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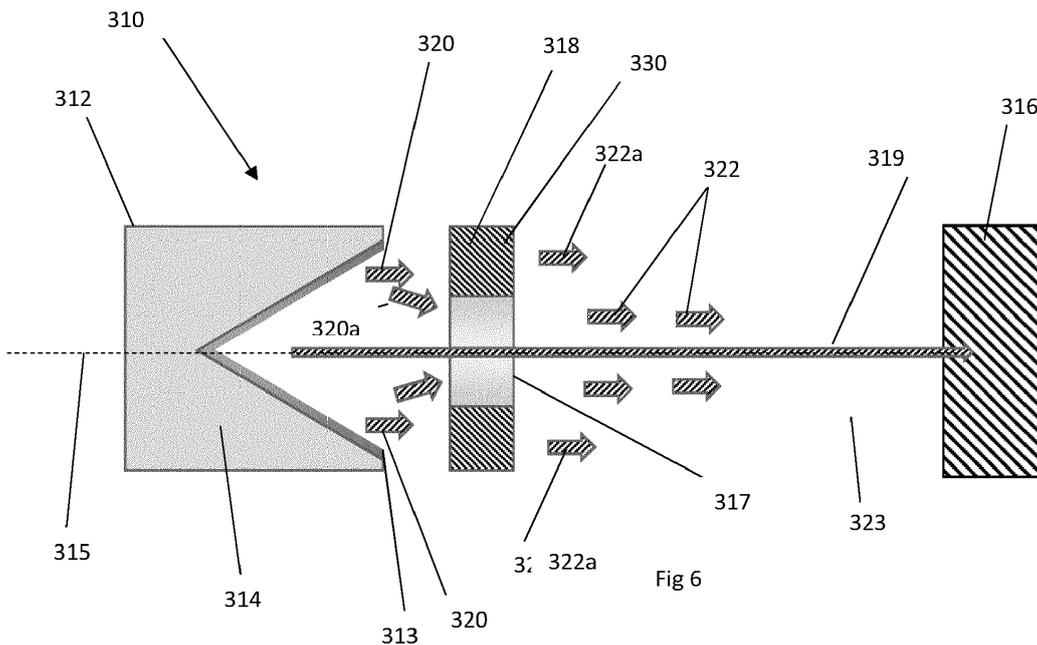
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(54) **IMPROVED SHAPED CHARGE DEVICE**

(57) This invention relates to an improved shaped charge perforator, especially to energy focusing device for a shaped charge perforator, said perforator comprising a high explosive and a liner, wherein the focussing device is located between the perforator and a target, the energy focusing device comprising an aperture there through, wherein the energy focussing device is located co-axial

with the perforator, such that in use said formed jet of the perforator, passes through said aperture, wherein the focussing device comprises a choke region co-axial with the perforator, said choke region has a diameter less than the diameter of the shape charge, to focus the output of the high explosive and remaining liner through said choke region and through said aperture.



## 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 focusing device for a shaped charge perforator, said perforator comprising a high explosive and a liner, wherein the focussing device is located between the perforator and a target, the energy focusing device comprising an aperture there through, wherein the energy focussing device is located co-axial with the perforator, such that in use said formed jet of the perforator, passes through said aperture, wherein the focussing device comprises a choke region co-axial with the perforator, said choke region has an effective diameter less than the effective diameter of the shape charge, to focus the output of the high explosive and remaining liner through said choke region and through said aperture.

**[0004]** The focussing device may be located less than two charge diameters in front of the perforator, more preferably less than a charge diameter, more preferably, the focusing device may have zero stand off from the base of the cone.

**[0005]** The effective diameter is the longest dimension of the cross section of the aperture and or choke region. The aperture and choke region may be of any shaped cross section, such as, for example any polygonal shape may be employed, preferably circular. For a circular aperture and circular choke region the effective diameter will be the diameter of the aperture or choke region.

**[0006]** The choke region has 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 95% of the perforator charge diameter, preferably less than 85%, less than 75%.

**[0007]** The channel may be substantially parallel along its length between the first and second ends, the device may take the form of an annulus or collar. The length of the channel may be selected depending on the munition to which it is being employed. The length of the channel, i.e. thickness of an annulus may be sufficient to withstand the initial detonative blast for long enough to converge and focus the detonative output blast and slower moving parts of the liner. In an alternative arrangement the channel may reduce in its effective diameter along its length from the first end to the second end. Any change in effective diameter along its length may be made.

**[0008]** The effective diameter of the second end of the channel may be the effective diameter of the aperture.

**[0009]** The reduction of the effective diameter of the

channel along its length may be linear, exponential, or cupola. In one arrangement the channel may have non-linear profile. The aperture may be the smallest effective diameter, or the channel may provide along its length a smallest effective diameter, such as for example a torus shape.

**[0010]** The aperture must not disrupt the formation of the perforating jet. The diameter of the aperture is preferably at least the diameter of the perforating jet diameter, preferably may be greater than the diameter of the perforating jet.

**[0011]** In use, the high explosive when detonated collapses the liner to produce a perforating jet, and the slower moving portions of the base of the liner and the detonation blast will have a diameter generally greater than that of the perforating jet, and therefore a diameter greater than that of the aperture, through which the perforating jet will pass. In use, the detonation blast and slower moving portions will impinge on the choke region, which has reduced effective diameter, of the focussing device, and will be converged/focussed into the channel and out through the aperture.

**[0012]** The detonation blast, slower moving portions of liner will arrive at the target after the perforating jet has impinged on the target, this will provide further damage to the target.

**[0013]** The reduction of the effective diameter of the channel along its length may be linear, exponential, cupola.

**[0014]** The target may be any target that is to be defeated or damaged by a shaped charge device, such as for example the target may be a vehicle, vessel, craft, or an oil and gas well.

**[0015]** In a further arrangement the focussing device may further comprise portions of reactive material to provide an energy enhancement device that comprises a choke region co-axial with the perforator.

**[0016]** 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.

**[0017]** 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.

**[0018]** The reactive material may be formed into shapes using hot or cold isostatic pressing techniques.

**[0019]** The reactive material may be selected from a metal, metal alloy, intermetallic, high density reactive material (HDRM).

**[0020]** 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.

**[0021]** 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.

**[0022]** 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.

**[0023]** The focussing device may be retrofitted forward of a shaped charge perforator located in a shaped charge delivery system. There are many munitions and systems in place which employ shaped charge devices, such as, for example, shells, mortars, missiles, torpedoes. The use of a focussing device enhances the penetration of the jet, by converging, focussing the detonative output and slower moving fragments to create further damage to the target. In tests a modelled system showed a 40% increase in performance using a focusing device compared to the same system without.

**[0024]** According to a further aspect of the invention there is provided a shaped charge delivery system comprising at least one shaped charge perforator and at least one device as defined herein.

**[0025]** The invention will now be described by way of example only with reference to the accompanying drawings, of which:-

Figure 1a and 1b shows a shaped charge perforator directed to a target across an air and water gap, respectively.

Figure 2 shows an end effect capture frame of a modelled sequence of the water gap of fig 1a

Figure 3 shows a shaped charge perforator directed to a target across a water gap, with focussing device in front of the perforator.

Figure 4 shows an end effect capture frame of a modelled sequence of the water gap of fig 3.

Figure 5 shows an alternative design of focussing device located between the perforator and the target.

Figure 6 shows a combined focussing and energy enhancement device located between the perforator and the target

**[0026]** Turning to Fig 1a 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 detona-

tion of the high explosive 4 the apex of the cone 7 will be ejected to form a perforating jet 9, which may traverse across an air gap 200, and 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 6. Figure 1b, shows the same arrangement with the air gap being replaced by a volume of water 201.

**[0027]** Turning to Fig 2, there is provided a simulation of a shaped charge being fired through a column of water in line with Figure 1b. The shaped charge was in the location of 101, which was detonated. The liner formed a perforating jet 109, which passed through a first test plate 115, the column of water 111, and into a series of test plates 114. The slower moving slug 110 trails behind the perforating jet 109.

**[0028]** The distance of penetration is measured in the test plates 114, and is represented by the distance 112.

**[0029]** Turning to Figure 3 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. A focussing device 21, is located between the perforator 10 and the target 16, which may be the hull of a vessel, wherein there is a body of water 23, between the focussing device 21 and the target 16. The perforator 10 is co-axially aligned with the aperture 17 of the energy focusing device 21.

**[0030]** 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, through the water 23, 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 will be ejected outwardly and thrown generally forward of the perforator 10, after the perforator jet 19. The detonation products 20 will impinge upon the choke region 18 of the focussing device 21, causing the detonation products 20a to be funnelled, focussed into the device and ejected through the aperture 17 in a more confined, more converged flow of detonation products 22. The converged flow of detonation products 22 impinges on the target 16 to cause further damage.

**[0031]** Turning to Figure 4, there is provided the same simulation as run in Fig 2, of a shaped charge being fired through a column of water in line this time with the arrangement as shown in Figure 3, including the focussing device 221 of the invention. The shaped charge was in the location of 201, which was detonated. The liner

formed a perforating jet 209, which passed through the focussing device 221, a first test plate 215, the column of water 211, and into a series of test plates 214. The slower moving slug 210 trails behind the perforating jet 209.

**[0032]** The distance of penetration is measured in the test plates 214, and is represented by the distance 212. The penetration distance 212 has been shown to be a 40% increase in length, compared to the exact same set up, without the focussing device being present. All other parameters were fixed. This is a significant increase in penetration depth, which has been caused by the focussing device directing and channelling the detonation products through a reduced diameter aperture to direct further energy to the target 214.

**[0033]** Turning to Fig 5, 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 focussing device 31, is located between the perforator 30 and the target 36, which may be an oil and gas completion or a hull of a ship. The perforator 30 is co-axially aligned with the aperture 37 of the focussing device 31.

**[0034]** Upon detonation of the high explosive 34 the apex of the cone 45 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 44 will also collapse inwardly and will form a slug (not shown) which will trail along behind the perforating jet. The detonating high explosive, 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 the detonation products 40 will impinge upon the reduced first diameter 41 of the choke region 38 of the device 31.

**[0035]** In the arrangement shown the choke region 38, has a narrower first diameter 41 than the base of the cone 44, such that other parts of the detonation output 40a are fed or funnelled into the choke region and are focussed by a narrowing diameter channel 43, to the diameter of the aperture 37, the second diameter. The detonation products 40a once focussed into the device are ejected through the aperture 37 in a more confined, more converged flow of detonation products 42. The converged flow of detonation products 42 impinges on the target 16 to cause further damage. The choke 38 has a diameter 41 less than the diameter of the perforator base 44, to allow the device to abut the base of the cone liner.

**[0036]** Turning to Figure 6 there is provided a shaped charge perforator 310, comprising a shaped charge housing 312, with a metallic liner 313, and a high explosive 314, encapsulated by the shaped charge housing 312 and liner 313. A combined focusing and energy device 318, is located between the perforator 310 and the target 316, which may be the hull of a vessel, wherein there is an air gap 323a, between the device 318 and the target 16. The perforator 310 is co-axially aligned with

the aperture 317 of the device 318.

**[0037]** Upon detonation of the high explosive 314 the apex of the cone will be ejected to form a perforating jet 319, which will follow the centre line 315 and traverse through the aperture 317 unimpeded, through the gap 323, and will impinge upon the target 316. 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 320, 320a will be ejected outwardly and thrown generally forward of the perforator 310, after the perforator jet 319. The detonation products 320a, will impinge upon the choke region of the device 318, causing the detonation products 320a to be funnelled, focussed into the device and ejected through the aperture 317 in a more confined, more converged flow of detonation products 322. The converged flow of detonation products 322 impinges on the target 316 to cause further damage. Concomitantly the detonation products 320 will impinge on the reactive material 330, causing a secondary thermal reaction product 322a, which will provide further damage to the target 316.

## 25 Claims

1. An energy focusing device for a shaped charge perforator, said perforator comprising a high explosive and a liner, wherein the focussing device is located between the perforator and a target, the energy focusing device comprising an aperture there through, wherein the energy focussing device is located co-axial with the perforator, such that in use said formed jet of the perforator, passes through said aperture, wherein the focussing device comprises a choke region co-axial with the perforator, said choke region has a diameter less than the diameter of the shape charge, to focus the output of the high explosive and remaining liner through said choke region and through said aperture.
2. A device according to any one of the preceding claims wherein the device is located at less than one charge diameter stand off from the perforator.
3. A device according to claim 2, wherein the device is located at zero or less charge diameter stand off from the perforator.
4. A device according to any one of the preceding claims, wherein the choke region has 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 95% of the perforator charge diameter.
5. A device according to claim 4, wherein the channel is substantially parallel along its length between the

first and second ends.

6. A device according to any one claims 1 to 4, wherein the channel reduces in its effective diameter along its length from the first end to the second end. 5
7. A device according to claim 6, wherein the reduction of the effective diameter of the channel along its length is linear, exponential, cupola. 10
8. A device according to claim 4 to claim 7 wherein the effective diameter of the second end is the effective diameter of the aperture. 15
9. A device according to any one of the preceding claims wherein the energy focussing device comprises a reactive material, such that in use, the detonation output from said perforator impinges on said reactive material to provide further thermal energy proximate to the target. 20
10. A device according to claim 9, wherein the reactive material is a metal, metal alloy, intermetallic, high density reactive material. 25
11. A device according to any one of claims 8 or 9, wherein the reactive material liner undergoes an exothermic chemical reaction with water proximate to the target. 30
12. 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. 35
13. A device according to any one of the preceding claims, wherein the device is affixed to the perforator, wherein the perforator has a conical liner, with an apex and a base, wherein said focussing device is abutting the base of the conical liner. 40
14. 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. 45
15. A shaped charge delivery system comprising at least one shaped charge perforator and at least one device as claimed in any one of the preceding claims. 50

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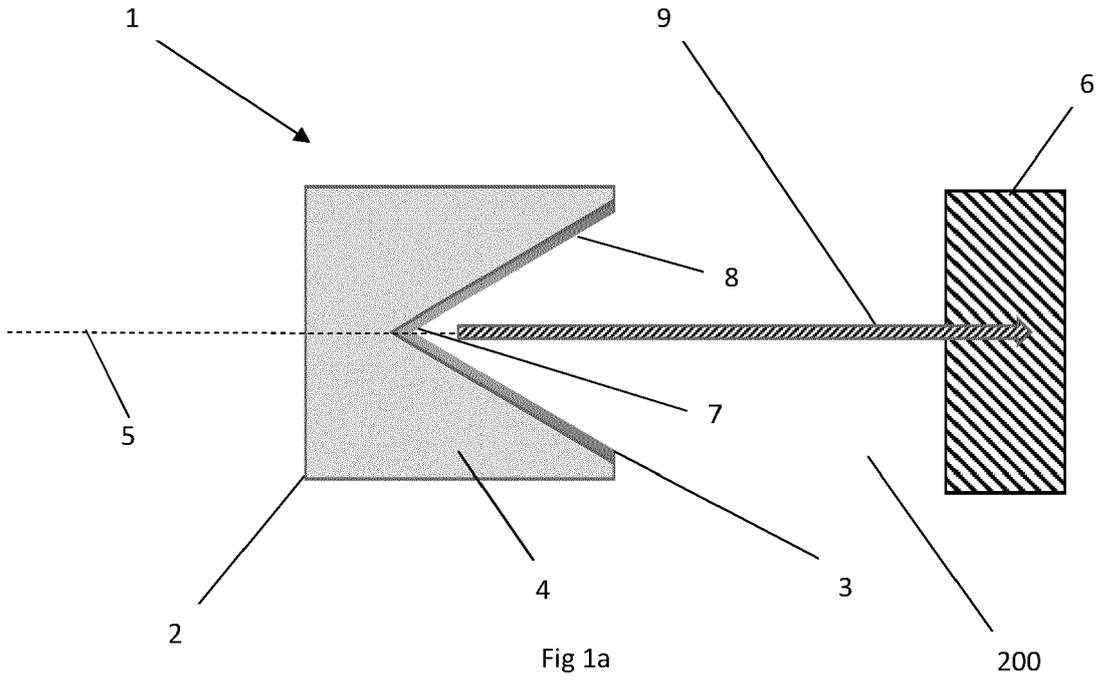


Fig 1a

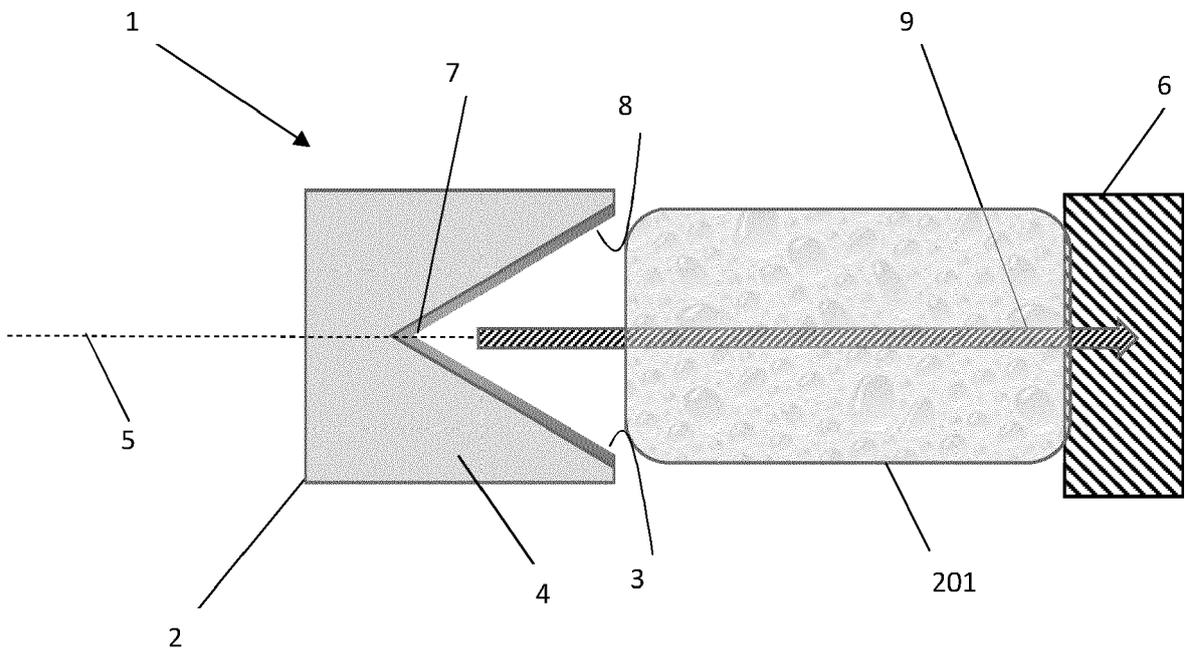


Fig 1b

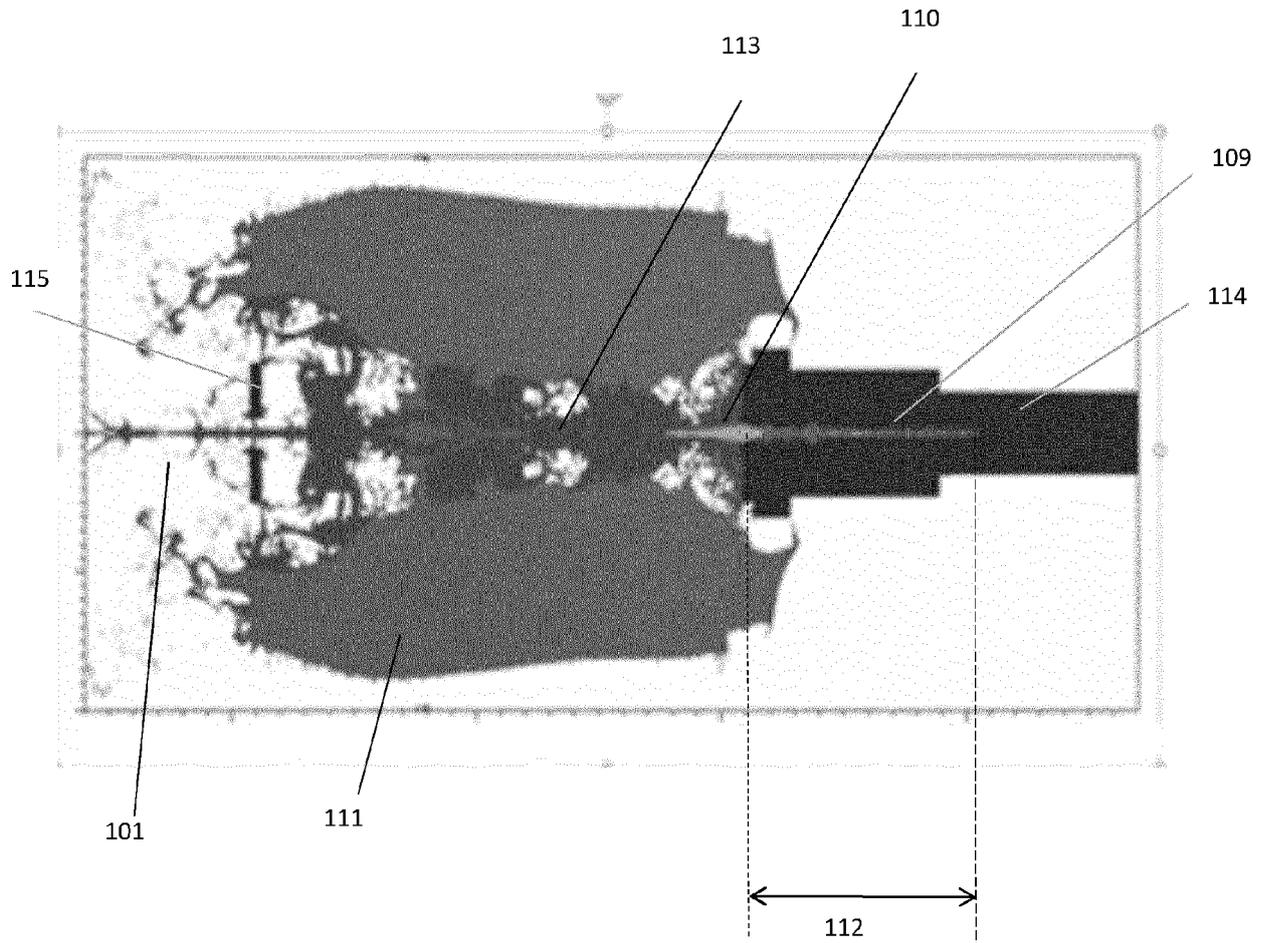


Fig 2



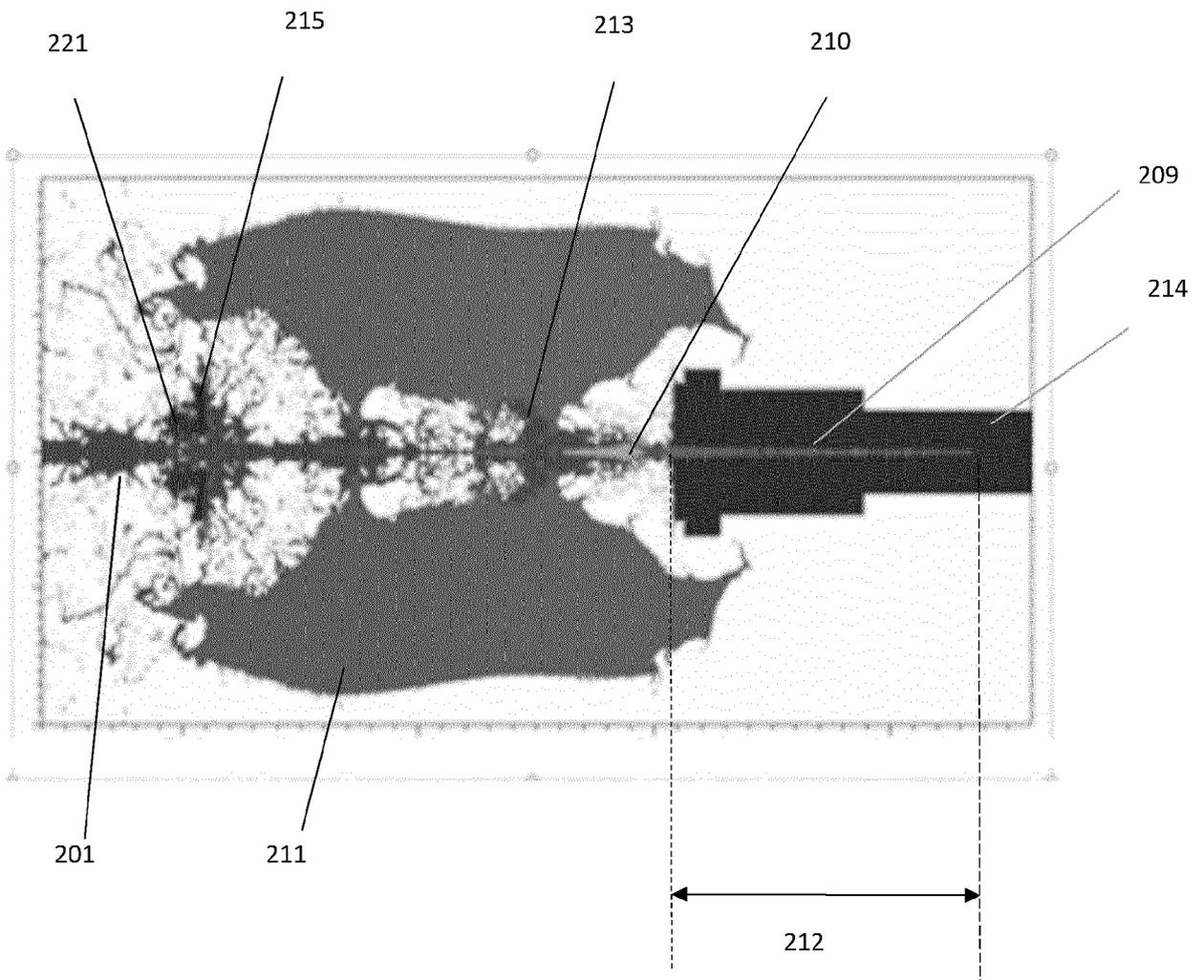


Fig 4

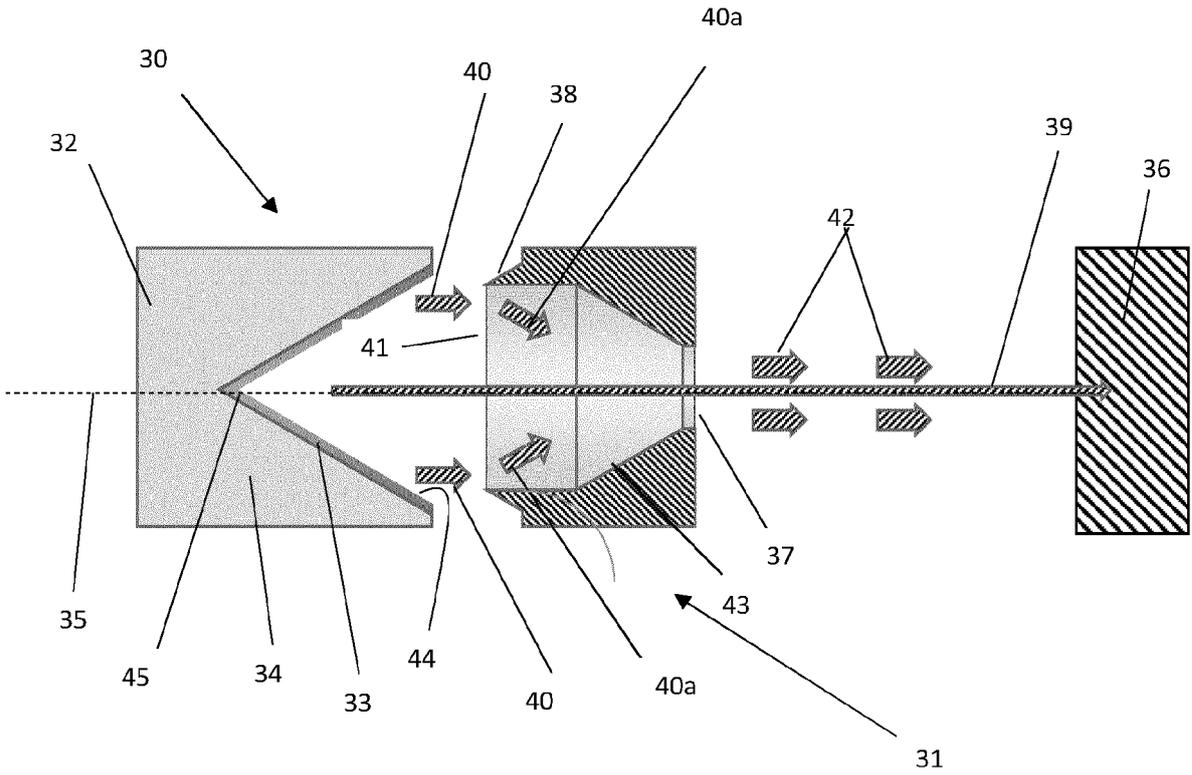


Fig 5

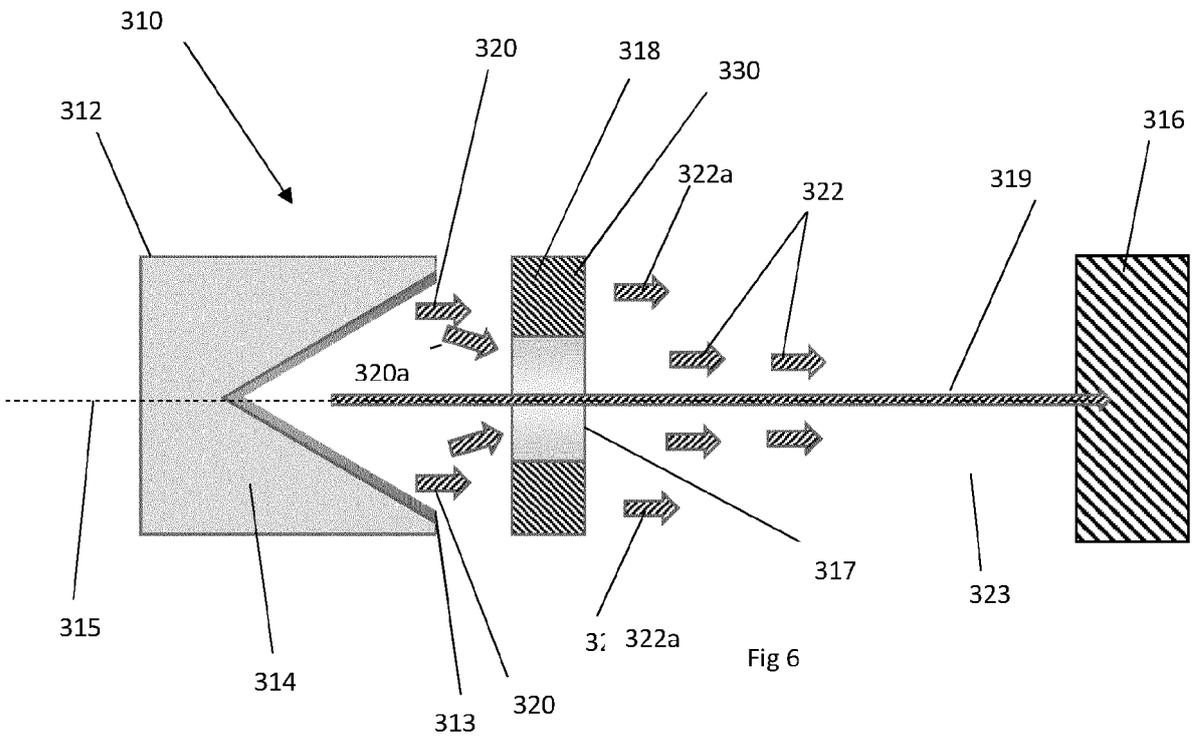


Fig 6



EUROPEAN SEARCH REPORT

Application Number  
EP 20 27 5101

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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 23 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	

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**ANNEX TO THE EUROPEAN SEARCH REPORT  
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EP 20 27 5101

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82