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(54) **Title:** METHOD AND APPARATUS FOR PRINTING IMAGES

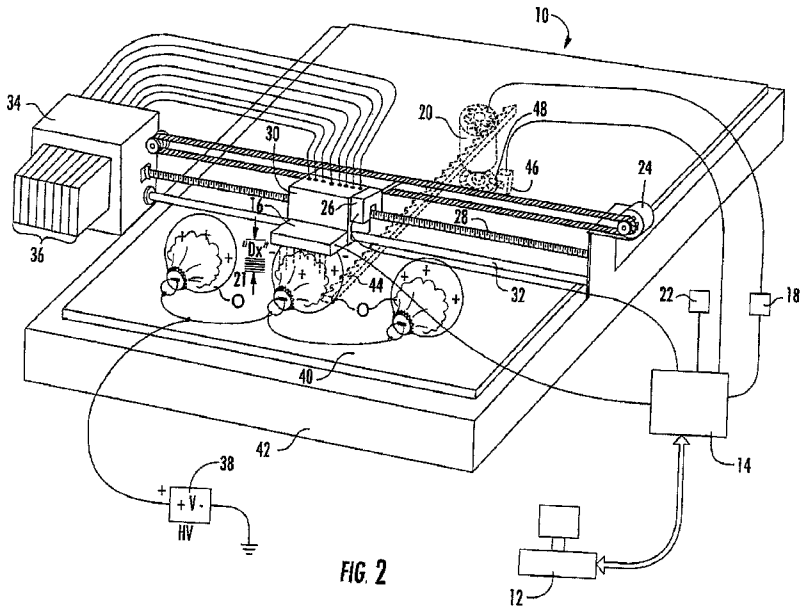

FIG. 2

(57) **Abstract:** An apparatus for printing an image on an object that includes electronic image storage for storing an image to be printed on a image surface of the object, and a print head positioned in spaced-apart relation to the object for receiving electronic data representing the image to be printed through the ink jet print head and applying the image to object using an ink that is applied with a predetermined electrical charge polarity. A voltage generator generates an electrical charge having an opposite polarity charge in relation to the predetermined charge polarity of the ink, and applies the opposite charge proximate the object and at a position to accelerate the ink being applied from the print head onto the object.

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METHOD AND APPARATUS FOR PRINTING IMAGES

Technical Field and Background of the Invention

[0001] The present invention relates to the field of image printing systems. In particular, the invention relates to an image printing apparatus and method capable of printing images on flat, curved, spherical, regular and irregular substrates.

[0002] Currently, there are several methods being used to print images on flat and irregular surfaces. However, these methods do not address the issue of varying distances between the substrates to be printed and print head; rather, they attempt to maintain a constant distance by curving the travel of the print head relative to the curvature of the substrate, or by moving the substrate during ink projection to maintain this distance. Additionally, these methods do not compensate for droplet loss due to droplets that are directed away from the substrate, causing density loss and an image that is out-of-focus or slightly fuzzy.

[0003] Thus, it is desirable to provide an image printing system and method to improve the image clarity and color when printing on flat, curved, spherical, regular and irregular surfaces by providing enhanced droplet control and improved dot gain.

[0004] This application therefore describes an apparatus and a related method that facilitate enhanced image printing and image control of in-flight ink solutions. The method allows a variance in distance between the ink jet head and substrate to occur during ink projection. Even droplet coverage occurs over flat or irregular surfaces as a result of the propagation of an electromagnetic field proximate the surface being printed with the surface being between the source of the electromagnetic field and the ink jet head.

[0005] The apparatus and method eliminates or reduces satellite droplets by a attracting a greater density of free airborne ink droplets to the substrate. These droplets may be diverted from their straight-line path by eddy air currents caused by the rapid movement of the ink jet head as it traverses rapidly back and forth during the printing process.

[0006] The disclosed apparatus and method may also assist in meeting certain safety regulations concerning use of potentially harmful chemicals and reduction of inhalant content in manufacturing and production environments.

Summary of the Invention

[0007] Therefore it is an object of the invention to provide an image printing system that controls in-flight ink droplets.

[0008] It is another object of the invention to provide an image printing system that controls ink droplets of various colors to hit specific destinations on substrates in order to generate and apply a clear image onto the substrate.

[0009] It is another object of the invention to provide an image printing system that permits accurate, clear application of images on flat, curved, spherical, regular and irregular substrates.

[0010] It is another object of the invention to provide an image printing system that controls droplet direction and/or droplet velocity during image creation.

[0011] These and other objects of the present invention are achieved in the preferred embodiments disclosed below by providing an apparatus for printing an image on an object that includes electronic image storage for storing an image to be printed on a image surface of the object, and a print head positioned in spaced-apart relation

to the object for receiving electronic data representing the image to be printed to the ink jet print head and applying the image to object using an ink that is applied with a predetermined electrical charge polarity. A voltage generator generates an electrical charge having an opposite polarity charge in relation to the predetermined charge polarity of the ink, and applies the opposite charge proximate the object and at a position to accelerate the ink being applied from the print head onto the object.

[0012] According to another embodiment of the invention, the object includes a charge conductive layer positioned proximate a side of the object opposite the image surface.

[0013] According to another embodiment of the invention, the object includes a charge conductive layer applied to a side of the object opposite the image surface.

[0014] According to another embodiment of the invention, the electrically conductive layer is electrically connected to the voltage generator.

[0015] According to another embodiment of the invention, the object includes a charge conductive layer positioned in spaced-apart relation to the voltage generator for receiving an induced electrical charge.

[0016] According to another embodiment of the invention, the apparatus includes an object holder for holding at least one object in a fixed orientation while an image is printed on the object.

[0017] According to another embodiment of the invention, the object holder comprises a tray adapted for receiving and holding a plurality of objects in a fixed fixed orientation while an image is printed on each of the objects.

[0018] According to another embodiment of the invention, the tray includes a plurality of individual cradles for receiving respective individual objects to be printed.

[0019] According to another embodiment of the invention, the tray includes a plurality of individual cradles for receiving respective individual objects to be printed, and a rotation assembly cooperating with the cradles to rotate the cradles in unison for positioning a desired surface in the proper orientation for printing.

[0020] According to a method embodiment of the invention, the steps for printing an image on an object include providing a print head positioned in spaced-apart relation to the object for receiving electronic data representing the image to be printed to the ink jet print head and applying the image to the object using an ink that is applied with a predetermined electrical charge polarity. An electrical charge having an opposite polarity charge in relation to the predetermined charge polarity of the ink is generated; and the opposite charge is applied proximate the object and at a position to accelerate the ink being applied from the print head onto the object.

Brief Description of the Drawings

[0021] The invention may be best understood by reference to the following description in conjunction with the accompanying drawing figures in which:

[0022] Figure 1 shows an image printing system according to an embodiment of the invention;

[0023] Figure 2 shows the image printing system of Figure 1 printing on an ornament; and

[0024] Figures 3 through 9 are sequential perspective views of an image printing system, including one particular embodiment of a tray for holding an array of similar or identical objects to be printed.

Description of the Preferred Embodiment and Best Mode

[0025] Referring now specifically to the drawings, an image printing system according to an embodiment of the invention is illustrated in Figure 1 and shown generally at reference numeral 10. The system 10 includes a computer 12 having image rendering software connected to a printer control board 14. The printer control board 14 includes electronic hardware and firmware for interpreting instructions from the computer 12 to control an ink jet print head 16. The printer control board 14 also provides signals to a platen advance motor driver 18 to control a platen motor 20 and a carriage motor driver 22 to control a carriage motor 24.

[0026] A carriage encoder sensor 26 interacts with the printer control board 14 and a carriage encoder strip 28 to provide accurate indication of the location of a carriage assembly 30. The carriage assembly 30 is supported by a carriage support rail 32 and is driven by the carriage motor 24. The carriage assembly 30 includes ink dampeners, a print head 16, and ink cable connectors. In the embodiments disclosed in this application, the print head 16 is an ink-jet print head. However, any printing technology, including future developments that project fine ink droplets onto a printable substrate under the control of a computer is encompassed within this invention.

[0027] A bulk ink housing 34 is connected to the carriage assembly 30 and includes individual ink containers 36, collectively indicated, for supplying ink to the print head 16.

[0028] A high voltage source 38 is electrically connected to a high voltage plate 40 for providing a positively-charged electromagnetic field to a substrate "S". The high voltage plate 40 is supported by a platen support 42 and is moved by a platen advance mechanism 44 operably connected to the platen motor 20. A platen motor encoder

sensor 46 is electrically connected to the printer control board 14, and operably connected to a platen motor encoder wheel 48 to determine the position of the platen support 42 and control the movements of the platen support 42 via the platen motor 20.

[0029] Referring now to Figure 2, as droplets are ejected from the print head 16 toward a the substrate "S", which may be the surface of an ornament or other object that has an internal conductive coating, the in-flight droplet stream is negatively charged in its natural state as it leaves the print head 16. Each droplet is thus influenced by the positive high voltage charge from the high voltage plate 40.

[0030] Application of the positive field of the high voltage plate 40 to the substrate "S" produces enhanced images due to the reduction of over-spray and satellite droplets that are effectively redirected for correct placement on the substrate "S" of the ornament.

[0031] Referring now to Figures 3-9 a specific example is shown, where the method is carried out on a printer 60 to apply an image on circular Christmas ornaments "O" where the ornament(s) may be printed individually or batched, as shown. Printer 60 may be any suitable printer, including an ink-jet printer such as an Epson Model 1280 or 4800. In the description that follows, general reference may be made to Figures 1 and 2 as the operating elements of the printer 60 are described. Printer 60 includes a housing 62 that includes the printer elements such as described above with reference to Figures 1 and 2, controlled by a computer, such as computer 12. The computer 12 renders a desired digital image to the required size and color, or accesses digital images previously rendered, before transferring the image by means of control software that interfaces with the ink jet print head 16. In the particular embodiment shown in Figures 3-9, the ink supplies are positioned in ink containers 64, as shown.

[0032] The printer 60 is a flatbed printer and includes a base, or platen support, 66 on which the housing 62 is also mounted. A pair of parallel, spaced-part carriage support rails 68, 70 are mounted on the platen support 66 perpendicular to the side-to-side motion of the print head. A tray 72 is mounted on the carriage support rails 68,70 and is controlled in the manner described above whereby objects carried on the tray 72 are precisely positioned in relation to the print head to receive ink in a pattern controlled by the computer 12 and associated software. The tray 72 shown is exemplary of any suitable tray as would be designed and sized to accept particular objects to be printed.

[0033] Tray 72 is provided with 30 "nests" ordered in 5x6 rows to accept, in this particular illustrative embodiment, 30 glass ornaments "O". The ornaments "O" are held in registration by individual cradles 73 formed of 30 sets of side supports 74, 76, 78 on which the ornaments "O" directly rest. The cradles are each spring-loaded with sufficient loading to by end supports 77 and 79 maintain the individual ornaments "O" in registration with each other. In particular embodiments, electrical conductively may be established through each of the ornaments "O", as described below. The printer 60 includes suitable controls contained on a control panel 80, such as shown in Figure 3 and following. The tray 72 is mounted on a high voltage plate 82 connected to a voltage source 84.

[0034] From the starting position shown in Figure 3, the tray 72 is driven into the printer housing 62 under the control of the computer 12, as the print head is moved back-and-forth, ejecting a precisely-controlled spray of ink towards the surface of the ornaments "O". The Ornaments "O" are printed on their top, curved surface. By way of example, as shown in Figures 4 and 5, the first two rows of Ornaments "O" are

printed, but ordinarily the printing process would continue until all of the Ornaments "O" had been printed on the top-most surface directly below the print head.

[0035] Referring now to Figure 6, a manual means of rotating the Ornaments "O" for printing on another surface is shown. Each of the 5 rows of Ornaments "O" are mounted for unison rotation on the cradle elements, including the side supports 74, 76, 78 and end supports 77 and 79.

[0036] Each row is driven by respective gears 86, 88, 90, 92 and 94. These gears are driven in unison by a drive gear 96 that directly rotates gear 90 and rotates gears 86, 88, 92 and 94 through intermediate gears 98, 100, 102 and 104. While this particular embodiment is manually-rotated, it is envisioned that commercial units will be rotated automatically by an electric motor, pneumatic cylinder or other suitable means. The Ornaments "O" are locked in a desired orientation by a locking finger 106 that fits into a notch 108 in the gear 100. The locking finger is controlled by a lever 110.

[0037] Referring now to Figure 7, the Ornaments "O" have been rotated clockwise 90 degrees and, as shown in Figure 8, the tray 72 is again moved into the housing 62 and a second side of each of the Ornaments "O" is printed.

[0038] As is shown in Figure 9, two sides of the first two rows of Ornaments "O" have been printed. The method can be repeated to place images on a third side or on all four sides, as desired.

[0039] The apparatus and method as described above may be applied in several ways.

[0040] First, the electromagnetic field may be generated beneath the ornament "O" or other object to be printed. The field, which may be between 2000 and 3000 Volts at a very low current on the order of 500 nano-amps or less, is sufficient to

overcome the effects of air currents generated by rapid movement of the print head 16 and associated mechanical parts, and allows the inertia of the ink droplets to maintain straight line flight directly onto the ornament "O" by attraction of the negatively-charged high voltage plate 82. Of course, this value will vary depending on the particular circumstances but would ordinarily be less than a milliamp. This would also be suitable when printing on objects that are not electrically conductive, such as objects made of plastics, rubber, resins, and the like.

[0041] Second, the electromagnetic field may be propagated in the object itself if the object is electrically conductive or has applied to it an electrically-conductive coating. For example, a hollow glass ornament, such as a Christmas tree ornament, may be rendered electrically conductive by coating the interior of the glass with an electrically-conductive coating such as silver. Current flow is achieved though contact between the current source and, for example, a metal cap inserted into the ornament, such as used to suspend the ornament during use. The charge applied to the ornament "O" is therefore only a very short distance from the print head, and a very accurate, non-dispersed image can be created.

[0042] Third, in appropriate circumstances an electromagnetic charge can be induced through an electrically non-conductive material into an electrically conductive layer on the other side of the electrically non-conductive material. In the case of the glass ornament "O", for example, the silver inner coating can be charged through the adjacent glass surface by charging the plate 82 beneath the tray 72, thereby avoiding the need to provide current leads to each of the ornaments "O".

[0043] In any of the options described above, the direction of in-flight ink droplets is controlled toward the desired registration on the ornaments "O" due to the orientation

of the field. By varying the strength of the electromagnetic field the acceleration of the ink-jet droplets may be controlled to achieve the desired results.

[0044] The increased bonding of ink droplets to the ornaments "O" is due to the increased electrical potential between the negatively-charged applied ink and the positive inner surface of the ornament. Increasing the velocity of the droplets of applied ink solution also increases bonding of the ink to the ornaments "O", and the 'dot gain' increases as a result of the higher kinetic energy in each droplet as it hits the surface. This method reduces 'banding' effects that plague ink jet printing processes; eliminates noticeable lines in the image and creates a contiguous look in the final printed image.

[0045] Droplets are typically on the order 3 to 17 Pico-liters in-flight and can be controlled and accelerated by the application of directive control fields.

[0046] By controlling the in-flight droplets using the application of an electromagnetic field, a higher number of droplets will hit the substrate with higher accuracy and not be affected by other forces created by the mechanical assemblies advancing the substrate or assemblies moving the ink jet head. These physical movements create undesired forces, such as air currents and stray electrostatic charges, that act on the ink droplets and misdirect ink droplets creating 'satellite droplets' that stray from their intended target. The result is noticeable blurred images and "over spray" outside the image border.

[0047] Eliminating satellite droplets and directing those droplets to their intended targets increases image resolution and density, thus increasing the total droplets of ink in the image. Controlling the in-flight droplets by the application of an electromagnetic field allows higher printing accuracy at faster print speeds, which increases productivity and printer output. The substrate advance and ink propulsion from the head can both

be increased in time while achieving quality image resolution on both irregular and flat surfaces. Using this method eliminates over-spray, loss of color density, and loss of resolution. These are problems that are most noticeable when printing an image onto an irregular surface.

[0048] Eliminating satellite droplets also reduces harmful contaminates that become airborne during manufacturing processes involving ink jetting of various ink solutions. This system may also be used to meet certain safety regulations concerning MSDS contents identifying harmful chemicals and reducing inhalant content.

[0049] The application of force used to control 'in-flight droplets' can include of one or more of the following: voltage fields, magnetic fields, pressure fields ie; acoustic or pressure waves, and/or optical electromagnetic energy.

[0050] The above example is merely illustrative, and other substrates that are spherical curved, or round in shape including but not limited to glass, tile and ceramic eggs or heart shaped ornaments, may be printed as described above, as well as flat substrates such as glass, tile or ceramic ornaments. Specific objects which can be printed as described above include round, spherical or curved objects such as sporting balls including but not limited to baseballs, golf balls, footballs, basketballs, softballs or soccer balls, paper, Mylar, cardboard, overlays, stickers and the like, or rigid substrates such as glass, tile, ceramics, wood, plastic, hardboard, and the like, as well as textile materials such as fabrics used in t-shirts and other clothing, hats, footwear, or other apparel.

[0051] An image printing apparatus and method is described above. Various details of the invention may be changed without departing from the scope of the invention. Furthermore, the foregoing description of the preferred embodiment of the

invention and best mode for practicing the invention are provided for the purpose of illustration only and not for the purpose of limitation, the invention being defined by the claims.

We claim:

1. An apparatus for printing an image on an object, comprising:

(a) electronic image storage for storing an image to be printed on a image surface of the object;

(b) a print head positioned in spaced-apart relation to the object for receiving electronic data representing the image to be printed to the ink jet print head and applying the image to object using an ink that is applied with a predetermined electrical charge polarity; and

(c) a voltage generator for generating an electrical charge having an opposite polarity charge in relation to the predetermined charge polarity of the ink, and applying the opposite charge proximate the object and at a position to accelerate the ink being applied from the print head onto the object.

2. An apparatus according to claim 1, wherein the object includes a charge conductive layer positioned proximate a side of the object opposite the image surface.

3. An apparatus according to claim 1, wherein the object includes a charge conductive layer applied to a side of the object opposite the image surface.

4. An apparatus according to claim 1, wherein the electrically conductive layer is electrically connected to the voltage generator.

5. An apparatus according to claim 1, wherein the object includes a charge conductive layer positioned in spaced-apart relation to the voltage generator for receiving an induced electrical charge.

6. An apparatus according to claim 1, and including an object holder for holding at least one object in a fixed orientation while an image is printed on the object.

7. An apparatus according to claim 1, wherein the object holder comprises a tray adapted for receiving and holding a plurality of objects in a fixed fixed orientation while an image is printed on each of the objects.

8. An apparatus according to claim 7, wherein the tray includes a plurality of individual cradles for receiving respective individual objects to be printed.

9. An apparatus according to claim 7, wherein the tray includes a plurality of individual cradles for receiving respective individual objects to be printed, and a rotation

assembly cooperating with the cradles to rotate the cradles in unison for positioning a desired surface in the proper orientation for printing.

10. A method for printing an image on an object, comprising:

(a) providing a print head positioned in spaced-apart relation to the object for receiving electronic data representing the image to be printed to the ink jet print head;

(b) applying the image to the object using an ink that is applied with a predetermined electrical charge polarity;

(c) generating an electrical charge having an opposite polarity charge in relation to the predetermined charge polarity of the ink; and

(d) applying the opposite charge proximate the object and at a position to accelerate the ink being applied from the print head onto the object.

11. A method according to claim 10, and including the step of storing the image to be printed on the image surface of the object in an electronic data store.

12. A method according to claim 10, and including the step of applying a charge conductive layer proximate a side of the object opposite the image surface.

13. A method according to claim 10, and including the step of applying a charge conductive layer to a side of the object opposite the image surface.

14. A method according to claim 10, and including the step of electrically connecting the voltage generator to the charge conductive layer.

15. A method according to claim 10, and including the stop of positioning a charge conductive layer in spaced-apart relation to the voltage generator for receiving an induced electrical charge.

16. A method according to claim 10, and including the step of holding at least one object in a fixed orientation while an image is printed on the object.

17. A method according to claim 10, and including the step of receiving and holding a plurality of objects in a fixed fixed orientation while an image is printed on each of the objects.

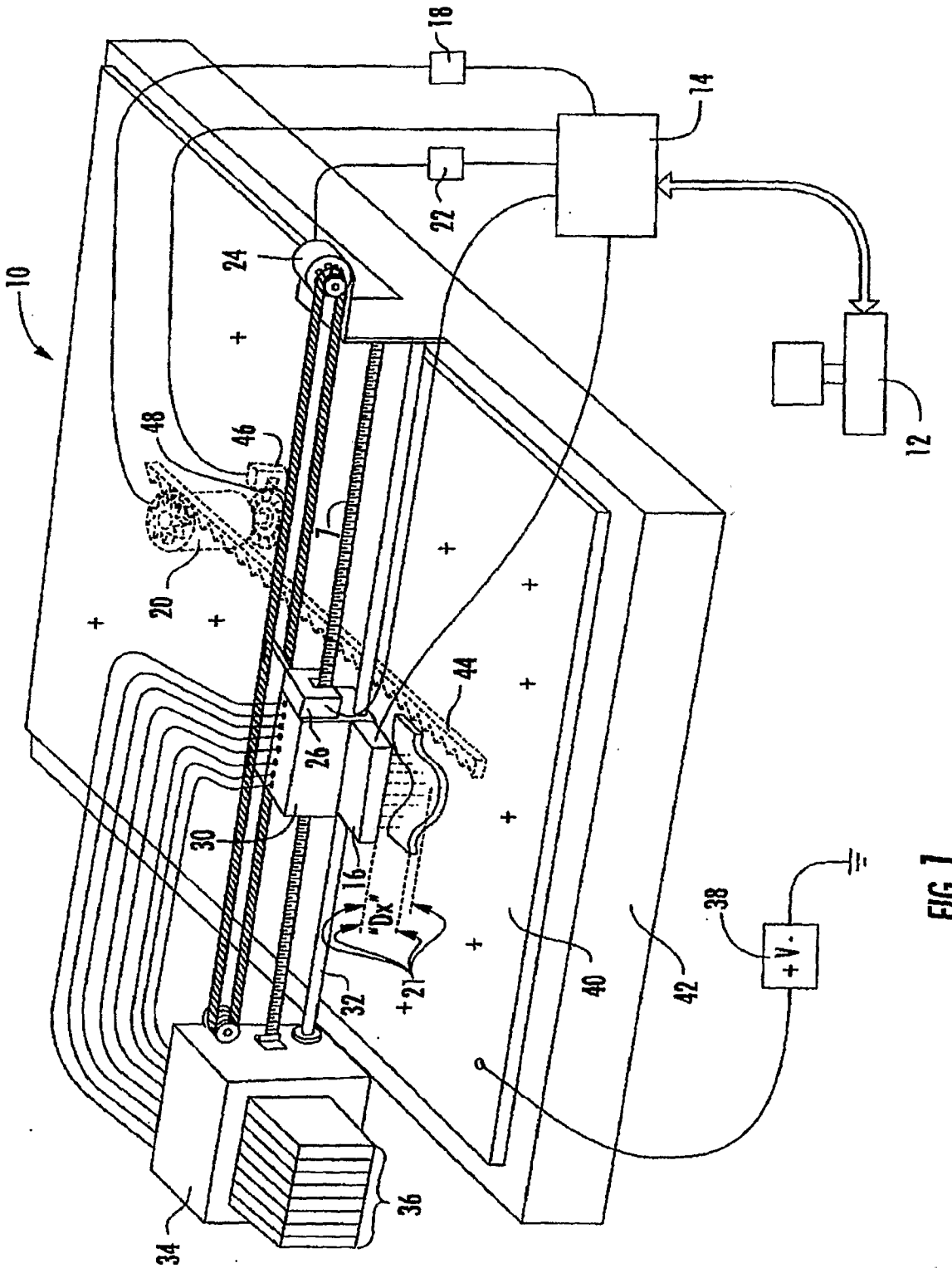

FIG. 1

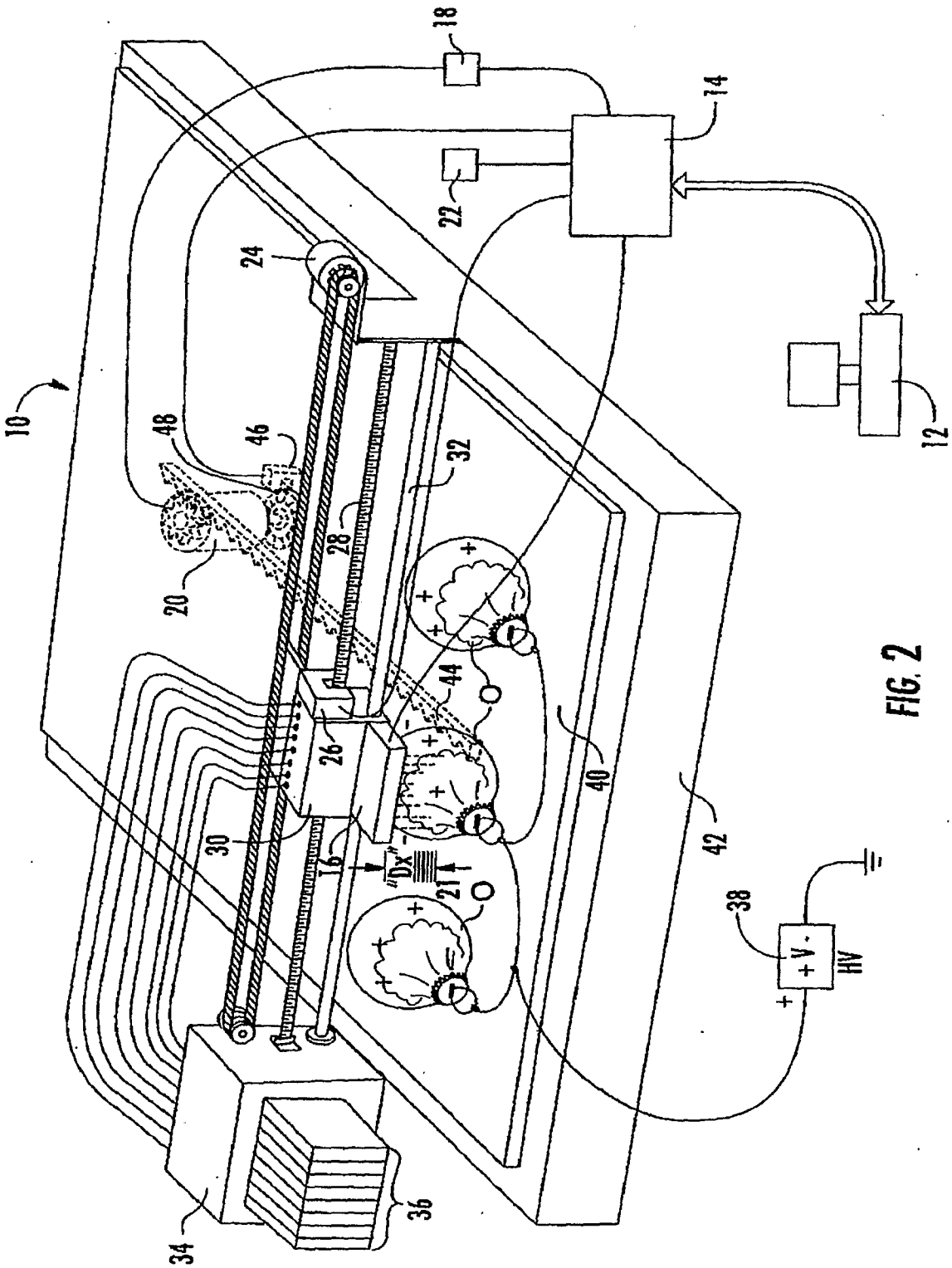

FIG. 2

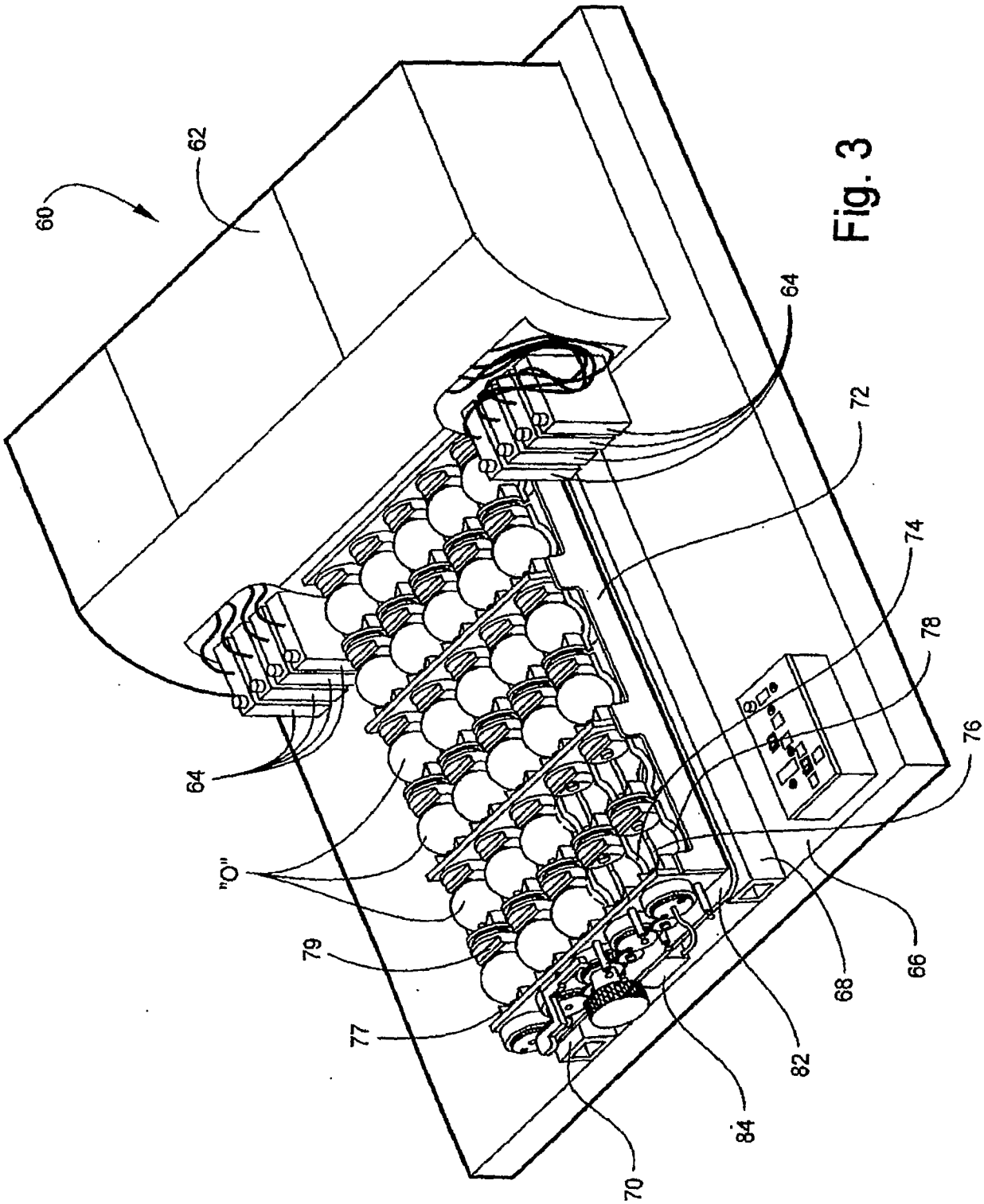

Fig. 3

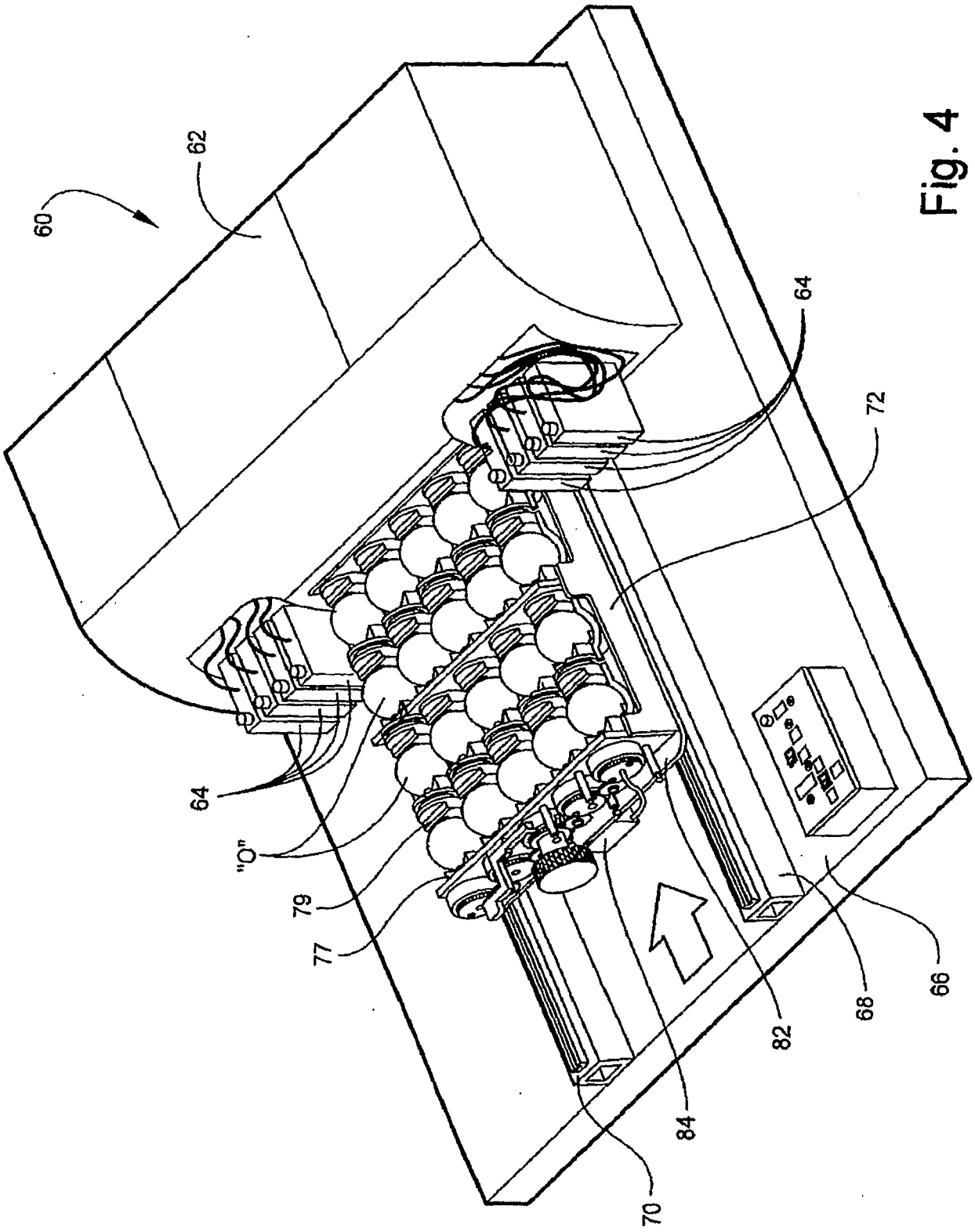

Fig. 4

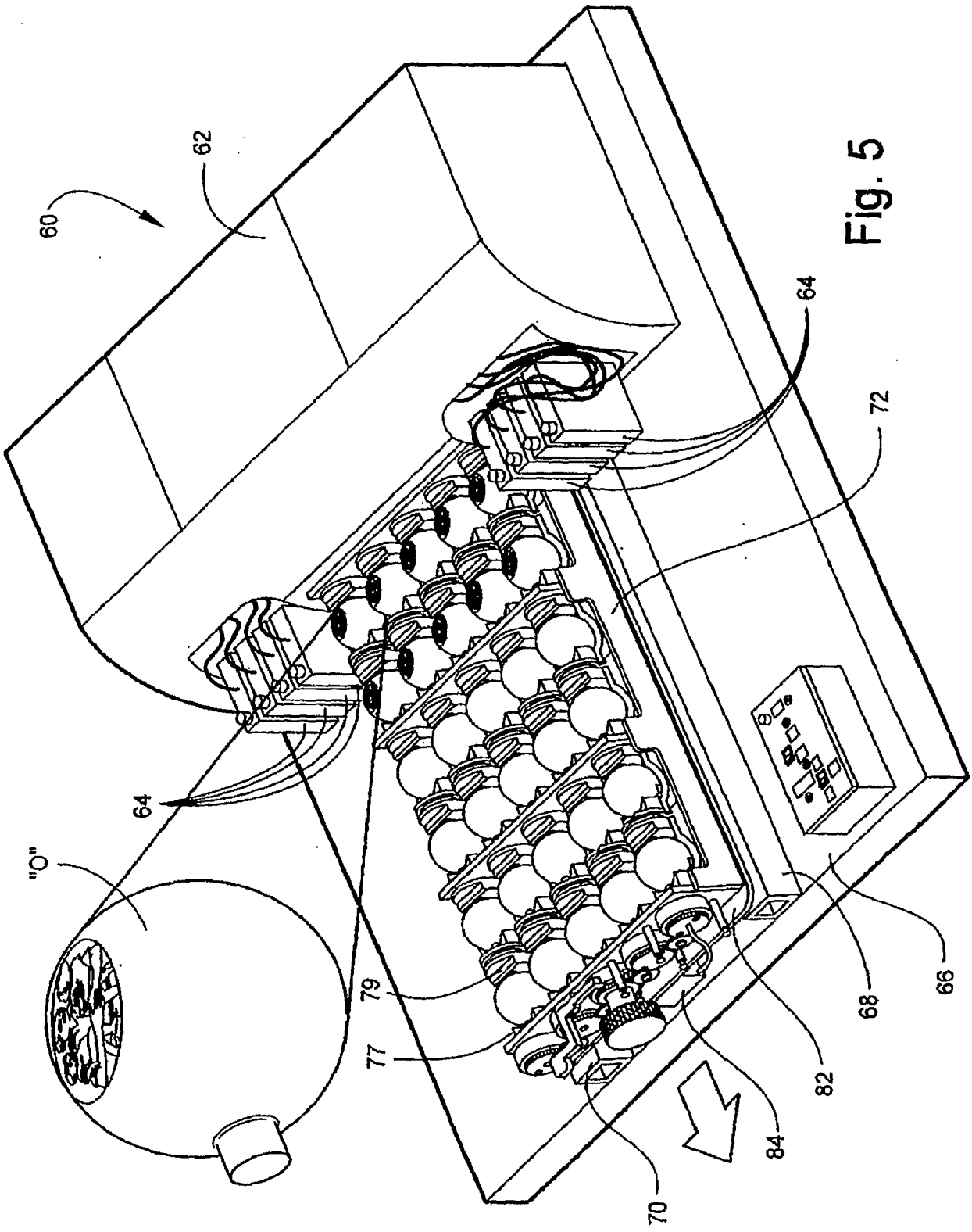

Fig. 5

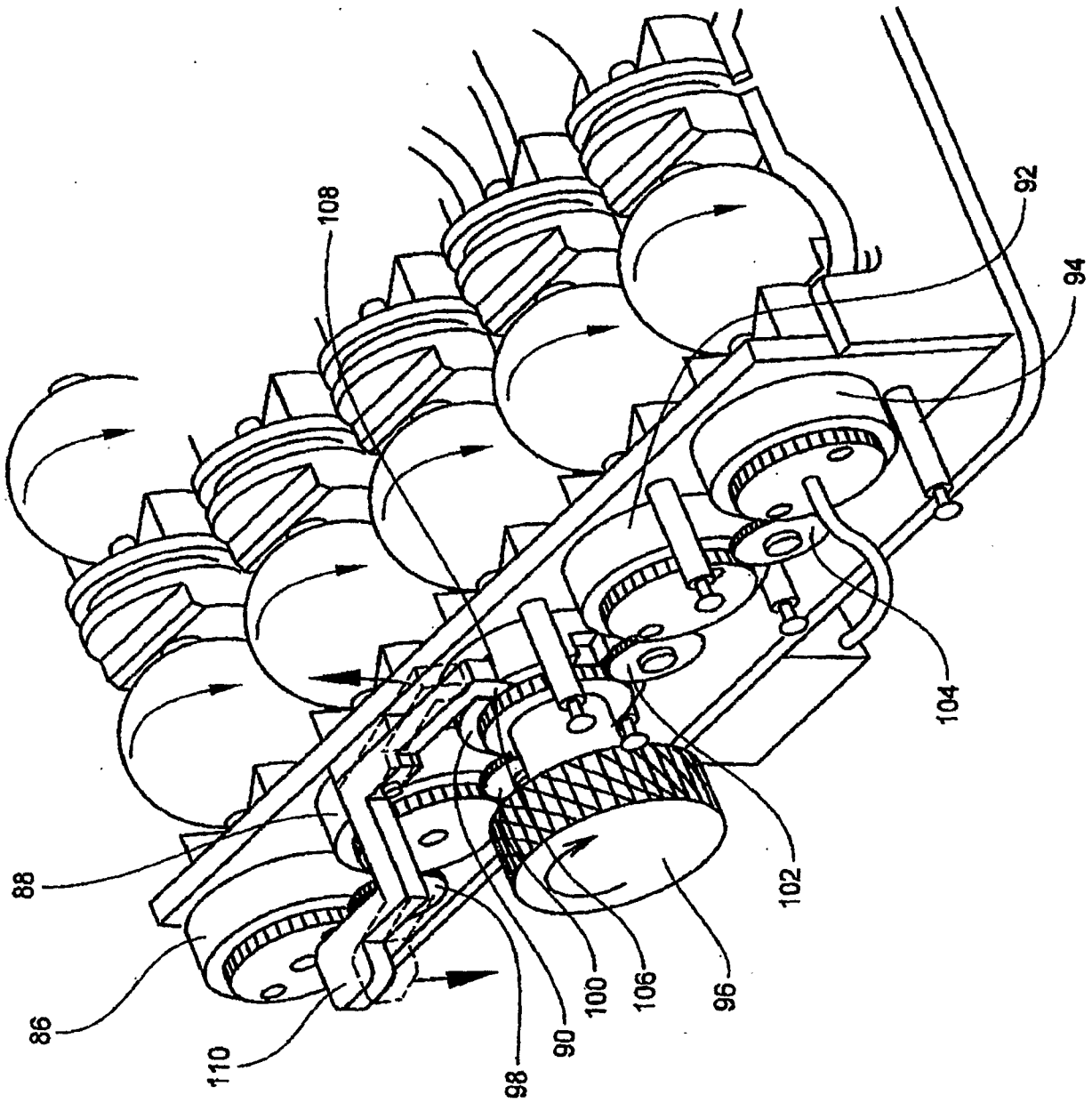

Fig. 6

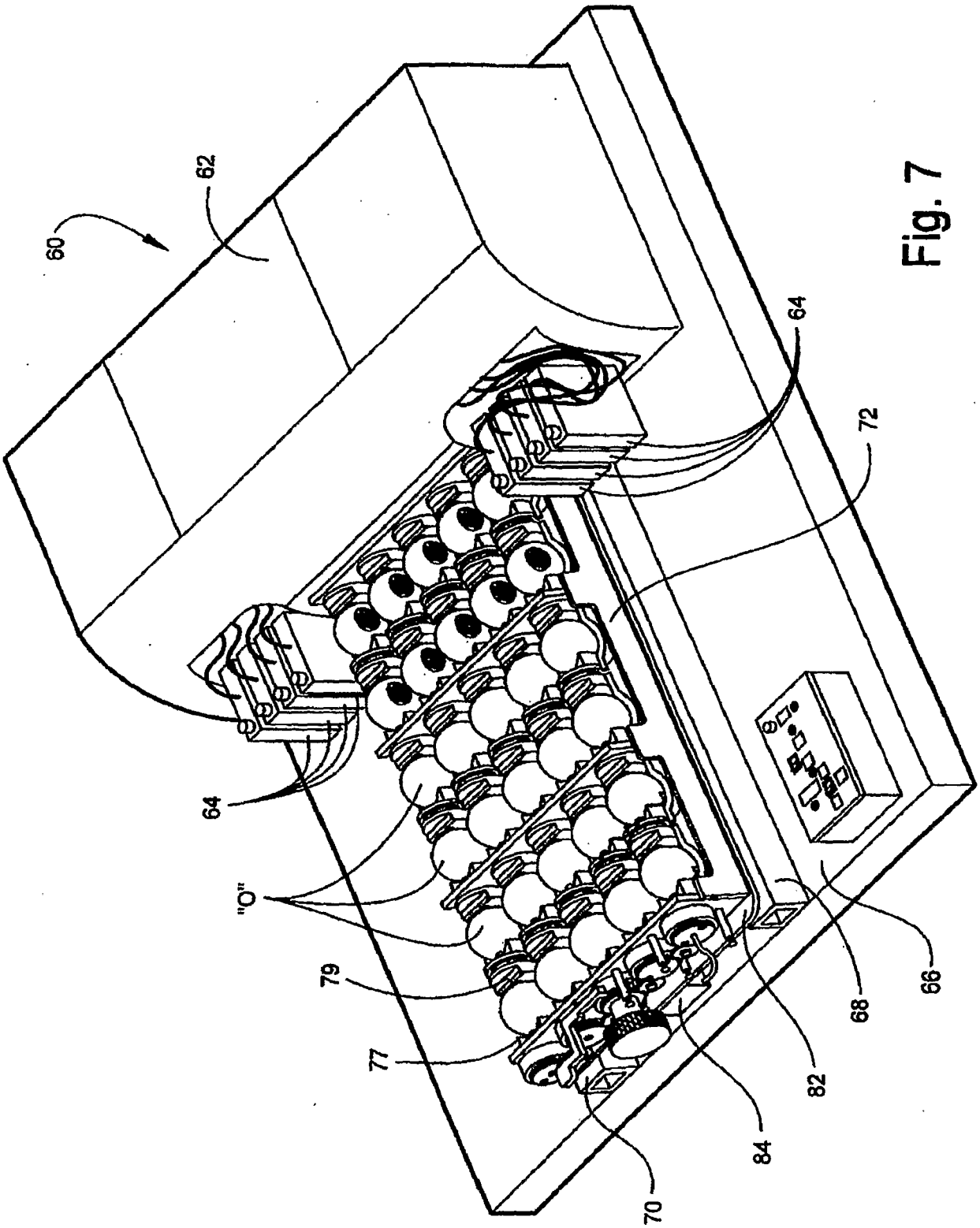

Fig. 7

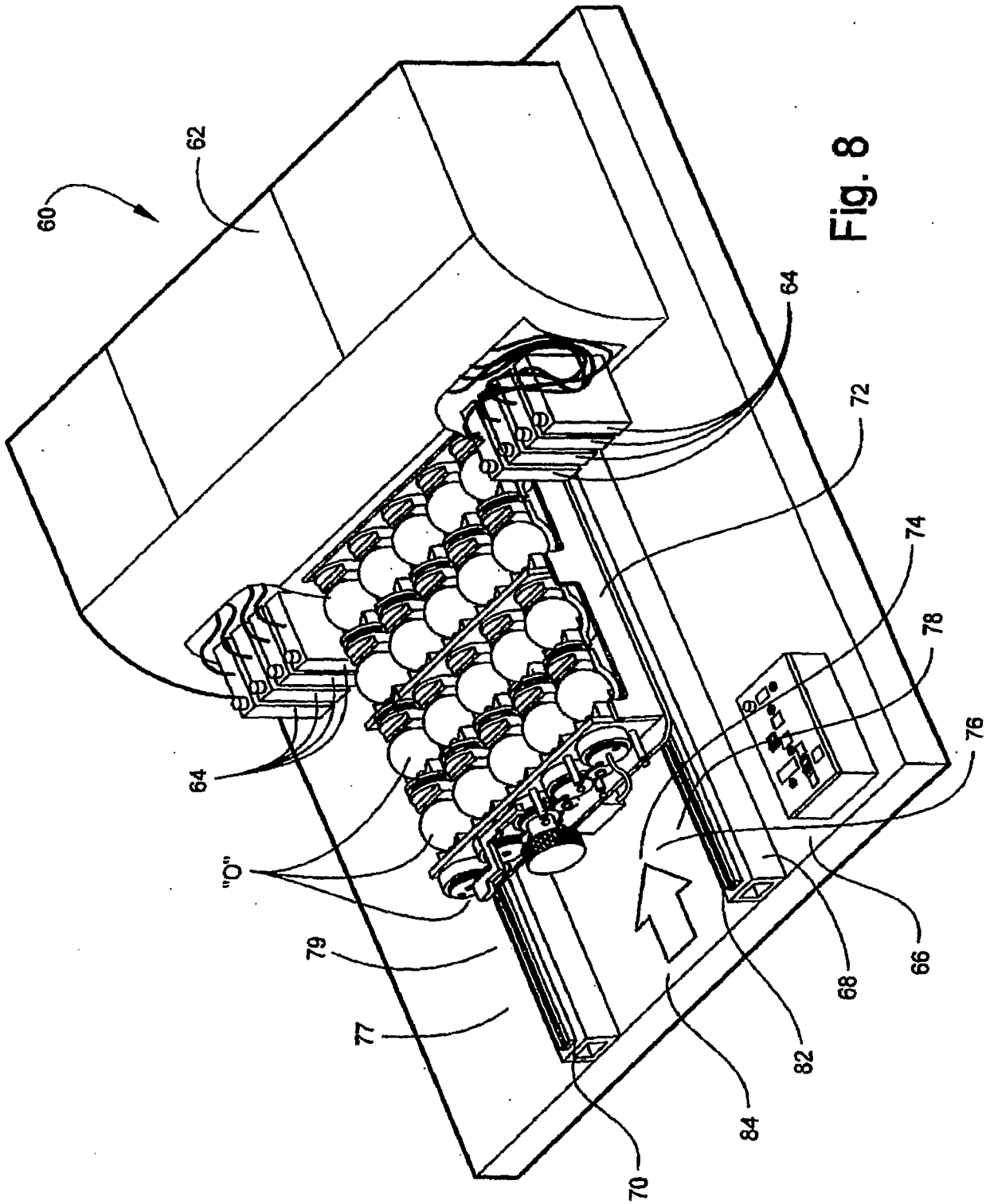

Fig. 8

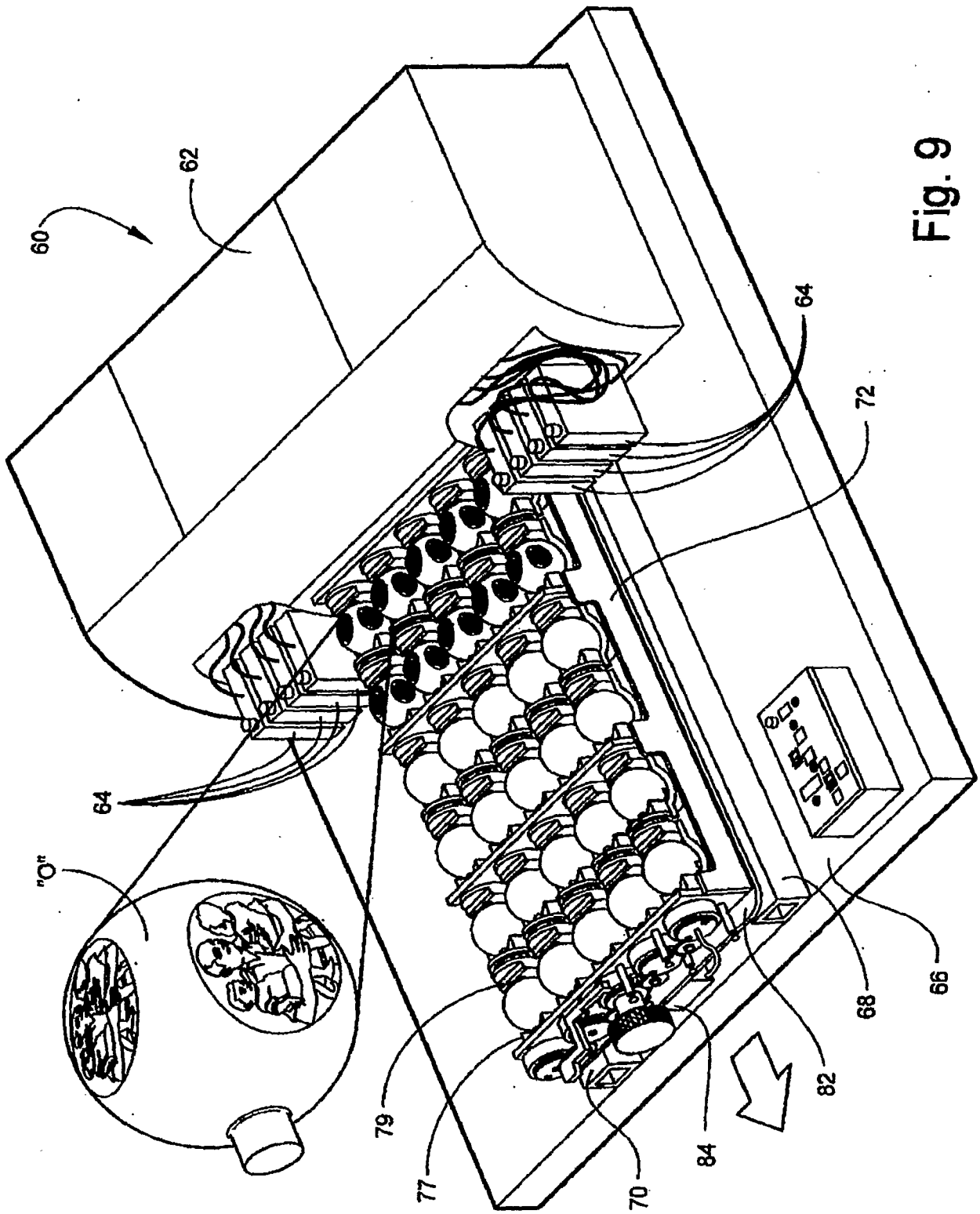

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US07/62064

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B41J 2/08 (2007.01)
USPC - 347/55
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)
IPC(8) - B41J 2/08,085 (2007.01)
USPC - 347/4,5,55,76,79,104; 101/38.1; 358/1.16,1.17

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)
USPTO EAST System (US, USPG-PUB, EPO, JPO, FPRS, DERWENT), GoogleScholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3,341,859 A (ADAMS) 12 September 1967 (12.09.1967) entire document	10, 12-15
Y		1-6, 11, 16
Y	US 4,769,648 A (KISHINO et al) 06 September 1988 (06.09.1988) column 2, lines 8-24, Fig. 2	1-6, 11
Y	US 6,332,680 B1 (OZAWA) 25 December 2001 (25.12.2001) Fig. 2	6, 16
A	US 6,923,115 B1 (LITSCHER et al) 02 August 2005 (02.08.2005) entire document	7-9, 17

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

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"A" document defining the general state of the art which is not considered to be of particular relevance
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 August 2007	27 MAR 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

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