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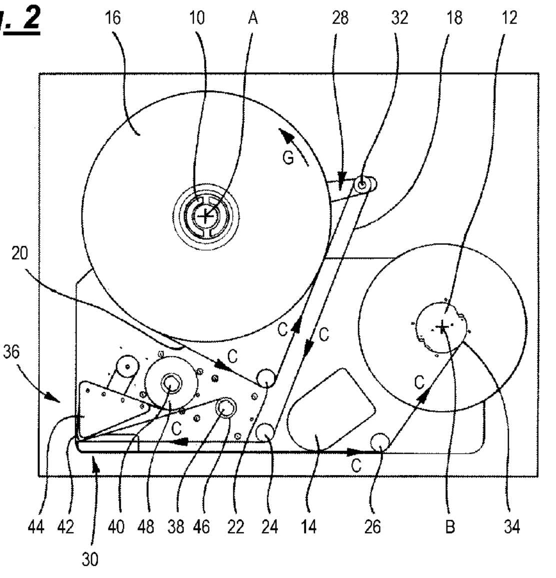
(54) Title: LABELLING MACHINE AND METHOD FOR ITS OPERATION

Fig. 2



(57) Abstract: A labelling machine comprises a supply spool support (10) for supporting a supply spool comprising label stock comprising a web and a plurality of labels attached to the web and which are separable from the web; a take-up spool support (12) adapted to take up a portion of web; a sensor (52) configured to produce a sensor signal (56) indicative of a periodic property of at least a portion of the label stock; and a controller configured to calculate a displacement of the web a web path defined between the supply spool and the take-up spool based upon the sensor signal and a length of a component of the label stock.

LABELLING MACHINE AND METHOD FOR ITS OPERATION

The present invention relates to a labelling machine and particularly to a labelling machine for use with label stock comprising a web and a plurality of labels attached to the web and which are separable from the web. Such machines are sometimes referred to as “roll-fed self-adhesive labelling machines”.

A label stock comprising a web carrying labels is usually manufactured and supplied as a wound roll (hereinafter referred to as a spool). For a given spool, all the labels are typically the same size, within manufacturing tolerances. However, in some instances, this is not the case.

Labels are commonly used to display information relating to an article and are commonly disposed on the article such that the information is easily readable either manually or automatically. Such labels may, for example, display product information, barcodes, stock information or the like. Labels may be adhered to a product or to a container in which the product is packaged.

In the manufacturing industry, where such labels are read automatically, it is important for the information to be printed such that it is clear and positioned accurately so that an automated reader can consistently and correctly read the information.

Some known labelling machines apply pre-printed labels to an article. Other known labelling machines print information onto labels immediately before printed labels are applied to an article. Such labelling machines may be referred to as print and apply labelling machines.

It is desirable to be able to advance a web of labels to be applied to an article accurately, so as to ensure that print is accurately positioned on the label and/or to ensure that the label is accurately positioned on the article. This may be particularly important in print and apply labelling machines in which printing is typically carried out while the label moves relative to the printhead, making accurate control of the label (and hence the label stock) important if printing is to be properly carried out such that the desired information is correctly reproduced on the label.

Given that labels are often removed from the moving web by passing the label stock under tension around a labelling peel beak (sometimes referred to as a peel beak, a peel blade or a label separating beak), it is sometimes desirable to ensure that a predetermined optimum tension in the web of the label stock is maintained. In some applications, it is also desirable that the label stock can be moved at a predetermined speed of travel along a defined web path, so as to ensure that the speed at which labels are dispensed is compatible with the speed at which products or containers move along a path adjacent the device.

A known labelling machine comprises a tape drive which advances the label stock from a supply spool support to a take up spool support. The tape drive has a capstan roller of known diameter which is accurately driven to achieve desired linear movement of the label stock along the web path. This capstan roller is also often referred to as a drive roller. The label stock is often pressed against the capstan roller by a nip roller, in order to mitigate risk of slip between the capstan roller and the label stock. For the reliable running of such machines the nip/capstan mechanical arrangement is designed so as to ensure respective axes of the two rollers are substantially parallel to one another and that the pressure exerted by the nip roller (which is typically sprung loaded) is generally even across the width of the label carrying web. This often results in relatively expensive and complex mechanical arrangements, and it is often a time consuming process to load the machine with a supply spool of label stock and feed the label stock from the supply spool support to the take-up spool support, through the nip/capstan rollers, before the labelling machine is operated. This is because the nip roller has to be temporarily disengaged or removed to allow the web of the label stock to be positioned along the web path between the supply spool support and the take up spool support. The nip roller is then repositioned such that the label stock is pressed against the capstan roller by the nip roller and the web of the label stock can be moved between the spool supports by rotation of the capstan roller.

Furthermore, in such labelling machines, the take-up spool (and hence the take up spool support) itself typically needs to be driven in order to maintain adequate tension in the web, between the nip/capstan roller and the take-up spool support. If the tension is too low, the web can become wrapped around the capstan roller, causing the machine to fail, and if the tension is too high, the capstan roller can be “over-driven” by the take-up spool support, resulting in the web being fed at the wrong speed, or indeed the web snapping. The drive for the take-up spool support must also deal with the changing diameter of the take-up spool which carries the web from which labels have been removed. This is because the diameter of the take-up spool increases from an initial value where the take-up spool is empty, to a value many times greater than the initial value, when the supply spool is exhausted.

Known tape drives of labelling machines have mechanisms for achieving appropriate drive of the take-up spool including so-called slipping clutch arrangements. The take-up spool support may be either driven by an independent drive means, such as a variable torque motor, or driven via a pulley belt and gears from a motor driving the capstan roller.

Tape drive mechanisms which rely upon capstan rollers add cost and complexity to the labelling machine, and have the disadvantages referred to above.

Another known problem associated with nip/capstan roller arrangements of the type described above is that the pressure exerted by the nip roller onto the web and against the capstan roller can cause label adhesive to “bleed” out, over time, from the edges of the label. This adhesive can eventually build up on the capstan or nip rollers. This adhesive can then cause the label stock to stick to the rollers such that it is not transported properly along the desired web path. Furthermore, it is common for labels to be accidentally removed from the web and become attached to the capstan roller or nip roller, impeding proper operation of the labelling machine.

It is therefore desirable in the manufacturing industry for there to be means and a method for transporting a label stock and applying labels from the web of the label stock to a product or container, which is accurate, reliable, simple to use and adaptable to different applications.

A further problem with known labelling machines is that it is difficult for an operator of the labelling machine to assess the amount of label stock that remains on the supply spool support at any given time and to act appropriately on the basis of diminishing label stock remaining on the supply spool support.

It is an object of embodiments of the present invention to obviate or mitigate one or more of the problems of known labelling machines whether set out above or otherwise, and/or to provide an alternative labelling machine.

According to an aspect of the invention there is provided a labelling machine comprising a supply spool support for supporting a supply spool comprising label stock comprising a web and a plurality of labels attached to the web and which are separable from the web; a take-up spool support adapted to take up a portion of web; a sensor configured to produce a sensor signal indicative of a periodic property of at least a portion of the label stock; and a controller configured to calculate a displacement of the web along a web path defined between the supply spool and the take-up spool based upon the sensor signal and a length of a component of the label stock.

By measuring displacement of the web along the web path as a function of the sensor signal, and hence as a function of a periodic property of a portion of the label stock, the controller can monitor movement and/or position of the web.

The sensor may be configured such that it does not contact the label stock. This may be advantageous in some applications because, in some applications, a component which contacts the label stock may be prone to wear or has the potential to impair movement of the label stock or misalign the label stock.

The sensor may comprise an electromagnetic radiation detector. Any suitable electromagnetic radiation may be used as a basis for sensing including, for example, visible light, infrared radiation and ultraviolet radiation. Any appropriate electromagnetic radiation detector may be used. An example of a suitable electromagnetic radiation detector is a photovoltaic cell.

The sensor may further comprise an electromagnetic radiation source. Any appropriate radiation source may be used. Likewise, any appropriate electromagnetic radiation source may be used. Examples of suitable electromagnetic radiation sources include a light emitting diode and a laser.

The label stock may comprise labels which are spaced from one another along the web.

Within the description, label stock may be used to refer to the web with attached labels. Label stock may also be used to refer to a portion of web from which labels have been separated.

The property of at least a portion of the label stock may be the electromagnetic transmittance or reflectance of at least a portion of the label stock.

The periodic property may arise from the spatial arrangement of labels on the web. For example the periodic property may arise from the label length and/or spacing between adjacent labels. This may be because the labels, the web and/or web with attached label may have different properties which give rise to the periodic nature of a property of the label web.

The sensor may be arranged to sense differences between a property of the web and a label attached thereto and a property of the web. For example, the electromagnetic transmittance of the label web with a label attached thereto may be lower than the electromagnetic transmittance of the web without a label attached thereto.

The portion of the label stock may comprise the web and attached labels.

The length of a component of the label stock may be selected from the group consisting of a length of a label, a pitch length between adjacent labels and a gap length between adjacent labels.

Where the periodic property arises from the spatial arrangement of the labels on web, the described method allows displacement of the web to be determined based upon a number of labels (which need not be an integer number) which pass the sensor and a distance related to label length (or label lengths in the case of label stocks having labels with differing lengths) in the direction of label web movement and/or label spacing

The labelling machine may further comprise a rotation monitor configured to monitor the rotation of one of said spool supports, the rotation monitor being configured to output a rotation signal indicative of the rotation of said one of said spool supports. Any appropriate rotation monitor may be used and any appropriate method may be used to produce a rotation signal indicative of the rotation of the spool support. Various rotation monitors are described throughout the specification, any of which may be used. For example, rotation monitors using optical or magnetic sensors can be employed.

The controller may be configured to calculate a diameter of a spool supported by one of said spool supports based upon the calculated displacement of the web and the rotation signal. That is, if it is known that a particular (linear) displacement of the web corresponds to a particular number (which need not be an integer number) of rotations of one of the spools, it is a straightforward matter to determine spool diameter (or radius) using the known relationship between spool diameter and spool circumference.

The displacement of the web calculated by the controller may be used to cause movement of web along the web path such that a target portion of the label stock is moved to a desired position along the web path.

The target portion of the label stock may a leading edge of a label and the desired position is adjacent an edge of a labelling peel beak. Any appropriate portion of the label stock may be the target portion. For example, the target portion may be a trailing edge of a label, or a portion of a label which is spaced from the leading or trailing edge of a label by a predetermined distance. The target portion may be a portion of the web. For example the target portion may be a portion of the web between adjacent labels. The desired position may be spaced a predetermined distance from an edge of a labelling beak. The desired position may be any appropriate position along the web path. For example, the desired position may be adjacent a printer or may be adjacent a component of the labelling machine.

The labelling machine may further comprise motive means for advancing the label stock along the web path from the supply spool support to the take up spool support.

The motive means may comprise a motor configured to rotate the take up spool support. The motor may be configured to rotate the take up spool support in the direction of transport of the label web.

The motor may be selected from the group consisting of a DC motor, an open loop position controlled motor (e.g. a stepper motor) and a closed loop position controlled motor (e.g. a torque controller motor, such as a DC motor, together with an appropriate positional sensor and feedback control circuit). However any suitable motor may be used. Those skilled in the art will be aware of control schemes which are suitable to control rotation of the motors to achieve the methods described herein, depending upon the type of motor selected for use. Those skilled in the art will further be aware of the relative merits of various motor types and will be able to select a suitable motor type on that basis.

The motive means may include a motor configured to rotate the supply spool support and/or a capstan roller which engages the label web. The motor may be configured to rotate the supply spool support and/or capstan roller in the direction of transport of the label web.

The controller may be configured to control the motive means to advance the label stock such that the target portion of the label stock is moved to the desired position (e.g. such that a particular part of the label stock – such as a label edge – is positioned in a predetermined spatial relationship with a label peel beak).

The sensor may be further configured to measure the length of the component of the label stock.

The controller may be configured to determine the length of the component of the label stock based upon monitored rotation one of said spool supports during sensing of a number of periods of said sensor signal. The number of periods may be an integer number. For example, the controller may count the number of steps that the take up motor is commanded to advance for a single period of the sensor signal. Based on the number of steps the take up motor is commanded to advance for a single period of the sensor signal and the diameter of the take up spool, the controller may determine a pitch length of the label stock. It will be appreciated that other similar parameters of the label stock may be similarly determined.

The controller may be configured to determine the length of the component of the label stock based upon a diameter of a spool supported by the spool support the rotation of which is monitored. Various methods of determining the diameter of a spool support are described within this specification. Any of these methods may be used to determine the diameter of the spool support.

The labelling machine may further comprise a further sensor configured to measure the length of the component of the label stock.

The labelling machine may further comprise a label applicator located in a location along said web path between said take up and supply spool supports and arranged to separate labels from the web for application to a receiving surface. The label applicator may include a labelling peel beak.

The labelling machine may be arranged to apply pre-printed labels to packages in a product packaging facility.

The labelling machine may further comprise a printer arranged to print onto labels prior to application of labels onto the receiving surface. The labels printed upon may be pre-printed. The labelling machine may be a print and apply labelling machine.

According to another aspect of the invention there is provided a method of controlling a labelling machine, the labelling machine comprising a supply spool support for supporting a supply spool comprising label stock comprising a web and a plurality of labels attached to the web and which are separable from the web; a take-up spool support adapted to take up a portion of web; a sensor; and a controller; wherein the method comprises the sensor producing a sensor signal indicative of a periodic property of at least a portion of the label stock; providing the sensor signal to the controller; and the controller calculating a displacement of the web along a web path defined between the supply spool and the take-up spool based upon the sensor signal and a length of a component of the label stock.

According to a further aspect of the invention there is provided a labelling machine configured to carry out labelling operations, the labelling machine comprising a supply spool support for supporting a replaceable supply spool; a take-up spool support adapted to take up a portion of web, a web path being defined between the supply spool and the take-up spool; and a controller configured to calculate a time indicative of when the supply spool requires replacement in order for the labelling machine to carry out further labelling operations.

The time may be a time of day and/or date.

In this way an operator of the labelling machine may be provided with an easy to understand indication of when supply spool replacement is required. This allows operators of the labelling machines to plan work accordingly. For example it allows operators to ensure that they are ready to replace a supply spool at the relevant time thereby minimising labelling machine downtime.

The controller may be configured to calculate the time indicative of when the supply spool requires replacement based on a diameter of the supply spool.

Although the above-described aspects of the invention relate to a labelling machine and a method of controlling a labelling machine, it will be appreciated that the invention may also be applied to a tape drive and method of controlling a tape drive. The tape drive may form part of a labelling machine or a printer (such as a thermal transfer printer). Whereas the tape in the labelling machine is label stock, the tape in a printer may be a print ribbon.

Where features have been described above in the context of one aspect of the invention, it will be appreciated that where appropriate such features may be applied to other aspects of the invention. Indeed, any of the features described above and elsewhere herein can be combined in any operative combination and such combination is expressly foreseen in the present disclosure.

To the extent appropriate, control methods described herein may be implemented by way of suitable computer programs and as such computer programs comprising processor readable instructions arranged to cause a processor to execute such control methods are provided. Such computer programs may be carried on any appropriate carrier medium (which may be a tangible or non-tangible carrier medium).

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

Figure 1 shows a schematic side elevation of a portion of a labelling machine in accordance with an embodiment of the invention;

Figure 2 shows a schematic side elevation of a portion of a labelling machine in accordance with a second embodiment of the invention;

Figure 3 shows a schematic cross section through a portion of a labelling peel beak which forms part of a labelling machine in accordance with an embodiment of the invention;

Figure 4 shows a schematic plan view of a portion of label stock which is utilised in conjunction with a labelling machine in accordance with an embodiment of the invention;

Figure 4a shows a schematic graph of a sensor signal produced by a sensor which forms part of a labelling machine in accordance with an embodiment of the present invention, the sensor signal being produced when the portion of label stock shown in Figure 4 is utilised in conjunction with the labelling machine;

Figure 5 shows a schematic perspective view of a portion of the labelling machine shown in Figure 2;

Figure 6 shows a further schematic perspective view of a portion of the labelling machine shown in Figure 2;

Figure 7 shows a schematic side elevation of a portion of the labelling machine shown in Figure 2;

Figure 8 shows a further schematic perspective view of the portion of the labelling machine shown in Figure 6, with a first mounting plate removed;

Figure 9 shows a further schematic perspective view of a portion of the labelling machine shown in Figure 2, with first and second mounting plates removed;

Figure 10 shows a schematic end-on view of a portion of the labelling machine shown in Figure 2, with the first mounting plate removed;

Figure 11 shows a further schematic end-on view of a portion of the labelling machine shown in Figure 2, with the second mounting plate removed;

Figure 12 shows a schematic cross-sectional view of a portion of the labelling machine shown in Figure 2;

Figure 13 shows a further schematic perspective cross-sectional view of a portion of the labelling machine shown in Figure 2;

Figure 14 shows a schematic diagram illustrating a solenoid armature position control algorithm which is implemented by a controller which forms part of a labelling machine in accordance with an embodiment of the invention;

Figure 15 shows a schematic view of a multipole strip magnet which forms part of a moving element position sensor which forms part of a labelling machine in accordance with an embodiment of the invention;

Figure 16 shows a schematic view of a portion of the labelling machine shown in either of Figures 1 or 2;

Figure 17 shows a schematic diagram illustrating a moving element position control algorithm which is implemented by a controller which forms part of a labelling machine in accordance with an embodiment of the invention;

Figure 18 shows a perspective view of a portion of an alternative braking assembly which in some embodiments of the present invention may take the place of the braking assembly shown in Figures 5 to 11;

Figure 19 shows a further view of the alternative braking assembly shown in Figure 18;

Figure 20 shows a view of a portion of a labelling machine according to an embodiment of the present invention including the alternative braking assembly shown in Figures 18 and 19 and further including a brake release mechanism;

Figure 21 is a flow chart showing operation of a labelling machine in accordance with an embodiment of the invention, including various features described herein;

Figure 22 is a speed/distance graph for a typical label feed operation; and

Figure 23 is a flow chart of processing carried out during the label feed operation of Figure 22.

Figures 1 and 2 show schematic side views of portions of two different types of labelling machine in accordance with separate embodiments of the present invention. Figure 1 shows a labelling machine with no integrated printer and Figure 2 shows a labelling machine with an integrated printer.

The labelling machines shown in Figures 1 and 2 both include a supply spool support 10 and a take up spool support 12. The supply spool support 10 and take up spool support 12 are both mounted for rotation about respective axes A and B. In the labelling machines shown in Figures 1 and 2 the axes A and B are substantially parallel to one another; however, in some embodiments this may not be the case. The take up spool is connected to a motor 14 such that the motor 14 can be powered in order to rotate the take up spool 12 about the axis B. In the labelling machines shown in Figures 1 and 2, the motor 14 is connected to the take up spool support 12 via a belt (not shown).

However, it will be appreciated that in other embodiments any appropriate linkage may be used to connect the motor 14 to the take up spool support 12. For example, while in the described embodiment the belt will provide a fixed transmission ratio between rotation of the motor shaft and rotation of the take up spool support, in other embodiments a linkage providing a variable transmission ratio (such as a gearbox) may be provided. Indeed, in still alternative embodiments the take up spool support 12 may be directly driven by the motor 14. By directly driven it is meant that the spool support may be mounted co-axially with the shaft of the motor 14, that is the shaft of the motor 14 may extend along the axis B. In the case where the take up spool support 12 is directly driven by the motor 14, the take up spool support may be mounted to a motor spindle of the motor 14. This arrangement is quite different from other arrangements which may use capstan rollers to contact the outside circumference of a spool or a spool support in order to rotate the spool and/or spool support.

In the labelling machine shown in Figures 1 and 2 the motor 14 is a stepper motor. An example of a suitable stepper motor is a 34H318E50B stepper motor produced by Portescap, USA. An example of a suitable belt which connects the motor 14 to the take up spool support 12 is a synchroflex timing belt. In this embodiment the gearing ratio for the belt drive is 4:1 whereby the motor revolves four times for every revolution of the take up spool support. It will be appreciated that in other embodiments any appropriate gearing ratio for the belt drive may be used.

In this case the stepper motor is capable of being controlled such that it can execute 1600 substantially equal angular movements per complete rotation of the stepper motor. These substantially equal angular movements may be referred to as micro-steps. Each micro-step is equivalent to a rotation of about 0.225º or about 0.00392 radians. In this case, the stepper motor has 200 steps per revolution, but the stepper motor is controlled to produce 8 micro-steps per step, such that the number of micro-steps per revolution is 1600. Because the belt drive gearing ratio is 4 to 1, the number of micro steps of the motor per revolution of the take up spool support is 6400. Stepper motors are generally driven by a stepper motor driver. In the case of the motor and control arrangement described above, if the stepper motor driver is commanded to advance one step, the stepper motor driver will provide a signal to the stepper motor which causes the stepper motor to rotate by one micro-step (i.e. about 0.225°). It will be appreciated that in other embodiments, the stepper motor may undertake any appropriate number of steps per complete rotation of the stepper motor, and the stepper motor may be controlled to produce any appropriate number of micro-steps per step of the stepper motor. Furthermore, the belt drive gearing ratio may be chosen such that the number of micro steps of the motor per revolution of the take up spool support is any appropriate desired number.

While the term ‘step’ is sometimes used to denote a physical property of a stepper motor, in the present description, the term ‘step’ is used to denote any desired angular movement of the stepper motor, for example a micro-step.

Stepper motors are an example of a class of motors referred to position-controlled motors. A position-controlled motor is a motor controlled by a demanded output rotary position. That is, the output position may be varied on demand, or the output rotational velocity may be varied by control of the speed at which the demanded output rotary position changes. A stepper motor is an open loop position-controlled motor. That is, a stepper motor is supplied with an input signal relating to a demanded rotation position or rotational velocity and the stepper motor is driven to achieve the demanded position or velocity.

Some position-controlled motors are provided with an encoder providing a feedback signal indicative of the actual position or velocity of the motor. The feedback signal may be used to generate an error signal by comparison with the demanded output rotary position (or velocity), the error signal being used to drive the motor to minimise the error. A stepper motor provided with an encoder in this manner may form part of a closed loop position-controlled motor.

An alternative form of closed loop position-controlled motor comprises a DC motor provided with an encoder. The output from the encoder provides a feedback signal from which an error signal can be generated when the feedback signal is compared to a demanded output rotary position (or velocity), the error signal being used to drive the motor to minimise the error. A DC motor which is not provided with an encoder is not a position-controlled motor.

It will be appreciated that in embodiments of the labelling machine other than those shown in Figures 1 and 2, the motor may take any convenient form. For example, the motor may be any appropriate open or closed loop position-controlled motor.

When the labelling machines shown in Figures 1 and 2 are in use, a supply spool of label stock may be mounted to the supply spool support such that the supply spool support 10 supports the supply spool. The label machine shown in Figure 1 does not have a supply spool mounted to the supply spool support 10. However, the labelling machine shown in Figure 2 does have a supply spool 16 mounted to the supply spool support 10. The supply spool 16 is mounted to the supply spool support 10 such that the supply spool 16 co-rotates with the supply spool support 10.

As can be seen best in Figure 2, in use, label stock 18 extends between the supply spool support 10 (and in particular the supply spool 16 mounted to the supply spool support 10) and the take up spool support 12. A web path 20 is defined between the supply spool support 10 and take up spool support 12 by various components and, in use, the label stock is transported along the web path 20. In the labelling machines shown in Figures 1 and 2, first, second and third rollers (22, 24 and 26) define the web path 20 between the supply spool support 10 and take up spool support 12. It will be appreciated that in other embodiments of the labelling machine, components other than rollers may be used to define the web path 20. Suitable components may be those which impart only a small friction force to label stock when label stock contacts it.

The web path 20 is also defined by a dancing arm 28 and a labelling peel beak 30. The dancing arm 28 includes a dancing arm roller 32 mounted at one end of the dancing arm 28.

In use, the label stock 18 extends along the web path 20 from the supply spool support 10 (and in particular from the supply spool 16) around the first roller 22, around the dancing arm roller 32, around the second roller 24, around the labelling peel beak 30, around the third roller 26 and is wound onto the take up spool support 12 to form a take up spool 34.

It will be appreciated that in other embodiments of a labelling machine according to the invention any appropriate number of rollers (or any other appropriate components) may be used to define a desired shape/length of web path 20.

The dancing arm 28 is a movable element which is rotatable about axis A. That is to say, in the labelling machines shown in Figures 1 and 2, the axis of rotation of the dancing arm 38 is coaxial with the axis of rotation of the supply spool support 10 (and the supply spool 16). In other embodiments this need not be the case. For example, the dancing arm 28 may rotate about an axis which is spaced from the axis A of rotation of the supply spool support 10 (and supply spool 16 if attached).

It will also be appreciated that in the labelling machine shown in Figures 1 and 2, the dancing arm 28 is a movable element which defines the web path 20 and movement of the dancing arm 28 changes the length of the web path between the supply spool support 10 and take up spool support 12. It will be appreciated that in other labelling machines any other appropriate movable element may be used, providing that movement of the movable element changes the length of the web path between the supply spool support and take up spool support.

The labelling machine shown in Figure 2 includes a printer 36 (however, as previously discussed, other embodiments of labelling machine according to the present invention need not include a printer). The printer in this case is a thermal transfer printer. However, it will be appreciated that other embodiments of labelling machine according to the present invention may include any appropriate type of printer, for example, an inkjet printer, a thermal printer or a laser marking system. The printer 36 includes a ribbon supply spool support 38, a ribbon take up spool support 40, a print head 42 and a ribbon guide member 44. In use, a spool of printer ribbon is mounted to the ribbon supply spool support 38, such that said spool of printer ribbon constitutes a supply spool 46 of printer ribbon which is supported by the ribbon supply spool support 38.

In use, print ribbon from the supply spool 46 passes along a print ribbon path past the print head 42 and is wound on to the ribbon take up spool support 40 so as to form a take up spool 48. In order for print ribbon to be transported from the ribbon supply spool support 38 to the ribbon take up spool support 40, at least the ribbon take up spool support 40 is connected to a motor such that the motor can rotate the ribbon take up spool support 40.

Because the printer 36 shown in Figure 2 is a thermal transfer printer, the print ribbon is thermally sensitive such that, as the print ribbon passes the print head 42, at least a portion of the print head 42 can be selectively energised to heat a desired portion of the print ribbon and transfer ink from that portion of the print ribbon to an adjacent substrate. In this case the adjacent substrate is a label that forms part of the label stock 18. During operation of the printer 36, the guide block 44 comprises guide rollers which help to guide the print ribbon as it is transported from the ribbon supply spool support 38 to the ribbon take up spool support 40.

The label stock which is used by either of the labelling machines shown in Figures 1 and 2 comprises a web and a plurality of labels attached to the web. The labels attached to the web are separable from the web. The labelling peel beak 30 is configured such that, during operation of either of the labelling machines shown in Figures 1 and 2, as the label stock 18 is transported along the web path 20 past the labelling peel beak 30, the labelling peel beak 30 separates a passing label from the web.

The separated label may then be attached to a desired article. An example of such a desired article is an item passing on a conveyor (not shown) of a production line. However, it will be appreciated that the desired article may be any appropriate article. In the case of the labelling machine shown in Figure 2, it will be appreciated that, prior to the label being attached to a desired article, the printer 36 may print a desired image on the label. In some embodiments the printing may occur prior to the labelling peel beak 30 separating the label from the web of the label stock, and in other embodiments the printing of the image may occur after the labelling peel beak 30 separates the label from the web of the label stock.

During operation of the labelling machines shown in Figures 1 and 2 the motor 14 is energised to rotate the take up spool support 12 about its axis B. As this is done, the take up spool support 12 winds label stock 18 onto the take up spool support 12 to form a take up spool 34. The take up spool 34 will include the web of the label stock. Any labels separated from the web of the label stock as they pass the labelling peel beak 30 will not form part of the take up spool 34. In some embodiments the labelling peel beak 30 may be configured to selectively separate labels from the web. In this case, any labels which are not separated from the web of the label stock by the labelling peel beak 30 will be wound onto the take up spool support 12 and therefore form part of the take up spool 34.

The winding of the label stock 18 (and in particular the web of the label stock) onto the take up spool support 12 will cause the label stock 18 to move along the web path 20 in the direction indicated by arrows C (Figure 2). The winding of the web of the label stock onto the take up spool support 12 causes label stock to be paid out from the supply spool 16 which is supported by the supply spool support 10.

This arrangement, whereby the take up spool support 12 is driven so as to transport the label stock in the direction C of label stock transport, and where the supply spool support 10 is not driven may be referred to as a pull-drag system. This is because, in use, as discussed below, the supply spool support 10 provides some resistance (or drag) to the movement of label web so as to provide tension in the label web. In this case friction within the system provides the drag. For example, the friction may include the friction between the supply spool support and the means which supports the supply spool support for rotation. Drag may also be provided by the inertia of the supply spool. In other embodiments the drag in a pull-drag system may be actively controlled. For example, in one embodiment a DC motor may be attached to the to the supply spool support and may be energised in a direction which is opposite to the direction in which the supply spool support rotates due to label stock being wound off the supply spool support and on to the take up spool support. In this case, the amount of drag that the DC motor provides to the system can be controlled by controlling the current supplied to the motor and therefore the torque applied by the motor.

In other embodiments of the labelling machine, the supply spool support 10 may be driven so that, in use, it rotates the supported supply spool 16. In some embodiments the supply spool support 10 may be driven for rotation in a direction which opposes movement of the label stock in the direction C of label stock transport (which is effected by the rotation of the take up spool support 12). This kind of arrangement is also referred to as a pull-drag system.

In other embodiments the supply spool support 10 may be driven such that it is rotated by a motor in a direction which is complementary to movement of the label stock in the direction C of label stock transport (which is effected by rotation of the take up spool support 12). This type of arrangement may be referred to as a push-pull system. It will be appreciated that in embodiments of the labelling machine which include a driven supply spool support 10, the supply spool support 10 may be driven by any appropriate motor. Examples of such motors include a DC motor or a position-controlled motor such as, for example, a stepper motor.

Figure 3 shows a schematic cross-section through a labelling peel beak 30 which forms part of a labelling machine in accordance with an embodiment of the present invention. The labelling peel beak 30 includes a sensor comprising an electromagnetic radiation source 50 and an electromagnetic radiation detector 52. The electromagnetic radiation source 50 is powered by a power source via a power line 54. The sensor, and in particular the electromagnetic radiation detector 52, is configured to produce a sensor signal 56. The sensor may commonly be referred to as a gap sensor and is generally arranged to produce a sensor signal which differentiates between portions of the web which carry labels and portions of the web that do not. Although in this embodiment the labelling peel beak 30 includes the gap sensor, in other embodiments, the gap sensor may be located remote to the labelling peel beak at any appropriate position along the web path. In some embodiments it may be advantageous for the gap sensor to be located close to the labelling peel beak. Locating the gap sensor close to the labelling peel beak may reduce potential error in positioning a portion of the label stock at the labelling peel beak based upon a signal produced by the gap sensor.

In use, the electromagnetic radiation source 50 produces a beam 58 of electromagnetic radiation. Label stock 18 comprising a web 60 and a plurality of labels 62 attached to the web (and which are separable from the web) passes between the electromagnetic radiation source 50 and electromagnetic radiation detector 52 as the label stock 18 is transported in a direction C along a web path past the labelling peel beak 30. The beam 58 of electromagnetic radiation which is produced by the electromagnetic radiation source 50 passes through the label stock 18 and is incident on the electromagnetic radiation detector 52. The sensor signal 56 output by the electromagnetic radiation detector 52 is a function of an amount of electromagnetic radiation which is incident on the electromagnetic radiation detector 52. That is to say, the sensor signal 56 output by the electromagnetic radiation detector 52 is a function of the amount of electromagnetic radiation which is produced by the electromagnetic radiation source 50 and which passes through the label stock 18.

Figure 4 shows a schematic plan view of a portion of label stock 18. The portion of label stock 18 shown in Figure 4 has labels which are all substantially the same size and shape. Other label stock which may be used by the labelling machine may have labels which are of a different size and/or which may have different spacing therebetween. For example, some label stock which may be used by the labelling machine includes two types of label, each type having a different size and/or shape. The label stock may be such that along the length of the label stock the labels alternate between labels of a first type and labels of a second type. It can be seen from Figure 3 that, when a portion of label stock 18 as shown in Figure 4 passes between the electromagnetic radiation source 50 and electromagnetic radiation detector 52, the beam 58 of electromagnetic radiation will propagate in a direction which is substantially out the page in Figure 4. The direction of propagation of the beam 58 of electromagnetic radiation may be substantially perpendicular to the plane of the substantially planar label stock 18.

The electromagnetic transmittance (i.e., what proportion of electromagnetic radiation incident on a material is transmitted through the material) of the web 60 of the label stock will commonly be different to the electromagnetic transmittance of the labels 52 of the label stock 18. Also the electromagnetic transmittance of two different thicknesses of a material will also be different (i.e., the electromagnetic transmittance through a relatively thick material will be less than the electromagnetic transmittance through a relatively thin material). Either of these two factors, or a combination of the two, will result in the electromagnetic transmittance of a portion of the label stock 18 which includes only the web 60 (for example at a position indicated by D, sometimes referred to in the art as a ‘gap’) will be different to (in this case greater than) the electromagnetic transmittance of a portion of the label stock 18 which includes both the web 60 and a label 62 (for example at a position indicated by E).

When the beam 58 of electromagnetic radiation produced by the electromagnetic radiation source 50 passes through a portion of the label stock with a relatively high electromagnetic transmittance (such as through the label stock 18 at position D within Figure 4), then the amount of electromagnetic radiation which is incident on the electromagnetic radiation detector 52 will be greater than when compared to the amount of electromagnetic radiation incident on the electromagnetic radiation detector 52 when the beam 58 of electromagnetic radiation produced by the electromagnetic radiation source 50 passes through a portion of the label stock 18 which includes both the web 60 and a label 62 (for example at a position indicated by E in Figure 4).

Consequently, the sensor signal 56 output by the electromagnetic radiation detector 52 will be different depending on whether the beam 58 of radiation produced by the electromagnetic radiation source 50 passes through a portion of the label stock 18 which has a relatively high transmittance (for example at the position D) or whether the beam 58 of electromagnetic radiation produced by the electromagnetic radiation source 50 passes through a portion of the label stock 18 which has a relatively low electromagnetic transmittance (for example at position E). For example, the sensor signal 56 produced by the electromagnetic radiation detector 52 of the sensor may be a voltage and the voltage may be greater when the beam of electromagnetic radiation 58 passes through a portion of the label stock 18 has relatively high electromagnetic transmittance compared to the voltage when the beam 58 of electromagnetic radiation passes through a portion of the label stock 18 with relatively low electromagnetic transmittance.

Because the label stock 18 will, in use, be transported along the web path in a transportation direction C, it will be appreciated that the beam 58 of radiation will alternate between passing through a portion of the label stock 18 which includes only the web 60 (e.g. as indicated at position D in Figure 4), and a portion of the label stock 18 which includes the web 60 and a label 62 (e.g. as indicated at position E in

Figure 4). For ease of reference, a portion of label web 60 which has no label attached to it and which is between two adjacent labels 62, may be referred to as a gap. Two such gaps are indicated by shading 64 in Figure 4.

The label stock 18 includes a plurality of labels 62 which have a label width W_L which is substantially perpendicular to the transportation direction C, and a label length L_L which is substantially parallel to the transportation direction C. The labels 62 are substantially similar as is the gap 64 between adjacent labels. The length of a gap is denoted $L_{G.}$ The pitch length L_P between adjacent labels is the sum of the label length L_L and the gap length L_G of the adjacent gap 64.

As the label stock 18 moves in the transportation direction C the electromagnetic radiation detector 52 of the sensor will produce a sensor signal 56 which is indicative of a periodic property of at least a portion of the label stock 18. In other words the sensor will produce a sensor signal 56 which is periodic given the nature of the label stock 18. In this case the electromagnetic transmittance of the label stock 18 can be said to be a periodic property of the label stock which varies along the length (in a direction generally parallel to the transportation direction C) of the label stock 18. That is to say, the sensor signal 56 will vary periodically as the beam 58 of electromagnetic radiation periodically passes through a gap 64, and then a label 62 affixed to the label web 60 in an alternating manner. The period of the periodic sensor signal 56 produced by the electromagnetic radiation detector 52 will be equal to the time taken for the label stock 18 to be transported in the transportation direction C by a distance equal to the pitch length L_P (i.e., the sum of the label length L_L and the gap length $L_{G.}$).

In general terms, where a leading label edge passes the electromagnetic radiation detector 52 the sensor signal 56 changes from having a relatively high value to a relatively low value. Similarly, where a trailing label edge passes the electromagnetic radiation detector 52 the sensor signal 56 changes from having a relatively low value to a relatively high value. The change in sensor signal 56 as the portion of label web shown in Figure 4 passes the electromagnetic radiation detector is shown in Figure 4a where the period of the signal p is marked. A transition from a gap to a leading edge of a label is represented by a signal transition from a relatively high value to a relatively low value. A transition from a trailing edge of a label to a gap is represented by a signal transition from a relatively low value to a relatively high value.

For some types of label stock the length of each label L_L and the length of each gap L_G will be substantially constant. Consequently, the pitch length L_P for a given label stock 18 will also be substantially constant. The pitch length L_P, label length L_L and/or gap length L_G for a particular label length may be provided by the supplier of the label stock 18. Alternatively, the pitch length L_P, label length L_L and/or gap length L_G may be measured using any appropriate known way of measuring length. Information relating to the pitch length L_P of a particular label stock 18 may be provided to a controller of the labelling machine. Alternatively, information relating to the label length and the gap length of a particular label stock may be provided to the controller of the labelling machine such that the controller may use this information in order to calculate the pitch length of the label stock 18. In a further embodiment, the labelling machine may include a device which measures the pitch length L_P (or the label length L_L and gap length L_G in order to calculate the pitch length L_P). It will be appreciated that any known measuring device may be used to measure such lengths.

In one embodiment the lengths L_P, L_L and L_G are measured as follows. The motive means which advances the label stock along the web path can be controlled by the controller such the controller can calculate the linear displacement of the label stock in any given time. Referring to Figure 4a, it can be seen that the sensor signal 56 varies with position of the label stock depending on whether there is a label or a gap adjacent to the sensor. Consequently, in order to determine the length L_L the controller can calculate the linear displacement of the label stock during the portion of the periodic signal 57 (which in this case has a relatively low value) measured by the sensor which is indicative of the presence of a label. Likewise, in order to determine the length L_G the controller can calculate the linear displacement of the label stock during the portion of the periodic signal 59 (which in this case has a relatively high value) measured by the sensor which is indicative of the presence of a gap. In order to determine L_P the controller can either add the linear displacements measured for L_L and L_G, or the controller can calculate the linear displacement of the label stock during a portion of the periodic signal p.

The controller can calculate the linear displacement of the label web in various ways. One example is that the controller may calculate the diameter of the spool supported by the take up spool support. An example of how the controller may calculate the diameter of the spool supported by the take up spool support is described at a later point within the description. The controller can then control a stepper motor which drives the take up spool support so that it monitors the number of steps the stepper motor is commanded to take in a given time. By multiplying the number of steps the stepper motor is commanded to take in a given time by the known angular movement of the stepper motor per step, the controller can calculate the angular movement of the stepper motor and hence the take up spool support in said given time. By multiplying the radius (half the diameter) of the spool supported by the take up spool support and the angular movement of the take up spool support in said given time, the controller can calculate the linear displacement of the label stock due to label stock being wound on to the take up spool support during said given time. Such displacement information can be used to determine L_L, L_G and/or L_P.

The controller of the labelling machine is configured to calculate a displacement of the web along the web path based upon the sensor signal 56 and a length of a component of the label stock 18. In this case, the sensor signal is provided by the electromagnetic detector and the length of a component of the label stock is the pitch length L_P (i.e., the sum of the label length L_L and the gap length L_G). In use the controller monitors the sensor signal 56 and counts the number of periods of the periodic sensor signal which are provided to it. As previously discussed, this corresponds to the number of times the beam 58 of electromagnetic radiation passes through a label 62 and an adjacent gap 64. Consequently, the controller calculates the displacement of the web along the web path by multiplying the number of periods of the sensor signal provided to it by the pitch length L_P of the label stock 18.

In some embodiments, the controller may also be configured to monitor the period of the periodic sensor signal 56. The controller may then calculate a speed of the web along the web path by dividing the pitch length L_P (i.e., the sum of the label length L_L and the gap length L_G) by the period of the sensor signal 56.

In some embodiments the controller may use a monitored period of the periodic sensor signal 56 in combination with a count of the number of periods of the sensor signal (which need not be an integer number) which have been supplied to the controller in order to determine the displacement of the web at times other than when an edge of a label 62 passes through the beam 58 of electromagnetic radiation. For example, if it is known that the time period since a label leading edge passed through the beam of electromagnetic radiation is half the monitored period, it can be deduced that the displacement is equal to half the pitch length L_P.

The displacement of the web along the web path calculated by the controller based on the sensor signal 56 may be used in several different contexts. For example, the displacement calculated by the controller may be used to provide information as to the total amount of label stock which has passed the sensor.

In another example, a desired displacement of the web may be effected to control the position of a given portion of label stock relative to a known position. For example, referring to Figure 3, the edge 66 of the labelling peel beak 30 (at which the labels are separated from the web) and the point at which the beam 58 of electromagnetic radiation passes through the label stock are separated by a distance along the web path marked by D_B. The controller may be configured such that when an edge of a label 62 passes through the beam 58 of electromagnetic radiation, the controller then energises the take up motor such that the take up motor takes up a length of web which is equal to the distance D_B to thereby position the edge which passed through the beam 58 of electromagnetic radiation at the edge 66 of the labelling peel beak 30.

It will be appreciated that the displacement of the web along the web path calculated by the controller based on the sensor signal 56 and the pitch length L_P (i.e., the sum of the label length L_L and the gap length L_G) may be used to both determine (i.e. in this particular context measure) and control the displacement of a portion of the label stock along the web path from any desired position and/or by any desired length.

It will be appreciated that in the described embodiment the sensor configured to produce a sensor signal 56 indicative of a periodic property of a portion of the label stock 18 is an electromagnetic radiation detector which produces a sensor signal indicative of the electromagnetic transmittance of the label stock. In other embodiments any appropriate sensor may be used in order to detect any appropriate periodic property of a portion of the label stock.

In the embodiment described, the electromagnetic radiation source may include a light emitting diode which emits electromagnetic radiation in the visible spectrum. The electromagnetic radiation detector is chosen such that it can detect electromagnetic radiation which is produced by the electromagnetic radiation source (in this case in the visible spectrum). It will also be appreciated that in other embodiments, any appropriate electromagnetic radiation source may be used, providing the electromagnetic radiation detector is sensitive to the electromagnetic radiation produced by the electromagnetic radiation source.

In other embodiments, the sensor may be configured to produce a sensor signal which is a function of a periodic property of a portion of the label stock other than its electromagnetic transmittance. Examples of such properties include, but are not limited to, the electromagnetic reflectivity of a portion of the label stock, the acoustic transmittance or reflectivity of a portion of the label stock, the electrical conductivity of a portion of the label stock, the thickness of at least a portion of the label stock, the capacitance of a region which includes a portion of the label stock and the colour of at least a portion of the label stock. It will be appreciated that, depending on the periodic property of the portion of the label stock which is to be measured by the sensor, any appropriate sensor must be used. Any known appropriate sensor may be used in this regard. For example, if it is desired to measure the acoustic transmittance of a portion of the label stock, the sensor may comprise an acoustic generator configured to direct acoustic energy through a portion of the label stock, and an acoustic detector upon which acoustic energy which passes through said portion of the label stock is incident. If it is desired to measure the capacitance of a region which includes a portion of the label stock, a capacitive sensor may be used. If it is desired to measure a thickness of a portion of the label stock, an example of a sensor which may be used in some applications is a microswitch. The microswitch may include a lever portion which contacts the label stock. The lever acts as a distance magnifier. The lever is configured to contact the label stock as the label stock passes the lever. An end of the lever which contacts the label stock moves a relatively small distance between its position when the end of the lever is contacting a label of the label stock and its position when the end of the lever contacts the web of the label stock between labels. The relatively small distance between these positions is magnified by the lever such that the other end of the lever to that which contacts the label stock moves a relatively large distance which is significant enough to cause a change in state between on and off states of the microswitch.

In the described embodiment, the portion of the label stock of which a periodic property is measured by the sensor comprises the web and the attached labels. In other embodiments, this need not be the case. For example, some embodiments may only measure a periodic property of the labels attached to the web. This may occur when the label stock includes labels which are attached to a web and which are adjacent to one another such that there is no gap between adjacent labels. In this case, the sensor may detect a periodic property of the labels attached to the web which varies periodically due to the fact that said property is different at the border between two adjacent labels compared to at another location on said label.

In another embodiment, the sensor may only measure a periodic property of the web. For example, a sensor may be configured to measure a property of the web after the labels have been detached from the web. For example, some label stock may have a web which, even once the labels have been removed, possesses some periodic feature. For example, if the labels are die-cut when the label stock is produced, then the web may include indentations resulting from said die-cutting which are present on the web even once labels have been removed. These indentations may have a property which is different to portions of the web which have not been indented. For example, the thickness of the web at the location of an indentation may be less than the thickness of the web at a position which has not been indented. Consequently, a sensor which is capable of measuring this difference in thickness of the web between indented portions and non-indented portions would be capable of producing a sensor signal indicative of a periodic property of a portion of the label stock such that the controller can calculate the displacement of the web and perform the functions set out above.

The displacement of the web along the web path calculated by the controller (based upon the sensor signal and the length of a portion of the label stock) may also be used to calculate the diameter of at least one of the take up spool or supply spool mounted on the take up spool support or supply spool support respectively. This may be done as follows.

The labelling machine may further include a rotation monitor configured to monitor the rotation of one of the spool supports (and thereby monitor the rotation of the spool attached to the spool support). An example of a suitable rotation monitor is a tachometer mounted to one of the spool supports. A further example of an appropriate rotation monitor is a trigger device which produces a signal every time the spool (and hence the spool support supporting the spool) rotates through a given portion of a complete rotation.

For example, a trigger device may include a reed sensor and at least one magnet, or a Hall Effect sensor and at least one magnet. In one embodiment, a pair of magnets are attached to a spool support such that they are angularly spaced about the axis of rotation of the spool support by 180 degrees. The Hall Effect sensor is located at a portion of the labelling machine which does not rotate with the spool support and such that for every full rotation of the spool support in a given direction, both of the two magnets pass the Hall Effect sensor in succession. Consequently, the Hall Effect sensor will output two pulses per rotation of the spool support.

As described above, a rotation monitor (e.g., tachometer, Hall Effect sensor or reed switch) is configured to output a rotation signal indicative of a rotation of one of the spool supports. The rotation signal is supplied to the controller and the controller is configured to calculate the diameter of the spool supported by the spool support based upon the calculated displacement of the web along the web path and the rotation signal. In particular, the controller may calculate the displacement of the web along the web path for a given time and for the same given time monitor the rotation signal so as to determine the amount of rotation of the spool support (and hence spool) during said given time. The controller may calculate the diameter of the spool D_S supported by the spool support as follows:

$$D_S = \frac{L_{WP}}{n\pi} \qquad (1)$$

where L_{WP} is the displacement of the web along the web path (determined, for example, by monitoring of the periodic signal 56 output from the electromagnetic radiation senor 52) and n is the number of rotations of the spool support.

In one embodiment including a rotation monitor comprising a reed switch and two magnets as described above, the controller may calculate the diameter of the spool supported by the spool support according to the above formula in the following manner. When a magnet attached to the spool support passes the reed switch the controller is triggered to start counting the number of steps that the motor driving the other spool support is commanded to undertake. The controller also monitors the signal supplied to the controller by the reed switch and counts the number of times a magnet has passed the reed switch after the controller was triggered to start counting the number of steps that the motor driving the other spool support is commanded to undertake.

When the controller counts that the number of times a magnet has passed the reed switch is equal to a predetermined number then the count of the number of steps that the motor driving the other spool support is commanded to undertake is stopped. The predetermined number may be any number corresponding to any desired rotation amount of the spool support. In this example the predetermined number is two, which corresponds to a single rotation of the spool support. The counted number of steps that the motor driving the other spool support is commanded to undertake is used to determine the displacement of the web along the web path by multiplying the counted number of steps by the angular rotation per step, and by the radius of the spool supported by the other spool support. The radius of the spool supported by the other spool support may have previously been determined either by measuring the change in web path length between the spool supports for a given rotation of the other spool support, or by measuring the amount of rotation of the other spool support for a given displacement of the web along the web path (for example, for the displacement of the web along the web path by the pitch length of the label stock). Both of these methods are discussed within this description. Any other appropriate method may be used for determining the radius of the spool supported by the other spool support.

It will be appreciated that this method of calculating spool diameter may be used to determine the diameter of either or both of the spools.

It will also be appreciated that although various sensors have been described as part of a rotation monitor which is configured to monitor rotation of the spool, any appropriate method may be used in order to determine the amount of rotation of the spool. For example, the rotation monitor may, if utilized to measure the amount of rotation of a spool which is driven by a position-controlled motor (such as a stepper motor), include a monitoring device which monitors the control signal provided to the position-controlled motor in order to monitor the amount of rotation the position-controlled motor has been commanded to undertake and use this as a measure of the amount of rotation that the motor and hence spool support has undertaken. For example, in the case of a stepper motor, the rotation monitor may include a counting device which counts the number of steps that the stepper motor has been commanded to advance. Where a rotation of the stepper motor comprises a predefined number of steps (as is usual) it is a straightforward matter to determine a number of rotations (or parts of rotations) which correspond to a particular number of steps through which the motor has moved.

Known labeling machines may provide an operator with information as to the number of labels remaining on the label stock before all of the labels have been used up.

Providing the operator of the labelling machine with an indication as to the number of labels remaining on the label stock before there are no remaining labels on the label stock has been found to be not particularly helpful. This is because the operator of the labelling machine has no useful indication as to when the label stock will require replacement, but only how many labels will be dispensed from the label stock before the label stock requires replacement.

A labelling machine according to the present invention may include a controller which is configured to calculate a time indicative of when the label stock (or more specifically the supply spool of label stock) will require replacement in order for the labelling machine to be able to carry out further labelling operations. That is to say, the controller is configured to calculate a time indicative of when the supply spool is empty (i.e., the labelling machine has used all of the available labels on the label stock).

In order to calculate a time indicative of when the supply spool requires replacement, the controller is provided with a signal which enables it to determine the amount of label stock on the supply spool and also with a signal which enables the controller to determine the rate at which label stock is being paid out from the supply spool.

One example of a signal which may be provided to the controller in order for it to determine how much label stock there is in the supply spool is to provide the controller with a signal indicative of the diameter of the supply spool. Any appropriate method may be used in order to provide the signal indicative of the diameter of the supply spool. For example, the method of determining the diameter of a spool discussed previously within this description may be used. Alternatively, optical measuring apparatus may be used to measure the diameter of the spool. Such an optical measuring apparatus is described in the international patent application published under the Patent Cooperation Treaty (PCT) with the publication number WO 02/22371 A2. Although the measuring apparatus described therein is for measurement of spools of inked ribbon used in a thermal transfer printer, the inventors have realised that such an apparatus can also be used to determine spool diameter in a labelling machine where the spools carry label stock.

Furthermore, a lever which contacts the outside of the spool and which is connected to a position sensor which has an output that is dependent upon the rotational position of the lever may also be used to determine the diameter of the supply spool.

In an alternative embodiment, the signal indicative of the amount of label stock on the supply spool may be a count of the number of labels which have passed a particular point in the web path. If the initial number of labels on the supply spool is known, then by counting the number of labels which have passed a particular point in the web path will enable the remaining number of labels on the supply spool to be calculated.

While various examples of ways of determining a remaining quantity of labels have been set out above, it will be appreciated that any appropriate method may be used for determining the amount of label stock remaining on the supply spool at any given time.

One example of how to determine the rate at which label stock is being paid out from the supply spool is to provide a signal to the controller which is indicative of the linear speed of a portion of the label stock along the web path. In one example the controller may calculate the time at which the supply spool requires replacement by using a signal indicative of the diameter of the supply spool in order to work out the length of label stock remaining on the supply spool and then dividing the length of label stock in the supply spool by the linear speed of the label stock along the web path. Again, it will be appreciated that any appropriate method may be used for determining the rate at which label stock is being paid out from the supply spool. In some embodiments the rate at which label stock is being paid out is determined by monitoring the period of the periodic signal 56 output from the electromagnetic radiation detector 52 as described above.

In any case, the controller will perform a calculation whereby the amount of label stock remaining on the supply spool is divided by the rate at which label stock is paid out by the supply spool in order to determine the time it will take for the supply spool to be used up.

Another example of how determination of a time at which further label stock will be required may be carried out is by using a sensor to count the number of labels that have passed a particular point in the web path and also use the sensor to measure the rate at which the labels are passing a particular point in the web path (which can be determined using a sensor of the type described above by monitoring the period of the periodic signal 56 output by the electromagnetic radiation detector 52). Then, given knowledge of the initial number of labels on the supply spool, the remaining labels on the supply spool can be determined by the controller. The remaining number of labels on the supply spool can then be divided by the rate at which labels are passing the particular point in the web path (and hence the rate at which labels are being paid out by the supply spool) in order to calculate a time indicative of when the supply spool will be used up (and hence require replacement).

It will be appreciated that other methods of measuring the remaining label stock on the supply spool and the rate of label stock being paid out from the supply spool may be used. For example, if the label pitch of the label stock is either known or determined, the displacement of the label stock along the web path may be used (given knowledge of the initial number of labels on the label stock) to determine the number of labels remaining on the supply spool. This may be done by calculating the number of labels that have been used and subtracting this from the initial number of labels. In order to calculate the number of labels used, a measured linear displacement of the label stock along the web path may be divided by the pitch length of the label stock. Measuring the linear speed of a portion of the label stock along the web path may also be used in order to determine the rate at which labels are paid out from the supply spool. This can be done by dividing the linear speed of a portion of the label stock along the web path by the pitch length of the label stock.

Another way to calculate the remaining number of labels is to measure the number of labels per unit cross-sectional area of label stock on the supply spool. In this case the cross-sectional area is measured perpendicular to the axis about which the supply spool rotates. Then, at any point in time, given the diameter of the supply spool – which may be measured using methods described previously – and also the diameter of the core holding the label stock on the supply (which may be measured or previously determined), cross-sectional area of label stock remaining on the supply spool may be calculated. This is done by subtracting the cross-sectional area of the core from the total cross-sectional area of the supply spool (i.e. including the core) which is determined using the outer diameter of the supply spool measured in the manner discussed above. By multiplying the cross-sectional area of the supply spool by the number of labels per unit cross-sectional area of label stock on the supply spool, the number of labels remaining can be calculated.

The number of labels per unit area may be calculated as follows. A first measurement of the spool diameter is made using any of the methods discussed above. A corresponding first cross-sectional area of the spool is calculated. Subsequently, after a known or measured number of labels have been dispensed, a second measurement of the spool diameter is made, and a corresponding second cross-sectional area of the spool is calculated. The number of labels per unit area may be calculated by dividing the known or measured number of dispensed labels by the difference between the first and second cross-sectional areas of the spool.

As previously discussed, information about the number of labels remaining on the supply spool and information about the rate at which labels are being utilised (e.g. dispensed) may be used to calculate a measure of the time it will take for the supply spool to be used up (i.e. a time remaining before the supply spool requires replacement).

In some embodiments of the invention, once the controller has calculated a time remaining before the supply spool requires replacement, the controller may be configured to use this information in combination with the time of the day in order to calculate the time of the day and/or date at which the supply spool will require replacement. For example, the controller may calculate that the supply spool will require replacement at 4.45pm or at 9.15am on 19th February. The controller may provide a signal indicative of the time of day and/or date at which the supply spool will require replacement to a suitable display. Calculating the time of the day and/or date at which the supply spool will require replacement may be useful because it will enable an operator of the labelling machine to determine at what time of the day he or she will need to be present in order to replace the label stock supply spool. Alternatively, or in addition, if the labelling machine is operated by operators which are employed in a shift pattern, the information provided by the labelling machine may enable the operator of the labelling machine to see on which operator shift the supply spool will require replacement.

Figure 5 shows a perspective view of a portion of an embodiment of a labelling machine of the type shown in Figure 1 or Figure 2. Figure 5 shows the supply spool support 10, the dancing arm 28 and a brake assembly 70. The supply spool support 10 includes a support disc 72 and a supply spool 16 of label stock supported by the supply spool support 10.

As previously discussed in relation to Figures 1 and 2, the labelling machine of which the supply spool 16 forms part also includes a take up spool support adapted to take up a portion of the web of the label stock. A web path is defined between the supply spool and the take up spool. The dancing arm 28 is a moveable element which, in use, defines a portion of the web path. In fact, in use, the label stock passes from the supply spool 16 and runs over the roller 32 which is mounted on the dancing arm 28. In Figure 5, neither the take up spool, nor the web of the label stock running along the web path, are shown so as to aid clarity of the figure.

As previously discussed, the dancing arm 28 and supply spool support 10 are both mounted for individual rotation about a common axis A. In other embodiments, the supply spool support 10 and dancing arm 28 may rotate about their own respective axes.

Figures 6 to 11 show further different views of the brake assembly 70 which is configured to apply a variable braking force to the supply spool support 10, the braking force resisting rotation of the supply spool support 10. The brake assembly 70 includes a brake disc 74 which is attached to the supply spool support 10 such that it co-rotates with the supply spool support 10 (and consequently any supply spool which is supported by the supply spool support 10).

The brake assembly also includes a brake belt 76 which extends around part of the outer circumference 88 of the brake disc 74. The brake belt is fixed at a first end 76a to an attachment pin 78 which is part of a mounting block 80 which is fixed so that it does not rotate with the supply spool support 10. The brake belt 76 is attached at second end 76b via a spring 82 to a pin 84 of a lever arm 86. The spring may be any appropriate resilient biasing member. In one embodiment the spring 82 is tension spring number 523 having a rate of 4.48N/mm produced by Kato-Entex Ltd, UK.

In the embodiment shown, the brake belt 76 has a generally rectangular cross-section and it contacts a portion of the outer circumference 88 of the brake disc 74 which has a substantially flat surface parallel to the axis A. That is to say, the substantially flat circumferential surface 88 of the brake disc 74 corresponds to the substantially flat surface of the belt 76 which engages the outer circumference 88 of the brake disc 74. It will be appreciated that in other embodiments of the labelling machine, the outer circumferential surface of the brake disc and the brake belt may have any appropriate corresponding profile. For example, the outer circumferential surface of the brake disc may include a v-shaped groove which cooperates with generally circular cross-section brake belt.

The brake belt 76 may be made from any appropriate material for example the brake belt may be made out of a combination of fabric and polymeric material or of polyurethane. In one embodiment the brake belt is 10mm wide, 280mm long and formed from a material referred to as Habasit TG04. In this embodiment the brake disc (which may be of any appropriate size in other embodiments) has a diameter of 100mm.

The lever arm 86 is pivotally mounted to the mounting block 80 by a pivot pin 90. A first end of the lever arm 86 includes the pin 84. A second end of the lever arm 86 engages an armature 92 of a solenoid 94. An example of a suitable solenoid is an MCSMT-3257S12STD solenoid supplied by Premier Farnell UK Limited.

As can be seen best in Figure 7, the distance between the pivot pin 90 and the point 96a on the pivot arm 86 at which the armature 92 of the solenoid 94 engages the pivot arm 86 is greater that the distance between the pivot pin 90 and the pin 84 to which the brake belt 76 is attached. In this way, the lever arm 86 provides a mechanical advantage such that any force applied by the armature 92 of the solenoid 94 to the lever arm 86 is magnified when it is applied to the brake belt 76 via the pin 84.

In use a resilient biasing member 98 (which in this embodiment is a spring different to the spring 82, but may be any other appropriate resilient biasing member) biases the lever arm 86 in a direction such that the spring 98 causes the brake belt 76 to contact the outer circumference 88 of the brake disc 74 so as to apply a braking force to the brake disc 74 and therefore resist rotation of the brake disc 74 and attached supply spool support 10. In one embodiment the spring 98 is compression spring number 940 having a rate of 0.94 N/mm produced by Kato-Entex Ltd, UK. The direction of the force applied by the spring 98 to the second end 76b of the brake belt 76 is denoted S in Figure 7. This ensures that, when no power is supplied to the solenoid 94 (for example when the labelling machine is powered down), the spring 98 causes a braking force to be applied to the brake disc 74 and hence the supply spool support 10.

Extension of the armature 92 of the solenoid 94 in the direction towards the lever arm 86 and as indicated by arrow F will cause the pin 84 to move in a direction of arrow F' which is substantially opposite to that of the arrow F. Consequently, if the solenoid 94 is energised such that the armature 92 moves towards the lever arm 86 in the direction F, this will cause the lever arm 86 to overcome the biasing force exerted on it by the spring 98 such that the pin 84 moves in the direction F'. This will cause the amount of braking force exerted by the brake belt 76 on the brake disc 74 to decrease. It follows that by controlling the position of the solenoid armature 92 (and hence controlling the position of the pin 84 via the lever arm 86) that the amount of braking force applied to the supply spool support 10 via the brake disc 74 can be varied.

The surface of the brake belt 76 which contacts the outer circumferential surface 88 of the brake disc 74 may be referred to as a first braking surface. The outer circumferential surface 88 of the brake disc 74 which is contacted by the first braking surface may be referred as a second braking surface. In a braking mode the controller controls the current supplied to the coil of the solenoid so as to urge the first braking surface against the second braking surface. As previously discussed, this is done by moving the armature 92 of the solenoid in a direction which is substantially opposite to the direction F (shown by arrow F'), thereby allowing the spring 98 to bias the end of the lever arm 86 which includes the pin 84 in a direction which is substantially parallel to the direction F (i.e. substantially in direction S). Due to the fact that the second end 76b of the brake belt 76 is connected to the pin 84 and due to the fact that the first end 76a of the brake belt 76 is attached to a fixed pin 78, movement of the pin 84 in a direction which is substantially parallel to the direction F causes the first braking surface to be urged against the second braking surface, thereby applying a braking force to the brake disc 74. The second braking surface 88 is part of the brake disc 74 which is attached to the supply spool support

10. Consequently the supply spool support 10 is associated with the second braking surface 88.

As seen best in Figures 7, 8 and 10, the solenoid 94 includes a coil (not shown) housed within a solenoid housing 96 and the armature 92 which is a linearly moveable relative to the coil. One end of the armature 92 engages the lever arm 86. Attached to the other end of the armature 92 is a reflective element 99 which forms part of an armature position sensor. In one embodiment the reflective element 99 is a generally annular machined part made from white acetal material.

The armature position sensor further includes a transmitter 100 configured to transmit electromagnetic radiation and a receiver 102 which is configured such that electromagnetic radiation transmitted by the transmitter 100 and reflected by the reflective element 99 is incident on the receiver 102. The transmitter 100 and receiver 102 can be seen most clearly in Figure 8. In this embodiment the transmitter 100 is a light emitting diode and the receiver 102 is a photodiode. Both the transmitter 100 and the receiver 102 are supported by a sensor support 104 which is in a fixed positional relationship with regard to the body 96 of the solenoid 94 (and hence the coil of the solenoid contained within the body 96). In one embodiment the transmitter 100 and receiver 102 are a single part, HDSL-9100-021 proximity sensor, produced by Avago Technologies, U.S. Inc.

In use, the transmitter 100 (in this case an LED) transmits electromagnetic radiation in a direction such that it is incident on the reflective element 99. The reflective element 99 reflects at least a portion of the electromagnetic radiation which is incident on it. Some of the electromagnetic radiation which is reflected by the reflective element 99 is incident on the receiver 102. As previously discussed, in this case, the receiver 102 is a photodiode. Consequently the voltage and/or current of a signal output by the photodiode is indicative of the amount of electromagnetic radiation which is reflected by the reflective element 99 and incident on the receiver 102.

When the armature 92 of the solenoid 94 is moved the position of the reflective element 99 relative to the transmitter 100 and receiver 102 will change. The further the reflective element 99 is away from the transmitter 100 and receiver 102 (i.e. the further the armature 92 of the solenoid 94 is moved in the direction F) the less electromagnetic radiation produced by the transmitter 100 and reflected by the reflective element 99 will be incident on the receiver 102. Consequently, in this case where the receiver is a photodiode, the less the magnitude of the voltage and/or current signal produced by the receiver 102. It follows that the receiver 102 of the armature position sensor outputs a signal (which may be referred to as an armature position signal) which is indicative of the position of the armature 92 relative to the coil of the solenoid 94. It will be appreciated that the armature position signal is also indicative of the position of a lever arm 86 and hence of the braking force which is being applied by the brake belt 76 (which is attached to pin 84 of the lever arm 86) to the brake disc 74 and hence to the supply spool support 10.

In a standard solenoid of the type used in Figure 7, the extent of relative movement between the armature and the coil is dependent on the current supplied to the coil. The armature of the solenoid is biased relative to the coil by a resilient biasing member (not shown) towards a first end position. Hence, when no current is supplied to the coil, the solenoid is biased towards the first end position. When current of a particular magnitude is applied to the coil of the solenoid the armature overcomes the biasing force which urges it into the first end position such that the armature moves towards a second end position. Removing the current provided to the coil will result in the armature being urged by the resilient biasing member back to the first end position. Consequently, solenoids tend to be bi-stable, i.e. depending on the operating state of the solenoid, the armature tends to be located relative to the coil at the first end position or the second end position. The armature cannot be reliably located relative to the coil at a position between the first end position and the second end position.

A labelling machine described herein includes a solenoid control system which includes a solenoid controller and is configured to control the current supplied to the coil of the solenoid based upon the armature position signal output by the armature position sensor so as to urge the armature towards a desired rest position relative to the coil which is intermediate the first and second end positions of the solenoid discussed above. The solenoid controller implements a conventional PID (proportional, integral and derivative) algorithm as part of a closed loop system in order to control the current supplied to the coil of the solenoid.

Figure 14 shows a diagrammatic representation of the PID control algorithm implemented by the solenoid controller. At any given time a set point value SP(t) is provided to the control algorithm. The set point value SP(t) is indicative of the desired position of the armature of the solenoid relative to the coil. The set point signal SP(t) is provided to one input of a subtractor 110. A feedback signal FB(t) which is indicative of the actual position of the armature relative to the coil of the solenoid is supplied to a second input of the subtractor 110. The subtractor 110 subtracts the feedback signal FB(t) from the set point signal SP(t) and outputs an error signal E(t).

The error signal E(t) is supplied to three portions of the PID algorithm. These are the proportional component P, the integral component I, and the derivative component D. As can be seen from the figure, the proportional component P outputs a signal which is given by a constant K_P multiplied by the error signal E(t). The integral component I outputs a signal which is given by a constant K_I multiplied by the integral of the error signal E(t). The derivative component D of the algorithm outputs a signal which is given by a constant K_D multiplied by a derivative of the error signal E(t) with respect to time.

An adder 112 combines the signals output by the proportional P, integral I and derivative D components of the algorithm. The output from the adder 112 is provided to a coil driver 114. The coil driver 114 is connected across the coil of the solenoid so that it can apply a voltage across the coil. The coil driver 114 supplies a pulse width modulated voltage signal across the coil of the solenoid. The coil driver 114 controls the duty cycle of the pulse width modulated voltage signal applied across the coil as a function of the signal output to it by the adder 112 of the PID control algorithm.

By varying the duty cycle of the pulse width modulated voltage applied across the coil of the solenoid, the current supplied to the coil, and hence the position of the armature of the solenoid relative to the coil, can be changed. An armature position sensor 116 outputs an armature position signal which is indicative of the position of the armature relative to the coil of the solenoid. The armature position signal may also be referred to as the feedback signal FB(t). In the previously described embodiment shown in Figures 5 to 13, the armature position sensor 116 includes the transmitter 100, the reflective element 99 and the receiver 102. As previously discussed, it is the receiver 102 which outputs the armature position signal. Details of the operation of the armature position sensor can be found in the description above. However, it will be appreciated that any appropriate armature position sensor (which is capable of producing an armature position signal which indicative of the position of the armature relative to the coil) may be used.

A conventional PID controller is configured such that an increase in the signal output by the adder which combines the proportional, integral and derivative components (e.g. 112 in Figure 14) causes an increase in the feedback signal. However in the case of the embodiment previously described with reference to Figure 14 the opposite occurs. An increase in the signal output by the adder 112 results in an increase in the current in the coil provided by the coil driver 114, which causes a decrease in the feedback signal FB(t) produced by the armature position sensor 116. This may be compensated for in a number of ways. For instance, the range of the feedback signal may be inverted such that a small signal is generated when the reflector is close to the transmitter, and a larger signal generated when the reflector is further away from the transmitter. Alternatively, the connections of the signals to the subtractor 110 may be swapped.

A suitable frequency for the pulse width modulated voltage is approximately 10 kHz. That is to say, during each 1/10,000 of a second the voltage applied is taken high, and then low again. Within each 1/10,000 of a second the duration for which the signal is high and the duration for which the signal is low are varied, however in each case the sum of the duration for which the signal is high and the duration for which the signal is low is always equal to 1/10,000 of a second. Of course, any appropriate frequency of pulse width modulated voltage may be used.

The armature position sensor is calibrated as follows. The solenoid is caused to enter a de-energised state by the controller. In this state, substantially no current is provided to the coil of the solenoid. The armature is urged to the limit of its movement in the direction F’ by the biasing force of the spring 98 (an also by any resilient biasing member within the solenoid). At this point the controller records the value of the signal output by the armature position sensor. This value may be referred to as the maximum braking value because it corresponds to the configuration of the brake assembly (in this case the position of the armature) in which the maximum braking force is applied to the spool support by the brake assembly.

The solenoid is then caused to enter a fully energised state by the controller. In this state, enough current is provided to the coil of the solenoid such that the armature is urged against the biasing force of the spring 98 to the limit of its movement in the direction F. At this point the controller records the value of the signal output by the armature position sensor. This value may be referred to as the minimum braking value because it corresponds to the configuration of the brake assembly (in this case the position of the armature) in which the minimum braking force is applied to the spool support by the brake assembly.

In this embodiment the exact relationship between armature position and braking force applied by the brake assembly to the spool support is unknown. What is known is that when the armature position sensor outputs a signal to the controller which has a value equal to the maximum braking value, then the braking force applied by the brake assembly to the spool support is a maximum. Likewise, when the armature position sensor outputs a signal to the controller which has a value equal to the minimum braking value, then the braking force applied by the brake assembly to the spool support is a minimum. When the armature position sensor outputs a signal to the controller which has a value between the minimum braking value and the maximum braking value, then the braking force applied by the brake assembly to the spool support is between the minimum and maximum braking force. The closer the value of the signal output by the armature position sensor to the maximum braking value, the closer the braking force applied by the brake assembly to the spool support is to the maximum braking force. Likewise, the closer the value of the signal output by the armature position sensor to the minimum braking value, the closer the braking force applied by the brake assembly to the spool support is to the minimum braking force. In other embodiments the armature position sensor may be calibrated such that the relationship between armature position and braking force applied by the brake assembly to the spool support is known.

In order to avoid the armature colliding with a portion of the coil or an end-stop (if present) during operation, a limited range of the full movement of the armature may be used. That is to say, the solenoid controller and/or PID algorithm may be configured such that the coil driver provides a maximum current to the coil which is less than the current required for the solenoid to enter its fully energised state; and such that the coil driver provides a minimum current to the coil which is greater than the current required for the solenoid to enter its de-energised state.

Extension of the armature 92 of the solenoid 94 in the direction towards the lever arm 86 and as indicated by arrow F will cause the pin 84 to move in a direction of arrow F' which is substantially opposite to that of the arrow F. Consequently, if the solenoid 94 is energised such that the armature 92 moves towards the lever arm 86 in the direction F, this will cause the lever arm 86 to overcome the biasing force exerted on it by the spring 98 such that the pin 84 moves in the direction F'. This will cause the amount of braking force exerted by the brake belt 76 on the brake disc 74 to decrease. It will be appreciated that in other embodiments the brake assembly may be configured such that energising the solenoid increases the braking force applied to the spool support and de-energising the solenoid decreases the braking force applied to the spool support. In other embodiments any suitable braking arrangement may be used, for example brake disc and brake pad, brake drum and brake shoe or appropriate motor as discussed in more detail below.

Any appropriate gain constants K_P, K_I and K_D may be used. In some embodiments, at least one of these constants may be equal to zero. However, in a preferred embodiment, all of these constants are non-zero.

In some embodiments, an offset may be applied to ensure that with zero error between the set point signal and the feedback signal, a control signal is generated which is in the centre of the range of valid control signals.

In some embodiments, the PID control algorithm may incorporate a dead band. In such embodiments, the error signal E(t) is set to zero if the feedback signal FB(t) is within a given range of the set point signal SP(t). For example, the dead band may operate such that if the difference between the set point signal SP(t) and the feedback signal FB(t) is less than ±1% of the set point signal SP(t) then the error signal E(t) is set to zero. Alternatively, if the difference between the set point signal SP(t) and the feedback signal FB(t) is less than ±1% of a maximum possible set point signal (i.e. the set point signal which is equivalent to a desired fully energised state of the coil of the solenoid, or a desired de-energised state of the solenoid) then the error signal E(t) is set to zero. If, in either of these cases, the feedback signal FB(t) falls outside of this range then the error signal E(t) is calculated in the manner already described by the subtractor 110.

Other embodiments incorporating a dead band may function in a slightly different manner. These embodiments operate in the same manner as the dead band previously described except that if the feedback signal FB(t) falls outside of the dead band then the error signal E(t) is calculated by calculating the difference between the feedback signal FB(t) and the edge of the dead band which is closest to the feedback signal FB(t). For example, if the dead band is ±1% of the set point signal SP(t), and the feedback signal FB(t) has a value of the set point signal SP(t) plus 1% of the set point signal SP(t) plus μ, then the value of the error signal is -μ. Likewise, if the dead band is ±1% of the set point signal SP(t), and the feedback signal FB(t) has a value of the set point signal SP(t) minus 1% of the set point signal SP(t) and minus μ, then the value of the error signal is μ. In an alternative example, if the dead band is ±1% of the maximum possible set point signal (i.e. the set point signal which is equivalent to a desired fully energised state of the coil of the solenoid, or a desired de-energised state of the solenoid), and the feedback signal FB(t) has a value of the set point signal SP(t) plus 1% of the maximum possible set point signal, plus μ, then the value of the error signal is -μ. Likewise, if the dead band is ±1% of the maximum possible set point signal, and the feedback signal FB(t) has a value of the set point signal SP(t) minus 1% of the maximum possible set point signal SP(t) and minus μ, then the value of the error signal is μ.

Where a non-zero value is used for K_D, some form of low pass filtering (a concept which is well known in the art) may be used to reduce the noise present in the feedback signal. That is to say low pass filtering may be used either to reduce the amount of relatively high frequency noise from the derivative component D of the PID algorithm (compared to the relatively low frequency desired portion of the derivative component D of the PID algorithm) or to reduce the amount of relatively high frequency noise from the feedback signal (compared to the relatively low frequency desired portion of the feedback signal). It will be appreciated that if a low pass filter is used as a form of low pass filtering, then the cut-off frequency of the low pass filter would be chosen (in a manner well known in the art) such that relatively high frequency noise from the derivative component D of the PID algorithm or feedback signal is attenuated but the relatively low frequency desired portion of the derivative component D of the PID algorithm or feedback signal is allowed to pass.

The reason a form of low pass filtering may be used to remove noise if a non-zero value of K_D is used is because the derivative term acts to amplify the rate of change of the feedback signal and is thus particularly sensitive to high frequency content as this has a greater rate of change than low frequency content (assuming equal amplitude). The noise may be caused by various factors. For example, the noise may be intrinsic to the emitter/detector arrangement, it may be electronic circuit noise, it may be electromagnetically-induced interference or it may be any other noise source. In the case where the armature position sensor comprises a radiation detector, noise may be caused by the presence of unintended radiation. One example of a form of low pass filtering includes a simple averaging algorithm. The averaging algorithm may take a number of samples of the feedback signal FB(t) or the derivative component D of the PID algorithm and then output the mean value of those samples. However, any appropriate form of low pass filtering or any appropriate known method of reducing noise may be used.

It will be appreciated that although the braking arrangement described is configured so as to enable a braking force to be applied to the supply spool support, in other embodiments, the same brake assembly may be used in conjunction with the take up spool support, so as to apply a braking force to the take up spool support.

It will also be appreciated that, although a particular brake assembly is described above which utilises a brake belt, brake disc and actuating solenoid, in other embodiments, any appropriate brake assembly may be used providing the brake assembly is capable of selectively applying a braking force to the relevant spool support.

For example, the brake assembly may include a motor that is mechanically linked to the relevant spool support (e.g. the supply spool support) such that the motor rotates with the spool support. In one example the motor may be a DC motor. As is well known, by controlling the amount of current provided to the DC motor, the amount of torque exerted by the DC motor can be controlled. Consequently, by driving the DC motor in a direction such that it opposes the direction of rotation of the spool support, and by controlling the amount of current provided to the DC motor, it is possible to control the amount of torque the DC motor applies to the relevant spool support in order to oppose (or resist) the rotation of the relevant spool support. The torque applied by the motor to oppose the rotation of the relevant spool support may be referred to as a braking torque.

In another example the motor may be a stepper motor. An un-powered stepper motor has a holdback torque, which is a torque of the stepper motor which opposes rotation of the stepper motor. The amount of holdback torque can be changed by changing an electrical resistance that is connected across each of the windings of the stepper motor. For example, such a technique is described in US patent US5366303. The greater the electrical resistance connected across each winding the greater the holdback torque of the stepper motor. Consequently, by controlling the electrical resistance connected across each winding of the stepper motor, it is possible to control the braking torque of the stepper motor.

As previously discussed in relation to Figures 2 and 5, the labelling machine includes a moveable element in the form of a dancing arm 28 having a roller 32.

Considering Figures 11, 12 and 13 together, the dancing arm 28 also includes a generally annular portion 120 which is mounted for rotation about the axis A and about shaft 122 by bearings 124. The shaft 122 connects the supply spool support 10 to the brake disc 74 such that the supply spool support 10 and the brake disc 74 co-rotate. The supply spool support 10, brake disc 74 and connecting shaft 122 are mounted for rotation relative to the mounting block 80 about axis A by a second set of bearings 126.

As seen best in Figure 11, an arm 128 projects from the annular portion 120 of the dancing arm 28. A first end 130a of a resilient biasing member 130 (which in this case is a tension spring, but may, in other embodiments, be any appropriate resilient biasing member) is attached to the arm 128 via a pin 132. In one embodiment the spring 130 is tension spring number 2137 having a rate of 1.05N/mm produced by Kato-Entex Ltd, UK. As can be seen best in Figure 7, a second end 130b of the resilient biasing member 130 is fixed via a pin to the mounting block 80. In Figure 7, the pin used to secure the second end 130b of the resilient biasing member 130 to the mounting block 80 has been omitted for clarity. The resilient biasing member 130 biases the dancing arm 28 in the clockwise direction as shown in Figure 7. This direction is indicated by arrow G.

The labelling machine includes a sensor configured to produce a sensor signal indicative of the position of the moveable element (in this case dancing arm 28). The sensor is configured to produce a sensor signal indicative of the position of the moveable element. In this case the sensor produces a sensor signal indicative of the rotational position of the moveable element. As best seen in Figure 11 the sensor includes a multipole strip magnet 140 which is attached to a circumferential surface 142 of the annular portion 120 of the dancing arm 28.

Figure 15 shows a schematic plan view of a portion of the multipole strip magnet 140 which has been removed from the annular portion 120 of the dancing arm 28 and has been laid flat in the plane of the paper. The multipole strip magnet 140 is such that along its length L_S there are alternating regularly spaced north N and south S magnetic pole regions 143. The length of each pole region 143 is L_P. In some embodiments the pole length L_P may be 1mm or 2mm. The multipole strip magnet 140 may be attached to the circumferential surface 142 of the annular portion 120 using any appropriate method, for example, using adhesive.

The sensor configured to produce a sensor signal indicative of the position of the moveable element also includes a magnetic sensor (not shown) which is mounted to sensor support 144. The magnetic sensor is mounted with sufficient proximity to the multipole strip magnet 140 such that the magnetic sensor can readily sense the magnetic field produced by the multipole magnetic strip 140. The magnetic sensor may be of any appropriate type. For example it has been found that a magnetic sensor which comprises a plurality of Hall Effect sensors (also referred to as Hall elements) is capable of providing approximately 1000 sensor pulses for a full sweep of the dancing arm 28 when using a multipole magnet strip which has a pole length

L_P of 2mm. In this example, the magnetic sensor which comprises a plurality of Hall elements is an AS5304 integrated Hall IC and the magnetic strip is an AS5000-MS20-50 multipole magnetic strip, both produced by ams AG, Austria. A full sweep of the dancing arm 28 is an angular displacement of the dancing arm between the extents of the dancing arm's angular movement.

It will be appreciated that, given the knowledge of the pole length L_P of the multipole strip magnet 140 and also knowing the diameter of the circumferential surface 142 to which the multipole magnetic strip 140 is attached, it is possible to count signal pulses provided by the magnetic sensor as the dancing arm 28 rotates in order to determine angular displacement of the dancing arm 28. Furthermore, if it is known that for a full sweep of the dancing arm 28 a particular number of pulses are generated by the magnetic sensor and further known that a full sweep of the dancing arm 28 represents motion of the dancing arm through an arc of a particular angle (which can be measured based upon physical restrictions on dancing arm movement) it is a straightforward matter to determine the angular displacement from a 'home' position (described below) based upon a number of pulses generated by the magnetic sensor since the dancing arm 28 was in that home position.

Figure 16 shows a schematic representation of a portion of a labelling machine as shown in the previous figures. It is explained with reference to Figure 16 how an angular displacement of the dancing arm 28 can be used to calculate a change in the length of the web path 20 between the supply spool support 10 and take up spool support 12.

A portion of the web path 20 is formed by the loop extending between the rollers 22 and 24 via the roller 32. The length L of the portion of the web path 20 extending between the rollers 22 and 24 via the roller 32 can be calculated as a function of the position of the dancing arm 28 (and hence roller 32).

With reference to Figure 16, the dancing arm 28 has a length r and defines an arc through which roller 32 travels. The length r is the linear distance between the axis of rotation A of the dancing arm 28 and the centre of the roller 32. The dancing arm 28 has a home position, which may be defined as the position in which the line r is coincident with a line r_h. During operation it can be determined whether the dancing arm 28 is in the home position by the triggering of a home position sensor (not shown), such as a micro-switch or any other appropriate position sensor.

Once the home position sensor has been triggered, an angular displacement of the dancer arm 28 from the home position can be measured by the sensor (in this case the magnetic sensor), which outputs a sensor signal indicative of the position of the moveable element. This position signal takes the form of a series of pulses indicating an angular displacement of the dancer arm 28 from the home position as described above.

For ease of reference, an angle θ representing the angular displacement of the dancer arm 28 is measured from a horizontal (x) axis, shown in Figure 16. It can be seen from Figure 16 that the angle θ can be calculated from an angle θ_h indicating angular displacement of the dancer arm from the home position, and an angle $\theta_{h'}$ of the home position from a vertical (y) axis by the equation:

$$\theta = \frac{\pi}{2} - \theta_h - \theta_{h'} \qquad (2)$$

The axis A of rotation of the dancer arm 28 is used as a reference point for relative measurements, with horizontal (x-axis) and vertical (y-axis) displacements referring to the horizontal and vertical distance from that point.

It will be appreciated that the relative positions of roller 22 and roller 24 to the axis of rotation A of the dancer arm 28 are fixed and as such are known. The position of the roller 22 is defined by coordinates (x_{r1}, y_{r1}). Similarly, the position of the roller 24 is described by coordinates (x_{r2}, y_{r2}).

The position of the roller 32 is defined by coordinates (x_{r3}, y_{r3}), although it will be appreciated that as the roller 32 moves (as the dancing arm 28 moves) the values of these coordinates will not be fixed, and as such, both x_{r3} and y_{r3} are functions of the angle θ and length r and can be calculated as follows:

$$y_{r3} = r\sin\theta \qquad (3)$$

$$x_{r3} = \sqrt{r^2 - y_{r3}^{\ 2}} \qquad (4)$$

The distance p_1 between the centre of roller 22 and the centre of roller 32, and the distance p_2 between the centre of roller 24 and the centre of roller 32, is given by Pythagoras' Theorem from the known positions of each of the rollers according to the following equations:

$$p_1 = \sqrt{(x_{r3} - x_{r1})^2 + (y_{r3} + y_{r1})^2} \qquad (5)$$

$$p_2 = \sqrt{(x_{r3} - x_{r2})^2 + (y_{r3} + y_{r2})^2} \qquad (6)$$

The line between the centres of rollers 22 and 32 has an angle ε from the y-axis, which can be calculated according to following equation:

$$\varepsilon = \tan^{-1}\left(\frac{x_{r3} - x_{r1}}{y_{r3} + y_{r1}}\right) \qquad (7)$$

The line between the centres of rollers 24 and 32 has an angle γ from the y-axis, which can be calculated according to the following equation:

$$\gamma = \tan^{-1}\left(\frac{x_{r3} - x_{r2}}{y_{r3} + y_{r2}}\right) \qquad (8)$$

The web path 20 will follow a substantially straight line between each of the rollers 22, 24, 32 it contacts. At the point of contact between the web path 20 and each of the rollers 22, 24, 32 (and in particular an outer circumferential surface of each of the rollers 22, 24, 32) the web path 20 is tangential to the respective roller.

The angle between the web path 20 (between rollers 22 and 32) and the line p_1 between the centres of the rollers 22 and 32 is α which can be calculated according to the equation:

$$\alpha = \sin^{-1}\left(\frac{\frac{d_{r1}}{2} + \frac{d_{r3}}{2}}{p_1}\right) \qquad (9)$$

where d_{r1} is the diameter of roller 22, and d_{r3} is the diameter of roller 32.

The angle between the web path 20 (between rollers 24 and 32) and the line p_2 between the centres of the rollers 24 and 32 is β, which can be calculated according to the equation:

$$\beta = \sin^{-1}\left(\frac{\frac{d_{r2}}{2} - \frac{d_{r3}}{2}}{p_2}\right) \quad (10)$$

where d_{r2} is the diameter of roller 24.

The length of the web path 20 between each of the rollers 22, 24 and 32 can now be calculated. The length l_1 of the web path 20 between the rollers 22 and 32 can be calculated according to the following equation:

$$l_1 = \sqrt{{p_1}^2 - \left(\frac{d_{r1}}{2} + \frac{d_{r3}}{2}\right)^2} \quad (11)$$

The length l_2 of web path 20 between the rollers 24 and 32 can be calculated according to the following equation:

$$l_2 = \sqrt{{p_2}^2 - \left(\frac{d_{r2}}{2} - \frac{d_{r3}}{2}\right)^2} \quad (12)$$

In order to calculate the total length L of the web path 20 between the location at which the web path 20 contacts roller 22 and the location at which the web path 20 contacts roller 24, the lengths of the arcs which are made by the web path 20 at the circumference of each of the rollers 22, 24 and 32 where the web path 20 contacts the rollers must be calculated.

As discussed above, at the point of contact with each roller, the web path 20 is tangential to the respective roller. Therefore, because the x-axis and y-axis are orthogonal, an angle between a normal to each respective roller at the point of contact of the web path to the respective roller and the x-axis is the same as the angle between the web path 20 and the y-axis.

The angle between the y-axis and the web path 20 between rollers 22 and 32 is given by $\varepsilon - \alpha$. The angle between the y-axis and the web path 20 between rollers 24 and 32 is given by $\gamma - \beta$.

The length of each arc can be calculated as the product of the radius of the respective roller and the angle subtended by the arc, with each of the arcs calculated as follows:

$$arc_1 = \left(\frac{\pi}{2} + \alpha - \varepsilon\right).\frac{d_{r3}}{2} \qquad (13)$$

where arc_1 is a length of an arc between a point at which the web makes contact with roller 32 on the left-hand side (with respect to Figure 16) and the uppermost point on the circumference of roller 32 (again with respect to Figure 16). arc_1 is illustrated in Figure 16 by the portion of the circumference of the roller 32 between the dotted line ‘a’ and the dotted line ‘b’.

The angle subtended by the arc in equation (13) is derived as follows. Angles at the rotational axis of roller 32 are considered. The angle subtended between the y-axis and the line p_1 between the centres of rollers 22 and 32 is ε. The line p_1, web path 20 and dotted line ‘a’ form a right angled triangle. Within this right angled triangle, the angle subtended between line p_1 and the web path 20 is α. Consequently, the angle subtended by the line p_1 and dotted line ‘a’ is π/2 – α. Because the angle subtended by the arc in equation (13) is the angle subtended between the y-axis and dotted line ‘a’, it is given by the sum of ε and π/2 – α, subtracted from π. This is equal to π/2 + α – ε as included in equation (13).

$$arc_2 = \left(\frac{\pi}{2} + \gamma - \beta\right).\frac{d_{r3}}{2} \qquad (14)$$

where arc_2 is the length of the arc between the uppermost point on the circumference of roller 32 (with respect to Figure 16) and the point at which the web makes contact with roller 32 on the right-hand side of roller 32 (again with respect to Figure 16). arc_2 is illustrated in Figure 16 by the portion of the circumference of the roller 32 between the dotted line ‘b’ and the dotted line ‘c’. The angle between the horizontal (having regard to the orientation of the figure) and dotted line ‘c’ is $\gamma - \beta$. Consequently, the angle between dotted line ‘b’ (i.e. the vertical) and dotted line ‘c’ is $\frac{\pi}{2} + \gamma - \beta$.

$$arc_3 = \left(\frac{\pi}{2} - \gamma + \beta\right).\frac{d_{r2}}{2} \qquad (15)$$

where arc$_3$ is the length of the arc between point at which the web makes contact with roller 24 on the right-hand side (with respect to Figure 16) and the lowermost point on the circumference of roller 24 (again with respect to Figure 16). arc$_3$ is illustrated in Figure 16 by the portion of the circumference of the roller 24 between the dotted line 'd' and the dotted line 'e'. The angle between the horizontal (having regard to the orientation of the figure) and dotted line 'd' is $\gamma-\beta$. Consequently, the angle between dotted line 'e' (i.e. the vertical) and dotted line 'd' is $\frac{\pi}{2}-\gamma+\beta$.

$$arc_4=\left(\frac{\pi}{2}+\alpha-\varepsilon\right).\frac{d_{r1}}{2} \qquad (16)$$

where arc$_4$ is the length of the arc between the point at which the web makes contact with roller 22 on the right-hand side (with respect to Figure 16) and the lowermost point on the circumference of roller 22. arc$_4$ is illustrated in Figure 16 by the portion of the circumference of the roller 22 between the dotted line 'f' and the dotted line 'g'. The angle subtended by the arc in equation (16) is derived as follows. Angles at the rotational axis of roller 22 are considered. The angle subtended between the y-axis and the line p$_1$ between the centres of rollers 22 and 32 is ε. The line p$_1$, web path 20 and dotted line 'f' form a right angled triangle. Within this right angled triangle, the angle subtended between line p$_1$ and the web path 20 is α. Consequently, the angle subtended by the line p$_1$ and dotted line 'f' is π/2 – α. Because the angle subtended by the arc in equation (16) is the angle subtended between the y-axis and dotted line 'f', it is given by the sum of ε and π/2 – α, subtracted from π. This is equal to π/2 + α – ε.

The total length L of web path 20 between where the web path 20 contacts roller 22 and where the web path 20 contacts roller 24 is calculated as follows:

$$L=l_1+l_2+arc_1+arc_2+arc_3+arc_4 \qquad (17)$$

It will be appreciated that while the length L has been calculated between the lowermost point on the circumference of roller 22 (being the point at which the normal to the web path 20 is parallel with the y-axis) and the lowermost point on the circumference of roller 24 (again being the point at which the normal to the web path 20 is parallel with the y-axis), the portion of the web path 20 considered could in fact be any portion which includes the portion of the web path 20 which has a length that varies as a function of the position of the movable element (in this case dancing arm

28) and in such a case it would be apparent to the skilled person, from the foregoing description, how the length of the portion of the web path 20 of interest should be calculated.

Furthermore, in use, the absolute length L may be used as an intermediate value to allow the measurement of a differential length ΔL which represents the difference in web path length between the dancer arm 28 being in a first position, having web path length L_{pos1} (determined using equation (17) above) and the dancer arm 28 being in a second position, having web path length L_{pos2} (also determined using equation (17) above. The differential length ΔL can be calculated according to the equation:

$$\Delta L = L_{pos1} - L_{pos2} \qquad (18)$$

It will be appreciated that the differential tape path length ΔL can be calculated for a plurality of further dancer arm positions, and that one of the positions may be the home position.

It will be appreciated from the foregoing description that given knowledge of various fixed dimensions (e.g. roller diameters, angular location of the home position relative to the y axis, distances between roller centres etc.) the length of the web path between the roller and roller 24 can the calculated in the manner described.

It will be appreciated that although one particular method of calculating a change in web path length has been described, any appropriate method of calculating a change in web path length may be utilised. For example, in one embodiment, the web path may extend from a first, fixed roller to a second, movable roller and then to a third, fixed roller adjacent to the first roller. The second, movable roller moves in a linear manner relative to the first and third rollers. In this embodiment, movement of the second roller by a distance d along its linear path results in a change in web path length of 2d. Furthermore, although in the described embodiment the sensor which produces a signal indicative of the position of the moveable element (in this case dancing arm 28) is an angular position sensor, any appropriate sensor may be used. For example, at least one ultrasonic or laser distance measurer may be used to measure the position of the moving element.

The controller may be configured to calculate a displacement of the web of the label stock along the web path based upon the sensor signal produced by the sensor which is indicative of the position of the moveable element.

For example, if the supply spool is paying out label stock at a known linear speed along the web path (determined, for example, using one of the techniques described above) for a known time, and during this time the sensor produces a signal which is indicative of a change in position of the moveable element, then the controller may calculate the change in the length of the web path between the take up spool support and supply spool support which has occurred during said time. Consequently, the controller may calculate the displacement of the web along the web path during said time by adding the displacement of the web along the web path due to the supply spool paying out the label stock and the displacement of the web along the web path due to a change in the length of the web path between the take up spool support and the supply spool support.

Similarly, if the take up spool is taking up label stock at a known linear speed along the web path for a known time, and during this time the sensor produces a signal which is indicative of a change in position of the moveable element, then the controller may calculate the change in the length of the web path between the take up spool support and supply spool support which has occurred during said time. Consequently, the controller may calculate the displacement of the web along the web path during said time by adding the displacement of the web along the web path due to the take up spool taking up the label stock and the displacement of the web along the web path due to a change in the length of the web path between the take up spool support and the supply spool support. For any given period of time the sum of the displacement of the web along the web path due to the take up spool taking up the label stock and the displacement of the web along the web path due to a change in the length of the web path between the take up spool support and the supply spool support is equivalent to the length of label stock removed from supply spool in said given period of time.

As previously discussed, if the displacement of the web along the web path on to a take up spool or off a supply spool is known in combination with the amount of rotation of the take up spool or supply spool whilst said known displacement of the web has occurred, then it is possible to calculate the diameter of said take up spool or supply spool in accordance with equation (1) above.

The controller may be configured to calculate the diameter of one of the spools in this manner based upon calculated displacement of the web along the web path (which is in turn based upon the sensor signal which is indicative of the position of the moveable element) and a rotation signal produced by a rotation monitor. The operation of a specific rotation monitor and its alternatives have been previously discussed and are therefore not referred to again so as to avoid repetition. Suffice to say, the rotation monitor may include a sensor which produces pulses indicative of a given degree of rotation which can be counted, or, alternatively, the rotation monitor may count step pulses which are provided to a position controlled motor, such as a stepper motor.

A labelling machine of the type described herein may include a brake assembly (for example, but not limited to, that previously described). In this embodiment the controller is configured to calculate the diameter of the spool mounted to one of the spool supports based upon the sensor signal indicative of the position of the moveable element and the rotation signal indicative of the rotation of the spool the diameter of which is to be measured. In addition, in this embodiment, the brake assembly is configured to apply a braking force to the other one of said spool supports (i.e. the spool support other than that supporting the spool whose diameter it is desired to calculate).

In this embodiment, the controller is configured to calculate the diameter of said spool supported by said one of said spool supports based upon the sensor signal which indicates movement of the dancing arm 28 when the brake assembly applies a braking force to the other of said spool supports which is sufficient to substantially prevent rotation of the other of said spool supports. This is now described in more detail.

Referring back to Figure 2 for ease of reference, in this embodiment, the brake assembly (not shown in Figure 2) applies a braking force to the supply spool support 10 which is sufficient to substantially prevent rotation of the supply spool support 10 and supported supply spool 16. Whilst the brake assembly substantially prevents rotation of the supply spool support 10 and supported spool 16, the controller controls the motor 14, which in this case is a stepper motor, so as to rotate the motor 14 a predetermined number of steps. Rotating the motor 14 a predetermined number of steps is equivalent to rotating the take up spool support 12 and supported spool 34 by a predetermined angle. This is due to the fact that, as noted above, the motor 14 rotates a known number of steps for a single complete rotation and also due to the fact that the nature of any gearing between the motor 14 and the take up spool support 12 is known.

In this case, the take up spool support 12 is rotated in a direction such as to wrap web of the label stock 18 on to the take up spool support 12 such that the web of the label stock travels along the web path in the direction C. It will be appreciated that, in other embodiments, the motor 14 and hence take up spool support 12 may be rotated in the opposite direction.

Rotation of the take up spool support 12 such that the web of the label stock 18 travels along the web path 20 in the direction C whilst a supply spool support 10 (and hence supported supply spool 16) are substantially prevented from rotating will cause tension in the web to increase. The increase in tension in the web will cause the dancing arm to move against the biasing force provided by the spring 130 (not shown in Figure 2, but shown in Figure 7, which biases the dancing arm in an anti-clockwise direction) in a clockwise direction so as to reduce the length of the web path 20 between the supply spool support 10 and take up spool support 12.

The clockwise movement of the dancing arm 28 whilst the motor 14 is driven a predetermined number of steps will be sensed by the sensor configured to produce a sensor signal indicative of the position of the moveable element (in this case the magnetic sensor). In accordance with the equations set out above, the controller calculates the change in the length (equation (18)) of the web path 20 between the supply spool support 10 and take up spool support 12 during the time the motor 14 is driven based upon the change of position of the dancing arm 28.

Due to the fact that the supply spool support (and hence supported supply spool 16) is prevented from rotating during this procedure, any change in the length of the web path 20 between the supply spool support 10 and take up spool support 12 will have been caused by that amount of web being wound on to the take up spool 34 supported by the take up spool support 12.

The controller can calculate the number of rotations of the take up spool support 12 (and hence supported take up spool 34) which have occurred due to the controller rotating the motor 14 a predetermined number of steps. The controller can also calculate the change in the length of the web path 20 between the supply spool support 10 and take up spool support 12 based upon the change in position of the dancing arm 28. Finally, the controller can calculate the diameter of the take up spool 34 supported by the take up spool support 12 in accordance with equation (1) above.

The apparatus and method used to calculate the diameter of one of the spools above may be utilised when the machine is started up (to thereby provide an initial measurement of spool diameter) and/or may be used periodically as the labelling machine is operating so as to periodically measure and update the diameter of the relevant spool. For example, the brake may be applied whilst the take up spool support is being rotated during labelling, the rotation of the take up spool causing movement of the dancing arm and thereby allowing determination of the take up spool diameter during labelling.

In one embodiment of the method described above, before carrying out the processing set out above, the controller is arranged to release the brake completely such that the dancing arm 28 assumes its home position (given action of the spring 130). This provides a known starting point for measurement of the angular displacement of the dancing arm 28 using the methods described above.

It will be appreciated that the sensor configured to produce a sensor signal indicative of the position of the moveable element of the labelling machine previously described is a sensor which measures relative displacement (in this case angular displacement) and uses this in combination with a known position (in this case the home position) in order to determine an absolute position (in this case angular position). In some embodiments the sensor configured to produce a sensor signal indicative of the position of the moveable element may be any appropriate sensor which measures relative displacement and uses this in combination with a known position in order to determine absolute position. In other embodiments the sensor configured to produce a sensor signal indicative of the position of the moveable element may only measure relative displacement. In further embodiments the sensor configured to produce a sensor signal indicative of the position of the moveable element may measure absolute position directly.

Some known labelling machines include a dancing arm which is mechanically linked to a brake assembly. In one example of these known labelling machines, if the tension within the label stock is too great then the tension in the label stock will cause the dancing arm to move so that a brake which forms part of the brake assembly and which is mechanically linked to the dancing arm is released to thereby reduce braking force acting on the supply spool support and thereby reduce the tension in the label stock. Conversely, if the tension in the label stock is too little, the tension in the label stock will cause the dancing arm to move such that the brake applies an increased braking force to the supply spool support to thereby increase tension in the label stock.

These known labelling machines suffer from several problems. First, the system can oscillate such that the dancing arm oscillates between two positions whilst trying to maintain tension in the label stock. This can be problematic due to the fact that the oscillating nature of the system may cause the label stock to become misaligned on the rollers which define the web path and hence become misaligned when it reaches the labelling peel beak. This may lead to incorrect positioning of labels on to a product or may lead to the labelling machine becoming jammed. Secondly, the oscillating nature of the dancing arm means that the movement of the dancing arm is not entirely predictable. As such, there is the possibility that the dancing arm will collide with other parts of the labelling machine or may present a hazard to a user operating the labelling machine. The labelling machine according to some of the embodiments described herein provides a way of obviating or mitigating at least one of these problems.

The dancing arm position is indicative of the tension within the label stock due to the fact that the dancing arm is mounted for rotation about axis A and is biased in the direction G by the spring 130. It will be appreciated that direction G in Figure 2 is opposite to direction G in Figure 7 because Figures 2 and 7 show opposite sides of the labelling machine, and in particular of the supply spool support and attached brake disc. Due to the fact that the spring 130 is a variable force spring (i.e. a spring which generally obeys Hooke's Law), the force exerted by the spring will vary with the position of the dancing arm 28 (and hence the amount of extension of the spring). In particular, the greater the extension of the spring i.e. the further the dancing arm 28 is rotated about axis A in the direction opposite to that indicated by G the greater the force exerted by the spring (in order to urge the dancing arm 28 in the direction G) will be. A component of the force applied by a spring 130 to the dancing arm will, in use, be applied to the label stock 20, thereby providing a tension within the label stock 20. Consequently, some embodiments described herein allow the dancing arm 28 to be maintained in a substantially constant position to thereby maintain tension in the label stock 18 substantially constant. For example, in some embodiments, the dancing arm may be maintained in a position such that if the labelling machine is orientated as shown in Figure 2 the dancing arm 28 is substantially horizontal.

In order to control the position of the dancing arm 28, an embodiment of the present invention is provided with a sensor configured to produce a sensor signal indicative of the position of the dancing arm 28. In this case the sensor is the magnetic sensor previously discussed which measures the change in magnetic field caused by the movement of the multipole strip magnet which is affixed to a portion of the dancing arm 28.

It will be appreciated that, although the moving element of this embodiment is a dancing arm, it is within the scope of the invention for the moveable element to be any appropriate moveable element which can define a portion of the web path. Furthermore, it will also be appreciated that although the sensor of this embodiment is the magnetic sensor as described, any appropriate sensor which is configured to produce a sensor signal indicative of the position of the moveable element may be used.

The present embodiment of the invention also includes a brake assembly configured to apply a variable braking force to one of said spool supports (in this case the supply spool support, however, in other embodiments, it may be the take up spool). The brake assembly may apply the variable braking force based upon the sensor signal indicative of the position of the moveable element. It will be apparent that the braking force applied to the supply spool support will resist rotation of the supply spool support (and hence of the supply spool supported by the supply spool support).

This arrangement has the advantage that, unlike the known labelling machines in which the dancing arm is mechanically linked to a brake of a brake assembly, the position of the dancing arm 28 is mechanically decoupled from the braking force which is applied to the supply spool by the brake assembly. By mechanically decoupling the brake assembly from the dancing arm it is possible for processing to be performed on the sensor signal indicating dancing arm position so as to calculate what braking force should be applied to the supply spool support by the brake assembly.

In one embodiment, the brake assembly previously discussed which utilises a controlled solenoid to provide a variable braking force via a brake belt acting on a brake disc may be used. In this situation, the braking force applied to the supply spool support 10 via the brake belt 76 and brake disc 74 depends upon the position of the armature 92 of the solenoid 94.

The control scheme used in order to control the current supplied to the coil of the solenoid in order to position the armature of the solenoid at a desired location relative to the coil has already been discussed and so will not be repeated here. However, that control scheme requires that the control algorithm as shown schematically in Figure 14 is provided with a set point signal SP(t). The set point signal SP(t) is determined by a second control algorithm which will be referred to as the dancing arm position control algorithm.

The dancing arm position control algorithm is implemented by a controller (which may or may not be the same controller as previously discussed controllers). A schematic view of the dancing arm position control system which includes the dancing arm position control algorithm implemented by the controller is shown schematically in Figure 17.

The controller is provided with a dancing arm position set point signal SP2(t) which is indicative of the desired position of the dancing arm (and hence the desired tension within the label stock) at any given time. For example, in some embodiments the dancing arm position set point signal SP2(t) may correspond to a position of the dancing arm such that if the labelling machine is the same as that in Figure 2, the dancing arm may be substantially horizontal. Of course, in other embodiments the dancing arm position set point signal SP2(t) may correspond to any desired dancing arm position. The dancing arm position set point signal SP2(t) is provided to one input of a subtractor 200. Another input of the subtractor 200 is supplied with a feedback signal FB2(t) (described below) and the subtractor 200 outputs an error signal E2(t) which is the difference between the dancing arm position set point signal SP2(t) and the feedback signal FB2(t).

The error signal E2(t) is supplied to three portions of the PID algorithm. These are the proportional component P, the integral component I, and the derivative component D. As can be seen from the figure, the proportional component P outputs a signal which is given by a constant K_{P2} multiplied by the error signal E2(t). The integral component I outputs a signal which is a constant K_{I2} multiplied by the integral of the error signal E2(t). The derivative component D of the algorithm outputs a signal which is given by a constant K_{D2} multiplied by a derivative of the error signal E2(t) with respect to time.

An adder 202 combines the signals output by the proportional P, integral I and derivative D components of the algorithm. The output of the adder 202 is a signal which is indicative of the desired position of the solenoid armature relative to the coil in order to produce a desired braking force which acts on the supply spool support. Consequently, the output of the adder 202 may be referred to as the set point signal SP(t) which forms part of the solenoid armature position control scheme described earlier. Consequently, the signal SP(t) output by the adder 202 is provided to a solenoid armature position control scheme 204 which was described above with reference to Figure 14.

By controlling the braking force which is applied by the brake assembly to the supply spool support, as previously discussed, this will affect the tension within the label stock and consequently affect the position of the dancing arm 28.

The position of the dancing arm 28 is measured by the magnetic sensor 206 which has previously been described. The magnetic sensor 206 outputs a sensor signal indicative of the position of the dancing arm. This signal constitutes the feedback signal FB2(t) which is provided to the first subtractor 200. It is preferred that the value of the signal FB2(t) should increase as output of the adder 202 (i.e. the control signal to the brake assembly via the solenoid armature position control scheme) is increased. If this is not the case then the same functionality may be achieved by swapping over the inputs to the subtractor 200.

Any appropriate gain constants K_{P2}, K_{I2} and K_{D2} may be used. In some embodiments, at least one of these constants may be equal to zero. However, in a preferred embodiment, all of these constants are non-zero.

As is common in the art, the gain constants K_{P2}, K_{I2} and K_{D2} of the dancing arm position control algorithm and the gain constants K_P, K_I and K_D of the solenoid armature position control algorithm may be determined empirically or by using commercially available PID tuning software. In either case, it is desirable that the value of the gain constants K_{P2}, K_{I2} and K_{D2} of the dancing arm position control algorithm are chosen such that the signal SP(t) output by the dancing arm position control algorithm to the solenoid armature position control algorithm has values which are substantially between the minimum braking value and the maximum braking value.

In some embodiments, the PID control algorithm may incorporate a dead band. In such embodiments, the error signal E2(t) is set to zero if the feedback signal FB2(t) is within a given range of the set point signal SP2(t). For example, the dead band may operate such that if the difference between the set point signal SP2(t) and the feedback signal FB2(t) is less than ±5% of the set point signal SP2(t) (or of the maximum possible value of the set point signal, which corresponds to a desired maximum braking value or a desired minimum braking value of the set point signal) then the error signal E2(t) is set to zero. If the feedback signal FB2(t) falls outside of this range then the error signal E2(t) is calculated in the manner already described by the subtractor 200.

As previously discussed, other embodiments incorporating a dead band may function in a slightly different manner. These embodiments operate in the same manner as the dead band previously described except that if the feedback signal FB2(t) falls outside of dead band then the error signal E2(t) is calculated by calculating the difference between the feedback signal FB2(t) and the edge of the dead band which is closest to the feedback signal FB2(t). For example, if the dead band is ±5% of the set point signal SP2(t), and the feedback signal FB2(t) has a value of the set point signal SP2(t) plus 5% of the set point signal SP2(t) plus μ, then the value of the error signal is -μ. Likewise, if the dead band is ±5% of the set point signal SP2(t), and the feedback signal FB2(t) has a value of the set point signal SP2(t) minus 5% of the set point signal SP2(t) and minus μ, then the value of the error signal is μ. In another embodiment, if the dead band is ±5% of the maximum possible set point (which corresponds to a desired maximum braking value or a desired minimum braking value of the set point signal), and the feedback signal FB2(t) has a value of the set point signal SP2(t) plus 5% of the set point signal SP2(t) plus μ, then the value of the error signal is -μ. Likewise, if the dead band is ±5% of the maximum possible set point signal SP2(t), and the feedback signal FB2(t) has a value of the set point signal SP2(t) minus 5% of the set point signal SP2(t) and minus μ, then the value of the error signal is μ.

In some embodiments, the derivative term D within the PID algorithm may be calculated not as a function of the derivative of the error signal E2(t), but rather by multiplying a speed of the dancing arm by a constant K_{s2}. The speed of the dancing arm may be calculated based upon the rate of change of the magnetic field detected by the magnetic sensor as the multipole magnetic strip attached to a portion of the dancing arm moves past the magnetic sensor. Alternatively, the speed of the dancing arm may be calculated based upon the rate of change of the signal output by the magnetic sensor.

In some embodiments, the dancing arm position control algorithm may be implemented such that if the measured dancing arm position differs from the desired dancing arm position set point in a direction such that the brake must be applied in order to bring the dancing arm position towards the set point, the algorithm may provide an output to the braking assembly which causes the braking assembly to apply the maximum braking force, the braking assembly only applying less than the maximum braking force when the measured dancing arm position differs from the desired dancing arm position set point in a direction opposite to that in which the brake must be applied in order to bring the dancing arm position towards the set point. When the measured dancing arm position differs from the desired dancing arm position set point in a direction opposite to that in which the brake must be applied in order to bring the dancing arm position towards the set point a PID algorithm as discussed above may be implemented in the usual way – in other words, a non-symmetric PID algorithm may be used.

In some embodiments, the integral term of the PID algorithm may have a relatively small constant K_{I2} or the set point for the integral term may be different to the set point for the proportional and differential terms. This may be useful in control systems which include an integral term because the integral portion of the PID algorithm 'remembers' previous positions of the dancing arm and hence attempts to apply an incorrect correction to that which is required. For example, the correction determined by the integral term may be greater than required, less than required or in the wrong direction. This problem may occur when a labelling machine is in a first steady state (for example, continual dispensing of labels at a first rate) and then changes to a second steady state (for example, continual dispensing of labels at a second rate). It may take time for the integral term to change its output from the ideal value for the first state, to the ideal value for the second state. In such a situation the integral term may be incorrect for a period of time after the operation of the labelling machine changes to the second state.

In order to mitigate the problem described above, in some embodiments, the set point for the integral component of the PID algorithm may be equivalent to a dancing arm position which, if the labelling machine is orientated as shown in Figure 2, is about 5 degrees clockwise from the set point position for the proportional and differential terms. Furthermore, in some embodiments, a limit to the degree of effect which the integral term may contribute to the overall amount of correction may be applied. For example, the contribution of the integral term to the applied braking may be limited. In one example, if the braking force is provided by a braking assembly including a stepper motor as shown in Figures 18 to 20, the contribution of the integral term of the PID sum may be limited to an equivalent of 50 microsteps of the stepper motor.

In the above described embodiment the controller implements the dancing arm position control algorithm such that the controller evaluates and applies the PID algorithm 1000 times per second. In other embodiments the controller may evaluate and control the dancing arm position at any appropriate rate.

It will be appreciated that although within the presently described embodiment the dancing arm position control scheme includes a PID algorithm, other embodiments of the invention may use any appropriate control scheme so as to control the position of the dancing arm (or other suitable moving element).

Some embodiments the labelling machine may include a motive means which is configured to propel the web along the web path from the supply spool towards the take up spool. For example, the motive means may include a single motor which drives the take up spool support, motors which drive each of the take up spool support and supply spool support, or a motor driving a platen roller in combination with a motor driving at least one of the take up spool support and supply spool support. The controller may be configured to control both the motive means and the brake assembly based upon the sensor signal (in this case the signal output by the magnetic sensor) so as to urge the dancing arm towards a desired position. Urging the dancing arm towards a desired position is equivalent to attempting to obtain a desired tension in the label stock, for the reasons previously discussed. Consequently, the controller enables control of the motive means and the brake assembly based upon the sensor signal so as to obtain a desired tension in the label stock and maintain said tension in the label stock between predetermined limits.

The brake assembly 70 within the described embodiments is said to be capable of applying a variable braking force. This is because, the position of the armature of the solenoid determines the extension of the spring 82 and therefore the braking force applied to the spool support. The armature is controlled so that it can take any position between the extents of movement of the armature.

In other embodiments, the brake assembly need not be capable of applying a variable braking force. For example, in some embodiments the brake assembly may only have two states: a braked state and an un-braked state. In the braked state the brake assembly applies a greater braking force to the spool support than in the un-braked state. In one embodiment, the brake assembly may be controlled by the controller as a function of the sensor signal indicative of the position of the movable member (e.g. dancing arm) such that when the controller determines that the sensor signal indicative of the position of the movable member indicates that more braking force applied to the spool support is required, then the controller commands the brake assembly to enter its braked state. Conversely, the brake assembly may be controlled by the controller as a function of the sensor signal indicative of the position of the movable member (e.g. dancing arm) such that when the controller determines that the sensor signal indicative of the position of the movable member indicates that less braking force applied to the spool support is required, then the controller commands the brake assembly to enter its un-braked state.

In another embodiment in which the brake assembly has only braked and un-braked states, the brake assembly (in particular, in this case, the coil of the solenoid of the brake assembly) may be provided with a pulse width modulated signal (in this case a voltage signal across the coil of the solenoid). A coil driver which is controlled by the controller may control the duty cycle of the pulse width modulated voltage signal applied across the coil as a function of the sensor signal provided to the controller which is indicative of the position of the movable member.

By varying the duty cycle of the pulse width modulated voltage applied across the coil of the solenoid, the current supplied to the coil can be changed. This results in a change in the position of the armature of the solenoid relative to the coil and hence a change in the braking force applied by the brake assembly to the spool.

The desired tension within the label stock (and hence the desired position of the dancing arm) may be dependent on various factors. For example the desired tension may be greater than the minimum tension required to keep the label stock taut enough as it passes a print head so that the printer can successfully print on the labels of the label stock. In addition, the desired tension may be dependent on the width and/or thickness of the web of the label stock (i.e. perpendicular to the web path). The desired tension may be chosen such that the stress within the web of the label stock (which is given by the tension in the web divided by the cross sectional area of the web; where the cross sectional area of the web is the product of the width of the web and the thickness of the web) is less than the breaking stress of the web. This ensures the tension in the web does not lead to the web of the label stock snapping. For example, in some embodiments, the desired tension in the web may be between 1N and 50N.

Although the above described embodiment discusses urging the moveable element (e.g. dancing arm) towards a desired position (for example, by setting a desired dancing arm position set point within the dancing arm position control algorithm) in order to control the tension of the label stock. In other embodiments the movable element may be urged towards a desired position for any other appropriate purpose.

For example, in some embodiments the movable element may be biased by a constant force spring (i.e. such that the spring does not obey Hooke's Law). In such embodiments, because the force applied to the movable element by the spring is substantially constant regardless of the position of the movable element, the tension of the label stock will be substantially constant regardless of the position of the movable element. It follows that, in such embodiments, moving the movable element will not change the tension in the label stock and hence urging the movable element towards a desired position cannot be used to set tension in the label stock.

Regardless of what type of biasing means biases the movable element, because the movable element defines a portion of the web path, movement of the movable element will cause the path length of the web path between the supply and take-up spools to change. Changing the path length of the web path between the supply spool and take-up spool may allow differences between the speed at which the take up spool is taking up label stock and the speed at which the supply spool is paying out label stock to be accommodated. For example, if the take up spool support is driven to advance label stock along the web path and the take up spool support is accelerated, the take up spool may accelerate more quickly than the supply spool. This may be because the supply spool has a relatively large moment of inertia. This difference in acceleration between the take up spool and supply spool may be compensated for by the dancing arm moving so as to reduce the path length of the web path between the supply spool and take-up spool. Conversely, if the take up spool support is driven to advance label stock along the web path and the take up spool support is decelerated, the take up spool may decelerate more quickly than the supply spool. Again, this may be because the supply spool has a relatively large moment of inertia. This difference in deceleration between the take up spool and supply spool may be compensated for by the dancing arm moving so as to increase the path length of the web path between the supply spool and take-up spool.

If the movable element has a limited extent of movement, between a first extent at which the path length of the web path between the supply and take up spools is a maximum, and a second extent at which the path length of the web path between the supply and take up spools is a minimum, it may be desirable to urge the movable element towards a position which minimises the likelihood that the movable element will reach the limits of its extent of movement in trying to compensate for differences between the speed at which the take up spool is taking up label stock and the speed at which the supply spool is paying out label stock during operation of the labelling machine. If the movable element reaches a limit of its extent of movement then it will be unable to compensate for any further difference between the speed at which the take up spool is taking up label stock and the speed at which the supply spool is paying out label stock. The inability to compensate for any further difference between the speed at which the take up spool is taking up label stock and the speed at which the supply spool is paying out label stock may result in excess tension in the label stock (which may result in breakage of the label stock) or may result in too little tension in the label stock (which may result in the label stock becoming slack).

In some embodiments the position which minimises the likelihood that the movable element will reach the limits of its extent of movement may be a position which is substantially equidistant between the limits of its extent of movement. In other embodiments, the characteristics of the labelling machine may be such that the position which minimises the likelihood that the movable element will reach the limits of its extent of movement may be a position which is closer to one of the limits of its extent of movement than the other. For example, in a labelling machine in which the take up spool support is driven to advance label stock along the web path and in which the supply spool can be braked, the position which minimises the likelihood that the movable element will reach the limits of its extent of movement may be closer to the limit of the extent of the movement of the movable element which corresponds to the maximum path length of the web path between the supply and take-up spools. The reason for this is that a brake on the supply spool support makes it a lot less likely that there will be a difference between the speed at which the take up spool is taking up label stock and the speed at which the supply spool is paying out label stock when the take-up and supply spools are decelerating. As such, the movable element is less likely to have to move in a direction towards the limit of the extent of movement of the movable element which corresponds to the maximum path length of the web path between the take-up and supply spools. It follows that the position which minimises the likelihood that the movable element will reach the limits of its extent of movement may be closer to the extent of the movement of the movable element which corresponds to the maximum path length of the web path between the supply and take-up spools.

Figures 18 and 19 show a perspective view of a portion of a further embodiment of labelling machine of the type shown in Figure 1 or Figure 2. Figure 18 shows the dancing arm 28 and an alternative brake assembly 70a. The brake assembly 70a may be substituted for the brake assembly 70 shown in Figures 5 to 11.

As before, the dancing arm 28 and supply spool support (not shown within Figure18) are both mounted for individual rotation about a common axis A. In other embodiments, the supply spool support and dancing arm 28 may rotate about their own respective axes.

The brake assembly 70a is configured to apply a variable braking force to the supply spool support, the braking force resisting rotation of the supply spool support. Although the brake assembly 70a is configured to apply braking force to the supply spool support, in other embodiments the brake assembly 70a may be used to apply a braking force to the take-up spool support.

The brake assembly 70a includes a brake disc 74 which is attached to the supply spool support such that it co-rotates with the supply spool support (and consequently any supply spool which is supported by the supply spool support).

The brake assembly also includes a brake belt 76 which extends around part of the outer circumference 88 of the brake disc 74. The brake belt 76 is fixed at a first end 76a to an attachment pin 78 which is mounted to a mounting block 80a which is fixed so that it does not rotate with the supply spool support. The brake belt 76 is attached at a second end 76b to an end piece 82a. The end piece 82a includes a socket 82b.

In the embodiment shown, the brake belt 76 has a generally rectangular cross-section and it contacts a portion of the outer circumference 88 of the brake disc 74 which has a substantially flat surface parallel to the axis A. That is to say, the substantially flat circumferential surface 88 of the brake disc 74 corresponds to the substantially flat surface of the belt 76 which engages the outer circumference 88 of the brake disc 74. It will be appreciated that in other embodiments of the labelling machine, the outer circumferential surface of the brake disc and the brake belt may have any appropriate corresponding profile. For example the outer circumferential surface of the brake disc may include a v-shaped groove which cooperates with generally circular cross-section brake belt.

The brake belt 76 may be made from any appropriate material. For example, the brake belt may be made of a combination of fabric and polymeric material, a combination of metal and polymeric material or of a polymeric material on its own. In one embodiment the brake belt is made out of steel reinforced polyurethane. In one embodiment the brake belt may be 10mm wide, 280mm long and formed from material referred to as Habasit TG04. In another embodiment the brake belt is a T2.5 synchroflex timing belt which has a width of 10mm and a length of 280mm. In this case the belt is formed from steel reinforced polyurethane and has teeth having a standard T profile according to DIN7721. Such belts are available from Beltingonline, Fareham, UK. Because this belt has teeth it is mounted such that the flat surface of the belt (i.e. the opposite surface to that which has the teeth) is the surface which contacts the brake disc. In other embodiments the belt may be mounted such that the toothed side of the belt contacts the brake disc. In the above described embodiments the brake disc (which may be of any appropriate size in other embodiments) has a diameter of 100mm.

A generally disc-shaped cam 82c (also referred to as cam piece) is mounted on the end of a shaft 82d which is supported for rotation relative to the mounting block 80a about an axis F via a bearing which supported by the mounting block 80a. The cam piece is 82c is mounted to the shaft 82d such that the cam piece 82c is eccentric with respect to axis F of rotation of the shaft 82d. The cam piece 82c is mounted to the shaft 82d such that the cam piece 82c rotates with the shaft 82d when the shaft 82d rotates about axis F. Furthermore, the cam piece 82 is received by the socket 82b of the end piece 82a such that the end piece 82a may freely rotate relative to the cam piece 82c. For example, a bearing may be located between cam piece 82c and end piece 82a to enable relative rotation therebetween.

The shaft 82d and attached cam piece 82c may be driven for rotation about axis F by any appropriate drive means. In some embodiments the drive means includes a position controlled motor which drives the shaft 82d. The position controlled motor may be any appropriate position controlled motor, for example a servo controlled motor or a stepper motor. In the present embodiment the shaft 82d is the shaft of the position controlled motor, the position controlled motor (indicated schematically by broken lines in Figure 19) being mounted to the mounting block 80a. In other embodiments the shaft 82d may be mechanically linked to the position controlled motor by an appropriate linking arrangement. For example, the position controlled motor and shaft may be mechanically linked by a belt, chain or the like. In other embodiments the cam (cam piece) may be driven for rotation by a position controlled motor in any appropriate manner. For example, in some embodiments the cam may be driven for rotation by the position controlled motor without driving an intermediate shaft to which the cam is mounted – for example a belt driven by the position controlled motor may directly drive the cam.

In the described embodiment the position controlled motor is a stepper motor. In particular it is a 42mm frame size Sanyo Denki motor (part number 103H5205-5210) marketed by Sanko Denki Europe SA, 95958 Roissy Charles de Gaulle, France.

Referring now to Figure 19, the position controlled motor and attached cam piece 82 are shown in an initialisation position. It will be appreciated that if the position controlled motor is energised so as to rotate the shaft 82d and attached cam piece 82c in a clockwise direction (as shown in Figure 19), then the end piece 82a may be urged in a direction (e.g. towards the brake disc 74) such that the brake belt 76 is loosened around the brake disc 74. In other words, the tension in the brake belt 76 is reduced. Put another way, when the shaft 82d and attached cam piece 82c are rotated in a clockwise direction, the cam will urge (in this case via the end piece 82a) at least a portion of the second braking surface (the surface of the brake belt 76b which may contact the brake disc 74 in order to produce the braking force) towards the first portion of the belt 76a or in other words away from the cam or the second portion of the belt 76b (along the path of the brake belt between first and second ends 76a, 76b), thereby urging the second braking surface (i.e. the relevant surface of the belt 76) in a direction out of contact with the first braking surface (i.e. the braking surface of the brake disc 74). Consequently, energising the position controlled motor such that it causes the shaft 82d and attached cam piece 82c to rotate in a clockwise direction from the initialisation position shown in Figure 19 will cause the braking force exerted by the belt 76 on the braking disc 74 (and hence attached spool support) to be reduced.

Conversely, if the position controlled motor is energised so as to rotate the shaft 82d and attached cam piece 82c in an anti-clockwise direction from the initialisation position shown in Figure 19, then this will cause at least a portion of the brake belt 76 to be moved away from the first end 76a of the brake belt 76 (along the belt path between the first and second ends 76a, 76b of the belt 76). In other words, when the position controlled motor is energised such that the shaft 82d and attached cam piece 82c are rotated in an anti-clockwise direction from the position shown in Figure 19, the tension in the brake belt 76 is increased, thereby increasing the braking force exerted on the brake disc 74. Put another way, then the cam (cam piece) is rotated in an anti-clockwise direction by the position controlled motor, the cam (cam piece) urges at least a portion of the second braking surface (surface of the belt 76 which contacts the brake disc 74 so as to apply the braking force) in a direction such that the second braking surface is urged towards (e.g. into contact with) the first braking surface (i.e. the outer circumference of the brake disc 74). In particular, the cam

(cam piece 82c) urges a portion of the second braking surface towards the cam or second portion of the belt 76b, or in other words away from the first portion of the belt 76a and retaining pin 78 (along the path of the brake belt between first and second ends 76a, 76b).

In the way described above, the braking force applied to the spool support by the frictional interaction between the brake disc 74 and brake belt 76 can be controlled by controlling the position of the cam (e.g. cam piece 82c) using the position controlled motor. The brake assembly 70a is capable of applying a variable braking force to the supply spool support via the attached brake disc 74. Within this context, variable braking force may be taken to mean a range of braking forces, not merely a first braking force when the brake assembly is in a brake engaged position and a second lesser braking force when the brake assembly is in a brake disengaged position. For example, controlling the position controlled motor such that, in the context of Figure 19, it causes the cam piece 82c to be rotated anti-clockwise will increase the braking force on the spool support, whereas controlling the position controlled motor such that the cam piece 82c is rotated clockwise will result in a reduced braking force applied to the spool support. It will be appreciated that within the embodiment shown in Figure 19, if the cam piece 82c were rotated by more than about 90º clockwise or anti-clockwise from the initialisation position shown in Figure 19, then the situation will be reversed (whilst the cam piece 82c is rotated by more than about 90º clockwise or anti-clockwise from the initialisation position) – i.e. further clockwise movement will result in increased braking force and anti-clockwise movement will result in decreased braking force.

Although within the previously described embodiment the first braking surface is the outside diameter of the brake disc 74 and the second braking surface is the surface of the brake belt 76, which can contact the brake disc, in other embodiments the first and second braking surfaces may be any appropriate first and second braking surfaces provided that when the first and second braking surfaces are urged into contact (or together, or towards one another) via the position controlled motor, friction between the first and second braking surfaces thereby producing the braking force. For example, the second braking surface may, in some embodiments, not be a brake belt – for example, it may be a brake pad, brake shoe etc. Likewise, the first braking surface may not form part of a brake disc. Any appropriate cooperating first and second braking surfaces and corresponding braking method may be used.

A resilient biasing member (which in this embodiment is a spiral spring 82e, but may be any other appropriate resilient biasing member) biases the shaft 82d and attached cam piece 82c in a direction such that, within Figure 19, the shaft 82d and cam piece 82c are urged in an anti-clockwise direction.

In the illustrated embodiment the spiral spring has a 25.4mm outer diameter and an 11mm inner diameter. The spring consists of 4.5 turns of 0.31mm thick spring steel having a width of 3.20mm and produces 33.6Nmm of force at 1.5 turns of deflection from its natural state. Of course, any appropriate type of spiral spring may be used in other embodiments.

The spiral spring 82e is fixed at a first, outer end to the mounting block 80a by fixing bolt 82f and at a second inner end (not shown) to the cam piece 82c. The resilient biasing member biases the cam piece 82c in a direction to cause the brake belt 76 to contact the outer circumference 88 of the brake disc 74 so as to apply a braking force to the brake disc 74 and therefore resist rotation of the brake disc 74 and attached spool support. The biasing of the cam by the resilient biasing member (and hence the biasing of the brake belt towards (e.g. into contact with) the brake disc) ensures that when no power is supplied to the position controlled motor (for example when the labelling machine is powered down), the resilient biasing member causes a braking force to be applied to the brake disc 74 and hence the spool support. This may help to prevent the spool support from undesirably rotating when the labelling machine is powered down.

During use of the labelling machine, if it is desired to reduce the amount of braking force applied by the brake belt 76 to the brake disc 74 (and hence to the spool support) the position controlled motor is energised such that the biasing force produced by the resilient biasing means is overcome in order to enable rotation of the cam in a clockwise direction as shown in Figure 19.

As previously discussed, by controlling the position controlled motor such that the rotary position of the shaft 82d and attached cam piece 82c is controlled, the amount of braking force applied to the spool support via the brake disc 74 can be varied. A position controlled motor controller may be used to control the position of the position controlled motor and hence the position of the cam piece 82c to thereby control the braking force. The position controlled motor controller may be configured such that it is programmed with a position which corresponds to a maximum braking force to be applied and a position which corresponds to a minimum braking force to be applied. In such embodiments, in order to control the braking force applied by the braking assembly, the position controlled motor is controlled such that, as required, its position is the position which corresponds to the maximum braking force; its position is the position which corresponds to the minimum braking force; or its position is between these two positions.

In some embodiments, the cam piece 82c may be urged in a direction by a resilient biasing member which urges the brake assembly to apply a braking force to one of the spool supports as previously discussed. The resilient biasing member acting on the cam may define a bias force defined maximum braking position of the cam and attached motor. The bias force defined maximum braking position corresponds to the position of the cam piece and attached motor when the resilient biasing means applies a given biasing force to the cam piece when the motor of the braking assembly is de-energised.

The position controlled motor controller may be programmed with the angular distance between a maximum braking position (for example the bias force defined maximum braking position, although any appropriately defined maximum braking position may be used) and a minimum braking position of the position controlled motor. The angular distance may, for example, be a number of encoder pulses produced by a servo motor or a number of steps of a stepper motor. However, any appropriate parameter may be programmed into the controller which corresponds to the angular distance between the maximum braking position and the minimum braking position of the position controlled motor. In such an embodiment, when the machine is started up, the position controlled motor controller will know that the current position of the position controlled motor is a maximum braking position which is equivalent to the bias force defined maximum braking position (because in the powered-down state of the labelling machine the resilient biasing means has biased the cam piece into the bias force defined maximum braking position) and that the minimum braking position of the position controlled motor is substantially a clockwise rotation of the cam piece by said known angular distance between the maximum braking position and the minimum braking position.

For example, if the position controlled motor is a stepper motor, then the position controlled motor controller may be programmed with information about the angular distance between the maximum braking position of the stepper motor and the minimum braking position of the stepper motor in the manner of a known number of motor steps. Of course, the exact number of steps will depend on many variables such as the particular type of stepper motor used, the type of mechanical linkage between the stepper motor and the cam piece, and the geometry of the braking arrangement.

In one embodiment of the present invention, the position controlled motor is a stepper motor. In this embodiment the stepper motor has 200 full steps per complete rotation. The stepper motor is driven by a stepper motor driver such that it is microstepped, as is well known in the art. In this embodiment each full step is split into 8 microsteps. Therefore, in this embodiment, there are 1600 microsteps per complete rotation. Other embodiments may utilise a stepper motor which has any appropriate number of steps/microsteps per full rotation.

The cam piece 82c may be urged towards a bias force defined maximum braking position by a resilient biasing member as previously discussed. When the labelling machine (and hence stepper motor) is in a powered off state the cam piece and attached stepper motor will be biased into the bias force defined maximum braking position by the resilient biasing member. When the labelling machine (and hence stepper motor) is energised from the powered off state the cam piece and stepper motor will enter the initialisation position as shown in Figure 19. The initialisation position may be slightly different to the bias force defined maximum braking position. The reason for this is that, when energised, the stepper motor rotor will move from the bias force defined maximum braking position to the closest stable position of the stepper motor rotor relative to the stepper motor stator. This may result in a movement between the bias force defined maximum braking position and initialisation position of up to 2 steps (equivalent to 16 microsteps in this case) either clockwise or anticlockwise. In order to compensate for the fact that in the initialisation position the cam may cause the brake belt to apply a braking force which is less than the bias force defined maximum braking force, upon initialisation the controller commands the stepper motor to rotate 2 steps (16 microsteps) anticlockwise (as shown in Figure 19) from the initialisation position. This position may be referred to as the compensated maximum braking position. The controller stores this position as the position of the stepper motor which corresponds to maximum applied braking force. The controller also sets the position of the stepper motor which corresponds to minimum applied braking force to be 355 microsteps clockwise rotation from the position of the stepper motor which corresponds to maximum applied braking force.

It will be appreciated that the compensated maximum braking position (and hence compensated maximum braking force) will be the same as the bias force defined maximum braking position in the case where the initialisation position is 2 steps clockwise of the bias force defined maximum braking position. Otherwise, if the initialisation position is 1 step clockwise of the bias force defined maximum braking position, the same as the bias force defined maximum braking position, or 1 or 2 steps anti-clockwise of the bias force defined maximum braking position, then the compensated maximum braking position will be anti-clockwise of the bias force defined maximum braking position, and hence the braking force at the compensated maximum braking position may be greater than the braking force at the bias force defined maximum braking position. In the case that the position controlled motor is a stepper motor, the position controlled motor controller may include a stepper motor driver. Where the position controlled motor is another type of motor, the person skilled in the art will appreciate that the position controlled motor controller will include appropriate drive means for the relevant type of motor.

The position controlled motor controller may replace the solenoid armature position control scheme 204 within the dancing arm position control algorithm shown schematically in Figure 17. The constants K_{P2}, K_{I2}, and K_{D2} within the dancing arm position control algorithm may be suitably adjusted to ensure that the set point value SP(t) provided to the position controlled motor controller fall within a suitable range for the position controlled motor controller. The position controlled motor controller may then be configured to convert the set point signal SP(t) into a desired position of the position controlled motor which is between the maximum braking position and minimum braking position. For example, in one embodiment $K_{P2} = 0.6$, $K_{I2} = 0.005$, and $K_{D2} = 0.6$.

In general terms, the dancing arm position control algorithm will co-operate with the position controlled motor controller such that if the dancing arm position is different to the desired dancing arm position, the position controlled motor controller will actuate the braking assembly in order to try to move the dancing arm towards to desired dancing arm position. In general, the greater the difference between the dancing arm position and the desired dancing arm position, the greater the magnitude of the change in dancing arm position that the position controlled motor controller will effect in order to attempt to correct the dancing arm position. For example, if the position controlled motor is a stepper motor, the greater the difference between the dancing arm position and the desired dancing arm position, the greater the number of steps the position controlled motor controller will effect in a given time in order to attempt to correct the dancing arm position. It will be appreciated that the exact behaviour of the position controlled motor controller will be determined by the dancing arm position control algorithm.

In embodiments of the invention in which the braking assembly includes a position controlled motor in the form of a stepper motor, the controller may be configured such that it implements a control scheme for controlling the stepper motor which reduces the likelihood of the stepper motor stalling and thereby preventing operation of the braking assembly. Such a control scheme may include any number of the following aspects. First, a ‘start delay’ may be used which prevents the stepper motor from executing a step until a predetermined amount of time has passed from the motor coils of the stepper motor being energised. This helps to ensure that the motor is in a steady state before it starts operating. In some embodiments the predetermined amount of time is 2ms, but any appropriate time may be used in other embodiments. Secondly, a turn-around delay may be implemented. This prevents the stepper motor from executing a step in the opposite direction to that in which the motor is currently travelling within a predetermined amount of time of the previous step. In some embodiments the predetermined amount of time is 5ms, but any appropriate time may be used in other embodiments.

As previously discussed, the brake assembly 70a is configured such that in a powered down state of the labelling machine the brake assembly applies a braking force to the spool support such that the spool support and supported spool is substantially prevented from rotating. In some situations it may be desirable to provide a manual override for the brake assembly which enables a user to manually reduce the braking force applied by the brake assembly whilst the machine is in a powered-down state. For example, if the spool support which is braked by the braking assembly is the supply spool support, and if it is desired to mount a new roll of label stock to the supply spool support whist the machine is powered off, it may be beneficial for the supply spool support and attached supply spool to be able to rotate so that the label stock can be mounted on the supply spool, pulled from the supply spool, fed along the label path and then attached to the take up spool support.

Figure 20 shows an arrangement which enables the braking force applied by the braking assembly to be manually reduced whilst the labelling machine is in a powered down state. In this embodiment the dancing arm 28a includes a brake release arm 28b which is attached to the dancing arm 28a such that the brake release arm 28b co-rotates with the dancing arm 28a.

A brake release catch 28c is mounted on the shaft 82d which supports the cam piece 82c (the cam piece is not shown in Figure 20, but located on the other side of the mounting block 80a to the brake release catch 28c). In the present embodiment the shaft 82d is the shaft of the position controlled motor. The shaft 82d extends out of both ends of the position controlled motor such that the cam piece 82c is mounted to the portion of the shaft 82d which extends out of a first end of the position controlled motor (and which in this case is on a first side of the mounting block 80a), and such that the brake release catch 28c is mounted to a portion of the shaft 82d which extends out of a second end (opposite to the first end) of the position controlled motor (and which in this case is on a second side (opposite the first side) of the mounting block 80a).

It will be appreciated that, whilst in this embodiment the brake release catch is mechanically linked to the second braking surface via the shaft 82d, cam piece 82c and end piece 82a, in other embodiments the brake release catch may be mechanically linked to the second braking surface in any appropriate manner. For example, in some embodiments the second braking surface may not be mechanically linked to a position controlled motor and the brake release catch may be mechanically linked to the second braking surface by another method. The brake release arm 28b and brake release catch 28c are configured such that when the dancing arm 28a is rotated clockwise as shown in Figure 20 beyond a certain position, the brake release arm 28b engages the brake release catch 28c. Once the brake release arm 28b and brake release catch 28c are engaged, further clockwise rotation of the dancing arm 28a causes the brake release catch 28c to rotate the shaft 82d in anti-clockwise direction as shown in Figure 20. This causes the brake release catch 28c to rotate the shaft 82d in an anti-clockwise direction as shown in Figure 20. Referring now to Figure 19, rotation of the shaft 82d within Figure 20 in an anti-clockwise direction as shown in Figure 20 will result in the cam piece 82c within Figure 19 rotating in a clockwise direction as shown in Figure 19, thereby reducing tension in the brake belt 76 and hence releasing the brake, reducing the braking force applied by the brake assembly to the spool support. It follows that, using the brake release arrangement shown in Figure 20, if an operator wants to release the braking force applied by the braking assembly, this can be achieved by the operator rotating and holding the dancing arm in a clockwise direction as shown in Figure 20 such that the brake release arm 28b and brake release catch 28c engage so as to cause the braking force applied by the brake assembly to be released as previously discussed. In some embodiments the dancing arm may be rotated and held in a clockwise direction as shown in Figure 20 by the action of a user passing label web from a new supply spool mounted to the supply spool support around the dancing arm and the user pulling the label web along the web path to the take up spool support. In this way, when a user is feeding label web along the web path to the take up spool support from a newly mounted supply spool, the brake assembly is automatically released thereby enabling the supply spool support to pay out label web from the supply spool.

Although the above described braking assembly utilises a position controlled motor, in other embodiments any appropriate type of motor may be used, providing the control scheme for its operation is suitably modified. For example, in some embodiments a torque controlled motor such as a DC motor may be used. In such an embodiment, as is well known in the art, the amount of braking force applied by the motor is proportional to the current supplied to the motor. Consequently, the control scheme for such an embodiment may be configured such that the current supplied to the motor is a function of the braking force required. For example, the output of the dancing arm position control algorithm may be a current determined by the dancing arm position control algorithm which is provided to the motor.

Furthermore, in the above described braking assembly movement of the motor is transmitted to the brake belt via a cam. In other embodiments any appropriate means may be used for transmitting movement of the motor to the brake belt (or any suitable second braking surface). For example, the motor may be linked to a crank which is moved by the motor so a portion of the brake belt is wound on to the crank or unwound from the crank by the motor in order to urge the second braking surface towards (e.g. into contact with) the first braking surface (or otherwise) and thereby control the braking force applied to the spool support.

It will be apparent from the foregoing description that the various features described can be used alongside one another in a single labelling machine. That is, unless the context otherwise requires, or unless explicitly stated to the contrary herein, it is envisaged that the features described can advantageously be used in a single labelling machine to realise the various benefits described herein. That said, it will also be appreciated that many of the features described herein can be used separately of one another and as such a labelling machine including one or more (but not necessarily all) of the features described herein is envisaged.

Where a labelling machine including various features described above is implemented, the following processing, as illustrated in Figure 21, may be carried out at start-up of the labelling machine.

At S1 the controller determines the position of the dancing arm 28. In order to do this the controller sends a control signal to the position controlled motor so as to energise the position controlled motor to rotate the shaft 82d and attached cam piece 82c in a clockwise direction (as shown in Figure 19), to the extent that substantially no braking force is applied by the brake belt 76 to the brake disc 74. Alternatively, the controller sends a control signal to the solenoid so as to energise the solenoid such that sufficient current is provided to the coil of the solenoid 94 to move the armature 92 of the solenoid 94 in the direction F to the extent that substantially no braking force is applied by the brake belt 76 to the brake disc 74.

Consequently, the supply spool support 10 (and the supported supply spool) is free to rotate.

Whilst the supply spool support 10 is free to rotate, the force provided by spring 130 on the dancing arm 28 is sufficient to rotate the dancing arm 28 about axis A in the direction G. In order to enable the dancing arm 28 to rotate about axis A in the direction G the supply spool support 10 may also rotate about axis A in the direction G (as previously discussed, the supply spool support 10 is free to move because the brake assembly is not applying a braking force to the supply spool support). The dancing arm 28 rotates about axis A in the direction G until it reaches the home position which is detected by the home position sensor. Processing passes from step S1 to step S2.

At steps S2 to S4 the controller determines the diameter of the take up spool supported by the take up spool support 12.

At S2 the controller places the supply spool support brake assembly under the control of the dancing arm position control algorithm, as described in relation to Figure 17. As such the controller supplies a control signal to the position controlled motor and attached cam piece 82c which will act to apply the brake fully, until such a time as the dancing arm moves from the home position beyond the setpoint. This allows tension to be introduced into the label web. Alternatively, in embodiments including a solenoid, the controller sends a control signal to the solenoid 94 (and more particularly to the coil driver 114) such an amount of current (which may be no current) is provided to the coil of the solenoid 94 in order for the armature 92 of the solenoid 94 to move sufficiently in the direction F’ such that the brake is applied fully, until such a time as the dancing arm moves from the home position beyond the setpoint. Again, this allows tension to be introduced into the label web.

The label stock is then tensioned as follows. At step S3 the controller energises the motor 14 so that it rotates the take up spool support 12 to wind web of the label stock on to the take up spool support 12. As this happens, the tension in the web of the label stock increases. Increasing tension in the web of the label stock causes the web of the label stock to apply greater force to the roller 32 of the dancing arm 28. The force applied by the label stock to the dancing arm opposes the spring biasing of the dancing arm 28 in the direction G by the spring 130. Consequently, increasing tension in the label stock due to rotation of the take up spool support causes the dancing arm 28 to move in the opposite direction to G. As previously discussed, the position of the dancing arm 28 is indicative of the tension in the label stock. When the controller is provided with a signal from the sensor which senses the position of the dancing arm which indicates that the dancing arm is at a desired position which is equivalent to a desired tension, processing then advances to step S4. In some embodiments the desired tension is a predetermined or calculated tension. In other embodiments the desired tension may be any appropriate tension other than no tension – that is to say, the desired tension may be any appropriate tension which removes slack from the label stock.

At step S4 the controller commands the motor 14 to rotate a given number of steps (for example 50 – 150 steps) so as to wind more label stock on to the take up spool support 12. This causes the dancing arm 28 to move from its position at the beginning of S4. Based upon the number of commanded steps the motor 14 advances in step S4 and on the movement of the dancing arm 28 detected by the dancing arm movement sensor (also referred to as the sensor configured to produce a sensor signal indicative of the position of the moveable element) during the rotation of the motor 14 the controller calculates the diameter of the spool supported by the take up spool support 12. This process has been discussed in detail above.

At S5 the controller determines the pitch length L_P of the label stock 18. This is achieved as follows. In this embodiment, this is done with the supply spool support brake assembly , under control of the dancing arm position control algorithm, although in other embodiments this need not be the case. For example, in other embodiments the pitch length of the label stock may be determined with the brake assembly released (i.e. not applying a braking force). Again, in order to release the brake assembly, the controller sends a control signal to the solenoid 94 (and more particularly to the coil driver 114) such that sufficient current is provided to the coil of the solenoid 94 to move the armature 92 of the solenoid 94 in the direction F to the extent that substantially no braking force is applied by the brake belt 76 to the brake disc 74. Consequently, the supply spool support 10 (and the supported supply spool) is free to rotate.

The controller advances the motor which drives the take up spool support. The controller also monitors the signal 56 provided by the detector 52 of the gap sensor. The controller counts the number of steps the motor 14 is commanded to advance whilst a label is sensed and, as previously described, uses this information and the diameter of the spool supported by the take up spool support (determined in step S4) to determine the length of a label L_L. Likewise, the controller counts the number of steps the motor 14 is commanded to advance whilst a gap is sensed and, as previously described, uses this information and the diameter of the spool supported by the take up spool support (as determined in step S4) to determine the length of a gap L_G. The controller then sums L_P and L_G in order to calculate L_P.

In some embodiments, the controller may count the number of steps the motor 14 is commanded to advance whilst a plurality of labels and gaps are sensed by the detector of the gap sensor. The controller may then work out the label length, gap length and/or pitch length by averaging the measured label length, gap length and/or pitch length. For example, the controller may count the number of steps the motor 14 is advanced whilst the controller monitors the signal 56 and senses that a total of three labels and three gaps have passed the gap sensor. The controller may then divide the number of steps counted by the controller by three to give the average pitch length L_P of the labels as a number of steps. This average pitch length of the labels given in steps can then be used in combination with the measured diameter of the take up spool in order to determine the label pitch in a desired unit.

In some embodiments in which the controller counts the number of steps the motor is commanded to advance whilst a plurality of labels and gaps are sensed by the detector of the gap sensor, the controller may count the number of steps whilst the motor is commanded to advance a number of steps which is at least a determined number of steps which is equivalent to a predetermined length of label stock. The controller may determine the determined number of steps N_S using the diameter of the take up spool (which may be obtained in any manner discussed within) and the predetermined length of label stock L_{LP} according to the equation:

$$N_S = \frac{2L_{LP}}{A_S D_S} \qquad (19)$$

where A_S is the angle by which the spool support rotates per step of the motor and D_S is the spool diameter.

The predetermined length of the label stock is preferably in excess of twice the greatest pitch length of label stock that will be utilised by the labelling machine. The predetermined length of label stock may be 300mm.

In some labelling machines the main source of inaccuracy in measuring the pitch length of the label stock may be the edge detection performance of the gap sensor. For instance the gap sensor may detect edges to within an error of +/- 0.25mm. Therefore the distance between two edges may be measured within an error of +/- 0.5mm. Shorter labels (hence label stock with a shorter label pitch) will have an error which is proportionally larger compared to that of longer labels (hence label stock with a longer label pitch). For this reason, it may be advantageous in certain embodiments to measure the length of a plurality of labels and gaps (as discussed above) and determine an average label length, average gap length and/or average pitch length.

In some embodiments erroneous data regarding measured label length or measured gap length may be rejected whilst determining an average label length, an average gap length and/or an average pitch length.

One potential cause of erroneous data may be missing labels. For example, if a label is missing then it will cause the controller to measure a large gap between the labels either side of where the missing label would have been located, the gap being larger than the standard gap between adjacent labels. It will be appreciated that if the length of such a large gap resulting from a missing label were measured and then averaged in addition to the length of other, standard, measured gaps, then this would result in an incorrect average of greater length than the average length of standard gaps which would otherwise be determined.

In some embodiments erroneous data regarding measured gap length is rejected as follows. The controller monitors the measured gap length for each measured gap. The controller may check that the measured gap length is above a minimum predetermined gap length and/or below a maximum predetermined gap length. In one embodiment the minimum predetermined gap length is 1mm and the maximum predetermined gap length is 10mm, however, it will be appreciated that other embodiments may use any appropriate minimum and/or maximum predetermined gap length. If a measured gap length is not greater than the minimum predetermined gap length and/or not less than the maximum predetermined gap length, then such a measured gap length is not included by the controller when determining an average gap length of the label stock and/or an average pitch length of the label stock.

In some embodiments erroneous data regarding measured label length is rejected as follows. The controller monitors the measured label length for each measured label. The controller may check the measured label length and compare it to the measured label length for the preceding measured label. If the difference in length between the measured label length and the measured label length of the preceding measured label is greater than a predetermined amount then the measured label length is not included by the controller when determining an average label length of the label stock and/or an average pitch length of the label stock. In one example the predetermined amount is 50% of measured label length for the preceding measured label. It will be appreciated that in other embodiments the predetermined amount may be any appropriate amount.

In some embodiments erroneous data regarding measured label length is rejected as follows. The controller monitors the measured label length for first measured label after the labelling machine has been switched on. The controller may then check the measured label length and compare it to the measured label length for the subsequent measured label. If the difference in length between the measured label length of the first measured label and the measured label length of the subsequent measured label is greater than a predetermined amount then the measured label length of the first label is not included by the controller when determining an average label length of the label stock and/or an average pitch length of the label stock. In one example the predetermined amount is 50% of measured label length of the subsequent label. It will be appreciated that in other embodiments the predetermined amount may be any appropriate amount.

At step S6 the controller positions the leading edge of a label at the edge of the labelling peel beak 30. This is achieved as follows. The controller monitors the signal 56 provided by the detector 52 of the gap sensor so as to detect the leading edge of a label. The controller then commands the motor 14 to advance a calculated number of steps such that the label stock advances by a linear displacement equal to the distance D_B (as shown in Figure 3) between the detector 52 and the edge 66 of the labelling peel beak 30. The number of steps is calculated by dividing the distance D_B by the radius of the take up spool and by the rotation angle per step in radians.

At S7 the labelling machine is ready to operate.

During operation, periodically steps S8 and S9 are carried out.

At step S8 the controller calculates and updates the diameter of the spool mounted to the supply spool support 10.

The process of calculating and updating the supply spool diameter is first discussed below in the case where the movable element (dancing arm) does not move during the process. Subsequently, the case where the movable element moves during the process is discussed.

In one embodiment, in order to achieve this, for a given amount of time the controller monitors the signal 56 provided by the detector 52 of the gap sensor. The controller counts the number of periods of the signal 56 during said given time and multiplies this by L_P in order to determine the linear displacement of the label stock during said given time. During said given time the controller also monitors a signal provided to it by a rotation monitoring sensor which monitors the rotation of the supply spool support 10 (and supported supply spool). Hence the controller determines the amount of rotation of the supply spool support 10 (and supported supply spool). As discussed above, the controller can then determine the diameter of the supply spool based upon the linear displacement of the label stock and the amount of rotation of the supply spool support 10 during said given time. The given amount of time may be defined as the time it takes for a predetermined number of periods of the signal 56 to be received by the controller, or may be defined as the time it takes for the supply spool to rotate by a predetermined number of rotations (as measured by the rotation monitoring sensor).

In an alternative embodiment at step S8 the controller calculates and updates the diameter of the spool mounted to the supply spool support 10 as follows. For a given amount of time the controller monitors the amount of rotation of the supply spool support by monitoring the signal produced by the supply spool rotation monitor. For example, the given amount of time may be the time it takes for the supply spool support to undergo an integer number of complete rotations (as measured by the supply spool rotation monitor). During the given amount of time the controller counts the number of steps that the take up motor is commanded to advance. Based upon this information and on the diameter of the take up spool which has been determined by the controller in either step S4 or step S9, the controller can calculate the length of label stock which has been wound on to the take up spool in the given amount of time. In alternative embodiments, the given amount of time may be defined as the time it takes to advance the take up motor a predetermined number of steps, and rotation of the supply spool measured by supply spool rotation monitor during this time may be used to determine the diameter of the supply spool.

During the given amount of time, given amount of rotation of the supply spool, or predetermined number of steps the controller also monitors the position of the dancing arm by monitoring the signal provided to the controller by the sensor configured to produce a sensor signal indicative of the position of the moveable element (dancing arm). By comparing the position of the dancing arm at the beginning of the given amount of time, given amount of rotation of the supply spool, or predetermined number of steps, and at the end of the given amount of time, given amount of rotation of the supply spool, or predetermined number of steps, as discussed above, the controller can determine the change in path length between the supply spool support and take up spool support which has occurred between the beginning of the given amount of time, given amount of rotation of the supply spool, or predetermined number of steps, and the end of the given amount of time, given amount of rotation of the supply spool, predetermined distance or predetermined number of steps. The controller then adds the change in path length (which is positive if the path length has increased and negative if the path length has decreased) between the supply spool support and take up spool support during the given amount of time to the amount of label stock wound onto the take up spool support during the given amount of time. This gives the amount of label stock which has been unwound from the from the supply spool support during the given amount of time given amount of rotation of the supply spool, or predetermined number of steps. Based upon the amount of rotation of the supply spool support during the given amount of time, given amount of rotation of the supply spool, or predetermined number of steps and on the amount of label stock which has been unwound from the supply spool support during the given amount of time the controller can determine the diameter of the supply spool.

At step S9 the controller calculates and updates the diameter of the spool mounted to the take up spool support 12. In one embodiment, in order to achieve this, for a given amount of time the controller monitors the signal 56 provided by the detector 52 of the gap sensor. The controller counts the number of periods of the signal 56 during said given time and multiplies this by L_P in order to determine the linear displacement of the label stock during said given time. For example, the given time may be such that the number of periods of the signal 56 during said given time is an integer number between 1 and 10. However, any appropriate given time may be used. During said given time the controller also counts the number of steps that the motor 14 is commanded to take. Hence the controller determines the amount of rotation of the take up spool support 12 (and supported supply spool). As discussed above, the controller can then determine the diameter of the take up spool based upon the linear displacement of the label stock and the amount of rotation of the take up spool support 10 during said given time.

In some embodiments the given amount of time the controller monitors the signal 56 provided by the detector 52 of the gap sensor may be the time it takes the label web to advance a predetermined linear distance. The predetermined linear distance is preferably in excess of twice the greatest pitch length of label stock that will be utilised by the labelling machine. The predetermined length of label stock may be 300mm.

In some embodiments the controller may determine the take up spool diameter and then wait until the take up spool has subsequently completed one rotation before re-determining the take up spool diameter. Likewise, in some embodiments the controller may determine the supply spool diameter and then wait until the supply spool has subsequently completed one rotation before re-determining the supply spool diameter.

In order to determine whether the take up spool has completed one rotation, the controller may wait for the take up motor to execute the number of steps equal to that for a complete rotation.

In order to determine whether the supply spool has completed one rotation, the controller may monitor the supply spool rotation monitor to determine when the supply spool has completed a rotation.

In some embodiments determination of the supply spool diameter at step S8 may occur concurrently with at least one of steps S3, S4, S5 and S6.

Whilst the controller calculates and updates the diameter of the spool mounted to the take up spool support 12 the controller may carry out checks to detect erroneous data regarding measured label length or measured gap length. If any erroneous data is detected then the process of calculating and updating the diameter of the spool mounted to the take up spool support 12 may be aborted (such that no update of the diameter is carried out based upon the erroneous data). Subsequently, process of calculating and updating the diameter of the spool mounted to the take up spool support 12 is restarted (such that an update can be carried out without being affected by erroneous data). The controller may detect the presence of erroneous data in any appropriate manner. For example, the controller may detect the presence of erroneous data in any of the manners discussed above in relation to step S5.

In some embodiments, the start-up procedure may include a check to see whether the dancing arm position changed while the machine was powered off. In order to do this the controller uses the sensor configured to produce a sensor signal indicative of the position of the moveable element to measure and record the position of the movable element before the machine is switched off. Subsequently, when the machine is switched on, the controller uses the sensor configured to produce a sensor signal indicative of the position of the moveable element to measure the position of the movable element and compare it to the position of the movable element recorded before the machine was switched off. If the position of the movable element is substantially the same when the machine is switched on compared to when it was switched off then certain steps within the above start-up routine may be omitted. For example, steps S2 to S4, S3 to S5, S3 to S6 or S3 to S4 may be omitted. In this case the labelling machine may resume operation using the last known value (i.e. before the machine was switched off) of the take-up spool diameter. This is based upon the assumption that the label stock cannot move (thereby changing the diameter of the spools) without changing the position of the movable element (e.g. dancing arm). The purpose of omitting unnecessary steps is to reduce start-up time which may be beneficial in some applications. In some embodiments data indicative of the position of the movable element, the diameter of the take up spool and/or any other appropriate parameter may be stored in a battery-powered memory or any other suitable non-volatile memory. In some embodiments, data indicative of position of the movable member may be updated to the memory every time movement of the arm is detected by the controller. In other embodiments data indicative of the position of the movable element, the diameter of the take up spool and/or any other appropriate parameter may be updated to the memory at a suitable regular time interval.

In some embodiments, the start-up sequence may be modified compared to that discussed above. For example, in some embodiments the start-up sequence may be modified such that it proceeds in the order S1, S2, S3, S4, S6, S7, S5, S8, S9. Subsequently, as before, steps S7, S8 and S9 then repeat during on-going operation of the machine. In some applications this start-up sequence may be advantageous because by not determining the label pitch until the labelling machine is operating so as to dispense labels on to an article to be labelled this can reduce the time the start-up procedure (e.g. up to the ready to operate state S7) takes to complete and also prevent wastage of labels. This is because, in this embodiment, the labels dispensed whilst determining the label pitch are used by the labelling machine (i.e. applied to articles) as opposed to wasted (i.e. not applied to an article and dispensed only in order to determine label pitch).

The previously described start-up sequence may equally be applied in conjunction with a braking assembly including a solenoid as shown in figures 5 to 11 or in conjunction with a braking assembly including a position controlled motor as shown in figures 18 to 20.

The construction and operation of various embodiments of a labelling machine have been described above. As has been mentioned, such labelling machines may be used to apply labels to articles/products passing on a conveyor of a production line. Having carried out a start-up procedure, for example, as described above, operation of the labelling machine to dispense labels can begin.

The controller determines a linear speed V_t at which the web is to be fed. In some applications it is necessary for this linear speed to match the speed at which a product is conveyed past the labelling machine by a conveyor. The speed at which the product is conveyed past the labelling machine can be provided as an input to the controller from a line encoder. Any appropriate encoder may be used to determine the speed of the conveyor (and hence the speed at which the product is conveyed past the labelling machine). In one example, the line encoder may be attached to a wheel of known diameter which runs against the conveyor such that the linear movement of the wheel matches the linear movement of the conveyor. The line encoder can thus provide details of a distance through which the wheel has turned. Given knowledge of the time taken to travel that distance, the speed of the conveyor can easily be determined.

In alternative applications the speed at which the label stock is to be moved may be input to the controller by an operator, as a manual input.

Operation of the labeller is normally initiated by a product sensor being triggered indicating that a product is approaching the labelling machine. It is preferred that the controller is programmed with a so-called “registration delay”. Such a registration delay can indicate a time which should elapse (monitored by a simple timer) after detection of the product by the product sensor before the labelling process begins, or alternatively indicate a distance through which the conveyor should move (as monitored by the encoder) before the labelling process begins. The registration delay may be input to the controller by an operator of the labelling machine. It will be appreciated that by adjusting the registration delay, the position at which a label is affixed to a passing product may be adjusted.

Movement of the label stock during a label feed operation is illustrated by the speed/distance graph of Figure 22. It can be seen that the total distance through which the label stock is moved in dispensing a single label is indicated N_p, denoting that the stepper motor turns through N_p steps to cause the movement of the label stock. Having detected a label edge, the stepper motor turns through N_0 steps before the label stock comes to rest, where N_0 is determined as described below to ensure that a label edge is aligned with the edge of the labelling peel beak.

The label stock is accelerated from rest to the target speed $V_{t.}$ The label stock then moves at the target speed V_t before being decelerated to rest. N_d indicates the number of steps through which the stepper motor driving the take up spool support turns to decelerate the label stock. It will be appreciated that the numbers of steps N_p N_0 and N_d are determined with reference to the diameter of the take-up spool d_t (which may be determined using any appropriate method, including those described above) as is now described. Although the graph of Figure 22 shows a simple speed/distance profile for the label stock, it will be appreciated that in some circumstances different speed/distance profiles may be appropriate. In particular, it may sometimes be appropriate to vary the target speed V_t as the label stock is moved. It will also be appreciated that to achieve a particular target linear speed (i.e. speed of label stock moving along the web path) the speed of the take up motor may change during the operation of the labelling machine as a function of changing take up / supply spool diameters.

Figure 23 is a flow chart showing operation of the labelling machine to feed a single label. Processing begins at step S25 where a check is carried out to determine whether the product sensor has been triggered by a passing product. If this is the case, processing passes to step S26 otherwise, processing remains at step S25 until the product sensor is triggered by a passing product.

At step S29 pulses provided by the line encoder discussed above are counted. At step S30 a check is carried out to determine whether the number of pulses received is equal to the distance which corresponds to a predetermined registration delay R_d. If this is not the case processing returns from step S30 to step S29 and a loop is thereby established until the conveyor has moved through the distance specified by the registration delay R_d. Processing then passes to step S26

At step S26 a check is carried out to determine whether an additional time registration delay is required. If an additional time registration delay is required, processing passes from step S26 to step S27 where a timer is initialised. Processing then passes to step S28 where a check is carried out to determine whether the elapsed time is equal to the required time registration delay R_{td}. Processing remains at step S28 until the elapsed time is equal to the required time registration delay R_{td}.

When the distance (and, if applicable, additional time) of the registration delay has passed, processing passes from step S28 or step S26 to step S31, where the controller calculates various parameters required to define the way in which the label stock will be moved. More particularly the controller computes the numbers of steps through which the stepper motor is to be turned to cause the desired movement of the label stock, the number of steps through which the stepper motor should be turned after detection of an edge so as to allow a label edge to be properly aligned with the labelling peel beak, and the step rate M_r at which the stepper motor which drives the take up spool support should be turned given the desired linear label stock speed which is determined as described above.

In some embodiments, the total number of steps N_p through which the stepper motor which drives the take up spool is to be turned is given by equation (20)

$$N_p = L_p \frac{N_{revolution}}{\pi d_t} \qquad (20)$$

where L_P is the pitch length of the label stock, $N_{revolution}$ is the number of steps through which the stepper motor turns to rotate the take up spool support a single revolution and d_t is the diameter of the take-up spool.

The distance E_0 through which the label stock should be fed following detection of an edge by the gap sensor in order to cause the leading edge of a label to be aligned with the edge of the labelling peal beak can be converted into a number of steps N_0 using equation (21):

$$N_o = E_o \frac{N_{revolution}}{\pi d_t} \qquad (21)$$

The step rate M_r at which the take up stepper motor should step is determined with reference to the desired linear speed of the label stock V_t which as described above can either by input by an operator, or alternatively determined using an encoder. The step rate M_r is given by equation (22):

$$M_r = V_t \frac{N_{revolution}}{\pi d_t} \qquad (22)$$

Referring again to Figure 23, having determined the necessary parameters at step S31, processing passes to step S33.

At step S33, the number of steps N_g remaining in the current feed is set to be equal to the total number of steps N_p in a single label feed. A parameter C_r indicating the current step rate is initialized to a value of zero.

Processing passes from step S33 to step S34 where a number of steps N_d required to decelerate the label stock from its current speed to rest is determined. D_{max} is the maximum deceleration of the label stock which can be achieved using the take up stepper motor. The maximum deceleration may be determined in any appropriate way known in the art. For example, it may be determined as described in PCT application WO2010/018368 which is incorporated herein by reference. The linear distances through which the label stock is moved to decelerate from a current linear speed V_c to a target linear speed U_t is given by the familiar equation:

$$U_t^2 = V_c^2 - 2D_{max}s \qquad (23)$$

where s represents distance.

Given that the target linear speed U_t is zero, and rearranging equation (23), the following expression for the linear distance s can be derived:

$$s = \frac{V_c^{\ 2}}{2D_{\max}} \qquad (24)$$

The linear distance s can be converted into a number of steps N_d, such that equation (24) becomes:

$$N_d = \left(\frac{V_c^{\ 2}}{2D_{\max}}\right)\left(\frac{N_{revolution}}{\pi d_t}\right) \qquad (25)$$

Processing passes from step S34 of Figure 23 to step S35. At step S35 a check is carried out to determine whether the label position sensor (also referred to as the gap sensor) has detected a label edge. If this is the case, processing passes from step S35 to step S36 where the number of steps remaining in the current label feed N_g is set to be equal to the number of steps N_0 through which the label stock should be moved to align a label edge with the labelling peel beak. Processing then passes to step S37. If a label edge has not been detected by the label position sensor 52, processing passes directly from step S35 to step S37.

At step S37 a check is carried out to determine whether the number of steps remaining in the current feed is equal to zero. If this is the case processing passes to step S38 where the feed ends.

If this is not the case, processing passes to step S39 where a check is carried out to determine whether the number of steps remaining in the current label feed N_g is less than or equal to the number of steps N_d required to decelerate the label stock. If this is the case, processing passes to step S40 where a deceleration step rate is determined.

The deceleration step rate is determined by determining the lowest rate C_{r+1} at which the motor can be caused to step, given the limitation of the maximum possible deceleration D_{max} and the current step rate C_r. It is determined using equation (26):

$$C_{r+1} = \sqrt{C_r^{\ 2} - \frac{2D_{\max} N_{revolution}}{\pi d_t}} \qquad (26)$$

Equation (26) is based upon equation (23) which can be expressed as follows:

$$V_{c+1}^{\ 2} = V_c^{\ 2} - 2D_{\max} S_w \qquad (27)$$

where V_c is the current linear label stock speed;

V_{c+1} is the new linear label stock speed; and

S_w is the linear distance through which the label stock is moved in a single step.

Equation (27) can be rearranged to give:

$$V_{c+1} = \sqrt{V_c^{\ 2} - 2D_{\max} S_w} \qquad (28)$$

The linear distance S_w through which the label stock is moved in a single step is given by equation (29):

$$S_w = \frac{\pi d_t}{N_{revolution}} \qquad (29)$$

The new linear label stock speed can be related to a step rate using equation (30):

$$V_{c+1} = \frac{C_{r+1} \pi d_t}{N_{revolution}} \qquad (30)$$

Equation (30) can be rearranged to give:

$$C_{r+1} = V_{c+1} \frac{N_{revolution}}{\pi d_t} \qquad (31)$$

Substituting equation (28) into equation (31) gives:

$$C_{r+1} = \sqrt{V_c^{\ 2} - 2D_{\max} S_w} \left(\frac{N_{revolution}}{\pi D_t} \right) \qquad (32)$$

The current linear label stock speed V_c is related to the current step rate by equation (33):

$$V_c = \frac{C_r \pi d_t}{N_{revolution}} \qquad (33)$$

Substituting equations (29) and (33) into equation (32) gives:

$$C_{r+1} = \left(\sqrt{\left(\frac{C_r . \pi d_t}{N_{revolution}} \right)^2 - 2D_{\max} \frac{\pi d_t}{N_{revolution}}} \right) \frac{N_{revolution}}{\pi d_t} \qquad (34)$$

Equation 34 can be rearranged to give equation (26), *viz*:

$$\begin{aligned}
C_{r+1}{}^2 &= \left(\left(\frac{C_r . \pi d_t}{N_{revolution} .} \right)^2 - 2D_{\max} \frac{\pi d_t}{N_{revolution} .} \right) . \left(\frac{N_{revolution} .}{\pi d_t} \right)^2 \\
&= \left(\frac{(C_r . \pi d_t)^2}{(N_{revolution} .)^2} - 2D_{\max} \frac{\pi d_t}{N_{revolution} .} \right) . \frac{(N_{revolution} .)^2}{(\pi d_t)^2} \\
&= \left(\frac{C_r{}^2 . \pi d_t{}^2}{(N_{revolution} .)^2} - 2D_{\max} \frac{\pi d_t}{N_{revolution} .} \right) . \frac{(N_{revolution} .)^2}{(\pi d_t)^2} \\
&= \left(\frac{C_r{}^2}{(N_{revolution} .)^2} - 2D_{\max} \frac{1}{N_{revolution} . . \pi d_t} \right) . (N_{revolution} .)^2 \\
&= C_r{}^2 - 2D_{\max} \frac{N_{revolution}}{\pi d_t}
\end{aligned}$$

$$\therefore \qquad C_{r+1} = \sqrt{C_r{}^2 - \frac{2D_{\max} N_{revolution}}{\pi d_t}} \qquad (26)$$

Referring back to Figure 23, having determined a step rate to effect deceleration at step S40, processing passes to step S51, which is described in further detail below.

If the check of step S39 determines that the number of steps remaining in the current label feed N_g is not less than or equal to the number of steps N_d required to decelerate the label stock, processing passes to step S41.

The check of step S39 is required to ensure proper operation where the target speed V_t and consequently the target step rate M_r varies during movement of the label stock. If it were the case that the target step rate did not vary, the check of step 39, need not be carried out.

At step S41 a check is carried out to determine whether the current step rate is too fast. This check determines whether the inequality of equation (35) is true:

$$C_r > M_r \qquad (35)$$

If this is the case, processing passes from step S41 to step S42, where a step rate to effect deceleration is calculated using equation (26) set out above. Processing passes from step S42 to step S43 where a check is carried out to determine whether the step rate determined at step S42 is less than the target step rate M_r if this is the case, the step rate is set to be equal to the target step rate M_r at step S44. Processing passes from step S44 to step S51, otherwise, processing passes directly from step S43 to step S51.

If the check of step S41 indicates that the step rate is not too high, processing passes from step S41 to step S45. At step S45 a check is carried out to determine whether it is possible to accelerate the label stock, and still have a sufficient number of steps to decelerate the label stock to rest, given the number of steps N_g remaining in the current feed. This is determined by determining whether the number of steps N_g remaining in the current feed is greater than or equal to one more than the number of steps required to decelerate the label stock to rest if the label stock is accelerated. If this is not the case, it is determined that the label stock should not be accelerated, and processing passes to step S46 where the step rate is set to remain constant, before processing passes to step S51.

If the check of step S45 is not satisfied (i.e. acceleration can be carried out while still allowing sufficient steps for deceleration of the label stock to rest), processing passes from step S45 to step S47. Here a check is carried out to determine whether the current step rate is less than a target step rate. If this is the case, a step rate to effect acceleration is calculated at step S48, according to equation (36):

$$C_{r+1} = \sqrt{C_r^2 + \frac{2A_{\max} N_{revolution}}{\pi d_t}} \qquad (36)$$

where A_{max} is the maximum possible acceleration.

It can be seen that equation (36) has a similar form to equation (26) and its derivation therefore has the general form set out above.

Processing passes from step S48 to step S49 where a check is carried out to determine whether the step rate C_{r+1} calculated at step S48 exceeds the target step rate M_r. If this is the case, the step rate C_{r+1} is set to be equal to the target step rate at step S50, before processing passes from step S50 to step S51. If the step rate C_{r+1} calculated at step S48 does not exceed the target step rate M_r processing passes directly from step S49 to step S51. At step S51 the motor is caused to turn one step at the determined step rate.

If the check of step S47 determines that the current step rate is not too slow, processing passes from step S47 to step S52. It is known (given operation of steps S41 and S47 that the step rate is equal to the target step rate, and the motor is turned through one step at that step rate at step S52.

Processing passes from each of steps S51 and S52 to step S53 where the number of steps remaining in the current feed N_g is decremented by one, before processing returns to step S34.

Various features of the labelling machine have been described above. In some cases, exemplary components, configurations and methods suitable for realising these particular features have been described. However in many cases the skilled person will know of other components, configurations and methods which can similarly be used to realise the particular features which are described. Many of these components, configurations and methods will be known to the skilled person from the common general knowledge. It is envisaged that such alternative components, configurations and methods can be implemented in the described embodiments without difficulty given the disclosure presented herein.

While references have been made herein to a controller or controllers it will be appreciated that control functionality described herein can be provided by one or more controllers. Such controllers can take any suitable form. For example control may be provided by one or more appropriately programmed microprocessors (having associated storage for program code, such storage including volatile and/or non-volatile storage). Alternatively or additionally control may be provided by other control hardware such as, but not limited to, application specific integrated circuits (ASICs) and/or one or more appropriately configured field programmable gate arrays (FPGAs).

Where angles have been specified herein, such angles are measured in radians although modifications to use other angular measurements will be apparent to the skilled person.

While various embodiments of labelling machine(s) have been described herein, it will be appreciated that this description is in all respects illustrative, not restrictive. Various modifications will be apparent to the skilled person without departing from the spirit and scope of the invention.

CLAIMS

1. A labelling machine comprising:

a supply spool support for supporting a supply spool comprising label stock comprising a web and a plurality of labels attached to the web and which are separable from the web;

a take-up spool support adapted to take up a portion of web;

a sensor configured to produce a sensor signal indicative of a periodic property of at least a portion of the label stock; and

a controller configured to calculate a displacement of the web along a web path defined between the supply spool and the take-up spool based upon the sensor signal and a length of a component of the label stock.

2. A labelling machine according to claim 1, wherein the sensor comprises an electromagnetic radiation detector, and, optionally, an electromagnetic radiation source.

3. A labelling machine according to claim 1 or 2, wherein the property of at least a portion of the label stock is the electromagnetic transmittance or reflectance of at least a portion of the label stock.

4. A labelling machine according to any preceding claim, wherein the periodic property arises from the spatial arrangement of labels on the web.

5. A labelling machine according to claim 4, wherein the sensor is arranged to sense differences between a property of the web and a label attached thereto and a property of the web.

6. A labelling machine according to any preceding claim, wherein the length of a component of the label stock is selected from the group consisting of a length of a label, a pitch length between adjacent labels and a gap length between adjacent labels.

7. A labelling machine according to any preceding claim, further comprising a rotation monitor configured to monitor the rotation of one of said spool supports, the rotation monitor being configured to output a rotation signal indicative of the rotation of said one of said spool supports; and wherein the controller is configured to

calculate a diameter of a spool supported by one of said spool supports based upon the calculated displacement of the web and the rotation signal.

8. A labelling machine according to any preceding claim, wherein the displacement of the web calculated by the controller is used to cause movement of web along the web path such that a target portion of the label stock is moved to a desired position along the web path, and, optionally, wherein the target portion of the label stock is a leading edge of a label and wherein the desired position is adjacent an edge of a labelling peel beak.

9. A labelling machine according to any preceding claim, further comprising motive means for advancing the label stock along the web path from the supply spool support to the take up spool support, and, optionally, wherein the motive means comprises a motor configured to rotate the take up spool support.

10. A labelling machine according to claim 9 as dependent upon claim 8, wherein the controller is configured to control the motive means to advance the label stock such that the target portion of the label stock is moved to the desired position.

11. A labelling machine according to any preceding claim wherein the sensor is further configured to measure the length of the component of the label stock.

12. A labelling machine according to claim 11, wherein the controller is configured to determine the length of the component of the label stock based upon monitored rotation one of said spool supports during sensing of a number of periods of said sensor signal, and, optionally, wherein the controller is configured to determine the length of the component of the label stock based upon a diameter of a spool supported by the spool support the rotation of which is monitored.

13. A labelling machine according to any preceding claim, further comprising a label applicator located in a location along said web path between said take up and supply supports and arranged to separate labels from the web for application to a receiving surface.

14. A labelling machine according to claim 13, arranged to apply pre-printed labels to packages in a product packaging facility, and/or further comprising a printer arranged to print onto labels prior to application of labels onto the receiving surface.

15. A method of controlling a labelling machine, the labelling machine comprising

a supply spool support for supporting a supply spool comprising label stock comprising a web and a plurality of labels attached to the web and which are separable from the web;

a take-up spool support adapted to take up a portion of web;

a sensor; and

a controller;

wherein the method comprises

the sensor producing a sensor signal indicative of a periodic property of at least a portion of the label stock;

providing the sensor signal to the controller; and

the controller calculating a displacement of the web along a web path defined between the supply spool and the take-up spool based upon the sensor signal and a length of a component of the label stock.

16. A labelling machine configured to carry out labelling operations, the labelling machine comprising:

a supply spool support for supporting a replaceable supply spool;

a take-up spool support adapted to take up a portion of web, a web path being defined between the supply spool and the take-up spool; and

a controller configured to calculate a time indicative of when the supply spool requires replacement in order for the labelling machine to carry out further labelling operations.

17. A labelling machine according to claim 16, wherein the time is a time of day and/or date.

18. A labelling machine according to claim 16 or 17, wherein the controller is configured to calculate the time indicative of when the supply spool requires replacement based on a diameter of the supply spool.

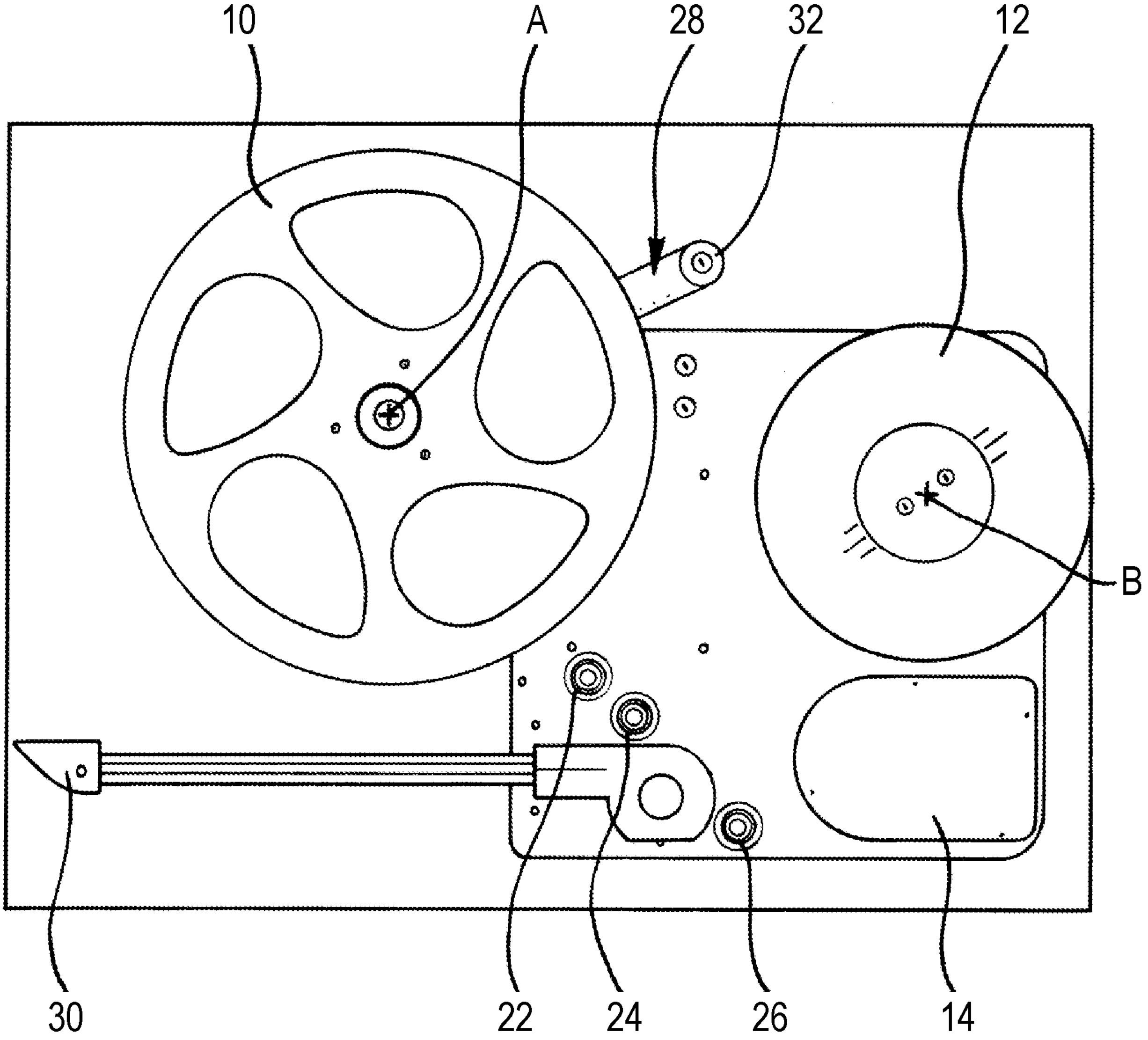


Fig. 1

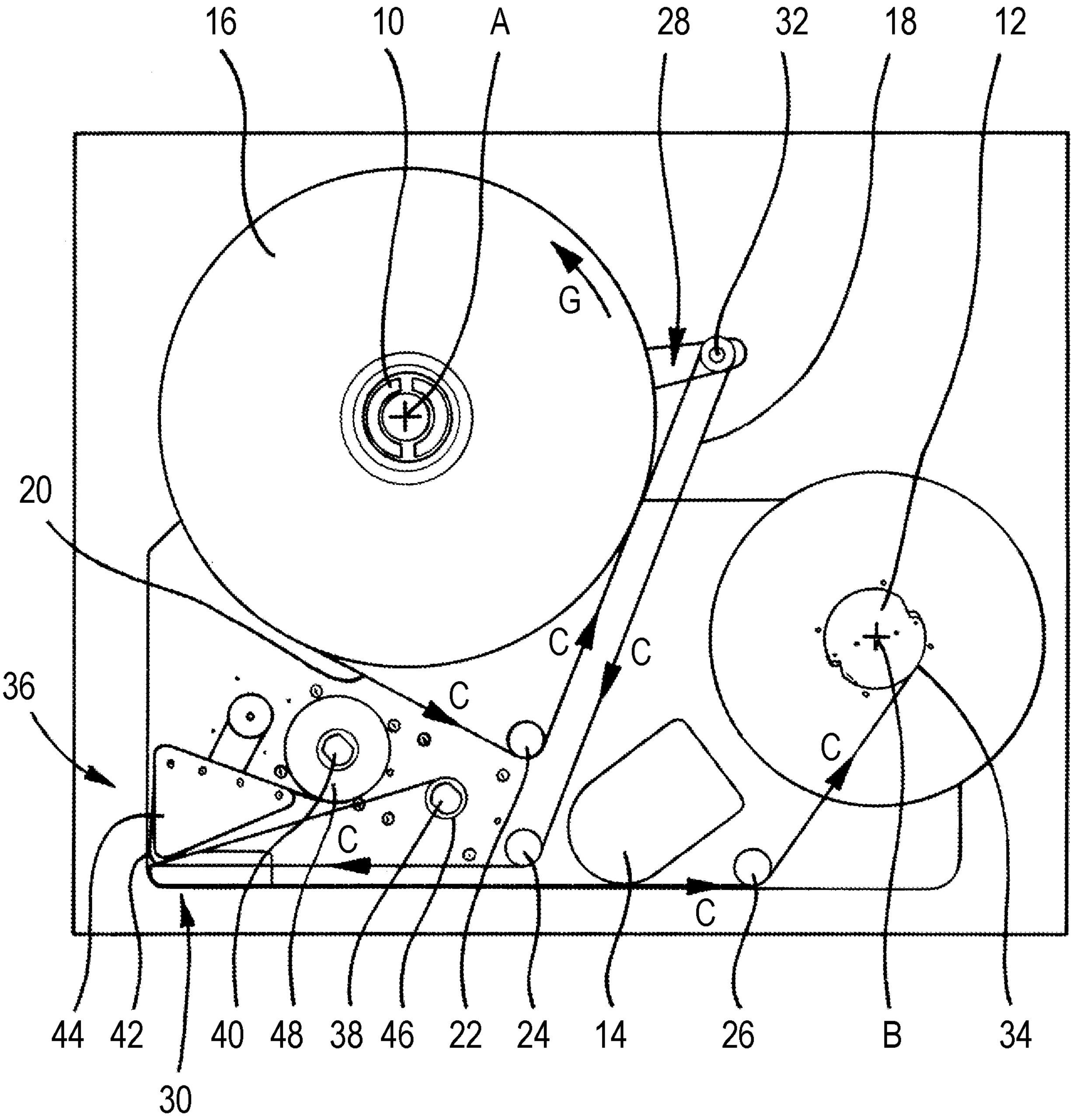


Fig. 2

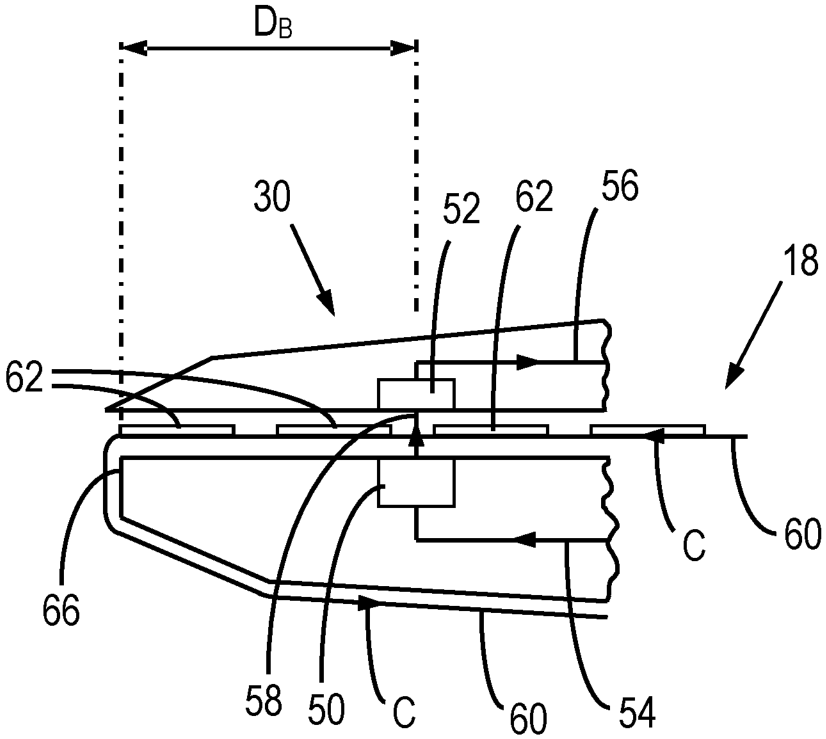


Fig. 3

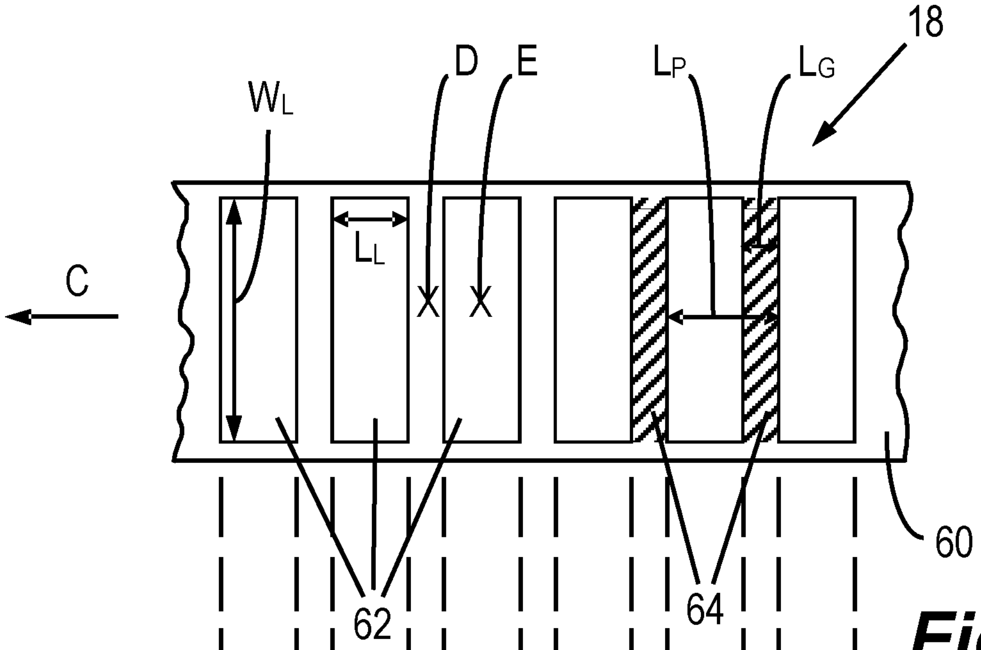


Fig. 4

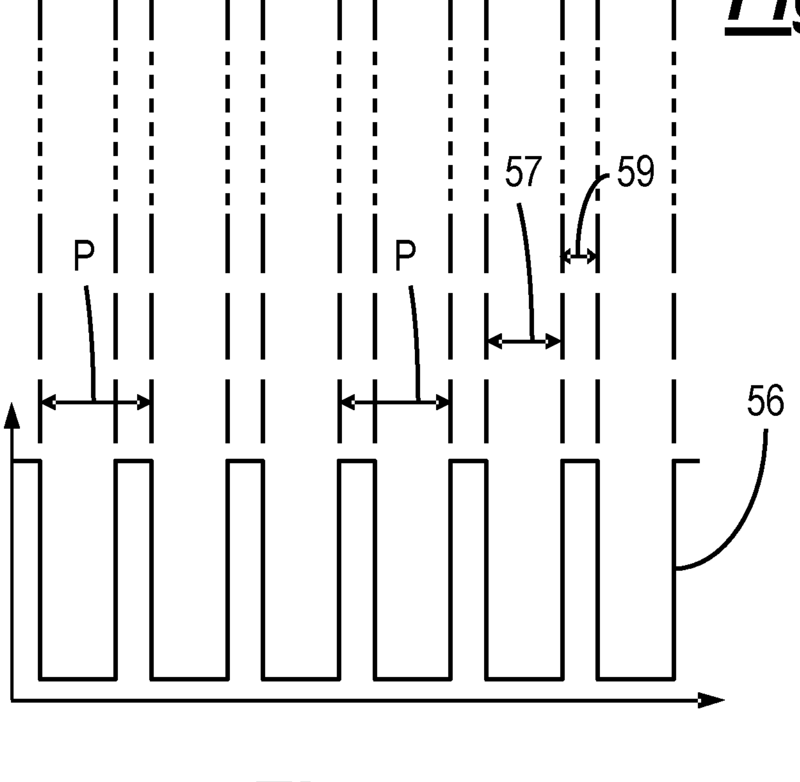


Fig. 4a

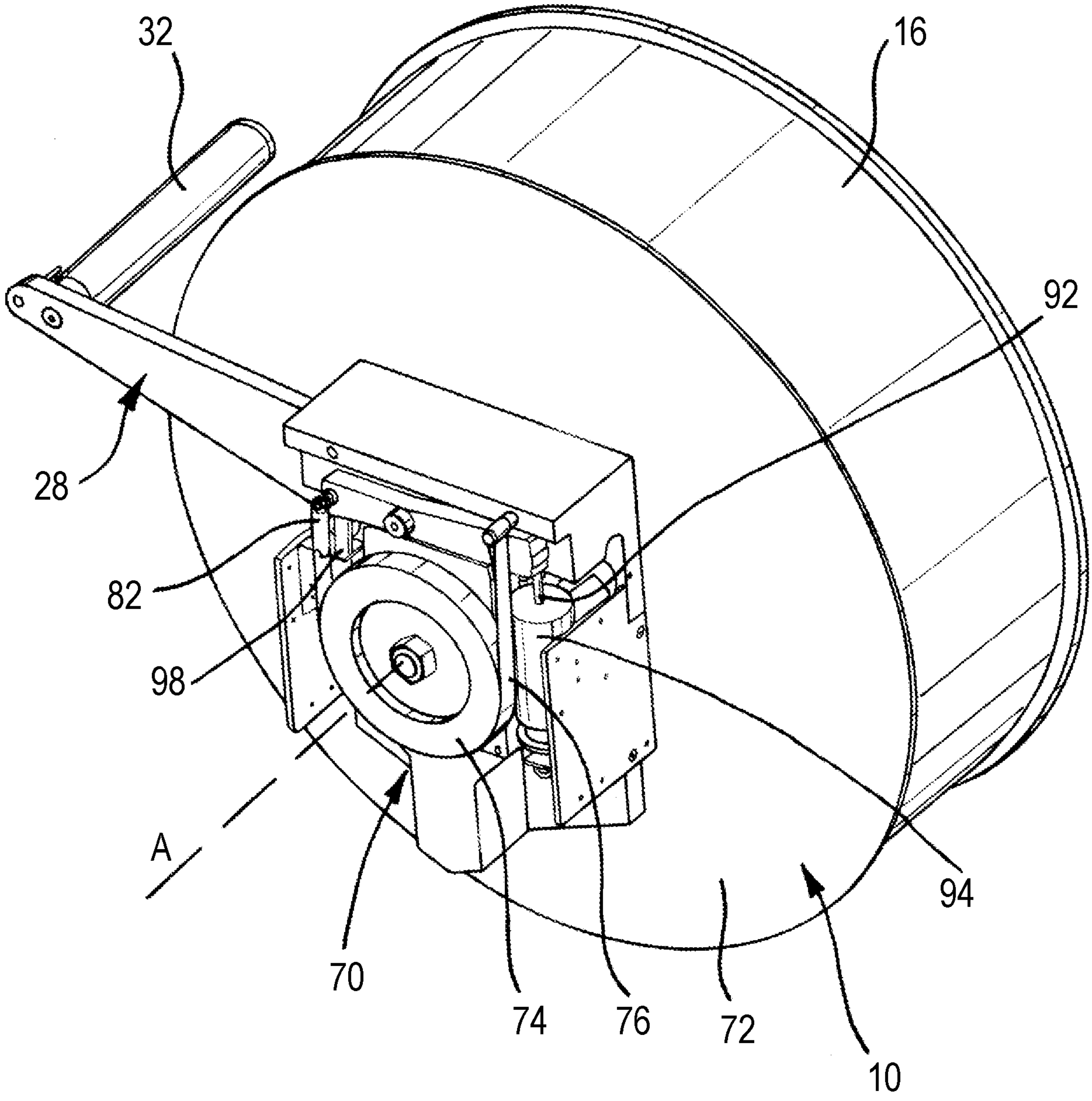


Fig. 5

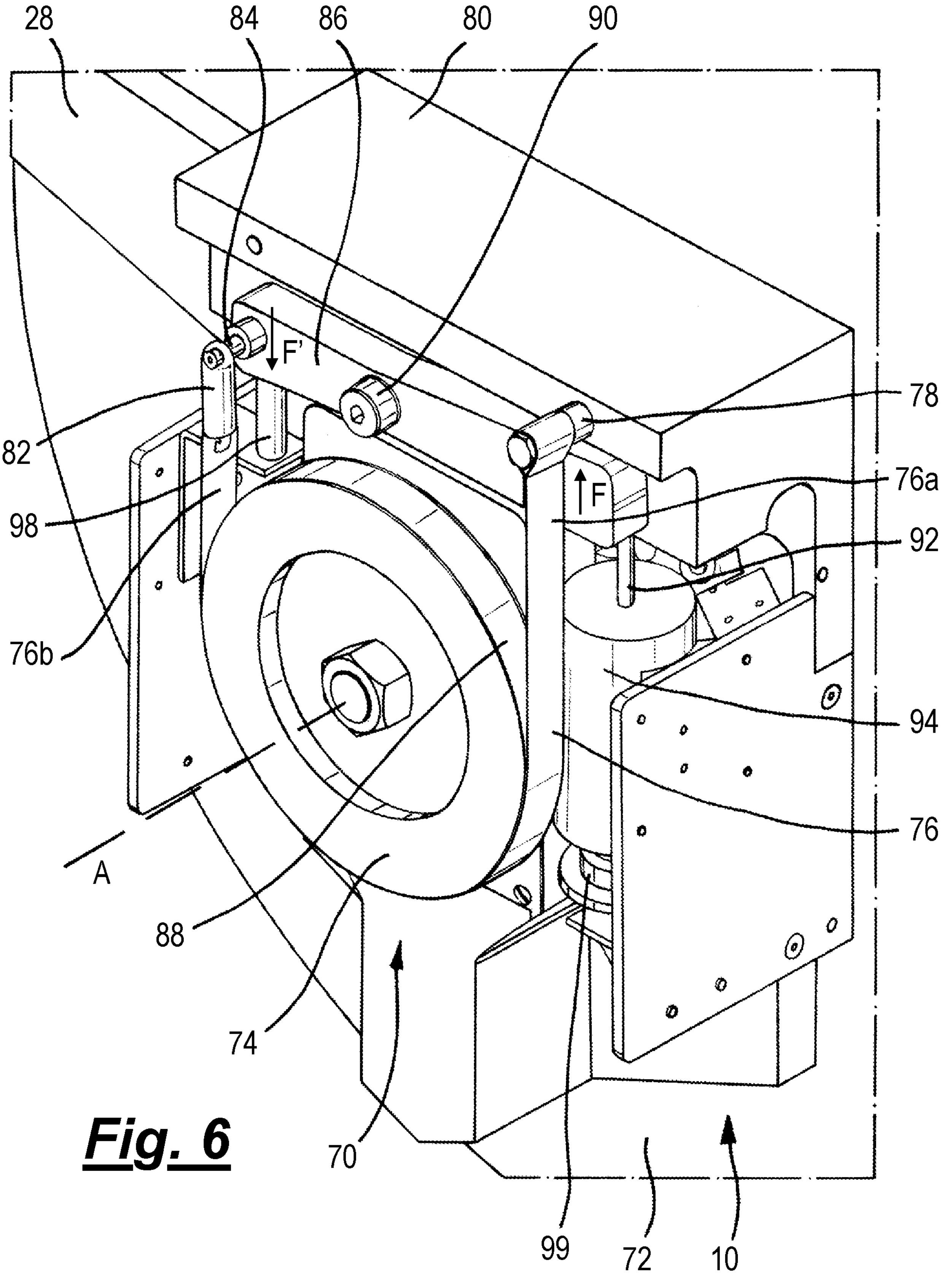


Fig. 6

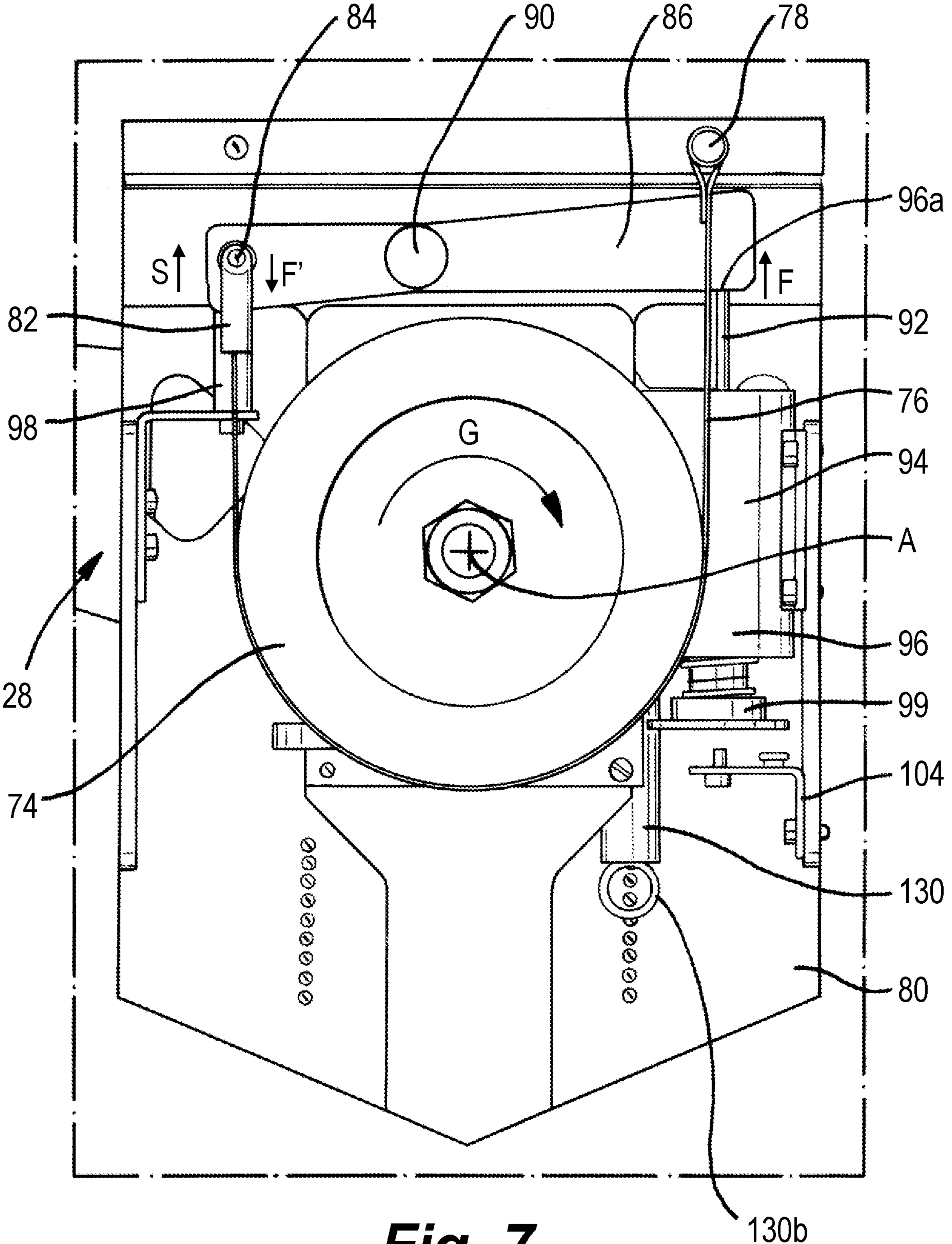


Fig. 7

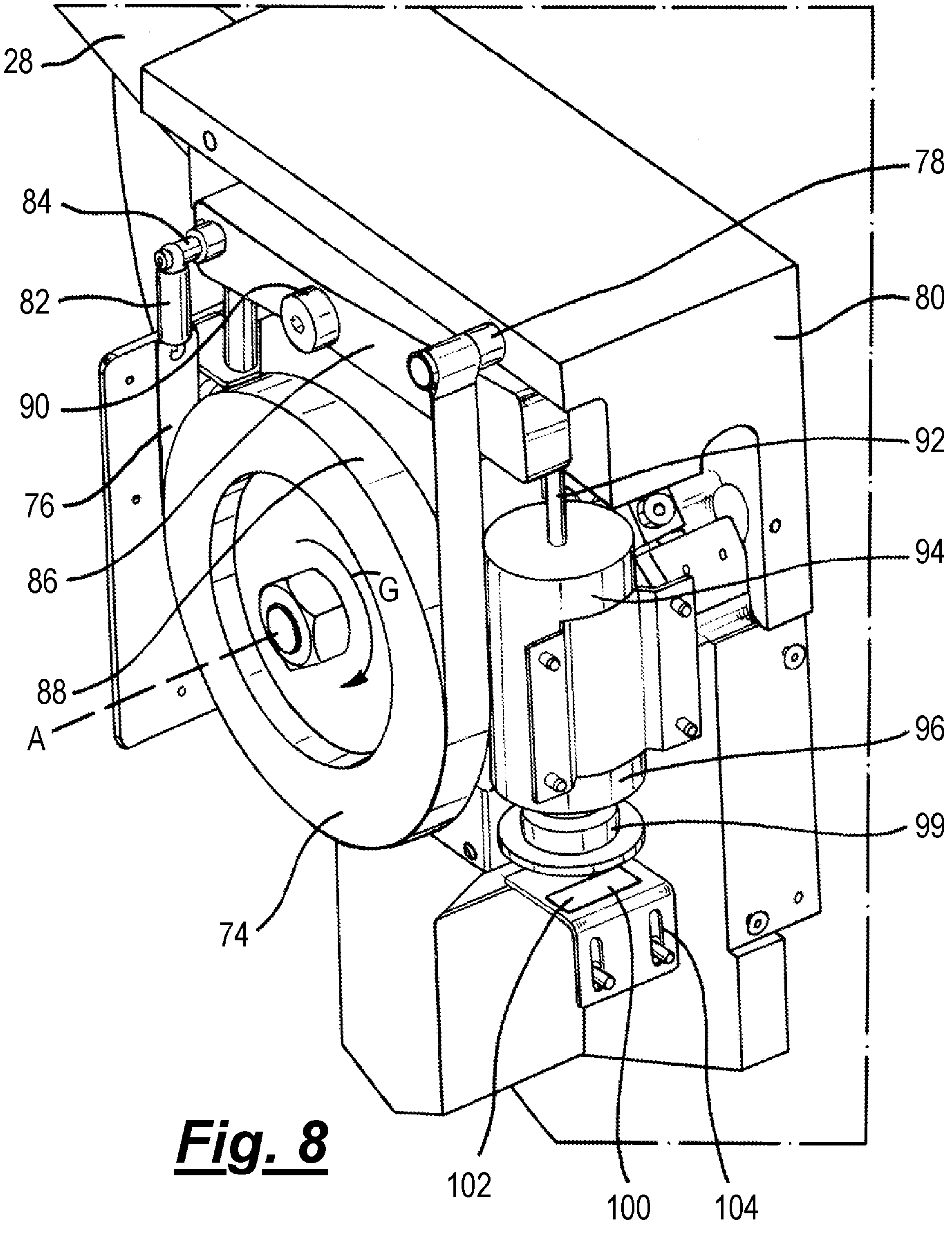


Fig. 8

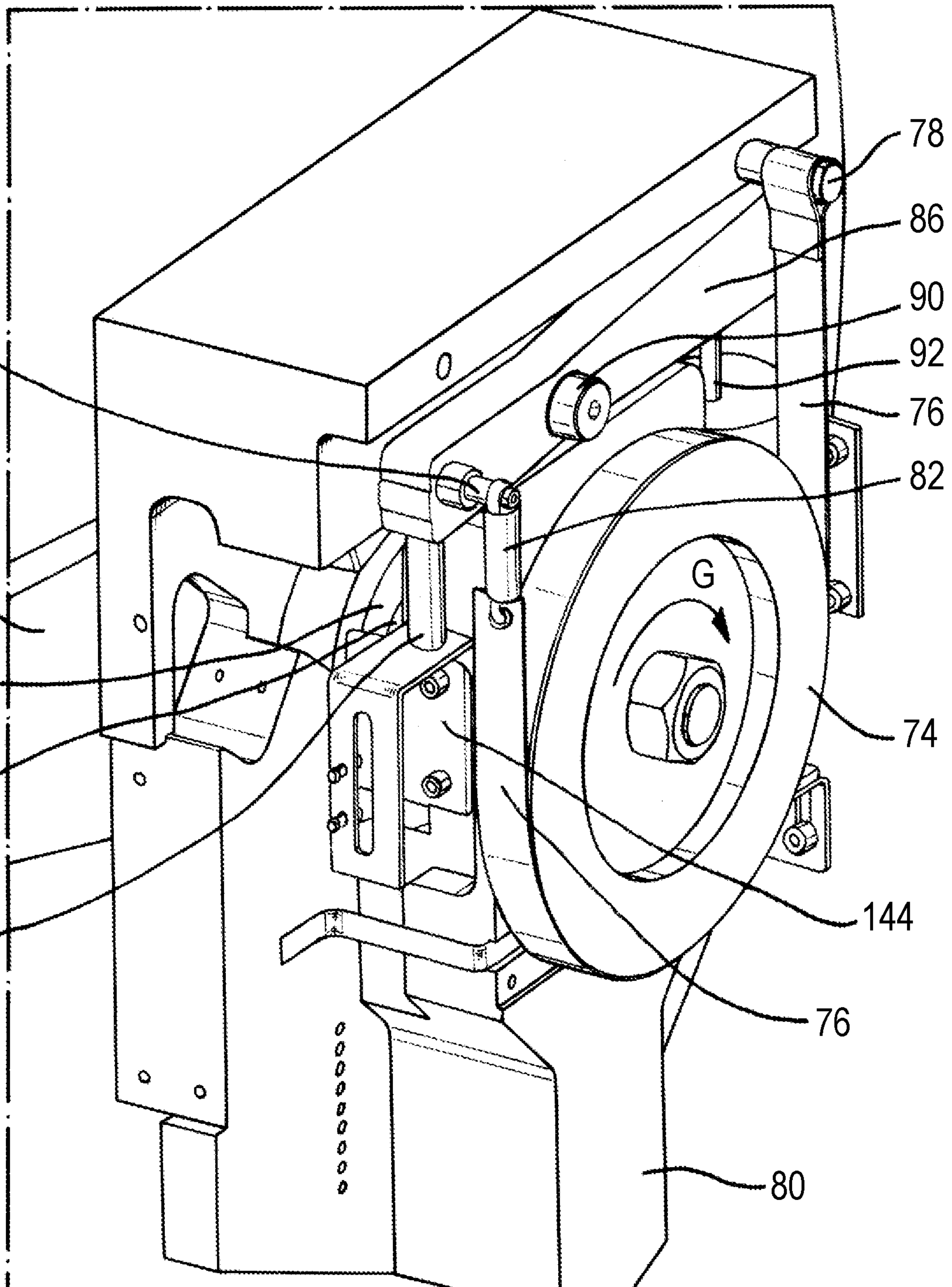


Fig. 9

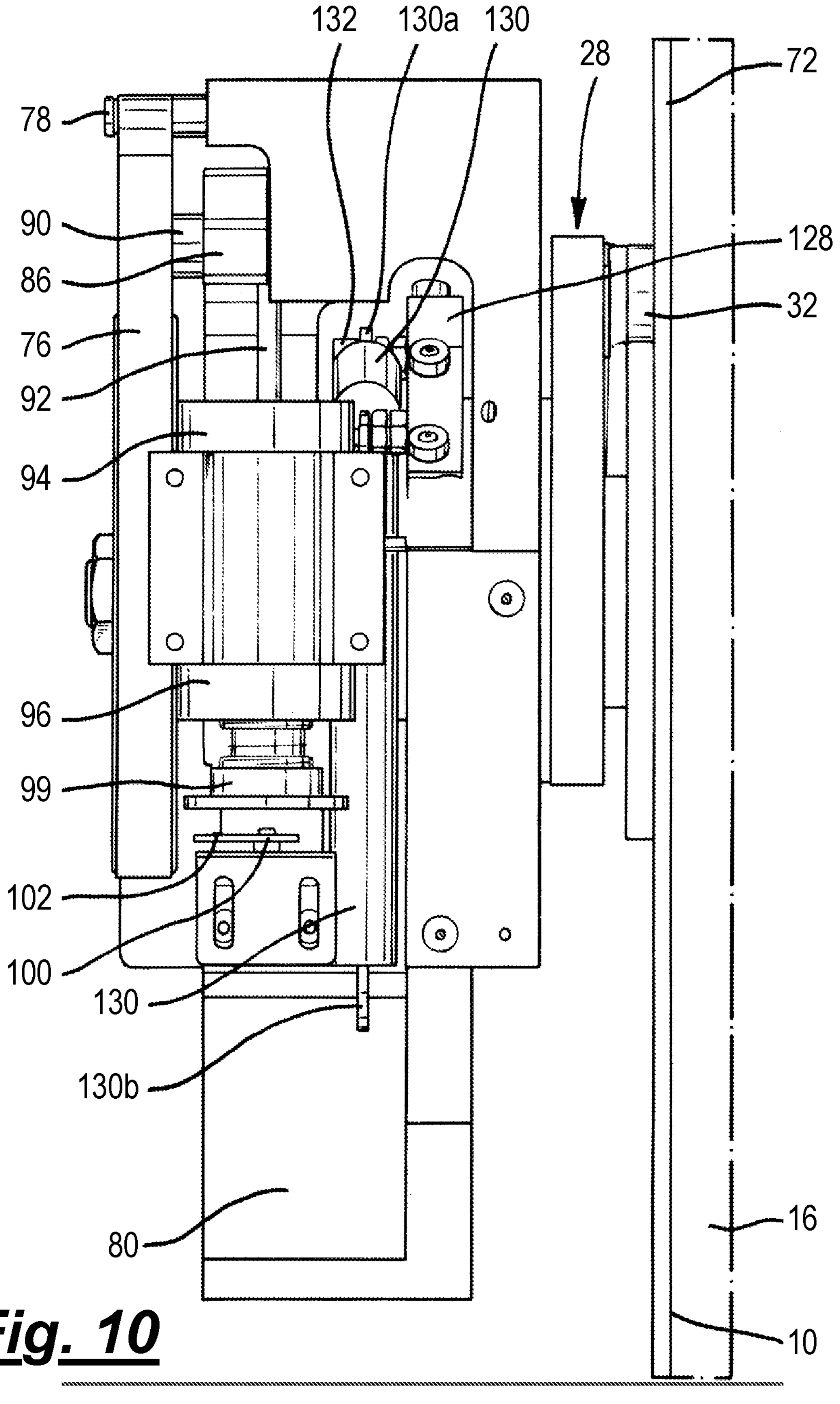

132
130a
130
28
72
78
90
86
76
92
94
128
32
96
99
102
100
130
130b
80
16
10

Fig. 10

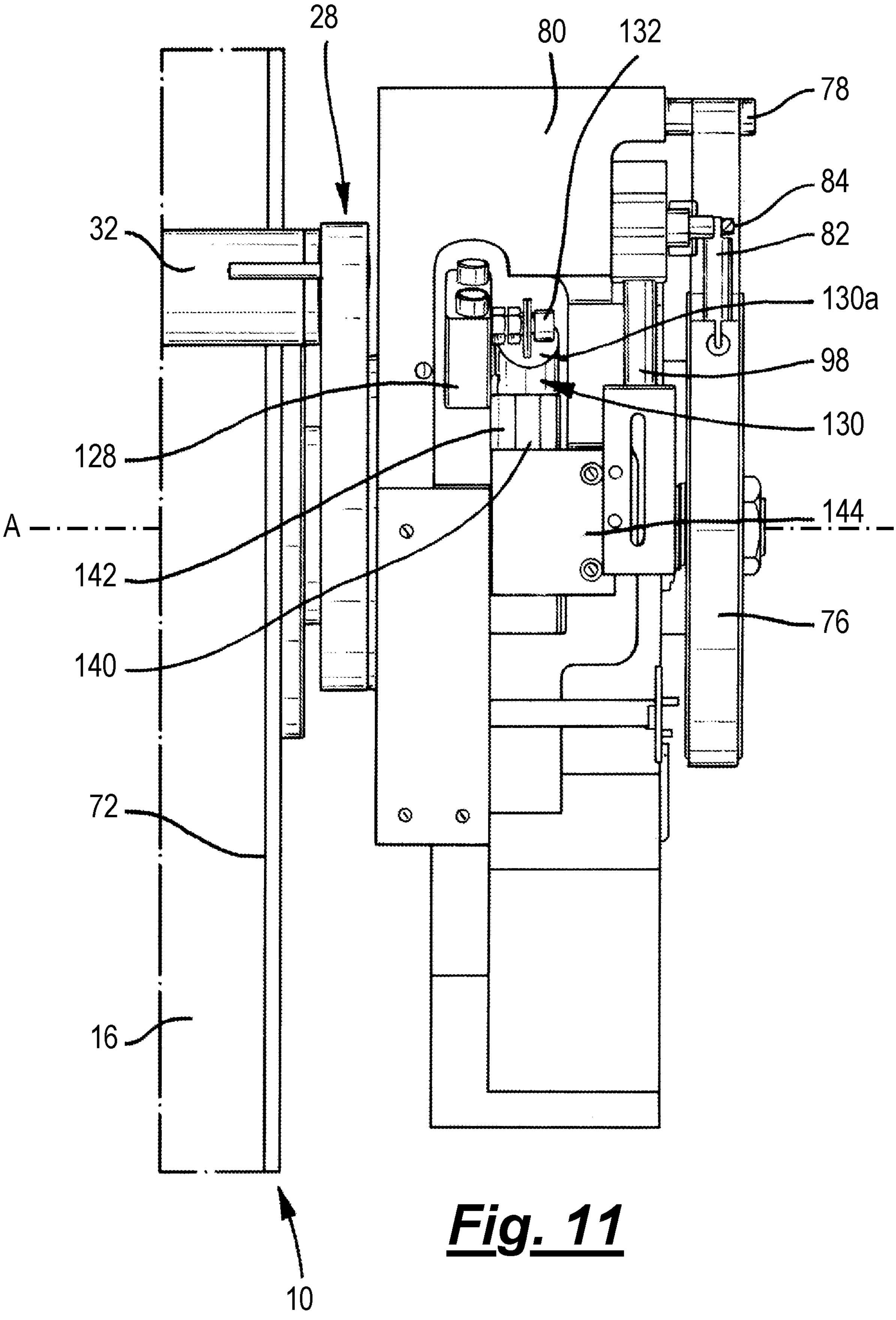


Fig. 11

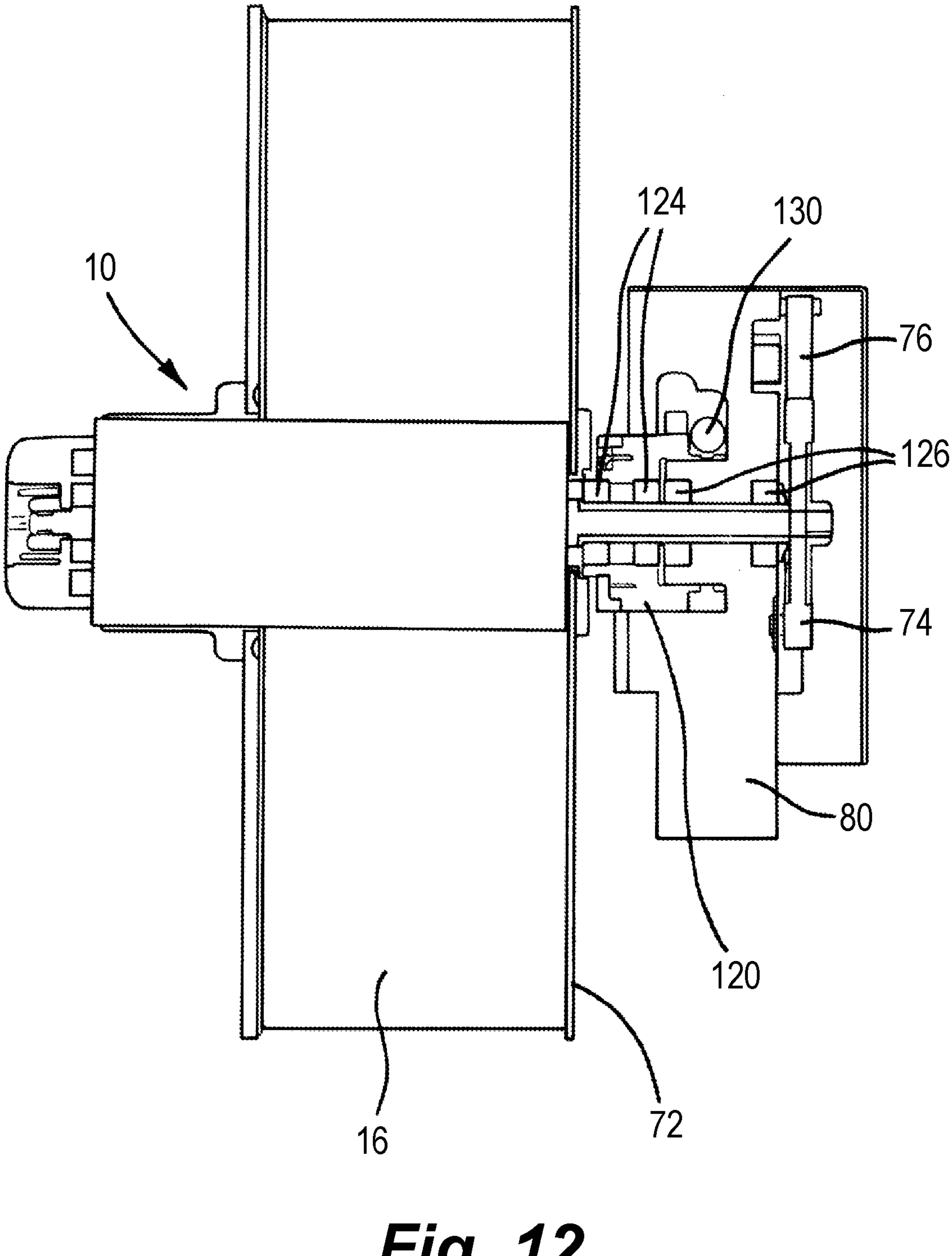


Fig. 12

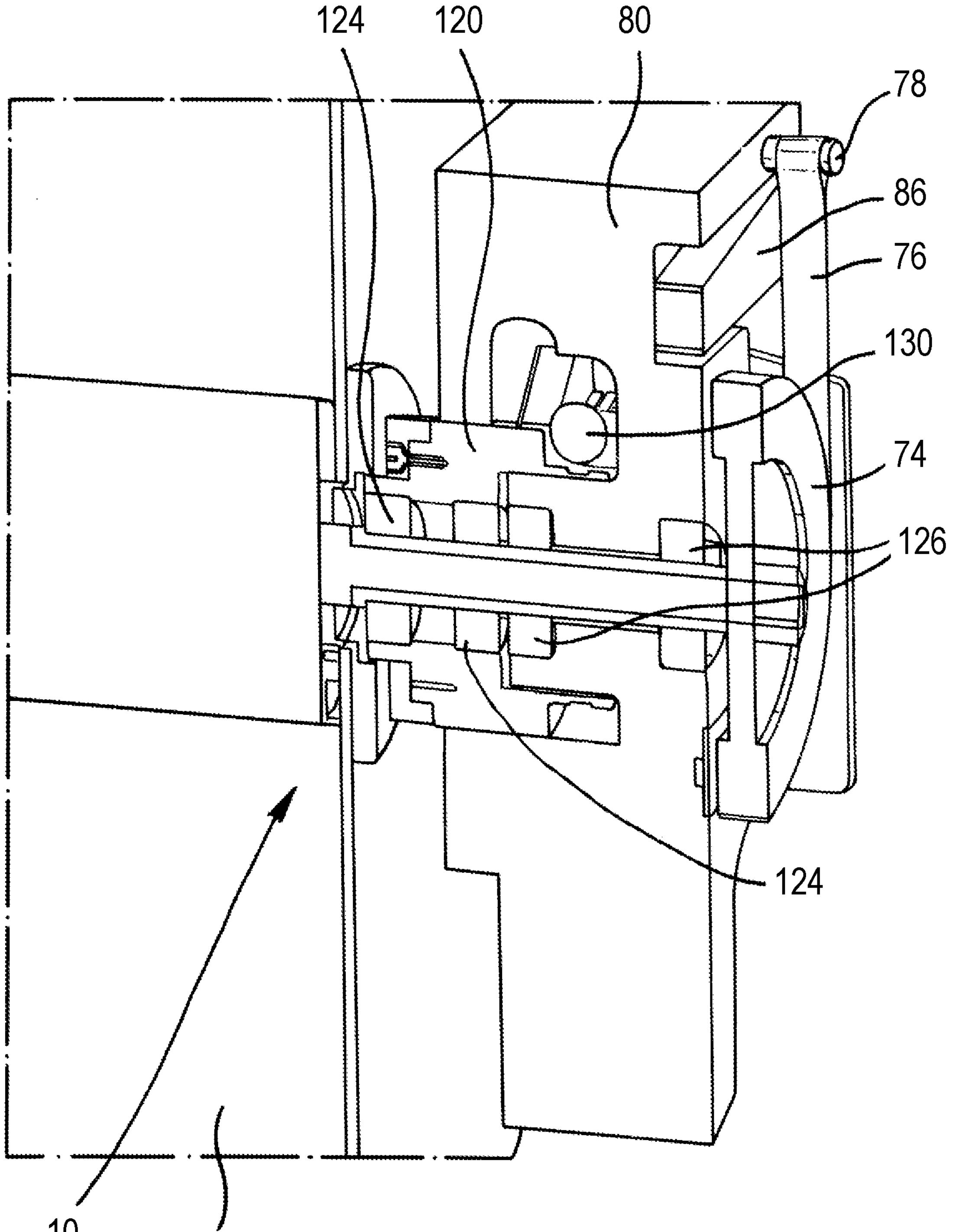


Fig. 13

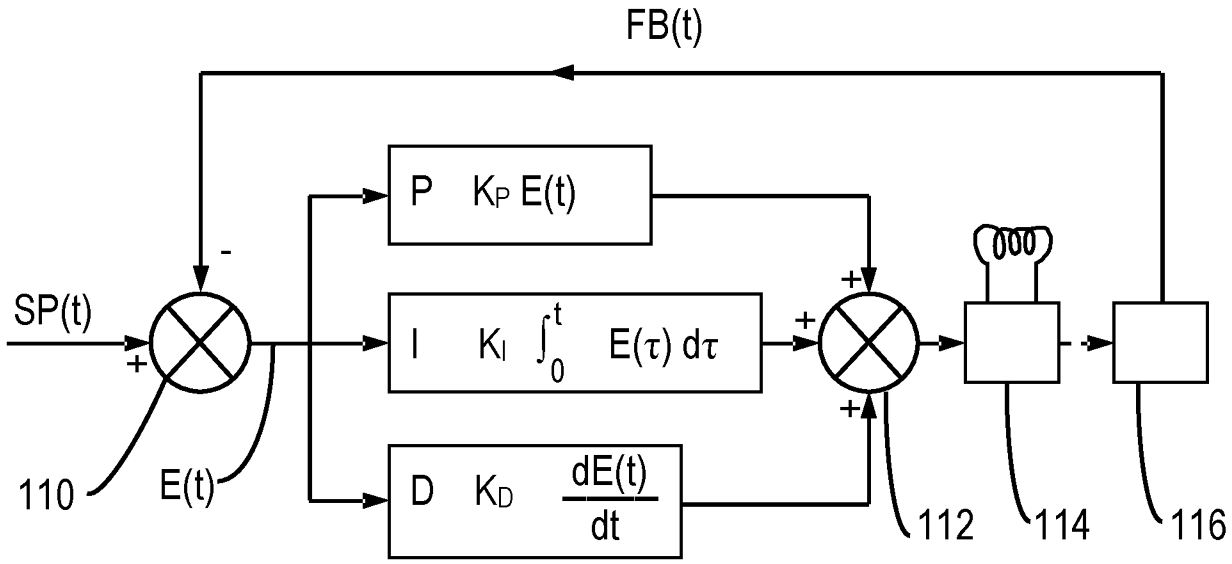

FB(t)
SP(t)
+
-
P K_P E(t)
I $K_I \int_0^t E(\tau)\, d\tau$
D $K_D \frac{dE(t)}{dt}$
+
+
+
110
E(t)
112
114
116

Fig. 14

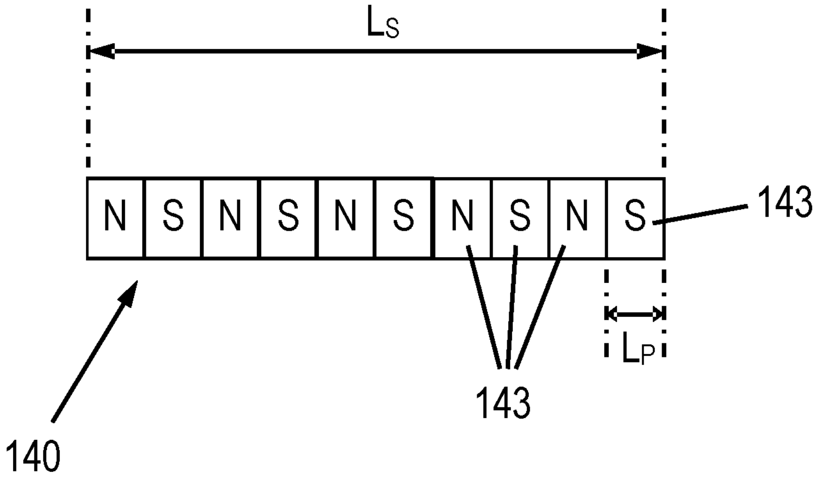


Fig. 15

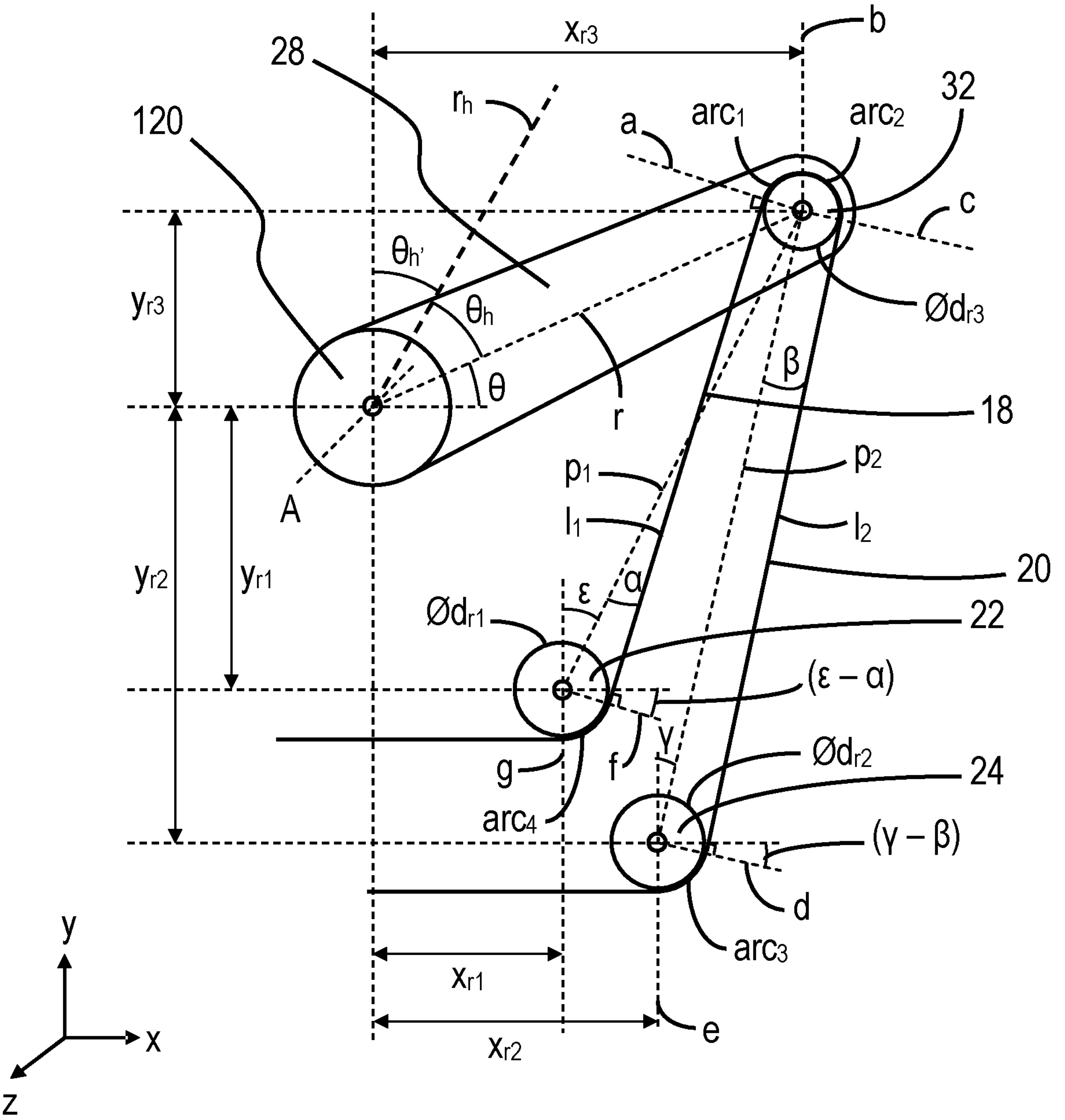

28
120
x_{r3}
b
r_h
a
arc_1
arc_2
32
c
$\theta_{h'}$
θ_h
θ
r
$Ød_{r3}$
y_{r3}
β
18
A
p_1
p_2
l_1
l_2
20
y_{r2}
y_{r1}
ε
α
$Ød_{r1}$
22
$(\varepsilon - \alpha)$
g
f
γ
$Ød_{r2}$
24
arc_4
$(\gamma - \beta)$
d
arc_3
y
x
z
x_{r1}
x_{r2}
e

Fig. 16

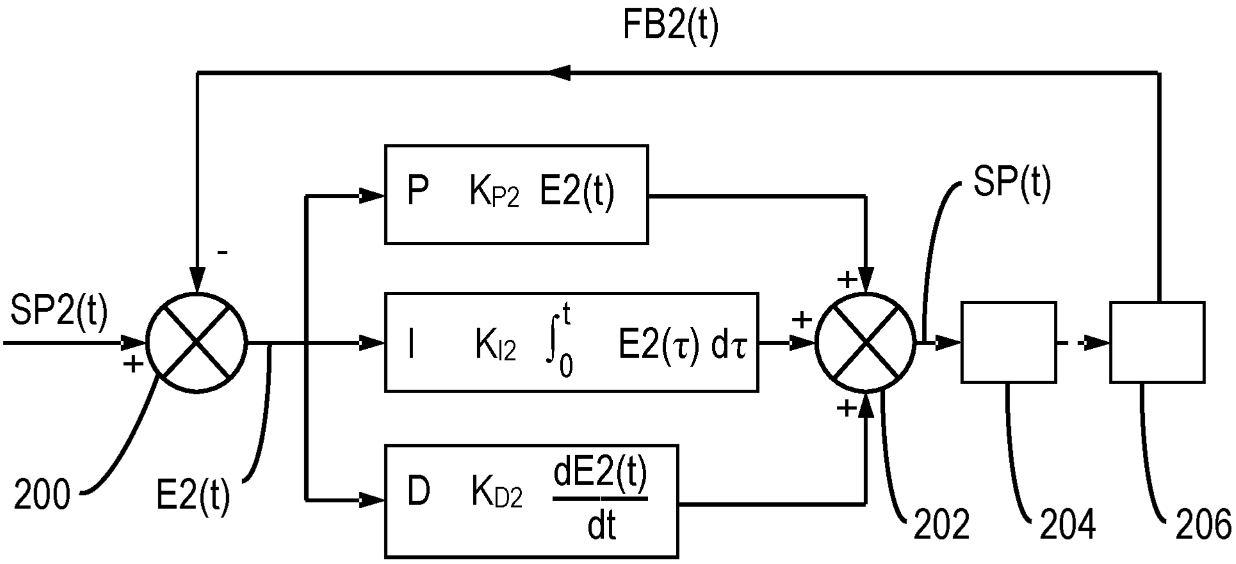

FB2(t)
SP2(t)
+
-
200
E2(t)
P K_{P2} E2(t)
I K_{I2} $\int_0^t$ E2(τ) dτ
D K_{D2} $\frac{dE2(t)}{dt}$
+
+
+
SP(t)
202
204
206

Fig. 17

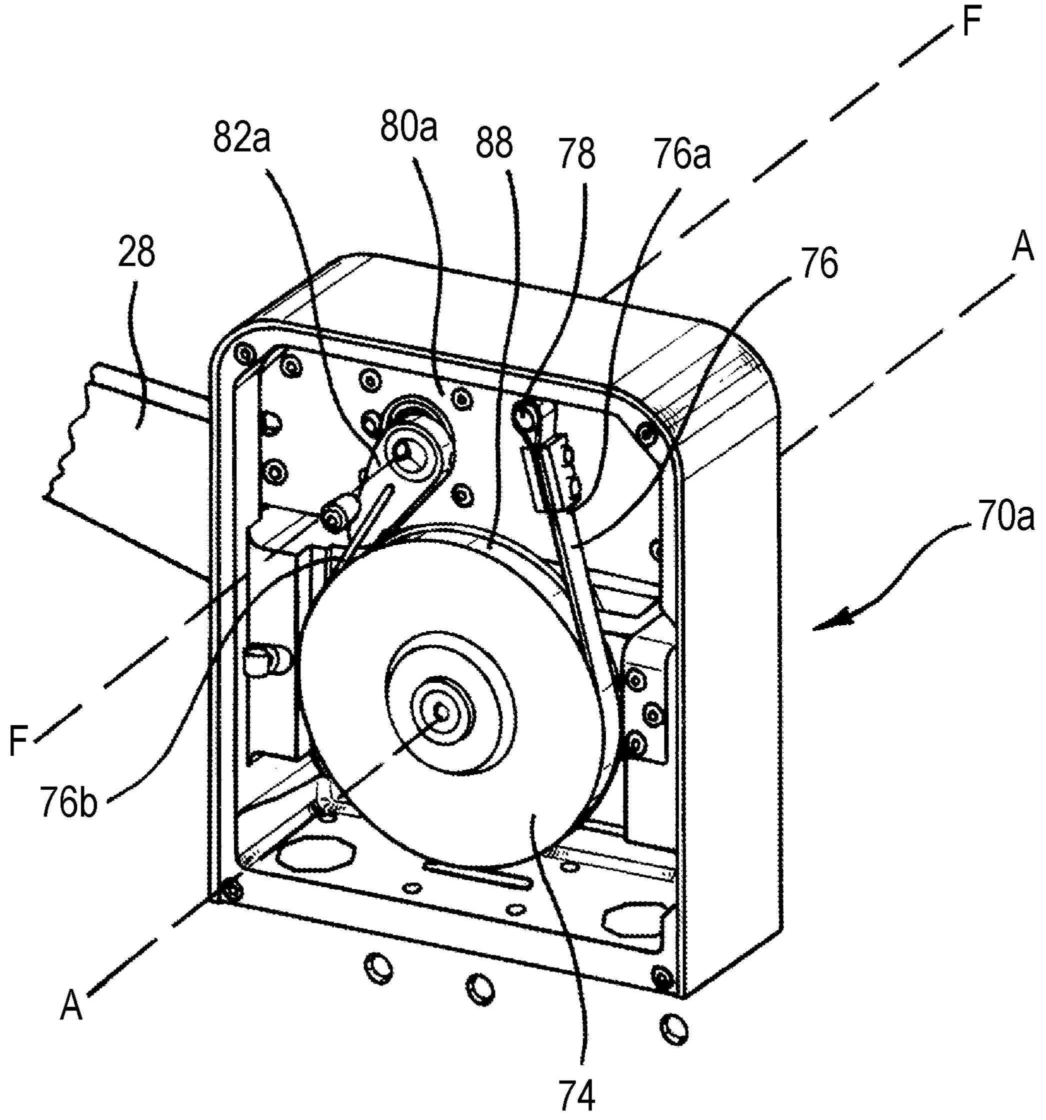


Fig. 18

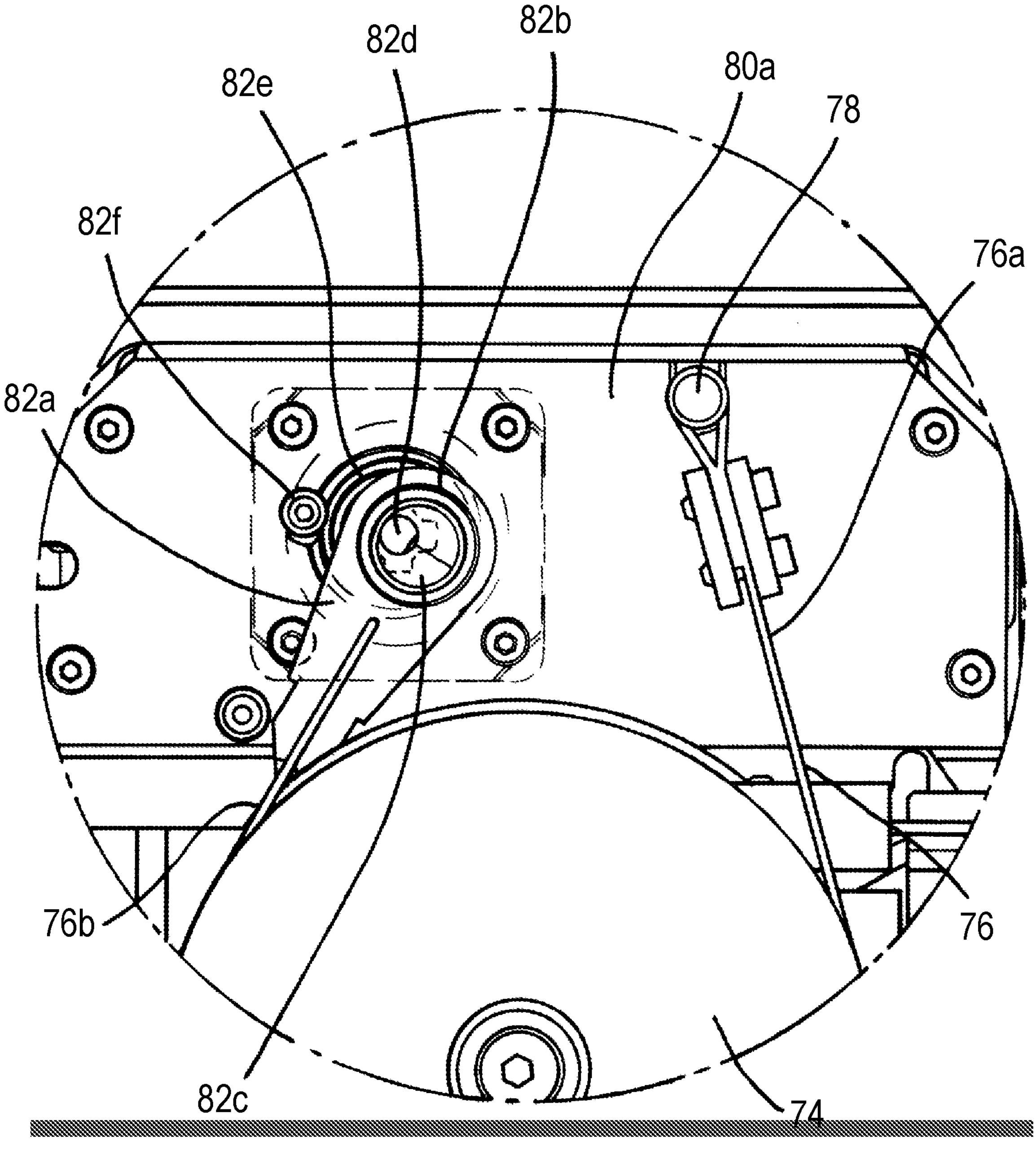


Fig. 19

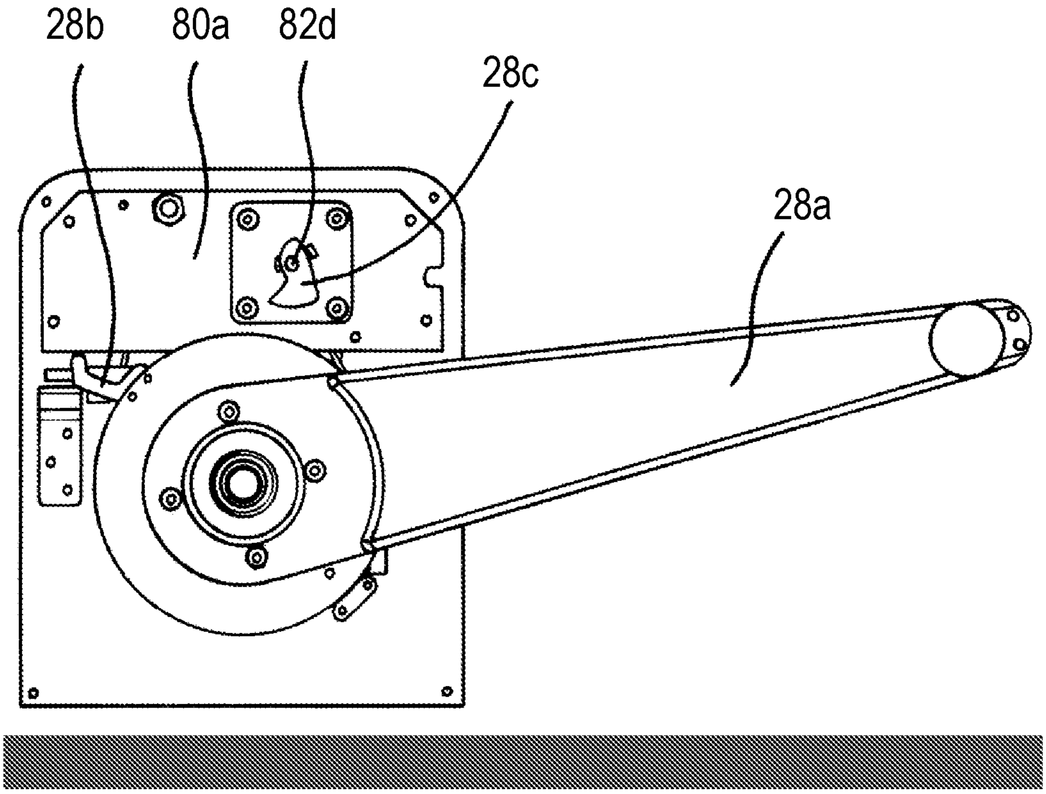


Fig. 20

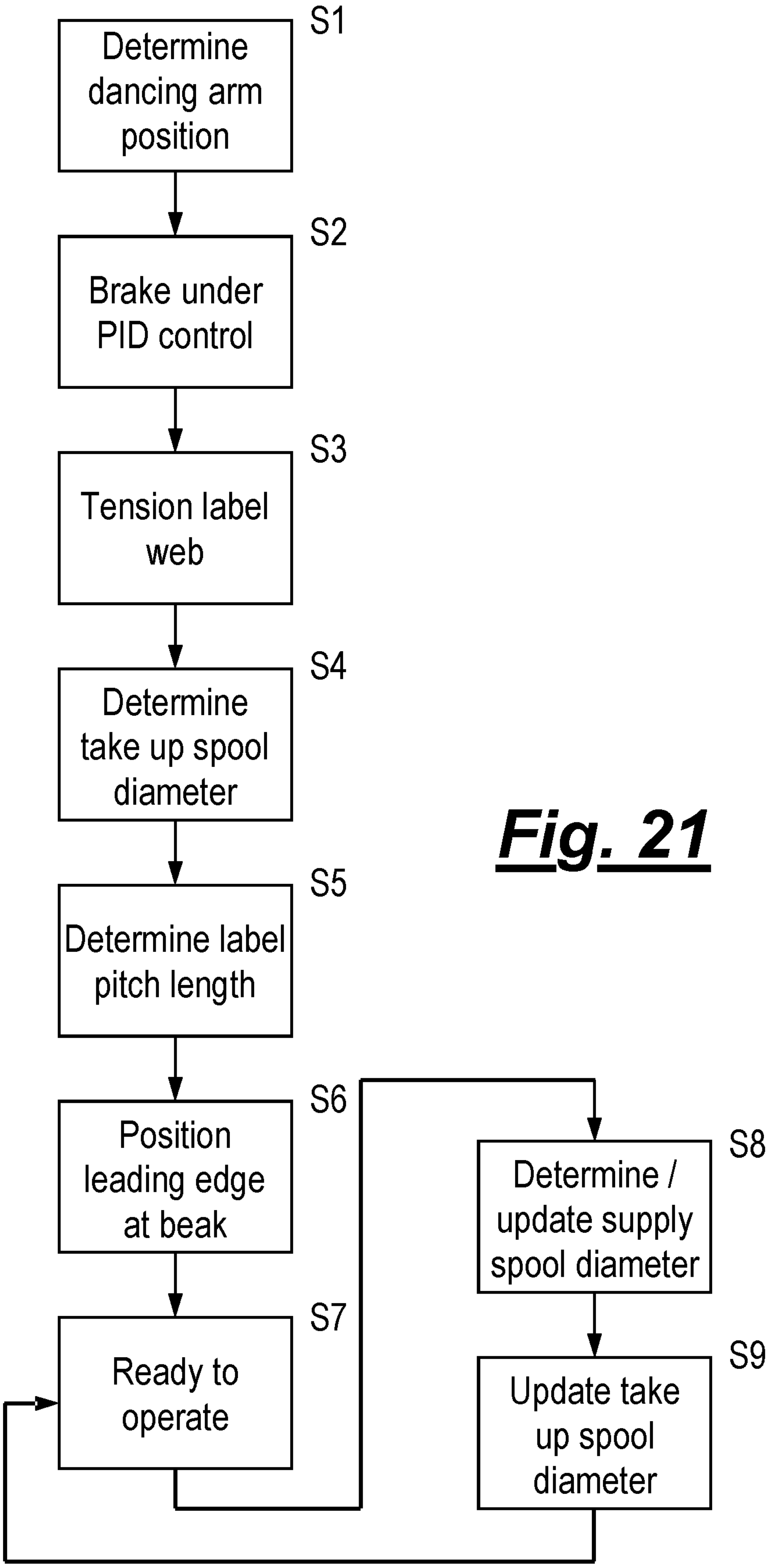

S1
Determine dancing arm position
S2
Brake under PID control
S3
Tension label web
S4
Determine take up spool diameter
S5
Determine label pitch length
S6
Position leading edge at beak
S7
Ready to operate
S8
Determine / update supply spool diameter
S9
Update take up spool diameter

Fig. 21

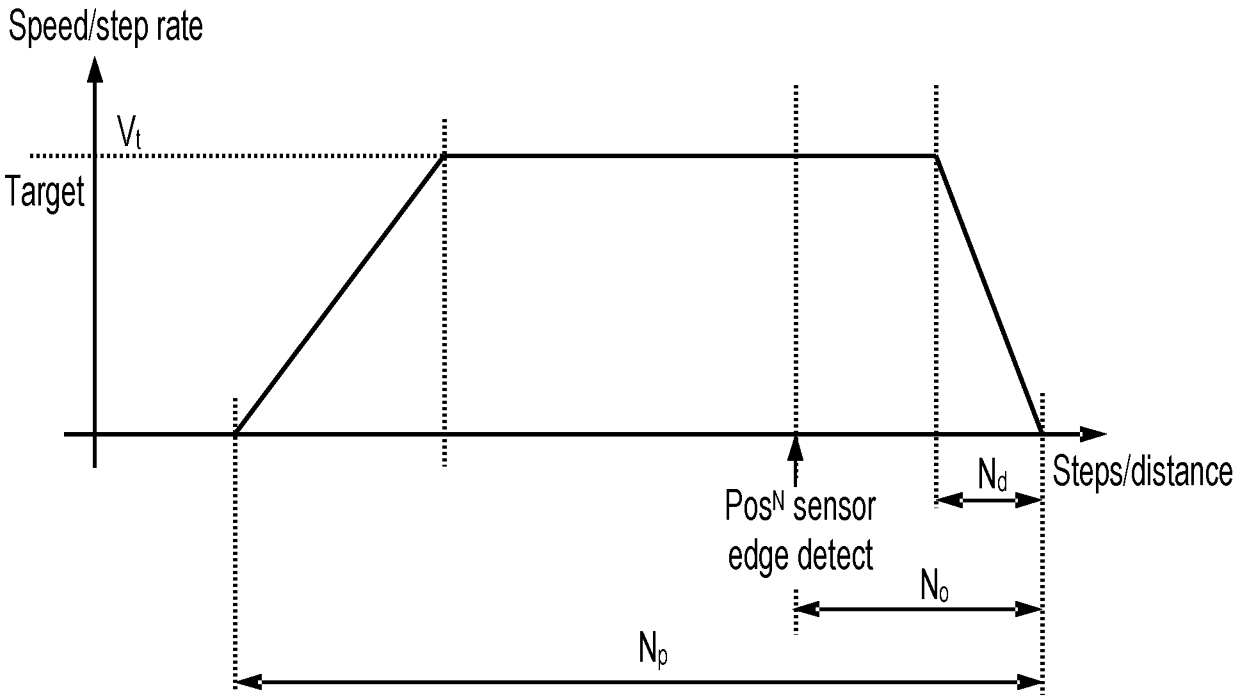

Speed/step rate
V_t
Target
Pos^N sensor edge detect
N_d
Steps/distance
N_0
N_p

Fig. 22

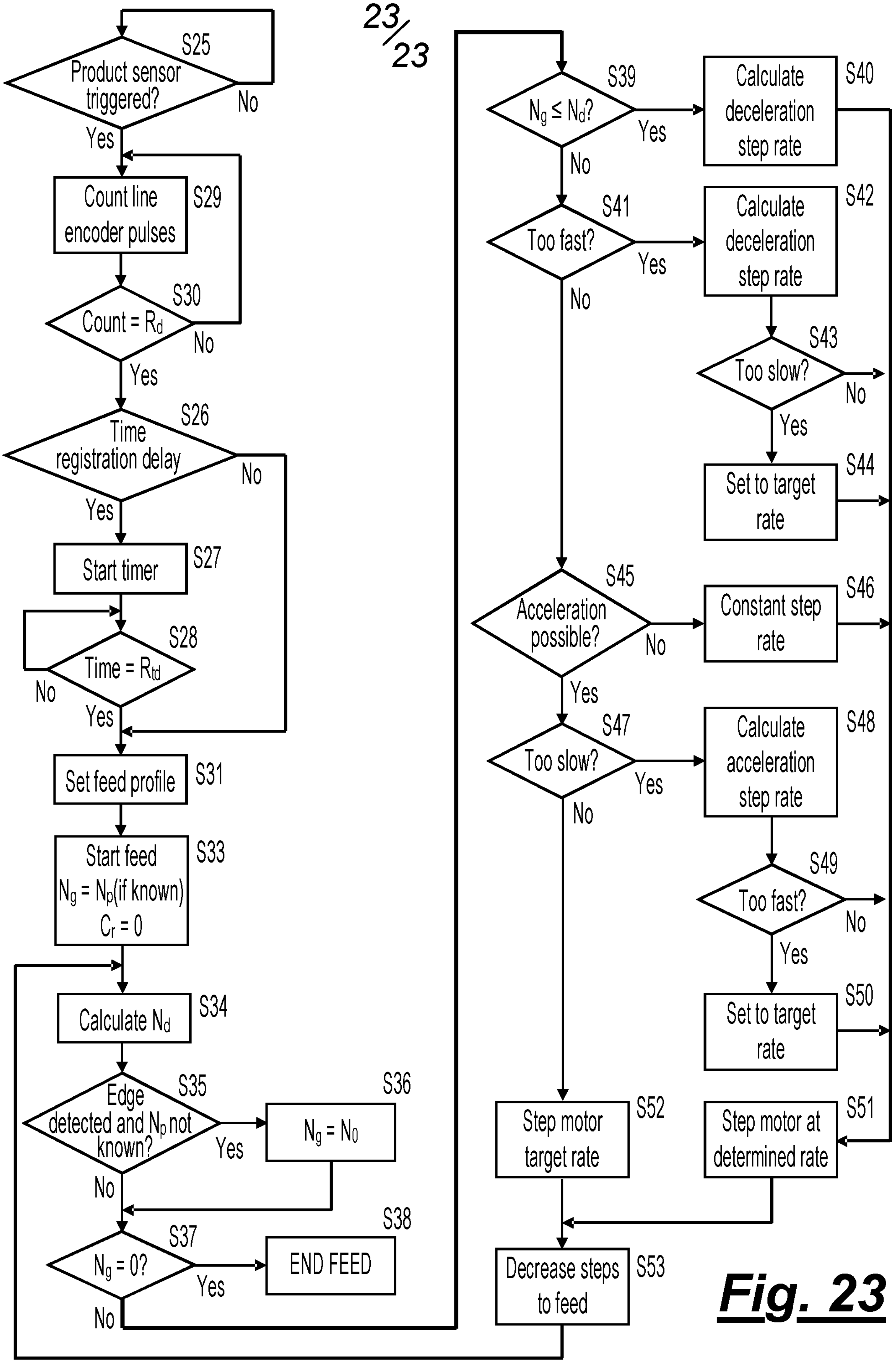

S25
Product sensor triggered?
No
Yes
S29
Count line encoder pulses
S30
Count = R_d
No
Yes
S26
Time registration delay
No
Yes
S27
Start timer
S28
Time = R_{td}
No
Yes
S31
Set feed profile
S33
Start feed
$N_g = N_p$(if known)
$C_r = 0$
S34
Calculate N_d
S35
Edge detected and N_p not known?
Yes
No
S36
$N_g = N_0$
S37
$N_g = 0$?
Yes
No
S38
END FEED
S39
$N_g \leq N_d$?
Yes
No
S40
Calculate deceleration step rate
S41
Too fast?
Yes
No
S42
Calculate deceleration step rate
S43
Too slow?
No
Yes
S44
Set to target rate
S45
Acceleration possible?
No
Yes
S46
Constant step rate
S47
Too slow?
Yes
No
S48
Calculate acceleration step rate
S49
Too fast?
No
Yes
S50
Set to target rate
S52
Step motor target rate
S51
Step motor at determined rate
S53
Decrease steps to feed

Fig. 23

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2013/052932

A. CLASSIFICATION OF SUBJECT MATTER
INV. B65C9/42
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B65C

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 556 492 A (VONDERHORST JAMES P [US] ET AL) 17 September 1996 (1996-09-17) column 5, line 47 - column 6, line 57 column 8, line 28 - line 47 figures 1, 4 -----	1,2,4-6, 8-18 3,7
Y	EP 2 042 828 A1 (LEUZE ELECTRONIC GMBH & CO KG [DE]) 1 April 2009 (2009-04-01) paragraphs [0002], [0003], [0014], [0015]; figure 1 -----	3
Y	EP 0 033 609 A1 (DATAFILE LTD [CA]) 12 August 1981 (1981-08-12) page 6, line 24 - page 7, line 9 page 10, line 12 - line 25 page 12, line 30 - page 13, line 14 figures 3, 6-8 ----- -/--	7

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

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search 11 February 2014	Date of mailing of the international search report 19/02/2014
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Luepke, Erik

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INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2013/052932

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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International application No

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