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F. NEUGEBAUER ET AL
AIRCRAFT ENGINES
Filed June 25, 1938

Serial No.
215,792
4 Sheets-Sheet 1

Fig.1

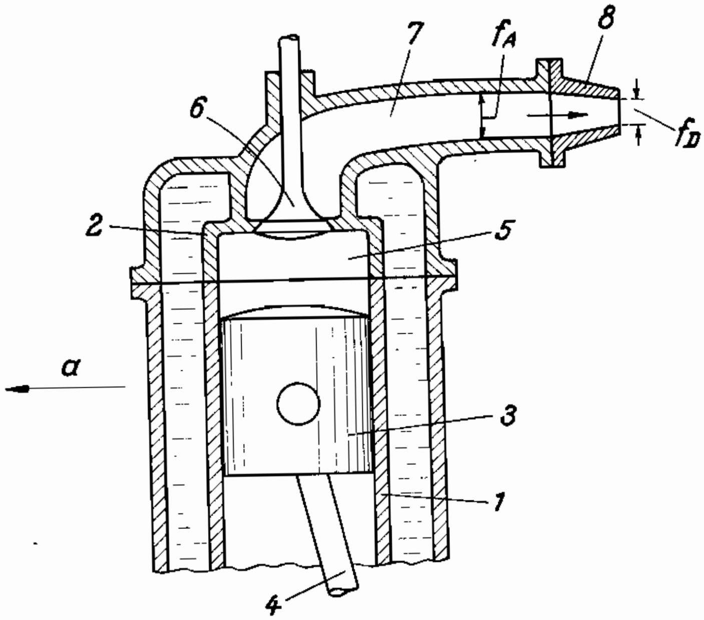

Fig.4

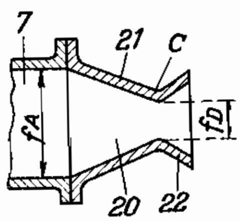

Fig.6

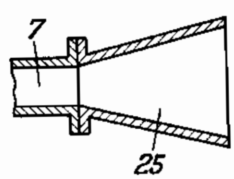

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Fig. 2

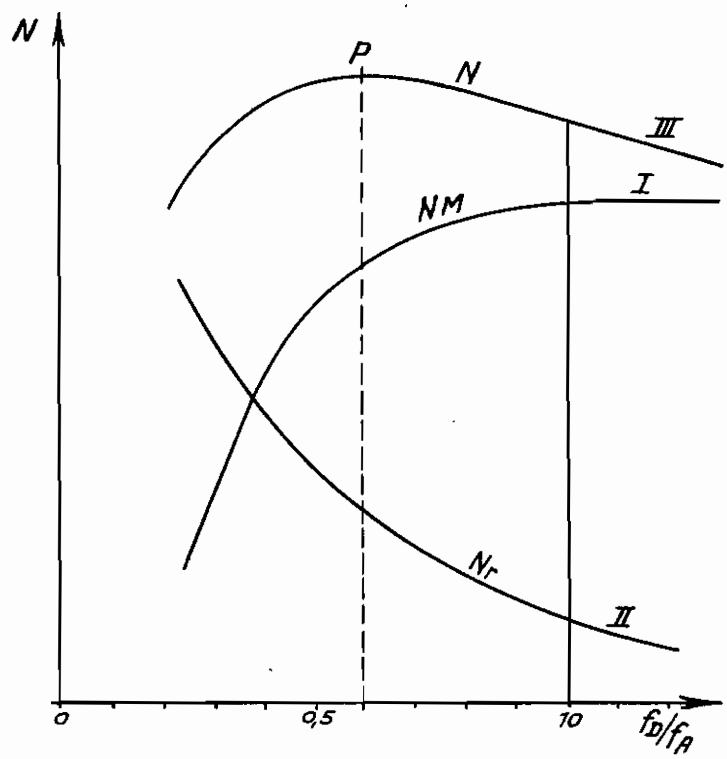

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Fig. 3

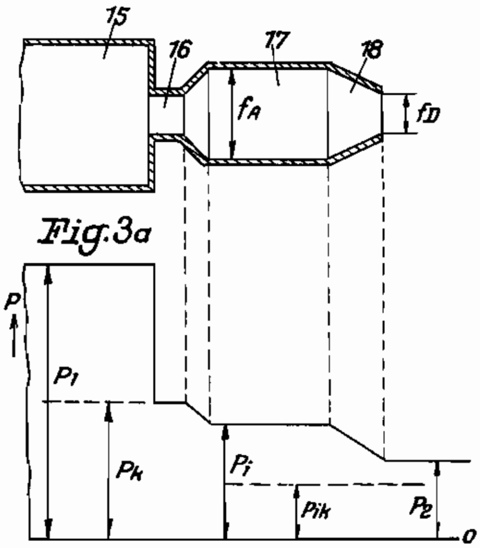

Fig. 5

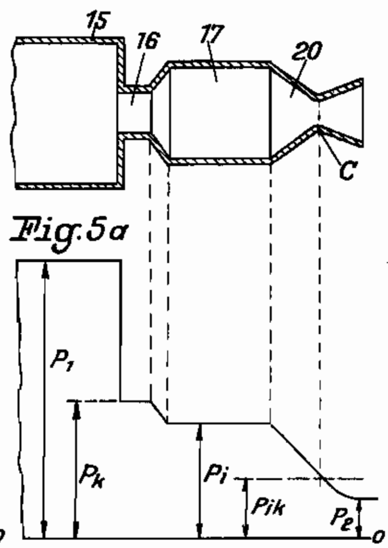

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Fig. 7

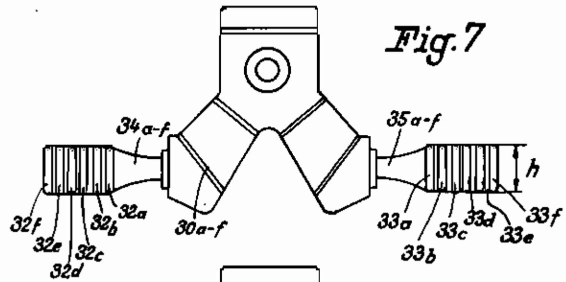


Fig. 8

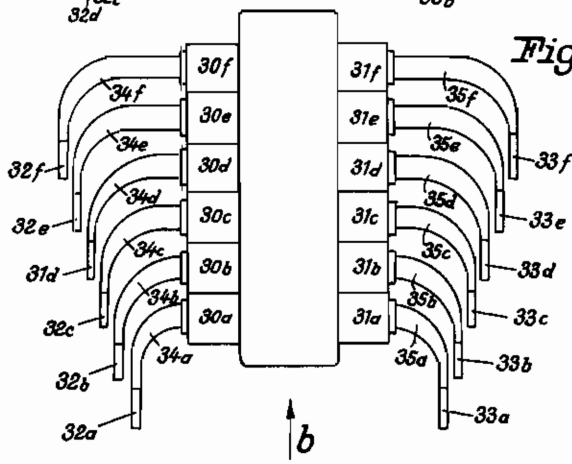
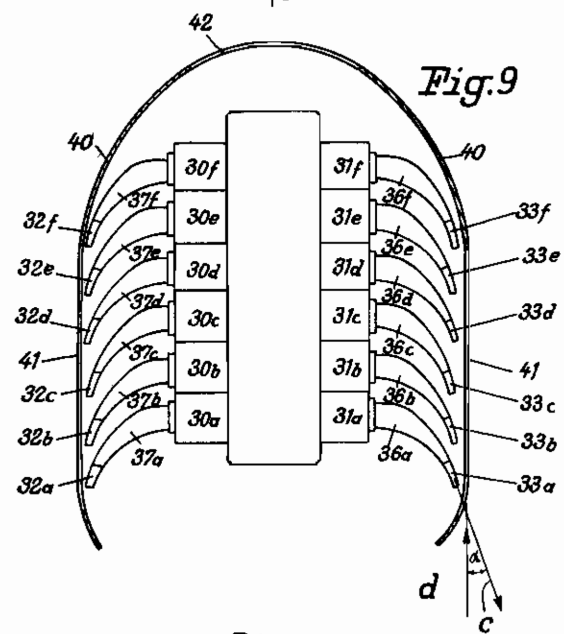


Fig. 9



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ALIEN PROPERTY CUSTODIAN

AIRCRAFT ENGINES

Franz Neugebauer, Allach near Munich, and Anselm Franz, Dessau, Germany; vested in the Alien Property Custodian

Application filed June 25, 1938

Our invention relates to the propulsion of aircraft and more especially flying machines. It has particular reference to the utilization of the energy of the exhaust gases of the propelling engines for the propulsion of the craft.

It is an object of our invention to provide means whereby the energy of the exhaust gases can be utilized for the purpose in view.

We are aware that it has already been suggested to utilize the energy of the exhaust gases of aircraft engines directly by utilizing the reaction effect arising during the exhaust into the ambient air. Either the exhaust gases issuing from the cylinders of the engine have been shoved into a collecting chamber and allowed to escape from this chamber in a direction counter to the direction of flight (jet drive with constant outflow). Alternatively the gases escaping from each cylinder individually have been allowed to escape rearwardly, i. e. counter to the direction of flight (jet drive with intermittent outflow).

It has now been found that this latter mode of utilization of the exhaust gases, while being superior to that mentioned in the first place, is still very imperfect since with the exhaust valves customarily used a comparatively great part of the energy of these gases is annihilated by vortex generation. In order to keep these losses low it has already been suggested to use exhaust valves of nozzle-shape, however such valves cannot always be used, since they require a great overall height of the cylinder heads, which is undesirable from the viewpoint of keeping the air resistance low. But even in those cases, where this drawback would not play a decisive role, it is practically impossible to altogether avoid annihilation of exhaust energy by using nozzle-shaped exhaust valves.

According to this invention means are provided for utilizing the energy of the exhaust gases, in which the exhaust gases are made to escape from the individual cylinders in such manner that with cylinder outlets formed in the usual manner a satisfactory efficiency is obtained and the degree of utilization of the exhaust energy, which can practically be attained with engines fitted with nozzle-shaped valves is still improved. We obtain this by providing at the outlet of the exhaust conduit adjoining the exhaust port of the engine cylinder, a nozzle which is so organized that on the gases of combustion passing from the cylinder into the exhaust gas conduit a short rise of pressure and in consequence thereof an increase of the exhaust velocity of the gases in the nozzle and consequently also an increase of the reaction force are obtained.

Our invention further relates to a satisfactory construction of such exhaust device in connection with internal combustion engines having a row of cylinders.

In the drawings affixed to this specification and forming part thereof several embodiments of our invention are illustrated diagrammatically by way of example.

In the drawings

Fig. 1 is an axial section of the cylinder head and the adjoining part of the cylinder of a propeller engine fitted with a device according to this invention.

Fig. 2 is a diagram illustrating the dependency of the engine performance from the ratio of tapering of the exhaust nozzle in a device according to Fig. 1.

Fig. 3 is a diagrammatic axial section of a device similar to that shown in Fig. 1, while

Fig. 3*a* is a diagram illustrating the run of the exhaust pressure in a device according to Fig. 3.

Fig. 4 is an axial section of another form of nozzle adapted for use in connection with the cylinder of Fig. 1, and

Fig. 5 is a similar view of another nozzle.

Fig. 5*a* illustrating the run of the exhaust pressure arising in the operation of the device of Fig. 5.

Fig. 6 illustrates still another form of a nozzle.

Figs. 7 and 8 are a front elevation and plan view of an internal combustion engine with two rows of cylinders arranged V-fashion and provided with a device according to this invention for utilizing the energy of the exhaust gases.

Fig. 9 is a plan view of a modified form of this engine.

Referring to the drawings and first to Fig. 1, 1 is the cylinder of an internal combustion engine in which the piston 3 is arranged for reciprocation under the action of the connecting rod 4 linked to the crank shaft (not shown). The cylinder is closed by the cylinder cover 2, in which is arranged an exhaust valve 6 controlled in any well known manner. The exhaust conduit 7 on the other side of the valve is so formed that its outlet is directed counter to the direction of flight indicated by the arrow *a*. On the conduit 7 is mounted a nozzle 8 which is formed at the inlet with the same cross-sectional area f_A as the conduit 7 and tapers constantly towards the outlet.

The action of this device is the following: After the outlet valve 6 has opened, the gases of combustion flow from the combustion zone 6 into the exhaust conduit 7. By means of the nozzle 8 adjoining the conduit 7 the flow of the gases of combustion from the conduit 7 into the atmosphere is throttled and a rise of pressure in the conduit 7 is effected. While this rise of pressure to a certain extent brakes the passage of the exhaust gases from the cylinder into the conduit 7 and in consequence thereof diminishes the performance available at the crank shaft of the engine, it also increases the velocity of the exhaust gases at the end of the nozzle and consequently also the reaction force.

The magnitude of the outflow velocity of the exhaust gases at the end of the nozzle and the magnitude of the reaction force depends, in a device according to Fig. 1, from the tapering ratio of the nozzle, i. e. from the value

$$\frac{f_D}{f_A}$$

of the cross-sectional areas f_D of the narrowest part of the nozzle at its end and the cross-sectional area f_A at the nozzle inlet.

In Fig. 2 the dependency of the propulsion performance of an engine provided with a device according to Fig. 1 from the tapering ratio

$$\frac{f_D}{f_A}$$

is illustrated in a diagrammatical manner with reference to a predetermined speed of flight. In this diagram the values of the tapering ratio

$$\frac{f_D}{f_A}$$

are plotted as abscissae and the performance M as ordinate. The curve I indicates the performance N_m available at the crank shaft of the engine, the curve II the reaction performance N_r. Curve III illustrates the total performance N, i. e. the sum of N_m+N_r. Fig. 2 shows that the crank shaft performance N_m becomes the smaller, the smaller the value

$$\frac{f_D}{f_A}$$

As mentioned above this is due to the throttling of the waste gas exhaust from the cylinder. In contrast thereto the reaction performance N_r rises in proportion as the tapering ratio

$$\frac{f_D}{f_A}$$

drops; in the case illustrated in Fig. 2 the rise of N_r occurs more quickly in the range between

$$\frac{f_D}{f_A}=1$$

and

$$\frac{f_D}{f_A}=0.6$$

than the dropping of N_m in the same range. In consequence therefrom the total performance $N=N_m+N_r$ rises in proportion as

$$\frac{f_D}{f_A}$$

drops, until it has reached a maximum about at the value

$$\frac{f_D}{f_A}=0.6$$

Therefore in a device according to Fig. 1 it is preferable to use a nozzle, the tapering ratio of which lies between 0.3 and 1.

It has further been found that the total performance available, when using a device according to Fig. 1, depends further in a similar manner from the value of the ratio

$$\frac{V_s}{V_s}$$

of the volume V_s of the conduit 7 to the stroke volume V_s of the engine cylinder. In the case of a device according to Fig. 1 it is advantageous to so dimension the conduit 7 that its volume ranges between about 0.3 and 1, calculated on the stroke volume.

The form of the nozzle according to claim 1 is more especially correct in the case where the outer pressure, i. e. the pressure in the space into which the exhaust gases escape (the atmosphere) is higher during the greater part of the exhaust period, than the critical pressure determined by the pressure and that velocity in the conduit 7, at which sound velocity is attained.

Fig. 3 is a diagram according to Fig. 1, while Fig. 3*a* is a diagram illustrating the course of pressure in such a device shortly after the outflow has begun, i. e. at high pressure in the working cylinder. 15 is the working cylinder of an internal combustion engine, 16 the cylinder outlet, 17 is the exhaust conduit adjoining this outlet and 18 the nozzle fixed to the exhaust end of the conduit. In the cylinder 15 prevails the pressure p_1 (Fig. 3*a*). When the cylinder outlets 16 are opened, the gases in the cylinder escape and the pressure p_1 drops within the range of the outlets 16 to p_k (critical pressure) which is reached in the narrow cross-sectional area. If the cross-sectional area of passage in front of the narrowest cross-sectional area gradually increases up to the value f_A, which is the cross-sectional area of the conduit 17, the pressure drops from p_k to p_i (inner pressure in the conduit 17), which remains approximately constant in this conduit. In the nozzle 18 the pressure p_i then drops further until it reaches the outer pressure p_2 which is higher than the critical pressure p_{ik} correlated to the pressure p_i and the gas velocity in the conduit. If during the greater part of the exhaust period the outer pressure is lower than the critical pressure determined by the pressure and gas velocity in the conduit 7, at which sound velocity is reached; and the speed at which the exhaust gases pass through conduit 7 (according to Fig. 1), below the critical value, the nozzle 8 in Fig. 1 or 18 in Fig. 3 is preferably replaced by a nozzle 20 according to Fig. 4. This nozzle uniformly tapers, viewed in the direction of flow (part 21) in such manner that its cross-sectional area at the inlet which is equal to the cross-sectional area f_A of the conduit 7, gradually drops to the value f_D at the point C. The part 22 of the nozzle 20 which extends in front of the point C, flares gradually in the direction of flow.

A diagram illustrating a device provided with a nozzle of this kind is shown in Fig. 5, while Fig. 5*a* shows the course of pressure shortly after the outlets have been opened and while the pressure in the cylinder is still high. This course of pressure up to the nozzle is similar to that according to Fig. 3*a*. In the nozzle the gases are then expanded to the outer pressure p_2, the critical pressure p_{ik} prevailing at the narrowest point C. If, during a material part of the exhaust period, the speed at which the exhaust gases in the conduit 7 or 17 flow towards the nozzle, is equal to or greater than the critical speed, the same conditions prevail as at the narrowest part C of nozzle 20 in the example of Fig. 5; consequently in this case a nozzle 25 according to Fig. 6 is attached to the conduit 7 or 17, which nozzle, viewed in the direction of flow, is merely formed with a constant flaring.

Figs. 7 and 8 are an end view and plan view, respectively, of an aircraft engine with two rows of cylinders arranged V-fashion and provided with a device of the kind above described. The exhaust tubes 34a—34f and 35a—35f, respectively, fitted to the exhaust ports of the working cylinders 30a—30f and 31a—31f, respectively, which carry at their ends exhaust nozzles 32a—32f and 33a—33f, respectively, are so curved that the exhaust of the gases into the atmosphere occurs counter to the direction of flight (arrow *b*). They have the form of hollow bodies with cross-sectional areas of passage uniform or approximately uniform throughout their length, the circular cross-section at the inlet of the tube gradually merging into a strongly flattened cross-section near the end of the tube. The nozzles are flattened also in a similar manner and the flattened portions of the tubes are arranged in substantially parallelly spaced relation, the exhaust ends of the nozzles being arranged in staggered relation. We thereby obtain a small length of the tubes transversely to the direction of flight, which is desirable in the interest of a low air resistance.

Fig. 9 illustrates a particularly favorable form of an engine similar to that shown in Fig. 8, where the exhaust tubes 36a—36f and 37a—37f, respectively, are so curved, that the direction, in which the exhaust gases escape (arrow C in Fig. 9) encloses an acute angle α with the direction of flight (arrow *d*). It is true that in this arrangement only that component of the reaction force, which coincides with the direction of flight, is utilized for propulsion, however with a small angle α, this component is only little less than the total reaction force and the loss is therefore only insignificant. At the same time however we thus obtain the advantage that, viewed in the direction of flight, the outflow ends of the nozzles can be arranged one behind the other, so that in view of the further reduction of the length of the tube transversely to the direction of flight the air resistance is reduced still further.

In the arrangements according to Figs. 7–9, it is preferable, in order to further reduce the air resistance, to provide a streamlined envelope (40 in Fig. 9), which must be formed with longitudinal slits 41 for the passage of the exhaust gases. In order to avoid unduly high temperatures at the exhaust tubes and nozzles, an aperture 42 for the entrance of cooling air is provided at the front end of the envelope. This air, after having taken up heat from the hot exhaust tubes and nozzles, escapes through the slits 41 together with the exhaust gases.

We wish it to be understood that we do not desire to be limited to the exact details of construction shown and described for obvious modifications will occur to a person skilled in the art.

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ANSELM FRANZ.