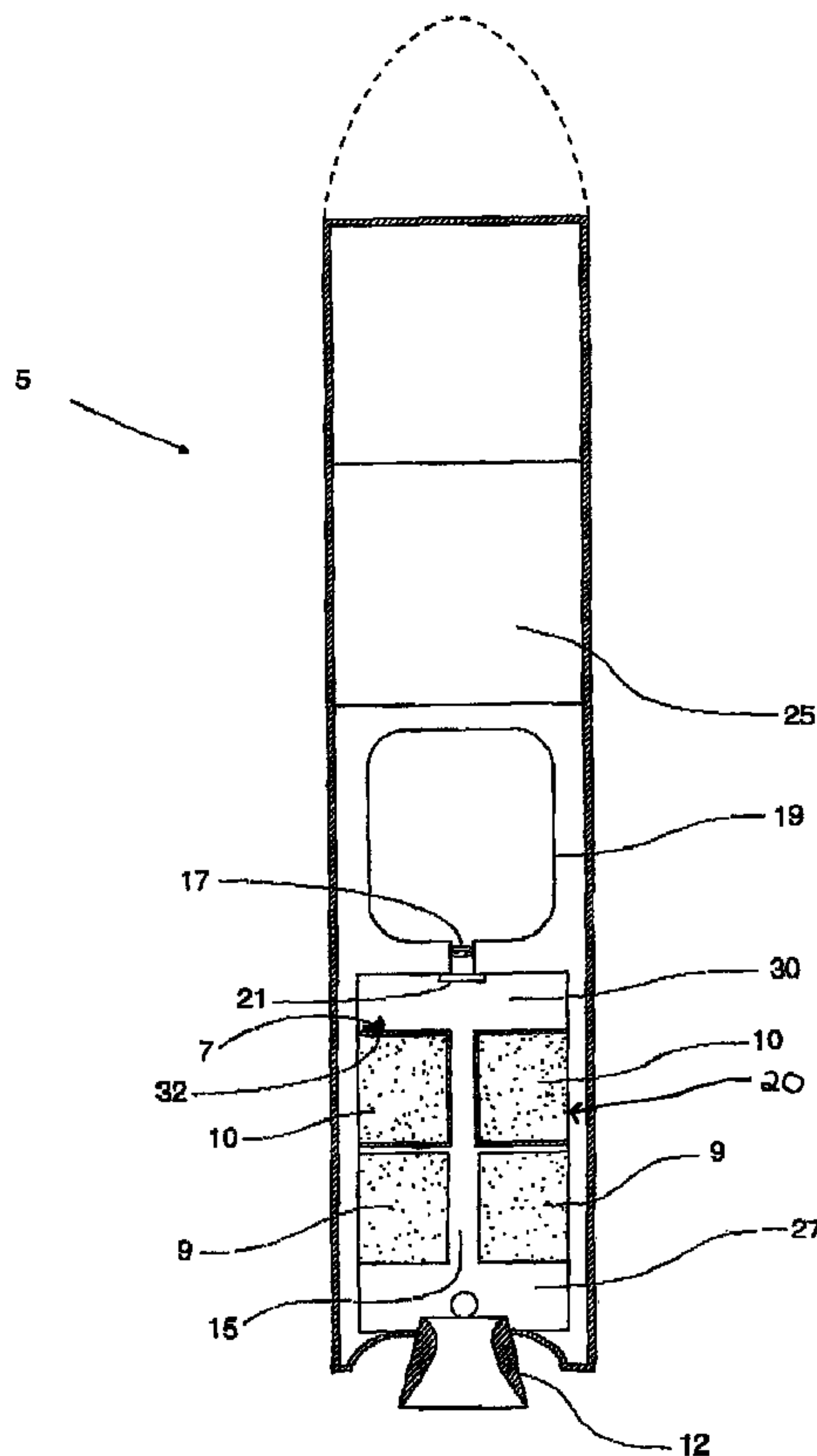




(86) Date de dépôt PCT/PCT Filing Date: 2006/12/07
(87) Date publication PCT/PCT Publication Date: 2007/06/14
(45) Date de délivrance/Issue Date: 2012/09/25
(85) Entrée phase nationale/National Entry: 2008/06/06
(86) N° demande PCT/PCT Application No.: AU 2006/001861
(87) N° publication PCT/PCT Publication No.: 2007/065220
(30) Priorité/Priority: 2005/12/08 (AU2005906887)

(51) Cl.Int./Int.Cl. *F02K 9/72* (2006.01),
F02K 9/08 (2006.01), *F02K 9/26* (2006.01),
F02K 9/84 (2006.01)
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(54) Titre : SYSTEME FUSEE HYBRIDE
(54) Title: HYBRID ROCKET SYSTEM



(57) Abrégé/Abstract:

The present invention describes a hybrid rocket motor that includes a first solid reactant and at least one thrust nozzle and at least one moveable combustion control member within the hybrid rocket motor that restricts the contact of a first fluid re-actant to the solid reactant in the combustion chamber. In this way it is then possible to regulate the exposure of the solid reactant to the fluid reactant and thus control thrust.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
14 June 2007 (14.06.2007)

PCT

(10) International Publication Number
WO 2007/065220 A1

(51) International Patent Classification:

F02K 9/72 (2006.01) *F02K 9/26* (2006.01)
F02K 9/08 (2006.01) *F02K 9/84* (2006.01)

(21) International Application Number:

PCT/AU2006/001861

(22) International Filing Date:

7 December 2006 (07.12.2006)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2005906887 8 December 2005 (08.12.2005) AU

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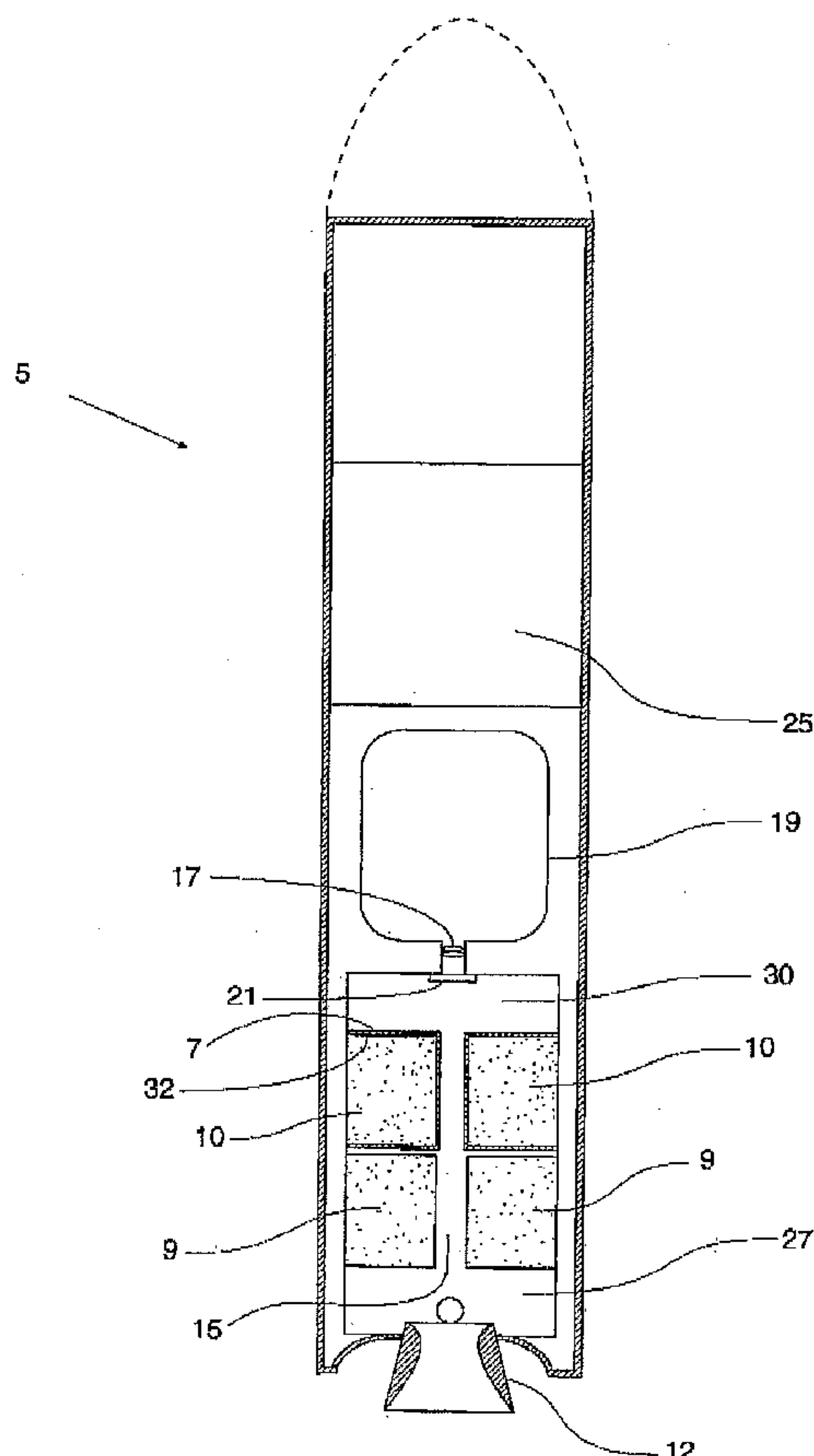
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: HYBRID ROCKET SYSTEM

(57) Abstract: The present invention describes a hybrid rocket motor that includes a first solid reactant and at least one thrust nozzle and at least one moveable combustion control member within the hybrid rocket motor that restricts the contact of a first fluid reactant to the solid reactant in the combustion chamber. In this way it is then possible to regulate the exposure of the solid reactant to the fluid reactant and thus control thrust.



WO 2007/065220 A1

WO 2007/065220 A1



Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

HYBRID ROCKET SYSTEM

FIELD OF THE INVENTION

The present invention relates to the field of rocket motors and in particular to a thrust modulated hybrid rocket system with hovering and manoeuvring
5 capability.

DESCRIPTION OF THE PRIOR ART

Existing hovering rocket propulsion systems utilise solid rocket technology and a thrust vector control unit to dump excess thrust in order to maintain the required altitude with lateral movement. This invention utilises a hybrid rocket
10 with thrust modulation capability that enables it to conserve thrust when it is not required and hence the potential for large performance gains in terms of increased range and flight time.

Hybrid rockets in which one component of the propellant is stored as a liquid while the other is stored as a solid have the combined performance benefits of
15 liquid rockets and the simplicity of solid rockets. It has the advantages of thrust controllability, low cost and increased safety (because the fuel and oxidiser are stored separately). Hybrid rocket boosters and motors with a pre-combustion chamber for flame stabilisation are described in the US patents 5,715,675 and US6,679,049 respectively. In general, hybrid rocket motors use a liquid or gel
20 oxidiser (such as hydrogen peroxide, nitrous oxide, oxygen) to burn a solid fuel (such as plastics, rubber, paraffin wax), although a liquid fuel and solid oxidiser are sometimes used. The configuration of the solid fuel grain is generally a tubular cylinder, defining the port of the combustion chamber.

In order to improve the mass flow rate to increase thrust, multi-ports fuel grain
25 configurations (such as quadrilateral, "wagon-wheel" designs) are sometimes used to increase the exposed fuel surface area. Such complex solid fuel grain geometries impose high fabrication costs and usually require structural web support to prevent large slivers of the solid fuel from breaking and blocking the nozzle.

OBJECT OF THE INVENTION

For the hovering and manoeuvring rocket application, the motor design is optimised to maintain a specified thrust to vehicle weight ratio for the required burn time within the boundaries of size and weight constraints. To achieve a
5 long burn time within the size and weight constraints and limitations of hybrid rocket design, this invention uses a hybrid rocket with one or more separate fuel grains with or without an extensible and moveable port sleeve and fuel grain separation mechanism.

The separate grains and extensible and moveable port sleeve prevent the
10 burning hot pressurised gas from reaching the other grain(s) and causing their inadvertent ignition. As well as extending the burn time for a fixed motor diameter, the separate fuel grains with extensible and moveable port sleeve concept provides an additional means of thrust management, to supply thrust on demand during flight.

15 It is an object of the present invention to provide a hybrid rocket with an adaptable thrust control system to maintain an altitude range with lateral movement.

Another objective is to provide a hybrid rocket with a maximised burn time and range for a fixed vehicle mass.

20 Another objective is to provide an adaptable thrust hovering and manoeuvring rocket system with autonomous (pre-programmed) or real-time flight control capability.

Another objective is to provide a means of adaptable thrust control for hybrid rockets.

25 Yet a further object of the invention is to provide a means of adaptable thrust control for hybrid rockets by automated control of the oxidiser flow rate from the injection system.

It is an object of the present invention to overcome, or at least substantially ameliorate, the disadvantages and shortcomings of the prior art.

Other objects and advantages of the present invention will become apparent from the following description, taking in connection with the accompanying
5 drawings, wherein, by way of illustration and example, an embodiment of the present invention is disclosed.

DEFINITIONS

The term "moveable combustion control member" as used herein refers to any device or system affecting the combustion flow path and rate of burning, such
10 as regulating the exposure of the solid reactant to the fluid reactant or regulating the flow to the combustion chamber to achieve a correct fuel-oxidiser ratio that can readily be burned.

SUMMARY OF THE INVENTION

For the hovering and manoeuvring rocket application, the motor design is
15 optimised to maintain a specified thrust to vehicle weight ratio for the required burn time within the boundaries of size and weight constraints. To achieve a long burn time within the size and weight constraints and limitations of hybrid rocket design, this invention uses a hybrid rocket with one or more separate fuel grains with an extensible and moveable port sleeve and fuel grain separation
20 mechanism.

The separate grains and extensible and moveable port sleeve prevent the burning hot pressurised gas from reaching the other grain(s) and causing their inadvertent ignition. As well as extending the burn time for a fixed motor diameter, the separate fuel grains with extensible and moveable port sleeve
25 concept provides an additional means of thrust management, to supply thrust on demand during flight.

According to the present invention, although this should not be seen as limiting the invention in any way, there is provided a hybrid rocket motor including a container having a first fluid reactant in the form of a gas, liquid or gel, a

combustion chamber containing at least a first and second solid reactant therein and having at least one thrust nozzle at one end thereof, wherein the second solid reactant is separated from the first solid reactant by at least one separation member, a conduit in fluid communication between the container
5 containing the first fluid reactant and the combustion chamber, and at least one moveable combustion control member within the hybrid rocket motor that restricts the contact of the first fluid reactant to the solid reactants in the combustion chamber, the at least one separation member being part of the at least one moveable combustion member. In this way it is then possible to
10 regulate the exposure of the solid reactants to the fluid reactant. As would be appreciated by a person skilled in the art, ignition is effected by an igniter (may include an ignition fluid source) or using a hypergolic (self igniting) fuel-oxidiser combination.

In preference, the at least two solid reactants have an aperture there through
15 that defines a port and the moveable combustion control member is adapted to be located substantially in the port in a first position to expose a first solid reactant to the first fluid reactant, upon release of the fluid reactant into the combustion chamber .

In preference, the moveable combustion control member can be removed from
20 the port to expose the second solid reactant to the first fluid reactant, upon release of the fluid reactant into the combustion chamber.

In preference, the moveable combustion control member is a port sleeve.

In preference the moveable combustion control member is an elongate member that can be moved in and out of the port to regulate exposure of the solid
25 reactants to the first fluid reactant.

In preference, the conduit in fluid communication between the container and the combustion chamber has a moveable combustion control member for controlling the delivery of the first fluid reactant to the combustion chamber.

As would be appreciated by a person skilled in the art, a plurality of solid reactants could be included so that the length of the burn and thrust level could be customised as required.

In preference, the combustion chamber is defined by the solid reactant.

5 In preference, the at least one thrust nozzle is movable.

In preference, the first fluid reactant is at least one of a gas, liquid or gel.

In preference, the flow of the first fluid reactant is controlled by regulation of the combustion control member and at least one injector orifice providing fluid reactant into the combustion chamber.

10 In preference, the at least one injector orifice is of an adjustable size.

In preference, the regulation of the combustion control member is characterised in the combustion control member includes an injector face and a selector plate.

In preference, the injector face has at least two apertures there through.

15 In preference, the at least two apertures of the injector face are of different diameters with respect to each other.

In preference, the at least two apertures on the injector face are spaced evenly.

In preference, the selector plate includes at least one aperture there through.

In preference, the selector plate is moveable relative to the injector face so that a desired aperture size may be selected.

20 In preference, the selector plate can pivot about a central axis of rotation.

In preference, the selector plate has a gear about its periphery.

In preference, the selector plate is operated remotely.

In preference, at least one aperture on the selector plate is aligned with an uppermost portion of an injector face so as to allow fluid connection there through.

5 In preference, the at least one thrust nozzle is moveable and automated to control the thrust direction.

For some performance requirements, the solid reactant is a multi-port solid reactant.

10 A further form of the invention resides in a method of propelling a rocket system including providing a hybrid rocket motor including a container having a first fluid reactant, a combustion chamber containing at least a first solid reactant and a second solid reactant therein and having at least one thrust nozzle at one end thereof, wherein the second solid reactant is separated from the first solid reactant by at least one separation member, a conduit in fluid communication between the container and the combustion chamber, and at least one moveable
15 combustion control member located within the hybrid rocket motor that restricts the contact of the first fluid reactant to the solid reactants in the combustion chamber, the at least one separation member being part of the at least one moveable combustion member, injecting the first fluid reactant into the combustion chamber to effect combustion of the solid fuel.

20 In preference, the moveable combustion control member then being moved to affect a control over the exposure of the first and second solid reactants to the first fluid reactant and thus controlling the degree of combustion.

BRIEF DESCRIPTION OF THE DRAWINGS

25 By way of example, an employment of the invention is described more fully hereinafter with reference to the accompanying drawings, in which:

Figure 1 is a cut away diagram of the hovering and manoeuvring hybrid rocket system with flight and navigation control and housing for the payload.

Figure 2 is a diagram of one form of two components for an automated combustion control member regulating the flow of the first fluid reactant from the container or storage tank into the combustion chamber.

Figure 3 is a diagram of one form of the moveable combustion control member
5 controlling the exposure of the solid reactants to the fluid reactant.

Figure 4 is a cut away view of the combustion chamber of the hybrid rocket of Figure 1 showing the combustion control member of Figure 3 in a rocket motor directing flow of the first fluid reactant to a first solid reactant.

Figure 5 is the cut away view as Figure 4 with the combustion control member
10 permitting flow of the first fluid reactant to a second solid reactant.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 1, the invention relates to a hybrid rocket 5 including a container or storage tank 19 for containing a first fluid reactant under pressure. The first fluid reactant acts as an oxidiser and is typically in the form of a gas,
15 liquid or gel (preferably nitrous oxide, liquid oxygen or hydrogen peroxide). The hybrid rocket 5 further includes a combustion chamber 20 which in the embodiment illustrated in Figure 1 has an aft combustion chamber 27 and forward combustion chamber 30. At least two solid reactants are provided in the combustion chamber 20. In the embodiment illustrated there is a first solid
20 reactant 9 being a solid fuel grain (preferably a polymeric plastic or rubber, eg. polybutadiene, nylon, polyethylene) and a second solid reactant 10 also being a solid fuel grain (preferably a polymeric plastic or rubber, eg. polybutadiene, nylon, polyethylene). An injection system 21 is provided through which the fluid reactant is injected from storage tank 19 into the combustion chamber 20. The
25 hybrid rocket also includes a moveable nozzle(s) 12 and an igniter, electronic or pyrotechnic, and may include an ignition fluid source (not shown). The fluid reactant mass flow rate is controlled by an (automated) combustion control member 17 between the storage tank 19 and injection system 21 and (automated) opening and closing of the injector orifice(s).

The main components of the hybrid rocket 5 are the moveable combustion control member 7 being the extensible and moveable port sleeve and separation mechanism in the fuel grain(s), which in the embodiment illustrated are the first and second solid reactants 9,10, the (automated) combustion control member 17 having moveable selector plates as described ante and one or more moveable nozzles 12. By moving the moveable combustion control member(s) 7, which is located substantially in the aperture 15 defining a port formed through the first and second solid reactants 9,10 or the (automated) combustion control member 17, which is located in the proximity of the injector 21, adaptive thrust control is achieved. Typically the shape of the solid reactants 9 and 10 is a cylinder, with an aperture 15 there through, the moveable combustion control member 7 would then be located substantially inside the aperture 15 defined by the solid reactant 10.

As can be seen in Figure 1, the first solid reactants 9 are exposed and will react with the injected fluid reactant (oxidiser) from the tank 19. When required the moveable combustion control member(s) 7 can be moved to expose the second solid reactant 10 to the injected fluid reactant (oxidiser). The solid reactants 9 and 10 may be the same or different according to requirements.

As would be appreciated by those skilled in the art there may be different shapes of movable combustion control members 7 according to the shape of the solid reactants 9,10, which may have more than one aperture.

As noted supra, the thrust management system also includes an automated combustion control member 17 between the storage tank 19 and injection system 21 and adjustable injector orifice size mechanism.

The automated combustion control member 17 can be of the type shown in Figure 2, in which there is a selector plate 60 having an aperture 62. Adjacent to the selector plate 60 is an injector face 63 having apertures 64, 65 and 66. The selector plate 60 and injector face 63 both fit within an injector housing assembly (not shown).

The selector plate 60 has a gear 68 located about its periphery such that another gear can engage gear 68 to turn the selector plate 60 about a pivot 71. In this manner the aperture 62 of the selector plate 60 can then align with any one of the apertures 64, 65 and 66 of the injector face 63, which is in a fixed position, to provide the desired mass flow rate of fluid reactant (oxidizer) from the storage tank 19 into the empty space 30, the forward combustion chamber, as determined by the flight and navigation control unit 25.

The number and size of the apertures on both the selector plate 60 and the injector face 63 can be varied according to specific requirements.

As one skilled in the art could appreciate, the way in which the automated combustion control member 17 operates could be in another way that falls within the scope of the invention, such as be interchanging the injector face and selector plate, such that the selector plate was fixed and the injector plate was capable of moving.

Additionally, the flow of the fluid reactant through the injector may be controlled by another combustion control member mechanism known to those skilled in this particular art.

The moveable combustion control member 7 may be in the form of a movable tube 70, as shown in Figure 3, which comprises a number of moveable segments 72, 74 and 76 that can nest one within the other that fit within the port 15 formed through the solid reactants 9,10. Such a tube 70 is formed to nest within the shape of the aperture or port 15 such that it could be moved along the length of the port 15 so as to regulate the rate of contact or exposure of the first fluid reactant with the solid reactants 9,10, as the second solid reactant 10 is physically separated from the first solid reactant 9.

By controlling the effective length of the tube 70, the moveable combustion control member 7 can then be controlled so as to regulate the exposure of the second solid reactant 10 to the injected oxidizer. The moveable combustion control member 7 has a partitioning portion 78 that prohibits the fluid reactant (oxidizer) in the empty space 30 after injection from the storage tank 19 from

reacting with the second solid reactant 10. The fluid reactant (oxidizer) travels down through the passageway 80 so it can react with the first solid reactant 9.

In Figure 4 the moveable segments 72, 74, 76 of tube 70 are shown extended so that the fluid reactant only contacts the first solid reactant 9.

- 5 By reducing the overall length of the tube 70 of the moveable combustion control member 7, as shown in Figure 5, where the moveable segments 72, 74, 76 of tube 70 are shown nested, the injected fluid reactant (oxidizer) will be able to react with both the first 9 and second 10 solid reactants, thus providing additional thrust.
- 10 A flight and navigation control unit 25 is also provided for. It consists of the flight computer, sensors (eg., inertial motion unit (IMU), altimeter, gyroscope, accelerometer) and radar receiver/transmitter. The flight control unit 25 can be pre-programmed or real time controlled via the radio frequency (RF) receiver/transmitter. The processor monitors the data from the sensors and,
- 15 based upon this data, controls the fluid reactant (oxidiser) mass flow rate via combustion control member 17 controlling the fluid reactant (oxidiser) flow from the tank 19 and/or size of the injector orifice, position of the extensible and moveable combustion control member 7 and nozzle 12 flow direction to achieve the desired altitude range and lateral movement.
- 20 According to the invention, when the motor design has more than one solid reactant 9,10, an moveable combustion control member 7 shown in Figure 3-5 as a port sleeve and grain separation mechanism are provided to prevent the burning hot pressurised gas from reaching the other grain(s) and causing their inadvertent ignition. The extensible port sleeve and separation mechanism 7
- 25 are made from a material (and may include thermal barrier coatings) that can withstand the high temperature and pressures from the hot combustion gases.

According to the invention, the empty space 27, downstream of the port before the nozzle(s) 12, and/or the empty space 30, between the injector 21 and the top 32 of the second solid reactant 10, houses the mounting for the moveable

30 combustion control member 17. The space 27 (aft combustion chamber) also

serves to make the combustion process more efficient by allowing any unburnt vaporised fuel to mix with the oxidiser and burn before exiting the end of the nozzle 12. The empty space 30, the forward combustion chamber, between the injector 21 and top 32 of the second solid reactant 10 also serves as housing for mounting for the injection system, igniter, sensors, actuators, etc. The forward combustion chamber also serves to increase the combustion efficiency. The igniter can also be placed in the aft combustion chamber 27 but the preferred position is in the forward combustion chamber 30.

Instead of using a separate storage tank 19, the rocket motor tank can be within the motor casing (monotube) and is filled with the fluid reactant (oxidiser) from the main oxidiser tank just before launch. The first and second solid reactants' 9, 10 geometry may have single or multi-ports, depending on the performance requirements and operating conditions.

According to one embodiment of the invention, the size of the orifice(s) of the injection system is adjustable (automated) to control the fluid reactant (oxidiser) flow rate. By varying the size of the injector orifice(s), it is possible to throttle the oxidiser flow over a wider range without large reductions in injector pressure drop. The injection system design (eg. central orifice injector, swirl injector, showerhead injector) is selected to suit the fuel grain configuration.

According to the invention, a moveable nozzle 12 (including gimbal or hinge, flexible bearing type, flexible sealed rotary joint) is the preferred means of changing the direction of the flight path. However, flexible joint multiple nozzles or other thrust vector control methods could be used to control the flight path.

Flight control algorithms, derived from propulsion system performance, trajectory and kinematics analyses, are used for pre-programmed and/or real-time control of the flight altitude and direction over time. The flight computer (microprocessor) monitors the data from the sensors (such as IMU, altimeter, gyroscope, magnetometer, accelerometer) and, based upon this data, uses the flight control algorithms to achieve the desired control of the fluid reactant (oxidiser or liquid fuel if used) mass flow rate (via a combustion control member from the storage tank and/or size of the injector orifice), position of the

extensible and moveable port sleeve and grain separation mechanism, and nozzle flow direction. When possible, commercial-off-the-shelf (COTS) software can be used for the navigation and guidance.

As can now be appreciated, the features herein described, either alone or in
5 combination are capable of providing a great deal of control over the rate of combustion between the oxidiser or liquid fuel (first reactant) and the solid reactants 9 and 10, which enables the provision of varying degrees of thrust to the rocket that have up until now not been achievable.

While the above description refers to a hybrid rocket motor, the present
10 invention is also applicable for multi-pulsed solid rocket motors in that the moveable / extensible port sleeve and grain separation mechanism can be implemented in multi-pulsed solid rocket motors to provide thrust on demand.

The separation of a first solid propellant from a second solid propellant, by a grain separation mechanism allows for combustion of the first solid propellant
15 without the combustion gasses from the first solid propellant initiating combustion of the second solid propellant.

When desired, the movable combustion control member that extends through the ports in the at least second solid propellant is moved to expose the second solid propellant; the combustion gasses from the combustion of the first solid
20 propellant, or an igniter, then initiate the combustion of the second solid propellant. In this way the movable combustion control member can be moved to effect combustion of the solid propellants and thus supply thrust on demand.

Although the invention has been herein shown and described in what is conceived to be the most practical and preferred embodiment, it is recognized
25 that various modifications may be made in details of design and construction. It is understood by a person skilled in the art that many of the details provided above are by way of example only and can be varied or deleted without departing from the scope of the invention as set out in the following claims.

CLAIMS

1. A hybrid rocket motor including a container having a fluid reactant selected from a gas, liquid or gel reactant, a combustion chamber containing a first solid reactant therein and having at least one thrust
5 nozzle at one end of the combustion chamber, a conduit in fluid communication between the container containing the fluid reactant and the combustion chamber having a valve as an automated combustion control member for controlling delivery of the fluid reactant, and at least one moveable combustion control member in the combustion chamber,
10 characterized in that the combustion chamber further contains at least a second solid reactant separated from the first solid reactant by at least one separation member which is part of the moveable combustion control member.
2. The hybrid rocket motor as in claim 1, wherein the first solid reactant has
15 an aperture there through that defines a port and the moveable combustion control member is located in the port in a first position.
3. The hybrid rocket motor as in claim 2, wherein the moveable combustion control member can be removed from the port to expose the second solid reactant to the fluid reactant.
- 20 4. The hybrid rocket motor as in claim 3, wherein the moveable combustion control member is a port sleeve.
5. The hybrid rocket motor as in claim 4, wherein the moveable combustion control member comprises an elongate member that can be moved in and out of the port to regulate exposure of the first and second solid
25 reactants to the fluid reactant.
6. The hybrid rocket motor as in any one of claims 1-5, wherein the at least one thrust nozzle is movable.

7. The hybrid rocket motor as in claim 1, wherein the flow of the fluid reactant is controlled by the moveable combustion control member and at least one injector orifice providing fluid reactant into the combustion chamber.
- 5 8. The hybrid rocket motor as in claim 7, wherein, the at least one injector orifice is of an adjustable size.
9. The hybrid rocket motor as in claim 8, wherein the automated combustion control member is characterised in that it includes an injector face and a selector plate.
- 10 10. The hybrid rocket motor as in claim 9, wherein the injector face has at least two apertures there through.
11. A method of propelling a rocket system including providing a hybrid rocket motor according to claim 1, the method comprising injecting the fluid reactant into the combustion chamber to effect combustion of the first solid reactant and characterized in that the moveable combustion control member is then moved to effect a control over the exposure of the second solid reactant to the fluid reactant and thus controlling the degree of combustion.
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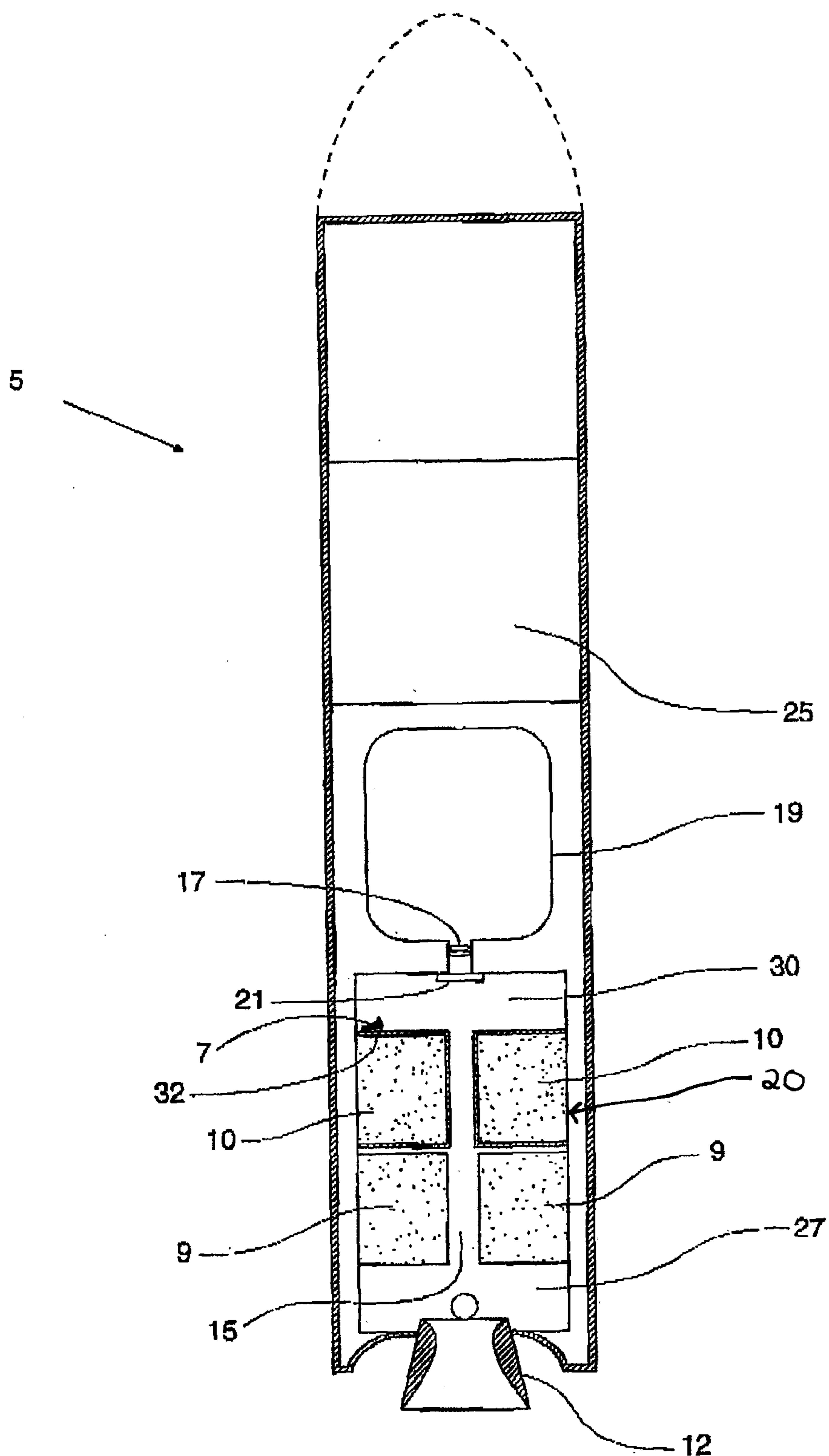


Fig 1

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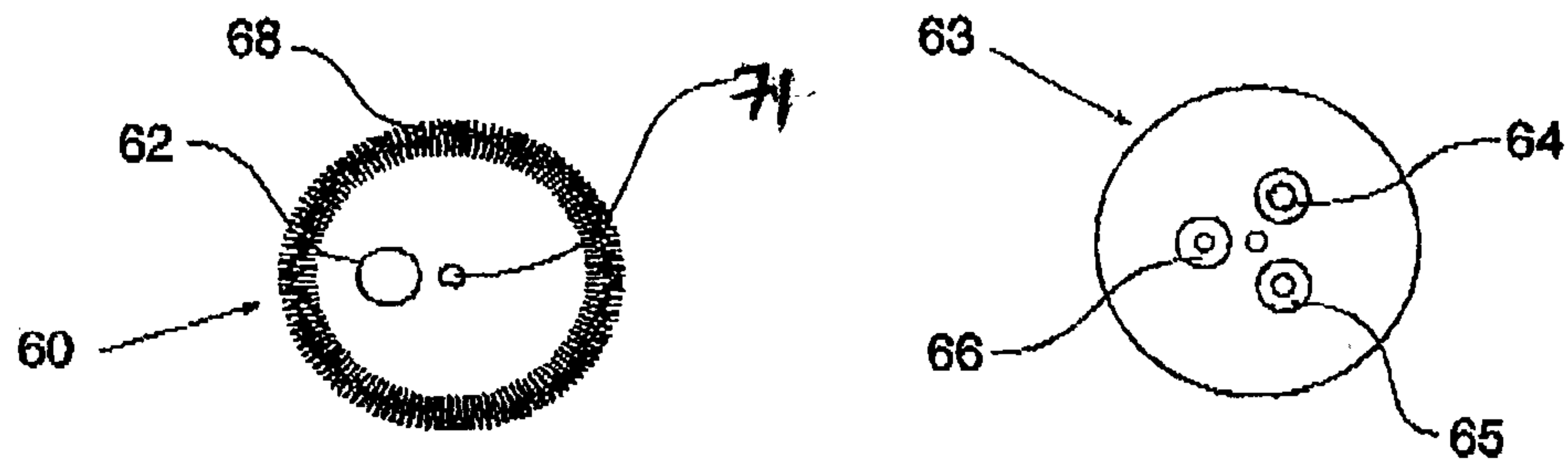


Fig 2

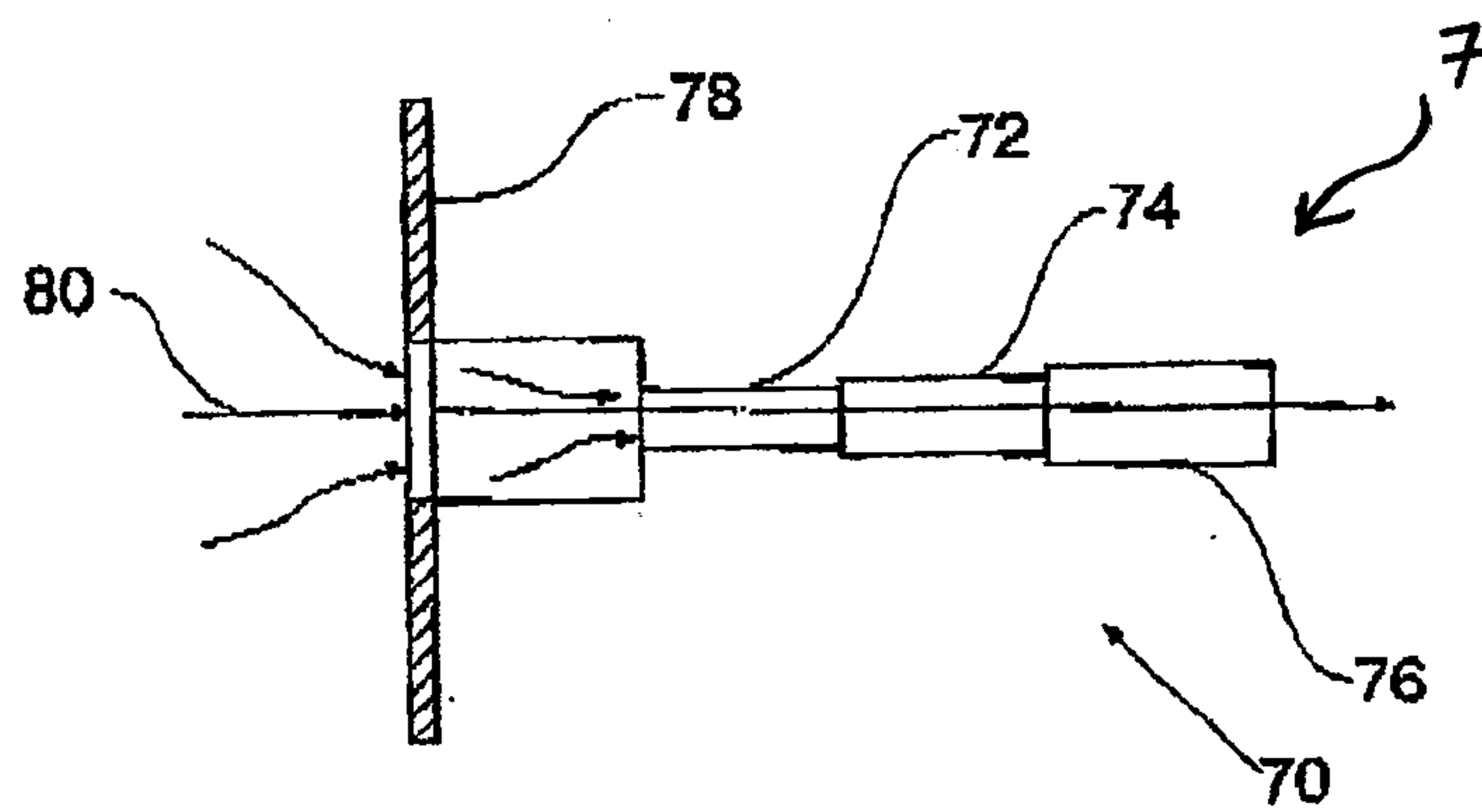
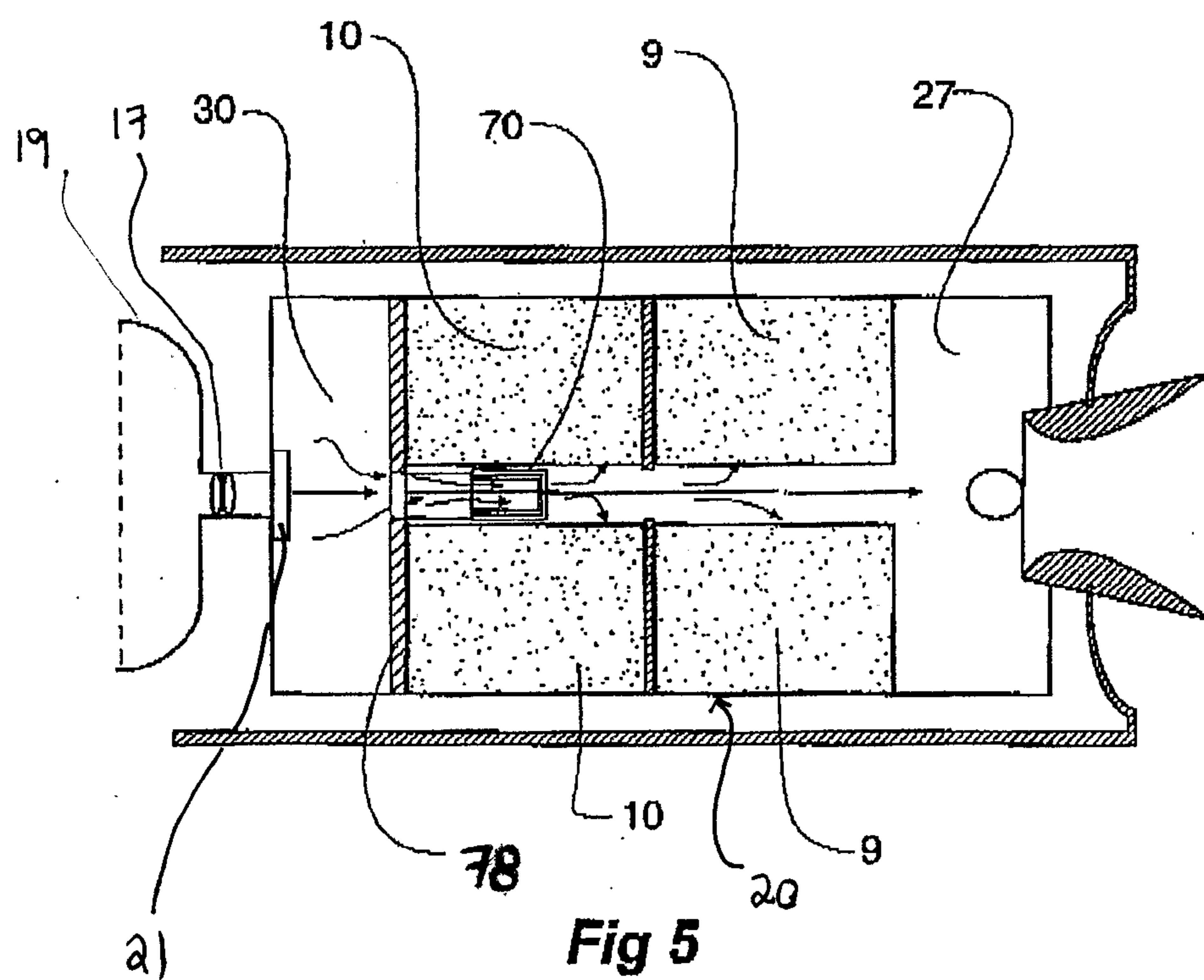
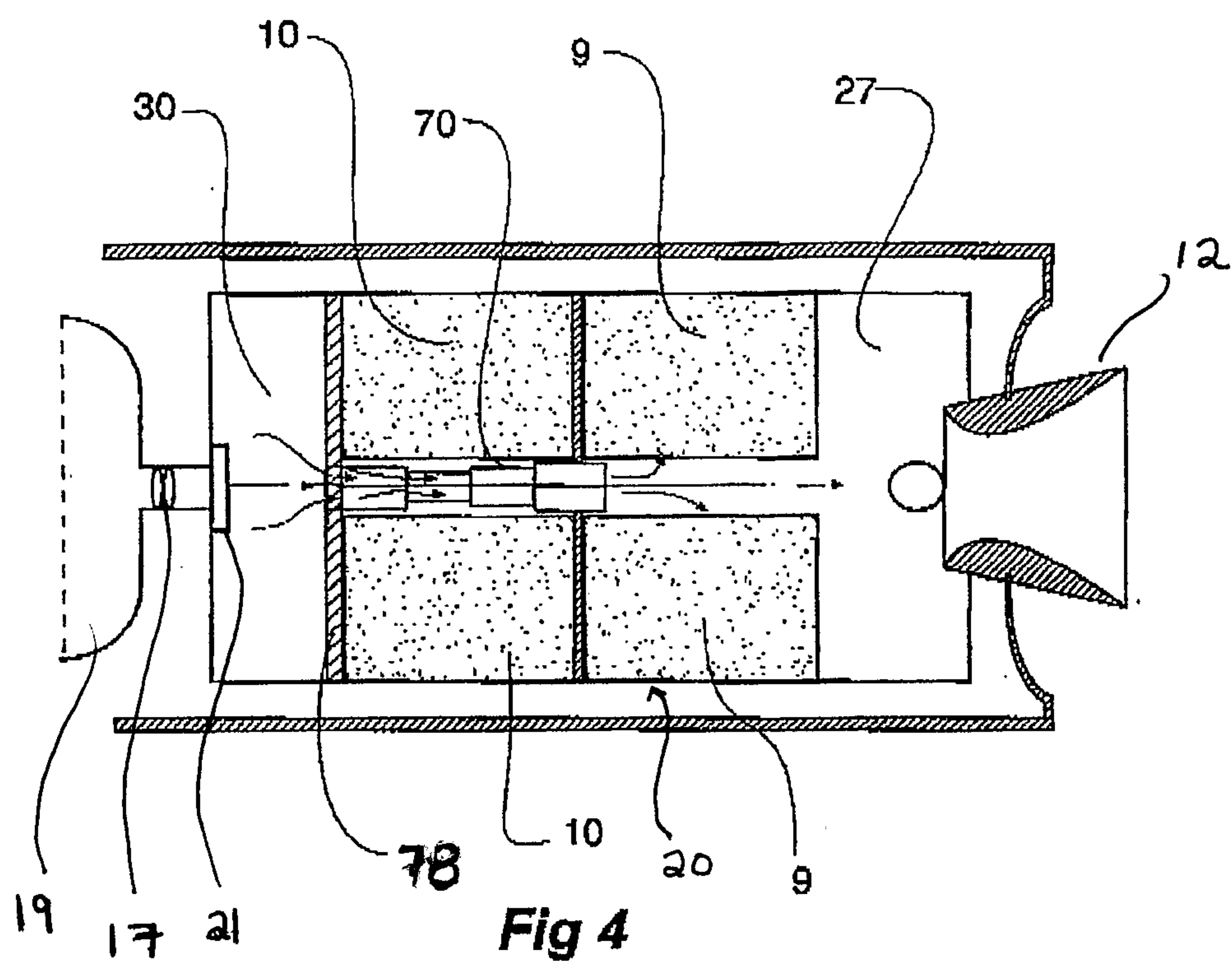


Fig 3

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