United States Patent

[11] 3,581,504

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[21] Appl. No. **755,948**
[22] Filed **Aug. 28, 1968**
[45] Patented **June 1, 1971**

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[54] **MONOPROPELLANT TURBO GAS GENERATOR**
14 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **60/259,**
60/39.46, 103/87, 103/97, 230/114, 415/182
[51] **Int. Cl.** **F02k 9/02,**
B01j 9/04, F04d 15/00
[50] **Field of Search** 60/257,
258, 259, 260, 39.46; 230/114K, 116; 103/87T,
97; 253/123, 97, 101, 52N

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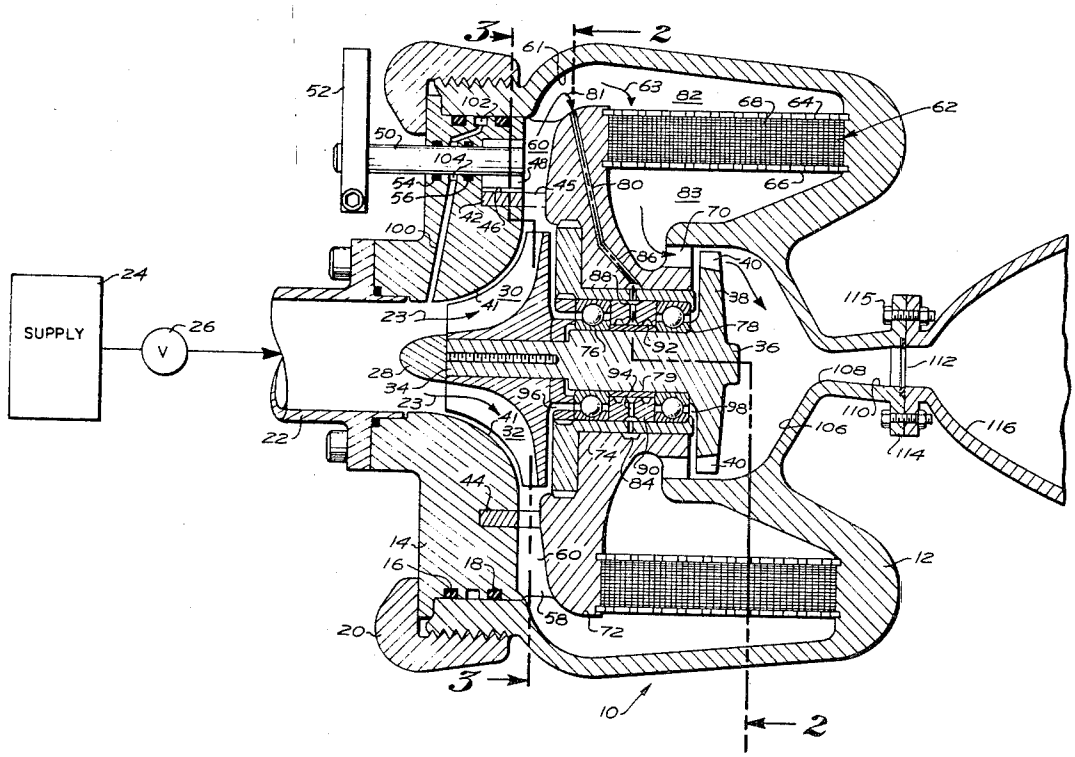
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ABSTRACT: A gas generator according to the present disclosure comprises a housing having an inlet opening for admitting monopropellant into the housing and an outlet having a back pressure control throat for expelling expanded gases therefrom. Impeller means is mounted within the housing for pressurizing the monopropellant. A turbine drive means is rotatably mounted within the housing adjacent the outlet for driving the impeller. Catalyst means is mounted within the housing intermediate the impeller and the turbine for decomposing the monopropellant.

The gas generator operates in a pressure-amplifying staged expansion cycle in that the impeller means increases the pressure of the monopropellant before the monopropellant reaches the catalyst, and the monopropellant decomposes in the presence of the catalyst to produce exhaust gas of relatively high pressure. The gas is expanded in the first stage of expansion to drive the turbine means. The gas may be further expanded through the back pressure control throat to form a second stage of expansion. If desired, the outlet of the back pressure control throat may be contoured to form a divergent nozzle so the gas generator may be used as a turborocket engine.



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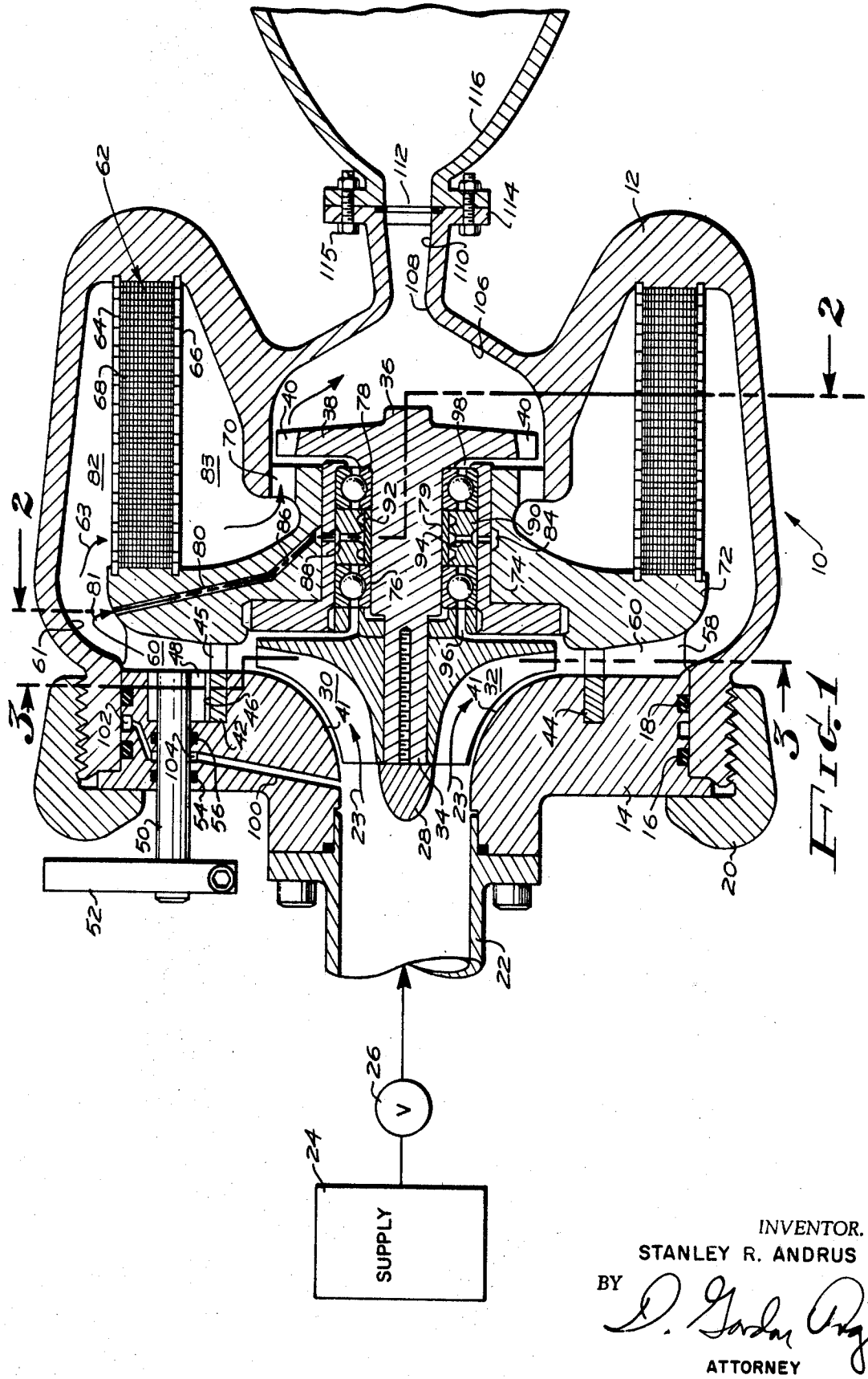


FIG. 1

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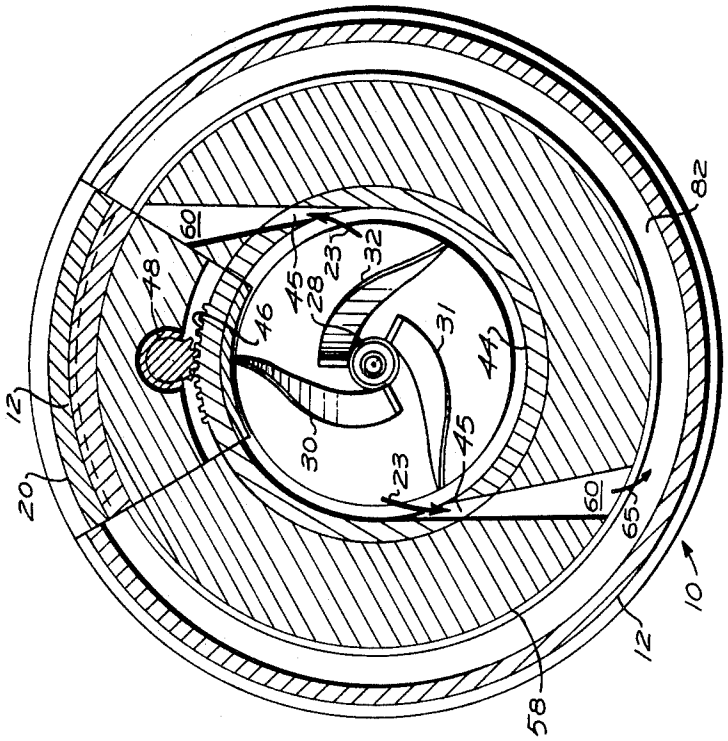


FIG. 3

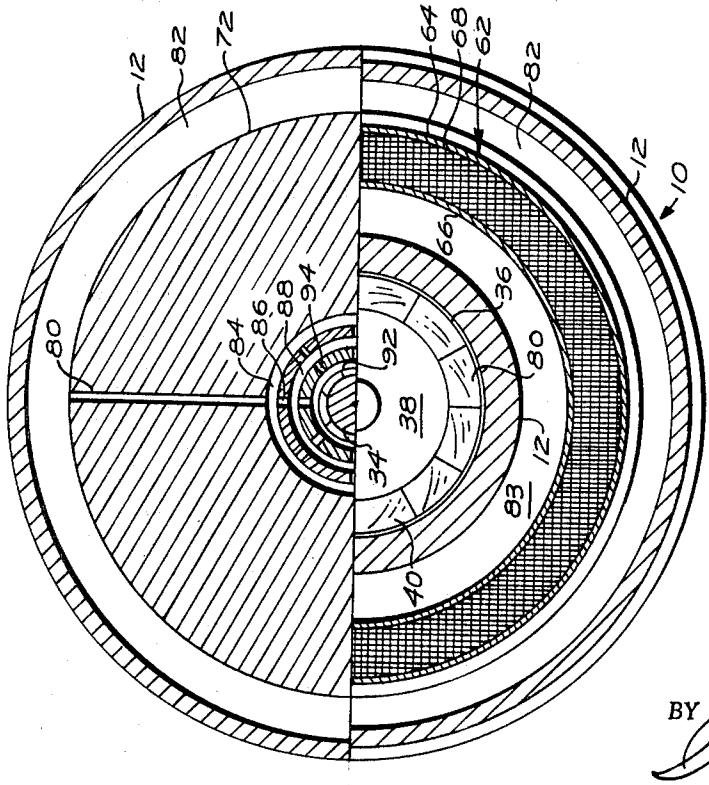


FIG. 2

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MONOPROPELLANT TURBO GAS GENERATOR

This invention relates to gas generators, and particularly to gas generators useful in vehicle propulsion and turborocket engines.

Heretofore, some gas generators and turborocket engines utilized monopropellants, such as hydrazine (N_2H_4) or hydrogen peroxide (H_2O_2), contained in supply tanks at relatively high pressure. The supply tanks were of sufficient weight as to provide adequate strength for supporting the pressure of the monopropellant. By way of example, the weight of many conventional rocket engines was such that the system propellant mass fraction, a fraction determined by dividing the weight of the propellant (W_p) when the fuel supply tanks are full, by the total weight of the system (W_t) including propellant, engine, tank and controls, was of the order of about 0.5. It is a desirable that the system propellant mass fraction be as great as possible, approaching unity, so that the weight of the propellant represents as great a portion of the system weight as possible. By increasing the system propellant mass fraction for a rocket engine, the fuel capacity, efficiency and specific impulse of the rocket can be increased.

It is an object of the present invention ro provide a gas generator having a greater system propellant mass fraction than achieved by prior gas generators.

Another object of the present invention is to provide a gas generator having a lower weight for a given weight of propellant than can be accomplished with prior monopropellant gas generators.

Another object of the present invention is to provide a gas generator capable of producing relatively high-pressure gas from relatively low-pressure monopropellant.

Another object of the present invention is to provide a gas generator capable of utilizing relatively low-pressure propellant. Since the propellant is at a low pressure, it may be contained in a relatively low-strength, lightweight vessel.

A gas generator according to the present invention provides a pressure-amplifying staged expansion cycle wherein relatively low pressure monopropellant is pumped by an impeller to a higher pressure. The monopropellant is then decomposed in the presence of a catalyst to produce a higher pressure exhaust gas. The exhaust gas is partially expanded in a first stage of the staged expansion cycle by driving a turbine which turbine drives the impeller. A second stage of expansion in the staged expansion cycle occurs when the turbine exhaust gas is partially expanded through a back pressure control nozzle.

According to one feature of the present invention, a higher system propellant mass fraction is achieved than can be achieved by prior systems by using a relatively low-pressure supply of monopropellant and by using relatively lightweight supply tanks.

According to another feature of the present invention, a pump diffuser is utilized between the impeller and the catalyst to diffuse the monopropellant entering the catalyst chamber.

According to another optional and desirable feature of the present invention, a nozzle assembly is mounted downstream from the turbine blades so that the gas passes through the nozzle throat to produce thrust, whereby the device operates as a monopropellant turborocket engine.

According to another optional and desirable feature of the present invention, the moving parts of the gas generator are lubricated by the propellant.

According to another optional and desirable feature of the present invention, throttling means is provided between the impeller and the catalyst to regulate the flow of propellant to the catalyst pack.

The above and other features of the present invention will be more fully understood from the following detailed description and the accompanying drawings, in which:

FIG. 1 is a side view elevation in cutaway cross section of a gas generator with a nozzle for use as a rocket engine according to the presently preferred embodiment of the present invention; and

FIGS. 2 and 3 are section views taken at lines 2–2 and 3–3, respectively, in FIG. 1.

Referring to the drawings, there is illustrated a gas generator **10** having a housing **12**. Header plate **14** is supported within housing **12** and is sealed to the housing by means of O-rings **16** and **18**. Lock plate **20** is threadably mounted to housing **12** to hold header plate **14** in the position illustrated. Inlet **22** is connected to header plate **14** and is in fluid communication with supply **24**. Valve **26** is between supply **24** and inlet **22** to regulate the flow of monopropellant from supply **24** to inlet **22**.

Supply **24** preferably contains a suitable monopropellant, such as hydrazine (N_2H_4) or hydrogen peroxide (H_2O_2). The particular monopropellant used is a matter of choice and depends upon the performance desired from the gas generator. Other monopropellants may, if desired, be used. The pressure of the monopropellant in supply **24** is relatively low, preferably less than 100 p.s.i.g. as related to ambient pressure.

MOunted within housing **12** and in fluid communication with inlet **22** is impeller pump **28** having impeller blades **30** and **32**. Impeller **28** is fixedly mounted to shaft **34** which in turn is integrally associated with turbine **36**. Turbine **36** includes a turbine disc **38** having a plurality of turbine blades **40**.

As illustrated particularly in FIG. **1**, header plate **14** includes flared passage **41** to direct axially flowing propellant radially toward throttle valve **42**. As illustrated particularly in FIG. **3**, throttle valve **42** comprises a throttle ring **44** having a gear portion **46** and apertures **45**. Gear portion **46** is engaged to gear **48** which in turn is mounted to shaft **50**. Shaft **50** is connected to valve actuator **52**. O-rings **54** and **56** provide a fluid seal between shaft **50** and header plate **14**.

Pump diffuser **58** comprises one or more flared apertures **60** adapted to be brought into fluid communication with apertures **45** of throttle ring **44**. As illustrated particularly in FIG. **3**, rotation of valve actuator **52** about the axis of shaft **50** causes rotation of gear **48**, which in turn drives cylindrical mechanism **44** about the axis of the gas generator. Cylindrical mechanism **42** rotates between two positions relative to diffuser **58**. In one extreme position, apertures **45** are in registration with apertures **60** to provide maximum flow of propellant therethrough, while in the other extreme position the flow is minimized. Flow regulation of propellant flowing through the pump impeller may be accomplished by means of the throttle valve.

The propellant is discharged from the pump diffuser **60** toward inner wall **61** of housing **12** which in turn directs it toward catalyst pack **62** as illustrated by arrows **63** in FIG. **1**. Catalyst pack **62** comprises a porous injector plate **64**, a porous backing plate **66**, and a catalyst material **68** sandwiched therebetween. The particular catalyst material may be any suitable catalyst material suitable for use with the monopropellant. By way of example, alumina pellets or granules with catalytic active material may be sandwiched between plates **64** and **66** to form a catalyst pack for use with hydrazine.

The catalyst pack causes decomposition of the monopropellant thereby generating hot exhaust gas in the region downstream from the catalyst pack. By way of example, if the monopropellant is hydrazine, the catalyst pack causes decomposition of the hydrazine to hydrogen, nitrogen and ammonia. Due to the high temperatures in decomposing hydrazine, the ammonia is discharged as a vapor from the catalyst pack.

It is to be understood that the catalyst pack may be any catalyst pack suitable for use with the particular monopropellant and the example set forth herein should not be construed as limiting on the invention. If desired, the catalyst material may be specially treated, such as by coating it with a porous rare earth material to prevent oxidation. Furthermore, the catalyst pack may be of any physical design. For example, the catalyst pack may comprise a plurality of stacked wafers constructed from catalyst material, as taught in copending application Ser. No. 698,856 by Robert J. Kuntz, filed Jan. 18, 1968 and assigned to the same assignee as the present invention.

The decomposed monopropellant in chamber 83 is discharged through turbine nozzles 70 toward turbine blades 40. The gas pressure and velocity of gas discharged through turbine nozzles 70 is relatively high, so the energy of the gas emitted through nozzles 70 operates on the turbine blades 40 of turbine 36, which in turn rotate impeller 28.

HOusing 72 is mounted within housing 12 and forms pump diffuser apertures 60 and turbine nozzles 70. Housing 72 also provides support for catalyst pack 62 so that injector plate 64 and backing plate 66 are mounted within suitable grooves within housing 12 and housing 72 to thereby support the catalyst material. If desired, housing 72 may be fixedly mounted to header plate 14 by means of suitable fasteners (not shown). HOusing 72 supports bearing plate 74 which in turn supports bearings 76 and 78. Bearings 76 and 78 journal shaft 34 to bearing plate 74 and spacer 79 separates bearings 76 and 78 so that the turbine and impeller are free to rotate about the axis of gas generator 10.

Channel 80 is formed within housing 72 and provides fluid communication between chamber 82 and annular channel 84, formed in housing 72. Apertures 86 provide fluid communication between channels 84 and 88. Channel 88 is formed within plate 90 which in turn includes labyrinth channels 92 which provide fluid communication between bearings 76 and 78. Passage 94 provides fluid communication between labyrinth channels 92 and channel 88. As illustrated in the drawings, bearings 76 and 78 are provided with openings 96 and 98, respectively. Opening 96 is open to the rear of impeller 28 while opening 98 is open to the rear of turbine disc 38.

Channel 100, which is formed in header plate 14, provides fluid communication from inlet 22 to annular groove 102 and annular groove 104. Groove 102 is positioned between O-ring seals 16 and 18 on the innerface between housing 12 and header plate 14, and annular groove 104 is positioned between O-rings 54 and 56 on the innerface between header plate 14 and shaft 50 of the valve-actuating mechanism.

Downstream from turbine 36, housing 12 forms a convergent nozzle 106, back pressure control throat 108, and divergent nozzle 110. Discharge outlet 112 is provided at the end of nozzle 110 and includes a flange portion 114 to which a divergent rocket nozzle 116 may be mounted by means of fasteners 115 for use as a turborocket engine.

In operation of the gas generator according to the present invention, valve 26 is opened to permit monopropellant to flow through inlet 22 toward impeller 28. The monopropellant is of such pressure as to assure flow of monopropellant past the initially nonrotating impeller, through the catalyst pack 62 to decompose the monopropellant, and thereafter through turbine nozzles 70. Flow of monopropellant through turbine nozzles 70 operates on turbine blades 40 to initiate rotation of turbine 36. Turbine 36 drives impeller 28 which in turn pumps more monopropellant to the catalyst pack. As impeller 28 rotates to pump low-pressure monopropellant toward catalyst pack 62, a pressure differential is created across the impeller blades 30—32 to increase the pressure of monopropellant at the catalyst pack. As the pressure increases, the velocity of gas through the turbine nozzles increases, to drive turbine 36 and impeller 28 at an even greater speed. The cycle continues until the gas generator produces maximum flow.

At maximum gas flow the monopropellant flows through inlet 22, impeller 28, to chamber 82 in the direction of arrows 23. The pressure differential generated across the impeller is sufficient to raise the pressure monopropellant in chamber 82 to as high as 5,000 p.s.i.a. The mainstream of the monopropellant in chamber 82 flows in the direction of arrow 63 through the catalyst material. The monopropellant decomposes to form a hot exhaust gas. The exhaust gas is expanded through turbine nozzle 70 to drive turbine 36. The gas, which downstream from nozzle 70 may be at a pressure as high as 4,000 p.s.i.a., is thereafter discharged through back pressure control throat 108 and thereafter through outlet 112 from nozzle 110.

From the foregoing it can be understood that the gas generator according to the present invention operates in essentially a pressure-amplifying staged expansion cycle wherein impeller 28 raises the pressure of the monopropellant to a high level and catalyst pack 62 decomposes the high-pressure monopropellant to generate a higher pressure exhaust gas. The high-pressure exhaust gas is discharged through turbine nozzle 70 as a first stage of expansion of the staged expansion cycle, and through the back pressure control throat as a second stage of the expansion cycle. After expansion, the gas is discharged through outlet 112 for its intended purpose. For example, if rocket nozzle 116 is utilized, the gas is used to produce thrust. The pressure differential across impeller 28 and diffuser 58 is dependent upon the design of the pump and the rotational velocity of the impeller as driven by the turbine.

Some of the monopropellant is directed in the direction of arrow 81 through channel 80 to labyrinth channels 92. In channels 92, the monopropellant is divided into two paths, one path toward bearing 76 and the other toward bearing 78. The propellant lubricates the respective bearings and is discharged through openings 96 and 98. The propellant discharged from opening 96 is recombined with propellant directed from the impeller toward throttle valve 42 and diffuser 58, while the propellant discharged through opening 98 is combined with the hot gas passing through turbine nozzle 70 and is decomposed in the chamber formed by nozzle 106 and discharged through outlet 112.

Channels 102 and 104 and associated passage 100 prevent leakage of monopropellant past the O-ring seals between housing 12 and header plate 14 and between header plate 14 and shaft 50. Since the pressure of the monopropellant in the region of throttle valve 42 and/or pump diffuser 58 is higher than that at the inlet due the operation of the impeller, any leakage occurring past O-ring seals 18 or 56 will be directed toward chambers 102 or 104, respectively. Since chambers 102 and 104 are in direct communication through passage 100 with the inlet, and since the pressure in chambers 102 and 104 is substantially lower than the pressure of the monopropellant in the region of pump diffuser 58, any propellant leakage past O-ring seals 18 or 56 will leak into passages 102 or 104 and thereby be discharged through passage 100 to the inlet and there be recombined with the inlet propellant. O-ring seals 16 and 54 prevent further leakage of propellant from chambers 102 and 104 to the atmosphere.

The present invention thus provides a monopropellant gas generator which is capable of use as a monopropellant rocket engine. Since the pressure of the monopropellant source can be maintained relatively low, for example less than 100 p.s.i.g. and in some cases as low as a few pounds per square inch more than environmental pressure, the strength requirements of the supply vessel need not be as great as those utilized with the relatively high-pressure systems. The pressure amplification of the monopropellant provided by the impeller eliminates the need for high-pressure inlet monopropellant. The apparatus is relatively lighter in weight and has a higher specific performance than gas generators and rocket motors heretofore known. With the present invention, the ratio of the weight of propellant to the weight of the overall system (known as the "system mass fraction") may be as high as 95 percent, as compared to 50 percent from previous systems.

The present invention may be used with any type of monopropellant, such as hydrazine (N_2H_4) or hydrogen peroxide (H_2O_2). The present invention provides a throttable gas generator which is driven by a monopropellant. Throttling is accomplished by rotation of shaft 50 about its axis to position apertures 45 of the throttle valve relative to the apertures 60 of pump diffuser 58 to regulate the flow of propellant to the catalyst pack. As an alternative means of throttling the gas generator, an annular ring may be moved axially to restrict apertures 60. As a second alternative, a controlled amount of monopropellant may be withdrawn from chamber 82 and delivered back to the supply 24 or to inlet 22. As another al-

ternative, a controlled amount of monopropellant may be passed past turbine **36** from either chamber **82** or **83** (on either side of the catalyst pack) into the chamber formed by nozzle **106**.

It is to be understood that the present invention is capable of a wide variety of uses. By way of example, the monopropellant gas generator according to the present invention may be utilized as a gas source for a jet engine starter, a submarine ballast expulsion system, or a turbine-driven supercharger. As other examples of the wide variety of used of a gas generator according to the present invention, the apparatus may be used for the propulsion of marine and land vehicles, aircraft, missiles and torpedoes, and for assisting takeoff of air flight vehicles from confined runways.

What I claim is:

1. A gas generator comprising: a housing having an outer wall; an inlet to said housing adapted to be connected in fluid communication with a supply of monopropellant; impeller means in said housing in fluid communication with said inlet; catalyst means fixedly mounted in said housing and in fluid communication with said impeller means of decomposing monopropellant, said fluid communication between said impeller means and said catalyst means being through a chamber within said housing adjacent said outer wall; first nozzle means in said housing in fluid communication with said catalyst means for directing the flow of substantially all the decomposed monopropellant; turbine means in said housing in fluid communication with said first nozzle means for driving said impeller means; second nozzle means in fluid communication with said turbine means, said second nozzle means having a back pressure control throat; and outlet means from said housing in fluid communication with said second nozzle means for discharging fluid from the housing, whereby said impeller means increases the pressure of monopropellant and directs it toward said catalyst means and said catalyst means decomposes said monopropellant to form an exhaust gas, and the exhaust gas expands through said first nozzle means to operate on said turbine means to drive said impeller and expands through said second nozzle means, the maximum flow through said second nozzle means being limited by said back pressure control throat.

2. Apparatus according to claim **1** further including throttle means in said housing for regulating the flow of monopropellant to said catalyst means.

3. Apparatus according to claim **1** wherein said impeller means includes a plurality of impeller blades adapted to direct monopropellant toward said catalyst means, and said turbine includes a plurality of turbine blades adapted to be driven by exhaust gas, drive means connecting said turbine blades to said impeller blades, bearing means journaling said drive means to said housing, and lubrication means for supplying monopropellant to said bearing means to lubricate the bearing means.

4. Apparatus according to claim **3** wherein said lubricating means includes means providing fluid communication between the bearing means and the flow of monopropellant upstream from said catalyst means.

5. Apparatus according to claim **1** wherein the pressure of the supply of monopropellant is less than the pressure of the exhaust gas.

6. Apparatus according to claim **1** wherein said outlet includes a nozzle forming a throat whereby the gas generator operates as a turborocket engine.

7. Apparatus according to claim **6** further including throttle means in said housing for regulating the flow of monopropellant to said catalyst means.

8. Apparatus according to claim **7** wherein said impeller means includes a plurality of impeller blades adapted to direct monopropellant toward said catalyst means, and said turbine includes a plurality of turbine blades adapted to be driven by exhaust gas, drive means connecting said turbine blades to said impeller blades, bearing means journaling said drive means to said housing, and lubrication means for supplying monopropellant to said bearing means to lubricate the bearing means.

9. Apparatus according to claim **8** wherein said lubrication means includes means providing fluid communication between the bearing means and the flow of monopropellant upstream from said catalyst means.

10. Apparatus according to claim **6** wherein the pressure of the supply of monopropellant is less than the pressure of the exhaust gas.

11. Apparatus according to claim **6** wherein said impeller means includes a plurality of impeller blades adapted to direct monopropellant toward said catalyst means, and said turbine includes a plurality of turbine blades adapted to be driven by exhaust gas, drive means connecting said turbine blades to said impeller blades, bearing means journaling said drive means to said housing, and lubrication means for supplying monopropellant to said bearing means to lubricate the bearing means.

12. Apparatus according to claim **11** wherein said lubrication means includes means providing fluid communication between the bearing means and the flow of monopropellant upstream from said catalyst means.

13. A gas generator comprising: housing; an inlet to said housing adapted positions; be connected in fluid communication with a supply of monopropellant; impeller means in said housing in fluid communication with said inlet; diffuser means in said housing and having a plurality of diffuser apertures in fluid communication with said impeller means for directing the flow of fluid from said impeller means; a rotatable throttle ring having a plurality of throttle apertures, said throttle ring being in operable association with said diffuser means and being movable between a first position wherein said throttle apertures are in maximum fluid communication with said diffuser apertures and a second position wherein said throttle apertures are in minimum fluid communication with said diffuser apertures; actuator means operably associated with said throttle ring for moving said throttle ring between its first and second positions catalyst means in said housing and in fluid communication with said diffuser means for decomposing monopropellant; first nozzle means in said housing in fluid communication with said catalyst means; turbine means in said housing in fluid communication with said first nozzle means for driving said impeller means; second nozzle means in fluid communication with said turbine means; and outlet means from said housing in fluid communication with said second nozzle means for discharging fluid from the housing, whereby said impeller means increases the pressure of monopropellant and directs it toward said diffuser means and throttle ring where monopropellant flow is regulated and directed toward said catalyst means and said catalyst means decomposes said monopropellant to form an exhaust gas, and the exhaust gas expands through said first nozzle means to operate on said turbine means to drive said impeller and expands through said second nozzle means.

14. Apparatus according to claim **13** wherein said outlet includes a nozzle forming a throat whereby the gas generator operates as a turborocket engine.