UNITED STATES PATENT OFFICE

2,620,621

DIESEL ENGINE HAVING CONTROLLABLE AUXILIARY BURNER MEANS TO SUPPLEMENT EXHAUST GAS FED TO TURBOCHARGER

Frederick Nettel, Manhasset, N. Y.
Application April 6, 1946, Serial No. 660,170
7 Claims. (C1. 60—13)

1. This invention relates to reciprocating internal combustion engines. More particularly, the invention pertains to means for supercharging reciprocating internal combustion engines, e.g. those running on the Otto or diesel cycles.

Conventional engines of the character described inherently furnish an approximately constant torque in the useful speed ranges. However, many uses of these engines require an approximately constant output over a considerable speed range. Examples of such uses are passenger automobiles, trucks, buses, locomotives and cranes. At the present time the desired torque-speed relationship (high torque at low drive shaft speed and low torque at high drive shaft speeds) is obtained by interposing a variable speed change device between the engine and the drive shaft, thus enabling the engine, for example, to run at a high speed and deliver a high output, when desired, while the drive shaft turns at a lower speed. Many different types of such speed change devices are used, automobile transmissions, hydraulic pump-turbine sets and electric generator-motor sets being exemplary. Said devices are expensive, bulky and heavy.

It is an object of my invention to provide an engine of the character described which is able to deliver greater crankshaft torques at low speeds than at high speeds.

It is a further object of my invention to provide an engine of the character described which is able to deliver an approximately constant power output within a wide speed range without the use of speed change devices.

It is another object of my invention to provide an engine of the character described which will accomplish the foregoing desirable results without an increase in the size, weight and cost of the engine and its auxiliaries large enough to offset the elimination of the aforementioned speed change devices.

In general I accomplish the above objects of my invention by employing a supercharger. It is known standard practice to supercharge reciprocating internal combustion engines by means of centrifugal or axial flow blowers driven by exhaust gas turbines. The most successful of these superchargers are those which are mechanically independent of the engine shafts. However, these superchargers, which are mainly used with four-cycle engines, primarily are designed to increase torque at high speeds and loads, obviously a desirable feature, and their degree of supercharging decreases as the load and speed of the engine drop.

It is, therefore, another object of my invention to provide a supercharger and system of engine operation differing from the conventional in that the pressure furnished by the supercharger remains constant, or even increases as the engine speed drops.

It is an additional object of my invention to provide a supercharger and system of engine operation in which the degree of supercharging can be varied so as to enable an engine to furnish substantial overloads at any speed.

It is a further specific object of my invention to provide a supercharger and system of engine operation which facilitates starting of highly supercharged four-cycle engines.

Still another object of my invention is to employ my improved supercharger and system of engine operation to enable two-cycle engines with mechanically independent supercharger sets to be started, and to be operated at low loads and speeds, including idling.

Yet another object of my invention is to provide in conjunction with improved superchargers of the character described control devices for the blowers and gas turbines which enable the superchargers to satisfy the charging and scavenging requirements of the engines under all conditions of engine operation.

Other objects of my invention will in part be obvious and in part hereinafter pointed out.

My invention accordingly consists in the features of construction, arrangements of elements, and combinations of parts illustrated in the drawings and described in detail hereinafter, and the scope of which will be apparent from the appended claims.

In the accompanying drawing, in which are shown various possible embodiments of my invention,

Fig. 1 is a schematic view of a diesel engine with a supercharger set embodying my invention;
Fig. 2 is a similar view of a modified form of my invention.
Fig. 3 is a schematic view of a modified form
of supercharger set according to my invention; and
Fig. 4 is a view similar to Fig. 1 showing another modified form of my invention.
In known supercharging systems the degree of supercharging adjusts or balances itself automatically in such a manner that the power extracted by the turbine from the energy of the exhaust gases just balances the power required by the blower, proportionately accomplishing this result by burning fuel outside of the engine and feeding the product of this combustion to the driving side of the turbo-blower set. Although the pressure differential necessary for effective scavenging and charging of the engine can, of course, be supplied by means independent of said set, it is desirable to derive the corresponding power from the output side of the set itself, e.g. the turbine driven shaft. Highly satisfactory results are obtainable and the mechanical elements kept few and simple when the requisite additional turbine power is secured by branching off a portion of the air issuing from the blower, burning fuel in said branch and then re-expanding the same in the turbine which drives the blower. The work produced by the branch off highly heated air is in excess of that needed for compressed air supply to the engine, and (b) at partial engine loads, for maintaining the degree of supercharge, or (c) with falling engine speed at constant fuel input to the engine, for increasing the charging pressure and consequently increasing the engine torque to maintain substantially constant the output of the engine or to approximate such condition.
Rephrasing now more particularly to Fig. 1 of the drawing, 10 denotes an engine having an intake manifold 11 and an intake pipe 11a for scavenging and charging air, an exhaust gas manifold 12 and an exhaust gas pipe 12a. A fuel inlet line 13 to the engine is provided with a control valve 13a. The intake pipe 11a is connected to the outlet of a blower 16 of a supercharging set S. At a point 15b in the pipe 11a, a bypass conduit 14 is branched off and connected to inlet nozzles of gas turbine 21 of the supercharger set S. Flow of atmospheric air through the conduit 14 is choreled by a flap valve 16 at the branch point. Interposed in the conduit 14 is an auxiliary combustion chamber 15 to which fuel is admitted by a pipe 17 having a control valve 18. The exhaust pipe 12a also leads to the inlet nozzles of the turbine 21. 20 and 22 denote the air intake from the atmosphere to the blower 19, and the exhaust gas discharge to the atmosphere from the turbine 21, respectively. As can be seen from the drawing the blower and turbine are mounted on a common shaft.
Normally, as is well known in the art, the exhaust gases from the engine drive the turbine 21 and enable the blower 19 to supply compressed air to the engine through the intake manifold 11.
The result of the supercharger set rises and falls with the engine load and/or speed, causing the charging pressure to vary accordingly. Under such operating conditions the valves 16 and 18 may be fully closed or preferably slightly opened, sufficiently only to admit enough air and fuel to the combustion chamber 15 to keep an idling flame burning therein.
If now an overload at constant engine speed is required, this may be obtained by admitting more fuel to the engine. There is, however, but a comparatively small margin left for such load increase due to the fact that the cylinder charge soon becomes insufficient to burn more fuel and incomplete combustion results. Pursuant to my invention, I increase the air charge at the same time that more fuel is admitted, achieving this result by raising the supercharging pressure. This higher pressure is secured by opening of valves 16 and 18 and by burning more fuel in the combustion chamber 15. Thus I obtain a substantial overload with good combustion.
At first glance this may appear to be an erroneous method for increasing the charging pressure since, instead of increasing pressure, this causes a pressure drop in the intake pipe 11a. However, such apparently erroneous operation is, as will presently be seen, quite correct. When the foregoing procedure is started, the supercharger set will continue to run for a while at about the same speed, since the engine begins to receive more fuel. But the larger quantity of air branched off through flap valve 16 is heated to a very high temperature (as high as is permissible for the turbine blades) in combustion chamber 16 and expands in the turbine 21 producing substantially more work. Since this added power is accompanied by a corresponding increase in air quantity in the blower 16. This extra power is added to the power produced in the turbine 21 by the engine exhaust and enables the supercharger set to speed up, supplying air of higher pressure both to the engine and to the turbine via the conduit 14. A new equilibrium speed for the supercharger will establish itself when the increased turbine power again equals the power required for the blower. Since the engine air charge is increased, the fuel supply to the engine also can be increased, enabling the engine to furnish the required overload.
Obviously this mode of operation is not restricted to overload but also can be adopted for partial loads. This means that the supercharging pressure at partial loads can be maintained at any desired value which may be desired in the circumstances.
If desired, I may subdivide the turbine nozzles to provide separate sets of nozzles for the exhaust gas pipe 12a and the bypass conduit 14.
Fig. 2 illustrates an example of the present invention. Flue gases from the auxiliary combustion chamber 15 mix with the engine exhaust gases before they reach the gas turbine. Parts equivalent to those of Fig. 1 are identified by the same numerals. As can be seen from the drawing, the auxiliary combustion chamber 15 is open at the bottom and is in communication with the
exhaust gas pipe 12a of the engine. The air branched off at 11b is used as combustion air in the chamber 15 producing combustion gases of very high temperature in the range of about 1500 to about 2500° F. The engine exhaust gases flow through an annular channel C surrounding the chamber 15 and mix with the gases therefrom. Then pass to the turbine 21 and thence to the atmosphere. The temperature of the gases in the exhaust gas pipe 12a varies with the load and speed of the engine, generally nearing about 1100°F at full load in a four-cycle engine and less in a two-cycle engine. When the engine speed drops it consumes less air and more air flows through the bypass 14 which is heated, as mentioned above, to very high temperatures. Thus, when the much cooler exhaust gases are mixed with the gases from the combustion chamber 15, a rather high resultant temperature of from about 1000 to 1300°F or even more results. The effect is that not only does the air from the bypass pipe 14 get energized, but also that the engine exhaust is reheated before being expanded to near-atmospheric pressure, securing a greatly increased power production in the turbine 21 and consequently a higher supercharge pressure in the engine.

Fig. 3 shows an alternative embodiment of a supercharger suitable for an installation such as illustrated in Fig. 1. Here the bypass conduit 15 leads to a separate turbine 21a mounted on the same shaft as the blower 10 and the exhaust gas turbine 21. If desired, the exhaust from the turbine 21a need not flow directly to the atmosphere but may be made to flow through a recuperative heat exchanger 23 interposed in an exhaust conduit 22a for the turbine 21a.

Pursuant to an ancillary feature of my invention, a starting motor 23 of any known kind e.g. electric is coupled to the supercharger set by an overrunning clutch 24 which is adjustable to uncouple the motor 23 if the set begins to run faster than the starting motor. Where compressed air is available, the sets may also be started from a source 25 of compressed air or other gas which is connected by a pipe 26 with a control valve 27 to the nozzle of the turbine 21a (or what would be the same, to turbine 21).

The purpose of the above explains itself, according to my invention, to enable the supercharging to operate as a self-power-supporting gas turbine blower independently of the engine which may be at standstill or running.

For starting, the sets are rotated by the motor 23 (or by compressed gas), with the valve 16 open to pass air to the conduit 14, at a speed such that an air flow is set up through the blower 19, the intake pipe 14a, the bypass 15, the combustion chamber 15, the turbine 21a, the exhaust conduit 22a, and the heat exchanger 25 to the atmosphere. Now, fuel is admitted to the combustion chamber 15 by opening the valve 18 and ignited. The hot gases reaching the turbine 21a begin to produce power and the sets speed up under its own power, uncoupling the clutch 24 when a certain speed is exceeded. With the engine 19 at standstill all of the air is available for turbine 21a so that the sets quickly will attain a high speed. During this operation the turbine 21 is idle since no gases reach it from the engine. A high pressure is set up in the intake pipe 14a, and, if the engine 19 now is cranked for starting, a high supercharge pressure immediately is available.

This is of special importance for highly supercharged engines which, when started with intake air of atmospheric pressure, do not produce high enough compression and temperatures to ensure reliable ignition for starting, particularly when the ambient air is very cold.

Such method of starting has even greater importance for two-cycle engines which up to now had to use scavenging pumps, either driven from the engine shaft or by an auxiliary power source. Two-cycle engines with exhaust turbine driven blowers of the known types cannot work satisfactorily at low loads or idling because the exhaust gas turbine when operating at the low temperatures prevailing under these conditions cannot provide sufficient power even for scavenging. My invention avoids all these complications by making the supercharging pressure independent of the working condition of the engine, and available even at engine standstill. All kinds of engines, including two-cycle engines of any type, can thus be successfully started and operated under all conditions with mechanically independent exhaust turbo-supercharger sets.

In installations where constant output at wide varying speeds is required, the present invention can be used to superimpose such characteristic on internal combustion engines, thus doing away with the mechanical, electric or hydraulic transmissions so far used for this purpose. If in an installation according to Figs. 1 and 3 on a locomotive to which a certain fuel quantity is fed, a higher torque is required, the engine speed drops and the air requirements of the engine drop in same proportion. With the position of control valve 16 unchanged, and speed of the supercharger set also practically unchanged for a second or so due to its inertia, more air will flow to the combustion chamber 15 in which correspondingly more fuel is burned so as to maintain the gas temperature at the entrance to the turbine 21a. This turbine, therefore, begins to supply extra power, with proper design, the blower now is capable of supplying substantially the same air weight to the engine as before but at a higher pressure, enabling it to burn the same fuel quantity efficiently at the reduced speed while supplying a higher torque in return. Naturally, a new higher equilibrium speed will be established for the supercharger set. This speed increases with the heating temperature in the chamber 15, the limit of which is fixed only by metallurgical considerations for the blade material used in the turbine 21a. With dropping torque requirements the reverse operation is effected by gradual closing of the control flap valve 16 and reduction of fuel feed to the combustion chamber 15.

The fuel consumed in the auxiliary combustion chamber of course has to be charged against the drive in the same manner as the losses incurred by electric or hydraulic transmission, for example on a locomotive. However, the drive according to my invention is superior to the present day transmission system because extra fuel is consumed in the auxiliary combustion chamber only during the time when excess load or excess torque are actually furnished. Fig. 4 shows an installation which preferably may be used in larger plants. Here the turbine/blower set 10, 21 is a normal supercharger set which will be referred to hereinafter as a "torque charger," while a turbine 21b drives a second blower 10b which discharges into the intake of the blower 19. This second set 19b, 21b will be referred to hereinafter as a "torque charger." 26a and 22b, respectively denote the intake and...
gas discharge ducts to blower 190 and from the
turbine 21b. The pressure charger operates conti-
nuously, while the torque charger may be nor-
mally idling or operating at low load, and in-
creasing its load only when required to force
the supercharging for overload or for high tor-
quency. Since the speeds of both these sets are inde-
pendent of each other, more favorable working and
regulating conditions for the two blowers result.
The effectiveness of the supercharging may be in-
creased further by provision of air cooling means
in the form of a cooling coil 30 in the intake pipe
20 and another cooling coil 31 in the intake pipe
11, respectively. In this case starting is
affected by the electric starting motor 23 coupled
via the overrunning clutch 25 to the torque charg-
er. The pressure charger set may, during start-
ing, be at a standstill, or be idling, and is started
automatically the moment the engine starts.

Fig. 4 also shows diagrammatically a non-
limiting example of a control means for coordi-
nating the operation of the engine with the pres-
sure and torque chargers to achieve plant opera-
tion characteristics which are desirable on loco-
motives and similar other drives. 40 denotes a
means to sense the engine speed, such as a fly-
ball speed governor, driven from the engine shaft
by bevel gears 41. A governor lever 42 operates the
fuel valve 13a for the engine by means of
rods 43, 45 and a double armed lever 44 in the
conventional manner. A valve 13b permits limi-
tation of the fuel supply by hand. The lever 42
further is connected by a rod 45 to a lever 47
whose left hand end is resiliently supported by a
spring 48 and whose right hand end operates the
flow control flap valve 16 through a crank C
and rod 49. Means to sense the engine intake
manifold pressure above a predetermined pres-
sure is provided. Said means comprises an elas-
tic bellows 50. The bellows is connected by a
tube 51 with the engine intake pipe 11 and
presses down the left hand end of the lever 47
against the pressure of the spring 48 in the event
that the engine intake pipe 11 exceeds a definite limit. A rod 52 with a screw and
handwheel 53 permits hand adjustment of the
fuel feed to the engine to be effected by moving
the left hand end of the lever 44. A vapor pres-
sure thermostat 54 is disposed in contact with
the gases issuing from the combustion chamber
15. Said thermostat constitutes a means to sense
the temperature of the hot gases leaving the
burner, said means is connected by a tube 54a
to an elastic bellows 55 which operates the fuel
valve 18 by a crank 56. 18a denotes a hand op-
erated flap valve in the air intake to the com-
bustion chamber and 18b denotes a hand oper-
ated fuel valve in the fuel intake line to said
chamber. The thermostat 54 is adjusted in such
a manner as to maintain a substantially con-
stant high temperature of the gases flowing to
the turbine 21b. The engine 10 may be of any
known type, for example a two-cycle compres-
sion-ignition engine.

The plant is started as follows: The motor 33
is energized. This causes the torque charger to
rotate thereby setting up an air stream from the
blower intake 20b through the torque charger
blower 190, the intake pipe 20, the pressure
charger blower 19, the engine intake pipe 11a,
past the control flap valve 16 which is open to
conduit 14, the open valve 15a, the combustion
chamber 15 (to which fuel is not yet allowed to
flow by keeping the valve 15a closed), the torque
charger turbine 21b and thence to the atmos-
phere, at the turbine outlet 22b. Fuel is now
admitted gradually to the combustion chamber
15 by opening the valve 15a, and then ignited
by the heating in said ignition coil 24. With
increasing gas temperature the power of the
torque charger turbine 21b increases fast caus-
ing the torque charger to speed up under its own
power and uncoupling the clutch 24. The motor
can now be deenergized. The torque charger
quickly attains said equilibrium speed when the
turbine and blowers powers balance. If the
blower pressure rises too much, and possibly to
prevent pumping (surgung) of the torque charger
blower 190, the pressure limiting device 50 comes
into action by expanding and pressing the left
hand side of the lever 47 down, thereby caus-
ing the control flap valve 16 to throttle the air
flow to the torque charger turbine 21b thus
reducing the speed of the torque charger.

The fuel valve 13a to the engine is set by
operating the handwheel 53 for starting, and
the engine is cranked. Since the connection from
the engine intake pipe 11a to the engine intake
manifold 11 is never fully closed, the engine re-
ceives scavenging air from said manifold under
pressure at the first moment it will start to
operate. Exhaust gases now begin to flow through
the engine exhaust pipe 12 to the pres-
sure charger turbine 21 and the pressure charger
set begins to operate. With increasing engine
speed the lever 42 rises and gradually throttles
the air flow to the bypass conduit 14 by moving
the flap valve 16 counterclockwise, until at full
speed only a slight flow of air is maintained
through the combustion chamber 15 to keep a
small flame burning. With reducing flow of
combustion gases to the torque charger turbine
21b the speed of the torque charger will drop to
a point where it is idling. In the meantime the
pressure charger speed has increased, enabling
it to supply the charging of the engine by itself.
(While this method of regulating may be pref-
erred for some engines, the scope of this
invention not to throttle the air flow to the
bypass conduit completely thus keeping the torque
charger always operating at reduced speed.)

With the fuel to the engine set by the valve
13a for a desired load, the pressure charger
contains a main speed and delivers (without or
with the help of the torque charger) charging
air of a certain pressure to the engine.

If now, due to increasing resistance, a higher
torque is required, the lever 42 will begin to
drop and normally would act to open the fuel valve
13a for admitting more fuel to the engine. The
fuel quantity to the engine is, however, limited
by the hand setting of valve 13b, so that the
lever 42 will continue to drop, turning the lever
41 clockwise until its left hand end as a fixed
point and admitting more air into the bypass con-
duit 14 by moving control flaps valve 16 clockwise.
Since the engine, due to its reduced speed, now
takes less air, this does not cause a material
decrease of pressure at 14b and, on the contrary,
as soon as a greater quantity of gases reaches the
turbine 21b, the torque charger speeds up
and its blower 19b begins to operate as precom-
pressor stage to the pressure charger blower 19
resulting in a higher charging pressure for the
engine, increasing its mean effective pressure and
consequently its torque. Due to the now higher
air charge per working stroke the engine can
burn the same fuel quantity at the lower speed
as efficiently as it did at the former higher speed,
and by proper choice of pressures and speeds the
engine output can remain substantially unchanged, a characteristic most desirable for all kinds of vehicles and similar drives.

If the torque requirement decreases, the reverse motions take place and the engine speeds up with the power output remaining constant or approximately so. The cooling coil may serve for cooling the air between the stage blowers \( 9b \) and \( 9f \), and, if desired, after cooling of the air charge to the engine may be achieved by the cooling coil \( 31 \).

It is immaterial for the purposes of my invention what particular type of engine is used. It may be of the compression-ignition or spark-ignition type working on two-cycle, four-cycle or dual cycle, single or multiple cylinder design.

It is also immaterial what types of machines are used for the supercharger means and whether or not cooling of the charging air is resorted to.

It is further immaterial for my invention what kind of fuel is burned in the engine and/or the auxiliary combustion chamber, and whether or not the same or different fuels are used in the engine and combustion chamber, respectively.

Having thus described the nature of my invention and in what manner the same is to be performed, I declare that what I claim is:

1. A combination with a reciprocating internal combustion compression-ignition engine having a turbine-driven blower set mechanically independent of the engine shaft and which set supplies compressed air to the engine: of a fuel burner externally of the engine and means for leading hot gases from said burner to said turbine, wherein there are provided means to sense the engine speed and means responsive to said sensing means to divert an increased portion of the air output of the turbine-driven blower to the burner as the engine speed falls to serve as combustion air therefor.

2. A combination with a reciprocating internal combustion compression-ignition engine having a turbine-driven blower set mechanically independent of the engine shaft and which set supplies compressed air to the engine: of a controllable fuel burner externally of the engine and means for leading hot gases from said burner to said turbine, wherein conduit means and a bypass valve in said conduit means controlled by the engine speed is provided to divert a varying portion of the air output of the turbine-driven blower to the burner to serve as combustion air therefor, said valve being arranged to pass an increased quantity of air to the burner with falling engine speed, and wherein means is provided to increase the quantity of fuel with increasing quantity of bypassed air so that the speed of the set is increased with falling engine speed whereby engine intake manifold pressure increases with falling engine speed.

3. The combination with an internal combustion compression-ignition engine having a turbine driven blower set mechanically independent of the engine shaft and which set supplies compressed air to the engine: of means connecting the air outlet of the blower of said set to the engine air intake pipe, means connecting the engine exhaust pipe with the inlet of the turbine of said set, a fuel burner externally of the engine, controllable bypass means to divert a portion of the air output of said burner to serve as combustion air therefor, means for leading hot gases from said burner to said turbine, means to sense the engine intake manifold pressure above a predetermined pressure, and means responsive to said sensing means to operate the controllable bypass means so as to reduce the quantity of air bypassed and thereby limit the degree of supercharging.

4. The combination with a reciprocating combustion compression-ignition engine having a turbine-driven blower set mechanically independent of the engine shaft: a second turbine-driven blower set mechanically independent of the engine shaft and of the first set, means to connect said blowers in series, means for connecting the outlet of the second blower in the series to the engine air intake pipe, a fuel burner externally of the engine, means to divert at least a portion of the air delivered to the engine air intake pipe to said burner to serve therein as combustion air, means for leading the hot gases from said burner to one of said turbines, and means directly connecting the engine exhaust pipe to the other turbine.

5. The combination with a reciprocating internal combustion compression-ignition engine having a turbine-driven blower set mechanically independent of the engine shaft, of means for connecting the outlet of the blower of said set to the engine air intake pipe, a controllable fuel burner externally of the engine, means to divert a portion of the air output of said blower to said burner to serve therein as combustion air, means for leading the hot gases from said burner to said turbine, means for connecting the engine exhaust pipe with the turbine of said set, means to sense the temperature of the hot gases leaving the burner, means responsive to said sensing means to vary the quantity of fuel to be fed to the burner as to maintain the temperature of said hot gases substantially constant, means to sense the engine speed, and means responsive to the second sensing means to increase the portion of the air diverted with falling engine speed so as to increase engine intake manifold pressure.

6. A combination with an internal combustion compression-ignition engine having regulatable means to feed fuel to it and supercharging blower means driven by exhaust gas turbine means, said blower and turbine means being mechanically independent of the engine shaft, of a fuel burner externally of the engine, regulatable means to feed fuel to the fuel burner, means to branch off a portion of the compressed air issuing from the blower means and lead it to the fuel burner, means for leading hot gases from the burner to the turbine means, and means simultaneously to control the fuel fed to the engine per working stroke, the air branched off from the blower means and the fuel fed to the burner.

7. The combination with an internal combustion compression-ignition engine having a turbine driven blower set mechanically independent of the engine shaft which set supplies compressed air to the engine: of means connecting the air outlet of the blower of said set to the engine air intake pipe, a fuel burner externally of the engine, means connecting the engine exhaust pipe with the inlet of the turbine of said set, means connecting the outlet of the burner to the inlet of the turbine, a controllable bypass means to divert a portion of the air output of said blower to said burner to provide fresh combustion air therefor, means to sense engine intake manifold pressure, means to sense the temperature of the hot gas issuing from the burner, and means responsive to said sensing means to control the quantity of air diverted to the burner and the amount of fuel.
burned therein in such manner as to maintain the engine intake manifold pressure at the degree of pressure necessary for operation.

FREDERICK NETTEL.

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