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(54) **COMPACT SAFETY IGNITION DEVICE FOR DUAL PULSE MOTOR**

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CPC ***F02K 9/38*** (2013.01); ***F02K 9/95*** (2013.01); *F05D 2260/99* (2013.01)

(58) **Field of Classification Search**
CPC F02K 9/12; F02K 9/28; F02K 9/38; F02K 9/95
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,046,076 A * 9/1977 Hampton F42C 15/31 102/202
5,600,946 A * 2/1997 Dombrowski F02K 9/346 60/253

(Continued)

FOREIGN PATENT DOCUMENTS

JP 2013060915 A 4/2013
KR 20050014016 A 2/2005

(Continued)

OTHER PUBLICATIONS

English Translation of Korean Notice of Allowance Application No. 10-2022-0074034; dated Dec. 9, 2022; pp. 7.

(Continued)

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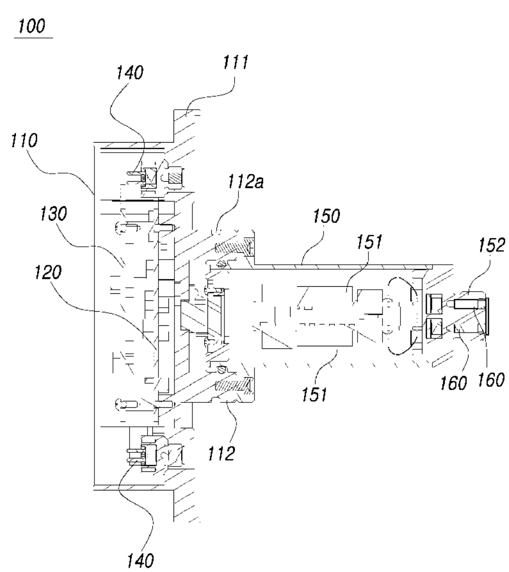
(57) **ABSTRACT**

A compact safety ignition device for a dual pulse motor capable of preventing accidental ignition of an ignition device includes a housing which forms an accommodation space and coupled to a front port of a combustion tube. Primary and secondary circuit portions mounted inside the housing for generating ignition signals for a primary and secondary propellant, respectively. A primary ignition device mounted at one end of the housing and electrically connected to the primary circuit portion and accommodated in the combustion tube. A secondary bulkhead initiator mounted inside the housing and electrically connected to the secondary circuit portion. The primary ignition device includes a primary detonation portion electrically connected to the primary ignition device and includes a primary bulkhead initiator electrically connected to the primary detonation portion at a protrusion protruding from an end of the primary detonation portion.

5 Claims, 4 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

10,378,482	B2 *	8/2019	Hwang	F02K 9/95
2013/0111874	A1 *	5/2013	Kawadu	F02K 9/08 60/256
2017/0097213	A1 *	4/2017	Villarreal	F02K 9/95
2019/0120175	A1 *	4/2019	Hwang	F02K 9/38
2021/0071621	A1 *	3/2021	Lefcourt	F02K 9/96
2021/0381468	A1 *	12/2021	Lefcourt	F02K 9/96
2022/0170432	A1 *	6/2022	Koehler	F02K 9/28

FOREIGN PATENT DOCUMENTS

KR	101063793	B1	9/2011
KR	101192203	B1	10/2012
KR	101494393	B1	2/2015
KR	101835496	B1	3/2018

OTHER PUBLICATIONS

English Translation of the Korean Notice of Allowance Application No. 10-2022-0074034; dated Dec. 9, 2022; pp. 7.

Office Action dated Aug. 26, 2022 Application No. 9-5-2022-064696315; pp. 4.

* cited by examiner

FIG. 1

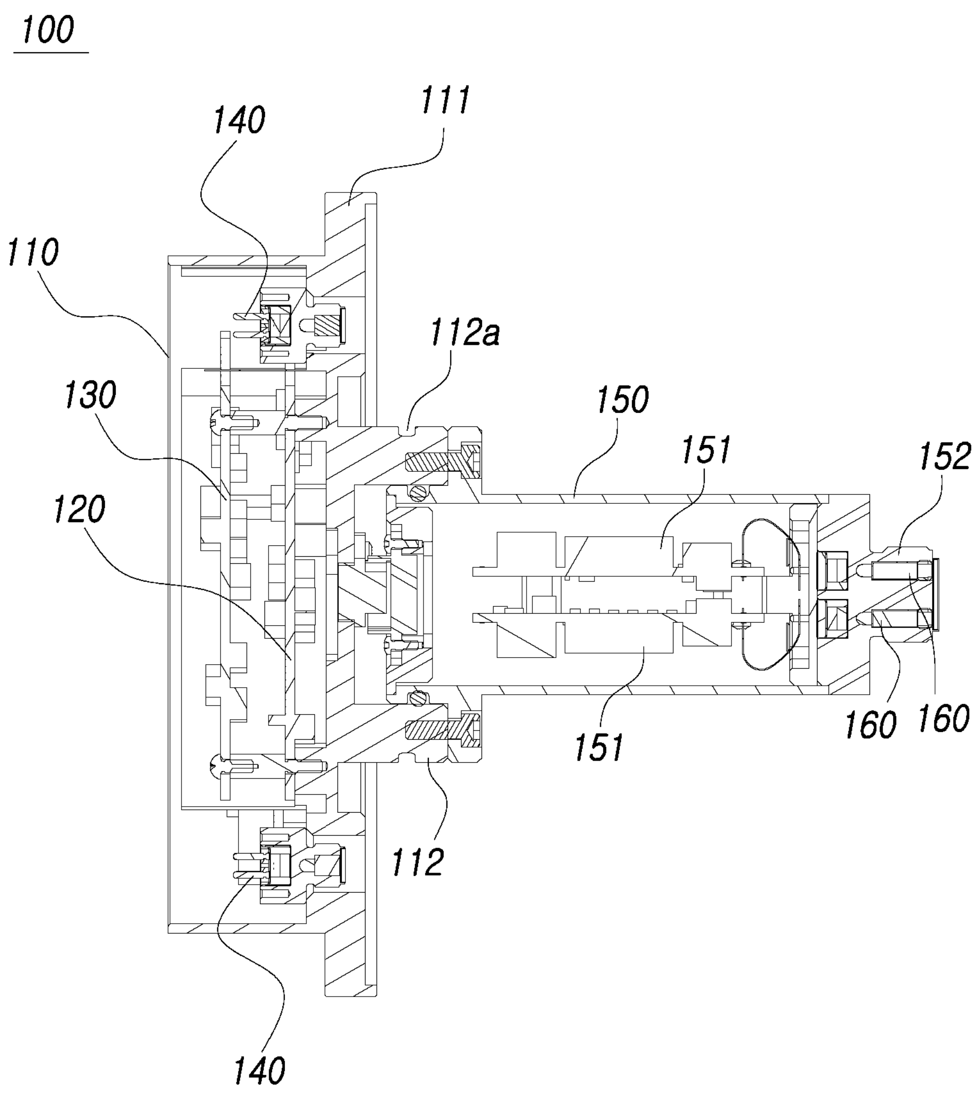


FIG. 2

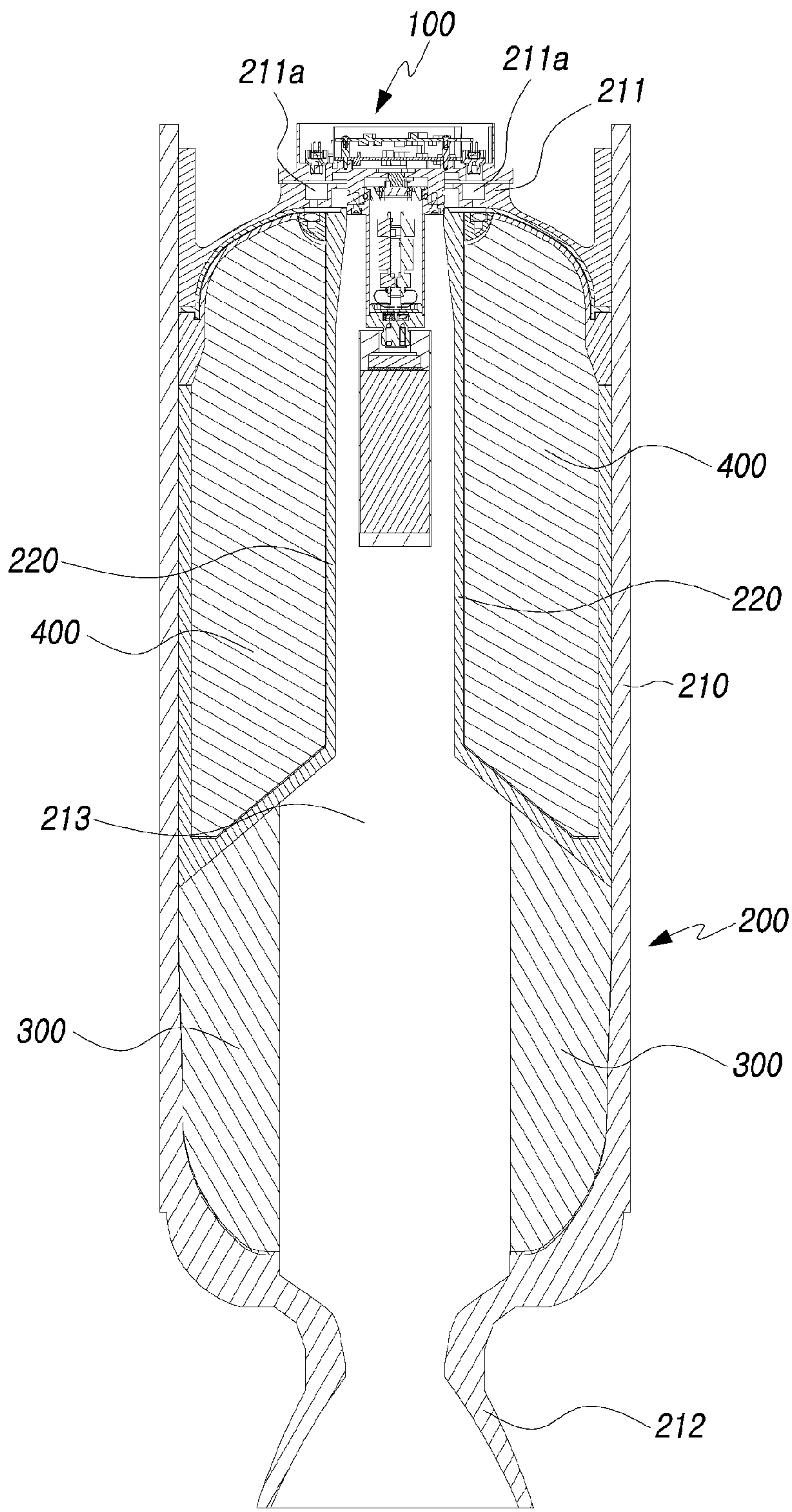


FIG. 3

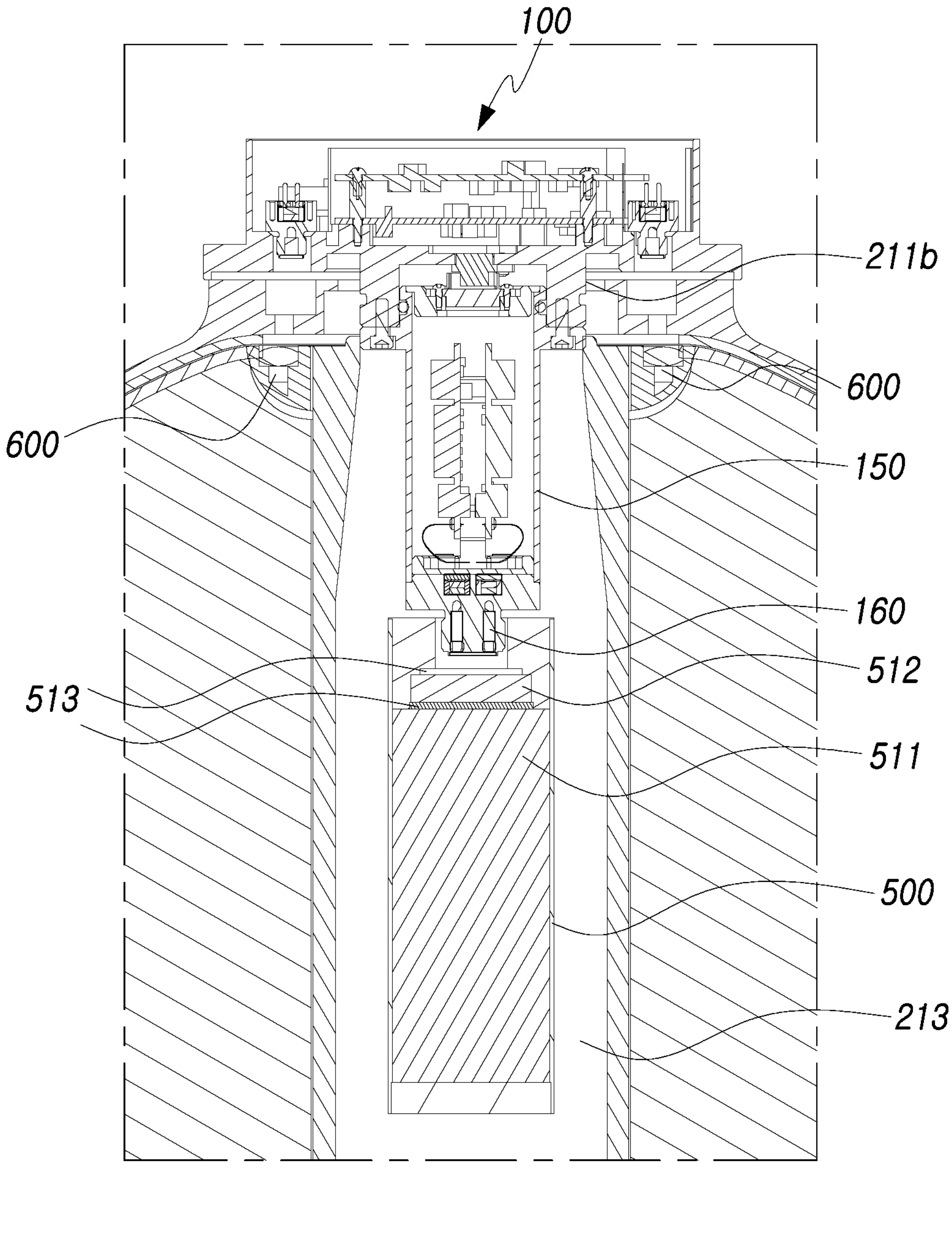
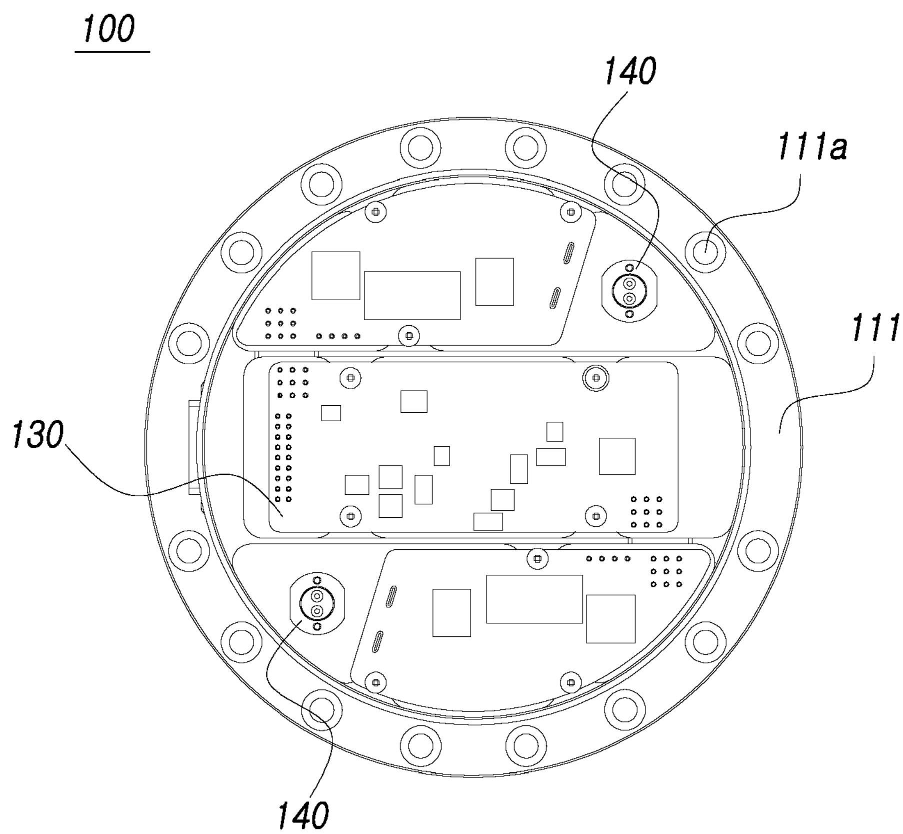


FIG. 4



COMPACT SAFETY IGNITION DEVICE FOR DUAL PULSE MOTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority under 35 U.S.C. § 119 to Korean Patent Application No. 10-2022-0074034, filed on Jun. 17, 2022, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The following disclosure relates to a safety ignition device applied to a dual pulse motor.

BACKGROUND

A dual pulse motor using a solid propellant is a rocket propulsion engine in which two propellant grains are separated by a thin diaphragm in one combustion tube.

Generally, combustion of a primary pulse propellant, among the two propellants, allows a rocket to fly toward a target. A secondary pulse propellant, which is burned after a certain period of time, further accelerates the rocket.

The dual-pulse motor has excellent space utilization compared to the use of a separate two-stage rocket. In addition, since the dual pulse motor uses a single combustion tube and a nozzle, manufacturing costs may be reduced.

However, in terms of an ignition device for igniting a propellant, the dual-pulse motor has difficulties in terms of space design. This is because igniters for igniting two pulse motors are separately installed in a single ignition device.

In general, the ignition device is assembled in front of a rocket propulsion engine of the separated two-stage rocket. Since the ignition device utilizes empty space (port) formed in front of each combustion tube, there is no difficulty in designing, manufacturing, and assembling.

However, the dual-pulse motor has difficulties in terms of space design. This is because the dual-pulse motor requires that the ignition device for the primary pulse propellant and the secondary pulse propellant be connected to a single housing and installed in an empty space (port) formed in front of the combustion tube.

Also, since the secondary pulse propellant in the dual pulse motor is located in front of the combustion tube and surrounded by a diaphragm to separate the secondary pulse propellant from the primary pulse propellant, it is more difficult to secure installation space.

Therefore, in the related art, an igniter for the secondary pulse propellant is installed inside the housing of the ignition device assembled in a front port of the propulsion engine. It is designed to form a flow path between the ignition device and the secondary pulse propellant to supply combustion gas from the igniter to the secondary pulse propellant.

In particular, when the primary pulse propellant is significantly separated from the front of the dual pulse motor, it may be difficult for energy generated by the igniter, for the primary pulse propellant, to reach the primary pulse propellant.

In addition, after the primary pulse propellant operates, the second pulse propellant burns after the lapse of a certain period of time. Here, an igniter housing for the first pulse propellant is exposed to flow and heat caused by the combustion gas of the second propellant, so there is a risk of rupture. The ruptured igniter housing for the primary pulse propellant may scatter and adversely affect a nozzle heat-resistant material.

In the related art, in order to solve the problem, the igniter housing for the primary pulse propellant is designed with aluminum or an aluminum alloy so that the igniter housing melts during combustion of the primary pulse propellant. However, when the primary pulse propellant and the primary pulse igniter are separated from each other, it may not be easy to melt the igniter housing and it may be difficult to melt the igniter housing uniformly.

In addition, in the related art, the igniter for the primary pulse propellant and an initiator are connected through a flow path. At this time, when a distance between the primary pulse propellant and the front of the dual pulse motor is large, the flow path should be lengthened and it may be difficult to initiate the igniter for the primary pulse propellant through the initiator.

The dual pulse motor has a small space for the ignition device. For dual pulse motors, it is very difficult to apply an ignition safety device for preventing accidental ignition together with a single ignition device.

In the related art, in order to solve this problem, only an initiator was installed in the ignition device of the dual pulse motor and an ignition safety device was installed in a separate space. Also, the ignition safety device and the initiator were connected using an explosive transfer line.

Due to the above problems, in the related art, the ignition safety device was not installed in front of the combustion tube in the dual pulse motor, and only the initiator, which is part of the ignition safety device, was installed. The ignition safety device was installed elsewhere, and the ignition safety device and initiator were connected by an explosive transfer line.

Therefore, it is necessary to design a safety ignition device that may solve the above problems.

RELATED ART DOCUMENT

Patent Document

US Patent Publication No. U.S. Pat. No. 5,675,966 A (1997 Oct. 14)

SUMMARY

An exemplary embodiment of the present invention is directed to providing a compact safety ignition device for a dual pulse motor capable of preventing accidental ignition of an ignition device or a propulsion engine, while efficiently using space, through a compact design in which an ignition safety device, an initiator, and an igniter are connected through one housing.

In one general aspect, a safety ignition device includes: a housing forming an accommodation space therein and coupled to a front port of a combustion tube; a primary circuit portion and a secondary circuit portion mounted inside the housing and generating ignition signals for a primary propellant and a secondary propellant charged in the combustion tube, respectively; a secondary bulkhead initiator mounted inside the housing and electrically connected to the secondary circuit portion; and a primary ignition device mounted on one end of the housing, electrically connected to the primary circuit portion, and accommodated in the combustion tube.

The primary circuit portion and the secondary circuit portion may be provided such that the secondary circuit portion is disposed on an upper side and the primary circuit portion is disposed below, and they are stacked with each other.

The secondary bulkhead initiator may be provided as two secondary bulkhead initiators spaced apart from each other in a circumferential direction.

The primary ignition device may include a primary detonation portion electrically connected to the primary circuit portion therein, and include a primary bulkhead initiator electrically connected to the primary detonation portion at a protrusion protruding from an end.

The primary detonation portion may be provided as two primary detonation portions disposed to face each other.

The primary bulkhead initiator may be provided as two bulkhead initiators disposed side by side at a predetermined interval inside the protrusion.

The housing may have a flange on an outer circumference and is coupled to the front port by the flange.

Other features and aspects will be apparent from the following detailed description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an enlarged side cross-sectional view of a safety ignition device according to an exemplary embodiment of the present invention.

FIG. **2** is a cross-sectional side view of a propulsion engine according to an exemplary embodiment of the present invention.

FIG. **3** is a partially enlarged view of FIG. **2**.

FIG. **4** is a front view of a safety ignition device of FIG. **2**.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

In order to fully understand the present invention, exemplary embodiments of the present invention will be described with reference to the accompanying drawings. Exemplary embodiments of the present invention may be modified in various forms, and the scope of the present invention should not be construed as being limited to the examples described in detail below. This exemplary embodiment is provided to more completely explain the present invention to those skilled in the art. Therefore, the shapes of elements in the drawings may be exaggerated to emphasize a clearer description. It should be noted that in each drawing, the same members are sometimes indicated by the same reference numerals. In addition, detailed descriptions of well-known functions and configurations that may unnecessarily obscure the subject matter of the present invention will be omitted.

Hereinafter, exemplary embodiments of the present invention will be described with reference to the accompanying drawings.

Referring to FIG. **1**, a safety ignition device **100** according to an exemplary embodiment of the present invention includes a housing **110**, a primary circuit portion **120**, a secondary circuit portion **130**, a secondary bulkhead initiator **140**, and a first ignition device **150**.

The housing **110** forms an outer appearance of the safety ignition device **100** and has an accommodation space therein. The primary circuit portion **120**, the secondary circuit portion **130**, the secondary bulkhead initiator **140**, and the like may be mounted in the accommodation space.

The housing **110** may be formed in a circular shape when viewed from a plane as shown in FIG. **4**, and may be fastened to a front port **211** formed at the front of a combustion tube **210** as shown in FIG. **3**.

Inside the accommodation space of the housing **110**, the primary circuit portion **120** generating an initiation signal for a primary propellant **300** and a secondary circuit portion **130** generating an initiation signal for a secondary propellant **400** may be installed.

The primary circuit portion **120** and the secondary circuit portion **130** may include a printed circuit board (PCB) configured as electronic circuits.

The primary circuit portion **120** and the secondary circuit portion **130** are co-located in one housing **110** so that the safety ignition device **100** may have increased space efficiency and may be designed to be compact.

Referring to FIG. **1**, the primary circuit portion **120** and the secondary circuit portion **130** are stacked and disposed inside the housing **110**, and the secondary circuit portion **130** is disposed above and the primary circuit portion **120** may be disposed and mounted below.

A secondary bulkhead initiator **140** may be mounted and provided inside the housing **110** to be electrically connected to the secondary circuit portion **130**. As shown in FIG. **4**, two secondary bulkhead initiators **140** may be disposed to be spaced apart from each other in a circumferential direction. That is, the two secondary bulkhead initiators **140** may be disposed to be close to an inner circumference of the housing **110** and spaced apart from each other and mounted to be located at circumferential ends.

One end of the housing **110** passes through the front port **211** of the combustion tube **210** and is accommodated inside the combustion tube **210**, and the first ignition device **150** electrically connected to the primary circuit portion **120** may be mounted at one end of the housing **110**.

The first ignition device **150** receives an ignition signal from the primary circuit portion **120** and ignites the primary propellant **300** charged in the combustion tube **210**.

Referring to FIG. **3** as well, the first ignition device **150** has a cylindrical shape and is mounted at one end of the housing **110** of the safety ignition device **100**. The first ignition device **150** has a primary detonation portion **151** electrically connected to the primary circuit portion **120** therein.

The primary detonation portion **151** receives the ignition signal from the primary circuit portion **120** and transfers the received ignition signal to the primary bulkhead initiator **160** to be described later. The primary detonation portion **151** may include a PCB-type electronic circuit card, and two primary detonation portions may be arranged to face each other in a longitudinal direction of the primary detonation portion **151**.

A protrusion **152** may be formed at an end of the primary ignition device **150**, and a primary bulkhead initiator **160** electrically connected to the primary detonation portion **151** may be provided at the protrusion **152**.

Two primary bulkhead initiators **160** may be arranged side by side at a predetermined interval inside the protrusion **152**.

Two primary detonation portions **151** and two primary bulkhead initiators **160** may be configured and connected to each other in a one-to-one manner. By configuring two primary detonation portions **151** and two primary bulkhead initiators **160**, the first propellant **300** may be ignited by transmitting an ignition signal from the other side even if a problem occurs in one side during an ignition process.

Therefore, by configuring the primary circuit portion **120**, the primary detonation portion **151**, and the primary bulkhead initiator **160** together in a space close to each other, utilization of space may be more efficient and the safety ignition device **100** itself may be designed to be compact. In addition, the reliability of ignition of the first propellant **300** may be increased by configuring two primary detonation portions **151** and two primary bulkhead initiators **160**.

Referring to FIG. **4**, the housing **110** may have a flange **111** on an outer circumference and be coupled to the front port **211** by the flange **111**.

The housing **110** may have the flange **111** with an outer circumference protruding so that the flange **111** may be coupled to the front port **211** by a fastening member, such as a bolt. To this end, a plurality of fastening holes **111***a* may be formed through the flange **111**.

Also, referring to FIG. **3**, the front port **211** formed at one end of the combustion tube **210** is connected to the hollow portion **213** inside the combustion tube **210** and has a through-portion **211***b* allowing the housing **110** to be inserted and coupled therein. Also, one end of the housing **110** may form a protruding insertion portion **112** to be inserted into the through-portion **211***b* of the front port **211**. A recess **112***a* may be formed around the insertion portion **112** to install an O-ring for sealing the inside of the combustion tube **210**.

Referring to FIG. **2** together, the propulsion engine **200** according to an exemplary embodiment of the present invention may include the combustion tube **210**, the primary propellant **300**, the secondary propellant **400**, the diaphragm **220**, and the safety ignition device **100** described above.

The combustion tube **210** includes the front port **211** formed at one end and a nozzle **212** formed at the other end. Inside the combustion tube **210**, a hollow portion **213** leading to the nozzle **212** is formed. The combustion tube **210** includes the hollow portion **213** through which the inside extends from the front port **211** to the nozzle **212**, and one end of the combustion tube **210** is sealed by coupling the safety ignition device **100** to the front port **211**.

The primary propellant **300** and the secondary propellant **400** are charged inside the combustion tube **210**, and are charged around an inner wall of the combustion tube **210**, while surrounding the hollow portion **213**. In addition, the primary propellant **300** and the secondary propellant **400** are charged to be distinguished from each other, and are separated from each other by the diaphragm **220**.

At the time of ignition, the primary propellant **300** is ignited first, and the secondary propellant **400** is ignited with a time difference. The secondary propellant **400** is surrounded by the diaphragm **400** so that the secondary propellant **400** may withstand heat and pressure generated as the primary propellant **300** burns for a predetermined time, and may be ruptured when ignited.

The secondary propellant **400** is surrounded by an inner wall of the combustion tube **210** and the diaphragm **400** and distinguished from the primary propellant **300**.

Since the primary propellant **300** is burned first, the primary propellant **300** is charged in the nozzle **212** side, and the secondary propellant **400** is charged in the front port **211** side.

The safety ignition device **100** is mounted on the front port **211** of the combustion tube **210** and may sequentially ignite the primary propellant **300** and the secondary propellant **400** at a predetermined time interval.

Referring back to FIG. **3**, a primary ignition portion **500** accommodating an ignition agent **510** ignited by the primary bulkhead initiator **160** therein may be fastened to the protrusion **152** of the safety ignition device **100**.

A male thread is formed on an outer surface of the protrusion **152** and a female thread is formed at one end of the primary ignition portion **500**, so that the protrusion **152** and the primary ignition portion **500** may be engaged with each other and fastened.

The primary ignition portion **500** has a cylindrical shape and may be formed of a fiber reinforced plastic (FRP) tube. The ignition agent **510** is contained in the primary ignition portion **500**, and the ignition agent **510** may include an auxiliary ignition agent **512** in a direction of the primary bulkhead initiator **160** and a main ignition agent **511** below the auxiliary ignition agent **512**.

A disk **513** formed of styrene is attached to one end of the primary ignition portion **500** so that the auxiliary ignition agent **512** may be contained therein. The disk **513** is also provided between the auxiliary ignition agent **512** and the main ignition agent **511** to prevent the two ignition agents from being mixed with each other.

BKNO3 granules may be used as the auxiliary ignition agent **512**, and magnesium teflon viton (MTV) granules may be used as the main ignition agent **511**.

Unlike general igniter baskets, the igniter tube is designed as a shot-gun type so that ignition flames are made only in a longitudinal direction of the tube and is devised to ignite a separated primary pulse propellant **23** without adversely affecting an adjacent separation diaphragm **25**. In addition, the thin tube is designed to be easily melted only when the primary pulse propellant burns without being deformed while the igniter burns. By designing in this manner, the primary pulse igniter tube may completely or almost completely melt before the secondary pulse motor operates, thereby eliminating a risk of rupture.

Referring back to FIG. **3**, the front port **211** is provided with a hole **211***a* formed in a position in contact with the secondary bulkhead initiator **140**, and a secondary ignition portion **600** is provided in a position corresponding to the hole **211***a* inside the diaphragm **220**, so that the secondary ignition portion **600** is ignited by the secondary bulkhead initiator **140** through the hole **211***a*.

The secondary bulkhead initiator **140** for ignition of the secondary propellant **400** is separated from one end portion of the combustion tube **210** and disposed at a circumferential end. The secondary bulkhead initiator **140** is disposed at one end portion of the combustion tube **210** and disposed inside the diaphragm **220**.

Two holes **211***a* are formed in positions corresponding to the secondary bulkhead initiator **140**, and two second ignition portions **600** are formed in positions corresponding to the hole **211***a*.

The secondary ignition portion **600** may be configured and installed to have a donut shape, and the secondary bulkhead initiator **140** may effectively ignite the secondary ignition portion **600**. In addition, even if an ignition failure occurs in one secondary bulkhead initiator **140**, the secondary ignition portion **600** may be ignited using another secondary bulkhead initiator **140**, thereby improving reliability of ignition.

The secondary ignition portion **600** is installed to be in contact with the secondary propellant **400** inside the diaphragm **220**. A fixing jig using urethane foam may be used to separate the secondary ignition portion **600** from the secondary propellant **400**. The secondary ignition portion **600** may be radially disposed, and BKNO3 gunpowder, which is manufactured in the form of pellets similar to pills may be used.

The hole **211***a* may accommodate high-temperature and high-pressure gas generated by the secondary bulkhead initiator.

The primary circuit portion **120** normally operates only when a rated loading signal and ignition signal are sequentially applied. A controller of the primary circuit portion **120** determines whether the loading signal is normal, transmits a loading command to a loading portion, and charges a built-in high voltage capacitor. Subsequently, when an ignition signal is applied at a predetermined time interval, the charge charged in the high voltage capacitor is quickly discharged and the connected primary bulkhead initiator **160** operates.

The secondary circuit portion **130** has the same function as that of the primary circuit portion **120**. The secondary propellant **400** has to operate after the primary propellant **300** is burned. In order to prevent accidental ignition of the secondary propellant **400**, the controller of the secondary circuit portion **130** may monitor the ignition signal transmitted to the primary propellant **300** and use the monitored ignition signal as a loading condition. To this end, a micro-controller unit (MCU) is installed in the controllers of the primary circuit portion **120** and the secondary circuit portion **130**, and input/output signals may be controlled using a driving program.

In addition, a rocket capable of adjusting an ignition timing of the primary propellant **300** and the secondary propellant **400** by configuring the propulsion engine **200** equipped with the safety ignition device **100** described above may be proposed.

In the safety ignition device applied to a dual pulse motor, by installing the safety ignition device in front of a combustion tube, accidental ignition of an ignition device or a propulsion engine may be prevented and reliability of ignition may increase, while space is efficiently used.

The exemplary embodiments of the present invention described above are merely exemplary, and those skilled in the art will appreciate that various modifications and equivalent other exemplary embodiments are possible therefrom. Therefore, it will be well understood that the present invention is not limited to the forms mentioned in the detailed description above. Therefore, the true technical protection scope of the present invention should be determined by the technical spirit of the appended claims. It is also to be understood that the present invention includes all modifications, equivalents and alternatives within the spirit and scope of the present invention as defined by the appended claims.

DETAILED DESCRIPTION OF MAIN ELEMENTS

100: safety ignition device
110: housing
111: flange
111*a*: fastening hole
11: insertion portion
112*a*: recess
120: primary circuit portion
130: secondary circuit portion
140: secondary bulkhead initiator
150: primary ignition device
151: primary detonation portion
152: protrusion
160: primary bulkhead initiator
200: propulsion engine
2210: combustion tube
211: front port
211*a*: hole
211*b*: through-portion
212: nozzle
213: hollow portion
220: diaphragm
300: primary propellant
400: secondary propellant
500: primary ignition portion
510: ignition agent
511: main ignition agent
512: auxiliary ignition
513: disk
600: secondary ignition portion

What is claimed is:

1. A safety ignition device comprising:
a housing forming an accommodation space therein and coupled to a front port of a combustion tube;
a primary circuit portion and a secondary circuit portion mounted inside the housing and generating ignition signals for a primary propellant and a secondary propellant charged in the combustion tube, respectively;
a secondary bulkhead initiator mounted inside the housing and electrically connected to the secondary circuit portion; and
a primary ignition device mounted on one end of the housing, electrically connected to the primary circuit portion, and accommodated in the combustion tube,
wherein the primary ignition device includes a primary detonation portion electrically connected to the primary circuit portion, and the primary detonation portion is provided as primary detonation portions disposed to face each other,
wherein the primary ignition device includes a primary bulkhead initiator electrically connected to the primary detonation portion at a protrusion protruding from an end of the primary detonation portion.

2. The safety ignition device of claim **1**, wherein the primary circuit portion and the secondary circuit portion are provided such that the secondary circuit portion is disposed above the primary circuit portion in a stacked configuration.

3. The safety ignition device of claim **1**, wherein
the secondary bulkhead initiator is provided as two secondary bulkhead initiators spaced apart from each other in a circumferential direction.

4. The safety ignition device of claim **1**, wherein
the primary bulkhead initiator is provided as two bulkhead initiators disposed side by side at a predetermined interval inside the protrusion.

5. The safety ignition device of claim **1**, wherein
the housing has a flange on an outer circumference and is coupled to the front port by the flange.

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