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(54)

Knotter

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A knotting unit for a warp tying machine for knotting together a first yarn and a second yarn, the knotting unit comprising:

i. a tube extending around a longitudinal axis for supporting a loop formed with the first and second yarns;

ii. a clamping part housed at least partially within the tube and moveable relative to the tube, the clamping part being adapted to cooperate with the tube, for clamping the first and second yarns therebetween, wherein in the clamping configuration, the axial position of the clamping part is fixed relative to the tube, and

iii. an extractor for tightening a knot formed with the first and second yarns.

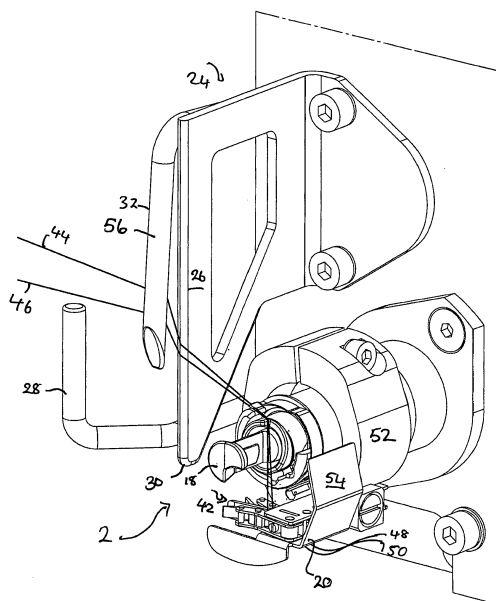


Fig. 2

## Description

**[0001]** This invention relates to a knotting unit for knotting two yarns together in a tying machine for warp sheets.

**[0002]** Warp tying machines are used to knot a first yarn from an old warp sheet that has been woven in a weaving loom, with a second yarn from a new warp sheet that is to be woven in the weaving loom until all the yarns of the sheets have been knotted.

**[0003]** Before tying, the yarns of the two warp sheets are stretched in a clamping frame.

**[0004]** The tying machine first separates one yarn from each warp sheet and then knots together the two separated yarns before pulling away the knotted yarns.

**[0005]** Once a knot has been formed, there will be knot tails extending from the knot to the free ends of the yarns.

**[0006]** It is desirable to be able to control the length of the knot tails.

**[0007]** The knot tails should be constant through the tying process, and also should be suitable for the fabric being woven. This means that a tying machine should be able to adjust the length of the knot tail in order to suit the fabric being woven.

**[0008]** It is known that a long knot tail can adversely affect the quality of the weaving process of certain fabrics. In addition, if the length of the knot tails is not constant during the knotting process, the quality of the knots can also be variable.

**[0009]** A known knotting unit usually comprises a rotating thread driver, a tube having an internal pulling needle associated therewith, an ejector and an extractor. A knotting unit of this type is shown in US 2,879, 095.

**[0010]** In the knotting unit disclosed in US '095, a thread driver winds the yarns around a tube as shown in Figures 5 and 6 of US '095, and then puts the threads into a needle hook. The needle pulls the yarn ends into the wound yarns loop to form a knot, and then the extractor pulls the yarns to tighten the knot.

**[0011]** During the extracting movement, the yarns are clamped between the moveable needle and an internal surface of the tube. The knot is thus tightened between the extractor and the pulling needle. This results in uncontrolled and variable tail lengths.

**[0012]** Solutions have been proposed which involve cutting the tails after the knot has been tightened. However, such solutions require additional scissors, as described in DE 1 230 369.

**[0013]** According to a first aspect of the present invention there is provided a knotting unit for a warp tying machine for knotting together a first yarn and a second yarn, the knotting unit comprising:

- i. a tube extending around a longitudinal axis for supporting a loop formed with the first and second yarns;
- ii. a clamping part housed at least partially within the tube and moveable relative to the tube, the clamping part being adapted to cooperate with the tube, for

clamping the first and second yarns therebetween, wherein in the clamping configuration, the axial position of the clamping part is fixed relative to the tube, and

iii. an extractor for tightening a knot formed with the first and second yarns.

**[0014]** In this specification, the terms "axial" and "longitudinal" relate to a central axis of the tube. The terms "front" and "forward" relate to a movement towards, or a position near to the yarns that are stretched in a clamping device. The terms "rear" and "rearward" have an opposite meaning.

**[0015]** An important feature of the invention as claimed is that in the clamping configuration in which the clamping part clamps the yarns, the axial position of the clamping part is fixed relative to the tube.

**[0016]** This means that, unlike the clamping part in known knotting units such as that described in US '095 which clamps the yarns while it moves axially within the tube, the knotting unit according to the invention comprises a clamping part that is able to clamp the yarns at an axially fixed clamping position relative to the tube.

**[0017]** In what follows, it must be understood that the yarns are clamped when they are pinched between the clamping part and a complementary surface of the tube, the pinching action maintaining the yarns relative to the tube up to a certain level of the pulling effort of the extractor on the yarns beyond which the yarns may slide in their clamp.

**[0018]** The axially fixed position of the clamping part relative to the tube in the clamping configuration results in the portion of each yarn that is clamped by means of the clamping part being fixed relative to the yarn end during tightening of the knot, and in the range of knot positions relative to the yarn ends being thus reduced, and also ensures that a knot does not slide towards the yarn ends, without being tightened. No additional scissors are required to obtain constant tail lengths during tying of the warp sheets.

**[0019]** The tube may have a fixed position relative to the knotting unit as a whole.

**[0020]** In embodiments of the invention the clamping position is located at, or close to the front end of the tube, the clamping part being adapted to cooperate with the tube for clamping the first and second yarns therebetween.

**[0021]** The tube may comprise an internal frustoconical surface, and the clamping part may comprise a frustoconical surface which is shaped to cooperate with the internal frustoconical surface of the tube for clamping the yarns therebetween.

**[0022]** The internal surface may extend inwardly within the tube towards the rear end thereof.

**[0023]** In such embodiments of the invention, the clamping part comprises a complementary shaped frustoconical portion which is shaped to fit with the internal surface of the tube, to thereby allow the clamping part to

cooperate with the tube.

**[0024]** The complementary frustoconical portions of the clamping part and the tube respectively aid in the positioning of the clamping part in cooperation with the tube, and also serve to ensure that the clamping force applied by the clamping part on the yarns is substantially evenly distributed over the yarns.

**[0025]** The tube may comprise a recess on the outer surface of the tube for supporting the loop formed with the first and second yarns, and a longitudinally projecting surface adjacent to the recess and formed at a front end of the tube.

**[0026]** In such embodiments, in use, a loop may be formed on the recess, and the longitudinally projecting surface is adapted to guide the yarns across the front end of the tube.

**[0027]** When the yarns are guided across the front of the tube, the projecting surface serves to locate the yarns so that they can extend across the front end of the tube in a predetermined position.

**[0028]** In use, once the yarn has passed round the tube once, it will be guided by the projecting surface so that it extends across the front of the tube, rather than being wound round the tube again.

**[0029]** In embodiments of the invention, when the knotting unit is in the clamping configuration, resilient means may maintain the clamping part in cooperation with the tube.

**[0030]** The knotting unit may comprise a pulling part with a hook for pulling the ends of the first and second yarns into the tube.

**[0031]** In such embodiments, the resilient means are located between the pulling part and the clamping part.

**[0032]** When the yarns are positioned accordingly across the front of the tube, they are engageable with the pulling part of the needle.

**[0033]** In such embodiments, the clamping part may be positioned in a front position relative to the pulling part.

**[0034]** In such embodiments, in use, the resilient means may be adapted to axially push the clamping part towards the pulling part.

**[0035]** In such embodiments, the pulling part and the clamping part together may form a needle which may be moveable axially relative to the tube.

**[0036]** Because the first clamping part is resiliently connected to the pulling part, axial movement of the pulling part in a direction towards the rear end of the tube will exert a resilient force on the clamping part when the clamping part cooperates with the internal surface of the tube.

**[0037]** Because the clamping part and the pulling part are resiliently connected to one another, the knotting unit according to embodiments of the invention may be used with a wide range of yarns without the need to make any adjustments to the clamping part. The more retracted is the pulling part within the tube, the more efficient is the resilient clamping of the yarns.

**[0038]** In some embodiments of the invention, the

clamping part may be formed separately to the pulling part such that it is not connected to the pulling part to form a needle but movable by its own drive.

**[0039]** In such embodiments there will be no resilient force acting on the first clamping part during use of the tying machine and therefore with such embodiments adjustments may be necessary in order to work with different types of yarns.

**[0040]** In some embodiments of the invention, the clamping part may clamp the yarns by cooperation with the front end of the tube instead of with an internal surface of the tube.

**[0041]** In some embodiments of the invention, the clamping part may clamp the yarns by cooperating with a complementary part that is different from the tube. As soon as the complementary part is itself axially fixed relative to the tube while the knot is tightened, it allows the clamping part to have an axially fixed position relative to the tube in the clamping configuration.

**[0042]** The pulling part is adapted to engage with the yarns after a portion of the yarns has been wound around the tube.

**[0043]** The knotting unit may further comprise a thread driver for winding the yarns around the tube, which thread driver comprises an end clamp for clamping ends of the yarns together.

**[0044]** The end clamp may comprise a fixed jaw and a spring actuated jaw for clamping the yarns together.

**[0045]** The thread driver is adapted to wind the yarns around the tube close to the front end of the tube. Since the clamping part clamps the yarn at a clamping position which is positioned at or close to the front end of the tube, the clamping position is positioned close to the wound yarns loop. This feature serves to reduce the variation and the position of the knot.

**[0046]** The knotting unit may further comprise a separator which is moveable with the thread driver. The separator may comprise a folded sheet made of any convenient material such as metal or a plastics material. The separator serves to guide the two separated yarns in order to prevent the yarn ends from becoming entangled with parts of the yarns that have already been wound around the loop former.

**[0047]** The knotting unit may further comprise a knot holder, which knot holder forms a passageway extending between the loop holder and the extractor, the passageway having a width dimension that is less than the dimension of a knot formed with the first and second yarns.

**[0048]** The dimension of the knot when tightened could be known from experimental tests from the two yarns used to form the knot, or, when not available, arbitrarily fixed to the sum of the diameters of the two yarns to be knotted together.

**[0049]** The knot holder may comprise a resiliently deformable tongue that delimits at least partially a slit forming the passageway, the slit width dimension in a free state of the tongue being less than the dimension of the knot.

[0050] The tongue may be formed from a resiliently deformable material, and the positioning of the tongue will set the slit between the tongue and a bushing.

[0051] The knot holder may be formed on a bushing, which bushing may partially or completely surround the tube.

[0052] The bushing is thus able to engage the yarns in the passageway.

[0053] The position of the tongue may be adjustable on the bushing to ensure that the width of the slit is as mentioned hereinabove.

[0054] In use, therefore the knot holder is able to exert a retaining force on a loosened knot and to restrict the knot position along the yarns. In that way it is possible to reduce tail lengths for the knotted yarns without requiring additional scissors.

[0055] The bushing may further comprise an ejector for ejecting the loop from the tube, which ejector is moveable axially relative to the tube and is positioned substantially diametrically opposite the passageway formed by the knot holder relative to a central axis of the bushing.

[0056] The relative position of the knot holder on the bushing may be adjustable according to the yarn being used.

[0057] The knotting unit may further comprise a position sensor for sensing the position, and therefore any deformation of the knot holder.

[0058] The sensor may be any convenient sensor and may for example comprise a piezoelectric sensor.

[0059] In other embodiments of the invention, the knotting unit may comprise a camera rather than a sensor, which camera may be used to check the deformation of the tongue.

[0060] It is usual in tying machines to have a knot counter which counts the number of knots formed by the knotting unit. However, it is usual for such a knot counter to be incremented when yarns are separated from their respective warp sheets, and not when they are knotted.

[0061] In embodiments of the present invention, a knot counter may be operably connected to the sensor, whereby detection of a knot may be used to indicate the number of knots that have been tightened.

[0062] The ejector may be fixed to the sildable bushing, and the tube may be formed with an external longitudinal groove in which the ejector is able to slide.

[0063] The longitudinal path of the ejector may intersect the surface of the tube on which the yarns are wound.

[0064] The ejector may be positioned diametrically opposite the slit and the longitudinal projecting surface formed on the tube.

[0065] The knotting unit may further comprise a prepositioning device for holding the separated yarns to be knotted away from their respective warp sheets.

[0066] The prepositioning device may comprise an abutment plate associated with a moveable deflecting arm.

[0067] The abutment plate may have rounded edges.

[0068] The extractor may be moveable relative to the

tube, and the knotting unit may further comprise an extractor adjustment device for adjusting the movement of the extractor.

[0069] Due to the adjustable extractor, tail lengths can be adjusted to the required length and additional scissors are not needed.

[0070] The knotting unit may have a single motor which drives all moving parts of the knotting unit, namely the thread driver, the pulling part, the bushing, the ejector, the deflecting arm and the extractor. This results in a simple structure. However in other embodiments it may be more convenient to have more than one motor.

[0071] According to a second aspect of the present invention there is provided a warp tying machine for tying together a first yarn having a first end and second yarn having a first end, the warp tying machine comprising a knotting unit according to the first aspect of the present invention, and further comprising a separating module for separating the yarns from their respective warp sheets, and a conveyor for conveying the first and second separated yarns to the knotting unit.

[0072] According to a third aspect of the present invention there is provided a method for knotting a first yarn to a second yarn, the method comprising the steps of:

- i. winding the first and the second yarns around an outer surface of a tube extending around a longitudinal axis;
- ii. passing the yarn ends of the first and second yarns behind the wound yarns to form a loop;
- iii. then passing the yarn ends in front of the loop across a front end of the tube;
- iv. ejecting the loop from the outer surface of the tube;
- v. clamping a portion of the first and second yarns extending between the loop and the yarn ends at a clamping position that is axially fixed relative to the tube and
- vi. pulling the first and second yarns away from the tube.

[0073] The method according to a third aspect of the present invention may be carried out using a knotting unit according to the first aspect of the present invention.

[0074] In some embodiments of the invention, the step of pulling the first and second yarns away from the tube begins before the step of ejecting the loop from the outer surface of the tube.

[0075] The invention will now be further described by way of example only with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of a tying machine with a knotting unit according to an embodiment of the invention in an initial position;

Figure 2 is a schematic representation of the knotting unit of Figure 1 showing in an intermediate position in which the yarns have been looped around the tube

forming part of the knotting unit;

Figure 3 is a cross-sectional representation of the knotting unit showing some of the parts forming the knotting unit, the clamping part being in the released configuration;

Figure 4 is a schematic representation of a the knotting unit showing the fixed tube and tongue in more detail;

Figure 5 is a schematic representation showing the front end of the tube in more detail;

Figure 6 is a schematic front view of the knotting unit showing the yarns having been thrown off the tube by the ejector;

Figure 7 is a cross-sectional representation of the knotting unit as shown in Figure 6, the clamping part being in the clamping configuration;

Figure 8 is a schematic front view of a part of the knotting unit showing the yarns when the knot is about to be tightened;

Figure 9 is a schematic front view of part of the knotting unit showing the knot tightened and extracted from the knotting unit; and

Figure 10 is a schematic representation showing details of the extractor.

**[0076]** Referring to the figures, a knotting unit according to an embodiment of the invention is designated generally by the reference numeral 2.

**[0077]** The knotting unit 2 forms part of a tying machine 4 which also comprises a separating module 6, a conveying gripper 12, and an advance module 14.

**[0078]** With the help of the advance module 14, the tying machine 4 is moveable on a clamping device on which an upper warp sheet 8 is stretched in a upper clamping frame 9 and on which a bottom warp sheet 10 is stretched in a bottom clamping frame 11, the upper and bottom clamping frames being partially drawn in Figure 1.

**[0079]** The tying machine is for tying together two warp yarns, a first yarn from an upper warp sheet 8, and a second yarn from a bottom warp sheet 10.

**[0080]** As shown in more detail in Figures 2, 3 and 4, the knotting unit 2 comprises a tube 16 adapted to receive a needle 18. The needle 18 is axially moveable within the tube 16. The tube 16 has an axially and rotatably fixed position within the knotting unit as a whole, i.e. it is subjected only to the advance movement provided by the advance module 14 relative to the clamping device but is not driven by motor means of the knotting unit. Longitudinally, the tube 16 extends perpendicular to the

direction of the yarns stretched in the clamping device.

**[0081]** The knotting unit further comprises a thread driver 20 that is adapted to rotate around the tube 16 in order to wind yarns around the tube and to form a loop as required for forming a knot, and a sliding bushing 22 which is axially moveable relative to the tube 16.

**[0082]** The knotter unit also comprises a prepositioning device 24 comprising a fixed abutment plate 26 and a moveable deflecting arm 28. In this embodiment, the abutment plate comprises rounded edges 30.

**[0083]** The knotting unit further comprises an extractor 32 adapted to tighten the knot and to extract the knotted yarns from the knotting unit by pulling the yarns away from the tube 16.

**[0084]** The components of the knotting unit will now be described in more detail.

**[0085]** The tube 16 comprises a front end 34 and an opposite rear end (not shown) spaced apart from the front end. The front end 34 is turned towards the warp sheets stretched in the clamping device.

**[0086]** The tube 16 further comprises an internal surface 36 formed in proximity to the front end 34 of the tube 16.

**[0087]** In this embodiment, the internal surface 36 extends inwardly from the front end 34, and forms a substantially frustoconical surface that is oriented towards the front end 34.

**[0088]** The front end 34 of the tube is formed with a longitudinal projection 38 in the form of a nose. The nose forms a longitudinal surface 39 that is positioned substantially in a plane perpendicular to the warp sheets as indicated in Figure 5. Positioned adjacent to the projection 38 is a low friction recess surface 40 on the outer surface of the tube 16. The recess surface 40 has a lower surface roughness than the remainder of the outer surface of the tube 16. The recess surface 40 extends through an angle of  $\pm 120^\circ$  around the longitudinal axis of the hollow tube with respect to the angular position of the longitudinal surface of the nose 38.

**[0089]** The thread driver 20 comprises an end clamp 42 which in turn comprises a fixed jaw and a spring activated jaw. The end clamp is adapted to clamp the two yarns 44, 46 that are to be knotted together as shown in Figure 2, for example.

**[0090]** The thread driver 20 is linked to a sleeve 52 that is moveable both around the tube 16, and axially with respect to the tube in order to wind the yarns to form a loop. A separator 54 comprising a folding metal sheet rotates with the thread driver.

**[0091]** The separator 54 serves to guide the separated yarns 44, 46 on an appropriate track in order to prevent the yarn ends 48, 50 of the yarns 44, 46 from becoming entangled with wound parts of the yarns.

**[0092]** The extractor 32 comprises an oscillating lever 56. The timing of the movement of the oscillating lever 56 is adjustable by adjusting the position of a screw within an adjustment groove, the screw fixing together the oscillating lever 56 and a rotating driven disc 62.

**[0093]** The oscillating lever 56 is moveable about a pin 58 shown in Figure 11 for example that is fixed to a plate 60. The angular position of the pin 58 is adjustable by means of screws 61, with respect to the driven disc 62.

**[0094]** Each screw 61 is inserted into an adjustment groove 64 of an extractor plate 66 with which the pin 58 is fixed and is tightened in a thread formed on the driven disc 62. The tightening position of the screw 61 in the groove 64 determines the start time of the extracting movement during the knotting cycle whereas movement of the oscillating lever 56 is predetermined and is unchanging during use.

**[0095]** The axially slideable bushing 22 completely or partially circumferentially surrounds the tube 16.

**[0096]** The bushing 22 comprises a knot holder 70, which in this embodiment comprises a tongue 72. In this embodiment the tongue is formed from steel and is substantially semi-circular in shape, as shown in Figure 4. The tongue is resiliently deformable, and is fastened to the bushing by means of a screw 73 or any other convenient method.

**[0097]** The tongue 72 delimits partially an axially extending slit 74 between the tongue 72 and the bushing 22. The position of the tongue is adjustable by the position of the fastening screw 73 explained hereinabove in a groove 75 of the tongue 72. The tongue is positioned relative to the bushing 22 before the tying process starts so that in the free state of the tongue, the slit width, or the smallest slit dimension in a direction transverse to a longitudinal direction, as shown in Figure 8, is less than the minimum external dimension of the tightened knot 100 formed with the yarns to be knotted by the knotting unit, and about equal to the diameter of the yarns to be knotted.

**[0098]** The knot holder 70 exerts a retaining force on a loosened knot 100 formed with the yarns that are introduced into the passageway formed by the slit 74. When the yarns are wound around the tube and pass through the slit, the slit cooperates with the yarn portions extending from the loop formed around the tube 16, and spaced apart from the yarn ends 48, 50.

**[0099]** The tongue 72 is equipped with a piezoelectric sensor 76 illustrated in Figure 9. The sensor 76 is able to detect deformation of the tongue 72 and to transmit a signal to a knot counter (not shown) which counts the number of knots formed, as will be described in more detail hereinbelow.

**[0100]** The slit 74 is positioned around the longitudinal axis of the tube at a maximum angle of 70° with respect to the angular position of the longitudinal surface 39 of the nose 38 as shown in Figure 6.

**[0101]** This position of the projecting surface 39 ensures that the yarns are clamped as close as possible to the slit 74 of the knot holder 70.

**[0102]** An ejector 80 as shown in Figure 8 is fixed to the bushing 22 and is adapted to slide axially along the tube. In this embodiment, the ejector 80 slides in a longitudinal groove 82 formed on an external surface of the

tube 16.

**[0103]** The path of the ejector 80 intersects the surface of the tube 16 on which the yarns are wound.

**[0104]** The ejector 80 is positioned substantially diametrically opposite to the slit 74 and to the longitudinal projecting surface 39 of the nose 38 with regard to the longitudinal central axis of the tube 16 that is coincident with the central longitudinal axis of the bushing 22.

**[0105]** The needle 18 comprises two parts: a pulling part 84 formed as a hook 92, and a clamping part 86 which are housed at least partially within the tube 16. The clamping part 86 extends axially at least partially in a front position relative to the pulling part 84. The clamping part 86 is pushed by a resiliently deformable member, which in this case is a spring 88, towards the pulling part 84 in a rear direction. The clamping part 86 is axially movable relative to the pulling part 84 in dependence on the axial position of the pulling part 84. The pulling part 84 is rigidly linked to a motor (not shown) which enables the needle 18 to move in a to and fro axial movement within the tube 16. In a forward position of the needle 18, the clamping part 86 is in abutment against the pulling part 84.

**[0106]** The clamping part 86 comprises a frustoconical surface 90 which extends around the longitudinal axis of the tube for approximately 240° and is oriented in the direction of the rearward part of the needle. The clamping part is positioned such that the open sector (i.e. the part through which the frustoconical surface 90 does not extend) is placed adjacent to the ejector groove 82. The clamping part 86 and the pulling part 84 are rotatably fixed relative to the tube 16 around the longitudinal axis.

**[0107]** When the needle 18, is moving from its forward position, in a rearward direction into the tube 16, the clamping part 86 and the pulling part 84 start to move together and movement of the clamping part 86 is then restricted by the tube 16. Specifically, the frustoconical surface 90 of the clamping part cooperates with the frustoconical surface 36 of the tube. Further movement of the clamping part 86 towards the rear end of the tube is prevented.

**[0108]** However, the pulling part 84 continues to move further rearward into the tube 16 at this point into its retracted position.

**[0109]** When the needle 18 is travelling in a forward direction from its retracted position, the pulling part 84 starts to move forward whereas the clamping part 86 is resiliently maintained axially in cooperation with the tube 16. The pulling part 84 then abuts against the clamping part 86 and drives the clamping part 86 forward until the frustoconical surface 90 and the hook 92 of the pulling part 84 extend beyond the front end 34 of the tube. Needle 18 has now reached its forward position.

**[0110]** The prepositioning device 24 serves to hold the separated yarns 44, 46 from the warp sheets and ensures that the yarns are in an appropriate position relative to the tube. This is achieved by abutment of the yarns with the abutment plate 26.

**[0111]** In the present embodiment, the thread driver 20, needle 18 and bushing 22, deflecting arm 28 and the driven disc 62 of the extractor are all actuated by a single motor, the movement for each of the components of the knotting unit 2 being converted from the main shaft of the motor in known manner.

**[0112]** In other embodiments, more than one motor may be used, and in some embodiments one motor may be used to drive each component.

**[0113]** The oscillating lever 56 is positioned between the tube 16 and the clamping frame of the separated yarns 44, 46 in the direction of the yarns when stretched in the clamping frame so that the oscillating lever 56 co-operates with portions of yarns that are opposite to the yarn ends 48, 50 regarding to the formed loop and further to the formed knot.

**[0114]** Now that all the components have been described in more detail, the knotting process will be described.

**[0115]** At the start of the process, the needle 18 is retracted within the tube 16 and the bushing 22 is positioned in its rearward position.

**[0116]** The thread driver 20 rotates from its rear position. The oscillating lever 56 is retracted and the deflecting arm 28 is in its forward position.

**[0117]** Two yarns 44, 46 that have been separated from their respective warp sheets and cut to form the yarn ends 48, 50 by the tying machine separation module 6, are brought towards the knotting unit 2 by a conveyor gripper 12. In particular, the two yarns 44, 46 are brought in close parallel relationship over the tube 16 and in the path of the deflecting arm 28.

**[0118]** The two yarns 44, 46 are then taken by the rotating thread driver 20. In this respect the yarns 44, 46 are introduced into the end clamp 42. The yarns are then carried around the tube 16 by the thread driver 20 (the two yarns follow the same path) in order that the yarns are wound around an external surface of the hollow tube, this external surface comprises the low friction recess 40.

**[0119]** Once the yarns have been wound round the tube 16 through an angle of approximately 270°, the needle 18 slides forward and the clamping part 86 and the hook 92 extend beyond the front end of the tube 16 as shown in Figures 2 and 3. The clamping part 86 is now in the released configuration in which the space between the frustoconical surface 90 and the complementary frustoconical surface 36 is bigger than the diameter of each of the yarns 44, 46.

**[0120]** The thread driver 20 moves axially towards the rear end of the tube so that the yarn ends are positioned rearwardly relative to the wound portion of the yarns.

**[0121]** The deflecting arm 28 then brings the yarns against the abutment plate 26. During rotation of the thread driver it is possible that the yarns may slide somewhat within the second clamping part 42.

**[0122]** The rotating thread driver 20 continues to rotate but also now moves axially forward in order to guide the yarns to the front of the tube 16 once the yarns have been

wound once round the tube and form a loop. At this point, the yarns are in contact with the longitudinal surface of the projection 38 at the front end 34 and are guided into an axial space between the tube and the hook 92 of the needle across the front end 34 of the tube.

**[0123]** At this moment, the bushing 22 slides forward into an intermediate position as also shown in Figures 2 and 3 where the two yarns 44, 46 are introduced into the slit 74 formed between the knot holder tongue 72 and the bushing 22.

**[0124]** The bushing 22 is formed to have rounded surfaces at its end, and the tongue is similarly formed. These rounded surfaces assist in guiding the yarns into the slit.

**[0125]** As has been previously mentioned, the initial width of the slit is larger than the diameter of the yarns 44, 46 and less than the size of the knot 100 to be formed. At this point (as shown in Figure 6) therefore there is no clamping action of the knot holder on the yarns although there will be some friction of the knot holder on the loosened knot once the knot is formed.

**[0126]** The yarns have now been guided across the front of the tube 16 and the needle 18 is in its forward position as shown in Figure 2. This means that the yarns 44, 46 are now in the path of the needle hook 92 and in the path of the clamping part 86, but the yarns 44, 46 are not yet in contact with the hook 92 and with the frustoconical surface 90 of the clamping part 86.

**[0127]** At this point the needle 18 is retracted rearwardly into the tube 16. The clamping part 86 follows this rearward movement since the clamping part is resiliently connected to the pulling part and the clamping part 86 moves relative to the tube 16.

**[0128]** The bushing 22 slides into its forward position and the ejector 80 on the bushing 22 throws off the loop formed with the yarns 46, 48 that were wound around the tube. In view of the position of the ejector 80 with regard to the tube 16 and the bushing 22, the ejector 80 acts on the yarns 44, 46 at distance from the slit 74.

**[0129]** This means that a loosened knot 100 is now in front of the tube 16 as shown in Figure 6.

**[0130]** When the clamping part 86 abuts with the tube 16, with the yarns 46, 48 therebetween, it clamps the yarns 44, 46, 48 at a portion of the yarns located between the yarn ends 48, 50 and the portion of yarns that have been wound onto the tube 16 to form the loop. This axial cooperation between the clamping part 86 and the tube 16 stops further axial rearward movement of the clamping part 86 within the tube 16, i.e. when the clamping part 86 is in the clamping configuration, the clamping part 86 is in an axially fixed position relative to the tube 16 and doesn't move any more relative to the tube 16. The clamping position 110 at which the yarns 44, 46 are clamped between the two frustoconical surfaces 36, 90 is fixed relative to the tube 16 and is positioned radially, i.e. transversally to the central longitudinal axis of the tube 16, between the projecting surface 39 and the path of the hook 92 of the pulling part 84 moving along the longitudinal axis of the tube 16. During rearward move-

ment of the needle, the hook 92 of the pulling part 84 continues its rearward movement whilst pulling the free ends 48, 50 of the yarns from the end clamp 42, through the tube 16 and thus through the loop formed by the wound yarns in order to form a knot.

[0131] The spring 88 between the clamping part 86 and the pulling part 84 is more compressed at this point than in the forward position of the needle 18. This means that the clamping action on the yarns 44, 46 between the two frustoconical surfaces is resiliently maintained.

[0132] In the clamping configuration, the clamping part 86 is retracted within the tube 16 so that the clamping part 86 doesn't interfere with the loop that is thrown off from the tube 16.

[0133] The throwing off of the loop by the ejector 80 takes place before or concomitantly to the clamping of the yarns 44, 46 by the clamping part 86.

[0134] The loosened knot is now restricted between the clamping position 110 and a holding position 112 defined by the slit (Figure 8). Both positions are in this phase fixed relative to the tube 16 and are arranged to be as close as possible to each other.

[0135] Because the yarns 44, 46 are clamped at the clamping position 110 by the clamping part 86, extracting action of the oscillating lever 56 on the yarns 44, 46 directly acts on the loosened knot to tighten the knot. The extracting movement caused by the extractor causes the loosened knot to come into contact with the knot holder 78 and tightens the knot. At this point the slit 74 acts as an obstacle to restrict the position of the knot with regard to the yarn ends 48, 50 that are themselves fixed relative to the tube 16 as the yarns 44, 46 are clamped at the clamping position 110.

[0136] When the knot is tightened, the extracting movement pulls directly on the clamped yarns that slide away from their clamp between the clamping part 86 and the tube 16. During the final extracting movement, the oscillating member 56 pulls the knot in a direction away from the tube 16 and the knot passes through the slit and resiliently deforms the tongue as it passes through. The deformation is sensed by the piezoelectric sensor. This causes the knot counter to increment by one. The tongue 72 comes back to its free state. The bushing 22 and the rotating thread driver 20 are then retracted rearwardly ready for a new knotting cycle to begin.

[0137] From the moment when the clamping part 86 cooperates with the tube 16 with the yarns 44, 46 therebetween and until the yarn ends 48, 50 slide away from their clamp between the clamping part 86 and the tube 16, the clamping part 86 remains in an axially fixed position relative to the tube 16. Moreover in the clamping configuration, the position of the clamping part 86 is fixed around the longitudinal axis of the tube 16.

[0138] The lever 56 oscillates about the pin 58 between a non-extracting configuration in which it is spaced apart from the yarns wound around the tube 16, and an extracting configuration in which it is in contact with the yarns and moves rearward to pull the yarns away from

the front end 34 of the tube 16 in order to effect extraction.

[0139] The extracting movement can be adjusted so that it starts pulling the yarns 44, 46 away from the tube 16 at the earliest when the loop has not yet been ejected from the tube as shown in Figure 2. In that case, the oscillating lever 56 pulls the yarns 44, 46 which slide in the clamp holder 42, reducing the length of the yarns between the portion of the yarns 44, 46 that will be clamped by the clamping part 86 and the ends 48, 50. This produces short knot tails of around 10mm. Alternatively, the timing of the extractor may be adjusted so that the extractor begins extraction at the latest when the yarns have just been clamped by the clamping part. This will produce longer tails of around 30mm.

[0140] In another embodiment movement of the extractor can be adjusted in dependence on the yarns to be knotted by using a dedicated motor for driving the extractor. The adjustment is done by directly controlling the motor with yarns in accordance with parameters such as tension, dimension, friction, etc.

[0141] In a knotting unit that knots yarns with short knot tails only, the needle need not comprise a pulling part, as the yarn ends are already located through the loop formed around the tube. In that case, the needle comprises a clamping part only that is moved relative to the tube.

[0142] Alternatively, the loop former can be made up of a plurality of parts defining a peripheral support around which the yarns are wound to form the loop. This peripheral support can be other than of cylindrical geometry but defines a central longitudinal axis.

[0143] Any conveying means such as a gripper, vacuum nozzle etc may convey the separated yarns to the knotting unit.

## Claims

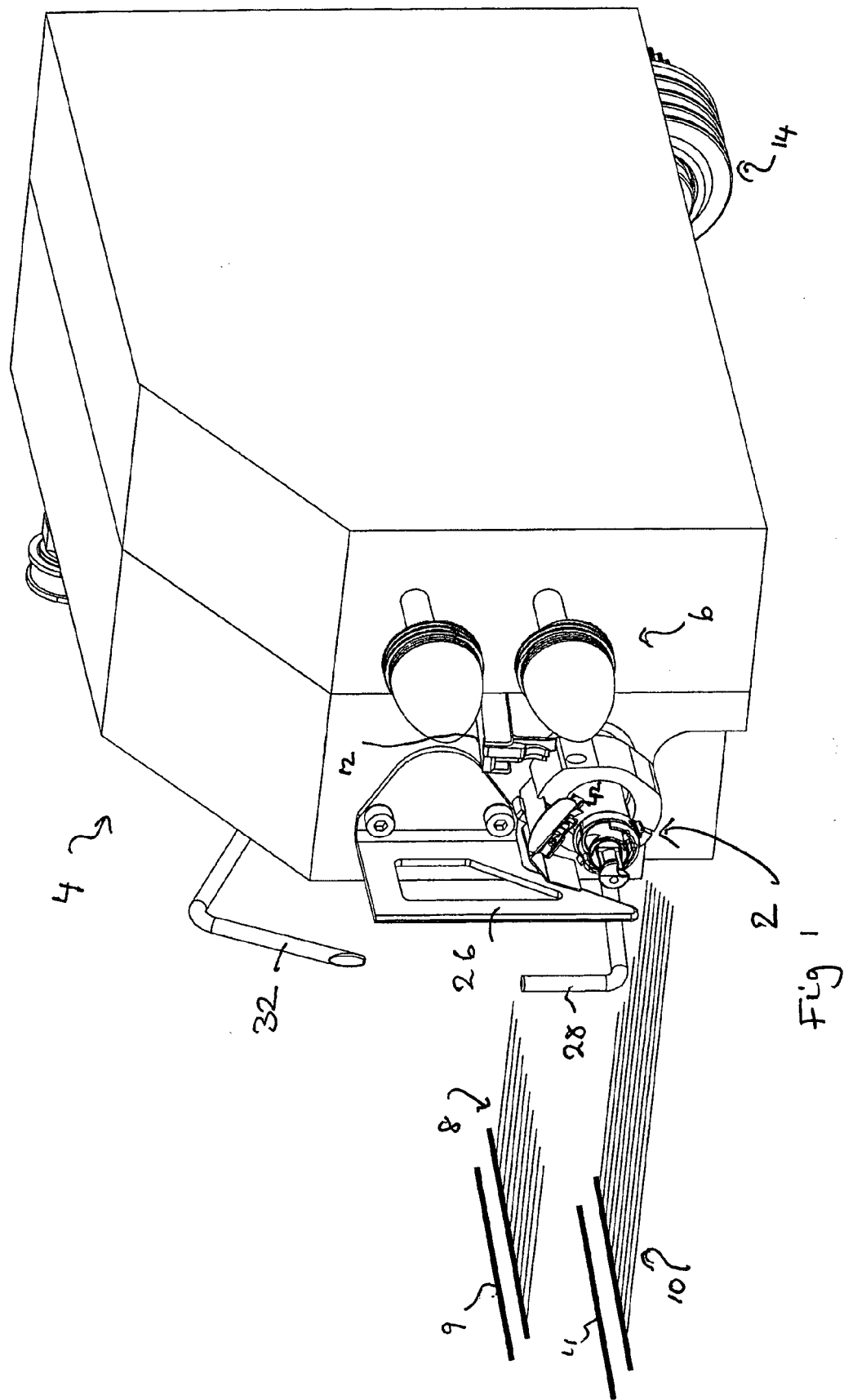
1. A knotting unit for a warp tying machine for knotting together a first yarn and a second yarn, the knotting unit comprising:
  - i. a tube extending around a longitudinal axis for supporting a loop formed with the first and second yarns;
  - ii. a clamping part housed at least partially within the tube and moveable relative to the tube, the clamping part being adapted to cooperate with the tube, for clamping the first and second yarns therebetween, wherein in the clamping configuration, the axial position of the clamping part is fixed relative to the tube, and
  - iv. an extractor for tightening a knot formed with the first and second yarns.
2. A knotting unit according to claim 1 wherein the tube comprises an internal frustoconical surface and wherein the clamping part comprises a frustoconical

surface which is shaped to cooperate with the internal frustoconical surface of the tube for clamping the yarns therebetween.

3. A knotting unit according to any one of the preceding claims, wherein the tube comprises a recess on the outer surface of the tube for supporting the loop formed with the first and second yarns, and a longitudinally projecting surface adjacent to the recess and formed at a front end of the tube. 5
4. A knotting unit according to any one of the preceding claims, wherein in the clamping configuration, resilient means maintain the clamping part in cooperation with the tube. 10
5. A knotting unit according to any one of the preceding claims further comprising a pulling part with a hook for pulling the ends of the first and second yarns into the tube. 15
6. A knotting unit according to claim 4 or claim 5, wherein the resilient means are located between the pulling part and the clamping part. 20
7. A knotting unit according to claim 6, wherein the clamping part is positioned in a front position relative to the pulling part. 25
8. A knotting unit according to any one of the preceding claims further comprising a knot holder forming a passageway extending between the tube and the extractor, the passageway having a width dimension that is less than the dimension of a knot formed with first and second yarns. 30
9. A knotting unit according to claim 8, wherein the knot holder comprises a resiliently deformable tongue that delimits a slit forming the passageway, the slit width dimension in a free state of the tongue being less than the dimension of the knot. 35
10. A knotting unit according to claim 3 and claim 9, wherein the slit is positioned around the longitudinal axis of the tube at a maximum angle of 70° with respect to the angular position of the longitudinally projecting surface of the tube. 40
11. A knotting unit according to claim 8, 9 or 10, wherein the knot holder is formed on a bushing, which bushing partially or completely surrounds the tube and is axially moveable relative to the tube. 45
12. A knotting unit according to claim 11 wherein the bushing further comprises an ejector for ejecting the loop from the tube, which ejector is moveable axially relative to the tube and is positioned substantially diametrically opposite the passageway formed by 50

the knot holder relative to a central axis of the bushing.

13. A knotting unit according to any one of the preceding claims wherein the extractor is moveable relative to the tube, and the knotting unit further comprises an extractor adjustment device for adjusting the movement of the extractor. 55
14. A warp tying machine for tying together a first yarn and a second yarn, the warp tying machine comprising a knotting unit according to any one of claims 1 to 13, further comprising a separating module for separating the first and second yarns from their respective warp sheets, and a conveyor for conveying the first and second separated yarns to the knotting unit. 60
15. A method for knotting a first yarn to a second yarn, the method comprising the steps of: 65
  - i. winding the first and the second yarns around an outer surface of a tube extending around a longitudinal axis;
  - ii. passing the yarn ends of the first and second yarns behind the wound yarns to form a loop;
  - iii. then passing the yarn ends in front of the loop across a front end of the tube;
  - iv. ejecting the loop from the outer surface of the tube;
  - v. clamping a portion of the first and second yarns extending between the loop and the yarn ends at a clamping position that is axially fixed relative to the tube and
  - vi. pulling the first and second yarns away from the tube.
16. A method for knotting a first yarn and a second yarn according to claim 15, wherein step vi. begins before step iv. 70



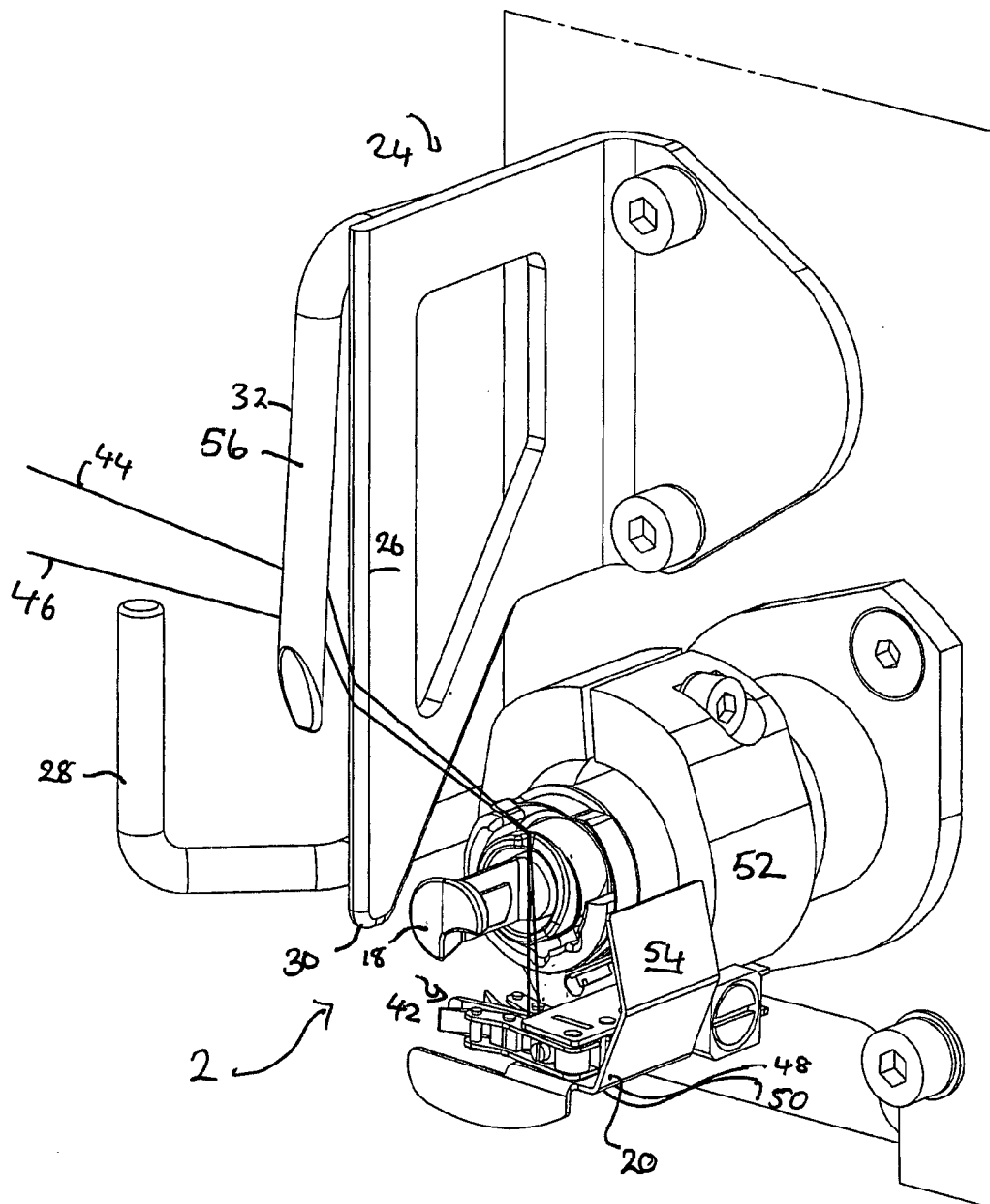


Fig 2

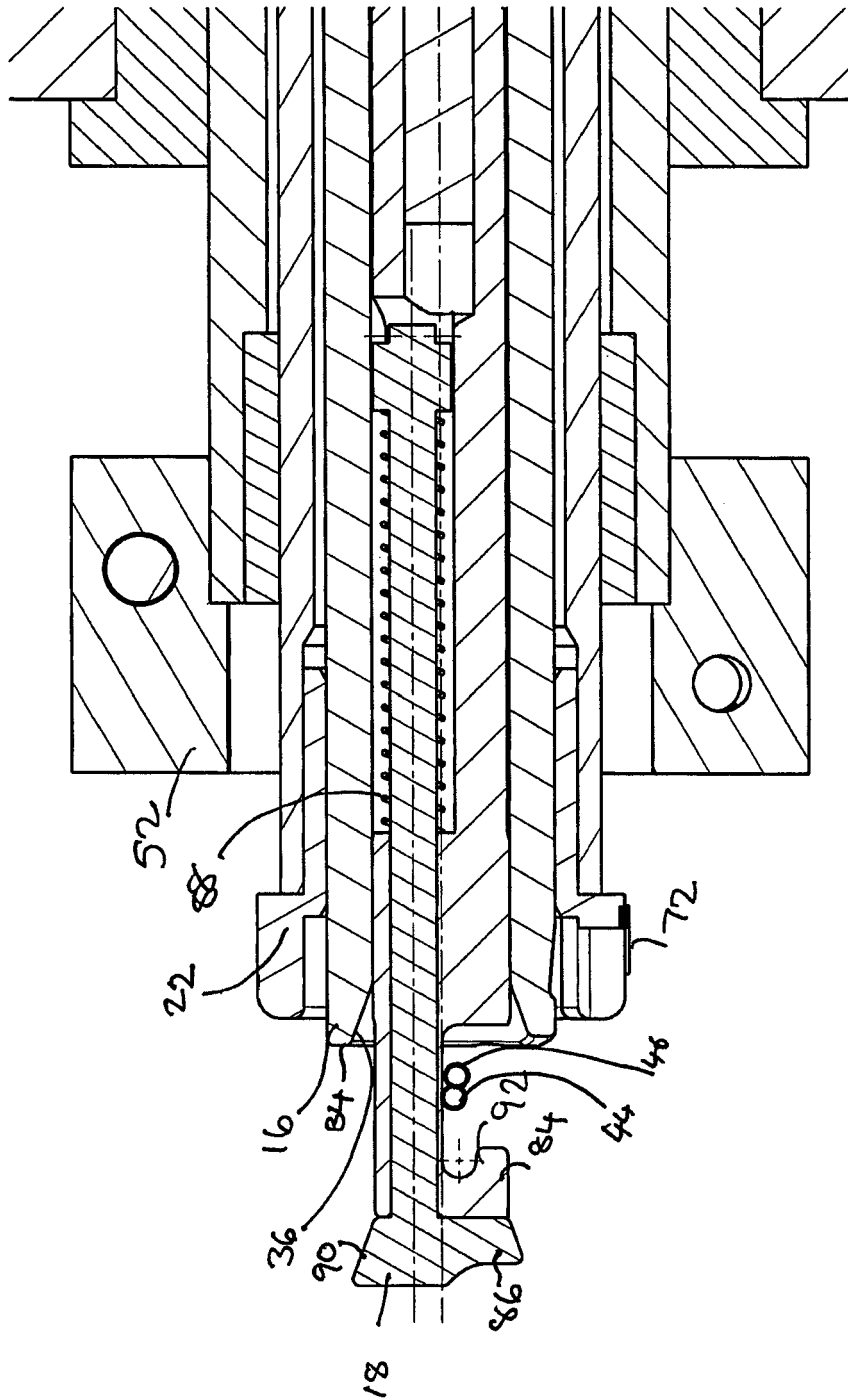


Fig 3

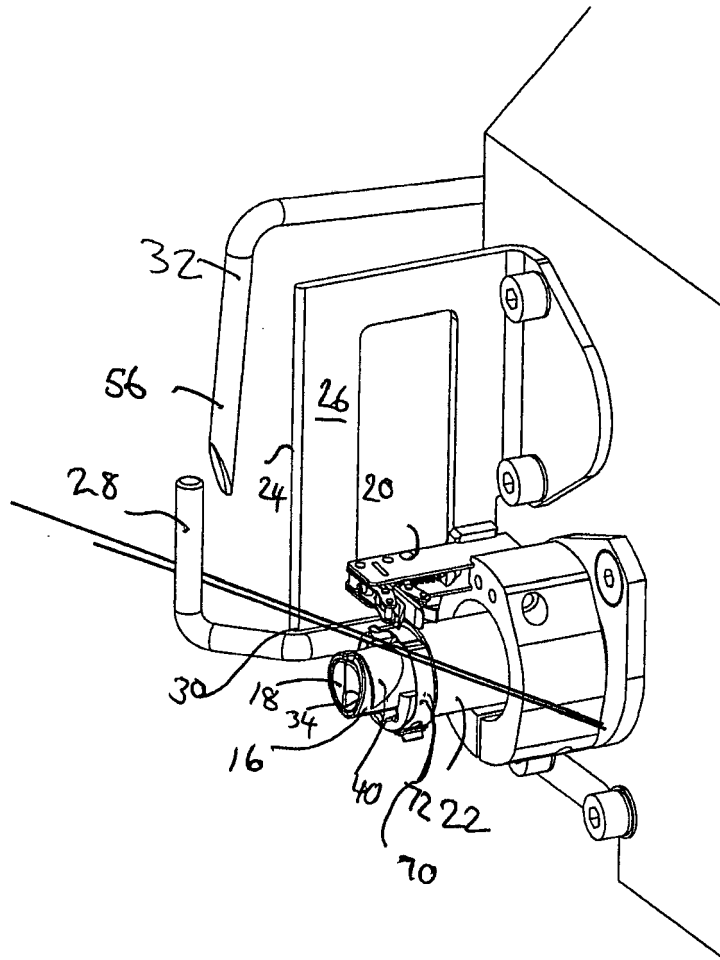
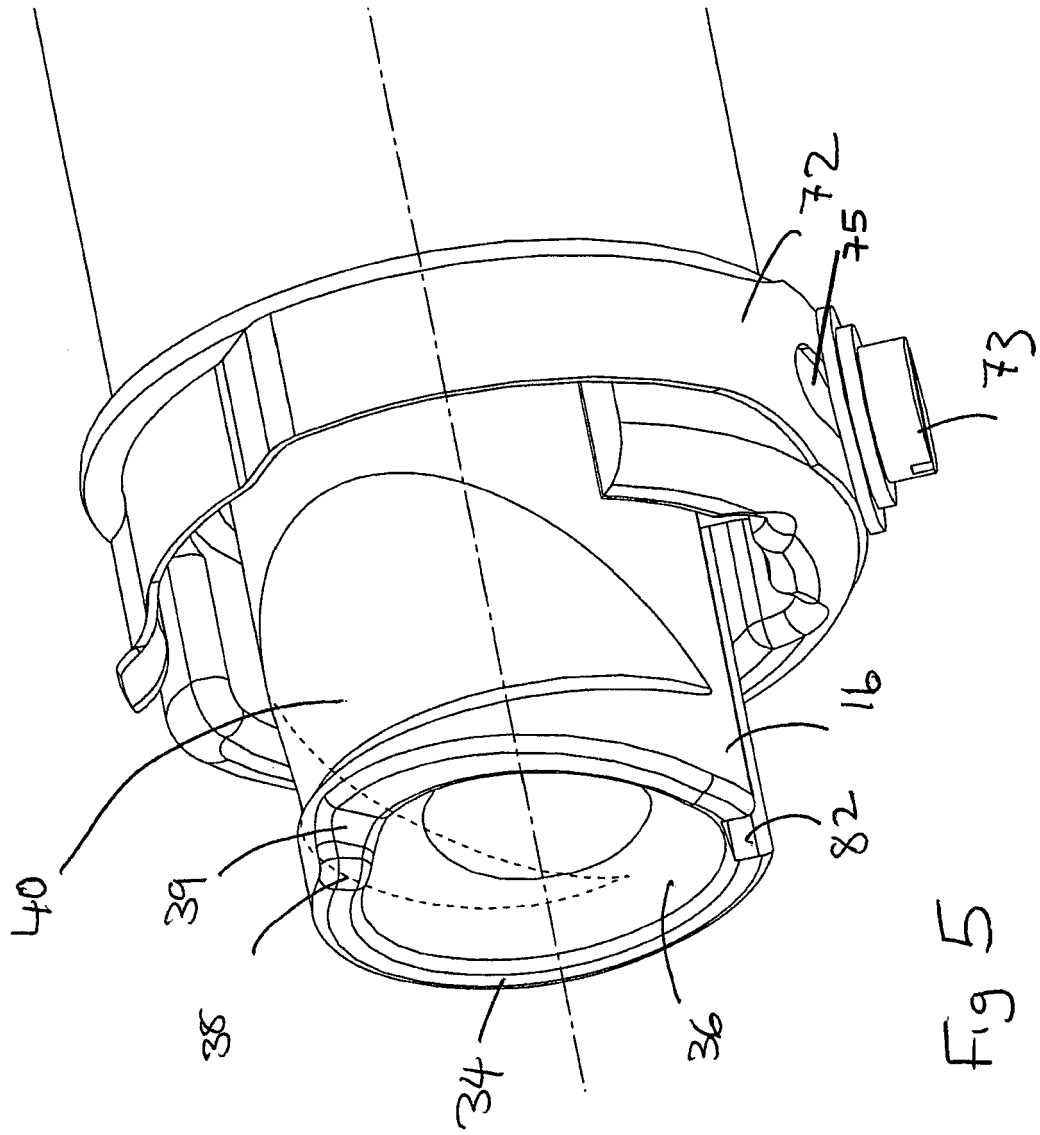
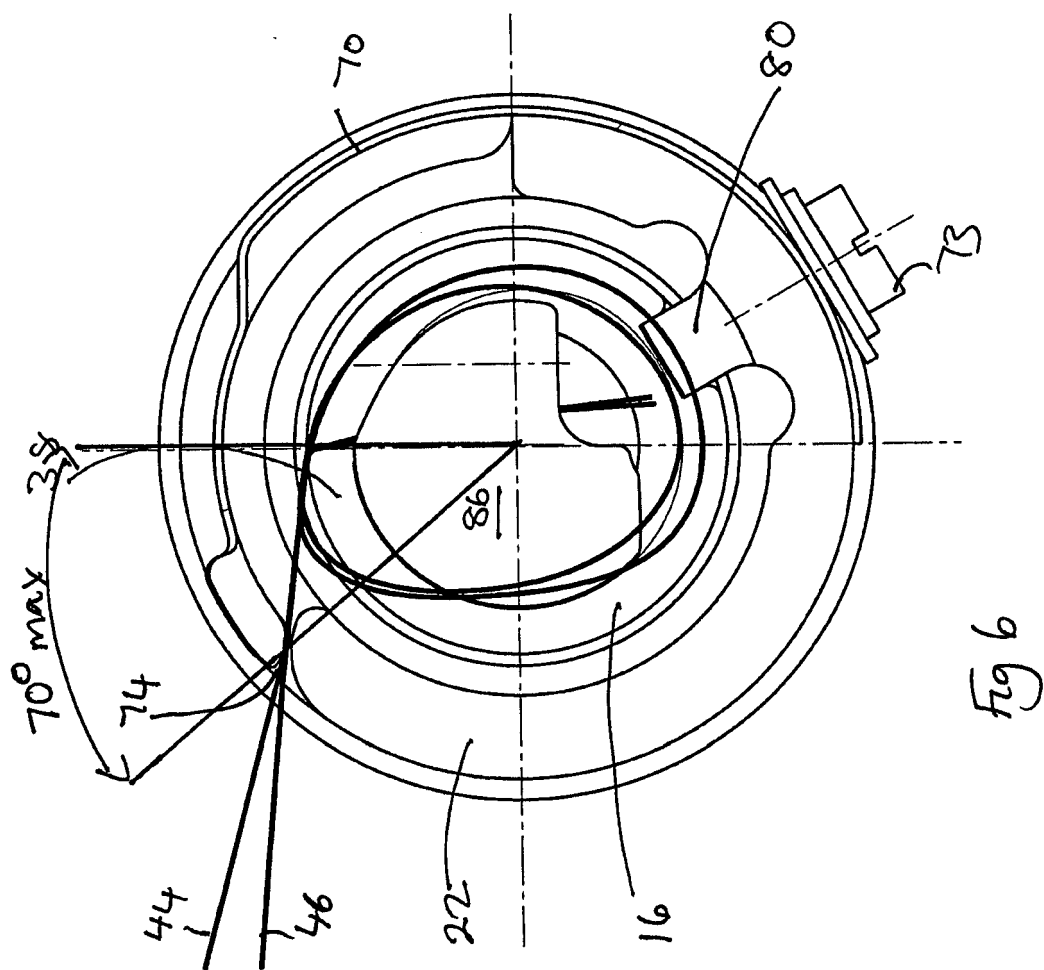


Fig 4





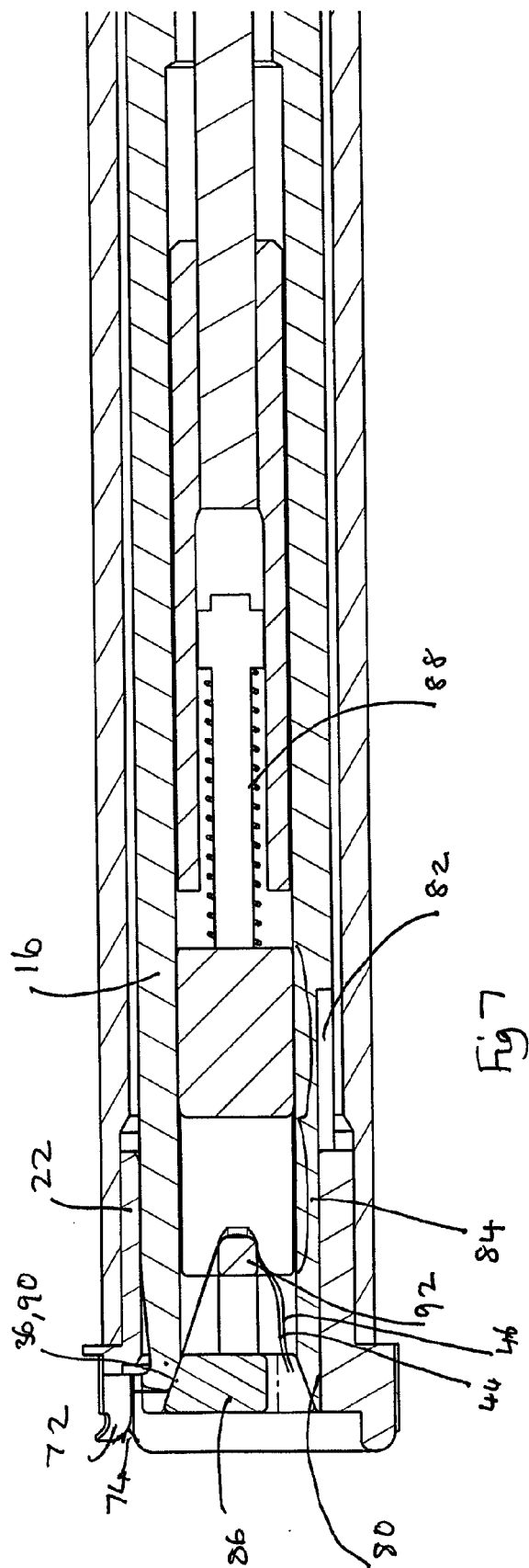


Fig. 7

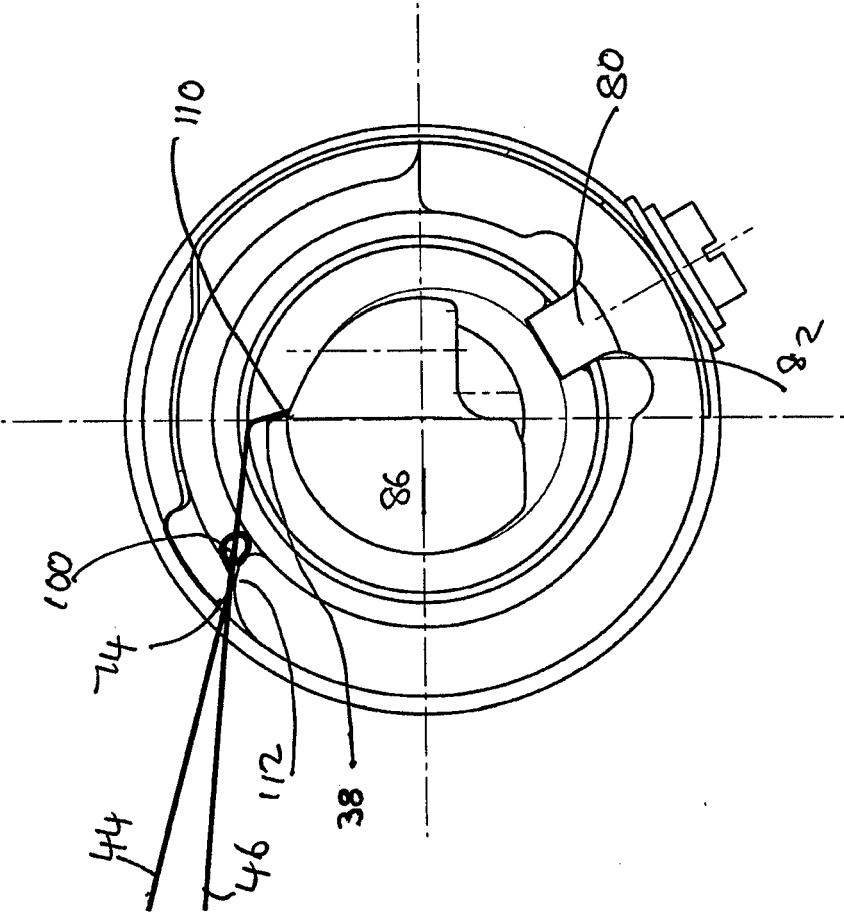


Fig 8

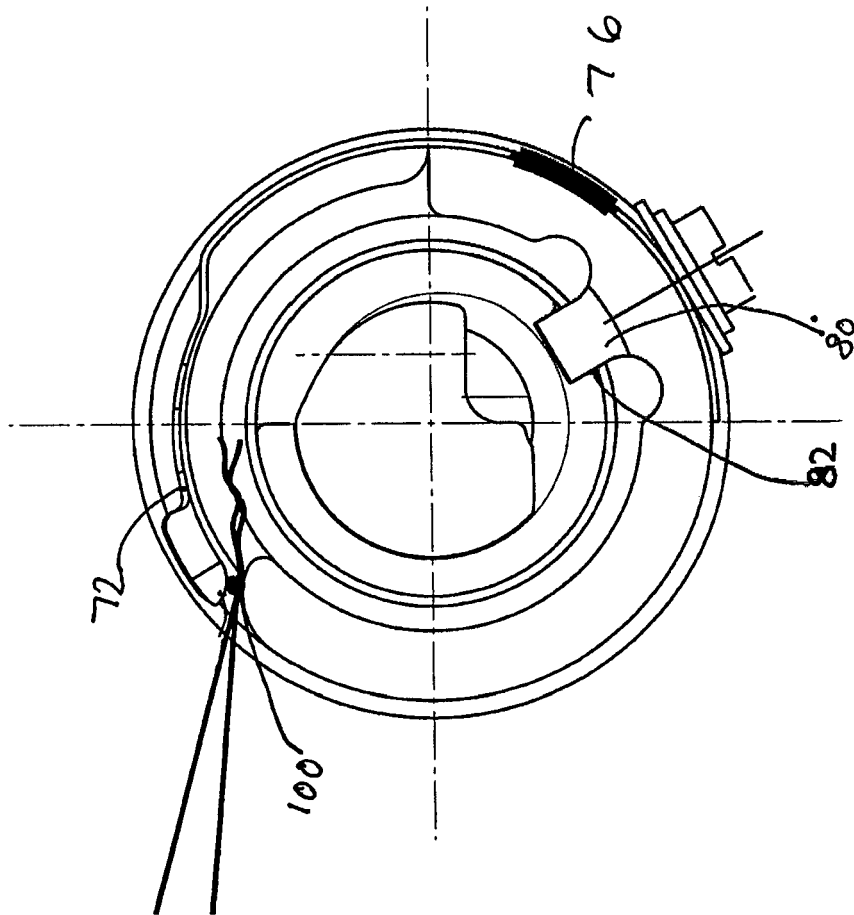


Fig 9

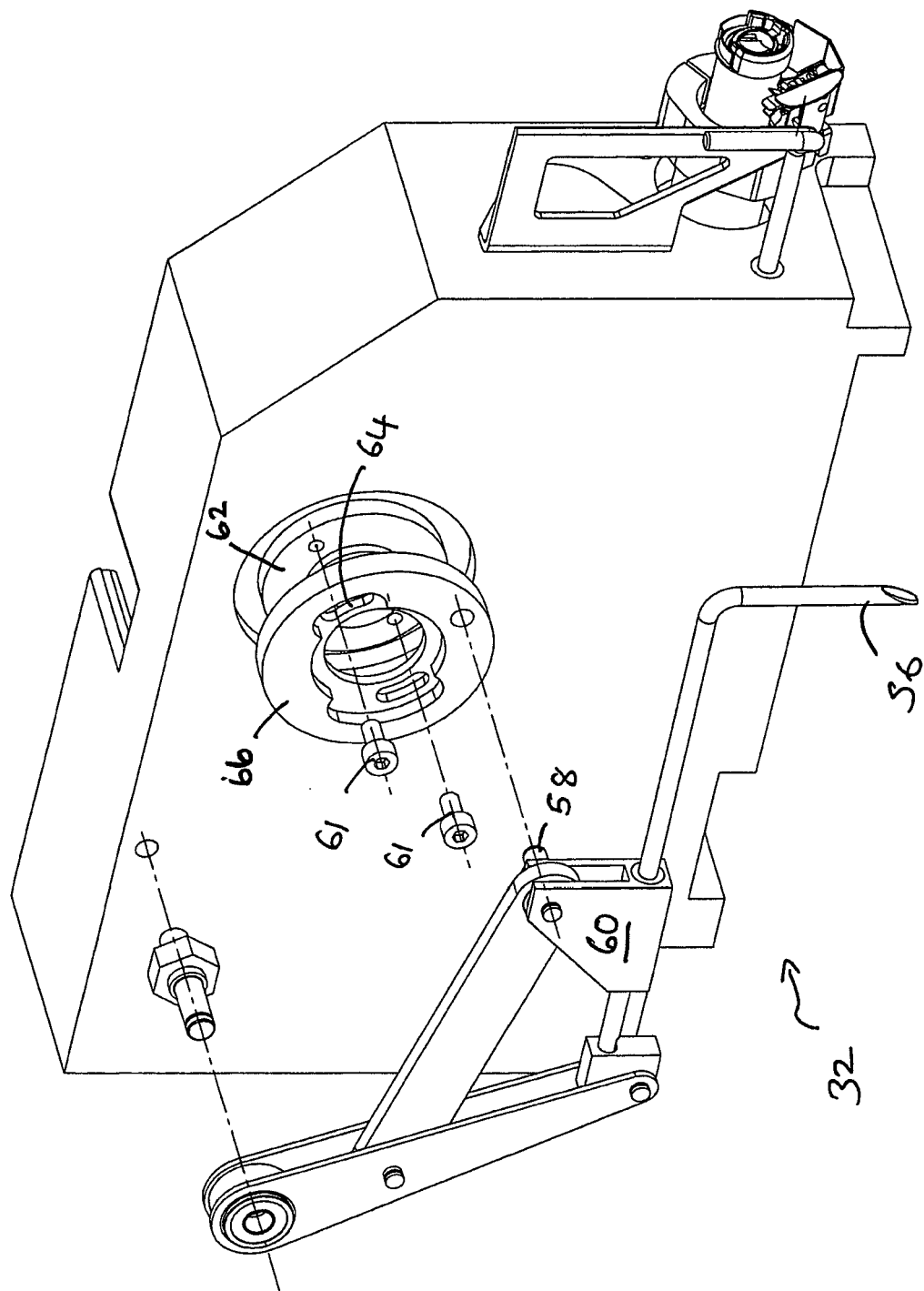


Fig. 10



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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                               |                                  |                                         |
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| Place of search                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                               | Date of completion of the search | Examiner                                |
| Munich                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                               | 9 January 2015                   | Iamandi, Daniela                        |
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