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ROCKET FUEL COMPOSITION

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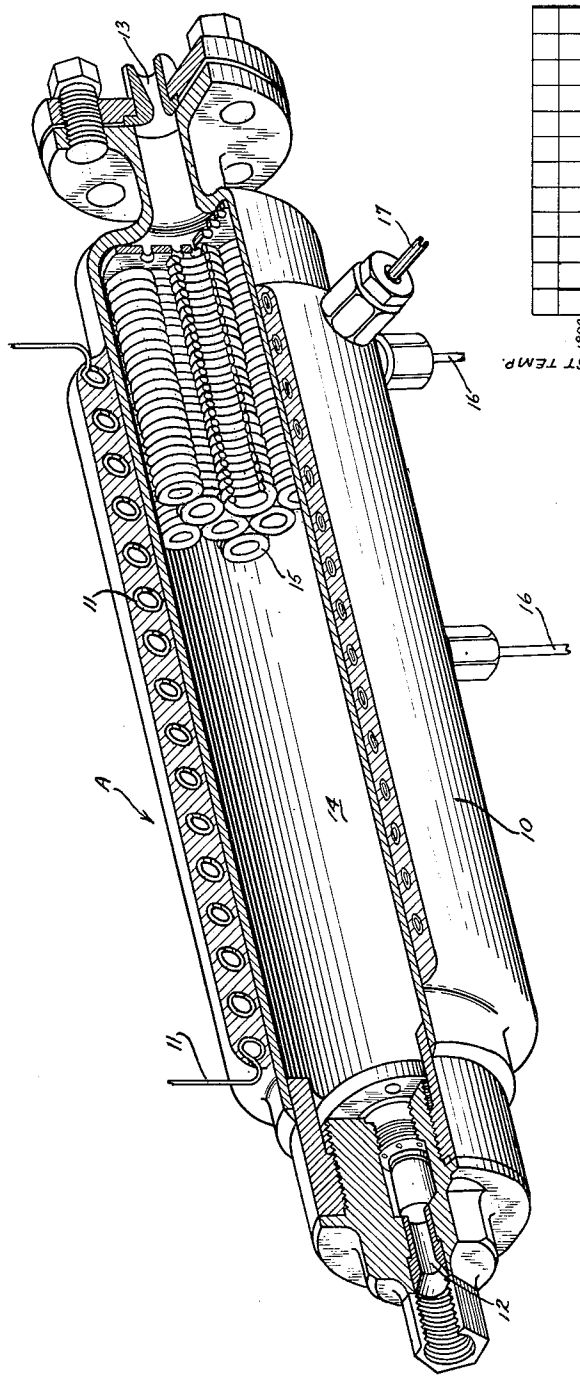


FIG. 1

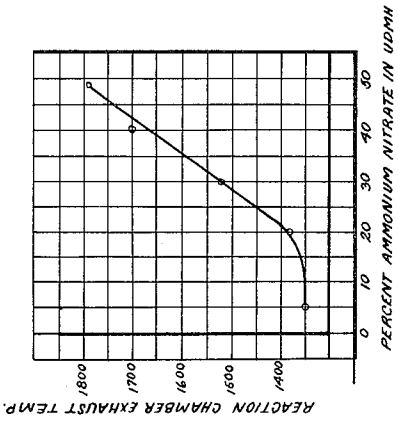


FIG. 2

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ROCKET FUEL COMPOSITION

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The present invention relates broadly to rocket fuel compositions, and is more particularly concerned with a new and improved mixture comprising unsymmetrical di-methyl hydrazine and ammonium nitrate.

Many of the mono-propellants heretofore known to the art are possessed of a number of disadvantages. Among those to be mentioned are the excessive reaction chamber temperatures associated therewith, poor starting characteristics, and excessive carbon deposition. Also, these prior art compositions are often characterized by detonability under impact, polymerization during storage, and violent reactions due to catalytic decomposition when exposed to commonly used materials. Further, it has been extremely difficult to develop sealants or bladder materials compatible with the known rocket fuels.

It is accordingly a primary aim of the present invention to provide a rocket fuel composition which effectively avoids the disadvantages associated with prior known rocket fuels.

Another object of the invention is to provide a rocket fuel composition which may be tailored to give any reaction temperature the turbine construction materials can withstand, and which has excellent storage characteristics.

Another object of this invention lies in the provision of a fuel which has good starting characteristics and which has no carbon deposition problems.

A further object of the invention is to provide a mixture of unsymmetrical di-methyl hydrazine and ammonium nitrate, and which is compatible with a wide range of materials and possesses insensitivity to catalytic action.

Other objects and advantages will become more apparent with the teachings of the principles of the invention in connection with the disclosure of the preferred embodiment in the specification, claims and drawings, in which:

FIGURE 1 is a fragmentary perspective view of a reaction chamber utilized by applicants; and

FIGURE 2 is a graph plotting exhaust gas temperature against mixture composition.

One of the features of the present invention is that the fuel composition disclosed by applicants may be tailored to give any reaction temperature that known turbine construction materials can withstand. It is accordingly now possible knowing the materials forming the turbine, to modify the composition by variations in the percentage of ammonium nitrate and thereby provide a fuel which will have no deleterious effects upon the turbine itself. A reaction chamber which may be utilized to obtain information such as chamber outlet temperature and other valuable data is disclosed in FIGURE 1. Upon reference thereto it will be seen that the chamber A includes a substantially cylindrical housing **10** and a heater coil **11** embedded in the housing walls and located in surrounding relation to said chamber. Provided at one

end of the chamber is an injector nozzle **12**, while at the opposite end there is included an exhaust nozzle **13**. Within the reaction zone **14** there is located a plurality of metal coils **15** to stabilize the flame front. Projecting circumferentially through the chamber walls are thermocouples **16**, while also arranged on said circumference but adjacent the exhaust end of the chamber is a pressure tap **17** by means of which pressure readings may be obtained.

A series of tests were conducted utilizing, in addition to the reaction chamber disclosed, apparatus including nitrogen bottles to pressurize the fuel tank which delivered the fuel through appropriate valving to the reaction chamber. A purge system which also drew nitrogen from the bottles was used to purge the reaction chamber after each run. All valves were rapid acting, and were either solenoid or electro-pneumatically operated. The instrumentation employed was Chromel-Alumel thermocouples, such as shown in the drawing at **16**, and were used to sense temperatures which were recorded on a multipoint Brown recorder. Pressures from the tap **17** were sensed by strain gauge transducers and were continuously recorded on Sanborn direct-writing oscillographs.

A series of runs were made by injecting into the reaction chamber A mixtures of ammonium nitrate and unsymmetrical di-methyl hydrazine (UDMH) ranging from 5 percent to 49 percent by weight of ammonium nitrate. Successful runs and smooth starts were made with all percentages of the compounds within the range noted. The results of the tests are given in the table in column 3, and it may be seen therefrom that the exhaust nozzle temperature varied from 1350° F. for 5 percent ammonium nitrate to 1790° F. for 49 percent ammonium nitrate. The range of ammonium nitrate presently preferred is from 25 to 40%.

The chart further makes reference to fuel flow rate in pounds per hour and this was determined by timing the run for a given charge, there being employed between five to ten pounds of the mixture which was loaded into the fuel tanks for each test run. Mixture density is also included in the chart, and this is obtained by adding together the densities of the components and multiplying this by the percentage in the mixture. The approximate freezing point readings were obtained by use of a Dry Ice cold box as is known in the art.

The column in the chart denoted by the legend L* refers to the characteristic length of the reaction chamber which is required for starting and smooth operation. In this instance

$$L^* = \frac{V}{A_t}$$

where V is chamber volume and A_t is exhaust nozzle throat area. The minimum L* at which good operation can be obtained varies greatly with generator design. It varies with the type of fuel injector nozzle, method of flame front stabilization, shape of the reaction chamber, and kind of material used for the internal surfaces thereof. In work performed to date, the minimum operational L* with the ammonium nitrate UDMH mixture would appear to be approximately 411".

Performance Data for Mixtures of Ammonium Nitrate and UDMH in Reaction Chamber

Concentration Percent Ammonium Nitrate	Fuel Flow Rate (p.p.h.)	Maximum Chamber Pressure (p.s.i.)	Chamber Outlet Temperature (° F.)	Mixture Density	Approximate Freezing Point (° F.)	L*	C*	Condition of Decomposition Chamber After Running	Smoke in Exhaust Gases
5	145	418	1,350	.828	−66	2,760	3,365	Clean	Pale Blue.
10	190	525	1,355	.860	−58	2,760	3,328	do	Do.
20	150	435	1,380	.923	−40	2,760	3,493	do	Do.
30	141	420	1,515	.986	−26	2,760	3,588	do	None.
40	164	380	1,677	1.045	−11	2,760	3,388	do	Do.
49	131	400	1,790	1.096	+3	2,760	3,678	do	Do.

The column in the table denoted C* represents the characteristic gas velocity, and primary reliance was placed on the values obtained as an indication of performance.

The formula employed to determine C* is

$$C^* = \frac{P_c A_t g}{W}$$

where P_c is the chamber pressure, A_t is exhaust nozzle throat area, g is acceleration of gravity, and W is weight flow of propellant.

An examination of the chamber after running for approximately 45 minutes showed no substantial carbon deposition. The amount of such deposits will, however, vary somewhat with the coil materials. It may be further seen from the chart that the smoke in the exhaust gases varied somewhat in color depending upon the concentration of ammonium nitrate. Specifically, with percentages of ammonium nitrate varying from 5 to 20% there was a pale blue color to the gas, while with the higher percentages of this material there was no perceptible color to the exhaust gases.

Prior to actual tests with the reaction chamber, a series of preliminary tests were conducted. Samples of selected mixtures were first exposed to a glowing wire in a nearly closed container to determine flammability limits. The tests were controlled remotely and sensing thermocouples were placed just above the level of the fluid being tested. Also, flame emitted by the container could be viewed. Continuous recordings of the temperature were made until the sample was consumed. Those samples with rapid ignition characteristics were considered to be the most likely suited to mono-propellant use. Also, experiments were made in connection with the detonation properties of the samples. In this case, a bottled sample of each mixture was set on a 6 x 9" lead plate on sand and subjected to the force of a No. 6 blasting cap. All mixtures below 87.5% ammonium nitrate showed no detonation tendencies. For mixtures containing above 60% ammonium nitrate at 110° F., there was an undissolved quantity of this compound in the mixture, while a mixture including 87.5% ammonium nitrate was mushy. This combination of compounds detonated.

In the actual tests with the reaction chamber, the chamber was started by heating the exterior walls of the generator until the space inside the chamber reached a temperature of 700 degrees F. or higher. This of course would not necessarily represent the starting temperature of the mixture since the interior walls of the chamber which were exposed to fuel were somewhat higher than 700° F. Where time permits a slow heat-up or where continuous heating can be tolerated, the external heat-up method is an excellent one. Where, however, instantaneous starts with a cold chamber are required, a bi-propellant start can be used. UDMH is hypergolic in the presence of red fuming nitric acid, and can therefore be started by introducing an initial charge of nitric acid into the chamber along with the fuel. Tests with all mixtures of UDMH ammonium nitrate show relatively smooth reactions with red fuming nitric acid.

FIGURE 2 of the drawings is a graph plotting variations in exhaust gas temperature against changes in the percentage of ammonium nitrate in the mixture with UDMH. It may be seen therefrom that the temperature rises more rapidly with increasing percentages of ammonium nitrate. With respect to the properties of the mixture, it was found that ammonium nitrate dissolved readily in UDMH for mixtures up to 60% ammonium nitrate at approximately 115° F., and upon cooling remained in solution. Upon freezing the mixtures solidified as an homogeneous mass. Solutions above approximately 25% ammonium nitrate appeared syrupy, but this did not effect their handling characteristics. The ammonium nitrate seemed to mask the odor of the UDMH for percentages of 35% or above.

Reviewing the new and improved results obtained by applicants, it may be seen that mixtures in all proportions had good stability and could not be made to detonate with No. 6 blasting caps. The reaction chamber temperatures varied from 1350° F. with 5% ammonium nitrate to 1790° F. with 49% ammonium nitrate. Approximate freezing points of the mixtures varied from −66° F. with 5% ammonium nitrate to +8° F. with 49% ammonium nitrate. Ammonium nitrate did not salt out at any temperature. It may be seen that the starting characteristics were good for all percentages of mixtures above approximately 5% ammonium nitrate, and that there were no deposits of carbon in the generator, as had been found with UDMH alone. The decomposition products were clear except for the 5% to 20% mixtures which emitted a slight blue smoke.

In summary, it may be noted that applicants have provided a novel rocket fuel composition which can be readily tailored to meet the maximum temperatures that can be tolerated by the mechanisms utilizing the exhaust gases. It will be further noted that no separate oxidizer such as liquid oxygen of nitric acid is required. The structure of the mixture is such that, upon applying the proper amount of heat in a closed bomb-type container, a reaction is initiated which continues and is self-sustained if the fuel is continously supplied to the container, and the container is properly vented to exhaust the gases generated in the process. By the composition and procedure herein disclosed all of the earlier noted disadvantages of prior mono-propellants are susbtantially entirely avoided.

It will be understood that modifications and variations may be effected wtihout departing from the scope of the novel concepts of the present invention. Generally, a range of between 5 and 85% by weight of ammonium nitrate will not detonate and is operative, but more specifically, a range of between 5 and 50% by weight of ammonium nitrate is preferred, as well as a freezing point range for the mixture of between −70° F. and +10° F. Other variations will of course be apparent to those skilled in the art.

We claim as our invention:

1. A monopropellant rocket fuel composition consisting essentially of unsymmetrical di-methyl hydrazine and from not less than 5% to not more than 85% by weight of ammonium nitrate.

2. A monopropellant rocket fuel composition consisting essentially of unsymmetrical di-methyl hydrazine and

from not less than 25% to not more than 40% by weight of ammonium nitrate.

3. A monopropellant rocket fuel composition consisting essentially of unsymmetrical di-methyl hydrazine and approximately 40% by weight of ammonium nitrate.

4. A method of varying the temperature of exhaust gases emitted by rocket engines and the like, which comprises injecting into the engine a monopropellant mixture of unsymmetrical di-methyl hydrazine and from not less than 5% to not more than 85% by weight of ammonium nitrate, and applying heat to said mixture while in said engines.

5. A method of varying the temperature of exhaust gases emitted by rocket engines and the like, which comprises injecting into the engine a mono-propellant mixture consisting essentially of unsymmetrical di-methyl hydrazine and not less than 25% nor more than 40% by weight of ammonium nitrate, and applying heat to said mixture while in said engine.

6. A method of varying the temperature of exhaust gases emitted by rocket engines and the like, which comprises continuously supplying to the engine a monopropellant mixture of unsymmetrical di-methyl hydrazine and from not less than 5% to not more than 85% by

weight of ammonium nitrate, applying heat to said mixture while in said engine to effect the decomposition thereof, and venting the exhaust gases generated during the decomposition step.

7. A method of varying the temperature of exhaust gases emitted by rocket engines and the like, which comprises continuously supplying to the engine a monopropellant mixture of unsymmetrical di-methyl hydrazine and not less than 25% nor more than 40% by weight of ammonium nitrate, applying heat to said mixture while in said engine to effect the decomposition thereof, and venting the exhaust gases generated during the decomposition step.

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