.

It is also an object to provide arrangements for permitting sudden opening or closing of the throttle of an engine without interfering with the proper operation of the engine either at high or low altitudes.

Still another object is to provide a two-stage blower system avoiding the need for variable-speed-change gearing.

Other and further objects and advantages will become apparent as the description proceeds.

It has been found that super-charged airplane engines actually produce less power at low altitude than at higher altitude, owing to the fact that the supercharger produces more intake pressure than necessary at low altitudes, where atmospheric pressure is a maximum, and it is necessary to throttle the intake to avoid overheating the engine. This throttling results in the waste of power by energy wasted in turbulence around the butterfly valve used as a throttle. The resultant excessive heating of the intake air may, in itself, be injurious.

Furthermore, particularly at high altitudes when an exhaust-driven blower-charger operates

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at high speed, or when the intake pipe of the engine is partially throttled, cutting down the air flow from the blower, there is a tendency for the blower to "pump" or cause pressure pulsation. It is desirable to avoid such pulsation in order to avoid ruining the engine by detonation. In addition it is necessary to avoid permitting such pressure pulsation to become great enough to produce a rarefaction travelling through the engine and the exhaust pipe, which leaves the exhaust turbine without any driving power and causes the blower-charger to stop, which in turn stalls the engine and prevents it from being restarted in rarefied upper altitude atmosphere.

It is accordingly an object of the invention to provide reliable, safe operation of a supercharged gas engine under all conditions of operation.

A more specific object of my invention is to provide means responsive to the pressure of the air from the exhaust turbine-driven blower and also responsive to velocity pressure of either such intake air or the exhaust gases from the engine to control the supply of exhaust gases to the turbine in such a manner as to prevent surging.

It is also an object to provide means responsive to one or more of the foregoing conditions for operating a waste gate in the intake air supply line to the engine in such a manner as to prevent the creation of a high pressure condition.

It is also an object to provide means for improving the operation of the apparatus by providing means responsive to the turbine speed coordinated with the foregoing control means to eliminate turbine stalling.

In accordance with my invention in its preferred form, I utilize a power plant for an aircraft comprising an internal combustion engine with a first stage blower driven by an exhaust turbine, and a second stage blower mechanically driven by the engine shaft. In the air line between the first and second stage blowers I provide an opening leading to an air-waste gate, and I provide a pressure control system preferably automatic which opens or closes the air-waste gate in accordance with variations in output pressure and output air velocity of the first stage blower in such a manner as to maintain a substantially fixed velocity head of the blower output. In this manner I obtain compensation for the effect of opening or closing the throttle of the engine which causes variations in the amount of air admitted to the engine. Furthermore, I may provide a delayed action control for reducing the speed of the exhaust-turbine-

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driven blower when intake air pressure becomes high.

A better understanding of the invention will be afforded by the following detailed description considered in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic diagram of an embodiment of the invention in which control apparatus is provided responsive to turbine speed and to velocity and total pressure of air from a first stage blower;

Fig. 2 is a fragmentary schematic diagram of apparatus employing means for controlling the supply of exhaust gas to a blower-driving turbine responsive to turbine speed and to the total pressure and velocity pressure of the exhaust gas.

Fig. 3 is a fragmentary diagram of a throttling arrangement controlling waste gas supply to the turbine.

The apparatus illustrated in Fig. 1 comprises an internal combustion engine 1 with a second stage intake air-compressing blower 2 which is driven by the engine, a first stage blower 3 and an exhaust gas turbine 4 for driving the blower 3. An exhaust pipe 5 is provided for connecting the engine and the turbine 4, and an air pipe 6 is provided for conveying the output of the first stage blower 3 to the second stage blower 2. An engine intake pipe 7 is provided for connecting the blower 2 to the engine 1. For controlling the mixture and quantity of air and fuel supplied to the engine, a conventional throttle and carburetor 8 is provided which is connected in the air pipe 6 in the arrangement illustrated.

For preventing adverse effects on the blower 3 when the air intake at the engine is throttled down and enabling the blower output to be bled away, a waste connection 9 and a waste gate 10 may be provided in an air pipe 6. Preferably, a spring 11, shown as a compression spring, is provided for normally biasing the waste gate 10 to an open position.

For controlling the operation of the waste gate 10, a pressure motor 12 of the diaphragm type is provided having a static pressure connection 13 through a pipe 14 to the air pipe 6 and having a velocity pressure connection 15 to the air pipe 6. The pipe 15 is in the form of a Pitot tube so that pressure supplied through it represents total pressure or the sum of static and velocity head in the pipe 6. The arrangement is such that the pressure exerted on the diaphragm 16 by the air conveyed through the pipe 15 tends to close the air-waste gate 10, whereas equalization of the pressure on both sides of the diaphragm 16 permits the spring 11 to open the air-waste gate 10.

Suitable means are provided for controlling the supply of exhaust gas to the turbine 4 in response to the pressure of the air in the air pipe 6 and also in response to the speed of the turbine 4. For speed limit control, a fly-ball governor arrangement 20 is provided, and a link 21 is connected to the fly-ball governor 20 with a floating pivot 21'. For controlling the speed of exhaust turbine 4 in response to the position of the fly-ball governor 20, an exhaust gate 22 in a branch exhaust pipe 23 is connected to the link 21.

For making the exhaust gate 22 responsive to the pressure in the pipe 6, a bellows arrangement 24 connected to the static pressure pipe 14 is provided and is arranged to control the position of the floating pivot 21' of the exhaust gate operating link 21. In order to compensate for varia-

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tions in barometric pressure when an aircraft is operated at different altitudes, a compensating bellows 25 is provided which is arranged to act in opposition to the intake air pressure bellows 25. The compensating bellows 25 may be filled with air to exert a substantially constant opposing force to the bellows 24 at all times, assuming a constant active pressure area of the bellows 24 and 25. For adjusting the effect of the bellows 24, an adjusting screw 25a may be provided for the compensating bellows 25. In order to provide some damping in the effect of the bellows 24 on the waste gate 22 and to provide delayed opening of the waste-gate 22 in the event of a sudden rise of pressure in the air pipe 6, and adjustable constriction 26 is preferably provided in the static pressure pipe 14 between the connections of the pipe 14 to the static tube 13 and to the bellows 24.

It will be understood that a suitable inter-cooler (not shown) may be included in the air pipe 6 between the two blower stages 3 and 2.

Under normal operating conditions, such as cruising conditions, when the engine 1 is being operated with full-open throttle or at such a throttle opening as to deliver a substantial fraction of its rated power, the velocity of the air intake in the pipe 6 is sufficient to create a velocity head overcoming the force of the biasing spring 11, and, accordingly, the air-waste gate 10 is kept closed by the pressure exerted on the right-hand side of the diaphragm 16. However, in the event that the throttle 8 is suddenly closed or partially closed to such an extent as to cut down seriously the velocity of the intake air in the pipe 6 and to cause pumping or pressure surge to take place in the blower 3, the velocity pressure conveyed through the pipe 15 to the right-hand side of the diaphragm 16 falls off to a negligible value, and the pressure in the pressure motor 12 equalizes on either side of the diaphragm 16. This permits the spring 11 to open the waste gate 10 and relieve the output pressure of the first stage blower 3 whereby its normal output flow is maintained and no surging or pumping takes place therein.

When the throttle 8 is suddenly closed, the pressure tends to rise suddenly in the pipe 6, but this circumstance does not directly affect the pressure motor 12, since the pressure rises on both sides of the diaphragm 16, and it is only the sudden lowering of the velocity head which permits the compression spring 11 to open the waste gate 10. Owing to the existence of the constriction 26 in the pipe 14, the pressure motor 12 will act more quickly than the exhaust gate operating bellows 24. Consequently, the waste gate 10 will be opened before the rise in pressure can cause the opening of the exhaust gate 22 and the consequent possible stalling of the exhaust turbine 4. Instead, the reduction in pressure in the static pipe 14 caused by the opening of the waste gate 10 gradually causes contraction of the bellows 24 and a closing of the exhaust gate 22 to increase the proportion of exhaust gases admitted to the turbine 4 and thus counteracts the effect of the reduction in the total air and gases passing through the engine 1. The rate at which the exhaust gate 22 is closed is, of course, determined by the flow of air through the constriction 26.

In the arrangement as just described, the air-waste gate 10 is normally closed during engine operation, and the exhaust gate 22 is normally partially throttled to maintain the air pressure in

the pipe 6 at a suitable value by venting more or less of the exhaust gases to the atmosphere in order to control the speed of the first stage blower 3 driven by the exhaust turbine 4.

If desired, the control apparatus may be made responsive to the velocity pressure of the exhaust through the branch pipe 23 instead of the pipe 6. An arrangement embodying this feature is illustrated fragmentarily in Fig. 2.

The arrangement of Fig. 2 includes certain elements bearing the same reference characters as similar elements in Fig. 1 and certain other modified elements identified by reference characters represented by numerals having values one hundred greater than the reference characters identifying similar elements in Fig. 1.

In the arrangement of Fig. 2, a simple pressure relief valve 110 is provided which is spring biased to the closed position by a compression spring 111. The strength of the spring 111 is so chosen to vent the pipe 6 upon the occurrence of a dangerous excessive pressure.

In this case a pressure motor 112 is provided which has a static pressure connection 113 to the exhaust pipe 105 and a Pitot-tube-type of total pressure connection 115 to the exhaust pipe 105. A floating link 116 is provided having an intermediate pivot 116a connected to the diaphragm 16 of the pressure motor 112 and about which the link 116 is adapted to rock. One end of the link 116 is connected to the floating pivot 121' carried by the bellows 124 and 125, and a second link 117 is provided connecting the opposite end of the link 116 to the exhaust gate 122 through a spring-biased broken lever or knee linkage comprising elements 118 and 119. The knee linkage 118, 119 is so constructed that a spring 119' normally holds it in the straight position, but the linkage is capable of being bent by movement of the center portion to the right against the tension of the spring 119'.

For limiting maximum speed of the turbine 4, a generator type of governor 120 is provided which is mechanically connected to the turbine 4 and has electrically connected thereto a solenoid 121 carrying an extending rod 127 biased to the left-hand position by a spring 128. The rod 127 is so mounted that it is adapted to engage the knee linkage member 119 when the solenoid 121 is strongly energized in response to high generator voltage resulting from excessive speed of the turbine 4.

When the velocity pressure in the exhaust pipe 105 falls, the pressure motor diaphragm 16 and the linkage 116 are moved to the left by the biasing spring 119', carrying the link 117 to the left and closing the exhaust waste gate 122.

When the air pressure in the air pipe 6 rises in response to throttling of the carburetor 8, for example, the bellows 124 rocks the link 116 clockwise about the pivot 116a to cause the exhaust waste gate 122 to be opened, whereupon less gas is supplied to the turbine 4, and the blower 3 will be slowed somewhat to cause reduction of air pressure in the pipe 6. As in the arrangement of Fig. 1, a restriction 126 dampens the action of the high-pressure bellows 124. Consequently, when the velocity pressure of the exhaust gases falls sharply, the exhaust waste gate will be moved quickly toward the closed position, enabling a proportionally increasing amount of exhaust gases to be supplied to the turbine 4. When the throttle is suddenly closed, the static pressure in the air pipe 6 tends to rise sharply, but owing to the existence of the restriction 26, the velocity

pressure-responsive motor 112 acts to correct for the condition before the high-pressure air will have had time to actuate the bellows pressure motor 124. Furthermore, the relief valve 110 operates to prevent excessive pressure in the pipe 6.

If the speed of the turbine 4 should exceed a predetermined upper limit, the rod 127 will be moved to the right against the tension of the spring 128 to break the knee link and rotate the arm 119 for opening the exhaust waste gate 122.

The adjustment screw 25a in Fig. 1, or 125a in Fig. 2 may be manipulated for altering the control point of the system as a whole. Such alteration of the control point varies the supply of air in the pipe 6 accordingly. It stands to reason that such alteration of the control point serves to control the power of the engine. Referring to Fig. 1, adjustment of the screw 25a to move the fixed end of the bellows 25 downward opposes the action of the bellows 24 so as to require higher static pressure in the bellows 24, and therefore higher intake manifold pressure so as to increase the power of the engine.

If desired, the setting of the control point of the bellows arrangement 24, 25 may be coordinated with the operation of the conventional carburetor and intake throttle 8 so as to utilize adjustment of the control point of the bellows arrangement 24, 25 for control of engine power or throttling when the intake air pressure is higher than atmospheric and permit the conventional throttling arrangement to be used for cutting down intake air to decrease engine power at low altitudes when the atmospheric pressure is substantially equal to sea-level pressure, and it may be necessary to hold a partial vacuum on the intake side of the engine in order to hold the fuel input down sufficiently.

The butterfly valve in the carburetor 8 may be biased to the "full open" position for minimum turbulence in the air stream passing therethrough whenever the air pressure required in the intake pipe is greater than atmospheric pressure. For example, as illustrated in Fig. 3, a link 31 may be provided interconnecting the bellows arrangement 24, 25 and a butterfly-valve-controlling arm 34. The bellows 25 is secured by a pivot pin 32 to one end of the link 31 and the other end of the link 31 is secured by pivot pin 33 to a controlling arm 34 of the butterfly valve (not shown) in the carburetor 8a. The carburetor 8a is provided with a limit stop 35 at the "full open" position of the butterfly-valve-controlling arm 34, and a relatively weak tension spring 36 is provided for closing the butterfly valve. The link 31 is mounted to rock about a pivot pin 37 mounted at the end of a push rod 38, the position of which is controlled by a throttle lever 39. For normally biasing the butterfly-valve-controlling arm 34 to the "full open" position, a relatively strong tension spring 41 is provided.

The arrangement of Fig. 3 is such that movement of the throttle lever 39 to the left increases engine power, and movement thereof to the right decreases engine power. Whenever high engine power is required so that the throttle 39 is moved to the left, or whenever atmospheric pressure is below sea level pressure, so that the bellows 25 tends to become distended, the relatively strong tension spring 41 overcomes the relatively weak tension spring 36 and moves the arm 34 against the limit stop 35 so that the butterfly valve in the carburetor 8a is wide open. Control of the engine power is then accomplished by movement

of the throttle lever 39 to change the position of the pin 32 supporting the bellows 25 and determining the pressure required within the bellows 24 in order to maintain a predetermined degree of opening of the exhaust gate 22. So long as the atmospheric pressure is less than the sea-level pressure for which the compensating bellows 25 is assumed to be designed, the bellows 25 tends to distend unless counterbalanced by the pressure within the bellows 24, and consequently any position of the pivot pin 37 is such that the relatively strong spring 41 can overcome the relatively weak spring 36.

However, at low altitudes when the atmospheric pressure is substantially sea-level pressure, the external pressure balances the internal sea-level pressure within the bellows 25 and there is substantially no tendency for it to distend. The action of the relatively strong spring 41 is thus opposed. If then the throttle 39 is moved to the right for the purpose of reducing engine power, the link 31 pivots around the point 32 and causes the butterfly valve operating arm 34 to move to the right (the closing direction) in an amount determined by the position of the throttle arm 39, and enables sufficient pressure difference to be set up in the carburetor 8a to reduce the engine power sufficiently.

I have herein shown and particularly described certain embodiments of my invention and certain methods of operation embraced therein for the purpose of explaining its principle of operation and showing its application, but it will be obvious to those skilled in the art that many modifications and variations are possible, and I aim, therefore, to cover all such modifications and variations as fall within the scope of my invention which is defined in the appended claims.

What is claimed is:

1. A turbo-supercharger system comprising a blower adapted to deliver a supply of air under pressure, a first pipe connected to said blower and adapted to transport said supply of air, an exhaust gas driven turbine connected to drive said blower, a second pipe connected to said turbine and adapted to supply impelling exhaust gases to said turbine, a first normally closed gate to the atmosphere in said first pipe, a second normally closed gate to the atmosphere in said second pipe, pressure-responsive means operatively connected to said first gate to open the same when the static pressure in said first pipe exceeds a predetermined limit, and pressure-responsive means operatively connected to said second gate to open the same when the static pressure in said first pipe exceeds a predetermined limit.

2. A turbo-supercharger system comprising a blower adapted to deliver a supply of air under pressure, a first pipe connected to said blower and adapted to transport said supply of air, an exhaust gas driven turbine connected to drive said blower, a second pipe connected to said turbine and adapted to supply impelling exhaust gases to said turbine, a first normally closed gate to the atmosphere in said first pipe, a second normally closed gate to the atmosphere in said second pipe, pressure-responsive means operatively connected to said first gate to open the same when the static pressure in said first pipe exceeds a predetermined limit, pressure-responsive means operatively connected to said second gate to open the same when the static pressure in said first pipe exceeds a predetermined limit, and pressure-responsive means operatively connected to said second gate to close the same as the velocity of the exhaust gases in the second pipe drops.

3. A turbo-supercharger system comprising a blower adapted to deliver a supply of air under pressure, a first pipe connected to said blower and adapted to transport said supply of air, an exhaust gas driven turbine connected to drive said blower, a second pipe connected to said turbine and adapted to supply impelling exhaust gases to said turbine, a first normally closed gate to the atmosphere in said first pipe, a second normally closed gate to the atmosphere in said second pipe, pressure-responsive means operatively connected to said first gate to open the same as the velocity of the air in the first pipe drops, and pressure-responsive means operatively connected to said second gate to open the same when the static pressure in the first pipe exceeds a predetermined limit.

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