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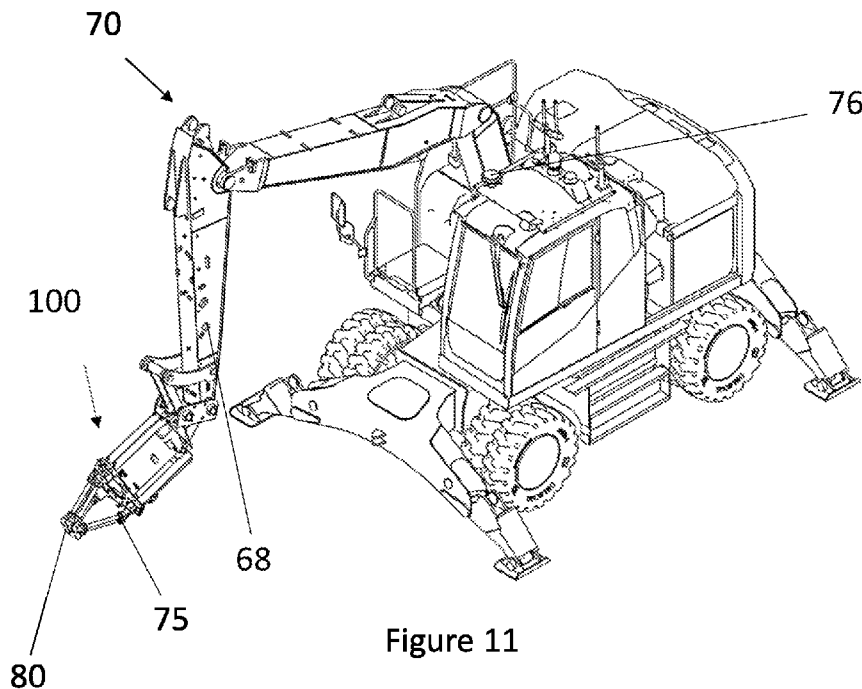


Figure 11

(57) Abstract: Systems, methods and apparatus that facilitate mechanisation and/or automation of blasting processes in mining and civil engineering applications are disclosed. The disclosure includes a trigger assembly for triggering an explosive in a hole in rock. The disclosure also includes a mining or civil engineering vehicle for working proximate an end face. The vehicle comprises a positioning unit for moving a functional unit to a selected location in relation to the end face. The positioning unit can include (a) a coarse positioning module and a fine positioning module and/or (b) a vision module for monitoring the position of the functional unit to facilitate guiding the functional unit to the selected location and/or (c) can be configured to move independently from an initial position to a second position closer to the selected location whilst the vehicle remains stationary.



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SYSTEMS AND METHODS FOR TRIGGERING EXPLOSIVES IN HOLES

TECHNICAL FIELD

5 The invention relates to systems, methods and vehicles for loading and triggering explosives in holes in underground and above-ground mining and civil engineering applications.

More particularly, although by no means exclusively, the systems, methods and apparatus of the invention facilitate mechanisation and/or automation of blasting processes.

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BACKGROUND

The following description of the invention is in the context of development tunnelling for extending underground mine drives, for example in the extraction level of block cave mines.

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However, it is emphasised that the invention is not limited to this application and extends generally to loading and triggering explosives in holes in any above-ground and underground applications, including, by way of example, drill and blast mining in benches in above-ground mines, up-hole and down-hole stope mining and civil tunnelling applications, including development tunnelling and production operations.

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There is a desire to reduce manual processes and remove personnel from the task of loading and triggering explosives in blast holes in underground mine drives.

25 There is limited space in underground mine drives, and this space limitation has a significant impact on the development of drives, with conventional machinery and automation methods being unsuited to reduce manual processes and remove personnel.

Therefore, to enable mechanisation of a blasting process, there is a need for new methods and systems for loading explosives into blast holes within a rock face and for triggering said explosives.

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Typically, in underground drive development, each blast may fracture and/or displace up to 200-400 tonnes of rock. Each blast may require explosives to be loaded into a plurality of distinct blast holes in an end face, i.e., heading of a drive. Typically, 70-80 drilled holes are

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required for a blast for larger drives. Fewer holes are typically required for smaller drives. The number of holes will vary depending on factors including geology, mineralogy, explosive selection, etc. Typically, in underground mine drive charging, blast holes range from 3-6m deep with a hole size of 45-50mm diameter, but the size and depth could be larger or
5 smaller depending on the application and/or the explosive used.

Drive development speed is important. One typical mining operation allows 45 minutes for operators to position and tie-in explosion triggers, such as detonators, and emulsion for each blast sequence at a heading of a drive.
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One conventional approach for extending underground mine drives is to:

- (a) drill a plurality of holes into an end face (i.e. heading) of a drive;
- (b) position explosives (typically - but not limited to - emulsion explosives) in the drilled holes;
- 15 (c) connect electric and/or non-electric detonators to the explosives within the holes in the face; and
- (d) trigger the explosives via an activation system to produce explosive a blast.

This process is typically repeated multiple times to establish a drive of a required length.
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This process typically requires several different operator-controlled vehicles at the end face. Moving multiple vehicles into an out of a drive that is being established is a time-consuming process.

25 A further factor is that vehicles working underground to carry out drill and blast operations must be located outside a high-risk zone in relation to a heading, typically at least 5 m from a heading – for safety reasons.

Step (c) of the above underground charge-up/blasting process generally includes either (i) a
30 physical connection via a trigger cord (such as a detonator cord, electrical wire or non-electric shock (“nonel”) tube e.g. in the form of a small diameter tube for transporting an initiation signal to explosives by means of a percussive wave travelling the length of the tube) or (ii) a chemical reaction connection between an external trigger system and each explosion triggers, such as a detonator.

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The explosion trigger (also described herein as a “trigger unit”) may be in any suitable form.

For example, the explosion trigger may be a detonator that itself may comprise a small explosive charge, such as a booster, also positioned within the hole. The term “small” means
5 small in comparison with the detonation unit body of the blast-generating explosive. The detonator and the small explosive charge may be separate components or a single assembly.

In order to achieve a required blast, triggering explosives has to be tightly controlled. This
10 requires accurate and careful locating of explosion triggers within holes. The selected location of an explosion trigger in any situation may be at an end or part way along the length of a hole.

One example of an explosion trigger is an assembly of a booster and a detonator.
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The term “booster” is understood herein to mean a sensitive explosive charge that acts as a bridge between a relatively weak conventional detonator and a low sensitivity bulk explosive.

A challenge to the mechanisation and/or automation of charge loading systems is the
20 placement of a plurality of explosion triggers in a plurality of holes at required locations in an end face without any or with minimal only physical, i.e., direct, personnel intervention.

A further factor is that current standards dictate that different classes of explosives must not be in intimate contact (assembled) until immediately before insertion into a hole. Typically, in
25 situations where an explosion trigger is an assembly of a booster and a detonator, these components are different explosive classes and must be assembled immediately before insertion into a hole.

Insertion and connection of explosion triggers to respective explosives (typically, a two-wire
30 system for explosion triggers, but could also be non-electric shock tube or a chemical reaction connection), as well as interconnection of explosion triggers to provide for a controlled blast of explosives in multiple holes, is difficult with a machine-based loading system, as there is lack of dexterity that a human operator offers, and that is generally required, during the conventional loading process.

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Additionally, careful management of, for example, 40-60 loose detonator cords or other trigger cords protruding from charged blast holes in an end face per blast is difficult with a machine-based loading system for explosion triggers.

- 5 The invention provides a method and an apparatus for triggering explosives in holes in both underground and above-ground mines that is an alternative to current practices.

The above description is not an admission of the common general knowledge in Australia and elsewhere.

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Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods, vehicles and other equipment and devices, and materials similar or equivalent to those described herein can also be used in the practice or testing of the present invention, a limited number of the exemplary methods, vehicles and other equipment and devices, and materials are described herein.

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SUMMARY OF THE INVENTION

- 20 The invention is an improvement of conventional drill and blast operations in underground and above-ground mines, such as drill and blast mining in benches in above-ground mines, up-hole and down-hole stope mining in underground mines, including development tunnelling and production operations.

- 25 As noted above, the invention also extends to other underground and above-ground applications, including, by way of example, civil tunnelling applications.

Conventional drill and blast operations in underground mines (for example), such as a block cave mine, include forming holes for explosives in a heading of a drive in the block cave mine and subsequent placement of detonators and explosives in holes and then initiating the explosives to form development and production drives in an extraction level of the block cave mine.

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The invention mechanises at least some of these conventional operations.

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There are a number of different aspects to the invention, as follows:

1. The use of at least one mining or civil engineering vehicle for carrying out required operations to facilitate placement of explosion triggers such as detonators and/or explosives in drilled holes in a heading and then initiating the explosives, for example to form a drive, with the vehicle having an arm, such as an articulated arm (but could be any other suitable element for the functional requirement), that can support a functional unit(s) on an end of the arm, with the vehicle having a positioning unit that includes (a) a module (which could also be described as a system) for coarse positioning the functional unit(s) in relation to a hole and (b) a module (which could also be described as a system) on the end of the arm for fine positioning the functional unit(s) in relation to the hole. The coarse and fine positioning modules allow quick and safe deployment of the functional unit(s) to required locations so that the functional unit(s) can carry out required operations in relation to each hole. The coarse and fine positioning modules make it possible to align functional unit(s) to a selected hand-over point, for example, a small, typically 20-50 mm (but could be larger), drilled hole in a heading whilst operators remain a safe distance, typically at least 5 m away. At the hand-over point, a selected functional unit(s) is operable to carry out operations in relation to the heading, such as inserting trigger assemblies into holes. The coarse positioning module typically has a large operational reach and range of motion allowing it to position the functional unit(s) proximate the hole. The fine positioning module typically has a high resolution and more limited range of motion, thus enabling it to align and locate the functional unit(s) with respect to the hole within the heading. It is noted that the coarse and fine positioning modules may be a single module with two functions, namely coarse positioning and fine positioning functions.
2. As an alternative to item 1, the at least one mining or civil engineering vehicle may only need to operate with a fine positioning module to bring a functional unit(s) to a hand-over point, such a location for carrying out operations in relation to a heading, such as inserting trigger assemblies into holes.
3. The configuration of the functional unit(s) makes it possible to handle and deploy sensitive components such as detonators and other types of explosion triggers, via the functional unit(s) whilst the coarse and fine positioning modules of the vehicle itself remain stationary or "parked". This may include picking up trigger assemblies from storage compartments. This may also include inserting trigger assemblies into holes in a heading. This combination of coarse positioning, fine positioning, and

hand-over via the functional unit(s) provides significant advantages over conventional explosives handling systems. For example, the applied torques and forces acting on the sensitive components are only those of the functional unit(s) itself, and thus are far lower than those of the coarse and fine positioning modules of the vehicle itself.

- 5 4. A trigger assembly for triggering an explosive in a blast hole to produce an explosive blast that is configured to be located in a hole in an end face, i.e., heading, and includes a connection unit that simplifies the process for connecting an external explosive activation system to a detonator of the trigger assembly for initiating an explosive in the hole.
- 10 5. Methods and systems for loading the trigger assemblies into the blast holes and for connecting the trigger assemblies to an external explosive activation system.

The aspects of the invention are described further below, albeit in a different order to the items in the above list.

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A. Trigger assembly – detonation cord

In one aspect, the invention relates to a trigger assembly for triggering an explosive in a hole in rock to produce an explosive blast, the trigger assembly being configured to be located in a hole in rock, for example in an end face, i.e., heading, of a drive, the trigger assembly including:

- 20 (a) a detonation unit body configured to be located at or proximate an open end of the hole;
- 25 (b) a trigger unit (described above as an explosion trigger) locatable at least partially within the detonation unit body for triggering the explosive in the hole, the trigger unit including a trigger cord connected to a proximal end of the detonation unit body; and
- (c) a connection unit for connecting a detonation cord of an external explosive activation system to the trigger unit to facilitate triggering an explosion in the hole.

30 The term “trigger cord” is understood herein to include, by way of example, (a) a detonator cord, (b) an electrical wire or (b) a non-electric shock tube (a Nonel tube) e.g., in the form of a small diameter tube for transporting an initiation signal to explosives by means of a percussive wave travelling the length of the tube.

The connection unit may be configured to receive the detonation cord of the external explosive activation system and to physically connect the detonation cord to the trigger cord when coupled thereto.

- 5 In one embodiment, the connection unit may comprise an element, such as a resilient element, to receive and connect the detonation cord to the trigger cord.

The resilient element may be any suitable form that can receive and connect the detonation cord to the trigger cord and takes advantage of the resilience of the element to facilitate
10 connecting the detonation cord to the trigger cord.

By way of example, the resilient element may comprise a generally key-hole shaped passage with two opposed open sides and two opposed closed sides, with the passage having a circular base section for receiving and connecting the detonation cord to the trigger
15 cord and a narrower width elongate throat section that communicates at one end with the circular base section and has an opening at the other end through which, in use, the detonation cord can be moved into the throat section and along the throat section to the circular base section and contact the trigger cord.

20 The resilient element may comprise a base and a pair of opposed arms extending from the base that define the passage, with the base defining the circular base section and the arms defining the throat section.

The arms may be resilient arms such that inserting the detonation cord into the opening and
25 moving the detonation cord through the throat section to the circular base section forces the arms apart from an original position against the resilience of the arms, with the arms returning to the original position after the detonation cord is in the circular base section, with the returned arms in the original position resisting release of the detonation cord from the circular base section and contributing to retaining the detonation cord in contact with the
30 trigger cord.

In another, but not the only other, embodiment the connection unit may be configured to be moveable relative to the detonation unit body from a first inoperative position, in which the detonation cord of the external explosive activation system is not connected to the trigger

unit, to a second operative position, in which the detonation cord is connected to the trigger unit.

5 By way of example, the connection unit may include a sleeve that fits over a proximal end of the detonation unit body as viewed looking at the hole, the sleeve being configured to receive the detonation cord and to physically connect the detonation cord to the trigger cord when coupled thereto.

10 By way of example, the sleeve may be moveable relative to the detonation unit body from the first inoperative position, in which the detonation cord is not connected to the trigger cord, to the second operative position, in which the detonation cord is connected to the trigger cord of the trigger assembly.

15 When the sleeve is in the second operative position, the detonation cord may be secured between the sleeve and the detonation unit body in contact with the trigger cord of the trigger assembly.

20 The connection unit and the detonation unit body may include complimentary mating members that can guide the connection unit and the detonation cord from the first inoperative position to the second operative position and bias together the trigger cord and the detonation cord in the second operative position.

25 The complimentary mating members may comprise (i) a plurality of projecting members that extend axially away from a proximal end of the sleeve and define a plurality of channels therebetween for receiving the detonation cord and (ii) a plurality of posts that extend from the proximal end of the detonation unit body and define slots therebetween, with the channels and the slots being aligned axially when the connection unit is in the first inoperative position.

30 Each projecting member may be shaped to have a taper from a tip of the projecting member, with the width of the projecting member increasing with distance from the tip, with the increasing width of the taper guiding the detonation cord into a channel.

35 The projecting members may be spade-shaped (or any other suitable shape).

The projecting members may include a notch for receiving the detonation cord when the connection unit is in the second operative position after being guided into the channel, with the detonation cord being held in contact with the trigger cord of the trigger assembly when in the notch.

5

The posts may be configured to cause rotational and axial movement of the connection unit with respect to the detonation unit body when the connection unit is moved relative to the detonation unit body from the first inoperative position to the second operative position, with this movement facilitating movement of the detonation cord located in one of the channels into contact with the trigger cord.

10

Each post may include a ramp that defines a cam surface for the projecting members to move along when the connection unit is moved axially towards the detonation unit, with the movement of the projecting members along the ramps causing the rotational and axial movement.

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In-use, the detonation cord may be received between a first pair of projecting members and a second pair of projecting members of the connection unit and contact the trigger cord of the trigger assembly and extend from the connection unit to a second connection unit of a second trigger assembly, the trigger cord being received between first and second pairs of projecting members of the second connection unit and contact the trigger cord of the second trigger assembly. These connections may be repeated so that the detonation cord connects together a plurality of the trigger assemblies in the end face.

20

25 The connection unit and the detonation unit body may include complimentary engagement members that couple the connection unit to the detonation unit body.

The engagement members may include plurality of tabs of the connection unit that engage within grooves of the proximal end of the detonation unit body when the connection unit is coupled thereto, to form a one-way connection therewith.

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The tabs may be disposed within apertures located at or towards a distal end of the connection unit.

The apertures may facilitate insertion of a clip member to disengage the tab members from the groove and allow uncoupling of the connection unit from the detonation unit body.

B. Trigger assembly – wireless receiver

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In another aspect, the invention relates to a trigger assembly for triggering an explosive in a hole in rock to produce an explosive blast, the trigger assembly being configured to be located in a hole in rock, for example a hole in an end face, i.e., heading, of a drive, the trigger assembly including:

- 10 (a) a detonation unit body configured to be located at or proximate an open end of the hole;
- (b) a trigger unit (also described as an explosion trigger) locatable at least partially within the detonation unit body for triggering the explosive in the hole; and
- 15 (c) a connection unit for connecting an external explosive activation system to the trigger unit to facilitate triggering an explosion in the hole, the connection unit including a wireless receiver in communication with the external activation means that may be triggered by laser, WiFi, Bluetooth or another communication medium.

20 The connection unit and/or the trigger assembly may include a power source such as a battery to power the receiver.

C. Trigger Assembly - general

25 In relation to both embodiments, the detonation unit body of the trigger assembly may include a compartment for housing the trigger unit of the trigger assembly.

30 As noted above, the trigger cord of the trigger assembly may include, by way of example, (a) a detonator cord, (b) an electrical wire or (c) a non-electric shock tube e.g., in the form of a small diameter tube for transporting an initiation signal to explosives by means of a percussive wave travelling the length of the tube.

The trigger unit of the trigger assembly may also include (i) a booster that includes a small explosive charge, typically a small explosive charge compared to the rock mass to be blasted and (ii) a detonator for detonating the small explosive charge. It is noted that the

trigger unit (also described as an explosion trigger) may be any suitable trigger unit and is not confined to detonator/booster arrangements.

5 The booster may include an elongate chamber for receiving the detonator such that the booster is insertable into the detonation unit body after the detonator is already installed therein.

10 The trigger unit may include a carrier configured to mount the detonator, the booster and the trigger cord in the compartment.

The carrier may be configured to be inserted into and close an open end of the detonation unit body so that the detonator and the booster are located in the housing.

15 The carrier may be detachable from the detonation unit body to thereby open the compartment and release the trigger unit when a force in excess of a threshold force is applied thereto.

20 The trigger assembly may comprise an adaptor that can cooperate with the carrier to facilitate use of the trigger assembly with any suitable trigger unit.

The trigger assembly may include a retaining means for retaining the detonation unit body at an initial position within the hole towards the open end thereof.

25 The retaining means may include a wider diameter section compared to the diameter of the detonation unit body.

30 In one embodiment, the retaining means may include a collar or other suitable member that has a wider diameter than the diameter of the detonation unit body and is configured to engage a section of an internal wall of the hole near the open end of the hole.

The retaining collar may be disposed around the housing of the detonation unit body and be configured to (a) engage the section of the internal wall of the hole to prevent axial movement relative to the housing and (b) allow the detonation unit body to rotate about a central longitudinal axis of the housing in use when the trigger cord is unwound as the

carrier moves forwardly from the initial position in the hole away from the detonation unit body.

5 In another embodiment, the retaining means may include a collar that is mounted on the detonation unit housing and has (i) a locating flange to contact a section of the heading that defines the hole, and (ii) a resilient biasing element that is configured to contact the side wall of the hole and hold the trigger assembly in position in the hole.

10 Alternatively, the collar may only provide the biasing element and the locating flange may be incorporated into the detonation unit body.

The collar may be mounted for relative rotational movement about a longitudinal axis of the detonation unit body to allow the body to rotate as the trigger cord is unwound as the carrier moves forwardly from the initial position in the hole away from the detonation unit body.

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The trigger assembly may be configured such that the trigger unit can be moved forward into the blast hole to a desired detonation position whilst the detonation unit remains in the initial position, with the trigger cord (when present) unwinding to maintain the physical connection between the detonation unit body and the trigger unit so that the trigger unit can be activated by the activation means to thereby trigger the explosive in the hole and produce the explosive blast.

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The detonation unit body may include an elongate housing that defines the compartment and is configured to extend into the hole and to receive and support the trigger unit within the compartment in the initial position of the trigger assembly in the hole.

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The elongate housing may include a first housing section that, in use, is located outside the hole and provides a sleeve-like (which may be described as spool-like) housing around which the trigger cord is wound.

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The elongate housing may include a first housing section that, in use, is located inside the hole and provides a sleeve-like (which may be described as spool-like) housing around which the trigger cord is wound.

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D. Method of triggering an explosive blast

In another aspect, the invention provides a method of triggering an explosive blast within rock, for example rock at an end of a drive in an extraction level of an underground block cave mine, the rock having a plurality of holes formed therein, the method comprising:

- 5 (a) positioning a detonation cord of an external explosive activation system in relation to the connection unit of the above-described trigger assembly,
- (b) physically connecting together the detonation cord and the trigger unit of the trigger assembly, and
- 10 (c) triggering an explosive within the trigger assembly to thereby initiate the explosive blast with the external activation means.

The method may include repeating steps (a) and (b) successively in relation to a plurality of other trigger assemblies and thereby connecting together the trigger assemblies with the detonation cord before carrying out step c).

15

E. Mining or civil engineering vehicle

In another aspect, there is provided a mining or civil engineering vehicle for working proximate an end face, for example proximate an end face, i.e. a heading, of a drive, the vehicle comprising: a positioning unit for moving a functional unit described further below, to a selected location, for example a hole in the end face, the positioning unit including: (i) a coarse positioning module (which can also be described as a system) configured to position the functional unit proximate the selected location, such as the hole in the end face, and (ii) a fine positioning module (which can also be described as a system) configured to facilitate adjustment of the position of the functional unit to locate and align the functional unit more accurately in relation to the selected location, such as the hole.

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In one embodiment, two vehicles are used, with one optimised for hole and heading cleaning functions and the other optimised for trigger assembly and emulsion delivery and detonation cord tie-in functions.

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In another embodiment, one vehicle is used.

The selected location may be the above-mentioned hole in the end face. The selected location may be any other location in the end face. The selected location may be any other

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required location, for example in a location to pick-up a trigger assembly stored on the vehicle.

5 The positioning unit may include a control system that can track the selected location, such as the hole, for example by video servo methods or similar hole monitoring options, and operate the fine positioning module to adjust, typically continuously, the position of the functional unit. This feature enables (once in position) the fine positioning module to “float” in a “correct” position if the vehicle moves for any reason and keep the functional unit aligned with the selected location.

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The positioning unit may further include a vision module for monitoring the position of at least one of the coarse positioning module and the fine positioning module to facilitate guiding the functional unit to the selected location.

15 The vision module may comprise a first range sensor mounted to a body of the vehicle.

The vision module may further comprise a second range sensor mounted to the fine positioning module.

20 In one embodiment, the positioning unit may include a vision module comprising:
- a first vision-based system on the vehicle to monitor the position of the coarse positioning module in relation to the selected location; and
- a second vision-based system on the end of the fine positioning module to monitor the position of the fine positioning module in relation to the selected location.

25

The fine positioning module may be coupled to the coarse positioning module.

The coarse positioning module may comprise an articulated arm.

30 The fine positioning module may comprise a hub configured to be coupled to the functional unit and a plurality of elongate links, with each link being connected at one end to the hub.

Each of the links may be independently moveable such that the hub is translatable and rotatably moveable with respect to the vehicle.

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The hub may include an aperture that, in use, is aligned co-axially with the hole.

The positioning unit may be operator-controlled, for example when in a cabin of the vehicle or tele-remotely, or autonomously controlled or semi-autonomously controlled.

5

In some embodiments, the vehicle may include at least one functional unit that is configured to carry out a series of tasks in relation to an end face and holes in the end face, such as preparing and loading a selected trigger assembly into a hole in the end face.

10 The at least one functional unit may be configured to move the trigger assembly with respect to the end face independently of the positioning unit of the vehicle.

The at least one functional unit may be configured to move the trigger assembly with respect to the end face independently of the coarse positioning module of the vehicle.

15

The at least one functional unit may be coupled to the fine positioning unit and be configured to move the trigger assembly with respect to the end face independently of the coarse positioning unit of the vehicle.

20 The vehicle may include a first functional unit, typically couplable to the fine positioning module, and configured to support a selected trigger assembly for example when the trigger assembly is moved to an aligned position in relation to a hole and when the trigger assembly is moved to an initial position within the hole.

25 The vehicle may include a housing for storing a plurality of the trigger assemblies.

The first functional unit may include (a) a housing for protecting the selected trigger assembly in use of the functional unit to position the selected trigger assembly in the hole and (b) gripper unit positioned at an opening of the housing, with the gripper unit being
30 movable between closed and open positions to allow insertion of a trigger assembly into the housing.

The first functional unit may include a moveable member that, in-use, is moved co-axially with the hole to move the selected trigger assembly from a pre-insertion position proximate
35 the hole to the initial position within the hole.

The first functional unit may include an insertion mechanism operable to move a detachable portion of the selected trigger assembly forward from the initial position to an operative position within the hole.

5

The insertion mechanism may comprise an emulsion charging hose that unspools to push the detachable portion from the initial position to the operative position. The emulsion charging hose may extend through the aperture of the base of the fine positioning module.

10 The functional unit may be a second functional unit in the form of a tie-in module that is couplable to the fine positioning module and configured to connect the detonation cord to the trigger assemblies after the trigger assemblies are located in the holes.

15 The tie-in module may include a moveable head that is engageable with a fixed portion of the selected trigger assembly. In use, forward movement of the moveable head may secure the detonation cord to the trigger assembly.

The head may include a guide through which the detonation cord is fed towards the fixed portion of the selected trigger assembly.

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The head may be disc-shape and the guide may be centrally located therewith, such that, in use, the guide is located coaxially with respect to the hole when connecting the detonation cord to the trigger assembly.

25 The tie-in module may include a rotatable drum from which the detonation cord is selectively dispensable.

In some embodiments the vehicle may be configured to clean and inspect the hole and/or the rock face surface proximate thereto in preparation of insertion of the trigger assembly.

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The functional unit may be a third functional unit, typically couplable to the fine positioning module, and configured to clear debris from the rock face surface proximate the hole.

35 The third functional unit may include a rake member configured to be drawn along the rock face surface to thereby wipe debris clear of the hole.

The functional unit may be a fourth functional unit couplable to the fine positioning module and configured to clear debris from within the hole.

- 5 The fourth functional unit may include a first hose that is selectively fed from a rotatable spool into the hole to measure a depth thereof. A terminal end of the first hose may provide an air jet for clearing light debris from the hole. The air jet may face away from the terminal end of the respective hose, such that debris is propelled towards the opening of the hole.
- 10 The fourth functional unit may include a second hose having a terminal end configured to grasp heavy debris and remove it from the hole.

The vehicle may further comprise a separate storage compartment for storing each of the functional units.

15

In another aspect, there is provided a mining or civil engineering vehicle for working proximate an end face, i.e. a heading, of a drive, the vehicle comprising: a positioning unit for moving a functional unit described above with respect to a selected location, the positioning unit including: a vision module for monitoring the position of the functional unit(s)
20 to facilitate guiding the functional unit to the selected location.

20

In another aspect, there is provided a mining or civil engineering vehicle comprising a functional unit for working an end face, the vehicle being configured to move a functional unit described above to an initial position proximate a selected location, and the functional unit
25 being configured to move independently from the initial position to a second position closer to the selected location whilst the vehicle remains stationary.

25

Various features, aspects, and advantages of the invention will become more apparent from the following description of embodiments of the invention, along with the accompanying
30 drawings in which like numerals represent like components.

30

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are illustrated by way of example, and not by way of limitation,
35 with reference to the accompanying drawings, of which:

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Figures 1a and 1b illustrate a trigger assembly according to an embodiment of the invention, showing the main components thereof, namely: a detonation unit body, a trigger cord, a connection unit and a trigger unit that is accommodated within the detonation unit body;

5

Figure 2 is a front view of a section of an end face of a drive of an underground mine, illustrating a plurality of the Figure 1a and 1b trigger assemblies inserted into drilled holes in the end face and a plurality of hard-wired connections in a daisy chain arrangement between detonators of the trigger assemblies and an activation system (not shown);

10

Figures 3a and 3b are diagrammatic sectional views of the trigger assembly of Figure 1 in use, illustrating the trigger unit thereof being moved from an initial position in the hole to a detonation position along the hole;

15

Figures 4a to 4d are perspective views of the detonation unit body of the trigger assembly as shown in Figure 3a, and components thereof;

20

Figure 5 is a perspective view of the detonation unit body of Figure 4a, showing a trigger cord being fed through a passage therein as a part of a process of assembling the trigger assembly shown in the Figure;

Figure 6a and 6b are perspective views of a collar that, in use, is fitted to the detonation unit body;

25

Figures 7a to 7d show a process of assembling the trigger unit of the trigger assembly, the process comprising inserting a booster into the detonation unit body, the booster enveloping a detonator previously fitted therein;

30

Figures 8a and 8b are perspective views of the connection unit of the trigger assembly, according to an embodiment thereof;

Figure 9a and 9b are perspective views showing a clip member being inserted into an aperture of the connection unit of Figure 10a, to facilitate removal of the connection unit from the detonation unit body;

35

Figures 10a to 10c are side views illustrating a process by which the connection unit is coupled to the detonation unit body;

5 Figure 11 is an isometric view of an embodiment of a vehicle in accordance with the invention that can be used to prepare the rock face and blast hole for receiving the trigger assembly;

10 Figure 12 is an isometric view of an embodiment of another vehicle in accordance with the invention that can be used to insert the trigger assembly into the blast hole;

Figures 13a to 13c are perspective views of a functional unit for use with the vehicle of Figure 11, the functional unit comprising a rake member for cleaning the rock face;

15 Figures 14a to 14 c are perspective views of another functional unit for use with the vehicle of Figure 11, comprising a hose that is used to remove debris from a blast hole;

Figure 15 is an isometric view of a slider of the vehicle shown in Figure 12 that is used for supporting and loading trigger assemblies;

20 Figures 16a to 16e illustrate another functional unit for use with the vehicle of Figure 12, comprising a gripper that is used to load the trigger assembly in the blast hole, and a process by which the gripper is used to transport the trigger assembly from the vehicle to a detonation position within the hole;

25 Figures 17a and 17b illustrate another functional unit for use with the vehicle of Figure 12, comprising a tie-in module that is used to connect together a plurality of trigger assemblies via a detonation cord;

30 Figures 18a to 18d illustrating a process by which the tie in module of Figures 17a and 17b is used to physically connect the detonation cord to the trigger assembly;

Figures 19a and 19b illustrate the tie in module of Figures 17a and 17b being used to interconnect a plurality of trigger assemblies;

Figures 20 and 21 are side and perspective views, respectively, that illustrate a trigger assembly according to another, although not the only other, embodiment of the invention;

Figures 22 and 22a are cross-sectional views of the trigger assembly shown in Figures 20
5 and 21 in an operative and pre-assembled configurations;

Figure 23 is an enlarged perspective view of the connection unit at one end of the trigger assembly shown in Figures 21 and 22;

10 Figure 24 is the enlarged perspective view of the connection unit shown in Figure 22 with a detonation cord of an external explosive activation system retained by the connection unit;

Figure 25 is a side view of the trigger assembly shown in Figures 20 to 24 that illustrates the components of the trigger assembly; and

15

Figure 26 is a side view of the trigger assembly shown in Figures 20 to 25 positioned in an opening of a drilled hole in an end face of a drive of an underground mine.

DETAILED DESCRIPTION

20

Embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which various embodiments, although not the only possible embodiments, of the invention are shown. The invention may be embodied in many different forms and should not be construed as being limited to the embodiments described below.

25

The invention relates generally to triggering explosives in holes in underground and above-ground mines and in civil engineering applications, such as drives.

The invention relates particularly, although by no means exclusively, to triggering explosives
30 in holes in underground mines, such as:

- a) in the development of horizontally extending drives in underground mines for the purpose of blasting rock and extending the drives, or
- b) for mine production purposes that require explosives and detonators to be placed in a combination of angled, horizontal or vertical for the purpose of blasting rock (e.g.
35 block cave development / infrastructure development.

The following description is in the context of underground block cave mines.

It is understood that the vehicles, methods and trigger assemblies described herein also
5 have application in other civil engineering and mining applications, for example civilian tunnelling and stope mining.

Terminology:

“drive” – with back (i.e. roof), sides, and shoulder that transitions a side to a roof.
10 “heading” – end face of drive to be drilled and blasted.
“burn” – central section of a heading that is detonated first. The rock expands on blasting and slumps out of the heading. The outer sections of the heading are detonated, and rock successively falls inwardly.

15 In broad terms, there is a number of different aspects to the invention, as follows:

1. The use of at least one mining or civil engineering vehicle for carrying out required operations to facilitate placement of detonators and explosives in drilled holes in a heading and then initiating the explosives, for example to form a drive, with the vehicle having an arm, for example an articulated arm, equipped with a functional
20 unit on an end of the arm, with the vehicle having a positioning unit that includes (a) a module (which could also be described as a system) for coarse positioning the functional unit(s) in relation to a hole and (b) a module (which could also be described as a system) on the end of the arm for fine positioning the functional unit(s) in relation to the hole. A functional unit is essentially a tool or end-effector that
25 is configured to undertake a particular function or task related to working/cleaning the heading and/or loading the trigger assembly into the drilled hole and connecting a detonation cord to multiple trigger assemblies. The coarse and fine positioning modules allow quick and safe deployment of the functional unit(s) to required locations so that the functional unit(s) can carrying out required operations in relation
30 to each hole. The functional units may, in some cases, themselves be configured to be moveable independently of the fine and coarse positioning modules of the vehicle. The coarse and fine position modules make it possible to align functional units to a selected hand-over point, for example, a small, typically 40-50 mm, drilled hole in a heading whilst operators remain a safe distance outside a high-risk zone in relation
35 to a heading, typically at least 5 m away from the heading. At the hand-over point, a

selected functional unit(s) is operable to carry out operations in relation to the heading, such as inserting trigger assemblies into holes. The coarse positioning module typically has a large operational reach and range of motion allowing it to position the functional unit(s) proximate the hole. The fine positioning module
5 typically has a high resolution and more limited range of motion, thus enabling it to align and locate the functional unit(s) with respect to the hole within the heading. It is understood that the coarse and fine positioning modules combine heavy and light “touch” movements.

2. The configuration of the functional units makes it possible to handle and deploy
10 sensitive components such as detonators via the functional units whilst the coarse and fine positioning modules of the vehicle itself remain stationary or “parked”. This may include picking up trigger assemblies from storage compartments. This may also include inserting trigger assemblies into holes in a heading. This combination of coarse positioning, fine positioning, and hand-over via the functional unit(s) provides
15 significant advantages over conventional explosives handling systems. For example, the applied torques and forces acting on the sensitive components are only those of each functional unit itself, and thus are far lower than those of the coarse and fine positioning modules of the vehicle itself. In some cases, the forces and torques are orders of magnitude lower to facilitate safe handling practices.

3. A trigger assembly for triggering an explosive in a blast hole to produce an explosive
20 blast that is configured to be located in a hole in an end face, i.e., heading, and includes a connection unit that simplifies the process for connecting an external explosive activation system to a detonator of the trigger assembly for initiating an explosive in the hole.

4. Methods and systems for loading a plurality of the trigger assemblies into the holes
25 and for connecting the trigger assemblies to a detonation cord of an external explosive activation system.

Overview of the embodiments of the trigger assembly

30

The embodiments of the trigger assembly shown in Figures 1-10 and in Figures 20-26 are improvements of the trigger assembly shown in international publication WO 2020/232506. The disclosure in the international publication is incorporated herein by cross-reference.

35 Embodiment of the trigger assembly shown in Figures 1-10

Overview – Figures 1-10

With reference to Figures 1a to 1b, the main components of the embodiment of an assembly
5 for triggering an explosive in a blast hole to produce an explosive blast (i.e., “trigger
assembly”) shown in Figures 1-10 are as follows:

- 10 (a) Detonation body unit 21 – in an assembled trigger assembly, a trigger cord 31 in the form a nonel cord (or any other suitable trigger option) is wrapped around the circumference of the detonation unit body. The detonation unit body includes a rearwardly opening perimeter channel a proximal end of the detonation unit body for receiving a section of the nonel cord. The nonel cord extends around the whole of the perimeter for contact at both ends to a section of a detonation cord of an external explosive activation system when positioned to extend across the opening, irrespective of the orientation of the detonation cord in relation to the crown.
- 15 (b) A trigger unit 17 in the form of a booster 19, a detonator 15, and the above-mentioned nonel cord that forms the trigger cord 31. The nonel cord is connected (i) at one end to the detonator 15 and (ii) at the other end to the proximal end of the detonation unit body, with the nonel cord positioned to be contacted by a detonation cord of the above-mentioned external activation system when the connection unit is
20 moved from an initial position to a locked position, as described further below. The detonation unit body includes an opening in the wall and an internal channel for a section of the nonel cord that extends between the section of the nonel cord that is wrapped around the detonation unit body and the section of the nonel cord that is connected to the connection unit.
- 25 (c) Carrier 29 – located at a forward end of the detonation unit body and configured to mount a detonator and a trigger cord, in this instance a non-electric cord, connected at one end to the detonator.
- 30 (d) Retaining means which, in the described Figures 1-10 embodiment, is provided, at least in part, by way of a collar - mounted on the detonation unit body. The collar may have (i) a locating flange to contact a section of the heading that defines the hole, and (ii) a resilient biasing element configured to contact the side wall of the hole and hold the trigger assembly in position in the hole. In other embodiments, the flange may be incorporated into the detonation unit body itself. In addition, the collar is mounted for relative rotational movement about the detonation unit body to allow
35 the body to rotate as the trigger cord, such as a nonel cord, is unwound as the

carrier moves forwardly from the initial position in the hole away from the detonation unit body - the collar facilitates efficient unwrapping of the trigger cord from the detonation unit body – accommodates built-in resilience of the trigger cord.

5 (e) Connection unit 27 – located at a rearward end of the trigger assembly. The connection unit is configured to provide a connection between the trigger unit 17 and an external activation means that is used to trigger (i.e., fire) the booster. In the embodiment illustrated in Figures 1-10, the connection unit is configured to respond to axially forward rotational movement about the axis from an initial position to a locked position, with the movement moving a detonation cord to be in physical contact with the nonel cord. The connection unit includes a plurality of channels between rearwardly-extending projections of the connection unit, with the channels being formed to receive a detonation cord of an external initiation system so that the detonation cord extends across a central hollow section of the connection unit and positions the detonation cord to be moved as described above to contact the nonel cord. The connection unit is configured so that there is a predetermined clamping force between the nonel cord and the detonation cord to prevent pinching or other damage to the detonation cord and the nonel cord that could compromise detonation. The connection unit includes a compressible element that is responsive to the clamping force applied by the detonation cord to control the clamping force. In other embodiments (not shown), the connection unit may include a wireless receiver that provides a wireless connection between the trigger unit 17 of the trigger assembly 7 and the external activation means.

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The Trigger Assembly 7 – Figures 1-10

25 Figure 2 is a front view of a section of an exposed end face 3, i.e., heading, of a drive 5 in an extraction level of underground block cave mine with a plurality of trigger assemblies 7 in drilled holes 9 (see Figures 3a and 3b) extending into a rock mass 11 in the end face 3 interconnected via a detonation cord 14 in a daisy chain arrangement to an activation system (not shown).

30

It is noted that the invention is not confined to the arrangement of drilled holes 9 and the daisy chain arrangement of the detonation cords 14 and extends to any suitable arrangements of the drilled holes 9 and the detonation cords 14.

35

Explained in more detail below with reference to Figures 4a-4d, 6a-6b, 7a-7d and 8a-8b, each trigger assembly 7 is an assembly of the following components:

- a. a detonation unit body generally identified by the numeral 21;
- b. a retaining collar 25;
- 5 c. a trigger unit 17 in the form of a booster 19 and a detonator 15 and a trigger cord 31 (in the form of a nonel tube) that is connected at one end to the detonation unit body 21 and at the other end to the detonator 15;
- d. a carrier cap 29 that supports the trigger unit 17; and
- 10 e. a connection unit 27 for connecting together the trigger cord 31 and the external activation system – either physically, i.e., by way of a detonation cord 13, or wirelessly.

The separate components that are assembled together to form the trigger assembly 7 may be made from any suitable material and by any suitable manufacturing method. By way of
15 example, the components may be 3-D printed from a polymeric material.

Each trigger assembly 7 can be located at an open end of the hole 9 in an initial position of the trigger assembly in the hole 9. In this initial position the trigger assembly 7 is in an assembled form, with the detonation unit body 21 housing and supporting the trigger unit 17
20 and with the trigger cord 31 being at least partially wrapped or wound around the detonation unit body 21.

Figure 18d shows in more detail than Figure 1 the inter-connection of one trigger assembly 7 and the detonation cord 14 of the external activation means. As is described further below,
25 the detonation cord 14 is positioned to extend across the trigger assembly 7 and is retained by the connection unit 27 in contact with the first end 31a of the trigger cord 31. Accordingly, in use, once the trigger unit 17 is at the detonation position, the activation means is actuated, triggering the explosive within the hole 11 and producing the explosive blast within
30 the rock mass 11.

The term “open end” is understood in this context to mean the exposed end of the hole 9 that would typically be facing an operator when inserting the trigger assembly 7 therein.

The Detonation Unit Body 21 – Figures 1-10

The detonation unit body 21 will now be described in detail, with particular reference to Figures 4a to 4d.

5 The detonation unit body 21 is formed from three sections and includes a drum 24 (located at the proximal end thereof) and an elongate housing 23 (see Figure 4a) that is configured to extend into the hole 9 and to receive and support the trigger unit 17 within a compartment 22 defined by the housing 23 in the initial position of the trigger assembly 7 in the hole 9. The trigger unit 17 is shown in the compartment 22 in Figure 1b.

10 The housing 23 is a tubular housing, extending from a proximal end to a distal end. The tubular shape of the housing 23 facilitates easy insertion into the blast hole 9, for it approximates the shape of a conventionally drilled hole and does not require any specific or particular rotational orientating. It is understood, however, that other geometries are possible. In this description the term "proximal" end refers to the end that is closest to the
15 operator, when the trigger assembly 7 is inserted into the hole 11. Put differently, the proximal end of the housing 23 is a near or forward end whilst the distal end of the housing 23 is a far or rearward end of the housing 23.

In the illustrated embodiments, the housing 23 is formed from two housing sections 23a, 23b
20 that are joined together. The drum 24 is also joined to the first housing section 23a. The profile of these sections is best shown in Figures 4b to 4d. It is understood that this is but one way of forming the housing 23, and the housing 23 can, alternatively, be formed as a single piece.

25 The drum 24 of the detonation unit body 21 is shown in Figure 4b and has a larger diameter than the housing 23. The drum 24 has a barrel-like shape and includes a plurality of open-ended slots 71 that extend axially along a length thereof. The slots are defined by posts 73. The upper ends of the posts 73 form ramps that are inclined axially from one side to the other side and serve as guides that aid the coupling of the connection unit 27 to the
30 detonation unit body 21. The drum 24 also includes a plurality of circumferential grooves 61. The grooves 61 form part of a coupling mechanism that couples the connection unit 27 to the detonation unit body 21.

The housing sections 23a, 23b of the housing 23 are shown in Figures 4c and 4d
35 respectively. These sections are tubular, and together provide the sleeve-like housing 23

around which the trigger cord 31 can be wound. The first section 23a may include features such as tabs configured to engage with the collar 25 to hold the collar 25 in place around the housing 23. Alternatively, the collar 25 may be a friction fit with the first section 23a. The second housing section 23b is open ended and serves as an end-piece within which the carrier cap 29 (see, for example, Figure 1b) of the trigger unit 17 is received. An interior of the end of the second housing section 23b is lined with raised protrusions 26 that are configured to engage with the carrier cap 29 to hold it in via friction fit. Together, the two housing sections 23a, 23b define the compartment 22 within which the trigger unit 17 is received and accommodated.

10

Best shown in Figures 1a and 1b, the trigger cord 31 of the trigger unit 17 is connected at one end 31a to the detonator 15 of the trigger unit 17 and at the other end 31b to the proximal end of the detonation unit body 21, with the end extending from the end. When the trigger assembly 7 is in the assembled form, the trigger cord 31 is wrapped in a spiral arrangement around at least a partial length of the trigger unit body 21. Specifically, in the illustrated embodiment, the trigger cord 31 is wrapped around the middle and rearward sections 24b, 24c of the housing 23.

15

Turning now to Figure 4c, the first housing section 23a includes an axially extending channel 47 that provides a passage for the trigger cord 31 to traverse past the collar 25 – as shown in Figure 5. In this way, the first end 31a of the trigger cord 31 is connected to the detonator 15 of the trigger unit 17 within the hole 9, whilst the second end 31b of the trigger cord 31 is exposed outside the hole 9, all the while with the trigger assembly 7 being retained within the hole via the collar 25.

25

It is understood, therefore, that the trigger cord 31 has a length that is a selected length to span the distance between the detonator 15 of the trigger unit 17 and the proximal end of the detonation unit body 21 when the trigger unit 17 is in the detonation position of the trigger assembly 7 in the hole 9, as shown in Figure 1b. Accordingly, when the trigger unit 17 is at the detonation position, it remains operably connected to the proximal end of the detonation unit body 21.

30

Retaining Collar 25 – Figures 1-10

With reference to Figures 6a and 6b, the retaining collar 25 is disposed around the housing 23 of the detonation unit body 21 and can rotate about a central longitudinal axis of the housing 23 but is restrained from axial movement relative to the housing 23. Specifically, the collar 25 is rotationally coupled around housing 23.

5

The retaining collar 25 has two main functions.

The primary function is to contact the inner wall of the hole 9 to further limit insertion of the housing 23 into the hole 9. The collar 25 includes a plurality of projections in the form of flaps 26 for this function. The flaps 26 are disposed in a circular array around the outer surface of the retaining collar 25. The flaps 26 are designed to engage with the rock mass 11 of the inner wall of the hole 9 to axially retain the housing 23 in position, resisting forward and backward movement. Further, because the retaining collar 25 is rotationally coupled to the housing 23, the trigger unit body 21 is able to rotate whilst being axially held in position during deployment.

15

It is understood that the geometry of the flaps 26 in the illustrated embodiment is but an example of one configuration of retaining collar 25. Other geometries that provide analogous functionality are also possible and contemplated within the scope of this invention.

20

The other function is to limit insertion of the housing 23 of the trigger assembly 7 into the hole 9. The retaining collar 25 may include a circumferential flange for this function. It is noted, however, that this second function can also be provided by the detonation unit body 21 itself – i.e. by incorporating a flange into the detonation unit body 21 itself. In the illustrated embodiments, a flange 24a is incorporated into the drum 24.

25

The Trigger Unit 17 – Figures 1-10

The trigger unit 17 will now be described in detail, with particular reference to Figures 7a to 7d.

30

In the embodiment shown in Figures, the detonator 15 of the trigger unit 17 is positioned ahead of the booster 19 within the housing 23 in the direction of insertion of the trigger assembly 7 into the hole 9. It is to be understood that the positions of the detonator 15 and

the booster 19 can, alternatively, be reversed with the booster 19 being positioned ahead of the detonator 15.

The detonator 15 and the booster 19 are configured so that the detonator 15 can be
5 received and housed within the booster 19. Specifically, the booster 19 includes an elongate chamber 39 (see Figures 7c and 7d) that is open at one end for receiving the detonator 15- with the detonator 15 being pre-fitted within the trigger assembly 7, being attached to the carrier 29. The booster 19 can be inserted into the housing 23 and moved forwards to envelop the detonator 15, which is pre-fitted within the trigger assembly 7. The insertion may
10 be by way of a T-shaped pusher device 28, as shown in Figure 7a. At this point, the detonator 15 is completely housed in the booster 19 and forms the trigger unit 17. In this way, the explosive (i.e. the booster 19) is kept separate from the detonator 15 and is only placed inside the trigger assembly 7 immediately before the trigger assembly 7 is to be used and inserted into the blast hole 11.

15 The detonation unit body 21 is configured to release the trigger unit 17 therefrom, where the trigger unit 17 comprising the booster 19 and the detonator 15 is separated from within the detonation unit body 21 and moved from the initial position in the hole 9 shown in Figure 3a to an operative or detonation position in the hole 9 shown in Figure 3b. As such, the trigger
20 unit 17 is a detachable portion of the trigger assembly 7. In this separated form of the trigger assembly 7, the detonator unit body 21 serves as a fixed portion of the trigger assembly 7 that remains at the open end of the hole 9 whilst the trigger unit 17 the detachable portion (i.e. the trigger unit 17) is located further into the hole 9 for detonating explosives in the hole 9 in the detonation position. The detonation position is typically at or proximate a closed end
25 of the hole H. What is meant by the term "closed end" is the far or terminal end of the hole 11.

The releasing of the trigger unit 17 from the detonation unit body 21 is facilitated by way of a
30 frangible wall 35 that extends radially across the interior of the housing 23 towards a distal end thereof. The frangible wall 35 defines forward end of the compartment 22 and prevents forward movement of the trigger unit 17 into the hole 9. The frangible wall 35 is configured to detach or otherwise break when a force in excess of a threshold force is applied to the wall 35. With this arrangement, when the trigger unit 17 is held in the housing 23 in the initial
35 position of the trigger assembly 7 in the hole 9, the wall 35 is a barrier to movement of the explosion trigger from within the compartment 22. Further forward movement of the trigger

unit 17 to the detonation position requires breaking the frangible wall 35. The trigger assembly is thus moved forwardly from the initial position of the trigger assembly 7 in the hole 9 to the detonation position of the trigger assembly 7 in the hole 9 for example via application of an axial force.

5

The Connection Unit 27 – Figures 1-10

The connection unit 27 will now be described in detail, with particular reference to the embodiment shown in Figures 8a and 8b.

10

The connection unit 27 is a cylindrical sleeve that, in use, is coupled to a proximal end of the detonation unit body 21. In the illustrated embodiment, a distal end of the connection unit 27 has an internal diameter that is larger than a dimension of the proximal end of the housing 23 of the detonation unit body 21, enabling the connection unit 27 to fit as a cuff around the housing 23.

15

The distal end of the connection unit 27 includes engagement features for coupling with the proximal end of the detonation unit body 21. Best shown in Figure 8b, the engagement features are provided as a plurality of tabs 55 that are pivotably attached to the sleeve within apertures 57 in the sleeve towards the distal end of the connection unit 27. In the illustrated embodiment there are three tabs 55, located within three corresponding apertures 57 equi-spaced around a perimeter of the sleeve of connection unit 27, however there could be more or less. The tabs 55 are removable, being pivotably mounted to the connection unit 27. This is beneficial, facilitating replacement of damaged and/or worn tabs 55 without requiring complete replacement of the connection unit 27.

20

Each tab 55 includes a pair of lips (not shown) that project inwardly with respect to the connection unit 27. The lips are configured to engage within the circumferential grooves 61 that are disposed around the proximal end of the housing 23 of the detonation unit body 21 (shown in Figure 4b). The lips define a V shaped mouth that is oriented towards the proximal end of the connection unit 27. As such, the engagement between the tabs 55 and grooves 61 provides a ratchet-like one-way coupling between the connection unit 27 and the detonation unit body 21. In this manner, whilst the connection unit 27 can be brought into engagement with the detonation unit body 21 by sliding the distal end of the connection unit

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27 over the proximal end of the housing 23 and sliding it axially there along, once the tabs 55 are engaged within the grooves 61, rearward axial movement is prevented.

If required, however, the connection unit 27 can be disengaged from the detonation unit
5 body 21 by inserting clip members 63 into the apertures 57. The clip members 63 have a complimentary profile to the tabs 55, and when inserted into the aperture 57, force the tab 55 to move outwardly with respect to the detonation unit body 21, such that the lips 55 disengage from the grooves 61. The clip members are shown in Figures 9a and 9b.

10 In other embodiments, not shown, the connection unit 27 may be coupled to the detonation unit body 21 by means other than the clip and groove connection which is described herein by way of a preferred example of a secure coupling.

Returning to Figures 8a and 8b, the connection unit 27 includes a plurality of projecting
15 members 65 that extend from the proximal end of the connection unit 27. The projecting members 65 are configured to receive the detonation cord 13 of an external explosive activation system therebetween. The projecting members 65 each have a spade-like shape, tapering from a spike-like tip towards the base on each side thereof. The taper of the projecting members 65 guides the detonation cord 13 into a channel 67 between adjacent
20 projecting members 65. The channels provide a passage for the detonation cord 13 to travel through, radially across the connection unit 27. In the illustrated embodiment there are six projecting members 65, defining three channels 67 equi-spaced around a perimeter of the connection unit 27, however there could be more or less.

25 It is understood that in other embodiments the connection unit 27 may include other shapes of projecting members 65 and/or different forms of locating means for guiding the detonation cord 13 into position with respect thereto.

Each projecting member 65 also includes a notch 69, located towards a base thereof. The
30 notch 69 is crescent shaped and configured to hold the detonation cord 13 captive therein.

Best shown in Figure 4b, the proximal end of the detonation unit body 21 – i.e. the drum 24-
includes the above-mentioned plurality of open-ended slots 71 that extend axially from the proximal thereof, with each slot 71 being defined on either side by two concentric rows of
35 upstanding posts 73. A trough 79 extends circumferentially around the proximal end of the

housing 23, between the concentric rows of posts 73. The trough 79 provides a passage around which the second end 31b of the trigger cord is wrapped, such that the trigger cord 31 extends around a complete perimeter of the proximal end of the housing 23. This wrapped section of the trigger cord 31 is positioned to contact the detonation cord 13.

5

The slots 71 each have a complimentary profile to that of the projecting members 65, so as to bias together therewith and guide the connection unit 27 into a coupled arrangement with the detonation unit body 21. Specifically, as noted above, the end of each post 73 is formed as an inclined ramp 75 that provides a cam surface along which a base of the projection members 65 travels when the connection unit 27 is moved from an inoperative position to an operative position. The ramp 75 defines a helix like path that guides the projecting members 65 into axial and rotational alignment with the respective slots 71.

10

In other embodiments, where the connection between the trigger assembly 7 and the external detonation means is not a physical connection, the connection unit 27 instead can include a wireless receiver. The wireless receiver may be positioned such that when the connection unit 27 is coupled to the detonation unit body 21, the wireless receiver is operatively coupled to trigger unit 17 via the trigger cord 31 providing a functional equivalent to the connection between the detonation cord and the trigger cord 31 as previously described.

15

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Coupling the Connection Unit 27 to the Detonation Unit Body 21 – Figures 1-10

With reference to Figures 10a to 10c, a method of coupling together the connection unit 27 with the detonation unit body 4 is described below.

25

In a first coupling step, the connection unit 27, which at this stage is a separate component from the detonation unit body 21 (see Figure 10a), is coupled together in a first inoperative position with a proximal end of the detonation unit body 21. In this first inoperative position the tabs 55 of the connection unit 27 are engaged within a first row of grooves 61 of the detonation unit body 21. The first, inoperative position of the connection unit 27 is shown in Figure 10b. In a second coupling step, the connection unit 27 is then moved axially along the detonation unit body 21 to a second operative position. In the second operative position, the tabs 55 are engaged with a subsequent row of grooves 61, the subsequent row of grooves 61 being distal of the first row. The second, operative position of the connection unit

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is shown in Figure 10c. In both positions, the connection unit 27 is coupled to the detonation unit body 4, thus enabling the trigger assembly 7 (including both the detonation unit body 21 and the connection unit 27) can be handled and moved together, as an integrated unit.

5 With the connection unit 27 in the second operative position, each of the projecting members 65 is in abutment with one of the posts 73. In this position, each notch 69 and associated post 73 form an opening within which the detonation cord 13 is held captive, the opening being in communication with the trough 79. In this way, when the detonation cord 31 is captured within the notch 69 of the connection unit 27 and the connection unit 27 is in the
10 second coupled position with respect to the detonation unit body 21, the detonation cord 13 is physically connected to the trigger cord 31. This interconnection is best captured by Figure 18d, which is described in more detail later.

Furthermore, should it be necessary to connect the trigger unit 17 with a subsequent trigger
15 unit 17, a free end of the detonation cord 13 can be fed through a gap 67 of the connection unit 27 towards a second or further connection unit 27' of a second or further trigger unit 17'. The detonation cord 13 can then be received by the connection unit 27' and the coupling steps repeated, thereby operably tying together the trigger units 17 in the heading.

20 Accordingly, an explosive blast in the hole 11 can thus be initiated in a subsequent step by triggering the booster 19 of the respective trigger unit or units 17 with the activation means, the activation means being operably connected to the booster 19 via the detonation cord 13 and trigger cord 31. This interconnection is best captured by Figure 19b, which is described in more detail later.

25 Furthermore, should the connection unit be wirelessly connected to the external activation means, the first coupling step may be all that is required to operably connect the external activation means to the trigger unit 17 of the trigger assembly 7. The two-step coupling movement – that is from a first inoperative position to a second operative position- is still
30 useful in such an embodiment, for it enables the wireless connection unit 27 to be fitted to the trigger assembly for handling/loading, prior to being “activated”.

Assembling the Trigger Assembly 7 – Figures 1-10

Summarily, the trigger assembly 7 is assembled in a multi-step process. Some or all of these steps can take place off-site (i.e., before the trigger assemblies are loaded onto the vehicle and transported to the working site).

- 5 The broad stages are as follows:
- Attach one end of the trigger cord 31 to the connection unit 27.
 - Position the detonator 15 in the carrier cap 29.
 - Wind the trigger cord 31 onto housing 23.
 - Position the connection unit 27 into the initial position with respect to the housing 23.
- 10 - Internal ratchet the carrier cap 29 into the end of the housing 23 so that the detonator 15 is within the housing 23.

Mechanisation of the Blasting Process – Figures 1-10

- 15 Whilst the trigger assembly 7 can be inserted into a blast hole 9 manually by an operator, that is by hand, the design of the trigger assembly 7, in particular that of the connection unit 27 has been driven with mechanisation in mind.

20 With reference to Figures 11 to 18, it is contemplated that the trigger assembly 7 be inserted into the blast hole 9 using at least one vehicle 70 that is equipped with at least one functional unit 100 that is specially adapted to do this.

The vehicle(s) 70 may be a purpose-built vehicle(s), or, alternatively, the vehicle(s) 70 may be a modified standard mining vehicle(s) such as, for example, a mining jumbo.

25

Embodiment of the trigger assembly shown in Figures 20-26

30 The following description highlights the main differences between the embodiments of the trigger assembly 7 shown in figures 1-10 and Figures 20-26, with the same reference numerals being used to describe the same structural features, using the same headings used above.

35 One of the main differences between the two embodiments is that the trigger cord 31 of the trigger assembly of the Figures 20-26 embodiment is at least substantially located outside the hole 9 when the trigger assembly 7 is first located in the hole 9, i.e., in the initial position

of the trigger assembly 7 in the hole 9 – see Figure 26. This is a quite different arrangement to that of the Figures 1-10 embodiment. This feature means that there are fewer components of the trigger assembly 7 in the hole 9 and this simplifies manufacture of the trigger assembly. In addition, locating the trigger cord 31 outside the hole 9 means that, in use, the trigger cord 31 unwinds as a straighter length than is the case with the Figures 1-10 embodiment. Specifically, the trigger cord 31 unwinds in a spiral motion and enters the hole as a straight length as an emulsion hose pushes a trigger unit 17 into the hole rather than as a helix motion as is the case with the Figures 1-10 embodiment. This is an advantage in terms of minimising risk of fouling of the trigger cord 31 as it unwinds.

10

Another main difference between the two embodiments is the structure of the connection unit 27. In the Figures 20-26 embodiment the connection unit 27 is a resilient element that receives and connects the detonation cord 13 of an external explosive activation system (not shown) to the trigger cord 31. This is a quite different arrangement to that of the Figures 1-10 embodiment which relies on the connection unit part being configured to respond to axially forward rotational movement about an axis of the trigger assembly 7 from an initial position to a locked position. It is noted that the reference to “resilient element” does not mean that the whole connection unit is formed from a resilient material, although this may be the case. The term is intended to focus on the operative parts of the resilient element that are involved in connecting the detonation cord 13 to the trigger cord 31.

20

As can best be seen in Figures 23 and 24, the connection unit 27 is generally crown-shaped and comprises a tubular body 97 that engages the first housing section 23a and a circular array of arms 99 that are spaced around a proximate end of the body 97. Successive arms 99 define a generally key-hole shaped passage with two opposed open sides and two opposed closed sides (with the open sides allowing a section of the detonation cord 13 to be positioned to extend from one side to the other side across the passage), with the passage having a circular base section 101 for receiving and connecting the detonation cord 13 to the trigger cord 31a (see Figure 24) retained by the connection unit 27 (described further below) and a narrower width elongate throat section 103 that communicates at one end with the circular base section 101 and has an opening 105 at the other end through such that, in use, the detonation cord 13 can be moved into the throat section 103 and along the throat section to the circular base section 101 and contact the trigger cord 31a. Figure 24 shows the detonation cord 13 in place in one circular base section 101 and being moved to be inserted into an opposed circular base section 101. The arms 99 are resilient arms such that

35

inserting the detonation cord 13 into the opening 105 and moving the detonation cord 13 through the throat section 103 to the circular base section 101 forces the arms apart from an original position against the resilience of the arms, with the arms 99 returning to the original position after the detonation cord 31 is in the circular base section 101, with the returned
5 arms in the original position resisting release of the detonation cord 31 from the circular base section 101 and contributing to retaining the detonation cord 13 in contact with the trigger cord 31a. It can be appreciated that the detonation cord 13 can be released from the circular base section 101 by applying sufficient force to overcome the resilience of the arms 99 and allow the detonation cord 13 to be removed via the throat 103.

10

Another main difference is the structure of the detonation unit body 21 and the retaining collar 25. This is in part due to the above differences.

The detonation unit body 21 includes an elongate housing 23 (see Figure 22) that is
15 configured to support the connection unit 27 at a distal end and to receive and support the trigger unit 17 at a proximal end within a compartment 22 defined by the housing 23 in the initial position of the trigger assembly 7 in the hole 9. The trigger unit 17 is shown in the compartment 22 in Figure 22.

20 The retaining collar 25 is disposed around the housing 23 of the detonation unit body 21 and is configured to engage a section of an internal wall of the hole 9 to prevent axial movement relative to the housing 23 and is also configured to allow the detonation unit body 21 to rotate about a central longitudinal axis of the housing 23.

25 The elongate housing 23 is a tubular housing, extending from the proximal end to the distal end. The tubular shape of the housing 23 facilitates easy insertion into the hole 9, for it approximates the shape of a conventionally drilled hole and does not require any specific or particular rotational orientation. It is understood, however, that other geometries are possible.

30

In this description the term "proximal" end refers to the end that is closest to the operator, when the trigger assembly 7 is inserted into the hole 11. Put differently, the proximal end of the housing 23 is a near or forward end whilst the distal end of the housing 23 is a far or rearward end of the housing 23.

35

The housing 23 is formed from two housing sections 23a, 23b that are joined together. The profile of these sections is best shown in Figures 22 and 22a. It is understood that this is but one way of forming the housing 23, and the housing 23 can, alternatively, be formed as a single piece.

5

The housing sections 23a, 23b of the housing 23 are tubular.

The first housing section 23a provides sleeve-like housing 23 around which the trigger cord 31 can be wound. As noted above, unlike the embodiment shown in Figures 1-10, the trigger assembly shown in Figures 20-26 is formed so that in use, the first housing section 23a and the trigger cord 31 wrapped around the first housing section 23a are outside the hole.

10

The second housing section 23b is open ended and serves as an end-piece within which the carrier cap 29 (see, for example, Figure 20) of the trigger unit 17 is received. An interior of the end of the second housing section 23b is lined with raised protrusions (not shown) that are configured to engage with the carrier cap 29 to hold it in via friction fit.

15

Together, the housing sections 23a, 23b define the compartment 22 within which the trigger unit 17 is received and accommodated.

20

In addition, the housing sections 23a, 23b may include features such as tabs (not shown) configured to engage with the retaining collar 25 to hold the collar 25 in place around the housing 23.

As can best be seen in Figures 24 and 25, the trigger cord 31 of the trigger unit 17 is connected at one end 31a to the detonator 15 of the trigger unit body 17 (Figure 25) and at the other end 31b to the proximal end of the detonation unit body 21 (Figure 24).

25

Turning now to Figures 22 and 22a, the housing section 23a and 23b include axially extending channels (not shown but can be envisioned from the Figures) that provide a passage for the trigger cord 31 to traverse underneath the retaining collar 25. In addition, the first housing section 23a includes an axially extending channel (not shown) that provide a passage for the trigger cord 31 to traverse underneath the connection unit 27.

30

In this way, the first end 31a of the trigger cord 31 is connected to the detonator 15 of the trigger unit 17 within the hole 9, whilst the second end 31b of the trigger cord 31 is exposed outside the hole 9 and retained in position by the connection unit 27, all the while with the trigger assembly 7 being retained within the hole 9 via the collar 25.

5

It is understood that the trigger cord 31 has a selected length to span the distance between the detonator 15 of the trigger unit 17 and the proximal end of the detonation unit body 21 when the trigger unit 17 is in the detonation position of the trigger assembly 7 in the hole 9. Accordingly, when the trigger unit 17 is at the detonation position, it remains operably connected to the proximal end of the detonation unit body 21.

10

The trigger unit body 17 and the carrier cap 29 of the Figures 20-26 embodiment are basically the same as the Figures 1-10 embodiment. The trigger unit body 17 comprises a detonator 15 and a booster 19 that are configured so that the detonator 15 can be received and housed within the booster 19. The carrier cap 29 includes a body 107 with a tapered forward end, and a sleeve 109 for receiving and retaining the trigger unit body 17.

15

The trigger assembly 7 of the Figures 20-26 embodiment is configured to be used generally as described above in relation to the Figures 1-10 embodiment.

20

The vehicles

The embodiment described in relation to the Figures includes two vehicles, one optimised for hole and heading cleaning and the other optimised for trigger assembly and emulsion delivery and detonation cord tie-in.

25

The vehicle 70 shown in Figure 11 is an embodiment of a "face inspection vehicle" that is configured to prepare a hole 9 for receiving a trigger assembly 7. The face inspection vehicle is a specialised mining vehicle that is designed to undertake preparations including cleaning and/or otherwise inspecting the blast hole 9 and/or the heading 11 surrounding the hole 9.

30

The vehicle 70' shown in Figure 12, on the other hand, is an embodiment of an "delivery vehicle" or "explosives charging and detonation cord tie-in vehicle" that is configured to (i) prepare and locate a trigger assembly 7 within a blast hole 9, (ii) pump or otherwise deliver the explosive into the blast hole 9 for triggering via the trigger assembly 7, and (iii) tie-in

35

together all of the trigger assemblies 7 of an external explosive activation system (not shown). With reference to step (iii) this tie in may be a physical tie in via the detonation cord 14 (as shown in the illustrated embodiments) or, alternatively, may be a wireless via connection units equipped with wireless receivers.

5

Each vehicle 70 may have a cabin for an operator to carry out the face inspection, trigger assembly location, explosives charging, and detonation cord tie-in functions. Alternatively, it is also contemplated that the vehicles 70 may be autonomous or semi-autonomous (i.e., remote-controlled) vehicles that do not require a cabin.

10

The invention is not confined to the use of two vehicles 70 and other possible embodiments are single vehicle embodiments carrying all the required functional units 100 in any given situation.

15

Specifically, the functions of both the “face inspection vehicle” and the ‘explosives charging vehicle’ may be undertaken by a single, combined multi-purpose mining vehicle. This multi-purpose vehicle is not shown in the Figures.

20

In addition, there may be situations where the 1st vehicle is not required. For example, there may be situations in which the functions of the “face inspection vehicle” are not required or are carried out via another option.

The 1st vehicle

25

An embodiment of the 1st vehicle 70 is a Robotic Excavator (REX) – see Figure 11.

30

The 1st vehicle is a specialised mining vehicle configured to clean holes to remove blockages and debris and to clean the face and floor of a heading by removing loose cuttings from the heading and pulling back cuttings from the heading – this is a baseline quality issue.

35

The 1st vehicle is configured to support and operate functional units (described further below) that are configured to carry out the above hole cleaning and debris removal functions.

The 1st vehicle shown in Figure 11 has an articulated arm 68 that is capable of movement up/down, forward/rearward, side-to-side, and a fine positioning module 100 on a forward end of the arm 68, which is mounted to rotate about an axis. The arm 68 serves as a coarse positioning module of the vehicle.

5

Together, the coarse positioning module 68 and the fine positioning module 100 form part of a positioning unit of the vehicle.

10 The coarse positioning module 68 is configured to position a functional unit (described below but shown as 100' in Figure 12) proximate a hole in the end face. The fine positioning module 100 is configured to locate and align the functional unit 100' more accurately in relation to the hole.

15 The positioning unit of the 1st vehicle (and the 2nd vehicle) also includes a control system (not shown) that can track a hole, for example by video servo methods or similar hole monitoring options, and operate the fine positioning module 100 to adjust, typically continuously, the position of the functional unit 100' (and any other selected functional unit). This feature enables (once in position) the fine positioning module to "float" in the "correct" position if the vehicle moves for any reason and keep the functional unit aligned with the
20 hole.

The positioning unit of the 1st vehicle – see Figure 11 - (and the 2nd vehicle) also includes a vision module comprising:

- 25 - a vision-based system 76 on the vehicle to monitor the position of the coarse positioning module 68 in relation to a hole to facilitate guiding the functional unit 100' to a required location in relation to the hole; and
- a second vision-based system 80 on the end of the fine positioning module 100 to monitor the position of the fine positioning module 100 in relation to a hole to facilitate guiding the functional unit 100' to a required location in relation to the hole.

30

By way of example, the 1st vehicle may have a +- 50mm cartesian-based X, Y, Z vision system – this can facilitate coarse positioning the functional unit 100' to be within 100-200 mm of a hole centre.

Typically, the vision-based system on the 1st vehicle sees the full heading (lighting provided by the vehicle).

5 The vision-based system on the 1st vehicle builds a “live” image of the heading (or part of the heading) that includes the topology of the heading.

10 The vision-based system on the 1st vehicle presents the image on a “touch screen” and is configured to allow an operator to point to the location of a hole on the screen and to actuate movement of the vehicle arm 68 to coarsely align the functional unit 100’ on the end of the arm with the hole – i.e. positioning to within 100-200 mm of a hole centre.

As noted above, the fine positioning module 100 then locates and/or aligns the functional unit 100’ more accurately in relation to the hole.

15 In the illustrated examples, the fine positioning module 100 includes a delta positioning system robotic unit 74, noting that invention not confined to the use of delta positioning systems.

20 The delta positioning system includes a hydraulic system to move the adjustment arms of the delta system. The invention not confined to the use of hydraulics.

The delta system unit operates with 3 degrees of freedom - up, down, and forward/back.

25 Other embodiments operate with 6 degrees of freedom – pitch, roll and yaw - in addition to the above-mentioned 3 degrees of freedom.

30 The delta system unit incorporates a video-based vision system that uses deep learning technology using AI technology, looking for patterns in images. The applicant adapted an open-source training package for use in underground block cave mine applications.

35 The delta system unit is preferably driven by servo motors and/or controllers. In use, the video-based vision system enables the delta system unit to track a hole by video servo methods or similar hole monitoring and feedback techniques and continuously correct the position accordingly. This enables the fine positioning module 100 to “float” in the correct position (i.e. in alignment with the hole) if the vehicle (or coarse positioning arm) is

accidentally moved. This is particularly useful in unstable terrain where the vehicle and the coarse positioning arm may be subject to fluctuations in position.

An alternative to using the video-based vision system to detect holes is to use drill data log.

5 This data is generated during drilling holes. It provides accurate information on the location of holes. There is an opportunity to use the information to allow fine positioning – rather than detecting the holes, the vision system is merely checking and verifying that the holes are in the expected location.

10 Cleaning holes is very important to ensure that there are no blockages in holes or to identify blockages and select emulsion explosive volumes for the holes.

A currently preferred unblocking system is an air/water nozzle – rearwardly-directed nozzle. Use air first, if blockage, flood with water, air again to pull out debris.

15

The 2nd vehicle

The 2nd vehicle shown in Figure 12 is similar to the 1st vehicle in that it has an articulated arm and a fine positioning module 100 on an end of the arm 68, with the vehicle having the
20 above-described vision-based positioning system for monitoring movement of the coarse positioning module 68 in relation to a hole and a delta positioning system unit on the end of the arm 68 for further monitoring movement of the fine positioning module 100 into closer alignment with the hole.

25 The 2nd vehicle also includes:

- (a) an emulsion explosive processing unit and hose reel,
- (b) a trigger assembly storage unit 96a storing multiple trigger assemblies 7 (without boosters 19) – typically, the number of trigger assemblies required for a given heading,
- 30 (c) a booster storage unit 96b storing multiple boosters 19 – typically, the number of boosters required for the heading, and
- (d) a detonation cord tie-in module storage unit for housing a tie-in module having sufficient length of detonation cord to tie-in the trigger assemblies in the heading.

35 The 2nd vehicle is configured to carry out the following functions:

- (a) locating trigger assemblies in holes;
- (b) filling holes with emulsion explosive; and
- (c) tying-in the holes with a detonation cord or any other suitable detonation system, such as any other cord – see triggering assembly portfolio. Also note, could use wireless and therefore not need tie-in.

The above process will now be described in broad terms, noting that further detail is provided later.

The procedure to locate a trigger assembly 7 (with a booster 19) in a hole includes a 1st step of an operator manually removing a booster 19 and a trigger assembly 7 from their separate storage compartments 96a, 96b and inserting the booster 19 into the trigger assembly 7 using a T shaped pusher tool 28l as shown in Figure 7a. It is noted that this step may be an automated step.

The process of assembling the trigger assembly 7 is preferably assisted via a hand-off unit of the vehicle.

Shown in Figure 15, the hand-off unit includes a slider 91 which provides a support in the form of a carriage for the assembled trigger assembly 7. Once the booster 19 has been inserted into the detonation unit body, the carriage can be actuated to move the assembled trigger assembly 7 from an initial, assembly position to an operative “hand-off” position where the trigger assembly 7 can be picked up by the functional unit 100’ (Figures 16a - 16d).

Best shown in Figure 16a, one such functional unit 100’ includes (a) a housing 93 for protecting a trigger assembly (with a booster) in use of the functional unit 100’ to position a trigger assembly (with a booster) in a drilled hole and (b) a gripper unit 95 positioned at an opening of the housing 93, with the gripper unit 95 being movable between closed and open positions to allow insertion of a trigger assembly 7 into the housing.

Referring to Figure 16b, the functional unit 100’ is moved – via the positioning unit of the vehicle - to a pick-up position adjacent to the slider 91. The gripper 95 is opened, and the slider 91 is then activated once more, such that the assembled trigger assembly 7 is inserted into the housing 93 and the gripper unit 95 moved to a closed position. It can be appreciated

that, when in the closed position, the functional unit 100' holds the assembled trigger assembly 7 safely and securely during movement to an aligned position in relation to a hole.

In other embodiments the hand-off unit 91 may incorporate a magazine type structure,
5 capable of sequentially holding several trigger assemblies 7 and/or trigger units 17 at the same time.

As illustrated, the positioning unit includes an articulated arm 68 that forms a coarse
10 positioning module 68, but it is understood other arrangements are possible.

With the assembled trigger assembly 7 located in the housing 93 of the functional unit 100',
the articulated arm 68 then moves from the loading position proximate the 2nd vehicle to an
unloading position in which the assembled trigger assembly 7 is located proximate the end
face. This is shown in Figure 16c. This movement is understood to be a positioning
15 movement of the coarse positioning module 68. Once this initial positioning movement is
completed, the fine positioning module 100 of the positioning unit operates to align the
functional unit 100' with a hole and the positioning unit, i.e. the coarse and fine positioning
modules, 100, 68, is "parked".

20 The assembled trigger assembly 7 is then inserted into the hole using a pusher mechanism
of the functional unit 100' (shown in Figure 16d). Together, the fine and coarse positioning
modules 68, 100 form the positioning unit of the 2nd vehicle.

In the unloading position, after the insertion of the assembled trigger assembly 7, the
25 emulsion explosive processing unit and hose reel deliver emulsion explosives to the hole 9
and the emulsion hose 86 moves the trigger unit 17 (with detonator 15 and booster 19) from
the trigger assembly 7 to a required location in the hole (shown in Figure 16e). Emulsion
explosive is injected into the hole as the hose is retracted from the hole.

Once all trigger assemblies 7 are located within the holes and in the detonation position,
30 another functional unit (or, alternatively, a combined functional unit 100 having the same
functions as the gripper), in the form of a tie-in module is configured to connect the trigger
cords of the of the respective trigger assemblies 7 to the external activation means. In the
case of a physical connection, the tie-in module is moved to successive tie-in positions in
which the tie-in module is aligned with a trigger assembly 7 in a 1st hole and ties-in the nonel
35 cord of that trigger assembly and moves to successive trigger assemblies 7 and repeats the

tie-in step. This step is best shown in Figures 18a and 18d and is described in more detail later.

Various aspects of this process will now be described in more detail below.

5

The positioning unit

Each vehicle 70 includes a positioning unit. The positioning unit is configured to move and locate a functional unit 100' with respect to a working position, to allow the functional unit to carry out required functions at, for example, the heading or in relation to the holes 11. It is noted that the functional unit 100' itself may be independently moveable with respect to the positioning unit - thus providing a third "level" or step of movement.

The positioning unit comprises a coarse positioning module 68 and a fine positioning module 100.

The different positioning modules 100, 68 are associated with different levels of applied force and torque, and range and resolution/accuracy. Specifically, the coarse positioning module 68 is designed for broad/heavy, "positioning" movements, whilst the fine positioning module 100 is designed for light/soft "locating" or "aligning" motions. As such, the dexterity of the combined positioning unit is increased- locating tasks retain the precision of the fine positioning module 100 while larger movements are handled by the coarse positioning module 68.

The coarse positioning module 68 is configured to position the functional unit proximate to the blast hole. In this sense, the term "proximate" means a rough or approximate positioning of the functional unit. The coarse positioning module 68 is an articulated arm. In some embodiments, the coarse positioning module 68 is an articulated arm or boom of a jumbo or other conventional mining vehicle.

30

The fine positioning module 100 is configured to adjust the position of the functional unit relative to the end face whilst the coarse positioning module 68 remains stationary or "parked". Specifically, such adjustment includes locating and aligning a functional unit 100' with respect to the blast hole. Furthermore, the fine movement module 100 is configured to

maintain “floating” alignment with the hole in the event that the vehicle and/or the coarse positioning module 68 moves or drifts from position.

5 In order to achieve the “floating” arrangement, the positioning unit includes a control system that can track a hole, for example by video servo methods or similar hole monitoring options, and operate the fine positioning module to adjust, typically continuously, the position of the functional unit 100’.

10 The fine positioning module 100 comprises a plurality of elongate links or arms 75 that are pivotably attached at one end to a base (i.e. hub) 76, with each link being coupled together at a central hub or travelling platform 77, to which the functional unit 100’ is couplable. In the embodiment shown in the Figures, the fine positioning module 100 includes a delta robot. Each of the elongate links 75 is independently moveable, with relative movement between the links 75 resulting in movement of the platform 77. The fine positioning module 100 is
15 best shown in Figures 16 and 18.

The travelling platform 77 is capable of both translational and rotational movement, to align and locate the functional unit with respect to the hole 9. The travelling platform 77 includes a central aperture 78. The central aperture 78 provides a passage through which elements or
20 parts of the functional units can be extended and passed. In use, the central aperture 78 is aligned co-axially with the hole 9.

The base 76 of the fine positioning module 100 is directly coupled with the coarse positioning module 68. In this way, movement of the coarse positioning module 68 results in
25 movement of the fine positioning module 100. This enables the fine positioning module 100 to have a reduced total range of motion, enabling for increased resolution in movement and control. This increased resolution enables the fine positioning module 100 to provide adjustment of the position of the functional unit coupled thereto, whilst the coarse movement module 68 remains stationery or otherwise parked – such that the only applied forces and/or
30 torques being exerted are those of the fine positioning module 100. It is to be understood, therefore, that the fine and coarse positioning modules 100, 68 work together to position the functional unit with respect to the hole 9.

35 A vision module is used to monitor and guide movements of the respective positioning modules 100, 68. The vision module is a video-based system, that utilises sensors that

provide feedback relating to the position of the blast hole 9. In this way, the positioning unit can be an autonomous positioning unit. Alternatively, the positioning unit can be a semi-autonomous positioning unit, with an operator controlling the positioning unit remotely via cameras.

5

The vision module includes a coarse range sensor 76 (see Figures 13 and 14) that is mounted to a body or chassis of the vehicle 70 and a fine range sensor 80 that is mounted to the fine positioning module 100. In this way, the coarse range sensor 76 serves to monitor and guide the coarse positioning module 68 whilst the fine range sensor 80 monitors and guides the fine positioning module 100. The range sensors can be, for example, 3D imaging sensors, cameras, proximity sensors and the like.

10

The Functional Units 100', 100''

15 The functional units 100', 100'' are essentially tools or end-effectors which are selectably couplable to the positioning unit of the or each vehicle 70.

Each functional unit 100', 100'' is configured to undertake a particular function-related or task-related to working the rock face 9 and/or loading the trigger assembly 7 into the blast hole 9. The vehicle or vehicles 70 may include a store or container 78 for holding several different functional units.

20

The functional units 100', 100'' are configured to handle all movements that directly interact with the trigger assembly 7. In this way, the fine and coarse positioning modules 100, 68 do not directly interact with the trigger assembly 7.

25

Accordingly, it is understood that in some functional units 100', 100'' are configured to be independently moveable with respect to the vehicle positioning unit. In this way, a functional unit 100', 100'' may, for example, move the trigger assembly 7 forward within a blast hole whilst the positioning unit of the vehicle (i.e. the fine and coarse positioning modules 100, 68) remains parked. Thus, the forces and torques applied to the trigger assembly 7 by the arm of the vehicle are limited to those of functional units 100', 100'' themselves. Such forces are significantly (in some cases orders of magnitude) lower than that of the respective positioning modules, protecting from inadvertent mishandling of the explosives and/or other delicate components.

30

35

A functional unit 100' of the 1st vehicle 70 is shown in Figures 13 to 14. This functional unit 100' is an integrated face and hole preparation unit. The functional unit 100' comprises a rake member 79 that is coupled to the fine positioning module 100 and at least one hose assembly 66. The rake member 79 may be hingedly attached to the positioning module, such that it can move between an operable extended position for working the rock face 3 (shown in Figure 13b), and a retracted or stowed position (shown in Figure 13a), for when the rake member 79 is not in use.

In other embodiments (not illustrated), the face and hole preparation units may be provided as separate functional units, that is a functional unit for preparing the rock face 11 and a separate functional unit for cleaning the blast hole 9.

In use, the 1st vehicle (with the functional unit coupled thereto) is trammed into position outside the safety risk zone, typically at least 5 m from the heading. With the rake member extended (as shown in Figure 13b), it is slid – via the positioning module - along the rock face 11 proximate or adjacent to the blast hole 9. In this way, the rock face 11 is wiped clear of debris, in preparation for insertion of the trigger assembly or assemblies 7 into respective blast holes 9. The cleaning process is best shown in Figure 13c.

Turning now to Figures 14a to 14c, the hose assembly 66 includes a hose 82 supplied via a rotatable spool of the integrated functional unit. The hose 82 is configured to clean debris from within a hole 9. Specifically, after the rock face 3 has been cleared of debris, the rake member 79 is retracted, enabling the functional unit to be positioned proximate a hole 9. The hose 82 is then selectively fed into the hole 9. The hose 80 is a pneumatic hose, that includes an air jet 81, disposed at an end thereof. Activation of the air jet 81 creates fluid pressure within the hole 9, loosening and clearing debris from the hole 9. The air jet 81 is directed rearwardly, such that debris is blown towards and out of the open or proximal end of the hole 9. The components of the hose assembly 66 are best shown in Figure 14a.

Feeding the hose 82 into the hole 9 is a selective feeding operation from the spool that has an encoder or other mechanism for determining a length of the hose 82 that has been dispensed therefrom and into the hole 9. In this way, the length of the hose 82 within the hole 9 can be determined and compared to a known pre-drilled depth of the hole 9. This acts as a verification that the hole 9 is clear of debris or other obstacles, and thus ready for the

trigger assembly 7 to be inserted therein, with the knowledge that the trigger unit 17 thereof will be able to be moved into the detonation position.

Should an obstacle or debris be detected, however (i.e. if the length of hose dispensed into
5 the hole is less than the pre-drilled, known depth thereof) a second hose 83 of the functional unit may be required. With reference to Figures 14b and 14c, the second hose 83 is used for clearing heavy debris such as rock from within the hole 9. The second hose 83 includes a claw 84 that is configured to grasp around the heavy debris, removing it from the hole. Once the heavy debris has been cleared, the first hose 82 is reinserted to verify that the hole 9 is
10 now clear and ready to receive the trigger assembly 7.

With the hole 9 now clear of debris, the same hole cleaning functions are repeated on each of the holes 9. When all the holes 9 are cleaned, the 1st vehicle 70 is trammed out of the drive and the 2nd vehicle 70 is trammed into position outside the safety risk zone.

15 The 2nd vehicle includes a different functional unit 100' coupled to the fine movement module 74.

This alternate functional unit 100' is shown in Figures 16a-16d. The functional unit 100'
20 includes the above-described housing 93 and gripper unit 95 configured to retain and support a trigger assembly 7 to be placed within a hole 9.

As described above, the procedure to locate a trigger assembly 7 (with a booster 19) in a hole includes a 1st step of an operator manually removing a booster 19 and a trigger
25 assembly 7 from their separate storage compartments 96a, 96b and inserting the booster 19 into the trigger assembly 7. It is noted that this step may be automated in the future.

The assembled trigger assembly 7 is then loaded into the housing 93 of the functional unit 100' and retained by the housing 93 and closed gripper arm unit 95 in a loading position of
30 the functional unit proximate the 2nd vehicle. This loading step is shown in Figure 16b.

Once the trigger assembly 7 is within the housing 93, the articulated arm is operable to move the trigger assembly 7 from the assembly area on the vehicle 70 and position the functional unit 100' in an aligned position in relation to the hole 8, with the functional unit
35 100' then being operable to move the trigger assembly within a hole 9 in an initial

deployment position within the hole 9. To do so, the coarse positioning module 68 is activated, transporting the functional unit 100' (and housed trigger assembly 7) to a pre-insertion position, proximate the hole 9, as shown in Figure 16c. The fine positioning module 100 is activated next, such that the trigger assembly 7 is aligned co-axially with the hole 9.

5 Finally, a pusher 86 is activated, extending through the opening of the gripper unit 95, such that the trigger assembly 7 is pushed into the hole 9 to the initial position, the collar 25 engaging with the rock face 3 such that the trigger assembly 7 is retained therein. This initial position is best shown in Figure 16c.

10 Once the trigger assembly 7 is in the initial position proximate the opening of the hole 9, the trigger unit 7 is pushed forward within the hole 9 to the detonation position via an insertion mechanism 87. Best shown in Figures 16d and 16e, this is achieved with an emulsion charging hose 86. In use, the emulsion charging hose 86 is threaded through the aperture 78 of the platform 77 of the fine positioning module 100 and into the opening at the proximal

15 end of the detonation unit body 21 and unspools through the housing 23. As the hose 86 passes through the housing 23, it pushes against the trigger unit 17, urging it forward against the frangible wall. The force of the trigger unit 17 against the frangible wall is sufficient to displace the wall 35, such that the trigger unit 17 is pushed, by the hose 86, to the detonation position. At this point, the emulsion charging hose 86 can be withdrawn,

20 delivering the explosive emulsion to the hole, ready for triggering via the trigger unit 17.

Turning now to Figures 17a and 17b, which show a further functional unit 100'', coupled to the fine movement module 100 of the 2nd vehicle. The functional unit 100'' includes a tie-in module 85 that is configured to physically interconnect a plurality of deployed trigger assemblies 7 together via the detonation cord 13. In use, the tie-in module 85 is connected

25 to the fine positioning module 100 once each of the required trigger assemblies 7 are installed within their respective blast holes 9.

The tie-in module 85 comprises a disc shaped moveable head 88 and a rotatable drum 89.

30 The rotatable drum 89 provides a supply of detonation cord 13. Best shown in Figure 17a, the moveable head 82 includes a guide 90 through which the detonation cord 13 is selectively dispensable. The head 88 is attached to a telescopic tube 92 that provides independent forward and rearward movement thereof whilst the positioning unit itself remains stationary – Figure 17b shows the extension of the telescopic tube 92 resulting in

35 the driving forward of the head 82 towards the trigger assembly 7.

Referring now to Figures 18a to 18d. The moveable head 88 is configured to engage with the connection unit 27 of the trigger assembly 7. Specifically, in use, the moveable head 88 is configured to apply an axial force to the connection unit 27, which moves the connection
5 unit 27 from the first inoperative position to the second operative position. As shown in Figures 18a and 18b, the head 88 is moved towards the connection unit 27 by the telescopic tube 92.

Once contacting the connection unit 27, the detonation cord 13 is selectively dispensed from
10 the rotatable drum 89 and threaded through opposing channels 67 of the connection unit 27 of the trigger assembly 7. After the detonation cord 13 has been dispensed, the head 88 drives forward again, pushing the connection unit 27 axially along detonation unit body 27 from the first inoperable position to the second, operable position. As the connection unit 27 is driven forwards, it rotates into position, the projecting members 65 being aligning with the
15 slots 71, with the detonation cord 13 being secured and locked within a notch thereof 69. In this way, the detonation cord 13 is physically locked in place within the notch of the respective connection units 27 of each trigger assembly 7. The head 88 is then retracted, with the detonation cord 13 remaining in place on the connection assembly, as shown in
Figure 18c.

20

As shown in Figure 18d, the detonation cord 13 is physically connected to the trigger cord 31 of the trigger assembly. Thus, the trigger unit 17 of each trigger assembly 7 is now operably connected to the activation means, and ready for the controlled blast.

25 With reference to Figures 19a and 19b, this tie-in process is then repeated, with the detonation cord 13 being continuously threaded through the connection unit 27 of respective trigger assemblies 7 within the rock face 11 – with the positioning unit of the vehicle moving the functional unit 100” into alignment with each of the subsequent trigger assemblies 7. In this way, each of the trigger assemblies 7 within the rock face 11 are operably joined
30 together to the activation means, via the detonation cord 13.

It is noted that the tie-in module 85 as described is used for instances where the connection of the trigger unit 17 to the external activation means is a physical connection. Where the connection is a wireless connection, the tie-in module 85 need not comprise the rotatable
35 drum and associated detonation cord. Rather, said tie in module 85 would be limited to

mechanical means of moving the connection unit to the operative position, such that the external connection means is operably connected with the trigger unit 17 of the trigger assembly 7.

5 Operation and working of the vehicles 70

A preferred or exemplary working process involving the two vehicles 70 will now be described. Generally speaking, this process involves the following steps or stages:

- i. inspecting the rock face of the heading 11;
- 10 ii. cleaning debris from the rock face 11;
- iii. inspecting the holes 9 within which the trigger assemblies 7 are to be installed;
- iv. cleaning the holes 9 in preparation for receiving the trigger assembly 8;
- v. assembly of the detonation systems of each trigger assembly;
- vi. installation/placement of the trigger assemblies in the holes 9;
- 15 vii. delivering emulsion explosive into the holes 9; and
- viii. tie-in of the respective detonation systems of each of the trigger assemblies 7.

The above stages are somewhat analogous to the stages of conventional blasting methods of drive advancement. The difference in this process lies in the fact that each of the stages
20 (i) to (viii) above are mechanised, involving the use of vehicles 70. In this way, workers/persons can be kept a safe distance away from the heading 9, whilst the efficiencies of automation result in faster advancement.

Without being limited to this preferred method, it is understood that stages (i) to (iv) utilise
25 the “face inspection” or first vehicle 70, whilst stages (v) to (viii) utilise the “explosive charging” or second vehicle 70.

During step (i), the face inspection vehicle 70 is driven or trammed along the drive to a position proximate the heading 11. This may be an autonomous or semi-autonomous
30 process, whereby the vision module provides location related feedback to an operator or controller or the vehicle 70. In particular, the coarse range sensor 76 is used for this purpose. Once in position, the articulated arm of the vehicle 70 is extended, such that the fine range sensor 80 is moved to a location close or adjacent to the heading 11. The coarse positioning module 68 is then activated, such that the articulated arm is moved across the
35 surface of the heading 11. During this movement, the vision module is used to perform a

preliminary surface scan of the heading 11. This scan is used to determine the existence of surface debris and the like, and any particular areas requiring smoothing and clearing. During this movement, the vision module 80 also scans the rock face of the heading 11 to identify and locate the pre-drilled holes 9 within the face. This location data is stored within a
5 controller of the vehicle 70. The scanning operation relies upon algorithms within the controller to identify the holes within the face. Alternatively, the controller may already have predetermined hole location data stored therein, in which case the scanning operation is used to confirm or verify the location of the holes 9. It is noted that this identification/locating of the hole locations can also be done after the heading 11 has been cleared, as part of step
10 (iii).

Once the scan of the rock face 11 is completed, step (ii) commences. During this step, debris is removed from the rock face or heading 11. Step (ii) utilises the rake member 79 of the integrated functional unit 100. In particular, the rake member 79 is extended to an
15 operable position, with the coarse movement module 68 being activated to move the articulated arm of the vehicle 70 across the rock face in a sweeping motion. The sweeping motion may be a substantially vertical motion or, alternatively, a horizontal motion. This sweeping movement brushes debris from the rock face 11. The removal of debris is a quality issue, and important to allow safe and accurate placement of the trigger assemblies within
20 the holes 9. The surface of the ground of the drive adjacent the heading 11 is also flattened and cleared by the rake member 79 in a similar process.

With the heading 11 has been cleared of debris, it is now time for step (iii), where the holes 9 to be inspected for debris. Specifically, the fine positioning module 100 is activated and used
25 to locate the aperture 78 of the platform 77 coaxially with the hole 9. The first hose 80 is then selectively fed from the spool 82 through the aperture 78 and into the hole 9. As the hose 80 is fed into the hole 9, the length of hose is determined via an encoder or similar on the spool 82. The hose 9 is fed until it encounters a resistance. The resistance can, for example, be the end of the hole 9. The length of unspooled hose 80 is then compared with a known
30 depth or length of the hole 9. The known depth of the hole 9 is stored within a controller of the vehicle 70 or on a chart available to an operator thereof. If the length of hose 80 is substantially the same as the known length, it is determined that the hole is clear. If, however, the length of hose dispensed is less than the known length of the hole, it can be determined that there is an obstruction that requires clearing. It is important to clear the hole

of such obstruction, for the trigger assemblies need to be positioned at known locations – nominally towards the end of – the holes 9.

Step (iv) involves the clearing of debris and obstacles from the hole 9. A first aspect of step
5 (iv) is undertaken simultaneously with the depth measurement of step (iii). Specifically, the
air jet 81 is incorporated into the end or head of the hose 80. As the hose 80 is retracted
back towards the front or proximal end of the hole 9, the air jet 81 is activated, such that mild
or small debris such as sand and small stones are blown towards the hole face. A second
aspect of clearing the hole 9 of debris, however, involves a separate or distinct cleaning
10 step. This cleaning step is undertaken when an obstruction is detected during step (iii).
Specifically, after the first hose 80 is retracted, the second hose 83 is fed into the hole 9.
Upon encountering the previously detected obstruction, the claw 84 is activated, grasping
the obstruction (i.e. stones, rocks, debris) therein. The hose 83 is then retracted and with it
the debris. This may be repeated several times as necessary. To ensure that the obstruction
15 has been cleared, step (iii) can be repeated after the second hose 83 has been used.

At the completion of steps (i) to (iv) for all holes 9 within the heading 11, it is time for the
trigger assemblies 7 to be prepared and inserted. The first vehicle 70 is driven or trammed
clear, with the second vehicle 70 being driven or trammed into its place proximate the
20 heading 11. The second vehicle includes a first storage compartment or housing 96a within
which a plurality of pre-assembled trigger assemblies 7 are housed (the boosters 19 are
housed in a separate compartment or housing 96b of the second vehicle 70). The
connection units 27 of the pre-assembled assemblies 7 are in the first inoperative position-
i.e., only partially engaged with the detonation unit.

25 The pre-assembled trigger assemblies 7 are fitted with colour coded connection units 27.
The colour coding is used to assist the operator/controller of the vehicle 70 with locating the
correct trigger assemblies 7 into the correct holes 9. For example, the colour coding may
indicate the type of booster to be installed therein or the length of nonel cord wrapped
30 around (i.e., determining the depth at which the respective trigger assembly is to be located).
Alternatively, or additionally, the colour coding may indicate the timing of the detonation if
the trigger unit 17 – i.e., the “order” in which the trigger assemblies 7 are fired after activation
via the external activation means. Alternatively, it is also contemplated that the trigger
assemblies 7 may be programmable trigger assemblies, with the timing of fire being based
35 on the location of the hole 9 within which the trigger assembly 7 is inserted – as such

placement of specific trigger assemblies in specific holes based on timing/sequence of fire is no longer necessary.

Step (v) comprises assembling the trigger units 17 of each of the trigger assemblies 7. In particular, the booster 19 is inserted into the compartment of the trigger assembly. When 5 positioned within the compartment 22, the detonator 15 (being pre-installed within the trigger assembly 7) is at least partially enveloped within the chamber 39 of the booster 19. Notably, prior to this step, the trigger units 17 of each trigger assembly 7 are not operable/assembled, with the explosive (i.e., booster 19) being located separate from the detonator 15. This step 10 may be a manual step, undertaken by an operator. A T-shaped insertion tool may be used by the operator to push the booster through the connection unit 27 and housing 23 into position within the compartment 22. Alternatively, this may be an automated step undertaken by a functional unit 100' of the second vehicle 70. In either event, it is preferred that during assembly, the trigger assemblies 7 are supported on the hand off slider 91, in an assembly 15 position that is away from the positioning unit/articulated arm of the vehicle. Once the trigger unit 17 is assembled with the booster therein, the carriage 91a of the hand off slider 91 is activated, and the assembled trigger assembly 7 is moved to a hand-off position.

With the assembled trigger assembly 7 in the hand off position, it is time for the trigger 20 assembly 7 to be positioned within the hole 9. During step (vi), the gripper 95 of the functional unit 100' is initially moved into a loading position proximate to the hand off slider 91. In this loading position, the opening of the housing 93 is concentrically aligned with the connection unit 27 of the trigger assembly 17. The carriage of the hand off slider 91 is activated once more and the gripper 95 opened, such that the trigger assembly 7 is fed into 25 the housing 93. The gripper 95 is then closed, such that the trigger assembly 7 is secured within the housing 93. The carriage of the slider 91 is then retracted clear of the gripper 95. The coarse movement module 68 is then activated, with the articulated arm moving the gripper 95 to the unloading position, proximate the hole 9. The fine positioning module 100 is then activated, such that the gripper 95 (and trigger assembly 7 within the housing 93 30 thereof) is coaxially aligned with the hole 9. At this point, the jaws of the gripper 95 are opened, with the pusher 86 inserting the trigger assembly 7 into the initial position within the hole. In this initial position. The respective connection units 27 protrude outwardly from the hole 9, whilst the housing 23 of the trigger assembly 7 extends into the hole, being retained in position relative thereto via the collar 25, which engages against the sides of the hole 9.

Once in the initial position, the trigger unit 7 is then moved forward towards its operative or detonation position via the emulsion charging hose 86. Specifically, the charging hose 86 is fed through the opening of the connection unit 27, and contacts against a proximal end of the booster 19. Continued feeding of the charging hose 86 pushes the trigger unit 17 of the trigger assembly 7 free of the housing 23 to the detonation position, with the housing 23 being retained at the proximal end of the hole 9 via the collar 25.

With the trigger unit 17 now in the detonation position, step (vii) involves the pumping of emulsion explosive, via the charging hose 86 into the hole 9. Advantageously, because the charging hose 86 is used to position the trigger unit in the detonation position, the charging hose 86 is already located within the hole 9, saving time and effort required to otherwise feed the hose therein. Once the emulsion explosive is fed into the hole, the hose 86 is retracted.

Steps (i) to (vii) are then repeated for all trigger assemblies 7, such that each hole 9 within the heading 11 receives a trigger assembly 7.

Finally, step (viii) involves the “tie in” of the detonation cords of each of the trigger assemblies 7. This step is conducted via the tie-in module 85 of the functional unit 100c. It is understood, therefore, that it may be necessary for an intermediary step of changing or “swapping out” the functional unit 100' in order for the functional unit 100” to be coupled to the articulated arm. Alternatively, the functional unit 100” can be adapted to work alongside the functional unit 100'. For example, the tie-in module 85 can be adapted so as to be receivable around an outside of the housing 93 of the functional unit 100'. In such an embodiment, the tie-in module can be installed into position via the slider unit 91 in a similar manner to the way in which the trigger assemblies 7 are received within the housing 93.

The tie-in module 85 is then moved into an operable tie-in position, proximate the connection unit 27 of a first of the trigger assemblies 7. As previously discussed, in the case of a physical connection between the external activation means and the trigger unit 17, the detonation cord 13 is selectively dispensed from the rotatable drum 89 and threaded through opposing channels 67 of the connection unit 27 of the first of the trigger assembly 7. The connection unit 27 is then moved from the inoperative position to the operative position via the moveably head 88 of the tie-in module 85.

This process is then repeated, with the tie-in module 85 being moved to a second tie-in position, such that the detonation cord 13 is continuously threaded through the connection unit 27 of respective trigger assemblies 7 within the rock face 11. In this way, each of the trigger assemblies 7 within the rock face 11 are operably joined together to the activation
5 means, via the detonation cord 13, ready for detonation.

Summarily, it is understood that the present invention provides a device for installing a protective lining to an underground drive such as a mining drive, that provides significant safety and productivity improvements over existing manual methods. Conventional industry
10 practise requires workers to work underground to manually unroll and fix protective mesh to the drive surfaces, an arduous task with a high level of injury risk. The present invention overcomes these problems by providing an assembly that enables this task to be undertaken by an otherwise conventional rock drilling jumbo. The assembly includes a pair of arms couplable to a boom of the jumbo, for holding a roll of protective lining
15 therebetween. The arms are configured such that throughout the installation process, the roll of lining is held clear of the boom and the remainder of the jumbo, reducing the chance of damage to both the jumbo and the lining itself.

Unless defined otherwise, all technical and scientific terms used herein have the same
20 meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can also be used in the practice or testing of the present invention, a limited number of the exemplary methods and materials are described herein.

25 It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word
30 “comprise” or variations such as “comprises” or “comprising” is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

Many modifications may be made to the embodiments described above in relation to the
35 Figures without departing from the spirit and scope of the invention.

By way of example, the invention is not confined to a two-vehicle solution and other possible embodiments are single vehicle embodiments, for example, with separate arms carrying functional units for hole cleaning, etc.

CLAIMS

1. A trigger assembly for triggering an explosive in a hole in rock to produce an explosive blast, the trigger assembly being configured to be located in a hole in rock, for example in an end face, i.e., heading, of a drive, the trigger assembly including:
- 5 (a) a detonation unit body configured to be located at or proximate an open end of the hole;
- (b) a trigger unit locatable at least partially within the detonation unit body for triggering the explosive in the hole, the trigger unit including a trigger cord connected to a proximal end of the detonation unit body; and
- 10 (c) a connection unit for connecting a detonation cord of an external explosive activation system to the trigger unit to facilitate triggering an explosion in the hole.
2. The trigger assembly defined in claim 1 wherein the connection unit is configured to receive the detonation cord of the external explosive activation system and to physically connect the detonation cord to the trigger cord when coupled thereto.
- 15 3. The trigger assembly defined in claim 2 wherein the connection unit may comprise a resilient element to receive and connect the detonation cord to the trigger cord.
- 20 4. The trigger assembly defined in claim 3 wherein the resilient element comprises a generally key-hole shaped passage with two opposed open sides and two opposed closed sides, with the passage having a circular base section for receiving and connecting the detonation cord to the trigger cord and a narrower width elongate throat section that communicates at one end with the circular base section and has an opening at the other end through which, in use, the detonation cord can be moved into the throat section and along the throat section to the circular base section and contact the trigger cord.
- 25 5. The trigger assembly defined in claim 4 wherein the resilient element comprises a base and a pair of opposed arms extending from the base that define the passage, with the base defining the circular base section and the arms defining the throat section.
- 30 6. The trigger assembly defined in claim 5 wherein the arms are resilient arms such that inserting the detonation cord into the opening and moving the detonation cord through the throat section to the circular base section forces the arms apart from an original position
- 35

against the resilience of the arms, with the arms returning to the original position after the detonation cord is in the circular base section, with the returned arms in the original position resisting release of the detonation cord from the circular base section and contributing to retaining the detonation cord in contact with the trigger cord.

5

7. The trigger assembly defined in claim 2 wherein the connection unit is configured to be moveable relative to the detonation unit body from a first inoperative position, in which the detonation cord is not connected to the trigger unit, to a second operative position, in which the detonation cord is connected to the trigger unit.

10

8. The trigger assembly defined in claim 7 wherein the connection unit includes a sleeve that fits over a proximal end of the detonation unit body as viewed looking at the hole, the sleeve being configured to receive the detonation cord and to physically connect the detonation cord to the trigger cord when coupled thereto.

15

9. The trigger assembly defined in claim 8 wherein the sleeve is moveable relative to the detonation unit body from the first inoperative position, in which the detonation cord is not connected to the trigger cord, to the second operative position, in which the detonation cord is connected to the trigger cord.

20

10. The trigger assembly defined in any one of claims 7 to 9 wherein the connection unit and the detonation unit body include complimentary mating members that can guide the connection unit and the detonation cord from the first inoperative position to the second operative position and bias together the trigger cord and the detonation cord in the second operative position.

25

11. The trigger assembly defined in claim 10 wherein the complimentary mating members comprise (i) a plurality of projecting members that extend axially away from a proximal end of the sleeve and define a plurality of channels therebetween for receiving the detonation cord and (ii) a plurality of posts that extend from the proximal end of the detonation unit body and define slots therebetween, with the channels and the slots being aligned axially when the connection unit is in the first inoperative position.

30

12. The trigger assembly defined in claim 11 wherein each projecting member is shaped to have a taper from a tip of the projecting member, with the width of the projecting member

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increasing with distance from the tip, with the increasing width of the taper guiding the detonation cord into a channel.

13. A trigger assembly for triggering an explosive in a hole in rock to produce an explosive
5 blast, the trigger assembly being configured to be located in a hole in rock, for example a hole in an end face, i.e., heading, of a drive, the trigger assembly including:

- (a) a detonation unit body configured to be located at or proximate an open end of the hole;
- (b) a trigger unit locatable at least partially within the detonation unit body for triggering
10 the explosive in the hole; and
- (c) a connection unit for connecting an external explosive activation system to the trigger unit to facilitate triggering an explosion in the hole, the connection unit including a wireless receiver in communication with the external activation means that can be triggered by laser, WiFi, Bluetooth or another communication medium.

15

14. The trigger assembly defined in claim 13 wherein the connection unit and/or the trigger assembly include a power source such as a battery to power the receiver.

15. The trigger assembly defined in any one of the preceding claims wherein the detonation
20 unit body includes a compartment for housing the trigger unit.

16. The trigger assembly defined in claim 15 wherein the detonation unit body includes an elongate housing that defines the compartment and is configured to extend into the hole and to receive and support the trigger unit within the compartment in the initial position of the
25 trigger assembly in the hole.

17. The trigger assembly defined in claim 16 wherein the elongate housing includes a first housing section that, in use, is located outside the hole and provides sleeve-like housing around which the trigger cord is wound.

30

18. The trigger assembly defined in claim 16 wherein the elongate housing includes a first housing section that, in use, is located inside the hole and provides sleeve-like housing around which the trigger cord is wound.

19. The trigger assembly defined in any one of the preceding claims wherein the trigger unit includes (i) a booster that contains a small explosive charge, typically a small explosive charge compared to the rock mass to be blasted and (ii) a detonator for detonating the small explosive charge.
- 5
20. The trigger assembly defined in claim 19 wherein the booster includes an elongate chamber for receiving the detonator such that the booster is insertable into the detonation unit body after the detonator is already installed therein.
- 10
21. The trigger assembly defined in claim 19 or claim 20, wherein the trigger unit includes a carrier configured to mount the detonator and/or the booster and the trigger cord in the compartment.
- 15
22. The trigger assembly defined in claim 21, wherein the carrier is configured to be inserted into and close an open end of the detonation unit body so that the detonator and the booster are located in the housing.
- 20
23. The trigger assembly defined in claim 21 or claim 22, wherein the carrier is detachable from the detonation unit body to thereby open the compartment and release the trigger unit when a force in excess of a threshold force is applied thereto.
- 25
24. The trigger assembly defined in any one of the preceding claims includes a retaining means for retaining the detonation unit body at an initial position within the blast hole towards the open end thereof.
- 30
25. The trigger assembly defined in claim 24 wherein the retaining means includes a wider diameter section of the detonation unit body.
- 35
26. The trigger assembly defined in claim 25 wherein the retaining means includes a collar that has a wider diameter than the diameter of the detonation unit body and is configured to engage a section of an internal wall of the hole near the open end of the hole.
27. The trigger assembly defined in claim 26 wherein the retaining collar is disposed around the housing of the detonation unit body and is configured to (a) engage the section of the internal wall of the hole to prevent axial movement relative to the housing and (b) allow the

detonation unit body to rotate about a central longitudinal axis of the housing in use when the trigger cord is unwound as the carrier moves forwardly from the initial position in the hole away from the detonation unit body.

- 5 28. The trigger assembly defined in claim 24, wherein the retaining means includes a collar that is mounted on the detonation unit body and has a resilient biasing element that is configured to contact the side wall of the hole and hold the trigger assembly in position in the hole.
- 10 29. The trigger assembly defined in claim 28, wherein the collar is mounted for relative rotational movement about a longitudinal axis of the detonation unit body to allow the body to rotate as the trigger cord is unwound as the detonator/booster carrier moves forwardly from the initial position in the hole away from the detonation unit body.
- 15 30. The trigger assembly defined in any one of the preceding claims configured such that the trigger unit can be moved forward into the blast hole to a desired detonation position whilst the detonation unit remains in the initial position, with the trigger cord (when present) unwinding to maintain the physical connection between the detonation unit body and the trigger unit so that the trigger unit can be activated by the activation means to thereby
20 trigger the explosive in the hole and produce the explosive blast.
31. A method of triggering an explosive blast within rock, the rock having a plurality of holes formed therein, the method comprising:
- 25 (a) positioning a detonation cord of an external explosive activation system in relation to the connection unit of the trigger assembly defined in any one of the claims 1 to 12,
- (b) physically connecting together the detonation cord and the trigger unit of the trigger assembly, and
- (c) triggering an explosive within the trigger assembly to thereby initiate the
30 explosive blast with the external activation means.
32. The method defined in claim 31, further including repeating steps (a) and (b) successively in relation to a plurality of other trigger assemblies and thereby connecting together the trigger assemblies with the detonation cord before carrying out step (c).

33. A mining or civil engineering vehicle for working proximate an end face, for example proximate an end face, i.e., a heading, of a drive, the vehicle comprising a positioning unit for moving a functional unit to a selected location, the positioning unit including:
- (i) a coarse positioning module configured to position the functional unit proximate the selected location; and
 - (ii) a fine positioning module configured to facilitate adjustment of the position of the functional unit to locate and align the functional unit more accurately in relation to the selected location.
34. The vehicle defined in claim 33, wherein the positioning unit further includes a control system that can track the selected location, for example by video servo methods or similar hole monitoring options, and operate the fine positioning module to adjust, typically continuously, the position of the functional unit.
35. The vehicle defined in claim 33 or claim 34, wherein the positioning unit further includes a system for monitoring the position of at least one of the coarse positioning module and the fine positioning module.
36. The vehicle defined in claim 35, wherein the system comprises a first range sensor mounted to a body of the vehicle.
37. The vehicle defined in claim 36, wherein the system further comprises a second range sensor mounted to the fine positioning module.
38. The vehicle defined in any one of claims 33 to 37, wherein the fine positioning module is coupled to the coarse positioning module.
39. The vehicle defined in any one of claims 33 to 38, wherein the coarse positioning module comprises an articulated arm.
40. The vehicle defined in any one of claims 33 to 39, wherein the fine positioning module comprises a hub configured to be coupled to the functional unit and a plurality of elongate links, with each link being connected at one end to the hub.

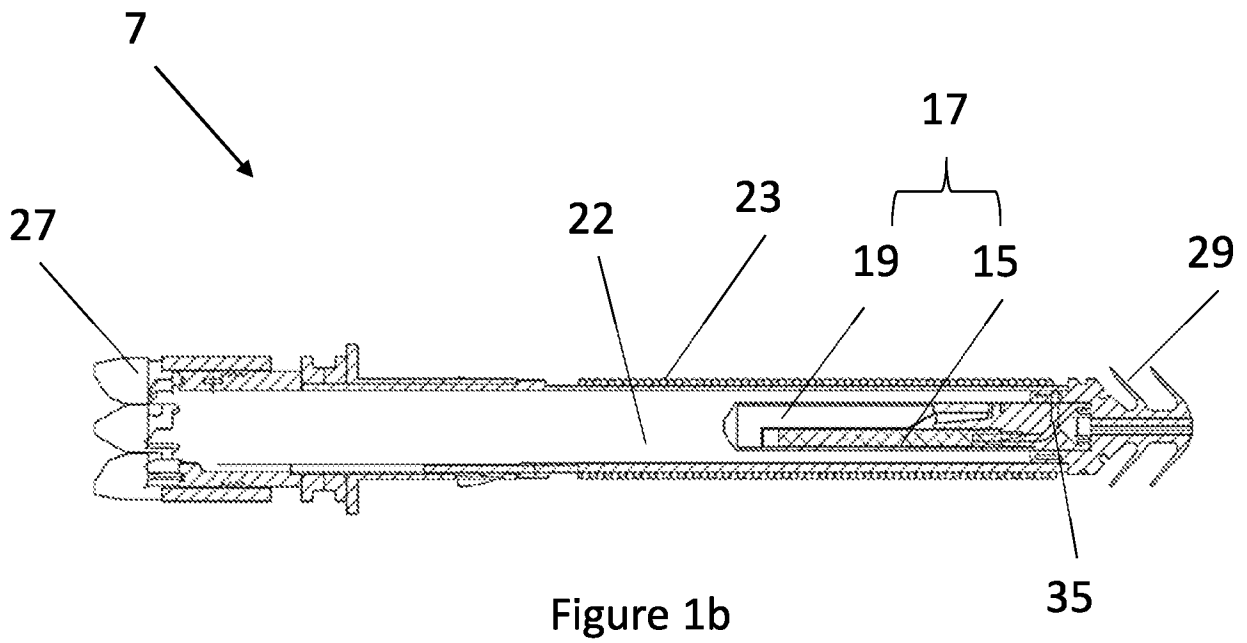
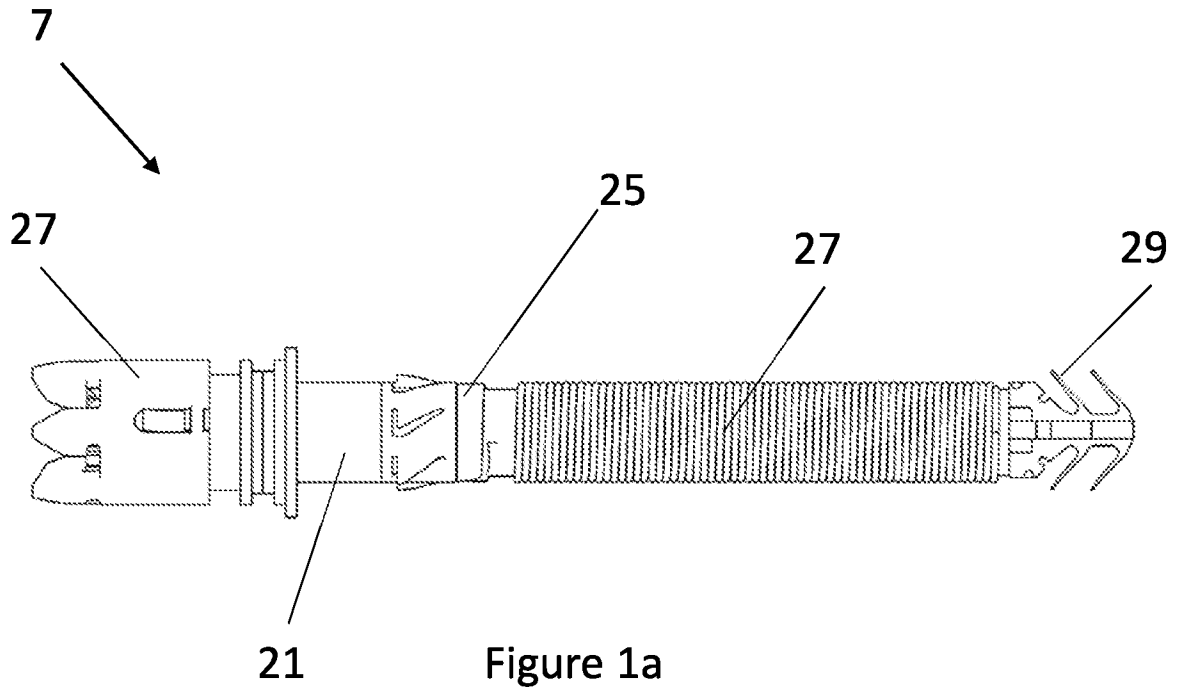
41. The vehicle defined in claim 40, wherein each of the links is independently moveable such that the hub is translatable and rotatably moveable with respect to the vehicle.
- 42 The vehicle defined in claim 40 or claim 41, wherein the hub includes an aperture that, in use, is aligned co-axially with a hole or other selected location in the end face.
43. The vehicle defined in any one of claim 33 to 42, further including at least one functional unit that is configured to prepare and load a selected trigger assembly into a hole in the end face.
44. The vehicle of claim 43, wherein the at least one functional unit is configured to move the trigger assembly with respect to the end face independently of the positioning unit of the vehicle.
45. The vehicle defined in claim 43, wherein the at least one functional unit is configured to move the trigger assembly with respect to the hole independently of the coarse positioning module of the vehicle.
46. The vehicle defined in claim 43, wherein the at least one functional unit is coupled to the fine positioning unit and is configured to move the trigger assembly with respect to the hole independently of the coarse positioning unit of the vehicle.
47. The vehicle defined in any one of claims 44 to 46, including a first functional unit includes (a) a housing for protecting the selected trigger assembly in use of the functional unit to position the selected trigger assembly in the hole and (b) a gripper unit positioned at an opening of the housing, with the gripper unit being movable between closed and open positions to allow insertion of a trigger assembly into the housing.
48. The vehicle defined in claim 47, further including a housing for storing a plurality of the trigger assemblies.
49. The vehicle defined in any one of claims 44 to 48, wherein the first functional unit, typically couplable to the fine positioning module, is configured to support the trigger assembly when the trigger assembly is moved to the initial position within the hole.

50. The vehicle defined in claim 49, wherein the first functional unit includes a moveable member that, in-use, is moved co-axially with the hole to move the selected trigger assembly from a pre-insertion position proximate the hole to the initial position within the hole.
- 5 51. The vehicle defined in claim 49 or claim 50, wherein the first functional unit includes an insertion mechanism operable to move a detachable portion of the selected trigger assembly forward from the initial position to an operative position within the hole.
52. The vehicle defined in claim 51, wherein the insertion mechanism comprises an
10 emulsion charging hose that unspools to push the detachable portion from the initial position to the operative position.
53. The vehicle defined in claim 52 when dependent on claim 42, wherein the emulsion charging hose extends through the aperture of the hub of the fine positioning module.
15
54. The vehicle defined in any one of claims 33 to 42, including a second functional unit in the form of a tie-in module that is typically couplable to the fine positioning module and configured to connect the detonation cord to the trigger assemblies after the trigger assemblies are located in the holes.
20
55. The vehicle defined in claim 54, wherein the tie-in module includes a moveable head that is engageable with a fixed portion of the selected trigger assembly, such that, in use, forward movement of the moveable head may secure the detonation cord to the trigger assembly.
- 25 56. The vehicle defined in claim 55, wherein the head is attached to a telescopic tube to facilitate forward movement thereof.
57. The vehicle defined in claim 55 or claim 56, wherein the head includes a guide through which the detonation cord is fed towards the fixed portion of the selected trigger assembly.
30
58. The vehicle defined in claim 57, wherein the head is disc-shaped and the guide is centrally located therewith, such that, in use, the guide is located coaxially with respect to the hole when connecting the detonation cord to the trigger assembly.

59. The vehicle defined in any one of claims 54 to 58, wherein the tie-in module includes a rotatable drum from which the detonation cord is selectively dispensable.
60. The vehicle of claim 59, wherein the rotatable drum is housed within the fine movement
5 module when the tie-in module is coupled thereto.
61. The vehicle defined in any one of claims 33 to 42, further including at least one functional unit that is configured to clean and inspect the hole and/or the rock face surface proximate thereto in preparation of insertion of the trigger assembly.
10
62. The vehicle defined in claim 61, including a third functional unit couplable to the fine positioning module and configured to clear debris from the rock face surface proximate the hole.
- 15 63. The vehicle of claim 62 wherein the third functional unit includes a rake member configured to be drawn along the rock face surface to thereby wipe debris clear of the hole.
64. The vehicle defined in claim 61, including a fourth functional unit couplable to the fine positioning module and configured to clear debris from within the hole.
20
65. The vehicle defined in claim 64, wherein the fourth functional unit includes a first hose that is selectively fed from a rotatable spool into the hole to measure a depth thereof.
66. The vehicle defined in claim 65, wherein a terminal end of the first hose provides an air
25 jet for clearing light debris from the hole.
67. The vehicle defined in claim 66, wherein the air jet is directed away from the terminal end of the respective hose, such that debris is propelled towards the opening of the hole.
- 30 68. The vehicle defined in any one of claims 65 to 67, wherein the fourth functional unit includes a second hose having a terminal end configured to grasp heavy debris and remove it from the hole.
69. The vehicle defined in any one of claims 43 to 68, further comprising a separate storage
35 compartment for storing the or each of the functional units.

70. A mining or civil engineering vehicle for working proximate an end face, for example proximate an end face, i.e., a heading, of a drive, the vehicle comprising: a positioning unit for moving a functional unit with respect to a selected location, the positioning unit including:
5 a vision module for monitoring the position of the functional unit(s) to facilitate guiding the functional unit to the selected location.

71. A mining or civil engineering vehicle comprising a functional unit for working an end face, the vehicle being configured to move the functional unit to an initial position proximate a
10 selected location in the end face, and the functional unit being configured to move independently from the initial position to a second position closer to the selected location whilst the vehicle remains stationary.



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Figure 2

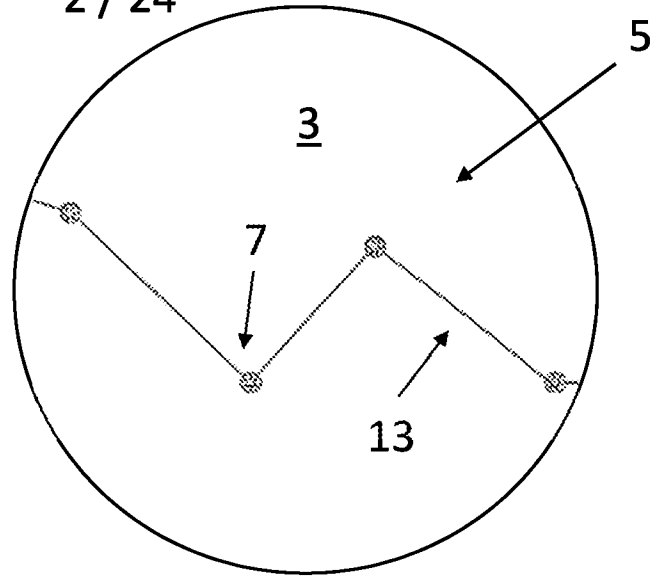


Figure 3a

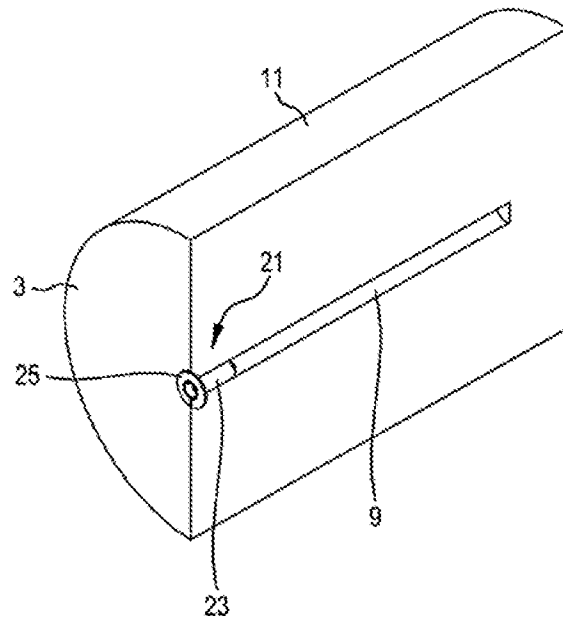
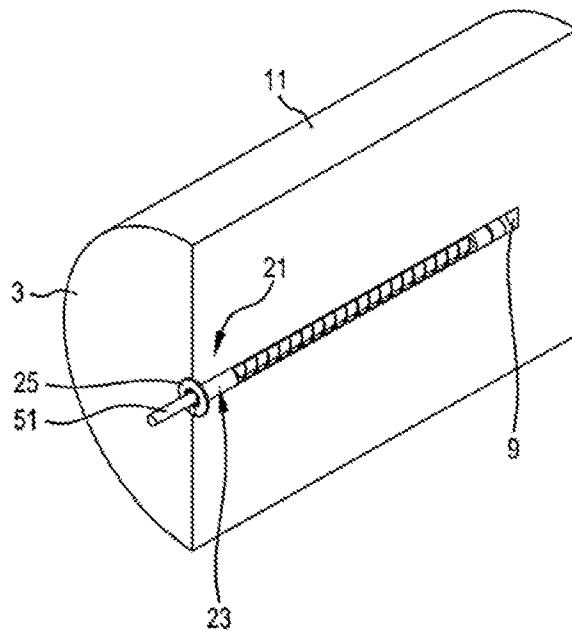


Figure 3b



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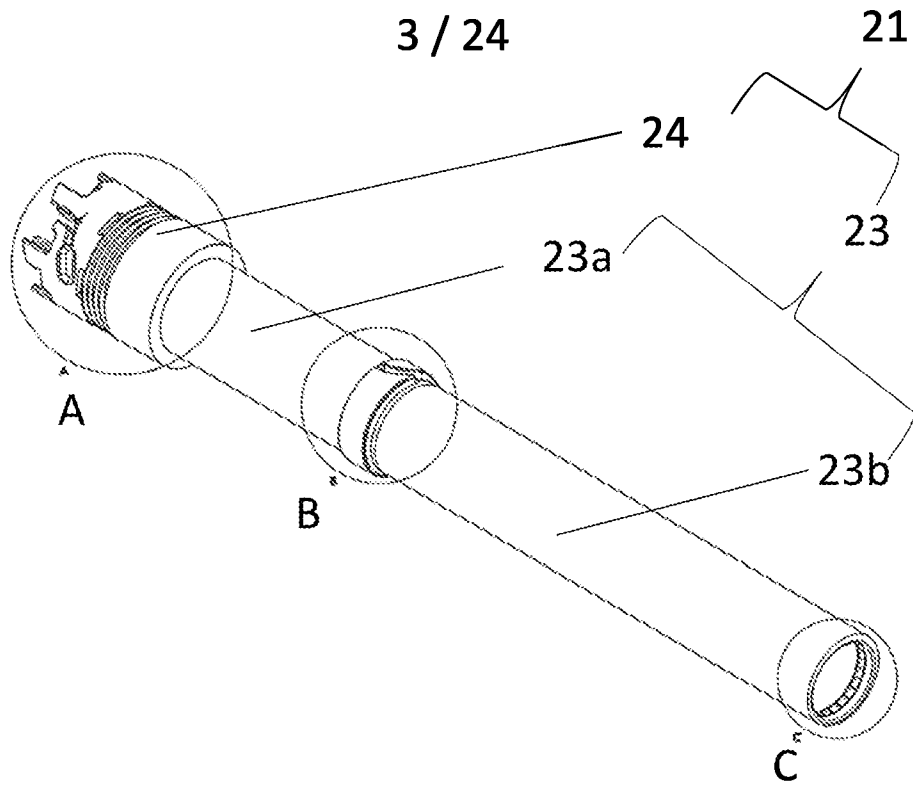


Figure 4a

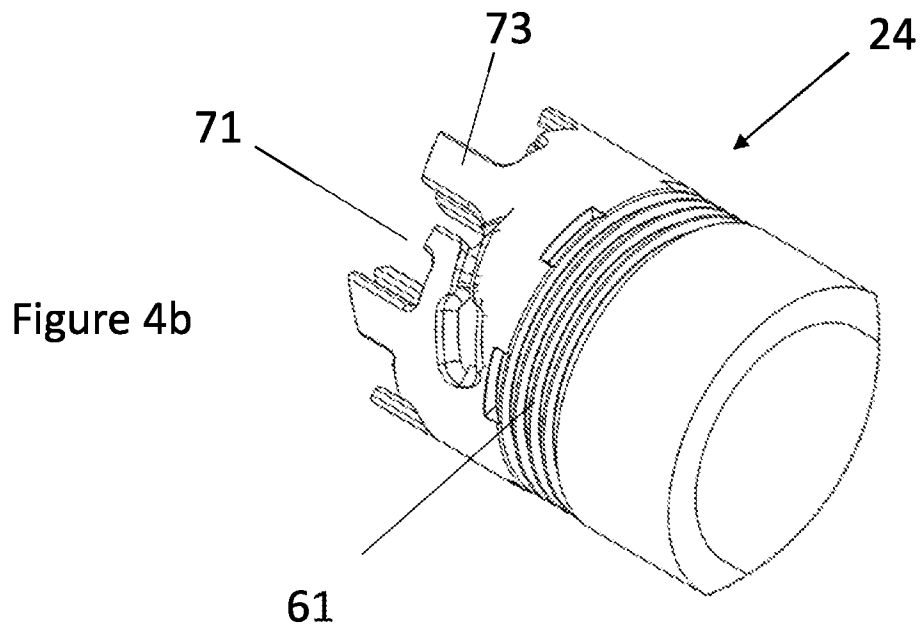


Figure 4b

Figure 4c

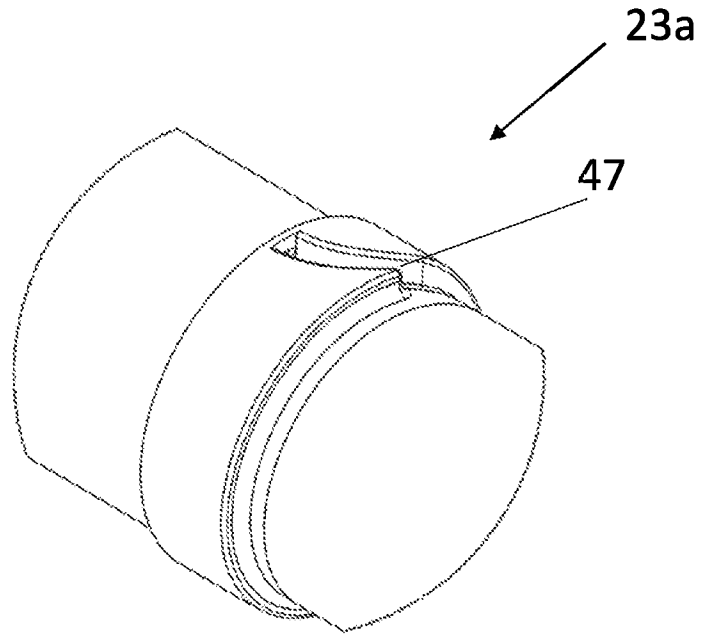
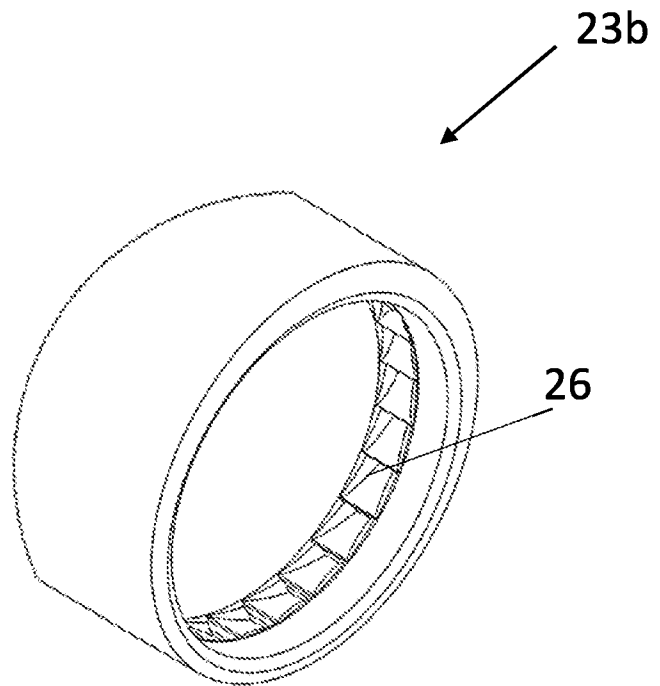


Figure 4d



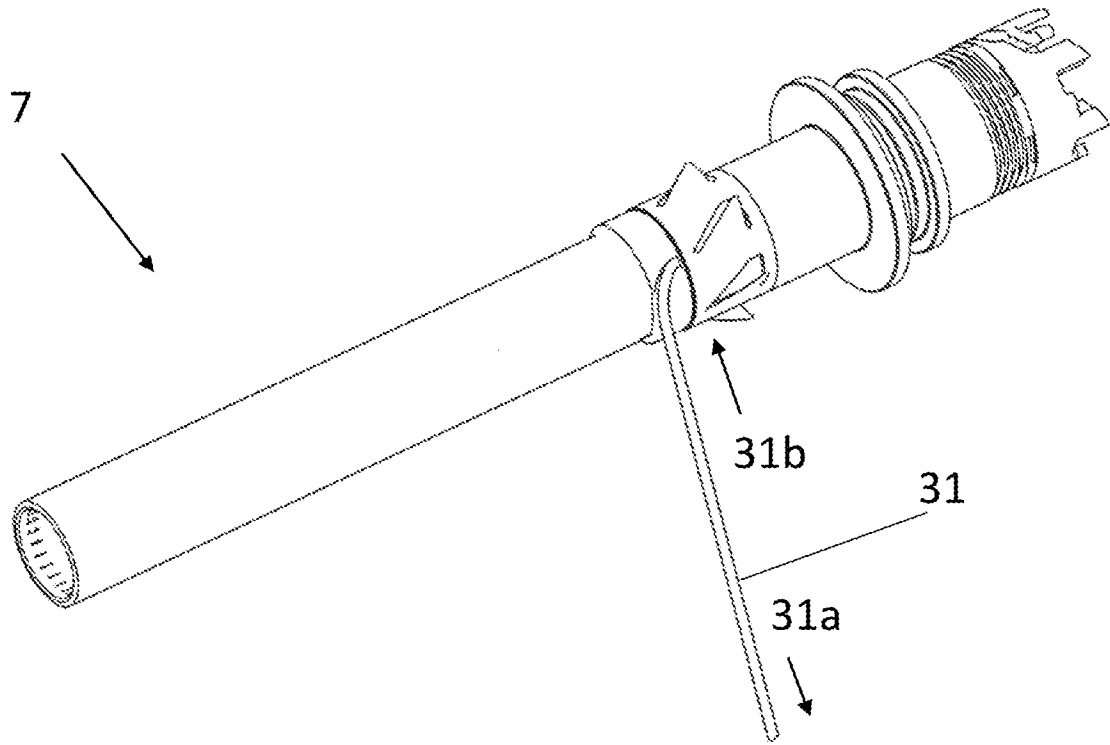


Figure 5

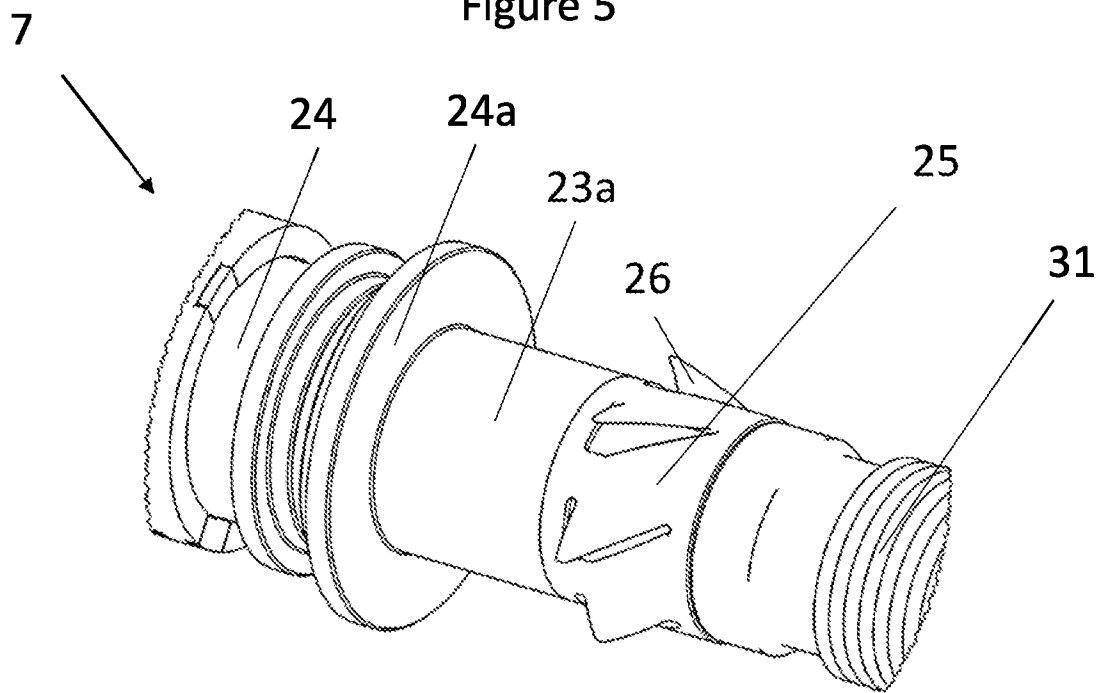


Figure 6a

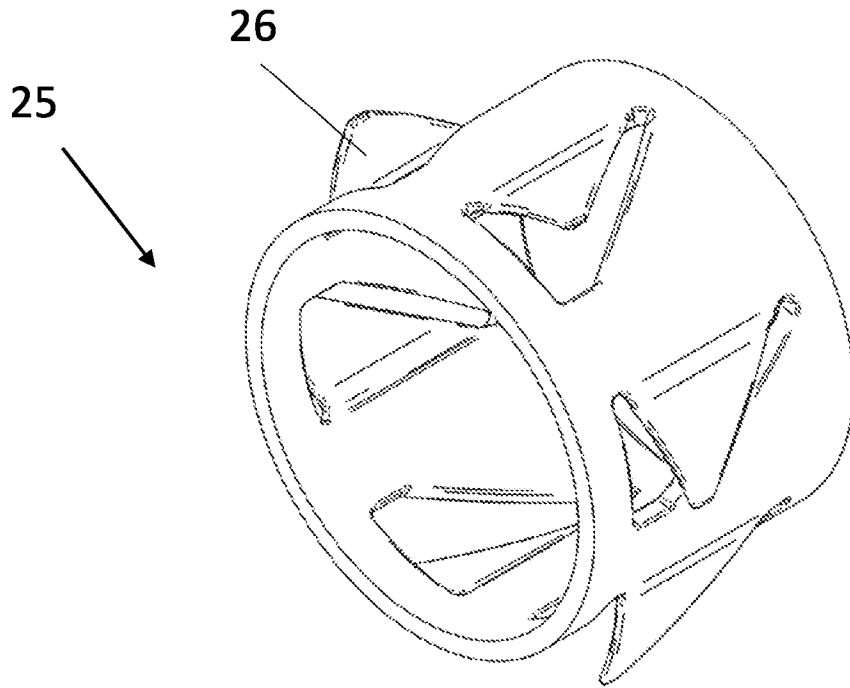


Figure 6b

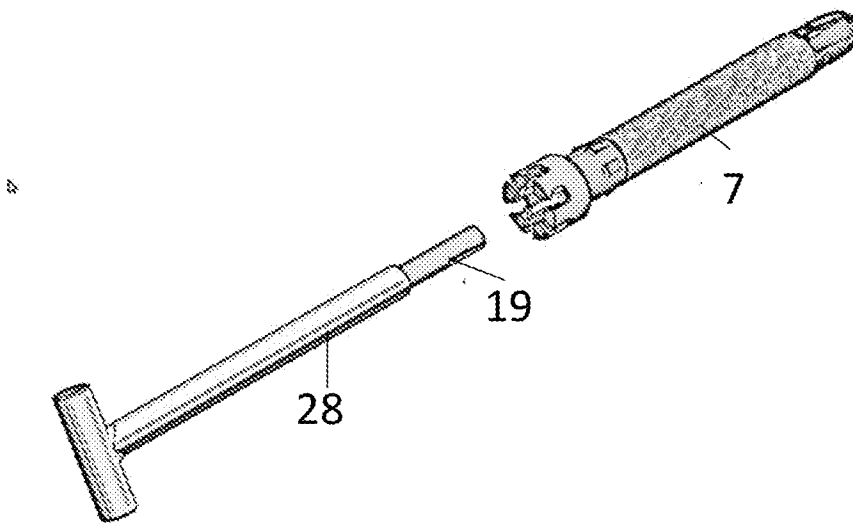


Figure 7a

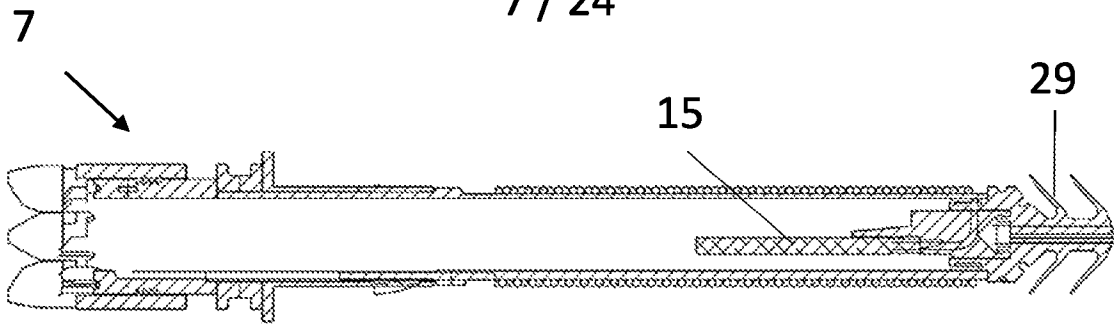


Figure 7b

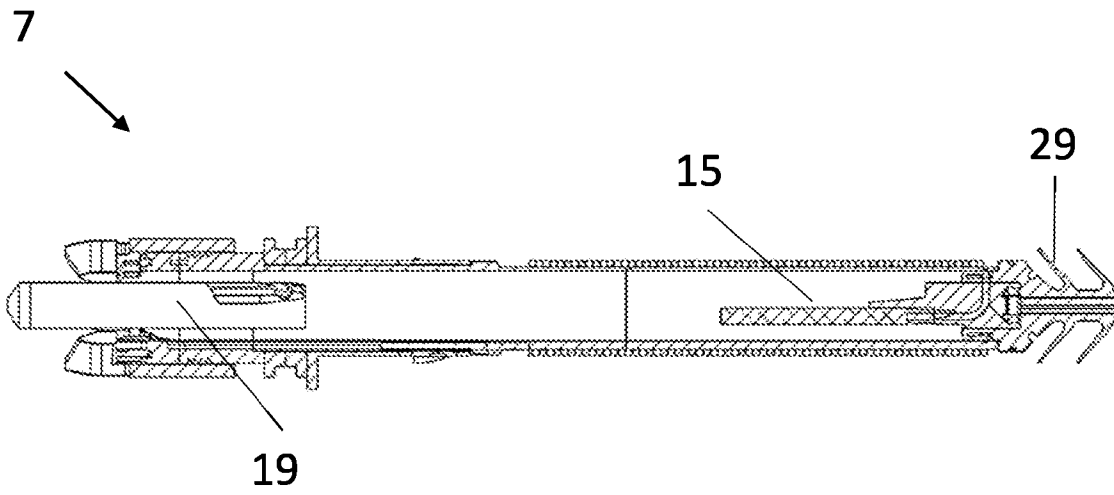


Figure 7c

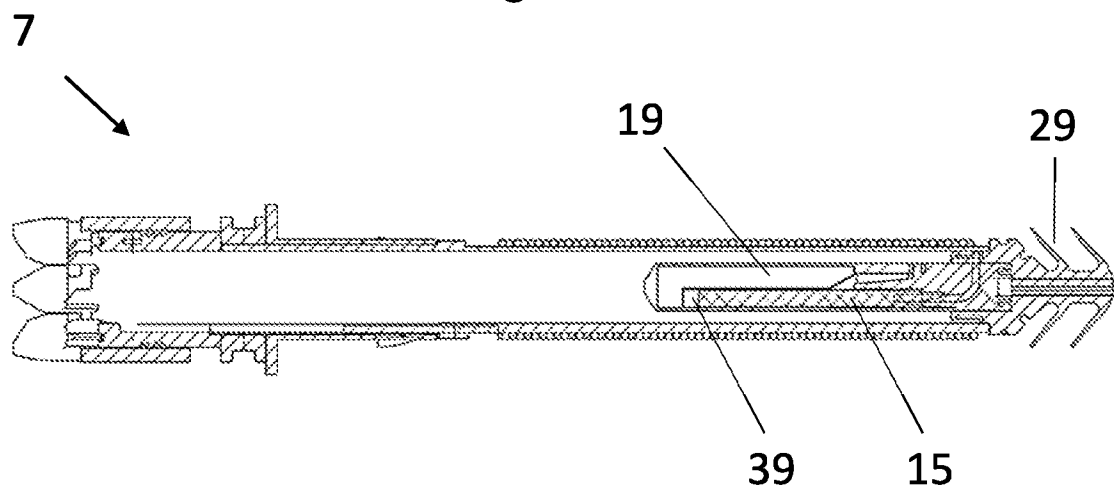


Figure 7d

Figure 8a

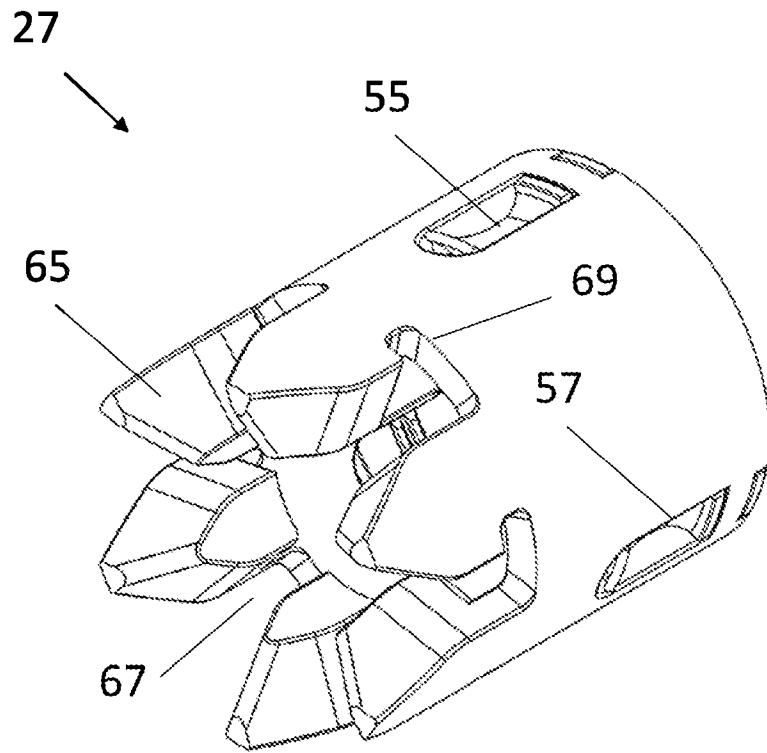


Figure 8b

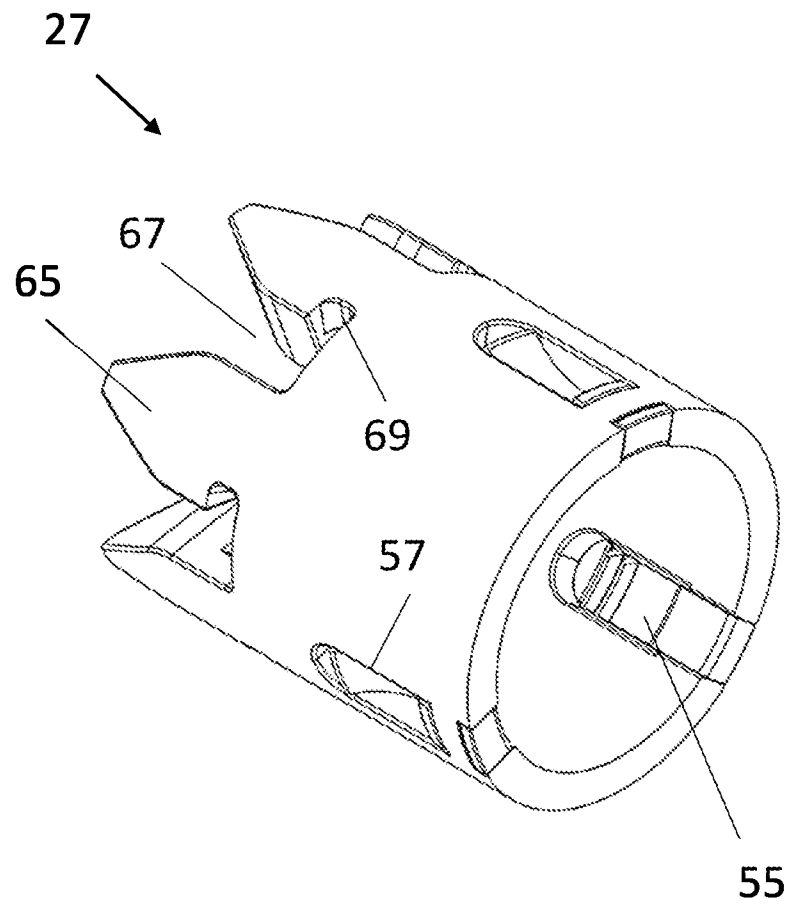


Figure 9a

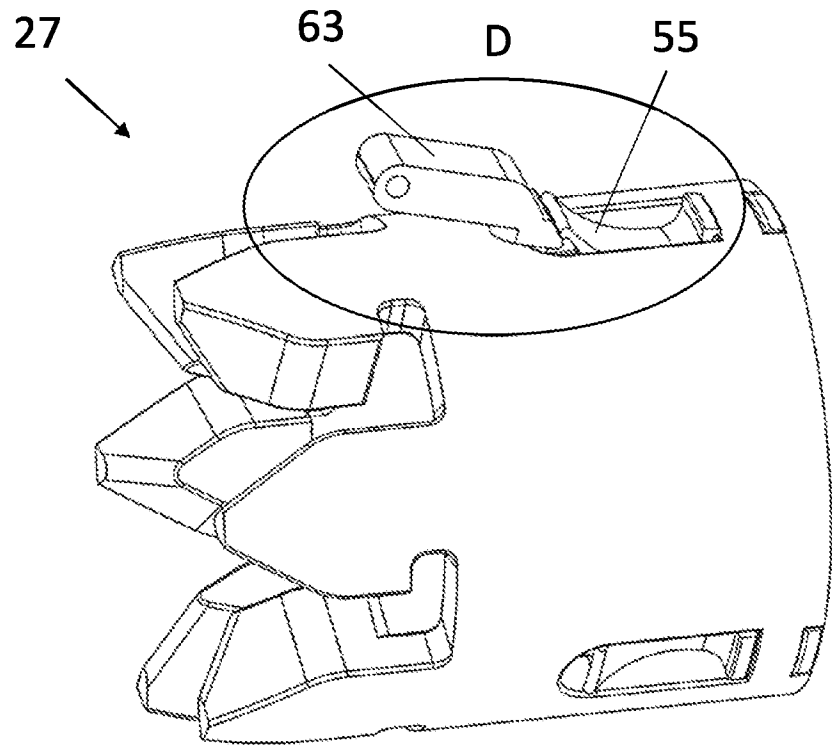
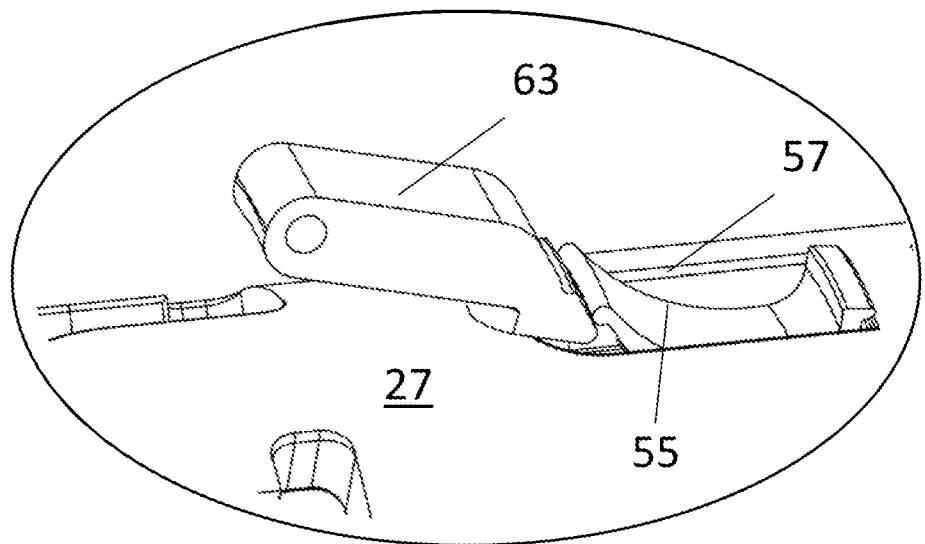


Figure 9b



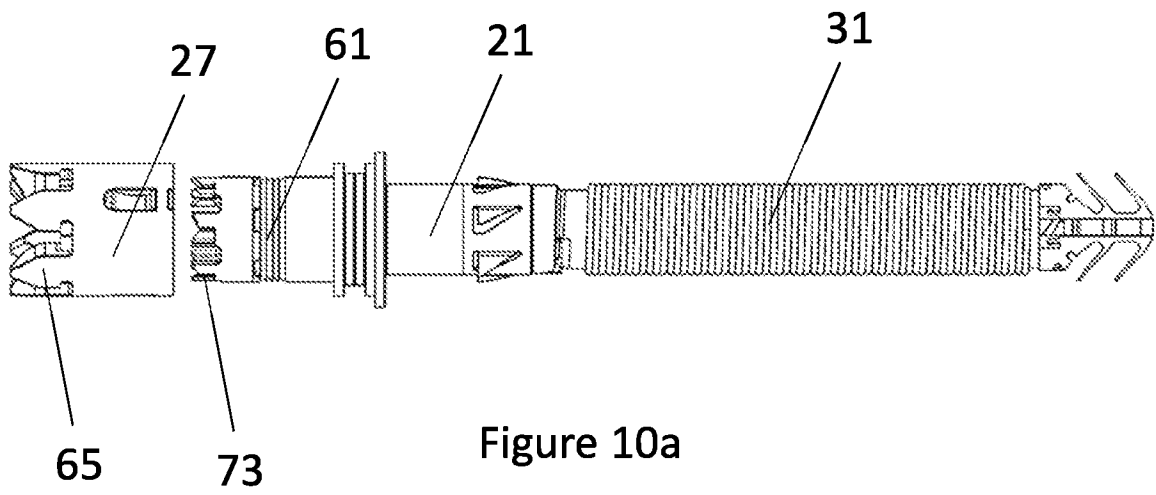


Figure 10a

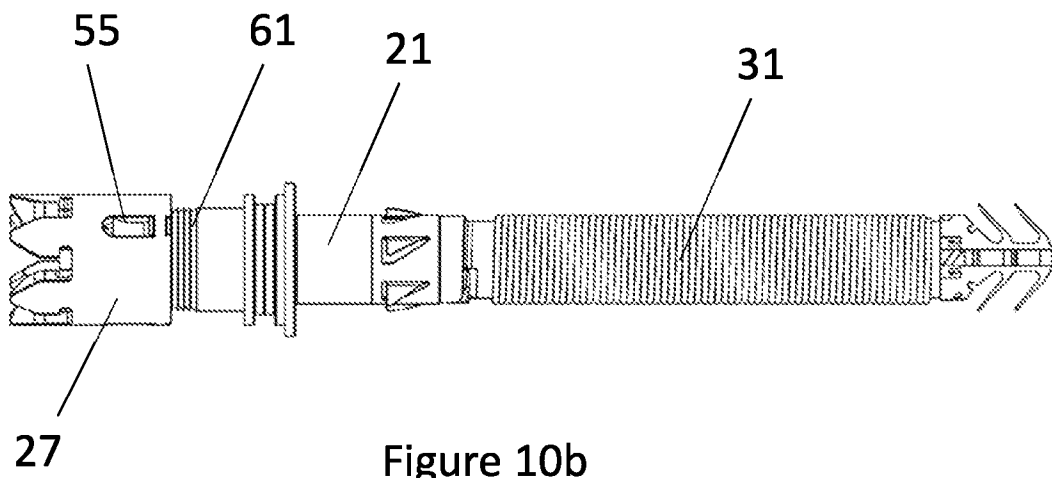


Figure 10b

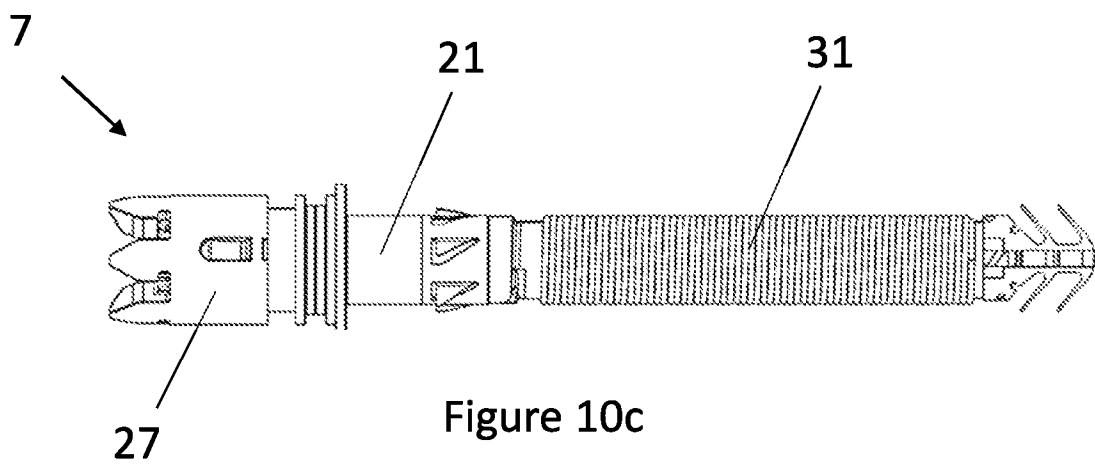


Figure 10c

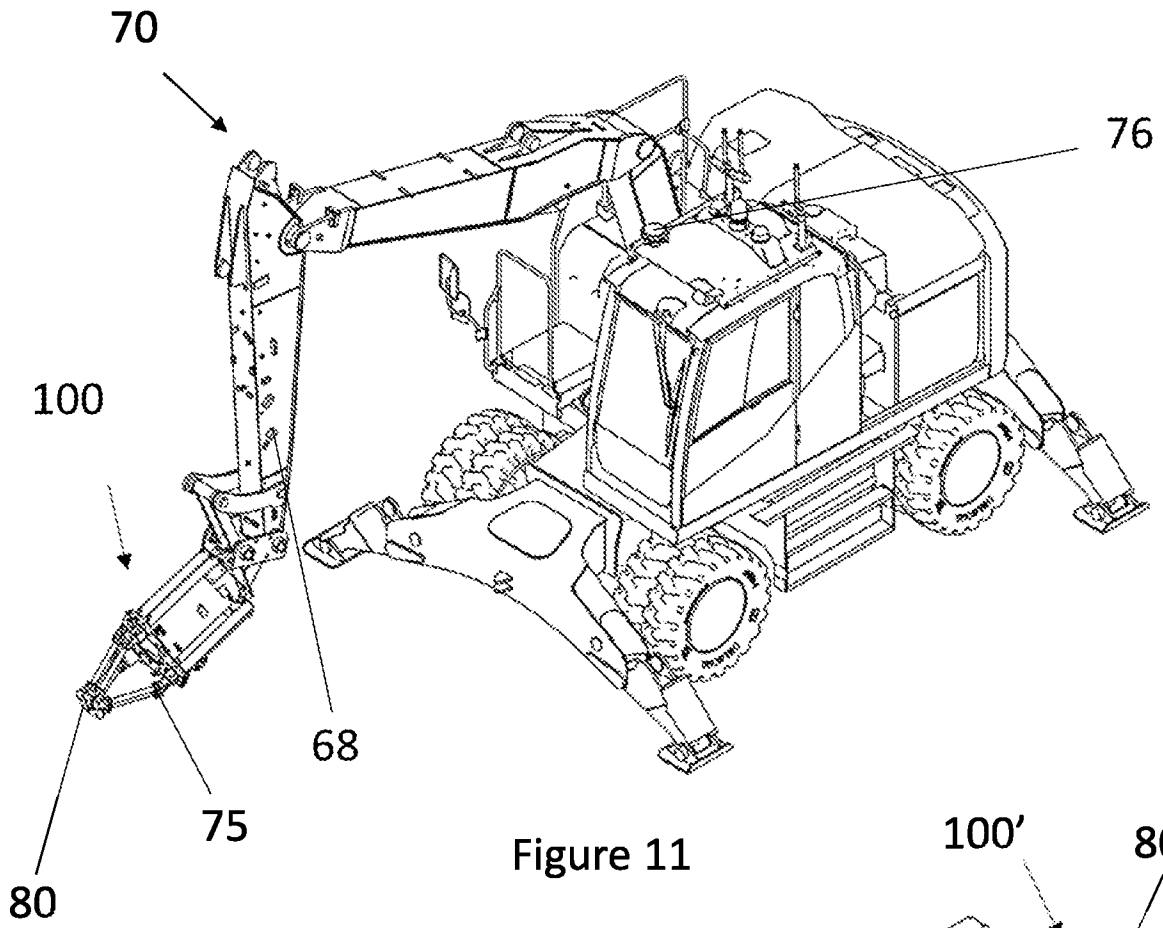


Figure 11

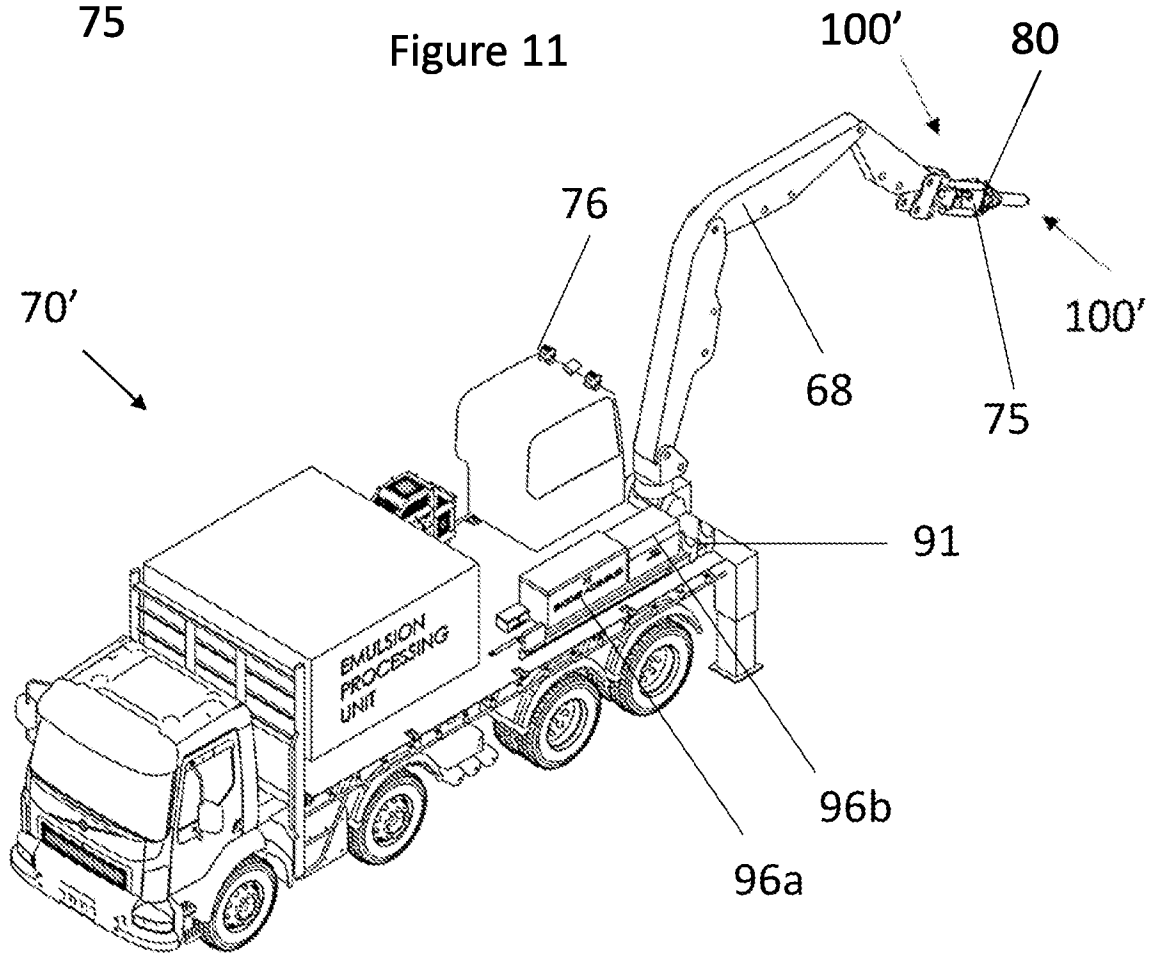
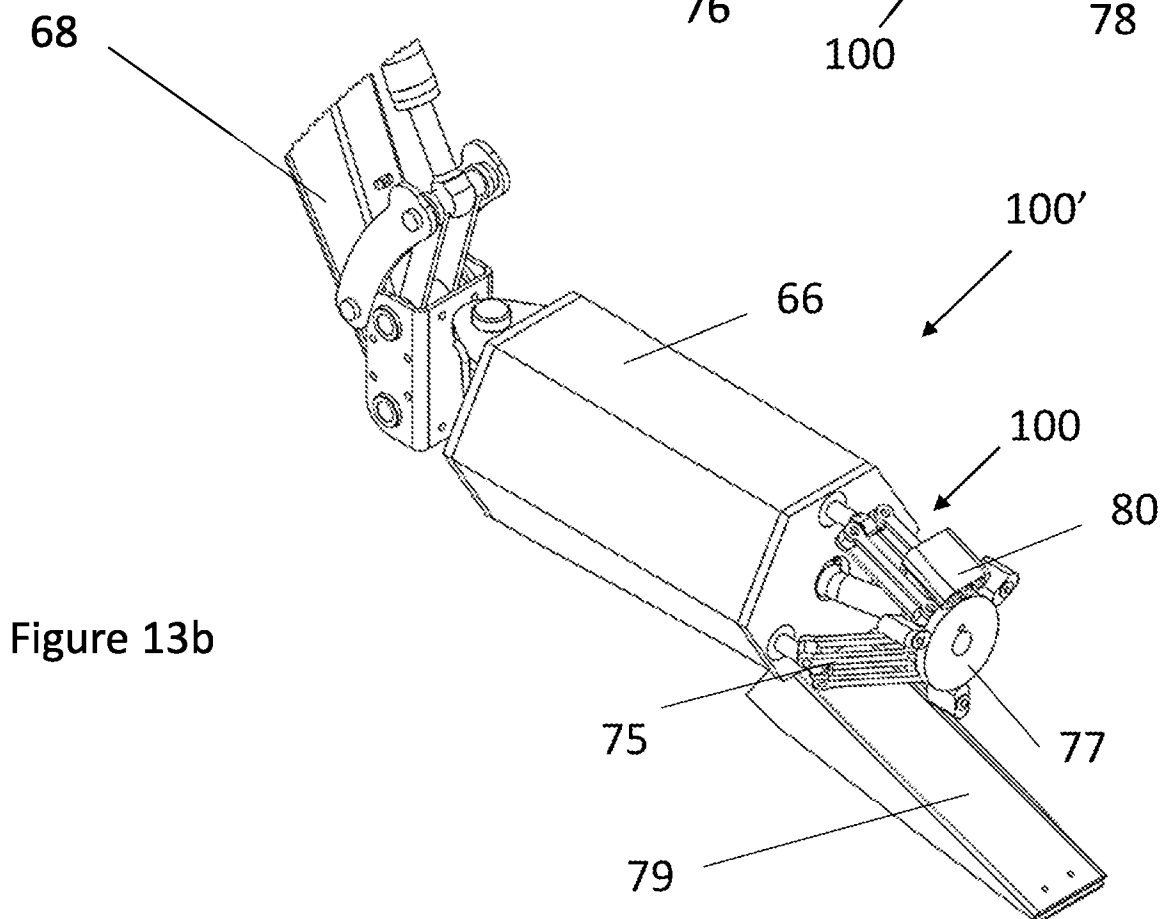
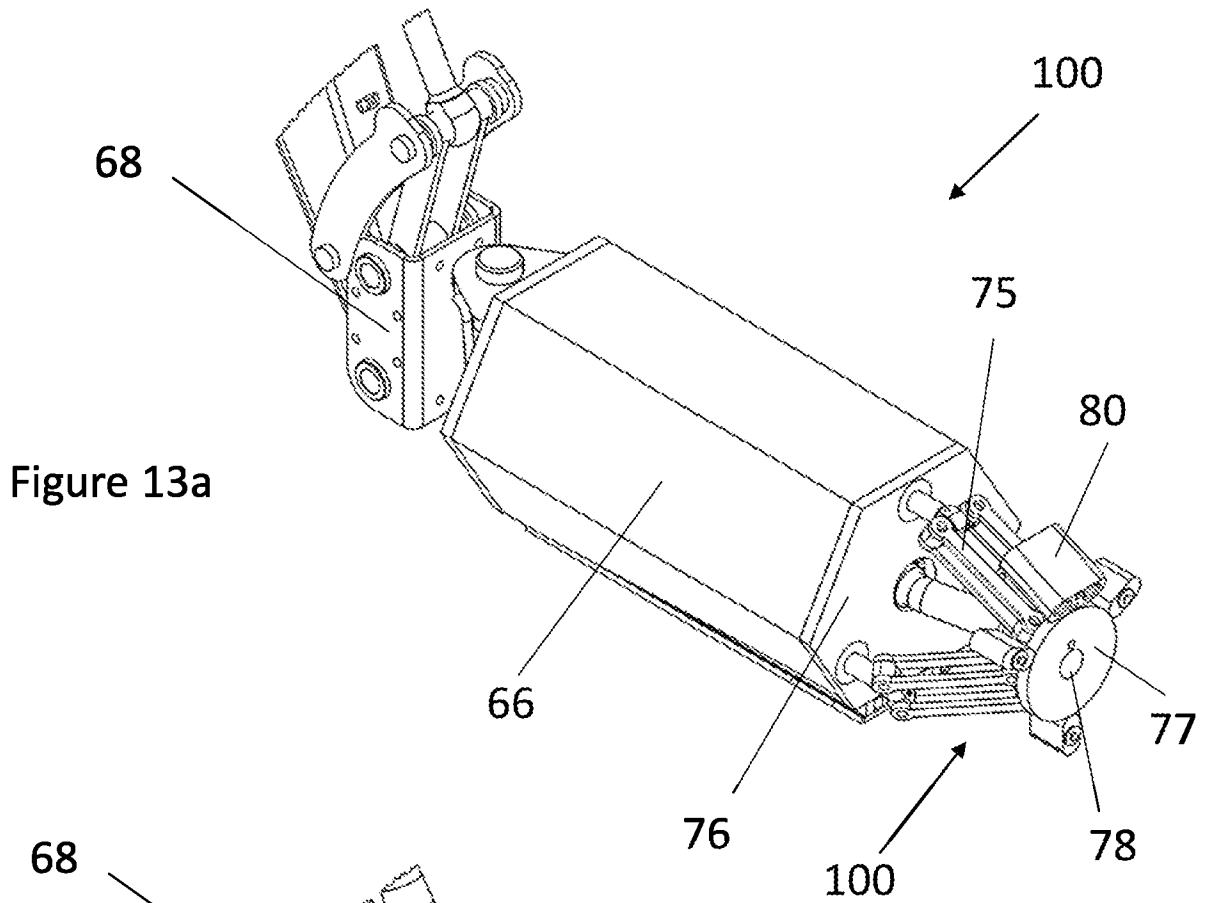


Figure 12



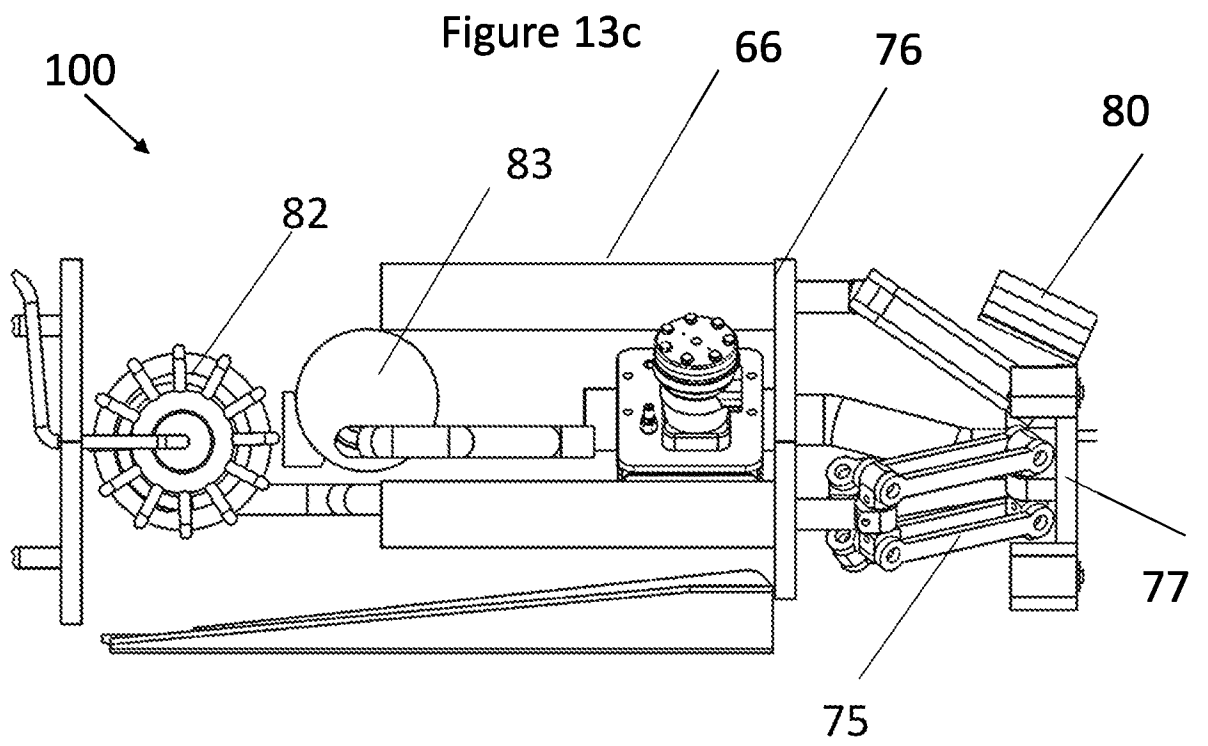
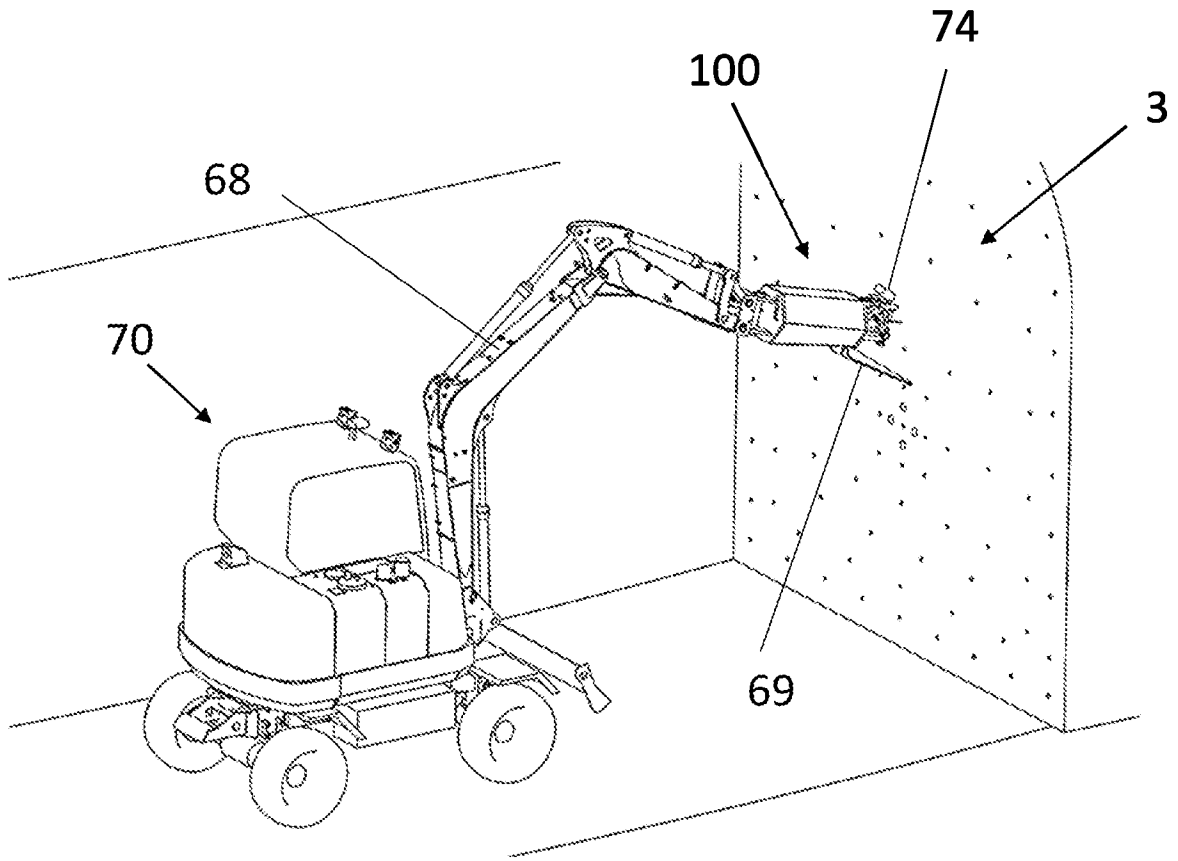


Figure 14a

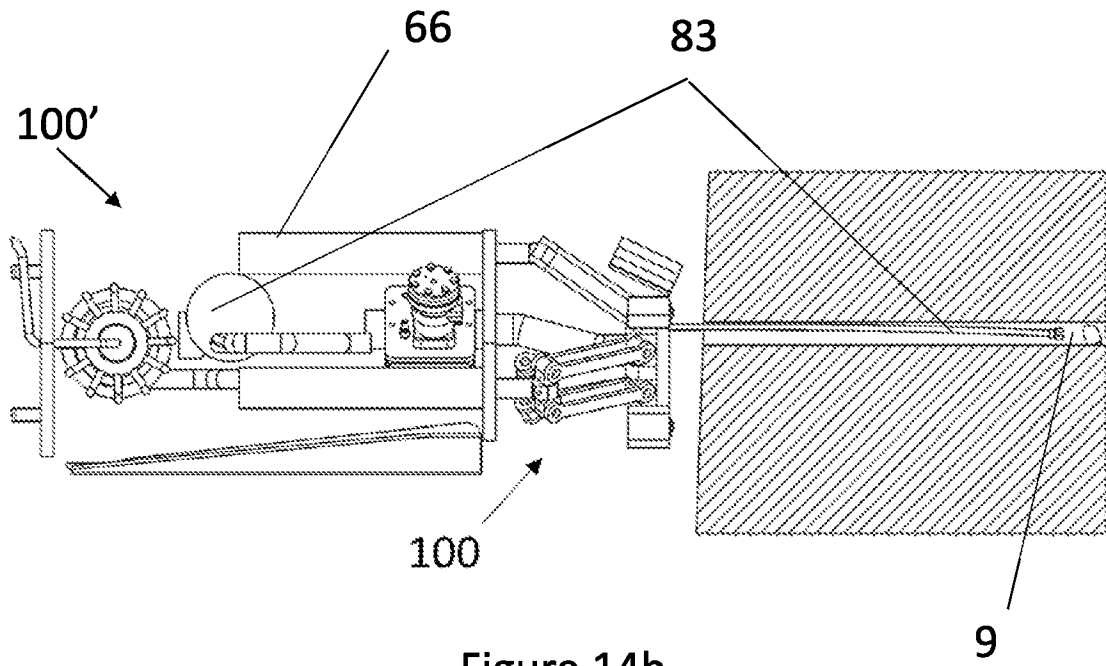


Figure 14b

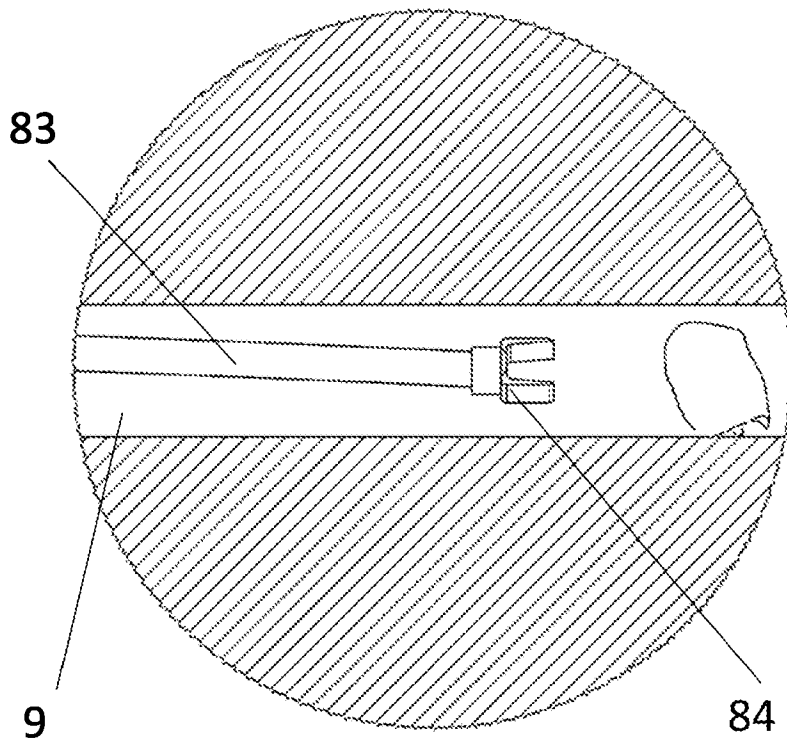


Figure 14c

Figure 15

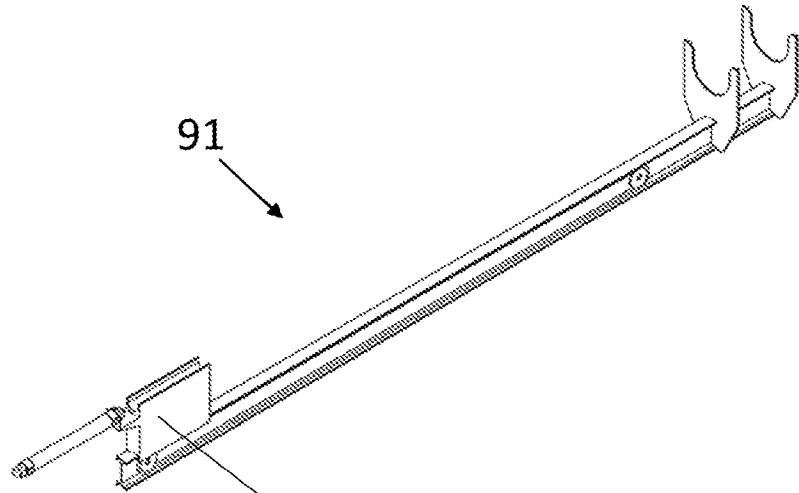


Figure 16a

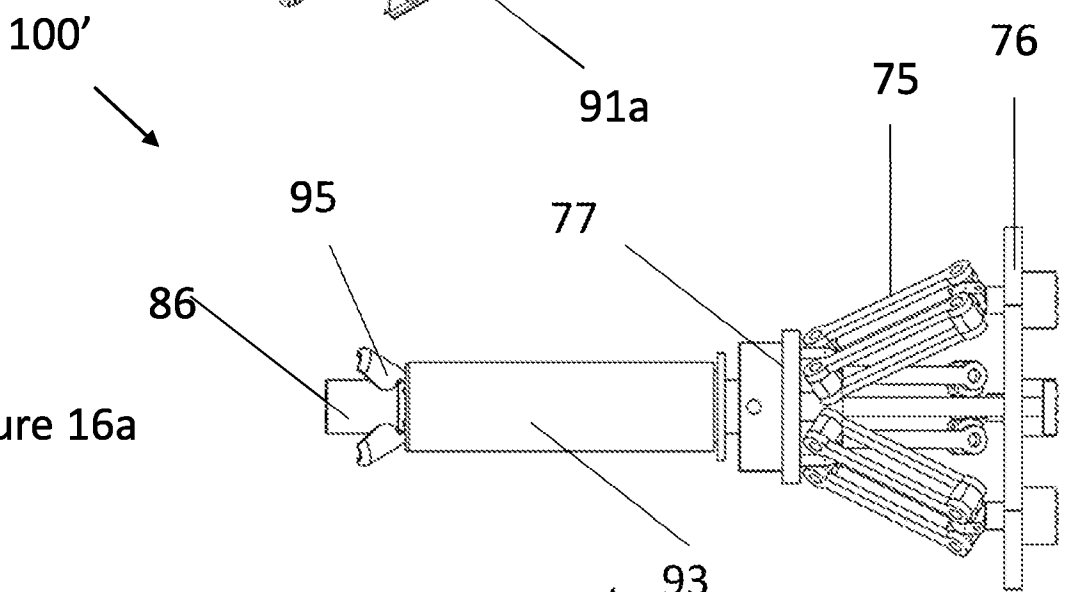
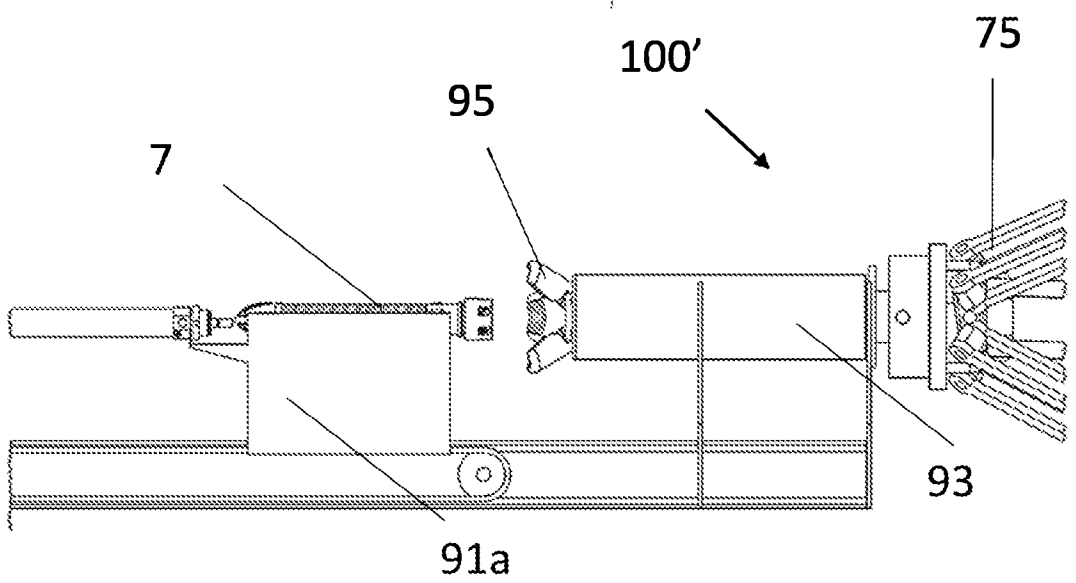
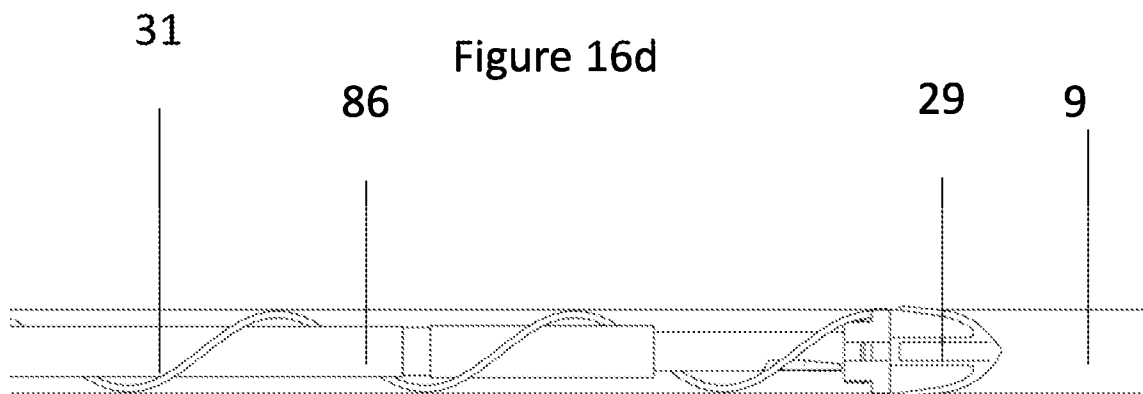
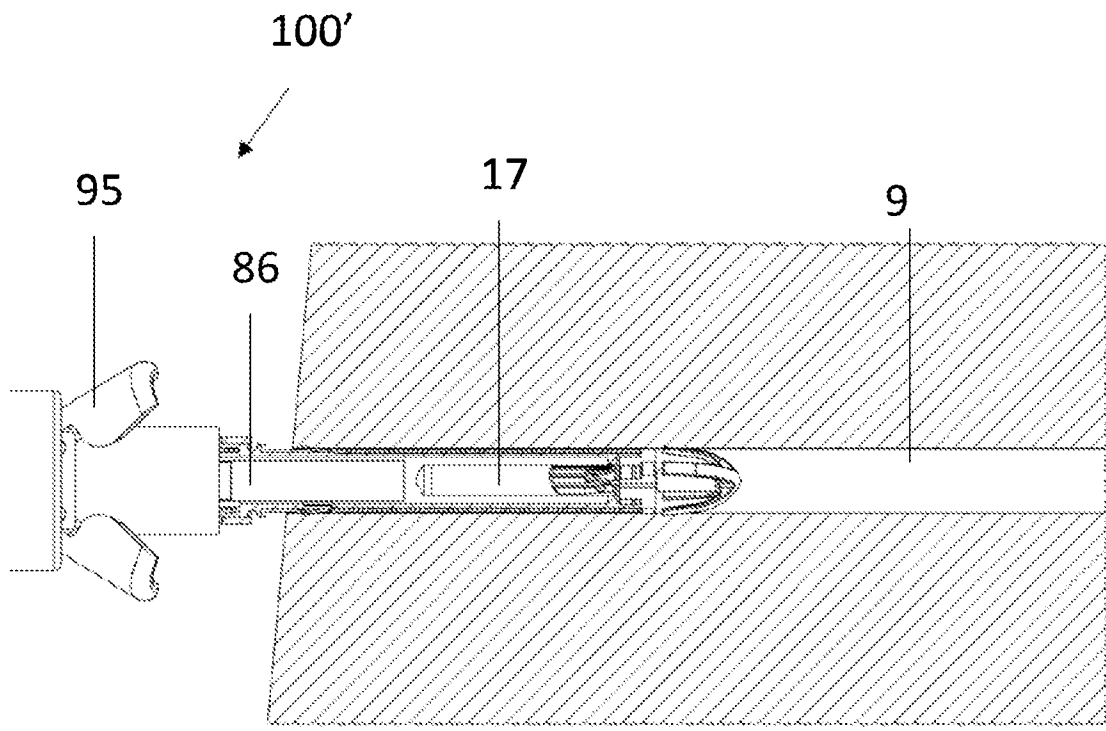
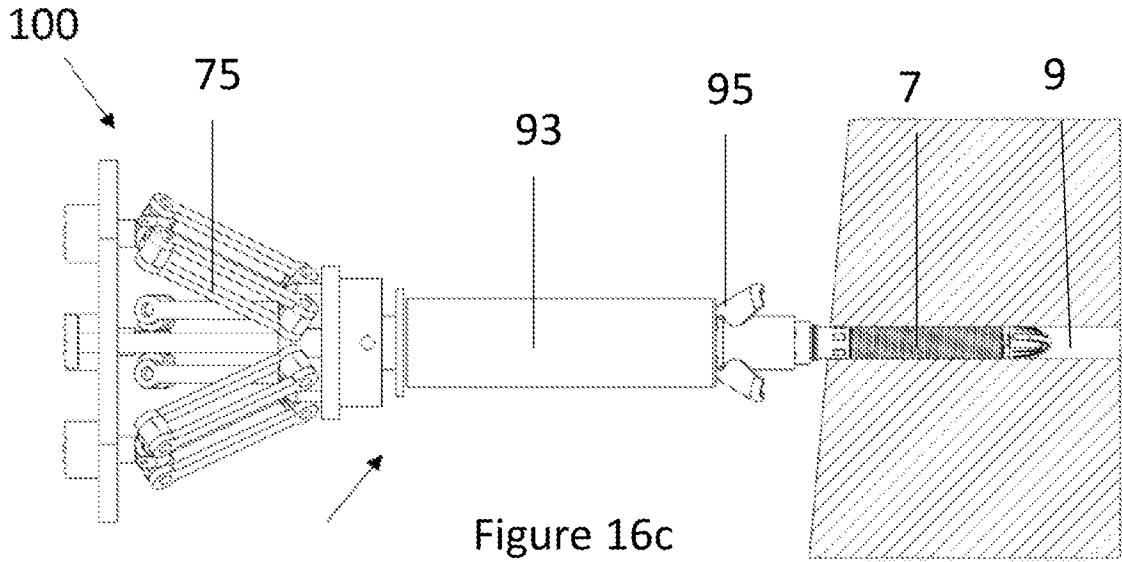


Figure 16b





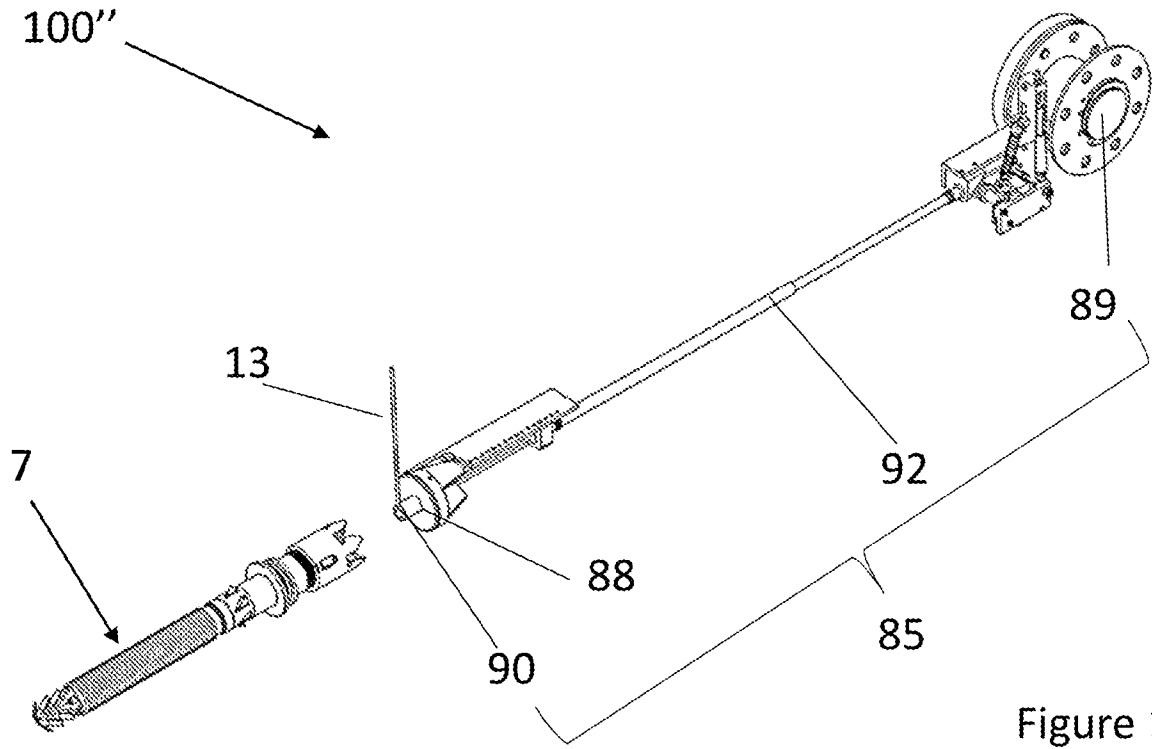


Figure 17a

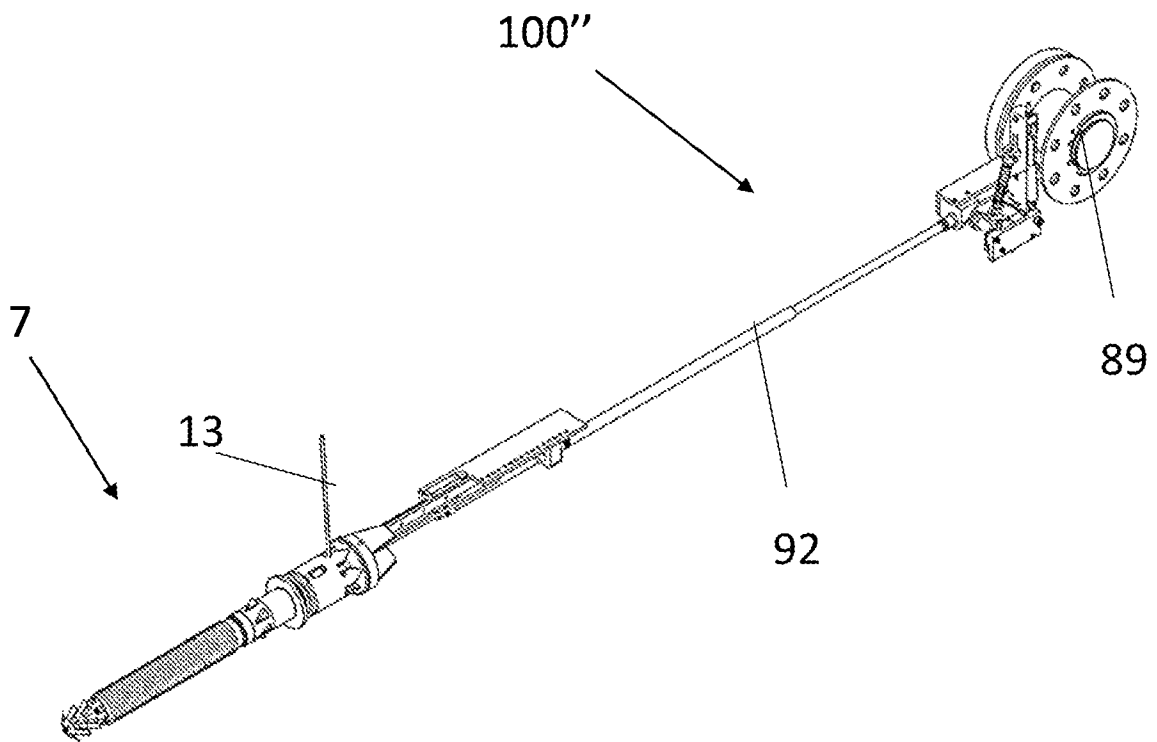


Figure 17b

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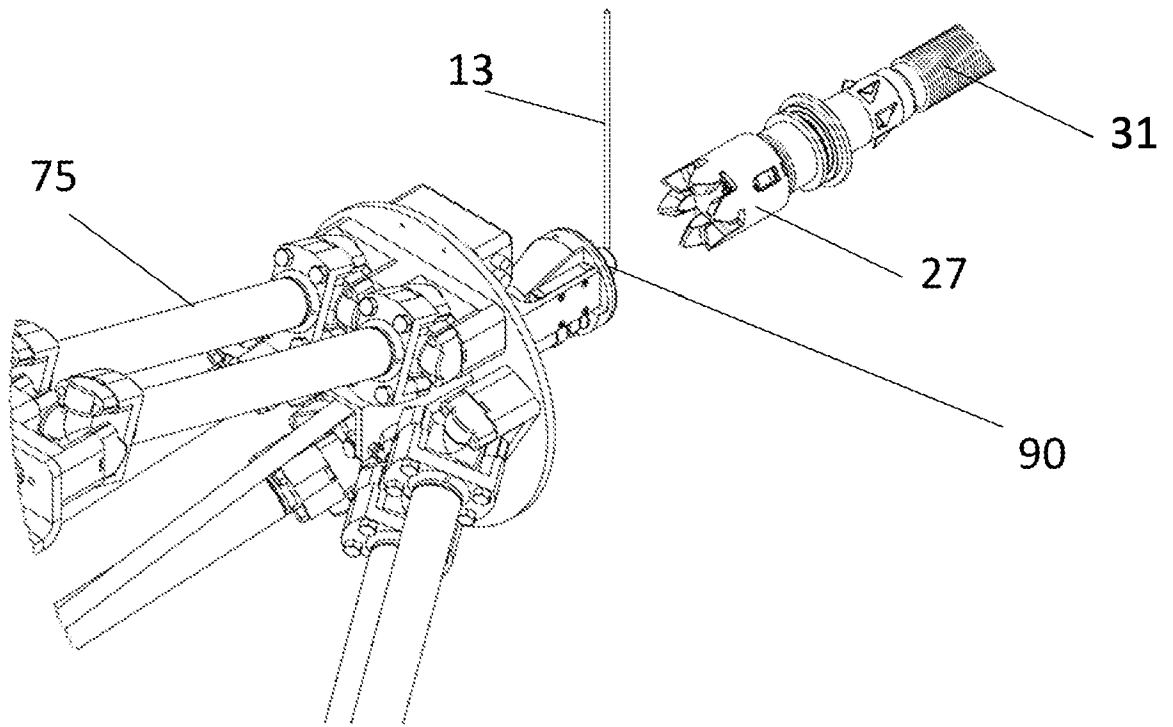


Figure 18a

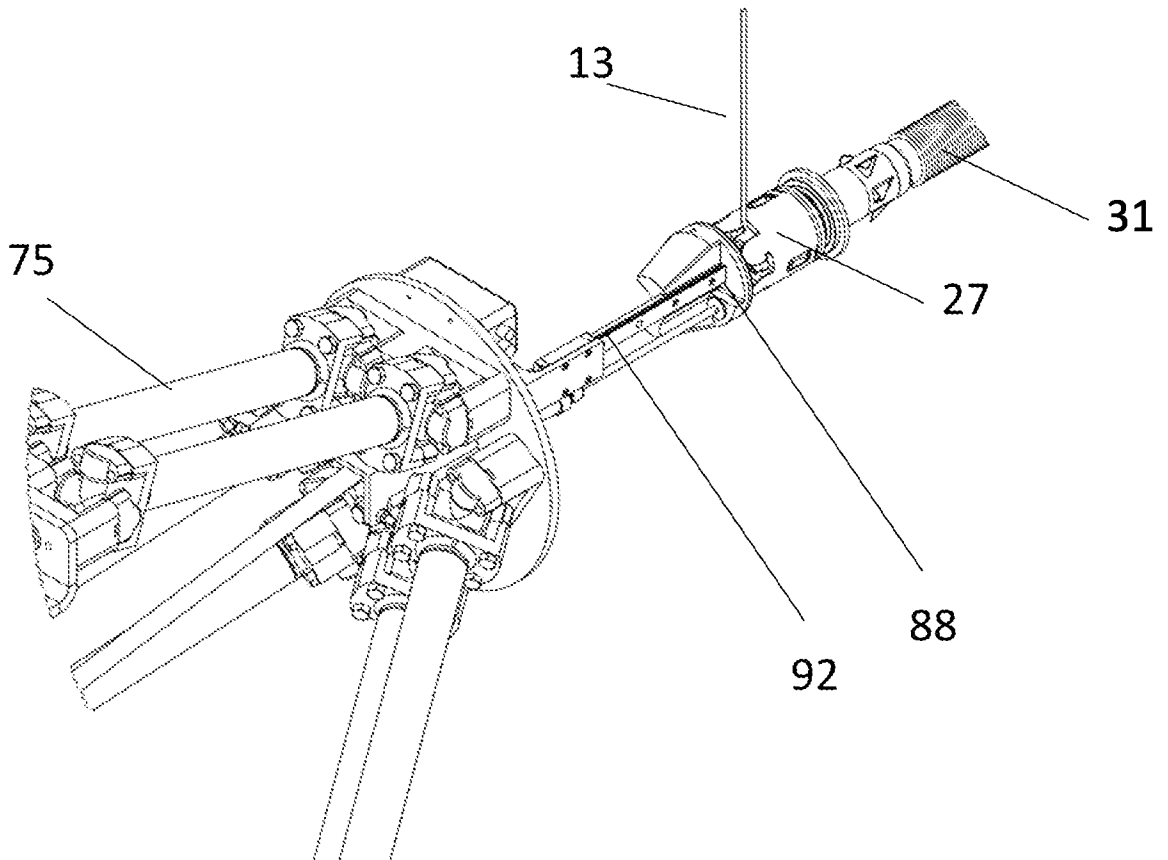


Figure 18b

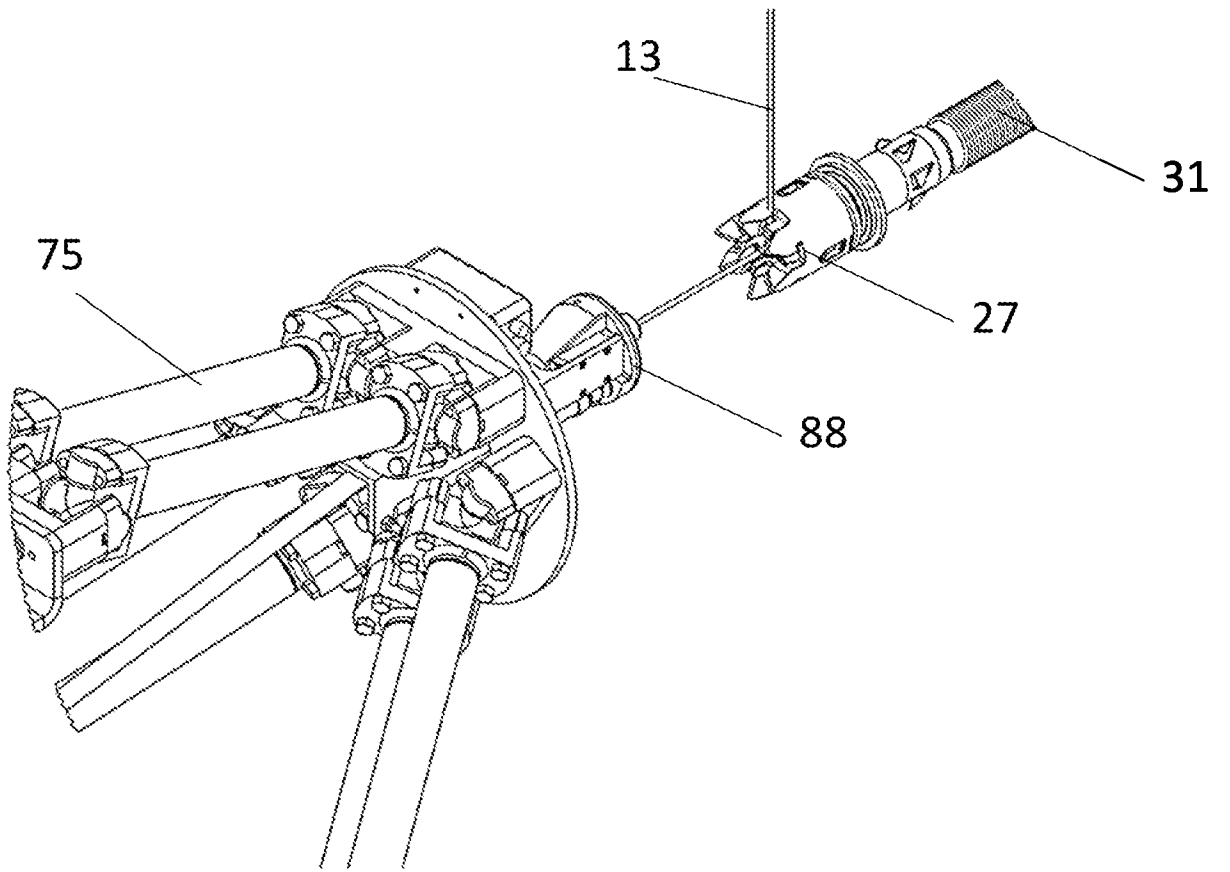


Figure 18c

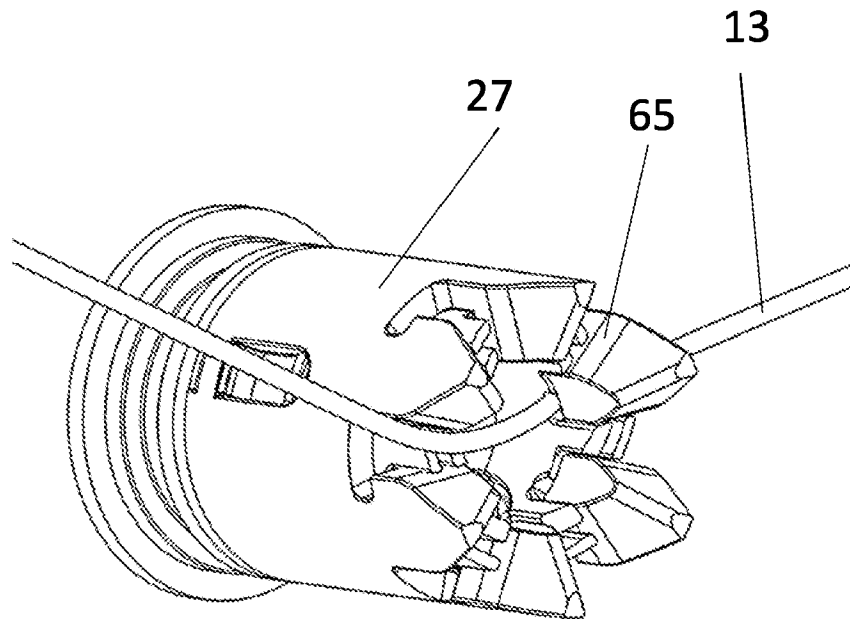
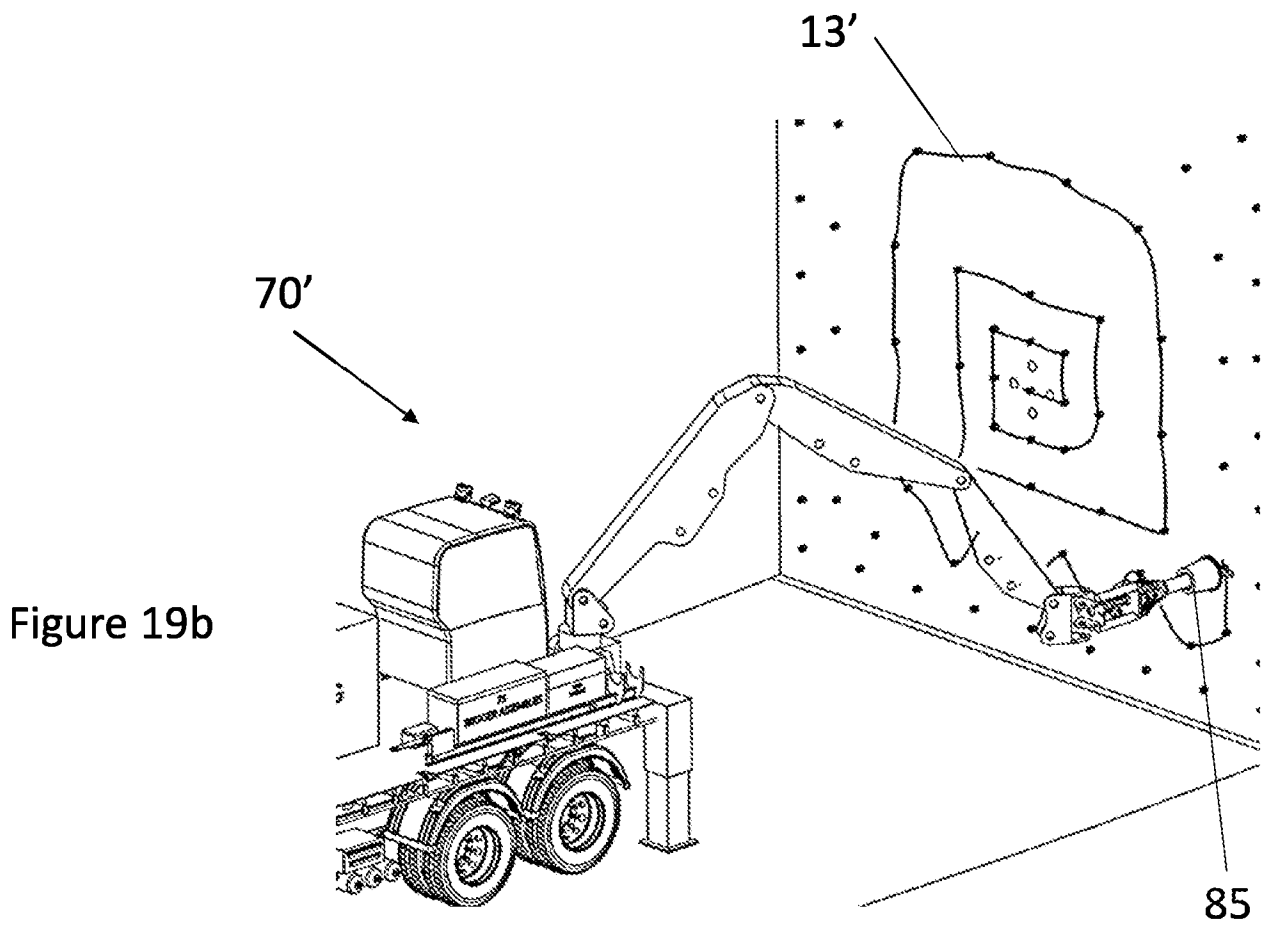
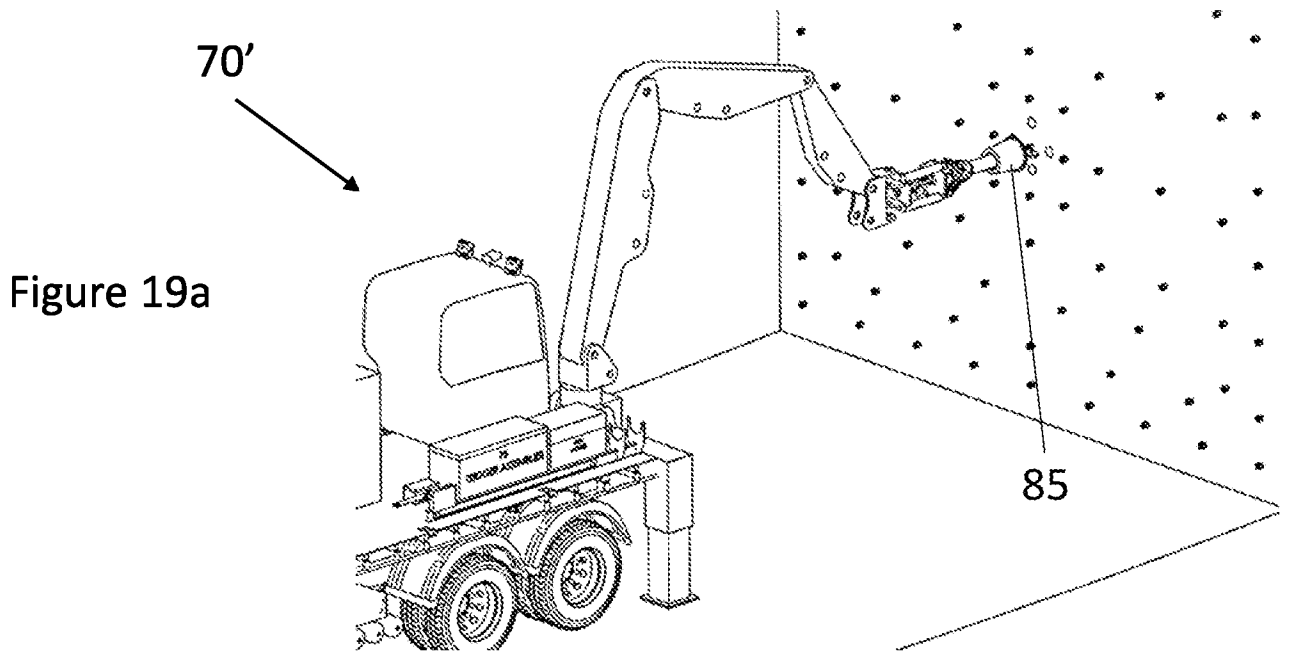
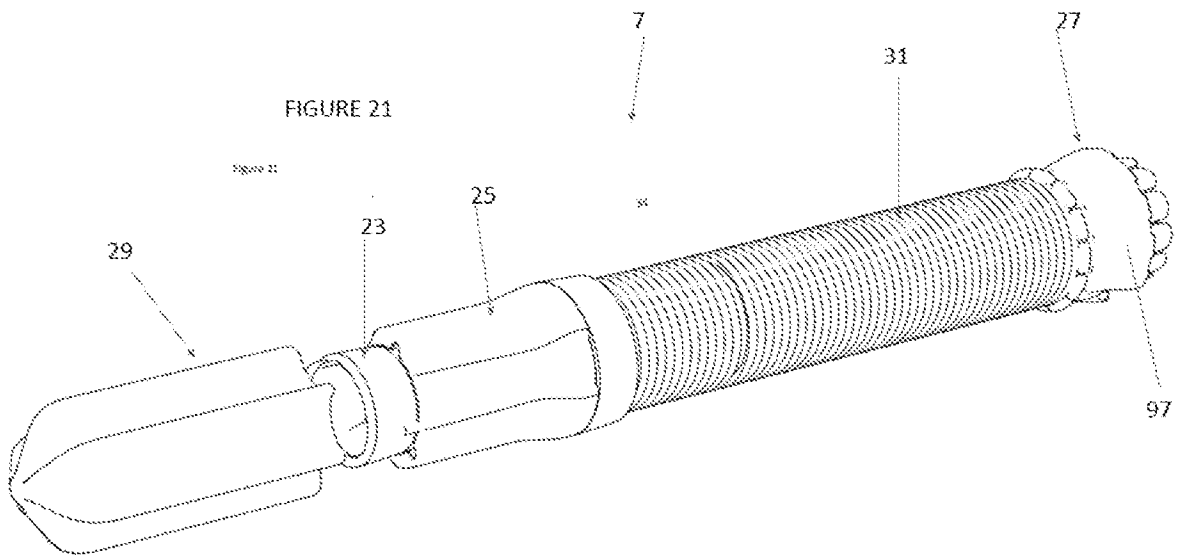
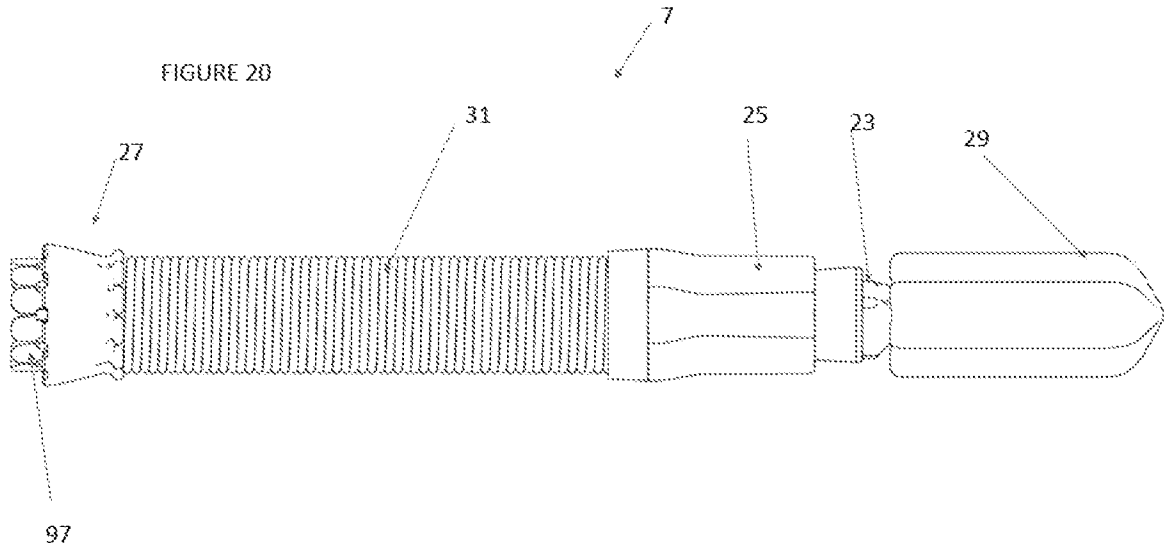
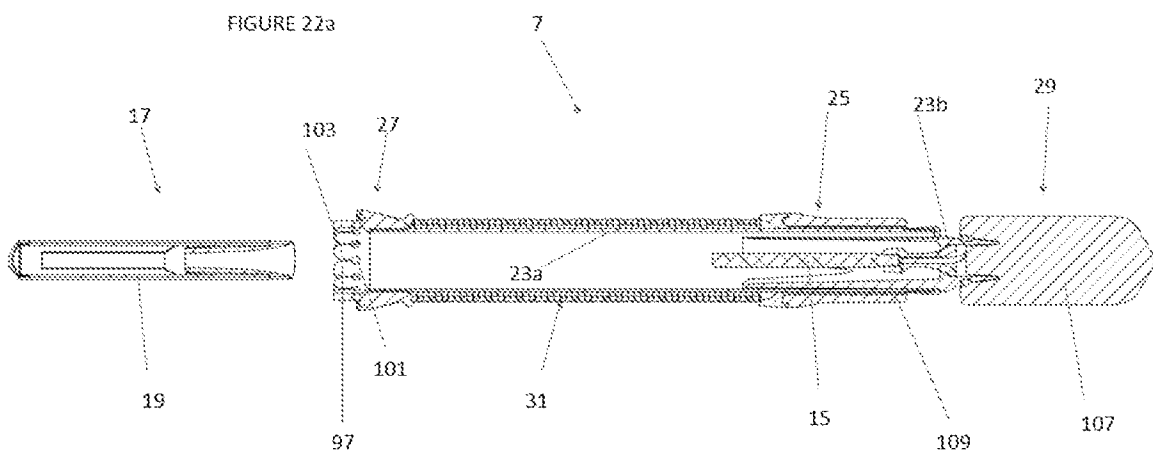
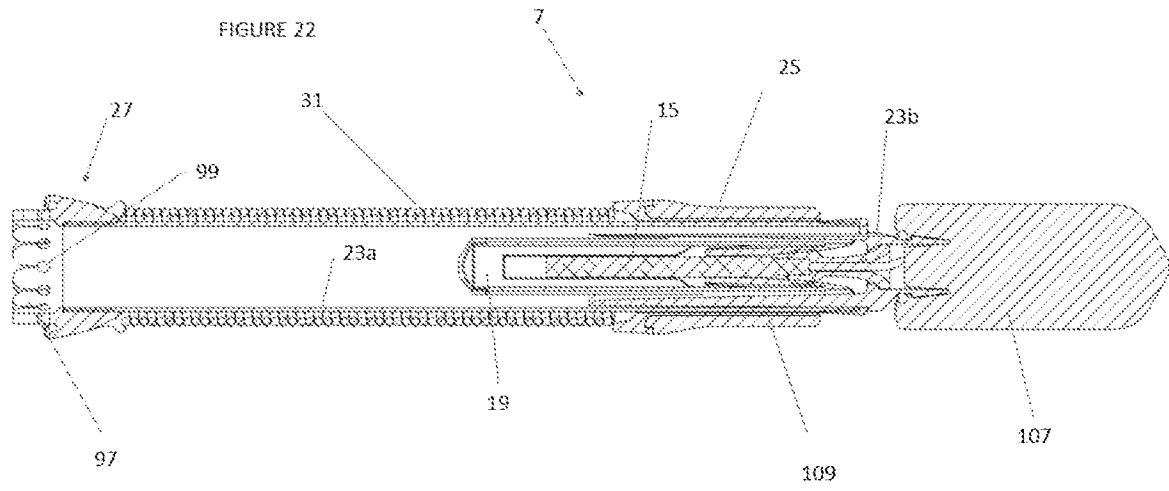


Figure 18d







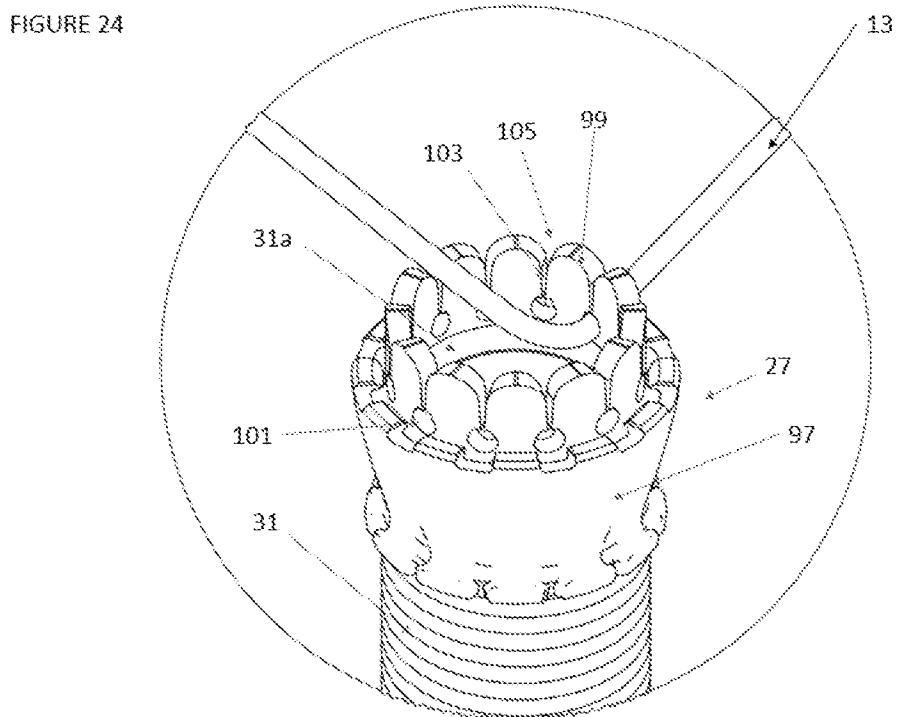
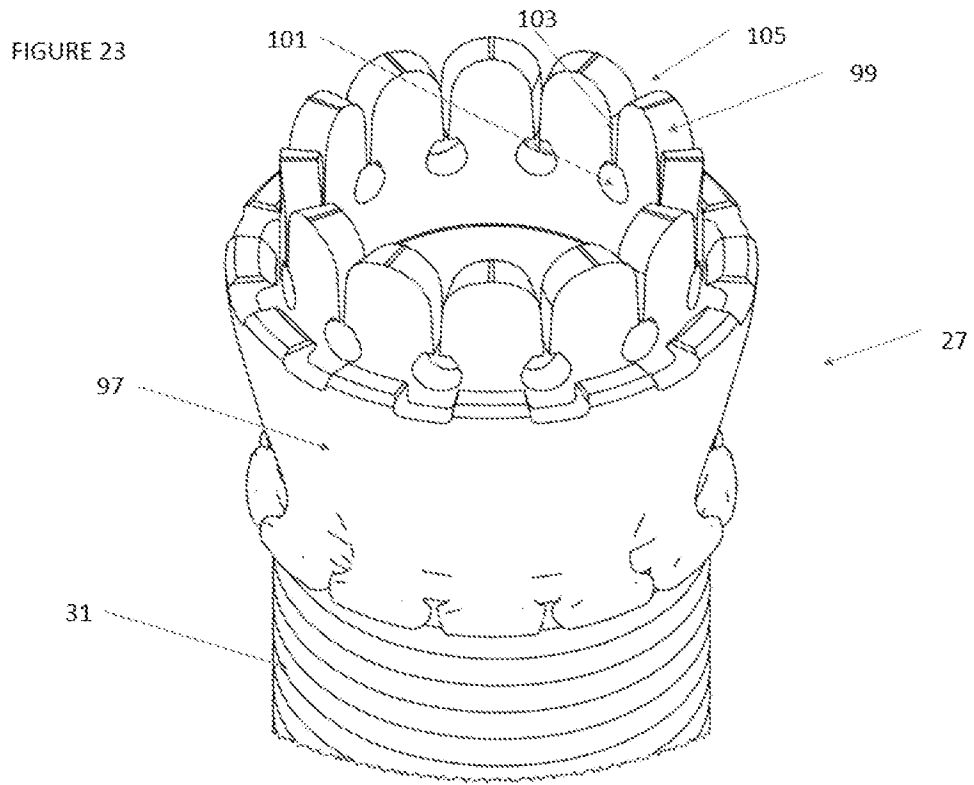


FIGURE 25

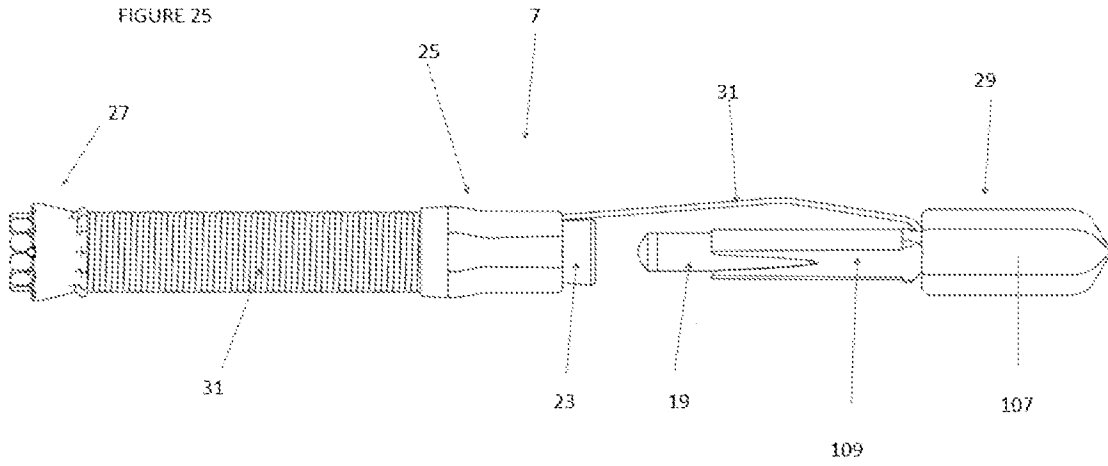
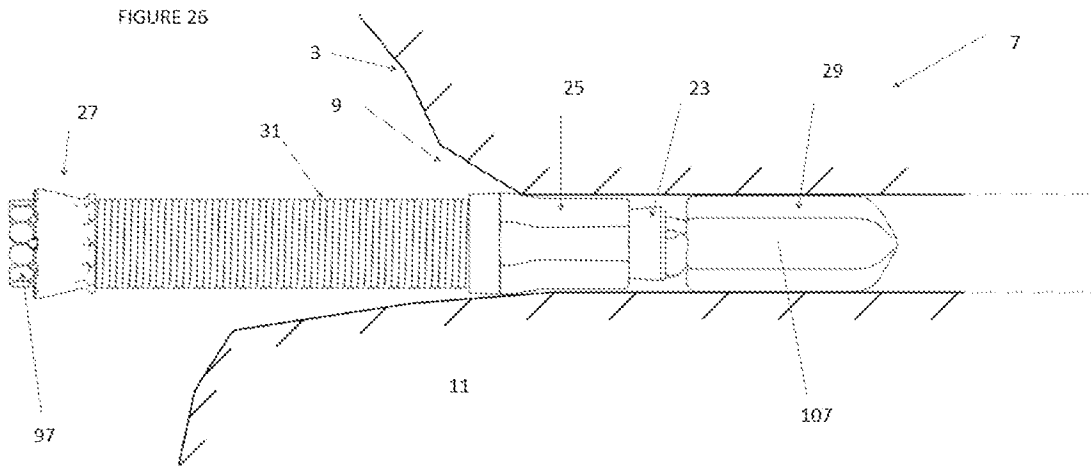


FIGURE 25



INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2023/050296

A. CLASSIFICATION OF SUBJECT MATTER

F42B 3/26 (2006.01) B25J 5/00 (2006.01) B25J 9/00 (2006.01) B25J 9/16 (2006.01) E21B 15/00 (2006.01) E21B 15/04 (2006.01) F42B 3/10 (2006.01) F42D 1/04 (2006.01) F42D 1/22 (2006.01) F42D 3/04 (2006.01)

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)

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)

IPC/CPC: F42D1/043, F42D1/02, F42B3/26, C06C5/0604, F42B3/02, F42D1/08, F42D1/04, F42D3/04, F42D1/22, B25J5/007, B25J9/0051, B25J5/00, B25J9/00, G05B2219/39001, F42B3/00, F42D1/00, G05D2201/021 and/or keywords - connect, attach, plug, join, engage, cord, line, cable, wire, arm, prong, flexible, elastic, resilient, initiator, booster, spin, turn, rotate, revolve, vehicle, truck, robot, remote, automatic, grip, arm, manipulate, tool and similar terms.

Applicant/Inventor name searched in internal databases provided by IP Australia.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

Further documents are listed in the continuation of Box C

See patent family annex

* Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance	"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	
"D" document cited by the applicant in the international application	"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	
"E" earlier application or patent but published on or after the international filing date	"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	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family	
"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		

Date of the actual completion of the international search
30 June 2023

Date of mailing of the international search report
30 June 2023

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
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Authorised officer

Ashwin Lazaro
AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)
Telephone No. +61 2 6283 2181

INTERNATIONAL SEARCH REPORT

International application No.

C (Continuation).

DOCUMENTS CONSIDERED TO BE RELEVANT

PCT/AU2023/050296

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO WO2020232506 A1 (NEWCREST MINING LIMITED) 26 November 2020 ABSTRACT; FIGURES 1-6, 9, 10; PAGES 2, 5-8, 13, 14, 19, 21, 25 ABSTRACT; FIGURES 1-6, 9, 10; PAGES 2, 5-8, 13, 14, 19, 21, 25	1-3, 13-26, 28, 30-32 4-6
Y	US 2952206 A (AUSTIN POWDER CO) 13 September 1960 FIGURES 1-4; COLUMNS 2, 3	4-6
X	US 20170356292 A1 (ABB TECHNOLOGY AG) 14 December 2017 ABSTRACT; FIGURE 1; PARAGRAPHS [0032], [0041]-[0046], [0062], [0074], [0097], [0131]	33-48, 51-55, 61-66, 69

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including
2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
1-69
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

Supplemental Box**Continuation of: Box III**

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1-32 are directed to a trigger assembly and method of triggering an explosive blast. The features of a detonation unit, a trigger unit, and a connection unit are specific to this group of claims.
- Claims 33-69 are directed to a mining or civil engineering vehicle. The features of a positioning unit without a vision module, a positioning unit including a coarse positioning module and a fine positioning module and; a functional unit are specific to this group of claims.
- Claim 70 is directed to a mining or civil engineering vehicle. The features of a positioning unit including a vision module and; the positioning unit without any coarse or fine positioning capability are specific to this group of claims.
- Claim 71 is directed to a mining or civil engineering vehicle. The features of the functional unit being configured to move independently from the initial position to a second position closer to the selected location whilst the vehicle remains stationary, without the use of a positioning unit is specific to this group of claims. Claim 71 does not include the use of a positioning unit of a vehicle utilising a vision module (as in claim 70) to move the functional unit, but rather some other means to move the functional unit to a second position (rather than the 'selected location' as in claim 70).

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention. In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship.

Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a priori*.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2023/050296

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
WO WO2020232506 A1	26 November 2020		
US 2952206 A	13 September 1960	US 2952206 A	13 Sep 1960
US 20170356292 A1	14 December 2017	US 2017356292 A1	14 Dec 2017
		US 10570736 B2	25 Feb 2020
		US 2017356729 A1	14 Dec 2017
		US 10378353 B2	13 Aug 2019
		US 2017356730 A1	14 Dec 2017
		US 10724371 B2	28 Jul 2020
		WO 2017214422 A1	14 Dec 2017

End of Annex