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Clark et al.

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(54) **CONTINUOUSLY UPDATABLE ROTARY PAD PRINTING APPARATUS AND METHOD**

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(51) **Int. Cl.**

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B41J 2/01	(2006.01)
B41F 17/00	(2006.01)
B41J 2/005	(2006.01)

(52) **U.S. Cl.**
CPC ***B41F 17/001*** (2013.01); ***B41J 2/0057*** (2013.01)
USPC **101/41**; 101/194; 101/287; 101/492; 347/103

(58) **Field of Classification Search**
CPC B41F 17/001; B41F 17/00; B41F 16/00; B41F 1/00; B41F 1/16; B41J 2/0057; B41J 3/543; B41J 3/4073; B41J 2/01
USPC 101/41, 40, 35, 42, 93, 193, 194, 195, 101/200, 287, 297, 492; 347/103
See application file for complete search history.

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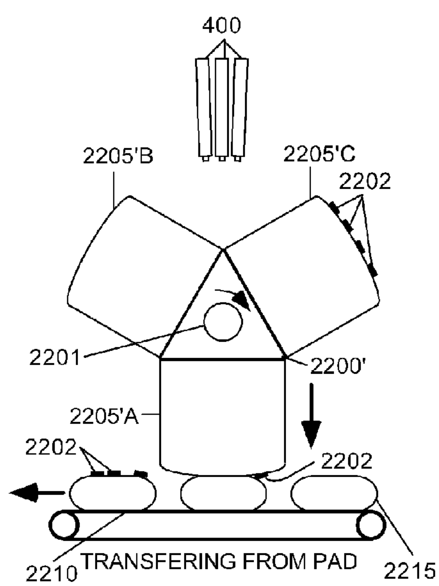
Primary Examiner — Daniel J Colilla
Assistant Examiner — Blake A Tankersley

(57) **ABSTRACT**

A rotary pad printing system comprises a compressible pad wheel (**105**), one or more inkjet or other image applicator heads (**400**), optional treatment stations (**500**), a shaft encoder (**535**), a control unit (**540**), and an image source (**565**). The image applicator heads apply an image to the wheel and the treatment stations can supply treatments such as heat, gas, light, overcoats, and undercoats. The image is then transferred to a receiving surface (**532**). An optional cleaning station (**510**) cleans the rotary pad prior to application of the next or a continuous image. Each image can be different and can be applied to a moving surface. Since the rotary pad can continuously receive updated image information, the area printed can range from a single pixel to an image of indefinite length. In an alternative embodiment, a domed pad is used. In another alternative embodiment, a flexible belt (**1000**) is used instead of a rotary wheel. In another alternative embodiment, a segmented pad (**2205**) is used.

25 Claims, 8 Drawing Sheets



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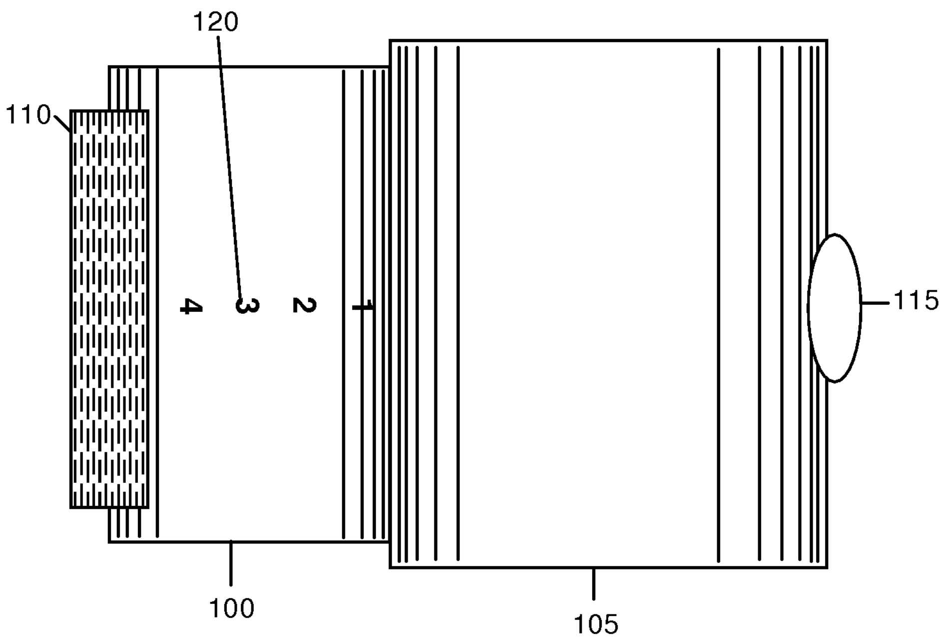

Fig. 1
Prior Art

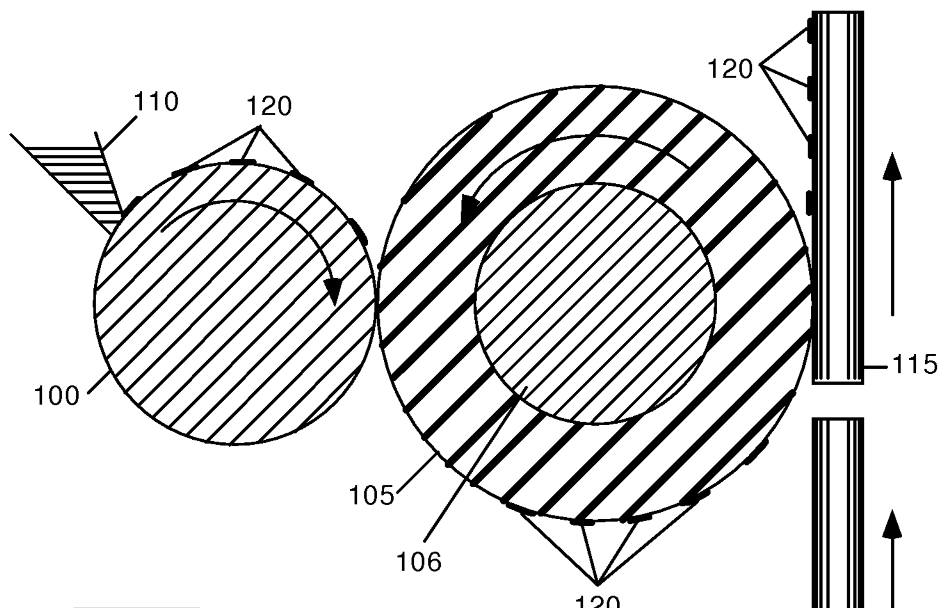

Fig. 2
Prior Art

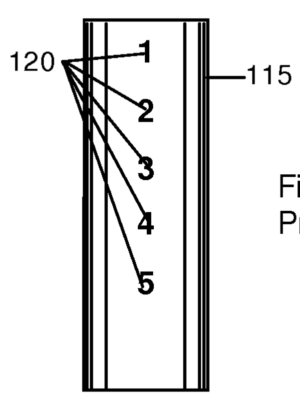

Fig. 3
Prior Art

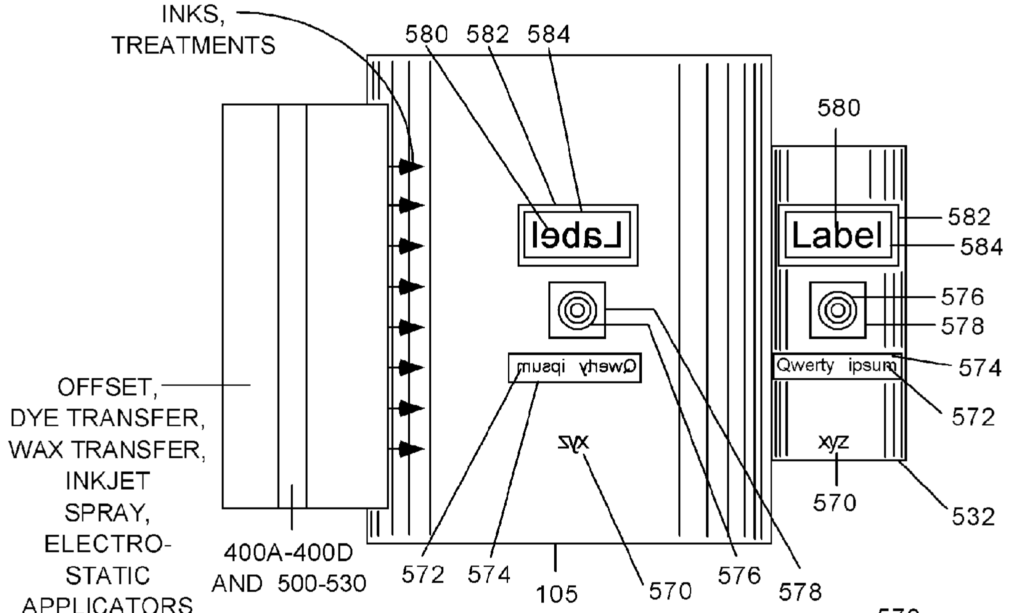

Fig. 4

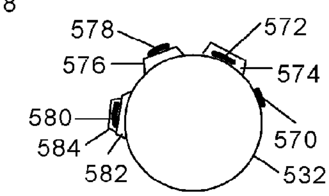

Fig. 6

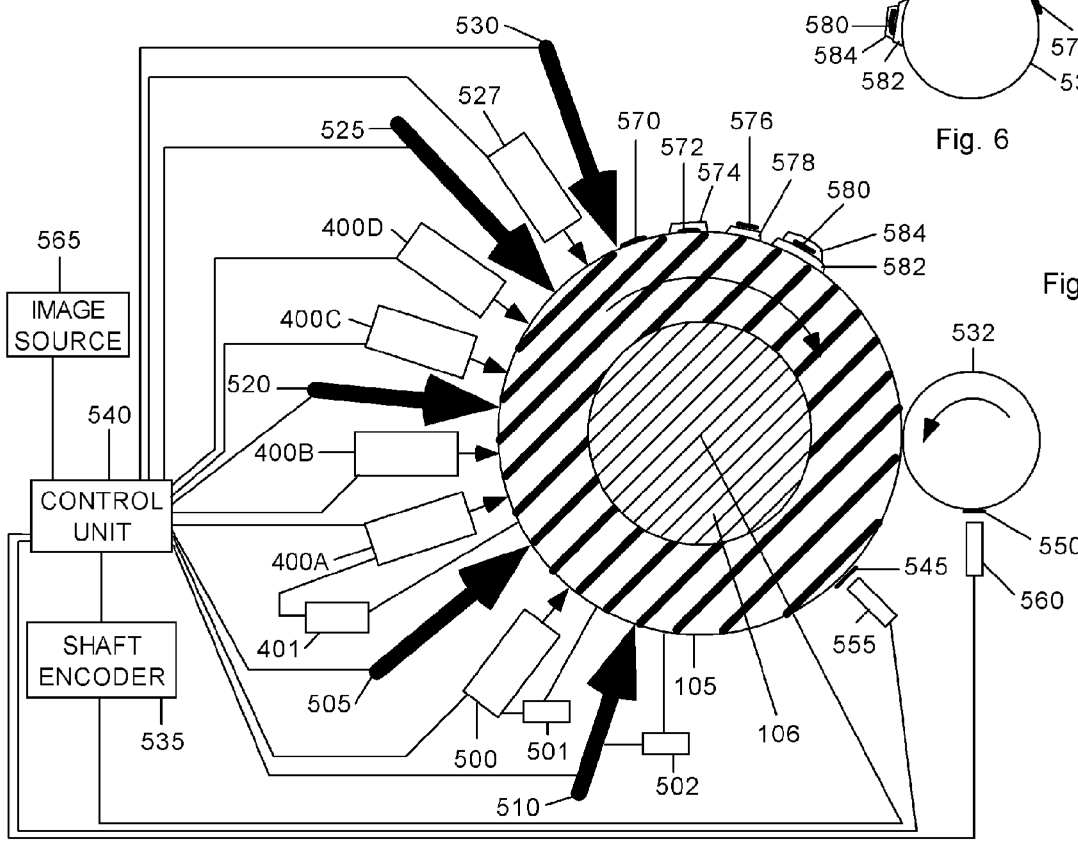

Fig. 5

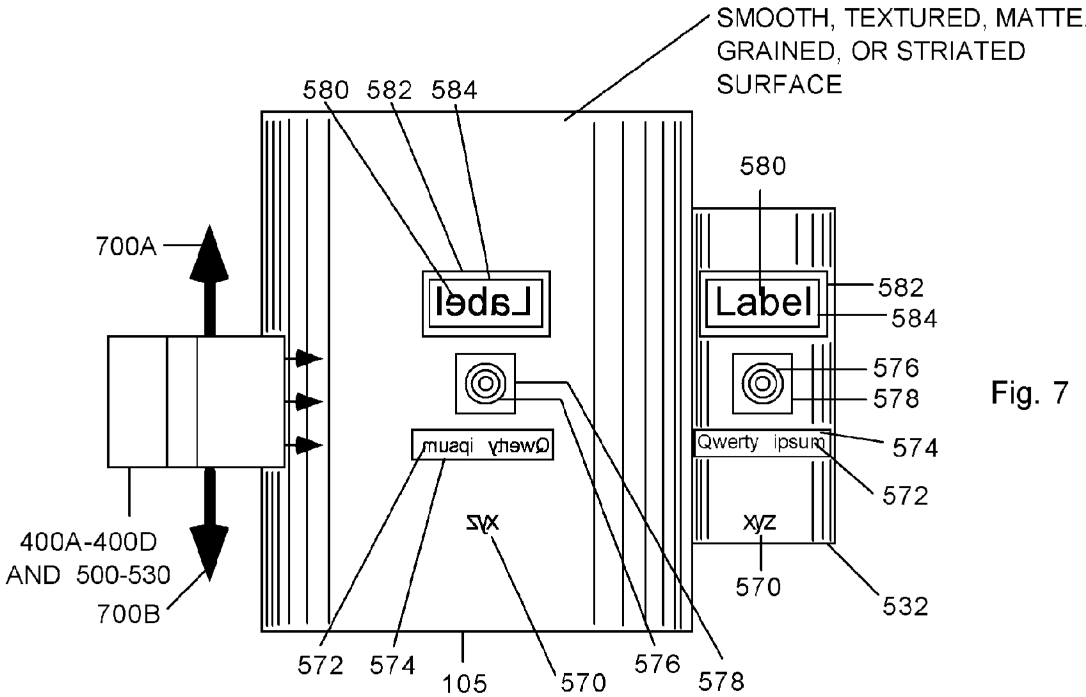
SMOOTH, TEXTURED, MATTE, GRAINED, OR STRIATED SURFACE
580 582 584
580
700A
Label
Label
582
584
576
578
Qwerty ipsum
Qwerty ipsum
574
572
xyz
xyz
400A-400D AND 500-530
700B
570
532
572 574 105 570 576 578

Fig. 7

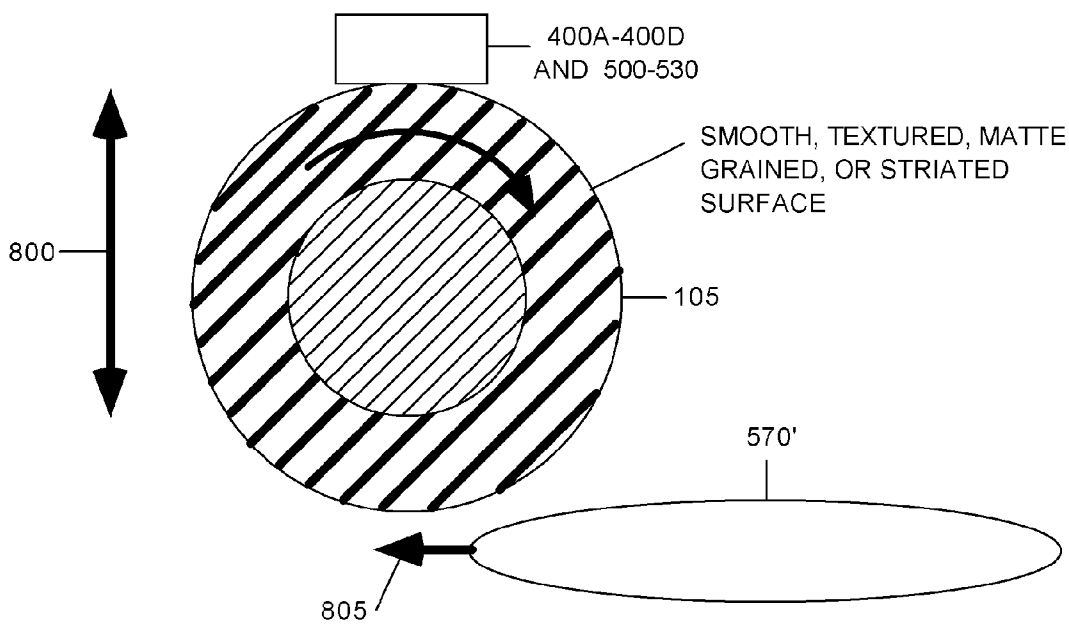
400A-400D AND 500-530
SMOOTH, TEXTURED, MATTE, GRAINED, OR STRIATED SURFACE
800
105
570'
805

Fig. 8

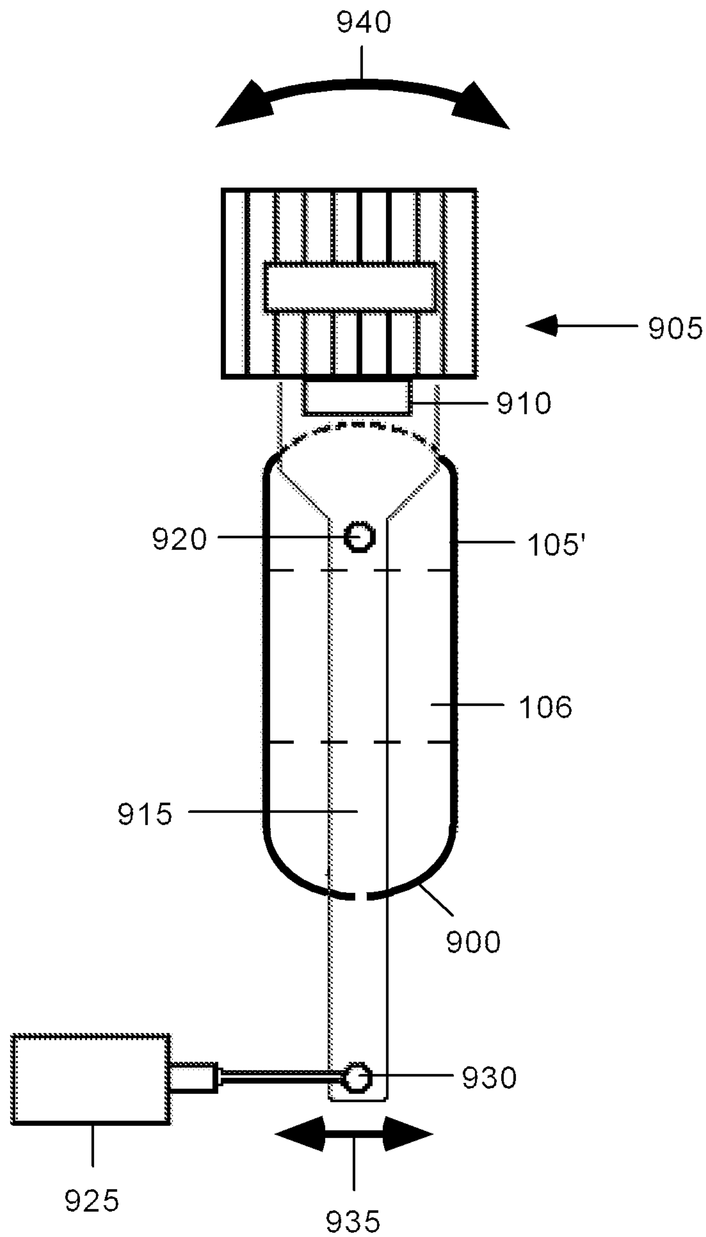

Fig. 9

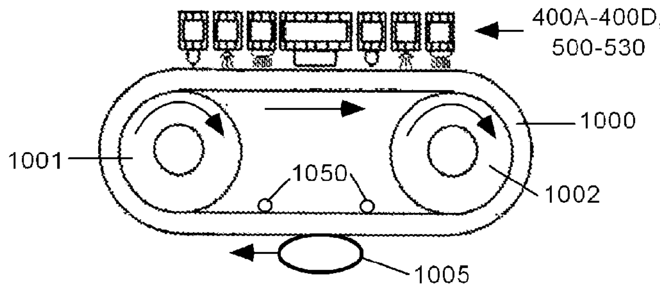

Fig. 10

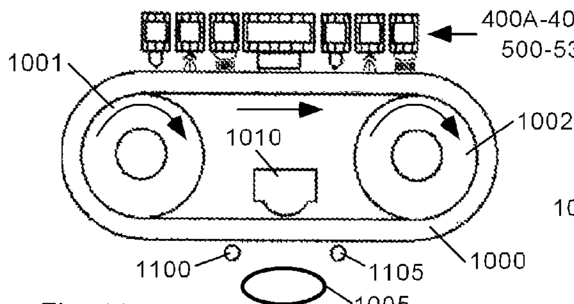

Fig. 11

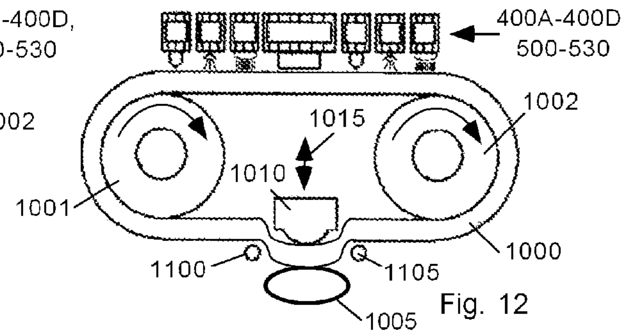

Fig. 12

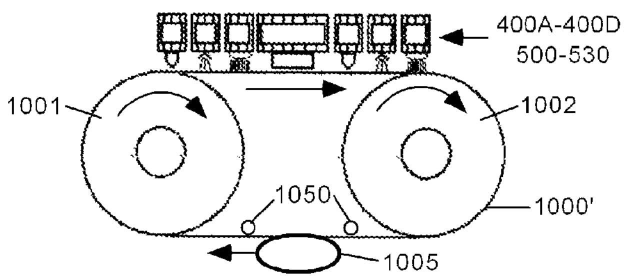

Fig. 13

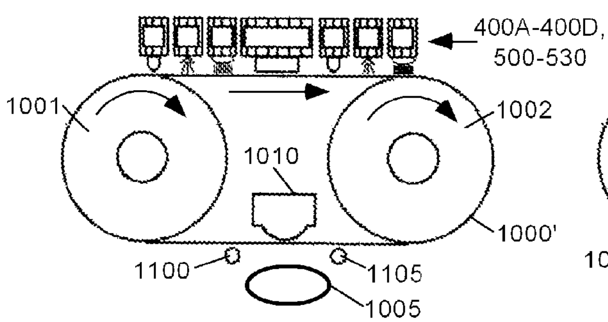

Fig. 14

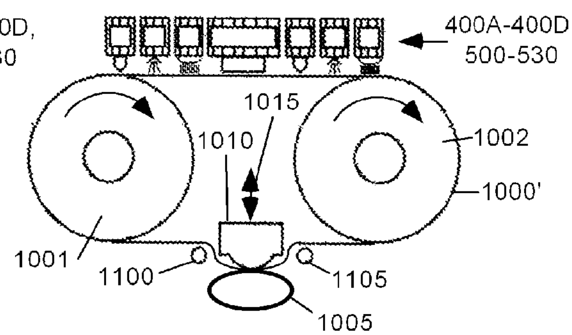

Fig. 15

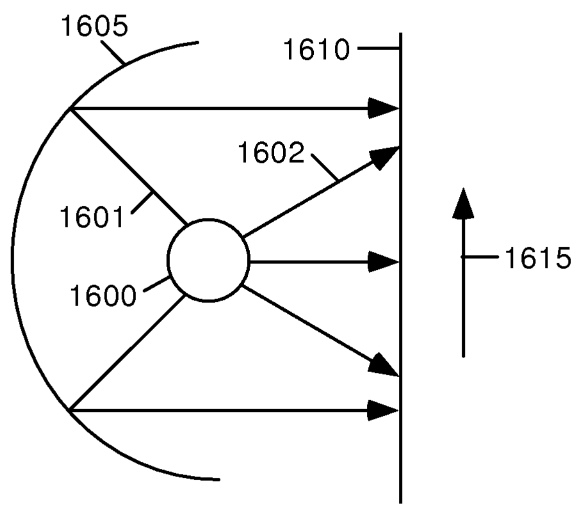

Fig. 16

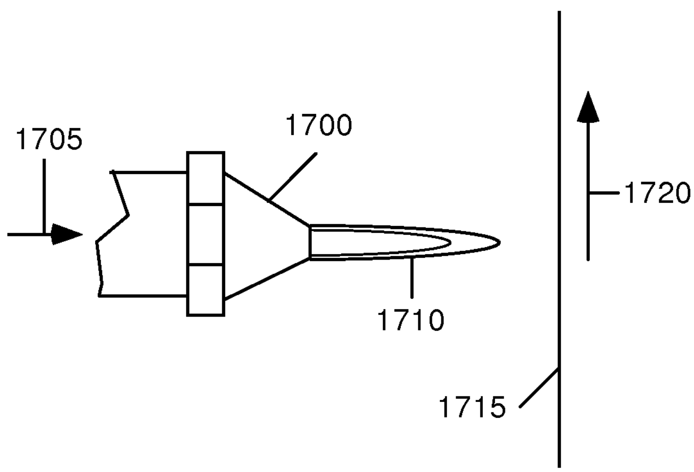

Fig. 17

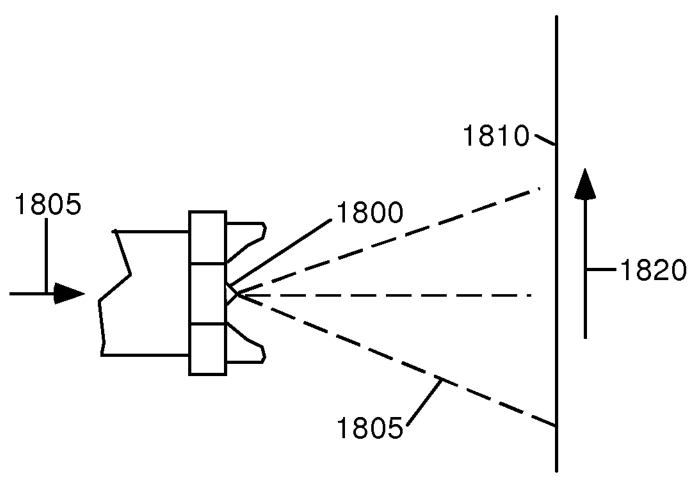

Fig. 18

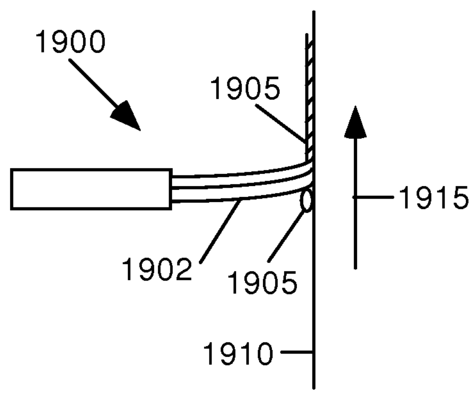

Fig. 19

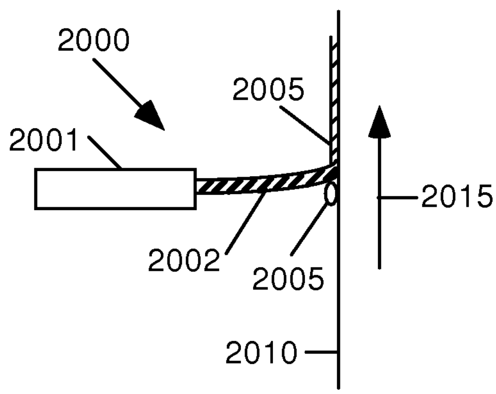

Fig. 20

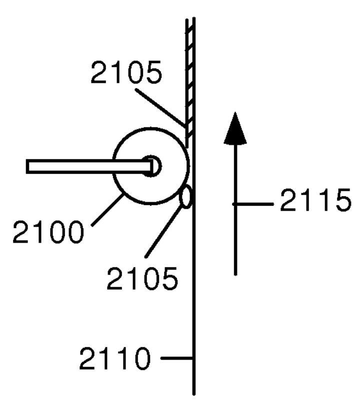

Fig. 21

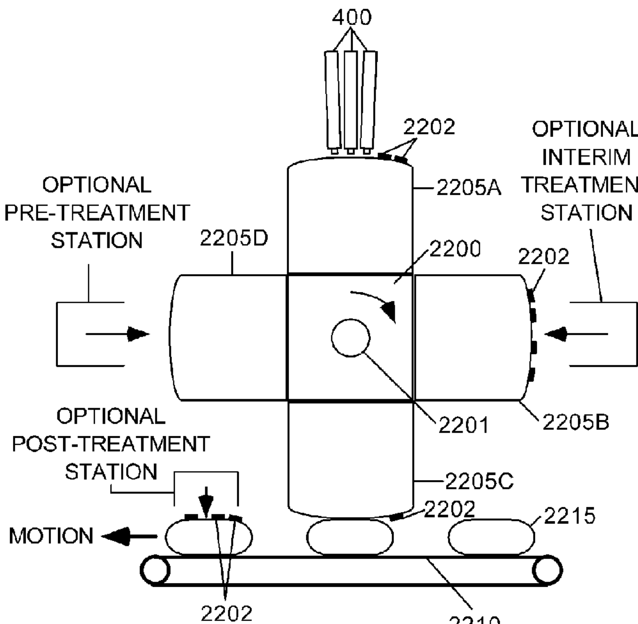

Fig. 22

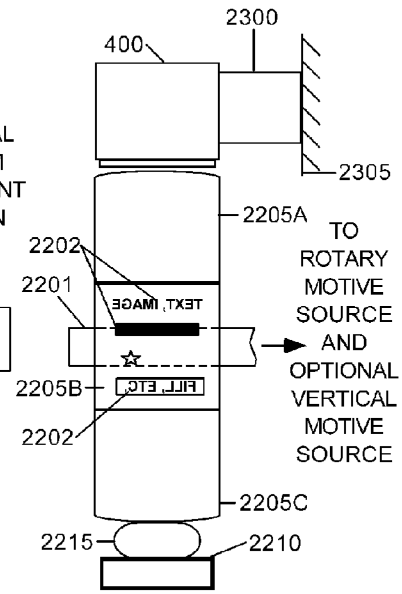

Fig. 23

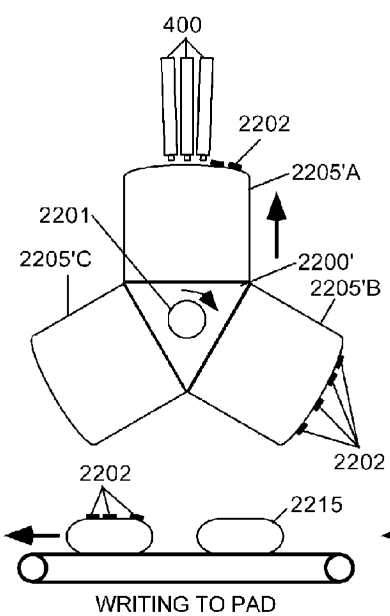

Fig. 24

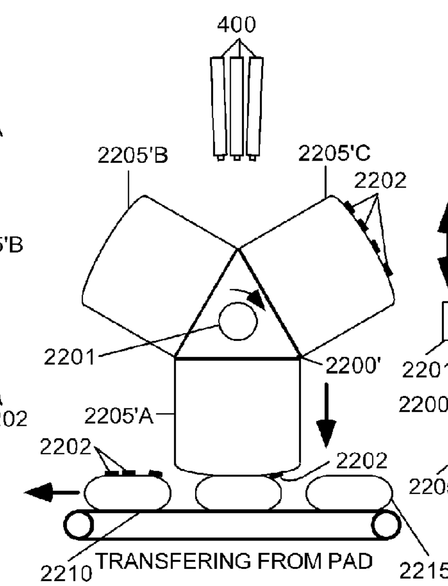

Fig. 25

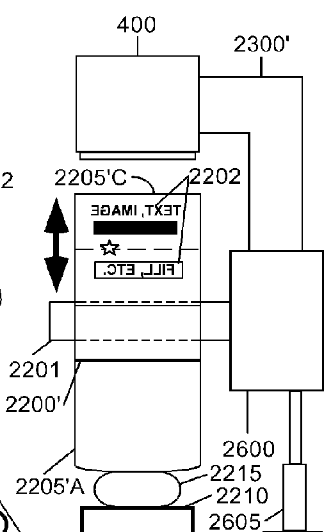

Fig. 26

CONTINUOUSLY UPDATABLE ROTARY PAD PRINTING APPARATUS AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority of our provisional patent application, Ser. No. 60/822,534, filed Aug. 16, 2006. This application is related to and incorporates for reference purposes our U.S. Pat. No. 6,840,167 and our pending U.S. patent application Ser. No. 11,464,203, filed Aug. 13, 2006, Ser. No. 11/558,911, filed Nov. 11, 2006, and Ser. No. 11/697,171, filed Apr. 5, 2007.

BACKGROUND

1. Field

The field is pad printing, and in particular rotary transfer pad printing.

2. Prior Art—FIGS. **1** through **3**

FIGS. **1** and **2** show a prior-art rotary pad printing system. FIG. **3** shows an elliptically-shaped object printed on such a system.

In the past, rotary pad printing has been used to decorate objects by printing images or text thereon. In its simplest form, a rotary pad printing apparatus comprises a rotary cliche ink-image donor roll **100** (FIG. **1**), a compressible rubber transfer pad in the form of a wheel **105** typically formed around a steel shaft **106**, and an ink source **110**. An object to be decorated **115** is arranged to move in contact with wheel **105**.

An image is first etched into rotary cliche **100**, in well-known fashion. In this case, the numbers **1** through **5** are etched in cliche **100** to a depth of approximately 0.03 mm. Although numbers are shown here, the image can comprise text, graphics, and even photographic information.

Next, cliché **100** is placed into the printing apparatus, as shown in FIGS. **1** and **2**. Ink supply **110** is filled with ink prior to printing. When printing commences, cliche **100** and wheel **105** are driven to rotate against one-another by a mechanism (not shown). Directions of motion are indicated by arrows. As cliché **100** turns, ink from source **110** is doctored into the etched surface of cliché **100** by ink source **110**, in well-known fashion.

As cliché **100** turns against wheel **105** (FIG. **2**), image-wise regions of ink **120** are transferred in near-entirety from cliché **100** to wheel **105**. As rotation of cliché **100** and wheel **105** continues, ink regions **120** on wheel **105** are brought into contact with object **115**. Object **115** is moved linearly as wheel **105** rotates. There is no slippage between the surfaces of object **115** and wheel **105**. As ink regions **120** come into contact with object **115**, they leave wheel **105** and most of ink in regions **120** transfers to object **115**. Thus the image originally present on cliché **100** is transferred to object **115**. Instead of using a flat object **115** and moving it linearly, an object with round or ellipsoid cross-section can be rotated against wheel **105** with axes of the object and the wheel parallel. This type of transfer motion is shown below.

Single-color images are transferred in the manner described above. If the user wishes to transfer multi-color images, color separations are required and a separate cliché is required for each color. Making a separate cliché for each color is expensive and time-consuming. Mounting and aligning separate cliché is also time-consuming. The objects to be decorated must be carefully aligned for subsequent passages through the rotary transfer pad printing apparatus. In general, this prior-art arrangement is suitable only for single-color transfers.

Since the image on the cliché is etched, each cliché contains only one image. Changing the image requires etching a new cliché and exchanging the new cliché for the old one. Thus it is impractical to use the prior-art apparatus to print small runs.

Furthermore, since the cliché transfers the etched and inked image to the rotary pad, the length of the image that can be transferred is limited by the circumference of the cliché.

SUMMARY

In accordance with one aspect of a first embodiment, a rotary pad printing apparatus is provided that can print constantly changing images of indefinite length in a plurality of colors. One or more print heads apply an ink image to the rotary pad, the pad transfers the image to a receiving surface, the pad is cleaned if necessary, and a new ink image is applied, ready for a subsequent transfer. In addition, the ink images can be underlaid or overlaid by surface treatments such as varnish, sealers, and other colors. The treatments can be applied using a spray, additional inkjet heads, or a brush, roller, or doctor blade. Substances applied to the rotary pad can be treated, before or after the ink image is applied to the receiving surface, by various methods including, but not limited to radiative processes, vapors, ionizing processes, plasma discharges, and the like.

In accordance with another aspect of the first embodiment, a rotary pad comprises a series of segments that have either fixed or variable shapes.

In accordance with one aspect of a second embodiment, a belt pad printing apparatus is provided. Images, coatings, and treatments are applied to and released from a belt instead of a wheel.

DRAWING FIGURES

FIGS. **1-3** show a prior-art rotary pad printing system.

FIGS. **4** and **5** show plan and schematic cross-sectional side views respectively of one embodiment of a rotary pad printing system using inkjets to apply an image to the pad.

FIG. **6** shows a cross-sectional view of images and coatings applied to a receiving cylinder.

FIG. **7** shows the embodiment of FIGS. **4** and **5** with a traversing head for applying ink images, coatings, and treatments.

FIG. **8** shows the embodiment of FIG. **4** or FIG. **7** incorporating relative motion between the pad wheel and an object.

FIG. **9** shows an embodiment with a curved wheel and apparatus for applying inks, coatings, and treatments to the wheel.

FIGS. **10-15** show embodiments incorporating a belt in place of a wheel surface.

FIGS. **16-21** show details of stations for applying coatings and treatments to a wheel or belt.

FIGS. **22-26** show additional embodiments using individual pads in a rotary apparatus.

DRAWING FIGURE REFERENCE NUMERALS

100	Cliché
105	Wheel

-continued

106	Shaft
110	Ink Source
115	Object
120	Ink Region
400	Station
401	Source
500	Station
501	Source
502	Source
505	Station
510-530	Stations
532	Object
535	Encoder
540	Control Unit
545	Indicia
550	Indicia
555	Detector
560	Detector
565	Image Source
570	Pixel
572	Pixel
574	Overcoat
576	Pixel
578	Overcoat
580	Pixel
582	Overcoat
584	Undercoat
700	Arrow
805	Arrow
900	Surface
905	Inking assembly
910	Head
915	Arm
920	Pivot
925	Servomechanism
930	Clevis
940	Arrow
1000	Belt
1001	Wheel
1002	Wheel
1005	Object
1010	Ram
1015	Arrow
1050	Roller
1100	Roller
1105	Roller
1600	Source
1601	Emission
1602	Emission
1605	Reflector
1610	Surface
1615	Arrow
1700	Tip
1705	Gas
1710	Flame
1715	Surface
1720	Arrow
1800	Nozzle
1805	Material
1810	Surface
1900	Applicator
1902	Bristles
1905	Substance
1910	Surface
1915	Arrow
2000	Blade assembly
2001	Clamp
2002	Blade
2005	Material
2010	Object
2015	Arrow
2100	Roller
2105	Material
2110	Surface
2115	Arrow
2200	Rotor
2201	Shaft
2205	Pad
2210	Conveyor

-continued

2215	Object
2300	Bracket
2600	Motive source
2605	Actuator

DESCRIPTION

First Embodiment—FIGS. 4 and 5

FIGS. **4** and **5** show plan and schematic cross-sectional side views of one aspect of an embodiment of an improved rotary pad printing system. This system comprises one or more ink applicator head stations **400**, a compressible rotary pad wheel **105** formed around an axial metal shaft **106**, a first optional auxiliary applicator head **500** for applying a first substance to pad **105**, a second optional auxiliary applicator head **505** for applying a second substance to pad **105**, and a series of optional treatment stations **510-530**, indicated by bold arrows. The surface of pad **105** is preferably smooth and continuous, although other textured surfaces such as matte, grained, striated, and the like can be used. Stations **510-530** can include spray heads for spraying liquid or powdered substances or vapors onto the surface of pad **105**, applicators of radiant energy such as sonic energy, heat, light including ultraviolet light, x-rays, gamma rays, magnetic fields, electrostatic fields, plasma discharges, and the like. As can be judged by their placement, stations **510-530** can affect the material deposited on, or about to be deposited on, pad **105** in a variety of ways. Preferably station **510** is a cleaning station that cleans pad **105** after each image is transferred to object **532**. Image residue on pad **105** can be removed by contact with blotting paper, adhesive tape, solvent rinse, and the like. At least one of stations **505** and **520-530** is preferably an ultraviolet or infrared source for treating substances applied by applicator head **500**.

Ink applicator head stations **400** are inkjet printers but can be electrostatic, offset, dye-transfer, wax-transfer, spray, or any other kind of printer capable of applying ink or other substances such as varnishes, shellacs, UV-curing coatings, and the like to a surface. The inks dispensed by station **400** can be frit, particle, metallic, magnetic, dye, or pigment-containing, and can be water-based, multi-component, solvent-based, oil-based, wax-based, ultra-violet curable, infra-red-curable, light-curable, heat-curable, cold-curable, catalyst-curable, microwave-curable, and evaporating inks.

Pad **105** typically comprises a silicone rubber of hardness between 5 and 85 durometer (Shore) units. Another elastomer such as gelatin, caoutchouc, latex rubber, synthetic rubber, plastic, or the like with suitable pad-printing properties can be used, if desired. The diameter of pad **105** is typically 15 cm, although smaller or larger diameters are usable. The length of pad **105** is typically 10 cm, although larger and smaller lengths can be used. The length of pad **105** is generally longer than the width of the image to be printed. Pad **105** is arranged to turn against an object to be printed, in this case a bottle or other cylindrical or semi-cylindrical object **532**. A mechanism (not shown) supports cylinder **532** as it rotates against pad **105**.

Pad **105** preferably is electrically insulating, but can be electrically conductive. If pad **105** is electrically conductive, it preferably is connected to a source of electrical potential **401** (FIG. **5**) which in turn is connected to one or more of stations **400**. Connection preferably is made to the surface of pad **105**, but can be to shaft **106**. Source **401** creates an electrical field between station **400** and pad **105** that attracts and guides droplets emitted by source **400** on their path toward pad **105**. Similarly, stations **500**, **505**, **510**, **520**, **525**, and **530** can be connected to electrical sources **501**, **502**, etc. to modify and improve their application of treatments and substances to the surface of pad **105**, or to substances deposited thereon. The electrical output of sources **401**, **501**, and **502** preferably are direct current of either polarity, but can be alternating current, or a combination of the two, and preferably are steady but can be time-varying in both amplitude and frequency.

The length of shaft **106** is longer than the length of pad **105** in order for shaft **106** to be gripped and rotated by activating machinery. Preferably both ends of shaft **106** are gripped or supported by the activating machinery, but if shaft **106** is short (e.g., less than about 15 cm) it can be supported or gripped at one end only.

This aspect of the embodiment further includes a shaft encoder **535**, and a control unit **540**. Control unit **540** is a computing device such as a microprocessor or microcomputer that sends and receives electronic signals to and from external sources and loads. Encoder **535** is coupled to shaft **106** within pad **105**. Encoder **535** reports the angular position of pad **105** to control unit **540**. In response, unit **540** can initiate, sustain, and terminate printing and treatments via stations **400** and **500**.

An image source **565** contains image information required in the printing process, including the image to be printed, the location and density of all coatings, and the kinds and amount of treatments to be applied to pad **105**. Source **565** preferably is a software program, but can be another computer, a hardware storage device, and the like. Source **565** delivers information to control unit **540**.

Further reporting of the position of pad **105** or cylinder **532** preferably is accomplished through indicia such as spots or lines **545** and **550**. Indicia **545** and **550** preferably are a detectable modality such as optical marks, but can be magnetic markers, and the like. These indicia are detected by detectors **555** and **560** which can be arranged to detect the presence of indicia **545** and **550**, whether they are magnetic or optical. Upon detecting the presence of indicia **545** and **550**, detectors **555** and **560** send a signal to control unit **540**, optionally causing unit **540** to take a predetermined action, such as the commencement of the printing of an image, and applications of coatings and treatments. Instead of electrical signals for timing, a mechanical arrangement, such as a switch closure, can be used.

OPERATION

First Embodiment—FIGS. **4-6**

FIG. **5** shows the rotary pad printing station in use. An image and one or more optional coating and treatment scenarios has been created in image source **565**. Upon receiving the printing information from source **565**, control unit **540** awaits a "start" signal from one or both of detectors **555** and **560**. Upon receiving this signal, control unit **540** next depends on shaft encoder **535** to know the angular position of pad **105**, and by calculation, the angular position of receiving object **532**. Encoder **535** preferably is type H3, sold by US Digital, of Vancouver, Wash., USA. This particular encoder is an optical type that delivers as many as 2,500 pulses per revolution of its shaft. Other encoders that have more or fewer pulses per revolution can be used, and use magnetic instead of optical sensing means. Still others report not only incremental rotation, but also give exact angular position.

Unit **540** preferably first activates treatment station **510**. Station **510** preferably provides a cleaning operation that removes residual substances from pad **105** prior to application of the next series of substances, but this activity can be omitted in cases where transfer of substances from pad **105** to object **532** is complete. Alternatively, station **510** is a heater which emits infrared radiation onto the surface of pad **105**, thereby warming it, or it may be a cooling station that applies a cooling gas to pad **105**, thereby cooling it.

After receiving a predetermined number of pulses from encoder **535**, unit **540** next activates station **500**. This station preferably is a spray head that applies a coating to the surface of pad **105**. By counting pulses from encoder **535** and relying on image information from source **565**, controller **540** will cause station **500** to be activated and deactivated according to the angular position of pad **105**. The coating applied by this station preferably is a varnish overcoat for the final image, but can be a paint or other substance.

After receiving an additional predetermined number of pulses from encoder **535**, unit **540** next activates station **505**. Station **505** provides any of the aforementioned treatments to the surface of pad **105** and its contents that may previously been applied by station **500**. Preferably the treatment is radiation, but can be another such as cooling gases, catalysts, and the like.

After receiving another additional predetermined number of pulses from encoder **535**, unit **540** next activates station **400**A. This station is uniquely designed to apply an ink image to the surface of pad **105**, on top of any previously applied substances. Preferably, this station applies the black content of a color-separated image.

After receiving more pulses from encoder **535**, unit **540** next activates station **400**B. Station **400**B preferably is arranged to apply the cyan component of a color-separated image to the surface of pad **105** and its previously-applied contents, but other colors can be used.

As the rotation of shaft **106** continues, additional pulses cause the activation of station **520**. This station is included between ink applications and preferably is used to harden previously-applied layers of ink by applying ultraviolet or infrared radiation to them. Alternatively, station **520** can apply a gas reactant or catalyst to previously applied layers.

After receiving more pulses from encoder **535**, unit **540** activates station **400**C. Station **400**C preferably is arranged to apply the magenta component of a color-separated image, but also can be another color.

After receiving still more pulses from encoder **535**, unit **540** activates station **400**D. Station **400**D preferably is arranged to apply the yellow component of a color-separated image, but also can be another color.

Next, after receiving more pulses from encoder **535**, unit **540** activates station **525**, causing it to apply any pre-arranged treatment to the surface contents of pad **105**. This treatment preferably is ultraviolet radiation, but can be magnetic, heating, cooling, and coating.

After receiving additional pulses from encoder **535**, control unit **540** next activates station **527**. Station **527** preferably is a spray head for applying an overcoat to the layers previously applied to pad **105**, but can also apply a powder layer or other substance.

After receiving still more pulses from encoder **535**, control unit **540** next activates station **530**. Station **530** preferably is arranged to apply a heating treatment to the previously applied contents on the surface of pad **105**, but also can apply any of the other aforementioned types.

Alternatively, instead of activating stations **400** and **500** in response to pulses from encoder **535**, control unit **540** can operate on an open-loop basis. Upon receiving a starting signal from one or more of sensors **550** and **560**, unit **540** can activate sources **400** and **500** at predetermined intervals determined by the rotational or surface speed of pad **105**. Shaft encoder **535** can report the rotational speed of pad **105** to unit **540**. Unit **540** can calculate the surface speed of pad **105**, if required, based on the radius of pad **105**, in well-known fashion.

The individual pixels to be transferred to object **532** can comprise a variety of types. Preferably, as pad **105** rotates in contact with object **532**, ink pixel **570** will be transferred to object **532** as-is with no undercoat or overcoat. Ink pixel **572** is accompanied by an overcoat **574**. When this pixel combination is transferred to object **532**, pixel **572** will be transferred with layer **574** as an undercoat. After transfer, pixel **576** will be accompanied with an overcoat layer **578**. After transfer, pixel **580** will be accompanied by an undercoat **584** and an overcoat **582**. There are numerous other possibilities.

Although there are four color stations **400**A-**400**D, more or fewer can be used as required by the printing operation at hand. Similarly more or fewer coating and treating stations can be used.

In some cases, receiving cylinder **532** is removed from contact with pad **105** and pad **105** is allowed to rotate two or more times while application of treatments and coatings continues before transfer. After such extra applications, cylinder **532** is again brought into contact with pad **105** for transfer of all layers to cylinder **532**.

Each of the stations is activated and deactivated by control unit **540** on a line-by-line basis. Some or all of ink applicators **400**A-**400**D and treatment stations **500-530**, are additionally activated on a pixel-by-pixel basis along the active line or lines. All applications are under the control of control unit **540**.

One or more of treatment stations, preferably station **530**, can apply a catalyst, moisture, heat, cold, or illumination to substances such as ink pixels and coatings **570-584**, in order to cause them to cure or partially cure while on pad **105**. This can be done to improve transfer to object **532**, and to improve image quality by preventing movement of pixels and coatings during transfer.

Instead of using encoder **535**, control unit **530** can alternatively supply image and treatment commands at a rate predetermined by an internal clock (not shown).

FIGS. **4** and **6** show the appearance of object **532** after transfer of a complete image.

DESCRIPTION AND OPERATION

Individual Components—FIGS. **4-6**

Stations **505**, **510**, **520**, **525**, and **530** are treatment stations. Preferably they apply coatings through the use of a spray head or a vapor-deposition applicator. They cause cooling gases to flow against the surface of pad **105** or whatever has been previously deposited thereon. Station **510**, in particular, can be a cleaning station that applies anything from a volatile solvent to adhesive tape to the surface of pad **105** in order to clean it in preparation for the next image and coatings transfer. A station can also apply a magnetic field to cause magnetic inks to stand erect from the surface of pad **105**. Alternatively, a station can apply an electric field to cause inks to stand erect from the surface of pad **105**. Stations can apply radiative energy such as ultraviolet or infrared radiation, or even gamma rays or x-rays. Stations can also optionally apply a flow of gas such as air or an inert or reactive gas to pad **105** and its contents.

Stations **400**A-**400**D preferably are inkjet heads provided with a source of ink, or they can be transfer stations for images printed on an external apparatus such as a xerographic printer, an inkjet printer, or other printing modality.

Alternative Embodiment—FIG. **7**

As shown in FIG. **7**, one or more of print heads **400**A-**400**D and stations **500-530** may extend over less than the full axial length of pad **105**. In this case, one or more of heads **400**A-**400**D and stations **500-530** can be arranged to traverse part or all of the length of pad **105**, as indicated by arrows **700**A and **700**B.

Alternative Embodiment—FIG. **8**

As shown in FIG. **8**, instead of printing on a cylindrical object that rotates, pad **105** and one or more of heads **400**A-**400**D and stations **500-530** can be arranged to move toward or away from the receiving surface. In FIG. **8**, pad **105**, heads **400**A-**400**D, and stations **500-530** are arranged to move up and down together, in the direction indicated by arrows **800**. Object **570'** moves from right to left, as indicated by arrow **805**. Object **570'** moves in synchrony with pad **105** so that there is no slippage between their contacting surfaces as object **570'** moves in contact with pad **105**. If the two surfaces were allowed to slide past one-another, the image being transferred from pad **105** to object **570'** would smear.

Although vertical motion of pad **105** is indicated, any angular motion that provides the proper contact with object **570'** can be used.

Instead of pad **105** and one or more of heads and stations **400**A-**400**D and **500-530** moving toward object **532**, the heads and stations can remain stationary and object **532** can be brought into contact with pad **105** by raising it, or simply maintaining object **532** at a fixed distance from pad **105** so that it presses against pad **105** as it moves by.

Alternative Embodiment—FIG. **9**

In the embodiment shown in FIG. **9**, pad **105'** has a convex, contoured surface **900**. Pad **105'** rotates on shaft **106**, as described above in connection with FIG. **5**. An inking assembly **905** is arranged to apply an ink image to pad **105'** as pad **105'** rotates. Assembly **905** includes an applicator head **910**, such as but not limited to an inkjet head. Head **910** preferably also incorporates treatment and coating stations such as **500-530**, described above.

In many cases, head **910** must operate at a nearly constant distance from surface **900** of pad **105'**. This is accomplished in this embodiment by a lever arm **915**, a pivot **920**, and a servomechanism **925**. Assembly **905** is attached to one end of arm **915**. At the other end of arm **915**, a clevis **930** attaches arm **915** to a servomechanism **925**.

Servomechanism **925**, head assembly **905**, and head **910** are all under the control of a control unit (not shown in this figure), as described above in connection with FIG. **5**. As pad **105'** rotates, servomechanism **925** moves clevis **930** in a left-right motion, as indicated by arrows **935**. This motion translates to rotational motion of head assembly **905**, as indicated by arrows **940**. The location of pivot **920** is chosen so that head **910** remains at a constant, predetermined distance from surface **900** of pad **105'**. Pad **105'** may execute more than one revolution, if required, prior to being brought into contact with a receiving surface (not shown in this figure) for transfer of the ink image.

Instead of moving head **910** in an arc around the surface of pad **105'**, the axis of pad **105'** can be made to oscillate in an equivalent way so that head **910** remains at a fixed distance from the surface of pad **105'**.

Alternative Embodiments—FIGS. **10-15**

FIGS. **10-15** show an alternative embodiment using a belt for transfer, instead of the surface of a wheel. Instead of being formed on and primarily supported by a central core or shaft **106** (FIG. **5**), the pad comprising belt **1000** is supported primarily by two shafts **1001** and **1002**. Pad belt **1000** is free to rotate around shafts **1001** and **1002**. This system comprises a control unit (not shown), heads **400**A-**400**D, stations **500**-**530**, two wheels, pulleys, or rollers **1001** and **1002**, an object to be printed **1005**, an optional ram **1010**, and optional rollers **1100** and **1105**.

Belt **1000** is made of a flexible silicone rubber or other material suitable for use in pad printing. It may be strengthened by an internal webbing made of cotton, plastic, or metal (not shown). In its thick aspect (FIGS. **10-12**), belt **1000** preferably is 1 cm thick, but can be thicker or thinner. In its thin aspect (FIGS. **13-15**), belt **1000** is approximately 1 mm thick, although other thicknesses can be used. Belt **1000** preferably is 15 cm wide, but can range from 0.5 to 25 cm in width, although even wider widths can be used.

Belt **1000** is driven by one or both of wheels **1001** and **1002**. The lengths of pulleys **1001** and **1002** are greater than or equal to the width of belt **1000**. One or both of pulleys **1001** and **1002** can be crown rollers in order to cause belt **1000** to remain centered on the pulleys, in well-known fashion to those skilled in the design of moving belts.

Instead of heads **400**A-**400**D and stations **500-530** being located at the top of belts **1000**, some or all of them can be located at the circumference of belt **1000** on wheel **1001** or **1002**, as shown in FIG. **5**.

With reference to FIGS. **10-15**, belt **1000** traverses beneath heads **400A-400**D and stations **500-530**, collecting depositions and treatments of inks and coatings in preparation for transfer to object **1005**, as described above in connection with FIG. **5**.

In FIGS. **10** and **13**, transfer of the ink image (not shown) is made to object **1005** by simple contact with belt **1000**. Object **1005** is caused to move from right to left with the speed of belt **1000** in order to prevent smearing of the ink image on object **1005**. Optional rollers **1050** prevent the displacement of belt **1000** by object **1005** and improve contact between the two during transfer of the ink image.

In FIGS. **11-12**, and **14-15**, a ram **1010** moves up and down as indicated by arrows **1015** in order to transfer the previously deposited ink image from belt **1000** to object **1005**. Belt **1000** is normally stopped during operation of ram **1010**.

In FIGS. **10-15**, the motion of belt **1000** can be continuous or intermittent, depending upon the requirements of the individual printing job.

Treatment Stations—FIGS. **16-21**

Treatment stations **500-530** preferably apply radiative emissions, but can comprise at least one of the following capabilities: radiative emission such as infrared, visible, and ultraviolet light, x-rays, radio waves, microwaves, plasma, and gamma rays; vapor emission, such as steam, hot air, chemical vapors such as solvent vapors or catalysts, and the like; spray emission such as coatings, adhesives, catalysts, and the like; flame emission; and other modalities such as infrasound (very low frequencies), audible sound, and ultrasound (very high frequencies).

An exemplary radiative emission station is shown in FIG. **16**. A source **1600** radiates emissions **1601** and **1602** in a plurality of directions. A wheel or belt surface **1610** receives the emissions. Although surface **1610** is depicted as flat, it can be curved or irregular. Emissions **1601** strike and are reflected by an optional reflector **1605**, preferably a parabolic reflector, although other shapes can be used. Emissions **1602** impinge directly onto surface **1610**. The emissions of source **1600** are delivered to surface **1610** and the substances thereon (inks, coatings, and the like) and preferably cause them to harden, but alternatively can cause them to soften, melt, evaporate, change color, or otherwise change its composition, appearance, or structure. Arrow **1615** indicates optional relative motion between surface **1610** and source **1600**.

Source **1610** preferably is an ultraviolet lamp, but alternatively can comprise one or more light-emitting diodes (LED), gas-discharge lamps, heating coils, x-ray source, microwave source, gamma ray source, sound source, and the like.

An preferred flame source for treating substances applied to the surface of an object **1715** is shown in FIG. **17**. A torch tip **1700** is supplied with gas indicated by arrow **1705** from a source (not shown). Gas **1705** preferably is a single or multi-component combustible agent. Gas **1705** is ignited to form a flame **1710**. Flame **1710** either contacts or comes into proximity with surface **1715**. The heat, and in some cases the chemical composition within flame **1710**, cause a change in the substances borne on surface **1715**, and surface **1715** itself, if desired. Arrow **1720** indicates optional relative motion between surface **1715** and flame **1710**.

FIG. **18** shows a spray source with a nozzle **1800** and a source **1805** of material to be sprayed. An ink image and one or more optional coatings have been or may soon be applied to a surface **1810**. Material **1805** is emitted as a spray of fine droplets or vapor by nozzle **1800**. Droplets or vapor **1805** apply a coating or vapor treatment to surface **1810** and any substances thereon or about to be applied thereon. Material **1805** can also be a release agent to facilitate release of all subsequently-applied layers from surface **1810** to the surface of the receiving object (not shown).

FIG. **19** shows a brush applicator **1900** with bristles **1902** applying a substance **1905** to belt or wheel surface **1910**. Surface **1910** moves with respect to brush **1900** as indicated by arrow **1915**. Bristles **1902** preferably are bristle, but alternatively can be any suitable material, including a plastic, animal hair, or plant fibers. In another aspect, brush **1900'** can be an anti-static brush. In this case, a large number of metal wires replace the bristles. These wires can either touch surface **1910**, or be placed very near to it. In either case, if the bristles and surface **1910** are held at the same potential, all static electricity will be discharged from surface **1910** in well-known fashion.

FIG. **20** shows the use of a doctor blade to meter a substance onto the surface of a receiving object. A doctor blade assembly **2000** comprises a clamp **2001** and a blade **2002**. Blade **2002** is typically made of a flexible urethane rubber of durometer (Shore) hardness value between 5 and 85. A coating material **2005** is supplied to the lower side of blade **2002** from a source (not shown). Material **2005** is smoothed out into a layer as object **2010** moves with respect to blade **2002**. The direction of motion is indicated by arrow **2015**.

FIG. **21** shows the use of an applicator roller to apply a substance to the surface of a receiving object. A roller **2100** is held in contact with receiving surface **2110** and any other substances which have been applied to surface **2110**. Surface **2110** moves with respect to roller **2100**, as indicated by arrow **2115**. A source (not shown) supplies coating material **2105** to the lower side of roller **2100**. As surface **2110** moves with respect to roller **2100**, a uniform thickness of material **2105** is deposited on surface **2110**. Roller **2100** preferably is a silicone rubber with durometer hardness values between 5 and 85.

The treatments shown in FIGS. **16-21** preferably are applied to the belt or wheel surfaces individually, but can be applied simultaneously or serially.

Alternative Embodiments—Segmented Pads—FIGS. **22-26**

FIGS. **22-26** show an aspect of the previous embodiments that employs segmented, revolving pads, with individual circularly arcuate surfaces replacing portions of a roller, as shown instead of continuous rollers or belts. In FIGS. **22** and

23, a rotor **2200** is mounted on a shaft **2201**. One or more pads **2205** are affixed to rotor **2200**. Ink applicators **400** are fixed in space by a bracket **2300** (FIG. **23**) secured to a datum **2305**, and are positioned above pad **2205**A. In response to signals from a control unit (not shown) applicators **400** apply an ink image **2202** to each of pads **2205** as shaft **2201** rotates in a continuous fashion, moving pads **2205** sequentially beneath them. As in the previous embodiments, a series of treatment stations are positioned to apply pre-treatments, interim treatments, and post-treatments to pads **2205** and substances that have been deposited thereon. Pre-treatment can include cleaning pad **2205** in preparation for its next use.

A conveyor **2210** moves in synchronism with pads **2205** as shaft **2201** rotates. Conveyor **2210** is positioned so that objects **2215** will come into contact with pads **2205** as they move from right to left. As objects **2215** come into contact with pads **2205**, image **2202** is transferred from pads **2205** to objects **2215**. An optional post-treatment step, preferably an overcoat, but alternatively UV exposure, etc. completes printing of objects **2215**.

FIGS. **24** through **26** show another aspect of the above embodiment. FIGS. **24** and **25** show front views of a printing assembly according to this aspect at two different times. FIG. **26** shows a side view of the printing assembly at the same time as in FIG. **25**. A rotary motive source (FIG. **26**) **2600** causes shaft **2201** to rotate under the control of a control unit (not shown). A vertical motive force actuator **2605**, preferably a hydraulic or pneumatic ram actuator, causes motive source **2600**, bracket **2300'**, applicators **400**, and shaft **2201** to move vertically, again under control of a control unit (not shown).

FIG. **24** shows a pad **2205'**A in a position to receive an ink image **2202** as it rotates beneath image applicators **400**. As shaft **2201** rotates, the top surface of pad **2205'**, mounted on rotor **2200'**, passes beneath applicators **400** and receives an ink image **2202**. Shaft **2201**continues to rotate until one of pads **2205'**, containing an ink image **2202**, is positioned above a receiving object **2215**. Instead of rotating continuously, shaft **2201** rotates intermittently. When pad **2205'** is located above an object **2215**, the controller causes shaft **2201** to stop rotating. Next, actuator **2605** (FIG. **26**) lowers rotor **2200'** and pad **2205'** so that pad **2205'** comes into contact with object **2215** directly beneath in a stamping action, thereby transferring ink image **2202** to object **2215**. In this embodiment, conveyor **2210** moves in a start-stop fashion. Each object **2215** to be printed is moved to a position beneath shaft **2201** and one of pads **2205'** and then held at that position while ink image **2202** is transferred from pad **2205'** to object **2215** with a stamping motion.

Although objects **2215** are shown moving on conveyor **2210**, they can instead be held in place beneath shaft **2201** and one of pads **2205'** when pad **2205'** is oriented as shown in FIG. **25**. Although three or four pads are shown, more or fewer pads can be used. Pads **2205** can be of a custom design, or they can be standard pads available for use in prior-art, non-rotary, pad printing systems. Instead of raising and lowering source **2600**, bracket **2300'** and sources **400**, actuator **2605** can raise and lower conveyor **2210** or individual objects **2215** to effect transfer of image portions **2202** to objects **2215** through a stamping action.

CONCLUSIONS, RAMIFICATIONS, AND SCOPE

The embodiments shown of our improved pad printing method and apparatus incorporate an inking station and a flexible, moving surface. An inking head, such as an inkjet, applies an ink image to the moving surface. The ink image on the surface is further optionally treated by one or more stations comprising emissive and radiative sources, spray sources, vapor sources, and the like. These sources provide overcoats, undercoats, additional chemical reactants and catalysts, additional ink colors, heat, infrared, visible, and ultraviolet light, and flames.

While the above description contains many specificities, these should not be considered limiting but merely exemplary. Many variations and ramifications are possible. While preferred materials, sizes, treatments, and the like have been indicated, these are merely the currently preferred parameters for one or more applications and obviously will change for other applications and at other times. For example, pads may be soft or firm and may be made of a variety of materials such as plastics, silicone rubbers, gelatin, caoutchouc, and the like. Many or few treatment stations and ink sources can be used.

Inkjet heads must typically be kept a distance of about one millimeter from the surface that receives the ink. A positioning servomechanism with sensors that sense the distance between the inkjet head and the pad surface can be used to maintain the proper distance between the inkjet head and the pad surface as the pad rotates.

While the present system employs elements which are well known to those skilled in the art of pad printing, it combines these elements in a novel way which produces one or more new results not heretofore discovered. Accordingly the scope of this invention should be determined, not by the embodiments illustrated, but by the appended claims and their legal equivalents.

The invention claimed is:

1. A pad printing system for printing onto a receiving surface, comprising:

(a) a rotatable shaft having an axis,

(b) a plurality of resilient pads secured to said rotatable shaft, each of said plurality of resilient pads having an arcuate ink-receiving-and-releasing surface, said arcuate ink-receiving-and-releasing surface having an axis that is coaxial with said axis of said rotatable shaft,

(c) a first motive source for rotating said shaft,

(d) an ink source containing ink of at least one color,

(e) an image source that supplies at least one reverse-reading image,

(f) at least one ink-applicator means extending parallel to said axis of said shaft and spaced a predetermined distance from said axis of said shaft, said applicator means being connected to said image source and supplied with said ink from said ink source and arranged to print said reverse-reading image with said ink directly and without use of an intermediate release surface onto said surface of at least one of said pads while said shaft rotates,

(g) a second motive source arranged to urge said receiving surface and said surface of said at least one of said pads into stamping contact at a predetermined time,

(h) a control unit where said control unit causes:

(1) said first motive source to cause said shaft to rotate,

(2) said ink applicator means to print said reverse-reading ink image directly onto said surface of said one pad while said pad rotates beneath said ink-applicator means,

(3) said first motive source to rotate said one pad over said receiving surface and stop with said one pad positioned over said receiving surface, and

(4) at said predetermined time, said second motive source to urge said one pad into stamping contact with said receiving surface while said first motive source is stopped so that said reverse-reading ink image is transferred by stamping onto said receiving surface as a right-reading ink image,

whereby said reverse-reading ink image is printed with said ink onto said one of said pads while said one of said pads rotates, and then rotation of said one of said pads is stopped and said one of said pads is urged into stamping contact with said receiving surface while said one of said pads is stopped in order to transfer said reverse-reading ink image from said one of said pads onto said receiving surface as said right-reading ink image, thereby printing said right-reading ink image onto said receiving surface while improving reliability by requiring few parts and eliminating degradation of said right-reading ink image by using only a single transfer of said ink from said pad to said receiving surface.

2. The system of claim **1**, wherein said ink is selected from the group consisting of frit, particle, metallic, magnetic, dye, pigment-containing, ultraviolet-curable, infrared-curable, light-curable, heat-curable, cold-curable, catalyst-curable, microwave-curable, water-based, wax-based, solvent-based, oil-based, and multi-component and evaporating inks.

3. The system of claim **1**, wherein said ink applicator is selected from the group consisting of offset, dye transfer, wax transfer, inkjet, spray, and electrostatic applicators.

4. The system of claim **1**, wherein said pads comprise a material selected from the group consisting of gelatin, caoutchouc, latex rubber, synthetic rubber, silicone rubber, and plastic materials.

5. The system of claim **1** wherein said surface of said pad is selected from the group consisting of smooth and textured surfaces.

6. The system of claim **1**, wherein said first and said second motive sources are selected from the group consisting of electrical, pneumatic, magnetic, and hydraulic sources.

7. The system of claim **1**, wherein said ink can be cured by a treatment selected from the group consisting of liquid sprays, powder sprays, vapors, sonic energy, heat, light including ultraviolet light, x-rays, gamma rays, magnetic fields, electrostatic fields, and plasma discharges.

8. The system of claim **1**, further including at least one treatment applicator responsive to said commands issued by said control unit and capable of applying at least one treatment selected from the group consisting of liquid spray, powder spray, vapor, sonic energy, heat, light including ultraviolet light, x-ray, gamma ray, magnetic field, electrostatic field, and plasma discharge applicators.

9. The system of claim **1**, wherein the material comprising said pad is selected from the group consisting of insulative and conductive materials.

10. The system of claim **1**, further including at least one source of electrical potential connected between said pad and said ink applicator means.

11. A method for pad printing an image onto a receiving surface, comprising:

(a) providing a rotatable shaft having an axis,

(b) providing a plurality of resilient pads secured to said rotatable shaft, each of said plurality of resilient pads having an arcuate ink-receiving-and-releasing surface, said arcuate ink-receiving-and-releasing surface having an axis that is coaxial with said axis of said rotatable shaft,

(c) providing a first motive source for rotating said shaft,

(d) providing an ink source containing ink of at least one color,

(e) providing an image source that supplies at least one reverse-reading image,

(f) providing at least one ink-applicator means extending parallel to said axis of said shaft and spaced a predetermined distance from said axis of said shaft, said applicator means being connected to said image source and supplied with said ink from said ink source and arranged to print said reverse-reading image with said ink directly onto said surface of at least one of said pads while said shaft rotates and without use of an intermediate release surface,

(g) providing a second motive source arranged to urge said receiving surface and said surface of said at least one of said pads into stamping contact at a predetermined time,

(h) providing a control unit where said control unit causes:

(1) said first motive source to cause said shaft to rotate,

(2) said ink applicator means to print said reverse-reading ink image directly onto said surface of said one pad while said pad rotates beneath said ink-applicator means,

(3) said first motive source to rotate said one pad over said receiving surface and stop with said one pad positioned over said receiving surface, and

(4) at said predetermined time, said second motive source to urge said one pad into stamping contact with said receiving surface while said first motive source is stopped so that said reverse-reading ink image is transferred by stamping onto said receiving surface as a right-reading ink image,

whereby said reverse-reading ink image is printed with said ink onto said one of said pads while said one of said pads rotates, and then rotation of said one of said pads is stopped and said one of said pads is urged into stamping contact with said receiving surface while said one of said pads is stopped in order to transfer said reverse-reading ink image from said one of said pads onto said receiving surface as said right-reading ink image, thereby printing said right-reading ink image onto said receiving surface while improving reliability by requiring few parts and eliminating degradation of said right-reading ink image by using only a single transfer of said ink from said pad to said receiving surface.

12. The method of claim **11**, wherein said first and said second motive sources are selected from the group consisting of electrical, pneumatic, magnetic, and hydraulic sources.

13. The method of claim **11** wherein said ink is selected from the group consisting of water based, wax-based, solvent-based, oil-based, and multi-component inks and coating materials.

14. The method of claim **11**, wherein said ink applicator is selected from the group consisting of offset, dye transfer, wax transfer, inkjet, spray, and electrostatic applicators.

15. The method of claim **11**, wherein said pads comprise materials selected from the group consisting of gelatin, caoutchouc, latex rubber, synthetic rubber, silicone rubber, and plastic materials.

16. The method of claim **11**, wherein said surface of said pads is selected from the group consisting of smooth and textured surfaces.

17. The method of claim **11** wherein the material comprising said pad is selected from the group consisting of insulative and conductive materials.

18. The method of claim **11**, further including at least one source of electrical potential connected between said at least one of said pads and said ink applicator.

19. The method of claim **11**, further including a plurality of said ink applicators.

20. The method of claim **11**, further including at least one ink applicator arranged to apply at least one treatment to said pad, said treatment selected from the group consisting of liquid sprays, powder sprays, vapors, sonic energy, heat, light including ultraviolet light, x-rays, gamma rays, magnetic fields, electrostatic fields, and plasma discharges in response to said commands issued by said control unit.

21. The method of claim **11**, wherein said receiving surface is selected from the group consisting of flat, curved, and irregular surfaces.

22. A pad printing system for printing a right-reading ink image onto a receiving surface, comprising:

(a) a plurality of non-contiguous, resilient pads, each pad having a circularly arcuate surface having an axis of curvature and arranged to directly receive and temporarily retain a reverse-reading copy of said ink image, each of said pads rigidly secured to a rotatable shaft having the same axis as said pads,

(b) a control unit for issuing commands for operation of said system,

(c) an actuable first motive source for rotating said shaft,

(d) a second motive source for urging said surface of at least one of said plurality of resilient pads into stamping contact with said receiving surface while said first motive source is inactivated,

(e) an image source containing at least one original image that has been separated into a plurality of reverse-reading images comprising a plurality of respective color components of said original image,

(f) said first and said second motive sources and said image source being responsive to commands from said control unit,

(g) a plurality of ink applicators, each of said ink applicators being connected to an ink source, each of said ink sources being arranged to supply ink of the same color as said respective color components of said original right-reading image, each of said ink applicators being an equal distance from said shaft,

(h) each of said ink applicators being responsive to said commands from said control unit for applying said color component portion of said original image directly, without use of an intermediate release surface, from said ink applicator onto said surface of said pad in registration with said original image while said first motive source is actuated and said shaft rotates,

whereby, when urged by said commands from said control unit, said color components of said image are applied as said reverse-reading images to said pad while said pad rotates, and then said pad is stopped and urged into stamping contact with said receiving surface, thereby simultaneously transferring all of said color components of said image in registration as a right-reading image onto said receiving surface at the same time while obviating the need for an intermediate release surface.

23. The system of claim **22**, wherein said ink applicator means are selected from the group consisting of offset, dye transfer, wax transfer, inkjet, spray, and electrostatic applicators.

24. The system of claim **22**, further including at least one treatment applicator responsive to said commands issued by said control unit and capable of applying at least one treatment selected from the group consisting of liquid spray, powder spray, vapor, sonic energy, heat, light including ultraviolet light, x-ray, gamma ray, magnetic field, electrostatic field, and plasma discharge applicators.

25. The system of claim **22**, wherein at least one of said inks can be cured by a treatment selected from the group consisting of liquid sprays, powder sprays, vapors, sonic energy, heat, light including ultraviolet light, x-rays, gamma rays, magnetic fields, electrostatic fields, and plasma discharges.

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