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AIRCRAFT POWER PLANTS FOR
HIGH ALTITUDE FLIGHT
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Serial No.
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Fig. 1.

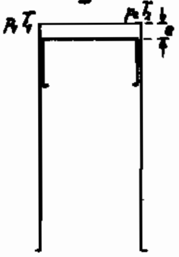


Fig. 2

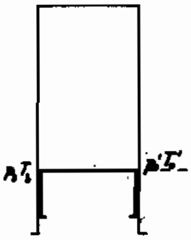


Fig. 3

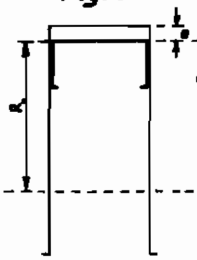


Fig. 4

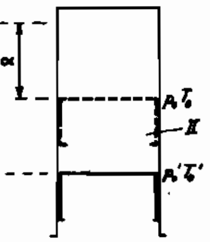


Fig. 5

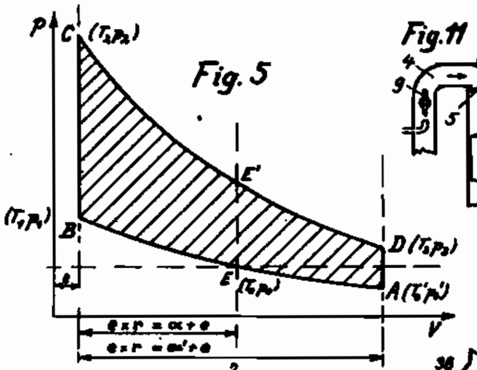


Fig. 11

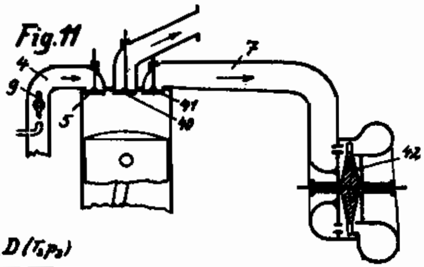


Fig. 12

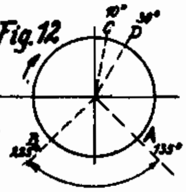


Fig. 10

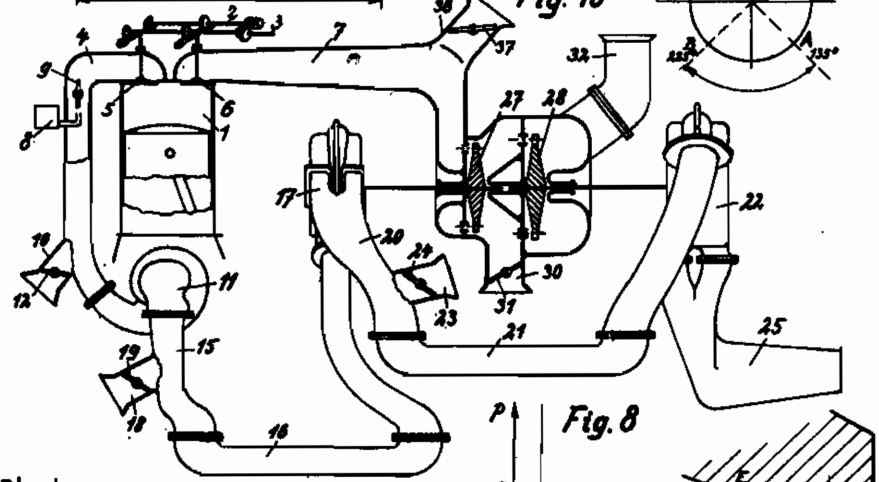


Fig. 8

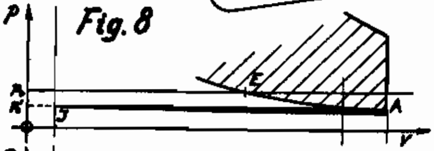


Fig. 9

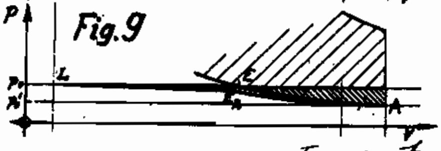


Fig. 6

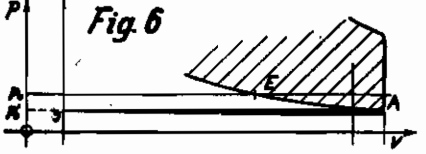
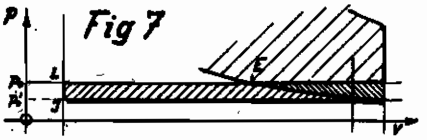


Fig 7



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ALIEN PROPERTY CUSTODIAN

AIRCRAFT POWER PLANTS FOR HIGH ALTITUDE FLIGHT

Georges Boulet, Plessis-Robinson, France; vested in the Alien Property Custodian

Application filed November 16, 1939

My present invention has for its object to provide an aircraft engine for flight at high altitude, more especially in the stratosphere, which is more particularly intended for long distances and has a low specific consumption, which is ensured by its cycle of operation, independently of the other known means that may likewise act to decrease such consumption (adjustable richness carburettor, injection of gasoline into the pipes or into the cylinder, injection of additional liquid, special chamber, etc.), said low consumption existing at its normal altitude of operation and preferably also under all conditions of operation at any intermediate altitude.

As the flying ranges are inversely proportional to the specific consumption, any decrease of consumption increases either the flying range or the loading capacity, or the ceiling or combinations of these qualities.

The constant power at all altitudes increases the speed and the safety of the flights, and gives the pilots or passengers the ability to support high speeds owing to a relative decrease of vertical accelerations in rising gusts.

For very long flights, these two abilities are therefore those which form the basis for the design of aircraft as a propelling and lifting machine.

In order to combine these two qualities, recourse is had to the usual combination of an engine of an engine of the explosion type and a system of air compression which is capable of supplying the engine at high altitude with fuel at the requisite pressure, but, and this is a remarkable pecularity of the invention, the engine used is of the high volumetric ratio type (higher than 8) and undercharged, that is to say wherein the pressure p'_0 at the end of the intake stroke with the throttle wide open is lower than the atmospheric pressure on the ground. This pressure p'_0 is dependent on the octane index of the fuel that can be employed in normal operation at the altitudes in question.

Said engine may be of the explosion type, operating by means of a carburettor or of an injection of gasoline either into the inlet pipe, or directly into the combustion chamber. In any case a high volumetric expansion ratio is used.

The undercharging may be obtained either by means of a throttling of the intake, or preferably by means of a distribution which is adjustable in flight, or by means of unequal strokes of the piston, etc.

The adjustable distribution is more particularly advantageous since it enables the duration of intake on the ground to be limited and a normal setting and a normal duration of intake to be restored the altitude Z_1 at which the external pressure is equal to the pressure p'_0 at the end of the intake. Furthermore, it enables when on the ground a small overlap to be obtained of the periods of closing of the exhaust and of opening of the intake, and a substantially greater overlap to be obtained at the altitude Z_1, which permits of a very considerable scouring (in particular a scouring by pure air in the case of gasoline injection), which favours the cooling of the chamber and increases its ability to support a higher volumetric ratio.

In the case of injection of gasoline directly into the combustion chamber, the under-charging by means of adjustable distribution may be effected on the ground by means of a delay or storing, that is to say that the closing (of the intake valve or valves or of the intake distributor or distributors) will be late, thereby driving the air into one or other of the pipes, preferably the intake pipe, the adjustment becoming normal again at the altitude Z_1 called reference altitude.

Similarly, the delay might be considered in engines provided with carburettors with a buffer chamber between the cylinders and the members controlling the intake.

Similarly a system called after-charging might be considered, in which the intake at the pressure Z_1 takes place at that part of the end of the intake stroke during which the piston only undergoes small movements.

The variable adjustment can be obtained either by a lateral movement of variable contour camshafts, or by the relative angular movement of two camshafts, the action of which on the distribution is added or subtracted, one or both being movable during operation relatively to their actuating member, or by means of distributions with wandering sleeves or the like which permit of a variable or invariable adjustment of the distribution, or any combinations of sleeves, valves, rotating plugs or slide-valves, which are suitable for obtaining the same results.

In all the cases, the device for controlling the adjustable distribution is preferably provided with a manometric capsule which is influenced by the pressure in the intake pipe before the intake valve, so as gradually to vary the closing point of the intake.

Whatever be the manner in which the undercharging is obtained, the system of air compression is preferably controlled by a manometric device which renders it operative automatically under predetermined conditions.

It ensues from the foregoing that the intake pressure in the engine can be kept constant from the ground up to the altitude Z_1 where the atmospheric pressure becomes equal to this intake pressure. The power of the engine therefore remains substantially constant between the same limits of altitude (for example between 0 and 5,000 metres) without the intervention of the air compressing system. The starting of the latter, which is preferably effected automatically as soon as the altitude Z_1 is passed, enables said intake pressure to be kept constant up to the maximum altitude Z at which said system is capable of restoring the intake pressure. From O to Z the engine consequently operates under the most efficient conditions.

The cycle of operation of an under-charged engine has as its particular feature a lower exhaust gas temperature than that of normal engines, owing to the high expansion ratio.

An advantageous development of the basic arrangement of the present invention consequently consists in forming the driving part of the pressure restoring system completely or partly by one or a plurality of turbines actuated by the exhaust gases, since the resistance and the efficient operation of said turbines are proportional to the moderation of the temperature, the part of the restoring system which is not driven by turbines being in this case actuated by the engine through a mechanical transmission.

In a preferred embodiment of this development, the engine is provided with a distribution which is adjustable during operation and the pressure restoring system comprises a mechanically driven compressor which is capable of restoring the pressure p'_o up to the altitude Z_2. There exists on the exhaust a valve controlled by a manometric capsule, in such a manner that from a predetermined altitude, at least equal to Z_1 where there is a pressure equal to the constant intake pressure, said valve maintains in the exhaust pipe a constant pressure p_e which is intermediate between said consant intake pressure p'_o and the atmospheric pressure at the maximum altitude Z_2 at which the compressor can restore said constant intake pressure, and there exists at least one turbo-compressor actuated by the exhaust gases, the turbine of which is adapted to operate at a pressure drop equal to the difference between said constant exhaust pressure and the pressure corresponding to the maximum altitude Z_3 at which the pressure Z_2 can be restored by the compressor which is driven by said turbine and the discharge pipe of which is connected to the suction pipe of the mechanical compressor.

This arrangement enables an automatic scouring of the engine to be obtained at the end of the intake at a pressure $p'_o—p_e$.

In this latter arrangement, an air radiator is preferably interposed in the pipe connecting the turbine-driven compressor to the suction pipe of the mechanically driven compressor.

This embodiment may be provided with a second compressor which is likewise driven by the exhaust gases and is capable of restoring the pressure which prevails at altitude Z_3 up to an altitude Z_4. In this case, the driving part of the restoring system may comprise a single turbine with convergent-divergent nozzles to absorb the total pressure drop from Z_e to Z_4, said turbine actuating the two compressors which restore the pressures Z_2 and Z_3; said driving part may also comprise two turbines in parallel which actuate separately each of said compressors and are each adapted to operate at the pressure drop from Z_e to Z_4, or again two separate turbines which are adapted to operate in series, one at the pressure drop from Z_e to Z_3 and the other from Z_3 to Z_4.

These pressure drops may be those which correspond to the critical pressure drop equal to 0.52 at which maximum efficiency is obtained.

Furthermore, these turbines which operate at a constant inlet pressure Z_e may be of the staged type or of any known type.

Similarly turbines might be considered which operate on the exhaust "puff"; they would be called variable pressure turbines. In this case several arrangements could be considered inter alia:

(*a*) The turbines would be connected to the exhaust outlets so that there would be no interference with the exhaust periods, each group formed being adapted to act on a turbine or a part of a turbine.

(*b*) A special exhaust valve or a device which only acts during the puff period, that is to say from the opening astride on the extreme low position, at which instant the piston is nearly stationary, the other valve or device being provided either with a normal control in the case of the pure under-charged engine, or a control for varying the adjustment.

In this case, the scouring pressure would constantly increase while climbing.

From the altitude Z_e, the cycle of the engine remains constant and its sole difference with the cycle up to the altitude Z_1 consists in the pressure drop at the exhaust between Z_1 and Z_e, thereby producing an increase of power which partly compensates for the power absorbed by the mechanical compressor.

The foregoing arrangement may be further improved by forming the air intake for the compressor which restores the pressure at the altitude Z_3 or Z_4, by a divergent nozzle which converts the velocity of the air into pressure and is preferably arranged in the zone located behind the propellers where the air is accelerated relatively to the actual speed of the aircraft. This improvement enables the pressure p'_o to be restored up to an altitude Z_m greater than Z_4 and called end of constant pressure altitude and which is consequently the end of constant power altitude.

Said air intake could also, for flying on a level from Z_1 to Z_2, eliminate the necessity of providing a mechanical compressor. However, the arrangement with an intermediate mechanical compressor is preferable, since when climbing the compression effect of the air intake is substantially decreased owing to the decrease of speed on the course.

The energy which is still available in the gases at the outlet of the turbines may again be recuperated by connecting an outlet shaft for said gases to a recuperating system of the known type.

The recuperable energy in the cooling liquid may also be recuperated by means of suitably designed radiators, as is known.

The chief advantage of the above defined arrangement is that the power to be supplied to the pressure restoring system relatively to the constant mass introduced and to the altitude Z_4 in question, is very much lower than that which would be required for normal engines, the thermic efficiency of which is lower. In fact, since the power produced per kilogramme introduced is in a ratio of 1 to 1.4 in favour of the high thermic efficiency engine, a greater intake mass is required to obtain the same power with a normal engine and consequently larger compressors which absorb more power, thereby reducing the final power output.

Furthermore, since the pressure to be restored is much lower, the temperatures at the end of the compression are lower and the air radiators smaller.

On the other hand, at the instant when the quick climb stops and when the flight continues with a very gentle climb, as the aeroplane becomes lighter, the mechanical compressor can be stopped and will then only act as a conveyor, or it can be cut out of the system and its action replaced by that of the dynamic pressure in the shaft. It will be reintroduced into the system when its action becomes necessary again, that is to say on the level located below the end of constant intake pressure altitude, by an amount corresponding to its compression ratio.

On the other hand, the engine itself offers relatively to normal engines the advantage of having a compression ratio which is adapted to the degree of use provided for a long operation, whereas a normal engine, which is used for example at $^{65}/_{100}$ of its power, is thermically inefficiently utilized.

In order to enable the invention to be better understood, four diagrams of the power cycle which serves as a basis for the present invention have been shown in Figs. 1 to 4 of the accompanying drawing.

Fig. 5 is an indicator diagram of said cycle.

Figs. 6 to 9 show partial diagrams at different altitudes of under-charged engines.

Fig. 10 shows diagrammatically, by way of a nonlimitative example, an embodiment provided with the various peculiarities mentioned above,

and Figs. 11 and 12 show diagrammatically a modified embodiment.

In the complex embodiment shown in Fig. 10, the basic combination of the whole arrangement is formed by that of an under-charged engine shown diagrammatically at **1** and by a compressor **11**. The general cycle of the type of engine **1** is shown in Figs. 1 to 5.

Each of Figs. 1 to 4 shows one of the strokes the four-stroke cycle of this under-charged engine, Fig. 1 corresponding to the end of the compression, Fig. 2 to the end of the expansion, Fig. 3 to the end of the exhaust and Fig. 4 to the end of the intake. In these figures, e designates the height of the combustion chamber and r' the volumetric expansion ratio. The pressure of the temperature is designated by p_1T_1, at the end of the compression stroke, p_2T_2 at the end of the explosion stroke, p_3T_3 at the end of the expansion stroke, $p'_oT'_o$ at the end of the intake stroke.

Fig. 5 shows the theoretical diagram corresponding to the (adiabatic) compression stroke (AB) and the (adiabatic) expansion stroke (CD). This diagram remains the same whatever be the manner in which the under-charging is effected.

The consequences of two different manners of effecting the under-charging are shown in Figs. 6 to 9 which are figurative diagrams of the intake and exhaust strokes. Figs. 6 and 7 relate to an engine which is under-charged by throttling the intake, Figs. 8 and 9 an engine which is under-charged by closing the intake valve long before the end of the stroke of the piston. In these diagrams, P_oT_o respectively designate the pressure and the temperature at altitude o.

Fig. 6 shows the operating diagram at the altitude at which the end of intake pressure p'_o prevails, whereas the diagram of Fig. 7 is that of the operation at the altitude o. It will be seen that in this latter case there exists a work of suction represented by the area AELI which is far from being negligible. This loss has almost entirely disappeared in the diagram of Fig. 9 in which the undercharging is obtained by closing the intake valve at a point E_1 corresponding to an intermediate position II of the piston in its intake stroke (Fig. 4) which is chosen in such a manner that the mass introduced expands during the remainder of the intake stroke according to the adiabatic curve E_2A which is as close as possible to the adiabatic curve AE of the compression stroke of the general cycle (Fig. 5). The diagram of Fig. 8 is equivalent to that of Fig. 6, save that this particular manner of undercharging the engine by varying the instant of closing the intake valve enables the intake valve to be closed at the altitude p'_o only after the closing of the exhaust valve and thereby enables a scouring to be obtained which has the effect of increasing the power owing to the fact that the cylinder is entirely cleansed of burnt gases and is consequently filled with a more considerable mass of fresh gas than when burnt gases remain; furthermore, the volumetric ratio of the combustion chamber can be made higher owing to the cooling of the combustion chamber by the fresh gases and to the lower temperature of the mass at the end of the intake.

In this embodiment of Fig. 10, the engine **1** is of the high volumetric compression type, for example higher than 9, and has two camshafts **2** and **3**, the camshaft **3** being angularly displaceable during the operation of the engine, for example by means of a device of the type described in French Patent No. 672.335, in the name of the same applicant. **4** designates the intake pipe, **5** the intake valve, **6** the exhaust valve, **7** the exhaust pipe, **8** a usual supply carburettor and **9** the usual butterfly valve for controlling the power of the engine; **10** is an air intake located on the intake pipe after a compressor **11** which is mechanically driven by the motor **1**; **12** is a throttle valve for the air intake **10** and is controlled by a manometric capsule not shown and subjected to the influence of the pressure prevailing in the intake pipe **4**. On the intake pipe of the compressor **11** which is connected through a pipe **15** and an air radiator **16** to the delivery pipe of another compressor **17**, is arranged at **18** an air intake direct from the atmosphere, which air intake is controlled by a valve **19** controlled by a manometric capsule not shown and subjected to the pressure that prevails in the intake pipe **4** or in the pipe **15**. Said compressor **17** has its intake pipe connected through a pipe **20** and an air radiator **21** to the delivery pipe of another compressor **22**, and **23** designates a direct air intake arranged on the intake pipe of the compressor **17**; a valve **24** controls said air intake **23** and is actuated by a manometric capsule not shown and subjected to the pressure in the intake pipe **4** or in one of the pipes **15**, **20**. The air intake of the compressor **22** is shown at **25**.

The compressors **17**, **22** are each respectively mounted on the shaft of a turbine **27**, **28**. Said turbines are coaxial and their outer case is common but divided into two compartments each containing one of the wheels **27**, **28**. It is into the compartment of the wheel **27** which drives the compressor **17** that the exhaust pipe **7** leads and said compartment is provided with a direct exhaust pipe **30** controlled by a valve **31**. The compartment of the wheel **28** is likewise provided with an exhaust pipe **32** opening directly into the atmosphere, without a valve, and it communicates with the other compartment. Finally, on the exhaust pipe **7** is arranged between the engine and the turbines an exhaust pipe **38** controlled by a valve **37** which is actuated by a manometric capsule subjected to the pressure prevailing in the exhaust pipe **7**.

The operation of this arrangement is as follows:

On the ground, all the valves **12**, **19**, **24**, **30** and **37** are open. The engine is designed to operate at an inlet pressure of 405 mm. which pressure is that prevailing at an altitude of 5.000 metres, and this is obtained by appropriately covering up the opening periods of the intake valves **5** and of the exhaust valves, by means of the movable camshaft **3**; the settings from the upper dead centre are for example +0 and +130 for the opening and the closing of the intake valve **5** and +135 and +10 for the opening and the closing of the exhaust valve. The exhaust takes place through the pipe **36**, the valve **37** being wide open. Up to the altitude of 5.000 metres, the intake pressure remains the same by an appropriate adjustment of the camshaft **3**, either by hand, or automatically by means of a manometric capsule subjected to the intake pressure. The setting at 5.000 metres is for example −10 and +225 for the intake valve **5** and +135 and +30 for the exhaust valve **6**. At 5.000 metres the valve **12** is closed, either automatically by a manometric capsule influenced by atmospheric pressure, or the pressure in the intake pipe, or by hand. At the same time, the mechanical compressor is started if same is not constantly driven by the engine. The suction then takes place through the air intake **18** and the valve **19** more or less throttles said air intake so that the intake pressure always remains equal to 405 mm. From 6,500 metres, the closing of the valve **37** starts and a portion of the exhaust gases passes through the turbine **27**, thereby actuating the compressor **17** which drives air through the pipe **15** but at a pressure which is that determined by the valve **19**. At 8,000 metres, the maximum altitude at which the compressor **11** can restore the pressure of 405 mm., the valve **19** closes completely and the valve **37** is completely closed; the exhaust is then effected completely through the turbine **27** and the pipe **30**, while the air intake takes place through the pipe **23** which is suitably throttled by the valve **24** so that the intake pressure is constant. The turbine **27** operates at that instant at a pressure drop equal to the difference of the pressures at 6,500 and 8,000 metres and the compressors **17** and **11** act in series and restore the pressure of 405 mm. up to 11,500 metres. Towards this altitude or slightly before, towards 10,700 metres for example, the closing of the valve **31** is effected so that the exhaust then takes place through the two wheels in cascade **27** and **28** and the pipe **32**; then at 11,500 metres the valve **24** closes, so that the supply of air to the engine is effected through the pipe **25** and the passage of the air successively through the three compressors **22**, **17** and **11**, which restore the pressure of 405 mm. up to 15,000 metres.

The power of the engine **1** therefore remains substantially constant between 0 and 15,000 metres. Above 15,000 metres there is a decrease of power of the engine. However, it can still be kept constant for some time by giving the air intake the shape of a divergent nozzle which converts the kinetic energy of the relative wind into pressure energy. Calculation in the example would show that the power could be kept constant up to 17,500 metres

In the modified embodiment of Fig. 11, the engine is provided, in addition to its normal exhaust valve **40**, with a special exhaust valve **41**, or with a similar device called "puff" device, that is to say which opens astride on the lower dead centre, at which instant the piston is nearly stationary and opens into a pipe leading to a variable pressure turbine **42**.

The valve **40** is provided with a normal control or with a control that can be adjusted in flight.

Fig. 12 gives an example of such a control; in this example, the puff valve **41** remains constantly open from A to B, whereas the normal valve **40** is open from A to C on the ground and from A to D at 5,000 metres.

Of course, the invention is in no way limited to the details of construction illustrated or described, which have only been given by way of example. Thus, the numerical data given above are in no way absolute and the plant described could be designed to operate between other limits of altitude without thereby exceeding the scope of the invention. The same applies to the location and to the number of the members such as carburettors, radiators, etc.

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