Aug. 2, 1966 S. F. REED 3,264,385

METHOD OF CASTING A PRINTED PATTERN ON A PLASTIC SHEET

Filed Jan. 14, 1963 3 Sheets-Sheet 1

Fig. 1

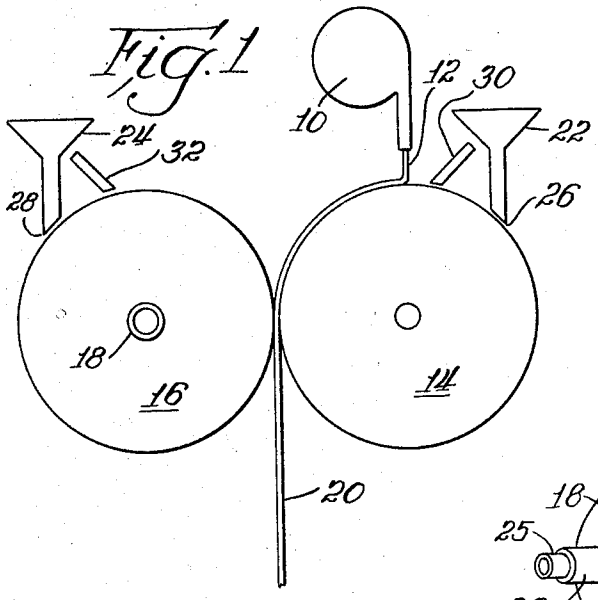


Fig. 2b

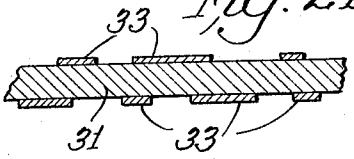
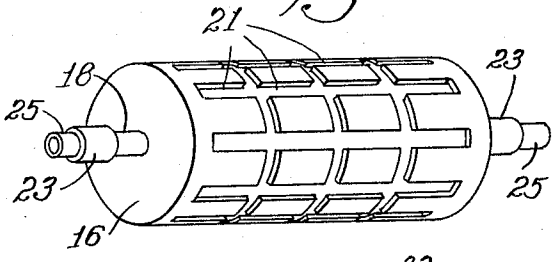


Fig. 2a



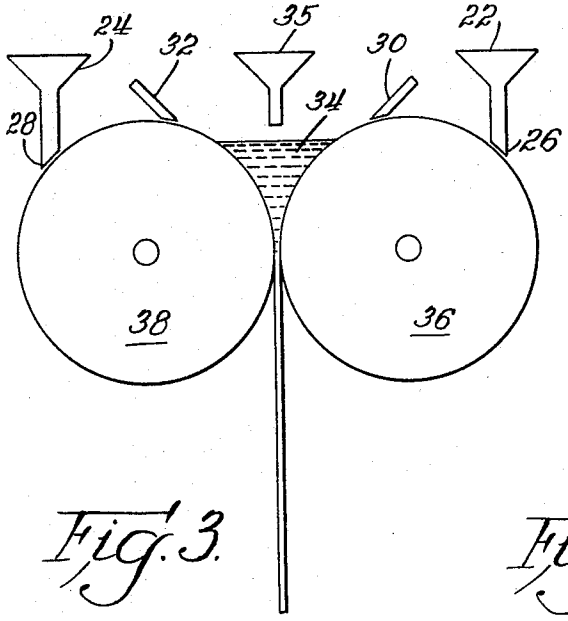


Fig. 3.

Fig. 2c

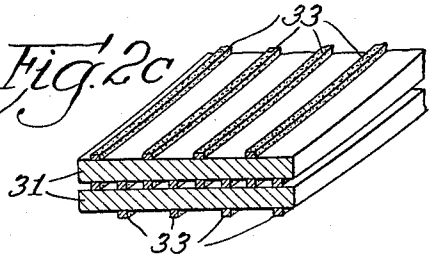


Fig. 4a

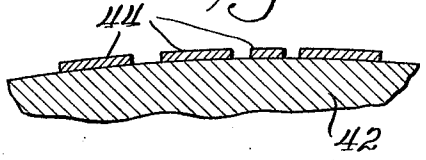


Fig. 4b

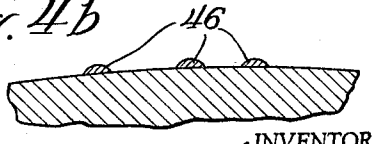


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Fig. 6.

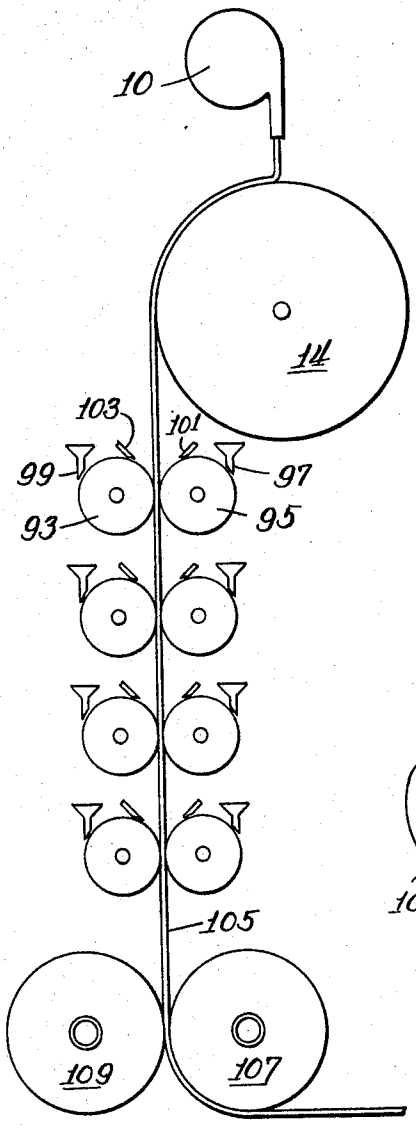

Fig. 5.

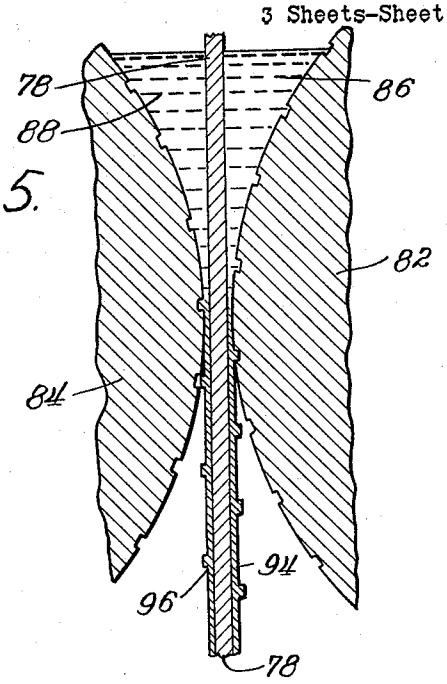

Fig. 7.

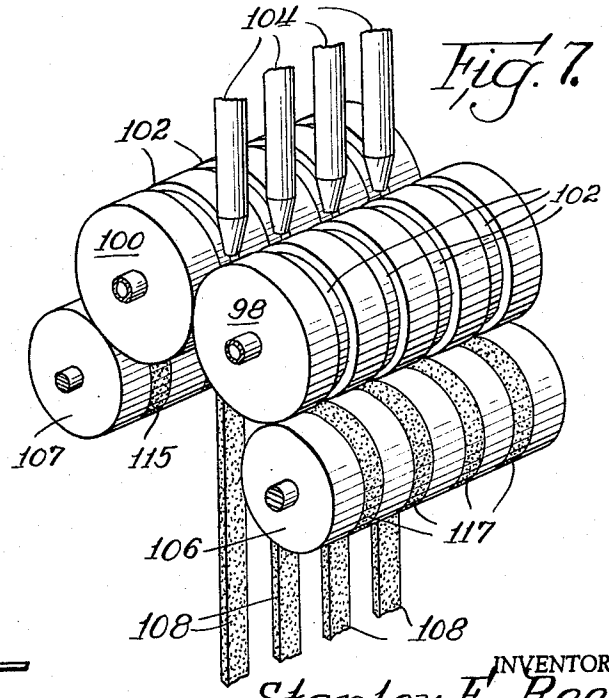

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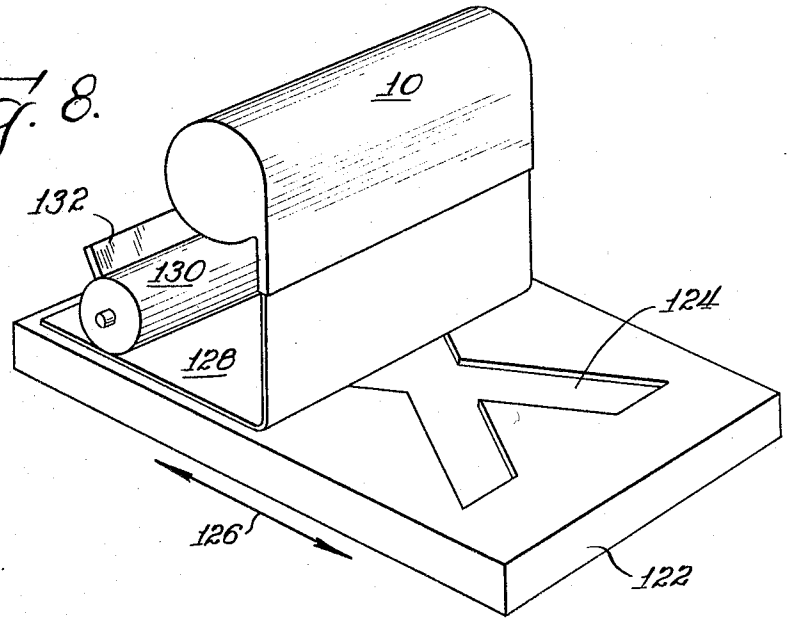
Fig. 8.



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United States Patent Office 3,264,385 Patented August 2, 1966

3,264,385

METHOD OF CASTING A PRINTED PATTERN ON A PLASTIC SHEET

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Filed Jan. 14, 1963, Ser. No. 252,016
5 Claims. (Cl. 264—104)

This invention relates to a process of printing, product thereof and to apparatus therefor. It has to do more particularly with a novel printing process wherein the material which is to form the pattern is applied to a solidifiable base or carrier material while the latter is in a fluid or semi-solid state and to novel apparatus for carrying out such process.

This application is a continuation-in-part of an original application, Serial No. 831,926, filed August 17, 1959, for printing processes and apparatus, and now abandoned.

In prior printing processes the material which is to form the pattern is customarily applied to the base or carrier material while the latter is in solid form. Where such base material is absorbent, as in the case of paper, for example, it is difficult to produce a pattern in very fine detail since the pattern-forming material, which is usually ink, strikes into the base material and spreads beyond the desired limits of the pattern to be produced. Where the base material is not readily absorbent, as in the case of high gloss papers, plastic materials and the like, it is difficult to prevent the pattern-forming material from spreading on the surface beyond the limits of the desired pattern. Moreover, great care is required to prevent blotting or smearing of the pattern-forming material. Printing processes employing conventional material, such as paper and common types of ink, result in products which are essentially short-lived under detrimental conditions such as those resulting from exposure to damp environment, rough usage, and the like. In addition, such products have an inherent lack of permanency, the paper being readily subject to tearing, abrasion and deterioration.

Where the base or carrier material is of a non-absorbent nature, as for example, when it is a high-gloss paper or is formed of a synthetic commercial plastic, it is difficult to prevent smearing and spreading of the pattern-forming material on the base material. Moreover, where the base is a plastic, the pattern-forming material usually may be readily rubbed or worn off the base material.

Patterns also heretofore have been formed in a coating carried on a base by etching away certain portions of the coating to leave only the portions which are to form the pattern. Such technique is employed for example in forming printed electrical circuits wherein a conductive material, such as a metal, is placed on a base of insulated material, such as a synthetic plastic or paper and the metal is etched away to leave the desired circuit elements. This process is both expensive and time-consuming. Furthermore, it is difficult to control the extent of the etching and, accordingly, the accuracy of the pattern formed by the conductive material which remains after the etching. Further, it is difficult, expensive, or impossible to derive an etched pattern wherein the depth and thickness of the coating may be made different at different points or places. Electrical conductors, for example, must in general, be made wider when more current carrying capacity is required.

Heretofore tapes for reproducing electromagnetic impulses have been formed by applying to a base material, such as a synthetic plastic, a uniform coating of magnetic particles. Electromagnetic impulses are then applied to the tape to magnetize the particles in such manner to form a pattern whereby the impulses may be reproduced by passing the tape through suitable apparatus which is responsive to the magnetization of the particles. It has been found difficult to produce such a tape wherein the information recorded thereon is truly permanent and not subject to unintentional erasure.

Patterns have heretofore been produced on sheets, webs and tapes by common photographic techniques but such techniques have been relatively expensive and time-consuming.

One of the objects of the present invention is to provide a novel method of printing which is capable of producing a pattern of extremely fine detail in a relatively permanent form.

Another object is to provide a printing process wherein the material which is to form the pattern is applied to the base or carrier material while the latter is in a fluid or semi-solid state.

Another object is to provide a printing process wherein a finely divided solid pattern-producing material is embedded in the surface of the base or carrier material.

A further object is to provide a method whereby the effective thickness of the pattern-forming material may be controlled and caused to vary throughout the pattern as desired.

Still another object is to provide a printing process wherein the pattern-forming material is applied to the material which is to form the base or carrier during the formation of a sheet or web from the base-forming material.

A further object is to provide a novel process for embedding finely divided solid particles in a base or carrier to form a pattern, which method is capable of reproducing a desired pattern to a very high degree of accuracy and is at the same time simple, rapid and economical.

A further object is to provide a method for printing in which the printed product is resistant to abrasion and tearing, and the printed pattern thereon is resistant to obliteration.

Another object is to provide a process for printing on a sheet or web principally composed of relatively low cost material but having a high quality surface.

Another object is to provide an inexpensive but efficient process for making permanently prerecorded magnetic tape. Still another object is to provide an inexpensive and efficient process for making permanently prerecorded optical tape.

A further object is to provide an inexpensive and efficient process for making printed circuits having a high degree of accuracy and a high uniformity of quality.

A further object is to provide a method of forming printed electrical circuits which is simple and inexpensive and which is capable of producing with a high degree of accuracy circuits including various desired components such as resistances, capacitances, inductances and simple conductors.

It is another object of the invention to provide inexpensive and efficient processes for making electrical cables having a plurality of mutually insulated conductors.

It is a further object of the invention to provide a process wherein the base or carrier material may be readily reclaimed and reused.

Other objects and advantages of the invention will appear from the following description taken in connection with the appended drawings, wherein:

FIG. 1 is a diagrammatic illustration of apparatus for carrying out the preferred embodiment of the invention;

FIG. 2*a* is a perspective view showing one of the cylinders of the apparatus of FIG. 1;

FIG. 2*b* is an enlarged, fragmentary, longitudinal cross-sectional view through a printed article formed in accordance with the invention;

FIG. 2*c* is a fragmeentary perspective view partially in cross-section showing a multi-conductor electrical cable manufactured in accordance with the invention;

FIG. 2*d* is a greatly enlarged fragmentary longitudinal cross-sectional view through a printed particle formed in accordance with the invention showing the pigment particles individually or collectively surrounded by the base material;

FIG. 3 is a diagrammatic illustration of apparatus for carrying out a second embodiment of the invention;

FIG. 4*a* is an enlarged fragmentary cross-sectional view of a portion of the surface of one of the printing rolls in accordance with the preferred form of the invention;

FIG. 4*b* is an enlarged fragmentary cross-sectional illustration of a portion of one of the rolls in accordance with an alternative embodiment of the invention;

FIG. 5 is an enlarged fragmentary view of a portion of apparatus for effecting high quality printing on a relatively low quality web;

FIG. 6 is a diagrammatic illustration of apparatus in accordance with still another embodiment of the invention in which information is printed on a semi-soft web of base or carrier material;

FIG. 7 is a diagrammatic perspective view of apparatus in accordance with a further embodiment of the invention which is especially adapted for manufacturing strips or tapes such as magnetic tapes;

FIG. 8 is a diagrammatic illustration of apparatus in accordance with a further embodiment of the invention in which a web-like stream of liquid is extruded onto a flat plate for printing thereby.

In accordance with the preferred embodiment of the invention, a base or carrier material is employed to form a sheet or web to which the pattern-forming material is applied to produce the desired pattern. The base or carrier material is initially in a liquid state and is caused to form a free-falling stream contacting a member carrying the pattern-forming material in the desired arrangement on its surface. The liquid base or carrier material is then solidified while contacting the member and, at the same time, the pattern-forming material is transferred into the surface of the base or carrier material, where it becomes permanently embedded.

In the preferred embodiment, the base or carrier material is initially in its liquid state while it is a free-falling stream. Upon contact with the member carrying the pattern-forming material, the material is transformed into a semi-solid state, and later is again charged into its solid state to form a continuous web. For convenience, the material while in any of these three states is sometimes referred to herein as "web" material.

Other embodiments of the invention effect the transfer of pattern-forming particles into the surface of the base or carrier material while it is in either a liquid or semi-solid state. For convenience, either or both of these states are sometimes referred to herein as "moldable" states, implying that the web material is in a visco-elastic state or in a condition where it will readily change its shape and permit the pattern-forming particles to be embedded in, and cast into, the surface of the web.

Referring now to FIG. 1, there is shown an extruder **10**, adapted to extrude a sheet of liquid web **12** onto the surface of a roller **14**.

The liquid web **12** is preferably a plastic maintained in its liquid state by reason of a high temperature within extruder **10**, but may be any material which is in its solid state at ordinary room temperatures, but capable of being easily melted. The web material may be either thermosetting or thermoplastic, and it is found that nylon which is in its liquid state at about 500° F., may conveniently be used. The web material preferably "wets" the material of which the rolls are constructed.

Roll **14** is rotated in a counterclockwise direction and carries with it the liquid web **12** on its surface. After the liquid web has travelled part way around the circumference of roll **14**, it encounters another roll **16**, rotating in a clockwise direction, at the same circumferential speed as roll **14**, which is chilled to a very low temperature by means of a cooling agent circulating therethrough which enters through pipe **18**. When the liquid web **12** contacts the chilling roll **16**, it solidifies and emerges at **20** as a solid web having a thickness approximately equal to the distance between rollers **14** and **16**.

Both rolls **14** and **16** have surfaces which are engraved or otherwise provided with depressions in accordance with the information to be printed on the web, in the manner shown in FIG. 2*a*.

FIG. 2*a* also shows the manner in which the coolant is introduced and extracted from chilling roll **16**. The pipes **18**, in addition to carrying the coolant, also form an axle for the roll. Each pipe is connected to a coupling-bearing assembly **23** which supports the roll and at the same time allows passage of coolant through tubes **25**, which remain stationary and do not rotate. The coolant, which may conveniently be ethylene glycol, is circulated through a refrigeration apparatus which closely controls its temperature before being re-introduced into the chilling roll. The roll is provided with a surface which has very high heat conductivity, and may conveniently be any suitable metal. The surface is preferably relatively thin to allow a large amount of heat to be transferred in a short time, thus maintaining the temperature at the surface of the chilling roll relatively constant and invariable.

The depressions **21** are filled during the course of the rotation of each roller with small particles of pigment fed through hoppers **22** and **24** to applicators **26** and **28**. Doctor blades **30** and **32** on each roller scrape off the excess pigment, allowing it to occupy only the depressions in the roll representative of information to be printed. The small particles of pigment may be either in dry powder form, or in a visco-elastic state as a thick suspension. In the latter case, the suspension may be formed in any liquid which will wet the rolls and be chemically compatible with the liquid web material.

The particles themselves are very finely divided solid matter, and are preferably of the order of a few microns in diameter. The particles are chemically compatible with the liquid web material and distinguishable therefrom by optical or magnetic characteristics and, preferably, of a material which does not dissolve in the hot liquid carrier. Many materials have these characteristics as, for example, finely divided iron or one of the oxides of iron, and any of these materials may be used.

As roller **14** receives the liquid web **12**, the liquid runs into the engraved portion of each roller and commingles with the solid pigment particles occupying those depressions.

The hot liquid is very fluid and easily runs around the particles of pigment, no matter how tightly they may be packed into the depressions, and completely surrounds them by wetting the roll around the depression. This effect may be greatly enhanced by selecting a material for the surfaces of the rolls **14** and **16** for which the liquid has great affinity, and readily wets. If nylon is used as the web material, the use of steel for the surfaces of the rolls will enhance this effect, because of hot nylon's great affinity for steel.

The liquid web does not solidify throughout its thickness immediately upon contact with roll **14**, although the

surface of the web next to the roll may be converted into the solid state. The outside surface remains in the liquid state until it encounters the chilling roll **16**. The liquid web is then converted into a solid state in a very short time, but not before it also has commingled with the solid pigment borne by the depressions in roll **16**. The solidified web emerges at **20**, in a solid state, with the solid particles borne by the engravings of both rolls cast into both its surfaces, thereby resulting in the finished product, shown in cross-section in FIGS. 2*b* and 2*c*.

It will be seen from FIG. 2*c* that the printed web comprises a base portion **31**, and raised portions **33** which contain the pigment particles embedded therein. The raised portions **33** are due to the casting effect of the web into the depressions in the rolls, and its solidification in that shape. The result of the casting of raised lines where the printed indicia represented by the pigment appear, is to increase the definition of the printed product. A "three-dimensional" effect is created in which the printed image has depth, as well as color and form.

The thickness of the base portion **31** of the printed product can be closely controlled by adjusting the extrusion speed of extruder **10**, the speed of rotation of rolls **14** and **16**, and the distance of the space between rolls **14** and **16**. The height of the raised portions **33** can be closely controlled by regulating the depth of the depressions formed in the rolls. Thus, by suitably forming the depressions in the rolls, the reproduction of paintings may be made more accurate by correctly depicting the third-dimensional effect created by the height of the brush strokes.

The definition attainable on the printed web is limited only by the size of the particles of pigment which are used, and the exactitude with which the depressions are formed in the rolls. The fineness of lines which may be accurately printed approaches the invisible.

FIG. 2*c* shows a transverse cross-sectional illustration of a cable which may be manufactured with the apparatus of FIG. 1. The cable is shown in two sections, a top section and an identical bottom section, each of which is provided with eight conductors **33** cast into their surfaces, four on each side of the base **31**. Each of the sections of the cable may be manufactured with the device of FIG. 1, with the depressions in rolls **14** and **16** forming circumferential grooves. Each of the grooves is filled with particles, as described, which are in this case electrically conductive, thus forming a cable section as shown.

The conducting particles making up the conductors of the cable form a continuous conductive path throughout the cable. However, to insure that such a conductive path exists, a high voltage is applied to the ends of each conductive portion in order to break down any insulating web material interrupting the conductive path. Alternatively, the entire cable is exposed to a high intensity magnetic field produced by an electromagnet fed by a high frequency alternating current. Eddy currents are produced in the conductive particles, in response to the magnetic field, and those currents raise the temperature of the particles. The magnetic field strength is sufficiently strong, and the resulting eddy currents are sufficiently large as to raise the temperature of the conductive particles above the melting point of the web. Any portion of the web material lying between the conductive particles is thus melted away, allowing the current path of the conductors to be completed.

The two steps of application of a high voltage and exposure to a magnetic field may conveniently be performed at the same time, thus insuring that the current carrying paths are completed.

The dimensions of rollers **14** and **16** are not critical for the casting of the particles into the web. They must, however, have a large enough diameter to accommodate the amount of information to be printed onto the web.

The temperature of roll **16** is maintained at a sufficiently low temperature by the coolant hereinbefore described to effect solidification of the liquid web almost instantly on contact. The temperature of roll **14**, on the other hand, may conveniently be at room temperature, and thus is shown in FIG. 1 as not having a pipe for insertion of coolant. At normal speeds of operation, the maintenance of roll **14** at room temperature will be sufficient to bring down the temperature of the liquid web to a semi-soft state whereby the lower temperature of roll **16** can best perform its function of simultaneously casting the pigment and solidifying the web. At greater speeds, however, it is necessary to also cool roll **14** in the same manner as has been described for roll **16**.

When nylon or other thermoplastic materials are used, the web material may be easily reclaimed from scrap, by the simple process of remelting. The pigment, being in the form of solid particles, will settle to the bottom of the reliquified web material, and may also be extracted by filtration. There is, therefore, no wastage involved in the process according to the invention.

An alternative form of apparatus for printing embodying the invention is shown in FIG. 3. In this figure, the liquid web is fed from a well **34** formed between two chilling rolls **36** and **38**, which are rotated together at the same peripheral speed. A thin film of the liquid web is solidified by the surface of each of the rolls **36** and **38** as the surfaces of those rolls pass through the well, thereby casting the particles into the surface of the web in the same manner as in FIG. 1. The two films of web, each of which is solidified on the roll side, but still hot and in its liquid state on the well side, proceeds around the rollers **36** and **38** and are squeezed together to form a single solid web into which the particles have been cast on or into both surfaces. This arrangement also produces the finished product of which FIGS. 2*b* and 2*c* are cross-sections.

In this embodiment, strands of cheap fiber-filling material may be used to reduce the cost of the printing by reducing the amount of web required to form a given final thickness. They are fed into hopper **35**, along with the liquid web which fills well **34**. The filler material is not forced into the depressions of the rolls, but remains in the body of the web, serving to strengthen it.

The well **34** of liquid web material is fed by a hopper **35** which maintains the well of hot web material at the correct level. This correct level is a function of the speed of the rolls **36** and **38**, and of the temperature of the liquid in the well. The hotter the material, the longer it will take to solidify a given thickness of it, thus necessitating a higher level to permit the cooling to be started earlier; and faster peripheral speeds of the rolls also make it necessary to raise the level to permit the proper cooling time.

These relationships also affect the final thickness of the printed product in the following manner. As a point on one of the rolls contacts the well by being rotated into it, a small amount of liquid runs into the depressions of the roll carrying the pigment, and immediately solidifies. As the roll continues to rotate, the chilling effect of the coolant will be felt farther into the well from the surface of the roll, and a progressively thicker film is solidified as that point travels through the well. The rate at which the thickness increases around the roll is dependent on the speed of the roll, and the temperatures of the liquid and the roll.

In both FIGS. 1 and 3, the solid particles comprising the pigment are applied to the rolls by applicators **26** and **28** which maintain the supply of particles, fed from hoppers **22** and **24**, at a suitable pressure, by means of a screw feed, for example. The pressure thus causes the pigment to fill the depressions in the rolls, and any excess pigment is removed by doctor blades **30** and **32**.

When the liquid web touches the rolls, it will completely occupy those depressions mingling around the solid particles. The detail of the printed representation attainable by the use of apparatus as shown in FIG. 3 is the same as that obtainable by the use of FIG. 1 apparatus,

described above. If only one side of the web is to be printed upon, only one of the rolls in FIGS. 1 and 3 need be provided with depressions.

Another embodiment of the invention employs the use of a web made liquid by solution in a highly volatile solvent. In that event, the apparatus of either FIG. 1 or FIG. 3 may be used, but instead of circulating a coolant through the rolls, a heated liquid will be used instead, causing the "chilling" rolls to maintain a very high temperature, sufficient to drive off the volatile solvent on contact. The pigment particles carried by the depressions in these rolls are cast into the web while it is in its dissolved state, and are retained in the surface of the web as it is simultaneously solidified by driving off the solvent.

The rolls in FIGS. 1 and 3 may be of the form shown in FIGS. *4a* and *4b*. The roll proper is made of an electrically conductive material **42** having a removable external shell **44** of non-conductive material. When the roll is engraved, or depressions are otherwise formed therein, the grooves thus produced extend through the thickness of the non-conductive material **44** thereby exposing the conductive roll material **42**. The pigment particles are held in the grooves by electrostatic forces produced by opposite electrical charges on the particles and on the conductive portion of the roll. This type roll is preferred when the rollers are rotating too fast to allow the normal force of gravity to overcome the inherent centrifugal force and hold the particles within the grooves. The brush **45** and slip ring **46** of FIG. 1 is connected to a positive source of potential **48** and permits a positive charge to be applied to the conductive portion of the surface of the roll, causing negatively charged particles to remain in the grooves, held there by electrostatic attraction. Of course, positively charged particles will require a negative charge on the roll material **42**.

The roll of FIG. *4a* may also be used to provide adherence of the particles by magnetic attraction. When the roller is thus used, the small solid particles are of the magnetically permeable material such as iron, nickel, and cobalt, or compounds of these elements. The outside channel is then composed of magnetically non-permeable material, whereas the roll proper is a material **42** in which a relatively strong magnetic field is set up, by either a permanent magnet or an electromagnet. The particles will tend to remain in those portions of the magnetic field in which the lines of flux are most highly concentrated, which, of course, are the grooves exposing the magnetic material.

FIG. *4b* shows a cross-sectional view of an alternative roll, which is composed uniformly of an electrically conductive or a magnetically permeable material, and which has a smooth surface without any engravings or other depressions formed therein. When this roll is used, the roll is caused to attract either electrically charged particles (by electrostatic attraction) or magnetically permeable particles (by magnetic attraction) in the same manner as the roll of FIG. *4a*. The particles thus attracted are caused to adhere to the surface of the roll at the place where they land, and there is, therefore, no shifting of position permitted of particles on the roll, and the particles are held in position in small "piles" **46**. When these particles are cast into the web, of course, no raised portions are formed, and the thickness of the web must be sufficient to accommodate these particles when they are cast into both sides of the web at the same point.

Some loss of definition of the printed web results from the use of rolls constructed as shown in FIG. *4b*, but the advantage in their use lies in the fact that no engraved surface need be provided on the roll. Thus preparatory steps need not be taken in the way of forming depressions, etc., to achieve the printing of the invention.

FIG. 5 illustrates apparatus embodying the invention in which it is possible to achieve the high quality image produced by the invention on the surface of web which is primarily composed of cheap, low quality paper. The paper **78** is fed from a paper supply (not shown), and passed between rolls **82** and **84**, which are of the same type as the chilling rolls hereinbefore described. Two wells, **86** and **88** are formed between the paper **78** and each of the rolls **82** and **84**. The wells contain the web surface, in liquid form, in the same manner as has been described in connection with FIG. 3. The operation of the apparatus is also the same as that of FIG. 3, with the exception that only a very thin film of web is allowed to solidify before the web reaches the nip between the rolls. The two solidified films of web, with their inside surfaces still liquid, are pressed together with the paper **78** between them. The paper **78** constitutes the supporting member of the finished web **92**, which is thus comprised primarily of inexpensive paper **78** but with high quality web surfaces **94** and **96**, into which the solid particles have been cast. This process produces the advantageous result of allowing high quality printing upon a web which is primarily of inexpensive material, and eliminates the necessity of providing high quality material throughout the entire web, or of providing a sufficiently thick surface portion to be self-supporting.

FIG. 6 illustrates apparatus embodying the invention in which the printing of the web is effected while it is in a semi-soft state. Extruder **10** extrudes the liquid web material onto a roll **14**. These elements are identical to the similarly numbered elements shown in FIG. 1. The roll **14** is uncooled for normal printing speeds, and the resulting web falling off roll **14** is in a semi-soft state, not yet completely solidified. The web falls between rolls **93** and **95** which are provided with depressions filled with pigment particles by applicators **97** and **99**, respectively, and excess pigment is removed by doctor blades **101** and **103**. Rolls **93** and **95** are also at room temperature and are rotated together at the same peripheral speed, thereby casting the pigment carried in the depressions into the surface of the web.

Even though rolls **93** and **95** are not chilled, they tend to lower the temperature of the semi-soft web, and the web is also cooled by its passage through the air. The speed of the semi-soft web is so fast, however, that a negligible amount of heat transfer takes place, and the web emerges at **105**, after having successively passed through three additional similar pairs of rolls, still in a semi-soft state. The web then passes through chilling rolls **107** and **109**, which are cooled in the manner hereinbefore described, so as to transform the web into its solid state.

Each of the pairs of printing rolls have depressions filled with particles of pigment, and the depressions in each set correspond to color separations of the information to be printed. The particles cast into the surface of the web by each set of rolls are of the color corresponding to the color separation represented by the depressions in the roll. The resultant web is therefore printed in four colors in accordance with the information to be printed, as for example, a picture.

For very slow speeds of operation, where there is considerable cooling of the semi-soft web before it reaches the chilling rolls **107** and **109**, each of the rolls in each set may be heated by passing a heated fluid through the inside of the roll, in the same manner as chilling rolls are cooled. The temperature of the web may thus be maintained in its semi-soft state until it reaches chilling rolls **107** and **109**. The particular temperature at which this semi-soft state is achieved is not critical and may be any temperature at which the liquid web enters the depressions of the rolls and the pigment particles are fully cast into the web surface. The correct temperature is in the vicinity of 430° F. when nylon is used as the web material.

FIG. 7 illustrates apparatus embodying the invention which is adapted for the cheap and efficient production of unrecorded magnetic tape. Rolls **98** and **100** are of the same form as those described in connection with FIGS.

1 and 3, except that the depressions therein take the form of circumferential grooves **102**. Above the place of intersection of each of the sets of grooves **102** of the two rolls **98** and **100**, is a nozzle **104** for supplying liquid web to a well formed between the two rolls. Third and fourth rolls **106** and **107'**, which each correspond to a selenium cylinder, are provided adjacent to rolls **98** and **100**. Rolls **106** and **107'** carry electrostatically charged particles by means of an electrostatic attraction. The particles fill the grooves **102** in rolls **98** and **100**, and are cast into the ribbons of webs **108** which emerge from between the two rolls **98** and **100**. The result is that each of the ribbons **108** has cast into both of its surfaces a uniform distribution of magnetically permeable particles and is therefore suitable for use as reversible magnetic tape. The advantage of this method of manufacture is its speed and uniformity of completed product.

This apparatus may be combined with the apparatus illustrated in FIG. 5 in order to produce paper having several stripes of magnetizable material bonded to its surface. Such paper is useful in business machines of various kinds in which it is desired to magnetically record data written on the paper, to enable automatic reading of that data.

FIG. 8 is an illustration of the apparatus embodying the invention which may be used if discontinuous sheets of printed web are desired. A flat plate **122** is provided with depressions **124** in accordance with the image desired to be produced and is reciprocated in the direction of arrows **126**. The liquid web is extruded from extruder **10** during the time that plate **122** is passing under it, and the liquid web **128** lying on the plate is carried forward to chilling roll **130**. Roll **130** may also be provided with depressions representative of an image desired to be printed on the opposite side of the web. The depressions on both the plate **122** and the roll **130** are filled with particles of pigment which are than cast into the surface of the web **128** as it solidifies. The particles may be applied to the engraved portions of roller **130** and held thereon either magnetically or electrostatically in the manner previously described, the excess being wiped off with a doctor blade **132**. Particles may similarly be applied to the engraved portions of plate **122** and the excess removed with a similar doctor blade. With this process, it is not necessary to provide any electrostatic or magnetic means for making the particles adhere to plate **122**, since gravity is sufficient.

It will therefore be seen that the invention shown and described herein satisfies the objects hereinbefore set out by providing methods and apparatus for producing extremely fine detail of printed indicia, which detail may be enhanced by the fact that the lines making up the indicia and containing the particles of pigment are raised above the surface of the web.

It can also be appreciated that the printed result is considerably more permanent in form than is paper, since the web may be composed of a very hard and durable plastic such as nylon. The speed of production of the printed articles is also extremely high because of the nature of the web in solidifying almost immediately upon contact with the chilling rollers.

It is evident that the product of the present invention has a high degree of resistance to abrasion and tearing and that the indicia printed thereon is highly resistant to being smudged, marred, or otherwise obliterated.

Having thus described certain exemplary embodiments of my invention, what I desire to claim is:

1. A method of producing an article having a pattern of predetermined configuration arranged therein, comprising the steps of

applying finely divided, solid particles to preselected portions only of at least one face of a base material while said base material is in a moldable state, said preselected portions of said base material defining the said pattern,

causing said base material to completely enclose said particles,

and thereafter solidifying said base material while maintaining the enclosed particles in said pattern,

whereby said particles are held in said pattern by said base material.

2. A method as set forth in claim **1** wherein said particles are applied to selected portions of said base material and are enclosed by said base material by the steps of

placing said particles in a cavity in a mold member having a surface more wettable by said base material than by said particles, and thereafter

supplying said base material in liquid form to said cavity,

whereby said base material flows around said particles as it follows the surfaces of said cavity.

3. A method as set forth in claim **2** wherein said particles are electrically conductive and said base material is an electrical insulator.

4. A printing process for casting a plastic sheet having a predetermined pattern of finely divided solid particles embossed thereon, comprising the steps of

providing a mold having depressions on one face thereof in the shape of said predetermined pattern,

at least partially filling said depressions with said finely divided solid particles,

thereafter covering said one face of said mold with a thin layer of fluid plastic material in which said particles are insoluble such that said fluid flows into said depressions and commingles with said particles while said particles remain in said depressions,

then causing said plastic material to set while maintaining said particles in said depressions to bind said particles together and to said plastic material, and

then removing said plastic material and said particles from said mold,

thereby to provide a plastic sheet on one surface of which said particles are embossed in said predetermined pattern.

5. A printing process as set forth in claim **4** wherein said particles are pigment having a color different from that of said plastic material.

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