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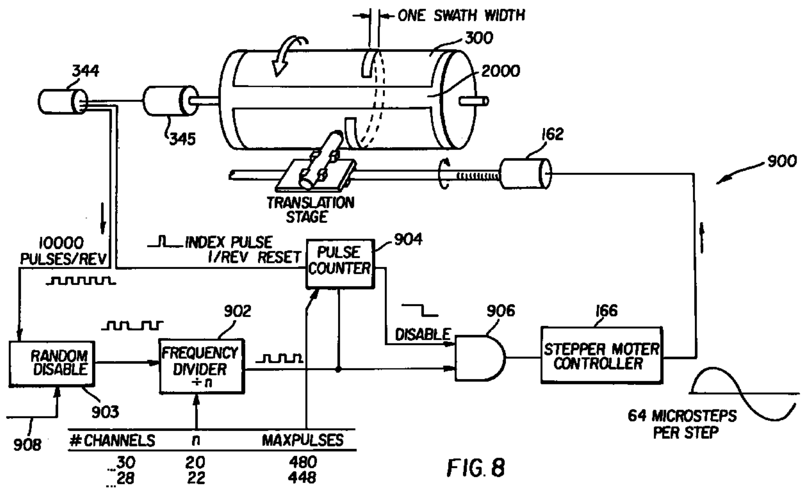
(54) Linear translation system dithering for improved image quality

(57) An image processing apparatus (**10**) for sheet thermal print media comprises a vacuum imaging drum (**300**) for holding thermal print media (**32**) and dye donor material (**36**) in registration on vacuum imaging drum (**300**). A printhead (**500**) moves along a line parallel to a longitudinal axis of vacuum imaging drum (**300**) by a linear motion control system (**900**) which is interrupted with a random delay as vacuum imaging drum (**300**) rotates. Printhead (**500**) receives information signals and produces radiation which is directed to dye donor material (**36**) which causes color to transfer from dye donor material (**36**) to thermal print media (**32**).



# CHANNELS	n	MAXPULSES
...30	20	480
...28	22	448
...20	31	320
...13	48	208

FIG. 8

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to image processors in general, and in particular to a laser thermal printer having the capability of dithering a linear translation system for improving the quality of intended images.

BACKGROUND OF THE INVENTION

[0002] Pre-press color proofing is a procedure that is used by the printing industry for creating representative images of printed material, without the high cost and time that is required to actually produce printing plates and set up a high-speed, high-volume, printing press to produce an example single of an intended image. The intended image may require several corrections and be reproduced several times to satisfy or meet the customer's requirements resulting in a loss of profits. By utilizing pre-press color proofing time and money can be saved.

[0003] One such commercially available image processing apparatus, which is depicted in commonly assigned EP Patent No. 528,441 is an image processing apparatus having half-tone color proofing capabilities. This image processing apparatus is arranged to form an intended image on a sheet of thermal print media by transferring dye from a sheet of dye donor material to a thermal print media by applying a sufficient amount of thermal energy to the dye donor material to form an intended image. This image processing apparatus is comprised generally of a material supply assembly or carousel, a lathe bed scanning subsystem (which includes a lathe bed scanning frame, a translation drive, a translation stage member, a print-head and a vacuum imaging drum), and thermal print media and dye donor material exit transports.

[0004] The operation of the above image processing apparatus comprises metering a length of the thermal print media (in roll form) from the material assembly or carousel. The thermal print media is then measured and cut into sheet form of the required length, transported to the vacuum imaging drum, registered, wrapped around and secured onto the vacuum imaging drum. Next a length of dye donor material (in roll form) is also metered out of the material supply assembly or carousel, measured and cut into sheet form of the required length. It is then transported to and wrapped around the vacuum imaging drum, such that it is superposed in the desired registration with respect to the thermal print media (which has already been secured to the vacuum imaging drum).

[0005] After the dye donor material is secured to the periphery of the vacuum imaging drum, the scanning subsystem or write engine provides the scanning function. This is accomplished by retaining the thermal print media and the dye donor material on the spinning vacuum imaging drum while it is rotated past the printhead that will expose the thermal print media. The translation drive then traverses the printhead and translation stage member axially along the vacuum imaging drum, in coordinated motion with the rotating vacuum imaging drum. These movements combine to produce the intended image on the thermal print media.

[0006] After the intended image has been written on the thermal print media, the dye donor material is then removed from the vacuum imaging drum. This is done without disturbing the thermal print media that is beneath it. The dye donor material is then transported out of the image processing apparatus by the dye donor material exit transport. Additional dye donor materials are sequentially superposed with the thermal print media on the vacuum imaging drum, then imaged onto the thermal print media as previously mentioned, until the intended image is completed. The completed image on the thermal print media is then unloaded from the vacuum imaging drum and transported to an external holding tray on the image processing apparatus by the receiver sheet material exit transport.

[0007] The material supply assembly comprises a carousel assembly mounted for rotation about its horizontal axis on bearings at the upper ends of vertical supports. The carousel comprises a vertical circular plate having in this case six (but not limited to six) material support spindles. These support spindles are arranged to carry one roll of thermal print media, and four rolls of dye donor material to provide the four primary colors used in the writing process to form the intended image, and one roll as a spare or for a specialty color dye donor material (if so desired). Each spindle has a feeder assembly to withdraw the thermal print media or dye donor material from the spindles to be cut into a sheet form. The carousel is rotated about its axis into the desired position, so that the thermal print media or dye donor material (in roll form) can be withdrawn, measured, and cut into sheet form of the required length, and then transported to the vacuum imaging drum.

[0008] The scanning subsystem or write engine of the lathe bed scanning type comprises the mechanism that provides the mechanical actuators, for the vacuum imaging drum positioning and motion control, to facilitate placement, loading onto, and removal of the thermal print media and the dye donor material from the vacuum imaging drum. The scanning subsystem or write engine provides the scanning function by retaining the thermal print media and dye donor material on the rotating vacuum imaging drum; which generates a timing signal to the data path electronics as a clock signal, while the translation drive traverses the translation stage member and printhead axially along the vacuum imaging drum in a coordinated motion with the vacuum imaging drum rotating past the printhead. This is done with positional accuracy maintained, to allow precise control of the placement of each pixel, in order to produce the intended image on the thermal print media.

[0009] The lathe bed scanning frame provides the structure to support the vacuum imaging drum and its rotational drive. The translation drive with the translation stage member and write head are supported by two translation bearing rods that are substantially straight along their longitudinal axis and are positioned parallel to the vacuum imaging drum and a lead screw. Consequently, they are parallel to each other therein forming a plane, along with the vacuum imaging drum and lead screw. The translation bearing rods are, in turn, supported by outside walls of the lathe bed scanning frame of the lathe bed scanning subsystem or write engine. The translation bearing rods are positioned and aligned therebetween, for permitting low friction movement of the translation stage member and the translation drive. The translation bearing rods are sufficiently rigid for this application, so as not to sag or distort between the mounting points at their ends. They are arranged to be as exactly parallel with the axis of the vacuum imaging drum, as is possible. The front translation bearing rod is arranged to locate the axis of the printhead precisely on the axis of the vacuum imaging drum with the axis of the printhead located perpendicular, vertical, and horizontal to the axis of the vacuum imaging drum. The translation stage member front bearing is arranged to form an inverted "V" and provides only that constraint to the translation stage member. The translation stage member with the printhead mounted on the translation stage member, is held in place by only it's own weight. The rear translation bearing rod locates the translation stage member with respect to rotation of the translation stage member about the axis of the front translation bearing rod. This is done so as to provide no over constant of the translation stage member which might cause it to bind, chatter, or otherwise impart undesirable vibration or jitters to the translation drive or printhead during the writing process, causing unacceptable artifacts in the intended image. This is accomplished by a rear bearing which engages the rear translation bearing rod only on a diametrically opposite side of the translation bearing rod on a line perpendicular to a line connecting the centerlines of the front and rear translation bearing rods.

[0010] The translation drive is for permitting relative movement of the printhead by synchronizing the motion of the printhead and stage assembly such that the required movement is made smoothly and evenly throughout each rotation of the drum. A clock signal generated by a drum encoder provides the necessary reference signal accurately indicating the position of the drum. This coordinated motion results in the printhead tracing out a helical pattern around the periphery of the drum. The above mentioned motion is accomplished by means of a DC servo motor and encoder which rotates a lead screw parallel with the axis of the vacuum imaging drum. The printhead is placed on the translation stage member in a "V" shaped groove, which is formed in the translation stage member, which are in precise relationship to bearings for the front translation stage member supported by the front and rear translation bearing rods. The translation bearing rods are positioned parallel to the vacuum imaging drum, so that it automatically adopts the preferred orientation with respect to the vacuum imaging drum. The printhead is selectively locatable with respect to the translation stage member, thus it is positioned with respect to the vacuum imaging drum surface. By adjusting the distance between the printhead and the vacuum imaging drum surface, as well as an angular position of the printhead about it's axis using adjustment screws, an accurate means of adjustment for the printhead is provided. An extension spring provides a load against these two adjustment means. The translation stage member and printhead are attached to a rotatable lead screw (having a threaded shaft) by a drive nut and coupling. The coupling is arranged to accommodate misalignment of the drive nut and lead screw so that only rotational forces and forces parallel to the lead screw are imparted to the translation stage member by the lead screw and drive nut. The lead screw rests between two sides of the lathe bed scanning frame of the lathe bed scanning subsystem or write engine, where it is supported by deep groove radial bearings. At the drive end the lead screw continues through the deep groove radial bearing, through a pair of spring retainers, that are separated and loaded by a compression spring to provide axial loading, and to a DC servo drive motor and encoder. The DC servo drive motor induces rotation to the lead screw moving the translation stage member and printhead along the threaded shaft as the lead screw is rotated. The lateral directional movement of the printhead is controlled by switching the direction of rotation of the DC servo drive motor and thus the lead screw.

[0011] The printhead includes a plurality of lasers diodes which are tied to the printhead and can be individually modulated to supply energy to selected areas of the thermal print media in accordance with an information signal. The printhead of the image processing apparatus includes a plurality of optical fibers coupled to the laser diodes at one end and at the other end to a fiber optic array within the printhead. The printhead is movable relative to the longitudinal axis of the vacuum imaging drum. The dye is transferred to the thermal print media as radiation, transferred from the laser diodes by the optical fibers to the printhead and thus to the dye donor material is converted to thermal energy in the dye donor material.

[0012] The vacuum imaging drum is cylindrical in shape that includes a hollowed-out interior portion; and further includes a plurality of holes extending through its housing for permitting a vacuum to be applied from the interior of the vacuum imaging drum for supporting and maintaining the position of the thermal print media and dye donor material as the vacuum imaging drum rotates. The ends of the vacuum imaging drum are enclosed by cylindrical end plates. The cylindrical end plates are each provided with a centrally disposed spindle which extends outwardly through support bearings and are supported by the lathe bed scanning frame. The drive end spindle extends through the support bearing and is stepped down to receive a DC drive motor armature which is held on by means of a nut. A DC motor stator is stationarily held by the lathe bed scanning frame member, encircling the armature to form a reversible, variable speed DC drive motor for the vacuum imaging drum. At the end of the spindle an encoder is mounted to provide the timing signals to the image processing apparatus. The opposite spindle is provided with a central vacuum opening, which is in alignment with a vacuum fitting with an external flange that is rigidly mounted to the lathe bed scanning frame. The vacuum fitting has an extension which extends within but is closely spaced from the vacuum spindle, thus forming a small clearance. With this configuration, a slight vacuum leak is provided between the outer diameter of the vacuum fitting and the inner diameter of the opening of the vacuum spindle. This assures that no contact exists between the vacuum fitting and the vacuum imaging drum which might impart uneven movement or jitters to the vacuum imaging drum during its rotation.

[0013] The opposite end of the vacuum fitting is connected to a high-volume vacuum blower which is capable of producing 50-60 inches of water (93.5 - 112.2 millimeters of mercury) at an air flow volume of 60-70 cfm (28.368 - 33.096 liters per second); and provides the vacuum to the vacuum imaging drum to support the various internal vacuum levels of the vacuum imaging drum required during the loading, scanning and unloading of the thermal print media and the dye donor materials to create the intended image. With no media loaded on the vacuum imaging drum the internal vacuum level of the vacuum imaging drum is approximately 10-15 inches of water (18.7 - 28.05 millimeters of mercury). With just the thermal print media loaded on the vacuum imaging drum the internal vacuum level of the vacuum imaging drum is approximately 20-25 inches of water (37.4 - 46.75 millimeters of mercury), which is the level that is required when a dye donor material is removed so that the thermal print media does not move, otherwise color to color registration will not be maintained. With both the thermal print media and dye donor material completely loaded on the vacuum imaging drum the internal vacuum level of the vacuum imaging drum is approximately 50-60 inches of water (93.5 - 112.2 millimeters of mercury) in this configuration.

[0014] The outer surface of the vacuum imaging drum is provided with an axially extending flat, which extends approximately 8 degrees of the vacuum imaging drum circumference. The vacuum imaging drum is also provided with a circumferential recess which extends circumferentially from one side of the axially extending flat, circumferentially around the vacuum imaging drum to the other side of the axially extending flat, and from approximately one inch (25.4 millimeters) from one end to approximately one inch (25.4 millimeters) from the other end of the vacuum imaging drum. The thermal print media when mounted on the vacuum imaging drum is seated in the circumferential recess and therefor the circumferential recess has a depth substantially equal to the thermal print media thickness seated therewithin, which is approximately 0.004 inches (.102 millimeters) in thickness.

[0015] The purpose of the circumferential recess on the vacuum imaging drum surface is to eliminate any creases in the dye donor materials, as they are drawn down over the thermal print media during the loading of the dye donor materials. This assures that no folds or creases will be generated in the dye donor materials which could extend into the image area and seriously adversely affect the intended image. The circumferential recess also substantially eliminates the entrapment of air along the edge of the thermal print media, where it is difficult for the vacuum holes in the vacuum imaging drum surface to assure the removal of the entrapped air. Any residual air between the thermal print media and the dye donor material, can also adversely affect the intended image.

[0016] The purpose of the vacuum imaging drum axially extending flat is two fold, first it assures that the leading and trailing ends of the dye donor material are somewhat protected from the effect of air turbulence during the relatively high speed rotation that the vacuum imaging drum undergoes during the imaging process. Thus the air turbulence will have less tendency to lift the leading or trailing edges of the dye donor material. Second, the vacuum imaging drum axially extending flat also ensures that the leading and trailing ends of the dye donor material are recessed from the vacuum imaging drum periphery. This reduces the chance that the dye donor material cannot come in contact with other parts of the image processing apparatus, such as the printhead, causing a jam and possible loss of the intended image or worse, catastrophic damage to the image processing apparatus.

[0017] The vacuum imaging drum axially extending flat also acts to impart a bending force to the ends of the dye donor materials when they are held onto the vacuum imaging drum surface by vacuum from within the interior of the vacuum imaging drum. Consequently when the vacuum is turned off to that portion of the vacuum imaging drum, the end of the dye donor material will tend to lift from the surface of the vacuum imaging drum. Thus turning off of the vacuum eliminates the bending force on the dye donor material, and is used as an advantage in the removal of the dye donor material from the vacuum imaging drum.

[0018] The task of loading and unloading the dye donor materials onto and off from the vacuum imaging drum, requires precise positioning of thermal print media and the dye donor materials. The lead edge positioning of dye donor material must be accurately controlled during this process. The existing image processing apparatus design, such as that disclosed in the above-mentioned commonly assigned U.S. patent, employs a multi-chambered vacuum imaging drum for such lead-edge control. One appropriately controlled chamber applies vacuum that holds the lead edge of the dye donor material. Another chamber, separately valved, controls vacuum that holds the trail edge of the thermal print media, to the vacuum imaging drum. With this arrangement, loading a sheet of thermal print media and dye donor material requires that the image processing apparatus feed the lead edge of the thermal print media and dye donor material into position just past the vacuum ports controlled by the respective valved chamber. Then vacuum is applied, gripping the lead edge of the dye donor material against the vacuum imaging drum surface.

[0019] Unloading the dye donor material or the thermal print media (to discard the used dye donor material or to deliver the finished thermal print media to an output tray) requires the removal of vacuum from these same chambers so that an edge of the thermal print media or the dye donor material are freed and project out from the surface of the vacuum imaging drum. The image processing apparatus then positions an articulating skive into the path of the free edge to lift the edge further and to feed the dye donor material, to a waste bin or the thermal print media to an output tray.

[0020] The sheet material exit transports include a dye donor material waste exit and an imaged thermal print media sheet material exit. The dye donor material exit transport comprises a waste dye donor material stripper blade disposed adjacent the upper surface of the vacuum imaging drum. In the unload position, the stripper blade is in contact with the waste dye donor material on the vacuum imaging drum surface. When not in operation, the stripper blade is moved up and away from the surface of the vacuum imaging drum. A driven waste dye donor material transport belt is arranged horizontally to carry the waste dye donor material, which is removed by the stripper blade from the surface of the vacuum imaging drum to an exit formed in the exterior of the image processing apparatus. A waste bin for the waste dye donor materials is separate from the image processing apparatus. The imaged thermal print media sheet material exit transport comprises a movable thermal print media sheet material stripper blade that is disposed adjacent to the upper surface of the vacuum imaging drum. In an unload position, the stripper blade is in contact with the imaged thermal print media on the vacuum imaging drum surface. In an inoperative position, it is moved up and away from the surface of the vacuum imaging drum. A driven thermal print media sheet material transport belt is arranged horizontally to carry the imaged thermal print media removed by the stripper blade from the surface of the vacuum imaging drum. It then delivers the imaged thermal print media with the intended image formed thereon to an exit tray in the exterior of the image processing apparatus.

[0021] Although the presently known and utilized arrangement is satisfactory, there is room for improvement. In a laser thermal image processing apparatus, as the vacuum imaging drum spins, the printhead moves along the vacuum imaging drum in a path that is parallel to the longitudinal axis of the vacuum imaging drum (slow scan direction). The linear motion system moves the printhead in the "slow scan" direction, from a home position to the start of scan point where it begins writing the image data to the opposite end of the drum. The combined movement of the printhead in the slow scan direction and the vacuum imaging drum rotation (fast scan direction) perpendicular to the motion of the printhead causes the resulting image to be written in a single, continuous helix about the vacuum imaging drum.

[0022] However, the intended image may suffer from various artifacts some of which are induced by cyclic disturbances due to the linear motion control system attempting to follow every small deviation in the drum motion. In practice, what occurs is that an attempt to track rotary motion upsets results in induced vibration in the linear system since the system response is finite due to the system inertia. These cyclic disturbances, depending on their frequency, amplitude and phase relative to each other may cause visually objectionable patterns to occur in the intended image.

SUMMARY OF THE INVENTION

[0023] It is an object of the present invention to artificially induce a random pattern of noise, which can be referred to as white noise, into the movement of the linear motion control system to overcome the above-described drawbacks.

[0024] With the arrangement of the present invention, only minor changes to the linear motion control system are required with no changes required to the rest of the image processing apparatus.

[0025] The present invention is directed to overcoming one or more of the problems set forth above. Briefly summarized, according to one aspect of the present invention, the invention resides in an imaging processing apparatus for receiving thermal print media and dye donor materials for processing an intended image onto the thermal print media. The image processing apparatus comprises a vacuum imaging drum for holding a sheet of dye donor material and a sheet of thermal print media. In the present invention, a random pattern of noise, commonly referred to as white noise, is artificially induced into the movement of a linear motion control system at a suitable amplitude and rate, both of which are randomly variable in a means that not only preserves the dimensional accuracy of the image over the length of the image but also does not induce any significant errors in dot placement. Therefore objectionable cyclic patterns are obscured or masked and not visible in the intended image, thus improving the image quality of the intended image.

[0026] The present invention relates to an image processing apparatus which comprises a printhead; a vacuum imaging drum adapted to receive a thermal print media thereon; a lead screw for moving the printhead; a motor for rotating the lead screw so as to provide for a linear motion of the printhead along a line parallel to a longitudinal axis of the vacuum imaging drum; and a liner motion control system which controls the linear motion of the printhead at a speed synchronous with a rotation of the vacuum imaging drum and interrupts a driving of the motor with a random delay as the vacuum imaging drum rotates.

[0027] The present invention relates to an image processing apparatus which comprises a printhead; a vacuum imaging drum adapted to receive a print media thereon; an encoder operationally associated with the vacuum imaging drum, with the encoder generating a once per revolution synchronized pulse signal upon a rotation of the vacuum imaging drum; a motor which provides a liner motion to the printhead along a line parallel to a longitudinal axis of the vacuum imaging drum; and a linear motion control system which receives the synchronized pulse signal from the encoder and generates a constant uniform pulse train which drives the motor and moves the printhead along a surface of the vacuum imaging drum at a speed synchronous with a speed of rotation of the vacuum imaging drum. The linear motion control system interrupts the uniform pulse train to provide for a random delay in the linear motion of the printhead as the vacuum imaging drum rotates.

[0028] The present invention relates to a method of exposing images on thermal print media. The method comprises the steps of rotating a vacuum imaging drum of an image processing apparatus, the vacuum imaging drum having a thermal print media thereon; generating a once per revolution synchronized pulse signal based on the rotation of the vacuum imaging drum; providing the synchronized pulse signal to a linear motion control system to generate a constant uniform pulse train to drive a printhead of the image processing apparatus in a linear direction along a line which is parallel to a longitudinal axis of the printhead, with a speed of the printhead in the linear direction being synchronous with a speed of rotation of the vacuum imaging drum; and interrupting the uniform pulse train to provide for a random delay in the drive of the printhead in the linear direction as the vacuum imaging drum rotates.

[0029] Although not described in detail it would be obvious to some one skilled in the art that this invention could be used in other applications that utilizes a linear motion control system. Such as film, plate or an ink-jet writer as an example.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030]

Fig. 1 is a side view in vertical cross section of an image processing apparatus of the present invention;

Fig. 2 is a perspective view of a lathe bed scanning subsystem or write engine of the present invention;

Fig. 3 is a top view in horizontal cross section, partially in phantom, of a lead screw of the present invention;

FIG. 4 is a perspective view of a printing swath created by drum rotation and lead screw movement for direct printing to an intermediate receiver;

Fig. 5 is a plane view of a vacuum imaging drum surface of the present invention;

Fig. 6a-6c are plane views of the vacuum imaging drum showing the sequence of placement of thermal print media and dye donor material;

FIG. 7 is a perspective view of a printing swath created by rotation of the vacuum imaging drum and lead screw movement of the print-head to print the intended image;

Fig. 8 is a schematic illustration of a linear motion control system in accordance with the present invention; and

Fig. 9 is a timing diagram indicating the relationship between index pulse, encoder pulses and step clock in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0031] Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, Fig. 1 illustrates an image processing apparatus **10** according to the present invention. Image processing apparatus **10** includes an image processor housing **12** which provides a protective cover. A movable, hinged image processor door **14** is attached to a front portion of image processor housing **12** permitting access to a lower sheet material tray **50a** and an upper sheet material tray **50b**, that are positioned in an interior portion of image processor housing **12** for supporting thermal print media **32** thereon. Only one of sheet material trays **50a ,50b** will dispense thermal print media **32** out of its sheet material tray to create an intended image thereon; the alternate sheet material tray **50a, 50b** either holds an alternative type of thermal print media **32** or functions as a back up sheet material tray. In this regard, lower sheet material tray **50a** includes a lower media lift cam **52a** for lifting lower sheet material tray **50a** and ultimately thermal print media **32** upwardly toward a rotatable, lower media roller **54a,** and toward a second rotatable, upper media roller **54b** which, when both are rotated, permits thermal print media **32** from lower sheet material tray **50a** to be pulled upwardly towards a movable media guide **56**.

Upper sheet material tray **50b** includes an upper media lift cam **52b** for lifting upper sheet material tray **50b,** and ultimately thermal print media **32** from upper sheet material tray **50b** towards upper media roller **54b** which directs it towards media guide **56**.

[0032] Movable media guide **56** directs thermal print media **32** under a pair of media guide rollers **58** which engages thermal print media **32** for assisting upper media roller **54b** in directing it onto a media staging tray **60**. Media guide **56** is attached and hinged to a lathe bed scanning frame **202** (Fig. 2) at one end, and is uninhibited at its other end for permitting multiple positioning of media guide **56**. Media guide **56** then rotates its uninhibited end downwardly, as illustrated in the position shown, and the direction of rotation of upper media roller **54b** is reversed for moving thermal print media **32** resting on media staging tray **60** under the pair of media guide rollers **58**, upwardly through an entrance passageway **204** and around a rotatable vacuum imaging drum **300**.

[0033] A roll **30** of dye donor material **34** is connected to a media carousel **100** in a lower portion of image processor housing **12**. Four rolls **30** are used, but only one is shown for clarity. Each roll **30** includes dye donor material **34** of a different color, typically black, yellow, magenta and cyan. These dye donor materials **34** are ultimately cut into dye donor sheet materials **36** and passed to vacuum imaging drum **300** for forming the medium from which dyes imbedded therein are passed to thermal print media **32** resting thereon, which process is described in detail herein below. In this regard, a media drive mechanism **110** is attached to each roll **30** of dye donor material **34**, and includes three media drive rollers **112** through which dye donor material **34** of interest is metered upwardly into a media knife assembly **120**. After dye donor material **34** reaches a predetermined position, media drive rollers **112** cease driving dye donor material **34** and two media knife blades **122** positioned at a bottom portion of media knife assembly **120** cut dye donor material **34** into dye donor sheet materials **36**. Lower media roller **54a** and upper media roller **54b** along with media guide **56** then pass dye donor sheet material **36** onto media staging tray **60,** and ultimately to vacuum imaging drum **300** and in registration with thermal print media **32,** using the same process as described above for passing thermal print media **32** onto vacuum imaging drum **300**. Dye donor sheet material **36** now rests atop thermal print media **32** with a narrow gap between the two created by microbeads imbedded in the surface of thermal print media **32**.

[0034] A laser assembly **400** includes a quantity of laser diodes **402** in its interior. Laser diodes **402** are connected via fiber optic cables **404** to a distribution block **406** and ultimately to a printhead **500**. Printhead **500** directs thermal energy received from laser diodes **402** causing dye donor sheet material **36** to pass the desired color across the gap to thermal print media **32**. As shown in Fig 2, printhead **500** is attached to a lead screw **250** via a lead screw drive nut **254** and drive coupling (not shown) for permitting movement axially along the longitudinal axis of vacuum imaging drum **300** and transferring the data to create the intended image onto thermal print media **32**.

[0035] For writing, vacuum imaging drum **300** rotates at a constant velocity, and printhead **500** begins at one end of thermal print media **32** and traverses the entire length of thermal print media **32** for completing the transfer process for the particular dye donor sheet material **36** resting on thermal print media **32**. After printhead **500** has completed the transfer process for the particular dye donor sheet material **36** resting on thermal print media **32,** dye donor material **36** is removed from vacuum imaging drum **300** and transferred out of image processor housing **12** via a skive or ejection chute **16**. Dye donor sheet material **36** eventually comes to rest in a waste bin **18** for removal by the user. The above described process is then repeated for the other three rolls **30** of dye donor materials **34**.

[0036] After the color from the four sheets but not limited to four of the dye donor sheet materials **36** have been transferred and the dye donor sheet materials **36** have been removed from vacuum imaging drum **300**, thermal print media **32** is removed from vacuum imaging drum **300** and transported via a transport mechanism **80** to a color binding assembly **180**. An entrance door **182** of color binding assembly **180** is opened for permitting thermal print media **32** to enter color binding assembly **180**, and shuts once thermal print media **32** comes to rest in color binding assembly **180**. Color binding assembly **180** processes thermal print media **32** for further binding the transferred colors on thermal print media **32** and for sealing the microbeads thereon. After the color binding process has been completed, a media exit door **184** is opened and thermal print media **32** with the intended image thereon passes out of color binding assembly **180** and image processor housing **12** and comes to rest against a media stop **20**.

[0037] Referring to Fig. 2, there is illustrated a perspective view of a lathe bed scanning subsystem **200** of image processing apparatus **10**, including vacuum imaging drum **300**, printhead **500** and lead screw **250** assembled in lathe bed scanning frame **202**. Vacuum imaging drum **300** is mounted for rotation about an axis **X** in lathe bed scanning frame **202**. Printhead **500** is movable with respect to vacuum imaging drum **300**, and is arranged to direct a beam of light to dye donor sheet material **36**. The beam of light from printhead **500** for each laser diode **402** (not shown in **Fig. 2**) is modulated individually by modulated electronic signals from image processing apparatus **10**, which are representative of the shape and color of the original image, so that the color on dye donor sheet material **36** is heated to cause volatilization only in those areas in which its presence is required on thermal print media **32**. This to reconstructs the shape and color of the original image.

[0038] Printhead **500** is mounted on a movable translation stage member **220** which, in turn, is supported for low friction slidable movement on translation bearing rods **206** and **208**. Translation bearing rods **206** and **208** are sufficiently rigid so that they do not sag or distort between their mounting points and are arranged as parallel as possible with axis **X** of vacuum imaging drum **300** with the axis of printhead **500** perpendicular to axis **X** of vacuum imaging drum **300**. Front translation bearing rod **208** locates translation stage member **220** in vertical and horizontal directions with respect to axis **X** of vacuum imaging drum **300**. Rear translation bearing rod **206** locates translation stage member **220** only with respect to rotation of the translation stage member **220** about front translation bearing rod **208** so that there is no over-constraint condition of translation stage member **220** which might cause it to bind, chatter, or otherwise impart undesirable vibration or jitters to printhead **500** during the generation of an intended image.

[0039] Referring to Figs. 2 and 3, lead screw **250** is shown which includes an elongated, threaded shaft **252** which is attached to linear drive motor **258** on its drive end and to lathe bed scanning frame **202** by means of a radial bearing **272**. Lead screw drive nut **254** includes grooves in its hollowed-out center portion **270** for mating with the threads of threaded shaft **252** for permitting lead screw drive nut **254** to move axially along threaded shaft **252** as threaded shaft **252** is rotated by linear drive motor **258**. Lead screw drive nut **254** is integrally attached to printhead **500** through a lead screw coupling (not shown) and translation stage member **220** at its periphery, so that as threaded shaft **252** is rotated by linear drive motor **258** lead screw drive nut **254** moves axially along threaded shaft **252,** which in turn moves translation stage member **220** and ultimately printhead **500** axially along vacuum imaging drum **300**.

[0040] As best illustrated in Fig. 3, an annular-shaped axial load magnet **260a** is integrally attached to the driven end of threaded shaft **252**, and is in a spaced apart relationship with another annular-shaped axial load magnet **260b** attached to lathe bed scanning frame **202**. Axial load magnets **260a** and **260b** are preferably made of rare-earth materials such as neodymium-iron-boron. A generally circular-shaped boss part **262** of threaded shaft **252** rests in a hollowed-out portion of annular-shaped axial load magnet **260a**, and includes a generally V-shaped surface at its end for receiving a ball bearing **264**. A circular-shaped insert **266** is placed in a hollowed-out portion of the other annular-shaped axial load magnet **260b**, and includes an accurate-shaped surface on one end for receiving ball bearing **264**, and a flat surface at its other end for receiving an end cap **268**. Endcap **268** is placed over annular-shaped axial load magnet **260b** and attached to lathe bed scanning frame **202** for protectively covering annular-shaped axial load magnet **260b** and providing an axial stop for lead screw **250**. Circular shaped insert **266** is preferably made of material such as Rulon J™ or Delrin AF™ , both well known in the art.

[0041] Lead screw **259** operates as follows. Linear drive motor **258** is energized and imparts rotation to lead screw **250**, as indicated by the arrows in Fig. 3, causing lead screw drive nut **254** to move axially along threaded shaft **252**. Annular-shaped axial load magnets **260a** and **260b** are magnetically attracted to each other which prevents axial movement of lead screw **250**. Ball bearing **264**, however, permits rotation of the lead screw **250** while maintaining the positional relationship of annular-shaped axial load magnets **260a, 260b**, i.e., slightly spaced apart, which prevents mechanical friction between them while obviously permitting threaded shaft **252** to rotate.

[0042] Referring to Fig. 4, there is illustrated an exploded view of vacuum imaging drum **300**. Vacuum imaging drum **300** has a cylindrical shaped vacuum drum housing **302** that has a hollowed-out interior portion **304**. Vacuum imaging drum **300** further includes a plurality of vacuum grooves **332** and vacuum holes **306** which extend through vacuum drum housing **302** for permitting a vacuum to be applied from hollowed-out interior portion **304** of vacuum imaging drum **300** for supporting and maintaining a position of thermal print media **32** and dye donor sheet material **36**, as vacuum imaging drum **300** rotates.

[0043] The ends of vacuum imaging drum **300** are closed by vacuum end plate **308**, and drive end plate **310**. Drive end plate **310**, is provided with a centrally disposed drive spindle **312** which extends outwardly therefrom through a support bearing **314**. Vacuum end plate **308** is provided with a centrally disposed vacuum spindle **318** which extends outwardly therefrom through another support bearing **314**.

[0044] Drive spindle **312** extends through support bearing **314** and is stepped down to receive a DC drive motor armature, which is held on by means of a drive nut. A DC motor stator **342** is held in a stationary fashion by lathe scanning frame member **202**, encircling the DC drive motor armature **316** to form a reversible, variable DC drive motor for vacuum imaging drum **300**. For the specifics of the drive elements of vacuum imaging drum **300** as described above, reference is made to, i.e., U.S. Patent No. 5,428,371. At the end of drive spindle **312** a drum encoder **344** (**FIG. 8**) is mounted to provide timing signals to image processing apparatus **10**.

[0045] Vacuum spindle **318** is provided with a central vacuum opening **320** which is in alignment with a vacuum fitting which is provided with an external flange that is rigidly mounted to lathe bed scanning frame **202**. The vacuum fitting has an extension which extends within but is closely spaced from vacuum spindle **318**, thus forming a small clearance. With this configuration, a slight vacuum leak is provided between an outer diameter of the vacuum fitting and an inner diameter of central vacuum opening **320** of vacuum spindle **318**. This assures that no contact exists between the vacuum fitting and vacuum imaging drum **300** which might impart uneven movement or jitters to vacuum imaging drum

300 during its rotation. As an example of this arrangement, reference is again made to U.S. Patent No. 5,428,371.

[0046] The opposite end of the vacuum fitting is connected to a high-volume vacuum blower which is capable of producing 50-60 inches of water (93.5 - 112.2 millimeters of mercury) at an air flow volume of 60-70 cfm (28.368 - 33.096 liters per second); and provides the vacuum to vacuum imaging drum **300** which supports the various internal vacuum levels of vacuum imaging drum **300** required during the loading, scanning and unloading of thermal print media **32** and dye donor sheet materials **36** to create the intended image. With no media loaded on vacuum imaging drum **300** the internal vacuum level of vacuum imaging drum **300** is approximately 10-15 inches of water (18.7-28.05 millimeters of mercury). With just thermal print media **32** loaded on vacuum imaging drum **300** the internal vacuum level of vacuum imaging drum **300** is approximately 20-25 inches of water (37.4 - 46.75 millimeters of mercury), which is the level required so that when a dye donor sheet material **36** is removed thermal print media **32** does not move, otherwise color to color registration will not be able to be maintained. With both thermal print media **32** and dye donor sheet material **36** completely loaded on vacuum imaging drum **300** the internal vacuum level of the vacuum imaging drum **300** is approximately 50-60 inches of water (93.5 - 112.2 millimeters of mercury) in this configuration.

[0047] An outer surface of vacuum imaging drum **300** is provided with an axially extending flat **322** (as shown in **Figs. 4** and **5**), which extends approximately 8 degrees of the circumference of vacuum imaging drum **300**. Vacuum imaging drum **300** is also provided with donor support rings **324** which form a circumferential recess **326** which extends circumferentially from one side of the axially extending flat **322,** circumferentially around vacuum imaging drum **300** to the other side of axially extending flat **322**, and from approximately one inch (25.4 millimeters) from one end of vacuum imaging drum **300** to approximately one inch (25.4 millimeters) from the other end of the vacuum imaging drum **300**.

[0048] Thermal print media **32** when mounted on vacuum imaging drum **300** is seated within circumferential recess **326** (as shown **Figs 6a** through **6c**) and therefore donor support rings **324** have a thickness substantially equal to thermal print media **32** thickness seated therebetween which is approximately 0.004 inches (0.102 millimeters) in thickness. The purpose of circumferential recess **326** on vacuum imaging drum **300** surface is to eliminate any creases in dye donor sheet material **36**, as they are drawn down over thermal print media **32** during the loading of dye donor sheet material **36**. This ensures that no folds or creases will be generated in dye donor sheet material **36** which could extend into the image area and seriously adversely affect the intended image. Circumferential recess **326** also substantially eliminates the entrapment of air along the edge of thermal print media **32**, where it is difficult for vacuum holes **306** in vacuum imaging drum **300** surface to assure the removal of the entrapped air. Any residual air between thermal print media **32** and dye donor sheet material **36** can also adversely affect the intended image.

[0049] Axially extending flat **322** assures that the leading and trailing ends of dye donor sheet material **36** are somewhat protected from the effect of increased air turbulence during the relatively high speed rotation that vacuum imaging drum **300** undergoes during the image scanning process. Thus increased air turbulence will have less tendency to lift or separate the leading or trailing edges of dye donor sheet material **36** off from vacuum imaging drum **300**; also axially extending flat **322** ensures that the leading and trailing ends of dye donor sheet material **36** are recessed from the periphery of vacuum imaging drum **300**. This reduces the chance that dye donor sheet material **36** can come in contact with other parts of image processing apparatus **10**, such as printhead **500**, which could cause a media jam within image processing apparatus **10**, resulting in the possible loss of the intended image or at worse catastrophic damage to image processing apparatus **10** possibly damaging printhead **500**.

[0050] The control circuitry shown in the block diagram of **FIG. 8** represents a linear motion control system **900** and shows how the present invention adjusts printhead **500** traversal speed programmably (based on the number of channels), and dynamically (responding to changes in vacuum imaging drum rotational speed). To drive lead screw **250**, the present invention uses a stepper motor **162** (**Fig. 8**) that can be driven in a microstepping mode.

[0051] As is illustrated in **FIG. 8**, a motor **345** drives vacuum imaging drum **300** in a rotatable manner. Encoder pulses from an imaging drum encoder **344** are input to a programmable frequency divider **902** via a random disable unit **903**. A programmed divisor (n) is applied to divide the input encoder frequency to a reduced output value. Pulses output from the programmable frequency divider **902** then act as clock pulses to drive a stepper motor controller **166** circuitry. (Stepper motor control **166** can be a standard component, such as the IM 483 High-Performance Microstepping Controller from Intelligent Motion Systems, Inc.) A pulse counter **904** tracks the number of input clock pulses generated in this circuit. When the programmed threshold value is reached (MAXPULSES), pulse counter **904** disables the clock pulse input to stepper motor controller **166** (using standard AND-gate logic control circuitry **906**), effectively stopping stepper motor **162**. This MAXPULSES value is reached at the end of each swath **450**, so that printhead **500** stops moving while vacuum imaging drum **300** rotates through a "dead band" **2000** (where there is no imaging since there is no receiver media). When ready to begin the next swath **450**, drum encoder **344** sends an index pulse. This resets pulse counter **904** and enables the input clock pulses to stepper motor controller **166**, thus restarting stepper motor **162** for the next swath **450**.

[0052] As the above description indicates, the control circuit is programmed with two values (n and MAXPULSES) that vary depending on the number of channels; wherein n is a truncated value equal to encoder resolution divided by desired microsteps per revolution (pulses/microsteps); and MAXPULSES equals the desired number of microsteps per revolution. As the table in **FIG. 8** indicates, a 28-channel swath requires an n value of 22 as input to programmable frequency divider **902**. Pulse counter **904** allows 488 (MAXPULSES) pulses to stepper motor controller **166** before disabling stepper motor controller **166** input. With a 10,000 pulse/revolution drum encoder **344**, the first 9,856 pulses, after division by programmable frequency divider **902** value (here, 22), provide 448 microsteps (which, in turn, yields 7 full steps at **64** microsteps per step). Stepper motor **162** rotation is then disabled during the remaining 144 (10,000 minus 9,856) pulses from drum encoder **344**. (These 144 pulses occur during the "dead band" between swaths **450**.)

[0053] The table in **Fig. 8** shows typical values for n and MAXPULSES given a variable number of channels. For each case, different values for n and MAXPULSES apply. It should be noted that this invention allows a different number of full steps for each number of channels specified, where each full step comprises a number of micropsteps (64 per step in the preferred embodiment of this invention). Progammed values for n and for MAXPULSES, determined in advance, are stored in a programmable memory so that these values can be accessed and used for a given number of channels. Using this method, the stepper motor speed changes appropriately, based on the number of channels used.

[0054] To generate the intended image vacuum imaging drum **300** is spun up to speed by actuation of motor **345**. Coupled to vacuum image drum **300** is drum encoder **344** as described above which generates 10,000 pulse per revolution synchronization signal to data path electronics and linear motion control system **900**. With each synchronized pulse the linear motion generates a constant uniform pulse train, which drives stepper motor **162** moving printhead **500** along vacuum imaging drum **300** at a speed synchronous with the rotation of vacuum imaging drum **300**, and proportional to a width of a writing swath **450** (**Fig. 7**). The pattern that printhead **500** traces out along the spinning vacuum imaging drum **300** is a helix as shown in **Fig. 7.** The writing swath **450** traced out on vacuum imaging drum **300** is shown separated in **Fig. 7** for the purposes of clarity. In actual operation, each writing swath **450** would be directly adjacent to a previous writing swath **450** traced out on the surface of vacuum imaging drum **300**. In **Fig. 7**, reference numeral **456** represents the position of printhead **500** at the start of the helix, and reference numeral **458** represents the position of printhead **500** at the end of the helix. Due to the sinusoidal nature of positional errors inherent to stepper motor drive systems, various types of visibly objectional image artifacts such as banding can be apparent. Some of the more prominent patterns are caused by swath-to-swath phase shifts.

[0055] To prevent this disturbance /banding, an artificial random pattern of noise **908** is added to linear motion control system **900** at a suitable amplitude and rate, both of which are randomly variable. This will cause the cyclic patterns to be obscured or masked and therefore not visible; but must be accomplished in a means that not only preserves the dimensional accuracy of the intended image over the length of the intended image, but also must not induce any significant errors in dot placement. This is done by artificially interrupting the uniform pulse train to control motor **162** randomly by means of a high frequency counter which rolls over periodically and ends the delay period. This delay time must be of a suitable range such that the end of one delay period occurs prior to the start of the next synchronized.

[0056] **FIG. 9** is a timing diagram (lines A-F) showing the normal non-dithered as well as the dithered relationships between the index pulse, encoder pulses and step clock shown in **FIG. 8**. For demonstration purposes, the example given uses a frequency divider of 10 and MAXPULSES of 9. The index pulse (line A) serves as a synchronization pulse for the stepper clock. The programmable frequency divider **902** (in this example 10) divides the encoder clock (line B) to generate the step clock (line C). When MAXPULSE (in this example 9) step clock pulses have occurred, the step clock is disabled until the index pulse occurs again.

[0057] The dithering function serves to randomly interrupt the encoder clock such that a random time shift occurs in the step clock as illustrated by STEP_CLK_DITHERED (line F) in FIG. 9.

[0058] DITHER_DISABLE (line D) (Random Noise 908) shows random periods where the encoder clock is desired to be disabled. ENCODER_CLK_GATED (line E) shows the interrupted encoder clock which results in variably random time delays in the step clock shown as STEP_CLK_DITHERED.

[0059] Care must be taken in the design such that the last step clock pulse, in this example the ninth one, occurs prior to the subsequent index pulse. If the cumulative time delays are too long, then positional control will be lost due to missed step clock pulses resulting in undesired image compression and excessive dot placement error.

[0060] The invention has been described with reference to the preferred embodiment thereof. However, it will be appreciated and understood that variations and modifications can be effected within the scope of the invention as described herein above and as defined in the appended claims, by a person of ordinary skill in the art without departing from the scope of the invention.

For example, the invention is applicable to any image processor including an ink-jet printer. Also, the dye donor may have dye, pigments, or other material which is transferred to the thermal print media. Thermal print media includes paper, films, plates, and other material capable of accepting or producing an image.

Claims

1. An image processing apparatus comprising:

a printhead;
a vacuum imaging drum adapted to receive a thermal print media thereon;
a lead screw for moving said printhead;
a motor for rotating said lead screw so as to provide for a linear motion of said printhead along a line parallel to a longitudinal axis of said vacuum imaging drum; and
a linear motion control system which controls the linear motion of said printhead at a speed synchronous with a rotation of said vacuum imaging drum, and interrupts a driving of said motor with a random delay as the vacuum imaging drum rotates.

2. An image processing apparatus according to claim 1, further comprising an imaging drum motor for rotating said vacuum imaging drum.

3. An image processing apparatus according to claim 1, wherein said image processing apparatus is a color proofer.

4. An image processing apparatus according to claim 1, wherein said image processing apparatus is a laser thermal printer.

5. An image processing apparatus according to claim 1, wherein a donor material overlays said thermal print media and said printhead writes an image to said thermal print media by transferring dye from said donor material to said thermal print media.

6. An image processing apparatus comprising:

a printhead;

a vacuum imaging drum adapted to receive a print media thereon;

an encoder operationally associated with said vacuum imaging drum, said encoder generating a once per revolution synchronized pulse signal upon a rotation of said vacuum imaging drum;

a motor which provides a linear motion to said printhead along a line parallel to a longitudinal axis of said vacuum imaging drum; and

a linear motion control system which receives said synchronized pulse signal from said encoder and generates a constant uniform pulse train which drives said motor and moves said printhead along a surface of said vacuum imaging drum at a speed synchronous with a speed of rotation of said vacuum imaging drum, said linear motion control system interrupting said uniform pulse train to provide for a random delay in the linear motion of said printhead as said vacuum imaging drum rotates.

7. An image processing apparatus according to claim 6, further comprising an imaging drum motor for rotating said vacuum imaging drum.

8. An image processing apparatus according to claim 6, wherein said image processing apparatus is a color proofer.

9. An image processing apparatus according to claim 6, wherein said image processing apparatus is a laser thermal printer.

10. A method of exposing images on thermal print media, the method comprising the steps of:

rotating a vacuum imaging drum of an image processing apparatus, said vacuum imaging drum having a thermal print media thereon;

generating a once per revolution synchronized pulse signal based on said rotation of said vacuum imaging drum;

providing said synchronized pulse signal to a linear motion control system to generate a constant uniform pulse train to drive a printhead of said image processing apparatus in a linear direction along a line which is parallel to a longitudinal axis of said printhead, a speed of said printhead in said linear direction being synchronous with a speed of rotation of said vacuum imaging drum; and

interrupting said uniform pulse train to provide for a random delay in the drive of said printhead in the linear direction as said vacuum imaging drum rotates.

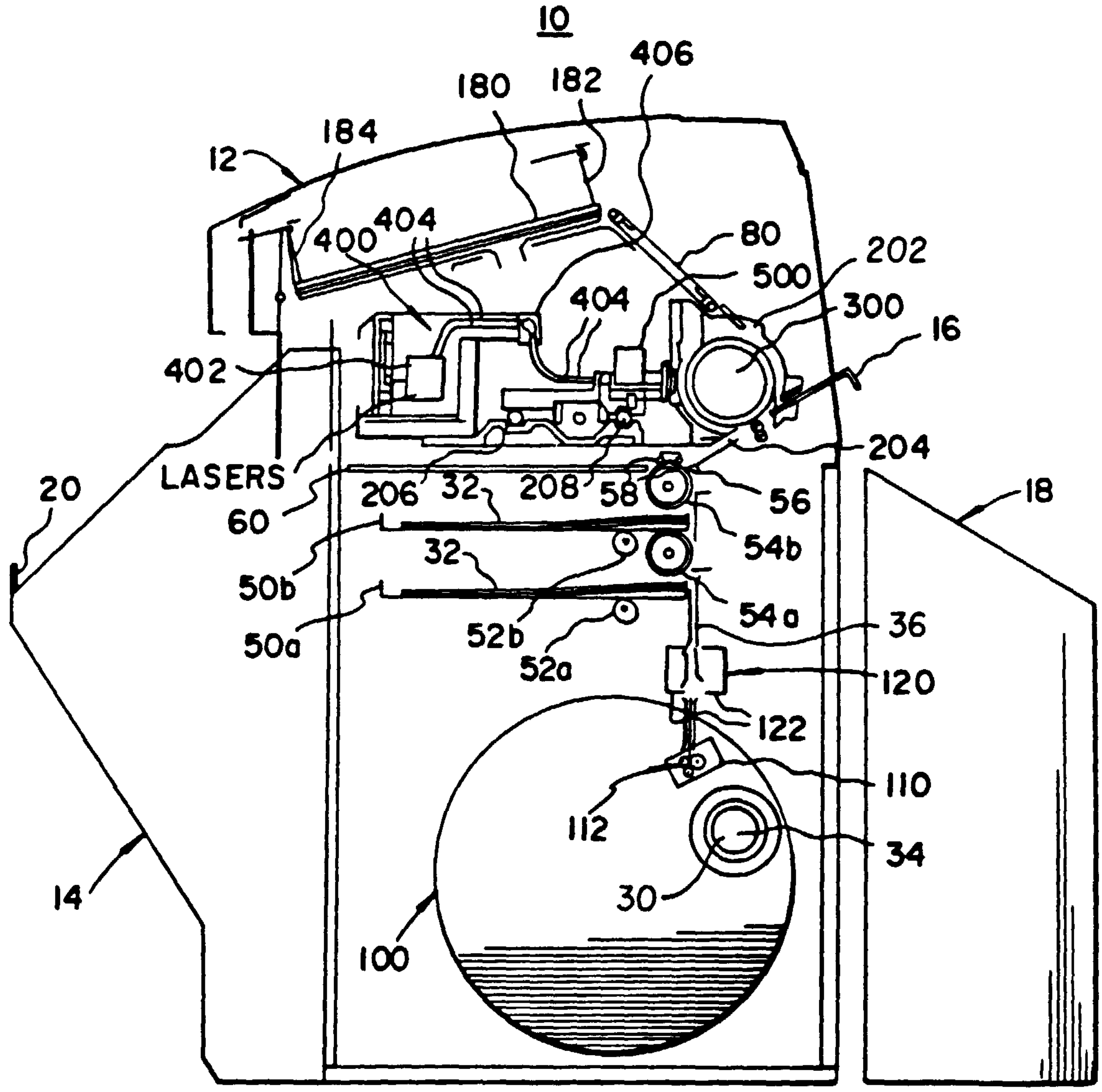
10
180
182
406
184
12
400
404
80
500
202
404
300
16
402
LASERS
204
20
60
206
32
208
58
56
18
54b
50b
32
50a
52b
52a
54a
36
120
122
110
112
34
30
14
100

FIG. 1

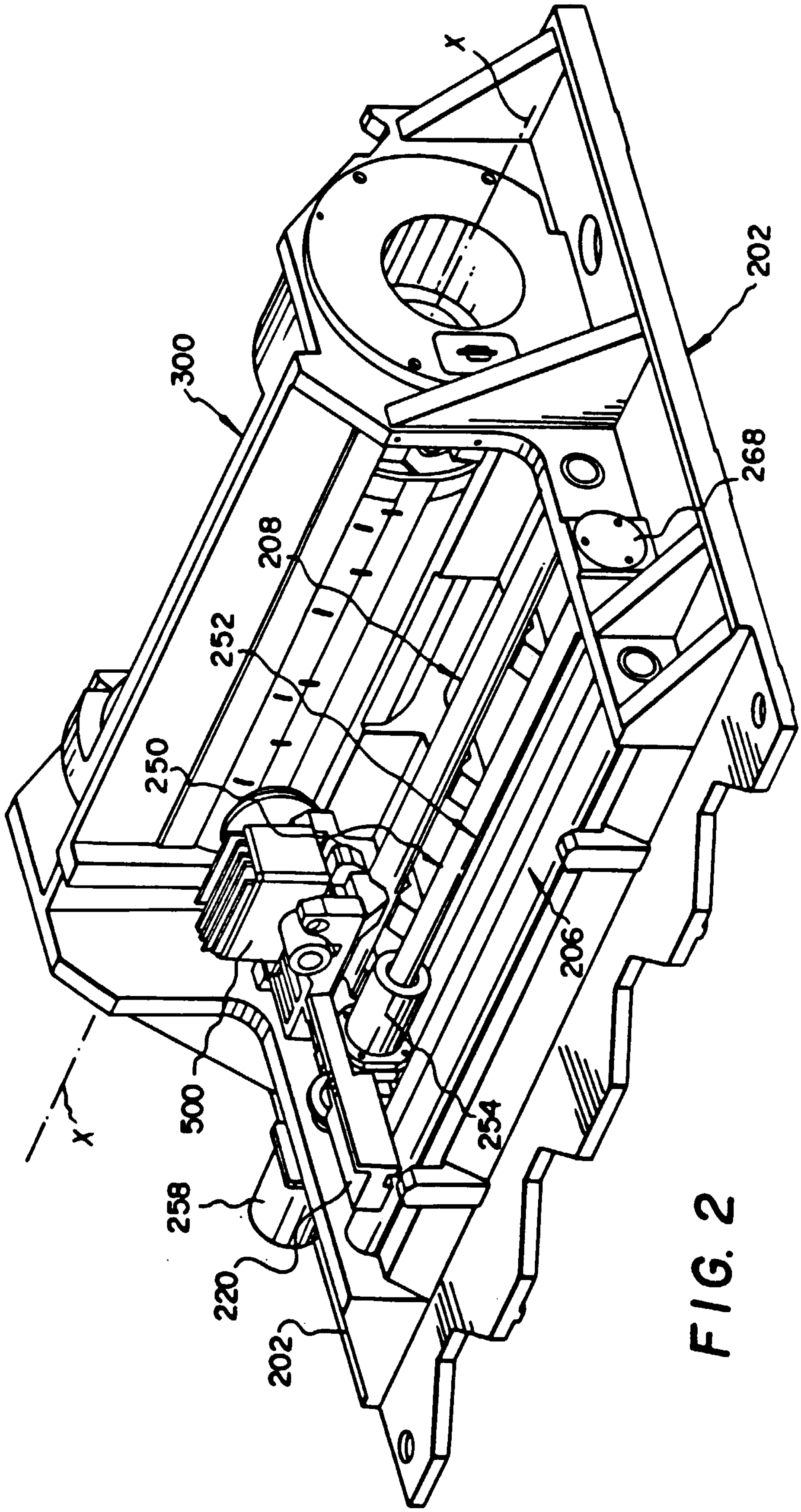

FIG. 2

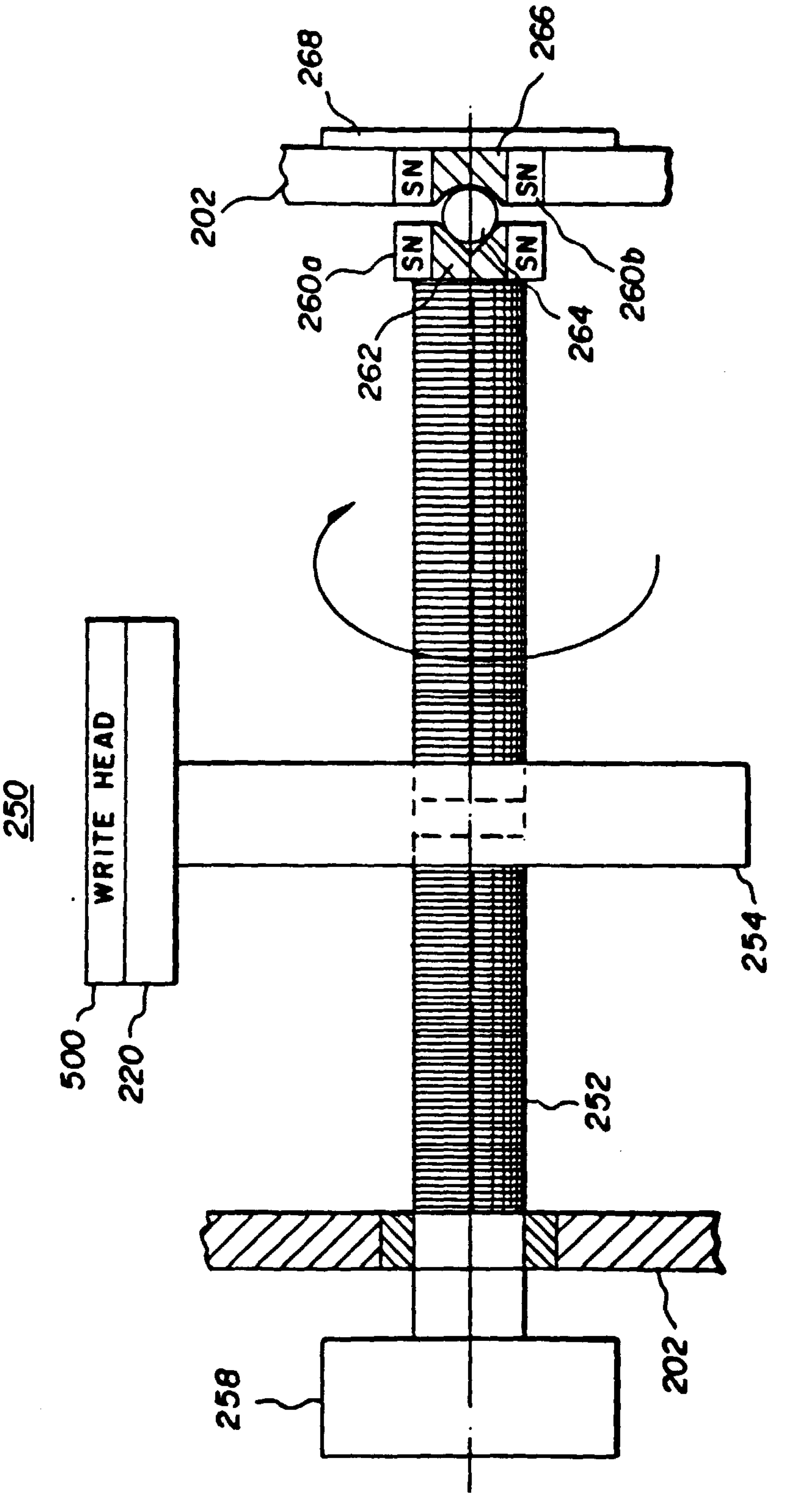
250
WRITE HEAD
500
220
268
266
202
SN
SN
SN
SN
260a
260b
262
264
252
254
202
258

FIG. 3

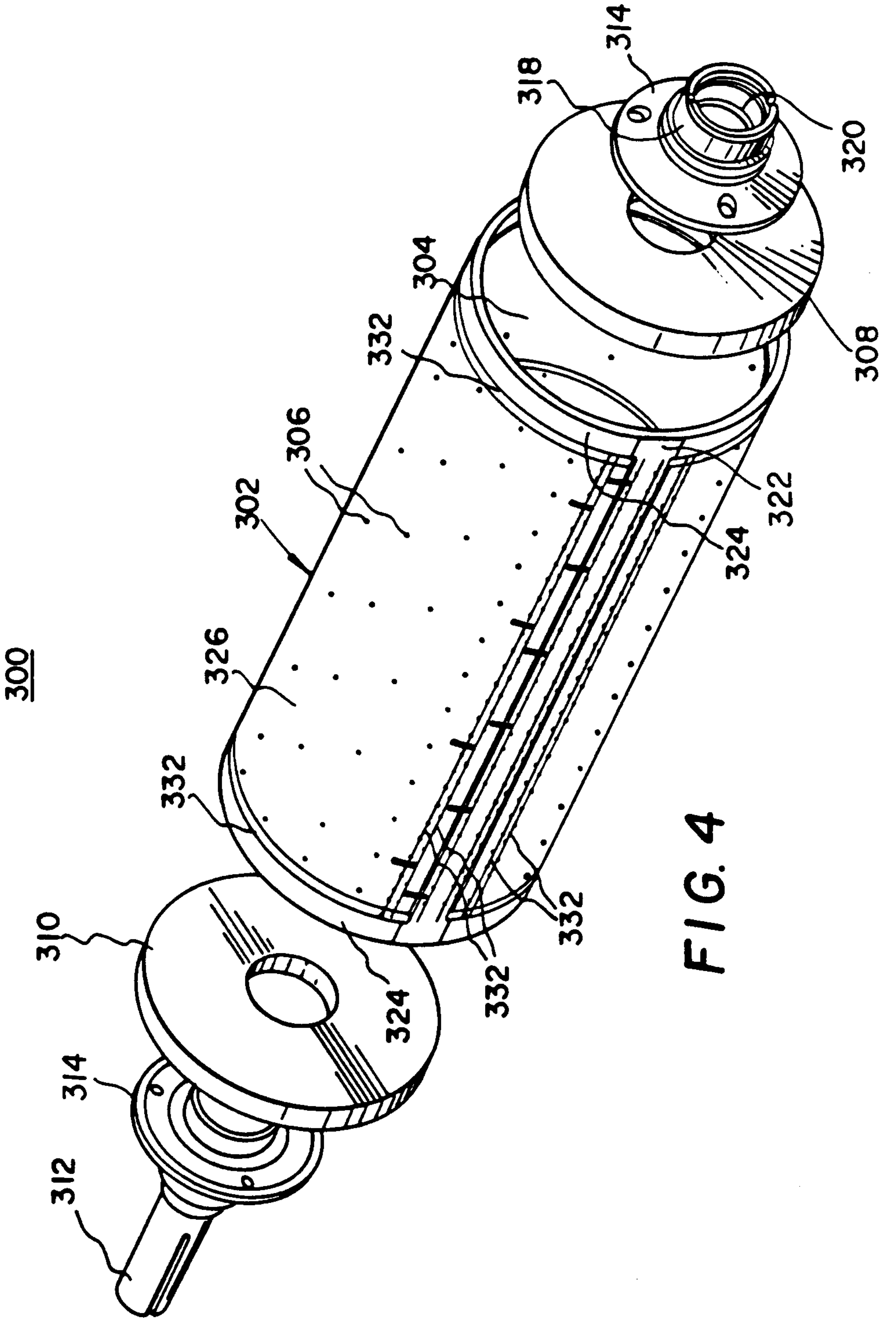
300
302
304
306
308
310
312
314
314
318
320
322
324
324
326
332
332
332
332
332

FIG. 4

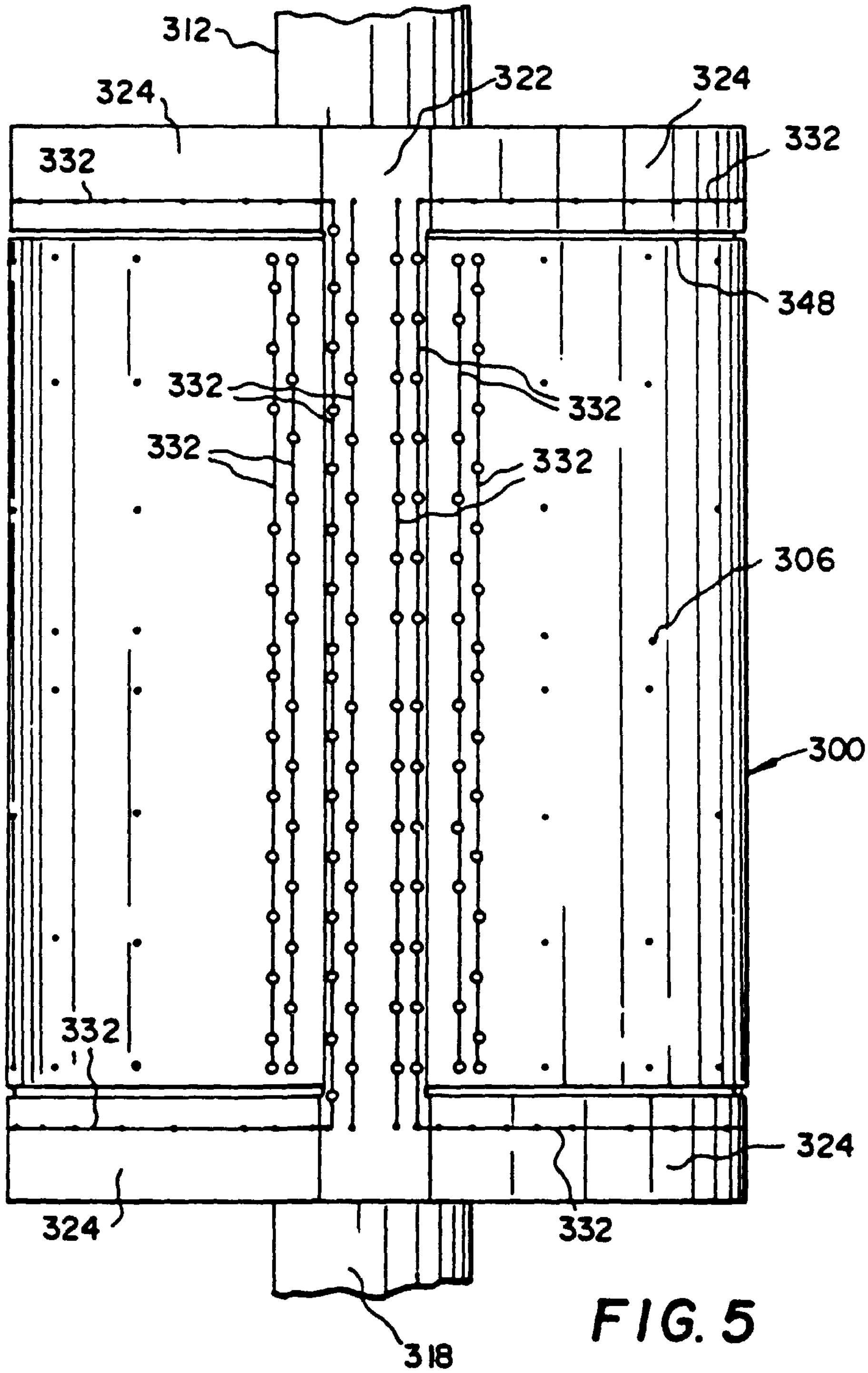
312
324
322
324
332
332
348
332
332
332
332
306
300
332
324
324
332
318

FIG. 5

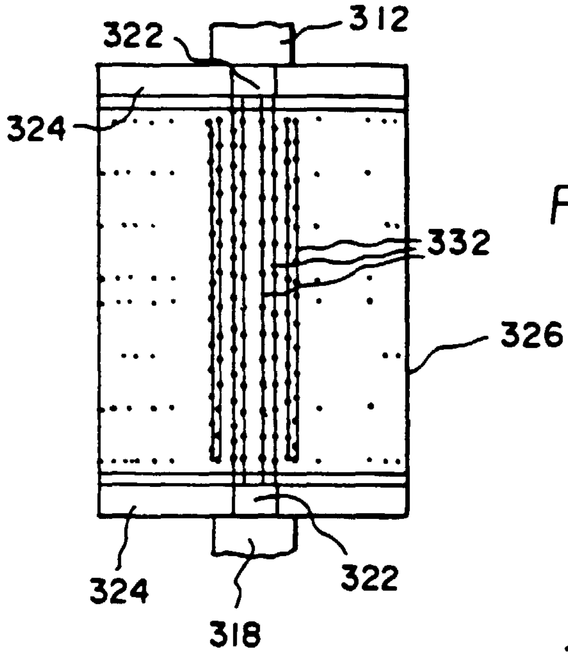

FIG. 6a

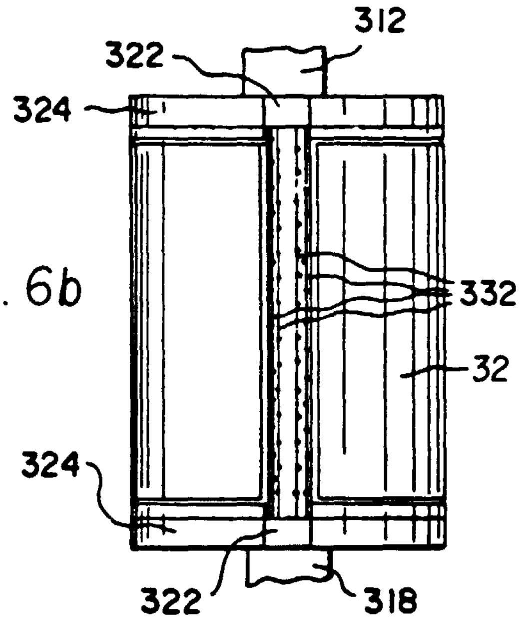

FIG. 6b

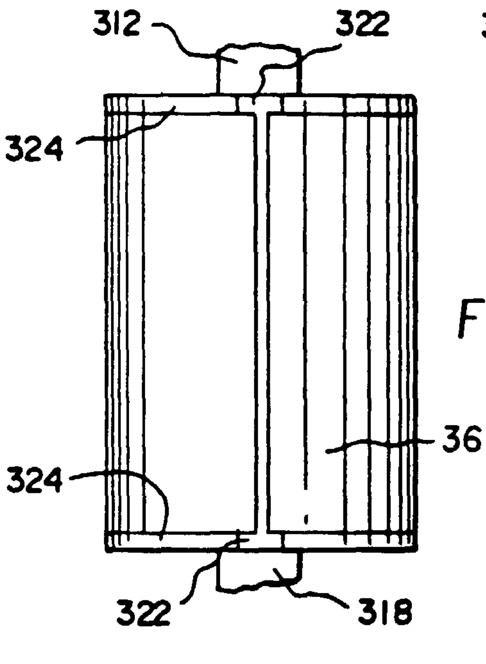

FIG. 6c

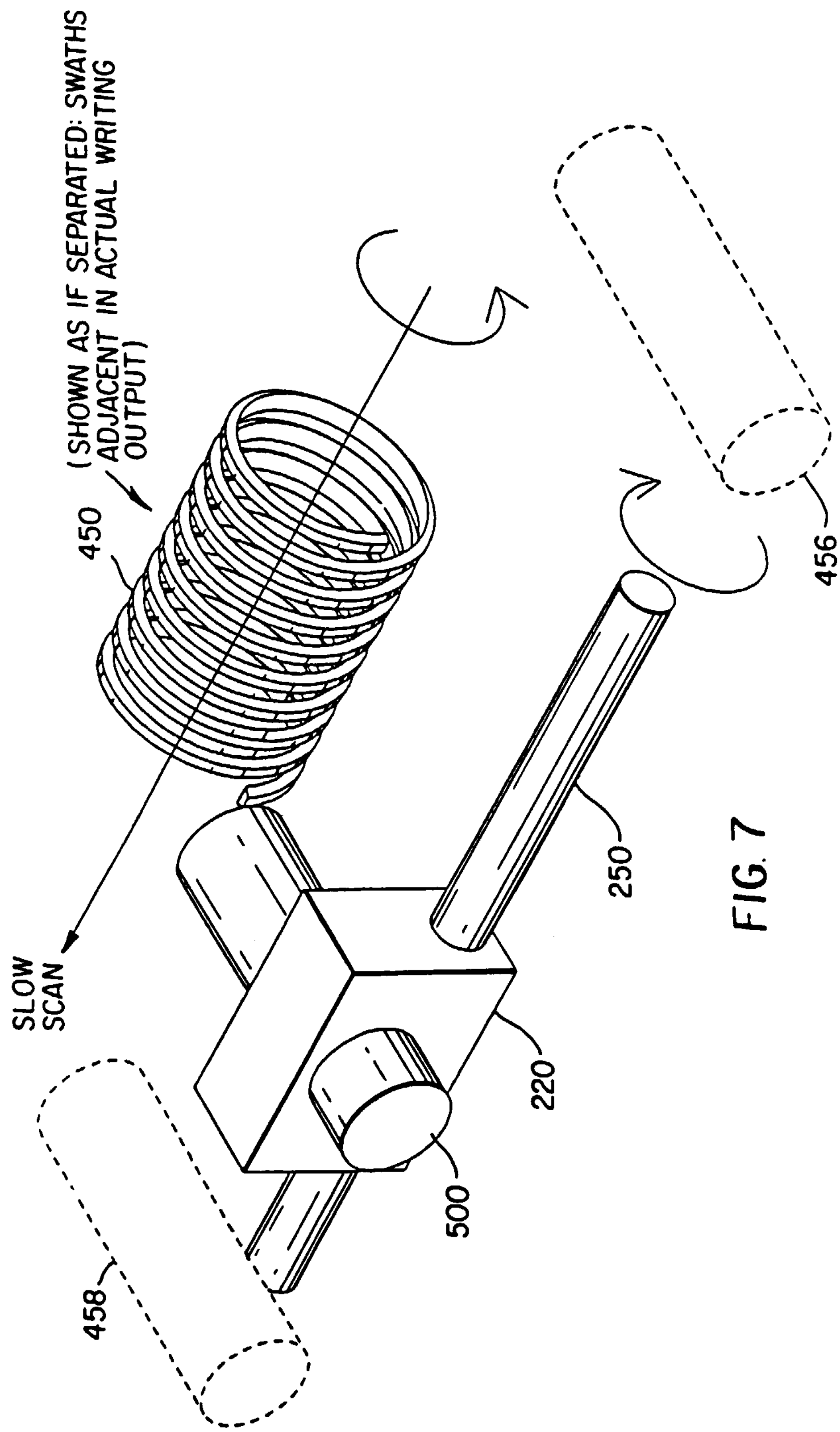
(SHOWN AS IF SEPARATED: SWATHS
ADJACENT IN ACTUAL WRITING
OUTPUT)
450
SLOW
SCAN
456
250
220
500
458

FIG. 7

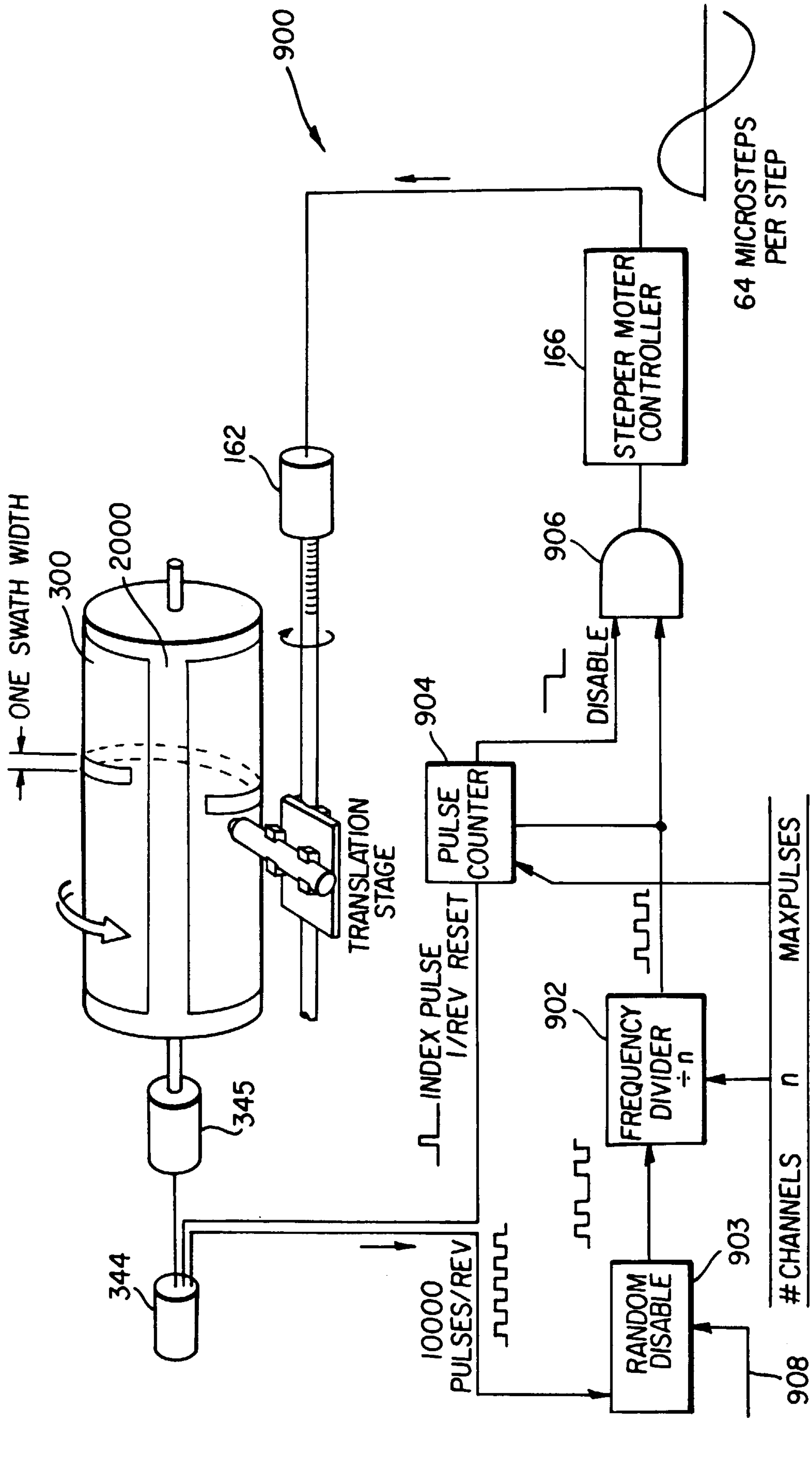
900
ONE SWATH WIDTH
300
2000
162
166
STEPPER MOTER CONTROLLER
64 MICROSTEPS PER STEP
906
DISABLE
904
PULSE COUNTER
TRANSLATION STAGE
INDEX PULSE 1/REV RESET
902
FREQUENCY DIVIDER ÷ n
345
344
10000 PULSES/REV
903
RANDOM DISABLE
908
#CHANNELS n MAXPULSES
...30 20 480
...28 22 448
...20 31 320
...13 48 208

FIG. 8

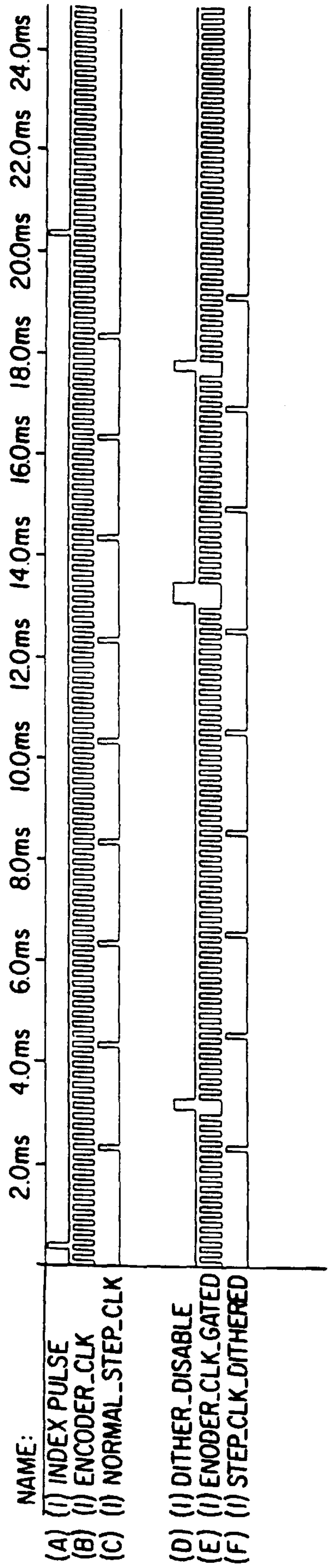
NAME:
(A) (I) INDEX PULSE
(B) (I) ENCODER_CLK
(C) (I) NORMAL_STEP_CLK
(D) (I) DITHER_DISABLE
(E) (I) ENODER_CLK_GATED
(F) (I) STEP_CLK_DITHERED
2.0ms
4.0ms
6.0ms
8.0ms
10.0ms
12.0ms
14.0ms
16.0ms
18.0ms
20.0ms
22.0ms
24.0ms

FIG. 9