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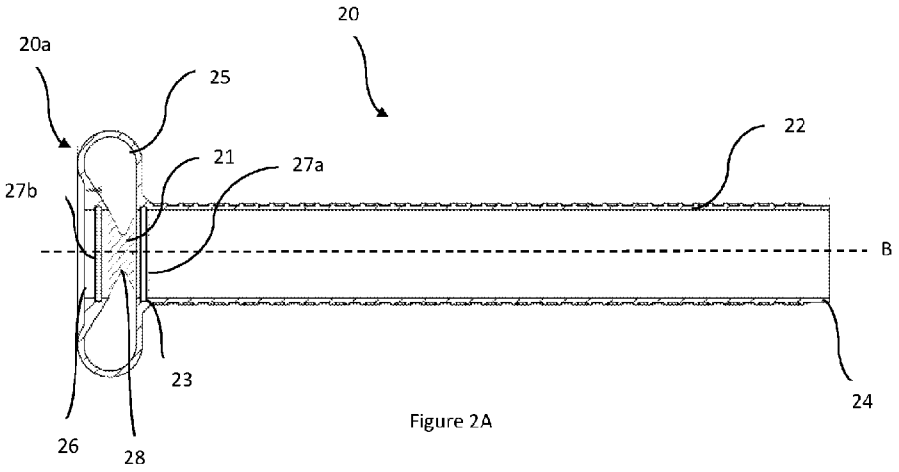

Figure 2A

(57) Abstract: A pneumatic propulsion apparatus (20), having a gun barrel (22) with a breach end (23) and a muzzle end (24), and a valve assembly (20a) having a gas reservoir (25) in fluid connection with the barrel (22) at the breach end (23), the valve assembly also comprising an initiation means. A shuttle (21) is held within the reservoir (25) in a blocking position in which gas from the gas reservoir (25) is prevented from entering the barrel (22). In use, the initiation means allows for the shuttle (21) to be translatable along the barrel (22) under the action of air pressure. The invention is particularly suited for use in underwater or compact systems. The invention also relates to a projectile launch apparatus.

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PNEUMATIC PROPULSION APPARATUS

Technical Field of the Invention

This invention relates to the field of pneumatic propulsion and in particular to pneumatic propulsion apparatuses comprising valves for fast and efficient delivery of propulsion gases.

Background to the Invention

Pneumatic propulsion systems use pressurised gases as a power source in propelling, moving, or translating an object. Pneumatic projectile launchers can be used in both above water environments (for instance airsoft, air rifle, or paint ball guns) and in underwater applications (for instance in harpoon guns or underwater mine disposal apparatuses). These projectile launchers often rely on spring operated valves to quickly deliver high pressure gas from a gas canister or other high pressure gas source into a barrel in order to propel a projectile located in the barrel using the associated air pressure force. The valves rely on a sufficient pressure differential across the valve to trigger the valve into, and maintain the valve in, an open position, allowing gas to flow.

Opening a spring operated valve in a pneumatic projectile launcher results in high pressure gas filling the volume in the gun barrel between the projectile and valve. This affects the pressure differential across the valve, and can cause the valve to inadvertently close. As the projectile subsequently translates along the barrel, the volume between the valve and projectile increases leading to a reduction in pressure. This again affects the pressure differential across the valve, which in this case can enable it to re-open. This process can repeat rapidly during the initial stages of launching a projectile, causing the valve to flutter between open and closed positions. This fluttering affects the flow of high pressure gas and consequential transfer of momentum to the projectile, and can lead to an inefficient projectile launch.

An alternative valve assembly comprises a shuttle within a gas reservoir that can be translated from a blocking position (in which gas from the reservoir is prevented from entering a gun barrel) to an open position (in which gas can flow). Such an arrangement is less susceptible to fluttering between open and closed positions owing to the shuttle translation (and thereby valve opening) being irreversible once initiated (in fact the shuttle may itself be propelled

along and out of the barrel). However the location of the shuttle within the gas reservoir occupies volume that otherwise would be utilised to hold expulsion gases for the pneumatic launcher. This compromises the thrust (force) that can be applied to a projectile being launched, particularly in otherwise constrained environments such as underwater applications or compact systems.

Therefore it is an aim of the present invention to provide a pneumatic propulsion apparatus that mitigates these issues.

Summary of the Invention

According to a first aspect of the invention, there is provided a pneumatic propulsion apparatus comprising a gun barrel having a breech and a muzzle, and a valve assembly comprising a gas reservoir in fluid connection with the barrel, wherein the gas reservoir contains a shuttle held arranged on the axis of the barrel in a blocking configuration in which gas from the gas reservoir is prevented from entering the barrel, wherein the shuttle is translatable along the barrel away from the blocking configuration under the action of an air pressure force, the valve assembly further comprising initiation means for initiating the translation of the shuttle such that gas in the gas reservoir can act on the shuttle to provide the air pressure force to translate the shuttle along the barrel, wherein the shuttle further comprises a shuttle neck.

By providing a valve assembly comprising a gas reservoir containing a shuttle translatable away from a blocking configuration, a reliable valve mechanism for providing propulsion gas into a gun barrel is provided that does not suffer from the aforementioned valve "fluttering" associated with prior art spring based fast-acting valves. This ensures a more efficient fluid flow of expulsion gases into the gun barrel and subsequent transfer of momentum to a projectile or object being launched. The shuttle having a shuttle neck ensures that the shuttle when located in the gas reservoir occupies minimal volume, leaving greater volume to store propulsion gases, ultimately leading to greater available thrust from a similar sized gas reservoir of prior art devices. The inventor has therefore found that the benefits of a shuttle based valve can be realised without compromising significantly on available gas storage volume within a gas reservoir. Furthermore the arrangement of the shuttle on the barrel axis and the presence of a shuttle neck provides a gas occupied volume adjacent the shuttle neck

that resides within the overall spatial extent of the gun barrel. The inventor has found that this improves fluid flow of propulsion gases acting on the shuttle when the valve assembly is initiated. This further improves the efficient transfer of momentum from the high pressure gases in the gas reservoir to the shuttle and projectile or object being launched.

The gun barrel of the pneumatic propulsion apparatus is intended to be elongate having a breech and a muzzle. The gun barrel may have any cross-sectional shape. The gun barrel is intended to be tubular such that a projectile and shuttle can translate along the barrel. The interior dimensions of the barrel will be sized and shaped to be compatible with translation of the projectile and shuttle. The muzzle of the gun barrel is the front of the gun barrel, more clearly the open end of the barrel from which a projectile is launched. The breech of the gun barrel is the rear of the gun barrel, more clearly the end of the barrel that is closed, opposite the muzzle end. The gun barrel may be constructed from metal such as Steel, Aluminium or Inconel alloy. Alternatively the gun barrel may comprise carbon fibre or may even comprise a plastic material dependent upon the gas pressures being utilised to launch a projectile.

The valve assembly comprises a gas reservoir. The gas reservoir stores the propulsion gases that will be deployed to provide the air pressure force acting on the shuttle and that will ultimately launch a projectile. The propulsion gases, by way of example, may comprise Helium, Nitrogen or Air, compressed to a desired and predetermined gas pressure and temperature within the reservoir. Helium has been found to provide greatest projectile speeds and so is preferred in a number of embodiments. The gas reservoir is in fluid connection with the barrel. The term 'fluid connection' is intended to mean that gas from the gas reservoir is able to flow into the gun barrel (when the shuttle is moved away from the blocking configuration). The gas reservoir further contains the shuttle, on the axis of the barrel. The axis of the gun barrel is the longitudinal concentric axis along the elongate direction of the barrel. The shuttle is arranged on this axis but also within the gas reservoir. By way of example, this may mean the shuttle is effectively located within the barrel and surrounded by the gas reservoir, for instance. Importantly the shuttle experiences the gas pressure within the gas barrel directly when located within the gas reservoir. The shuttle itself, within the reservoir, is held arranged in a blocking configuration. This configuration locates the shuttle in a position in which gases are prevented in flowing from the gas reservoir into the gun barrel. This is, in effect, a pre-launch configuration of the pneumatic propulsion

apparatus i.e. the shuttle does not experience a net air pressure force urging the shuttle along the barrel. The shuttle is unable to deviate from this configuration without some form of initiation. The shuttle may be sized to provide an interference type fit to the gun barrel, thereby providing the desired blocking effect when in the blocking configuration. The shuttle may alternatively be sized to abut a sealing means, such as o-rings arranged internally to the gun barrel. Said sealing means may alternatively from part of the exterior surface of the shuttle. The shuttle itself may be of generally cylindrical form as would be compatible with the majority of cylindrical gun barrel designs.

The shuttle is translatable along the barrel under action of an air pressure force. In this regard, the shuttle can be translated away from the blocking configuration along the barrel under the influence of the pressurised gases contained within the gas reservoir. The shuttle therefore must be sized to allow transit through the gun barrel in addition to being suitably sized and arranged to provide the prevention of gas flow, in cooperation with any sealing means, when in the blocking configuration. The shuttle itself is also intended to be elongate having a muzzle facing end and a breech facing end.

An initiation means is provided to initiate the translation of the shuttle away from the blocking configuration. The shuttle is held in the blocking configuration prior to initiation of the pneumatic propulsion apparatus. Gases from the gas reservoir are prevented from flowing into the gun barrel in this configuration, meaning gases cannot enter the gun barrel ahead of, or behind, the shuttle. Therefore the shuttle may be held in the blocking configuration in an equilibrium state, in which no net air pressure force is acting on the shuttle axially along the length of the barrel. The initiation means initiates the translation of the shuttle away from such a position, such that an air pressure force from the gases within the gas reservoir can act on the shuttle to provide a net air pressure force, and therefore propulsion, along the barrel. The initiation means may comprise any device that can provide some translation of the shuttle away from the equilibrium state. For instance this may comprise a mechanical based actuation of the shuttle or may alternatively comprise pneumatic actuation such as venting of a small amount of gas from the gas reservoir into the gun barrel at the breech end (i.e. 'behind' the shuttle). Once the shuttle has move translated away from the blocking configuration, for instance in the direction of the muzzle, gases from the gas reservoir can enter the gun barrel behind the shuttle and provide a net air pressure force that continues

the translation of the shuttle towards the muzzle. The propulsion apparatus may comprise a locking connection (such as a pin) for safety reasons, or other suitable means for retaining the shuttle in the blocking position up until launch. Advantageously, a ball bearing coupler assembly (sometimes described as a quick fit connector) can be used to pneumatically lock the shuttle in the equilibrium state, such that filling of the reservoir occurs by gas flow through the ball bearing coupler assembly through fluid conduits in the shuttle and into the reservoir. This provides further reassurance the shuttle would not inadvertently migrate away from the blocking position, as pressure within the ball bearing coupler assembly ensures the coupler remains locked.

The shuttle comprises a shuttle neck, meaning a narrow connecting part between two opposing ends (muzzle facing and breech facing ends) of the shuttle. The shuttle neck is narrow with respect to the opposing ends of the shuttle. This ensures the volume of the gas reservoir occupied by the shuttle is reduced, whilst still allowing a shuttle-based valve operation. The location of the shuttle on the barrel axis, and the shuttle neck, allow gases in the gas reservoir to occupy space within the spatial extent of the barrel (i.e. adjacent the shuttle neck) which has been shown to improve fluid flow of propulsion gases during launch of the shuttle. The shuttle neck may be more practically considered to be a cut-out or groove peripherally extending around the shuttle about the barrel axis. The shuttle may be formed of metal, for instance Aluminium or an Inconel Alloy, or may comprise carbon fibre or a plastics material, dependent upon the gas pressures being used within the pneumatic propulsion apparatus.

In preferred embodiments of the invention the gas reservoir extends radially outwards from the barrel. This provides a gas reservoir that has minimally effect on the overall length of the pneumatic propulsion apparatus. This also reduces the required length, along the axis of the barrel, of the shuttle within the gas reservoir. Even more preferred is that the gas reservoir has a toroidal cross section. The toroidal shaping provides for smoother gas flow from the gas reservoir when the shuttle is initiated. This is a result of the reduction in sharp or abrupt edges within the gas reservoir.

In some embodiments, the gas reservoir is arranged at the breech of the barrel. This allows for extended projectiles to be launched such as barrier penetrators that can extend forwards

from the shuttle position along the majority of the length of the gun barrel. Locating the gas reservoir at the breech of the barrel also allows for breech loading in some preferred embodiments, for instance by providing a removable stop plug at the rear of the gas reservoir through which a projectile and shuttle can be loaded prior to filling the gas reservoir with high pressure gas. Muzzle loaded variants are also envisaged.

In some embodiments the gas reservoir comprises sealing means at the interface with the barrel for sealing the barrel against the shuttle in the blocking configuration. Alternatively the sealing means may form part of the shuttle itself. This ensures in the blocking configuration a reliable gas tight seal is achieved between the shuttle and gas reservoir/barrel. The sealing means preferably is one or more o-rings and may include back up rings. These may be provided at both the muzzle facing and breech facing ends of the shuttle, to seal the gun-barrel at both ends. The o-rings may comprise Viton or polyurethane materials. Alternatively the sealing means may comprise piston seals.

In preferred embodiments the shuttle is cylindrical having a rear-end facing the breech and a front-end facing the muzzle. Gun barrels are typically of circular cross-section, particularly on their interior side. A cylindrical shuttle is therefore considered compatible with the majority of gun barrels.

Preferably, the shuttle neck comprises a substantially v-shaped notch extending around the shuttle. The two sides (faces) of the v-shape of the notch may be oriented at the same or different angles to the shuttle axis. For instance an angle of 30 degrees may be used for each making a V-shaped notch or 90 degrees for one and 45 degrees for the other making an N-shaped notch. The notch depth, and angles, can be specified to affect fluid flow, impulse, and balance the volume of the gas reservoir occupied by the shuttle, with the structural rigidity of the shuttle in view of the gas pressures of operation of the propulsion apparatus. A v-shape notch is balanced.

In some embodiments, the shuttle rear-end and front-end may be shaped to enable greater propulsion. For instance the shuttle rear-end may be shaped to provide blast deflection and the shuttle front-end may be shaped to have a more aerodynamic presentation. The rear-end may in preferred embodiments be frustoconical for instance. The precise cone-angle may be optimised for particular propulsion effects, however embodiments using a cone angle of

approximately 20-30 degrees, even more preferably 24 degrees, have been found effective by the inventor. The front-end may in preferred embodiments be frustoconical also. This may be implemented merely by providing clipped corners or edges on the front-end, for instance, which allow for smoother transition of the shuttle along the barrel.

In some embodiments, the shuttle front-end comprises a tapered hollow arranged concentrically to the barrel axis. Such a tapered hollow may be implemented to mate with or provide a seat for a projectile being launched, for instance, when a projectile is launched out of the barrel from the shuttle and the shuttle is stopped from exiting the barrel allowing the projectile to propagate away from the shuttle.

In some embodiments, the shuttle neck is frangible when exposed to a gas pressure exceeding a predetermined pressure value, such that in-use the shuttle can be broken into forward and rear sections, the forward section being translatable along the barrel. Such embodiments seek to operate in a manner similar to a conventional burst disc used in pressurised systems. However conventional burst disks will typically break and leave around their periphery within a gun barrel disposable materials preventing re-loading and re-use of the launcher. The inventor has found that by providing a shuttle with a shuttle neck that breaks when exposed to a gas pressure exceeding the predetermined pressure value, a burst disc effect can be achieved with at least the forward section (ahead of the shuttle neck) of the shuttle being propelled out of the gun barrel, and the rearward section of the shuttle being removable from the gun barrel for instance through a breach loading mechanism or expulsion as per the manner in which standard shell casings are expelled from gun barrels. Hence the launcher can be reloaded and used again. The frangible nature of the shuttle neck can be tailored to particular predetermined pressure values through construction material but also dimensions. For instance, more simpler embodiments may maintain a shuttle made of a homogenous material, but narrow the shuttle neck sufficiently to be breakable at the predetermined pressure value.

Even more preferred is that for embodiments comprising a shuttle with a frangible shuttle neck, the initiation means comprises gas compression means for increasing the gas pressure within the gas reservoir above the predetermined pressure value. In these embodiments the gas pressure within the gas reservoir is set or charged to a pressure value below the

predetermined pressure value when the propulsion apparatus is in a pre-launch configuration. Upon initiation, this gas pressure is increased above the predetermined pressure value in order to cause the shuttle neck to break and the gas from the gas reservoir to flow into the gun barrel to propel a projectile. The gas compression means may comprise an external higher gas pressure reservoir that is connected to the gas reservoir of the propulsion apparatus. Upon initiation, the higher pressure gas flows into the lower pressure gas reservoir of the propulsion apparatus until an equilibrium pressure between the two reservoirs is reached. Alternatively the gas reservoir of the propulsion apparatus may be connected to a high pressure gas feed that provides gas into the gas reservoir. As a further alternative, a combustible material or a pyrotechnic charge may be initiated to generate additional propulsion gas that enters the gas reservoir and causes a gas compression effect, increasing the internal gas pressure of the gas reservoir above the predetermined pressure value. In further preferred embodiments however, the gas compression means comprises a piston arranged within the gas reservoir, the piston being arranged to be pneumatically actuated by an air pressure force from a secondary gas reservoir. The operation of these embodiments is similar to a two staged gas gun where a primary stage is used to propel a mass to compress a secondary stage to achieve high gas pressures. The gas reservoir of the propulsion apparatus in such embodiments is filled with a gas up to a particular gas pressure. Within the same reservoir is a piston, which may only be a piston plate, for instance. The piston is translatable within the gas reservoir to compress gas within the gas reservoir to a higher gas pressure. In order for the translation and gas compression to occur, the piston must itself experience a force that overcomes the force acting on it by the gas in the gas reservoir. This additional translating force can be generated by using higher pressure gas from a secondary gas reservoir to act on the piston, for instance.

In some embodiments, the initiation means comprises venting means for venting gas from the gas reservoir into the breech end of the barrel. This is a convenient mechanism for initiating the translation of the shuttle because it utilises components and gases already present and available in the propulsion apparatus without the requirement for additional complex mechanical parts.

According to a second aspect of the invention, there is provided a projectile launch apparatus comprising the pneumatic propulsion apparatus of any preceding claim and a projectile receivable into the barrel. The projectile may be a shell, a bullet, a harpoon, a dart, for above or underwater applications, for instance. The projectile is receivable into the barrel such that it can be launched from the barrel through the muzzle. The projectile may be breech or muzzle loaded, depending on the embodiment of the pneumatic propulsion apparatus being used. In some embodiments the shuttle and projectile are separate components, in other preferred embodiments they are attached to each other i.e. the projectile is propelled and launched from the gun barrel with the shuttle. In some embodiments, for instance, the shuttle may be integrated into the projectile. This allows for further elongate projectiles that may, for instance, comprise a forward section ahead of the shuttle neck that is a barrier penetrator, and a rear section behind the shuttle neck that comprises an eyelet or other means for attaching a rope or cabling (the rope or cabling optionally be pre-attached). This allows for the projectile to be fired into a target to provide an anchoring system in applications such as recovery or attachment to submerged articles, rock cliffs, trees or buildings, for instance.

The filling of the gas reservoir with high pressure gas in some embodiments may be achieved through a dedicated port to the gas reservoir. The port may in some embodiments transit through the shuttle (for instance longitudinally) such that the gas reservoir can be filled from the rear or breech of the apparatus. The port itself may connect physically the breech of the gun barrel to the shuttle via an appropriate connection, such as a ball bearing connection comprising male and female parts. Such a connection would lock tight when the port is pressurised during and after filling of the gas reservoir owing to internal gas pressures acting on the bearings. This would effectively lock the shuttle in position safely prior to initiation. However, as may be utilised in some embodiments, a one way valve in the port that prevents gases escaping the gas reservoir after filling, would mean upon the evacuation of the port on the filling side of the one-way valve, the ball bearing connection would loosen meaning an initiation means could more readily trigger the translation of the shuttle and initiate the launch mechanism. Such initiation means may comprise a regulator that maintains some gas from the gas reservoir or other gas source behind the shuttle in a space adjacent the breech, such that when the ball bearing connection is loosened from venting of the port, sufficient gas pressure behind the shuttle exists to overcome the ball bearing connection, initiate

translation of the shuttle, and the subsequent gas flow from the gas reservoir into the gun barrel behind the shuttle enabling launch.

Any feature in one aspect of the invention may be applied to any other aspects of the invention, in any appropriate combination. The invention extends to a device, as herein described, with reference to the accompanying drawings.

In all aspects, the invention may comprise, consist essentially of, or consist of any feature or combination of features.

Brief Description of the Drawings

Embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 provides an illustration in side view of an embodiment of a pneumatic propulsion apparatus;

Figure 2a provides an illustration in cut-away side view of an embodiment of a pneumatic propulsion apparatus with a shuttle in the blocking configuration;

Figure 2b provides an illustration in cut-away side view of the embodiment of Figure 2a with shuttle translated away from the blocking configuration;

Figure 3a provides an illustration in cut-away side view of a further embodiment of a pneumatic propulsion apparatus with a shuttle in the blocking configuration;

Figure 3b provides an illustration in cut-away side view of the embodiment of Figure 3a with shuttle translated away from the blocking configuration.

Figure 4a provides an illustration in side view of an embodiment of a shuttle comprising a shuttle neck; and

Figure 4b provides an illustration in cut-away side view of the embodiment of a shuttle shown in Figure 4a.

Detailed Description

Figure 1 provides an illustration in side-view of an embodiment of a pneumatic propulsion apparatus 10. The apparatus 10 comprises an elongate gun barrel 11 extending from a breech 12 to a muzzle 13. The gun barrel 11 is of tubular construction and is cylindrical in shape. The gun barrel 11 is shown with a honeycomb outer surface providing structural rigidity with reduced weight, although the gun barrel 11 has a completed smooth and fluid tight inner surface. The gun barrel 11 is manufactured from metal (such as aluminium) or composite (such as carbon fibre) and is approximately 400mm in length and 42mm in diameter. The gun barrel 11 is attached to a gas reservoir 14 at the breech 12. The gas reservoir 14 extends radially outwards from the axis 'A' of the gun barrel 11 to have an overall diameter of 150mm. The gas reservoir 14 only extends a short distance along the axis 'A' of the gun barrel 11, approximately 50mm, and so is considered elongate in a radial direction relative the axis 'A'. The gas reservoir 14 is in fluid connection with the gun barrel 11. The reservoir 14 is shown as having a toroidal cross section and is manufactured from metal (such as aluminium, steel or Inconel). The internal configuration of the pneumatic propulsion apparatus 10 is not shown, but is discussed for the subsequent figures.

Figure 2a provides an illustration in cut-away side view of an embodiment of a pneumatic propulsion apparatus 20 with a shuttle 21 in the blocking configuration. The size, dimensions and materials of construction are those described for Figure 1. The apparatus 20 comprises an elongate gun barrel 22 having a breech 23 and muzzle 24. The barrel 22 is shown as tubular. The valve assembly 20a comprises a gas reservoir 25 and shuttle 21, and initiation means not show. The gas reservoir 25 is clearly shown connected at the breech end 23 of the gun barrel 22. The gas reservoir 25 extends radially from the axis "B" of the gun barrel 22. The shape of the gas reservoir 25 is toroidal. The shuttle 21 is shown arranged within the gas reservoir 25 and on the axis "B" of the gun barrel 22. The shuttle 21 is seated in a removable stop plug 26 at the rear or breech end of the gas reservoir 25. The shuttle 21 extends along the axis "B" of the gun barrel 22 through the gas reservoir 25 and into the gun barrel 22. The shuttle 21 provides an interference fit to the gun barrel 22 and stop plug 26 via peripheral o-rings 27a and 27b. The shuttle 21 therefore seals the gas reservoir 25 and pressurised gases therein from being in fluid connection with the gun barrel 22. The shuttle 21 is also shown with a substantially "V" shaped neck 28 located within the gas reservoir 25. This shuttle neck 28 provides additional volume within the gas reservoir 25 for containing pressurised gases. The

shuttle 21 is in an equilibrium position with no net gas pressure force acting along the axis "B" of the gun barrel 22. Owing to the sealed gas reservoir 25, no pressurised gases contained therein can act on the shuttle 21 to propel the shuttle 21 along the gun barrel 22. The shuttle 21 itself is constructed from metal (such as aluminium), composite (such as carbon fibre) or semi crystalline thermoplastic (such as Polyether ether ketone (PEEK)). Not shown is an initiation means comprising a vent for allowing a portion of pressurised gas from reservoir 25 to propagate into the stop plug 26 behind the shuttle 21. Such a vent comprises a port that can be opened or closed by a user to initiate the apparatus 20.

Figure 2b provides an illustration in cut-away side view of the embodiment 20 of Figure 2a with shuttle 21 translated away from the blocking configuration. An initiation means (not shown) has translated the shuttle 21 along the axis "B" away from its seated position within the stop plug 26. This has caused the shuttle 21 to translate further into gun barrel 22. As a result, the shuttle 21 no longer seals against the stop plug 26 and o-ring 27b, allowing pressurised gases in gas reservoir 25 to flow behind the rear-end 29 of the shuttle 21 facing the breech 23. Owing to the pressurised gases now acting on the rear-end 29 of the shuttle 21, a net force propels the shuttle 21 along the axis "B" of the gun barrel 22. The gas reservoir 25 is in full fluid connection with the gun barrel 22 and because the shuttle 21 has physically translated along the barrel 22, there is no return of the shuttle 21 to the blocking configuration shown in Figure 2a. This means there is no equivalent of the "fluttering" effect experienced with prior art spring based valves.

Figure 3a provides an illustration in cut-away side view of a further embodiment of a pneumatic propulsion apparatus 30 with a shuttle 31 in the blocking configuration. An elongate gun barrel 32 is shown having an open muzzle end 33 and a breech end 34. The gun barrel 32 is connected to a gas reservoir 35 at the breech 34. The gas reservoir 35 extends radially outwards from an axis "C" of the gun barrel 32. On the axis "C" and within the gas reservoir 35 is a shuttle 31. The shuttle 31 is arranged to block the gun barrel 32 from the gas reservoir 35 such that pressurised gases in the gas reservoir 35 cannot escape into the gun barrel 32. The shuttle 31 is also arranged within the gas reservoir 35 such that the rear breach-facing end of the shuttle 31 is against a wall of the reservoir 35 such that it is not exposed to pressurised gases within the reservoir 35. The shuttle 31 itself comprises a shuttle neck 36. The shuttle neck 36 has a diameter that renders it frangible when exposed to pressures within

the gas reservoir 35 that exceed a predetermined pressure value. Also shown within the gas reservoir 35 is a piston 37. The piston 37 is arranged such that on a first side 38 the piston 37 is exposed to the gas pressure within the gas reservoir 35. The piston 37 is further arranged such that on a second side 39 the piston 37 is exposed to a secondary gas pressure within a secondary reservoir 40. In the arrangement shown, the gas pressure within the gas reservoir 35 is below the predetermined pressure value for breaking the shuttle neck 36. The gas pressure within the secondary reservoir 40 is equal to the pressure within the gas reservoir 35. As a result, the piston 37 is in an equilibrium state and not moving.

Figure 3b provides an illustration in cut-away side view of the embodiment 30 of Figure 3a with shuttle 31 translated away from the blocking configuration. A gas of higher pressure than that in gas reservoir 35 has been injected into the secondary reservoir 40. This has caused piston 37 to translate within the gas reservoir 35 towards the gun barrel 32. This has reduced the volume within gas reservoir 35 and compressed the gas therein causing the gas pressure within gas reservoir 35 to exceed the predetermined pressure value. This has resulted in shuttle neck 36 breaking and part of shuttle 31 translating along the gun barrel 32 along axis "C". Gases from gas reservoir 35 can now flow into the gun barrel 32 propelling the shuttle 31 and any projectile out of the muzzle 33.

Figure 4a provides an illustration in side view of an embodiment of a shuttle 41 comprising a shuttle neck 42. The shuttle 41 has a shape resembling a shuttle cock. The shuttle 41 is substantially cylindrical with a substantially "V" shaped shuttle neck 42 between rear-end 43 and front-end 44. The angle subtended between the sides of the shuttle neck 42 is 60 degrees. The shuttle neck 42 has a diameter of approximately 18mm. The rear-end 43 of the shuttle 41 is frustoconical with a tapered edge 45 subtending an angle of approximately 24 degrees to the vertical. The front-end 44 is substantially cylindrical. The shuttle 41 is constructed from metal (such as aluminium), composite (such as carbon fibre) or semi crystalline thermoplastic (such as PEEK) and has an overall maximum diameter of approximately 42mm.

Figure 4b provides an illustration in cut-away side view of the embodiment of a shuttle 41 shown in Figure 4a. The illustration shows the shuttle 41 being formed from a single piece of homogenous material. A conical carving 45 is now visible in the front end 44 of the shuttle 41. The conical carving 45 provides locating space for a projectile.

Whilst the embodiments have been described in detail, they are provided by way of example only and are not intended to be limiting. In particular, materials of construction, shapes and dimensions can be varied and adjusted in accordance with particular applications. The invention has been described with specific reference to pneumatic launch apparatus, however although projectiles have not been shown or described in the drawings in detail, it would be clear to the skilled person that the embodiments described may be used to launch projectiles of the type typically propelled by pneumatic launch systems such as harpoons, darts, bullets, shells, as examples. Additional applications of the invention will occur to the skilled person.

CLAIMS

1. Pneumatic propulsion apparatus comprising a gun barrel having a breech and a muzzle, and a valve assembly comprising a gas reservoir in fluid connection with the barrel, wherein the gas reservoir contains a shuttle held arranged on the axis of the barrel in a blocking configuration in which gas from the gas reservoir is prevented from entering the barrel, wherein the shuttle is translatable along the barrel away from the blocking configuration under the action of an air pressure force, the valve assembly comprising initiation means for initiating the translation of the shuttle such that gas in the gas reservoir can act on the shuttle to provide the air pressure force to translate the shuttle along the barrel, wherein the shuttle comprises a shuttle neck.

2. The pneumatic propulsion apparatus of claim 1, wherein the gas reservoir extends radially outwards from the barrel.

3. The pneumatic propulsion apparatus of claim 2, wherein the gas reservoir has a toroidal cross section.

4. The pneumatic propulsion apparatus of any preceding claim, wherein the gas reservoir is arranged at the breech of the barrel.

5. The pneumatic propulsion apparatus of claim 4, wherein the gas reservoir comprises a removable stop plug on the barrel axis for breech loading of the shuttle.

6. The pneumatic propulsion apparatus of any preceding claim, wherein the gas reservoir comprises sealing means at the interface with the barrel for sealing the barrel against the shuttle in the blocking configuration.

7. The pneumatic propulsion apparatus of claim 6, wherein the sealing means comprises an o-ring.

8. The pneumatic propulsion apparatus of any preceding claim, wherein the shuttle is cylindrical having a rear-end facing the breech and a front-end facing the muzzle.

9. The pneumatic propulsion apparatus of claim 8, wherein the shuttle neck comprises a substantially v-shaped notch extending around the shuttle.

10. The pneumatic propulsion apparatus of any one of claims 8-9, wherein the shuttle rear-end is frustoconical.

11. The pneumatic propulsion apparatus of any one of claims 8-10, wherein the shuttle front-end is frustoconical.

12. The pneumatic propulsion apparatus of any one of claims 8-11, wherein the shuttle front-end comprises a tapered hollow concentric to the barrel axis.

13. The pneumatic propulsion apparatus of any preceding claim, wherein the shuttle neck is frangible when exposed to a gas pressure exceeding a predetermined pressure value, such that in-use the shuttle can be broken into forward and rear sections, the forward section being translatable along the barrel.

14. The pneumatic propulsion apparatus of claim 13, wherein the initiation means comprises gas compression means for increasing the gas pressure within the gas reservoir above the predetermined pressure value.

15. The pneumatic propulsion apparatus of claim 14, wherein the gas compression means comprises a piston arranged within the gas reservoir, the piston being arranged to be pneumatically actuated by an air pressure force from a secondary gas reservoir.

16. The pneumatic propulsion apparatus of any one of claims 1-12, wherein the initiation means comprises venting means for venting gas from the gas reservoir into the breech end of the barrel.

17. A projectile launch apparatus comprising the pneumatic propulsion apparatus of any preceding claim and a projectile receivable into the barrel.

18. The projectile launch apparatus of claim 17, wherein the projectile is attached to the shuttle.

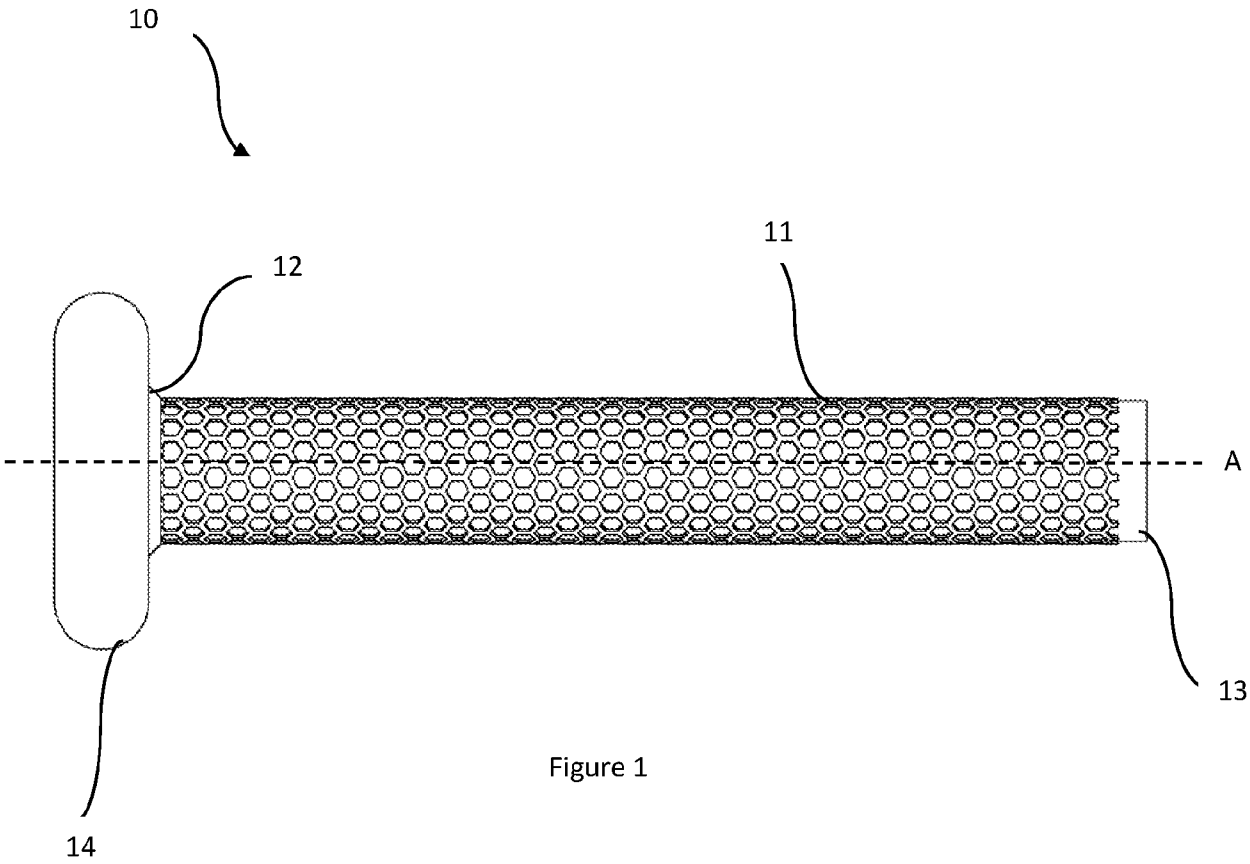

Figure 1

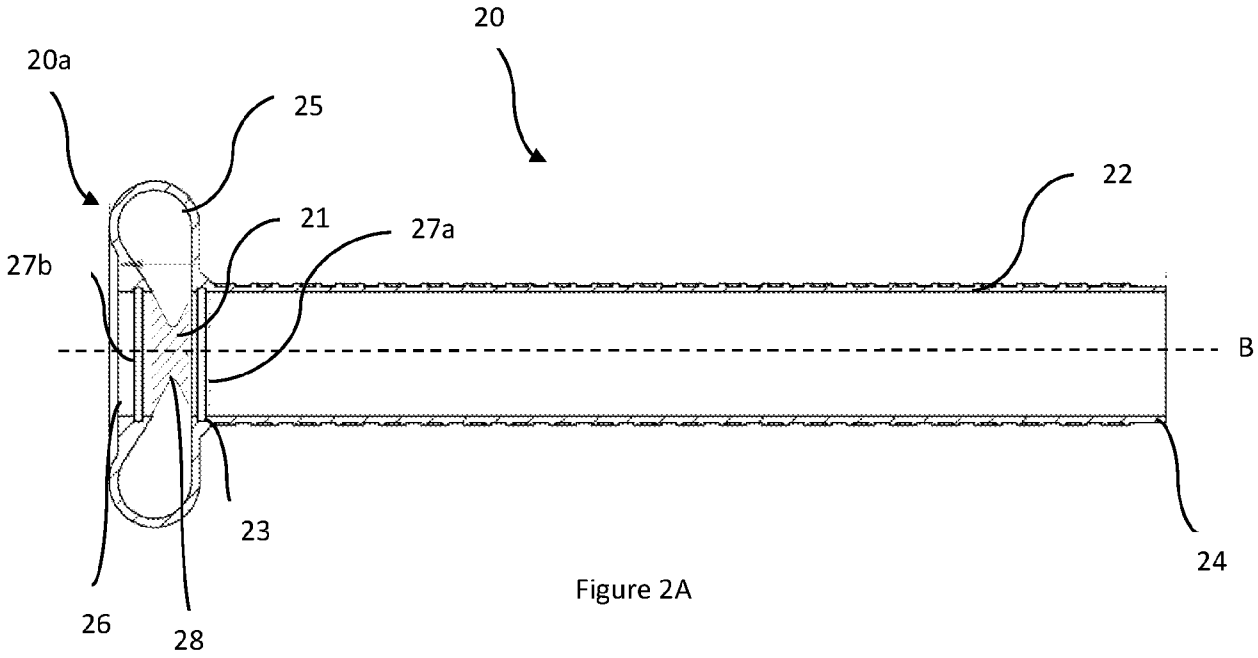

Figure 2A

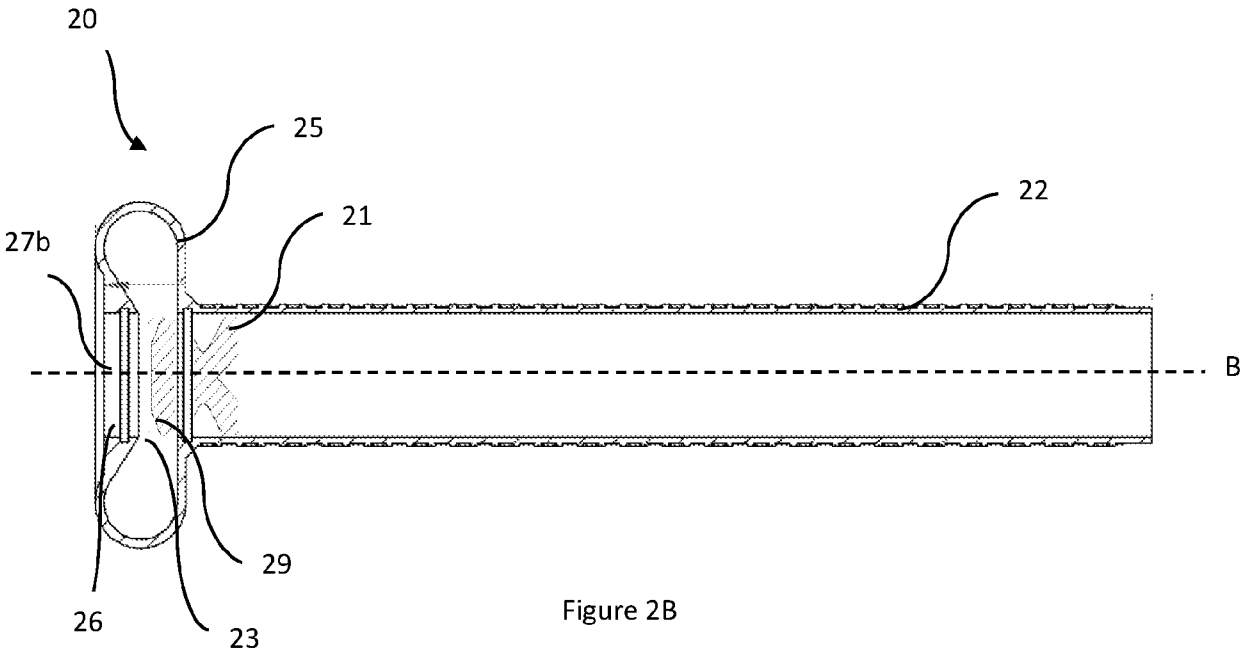

Figure 2B

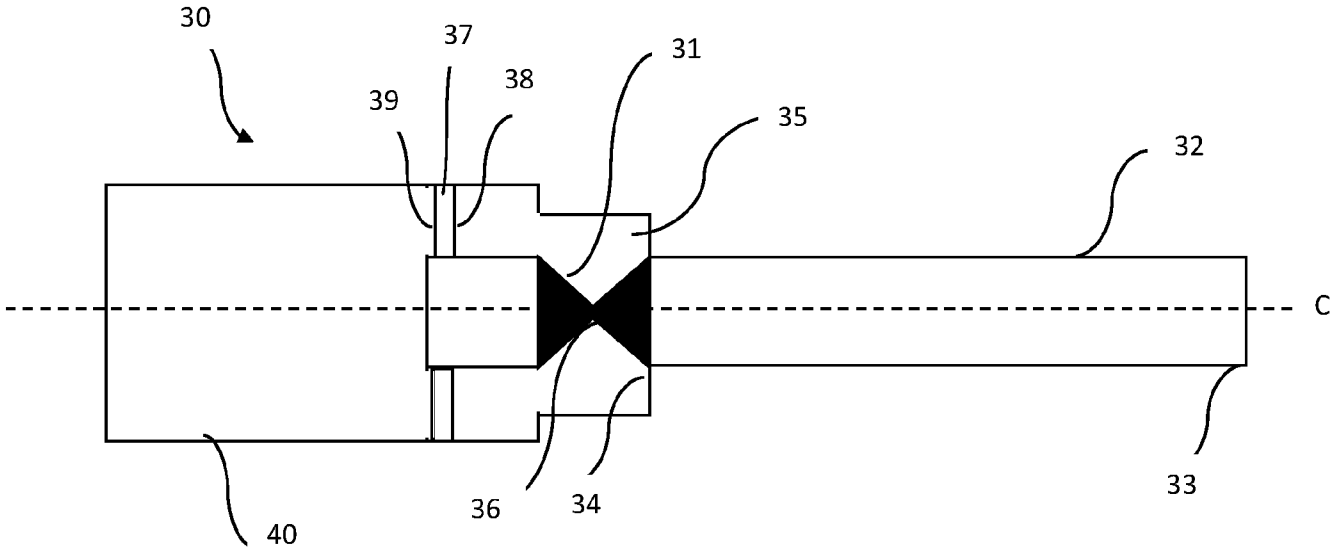

Figure 3A

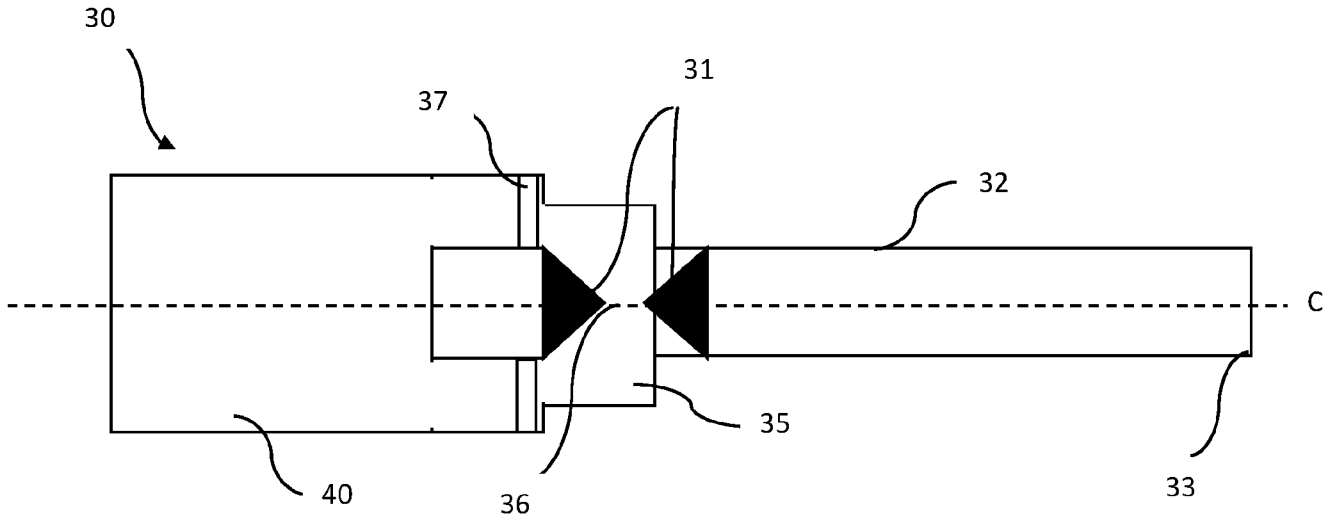

Figure 3B

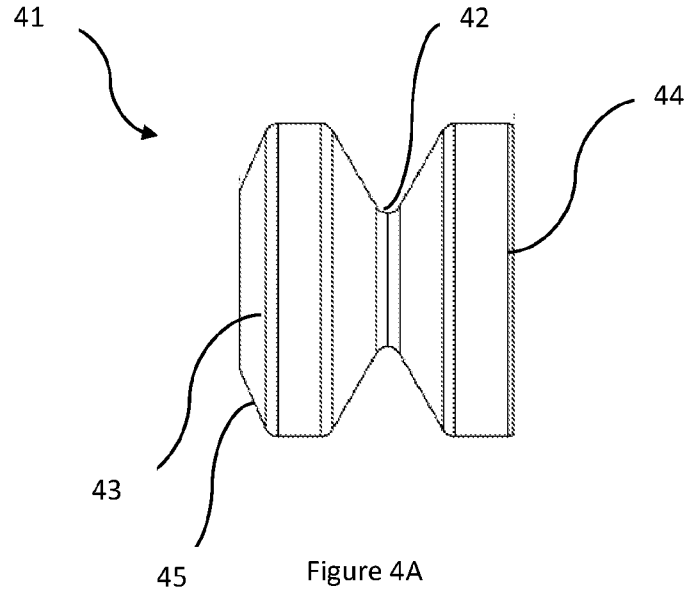

Figure 4A

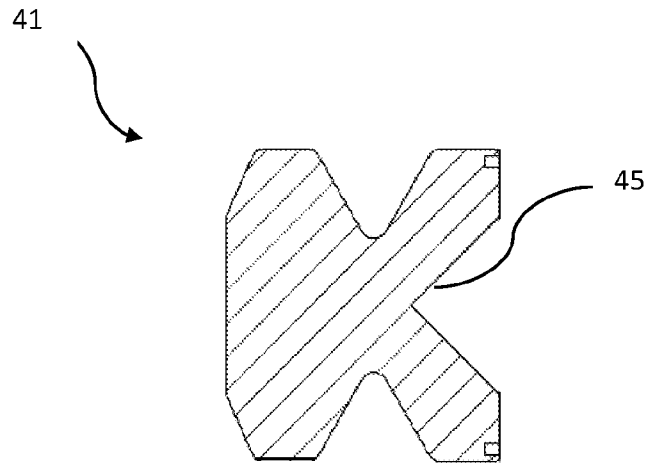

Figure 4B

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2023/061873

A. CLASSIFICATION OF SUBJECT MATTER
INV. F41B11/68 F41B11/723
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F41B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 4 282 852 A (OMANA JULIO A) 11 August 1981 (1981-08-11) claim 1; figures 1-9	1-12,16, 17 13-15
X	EP 2 700 898 B1 (IABG INDUSTRIEANLAGEN-BETRIEBSGESELLSCHAFT MBH [DE]) 10 January 2018 (2018-01-10) paragraph [0039]; claim 1; figures 1-4	1,2,4,8, 16-18
X	US 9 546 855 B2 (LINE LAUNCHER HOLDINGS LTD [NZ]) 17 January 2017 (2017-01-17) claim 1; figures 1-8	1,2,4,8, 16-18

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 January 2024	05/02/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Beaufumé, Cédric

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2023/061873

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