

(19)



Europäisches Patentamt

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(11)

**EP 1 225 053 A2**

(12)

## EUROPEAN PATENT APPLICATION

(43) Date of publication:

**24.07.2002 Bulletin 2002/30**

(51) Int Cl.7: **B41J 3/407**

(21) Application number: **02250312.2**

(22) Date of filing: **16.01.2002**

(84) Designated Contracting States:

**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU  
MC NL PT SE TR**

Designated Extension States:

**AL LT LV MK RO SI**

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(30) Priority: **17.01.2001 GB 0101186**

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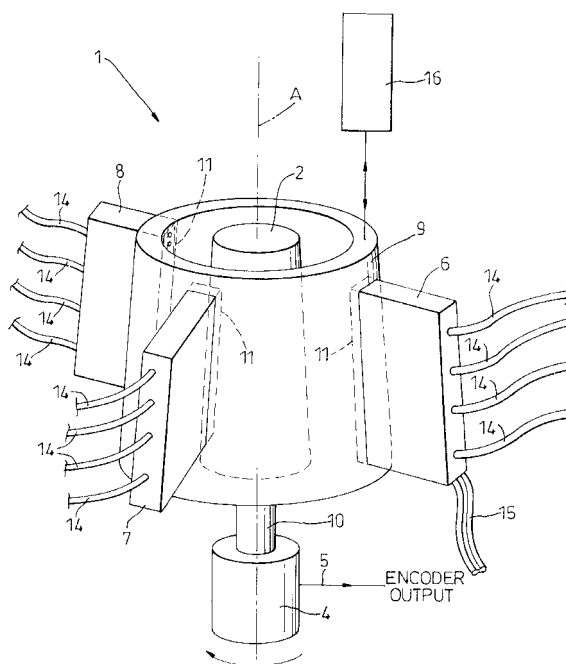
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### (54) Printing process and apparatus

(57) A method of printing the sidewall (13) of a three-dimensional article such as a plastics cup (12), comprises rotating the article about the principal axis (A) thereof such that the sidewall is caused to pass a plurality of ink-jet heads (6, 7, 8; 20, 21, 22, 23) directed towards the axis (A), and controlling the firing of the ink-jet heads in response to a measure (5) of the angular position of

the article about said axis, as provided by an encoder (4) on the drive (10) to an article mandrel (2), to deposit components of a required design onto the sidewall (13). Different components of the design may be applied at a single station, or at different stations in which case the mandrels (2) may be carried by an indexing table (18). The ink-jet heads are arranged to be retractable, either axially or radially relative to the article mandrel.



**Fig. 1**

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## Description

[0001] This invention relates to a printing process and printing apparatus, and particularly, but not exclusively, to the printing of containers such as tubs in which food products are sold.

[0002] It is common practice to print the walls of thermo-formed and injection-moulded tubs by offset printing methods in which inked intaglio rollers apply the coloured components of a multi-coloured design to an off-set roller against which a tub is urged to receive the composite ink design. This process is employed for various shapes of tubs, such as frusto-conical tubs, and tubs of square or hexagonal shape in plan. It is costly to produce the intaglio rollers, and since these must be changed to print articles with a different design, it is not generally economic to do small printing runs of different designs.

[0003] The present invention is concerned with applying designs by ink-jet printing onto the sidewall of a three-dimensional article. The term three-dimensional article is used herein to distinguish from flat sheets or continuous webs of sheet material. The invention may, however, be applied to thin-wall cylinders.

[0004] According to one aspect of the invention we provide a method of printing the sidewall of a three-dimensional article, comprising rotating the article about the principal axis thereof such that the sidewall is caused to pass a plurality of ink-jet heads directed generally towards the axis, and controlling the firing of the ink-jet heads in response to a measure of the angular position of the article about said axis to deposit components of a required design onto the sidewall.

[0005] Preferably the ink-jet heads are elongated heads provided with a large number of ink-jet orifices arranged substantially in a line or lines extending along the head, the longitudinal axis of the head lying substantially in a plane that includes the axis of rotation of the article, the heads incorporating individual excitation means for controlling respective orifices (such as piezo-electric excitation means).

[0006] According to a second aspect of the invention we provide a printing apparatus suitable for printing the sidewall of a three-dimensional article, comprising at least one rotatable article support adapted to rotate a three-dimensional article about a principal axis of the article, support drive means for rotating the article support about said axis, a plurality of elongate ink-jet heads arranged, or adapted to be arranged, circumferentially about the support rotational axis with the longitudinal axis of the heads lying substantially in planes that include the support rotational axis, and control means for controlling the timing of the firing of the ink-jet heads in response to the output of an encoder associated with the support or the support drive means.

[0007] The ink-jet heads usually need to be positioned relatively close to the sidewall of the article during firing of the heads, and in order to accommodate loading and

unloading of the article from the article support, the ink-jet heads may need to be made retractable in some way relative to the article support from an operative position to a retracted position.

[0008] In one embodiment we mount a plurality of ink-jet heads on a substantially cylindrical cage which is arranged to be retractable in an axial direction relative to the rotatable support means whereby in the retracted position of the cage a printed article can be unloaded from the support means and a fresh article loaded onto the support means.

[0009] Any convenient form of pick and place mechanism may be employed for loading and unloading the articles from the support means.

[0010] It will be appreciated that consistently precise positioning of the ink-jet heads in their operative positions is required in order to ensure that the component images which are being delivered by the respective heads build up to provide a crisp composite image on the article. However, the software which controls the relative timing of the firing of the respective ink-jet heads preferably comprises a timing adjustment facility which can be adjusted during a setting up procedure to take account of any differences in precise angular position of a head, due for example to replacement of one head with another.

[0011] The article may be rotated more than once during firing of the ink-jet heads and a particular head may be caused to apply a different image component to the article on different passes of the article sidewall. The reason for this is that ink-jet heads generally provide an image component which is an array of dots, built up from parallel lines of dots extending parallel to the longitudinal axis of the ink-jet head. There are spaces between the dots, and with advantage at least some of the spaces can be filled with the same colour by a second firing of the head which applies dots in the spaces between the dots produced on the preceding firing of the head. Thus a second firing of the same head can be provided on a second pass of the article sidewall accommodated by rotating the article by more than one revolution.

[0012] For multi-coloured images it is generally required to provide component images in three component colours, usually cyan, magenta and yellow, and often an additional black image component is provided. Therefore, except for images using only a small number of colours, it will generally be necessary to provide a minimum of four ink-jet heads, each one applying one of the component colours. Since the ink-jet heads generally need to be positioned close to the sidewall of the article during firing of the heads, and the heads require supply tubes for ink and associated ink reservoirs, it will not always be possible to arrange the various heads at a single station.

[0013] In accordance with a preferred feature of the invention, the article support is conveyed from one station to one or more further stations at each of which the support is rotated relative to one or more ink-jet heads

provided at the respective stations.

**[0014]** Preferably the article support is mounted on a rotary table or star-wheel that is indexed between a plurality of stations and most preferably the rotary table carries a plurality of such article supports that are individually rotatable with respect to the table.

**[0015]** In the case where there are two ink-jet heads at a particular station, these are preferably positioned along a radial direction relative to the table axis to enable the table to be indexed to carry an article from between those ink-jet heads at that station to the next station, where the ink-jet heads are similarly arranged.

**[0016]** In order to synchronise the rotation of the article supports carried by the table, the article supports are preferably all driven by a common toothed-belt drive, and an encoder for providing timing signals for firing of all of the ink-jet heads at the various stations is associated with the belt drive means.

**[0017]** In order to accommodate articles of non-round section, as viewed perpendicular to the principal axis of the articles, the ink-jet heads may be mounted on carriers that are driven towards and away from the rotational axis of the article support as the article is rotated. The carrier drive means for reciprocating the ink-jet heads in this way may be a servo-drive mechanism which can be programmed to provide the appropriate reciprocation of the heads in time with the rotation of the article. Preferably, however, the carrier drive means is a mechanical camming mechanism which utilises a cam plate associated with the article support, and cam followers which actuate the carriers.

**[0018]** When the article to be decorated is a thin-walled article, such as a thermo-formed tub for a food product, the article is preferably held in position by vacuum suction on an article support in the form of a mandrel of complementary shape to that of the interior of the article.

**[0019]** Since the ink-jet printing process does not involve pressure of a printing roller against the article, which can deform the article, it is possible in some cases to tolerate larger variations in wall thickness by using the inventive process. Also, in the past it was usually impossible to use the offset printing process to print a ribbed article. The invention makes it possible to provide structural ribs in the sidewall of the article, thereby permitting a reduction in the wall thickness of the remaining parts of the sidewall and in some cases a saving in overall article material costs.

**[0020]** It will often be necessary to provide for curing of the ink prior to subsequent handling of the printed article. This is particularly because the inventive process permits the build-up of a thicker composite ink image on the article than is generally possible with existing offset printing.

**[0021]** When the inventive process is used with a particularly tall article, different axial regions of the article may be provided with image components by different printing heads, which may be at different stations, by

mounting the different ink-jet heads at different axial positions relative to the article support.

**[0022]** A particular advantage of the inventive process as compared with offset printing is that lap problems associated with the ends of the offset image can be overcome. Since an offset image is effectively wrapped around an article there are problems in abutting the opposite ends of the wrapped image when this is required. However, with the inventive process the image can continuously encircle the article because the opposite ends of the image can be allotted to successive encoder pulses in the memory which drives the firing of the ink-jet heads, to provide a seamless connection between the ends of the image.

**[0023]** A particular advantage of the invention is the ability to print articles having a sloping sidewall, such as the frusto-conical sidewall of a tapered disposable drinks beaker. This is in part because it is possible to angle the ink-jet heads to accommodate the slope of the sidewall of the beaker.

**[0024]** It will be appreciated that the software for creating the image components held in memory can incorporate feature(s) which facilitate any adaption of a planar image to that which may be required for presentation on a non-cylindrical article, such as a square article.

**[0025]** Some embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which:

**Figure 1** is a schematic perspective view of a single station printing apparatus,

**Figure 2** is a schematic vertical cross-section of the printing apparatus of Figure 1,

**Figure 3** is a partial plan view of a multi-station printing apparatus,

**Figure 4** is a schematic perspective view of a support mandrel for a tapered square pot and associated camming arrangement, and

**Figure 5** is a block diagram of the control system for the ink-jet heads.

**[0026]** With reference to Figures 1 and 2, a single station ink-jet printing apparatus 1 is shown which is suitable for printing on the frusto-conical sidewall of thermo-formed tapered drinks cups.

**[0027]** A frusto-conical mandrel 2 is supported on a drive shaft 10 driven by a motor 3 and an associated encoder 4 provides a timing signal 5 which is employed to control the firing of ink-jet heads 6, 7, 8 mounted on an axially reciprocable rigid cage 9 which surrounds the mandrel 2 in the operative position of the cage, shown in Figures 1 and 2.

**[0028]** As shown in Figures 1 and 2, the heads 6, 7, 8 are of elongate shape with the longitudinal axes of the

heads extending in planes that include the axis A of rotation of the mandrel 2. The cage 9 is provided with circumferentially-spaced vertical apertures in which the heads are clamped, the operative faces 11 of the heads facing towards the mandrel 2 such that the head faces 11 are closely spaced from the sidewall of an inverted thermo-formed cup 12 when mounted on the mandrel 2.

**[0029]** The ink-jet heads 6, 7 and 8 are used to apply three colour components of an image to the sidewall 13 of the cup. For example ink-jet head 6 may be supplied with yellow ink by way of flexible supply tubes 14, ink-jet head 7 may be supplied with magenta ink, and ink-jet head 8 with cyan ink.

**[0030]** Typical ink-jet heads which are suitable for use in printing articles of the size of drinks beakers and small food tubs are available from Xaar under designation XJ500 S greyscale heads. Such heads are configured to provide 180 dots per inch, and the use of two heads can provide, in effect, 360 dots per inch when the image components printed by those heads are superposed out of phase by one dot space in the longitudinal direction of the heads.

**[0031]** The firing of the ink-jet heads is provided by firing control signals on a respective flexible bus 15.

**[0032]** It will be appreciated that control of the firing signals on buses 15 is determined by appropriate software utilising the encoder timing signal 5 which is a measure of the angular position of the supported cup 13 relative to the cage 9 and thus relative to the ink-jet heads 6, 7, 8.

**[0033]** The cage 9 is mounted on an axially reciprocable cradle, not shown, which utilises a hydraulic or pneumatic actuator, indicated schematically at 16, for raising the cage 9 vertically by more than the height of mandrel 2, to enable a printed cup to be removed from mandrel 2 and a fresh cup installed on mandrel 2 by a suitable pick and place mechanism, known in the art.

**[0034]** It will be appreciated that the relative angular positions of the heads 6, 7 and 8 is maintained by the heads being clamped to the cage 9, so that the relative phase difference required for firing of the heads is maintained during retraction of the cage.

**[0035]** In Figure 3 part of a multi-station machine is shown. A circular table 18 is indexable between, for example, twelve positions, only two of which are shown in the drawing. There are a corresponding number of stations at the various indexed positions of a plurality of rotatable mandrels 2a, 2b. At some of the stations, such as the two stations shown, there are pairs of ink-jet heads, such as the heads 20, 21; 22, 23 shown, the heads being supported on a stationary support, not shown. The pairs of heads 20, 21; 22, 23 are each adjustable radially of table 18 in opposite radial directions of table 18, to accommodate articles of different dimensions. The positioning of the heads on radii of the table 18 enables the mandrels 2a, 2b etc to be indexed between stations whilst supporting the articles to be printed.

**[0036]** The mandrels 2a, 2b are rotatable, and preferably rotate continuously and are preferably all driven by a common toothed belt, not shown, an encoder being associated with the belt drive to provide a timing signal which is used to control firing of the various heads 20, 21; 22, 23 etc.

**[0037]** At another of the stations of the apparatus of Figure 18 a UV ink drying means is provided in advance of an unloading station, not shown.

**[0038]** Each of the mandrels 2a, 2b etc is provided with vacuum suction which is employed to hold the article against turning relative to the mandrel. A timing mechanism associated with rotation of the table 18 releases the vacuum for removal of the printed article.

**[0039]** With reference to Figure 4 this shows a mandrel 25 of shape complementary to the interior of a thermo-formed, tapered square pot. In fact the sidewall faces of the pot are convex and the pot has rounded corners. In order to control the radial position of the ink-jet heads relative to the axis of rotation of mandrel 25, a camming plate 26 is provided integral with the mandrel 25, and a cam follower 27 causes an ink-jet head support arm 28 to be retracted and advanced as the mandrel 25 is rotating, the respective ink-jet head being mounted on arm 28.

**[0040]** Figure 5 shows some of the control functions applicable to a multi-station machine having printing heads 15a, 15b, 15c, 15d, 15e, 15f which deposit different components of the composite image.

**[0041]** A graphic input unit 30 is used to determine/create/receive data on the image that is required to be printed onto the article. The input unit 30 preferably has a floppy drive and a CD drive to receive previously composed article print designs. A design manipulation and editing unit 31 enables the design to be tailored to fit the surface of the article. Suitable software for unit 31 is Adobe Photoshop™ software.

**[0042]** Xaar provide software under the name PCI plus which can be used to set up the respective memories in unit 32 for the image components to be applied by the various heads.

**[0043]** Unit 32 takes account of the fact that different ink-jet heads need to apply the different image components at different times to take account of the time required for a location on the article sidewall to be angularly turned between one head and another.

**[0044]** In the case that the image on the sidewall is to appear to be seamless, for example a stripe extending continuously around the pot, this can be achieved by allocating a complete number of encoder pulses, that number which corresponds to an angular displacement of the article support by 360° (typically 5000), to the entire length of the image as input/created by the graphic input unit 30. Thus, provided that the opposite 'ends' of the image in memory join up, this allocation of that image length to the total number of encoder pulses for a 360° rotation of the article will result in a seamless application of the image to the sidewall of the article.

**[0045]** With regard to a frusto-conical article, such as that shown in Figure 2, the process of applying the ink by the use of inclined ink-jet heads, which is required in order to provide the required substantially uniform spacing between the heads and the article sidewall, does not, in general, require any special measures to fit an elongate rectangular image, as contained in memory of the graphic input unit 30, to the tapered pot. It will be appreciated that the vertical lines of dots which make up the composite image will be slightly more spaced-apart circumferentially of the article towards the larger diameter end of the article than the corresponding spacing towards the smaller diameter end of the article, but this will not be apparent in the decorated article. It is possible that this might in some cases lead to a slightly denser image at the narrower bottom of the article than at the wider top, which could be compensated if necessary by a software adjustment to the required density of colour as between the top and bottom, but in many cases no adjustment will be found necessary.

**[0046]** In the case of a substantially square pot, such as that which would fit the mandrel 25 in Figure 4, it may be found necessary to stretch or contract part of the image in memory in order to take account of the fact that one encoder pulse will represent a different 'circumferential length' of the pot sidewall at different angular positions of the pot.

**[0047]** This alternate stretching and contraction of the image can readily be achieved by utilising the Adobe Photoshop™ software of unit 31.

## Claims

1. A method of printing the sidewall (13) of a three-dimensional article (12), comprising rotating the article about the principal axis (A) thereof such that the sidewall is caused to pass a plurality of ink-jet heads (6, 7, 8; 20, 21, 22, 23) directed generally towards the axis (A), and controlling the firing of the ink-jet heads in response to a measure (5) of the angular position of the article about said axis to deposit components of a required design onto the sidewall (13).
2. The method of claim 1 in which the ink-jet heads are elongated heads provided with a plurality of ink-jet orifices arranged substantially in a line or lines extending along the head, the longitudinal axis of the head lying substantially in a plane that includes the axis of rotation of the article, the heads incorporating individual excitation means for controlling respective orifices.
3. The method of claim 1 or claim 2 in which the article is rotated more than once during firing of the ink-jet heads and at least one of said heads is caused to apply a different image component to the article on

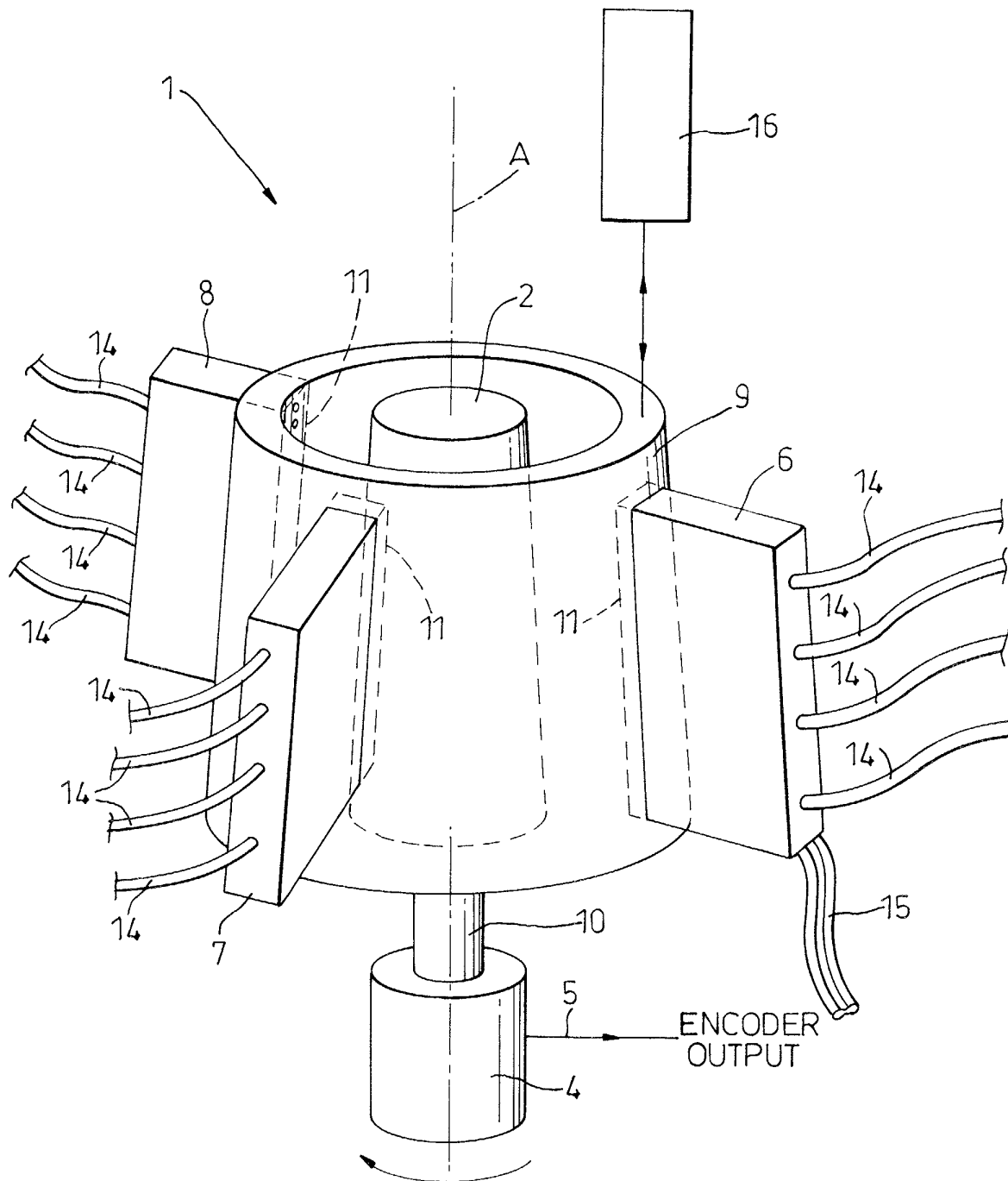
different passes of the article sidewall.

4. The method of claim 1 or claim 2 in which the article is conveyed from one station (2a) to one or more further stations (2b) at each of which the article is rotated relative to one or more ink-jet heads (20, 21, 22, 23) provided at the respective stations.
5. The method of any one of claims 1 to 4 in which the firing of the ink-jet heads is determined by image components held in memory, the image components having been determined so as to provide a printed image extending seamlessly circumferentially around the article sidewall.
6. A printing apparatus suitable for printing the sidewall of a three-dimensional article, comprising at least one rotatable article support (2; 2a, 2b; 25) adapted to rotate a three-dimensional article (12) about a principal axis (A) of the article, support drive means (3, 10) for rotating the article support about said axis, a plurality of elongate ink-jet heads (6, 7, 8; 20, 21, 22, 23) arranged, or adapted to be arranged, circumferentially about the support rotational axis with the longitudinal axis of the heads lying substantially in planes that include the support rotational axis, and control means (32) for controlling the timing of the firing of the ink-jet heads in response to the output (5) of an encoder (4) associated with the support or the support drive means.
7. A printing apparatus as claimed in claim 6 in which in order to accommodate loading and unloading of the article from the article support, the ink-jet heads are retractable relative to the article support from an operative position to a retracted position.
8. A printing apparatus as claimed in claim 7 in which a plurality of said ink-jet heads (6, 7, 8) is mounted on a substantially cylindrical cage (9) which is arranged to be retractable in an axial direction relative to the rotatable support means whereby in the retracted position of the cage a printed article can be unloaded from the support means and a fresh article loaded onto the support means.
9. A printing apparatus as claimed in any one of claims 6 to 8 in which the control means comprises software which controls the relative timing of the firing of the respective ink-jet heads, the software providing a timing adjustment facility which can be adjusted during a setting up procedure to take account of any differences in precise angular position of a head.
10. A printing apparatus as claimed in any one of claims 6 to 9 in which the article support is mounted on a rotary table (18) or star-wheel that is indexed between a plurality of stations, each station being pro-

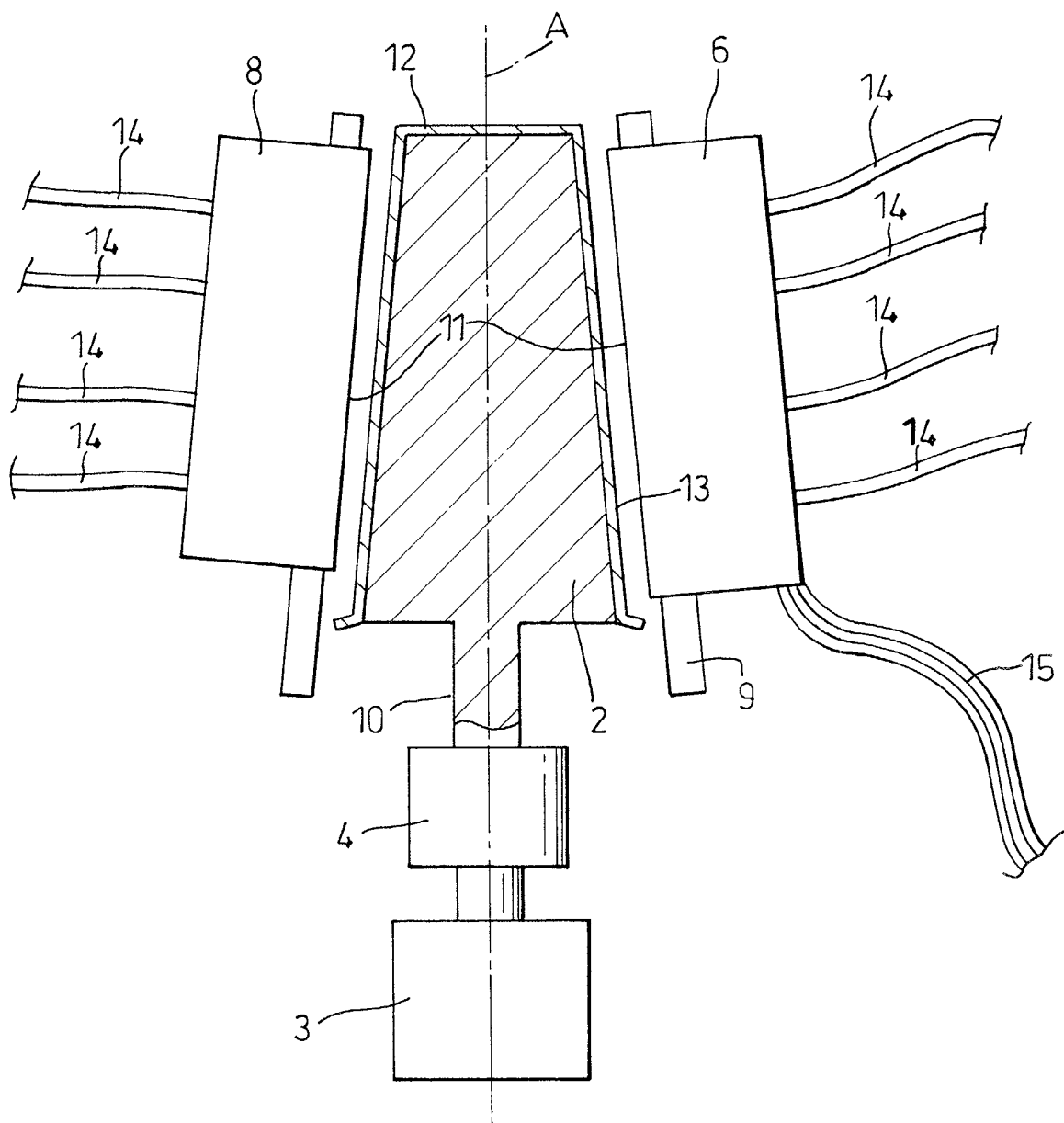
vided with one or more of such ink-jet heads.

encoder pulse generation positions.

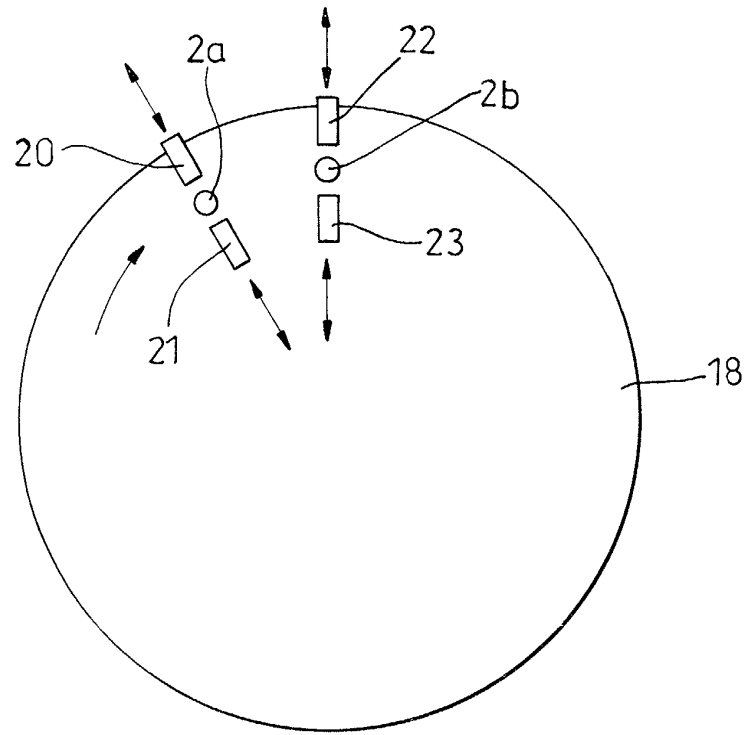
11. A printing apparatus as claimed in claim 10 in which the rotary table (18) carries a plurality of such article supports (2a, 2b) that are individually rotatable with respect to the table. 5
12. A printing apparatus as claimed in claim 11 in which there are two ink-jet heads (20, 21; 22, 23) at each station, the ink-jet heads at each station being positioned along a respective radial direction relative to the table axis to enable the table to be indexed to carry an article from between the ink-jet heads (20, 21) at one station to be positioned between the ink-jet heads (22, 23) at the next station. 10 15
13. A printing apparatus as claimed in claim 10, 11 or 12 in which in order to synchronise the rotation of the article supports carried by the table, the article supports are all driven by a common toothed-belt drive, and an encoder for providing timing signals for firing of all of the ink-jet heads at the various stations is associated with the belt drive means. 20
14. A printing apparatus as claimed in any one of claims 6 to 13 in which each ink-jet head is used to apply a different component colour. 25
15. A printing apparatus as claimed in claim 6 or 7 in which in order to accommodate articles of non-round section, as viewed perpendicular to the principal axis of the articles, the ink-jet heads are mounted on carriers (28) that are adapted to be driven towards and away from the rotational axis of the article support as the article is rotated. 30 35
16. A printing apparatus as claimed in claim 15 in which the carrier drive means is a mechanical camming mechanism (26, 27) which utilises a cam plate (26) associated with the respective article support (25), and cam followers (27) which actuate the carriers (28). 40
17. A printing apparatus as claimed in any one of claims 6 to 16 in which each article support is in the form of a mandrel of complementary shape to that of the interior of the article, and comprising vacuum suction means for holding the articles on the mandrel. 45
18. A printing apparatus as claimed in any one of claims 6 to 17 comprising ink curing means adapted to cure the printed ink prior to removal of the printed article from the support. 50
19. A printing apparatus as claimed in any one of claims 6 to 18 in which the control means (32) comprises an image memory which contains image component storage locations corresponding to respective 55
20. A printing apparatus in which the control means comprises image adaption means (31) for adapting a planar image to that which is required for presentation on a non-cylindrical article.



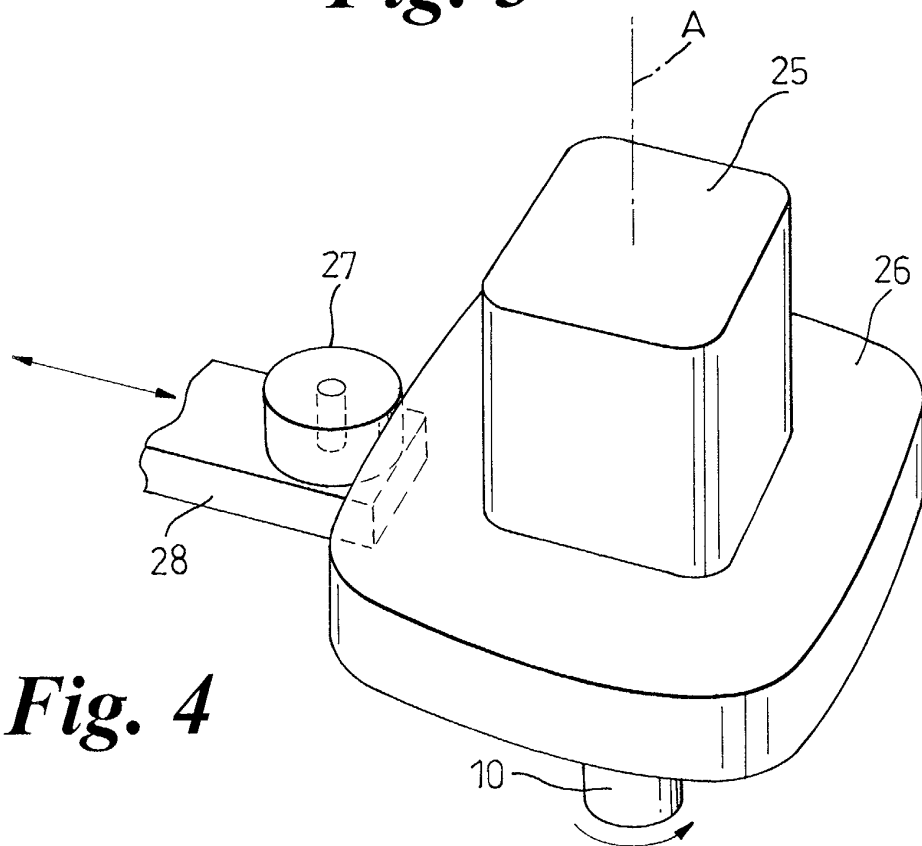
*Fig. 1*



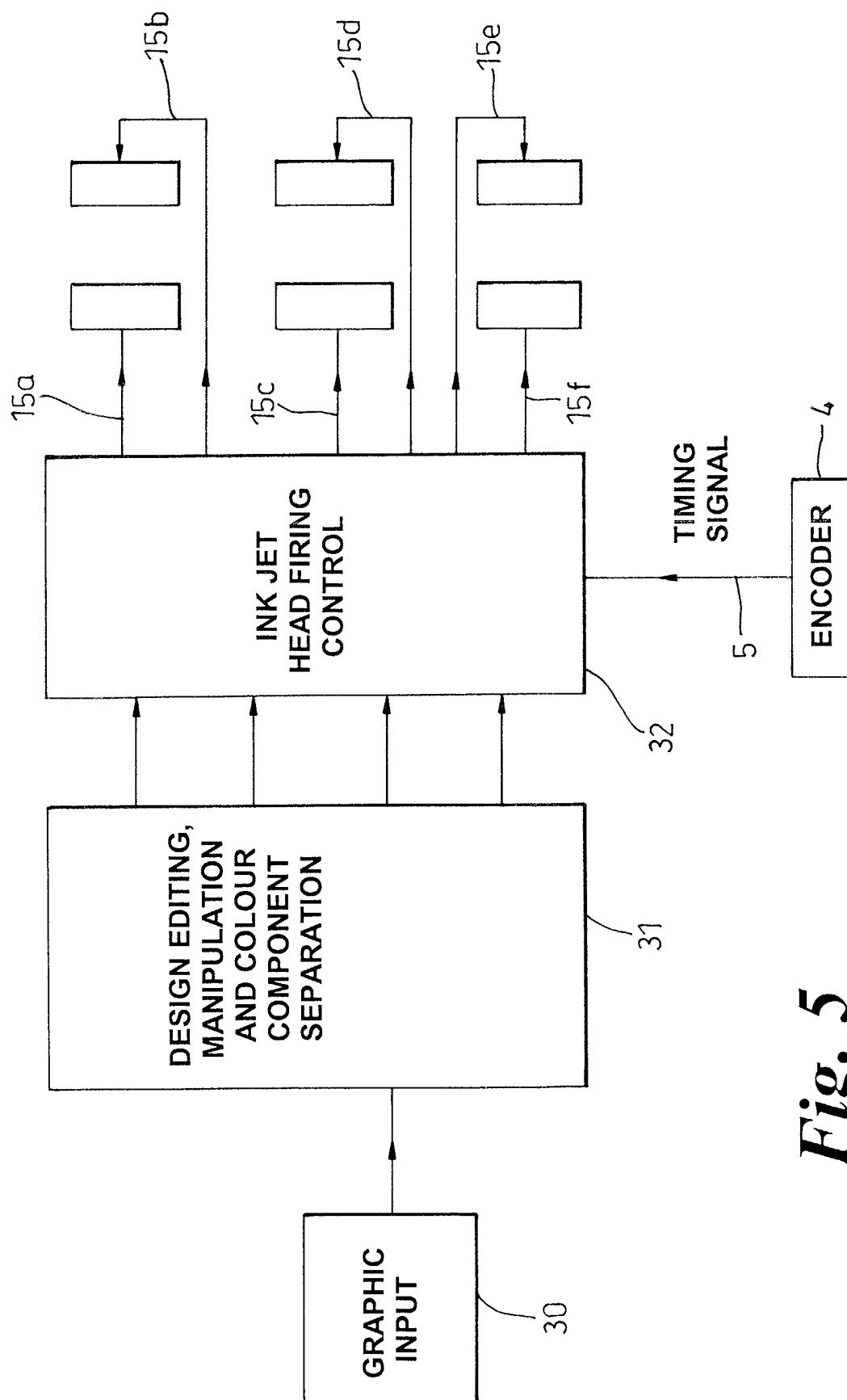
**Fig. 2**



**Fig. 3**



**Fig. 4**

**Fig. 5**