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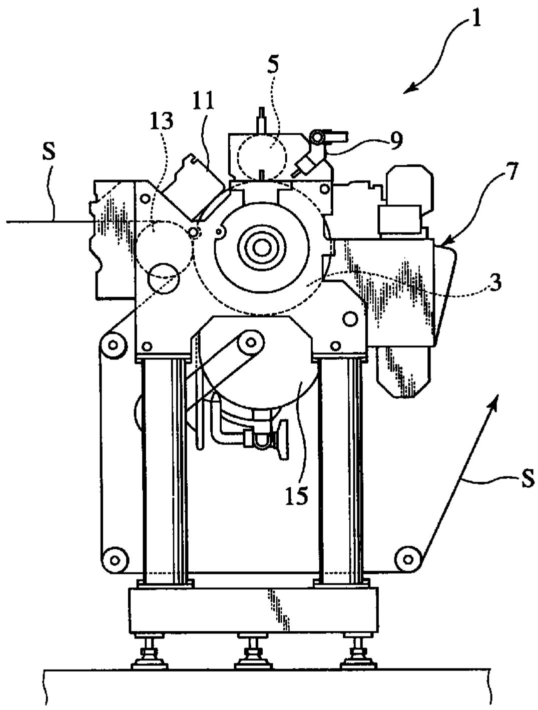
(54) Positive electrode for electrocoagulation printing

(57) A positive electrode for an electrocoagulation printing made of an iron alloy consisting essentially of at least 20 wt.% Cr, 5 to 15 wt.% Ni, 1 to 2 wt.% Si, 0.9 to 1.5 wt.% Mn and 0.1 to 0.3 wt.% C with the balance consisting of iron and unavoidable impurities is used for reproducing an image by electrocoagulation of a ink. Such a positive electrode can be thoroughly cleaned without undergoing abrasion and/or pitting during cleaning. The alloy composition does not adversely affect passivation.

FIG.1



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Description

TECHINICAL FIELD

[0001] The present invention pertains to improvements in the field of electrocoagulation printing. More particularly, the invention relates to an improved anode for use in an electrocoagulation printing method and apparatus.

BACKGROUND ART

[0002] US Patent N° 4,895,629 of January 23, 1990, has disclosed a high-speed electrocoagulation printing method and apparatus in which use is made of a positive electrode in the form of a revolving cylinder having a passivated surface onto which dots of colored, coagulated ink representative of an image are produced. These dots of colored, coagulated ink are thereafter contacted with a substrate such as paper to cause transfer of the colored, coagulated ink onto the substrate and thereby imprint the substrate with the image. As explained in this patent, the positive electrode is coated with a dispersion containing an olefinic substance and a metal oxide prior to electrical energization of the negative electrodes in order to weaken the adherence of the dots of coagulated ink to the positive electrode and also to prevent an uncontrolled corrosion of the positive electrode. In addition, gas generated as a result of electrolysis upon energizing the negative electrodes is consumed by reaction with the olefinic substance so that there is no gas accumulation between the negative and positive electrodes.

[0003] The electrocoagulation printing ink which is injected into the gap defined between the positive and negative electrodes consists essentially of a liquid colloidal dispersion containing an electrolytically coagulable polymer, a dispersing medium, a soluble electrolyte and a coloring agent. Where the coloring agent used is a pigment, a dispersing agent is added for uniformly dispersing the pigment into the ink. After coagulation of the ink, any remaining non-coagulated ink is removed from the surface of the positive electrode, for example, by scraping the surface with a soft rubber squeegee, so as to fully uncover the colored, coagulated ink which is thereafter transferred onto the substrate. The surface of the positive electrode is thereafter cleaned by means of a plurality of rotating brushes and a cleaning liquid to remove any residual coagulated ink adhered to the surface of the positive electrode.

[0004] When a polychromic image is desired, the negative and positive electrodes, the positive electrode coating device, ink injector, rubber squeegee and positive electrode cleaning device are arranged to define a printing unit and several printing units each using a coloring agent of different color are disposed in tandem relation to produce several differently colored images of coagulated ink which are transferred at respective transfer stations onto the substrate in superimposed relation to provide the desired polychromic image. Alternatively, the printing units can be arranged around a single roller adapted to bring the substrate into contact with the dots of colored, coagulated ink produced by each printing unit, and the substrate which is in the form of a continuous web is partially wrapped around the roller and passed through the respective transfer stations for being imprinted with the differently colored images in superimposed relation.

[0005] The positive electrode which is used for electrocoagulation printing must be made of an electrolytically inert metal capable of releasing trivalent ions so that upon electrical energization of the negative electrodes, dissolution of the passive oxide film on such an electrode generates trivalent ions which then initiate coagulation of the ink. Examples of suitable electrolytically inert metals include stainless steels, aluminium and tin.

[0006] As explained in Canadian patent No. 2,138,190 of October 13, 1998, a breakdown of passive oxide films occurs in the presence of electrolyte anions, such as Cl^-, Br^- and I^-, there being a gradual oxygen displacement from the passive film by the halide anions and a displacement of absorbed oxygen from the metal surface by the halide anions. The velocity of passive film breakdown, once started, increases explosively in the presence of an applied electric field. There is thus formation of a soluble metal halide at the metal surface. In other words, a local dissolution of the passive oxide film occurs at the breakdown sites, which releases metal ions into the electrolyte solution. Where a positive electrode made of stainless steel or aluminium is utilized, dissolution of the passive oxide film on such an electrode generates Fe^{3+} or Al^{3+} ions. These trivalent ions then initiate coagulation of the ink.

[0007] Stainless steels are preferred due to their low cost and availability. These are iron alloys containing a minimum of approximately 11 wt.% chromium. This amount of chromium prevents the formation of rust in unpolluted atmospheres. Their corrosion resistance is provided by the aforesaid passive oxide film which is self-healing in a wide variety of environments.

[0008] The stainless steels hitherto used consisted of 12 to 20 wt.% Cr, 3 to 10 wt.% Ni, 0.5 to 2.5 wt.% Mo and 0.03 to 0.09 wt.% C, with the balance consisting of iron and unavoidable impurities. Although such alloys give satisfactory results in respect of electrocoagulation, the inventor has observed that they do not have a hardness sufficient to withstand the harsh conditions encountered during cleaning of the positive electrode, resulting in abrasion and pitting of such an electrode. It is therefore necessary to regrind the surface of the electrode after every forty hours of printing. This, of course, requires shutdown of the printing apparatus and removal of the electrode.

[0009] As it is known, many elements other than chromium are added to iron to provide specific properties or ease of fabrication. For example, nickel, nitrogen and molybdenum are added for corrosion resistance; carbon, nitrogen and titanium for strength; sulfur and selenium for machinability and nickel for formability and toughness. The inventor has observed that a stainless steel with a high carbon content adversely affects passivation. A stainless steel with a high nickel content, on the other hand, is difficult to clean so that a residual film of ink containing non-coagulated ink is left on the surface of the positive electrode and is transferred with the colored, coagulated ink onto the substrate during contacting same. Thus, when black, cyan, magenta and yellow coloring agents are used to provide a polychromic image, the residual films containing these coloring agents upon being transferred onto the substrate in superimposed relation create on the printed image an undesirable colored background.

SUMMARY OF THE INVENTION

[0010] It is therefore an object of the present invention to provide an improved stainless steel positive electrode (anode) for use in an electrocoagulation printing method and apparatus, that can be thoroughly cleaned without undergoing abrasion and/or pitting during cleaning and has an alloy composition which does not adversely affect passivation.

[0011] According to one aspect of the invention, there is provided a positive electrode for an electrocoagulation printing made of an iron alloy consisting essentially of:

Cr:	at least 20 wt.%
Ni:	5 to 15 wt.%
Si:	1 to 2 wt.%
Mn:	0.9 to 1.5 wt.%
C:	0.1 to 0.3 wt.%
balance:	iron and unavoidable impurities.

[0012] Such a positive electrode can be thoroughly cleaned without undergoing abrasion and/or pitting during cleaning. The alloy composition does not adversely affect passivation.

[0013] According to another aspect of the invention, there is provided an improved electrocoagulation printing method comprising the steps of:

a) providing a positive electrolytically inert electrode having a continuous passivated surface moving at substantially constant speed along a predetermined path, the passivated surface defining a positive electrode active surface;

b) forming on the positive electrode active surface a plurality of dots of colored, coagulated ink representative of a desired image, by electrocoagulation of an electrolytically coagulable polymer present in an electrocoagulation printing Ink comprising a liquid colloidal dispersion containing the electrolytically coagulable polymer, a dispersing medium, a soluble electrolyte and a coloring agent; and

c) bringing a substrate into contact with the dots of colored, coagulated ink to cause transfer of the colored, coagulated ink from the positive electrode active surface onto the substrate and thereby imprint the substrate with the image;

in which the positive electrode is the electrode according to the present invention.

[0014] The present invention also provides, in a further aspect thereof, an improved multicolor electrocoagulation printing method comprising the steps of:

a) providing a positive electrolytically inert electrode having a continuous passivated surface moving at substantially constant speed along a predetermined path, the passivated surface defining a positive electrode active surface;

b) forming on the positive electrode active surface a plurality of dots of colored, coagulated ink representative of a desired image, by electrocoagulation of an electrolytically coagulable polymer present in an electrocoagulation printing ink comprising a liquid colloidal dispersion containing the electrolytically coagulable polymer, a dispersing medium, a soluble electrolyte and a coloring agent;

c) bringing an endless non-extensible belt having a porous surface on one side thereof and moving at substantially the same speed as the positive electrode, into contact with the positive electrode active surface to cause transfer of the dots of colored, coagulated ink from the positive electrode active surface onto the porous surface of the belt and to thereby imprint the porous surface with the image;

d) repeating steps (b) and (c) several times to define a corresponding number of printing stages arranged at predetermined locations along the path and each using a coloring agent of different color, to thereby produce several differently colored images of coagulated ink which are transferred at respective transfer positions onto the porous surface in superimposed relation to provide a polychromic image; and

e) bringing a substrate into contact with the porous surface of the belt to cause transfer of the polychromic image from the porous surface onto the substrate and to thereby imprint the substrate with the polychromic image;

in which the positive electrode is the electrode according to the present invention.

[0015] According to another aspect of the invention, there is also provided an improved electrocoagulation printing apparatus comprising:

- a positive electrolytically inert electrode having a continuous passivated surface defining a positive electrode active surface;
- means for moving the positive electrode active surface at a substantially constant speed along a predetermined path;
- means for forming on the positive electrode active surface a plurality of dots of colored, coagulated ink representative of a desired image, by electrocoagulation of an electrolytically coagulable polymer present in an electrocoagulation printing ink comprising a liquid colloidal dispersion containing the electrolytically coagulable polymer, a dispersing medium, a soluble electrolyte and a coloring agent; and
- means for bringing a substrate into contact with the dots of colored, coagulated ink to cause transfer of the colored, coagulated ink from the positive electrode active surface onto the substrate and thereby imprint the substrate with the image;
  in which the positive electrode is the electrode according to this invention.

[0016] It is preferable that the means for forming the dots of colored, coagulated ink and the means for bringing a substrate into contact with the dots of colored, coagulated ink are arranged to define a printing unit, and there are several printing units positioned at predetermined locations along the path and each using a coloring agent of different colored for producing several differently colored images of coagulated ink which are transferred at respective transfer stations onto the substrate in superimposed relation to provide a polychromic image.

[0017] In a preferred embodiment, the positive electrode is a cylindrical electrode having a central longitudinal axis and rotating at substantially constant speed about the longitudinal axis, and the printing stages are arranged around the positive cylindrical electrode.

[0018] According to yet another aspect of the invention, there is provided an improved electrocoagulation printing apparatus comprising:

- a positive electrolytically inert electrode having a continuous passivated surface defining a positive electrode active surface;
- means for moving the positive electrode active surface at a substantially constant speed along a predetermined path;
- an endless non-extensible belt having a porous surface on one side thereof;
- means for moving the belt at substantially the same speed as the positive electrode;
- a plurality of printing units arranged at predetermined locations along the path, each printing unit comprising:
  - means for forming on the positive electrode active surface a plurality of dots of colored, coagulated ink representative of a desired image, by electrocoagulation of an electrolytically coagulable polymer present in an electrocoagulation printing ink comprising a liquid colloidal dispersion containing the electrolytically coagulable polymer, a dispersion medium, a soluble electrolyte and a coloring agent, and
  - means for bringing the belt into contact with the positive electrode active surface at a respective transfer station to cause transfer of the dots of colored, coagulated ink from the positive electrode active surface onto the porous surface of the belt and to imprint the porous surface with the image, thereby producing several differently colored images of coagulated ink which are transferred at the respective transfer stations onto the porous surface in superimposed relation to provide a polychromic image; and
  - means for bringing a substrate into contact with the porous surface of the belt to cause transfer of the polychromic image from the porous surface onto the substrate and to thereby imprint the substrate with the polychromic image;
    in which the positive electrode is the electrode according to the present invention.

[0019] It is preferable that the positive electrode is a cylindrical electrode having a central longitudinal axis and the means for moving the positive electrode active surface includes means for rotating the positive cylindrical electrode about the longitudinal axis, the printing units being arranged around the positive cylindrical electrode.

BRIEF DESCRIPTION OF THE DRAWING

[0020]

Figure 1 shows a schematic illustration of an electrocoagulation printing apparatus according to a preferred embodiment of the invention.

Figure 2 shows an enlarged schematic illustration of a printing unit of an electrocoagulation printing apparatus according to a preferred embodiment of the invention, explaining the steps of the method of the present invention.

Figure 3 shows a schematic illustration of a multicolor electrocoagulation printing apparatus according to a preferred embodiment of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0021] A positive electrode according to this invention is made of an iron alloy consisting essentially of:

Cr:	at least 20 wt.%
Ni:	5 to 15 wt.%
Si:	1 to 2 wt.%
Mn:	0.9 to 1.5 wt.%
C:	0.1 to 0.3 wt.%
balance:	iron and unavoidable impurities.

[0022] The inventor has found quite unexpectedly that a stainless steel anode with the above alloy composition is sufficiently hard so that it can be thoroughly cleaned without undergoing abrasion and/or pitting during cleaning and that such an alloy composition does not adversely affect passivation. The stainless steel must have a chromium content of at least 20 wt.% since, when the chromium content is lower than 20 wt.%, the passive oxide film does not have sufficiently rapid self-healing properties and there is a release of undesirable Fe^{+2} ions. A chromium content ranging between 20 and 30 wt.% is preferred. The stainless steel must also have a nickel content within the range of 5 to 15 wt.% since, when the nickel content is higher than 15 wt.%, the anode cannot be thoroughly cleaned so that a residual film of ink containing non-coagulated ink is left on the surface of the anode, leading to the formation of undesirable background on the printed image. On the other hand, when the nickel content is lower than 5 wt.%, the steel is not sufficiently ductile and corrosion-resistant. A carbon content within the range of 0.1 to 0.3 wt.% is essential since, when the carbon content is higher than 0.3 wt.%, passivation is adversely affected and, when the carbon content is lower than 0.1 wt.%, the steel is not sufficiently hard. Manganese is an alloying agent added for providing depassivation initiation sites, whereas silicon is an alloying agent added for increasing the resistance to chloride corrosion.

[0023] Use is preferably made of an iron alloy consisting essentially of 25 to 28 wt.% Cr, 8 to 11 wt.% Ni, 1 to 2 wt.% Si, 0.9 to 1.5 wt.% Mn and 0.1 to 0.2 wt.% C, the balance consisting of iron and unavoidable impurities. A particularly preferred iron alloy consists essentially of 26.4 wt.% Cr, 9.7 wt.% Ni, 1.08 wt.% Si, 0.95 wt.% Mn and 0.12 wt.% C, the balance consisting of iron and unavoidable impurities. Such an alloy has a Brinell hardness of about 225. It is possible to increase the Brinell hardness of this alloy up to about 325, without adversely affecting passivation, by subjecting the alloy after casting to a heat treatment at a temperature of about 1120°C (2050°F) and to a subsequent water quenching. The alloy thus treated has an austenitic-ferritic structure.

[0024] An electrocoagulation printing method using the positive electrode according to the invention comprises the steps of:

a) providing a positive electrolytically inert electrode having a continuous passivated surface moving at substantially constant speed along a predetermined path, the passivated surface defining a positive electrode active surface;

b) forming on the positive electrode active surface a plurality of dots of colored, coagulated ink representative of a desired image, by electrocoagulation of an electrolytically coagulable polymer present in an electrocoagulation printing ink comprising a liquid colloidal dispersion containing the electrolytically coagulable polymer, a dispersing medium, a soluble electrolyte and a coloring agent; and

c) bringing a substrate into contact with the dots of colored, coagulated ink to cause transfer of the colored, coagulated ink from the positive electrode active surface onto the substrate and thereby imprint the substrate with the image.

[0025] Referring now to Fig. 1, there is illustrated an embodiment of an electrocoagulation printing apparatus having the positive electrode according to the present invention for carrying out the method of the present invention. This apparatus 1 comprises a positive electrode 3 made of an improved stainless steel, a plurality of negative electrodes 5 having a diameter of 50 μm and spaced from the positive electrode 3 by a constant predetermined gap, a coating unit 7 for coating the positive electrode surface with a coating agent to form microdroplets thereof on the positive electrode surface, an ink discharge unit 9 for supplying electrocoagulation printing ink to the positive electrode 3, a removing unit 11 using a soft polyurethane squeegee for removing non-coagulated ink from the positive electrode surface, a transferring unit 13 using a pressure roller formed of polyurethane for transferring the dots of coagulated ink onto the substrate from the positive electrode surface, and a cleaning unit 15 for cleaning the positive electrode surface by jetting a cleaning liquid thereagainst. Figure 2 shows an enlarged schematic illustration of a printing unit of an electrocoagulation printing apparatus, explaining the method of the steps of the present invention, in which parts similar to those previously described with reference to Fig. 1 are denoted by the same reference numerals.

[0026] In a preferred embodiment, the positive electrode used can be in the form of a moving endless belt as described in US Patent No. 4,661,222, or in the form of a revolving cylinder as described in US Patent Nos. 4,895,629 and 5,538,601. In the later case, use can preferably made of a cylindrical electrode having a central longitudinal axis and rotating at substantially constant speed about the longitudinal axis, and the printing stages or units are arranged around the positive cylindrical electrode as shown in Fig. 1. Preferably, the positive electrode active surface and the ink are maintained at a temperature of about 35-60°C, preferably about 40°C, to increase the viscosity of the coagulated ink in step (b) so that the dots of colored, coagulated ink remain coherent during their transfer in step (c), thereby enhancing transfer of the colored, coagulated ink onto the substrate or belt. For example, the positive electrode active surface can be heated at the desired temperature and the ink applied on the heated electrode surface to cause a transfer of heat therefrom to the ink.

[0027] When use is made of a positive electrode of cylindrical configuration rotating at substantially constant speed about its central longitudinal axis, step (b) of the above electrocoagulation printing method is carried out by:

i) providing a plurality of negative electrolytically inert electrodes 5 electrically insulated from one another and arranged in rectilinear alignment to define a series of corresponding negative electrode active surfaces disposed in a plane parallel to the longitudinal axis of the positive electrode and spaced from the positive electrode active surface by a constant predetermined gap 6, the negative electrodes 5 being spaced from one another by a distance at least equal to the electrode gap 6;

ii) coating the positive electrode active surface with an oily substance to form on the surface micro-droplets of oily substance;

iii) filling the electrode gap 6 with the electrocoagulation printing ink;

iv) electrically energizing selected ones of the negative electrodes to cause point-by-point selective coagulation and adherence of the ink onto the oil-coated positive electrode active surface opposite the electrode active surfaces of the energized negative electrodes while the positive electrode is rotating, thereby forming the dots of colored, coagulated ink; and

v) removing any remaining non-coagulated ink from the positive electrode active surface.

[0028] As explained in US Patent No. 4,895,629, spacing of the negative electrodes from one another by a distance which is equal to or greater than the electrode gap prevents the negative electrodes from undergoing edge corrosion. On the other hand, coating of the positive electrode with an oily substance prior to electrical energization of the negative electrodes weakens the adherence of the dots of coagulated ink to the positive electrode and also prevents an uncontrolled corrosion of the positive electrode. In addition, when an olefinic substance is used as an oily substance, gas generated as a result of electrolysis upon energizing the negative electrodes is consumed by reaction with the olefinic substance so that there is no gas accumulation between the negative and positive electrodes. The inventor has found that it is no longer necessary to admix a metal oxide with the oily substance; it is believed that the passive oxide film on currently available electrodes contains sufficient metal oxide to act as catalyst for the desired reaction.

[0029] Examples of suitable electrolytically inert metals from which the negative electrodes can be made are stainless steel, platinum, chromium, nickel and aluminium. The gap that is defined between the positive and negative electrodes can range from about 50 μm to about 100 μm, the smaller the electrode gap the sharper are the dots of coagulated ink produced. Where the electrode gap is of the order of 50 μm, the negative electrodes are the preferably spaced from one another by a distance of about 75 μm.

[0030] Examples of suitable oily substances which may be used to coat the surface of the positive electrode in step (b) (ii) include unsaturated fatty acids such as arachidonic acid, linoleic acid, linolenic acid, oleic acid and palmitoleic acid and unsaturated vegetable oils such as corn oil, linseed oil, olive oil, peanut oil, soybean oil and sunflower oil. Oleic acid is particularly preferred. The micro-droplets of oily substance formed on the surface of the positive electrode active surface generally have a size ranging from about 1 to about 5 μm.

[0031] As shown in Fig. 2, the oily substances are preferably applied onto the distribution roller 71 by disposing an applicator roller 73 parallel to the distribution roller 71, and rotating the applicator roller 73 and the distribution roller 71 in register while feeding the oily substances by using a feeding device 77. The micro-droplets are advantageously transferred from the distribution roller 71 to the positive electrode 3 by disposing a transfer roller 75 parallel to the distribution roller 71 and in contact engagement therewith, positioning the transfer roller 75 in pressure contact engagement with the positive electrode 3, and rotating the transfer roller 75 and the positive electrode 3 in register for transferring the micro-droplets from the distribution roller 71 to the transfer roller 75 and thereafter transferring the micro-droplets from the transfer roller 75 to the positive electrode 3. Such an arrangement of rollers is described in US Patent No. 5,449,392.

[0032] The oil-coated positive active surface is preferably polished to increase the adherence of the micro-droplets onto the positive electrode active surface, prior to step (b) (iii). For example, use can be made of a rotating brush 8 provided with a plurality of radially extending bristles 81 made of horsehair and having extremities contacting the surface of the positive electrode 3. The friction caused by the bristles 81 contacting the surface upon rotation of the brush has been found to increase the adherence of the micro-droplets onto the positive electrode active surface.

[0033] Where the positive cylindrical electrode extends vertically, step (b) (iii) of the above electrocoagulation printing method is advantageously carried out by continuously discharging the ink onto the positive electrode active surface from a fluid discharge means 9 disposed adjacent the electrode gap 6 at a predetermined height relative to the positive electrode and allowing the ink to flow downwardly along the positive electrode active surface, the ink being thus carried by the positive electrode upon rotation thereof to the electrode gap 6 to fill same. Preferably, excess ink flowing downwardly off the positive electrode active surface is collected and the collected ink is recirculated back to the fluid discharge means.

[0034] An electrocoagulation printing ink contains at least electrolytically coagulable polymer, a dispersing medium, a soluble electrolyte and a coloring agent.

[0035] The electrolytically coagulable polymer generally used is a linear polymer of high molecular weight, that is, one having a weight average molecular weight between about 10,000 and about 1,000,000, preferably between 100,000 and 600,000. Examples of suitable polymers include natural polymers such as albumin, gelatin, casein and agar, and synthetic polymers such as polyacrylic acid, polyacrylamide and polyvinyl alcohol. A particularly preferred polymer is an anionic copolymer of acrylamide and acrylic acid having a weight average molecular weight of about 250,000 and sold by Cyanamid Inc. under the trade mark ACCOSTRENGTH 86. Water is preferably used as the medium for dispersing the polymer to provide the desired colloidal dispersion.

[0036] Preferred electrolytes include alkali metal halides and alkaline earth metal halides, such as lithium chloride, sodium chloride, potassium chloride and calcium chloride. Potassium chloride is particularly preferred. The coloring agent can be a dye or a pigment. Examples of suitable dyes which may be used to color the ink are the water soluble dyes available from HOECHST such a Duasyn Acid Black for coloring in black and Duasyn Acid Blue for coloring in cyan, or those available from RIEDEL-DEHAEN such as Anti-Halo Dye Blue T. Pina for coloring in cyan, Anti-Halo Dye AC Magenta Extra V01 Pina for coloring in magenta and Anti-Halo Dye Oxonol Yellow N. Pina for coloring in yellow. When using a pigment as a coloring agent, use can be made of the pigments which are available from CABOT CORP. such as Carbon Black Monarch® 120 for coloring in black, or those available from HOECHST such as Hostaperm Blue B2G or B3G for coloring in cyan, Permanent Rubine F6B or L6B for coloring in magenta and Permanent Yellow DGR or DHG for coloring in yellow. A dispersing agent can be added for uniformly dispersing the pigment into the ink. Examples of suitable dispersing agents include the anionic dispersing agent sold by Boehme Filatex Canada Inc. under the trade mark CLOSPERSE 25000.

[0037] After coagulation of the ink, any remaining non-coagulated ink is removed from the positive electrode active surface in step (b) (v), for example, by scraping the surface with a soft rubber squeegee 11, so as to fully uncover the colored, coagulated ink. Preferably, the non-coagulated ink thus removed is collected and recirculated back to the aforesaid fluid discharge means.

[0038] The optical density of the dots of colored, coagulated ink may be varied by varying the voltage and/or pulse duration of the pulse-modulated signals applied to the negative electrodes.

[0039] According to a preferred embodiment, as shown in Fig. 2, step (c) is preferably carried out by providing at each transfer position a pressure roller 13 extending parallel to the positive cylindrical electrode 3 and pressed thereagainst to form a nip 14 and permit the pressure roller 13 to be driven by the positive electrode 3 upon rotation thereof, and passing the substrate S through the nip 14. Preferably, the pressure roller is provided with a peripheral covering of a synthetic rubber material such as a polyurethane having a Shore A hardness of about 95. A polyurethane covering with such a hardness has been found to further improve transfer of the coagulated ink from the positive electrode surface onto the substrate. The pressure exerted between the positive electrode and the pressure roller preferably ranges from about 50 to about 100 kg/cm^2.

[0040] After step (c), the positive electrode active surface is generally cleaned to remove therefrom any remaining coagulated ink. According to a preferred embodiment, the positive electrode 3 is rotatable in a predetermined direction and any remaining coagulated ink is removed from the positive electrode active surface by providing an elongated rotatable brush 151 extending parallel to the longitudinal axis of the positive electrode, the brush being provided with a plurality of radially extending bristles 152 made of horsehair and having extremities contacting the positive electrode active surface, rotating the brush in a direction opposite to the direction of rotation of the positive electrode so as to cause the bristles to frictionally engage the positive electrode active surface, and directing jets of cleaning liquid produced by high pressure injectors 153 under pressure against the positive electrode active surface, from either side of the brush 151. In such an embodiment, the positive electrode active surface and the ink are preferably maintained at a desired temperature by heating the cleaning liquid to thereby heat the positive electrode active surface upon contacting same and applying the ink on the heated electrode surface to cause a transfer of heat therefrom to the ink.

[0041] Where a polychromic image is desired, steps (b) and (c) of the above electrocoagulation printing method are repeated several times to define a corresponding number of printing stages arranged at predetermined locations along the aforesaid path and each using a coloring agent of different color, and to thereby produce several differently colored images of coagulated ink which are transferred at the respective transfer positions onto the substrate in superimposed relation to provide a polychromic image. It is also possible to repeat several times steps (a), (b) and (c) to define a corresponding number of printing stages arranged in tandem relation and each using a coloring agent of different color, and to thereby produce several differently colored images of coagulated ink which are transferred at respective transfer positions onto the substrate in superimposed relation to provide a polychromic image, the substrate being in the form of a continuous web which is passed through the respective transfer positions for being imprinted with the colored images at the printing stages. Alternatively, the printing stages defined by repeating several times steps (a), (b) and (c) can be arranged around a single roller adapted to bring the substrate into contact with the dots of colored, coagulated ink of each printing stage and the substrate which is in the form of a continuous web is partially wrapped around the roller and passed through the respective transfer positions for being imprinted with the colored images at the printing stages. The last two arrangements are described in US Patent No. 4,895,629.

[0042] When a polychromic image of high definition is desired, it is preferable to bring an endless non-extensible belt moving at substantially the same speed as the positive electrode active surface and having on one side thereof a ink retaining surface adapted to releasably retain dots of electrocoagulated ink to cause transfer of the differently colored images at the respective transfer positions onto the ink retaining surface of such a belt in superimposed relation to provide a polychromic image, and thereafter bring the substrate into contact with the ink retaining surface of the belt to cause transfer of the polychromic image from the ink retaining surface onto the substrate and to thereby imprint the substrate with the polychromic image. By utilizing an endless non-extensible belt having a ink retaining surface such as a porous surface on which dots of colored, coagulated ink can be transferred and by moving such a belt independently of the positive electrode, from one printing unit to another, so that the ink retaining surface of the belt contacts the colored, coagulated ink in sequence, it is possible to significantly improve the registration of the differently colored images upon their transfer onto the ink retaining surface of the belt, thereby providing a polychromic image of high definition which can thereafter be transferred onto the paper web or other substrate. For example, use can be made of a belt comprising a plastic material having a porous coating of silica.

[0043] Thus, a multicolor electrocoagulation printing method using the positive electrode according to the invention comprises the steps of:

a) providing a positive electrolytically inert electrode having a continuous passivated surface moving at substantially constant speed along a predetermined path, the passivated surface defining a positive electrode active surface;

b) forming on the positive electrode active surface a plurality of dots of colored, coagulated ink representative of a desired image, by electrocoagulation of an electrolytically coagulable polymer present in an electrocoagulation printing ink comprising a liquid colloidal dispersion containing the electrolytically coagulable polymer, a dispersing medium, a soluble electrolyte and a coloring agent;

c) bringing an endless non-extensible belt having a porous surface on one side thereof and moving at substantially the same speed as the positive electrode, into contact with the positive electrode active surface to cause transfer of the dots of colored, coagulated ink from the positive electrode active surface onto the porous surface of the belt and to thereby imprint the porous surface with the image;

d) repeating steps (b) and (c) several times to define a corresponding number of printing stages arranged at predetermined locations along the path and each using a coloring agent of different color, to thereby produce several differently colored images of coagulated ink which are transferred at respective transfer positions onto the porous surface in superimposed relation to provide a polychromic image; and

e) bringing a substrate into contact with the porous surface of the belt to cause transfer of the polychromic image from the porous surface onto the substrate and to thereby imprint the substrate with the polychromic image.

[0044] Figure 3 shows an embodiment of a multicolor electrocoagulation printing apparatus for carrying out the method of the present invention. This apparatus 2 comprises a central positive electrode 3 made of an improved stainless steel in the form of a revolving cylinder and four identical printing units 20 (20A, 20B, 20C, 20D) arranged around the positive cylindrical electrode 3, wherein the first printing unit 20A is adopted to print in yellow color, the second printing unit 20B in magenta color, the third printing unit 20C in cyan color and the forth printing unit 20D in black color, respectively.

[0045] In a particularly preferred embodiment, there are at least two printing stages each including one pressure roller 131 and wherein the pressure rollers are arranged in pairs with the pressure rollers of each pair being diametrically opposed to one another. The provision of two pairs of diametrically opposed pressure rollers arranged around the positive cylindrical electrode 3 prevents such an electrode from flexing since the forces exerted by the pressure rollers of each pair cancel each other out.

[0046] An endless non-extensible belt 17 moving at substantially the same speed as the positive electrode 3 has on one side thereof a coagulated ink retaining surface 171 and is brought into contact with the positive electrode surface 3 by the pressure rollers 131 to cause transfer of the dots of coagulated ink from the positive electrode surface onto the coagulated ink retaining surface 171.

[0047] Preferably, the electrocoagulation printing ink contains water as the dispersing medium and the dots of differently colored, coagulated ink representative of the polychromic image are moistened between the aforementioned steps (d) and (e) so that the polychromic image is substantially completely transferred onto the substrate in step (e). As shown in Fig. 3, use can be made of a moistening unit 19 comprising a plurality of spray nozzles 191.

[0048] According to another preferred embodiment, the substrate S is in the form of a continuous web and step (e) is carried out by providing a support roller 135 and a pressure roller (not shown) extending parallel to the support roller 135 and pressed thereagainst to form a nip through which the belt 17 is passed, the support roller 135 and pressure roller being driven by the belt 17 upon movement thereof, and guiding the web S by a pair of guide rollers 137 so as to pass through the nip between the pressure roller and the porous surface of the belt for imprinting the web S with the polychromic image 200. Preferably, the belt with the porous surface thereof imprinted with the polychromic image is guided so as to travel along a path extending in a plane intersecting the longitudinal axis of the positive electrode at right angles, thereby exposing the porous surface to permit contacting thereof by the web. Where the longitudinal axis of the positive electrode extends vertically, the belt is preferably guided so as to travel along a horizontal path with the porous surface facing downwardly, the support roller and pressure roller having rotation axes disposed in a plane extending perpendicular to the horizontal path. Such an arrangement is described in Canadian application No. 2,214,300.

[0049] After step (e), the porous surface of the belt is generally cleaned to remove therefrom any remaining coagulated ink. According to a preferred embodiment, any remaining coagulated ink is removed from the porous surface 171 of the belt 17 by providing at least one elongated rotatable brush 211 disposed on the one side of the belt and at least one support roller 213 extending parallel to the brush and disposed on the opposite side of the belt, the brush 211 and support roller 213 having rotation axes disposed in a plane extending perpendicular to the belt 17, the brush being provided with a plurality of radially extending bristles 212 made of horsehair and having extremities contacting the porous surface, rotating the brush in a direction opposite to the direction of movement of the belt so as to cause the bristles to frictionally engage the porous surface while supporting the belt with the support roller, directing jets of cleaning liquid under pressure against the porous surface 171 by using at least one high pressure injector 215 from either side of the brush, and removing the cleaning liquid with any dislodged coagulated ink from the porous surface.

[0050] It is to be noted that, besides those already mentioned above, many modifications and variations of the above embodiments may be made without departing from the novel and advantageous features of the present invention. Accordingly, all such modifications and variations are intended to be included within the scope of the appended claims.

Claims

1. A positive electrode for an electrocoagulation printing made of an iron alloy consisting essentially of:

Cr:	at least 20 wt.%
Ni:	5 to 15 wt.%
Si:	1 to 2 wt.%
Mn:	0.9 to 1.5 wt.%
C:	0.1 to 0.3 wt.%
balance:	iron and unavoidable impurities.

2. A positive electrode as claimed in claim 1, wherein the iron alloy consists essentially of:

Cr:	25 to 28 wt.%
Ni:	8 to 11 wt.%
Si:	1 to 2 wt.%
Mn:	0.9 to 1.5 wt.%
C:	0.1 to 0.2 wt.%
balance:	iron and unavoidable impurities.

3. A positive electrode as claimed in claim 1 or 2, wherein the iron alloy is a cast alloy which has been subjected after casting to a heat treatment at a temperature of about 1120°C and to a subsequent water quenching.

4. A positive electrode as claimed in claim 3, wherein the cast alloy has an austenitic-ferritic structure.

5. An electrocoagulation printing method comprising the steps of:

    a) providing a positive electrolytically inert electrode having a continuous passivated surface moving at substantially constant speed along a predetermined path, the passivated surface defining a positive electrode active surface;

b) forming on the positive electrode active surface a plurality of dots of colored, coagulated ink representative of a desired image, by electrocoagulation of an electrolytically coagulable polymer present In an electrocoagulation printing ink comprising a liquid colloidal dispersion containing the electrolytically coagulable polymer, a dispersing medium, a soluble electrolyte and a coloring agent; and

c) bringing a substrate into contact with the dots of colored, coagulated ink to cause transfer of the colored, coagulated ink from the positive electrode active surface onto the substrate and thereby imprint the substrate with the image;

characterized in that the positive electrode is a positive electrode as claimed in claims 1 to 4.

6. A multicolor electrocoagulation printing method comprising the steps of:

a) providing a positive electrolytically inert electrode having a continuous passivated surface moving at substantially constant speed along a predetermined path, the passivated surface defining a positive electrode active surface;

b) forming on the positive electrode active surface a plurality of dots of colored, coagulated ink representative of a desired image, by electrocoagulation of an electrolytically coagulable polymer present in an electrocoagulation printing ink comprising a liquid colloidal dispersion containing the electrolytically coagulable polymer, a dispersing medium, a soluble electrolyte and a coloring agent;

c) bringing an endless non-extensible belt having a porous surface on one side thereof and moving at substantially the same speed as the positive electrode, into contact with the positive electrode active surface to cause transfer of the dots of colored, coagulated ink from the positive electrode active surface onto the porous surface of the belt and to thereby imprint the porous surface with the image;

d) repeating steps (b) and (c) several times to define a corresponding number of printing stages arranged at predetermined locations along the path and each using a coloring agent of different color, to thereby produce several differently colored images of coagulated ink which are transferred at respective transfer positions onto the porous surface in superimposed relation to provide a polychromic image; and

e) bringing a substrate into contact with the porous surface of the belt to cause transfer of the polychromic image from the porous surface onto the substrate and to thereby imprint the substrate with the polychromic image;

characterized in that the positive electrode is a positive electrode as claimed in claims 1 to 4.

7. An electrocoagulation printing apparatus comprising:

- a positive electrolytically inert electrode having a continuous passivated surface defining a positive electrode active surface;

- means for moving the positive electrode active surface at a substantially constant speed along a predetermined path;

- means for forming on the positive electrode active surface a plurality of dots of colored, coagulated ink representative of a desired image, by electrocoagulation of an electrolytically coagulable polymer present in an electrocoagulation printing ink comprising a liquid colloidal dispersion containing the electrolytically coagulable polymer, a dispersing medium, a soluble electrolyte and a coloring agent; and

- means for bringing a substrate into contact with the dots of colored, coagulated ink to cause transfer of the colored, coagulated ink from the positive electrode active surface onto the substrate and thereby imprint the substrate with the image;

  characterized in that the positive electrode is a positive electrode as claimed in claims 1 to 4.

8. An apparatus as claimed in claim 7, wherein the means for forming the dots of colored, coagulated ink and the means for bringing the substrate into contact with the dots of colored, coagulated ink are arranged to define a printing unit, and wherein there are several printing units positioned at predetermined locations along the path and each using a coloring agent of different colored for producing several differently colored images of coagulated ink which are transferred at respective transfer stations onto the substrate in superimposed relation to provide a polychromic image.

9. An apparatus as claimed in claim 8, wherein the positive electrode is a cylindrical electrode having a central longitudinal axis and rotating at substantially constant speed about the longitudinal axis, and wherein the printing units are arranged around the positive cylindrical electrode.

10. A multicolor electrocoagulation printing apparatus comprising:

- a positive electrolytically inert electrode having a continuous passivated surface defining a positive electrode active surface;
- means for moving the positive electrode active surface at a substantially constant speed along a predetermined path;
- an endless non-extensible belt having a porous surface on one side thereof;
- means for moving the belt at substantially the same speed as the positive electrode;
- a plurality of printing units arranged at predetermined locations along the path, each printing unit comprising:
    - means for forming on the positive electrode active surface a plurality of dots of colored, coagulated ink representative of a desired image, by electrocoagulated of an electrolytically coagulable polymer present in an electrocoagulation printing ink comprising a liquid colloidal dispersion containing the electrolytically coagulable polymer, a dispersion medium, a soluble electrolyte and a coloring agent, and
    - means for bringing the belt into contact with the positive electrode active surface at a respective transfer station to cause transfer of the dots of colored, coagulated ink from the positive electrode active surface onto the porous surface of the belt and to imprint the porous surface with the image,
      thereby producing several differently colored images of coagulated ink which are transferred at the respective transfer stations onto the porous surface in superimposed relation to provide a polychromic image; and
    - means for bringing a substrate into contact with the porous surface of the belt to cause transfer of the polychromic image from the porous surface onto the substrate and to thereby imprint the substrate with the polychromic image;

characterized in that the positive electrode is a positive electrode as claimed in claims 1 to 4.

FIG.1

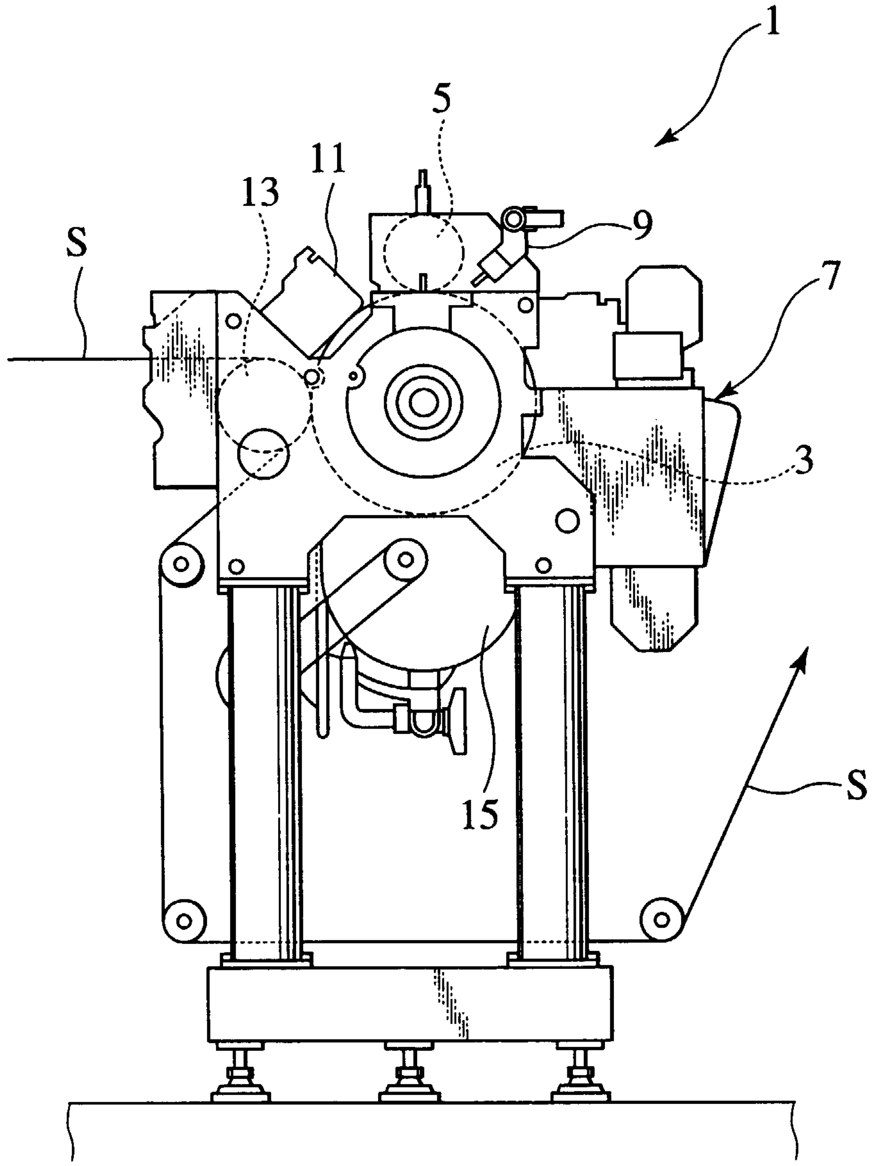
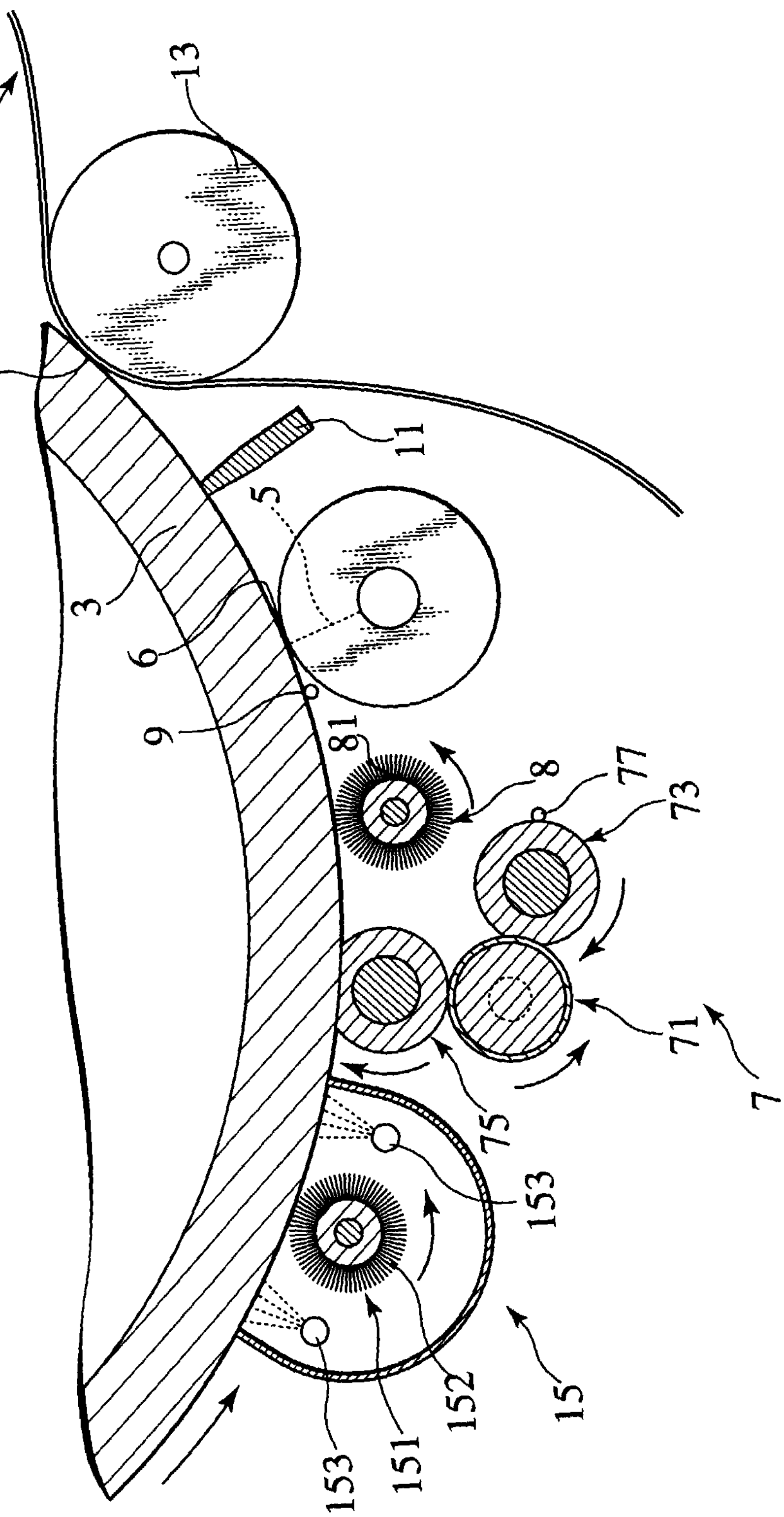
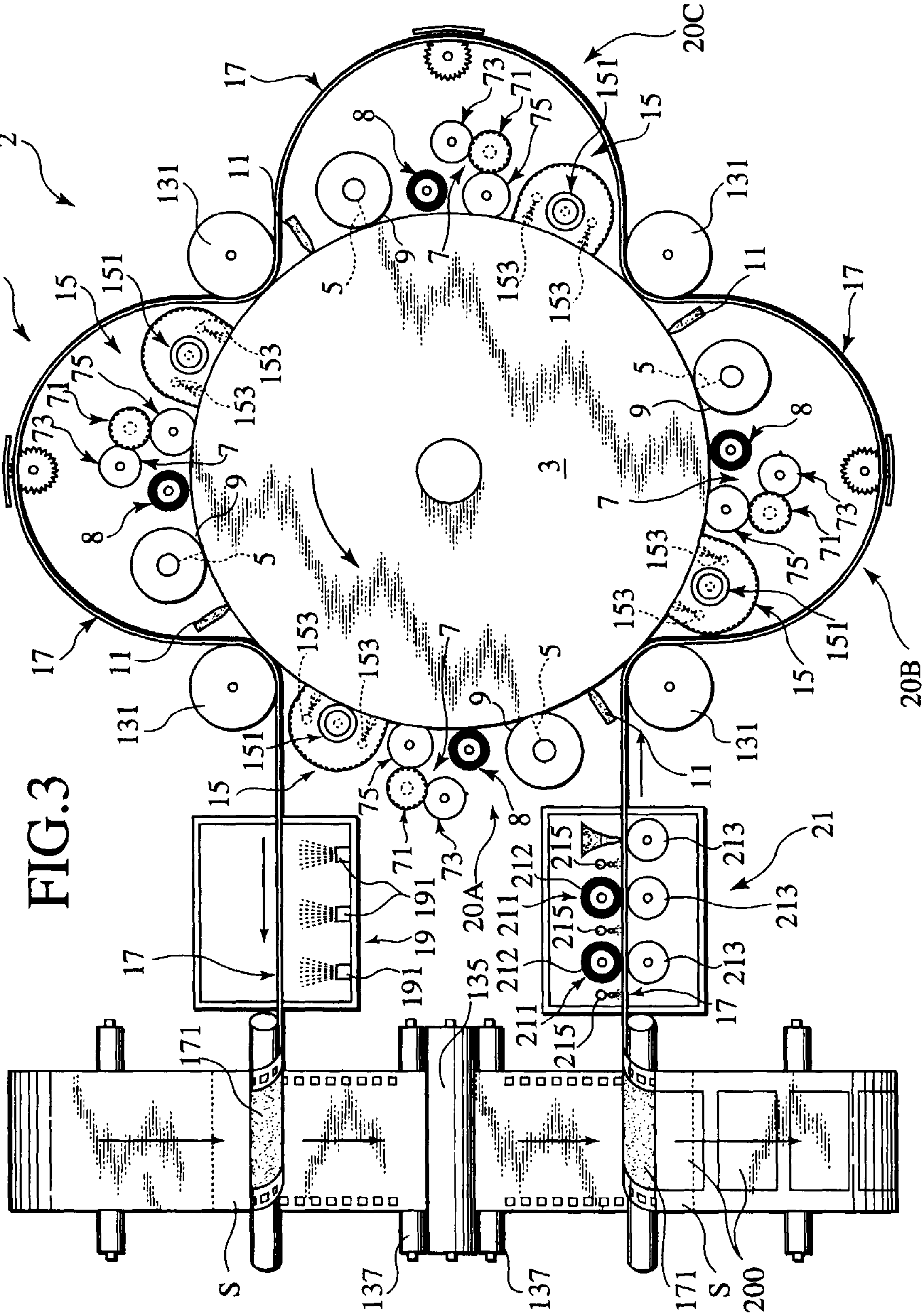


FIG.2




2
20A
20B
20C
20D
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11
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17
19
21
71
73
75
131
135
137
151
153
171
191
200
211
212
213
215
S

FIG.3