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METHOD OF IGNITING ROCKET FUELS

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Fig-1

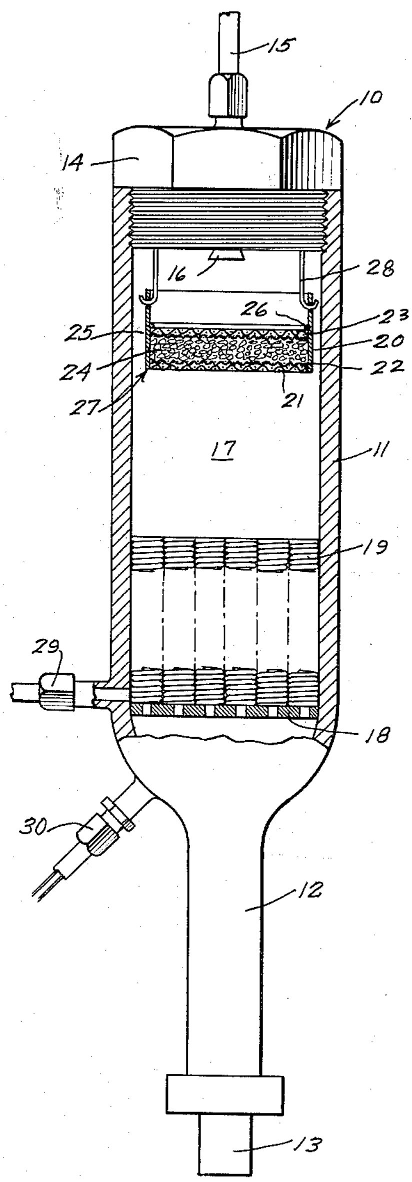
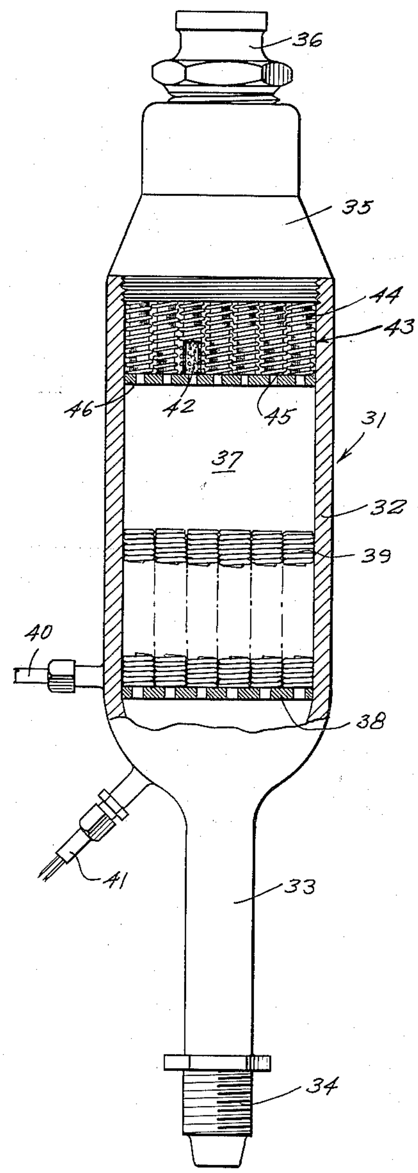


Fig-2



Inventors
Joseph T. Hamrick
Leslie C. Rose

by Hill, Sherman, Meroni, Gross & Simpson Attys.

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METHOD OF IGNITING ROCKET FUELS

Joseph T. Hamrick, Roanoke, and Leslie C. Rose, Rocky Mount, Va., assignors to Thompson Ramo Wooldridge Inc., Cleveland, Ohio, a corporation of Ohio

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The present invention relates broadly to the decomposition of fuels especially suitable for rocket propulsion, and is more particularly concerned with a new and improved method of initiating exothermic decomposition of hydrazine type fuels featuring the use of solid oxidizing agents.

It is a primary aim of the present invention to provide a method of spontaneously igniting fuel compositions by use of oxidizing agents hypergolic therewith.

Another object of this invention lies in the provision of a starting method for hydrazine type fuels which features as an essential step thereof the injection of the fuel into an essentially closed chamber into contact with a solid oxidizer positioned therein.

Another object of this invention is to provide a procedure for starting gas generators which comprises admitting therein hydrazine fuel and effecting contact between said fuel and a solid oxidizer contained in said gas generator to spontaneously ignite the hydrazine fuel and initiate exothermic decomposition thereof with release of substantial gas pressures from the generator.

A further object of the invention lies in the provision of an improved igniting method for hydrazine type fuels, featuring the combination therewith of a solid oxidizer selected from the group consisting essentially of lead dioxide, potassium permanganate, calcium hypochlorite, molybdic acid, tungstic acid, iodine pentoxide and sodium chlorite.

Other objects and advantages of the present invention will become more apparent during the course of the following description, particularly when taken in connection with the accompanying drawings.

In the drawings, wherein like numerals are employed to designate like parts throughout the same:

FIGURE 1 is a fragmentary perspective view of one form of gas generator which may be employed in the practice of the method of this invention; and

FIGURE 2 is a fragmentary perspective view of a different form of gas generator effective in performance of the novel steps herein disclosed.

Applicants' invention lies in the discovery that fuel compositions of the hydrazine type may be spontaneously ignited and exothermically decomposed with essentially instantaneous development of maximum pressures by combining with the fuel an oxidizing agent selected from the group consisting of lead dioxide, potassium permanganate, calcium hypochlorite, molybdic acid, tungstic acid, iodine pentoxide and sodium chlorite. The utilization of solid oxidizers in accordance iwth this invention produces in all cases smooth starts, and the emission of combustion products having no marked deleterious effects upon the gas generator and structure related thereto. Substantial investigations have demonstrated that the starts using solid oxidizers proceed extremely rapidly and are essentially instantaneous, only requiring on the order of about one-fifth to two-fifths of a second to reach maximum pressures. While reaction chambers of various structural characteristics may be employed in the practice of the present method, there is illustrated in FIGURES 1 and 2 particular gas generators employed by applicants to effect instantaneous starts of hydrazine compounds.

Referring now to FIGURE 1, there is shown a gas generally designated by the numeral **10** and of proven effectiveness in initiating a spontaneous decomposition of hydrazine employing either potassium permanganate or iodine pentoxide as the oxidizing agent. The generator comprises a hollow generally cylindrical main body portion **11** and an integral, hollow reduced diameter tail pipe portion **12** providing at one end an exhaust nozzle **13**. The main body portion **11** receives at one end a threaded cap member **14** having at generally its radial center a fuel line connection **15** communicating interiorly of the main body portion with a fuel injector nozzle **16**. It is to be seen that the fuel line connection and injector nozzle are in general axial alignment with one another.

The main body portion **11** of the generator **10** provides interiorly thereof a reaction chamber **17** and welded or otherwise secured to the walls of the chamber **17** is a retainer plate **18** suitably apertured and providing a mounting surface for a plurality of metal coils **19** which function as a catalyst and to stablize the flame front of the decomposition reaction. A material found suitable for the coil springs **19** is 304 stainless steel.

While the solid oxidizer may be mounted interiorly of the generator body portion **11** in various ways, particularly good results have been obtained with the support arrangement of FIGURE 1. This arrangement comprises a generally cylindrical shell member **20** at one end of which is welded or otherwise secured a relatively heavy wire screen **21**. Carried upon the screen **21** is a screen **22** of relatively finer mesh, and between said screen **22** and an identical screen member **23** is a quantity of the selected oxidizer **24**. To complete the oxidizer support arrangement there is preferably superimposed upon the screen **23** a relatively heavy mesh screen **25**, which may correspond to the bottom screen **21**, and it is to be seen from FIGURE 1 that the screen assembly and oxidizer are held firmly in place by means of retaining ring or the like **26** which is snapped into proper position. The shell **20**, screens **21**, **22**, **23** and **25**, and the retaining means **26** accordingly provide a support basket **27** for the oxidizer **24**, and a preferred manner of mounting the basket **27** whereby the oxidizer therein is in impinging relation to the fuel injected through the nozzle **16** is shown in FIGURE 1. The support means disclosed may include hook means **28** carried by the cap member **14** and receivable in suitable openings in the walls of the shell **20**. This provides a convenient removable mounting although the basket **27** could of course be supported in other ways.

At the end of the main body portion **11** adjacent the tail pipe portion **12** there is arranged a pressure tap connection **29** by means of which pressure readings are obtained, and downstream thereof is thermocouple **30** to provide the desired temperature information. Other pressure and temperature connections may be made at other locations along the gas generator **10** when desired.

A series of runs have been made utilizing the gas generator **10** of FIGURE 1 supporting in the reaction chamber **17** thereof potassium permanganate or iodine pentoxide. The results obtained from these tests employing anhydrous hydrazine as the fuel are set forth in the illustrative examples below.

EXAMPLE I

Twenty grams of potassium permanganate in crystalline form was located in the basket **27** between screens **22** and **23** of 200 mesh size. A variable area injector nozzle **16** was employed, and the exhaust nozzle **13** had a diameter of 0.239 inch. The net volume of the generator **10** when empty was 530 cc. No external heating means were employed, and the catalyst was 414 grams of 304 stainless steel springs. The weight of the oxidizer basket with oxidizer loaded therein before the start of the run was 90.6 grams, while after completion of the run the total weight was 77.6 grams.

Anhydrous hydrazine was admitted to the reaction chamber **17** in spray form through the fuel line **15** at a pressure of 600 p.s.i. The run was permitted to continue for eight minutes and continuously therethrough temperature and pressure readings were obtained. Temperatures sensed by the thermocouple connection **30** were recorded on a multipoint Brown recorder, while fuel flow rate, fuel supply pressure and reaction chamber pressure was continuously recorded on Sanborn direct writing oscillographs. A base flow rate of 0.5 g.p.m./cm. was used, and the base rates of supply and chamber pressures were each 250 p.s.i./cm. The amount of time required for each start was observed from the oscillograph pressure trace of supply pressure, the starting point of the reaction being shown by a sudden drop in supply pressure, and the time interval required for starting was measured from the pressure drop point to the point at which maximum pressure was achieved. In the case potassium permanganate as the solid oxidizer, the start was made in one-fifth of a second. As noted, continuously throughout the run pressure and temperature information was recorded, and the results obtained during the eight minute run are set forth in tabular form below.

Table 1

Read. No.	Read. time (min.)	Fuel rate (lb./hr.)	Fuel rate (g.p.m.)	Chamber press. (p.s.i.)	Supply press. (p.s.i.)	Calc. C*	Temp. (° F.)
1	6/25 sec	Press.	Peak	410	--------	--------	--------
2	15/25 sec	--------	--------	355	--------	--------	--------
3	1 Min	560	1.11	405	605	3,800	1,574
4	2 Min	555	1.10	400	600	3,700	1,563
5	4 Min	555	1.10	400	600	3,700	1,565
6	6 Min	550	1.09	400	600	3,800	1,570
7	8 Min	545	1.08	400	600	3,800	1,574

It is to be observed from the foregoing data that potassium permanganate initiated a spontaneous decomposition of hydrazine, causing attainment of maximum pressures in about one-fifth of a second. The table includes as one column thereof the values of C*, and this represents the characteristic gas velocity. 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 the exhaust nozzle throat area, g is acceleration of gravity, and W is weight flow of propellant.

The characteristic length of the reaction chamber **17** as employed in the decomposition of hydrazine utilizing potassium permanganate was 638. Characteristic length is determined from the equation

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

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 **16**, method of flame front stabilization (coils **19**), shape of the reaction chamber **17**, and kind of material used for the internal surfaces thereof.

EXAMPLE II

Tests were also conducted utilizing iodine pentoxide as the solid oxidizer in initiating spontaneous decomposition of anhydrous hydrazine. The gas generator **10** of FIGURE 1 was employed, again using a variable area type injector and an exhaust nozzle having a diameter of 0.239 inch. The catalyst was 425 grams of 304 stainless steel springs, approximately one inch in length and positioned as shown in FIGURE 1. The calculated characteristic length of the reaction chamber **17** in the iodine pentoxide runs was 636. Five grams of iodine pentoxide were loaded in the basket **27** in the manner shown, and hydrazine was admitted to the chamber in the form of a spray at an initial supply pressure of 600 p.s.i. The running time of the test was three minutes, and readings of temperature and pressure were taken continuously throughout. The iodine pentoxide was in powder form, and when contacted by the hydrazine spray a smooth start was obtained and a minor amount of blue vapors issued from the exhaust nozzle **13**. It was observed subsequent to the test that the basket **27** and screens therein were in good condition. A minor pressure spike was noted, and the pressures and temperatures observed are set forth in tabular form below.

Table 2

Read. No.	Read. time (min.)	Fuel rate (lb./hr.)	Fuel rate (g.p.m.)	Chamber press. (p.s.i.)	Supply press. (p.s.i.)	Calc. C*	Temp. (° F.)
1	5/25 sec	Press.	Spike	420	--------	--------	--------
2	7/25 sec	--------	--------	290	--------	--------	--------
3	8/25 sec	--------	--------	350	--------	--------	--------
4	1 Min	500	.99	400	635	4,200	1,507
5	2 Min	500	.99	400	635	4,200	1,544
6	3 Min	495	.98	400	630	4,200	1,548

As in the test of the first example, pressure traces of pressures sensed from the tap **29** by strain gauge transducers were continuously recorded on Sanborn direct writing oscillographs, employing as a base flow 0.5 g.p.m./cm., a supply pressure base of 250 p.s.i./cm. and a pressure chamber base of 250 p.s.i./cm. The pressure trace of supply pressure was carefully observed and the time interval between the pressure drop and the point at which maximum pressure was achieved noted. The time interval with iodine pentoxide was approximately one-fifth of a second, approximately the same starting time for spontaneous decomposition as with potassium permanganate. It is thus to be seen that ignition of the hydrazine with both potassium permanganate and iodine pentoxide occurs essentially instantaneously with the initiation of exothermic decomposition of the hydrazine and development of maximum pressures in time intervals not exceeding about one-fifth of a second. This is of course markedly less than the starting time required for a mono-propellant start utilizing external heating means or a squib starter. In addition, with each of the solid oxidizers herein disclosed a smooth start is obtained, and accordingly there is avoided the likelihood of violent reactions occasionally associated with the use of red fuming nitric acid for bi-propellant starts.

An alternate form of gas generator is shown in FIGURE 2, and this construction has proven particularly effective when utilizing lead dioxide as the solid oxidizer for spontaneous decomposition of anhydrous hydrazine. The exemplary form of gas generator designated as **31** in FIGURE 2 comprises a hollow, generally cylindrical main body portion or housing **32** having a reduced diameter generally cylindrical passaged tail pipe portion **33** carrying an exhaust nozzle at the end thereof. A cap assembly **35** is threadably received in the opposite end of the housing **32**, and said assembly is provided with a fuel injector nozzle **36** which is preferably of the variable area type. The cap assembly **35** is of course suitably passaged to provide communication with a reaction chamber **37** interiorly of the main body portion **32**.

Within the reaction chamber **37** there is located an apertured retainer plate **38** supporting a plurality of coil springs **39** performing a catalytic action and stabilizing the flame front produced by reaction of the fuel and solid oxidizer within said reaction chamber. The coil springs are preferably of 304 stainless steel, and a particular quantity thereof are packed within the reaction chamber in the manner shown in the drawing. Pressure tap and thermocouple connections **40** and **41** of the character earlier described are employed, and an additional number of said connections may be utilized at other locations along the gas generator to record information at said locations.

The supporting arrangement for the oxidizer in the generator of FIGURE 2 is to be seen as different from that of FIGURE 1. Lead dioxide or other solid oxidizer **42** is contained in a plurality of capsules **43** of generally cylindrical shape formed of wire screen **44**, each cylindrical screen being wrapped with coils **45** of stainless steel wire. The wire screen may be of a mesh corresponding to 96 openings per inch utilizing 0.0035 inch diameter 304 stainless steel wire. The wire coils **45** are preferably formed from 0.040 inch diameter 304 stainless steel wire shaped on a 3/16 inch rod at eight threads to the inch. While variations may be practiced, the capsules **43** in tests performed to date have been about 1¼ inches long and approximately 3/16 inch in diameter. The capsules **43** with oxidizer **42** contained therein may be packed tightly within the reaction chamber **37** in approximately the position shown in FIGURE 2, or if desired the capsules may be supported by a retainer plate **46**, apertured as shown and corresponding generally to the retainer plate **38**. The capsules **43** may also be suspended from the cap assembly **35**, and mounted in the reaction chamber **37** in various other ways. As earlier noted, the gas generator **31** is of proven effectiveness with solid oxidizers such as lead dioxide, and the results obtained will now be described in connection with the example following.

EXAMPLE III

Fifty coil springs **39** having a total weight of 534 grams and formed of 304 stainless steel wound on a ¼ inch rod twenty-four threads to the inch and each 3¾ inches long were located in the reaction chamber **37** in the manner shown in FIGURE 2. Fifty-eight grams of lead dioxide contained in capsules **43** were then inserted in the reaction chamber as illustrated. The gas generator had a net volume of 25.19 cubic inches, a variable area injector nozzle **36** was used, and the exhaust nozzle **34** had a diameter of 0.239 inch. The characteristic length L* of the reaction chamber was 562. The weight of the gas generator **31** when empty was 5672 grams.

Hydrazine was admitted to the gas generator **31** through the injector nozzle **36** at a supply pressure of 300 p.s.i., and during a running time of eighteen minutes observations were continuously made of flow rates, pressures and temperatures. It was observed that initially a substantial quantity of smoke was expelled from the generator, although the lead dioxide provided a very smooth start with anhydrous hydrazine as admitted in spray form. It was noted that the tail pipe **33** initially turned a red color, and a reddening of the housing **32** immediately upstream of the tail pipe **33** was seen. The smoke cleared in approximately one-half minute, and some sparking from the tail pipe **33** was seen during the first stages of the run. The fuel flow, pressure and temperature readings as recorded are reproduced in tabular form below.

Table 3

Read. No.	Read. time (min.)	Fuel rate (lb./hr.)	Fuel rate (g.p.m.)	Chamber press. (p.s.i.)	Supply press. (p.s.i.)	Calc. C*	Temp. (° F.)
1	Peak Press. at start			205	----	----	----
2	Immediately following Peak			170	----	----	----
3	1	178	.36	140	304	4,100	1,788
4	2½	178	.36	140	301	4,100	1,799
5	4	177	.355	137	300	4,000	1,779
6	5½	177	.355	135	300	4,000	1,760
7	7	175	.351	133	299	4,000	1,747
8	8½	178	.36	133	300	3,900	1,740
9	10	178	.36	133	300	3,900	1,740
10	11½	178	.36	135	300	3,900	1,735
11	13	180	.362	133	300	3,800	1,726
12	14½	180	.362	132	300	3,800	1,722
13	16	180	.363	133	300	3,800	1,715
14	17½	181	.364	133	300	3,800	1,710

Pressure traces were made in the manner of the earlier disclosed examples, utilizing as the basis for fuel flow, supply pressure and chamber pressure 0.2 g.p.m./cm., 100 p.s.i./cm., and 100 p.s.i./cm., respectively. The oscillograph readings on supply pressure were particularly noted to observe the pressure drop occurring as the starting point of the ignition of hydrazine by lead dioxide, and the time interval between the pressure drop and the point at which maximum pressure was reached was slightly less than two-fifths of a second. While the starting time with lead dioxide is relatively greater than with potassium permanganate and iodine pentoxide, all starting times are substantially less than those which are obtained with external heat means, starting squibs and the like. Further, as earlier stated, red fuming nitric acid has the characteristic of from time to time producing violent reactions, as contrasted with the smooth starts obtained from the solid oxidizers of this invention, and there is presented handling problems with the nitric acid compound.

The foregoing described investigations have been directed to the spontaneous decomposition of hydrazine; however, equally successful results are obtained with unsymmetrical dimethyl hydrazine, as well as with mixtures of hydrazine and unsymmetrical dimethyl hydrazine, as for example, a mixture consisting essentially of 5 to 25% by weight of unsymmetrical dimethyl hydrazine in hydrazine. In addition, the fuel employed may consist of a mixture of from 5 to 50% of ammonium nitrate in hydrazine. Further, while there is not set forth in tabular form pressure and starting time information with respect to calcium hypochlorite, molybdic acid and tungstic acid, these materials have been subjected to hypergolic reactivity tests in which hydrazine was injected onto the surfaces areas of these materials. In all cases, hypergolic reactivity was evidenced, and accordingly the named compounds are effective to initiate decomposition of hydrazine.

Other variations and modifications may of course be effected in the compositions and procedures herein disclosed without departing from the novel concepts of the present invention.

We claim as our invention:

1. A method of initiating decomposition of fuel which comprises:
   locating in a reaction chamber an oxidizing agent selected from the group consisting of lead dioxide, potassium permanganate, calcium hypochlorite, molybdic acid, tungstic acid, iodine pentoxide, and sodium chlorite, and
   directing into said reaction chamber and in impinging contact with said oxidizing agent a fuel hypergolic with said oxidizing agent, said fuel being selected from the group consisting of hydrazine and unsymmetrical dimethyl hydrazine.

2. A method of spontaneously igniting and decomposing a fuel which comprises:
   introducing the fuel into a reaction chamber in contact with a solid oxidizer,
   said fuel consisting of hydrazine,
   said oxidizer selected from the group consisting of lead dioxide, potassium permanganate, calcium hypochlorite, molybdic acid, tungstic acid, iodine pentoxide, and sodium chlorite, and
   venting from the reaction chamber the exhaust gases produced therein.

3. A method of imparting propulsive force to missiles which comprises:
   locating in the reaction chamber of said missile a solid oxidizer
   said solid oxidizer selected from the group consisting of lead dioxide, potassium permanganate, calcium hypochlorite, molybdic acid, tungstic acid, iodine pentoxide, and sodium chlorite,
   introducing into said chamber in contact with said solid oxidizer a fuel,
   said fuel selected from the group consisting of hydra-

zine, and hydrazine and unsymmetrical dimethyl hydrazine, and

venting from the chamber the exhaust gases produced therein.

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