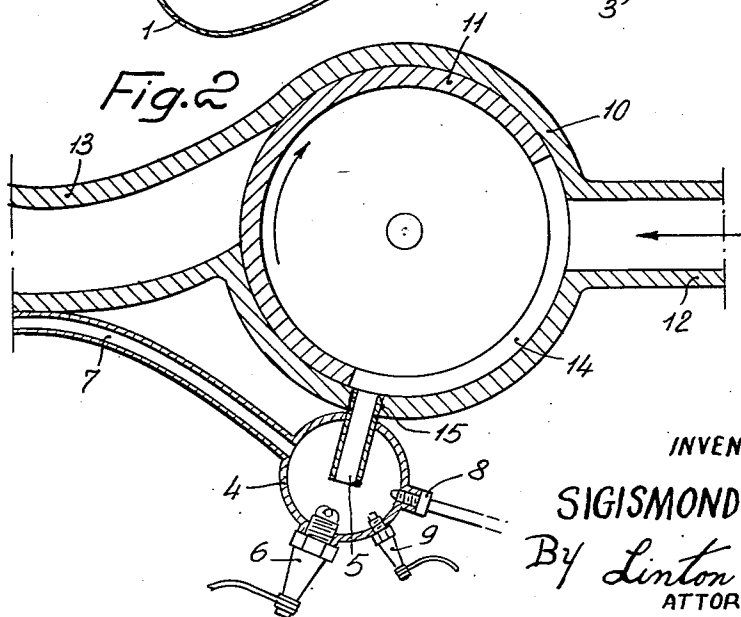
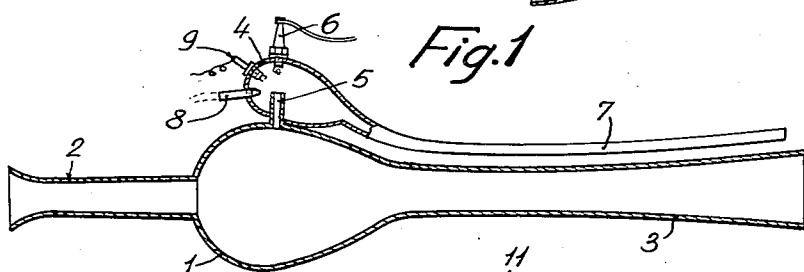
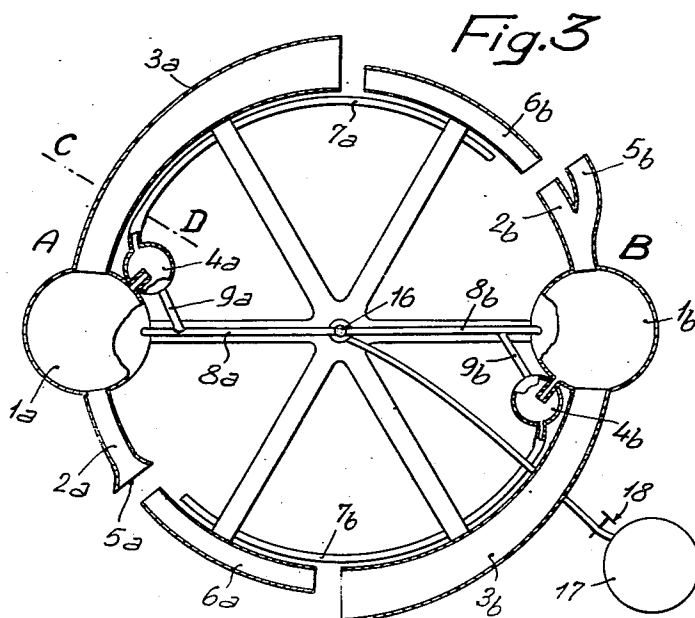


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METHODS OF AND DEVICES FOR PROMOTING THE FILLING
OF COMBUSTION CHAMBERS AND FACILITATING THE
IGNITION IN PULSATORY REACTION JETS

2 Sheets-Sheet 1



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Filed Oct. 31, 1952

2 Sheets-Sheet 2

Fig. 4

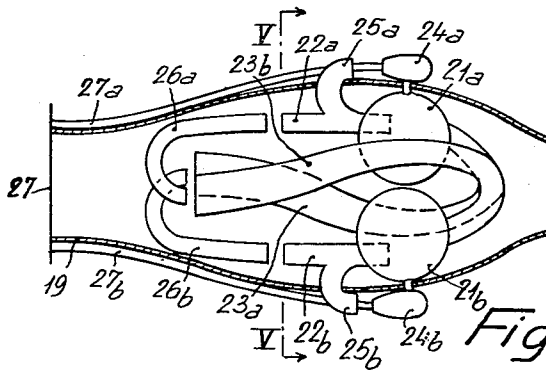


Fig. 5

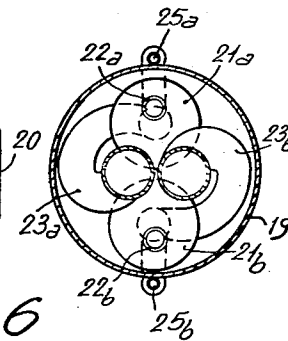


Fig. 6

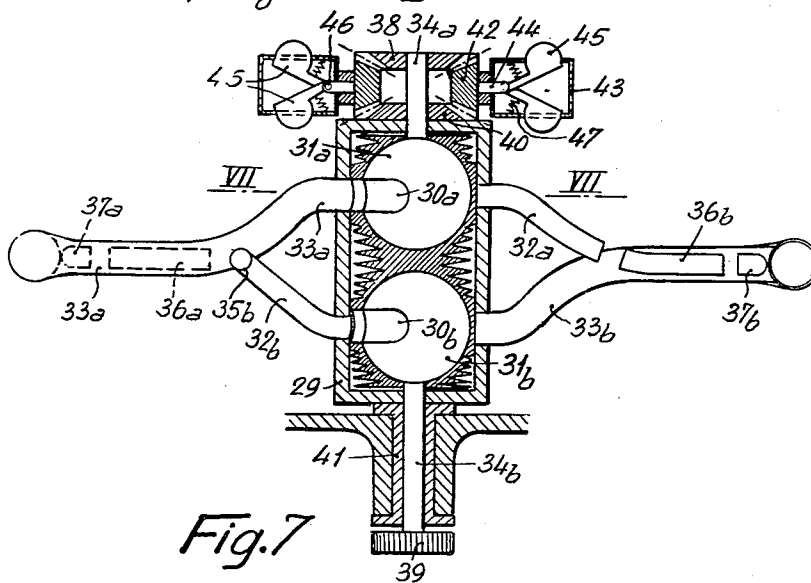
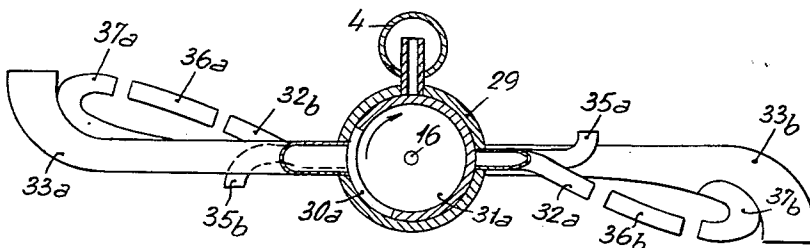


Fig. 7



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METHODS OF AND DEVICES FOR PROMOTING THE FILLING OF COMBUSTION CHAMBERS AND FACILITATING THE IGNITION IN PULSATORY REACTION JETS

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Application October 31, 1952, Serial No. 317,902

Claims priority, application France October 31, 1951

2 Claims. (Cl. 60—35.6)

This invention relates to pulsatory reaction jets, according to the principle disclosed by the same Applicant in his French Patent 844,442, dated April 2, 1938. Since then, other improvement patent applications have been filed by the applicant, such as the French Patent 942,386, dated February 19, 1947, describing an arrangement comprising two pulsatory reaction jets coupled to each other in view of utilizing the exhaust gas energy of one jet to improve the filling of the combustion chamber of the other and vice versa, both pulsatory reaction jets being displaced by 180° relative to each other so that the induction of one jet occurs simultaneously with the exhaust of the other.

This solution offered various advantages but suffered from a few inconveniences, notably in that one portion of the exhaust gases mixed with the induction air entered the combustion chamber in spite of the provision of a device specially designed to avoid this phenomenon, because this device was only partly effective in practice.

Now it is an essential object of this invention to avoid this drawback by providing an original arrangement of the induction and exhaust pipes in two or more associated pulsatory reaction jets so as to obtain, in a first stage, a spontaneous filling resulting from the depression or vacuum caused by the exhaust of burnt gases and, in a second stage, an additional fuel mixture intake following the spontaneous filling. This additional intake is obtained by causing the exhaust gases from another pulsatory reaction jet to push the air contained in the inlet manifold of the first reaction jet and vice versa, this thrust becoming effective at the time where the intake air column induced by the depression within the chamber is just about to come to a standstill. Of course the length and cross-sectional area of the inlet pipe should be so calculated that the exhaust gas column will stop just at the entrance of the combustion chamber without entering it.

To afford a clearer understanding of the solutions of this problem which are set forth hereafter, it is necessary to point out that the time of gas flow through the exhaust pipe is equal to one half-cycle of the stationary wave of the fundamental sound brought about in the pulsatory reaction jet which, for the purposes of the present invention, must be considered as an acoustic resonance cavity; this time factor is dependent on temperature. This is the reason why the intake pipe must be shorter than the exhaust pipe in order to have equal intake and exhaust times, because as cold or atmospheric air has a greater density this column of air must be shorter in order to prevent it from having a lower force of inertia than hot exhaust gases.

It is another object of this invention to provide a method of simplifying and improving the ignition in a main pulsatory reaction jet by blowing out the flame from the combustion of a smaller igniting combustion chamber operating synchronously with the main reaction jet.

Other advantages and characteristic features of this invention will become apparent as the following descrip-

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tion made with reference to the accompanying drawings proceeds. In the drawings:

Figure 1 is a diagrammatic axial section showing a pulsatory reaction jet having a fixed explosion chamber associated with an auxiliary ignition combustion chamber;

Figure 2 is a diagrammatic section taken at right angles to the axis of a rotary explosion chamber pulsatory reaction jet associated with an auxiliary ignition combustion chamber;

Figure 3 is a diagrammatic sectional view showing a rotary engine having two associated pulsatory reaction jets;

Figure 4 is another diagrammatic view of a propelling engine having two associated stationary pulsatory reaction jets;

Figure 5 is a section taken upon the line V—V of figure 4; and

Figures 6 and 7 are an elevational and part-sectional view and a section according to the line VII—VII of Figure 6 respectively showing diagrammatically a rotary engine having two associated pulsatory reaction jets comprising chambers mounted for rotation about an axis passing through them.

The description will first be made of the arrangements of an auxiliary ignition combustion chamber which may be combined with the various embodiments of pulsatory reaction jets either coupled or associated in greater number in view of improving the filling of their combustion chambers.

In the example illustrated in Figure 1 the main pulsatory reaction jet consists of an explosion chamber 1; comprising in alignment an intake pipe 2 and an exhaust pipe 3, the latter having a greater length and cross-sectional area than the intake pipe to account for the considerably higher temperature of the exhaust gases.

The auxiliary combustion chamber (which will be termed hereafter "igniter" for the sake of brevity) consists of a resonance chamber 4 communicating with the explosion chamber of the main pulsatory reaction jet through a relatively short pipe 5 emerging to a substantial extent within the igniter so that this emerging pipe portion will be constantly raised to a red heat during operation. Diametrically opposite to this connecting pipe is a resistor plug 6 to be used for cold starting only. Moreover, the igniter chamber 4 is provided with a relatively long exhaust pipe 7 which may even exceed in length the exhaust pipe 3 of the main reaction jet; this igniter exhaust pipe 7 is directed the same way as the main exhaust pipe 3 so that the gases expelled through the former will contribute to the thrust exerted by those expelled through the latter. In addition, this chamber 4 is provided with a spray nozzle 8 and a sparking plug 9.

This apparatus operates as follows: the fuel mixture enters the main jet chamber 1 through the intake pipe 2. As the inner walls of this chamber are cold the fuel gasoline cannot evaporate at the atmospheric pressure and therefore no ignition can be obtained through a spark or the red filament of a resistor plug. Air (which practically) is not mixed yet with the gasoline vapor will enter through pipe 5 into the chamber 4 already filled with a sufficient amount of gasoline vapor by the spray nozzle 8 which injects the fuel partly onto the short connecting pipe 5, part onto the resistor plug. Besides, this resistor plug has raised the temperature within the chamber 4 to a degree sufficient to cause the fuel to be evaporated instantaneously. This fuel in admixture with air will form an explosive mixture ready to explode when contacting a hot-spot or an electric spark. The pressure wave developed by the explosion will scavenge instantaneously (within a few thousandths of a second) the major portion of the mixture ignited into the main chamber 1. The heat conveyed by this explosion is

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such that the gasoline contained in chamber 1 is ignited although it is not completely evaporated. Another portion of the burnt gases is expelled to the atmosphere through the exhaust pipe 7 the length of which is sufficient to produce a depression in chamber 4 at the time where chamber 1 is being filled again with a fresh mixture. Cold or atmospheric air is introduced once more into the auxiliary reaction jet chamber 4 and another explosion takes place, and so forth.

When the combustible mixture is ignited in the main chamber 1, as a consequence of the entrance of flames from the igniter 4, the explosion is initiated in chamber 1 and the explosive wave propagates through the pipes 2 and 3 but in a very different manner, due to the differences of sections and lengths of these pipes. Whereas the greater part of the gases escape through the exhaust pipe 3, which is of larger section, a smaller part penetrates into the intake pipe 2 but during a very small period, because the explosive wave causes a vacuum in the combustion chamber and the minimum of pressure takes place very rapidly at the end of the short intake pipe 2, in such a manner that immediately a new suction of fresh air takes place through the shorter intake pipe.

Of course at the start a richer fuel mixture is required because the insufficient evaporation in chamber 1 prevents the combustion from taking place completely, but as the temperature rises in this chamber a normal mixture ratio may be used.

After a certain number of explosions the resistor plug 6 can be disconnected since the short pipe 5 raised to red heat by these explosions will be amply sufficient for ensuring an instantaneous evaporation and even an instantaneous ignition.

Figure 2 illustrates the adaptation of the acoustic resonance igniter to a rotary-chamber pulsatory reaction jet of the kind disclosed in the French Patent 959,645, dated 6th January 1948.

This apparatus comprises a casing 10 provided with an inlet pipe 12 and an exhaust pipe 13. In this casing 10 is rotatably mounted a combustion chamber 11 rigid with the engine shaft and formed with a substantially oval aperture 14 which, by properly rotating the chamber, may be caused to register alternately with the inlet pipe 12 or the exhaust pipe 13. An igniter 4 of the type disclosed hereabove is connected through a relatively short pipe 5 with the inside of the casing 10.

This apparatus operates as follows: the resistor plug 6 is heated and the reaction jet chamber caused to rotate about its axis by blowing air through the inlet pipe 12. During the filling, the orifice 15, in which the relevant end of pipe 5 is fitted, will be uncovered when the pressure in chamber 11 exceeds the atmospheric pressure. Thus, fresh air, with a very small amount of non-evaporated gasoline will enter the chamber 4 through the connecting pipe 5. On the other hand, gasoline is injected in the auxiliary chamber 4 by the spray nozzle 8. The air-fuel mixture is ignited by a suitable plug either of the red-hot resistor or sparking type, and the resulting explosion will scavenge the major portion of the ignited gases into chamber 11 while a minor portion of these gases will be exhausted to the atmosphere through the exhaust pipe 7 exactly as in the case of the apparatus illustrated in Figure 1. However, the fact that the exhaust end of the connecting pipe 5 is always opened at the proper time this characteristic feature is highly advantageous for obtaining an extremely accurate ignition timing.

Of course, cold starting may be facilitated by using a sparking plug 9 simultaneously with a resistor plug 6, the essential function of the resistor plug consisting in evaporating the liquid fuel which is subsequently ignited by a spark. It is also within the scope of the invention to utilize the ignition system incorporating a small combustion chamber (igniter) as described hereinabove

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either for a single main pulsatory reaction jet operating independently of the others, or in a combination of a plurality of synchronized pulsatory reaction jets, as will be described hereafter by way of example with reference to Figures 3 to 7 of the drawings.

The following description has particular reference to the problem of improving the chamber filling, the above-description of an ignition device having the sole purpose of proving the possibility of combining both methods which together contribute in improving the efficiency of pulsatory reaction jets.

In the example illustrated in Figure 3 a rotary engine consists of a pair of pulsatory reaction jets A and B which are phase displaced by 180° with each other; each rotary engine comprises as shown a resonance chamber 1a—1b, an inlet pipe 2a—2b and an exhaust pipe 3a—3b. The inlet pipes 2a and 2b are shorter than those which would be required to obtain an inlet time equalling the exhaust time. Each inlet pipe may be provided at its intake end with either a funnel-shaped member 5a or a branch pipe 5b adapted to facilitate the filling of the relevant chamber due to the velocity of the wind blowing therein. The combustion chambers 1a and 1b are displaced by 180° from each other about the axis of rotation 16. The exhaust pipes 3a and 3b flare gradually toward their outlet ends in order to improve the thrust. Transfer pipes 6a and 6b are interposed between the inlet pipe of one reaction jet and the exhaust pipe of the other so as to enable part of the exhaust energy from each reaction jet to be transmitted to its companion reaction jet. The ignition is ensured by the corresponding igniters 4a and 4b similar in design to the igniters 4 of the embodiments shown in Figures 1 and 2. The exhaust pipes 7a and 7b of these igniters by developing an acoustic resonance, bring about a depression between the igniters. The fuel stored in a pressure tank 17 controlled by a valve 18 is fed to the chambers through suitable pipes 8a and 8b each ending with a spray nozzle 9a—9b.

This apparatus operates as follows:

To start the engine rotating, two different modes of operation are available. For example, the resistors in the igniters are heated and then air is blown through the funnel-shaped members 5a or branch pipes 5b and the fuel valve 18 is opened at the same time. Ignition occurs in both chambers, for example in chamber 1a and the resulting explosion will scavenge the exhaust gases in two opposite directions: the major portion through the exhaust pipe 3a having the greater cross-sectional area and a minor portion through the intake pipe 2a having a smaller diameter.

Since the intake pipe is shorter than the exhaust pipe the inertia of the gas column contained therein is lower than that of the corresponding column in the exhaust pipe. This is the reason why the velocity of the exhaust gases will attain its maximum value more rapidly in the intake pipe 2a than in the exhaust pipe 3a. Thus, a depression is obtained very rapidly at the point of emergence of the intake pipe in the combustion chamber 1a. This depression will reverse the direction of flow and bring about an air induction through the intake pipe before the flow of gases through the exhaust pipe has come to an end, so that at the end of the exhaust period the direction of flow in the intake pipe 2a will be the same as in the exhaust pipe 3a.

As the gas column circulating through the exhaust pipe develops behind it a depression still higher than that produced in the intake, the air column following the exhaust gases through the exhaust pipe 3a will undergo a strong suction, thereby filling the combustion chamber 1a through the intake pipe 2a. The sucked air and the injected fuel will form an explosive mixture which is then ignited by the igniter 4a. The resulting explosion will scavenge the exhaust gases in the opposite two directions as before and so forth.

Thus, a single reaction jet could operate independently.

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of the other; however, during the operation of reaction jet A an ignition always takes place in the other reaction jet B and, practically, the two explosions never occur simultaneously because there is a permanent shift of a very small fraction of a second therebetween due to the fact that the two apparatus are never absolutely identical as to the intake diameter, nozzle orifices, ignition energy, etc.

After a few irregular explosions an extremely regular alternating ignition rate will be established now in one, now in the other of the explosion chambers 1a, 1b. This is due to the fact that each reaction jet affects the operation of the companion reaction jet by blowing exhaust gases toward the intake of the other reaction jet after the latter is filled so as to compress the fuel mixture and promote the filling. For this purpose it is necessary properly to calculate the lengths of the transfer pipes 6a and 6b as the pressure wave passing through these pipes requires a certain time before attaining the respective intake pipe; meanwhile, the spontaneous induction brought about by the aforesaid depression has had enough time to take place.

To ensure the maximum efficiency of operation the diameter of the induction pipe must be so calculated that it can suck in more air than permitted by the volume of the relevant chamber. This air will partly enter the exhaust pipe and attain a certain line CD. Thus, the explosion of the companion reaction jet will scavenge this excess air back into the combustion chamber together with the air contained in the induction pipe.

Thus a series of alternating explosions are produced in both chambers and each explosion is utilized to compress air in the other chamber. The excess energy is utilized to produce a reaction thrust. This excess energy is always very important and higher than 50% since the cross-sectional area of the exhaust pipe is several times greater than that of the transfer pipe.

The apparatus of Figure 3 may also be started by operating its starter motor at a velocity sufficient to cause the surrounding air to be blown through the induction pipe 2a—2b across the funnel-shaped member 5a or the branch pipe 5b.

Figures 4 and 5 illustrate a pair of coupled pulsatory reaction jets not of the rotary type as in the embodiment described hereabove with reference to Figure 3 but designed to travel in the atmosphere along a line of flight if mounted on an aircraft. Propulsive apparatus of this type may also be mounted on the blade-tips of a helicopter.

The structure of this apparatus is as follows: a pair of pulsatory reaction jets of a type similar to that shown in Figure 3 are arranged within a streamlined housing 19. Cooling air enters this housing through the front aperture 20 and combustive air is induced through diametrically opposite bent pipes 25a and 25b the external or inlet portions of which emerge from the housing and face the direction of motion of the apparatus. The exhaust gases, mixed with the heated air having cooled the reaction jets, are vented to the atmosphere through the rear aperture 27. Both induction pipes 22a and 22b extend through the chambers 21a—21b in order to save length and present a hot surface likely to promote the evaporation of fuel. The transfer pipes 26a and 26b are bent in such a manner that their ends register with the similarly bent exhaust pipes 23a—23b. The hitherto described assembly is mounted inside the housing so as to have the smallest overall dimensions possible and reduce drag to a minimum. In each main reaction jet the ignition is effected by means of an igniter 24a—24b similar in design to the igniter 4 of Figure 1 and fuel is injected through nozzles of the type illustrated in Figure 3.

The operation of this apparatus is the same as that of the preceding embodiment the explosions occurring alternately in both reaction jets.

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Moreover, if the fuel mixture is too rich the excess fuel may be burned in the rear orifice 27 so as to develop an additional propulsive thrust with the assistance of the cooling air induced through the front orifice 20.

The volume of the cavity constituted by the external housing 19 as well as the diameters of the inlet and outlet orifices 20 and 27 respectively must be so calculated that the frequency of the acoustic resonance of this cavity (due account being taken for the temperature) shall be twice the frequency of each pulsatory reaction jet, that is, equal to that of the assembly consisting of the coupled pair of pulsatory reaction jets operating in alternate relationship in this housing. Thus, the alternating exhaust periods produced through the exhaust pipes 23a and 23b will bring about the resonance of the aforementioned cavity, and the amplitude thereof will be magnified by the conveyance of heat dissipated across the walls of chambers 21a and 21b. Therefore, this heat will not be lost; it will be made available for increasing the reaction thrust of the assembly. The exhaust pipes of the igniters 24a and 24b are designated at 27a and 27b.

On the other hand, the dimensions of the various parts of the apparatus may be so calculated that the pressure phase within the housing will be coincident with the spontaneous induction through the intake pipes 22a and 22b whereby the latter will have to suck in air at a pressure higher than the atmospheric value, thus further improving the filling of the combustion chambers.

Figures 6 and 7 illustrate a rotary pulsatory reaction jet comprising two chambers 31a and 31b fast with each other, each provided with a substantially oval port 30a—30b and arranged within a casing 29 provided with induction pipes 32a, 32b and exhaust pipes 33a, 33b.

By rotating the chamber assembly about the axis of shafts 34a—34b both ports 30a—30b may be caused to register with the relevant exhaust and induction pipes. The induction pipes are formed with bent portions 35a and b.

The transfer pipes 36a and 36b are interposed between the ends of the induction pipes of one reaction jet and the branch elements 37a and 37b emerge from the exhaust pipes of the other reaction jet so as to constitute a means for causing the exhaust gases of one reaction jet to blow through the induction pipe of the other and vice-versa, exactly as in the embodiment described hereinabove with reference to Figure 1.

Both chambers 31a and 31b are rigid with a bevel gear 38 and a driving gear 39 through the medium of shafts 34a and 34b, respectively.

The casing 29 together with the induction and exhaust pipes is rigid with a bevel gear 40 on the one hand and a hollow shaft 41 having rotatably mounted therein the aforesaid shaft 34b fast with the combustion chambers, on the other hand.

Between the bevel gears 38 and 40 and in meshing engagement therewith are interposed planet pinions 42 the velocity of rotation of which is limited by blade governors. Each governor consists of a hollow cylinder 43 of thin sheet metal rigid with the stub shaft 44 of the relevant pinion 42; at the outer end of each stub shaft 44 are pivotally mounted through pivot pins 46 a pair of blades 45 as shown. Due to the centrifugal force developed by the rotation of the stub shafts 44 the blades of each pair tend to move away from each other while spring means 47 tend to restore them to their position near the axis of the relevant stub shaft. As the centrifugal force overcomes the resistance of spring means 47 the blades 45 move away from each other and protrude from their respective cylinders 43 through suitable slots formed therein.

The speed of rotation of the planet pinions 42 about the axes 44 is regulated automatically by the blades 45 because, beyond a certain speed, these blades, submitted to the centrifugal action of their springs, emerge out of their casing 33 and then the aerodynamic resistance in-

creases with the degree of emergence of the blades, ensuring thus an automatic braking action. An equilibrium takes place for the speed of the planet pinions 42. If the casing 29 is stationary, the chambers 31a and 31b drive the pinion 38 at the speed which alone ensures the equilibrium speed of planet pinions 42.

If the casing rotates very slowly, the chambers secured to pinion 38 rotate in the opposite direction and in such a case the sum of the two speeds of the casing and of the chambers is proportional to the speed of the planet pinions 42, limited by the regulating blades 45.

If the speed of the casing 29 increases, the speed of the chambers decreases, the sum of the two speeds remaining limited. At a certain instant, the chambers become stationary and the speed of the casing alone is limited by the governor.

However the speed of the casing may increase again, whereas the pinions 42 remain at a limited speed, but this increase of the casing speed, the speed of pinions 42 being limited, causes the inversion of the rotation direction of the chambers which, from this instant, begin to rotate in the same direction as the casing but with less speed, the difference between the two speeds, of the casing and of the chambers, being proportional to the speed of the planet pinions 42.

In addition, the apparatus is fitted with igniters 4 of the type illustrated in Figure 2, and also with fuel spray nozzles and a pressure fuel tank of the type shown in Figure 3 but omitted from Figure 6 for the sake of clarity.

The operation of this apparatus is similar to that of the apparatus shown in Figure 3. To start the apparatus, air is blown through the bent pipes 35a and 35b while opening the fuel valve and causing the chambers to rotate by means of a starter motor in driving connection with the driving gear 39. The velocity of rotation should be at least equal to the acoustic frequency of these chambers. As the casing 29 and bevel gear 40 remain stationary, the velocity of the planet pinions 42 will be a direct function of the velocity of rotation of chambers 31a—31b and therefore this latter velocity can be limited to the desired value.

When the ignitions have taken place the reactive force developed will rotate the casing 29 and the hollow shaft 41 rigid therewith. The velocity of rotation of bevel gear 38 will increase as that of bevel gear 40 decreases, the resultant of both velocities being constant due to the provision of planet pinions 42 which are limited in speed by the blade governors.

At a given moment the coupled chambers and their associated bevel gear 38 come to a standstill, the starter motor is stopped, and subsequently the chambers and bevel gear 38 start rotating in the opposite direction, that is, in the same direction as casing 29 but at lower velocity than this casing so as to have a constant angular velocity in relation to the casing irrespective of the velocity of rotation thereof, this feature resulting from the fact that the governors act directly on the velocity of the planet pinions 42.

Under these conditions and whatever the velocity of rotation of casing 29 may be, the frequency or rate at which the ports 30a—30b open and close will be always constant. For example, assuming that the casing is fixed to the blade tips of a helicopter having a maximum velocity of rotation of 900 R. P. M. the angular velocities of the chambers can be adjusted to a value of 600 R. P. M.

for example, in relation to the casing. Of course, the volumes of the combustion chambers as well as the dimensions of the induction and exhaust pipes must be so calculated that the acoustic resonance occurs at exactly 600 pulsations per minute, that is 10 pulsations per second.

Thus, when the casing 29 will have attained the angular velocity of 600 R. P. M. the rotary motion of the chambers must be stopped and beyond this velocity the chambers must begin to rotate in the opposite direction, that is in the same direction as the casing as they are driven by this casing through the intermediary of the planet pinions which are limited in speed by the provision of the aforesaid governors.

It may happen that the desired frequency implies the construction of chambers having an excessively large volume. Therefore, to reduce the dimensions of these chambers it is advantageous to provide each of them with two or more induction pipes and an identical number of exhaust pipes.

A rotating engine somewhat similar to that of Figure 3 may comprise in each casing such as 1a—1b a rotating chamber having its shaft radially arranged toward the axis of the engine, the shafts being driven in synchronism by a suitable central gearing mechanism.

What I claim is:

1. A pulsatory reaction jet engine comprising a structure adapted for moving in the atmosphere, at least two pulsatory reaction jets, each carried by said structure and provided with a combustion chamber forming an acoustic resonance cavity and with at least an induction pipe and an exhaust pipe, and transfer pipes in a number equal to that of the induction pipes, each transfer pipe forming at one of its ends an extension of one of said exhaust pipes of one of said pulsatory reaction jets and registering at its other end with the inlet of an induction pipe of another of said pulsatory reaction jets and each exhaust pipe having an enlarged outlet registering with an outlet of a smaller cross-sectional area of a transfer pipe associated therewith.

2. A pulsatory reaction jet engine comprising a structure adapted for moving in the atmosphere, at least two pulsatory reaction jets, each being carried by said structure and provided with a combustion chamber forming an acoustic resonance cavity and with at least an induction pipe and an exhaust pipe, each of said jet combustion chambers being disposed ringwise, said induction and exhaust pipes being arranged as an endless succession in the fashion of a rotary ring, and transfer pipes in a number equal to that of the induction pipes, each transfer pipe forming at one of its ends an extension of one of said exhaust pipes of one of said pulsatory reaction jets and registering at its other end with the inlet of an induction pipe of another of said pulsatory reaction jet.

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