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Watkins

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(54) **ROCKET PROPULSION SYSTEM**

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(51) **Int. Cl.**[7] **F02C 7/00**
(52) **U.S. Cl.** **60/259**; 60/723; 60/787
(58) **Field of Search** 60/218, 723, 259, 60/39.462, 787

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(57) **ABSTRACT**

A rocket propulsion system, comprising: a rocket engine; and a turbopump supplying fuel or oxidizer to the rocket engine. The turbopump can supply an; adjustable flow of the fuel or oxidizer to throttle the rocket engine. The turbopump includes a catalyst bed for decomposing a material to produce a discharge; a mixer section downstream of the catalyst bed for introducing an additional amount of the material to the discharge to produce an exhaust stream having a mass flow; a nozzle downstream of the mixer section; a turbine downstream of the nozzle; and a pump driven by the turbine. The additional amount of said material is selected to produce a desired amount of mass flow.

6 Claims, 9 Drawing Sheets

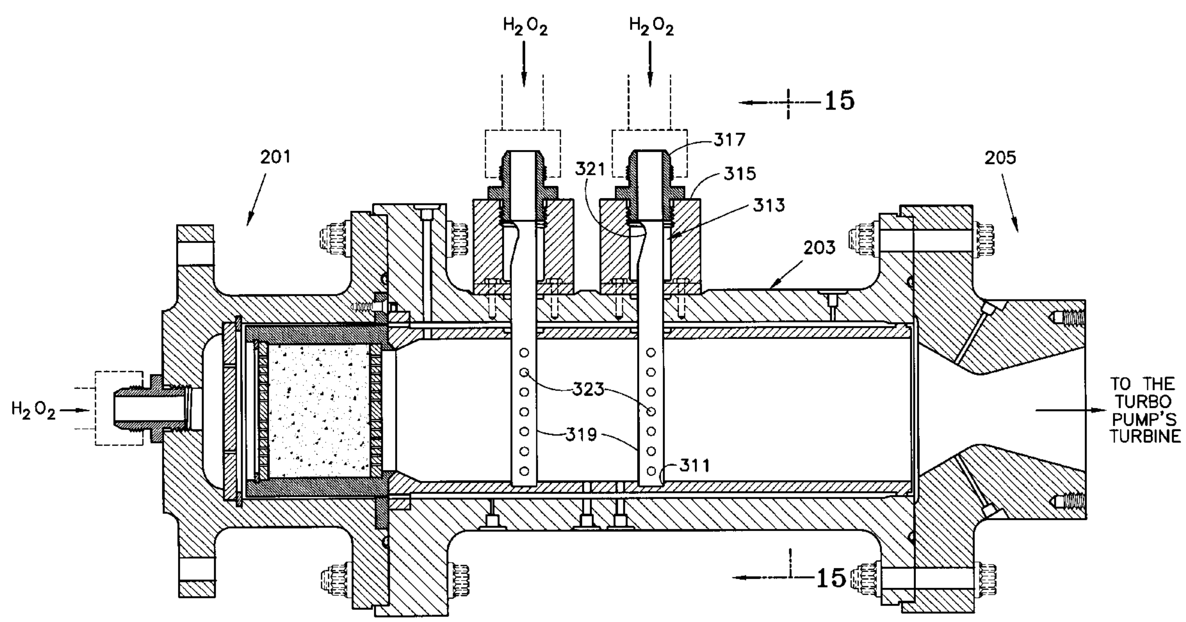


FIG. 1

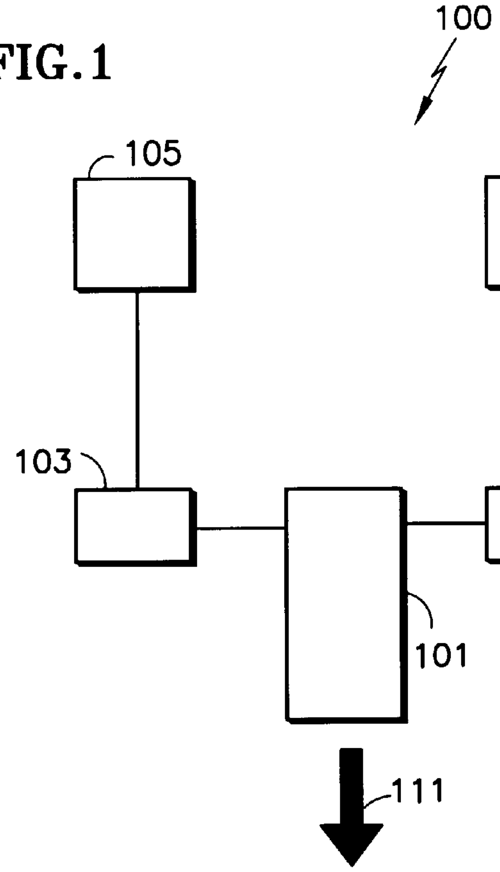


FIG. 2

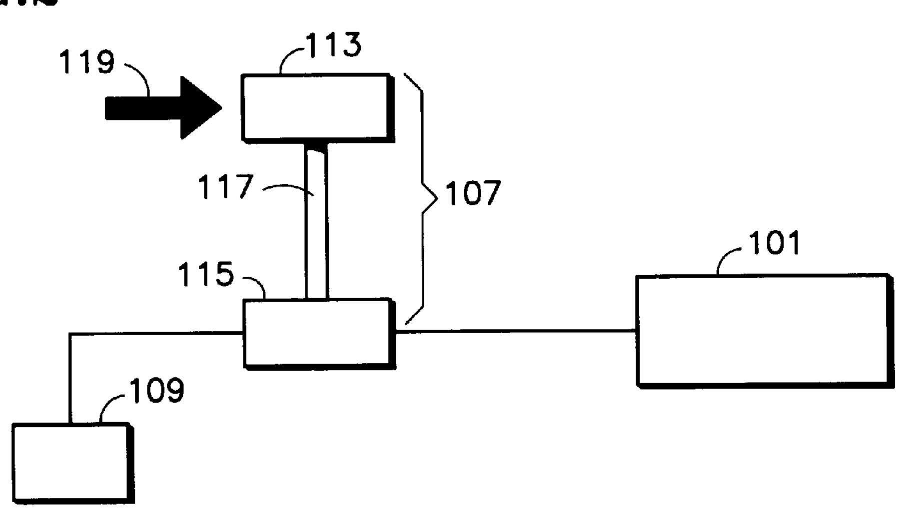


FIG.3

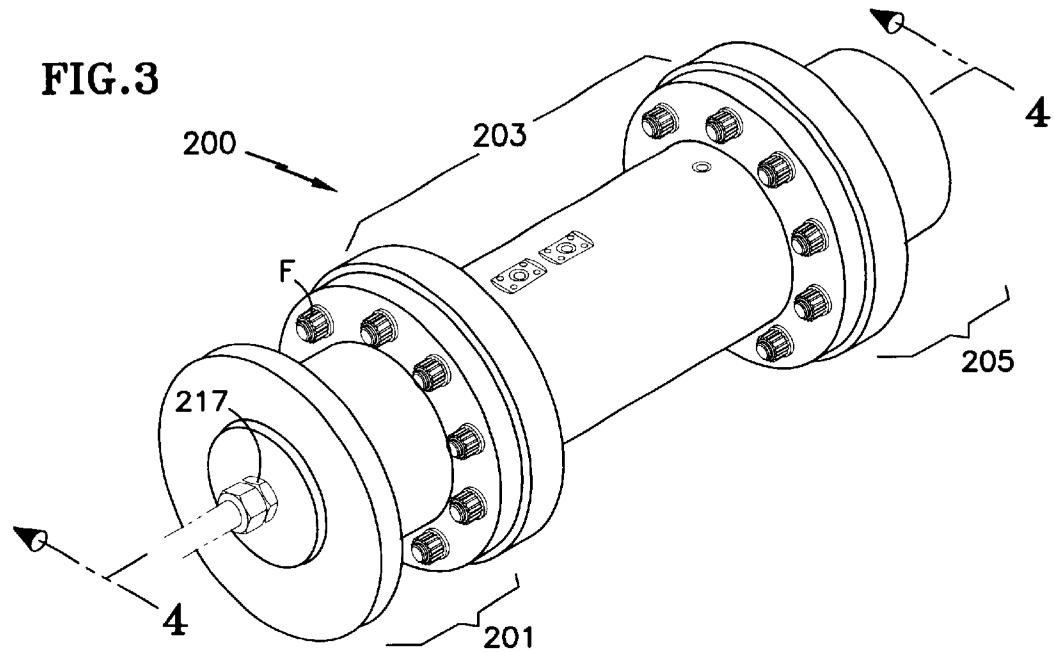
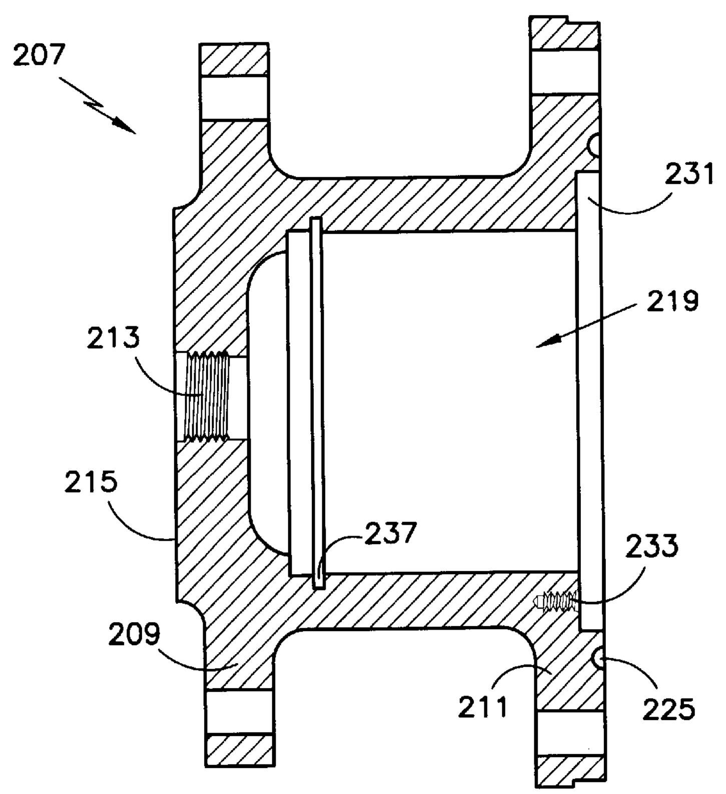


FIG.5



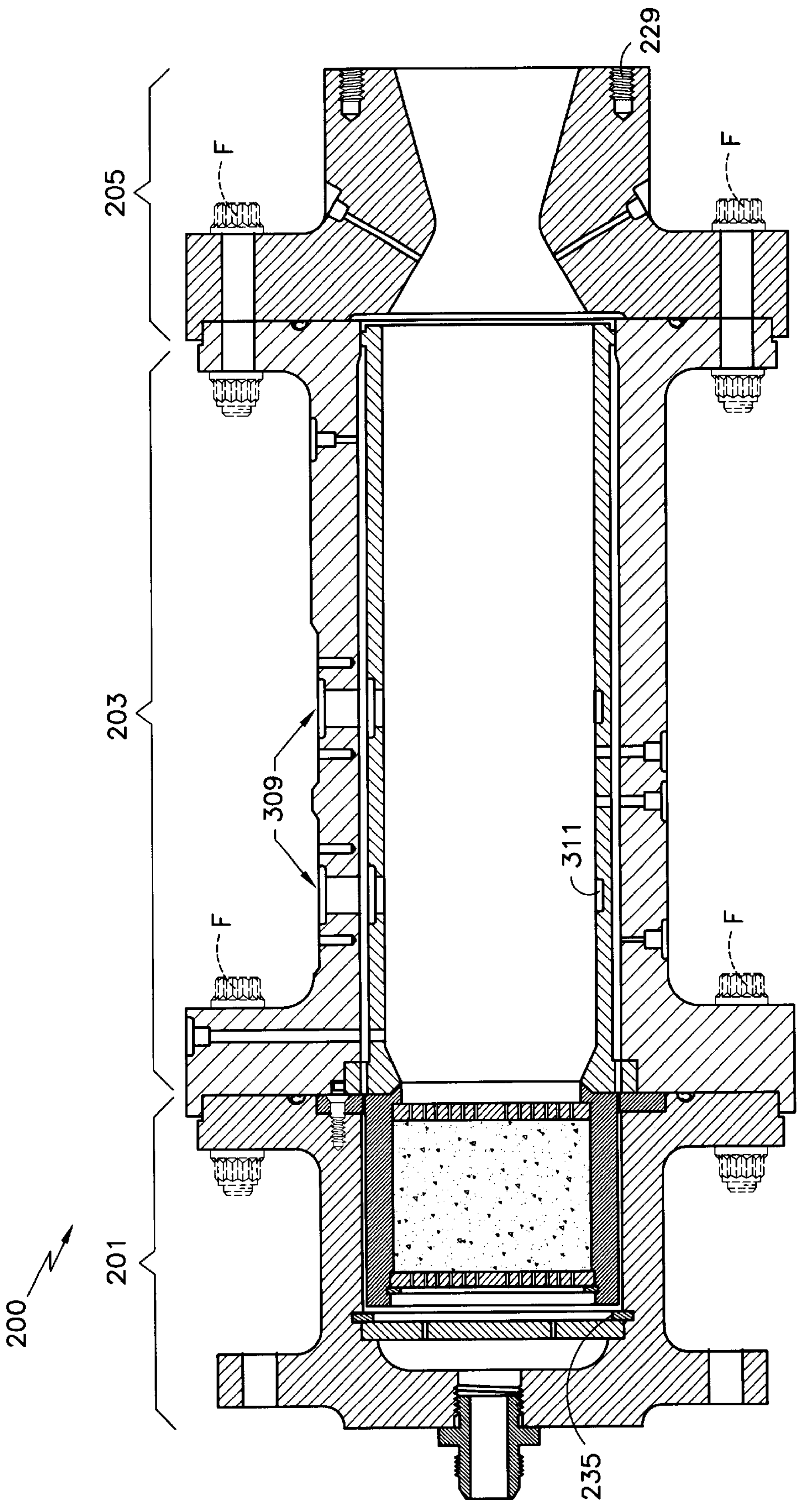


FIG.4

FIG.6

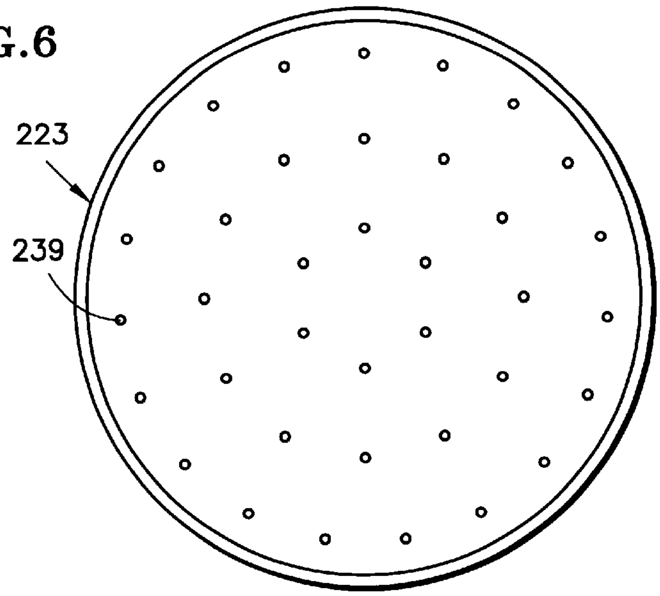


FIG.9

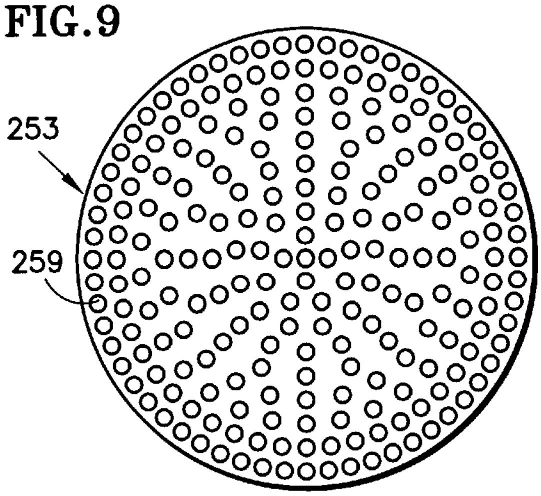


FIG.10

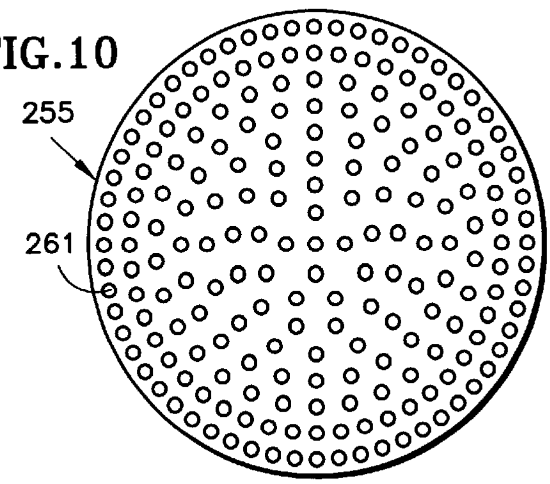
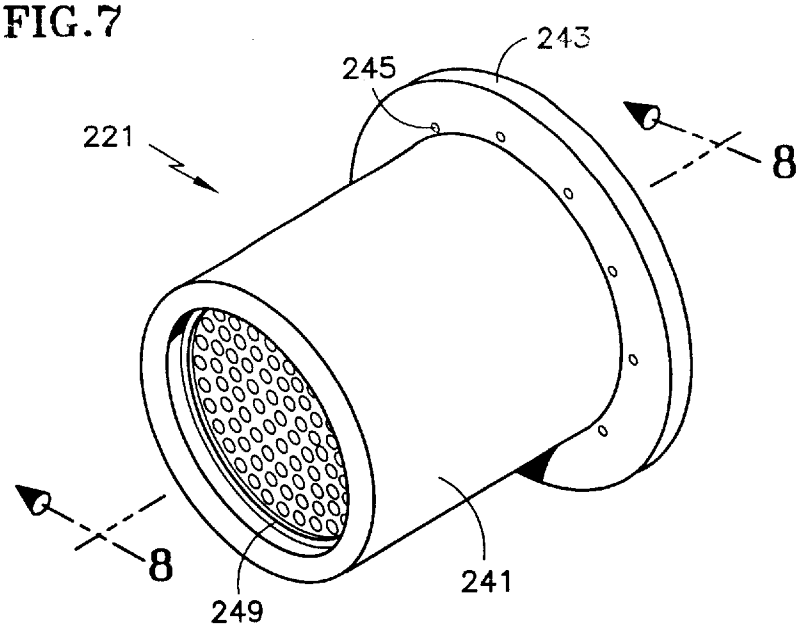


FIG.7



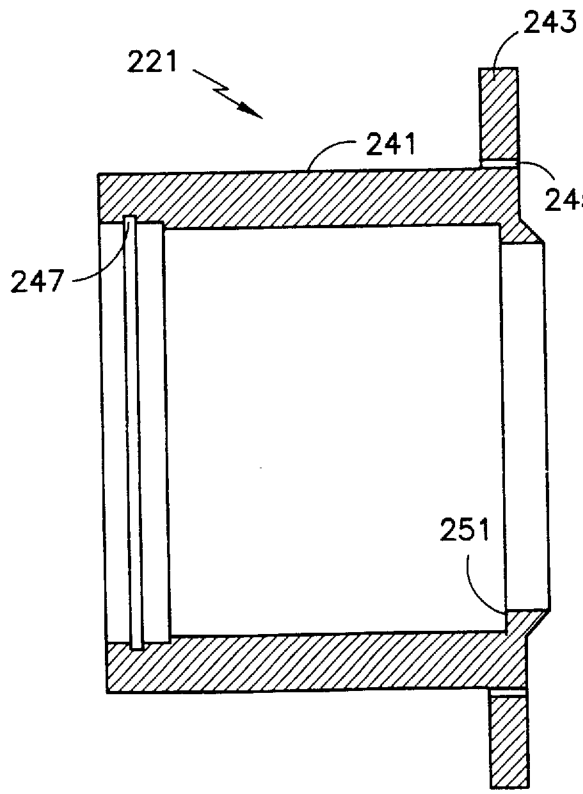


FIG.8

FIG. 11

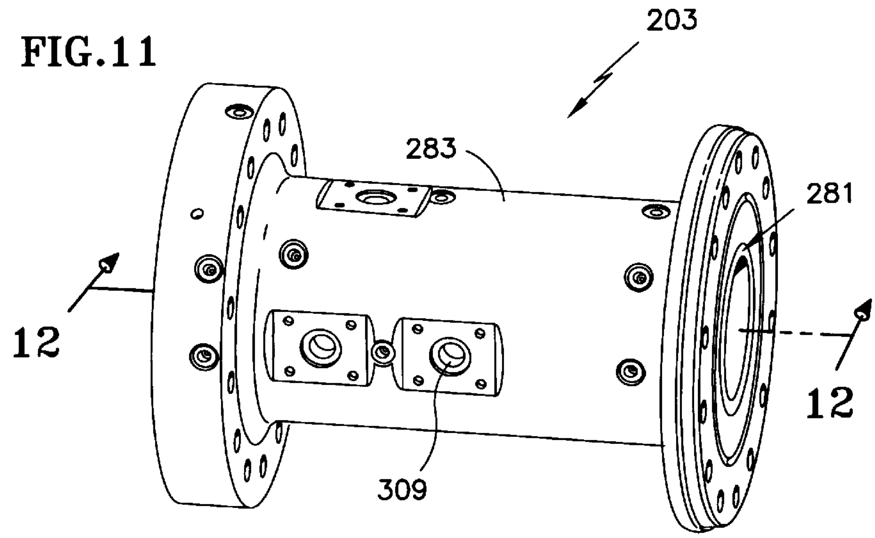
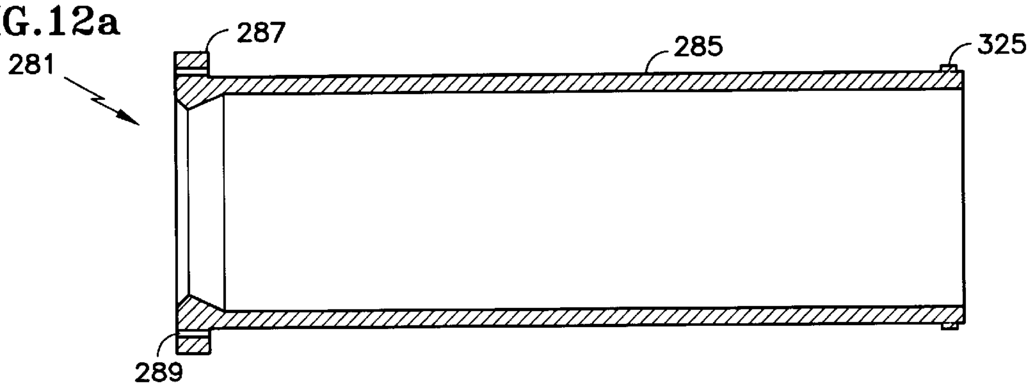


FIG. 12a



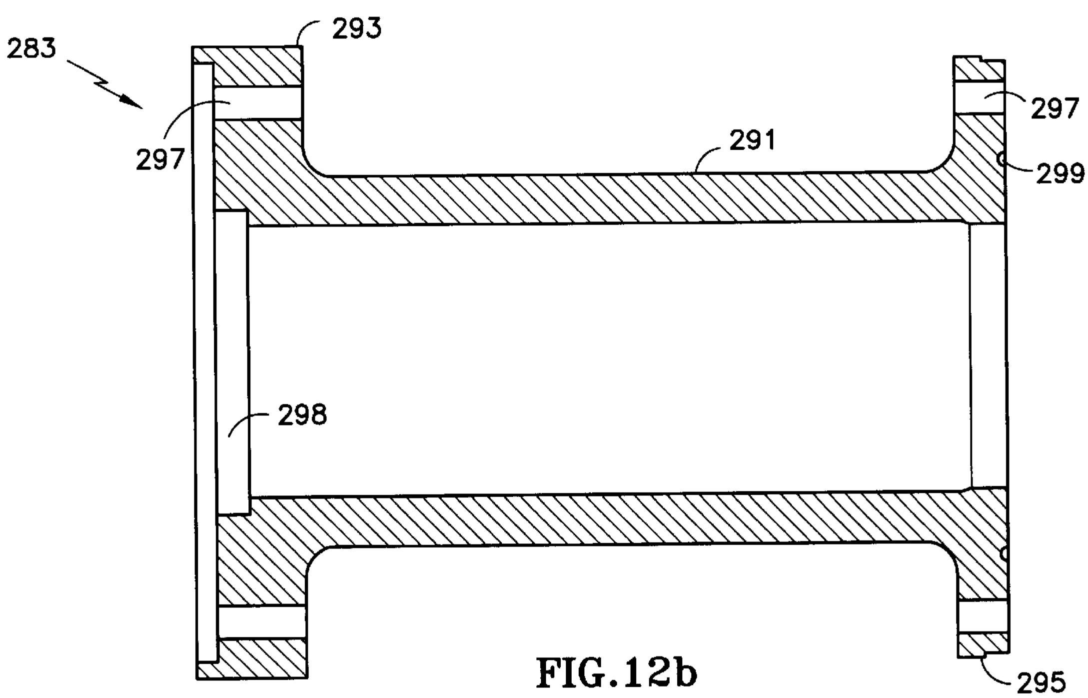


FIG. 12b

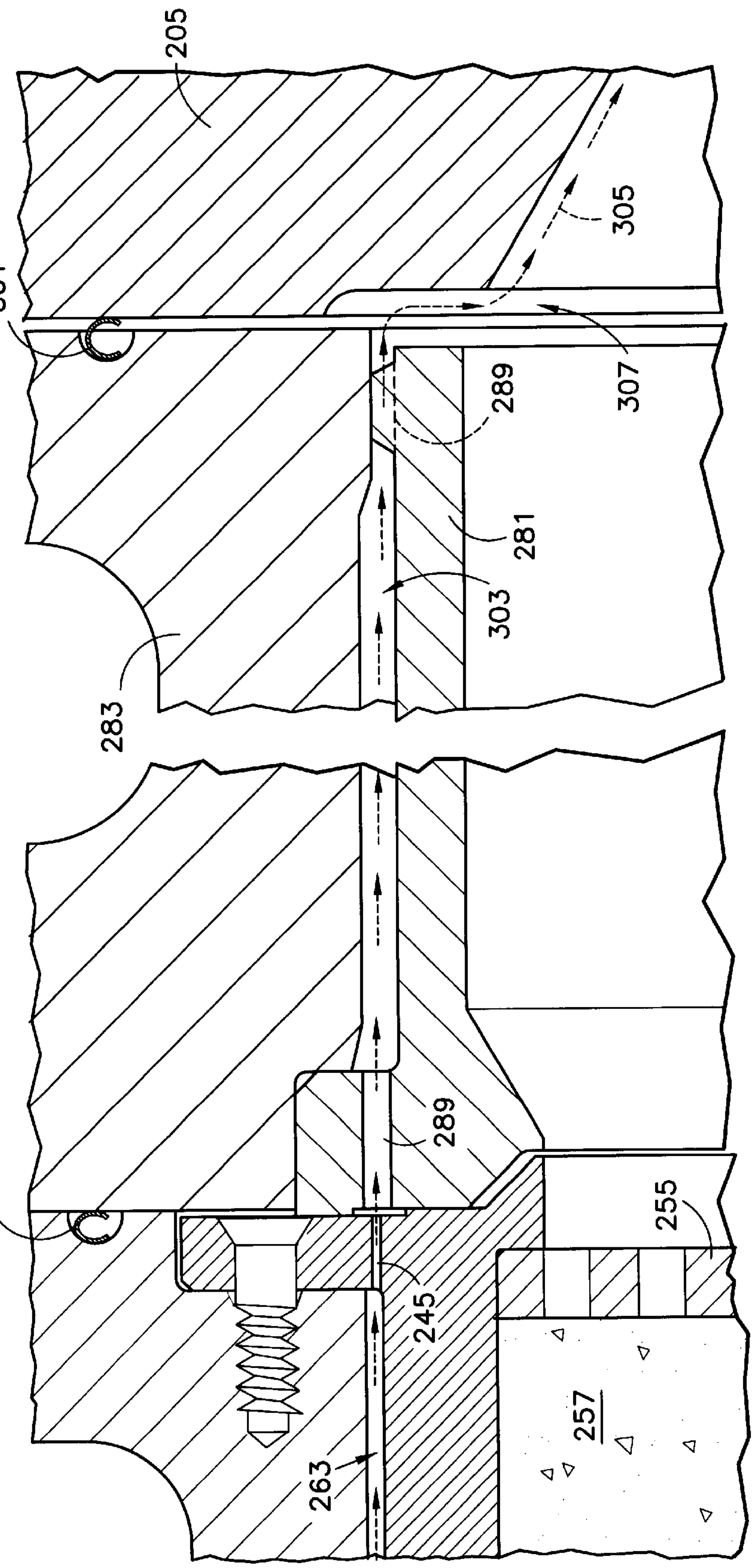


FIG. 13

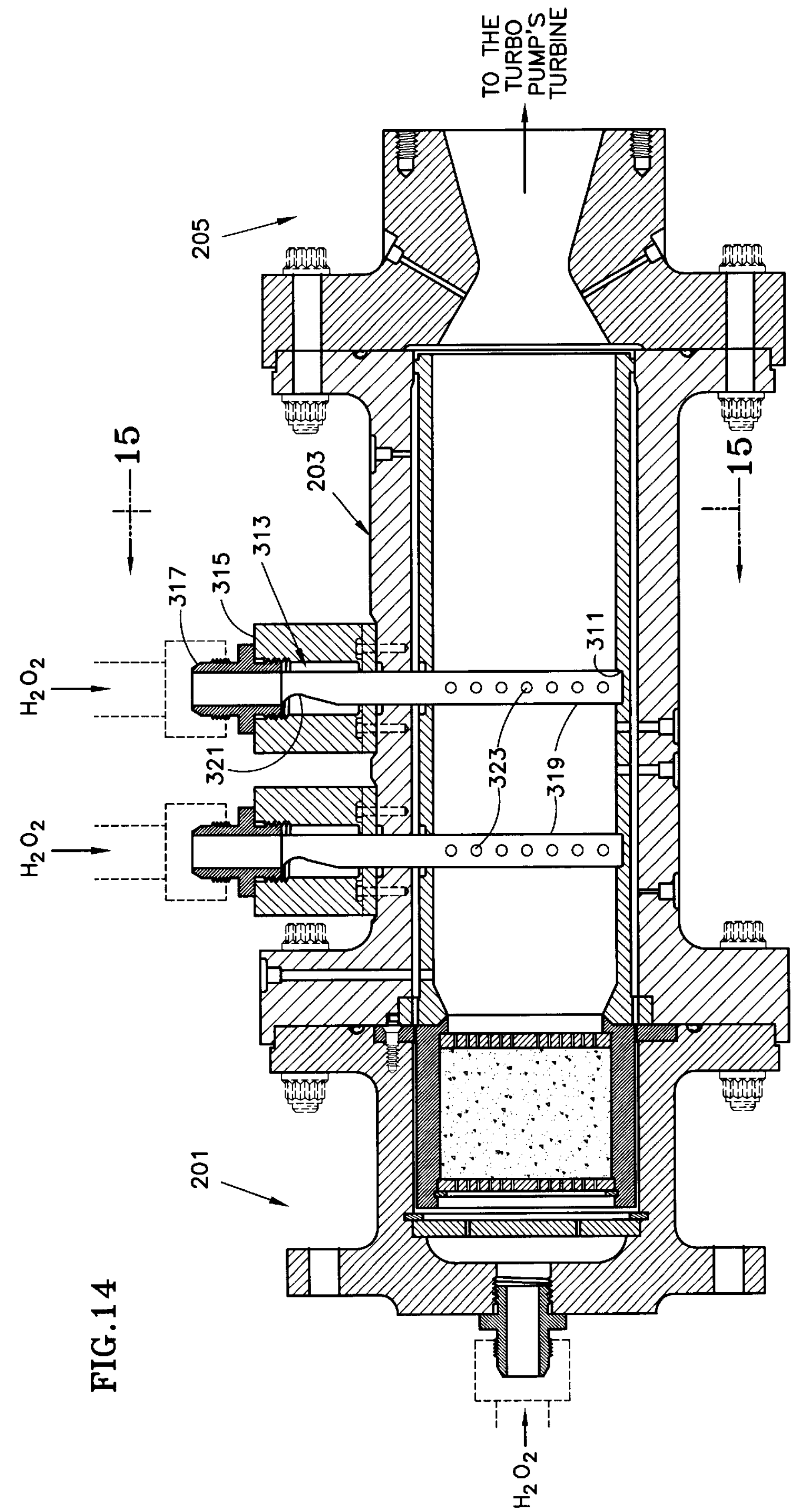
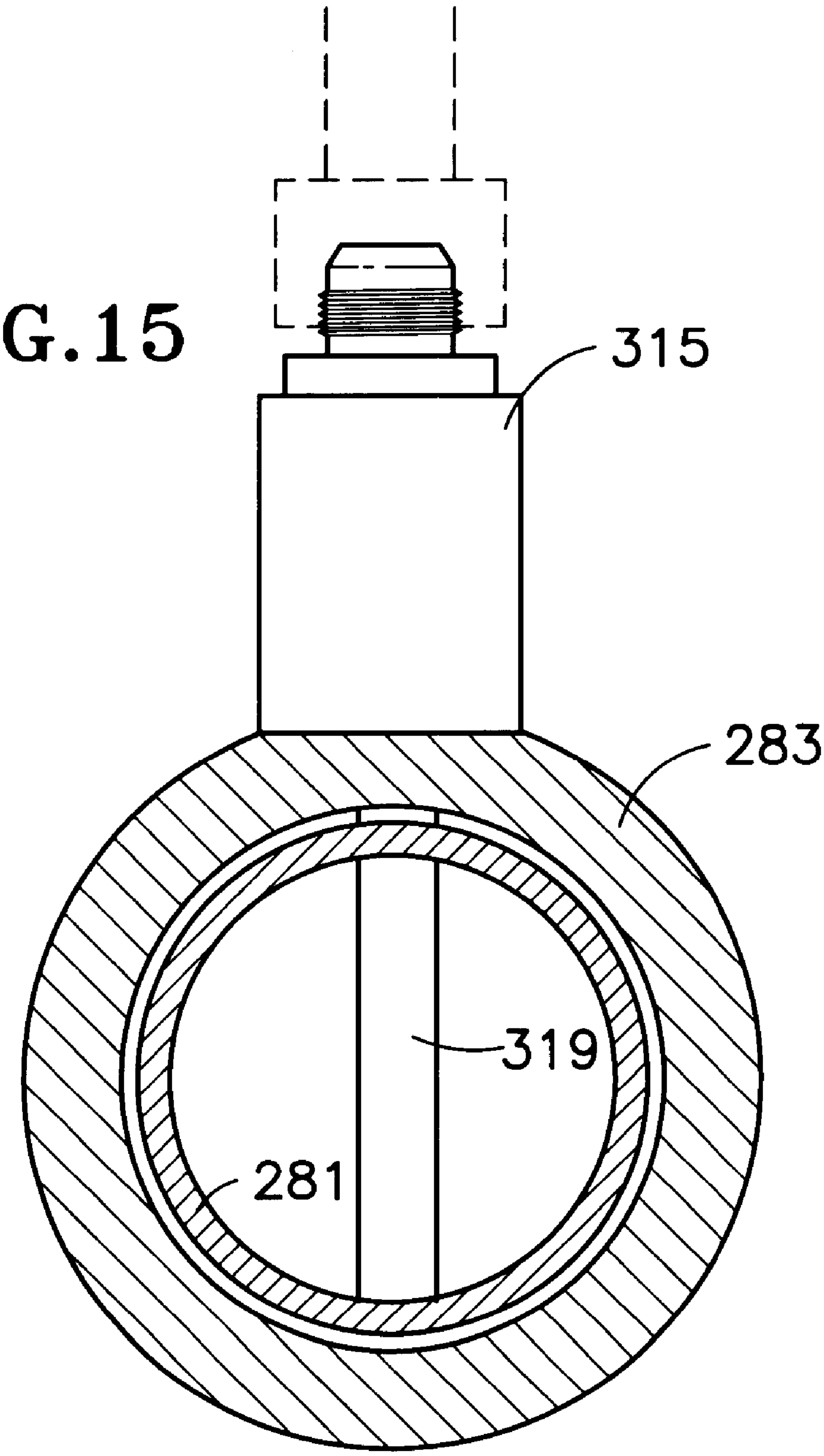

TO THE TURBO PUMP'S TURBINE
205
15
15
203
313
315
317
311
321
323
319
H_2O_2
H_2O_2
H_2O_2
201

FIG.14

FIG. 15



ROCKET PROPULSION SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a divisional of U.S. patent application Ser. No. 09/896,608 filed on Jun. 29, 2001 and is related to U.S. patent application Ser. No. 09/896,355 filed on Jun. 29, 2001, both of which are herein incorporated by reference.

BACKGROUND OF INVENTION

This invention relates to rocket propulsion systems. More particularly, this invention relates to a throttleable rocket engine.

FIG. **1** is a schematic of a rocket propulsion system **100**. The system **100** includes a rocket engine **101**. A fuel pump **103** supplies fuel to the rocket engine **101** from a fuel supply **105**. Likewise, an oxidizer pump **107** supplies oxidizer to the rocket engine from an oxidizer supply **109**. The rocket engine **101** combines the fuel and oxidizer, and ignites the mixture in a combustion chamber (not shown). The exhaust **111** exits a nozzle (not shown) to produce thrust.

To provide the amount of fuel and oxidizer required by the rocket engine **101**, pumps **103**, **107** are preferably turbopumps. FIG. **2** is a schematic of a turbopump assembly **107**. Generally speaking, the turbopump assembly **107** includes a turbine **113** connected to an impeller **115** by a shaft **117**. The turbine **113** converts the kinetic energy from an exhaust stream **119** into shaft horsepower to drive the impeller **115**.

The impeller **115** transports the oxidizer from the supply **109** to the rocket engine **101**. Turbopump **103** for the fuel operates in a similar manner, and is not described in further detail.

In conventional operations, the turbopumps **103**, **107** provide a constant supply of oxidizer and fuel to the rocket engine **101**. This uniform supply of oxidizer and fuel by the turbopumps **103**, **107** produces a constant thrust in the rocket engine **101**.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a rocket engine having adjustable thrust.

It is a further object of the present invention to provide a turbopump assembly that can adjust the thrust of a rocket engine.

It is a further object of the present invention to provide a turbopump assembly having a gas generator having a mixer section that can adjust output flow.

It is a further object of the present invention to provide a gas generator with a catalyst bed section that decomposes a material upon exposure to a catalyst and a mixer section that decomposes the material without exposure to a catalyst.

It is a further object of the present invention to provide a gas generator with a catalyst bed section that decomposes a material upon exposure to a catalyst and a mixer section that thermally decomposes a material without exposure to a catalyst.

It is a further object of the present invention to provide a gas generator having a catalyst bed assembly and which bypasses a portion of a material around the catalyst bed section for cooling.

These and other objects of the present invention are achieved in one aspect by a rocket propulsion system, comprising: a rocket engine; and a turbopump supplying

fuel or oxidizer to the rocket engine. The turbopump can supply an adjustable flow of the fuel or oxidizer to throttle the rocket engine.

These and other objects of the present invention are achieved in another aspect by a turbopump assembly. The turbopump assembly comprises: a catalyst bed for decomposing a material to produce a discharge; a mixer section downstream of the catalyst bed for introducing an additional amount of the material to the discharge to produce an exhaust stream having a mass flow; a nozzle downstream of the mixer section; a turbine downstream of the nozzle; and a pump driven by the turbine. The additional amount of the material is selected to produce a desired amount of mass flow.

These and other objects of the present invention are achieved in another aspect by a method of throttling a rocket engine. The method comprises the steps of: providing a catalyst bed; introducing an amount of a material into the catalyst bed so that the catalyst bed decomposes the material to produce a discharge; and selectively adding an additional amount of the material into the discharge to produce an exhaust stream having a mass flow. The additional amount of material increases the mass flow of the exhaust stream.

BRIEF DESCRIPTION OF DRAWINGS

Other uses and advantages of the present invention will become apparent to those skilled in the art upon reference to the specification and the drawings, in which:

FIG. **1** is a schematic of the components of a rocket propulsion system;

FIG. **2** is a schematic of a turbopump assembly;

FIG. **3** is a perspective view of a partially assembled gas generator of the present invention;

FIG. **4** is a cross-sectional view of the gas generator of FIG. **3** taken along line IV—IV;

FIG. **5** is a cross-sectional view of the outer housing of the catalyst bed section;

FIGS. **6**, **9** and **10** are front views of pressure baffles used in the catalyst bed assembly of FIG. **3**;

FIG. **7** is a perspective view of the catalyst can of the catalyst bed section;

FIG. **8** is a cross-sectional view of the catalyst can of FIG. **7** taken along line VIII—VIII;

FIG. **11** is a perspective view of the mixer section;

FIGS. **12***a* and **12***b* are cross-sectional views of the components of the mixer section of FIG. **11** taken along line XII—XII;

FIG. **13** is a detailed cross-sectional view of the gas generator of FIG. **4**;

FIG. **14** is a cross-sectional view of a fully assembled gas generator; and

FIG. **15** is a cross-sectional view of the gas generator of FIG. **14** taken along line XV—XV.

DETAILED DESCRIPTION

FIG. **3** is a perspective view of a partially assembled gas generator **200** of the present invention. The gas generator **200** includes several sections. Starting from the upstream end, the gas generator **200** has a catalyst bed section **201**, a mixer section **203** and a nozzle section **205**. Fasteners F can secure the various sections **201**, **203**, **205** of the gas generator **200** together in a conventional manner.

FIG. **4** displays a cross-sectional view of the gas generator **200**. Generally speaking, the catalyst bed section **201** decomposes a highly concentrated (e.g. 98 wt-%) hydrogen peroxide using a catalyst material. The mixer section **203** receives the discharge from the catalyst bed section **201**, namely water vapor, oxygen and heat. The mixer section **203** introduces a selected additional amount of hydrogen peroxide to the discharge. This additional hydrogen peroxide decomposes without exposure to the catalyst material, i.e. due to the temperature of the discharge. The nozzle **205** receives the discharge from the mixer **203** to produce an exhaust stream. The additional hydrogen peroxide injected into the mixer **203** augments the discharge from the catalyst bed section **201**. The amount of additional hydrogen peroxide used is selected to produce a desired mass flow of the exhaust stream. Each section of the gas generator **200** will now be described in greater detail.

As seen in FIG. **4**, the nozzle section **205** resides at the downstream, or outlet, end of the mixer **203**. The nozzle **205** receives the output from the mixer **203**, and accelerates the output from the mixer **203** to form the exhaust stream **119**. As described earlier, the exhaust stream **119** leaving nozzle **205** can drive the turbine **113** in the turbopump **107**. Although shown as a convergent-divergent nozzle, the present invention could use any suitable nozzle arrangement.

The nozzle **205** can have threaded openings **229** for securing to the turbopump **107**. Also, the nozzle **205** could be made from any suitable material, such as a high temperature, non-catalytic aerospace alloy.

The catalyst bed section **201** includes a catalyst can **221** within an outer housing **207**. As seen in FIG. **5**, the outer housing **207** can be a cylindrical pipe having flanges **209**, **211** to secure the catalyst bed section **201** to other components. However, other arrangements are possible. Outer housing **207** could be made from any suitable material, such as a high temperature, non-catalytic aerospace alloy.

The outer housing **207** secures to mixer **203** using fasteners F. As seen in FIG. **5**, flange **211** includes an annular groove **225** within which a C-shaped (in cross-section) annular metal seal **227** resides. The seal **227** keeps the decomposed hydrogen peroxide from escaping from the joint between the catalyst bed section **201** and the mixer **203**. Although described as a metallic C-shaped annular seal, any suitable seal or sealing arrangement could be used.

The outer housing **207** includes a threaded opening **213** in a front face **215**. The opening receives a correspondingly threaded coupling **217** to create an inlet. The coupling **217** secures to a pipe (shown in phantom in FIG. **3**) supplying liquid hydrogen peroxide to the gas generator **200**.

The outer housing **207** includes an open interior **219**. The open interior **219** has a suitable size to receive a catalyst can **221**. As seen in FIG. **5**, the outer housing **207** has an annular shoulder **231** in which a portion of the catalyst can **221** rests. The outer housing **207** also has at least one threaded opening **233** for securing the catalyst can **221** on the shoulder **231** with a suitable fastener (not shown).

A first pressure baffle **223** resides within the open interior **219** of the outer housing **207**. The pressure baffle **223** is preferably made from a high temperature, non-catalytic aerospace alloy. As seen in FIG. **6**, the baffle **223** has an array of openings **239** therethrough. Preferably, the baffle **223** has an outer diameter of approximately 3.96" and the openings **239** have a diameter of approximately 0.063".

However, other sizes, numbers and arrangements of the apertures could be used to achieve a suitable result. A ring **235** placed in an annular groove **237** on the inner surface of the outer housing **207** retains the pressure baffle **223** within the outer housing **207**.

The baffle **223** reduces the pressure of the liquid hydrogen peroxide in the direction of flow. In other words, the pressure of the hydrogen peroxide downstream of the baffle **223** is less than the pressure of the hydrogen peroxide upstream of the baffle.

Although the decomposition of the hydrogen peroxide in the catalyst can **221** produces a temperature of approximately 2192° R, neither the outer housing **207**, the mixer **203** nor the nozzle **205** require any external cooling lines. Rather, the present invention uses bypass hydrogen peroxide (i.e. hydrogen peroxide that does not enter the catalyst can **221**) to travel within the gas generator **200** and to cool the catalyst bed section **201**, the mixer **203** and the nozzle **205**. In the catalyst bed section, a gap **263** exists between the catalyst can **221** and the outer housing **207**. The gap **263** allows some hydrogen peroxide to bypass the interior of the catalyst can **221**. Similar passageways exist in the mixer **203**. These features are described in more detail below.

FIGS. **7** and **8** display the catalyst can **221**. The catalyst can **221** is preferably made from a suitable material, such as a high temperature, non-catalytic aerospace alloy. The catalyst can **221** has a cylindrical outer wall **241** with a flange **243**. The flange **243** includes a plurality of apertures **245**. Preferably, the flange **243** includes 12 equally spaced apertures **245**, each having a diameter of 0.050". Again, the size, number and arrangement of apertures could be adjusted to achieve a desired result. The apertures **245** are in communication with the gap **263** between the catalyst can **221** and the outer housing **207** to allow the bypass hydrogen peroxide to flow towards the mixer section **203**.

The interior of the catalyst can **221** has an annular groove **247** adjacent the upstream end. As seen in FIGS. **4** and **7**, the groove **247** receives a metal ring **249**. The downstream end of the catalyst can **221** includes an annular shoulder **251**. As seen in FIG. **4**, the contents within the catalyst can **221** are retained between the metal ring **249** and the shoulder **251**.

The contents of the catalyst can **221** include a second pressure baffle **253**, a third pressure baffle **255**, and catalyst material **257**. The second pressure baffle **253** is located adjacent the ring **249**. The second pressure baffle **253** is also preferably made from a high temperature, non-catalytic aerospace alloy. As seen in FIG. **9**, the baffle **253** has an array of openings **259** therethrough. Preferably, the baffle **253** has an outer diameter of approximately 2.70 and the openings **259** have a diameter of approximately 0.093". However, other sizes, numbers and arrangements of the apertures **259** could be used to achieve a suitable result.

The ring **249** placed in the annular groove **247** retains the pressure baffle **253** in the catalyst can **221**. The baffle **253** serves to reduce the pressure of the liquid hydrogen peroxide in the direction of flow. In other words, the pressure of the hydrogen peroxide downstream of the baffle **253** is less than the pressure of the hydrogen peroxide upstream of the baffle.

The third pressure baffle **255** rests against the shoulder **251**. The third pressure: baffle **255** is also preferably made from a high temperature, non-catalytic aerospace alloy. As seen in FIG. **10**, the baffle **255** has an array of openings **261** therethrough. Preferably, the baffle **255** has an outer diameter of approximately 2.70" and the openings **261** have a diameter of approximately 0.078". However, other sizes, numbers and arrangements of the apertures **261** could be used to achieve a suitable result.

The catalyst material **257** resides between the second pressure baffle **253** and the, third pressure baffle **255**. Preferably, the catalyst material **257** comprises a bed of silver alloy. However, any catalyst that is useful in decomposing the hydrogen peroxide could be used.

The assembly of the catalyst can **221** will now be described with reference to FIGS. **4**, **5** and **7**. First, the third pressure baffle **255** is seated on the shoulder **251** of the catalyst can **221**. Next, the catalyst material **257** is placed into the catalyst can **221**. Then, the second pressure baffle **253** is placed into the catalyst can. Finally, the ring **249** is seated into the groove **247** of the catalyst can. The catalyst can **221** is now fully assembled.

Before the catalyst can **221** is placed into the outer housing **207**, the first pressure baffle **223** is placed in the upstream end of the open interior **219** of the outer housing **207** and secured with the ring **235**. The catalyst can **221** is then placed into the open interior **219** of the outer housing **207**. The flange **243** of the catalyst can rest on the shoulder **231** of the outer housing **207**. To ensure suitable retention, the catalyst can **221** can be secured to the outer housing **207** using suitable fasteners (not shown). Finally, the coupling **217** is secured to the opening **213** in the front face **215** of the outer housing **207**. The catalyst bed section **201** is now fully assembled.

The catalyst bed section **201** preferably receives a uniform supply of liquid hydrogen peroxide to produce a constant discharge. Specifically, the supply pipe has a diameter of approximately 3" and supplies approximately 4–8 pounds per second of liquid hydrogen peroxide at a temperature of approximately 100° F. The catalyst bed section **201** decomposes the liquid hydrogen peroxide to produce a discharge. The mixer **203** receives this discharge, comprising water vapor and oxygen at approximately 750 psi and 2192° R.

FIG. **11** shows a perspective view of the mixer **203**. The mixer **203** includes an inner housing **281** located within an outer housing **283**. Both the inner housing **281** and the outer housing **283** are made from a suitable material, such as a high temperature, non-catalytic aerospace alloy.

FIG. **12***a* displays a cross-sectional view of the inner housing **281**. The inner housing **281** has a cylindrical body **285** with a flange **287** at one end. The flange **287** includes a plurality of apertures **289**. The apertures **289** preferably align with the apertures **245** on the flange **243** of the catalyst can **221** to form a passageway for the bypass hydrogen peroxide. To align with the apertures **245**, the flange **287** should have 12 equally spaced apertures **289**, each having a diameter of 0.050". Again, the size, number and arrangement of the apertures **289** could be adjusted to achieve the desired cooling of the mixer **203** by the bypass hydrogen peroxide. This feature will be explained in more detail below.

As seen in FIG. **12***a*, a plurality of fins **325** extend from the outer diameter of the inner housing **281**. The fins **325** abut the inner diameter of the outer housing **283** to align the inner housing **281** relative to the outer housing **283**. This creates a gap **303** between the remainder of the inner housing **281** and the outer housing **283**. The gap **303** allows the bypass hydrogen peroxide to flow between the inner housing **281** and the outer housing **283** of the mixer **203** for cooling. Since the fins **325** are circumferentially spaced from each other along the outer diameter of the inner housing **281**, the bypass hydrogen peroxide can pass between adjacent fins **325** to exit towards the nozzle **205**.

FIG. **12***b* displays a cross-sectional view of the outer housing **283**. The outer housing **283** has a cylindrical body **291** with a flange **293** at one end and a flange **295** at the opposite end. The flanges **293**, **295** include openings **297** for the fasteners F used to secure the sections **201**, **203**, **205** together. The one end of the outer housing **283** has a recess **298** that receives the flange **287** of the inner housing **281**. The other end of the outer housing **283** includes a groove **299** that receives a seal **301** positioned between the mixer **203** and the nozzle **205**. As described earlier, the seal **301** could be a C-shaped annular metal seal, or any other suitable seal.

FIG. **13** shows the inner housing **281** positioned within the outer housing **283** (and with the sections **201**, **203**, **205** secured together). The figure also clearly shows a path **305** (shown in dashed line) taken by the liquid bypass hydrogen peroxide. Specifically, the path **305** of the bypass hydrogen peroxide begins in the gap **263** between the catalyst can **221** and the outer housing **207** of the catalyst bed section **201**. The bypass hydrogen peroxide then travels through the apertures **245** in the flange **243** of the catalyst can **221** and into the apertures **289** in the flange **287** of the inner housing **281**. The bypass hydrogen peroxide then enters the gap **303** between the inner housing **281** and the outer housing **283** and past the fins **325** on the inner housing **281** to exit the mixer **203**.

Since the nozzle **205** is likewise exposed to the heat created by the decomposition of the hydrogen peroxide in the catalyst can **221**, heat build-up in the nozzle **205** must also be controlled. Similar to the annular gap **263** in the catalyst bed section and the annular gap **303** in the mixer **203**, a gap **307** exists between the nozzle **205** and the catalyst can **221** downstream of the catalyst can **221**. The bypass hydrogen peroxide travels along this gap **307** and into the interior section of the nozzle **205** where it merges with the decomposed hydrogen peroxide. Preferably, the liquid bypass hydrogen peroxide provides film cooling along the inner diameter of the nozzle **205**.

Preferably, approximately 95 percent of the hydrogen peroxide introduced through coupling **217** and into the catalyst bed **201** enters the catalyst can **221**. This portion of the hydrogen peroxide undergoes decomposition by the catalyst material **257**.

The remaining 5 percent of the hydrogen peroxide bypasses around the catalyst can **221** and does not contact the catalyst material **257**. As discussed above, this remainder of the liquid hydrogen peroxide is used to cool the gas generator **200**. Although a 5 percent bypass percentage is discussed, any suitable percentage could be used. The amount of bypass could be controlled by the size of the annular gaps **263**, **265**, the gap **307**, or by the number and the size of the apertures **245**, **289** or fins **325**.

The main purpose of the mixer **203** is to augment the constant discharge from the catalyst bed section **201** with a selected amount of additional mass flow. This additional amount increases the exhaust stream exiting the nozzle **205**. Since the gas generator **200** is preferably part of a turbopump assembly, the turbine converts the increased mass flow of the exhaust stream into additional torque to drive the impeller. The increased torque on the impeller increases the supply of either the oxidizer or the fuel to the rocket engine. The increased supply of fuel or oxidizer to the rocket engine increases thrust. In other words, the mixer section **203** can be used to throttle the rocket engine.

To achieve this result, FIGS. **4** and **11** show the mixer **203** with openings **309** through the inner housing **281** and the outer housing **283**. Opposite each opening **309**, the inner housing **281** includes a recess **311**. Each opening **309** and corresponding recess **311** receives a spray bar assembly **313**.

The spray bar assemblies **313** inject liquid hydrogen peroxide into the discharge within the inner housing **281** of the mixer **203**. Due to the temperature of the discharge (2192° R), the injected liquid hydrogen peroxide will decompose merely upon exposure to the discharge. In other words, the injected liquid hydrogen peroxide decomposes even without exposure to the catalyst material **257** in the catalyst bed section **201**.

Although FIG. **11** displays that the mixer **203** could receive three spray bar assemblies **313**, any number is possible. In addition, although FIG. **15** displays the spray bar assemblies centrally located within the mixer, the position of the spray bar assemblies **313** could be adjusted to achieved a desired result.

The spray bar assembly **313** includes a body **315** secured to the mixer **203** and a coupling **317** threaded into the body **315**. The coupling **317** receives a pipe (shown in phantom in FIG. **14**) supplying hydrogen peroxide to the mixer **203**. The spray bar assembly **313** also includes a tube **319**. Preferably, the tube **319** is made from a suitable high temperature, non-catalytic aerospace alloy and has a diameter of approximately 0.500", although any suitable size could be used.

The tube **319** has one end **321** located within the body **315**. The tube **319** has ports.**323** arrayed along the other end located within mixer **203**. Preferably, the ports **323** have a diameter of approximately 0.040. A pump (not shown) can be used to inject the liquid hydrogen peroxide into the mixer **203**. The liquid hydrogen peroxide travels from the pipe, into the body **315**, down the tube **319** and through the ports **323** into the mixer **203**. Although the spray bar assembly **313** has been described as using a pump, any other mechanism (e.g. a venturi tube) could be used to inject the hydrogen peroxide into the mixer **203**.

Preferably, the amount of liquid hydrogen peroxide supplied to the spray bar assemblies **313** is selected to achieve a desired mass flow of the exhaust stream exiting the nozzle **205**. For example, each spray bar assembly could inject approximately 4 pounds per second of hydrogen peroxide at approximately 750 psi into the mixer **203**. The hydrogen peroxide supplied to the mixer **203** could be from the same source as the hydrogen peroxide supplied to the catalyst bed section **201**. Other arrangements, such as discrete sources, could be used.

FIG. **11** shows various other openings in the mixer **203** that receive conventional thermocouples (not shown) to sense the temperature within the gas generator **200**. These conventional features will not be discussed in further detail.

The present invention has been described in connection with the preferred embodiments of the various figures. It is to be understood that other similar embodiments may be used or modifications and additions may be made to the described embodiment for performing the same function of the present invention without deviating therefrom. Therefore, the present invention should not be limited to any single embodiment, but rather construed in breadth and scope in accordance with the recitation of the appended claims.

What is claimed is:

1. A rocket propulsion system, comprising:

a rocket engine; and

a turbopump supplying fuel or oxidizer to said rocket engine;

wherein said turbopump is supplying an adjustable flow of said fuel or

oxidizer to throttle said rocket engine;

said turbopump including a gas generator producing an adjustable exhaust stream that drives said turbopump;

said gas generator decomposing a material to produce said adjustable exhaust stream;

wherein said gas generator uses a catalyst to decompose a portion of said material and thermal decomposition for another portion of said material.

2. The rocket propulsion system of claim **1**, wherein said material comprises hydrogen peroxide.

3. The rocket propulsion system of claim **2**, wherein said hydrogen peroxide comprises highly concentrated hydrogen peroxide.

4. A rocket propulsion system having a turbopump assembly that comprises:

catalyst bed for decomposing a material to produce a discharge;

a mixer section downstream of said catalyst bed for introducing an additional amount of said material to said discharge to produce an exhaust stream having a mass flow;

a nozzle downstream of said mixer section;

a turbine downstream of said nozzle; and

a pump driven by said turbine;

wherein said additional amount of said material is selected to produce a desired amount of said mass flow.

5. The rocket propulsion system of claim **4**, wherein said material is hydrogen peroxide.

6. The rocket propulsion system of claim **5**, wherein said hydrogen peroxide comprises highly concentrated hydrogen peroxide.

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