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(54) **ENHANCED ENERGY SHAPED CHARGE**

(57) This invention relates to an improved shaped charge perforator, especially an energy enhancement device for a shaped charge perforator, said energy enhancement device located between the perforator and a target, the energy enhancement device comprising a first region comprising a reactive material, and a second region comprising an aperture extending through said en-

ergy enhancement device, wherein said energy enhancement device is located coaxial with the perforator, such that in use the formed jet of the perforator, passes through said aperture, and wherein the detonation output from said perforator impinges on said reactive material to provide further thermal energy to the target.

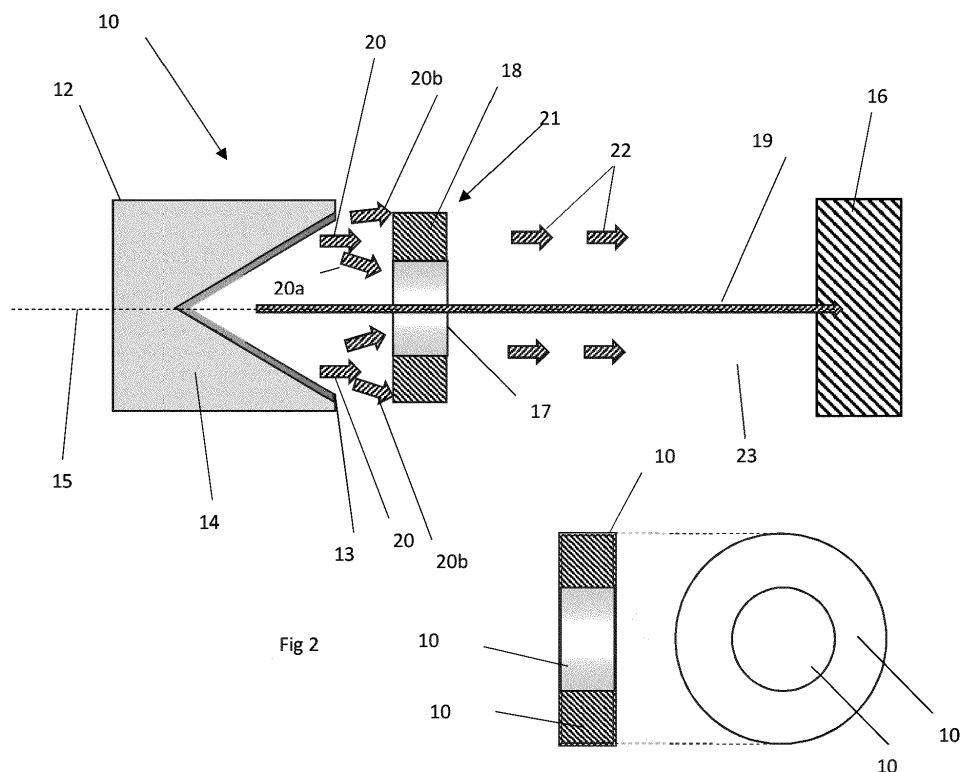


Fig 2

Description

[0001] This invention relates to an improved shaped charge perforator device, especially to energy focussing device to channel more energy from a perforator to a target.

[0002] Shaped charges, perforators, directed energy devices, explosive driven liners have been used to provide a high kinetic energy jet of metal to cut, slice, and penetrate targets.

[0003] According to a first aspect of the invention there is provided an energy enhancement device for a shaped charge perforator, said energy enhancement device located between the perforator and a target, the energy enhancement device comprising a first region comprising a reactive material, and a second region comprising an aperture extending through said energy enhancement device, wherein said aperture of the energy enhancement device is located co-axial with the perforator, such that in use the formed jet of the perforator, passes through said aperture, and wherein the detonation output from said perforator impinges on said reactive material to provide further thermal energy to the target.

[0004] The reactive material may be selected from a solid, powder, powder encapsulated in a binder composition and sintered; reactive materials may also be in the form of liquids, gels or even gases, however the stability of fluids at elevated temperatures and/or high pressures, may cause a hazard. Preferably the reactive material may be a solid, more preferably a powder.

[0005] It is desirable to increase the surface area of the reactive material. For powders and powder compositions they may use micron-, sub-micron- or nano-powder particle sizes, or bi- multi- modal systems thereof, to achieve a high surface area reactive material. Preferably, less than 100microns, preferably less than 1micron.

[0006] Solid materials may also be provided as low density foams or lattices, which have a high internal surface area. The lattices may also be filled with high surface area powders. Preferably to provide the highest mass of material for a given volume, a high surface area powder, or high surface area powder compositions may be used. Powders may take the form of spherical, high aspect ratio, flaked particulates.

[0007] The device may comprise a housing which comprises reactive material composition, the housing may comprise a powdered reactive material. The housing may preferably be formed with the aperture there through. The energy enhancement device may contain only the housing with the reactive material encapsulated therein, with the aperture located in the housing.

[0008] The housing comprising the reactive material may form some, part (a region) or all of the energy enhancement device.

[0009] Whilst not bound by this mode of operation, the reactive material may be used for direct ignition and burn following shock loading from the explosive loading caused by the detonation of the high explosive in the

shaped charge perforator. The powder may be confined in a housing or the powder incorporated into an advanced manufactured part of a component of a munition or perforator. Preferably simple hollow cavity fillings located in front of the perforator with optional further energy enhancement devices located around the shaped charge perforator device, to provide further output.

[0010] The reactive material may be formed into shapes using hot or cold isostatic pressing techniques.

[0011] The reactive material may be selected from a metal, metal alloy, intermetallic, high density reactive material (HDRM).

[0012] Reactive metals may be those that are pyrophoric and/or react with oxygen, water and moisture in the air, such as, for example powdered metals, metal alloys or mixtures thereof for example aluminium.

[0013] Intermetallic compositions, such as for example NiAl, are well known systems for providing thermal energy when activated, such as by thermal or shock means. They provide thermal energy and may provide rapid thermal and/or chemical reactions with water to provide large volumes of gas.

[0014] HDRM compositions are high density materials that when activated, such as by a shock pulse undergo high exothermic reactions, such as rapid thermal and/or chemical reactions with an oxidiser, such as oxygen, in oxygen rich environments to provide large volumes of gas. As a secondary effect the reaction products of the reactive material may further react with water.

[0015] The high density alloying product gives rise to a reaction product with a high unit mass, to provide a high kinetic energy projectile to impact the target. HDRM compositions, may comprise a binder that is capable of providing its own oxidising agent, which may provide large volumes of gas, such as for example perfluorinated binders, to evolve large volumes of gas. Particularly, preferred metal combinations use group IV metals such as hafnium, zirconium, titanium, and preferably mixtures of at least two group IV metals. The metals may be combined with agents, such as boron, carbon, cupric oxide

[0016] In a preferred arrangement the reactive material may undergo an exothermic chemical reaction proximate to the target. The target may be any target typically defeated by shaped charge devices, such as for example a vehicle, vessel, craft, or an oil and gas well.

[0017] For targets that are in a water environment, such as a ship's hull or underwater structure, the reactive material may undergo a chemical exothermic reaction, to create large volumes of gas. This shock energy is in addition to the blast from the action of the high explosive and the perforating jet of the perforator. The formation of large volumes of gaseous products from the reaction of the reactive material and the water, will cause further shock and impact damage to the hull or underwater structures and internal systems.

[0018] Where the target is an oil and gas well completion, the reactive material may react with moisture in the rocks, the rocks may have water in the cracks, fissures

and the tunnels formed by the initial perforating jet of the perforator, this secondary reaction may cause the rapid and violent expansion of water and hence cause further damage to the rocks that have been fractured by the perforator jet, to improve the release and flow of the hydrocarbons therein.

[0019] The energy enhancement device is located between the perforator and the target, such that the detonation of the high explosive causes the initiation of the energy enhancement device, and further causes the reactive material to be ejected/thrown in the direction of the blast towards the target.

[0020] The further energy enhancement devices, as defined herein before may be located rearward of the shaped charge device, or located around the housing of the shaped charge perforator.

[0021] Preferably at least part of the energy enhancement device is located in front of the shaped charge perforator, other parts of the energy enhancement device may extend around the perforator.

[0022] The energy enhancement device when located in front of the perforator may be located at any stand-off, preferably less two charge diameters in front of the perforator more preferably one charge diameter or less, more preferably less than one charge diameter. The device may have substantially zero or less stand-off. The energy enhancement device may be located at the base of the cone of the liner of the shaped charge perforator.

[0023] The device may be affixed to the perforator. The device may be affixed to the housing. The device may be affixed to the liner

[0024] The perforator may have a conical liner, with an apex and a base, wherein the said energy enhancement device may be located such that it may abut the base of the conical liner, therefore providing a less than zero stand-off. The energy enhancement device may be located at less than zero stand-off, it may be in the area defined by the cone liner.

[0025] In use perforators work by using a high explosive charge to collapse a conical liner. The apex region of the cone typically forms the perforating jet and the lower base regions of the cone form the slower moving slug which follows afterwards.

[0026] The aperture must not disrupt the formation of the perforating jet. The aperture may run through the energy enhancement device, to ensure there is no disruption of the perforating jet. It may be there is a thin perforation disc on the entrance or exit of the aperture comprising reactive material to assist in the initiation of the reactive material. Any perforation disc may not disrupt the formation of the perforating jet.

[0027] The aperture must be co-axial with the perforator, specifically co-axial with the apex of the liner, to ensure the jet is not disrupted. The aperture may be any cross section in shape, provided it allows the jet to pass through, typically it may be circular.

[0028] The diameter of the aperture is preferably at least the diameter of the perforating jet diameter, prefer-

ably may be greater than the diameter of the perforating jet.

[0029] In use the high explosive collapses the liner, and the slower moving portion of the base of the liner and the detonation blast may have a diameter greater than that of the perforating jet and therefore a diameter greater than that of the aperture, and so in use, the detonation blast and slower moving portions will impinge on the energy enhancement device thereby causing the activation of the energy enhancement device and concomitantly the blast will cause the activated energy enhancement device to be moved towards the target. The activated energy enhancement device may then react to provide larger volumes of gas either as a result of release of oxidising binders of the composition, or by thermal and/or chemical reaction with the environment near to the target.

[0030] The detonation blast, slower moving portions of liner and the activated energy enhancement device will arrive at the target after the perforating jet has impinged on the target. The additional energy, such as the secondary blast energy from the exothermic reaction of the reactive material, will provide further damage to the target.

[0031] The energy enhancement device may comprise a choke region co-axial with the perforator, said choke region having a diameter less than the diameter of the shaped charge perforator, to channel the detonative output of the high explosive and remaining liner through said choke region and through said aperture. The choke region may further focus i.e. converge the slower moving liner components and detonation blast output through the choke region down to the dimensions of the aperture.

[0032] The choke region in the energy enhancement device may have a first end facing the perforator and a second end which faces the target, a channel connecting the first and second ends, wherein the first end has an effective diameter of less than the perforator charge diameter, more preferably less than 95%, more preferably less than 85% of the perforator charge diameter. The channel may be manufactured such as to reduce its effective diameter along its length from the first end to the second end, thereby providing a focussing effect for the detonation blast and slower moving projectiles.

[0033] In one arrangement the choke and or channel may be parts of the housing. Parts of the choke and or channel may be substantially inert, such that parts of the choke and channel portions do not comprise a reactive material, whilst other regions comprise the reactive material. This may provide enhanced focussing of the detonation blast and slower moving parts of the liner.

[0034] The reduction of the effective diameter of the channel along its length may be linear, exponential, cupola.

[0035] The energy enhancement device may be retrofitted forward of a shaped charge perforator located in a shaped charge delivery system. This allows shaped charge warheads in a munition or oil and gas well perfo-

rators to be provided with an energy enhancement device, without adding further detonative material.

[0036] According to a further aspect of the invention there is provided an energy enhancement device for a shaped charge perforator, said energy enhancement device co-axially located with the perforator and a target, the energy enhancement device comprising a reactive material, such that in use the formed jet of the perforator impinges on the target, and wherein the detonation output from said perforator impinges on said reactive material to provide further thermal energy to the target.

[0037] According to a further aspect of the invention energy enhancement devices may be located around the circumference of the shaped charge device. However, if the device is located in a fixed diameter munition, the use of a collar may cause the diameter of the shaped charge to be reduced to accommodate said collar and shaped charge with an existing device. The use of rearward and/or forward located energy enhancement devices allows the dimensions of the munitions internal cavity to be maintained at the same size. Therefore, any voids within a current munition may be usefully filled with energy enhancement devices.

[0038] According to a further aspect of the invention there is provided a shaped charge delivery system comprising at least one energy enhancing device defined herein.

[0039] The invention will now be described by way of example only with reference to the accompanying drawings, of which:-

Figure 1 showing a shaped charge perforator directed to a target

Figure 2 shows an energy enhancement device located between the perforator and the target

Figure 3 shows a choked energy enhancement device located between the perforator and the target.

Figure 4 shows further arrangements of energy enhancement devices.

[0040] Turning to Fig 1 it shows a shaped charge perforator 1, comprising a shaped charge housing 2, with a copper liner 3, and a high explosive 4, encapsulated by the shaped charge housing 2 and liner 3. Upon detonation of the high explosive 4 the apex of the cone 7 will be ejected to form a perforating jet 9, which will follow the centre line 5 and impinge upon the target 6, which may be an oil and gas well completion, or the hull of a vehicle, vessel or craft. The remainder of the cone 8, will progressively collapse inwardly, with the base forming a slug (not shown) which will trail along behind the perforating jet. The high explosive and housing and slower liner parts are products of the detonation blast and will be ejected outwardly and thrown generally forward of the perforator 1, in the direction of the target.

[0041] Turning to Fig 2, there is provided a shaped charge perforator 10, comprising a shaped charge housing 12, with a metallic liner 13, and a high explosive 14, encapsulated by the shaped charge housing 12 and liner 13. An energy enhancement device 21, is located between the perforator 10 and the target 16, which the hull of a vessel, wherein there is a gap 23, which may be an air gap, or a body of water between the energy device 21 and the target 16. The perforator 10 is co-axially aligned with the aperture 17 of the energy enhancement device 21.

[0042] Upon detonation of the high explosive 14 the apex of the cone will be ejected to form a perforating jet 19, which will follow the centre line 15 and traverse through the aperture 17 unimpeded, and will impinge upon the target 16. The base of the cone will also collapse inwardly and will form a slug (not shown) which will trail along behind the perforating jet. The high explosive and housing and slower liner parts are products of the detonation blast 20 and will be ejected outwardly and thrown generally forward of the perforator 10, after the perforator jet 19. Some detonation products 20b will impinge upon the reactive material 18 in the energy enhancement device 21, causing the reactive material to react and thrown in the direction of the target 16, so that the activated reactive material 22 impinges on the target 16 to cause further damage. In this arrangement the activated reactive material may chemically react with oxidisers whilst transitioning across the gap 23 to provide a secondary blast in the vicinity of the target 16.

[0043] Turning to Fig 3, there is provided a shaped charge perforator 30, comprising a shaped charge housing 32, with a metallic liner 33, and a high explosive 34, encapsulated by the shaped charge housing 32 and liner 33. An energy enhancement device 31, is located between the perforator 30 and the target 36, which is an oil and gas completion.. The perforator 30 is co-axially aligned with the aperture 37 of the energy enhancement device 31.

[0044] Upon detonation of the high explosive 34 the apex of the cone will be ejected to form a perforating jet 39, which will follow the centre line 35 and traverse through the aperture 37 unimpeded, and will impinge upon the target 36. The base of the cone will also collapse inwardly and will form a slug (not shown) which will trail along behind the perforating jet. The high explosive and housing and slower liner parts are products of the detonation blast 40 and will be ejected outwardly and thrown generally forward of the perforator 30, and some detonation products 40b will impinge upon the reactive material 38 in the energy enhancement device 31, causing the reactive material to react and thrown in the direction of the target 36, so that the activated reactive material 42 impinges on the target 36 to cause further damage. In this arrangement the activated reactive material may provide a secondary blast in the oil and gas well completion to further fracture the tunnel created by the perforator jet 39.

[0045] In the arrangement shown, the energy enhancement device 31 comprises a choke region 41, which has a narrower diameter than the base of the cone, such that other parts of the detonation output 40a are fed into the choke region and are focussed by a narrowing diameter channel 43, to the diameter of the aperture. In this arrangement the energy enhancement device 31 may also provide energy focussing. The choke has a diameter less than the diameter of the perforator, to allow the reactive material in the housing to abut the base of the cone liner.

[0046] Turning to Fig 4, there is provided a shaped charge perforator 50, comprising a shaped charge housing 52, with a metallic liner 53, and a high explosive 54, encapsulated by the shaped charge housing 52 and liner 53. An energy enhancement device 51b, is located between the perforator 50 and the target 56, wherein there is a gap 53 which may be an air gap, or a body of water between the energy device 51b and the target 56. The perforator 50 is co-axially aligned with the aperture 57 of the energy enhancement device 51b.

[0047] Alternatively, the arrangement may be a rearwardly located energy device 51a. The shaped charge system which comprises said shaped charge 50, may have a forward 51b, and/or rearward 51a located energy device.

[0048] Upon detonation of the high explosive 54 the apex of the cone will be ejected to form a perforating jet 59, which will follow the centre line 55 and traverse through the aperture 57 unimpeded, and will impinge upon the target 56. The base of the cone will also collapse inwardly and will form a slug (not shown) which will trail along behind the perforating jet.

[0049] The high explosive and housing and slower liner parts are products of the detonation blast 60a, 60b and will be ejected outwardly. Some detonation products 60b will impinge upon the reactive material 58b in the energy enhancement device 51b, causing the reactive material to react and thrown in the direction of the target 56, so that the activated reactive material impinges on the target 56 to cause further damage.

[0050] The detonation products 60a impinge on the rearwardly located 51a energy device, and causes initiation of the reactive material 58a therein.

[0051] The energy enhancement devices 51a and/or 51b when initiated by the detonation products provide increased thermal energy to the target. The gap 53 has been shown as a large distance and the stand-off between the shaped charge 50 and the target may be only a few charge diameters; for a certain munitions which are moving, the shaped charge 50 and said energy enhancement devices may have forward momentum so the device may be travelling at high speed towards the target.

[0052] In this arrangement the activated reactive material may chemically react with oxidisers either in the gap 53 environment (air, water) or with internal oxidisers within the reactive material formulations, whilst transitioning across the gap 53 to provide a secondary blast

in the vicinity of the target 56.

Claims

1. An energy enhancement device for a shaped charge perforator, said energy enhancement device located between the perforator and a target, the energy enhancement device comprising a first region comprising a reactive material, and a second region comprising an aperture extending through said energy enhancement device, wherein said aperture of the energy enhancement device is located co-axial with the perforator, such that in use the formed jet of the perforator, passes through said aperture, and wherein the detonation output from said perforator impinges on said reactive material to provide further thermal energy to the target.
2. A device according to claim 1, wherein the reactive material is selected from a solid, powder, powder encapsulated in a binder and sintered
3. A device according to claim 2, wherein the device comprises a housing which comprises a powdered reactive material.
4. A device according to any one of the preceding claims wherein the device is located less than one/two charge diameters in front of the perforator.
5. A device according to any one of the preceding claims, wherein the device is affixed to the perforator.
6. A device according to claim 5, wherein the perforator has a conical liner, with an apex and a base, wherein the said energy enhancement device is abutting the base of the conical liner.
7. A device according to any one of the preceding claims, wherein the reactive material is a metal, metal alloy, intermetallic, high density reactive material.
8. A device according to any one of the preceding claims, wherein the reactive material undergoes an exothermic chemical reaction with water proximate to the target.
9. A device according to any one of the preceding claims wherein the target is a hull of vehicle, vessel, craft, or an oil and gas well.
10. A device according to any one of the preceding claims, wherein the device comprises a choke region co-axial with the perforator, said choke region having a diameter less than the diameter of the shaped charge perforator, to channel the detonative output of the high explosive and remaining liner through

said choke region and through said aperture. non-jet forming liner

11. A device according to any one of the preceding claims, wherein the device is retrofitted forward of a shaped charge perforator located in a shaped charge delivery system. 5
12. A shaped charge delivery system comprising at least one device as claimed in any one of the preceding claims. 10
13. An energy enhancement device for a shaped charge perforator, said energy enhancement device co-axially located with the perforator and a target, the energy enhancement device comprising a reactive material, such that in use the formed jet of the perforator impinges on the target, and wherein the detonation output from said perforator impinges on said reactive material to provide further thermal energy to the target. 15 20
14. An energy enhancement device according to claim 13, wherein the energy enhancement device co-axially located forward and/or rearward of the perforator. 25

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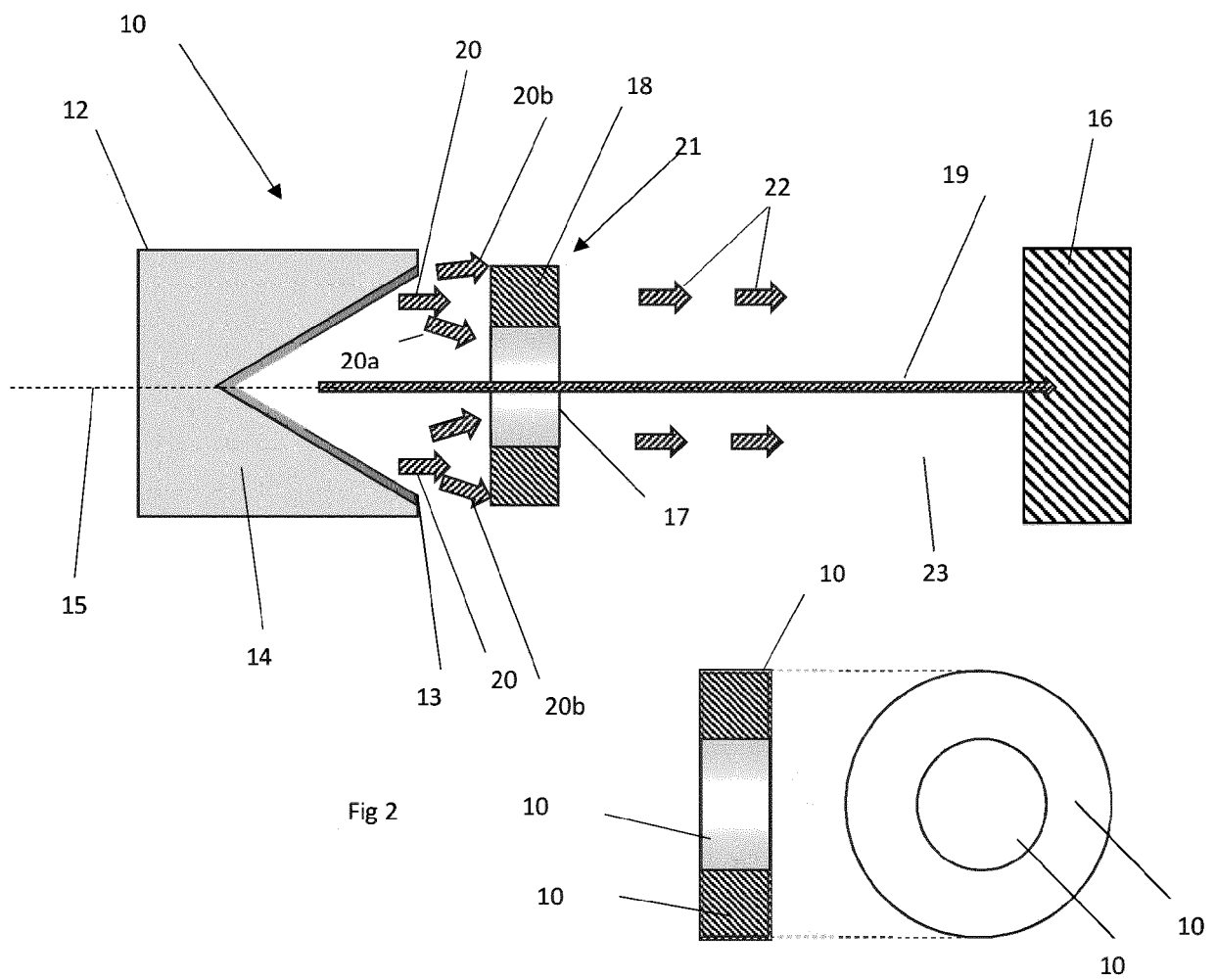
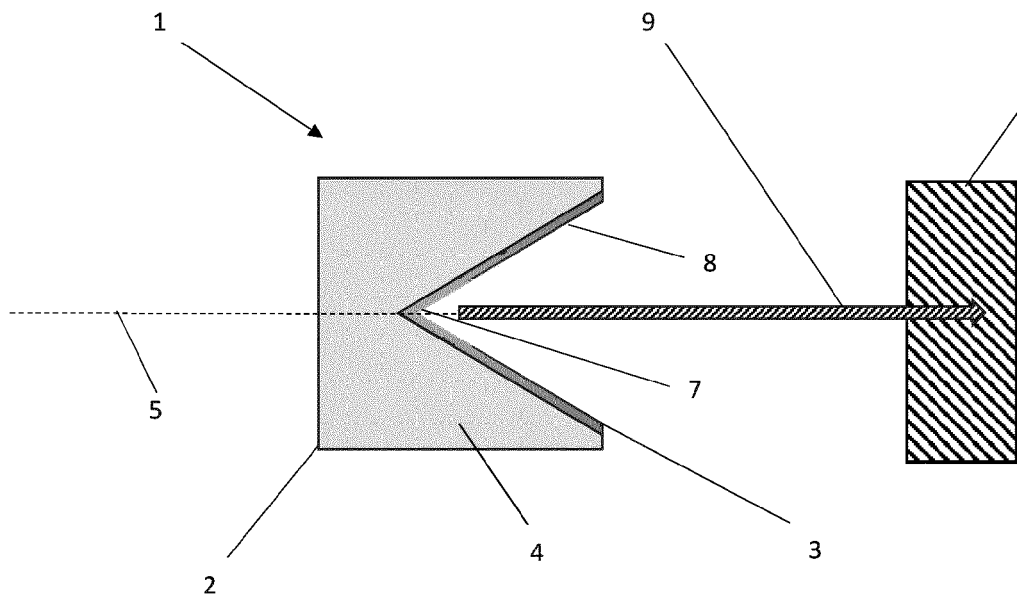
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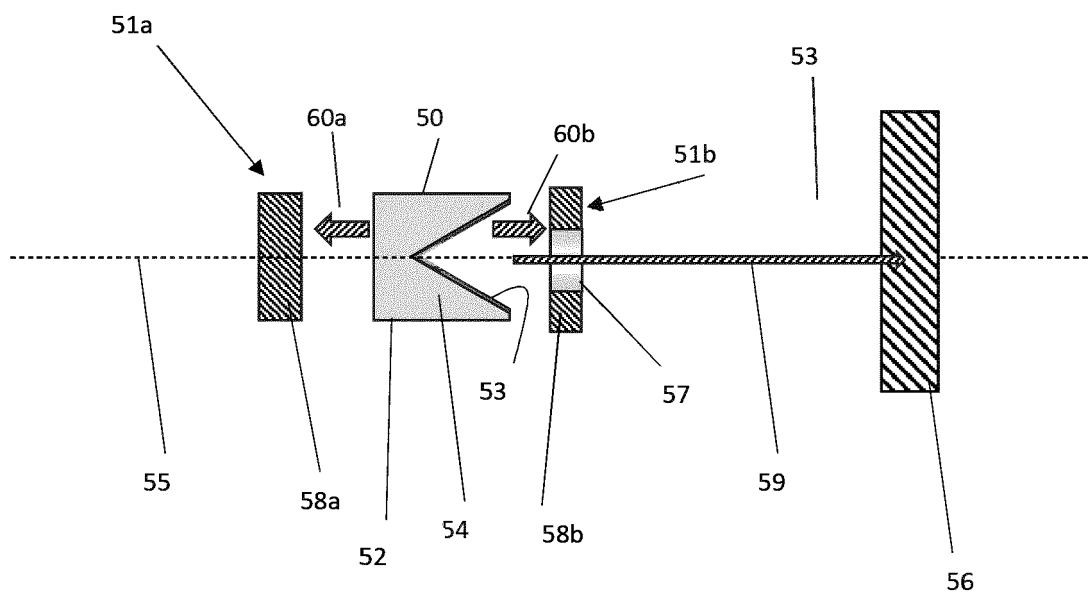
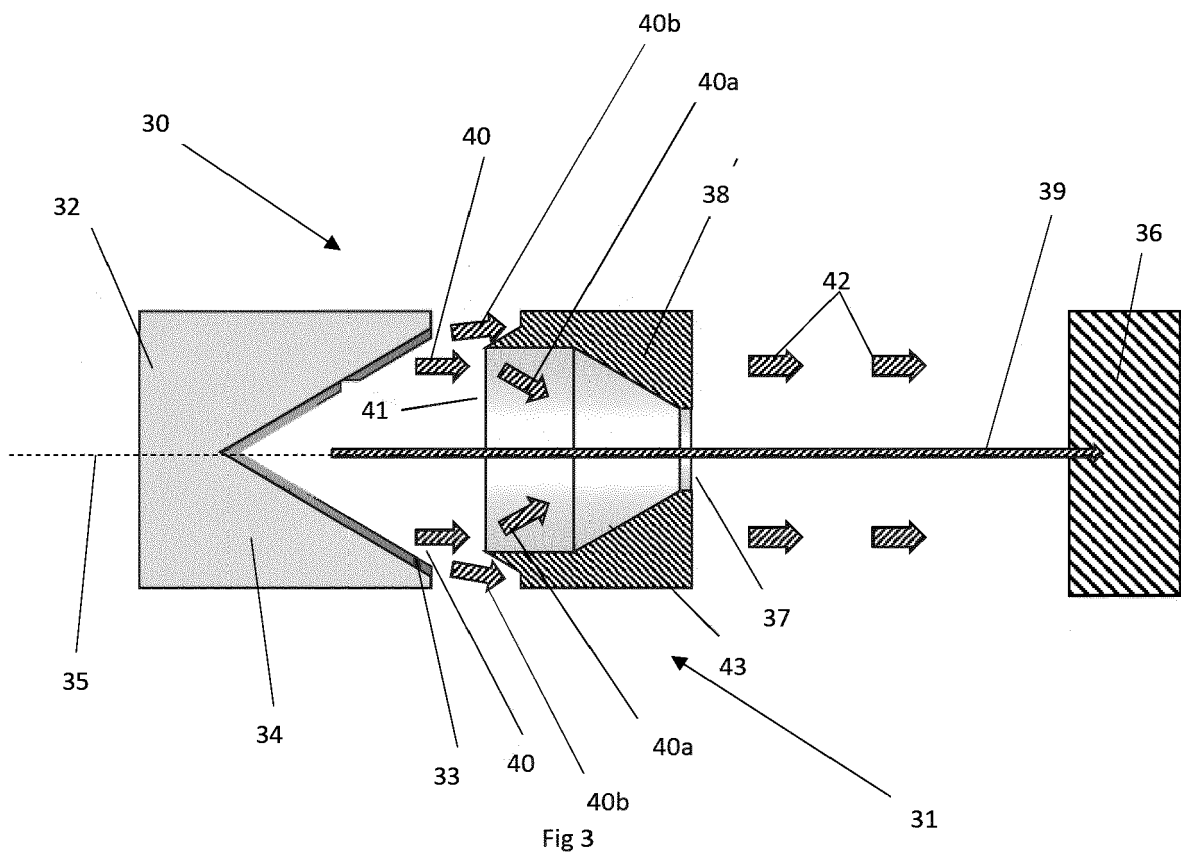
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EUROPEAN SEARCH REPORT

Application Number
EP 20 27 5102

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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			TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 24 November 2020	Examiner Kasten, Klaus
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 20 27 5102

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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