May 20, 1958 J. M. CARTER 2,835,106

METHOD OF JET PROPULSION BY SPONTANEOUS COMBUSTION OF FURFURAL

Filed July 20, 1946 2 Sheets-Sheet 1

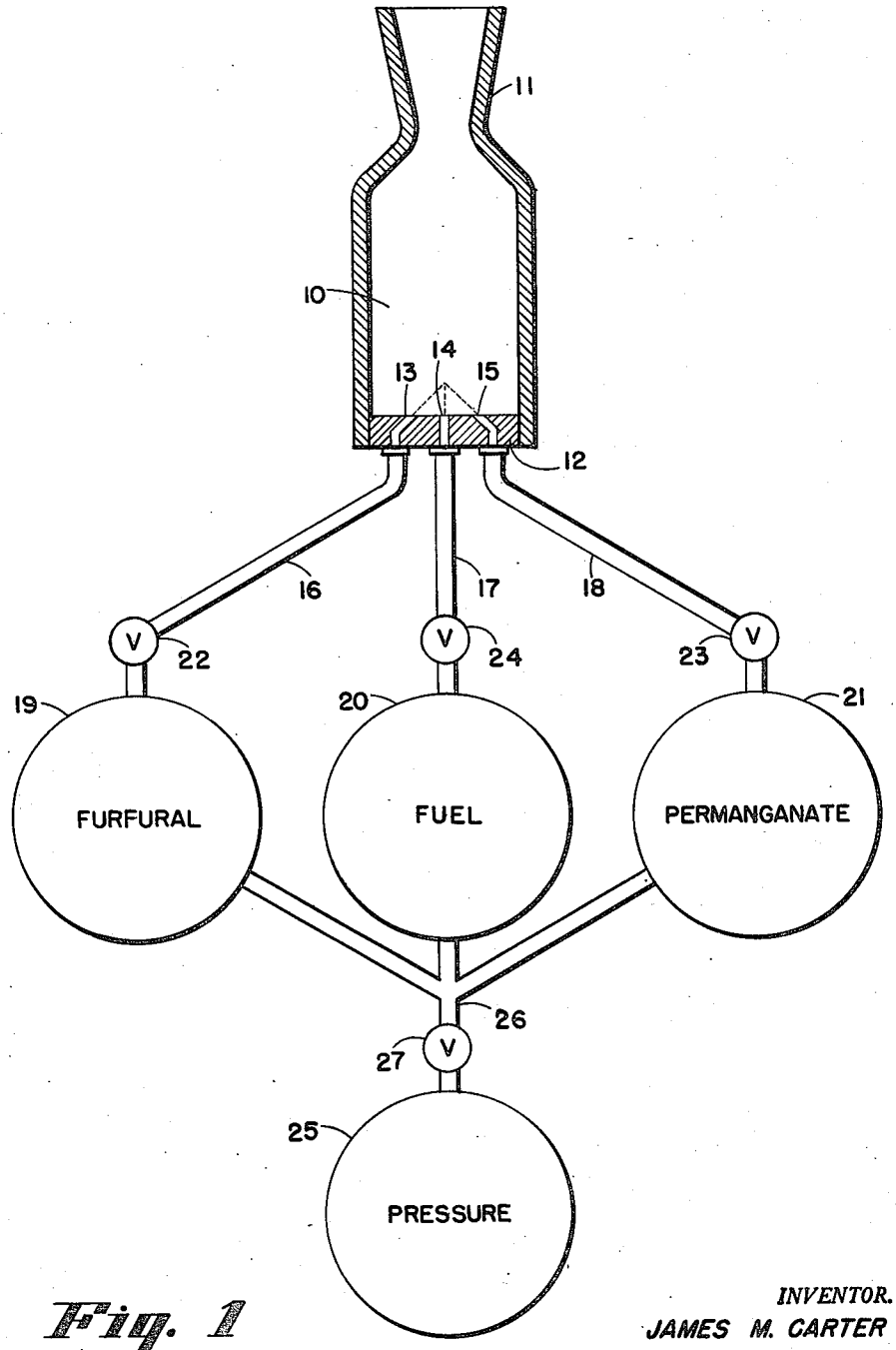


Fig. 1

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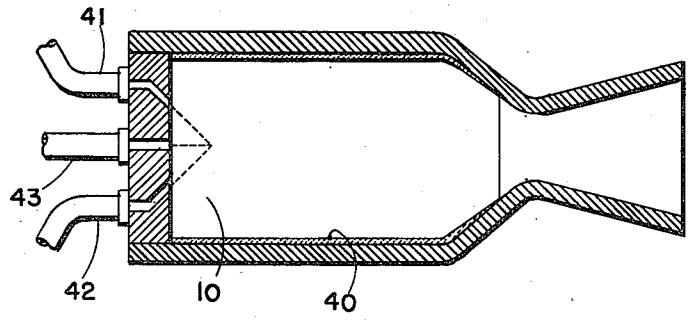


Fig. 2

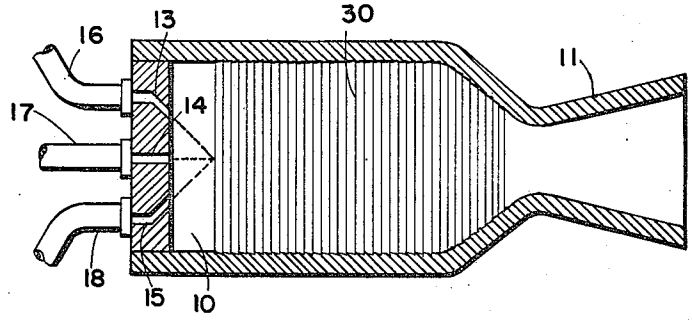


Fig. 3

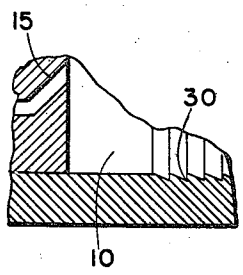


Fig. 4

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METHOD OF JET PROPULSION BY SPONTANEOUS COMBUSTION OF FURFURAL

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Application July 20, 1946, Serial No. 685,047

4 Claims. (Cl. 60—35.4)

This invention is concerned with jet propulsion and contemplates improvements in generation of gas for such purpose.

This application is a continuation-in-part of my co-pending application Serial No. 530,507 filed April 11, 1944, now abandoned.

Propulsive jets for rockets, jet motors etc. are produced by generating gas in a combustion chamber or the like and expelling it through a nozzle. Sometimes the reactants which generate the gas are introduced separately into the chamber; sometimes they are mixed together beforehand and sometimes a single self-combustible compound is introduced. In all cases, however, the reaction which results in the evolution of the gas is initiated and sustained in the chamber.

Initiation of the reaction may be accomplished by various types of igniters, such as electric sparks, or heat or flame generated by primers of various types. In many cases, the gas generation reaction proceeds until the reactant or reactants are exhausted; in other instances it tends to die out unless it is primed by auxiliary means, such as a flame source, an auxiliary explosion frequently repeated or a catalyst.

Nitroparaffins may be taken to exemplify so-called self combustible propellants. If they are sufficiently nitrated, their own oxygen content is sufficient to promote self combustion, i. e. the oxygen combined in each molecule is adequate to burn the rest of the molecule.

The lower paraffins become self combustible with but a small degree of nitration. Thus mono-, di-, tri- and tetranitro methane all contain sufficient oxygen. With higher paraffins, a higher degree of nitration is required to make them completely self combustible.

In any case, self propellants of the nitro-paraffin and other classes must be ignited in the beginning, and in some cases ignition must be continued or repeated in order that the decomposition be sustained.

I have developed a novel ignition system involving a reaction which may, if desired, be employed alone as a jet propellant and in any event to supply additional gas for the jet. Thus I have discovered that furfural and a permanganate, if brought together at a sufficiently high concentration, will ignite spontaneously with a sustained and vigorous evolution of carbonaceous gases and of metallic substances (principally oxides) which serve to catalyze other jet producing reactions—especially the decomposition of nitro paraffins. Accordingly, the entire propulsive force for driving a jet motor may be generated through the spontaneous combustion of furfural and permanganate in the combustion chamber of the motor. But the invention also finds application in initiating or sustaining (or both) the combustion of other jet motor fuels. As already indicated, nitro-paraffins, especially those of high oxygen content, tend to be self-combustible, but the combustion is aided by burning furfural spontaneously in permanganate in the same combustion zone with resultant production of additional heat as well as of catalyst to aid in the decomposition of the nitroparaffin.

By thus conducting both gas producing reactions together the furfural-permanganate reaction will not only initiate the other reaction but will sustain it and greatly increase reliability of operation.

The application of the invention is not limited to initiating or aiding the combustion of nitromethane or other self-combustible or partially self-combustible jet fuels, and is applicable to ordinary fuels such as hydrocarbons (gasoline, kerosene, etc.) which contain no oxygen and require an independent oxidizer.

It has been proposed heretofore to react furfural with permanganate at low concentration, say in relatively dilute water solution with resulting formation of pyromucic acid, but the spontaneous combustion of the compounds at higher concentration has not been appreciated or applied.

The spontaneous combustion of furfural with permanganate may be obtained by contacting furfural with solid permanganates of many metals, and also with sufficiently concentrated permanganate solutions. Since permanganates in aqueous solution may be introduced conveniently into a reaction zone, those which have high solubility in water are preferred.

Calcium permanganate is a preferred example, since some two parts by weight may be dissolved in one part of water. But other permanganates having high solubility are also useful in that phase of my invention which involves the separate introduction of streams of liquid furfural and liquid permanganate oxidizer into a reaction zone, and substantially all are applicable in solid state to the practice of the invention.

Permanganates (other than that of calcium) which form solutions sufficiently strong to burn furfural spontaneously include those of aluminum, sodium, magnesium and barium. Others, including potassium permanganate are precluded from use in this phase of the invention by insufficient solubility in water, but may be employed in the solid state, or in some cases as concentrated solutions in other solvents.

The violent spontaneous combustion obtainable through the reaction of furfural with a concentrated permanganate and the valuable end products of this reaction offer outstanding advantages in the ignition or maintenance of other jet propulsion reactions. Thus, the manganese oxide and other metallic oxides formed through the spontaneous combustion of furfural and permanganates are, especially as freshly formed, exceedingly active catalysts for other propellant reactions, including the combustion, with or without an additional oxidizer, of a variety of nitro-paraffins. The invention, therefore, contemplates the formation of manganese oxide in the combustion chamber of a jet motor through the reaction of furfural with a permanganate, and the catalysis of a principal gas producing reaction, say the combustion of a nitroparaffin, in the chamber by the oxide thus formed. If desired, the operation may be so conducted that the oxide is deposited on the wall of the chamber, thereby prolonging its effects, but even in those cases in which no accumulation of oxide takes place in the chamber, the catalytic effect of the freshly formed manganese oxide is marked.

The practice of the invention need not involve the use of novel apparatus, since all that is required is the separate introduction of the permanganate and the furfural into the reaction chamber of a jet motor. Thus the furfural and a solution of permanganate may be directed simultaneously as converging streams into the chamber. But the permanganate may be introduced first into the chamber, say as a solid or porous mass held to the wall of the chamber, and a stream of furfural directed upon the mass. This latter method of operation may be advantageous through leaving a residue of freshly formed

manganese oxides and other oxides, which will serve to catalyze the decomposition of a stream of a self-combustible propellant (say a nitroparaffin) directed upon it. The same scheme may be employed to catalyze the reaction between two converging streams of reactants.

These and other aspects of the invention will be apparent in the light of the following detailed description of a variety of forms of the invention, taken in conjunction with the accompanying drawings in which—

Fig. 1 is a diagram illustrating the application of the spontaneous combustion of furfural and a concentrated permanganate solution to initiate or sustain the decomposition of a main fuel or reactant in a jet motor;

Fig. 2 is a diagram illustrating the use of a solid charge of permanganate disposed initially in the combustion chamber of a jet motor for reaction with a stream of furfural directed upon it;

Fig. 3 is a diagram illustrating the use of baffles to collect and utilize for their catalytic action (on a main jet propulsion reaction) the oxides of manganese and other metallic oxides formed through reaction of converging streams of furfural and permanganate solution in a jet motor; and

Fig. 4 is an enlarged fragmentary section of the baffles of Fig. 3.

Fig. 1 shows in section a jet motor provided with a combustion chamber **10** opening at one end into an exhaust nozzle **11**, and closed by an injector plug **12** at the other end. The injector plug has three small jet openings **13**, **14**, **15**, to which are connected fluid conduits **16**, **17**, **18** respectively from tanks, **19**, **20**, **21**.

The tank **19** contains liquid furfural which may be forced through the conduit **16** and an associated control valve **22** to its jet opening **13**. Permanganate solution contained in the tank **21** may be forced through the conduit **18** and an associated valve **23** to its jet opening **15**. Streams from these two jet openings converge and meet each other in the combustion chamber.

The central tank **20** contains the main supply of fluid fuel or propellant, for example nitromethane or other nitrated paraffin containing in its molecules sufficient oxygen to complete its self-combustion. It may be forced through the conduit **17** and an associated control valve **24** to the jet opening **14**, from which a stream is directed to strike the point at which the streams of furfural and permanganate intersect.

A pressure tank **25** containing nitrogen or other suitable inert gas is connected respectively to the three supply tanks through a three branch conduit **26** provided with a centrally disposed control balve **27**.

In operation, the outlet valves **22**, **23**, **24** are set for proper flow rates of the furfural, permanganate and main propellant.

If desired, the furfural and permanganate may be introduced simultaneously into the chamber in advance of the main propellant, so that the spontaneous combustion of the first two establishes proper conditions for the ignition of the third.

If desired, injection of the main propellant may be omitted, and the jet created by the reaction of the furfural and permanganate alone.

Preferred practice is to inject all three substances simultaneously, relying upon the reaction of the furfural and the permanganate to ignite the main propellant, say a self combustible mixture of nitroethane and nitromethane.

Whatever be the mode of operation, the furfural ($C_4H_3O.CHO$) reacts with the permanganate, say $Ca(MnO_4)_2$, to produce rapid combustion, with evolution of carbonaceous gases and water vapor, together with finely divided manganese oxide (and finely divided calcium oxide in the case of calcium permanganate). The evolved gases form the jet expelled from the nozzle of the motor. The oxides are also expelled, save for what lodges within the motor.

When the furfural-permanganate reaction is employed alone to power the jet, no great advantage attaches to the metallic oxide reaction products. However, it is possible to obtain outstanding advantages when the furfural-permanganate reaction is employed to initiate or sustain some other gas-producing reaction, which also contributes to the thrust of the motor and which is catalyzed by the aforementioned solid reaction products. By way of example, the decomposition of nitroparaffins, for example nitromethane, is catalyzed by manganese dioxide and other oxides. Hence the presence of these oxides in the reaction zone, either suspended in the gas stream or deposited on surfaces within the chamber or nozzle, aids markedly in generating thrust from the nitroparaffin combustion.

The catalytic effect may be prolonged and enhanced, especially in a case in which the supply of furfural and permanganate is interrupted after the combustion of the main fuel is initiated, by providing means for catching and holding some of the oxides within the chamber. Normally some of the oxides tend to accumulate in the chamber on the walls near the nozzle, and this effect can be enhanced by providing baffles or catchment surfaces within the chamber as illustrated in Fig. 3, wherein a jet motor (otherwise like that of Fig. 1) is provided with a set **30** of baffles formed as small annular serrations on the wall of the reaction chamber so as to interfere as little as possible with the passage of the jet while providing surface for the collection of the solid oxides. As shown in larger scale on Fig. 4, the baffles are formed by cutting annular grooves around the inner periphery of the chamber and in section appear as a series of saw teeth. In practice it has been found that ordinary rough lathe markings serve to catch a catalytic layer which is adequate in many instances.

As I have already indicated, the permanganate need not be employed as a solution. It may be blown into the reaction chamber as a slurry or a powder, or may be placed in solid state within the chamber in the path of the furfural before the latter is introduced. One type of such an arrangement is illustrated in Fig. 2, wherein a coherent and adherent lining **40** of solid permanganate is deposited on the wall of the reaction chamber **10** of a jet motor adjacent its nozzle, and furfural is squirted upon the mass from a plurality of inlet pipes **41**, **42**. Some of the manganese and other oxides formed in this operation tend to remain as a residue on the chamber walls to catalyze the combustion of a main fuel supply introduced through a main fuel supply line **43**.

In forming the permanganate lining it is desirable to employ a combustible binder, such as a small proportion of resin, which holds the permanganate particles together and to the wall of the chamber.

The main fuel supply may be a self-combustible substance, such as an adequately nitrated paraffin or mixture of nitroparaffins, or it may be one such as a hydrocarbon which requires additional oxygen. A number of combustion reactions of the latter type are catalyzed by manganese oxides and the other solid reaction products of furfural with concentrated metallic permanganates.

The proportions of furfural to permanganate required to obtain spontaneous ignition or combustion are not particularly critical. From 1 to 3 parts by weight of permanganate may be employed for each 2 parts by weight of furfural, although of course it is advantageous to introduce them in the proportions in which they combine.

Only relatively small proportions of furfural and permanganate are required for the ignition and maintenance of the combustion of other fuels. Thus 4 parts by weight of furfural and 4 parts by weight of calcium permanganate will ignite 100 parts by weight of nitromethane introduced simultaneously.

Generally speaking, the more concentrated the solution of permanganate the better. Saturated aqueous solu-

tions of calcium permanganate and other highly soluble permanganates are preferred and, except in unusual instances, spontaneous combustion of furfural and a permanganate, as distinguished from a relatively slow reaction below the fire point, is not obtainable with solutions containing more water by weight than the dissolved permanganate.

The spontaneous combustion of furfural and permanganate as a jet propulsion reaction per se and as a means of igniting other jet propellants possesses a number of inherent advantages other than those already described. Among them may be noted the fact that neither reactant is corrosive or gives off poisonous vapors and the fact that both are relatively safe to handle.

I claim:

1. In jet propulsion involving the combustion of nitromethane to generate gas to form the jet, the improvement which comprises igniting the nitromethane by spontaneously combusting furfural with an aqueous solution of a permanganate selected from the group consisting of calcium, aluminum, sodium, magnesium and barium permanganate wherein the proportion of the permanganate to the furfural lies from one to three parts by weight of permanganate for each two parts by weight of furfural.

2. In jet propulsion involving the combustion of a mixture of nitromethane and nitroethane to generate gas to form the jet, the improvement which comprises igniting the mixture by spontaneously combusting furfural with an aqueous solution of a permanganate selected from the group consisting of calcium, aluminum, sodium, magnesium and barium permanganate wherein the proportion of the permanganate to the furfural lies from one to three parts by weight of permanganate for each two parts by weight of furfural.

3. In jet propulsion, the improvement which comprises generating gas to form the jet by spontaneously combusting furfural with an aqueous solution containing a permanganate selected from the group consisting of calcium, aluminum, sodium, magnesium and barium permanganate, the proportion of the permanganate to the furfural being from one to three parts by weight of permanganate for each two parts by weight of furfural.

4. In jet propulsion, the improvement which comprises generating gas to form the jet by combusting furfural with an aqueous solution containing calcium permanganate wherein the proportion of the calcium permanganate to the furfural lies from one to three parts by weight of the permanganate for each two parts by weight of furfural.

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