

Sept. 2, 1969

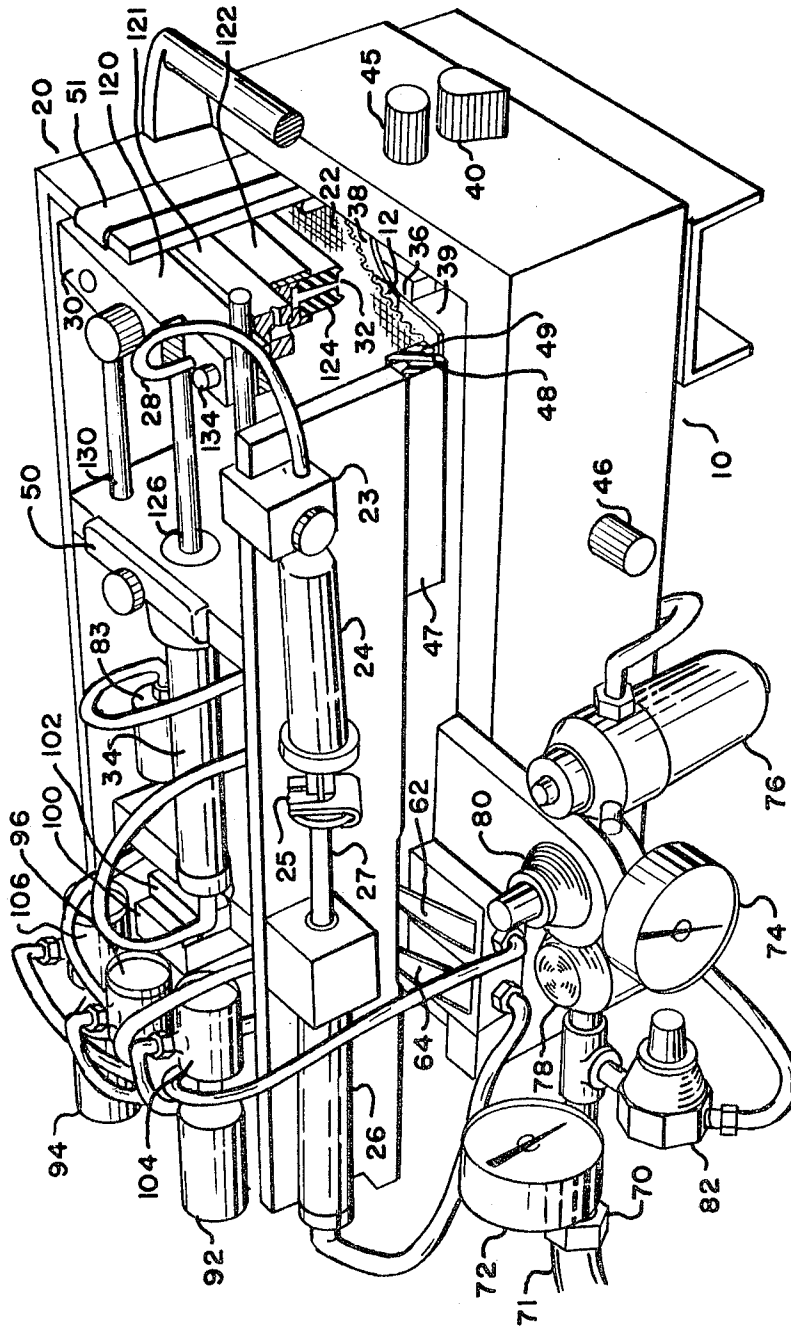
E. G. DE HART ET AL
CIRCUIT SCREENING MACHINE

3,464,351

Filed June 23, 1966

4 Sheets-Sheet 1

FIG. 1



INVENTORS

Edward G. De Hart
Daniel H.O. Froehling

Sept. 2, 1969

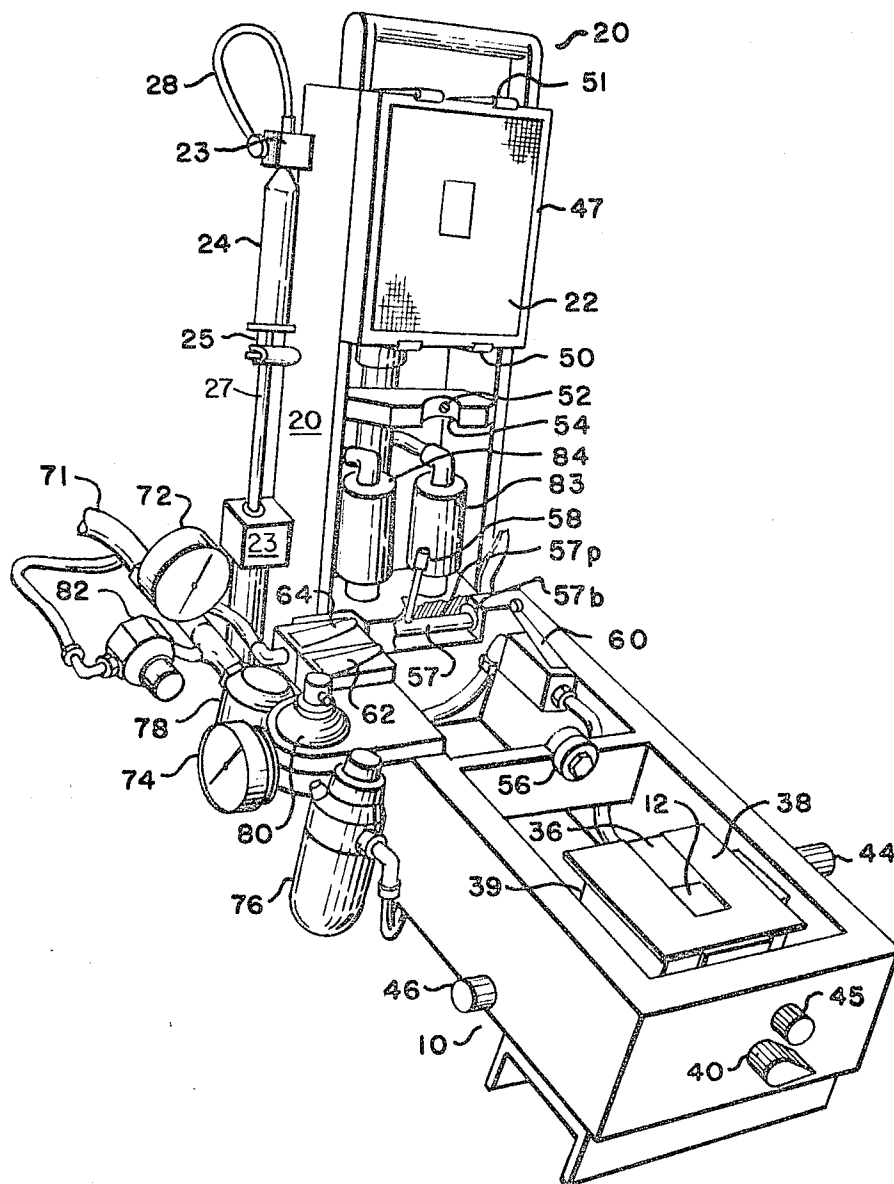
E. G. DE HART ET AL
CIRCUIT SCREENING MACHINE

3,464,351

Filed June 23, 1966

4 Sheets-Sheet 2

FIG. 2



INVENTORS

Edward A. De Hart
Dickes H.O. Trueschling

Sept. 2, 1969

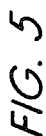
E. G. DE HART ETAL

3,464,351

CIRCUIT SCREENING MACHINE

Filed June 23, 1966

4 Sheets-Sheet 3



INVENTORS
EDWARD G. DEHART
DIETER K.O. FROEHLING

Tarzan and Santa
ATTORNEYS

Sept. 2, 1969

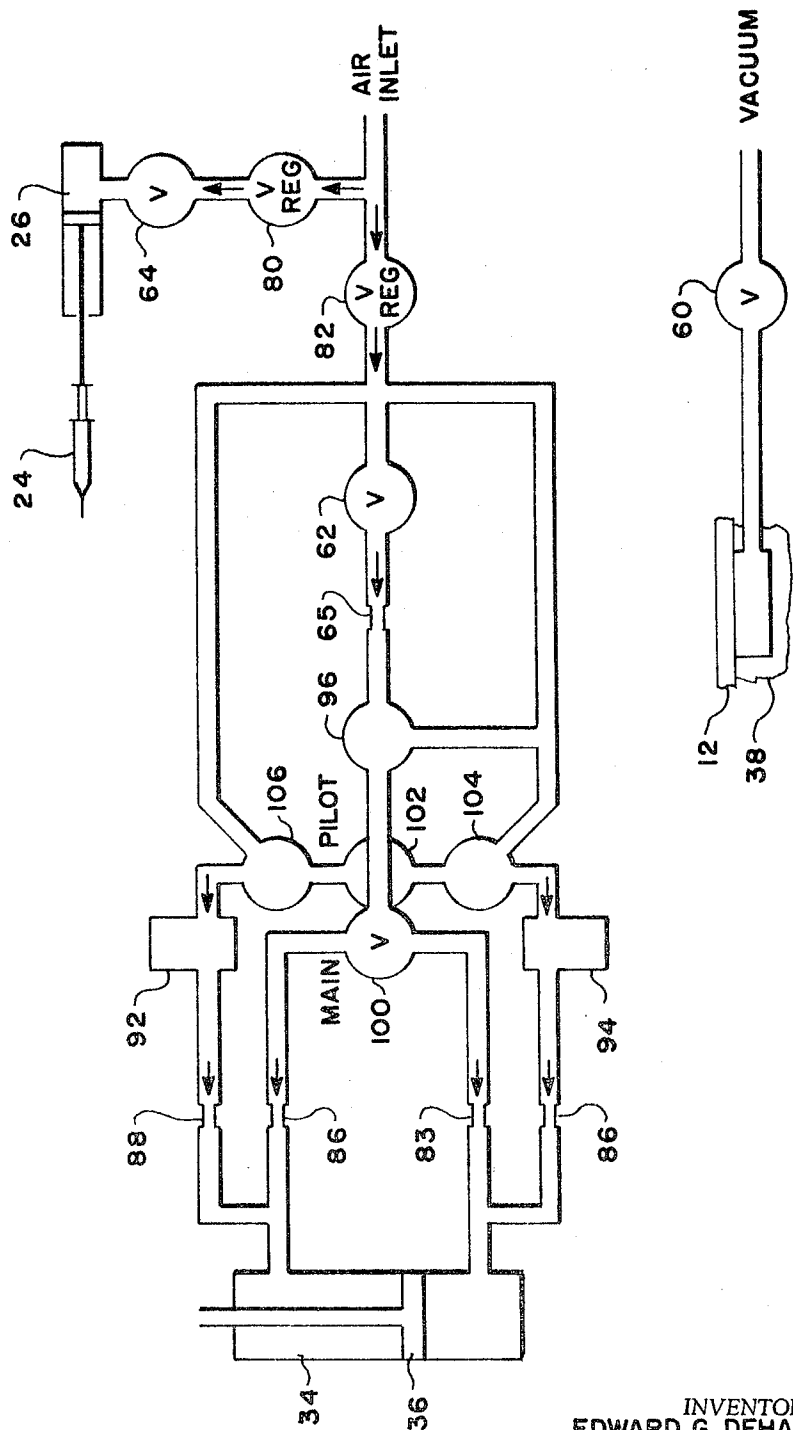
E. G. DE HART ET AL
CIRCUIT SCREENING MACHINE

3,464,351

Filed June 23, 1966

4 Sheets-Sheet 4

FIG. 6



INVENTORS
EDWARD G. DEHART
DIETER K. Q. FROELING
BY *Jack Larsen*
ATTORNEY

1

3,464,351

CIRCUIT SCREENING MACHINE

Edward G. De Hart, 100 Memorial Drive, Cambridge,
Mass. 02142, and Dieter K. O. Froehling, Burlington,
Mass. 01803

Filed June 23, 1966, Ser. No. 559,975

Int. Cl. B41f 15/44

U.S. Cl. 101-126

14 Claims

ABSTRACT OF THE DISCLOSURE

A semi-automatic machine for screening patterns of conducting ink on small ceramic substrate for the electronic industry is shown. Substrates **12** are placed one at a time into printing position by hand. A pivotally mounted printer **20** is then depressed to bring the screen **22** in printing register with the substrate. Lowering the printer initiates the automatic printing cycle. Vacuum is applied to hold the substrate in place; force is applied to a syringe piston **25** to dispense special inks or pastes between the wipers **152** of a double-edged squeegee blade **124**. Numerous adjustments are provided to afford accurate registry between substrates and screen and to adjust screen spacing and tilt, and the amount by which the squeegee depresses the screen. The two squeegee wipers only about $\frac{1}{8}$ inch deep, separated by about $\frac{1}{4}$ inch, and both part of the same block of neoprene are clamped at the same height above the substrate and unlike windshield wipers, rock only imperceptibly as a pneumatic cylinder **34** drives the squeegee back and forth over the screen to print. To facilitate change of job, ink, syringe, ink hose **28**, squeegee-blade holder **122** and screens, all the parts in contact with ink are arranged to be quickly removed and replaced without tools. All of the automatic functions are pneumatic; none are electric.

This invention relates to the graphic arts. More particularly it relates to improvements in silk-screen type printers for depositing multiple-layer patterns to be fused to ceramic substrates or the like. The successive layers may be of different colors deposited for artistic ends; but the preferred utility of the invention is for the laying down of successive electrically differentiated layers for the production of so called thick-film electronic modules.

The production of such circuits has much in common with the production of colored enamel art work. In color printing, the successive layers have different colors. In thick-film circuit printing, the successive layers have different electrical properties, differing in conductivity, dielectric, and magnetic properties. After each layer is printed on a substrate, it is fired in an oven to form a permanent, electrically stable, adherent film; then the printed substrate is returned to the printer for application of a further layer. The thick-film printed circuit process is adapted to the mass production of circuits. It is desirable in this art to produce circuits which are minimum in size and have a minimum variation in electrical properties from circuit to circuit. To achieve these ends it is necessary that successive layers be uniformly deposited in accurate registry each with the next. In the silk-screen process the images for the successive layers are reproduced first on photographic film in the desired size of a photo chemical process. This image is transferred to the screen with an adherent film blocking the

2

pores of the screen in unexposed areas and washed out in exposed areas thereby permitting the screen to pass an appropriate ink or paste. It will be clear then that accurate registries between screens and the photographic image, between the screen and the printing mechanism and between each substrate and the printing mechanism must all be assured if successive prints are to be substantially identical. It is also desirable that a machine to print such circuits be simple to operate, use a minimum of printing materials (since silver, gold and platinum are common constituents of the circuit materials) and that it be simple and inexpensive. Prior-art devices for the screening of such patterns have been deficient in one or more of the desired properties, and accordingly the objects of the present invention are to overcome at once each of these deficiencies and to achieve unprecedented uniformity and registration in the printing of ceramic substrates in an inexpensive machine which is simple and reliable in its operation. Other objects of the invention will in part be obvious and will in part appear hereinafter.

A feature of the invention by which those objects are achieved is a mechanism for supporting the substrates which utilizes vacuum and magnetic holding of the substrates. Another feature of the invention is the use of micrometer screws for adjustment of the registry of the substrates. Another feature is the automatic application of the holding vacuum when the screen is pressed to a substrate. Yet another feature is the wholly pneumatic automatic operation of the machine. A still further feature is the automatic dispensing of the screening paste from disposable syringes of the kind used medically for hypodermic injections. A further feature is a novel double-bladed squeegee and yet the other feature is a squeegee structure which is both readily replaced and easily cleaned. The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts, which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

For fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a partially-sectioned view of the invention in position for screening a substrate,

FIG. 2 is a view of the machine open position for loading a substrate,

FIG. 3 is a further view of the chuck partially shown in FIG. 2,

FIG. 4 is an exploded view of the squeegee part of FIG. 1,

FIG. 5 is a perspective view of an accessory used in preparing screens for the machine and,

FIG. 6 is a schematic diagram of the pneumatic system of the machine.

The machine comprises a bed **10** which is provided with accurately adjustable means for holding and positioning a ceramic substrate **12**, and a printer **20** which is hinged to the end of the bed **10** and holds a printing screen **22**. The printer is raised to unload a printed substrate from the bed or to insert a new substrate for printing. Lowered into its printing position, the printer adjustably seating against a stop, holds the screen over the substrate in optimum position for printing while printing paste is pressed through a permeable pattern in

the screen. A supply of paste is detachably fixed to the printer 20 by a clamp 23 and contained in the syringe cylinder 24 and is expelled by force against the piston 25 of the ram 27 of the syringe by the pneumatic actuator 26 through the hose 28 into a chamber 29 in squeegee assembly 30 whence it is discharged through channels 32 against the top of the screen 22. The squeegee assembly 30 is automatically carried backwards and forwards by pneumatic cylinder 34 thereby transferring a thin uniform layer of the paste onto the substrate in a pattern determined by an image previously formed on the screen 22. As more fully shown in FIG. 2 the substrate, which is typically postage stamp size and .010 to .060 inch thick is placed by the operator in a corner of a shallow groove 36 in a holding plate 38. The depth of the groove is .003 to .005 inch less than the wafer thickness. The holding plate 38 is made of mild steel and is in turn supported from below by a permanent magnet chuck 39, the operating handle 40 of which the chuck extends from the front end of the base 10. The pole faces 41, FIG. 3, of the magnetic chuck are modified by a vacuum chamber 42 which communicates with the substrate 12 by small holes (covered) through the bottom of the groove 36 in the base plate 38 whereby the vacuum holds the substrate in position against the base plate. The base plate in turn may be positioned by turning the handle 40 to a partial release condition and the plate advanced to the left by micrometer screw 44 and backward by micrometer 45. A third micrometer screw 46 rotates the plate. When the plate is positioned it is held firmly by turning the handle 40 to the "hold" position where full holding force is applied to the plate 38. The screen 22 is stretched and supported on a molded plastic frame 47 by pressing tubes 48 into the peripheral grooves 49. The frame is indexed to the printer by two pins (not shown) and held into position by clamps 50 and 51. The printer 20 is hinged at the back and may be lowered until the screen 22 makes contact with the substrate 12. The pressure of the screen against the substrate is controlled by a screw 52 which is near the top of the striker-notch 54. The large cylindrical surface of the stop 56 guides it into the notch 54 as the printer is lowered. The off-center position of screw 52 loads the printer to one side, and eliminates any play due to the necessary looseness of the hinge pin in the base. The hinge pin 57 is journaled in the back ends of both the base 10 and the printer 20, the journal portions 57b and 57p in base and printer are however, eccentric, whereby rotation of the hinge-pin by a handle 58 effects a smooth adjustment of the elevation of the back of the printer with respect to the base. Adjustment of the hinge pin in combination with the screw 52 permits both the spacing and the parallelism of the screen 22 relative to the substrate 12 to be adjusted.

The screening process is initiated when the printer 20 is lowered to the base 10. In addition to FIGS. 1 and 2 reference should be made to FIG. 6 for functional relationships of pneumatic parts of which resistances 65, 86, and 88 are not shown in FIGS. 1 and 2. Lowering the printer 20 actuates the push-button valves 60, 62, and 64. First to be actuated is the valve 60 which applies the vacuum to the mounting plate 38. The valves 64 and 62 apply air pressure respectively to the actuator 26 and through resistance 65 to valve 96 respectively. Other pneumatic elements include the quick-disconnect fitting 70 for the air supply line 71, pressure gauges 72 and 74, filters 76 and 78, constant output pressure regulators 80 and 82, resistances 83, 84, 86 and 88, accumulators 92 and 94, main pressure control valve 96, the main control valve 100, the pilot valve 102, and a pair of pressure control valves 104, 106 mounted on the two accumulators 92 and 94. Detailed functioning of pneumatic parts is described below.

FIG. 3 shows the magnetic chuck 39 of which only a glimpse is shown in FIG. 1. Permanent magnetic chucks

have become a standard item in commerce since the invention of the "Alnico" permanent magnetic materials.

These chucks include rotating parts which interrupt or shunt the magnetic circuit to change the holding force. The chuck shown in FIG. 3 is a simple form of such a chuck with but one pair of external poles 41 separated by brass spacer 108. The chuck is modified by milling a wide groove 42 across the holding face. This groove is closed at the ends by brass plates 109 and 110. The plate 109 has a vacuum attachment 111.

The plate 38 is supported around its edges by the plates 109 and 110 and the undisturbed edges of the poles 41.

The chuck is fastened to a base plate 112 which turns on a pivot 113. Hinged to the base plate are shoes 114 and 115 which at their upper ends bear against edges of the plate 38 and are positioned by screws 44 and 45. These shoes prevent rotation of the plate 38 by the screws 44 and 45. Rotation is provided by the screw 46.

Referring now to FIG. 4 showing details of the sections and of the parts 120, 121, 122 and 124, also shown in FIG. 1, which are, respectively, a slide 120, a body 121, a holder 122, and a blade 124, all of which comprise the squeegee assembly 30.

The slide 120 is connected to the end of the ram 126 by a fitting 127 and slides parallel to the screen 22 on rods 130 and 132 supported on ball bushings 133. The body 121 is linked to the slide 120 by two rods 134 and 136 which are at their lower ends pierced and fastened to the body by pins 137 and which at their upper ends pass through the slide 120 perpendicular to the screen 22 under the control of a micrometer screw 140 which is threaded into the slide 120, is turned by a knob 141, and carries the body 121 on a washer 142 and pin 143.

The blade 124, preferably molded of neoprene elastomer, is clamped in the holder 122 by screws 144. The holder 122 is held solely by friction and readily removed.

Two parallel pins 145 (one not shown) are pressed permanently into the top of holder 122 and mate with sockets 146. Holding friction against the pins 145 in the sockets 146 is provided by bearing balls 148, springs 149, and set screws 150. Detent grooves in the pins 145 have not been found to be necessary.

When the holder 122 is pulled free from the body 121, the hose 28 may be slipped off an angle fitting 151 by which it is connected to the holder 122 and the chamber 29 therein.

The chamber 29 opens against the top of the blade 124. Ink leaves the chamber through one or more holes 32 in the blade which pass through the blade top to bottom between a pair of integral spaced wiper portions 152 which extend downward from the main block of the squeegee from $\frac{1}{8}$ inch to $\frac{1}{16}$ inch, and are approximately $\frac{1}{4}$ inch apart, thus forming a channel 153 between the wipers which receives the paste which is to be wiped through the screen by action of the squeegee. Ribs 154 close off the ends of the channel to prevent loss of paste, and the blades are produced in various lengths. A blade is selected for use with a particular substrate to have sufficient length to cover the substrate but not to be so long as to waste valuable pastes.

The printing process is a modification of the well-known silk-screen process except that here a stainless steel screen of fine mesh is preferred. The desired pattern is printed by forcing through the fine screen as much of the paste as required to provide the predetermined properties. The screen stencil has apertures defining the pattern; and the paste is forced through these apertures by the pressure applied to the paste by the piston 25 and by the increased pressure which is developed under the trailing wiper as the blade moves in a longitudinal direction substantially perpendicular to the transverse line of contact between the wipers and the screen. As the blade is driven from the foot of the impression backward to the head of the impression, it is the frontmost of the wipers 152 that prints while it is the rearmost wiper that

is most effective when a print is made by a forward motion of the squeegee. When the seal between the stencil and the wipers is imperfect, some small film of paste may remain on top of the screen after the blade has made a backward stroke, for example. On the subsequent forward stroke, a portion of this film is pressed through the screen by the forwardmost wiper which leads when motion is frontward. The rods 130 and 132, fixed parallel to the screen, the ball bushings 133, the interconnections, of slide 120, body 121, and holder 122, and the proportions of the blade 124, all constrain the wipers 152 to move forward and backward in contact with the screen without substantial tilt about lateral axis transverse to their direction of motion. Circuits are made by laying down successive layers of different pastes. The desired patterns are initially prepared as large black and white patterns by drafting processes. They are photographically reduced onto a sticky film which is transferred to the screens. The film is washed out at unexposed places leaving the screen to be penetrated at those points by the paste. To facilitate registry between the developed film and the screen, the fixture shown in FIG. 5 is employed. The fixture is in two parts: a film holder 400 and a screen holder 410 hinged together by a hinge 412. Mounted in the aperture of the film holder is a glass plate 421 having index marks, 422 and 424. A film is mounted to the glass plate with the index marks of the plate made to overlay lines inscribed on the pattern by the draftsman at the time he prepares it. The screen in turn is indexed to the screen holder 410 by pins 430 and 432 which are of the same kind and spacing as the pins which index the screen to the printer. A film and screen thus each indexed to the fixture, are brought into accurate union by hinged them together.

FIG. 6 is a schematic diagram helpful in explaining the operation of the pneumatic system. As the cover is closed the valve 60 is opened thereby applying vacuum to the base plate 38. As the printer is lowered slightly further, valves 64 and 62 are opened, valve 64 admits air pressure to the cylinder 26 which presses against the syringe 24 expelling paste into the squeegee. The opening of the valve 62 admits pressure to the main pressure operated valve 96 which in turn admits pressure to the pilot valve 102 and the main air valve 100. Each of these has two positions. In one position of valve 100 the piston of the cylinder 34 moves to the left and the other is to move to the right. Assuming that the air pressure is applied to the pilot valve 102 by the operation of the valve 96 and that the valve 102 and 100 positions are to drive the piston 36 to the right by air passing through the resistance 83, air continues to flow and the piston continues to move to the right until it reaches the end of the cylinder. Timed to follow immediately, the pressure in the reservoir 94, filling through the resistance 86, reaches the trigger point of the valve 104. At that time, the pilot valve 102 is driven to the right shutting off the air to the resistance 83 and passing air through resistance 84 thereby reversing the direction of piston 36 until, at the end of the stroke, the pressure in reservoir 92 rises, under a control of the resistance 88, to the trigger point of the valve 106, at which point the pilot valve is driven back to the opposite side and the direction is again reversed. Thus the piston 36 moves backward and forward at a speed depending on the resistances 83 and 84 and applied air pressure.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained, and since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all the generic and specific features of

the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described our invention, what we claim as new and desire to secure by Letters Patent is:

1. In a screening machine for printing circuit patterns for thick-film circuits comprising a bed for holding successive substrates to be printed and a printer for holding a screen stencil and a paste delivering system for pressing impression paste through apertures in said stencil distributed laterally and longitudinally to define a circuit pattern on each of said substrates, said machine having an open position wherein said stencil is separated from said bed for loading said substrates and a closed position for printing, wherein said bed has provisions for holding each of said substrates accurately indexed relative to said bed, wherein said printer has indexing means to maintain said stencil in position on said printer, said machine having stop means for maintaining in said closed position, said closed position, said printer in fixed registry with said bed, and wherein said delivering system comprises a source of said paste, a squeegee having a laterally extending blade, and guide means for constraining said blade to longitudinal wiping motion substantially parallel to said stencil, motor means for moving said blade over said stencil, means including a conduit for delivering said paste from said source to said blade, and means for regulating the flow of said paste through said conduit, the improvement characterized in that:

- (a) said squeegee comprises,
 - (i) a slide portion,
 - (ii) a squeegee blade holder, said holder being rigidly and detachably connected to said slide, and
 - (iii) a pair of ribs extending longitudinally and at the ends of said blade,
- (b) said blade
 - (i) is of compliant elastomeric composition, and
 - (ii) has a pair of similar downwardly protruding, generally parallel and, symmetrically spaced-apart wipers extending laterally to span said pattern,
- (c) said ribs join the ends of said wipers, extending downwardly with said wipers a like distance to a plane,
- (d) said ribs and wipers being adapted at their lower extremities to engage said stencil and to bound with said stencil a paste-receiving channel connected to said conduit, and
- (e) said guide means substantially restrain said blade from rotation about an axis transverse to said motion.

2. The improvement as defined by claim 1 wherein

- (a) said delivering system comprises a supply of compressed gas, a first regulator for delivering said gas from said supply at a first predetermined pressure, and means for utilizing said first pressure to exert constant pressure upon said paste in said source, and
- (b) said motor means comprises a second regulator for delivering said gas from said supply at a second predetermined pressure, a pneumatic motor having a ram connected to said squeegee, and pressure-operated valves to apply said gas at said second pressure to control back-and-forth motion of said ram.

3. Apparatus as defined by claim 1 wherein

- (a) said source is a syringe containing said paste having a cylinder, and a piston for expelling said paste through said conduit
- (b) said delivering system comprises an actuator means having a first ram for engaging and driving said piston and a first regulator for controlling said motor to regulate the amount of paste expelled for each substrate,

- (c) said motor means comprise a second regulator to control back and forth motion of said second ram, and
- (d) said machine having control means to operate said provisions and motors in concert.
4. In a screening printer wherein a pattern is printed on an object by forcing a screening paste onto said object through apertures in a stencil which apertures are distributed laterally and longitudinally to define said pattern, a system for dispensing said paste comprising,
- (1) a squeegee comprising a squeegee blade holder, and a squeegee blade,
 - (2) a source of said paste,
 - (3) a conduit,
 - (4) wherein said blade
 - (a) is of compliant elastomeric composition,
 - (b) has a pair of similar downwardly protruding, generally parallel and, symmetrically spaced apart wipers extending laterally to span said pattern and
 - (c) joining the ends of said wipers a pair of downwardly protruding ribs,
 - (d) said ribs and wipers extending downwardly a like distance to a plane,
 - (e) said ribs and wipers being adapted at their lower extremities to engage said stencil and to bound with said stencil a paste-receiving channel,
 - (f) said channel being connected by a hole through said blade to said conduit
 - (5) means for connecting said conduit to said source and to said hole to enable paste to flow from said source to said channel, and
 - (6) means for fixing said blade to said holder.
5. A system as defined by claim 4 comprising
- (7) means for delivering said paste from said source through said conduit to said channel at a controlled rate,
 - (8) motor means for wiping said blade across said apertures at a controlled speed to press said paste through said stencil, and
 - (9) guiding means to restrain said blade from rotation about a lateral axis.
6. A system as defined by claim 5,
- (10) wherein
- (a) said delivering means comprise a supply of compressed gas, a first regulator for delivering said gas from said supply at a first predetermined pressure, and means for utilizing said first pressure to exert constant pressure upon said paste in said source,
 - (b) said motor means comprise a second regulator for delivering said gas from said supply at a second predetermined pressure, a pneumatic motor having a ram connected to said squeegee, and pressure-operated valve means to apply said gas at said second pressure to control longitudinal motion of said ram, and
- (11) comprising control means to apply said first and second pressures in synchronism.
7. A system as defined by claim 5
- (10) wherein
- (a) said conduit comprises a flexible hose,
 - (b) said means for connecting comprise a fitting for said hose,
 - (c) said holder has parallel pins projecting from its top, and a chamber at its bottom open to said hole and receiving said fitting, and
 - (d) said guiding means comprise, a pair of parallel rods fixed to said printer and extending longitudinally, a slide having bushings to guide its motion on said rods parallel to said stencil, a body having sockets in the lower face thereof to receive said pins, and, extending upwardly,

- a second pair of parallel rods slideably interconnecting said blade and said body.
8. A system as defined by claim 6
- (11) wherein
- (a) said conduit comprises a flexible hose,
 - (b) said means for connecting comprise a fitting for said hose,
 - (c) said holder has parallel pins projecting from its top, and a chamber at its bottom open to said hole and receiving said fitting, and
 - (d) said guiding means comprise, a pair of parallel rods fixed to said printer and extending longitudinally, a slide having bushings to guide its motion on said rods parallel to said stencil, a body having sockets in the lower face thereof to receive said pins, and, extending upwardly, a second pair of parallel rods slideably interconnecting said slide and said body.
9. A system as defined by claim 4 comprising
- (7) means for applying pressure to said paste in said channel,
- (8) motor means for wiping said blade across said apertures at a controlled speed to press said paste through said stencil, and
- (9) guiding means to restrain said blade from rotation about a lateral axis and to press said ribs and wipers against said stencil to prevent loss of paste.
10. A system as defined by claim 9
- (10) wherein
- (a) said conduit comprises a flexible hose,
 - (b) said means for connecting comprise a fitting for said hose,
 - (c) said fitting is fitted to said holder, and
 - (d) said guiding means comprise a slide, and a body, said slide being connected to said printer by structure to enable motion of said slide in the longitudinal direction of said pattern on said stencil; but to restrain said slide from translation along, and rotation about a lateral axis, said body being slideably interconnected with said holder by a pair of parallel pins, and slideably interconnected to said slide by a pair of upwardly extending parallel rods, said rods fitting pairs of parallel holes in said slide and body.
11. A system as defined by claim 9
- (10) wherein
- (a) said source is a syringe having a piston, and
 - (b) said pressure applying means comprise an actuator fastened to said piston to press against said piston with a predetermined force.
12. A system as defined by claim 11
- (11) wherein
- (a) said source is a syringe having a piston, and connected to said hose, and
 - (b) said pressure applying means comprise an actuator engaging said piston to press said piston into said syringe with a predetermined force.
13. A system as defined by claim 12
- (11) wherein
- (a) said applying means comprise a source of compressed gas, a first regulator for delivering said gas from said supply at a first predetermined pressure,
 - (b) said actuator is a first pneumatic controlled by said regulator to apply said force proportional to said first predetermined pressure,
 - (c) said motor means comprise a second regulator for delivering said gas from said supply at a predetermined pressure, a second pneumatic motor, and pressure-operated valve means to apply said second pressure to control said wiping, and
- (12) comprising control means to apply said first and second pressures in synchronism.

14. A system as defined by claim 13

(12) wherein

- (a) said applying means comprise a source of compressed gas, a first regulator for delivering said gas from said supply at a first predetermined pressure, 5
- (b) said actuator is a pneumatic actuator controlled by said regulator to apply said force proportion to said first pressure,
- (c) said motor means comprise a second regulator 10 from delivering said gas from said supply at a second predetermined pressure, a second pneumatic motor having a ram connected to said

slide, and pressure-operated valve means to apply said gas at said second pressure to control motion of said ram, and

- (13) comprising control means to apply said first and second pressures in synchronism.

References Cited

UNITED STATES PATENTS

2,997,948	8/1961	Scheeler et. al.	101—126
3,001,786	9/1961	Carrozza et al.	101—126

WILLIAM B. PENN, Primary Examiner