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(54) **MINIATURE ELECTRO-PYROTECHNIC IGNITER, AND IGNITION HEAD FOR THE SAME**

ELEKTRO-PYROTECHNISCHER MINIATURZÜNDER UND ZUGEHÖRIGER ZÜNDKOPF

ALLUMEUR ÉLECTROPYROTECHNIQUE MINIATURE ET TÊTE D'ALLUMAGE POUR CELUI-CI

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• **SCHUURBIERS, Cornelis Anthonius Hubertus**
2595 DA Den Haag (NL)

• **TATA NARDINI, Flavia**
2595 DA Den Haag (NL)

(30) Priority: **11.12.2012 EP 12196435**

(74) Representative: **V.O.**

P.O. Box 87930

2508 DH Den Haag (NL)

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(73) Proprietor: **Nederlandse Organisatie voor
toegepast-
natuurwetenschappelijk onderzoek TNO**
2595 DA 's-Gravenhage (NL)

(56) References cited:

EP-A1- 1 452 824

EP-A1- 1 662 224

EP-A2- 0 779 492

FR-A5- 2 053 791

US-A- 3 059 576

US-A- 3 134 329

US-A- 5 254 838

US-A1- 2002 096 078

US-A1- 2004 164 069

(72) Inventors:

• **VAN VLIET, Laurens Daniël**
2595 DA Den Haag (NL)

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Description

Field of the invention

[0001] The present invention relates to a miniature electro-pyrotechnic igniter suitable for use in miniature spacecraft, and to an ignition head for the same.

Background

[0002] Spacecraft, and in particular miniature spacecraft such as cubesats, place stringent demands on, inter alia, the volume, weight, safety and reliability of their components. Common components include cool gas generators and rocket motors, both of which may include electro-pyrotechnic ignition heads.

[0003] A conventional electro-pyrotechnic ignition head may typically include an electrically resistive bridge wire that is at least partially embedded within a pyrotechnic primer charge. By passing an electric current through the bridge wire, the bridge wire may be heated to set off the primer charge. The primer charge may in turn ignite a further pyrotechnic charge, such as a cool gas generator charge in the case of a cool gas generator, or a propellant grain in the case of a rocket motor.

[0004] US3059576A discloses an electrically fired detonator, having a ceramic body with in lead wires, and bridge wires connecting ends of the lead in wires.

[0005] US2002/096078A1 describes an initiating device for an electronic detonator, having thick film resistive bridges extending between electrical conductors.

[0006] EP0779492A2 teaches an initiator for a vehicle occupant restraint airbag system.

[0007] US3134329 concerns an exploding bridgewire squib, the bridgewire having a coating of finely divided particles of a secondary explosive.

Summary of the invention

[0008] One drawback of such conventional ignition heads, in particular when used in cool gas generators, is that they may not be able to uniformly heat and ignite an end surface of an elongate, for instance cylindrical, cool gas generator charge. Instead, they may unevenly heat the end surface and cause only a certain spot thereof to ignite, as a result of which the charge may undergo a decomposition reaction in a non-uniform, irregular fashion.

[0009] Another drawback of such conventional ignition heads is that the amount of electric energy required to set off the primer charge may be in the order of a tenth or several tenths of a Joule. Although this low ignition threshold renders the ignition head fast and responsive, it also entails the inherent risk that the primer charge is unintentionally fired when the relatively low amount of electric energy is generated via, for instance, magnetically-induced currents or electromagnetic radiation. To overcome this issue, conventional ignition heads are of-

ten fitted with a safe and arm (S&A) mechanism that prevents accidental ignition. S&A mechanisms, however, are typically mechanical in nature, and relatively large and heavy. They may, for instance, easily have a mass of 500 grams, which makes them unsuitable for use in miniature satellites whose overall allowed maximum mass may be as low as 1.33 kg.

[0010] It is an object of the present disclosure to provide for a miniature, lightweight, safe, and reliable ignition head that overcomes or at least mitigates one or more of the aforementioned drawbacks, and that is suitable for use in an electro-pyrotechnic igniter.

[0011] It is a further object of the present invention to provide for a miniature, lightweight, safe, and reliable electro-pyrotechnic igniter that is suitable for use in spacecraft, such as cubesats.

[0012] To this end, a first aspect of the present disclosure is characterised by the features of claim 1.

[0013] To prevent spot heating of a pyrotechnic charge to be ignited, the presently disclosed ignition head features a bridge filament having multiple cross-over portions that extend over a frontal heating surface of an electrically insulative, thermally conductive bridge filament support body. The electrically insulative nature of the bridge filament support body allows for multiple spread apart cross-over portions to extend over the same frontal heating surface without short-circuiting. The thermally conductive nature of the bridge filament support body additionally facilitates the distribution of heat therein. Accordingly, heat generated by the cross-over portions of the bridge filament may quickly spread across the entire frontal heating surface to enable the uniform heating of an end face of a pyrotechnic charge that is in contact therewith.

[0014] In one embodiment, the ignition head may further comprise a non-pyrotechnic, electrically insulative, thermally conductive shield film, for instance made of Kapton®, that is applied over the at least one cross-over portion of the bridge filament. In embodiments wherein the shield film does not form part of the ignition head, it may alternatively form part of a pyrotechnic charge to be ignited, e.g. as a coating of the pyrotechnic composition of the pyrotechnic charge. At any rate, in an operational setting, the shield film may be interposed between at least the bridge filament's cross-overs and the pyrotechnic composition of the pyrotechnic charge, and preferably between the entire frontal heating surface of the bridge wire support body and the pyrotechnic composition of the pyrotechnic charge.

[0015] The shield film may act as an ignition retardation control, and as such as a lightweight safety mechanism that prevents accidental ignitions much like a conventional safe and arm device. It enables the transfer of heat from the cross-over portions of the bridge filament, and preferably from the entire frontal heating surface of the bridge filament support body, to the pyrotechnic composition of the pyrotechnic charge. By properly selecting the thermal conductivity of the material of the shield film

and/or the thickness of the shield film, the shield film may be provided with a heat transfer coefficient that - in a given, overall configuration - ensures that a minimum amount of electric ignition energy is required to effect ignition of the pyrotechnic charge. Since the thickness of the shield film is an easily variable parameter, the presently disclosed ignition head is conveniently tunable for different ignition times.

[0016] A second aspect of the present disclosure is directed to an electro-pyrotechnic igniter as defined by the features of claim 13.

[0017] According to a further embodiment, the electro-pyrotechnic igniter further comprises: a non-reclosing pressure relief device, for instance a burst disc, that closes off the at least one exhaust orifice, and that is configured to open said at least one exhaust orifice once a predetermined pressure has developed within the reaction chamber.

[0018] according to a further embodiment of the electro-pyrotechnic igniter, said at least one exhaust orifice comprises a plurality of exhaust orifices. according to a further embodiment, said at least one ignition head comprises a plurality of ignition heads (100).

[0019] A third aspect of the present disclosure is directed to a spacecraft, for instance a satellite such as a cubesat, including at least one of an ignition head according to the first aspect of the present disclosure and/or an electro-pyrotechnic igniter according to the second aspect of the present disclosure.

[0020] These and other features and advantages of the invention will be more fully understood from the following detailed description of certain embodiments of the invention, taken together with the accompanying drawings, which are meant to illustrate and not to limit the invention.

Brief description of the drawings

[0021]

Fig. 1 schematically illustrates an exemplary embodiment of an electro-pyrotechnic igniter according to the present disclosure in, respectively, a bottom perspective view (Fig. 1A), a top perspective view (Fig. 1B), an orthogonal top view (Fig. 1C), and a cross-sectional side view taken along line D-D indicated in Fig. 1C (Fig. 1D); and

Fig. 2 schematically illustrates an ignition head comprised by the electro-pyrotechnic igniter shown in Fig. 1 in, respectively, a perspective view (Fig. 2A), an exploded perspective view (Fig. 2B), a side view (Fig. 2C), a cross-sectional side view taken along line D-D indicated in Fig. 2C (Fig. 2D), a top perspective view of the bridge filament support body and the bridge filament (Fig. 2E), and a bottom perspective view of the bridge filament support body and the bridge filament (Fig. 2F).

Detailed description

[0022] Fig. 1 schematically illustrates an exemplary embodiment of an electro-pyrotechnic igniter 1 according to the present disclosure. Such an electro-pyrotechnic igniter 1 may include at least one ignition head 100. The embodiment of the electro-pyrotechnic igniter depicted in Fig. 1 includes two identical ignition heads 100, whose construction is schematically illustrated in more detail in Fig. 2. Below, the construction and operation of the ignition head 100 and the electro-pyrotechnic igniter 1 according to the present disclosure are described in general terms, where appropriate with reference to Figs. 1-2.

[0023] The ignition head 100 according to the present disclosure may be characterized as a non-pyrotechnic, electric ignition head 100. That is, the electrically powered ignition head 100 may itself be void of any pyrotechnic composition, and merely be configured to effect the ignition of a separate or external pyrotechnic charge 300 when it is brought in contact therewith, for instance when it is applied to ignite a cool gas generator charge in a cool gas generator or a booster-pellet in an electro-pyrotechnic igniter 1. In this respect some conventional ignition heads that are suitable for igniting pyrotechnic charges may differ from the presently disclosed ignition head 100. Such conventional ignition heads may in particular comprise a pyrotechnic primer charge or primer composition in which a bare/uncoated bridge wire of the ignition head is embedded. It is understood that the non-pyrotechnic ignition head 100 according to the present disclosure may include no such pyrotechnic primer charge, and that its bridge filament 120 may not be embedded in a pyrotechnic composition. As will be clarified below, any pyrotechnic composition to be ignited with the presently disclosed ignition head 100 may be separated from the bridge filament 120 by an electrically insulative, thermally conductive shield film 140, which may either form part of the ignition head 100 or part of the pyrotechnic charge 300.

[0024] The ignition head 100 may include a housing 102. The housing 102 may in principle have any suitable shape, and be made from any suitable material. In one embodiment, such as the depicted embodiment, the housing 102 may be generally cylinder-jacket shaped. For reasons of robustness and easy machinability, the housing 102 may preferably be made of metal or a metal alloy; preferred materials may include copper, brass, titanium, aluminum, and stainless steel. To facilitate a fluidtight connection to/integration with a casing of a device in which the ignition head 100 may be incorporated, for instance the casing 200 of an electro-pyrotechnic igniter 1, an outer surface of the housing 102 may define one or more circumferential grooves 103 in which an O-ring 114 may be provided. The housing 102 may further define an interior space 104, and a front opening 106 giving access to the interior space 104. Optionally except for the front opening 106, the interior space 104 of the housing 102 may be fluidtightly sealed.

[0025] The ignition head 100 may also include a bridge filament support body 130. Although the bridge filament support body 130 may in principle have any suitable shape, it may preferably take the form of a relatively thin plate, for example with an average thickness in the range of 0.2-2 mm (measured in a direction that is normal with respect to frontal heating surface 132b). The bridge filament support body 130 may be circumferentially dimensioned such that it is approximately fittingly receivable in the front opening 106 of the housing 102, and be at least partially disposed therein such that an inner surface 132a of the bridge filament support body 130 faces the interior space 104 of the housing 102, and an outer frontal heating surface 132b of the bridge filament support body 130 faces outward from the interior space 104. As will become clear below, the bridge filament support body 130 may serve to mechanically support a thin bridge filament 120, to electrically insulate the cross-overs 122 of the bridge filament 120 from each other and the housing 102, and to distribute heat produced by the bridge filament 120 over its frontal heating surface 132b. Accordingly, the bridge filament support body may preferably be (one or more of) substantially rigid, electrically insulative, heat resistant and thermally conductive. In addition, at least the frontal heating surface 132b of the bridge filament support body 130 may preferably be heat reflective, such that it reflects radiative heat given off the bridge filament's cross-overs 122. To this end, the frontal heating surface 132b may be provided with a heat reflective coating. In one embodiment, the bridge filament support body 130 is at least partially made of a ceramic material, such as, for instance, silicon nitride (Si_3N_4), silicon carbide (SiC), or aluminum oxide (Al_2O_3).

[0026] In a preferred embodiment, the frontal heating surface 132b may define a plurality of pairs of cross-over terminals 136, i.e. locations where the bridge filament 120 may pass, e.g. extend through or around, the bridge filament support body 130, from its back side 132a to its front side 132b and/or vice versa. In one embodiment, the cross-over terminals 122 may take the form of through-holes or circumferentially bounded passages. In another embodiment, such as the depicted embodiment (see Figs. 2E-F), the cross-over terminals 122 may take the form of indentations or recesses defined by an outer circumferential edge 134 of the frontal heating surface 134. The cross-over terminals 136 may be arranged such that straight lines interconnecting the terminals of respective pairs do not intersect each other. A bridge filament 120 may thus be provided on, e.g. wrapped around, the bridge filament support body 130 to define a plurality of cross-overs 122, each of which cross-overs 122 may be uniquely associated with a pair of cross-over terminals 136, and each of which may extend only between its associated pair of cross-over terminals 136 across the frontal heating surface 132b and without intersecting other cross-overs.

[0027] The bridge filament 120 may be a relatively thin, relatively high-electrical-resistance element in the form

of a continuous wire, ribbon (flat wire) or the like. In some embodiments, the bridge filament 120 may be at least partially printed, e.g. screen-printed, onto the bridge filament support body 130, and/or be at least partially embedded therein. The bridge filament 120 may extend between a first end 120a and a second end 120b. The first and second ends 120a, 120b may typically be mutually electrically insulatively arranged within the interior space 104 of the housing 102 and thus on the inner side of the bridge filament support body 130. In between its first and second ends 120a, 120b, the bridge filament 120 may include at least one portion that extends over the frontal heating surface 132b of the bridge filament support body 130. It is understood that each such portion 122 of the bridge filament 120 that extends over the frontal heating surface, typically between two cross-over terminals 136, may be referred to as a 'cross-over' or 'cross-over portion'. The bridge filament 120 may be made of any suitable material, such as, for instance, a Nickel-Chromium (NiCr) alloy (e.g. Evanohm®), Alloy 815, Alloy 837, or Alloy 875. Preferably, the cross-over sections 122 of the bridge filament 120 extends continuously over the frontal heating surface (being continuously supported thereby), uninterrupted contacting that surface, to provide a relatively high heat transfer contact area there-between.

[0028] The first and second ends of the bridge filament 120 may be electrically conductively connected to respective relatively thick, relatively low-electrical-resistance lead wires 110. As follows from the drawing, the connections may e.g. be located within the interior space 104. In the example, the bridge filament support body 130 is spaced-apart from the nearby ends of the lead wires 110. Also, in the example, the bridge filament support body 130 is spaced-apart from sealing means 112 of the back of the housing 102. It follows that in this case, the bridge filament support body 130 is a separate element with respect to those sealing means 112, so that it has a relatively small thermal mass.

[0029] The lead wires 110 may be made from any suitable material, such as metals or alloys like copper, titanium or stainless steel, and be bare or uncoated. The lead wires 110 may exit the housing 102 via respective lead wire outlets 108, e.g. including an opening in the (back of the) housing 102, which lead wire outlets 108 may provide for a respective fluidtight seals 112 (i.e. distal ignition head sealing means) between the housing 102 and the respective lead wire 110. The fluidtight seal may, for instance, take the form of a glass mass, which, in case the housing 102 and the lead wires 110 are made of metal, may provide for an hermetic glass-to-metal seal. In a preferred embodiment the lead wires 110 may be made of a material with approximately the same (e.g. $\pm 10\%$) thermal expansion coefficient as the material from which the housing 102 of the ignition head 100 is manufactured; this may ensure that no residual tension remains in the seal 112 when the ignition head is subject to temperature variations during operation/use.

[0030] The bridge filament 120, and in particular its

cross-overs 122 (122a, 122b, 122c, 122d), may preferably not electrically conductively contact a pyrotechnic charge 300 to be ignited. Such direct electric contact may be prevented by interposing a shield film 140 in between the bridge filament 120 and the pyrotechnic charge 300.

[0031] In one embodiment, the shield film 140 may be applied to the bridge element 120, in particular to its cross-overs 122. The shield film 140 may, for instance, be 'wrapped around' at least a portion of the bridge element 120 as such and thus take the form of an electrically insulative jacket. Alternatively or in addition, the shield film 140 may take the form of a layer that overlays or covers at least part of the frontal heating surface 132b of the bridge filament support body 130, including the cross-overs 122 of the bridge filament 120 running over it. In this latter case, which is illustrated in the depicted embodiment (see Figs. 2A-B), the shield film 140 may have an inner surface 142a that faces the frontal heating surface 132b of the bridge filament support body 130, and an outer surface 142b that faces outward for direct physical contact with a pyrotechnic charge 300 to be ignited.

[0032] In another embodiment, the pyrotechnic charge 300 - typically instead of the bridge filament 140 and/or the frontal heating surface 132b - may be coated with a shield film 140. For instance, in case the pyrotechnic charge is a pellet, a shield film 140 may be applied to at least a portion of an outer surface of the pellet that is configured for contact with the (frontal heating surface 132b of the) ignition head 100. It is understood, however, that this embodiment is functionally equivalent to that in which a shield film 140 is applied to the frontal heating surface 132b of the bridge filament support body 130: in both cases, a shield film is interposed between the bridge filament's cross-overs 122 and the pyrotechnic composition of the pyrotechnic charge 300.

[0033] The shield film 140 may be electrically insulative so as to prevent short-circuiting any cross-overs 122 of the bridge filament 120, and thermally conductive so as to enable the transfer of heat generated by the bridge filament 120 to the pyrotechnic charge 300. The shield film 140 may preferably have a heat transfer coefficient in the range of 240-24.000 W/m²K, and more preferably in the range of 1.250 - 4800 W/m²K. Depending on the envisaged application of the ignition head 100, the shield film 140 may additionally be (i) chemically inert with respect to the chemical composition of a pyrotechnic charge 300 to be ignited (and its decomposition products) so as to enable the generation of clean gases, and/or (ii) low outgassing to enable the generation of clean gases and to render the ignition head 100 suitable for use under vacuum conditions, e.g. in space environments, and/or (iii) non-porous, and crack-resistant when subject to operational temperature variations, to prevent electrically conductive decomposition products of an ignited pyrotechnic charge from short-circuiting any cross-overs 122.

[0034] Preferred materials for the shield film 140 may include Kapton®, in particular Kapton® MT and Kapton®

MTB. Kapton is a registered trademark of DuPont, headquartered in Wilmington, Delaware, U.S.A. Other materials may include glass, glass-mica, glass-fiber, phenolic/bakelite, silicon, plastic, ceramics, and laminates of these materials. A thickness of the shield film 140 may typically be in the range of 5-500 µm, and, in case the shield film is at least partially made of Kapton®, preferably in the range of 25-125 µm.

[0035] It is understood that the shield film 140 may act as a thermal buffer in between the bridge filament 120 and the pyrotechnic composition of the pyrotechnic charge 300. As such, it may protect the bridge filament 120 from burning out early due to the development of heat upon ignition of the pyrotechnic charge 300. Moreover, the shield film 140 may act as an ignition retardation control, and as such as a lightweight safety mechanism that prevents accidental ignitions much like a conventional safe and arm device. It enables the transfer of heat from the cross-over portions 122 of the bridge filament 120, and preferably from the entire frontal heating surface 132b of the bridge filament support body 130, to the pyrotechnic composition of the pyrotechnic charge 300. By properly selecting the thermal conductivity of the material of the shield film 140 and/or the thickness of the shield film, the shield film may be provided with a heat transfer coefficient that - in a given, overall configuration - ensures that a minimum amount of electric ignition energy (or more accurately: a minimum average electric ignition energy supply rate (Watt) for a certain period of time) is required to effect ignition of the pyrotechnic charge 300. Since the thickness of the shield film 140 is an easily variable parameter, the presently disclosed ignition head is conveniently tunable for different ignition times. It will be clear however, that in the overall configuration of an ignition system 1, the ignition energy required to effect ignition of a pyrotechnic charge 300 may also depend on other factors, such as the amperage and voltage at which electric energy is provided to the ignition head 100, the thickness and type of the bridge filament 120, and the pyrotechnic composition of the pyrotechnic charge 300; in practice, these factors may preferably be considered in conjunction, and tailored to each other so as to achieve the desired ignition time.

[0036] The electro-pyrotechnic igniter 1 according to the present disclosure may include a casing 200, at least one ignition head 100 of the above-described type, and at least one pyrotechnic charge 300.

[0037] The casing 200 may in principle have any suitable shape, and be manufactured from any suitable material. For reasons of robustness and easy machinability, the casing 200 may preferably be made of a metal or a metal alloy; preferred materials may include copper, titanium and stainless steel. The casing 200 may define an interior reaction chamber 214, which may be dimensioned to typically snugly receive the pyrotechnic charge 300. Where desired, a flexible sheet 218, for instance made of rubber, may be provided to fix or clamp the pyrotechnic charge 300 within the reaction chamber 214,

i.e. between the walls of the housing 200. The flexibility of the sheet 218 may accommodate a possible difference in thermal expansion of the housing 200 and the pyrotechnic charge 300, such that such a difference does not lead to mechanical failure of the latter.

[0038] The casing 200 may further define at least one exhaust orifice 204 via which the reaction chamber 214 is fluidly connected to an external environment of the electro-pyrotechnic igniter 1, e.g. the reaction chamber of a second-stage igniter. The exhaust orifice 204 may typically have a diameter in the order of millimeters. In one embodiment, such as the depicted embodiment, the casing 200 may define a plurality of exhaust orifices 204, e.g. three identical orifices angularly spaced 120° apart in a same plane. A plurality of exhaust orifices may improve the reliability of the igniter 1, since having multiple orifices 204 may reduce the chance of ignition failure (of a main charge) in case the pyrotechnic charge 300 of the igniter breaks or decomposes into different pieces which can clog or block an exhaust orifice 204. The number, size and arrangement of the exhaust orifices may be tailored to the application at hand.

[0039] As in the depicted embodiment of Fig. 1, the casing 200 may comprise two parts: a main body 202a, and a nozzle plate 202b; the latter may include the at least one exhaust orifice 204. With the nozzle plate 202b removed from the main body 202a, the reaction chamber 214 is easily accessible, which allows for installation, removal and/or replacement of the pyrotechnic charge 300 during assembly or subsequent use. The nozzle plate 202b and the main body 202a may be preferably be connectable to each other by releaseable fastening means, such as screws 206.

[0040] To facilitate the mounting of the igniter 1 to another body, its casing may be provided with one or more mounting holes 208. Furthermore, a mounting surface of the igniter 1, which may typically comprise the normally planar outer surface of the casing 200 including the at least one exhaust orifice 204, may include at least one endless groove in which a respective O-ring 210, 212 may be provided. The at least one groove and O-ring 210, 212 may preferably encircle the at least one exhaust orifice 204 in order to enable the fluidtight fluid communication with another chamber provided in the body onto which the igniter 1 may be mounted, such as the aforementioned reaction chamber of a second-stage igniter. For improved reliability, multiple grooves and respective O-rings may be provided. As in the depicted embodiment, for instance, one groove and O-ring 210 may be provided in the mounting surface of the main body 202a of the casing 200 to encircle a seam between the main body 202a and the nozzle plate 202b, while another groove and O-ring 212 may be provided in the nozzle plate 202b to encircle the at least one exhaust orifice 204.

[0041] To enable the build-up of a certain amount of pressure in the reaction chamber 214 upon ignition and initial decomposition of the pyrotechnic charge 300 before any gases are exhausted via the at least one exhaust

orifice 204, the igniter 1 may include a non-reclosing pressure relief device 218, such as a burst disc. The non-reclosing pressure relief device, which in itself may be of a conventional design, may be arranged to close off the at least one exhaust orifice 204 in the nozzle plate 202b, and be configured to open it once a predetermined pressure has developed within the reaction chamber 214. The pressure at which the non-reclosing pressure relief device is configured to open the at least one exhaust orifice 204 may preferably be chosen such that further autonomous decomposition of the pyrotechnic charge 300 is facilitated and effectively guaranteed.

[0042] In one embodiment, such as the embodiment of Fig. 1, the electro-pyrotechnic igniter 1 may be provided with a plurality of ignition heads 100 to provide for redundancy and reliability, which is a practical requirement for space applications given the lack of opportunities to repair or replace malfunctioning parts. In embodiments of the igniter 1 including a plurality of ignition heads 100, the frontal heating surfaces 132b of the ignition heads may preferably (pairwise) face each other and clasp the pyrotechnic charge 300 in between them, so as to enable ignition of the charge from opposite sides.

[0043] The pyrotechnic charge 300 may typically be provided in the form of a pellet that is at least partially made of a certain pyrotechnic composition, such as, for instance, boron potassium nitrate (BKNO_3). As mentioned, some embodiments of the pyrotechnic charge 300 may be at least partially coated with a non-pyrotechnic, electrically insulative and thermally conductive shield film. The pyrotechnic charge 300 may then be installed in the reaction chamber 214 such that the shield film is interposed between the cross-overs 122 of the bridge filament 120 of the at least one ignition head 100 and the pyrotechnic composition of the charge.

[0044] The electro-pyrotechnic igniter 1 may be integrated into an ignition system that may further include a power supply to which the at least one ignition head 100 of the electro-pyrotechnic igniter may be operably connected. The power supply may typically be configured to provide electrical energy at a certain amperage and voltage, and the ignition system as a whole may preferably be configured such that an ignition energy to be supplied by the power supply at said amperage and voltage in order to ignite the pyrotechnic charge is at least 10 Joules, for instance in the safe range of 10-200 Joules, and preferably in the range of 25-100 Joules.

[0045] Although illustrative embodiments of the present invention have been described above, in part with reference to the accompanying drawings, it is to be understood that the invention is not limited to these embodiments. Variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with

the embodiment is included in at least one embodiment of the present invention. Thus, the appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, it is noted that particular features, structures, or characteristics of one or more embodiments may be combined in any suitable manner to form new, not explicitly described embodiments of the invention as defined by the claims.

List of elements

[0046]

1	electro-pyrotechnic igniter	
100	non-pyrotechnic, electric ignition head	
102	housing	
103	circumferential groove	
104	interior space	20
106	front opening	
108	lead wire outlet	
110	low-electrical-resistance lead wire	
112	fluidtight seal	
114	O-ring	25
120	bridge filament	
120a,b	first (a) and second (b) end of bridge filament	
122	cross-over (portion), i.e. portion of bridge filament that extends over the frontal heating surface of the bridge filament support body	30
130	bridge filament support body	
132a,b	inner surface (a) and outer, frontal heating surface (b) of bridge filament support body	35
134	circumferential edge of frontal heating surface	
136a,b,c,...	pairs (a,b,c) of cross-over terminals	40
140	shield film	
142a,b	inner (a) and outer (b) surface of shield film	
200	casing	
202a	main body	
202b	nozzle plate	45
204	exhaust orifice / nozzle in nozzle plate	
206	screw	
208	mounting hole in main body of casing	
210	O-ring	
212	O-ring	50
214	reaction chamber	
216	rubber mat	
218	non-reclosing pressure relief device (burst disc)	
300	pyrotechnic charge	55

Claims

1. An electric non-pyrotechnic ignition head (100) suitable for use in an electro-pyrotechnic igniter (1), comprising:

- a housing (102) defining a front opening (106);
- an electrically insulative, thermally conductive bridge filament support body (130) that is at least partly disposed in said front opening, and that defines a frontal heating surface (132b); and
- a bridge filament (120) including at least one cross-over portion (122) that extends over the frontal heating surface (132b) of the bridge filament support body (130),

characterised in that

the frontal heating surface (132b) defines a plurality of pairs of cross-over terminals (136), wherein the at least one cross-over portion (122) includes a plurality of cross-over portions, each of said cross-overs portions being uniquely associated with a pair of cross-over terminals (136), such that a respective cross-over portion extends over the frontal heating surface (132b) only in between the cross-over terminals of the pair of cross-over terminals with which it is associated.

2. The ignition head according to claim 1, further comprising a non-pyrotechnic, electrically insulative, thermally conductive shield film (140) that is applied over the cross-over portions (122).
3. The ignition head according to claim 2, wherein the shield film (140) has a heat transfer coefficient in the range of 240-24.000 W/m²K, and more preferably in the range of 1.250 - 4.800 W/m²K.
4. The ignition head according to any of the preceding claims, wherein the cross-over terminals (136) include at least one of: indentations defined by a circumferential edge (134) bounding the frontal heating surface (132b) of the bridge filament support body (130), and through-holes in the bridge filament support body (130).
5. The ignition head according to any of the claims 1-4, wherein the bridge filament support body (130) is a plate-like body, wherein the bridge filament support body (130) is at least partially made of a ceramic material.
6. The ignition head according to any of the preceding claims, wherein the bridge filament support body (130) has an average thickness in the range of 0.2-2 mm, measured in a direction that is normal with respect to the frontal heating surface (132b).

7. The ignition head according to any of the preceding claims, wherein the bridge filament support body (130) is circumferentially dimensioned such that it is fittingly receivable in the front opening (106) of the housing 102.

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8. The ignition head according to any of the preceding claims, wherein the housing defines an interior space (104), wherein the support body (130) extends along or in the front opening (106) and covers the interior space (104).

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9. The ignition head according to claim 8, wherein an inner surface of the filament support body (13) faces the interior space (104), the inner surface extending opposite ignition head sealing means (112).

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10. The ignition head according to claim 8 or 9, wherein lead wires extend through sealing means towards the interior space (104), wherein the lead wires are connected to proximal ends of the bridge filament, for example at connections located within the interior space (104).

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11. The ignition head according to any of the claims 1-10, wherein the frontal heating surface (132b) has an area in the range of 4-1.000 mm², preferably in the range of 4-160 mm², and more preferably in the range of 9-36 mm².

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12. The ignition head according to any of the claims 1-11, wherein the housing (102), optionally except for the front opening (106) thereof, is fluidtightly sealed, and wherein the bridge filament (120) extends between a first end (120a) and a second end (120b), which ends (120a, 120b) are disposed inside the housing (102) and electrically conductively connected to respective low-electrical-resistance lead wires (110) that extend from the housing (102) via at least one fluidtightly sealed lead wire outlet (108).

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13. An electro-pyrotechnic igniter (1), comprising:

- a casing (200) defining an interior reaction chamber (214) and at least one exhaust orifice (204) via which the reaction chamber is fluidly connected to an external environment of the electro-pyrotechnic igniter;
- at least one electric non-pyrotechnic ignition head (100) according to any of the claims 1-12, wherein the housing (102) of the ignition head (100) is integrated with the casing (200), such that the bridge filament (120) is at least partially disposed within the reaction chamber (214); and
- a pyrotechnic charge (300) that is disposed within the reaction chamber (214), such that a pyrotechnic composition of the pyrotechnic charge (300) is in contact with the bridge fila-

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ment (120) of the at least one ignition head (100) via an interposed non-pyrotechnic, electrically insulative, thermally conductive shield film (140).

14. An ignition system, including:

- a power supply; and
- an electro-pyrotechnic igniter (1) according to claim 13, whose at least one ignition head (100) is operably connected to the power supply, said system being configured such that an ignition energy to be supplied by the power supply in order to ignite the pyrotechnic charge (300) is in the range of 10-200 Joules, and preferably in the range of 25-100 Joules.

15. A spacecraft, for instance a satellite, including at least one of an ignition head (100) according to any of the claims 1-12 or an electro-pyrotechnic igniter (1) according to claim 13.

Patentansprüche

1. Elektrischer, nicht-pyrotechnischer Zündkopf (100), geeignet zur Verwendung in einem elektro-pyrotechnischen Zünder (1), umfassend:

- ein Gehäuse (102), das eine vordere Öffnung (106) definiert;
- einen elektrisch isolierenden, wärmeleitenden Brückenfilament-Stützkörper (130), der mindestens teilweise in der vorderen Öffnung angeordnet ist und der eine frontale Heizfläche (132b) definiert; und
- ein Brückenfilament (120), einschließlich mindestens eines Kreuzungsabschnitts (122), der über die frontale Heizfläche (132b) des Brückenfilament-Stützkörpers (130) verläuft,

dadurch gekennzeichnet, dass

die frontale Heizfläche (132b) eine Vielzahl von Paaren von Kreuzungsklemmen (136) definiert, wobei der mindestens eine Kreuzungsabschnitt (122) eine Vielzahl von Kreuzungsabschnitten umfasst, die jeweils eindeutig einem Paar Kreuzungsklemmen (136) zugeordnet sind, sodass ein jeweiliger Kreuzungsabschnitt über die frontale Heizfläche (132b) nur zwischen den Kreuzungsklemmen des ihm zugeordneten Kreuzungsklemmenpaares verläuft.

2. Zündkopf nach Anspruch 1, ferner umfassend einen nicht-pyrotechnischen, elektrisch isolierenden, wärmeleitenden Abschirmfilm (140), der über den Kreuzungsabschnitten (122) angebracht ist.

3. Zündkopf nach Anspruch 2, wobei der Abschirmfilm

(140) einen Wärmeübertragungskoeffizienten im Bereich von 240-24.000 W/m²K und bevorzugter im Bereich von 1.250-4.800 W/m²K hat.

4. Zündkopf nach einem der vorhergehenden Ansprüche, wobei die Kreuzungsklemmen (136) mindestens eines der Folgenden umfassen: Vertiefungen, definiert von einem Umfangrand (134), der die frontale Heizfläche (132b) des Brückenfilament-Stützkörpers (130) begrenzt, und Durchgangslöcher in dem Brückenfilament-Stützkörper (130). 5
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5. Zündkopf nach einem der Ansprüche 1-4, wobei der Brückenfilament-Stützkörper (130) ein plattenähnlicher Körper ist, wobei der Brückenfilament-Stützkörper (130) mindestens teilweise aus einem Keramikmaterial hergestellt ist. 15
6. Zündkopf nach einem der vorhergehenden Ansprüche, wobei der Brückenfilament-Stützkörper (130) eine durchschnittliche Dicke im Bereich von 0,2-2 mm hat, gemessen in der Richtung, die normal in Bezug auf die frontale Heizfläche (132b) ist. 20
7. Zündkopf nach einem der vorhergehenden Ansprüche, wobei der Brückenfilament-Stützkörper (130) ringsum so dimensioniert ist, dass er passend in die vordere Öffnung (106) des Gehäuses (102) aufgenommen wird. 25
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8. Zündkopf nach einem der vorhergehenden Ansprüche, wobei das Gehäuse einen Innenraum (104) definiert, wobei der Stützkörper (130) entlang oder in der vorderen Öffnung (106) verläuft und den Innenraum (104) abdeckt. 35
9. Zündkopf nach Anspruch 8, wobei eine Innenfläche des Filament-Stützkörpers (13) gegenüber dem Innenraum (104) liegt, welche Innenfläche entgegengesetzt zu Zündkopfabdichtungsmitteln (112) verläuft. 40
10. Zündkopf nach Anspruch 8 oder 9, wobei Zuleitungsdrähte durch Dichtungsmittel zu dem Innenraum (104) verlaufen, wobei die Zuleitungsdrähte mit proximalen Enden des Brückenfilaments verbunden sind, zum Beispiel an Verbindungen, die in dem Innenraum (104) angeordnet sind. 45
11. Zündkopf nach einem der Ansprüche 1-10, wobei die frontale Heizfläche (132b) eine Fläche im Bereich von 4-1.000 mm² hat, bevorzugt im Bereich von 4-160 mm² und bevorzugter im Bereich von 9-36 mm². 50
12. Zündkopf nach einem der Ansprüche 1-11, wobei das Gehäuse (102) optional, mit Ausnahme seiner vorderen Öffnung (106), flüssigkeitsdicht abgedich-

tet ist und

wobei das Brückenfilament (120) zwischen einem ersten Ende (120a) und einem zweiten Ende (120b) verläuft, welche Enden (120a, 120b) in dem Gehäuse (102) angeordnet sind und elektrisch leitend mit entsprechenden Zuleitungsdrähten (110) mit niedrigem elektrischem Widerstand verbunden sind, die von dem Gehäuse (102) über mindestens einen flüssigkeitsdicht abgedichteten Zuleitungsdrahtausgang (108) verlaufen.

13. Elektro-pyrotechnischer Zünder (1), umfassend:

- eine Umhüllung (200), die eine innere Reaktionskammer (214) definiert, und mindestens eine Abzugsöffnung (204), über die die Reaktionskammer fließend mit einer Außenumgebung des elektro-pyrotechnischen Zünders verbunden ist;
- mindestens einen elektrischen nicht-pyrotechnischen Zündkopf (100) nach einem der Ansprüche 1-12, wobei das Gehäuse (102) des Zündkopfes (100) mit der Umhüllung (200) so integriert ist, dass das Brückenfilament (120) mindestens teilweise in der Reaktionskammer (214) angeordnet ist; und
- eine pyrotechnische Ladung (300), die in der Reaktionskammer (214) so angeordnet ist, dass eine pyrotechnische Zusammensetzung der pyrotechnischen Ladung (300) über einen zwischengeschalteten nicht-pyrotechnischen, elektrisch isolierenden, wärmeleitenden Abschirmfilm (140) in Kontakt mit dem Brückenfilament (120) des mindestens einen Zündkopfes (100) ist.

14. Zündsystem, umfassend:

- eine Stromversorgung; und
- einen elektro-pyrotechnischen Zünder (1) nach Anspruch 13, dessen mindestens eine Zündkopf (100) betriebsfähig mit der Stromversorgung verbunden ist, welches System so konfiguriert ist, dass eine von der Stromversorgung zu liefernde Zündenergie zum Zünden der pyrotechnischen Ladung (300) im Bereich von 10-200 Joule und bevorzugt im Bereich von 25-100 Joule ist.

15. Weltraumfahrzeug, zum Beispiel ein Satellit, umfassend mindestens einen eines Zündkopfes (100) nach einem der Ansprüche 1-12 oder eines elektro-pyrotechnischen Zünders (1) nach Anspruch 13.

Revendications

1. Tête d'allumage électrique non pyrotechnique (100)

apte à être utilisée dans dispositif d'allumage électro-pyrotechnique (1), comprenant :

- un boîtier (102) définissant une ouverture avant (106) ;
- un corps de support de filament de pont électriquement isolant et thermo-conducteur (130) qui est au moins partiellement disposé dans ladite ouverture avant, et qui définit une surface chauffante frontale (132b) ; et
- un filament de pont (120) comprenant au moins une partie de traversée (122) qui s'étend au-dessus de la surface chauffante frontale (132b) du corps de support de filament de pont (130),

caractérisé en ce que

la surface chauffante frontale (132b) définit une pluralité de paires des bornes de traversée (136), dans lequel la au moins une partie de traversée (122) comprend une pluralité de parties de traversée, chacune desdites parties de traversée étant associée de manière unique à une paire de bornes de traversée (136), de sorte qu'une partie de traversée respective s'étend au-dessus de la surface chauffante frontale (132b) uniquement entre les bornes de traversée de la paire de bornes de traversée à laquelle elle est associée.

2. Tête d'allumage selon la revendication 1, comprenant en outre un film de protection non-pyrotechnique, électriquement isolant et thermiquement conducteur (140) qui est appliqué au-dessus des parties de traversée (122).
3. Tête d'allumage selon la revendication 2, dans laquelle le film de protection (140) a un coefficient de transfert de chaleur dans la plage de 240 à 24 000 W/m²K, et de manière plus préférée dans la plage de 1 250 à 4 800 W/m²K.
4. Tête d'allumage selon l'une quelconque des revendications précédentes, dans laquelle les bornes de traversée (136) comprennent au moins l'un : d'indentations définies par un bord circonférentiel (134) délimitant la surface chauffante frontale (132b) du corps de support de filament de pont (130) et de trous traversants dans le corps de support de filament de pont (130).
5. Tête d'allumage selon l'une quelconque des revendications 1 à 4, dans laquelle le corps de support de filament de pont (130) est un corps en forme de plaque, dans lequel le corps de support de filament de pont (130) est au moins partiellement constitué d'un matériau de céramique.
6. Tête d'allumage selon l'une quelconque des revendications précédentes, dans laquelle le corps de

support de filament de pont (130) a une épaisseur moyenne dans la plage de 0,2 à 2 mm, mesurée dans une direction qui est perpendiculaire par rapport à la surface chauffante frontale (132b).

7. Tête d'allumage selon l'une quelconque des revendications précédentes, dans laquelle le corps de support de filament de pont (130) est dimensionné circonférentiellement de manière à pouvoir être reçu de manière appropriée dans l'ouverture avant (106) du boîtier (102).
8. Tête d'allumage selon l'une quelconque des revendications précédentes, dans laquelle le boîtier définit un espace intérieur (104), dans lequel le corps de support (130) s'étend le long ou dans l'ouverture avant (106) et recouvre l'espace intérieur (104).
9. Tête d'allumage selon la revendication 8, dans laquelle une surface interne du corps de support de filament (13) fait face à l'espace intérieur (104), la surface intérieure s'étendant sur des moyens d'étanchéité de tête d'allumage opposés (112).
10. Tête d'allumage selon la revendication 8 ou 9, dans laquelle des fils conducteurs s'étendent à travers des moyens d'étanchéité vers l'espace intérieur (104), dans lequel les fils conducteurs sont reliés aux extrémités proximales du filament du pont, par exemple au niveau de connexions situées dans l'espace intérieur (104).
11. Tête d'allumage selon l'une quelconque des revendications 1 à 10, dans laquelle la surface chauffante frontale (132b) a une surface dans la plage de 4 à 1 000 mm², de préférence dans la plage de 4 à 160 mm², et de manière plus préférée dans la plage de 9 à 36 mm².
12. Tête d'allumage selon l'une quelconque des revendications 1 à 11, dans laquelle le boîtier (102), éventuellement à l'exception de l'ouverture avant (106) de celui-ci, est rendue étanche aux fluides, et dans lequel le filament de pont (120) s'étend entre une première extrémité (120a) et une seconde extrémité (120b), lesquelles extrémités (120a, 120b) sont disposées à l'intérieur du boîtier (102) et connectées de manière électriquement conductrice à des fils conducteurs à faible résistance électrique (110) qui s'étendent depuis le boîtier (102) via au moins une sortie de fil conducteur rendue étanche aux fluides (108).
13. Dispositif d'allumage électro-pyrotechnique (1), comprenant :
 - un carter (200) définissant une chambre de réaction intérieure (214) et au moins un orifice

d'échappement (204) via lequel la chambre de réaction est reliée de manière fluide à un environnement externe du dispositif d'allumage électro-pyrotechnique ;

- au moins une tête d'allumage électrique non pyrotechnique (100) selon l'une quelconque des revendications 1 à 12,

dans lequel le boîtier (102) de la tête d'allumage (100) est intégré avec le carter (200), de sorte que le filament de pont (120) est au moins partiellement disposé à l'intérieur de la chambre de réaction (214) ; et

- une charge pyrotechnique (300) qui est disposée dans la chambre de réaction (214), de sorte qu'une composition pyrotechnique de la charge pyrotechnique (300) est en contact avec le filament de pont (120) de la au moins une tête d'allumage (100) via un film de protection non-pyrotechnique, électriquement isolant, et thermiquement conducteur (140) interposé.

14. Système d'allumage, y compris :

- une alimentation électrique ; et
 - un dispositif d'allumage électro-pyrotechnique (1) selon la revendication 13, dont au moins une tête allumage (100) est reliée de manière opérationnelle à l'alimentation électrique, ledit système étant configuré de telle sorte qu'une énergie d'allumage devant être fournie par l'alimentation électrique pour allumer la charge pyrotechnique (300) soit dans la plage de 10 à 200 Joules, et de préférence dans la plage de 25 à 100 Joules.

15. Engin spatial, par exemple un satellite, comprenant au moins un parmi une tête d'allumage (100) selon l'une quelconque des revendications 1 à 12 ou un dispositif d'allumage électro-pyrotechnique (1) selon la revendication 13.

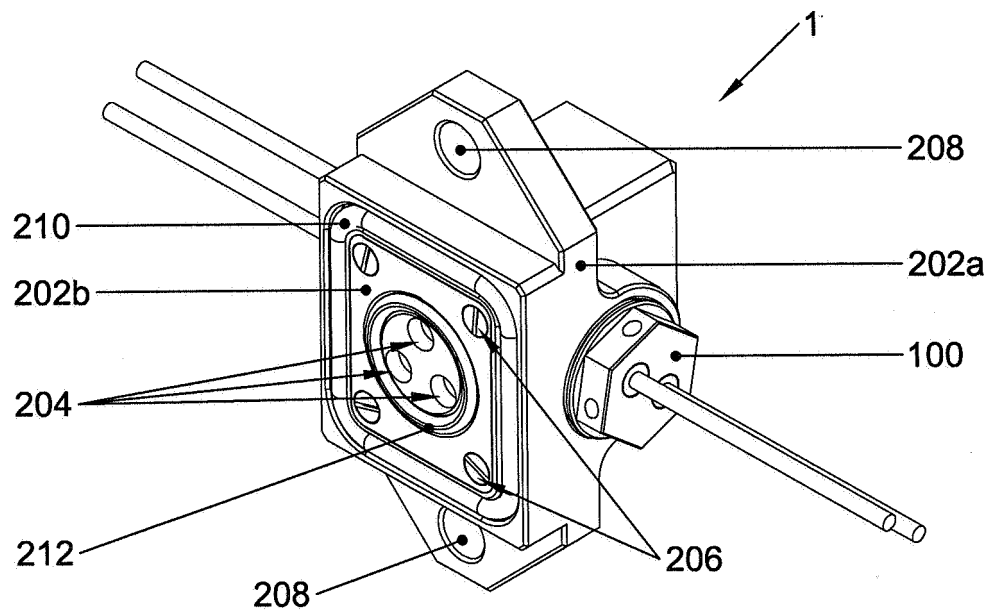


Fig. 1A

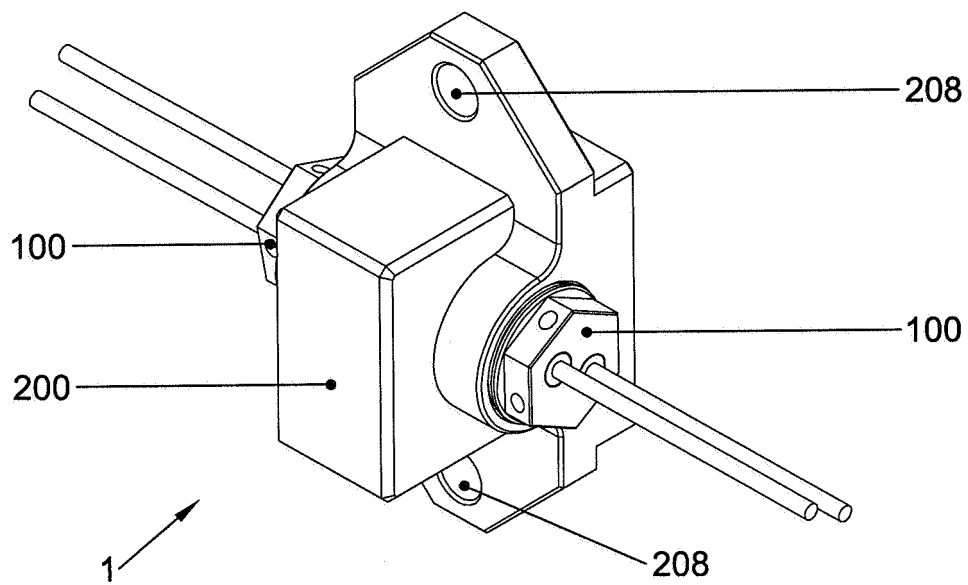


Fig. 1B

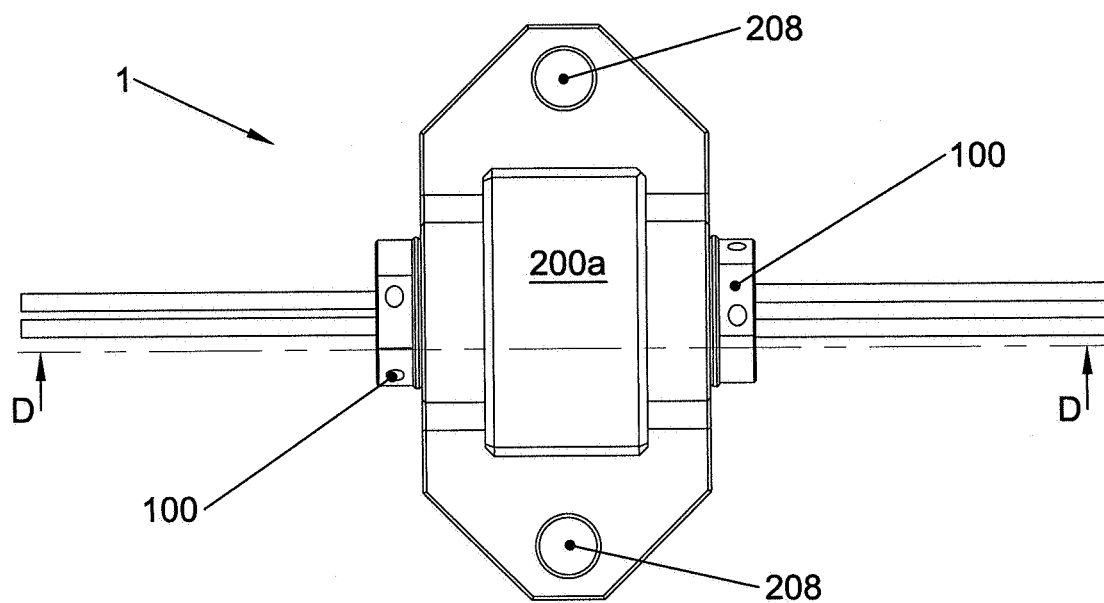


Fig. 1C

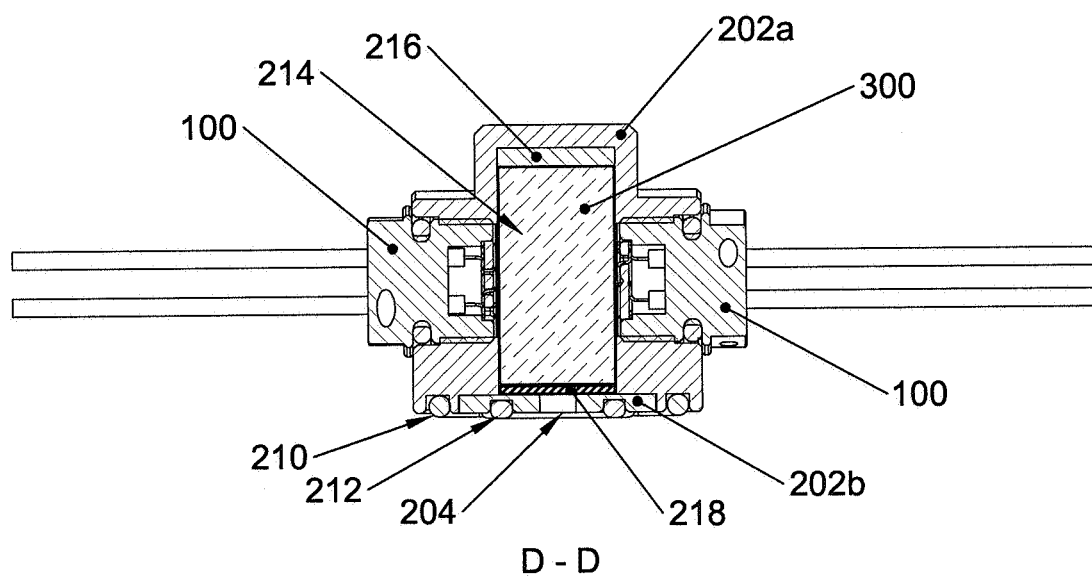


Fig. 1D

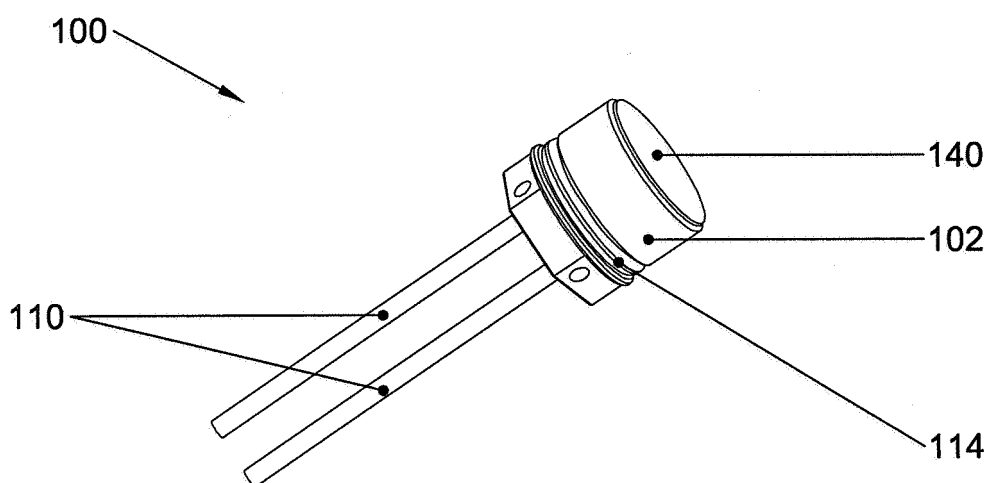


Fig. 2A

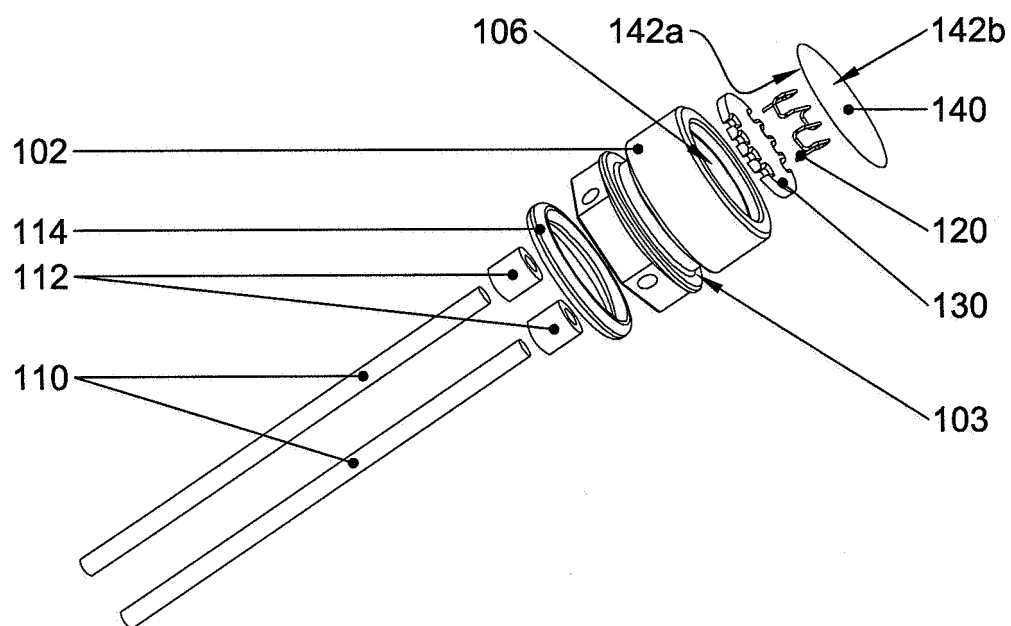


Fig. 2B

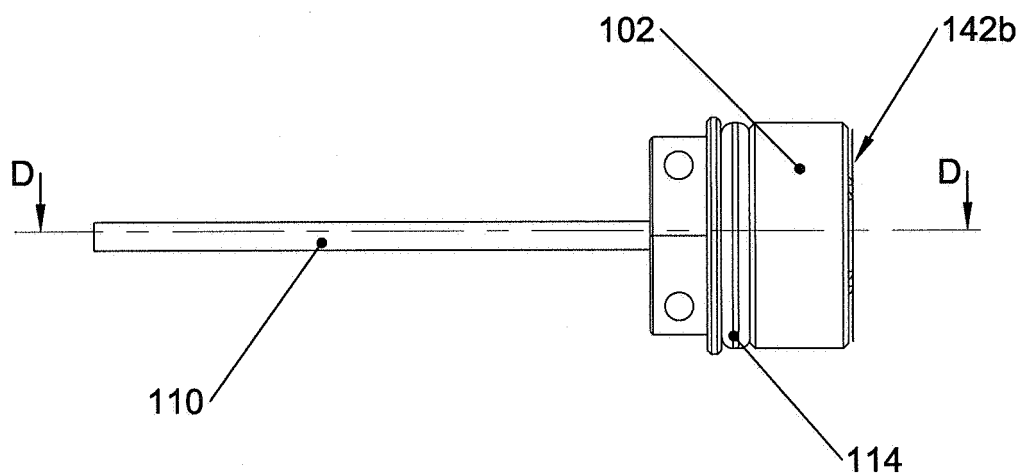


Fig. 2C

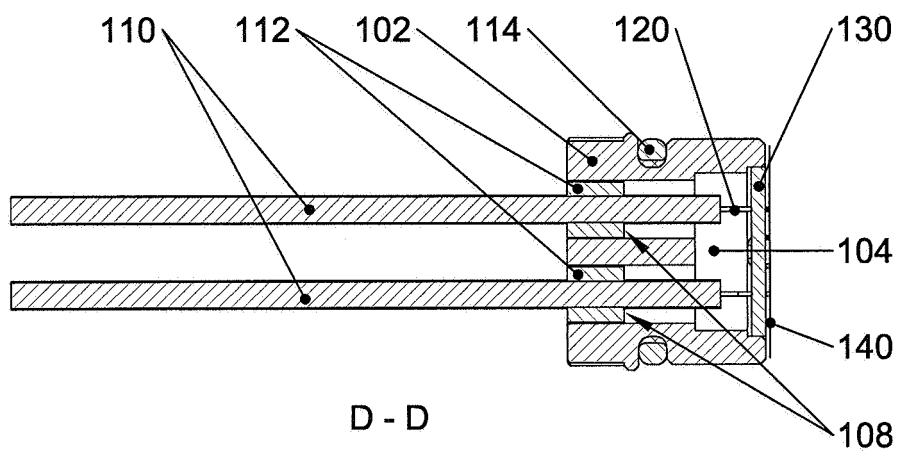


Fig. 2D

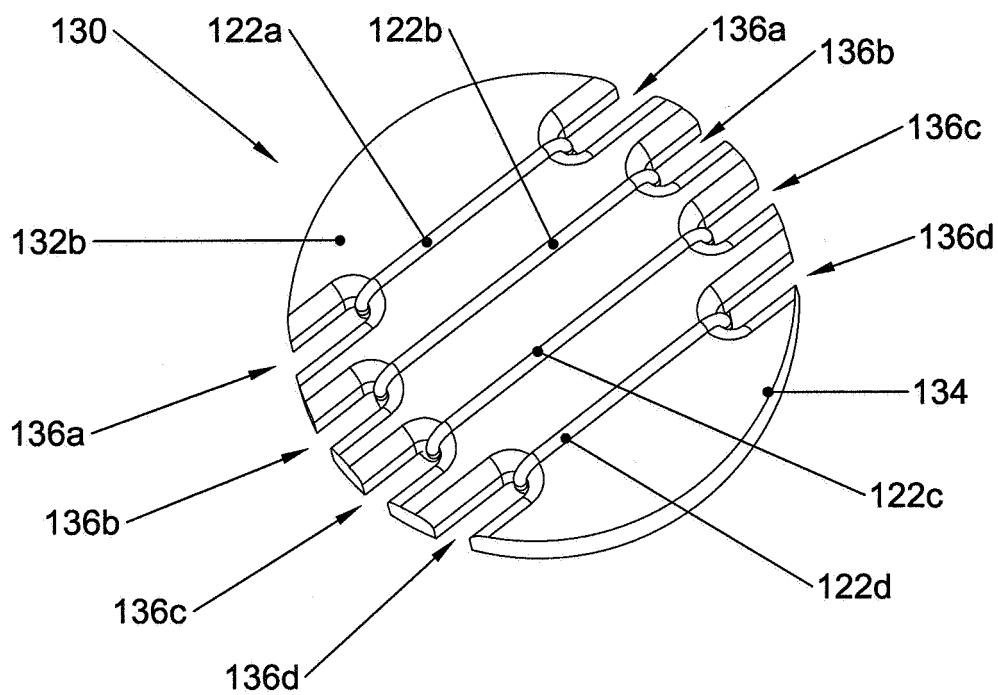


Fig. 2E

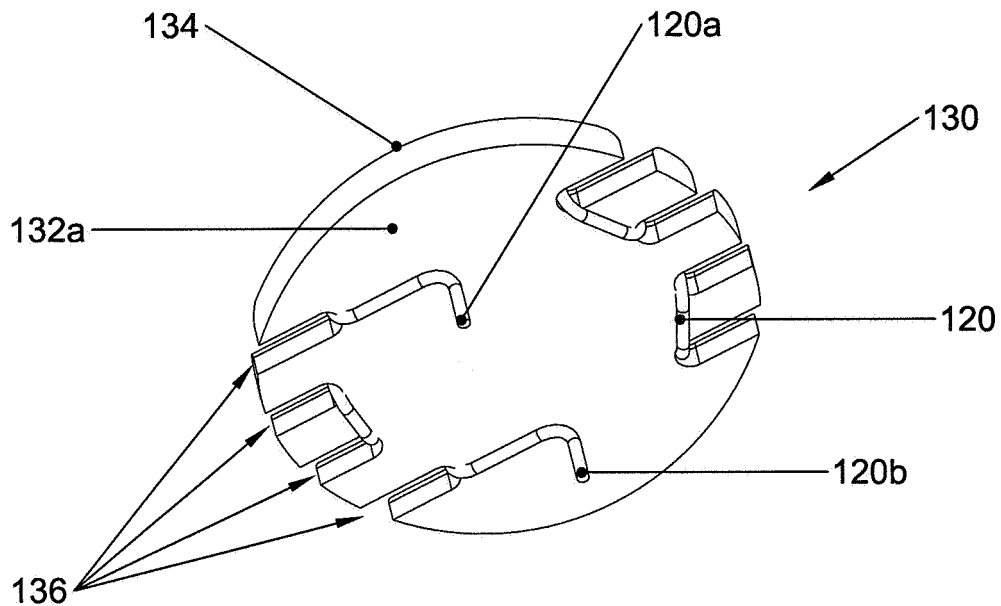


Fig. 2F

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 3059576 A [0004]
- US 2002096078 A1 [0005]
- EP 0779492 A2 [0006]
- US 3134329 A [0007]