Jan. 6, 1948. F. ZWICKY ET AL 2,433,943

OPERATION OF JET PROPULSION MOTORS WITH NITROPARAFFIN

Filed March 11, 1944 2 Sheets-Sheet 1

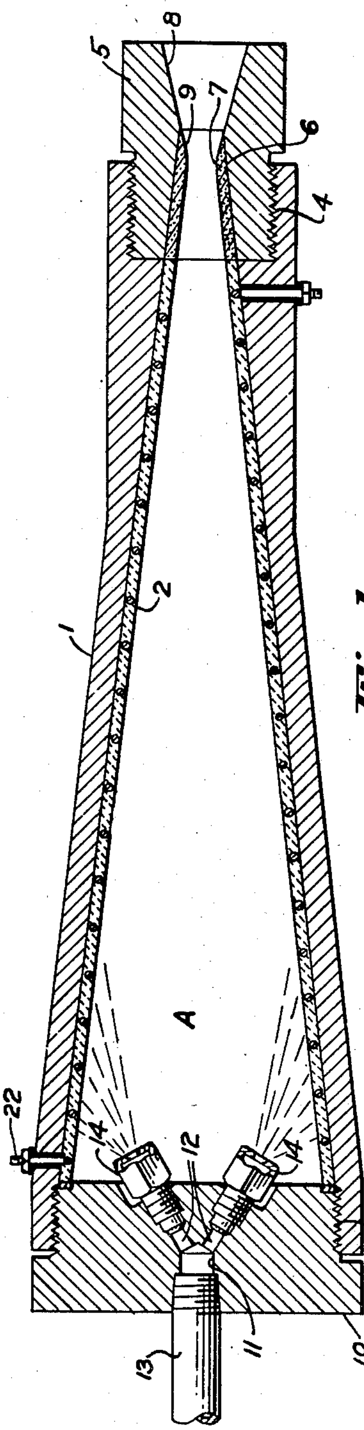

Fig.1.

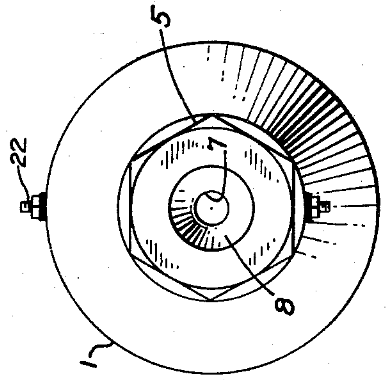

Fig.2.

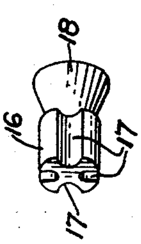

Fig.4.

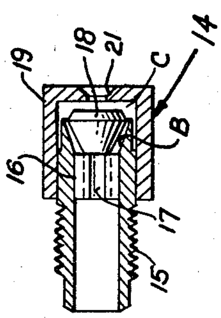

Fig.3.

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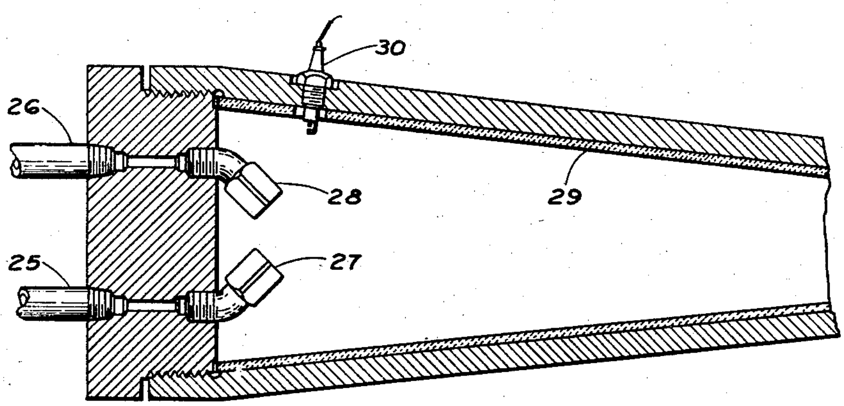

FIG-5

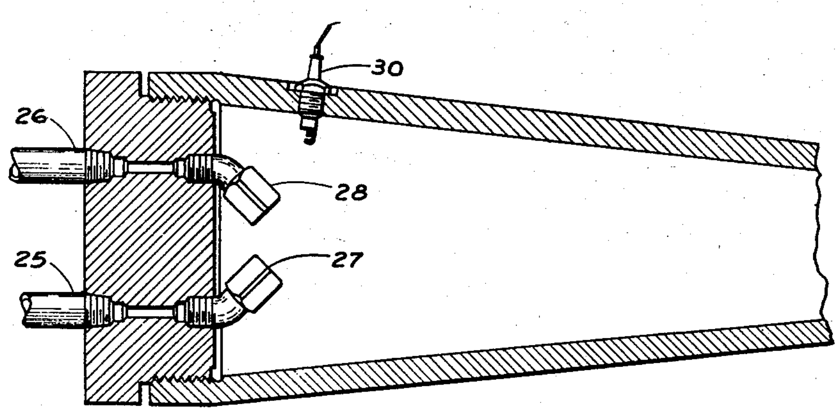

FIG-6

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Patented Jan. 6, 1948 2,433,943

UNITED STATES PATENT OFFICE

2,433,943

OPERATION OF JET PROPULSION MOTORS WITH NITROPARAFFIN

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Application March 11, 1944, Serial No. 526,064

12 Claims. (Cl. 60—35.6)

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This invention relates to motors and particularly to jet propulsion motors. It is concerned especially with the production of the impelling force for such motors. It provides a liquid which combines fuel and all the elements required for its combustion and which can safely be used without exploding but with the production of great power.

Motors of the jet propulsion type are well-known. They ordinarily comprise a combustion chamber in which fuel is burned and an exhaust nozzle leading from the chamber to the atmosphere. There have heretofore been used in such motors solid and liquid materials containing fuel and other substances which make them self-combustible in the motor. Such self-combustible motor charges are advantageous in that they permit the elimination of separate storage and feed systems for the oxidizing element—a matter of great importance in aircraft, etc., where weight must be kept to a minimum.

As a result of our investigations we have discovered that liquid nitroparaffins are particularly well adapted as charges for jet propulsion motors. These substances are self-combustible and hence permit the elimination of a separate system for the oxidizer employed. The fact that they are liquid facilitates control of admission of the substances to the combustion zone of the motor. And these advantages are combined with two other important ones, for the substances are stable under a variety of conditions and hence much safer than liquid charges heretofore proposed. At the same time the substances generate great power upon decomposition.

The nitroparaffins useful in the practice of the invention should contain at least enough oxygen for the combustion of substantially all carbon in the molecule to carbon monoxide. Preferably they should contain at least 42.6% oxygen by weight. Nitroparaffins containing greater percentages of oxygen, provided they are sufficiently stable, may be used, although in general a nitroparaffin containing more oxygen by reason of having more than one nitrogroup per carbon atom may tend to be unstable and easily detonated. Such unstable compounds should generally be avoided as they might be unsafe for continuous injection into a jet propulsion motor unless suitably desensitized. Nitroparaffins containing up to about 53.4% oxygen by weight are suitable, although in general, the lower molecular weight nitroparaffins are the most satisfactory. Thus, nitromethane or a mixture of nitromethane with nitroethane are for most purposes more satisfactory than nitroethane alone or dinitroethane, for example.

A further feature of the invention is the provision, within the combustion chamber, of a catalytic surface. Means are provided for impelling

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into contact with this lining a liquid which is self-combustible in the presence of the catalyst. Thus a surface of cerium oxide in the chamber aids in the combustion of nitromethane, etc.

The invention will be better understood from the following description and the accompanying drawing in which:

Fig. 1 is a cross section elevation view of a jet propulsion motor in which self-combustible liquid fuel may be used in accordance with this invention;

Fig. 2 is an end view of the motor;

Fig. 3 shows in cross section a detail of the spray injectors used in the motor;

Fig. 4 shows a detail of the spray nozzle of Fig. 3 in perspective;

Fig. 5 is a view in cross section of part of a combustion chamber showing means for introducing oxygen or an oxidizing agent; and

Fig. 6 is another cross section view of a modification of the combustion chamber shown in Fig. 5.

Nitromethane and mixtures of nitromethane and nitroethane are preferred propellants for the practice of the invention. These contain both the necessary fuel and the oxygen required for self-combustion in the motor and possess a high degree of energy release upon combustion. Nitroethane alone is somewhat low in its energy release and furthermore is inclined to produce undesirable amounts of carbon. When used together with nitromethane, however, it gives a very satisfactory performance.

The drawing shows a form of jet propulsion motor of a type useful on vehicles such as glider bombs, torpedoes, aircraft or the like. The motor comprises an elongated body portion 1, shown in the general form of a long frustum of a cone enclosing a combustion chamber A. The inner surface is lined with a lining 2 of a suitable material, preferably a refractory catalytic substance. The two ends of the conical motor are threaded at 3 and 4 respectively. An exhaust nozzle 5 is applied to the threads 4. This nozzle is in the form of a plug having a central opening 6 which conforms and continues the internal opening of the motor itself. The nozzle is constricted to a narrowest diameter 7 and then flares to a somewhat larger diameter 8 at its exhaust opening. The inner wall of the exhaust nozzle is lined by a suitable refractory jacket 9, for example carbon, to protect it against erosion from hot exhaust gases.

At the opposite enlarged end of the conical motor there is threaded a closure plug 10 having a centrally disposed opening 11 leading into it from the exterior, and this branches partway through the plug to form two or more openings 12, completing the passageway through the interior of the motor. An inlet pipe 13 is threaded into opening 11 and spray injectors 14 are threaded through the passageways 12.

The spray injectors are shown in more detail in Figs. 3 and 4. They comprise a threaded nipple 15 into the front end of which there is force-fitted a pintle 16 in the shape of a plug having longitudinal grooves 17 at its periphery and having a conical deflector 18 fastened at the front end as shown. Over the front of the spray nozzle there is fitted a cap 19 which may be force-fitted or otherwise attached to the body of the nipple. A centrally located hole 21 is located at the front end of the cap and aligned with the cone 18.

In operation the liquid propellant, say nitromethane or a mixture of nitromethane and nitroethane, is forced through the pipe 13 at a high enough pressure to overcome the internal pressure in the combustion chamber A of the motor during combustion. A pressure of 300 to 600 pounds per square inch is ordinarily satisfactory. The liquid propellant passes through all the spray injectors 14 and a fine spray is formed at each due to the passage of the liquid through a constricted space B around the cone 18, then into a space C in front of the cone and thence through the opening 21. In this way a fine spray from the injectors is spread substantially all over the lining 2 of the motor as indicated by the spray lines, the major amount of the spray being concentrated at the region close to the injectors.

Upon striking the catalyst lining 2 spontaneous self-combustion of the propellant occurs, attended by the rapid production of large amounts of gas which pass out through the exhaust nozzle at a very high velocity at the constricted portion 7 to produce the propelling effect of the motor.

Good operating properties have been found for both nitromethane alone and the mixture of nitromethane with nitroethane. In the use of them, temperatures created in the combustion chamber and at the exhaust nozzle, and exhaust jet velocities and specific impulses for the motor, have been found according to the following tabulation for a combustion chamber operated at about 300 lbs./sq. in. combustion pressure:

Propellant	Chamber Temp.	Exit Temp.	Jet Velocity	Specific Impulse
	° K.	° K.	Ft./sec.	Lbs./lb./sec.
Nitromethane	2,640	1,330	6,970	216.5
⅔ mol nitromethane+⅓ mol nitroethane	1,840	915	6,308	195.9
½ mol nitromethane+½ mol nitroethane	1,570	767	5,813	179.0

This tabulation shows that nitromethane alone produces the highest jet velocity and consequently the highest impulse and it also produces the highest temperatures. If it be desired to operate the motor at lower temperatures the mixture of nitroethane with the nitromethane (as shown by the tabulation) will produce the lower temperatures and without serious decrease in jet velocity and specific impulse. Thus, the use of one third nitroethane reduces the jet nozzle temperature from about 1330° K. to 915° K. while incurring a loss of impulse of only from about 216.5 lbs./lb./sec. to about 195.9 lbs./lb./sec.

A number of catalysts are satisfactory for the lining. Some of these may be brought to incandescence from initial temperatures as low as 150° C. simply by contact with the liquid or its vapor. Among the best catalysts for nitromethane are the oxides of multivalent metals, particularly the rare earths. Thus zirconium oxide, thiorium oxide, cerium oxide, chromium oxide, uranium oxide, and mixtures of these compounds are satisfactory. Steel and stainless steel turnings are also good catalysts, and platinum and other high-melting non-oxidizing metals are very good catalysts. In fact, most of the heavy metals and particularly their oxides and also the alkaline earth oxides give catalyst effects.

In addition there are other catalysts which give fairly good results such as magnesium oxide, aluminum oxide, and mixtures of these compounds with the oxides hereinbefore mentioned.

In the motor shown in the drawing the catalyst should ordinarily be embedded into the refractory material as part of the lining 2, although it would be possible in some cases to make the lining 2 entirely of catalyst, for example, sheet steel, platinum, or pressed oxides.

The nitromethane and mixtures of nitromethane with nitroethane will not ignite in a cool motor—a highly desirable safety factor. Accordingly, suitable ignition or starting devices should be used. This may be a heating wire 22 at lining 2 illustrated in the drawing, or some other ignition mechanism such as an electric arc, a hot filament, or an auxiliary flame introduced at a suitable place in the combustion chamber and caused to operate at the moment of starting.

A small quantity of oxygen or other fluid oxidizing agent may be introduced into the combustion chamber, and combustion easily initiated by a spark or other means. Fig. 5 illustrates a combustion chamber adapted for the introduction of oxygen or a fluid oxidizing agent. Two conduits 25 and 26 are provided, and they terminate in respective spray nozzles 27 and 28 inside the chamber. One of these conduits 25 may for example carry the propellant, and the other the oxygen or fluid oxidizing agent. The catalytic liner 29 facilitates the decomposition as explained above and the spark plug 30 may be used to initiate the decomposition. Combustion of only a small amount of the propellant in this manner is sufficient to heat up the catalytic surface to a temperature sufficient for initiation and maintenance of self-combustion. Thermal decomposition of nitromethane or a mixture of nitromethane and nitroethane may be maintained even in the absence of a catalyst by continuous injection of a fluid oxidizing agent and combustion of a portion of the propellant thereby. Fig. 6 illustrates a combustion chamber adapted for doing this. The arrangement is similar to that of Fig. 5 except that the catalytic liner 29 is omitted. Addition of a suitable oxidizing agent in an amount not in excess of 5% by weight of the propellant is sufficient to cause such thermal decomposition.

It may be desirable in some cases to add promoters of ignition or combustion to the liquid propellant. Thus, the addition of methyl nitrate, ethyl nitrate, methyl oxide, and the like to the nitromethane improves the ease of its ignition and combustion.

When the length of time of combustion is to be long, such as a large part of a minute, the lining 2 should have a high melting point, although for shorter operations high melting points are not essential and even such materials as steel turnings may be used.

It is preferable to prepare the catalyst in the form of a refractory material such as chromite fire brick, zirconia combustion tubes, pressed magnesia bricks, etc.

The catalyst may be placed either in the combustion chamber or in a suitable auxiliary catalyst chamber as a liner, a bundle of tubes, a bed of fragments, or the like.

Means should be provided to hold the catalytic elements in place so that they do not reach and plug the exhaust nozzle.

To guard against possible explosion of the storage tank supplying the inlet pipe 13 due to detonation waves in the motor, the feed orifices 12 leading into the motor should be made of small diameter. This will minimize the transmission of the detonation waves back into the tank.

The propellants provided by this invention possess many advantages. By reason of their being single self-combustible liquids they permit great savings in weight and consequently a great gain in the ratio of total impulse to total weight, due to elimination of one storage vessel, feed line, propellant valve, and pump or pressurization unit from the twin assemblies heretofore necessary. They permit greatly increased simplicity of construction and operation, with easy throttling control and predetermined constancy of "mixture ratio" and available energy. They are non-corrosive, permitting lighter assemblies, simpler pumps, and so on, and are non-toxic. They are capable of giving a higher specific impulse with lower combustion and exhaust temperatures than other propellants or propellant combinations heretofore proposed. They are stable when stored and relatively insensitive to detonation.

We claim:

1. In the development of thrust in a jet motor having a combustion chamber and an exhaust nozzle, the improvement which comprises injecting into the chamber a liquid nitroparaffin from the group consisting of nitromethane and a mixture of nitromethane and nitroethane, and igniting the nitroparaffin therein.

2. In the development of thrust in a jet motor having a combustion chamber and an exhaust nozzle, the improvement which comprises injecting nitromethane into the chamber, and combusting it therein catalytically.

3. In the development of thrust in a jet motor having a combustion chamber and an exhaust nozzle, the improvement which comprises simultaneously injecting a liquid nitroparaffin selected from the group consisting of nitromethane and a mixture of nitromethane with nitroethane and a lesser quantity of a fluid oxidizer into the chamber and igniting them therein.

4. In the development of thrust in a jet motor having a combustion chamber and an exhaust nozzle, the improvement which comprises simultaneously injecting into the chamber a self-contained fuel and oxidizer consisting of self-combustible liquid nitroparaffin selected from the group consisting of nitromethane and a mixture of nitromethane with nitroethane and a fluid oxidizer in an amount not greater than 5% by weight of the nitroparaffin, and igniting them therein.

5. In developing thrust in a jet motor comprising a combustion chamber and an exhaust nozzle, the improvement which comprises injecting a liquid nitroparaffin propellant selected from the group consisting of nitromethane and a mixture of nitromethane with nitroethane into the chamber, and catalytically initiating and maintaining self-combustion of the nitroparaffin therein.

6. A method of developing thrust in a jet motor having a combustion chamber and an exhaust

nozzle, which comprises combusting nitromethane by a catalyst in such chamber.

7. A method of developing thrust in a jet motor having a combustion chamber and an exhaust nozzle, which comprises igniting a liquid nitroparaffin propellant selected from the group consisting of nitromethane and a mixture of nitromethane with nitroethane in said chamber with a catalyst from the group comprising high melting non-oxidizing metals and difficultly reducible oxides of multivalent metals.

8. A method of developing thrust in a jet motor having a combustion chamber and an exhaust nozzle, which comprises combusting in said chamber a liquid nitroparaffin propellant from the group consisting of nitromethane and a mixture of nitromethane and nitroethane with a catalyst from the group consisting of high melting non-oxidizing metals and difficultly reducible oxides of multivalent metals.

9. A method of developing thrust in a jet motor having a combustion chamber and an exhaust nozzle, which comprises initiating and maintaining combustion of nitromethane in such chamber by addition of an oxidizer in an amount not greater than 5% by weight of the nitromethane.

10. A method of developing thrust in a jet motor having a combustion chamber and an exhaust nozzle, which comprises igniting nitromethane in said chamber with a catalyst from the group consisting of high melting non-oxidizing metals and difficultly reducible oxides of multivalent metals.

11. In the development of thrust in a jet motor having a combustion chamber and an exhaust nozzle, the improvement which comprises injecting nitromethane into the chamber and igniting the nitromethane in said chamber.

12. In the development of thrust in a jet motor having a combustion chamber and an exhaust nozzle, the improvement which comprises injecting a mixture of nitromethane and nitroethane into the chamber and igniting the mixture in said chamber.

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