Dec. 31, 1968 R. C. BENTON 3,419,446

METHOD AND MEANS FOR CONTINUOUS CONTROL OF ETCHING RATE

Filed Feb. 15, 1965 Sheet 1 of 3

FIG. 1.

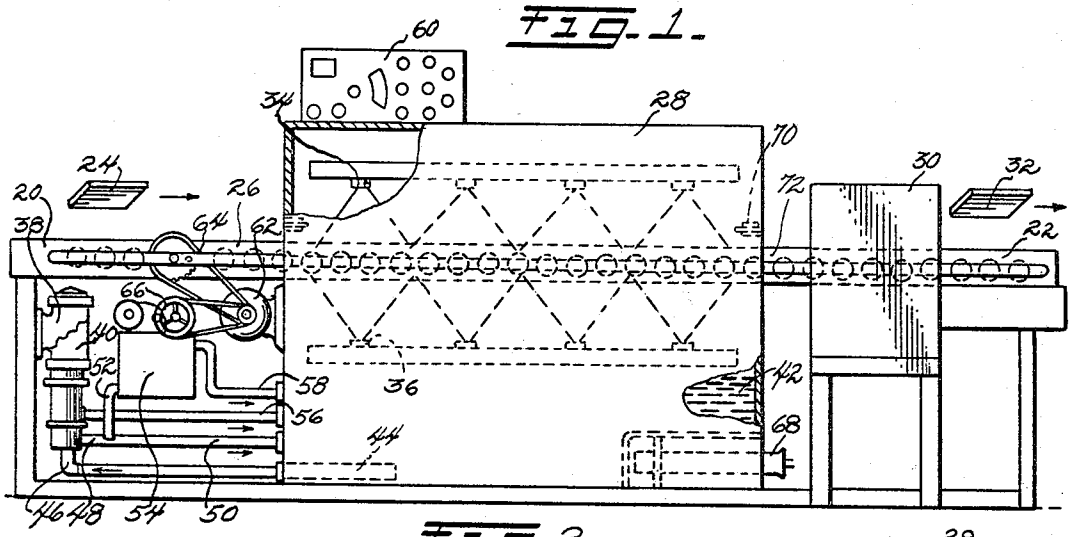


FIG. 2.

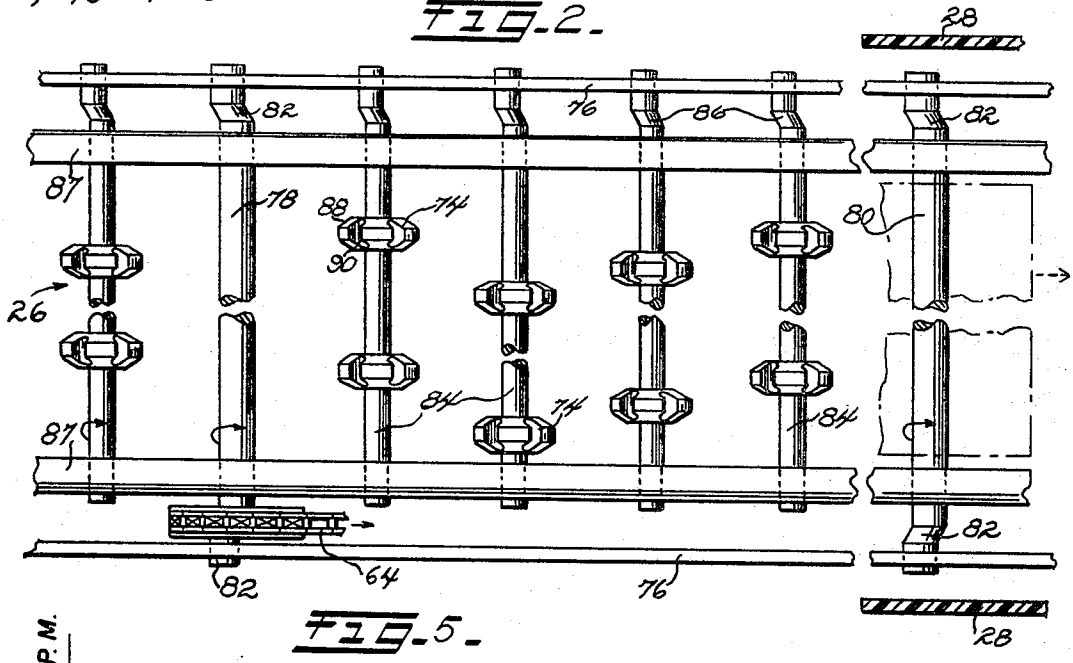
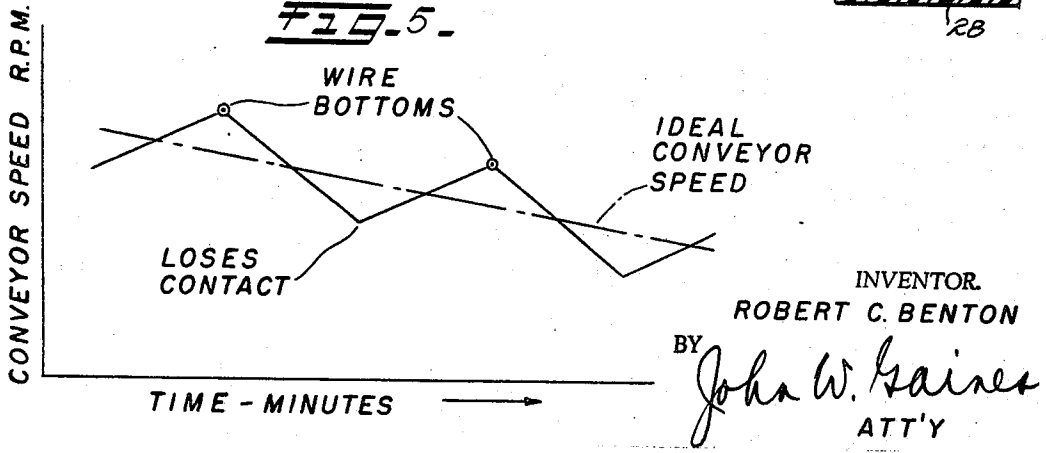


FIG. 5.



INVENTOR.
ROBERT C. BENTON
BY John W. Gaines
ATT'Y

Dec. 31, 1968 R. C. BENTON 3,419,446

METHOD AND MEANS FOR CONTINUOUS CONTROL OF ETCHING RATE

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Fig. 3.

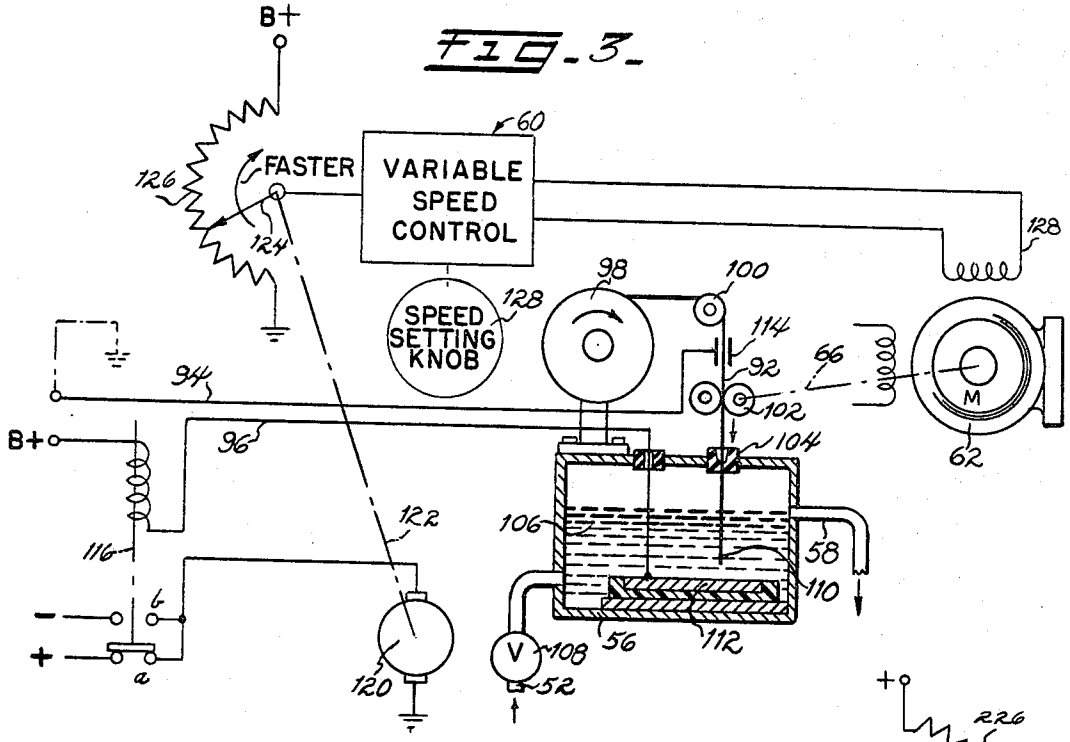


Fig. 6.

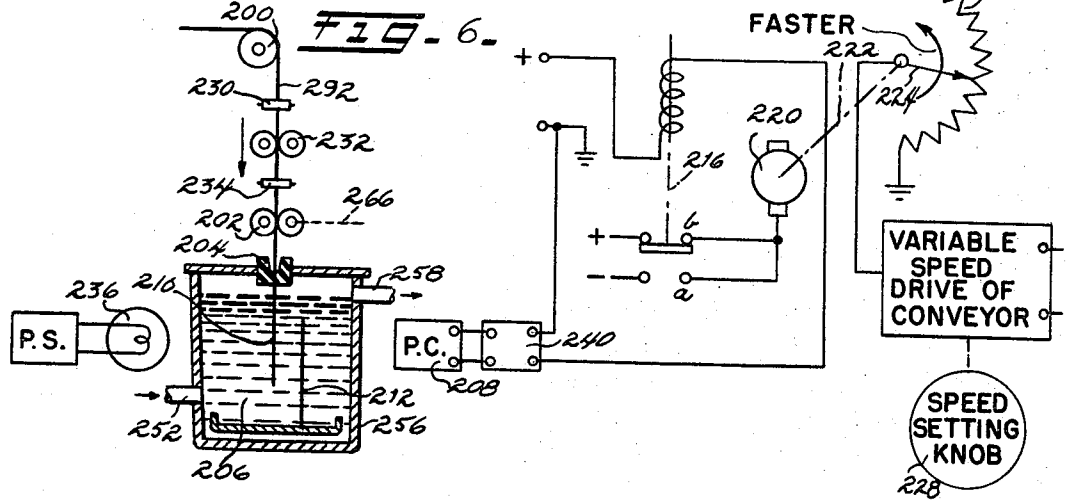
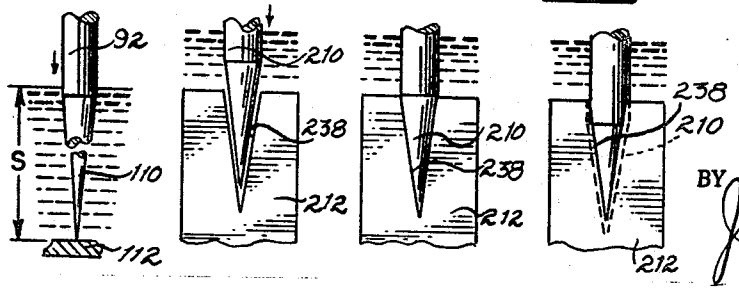


Fig. 4. Fig. 7. Fig. 8. Fig. 9.



INVENTOR.
ROBERT C. BENTON
BY John W. Haines
ATT'Y

Dec. 31, 1968 R. C. BENTON 3,419,446

METHOD AND MEANS FOR CONTINUOUS CONTROL OF ETCHING RATE

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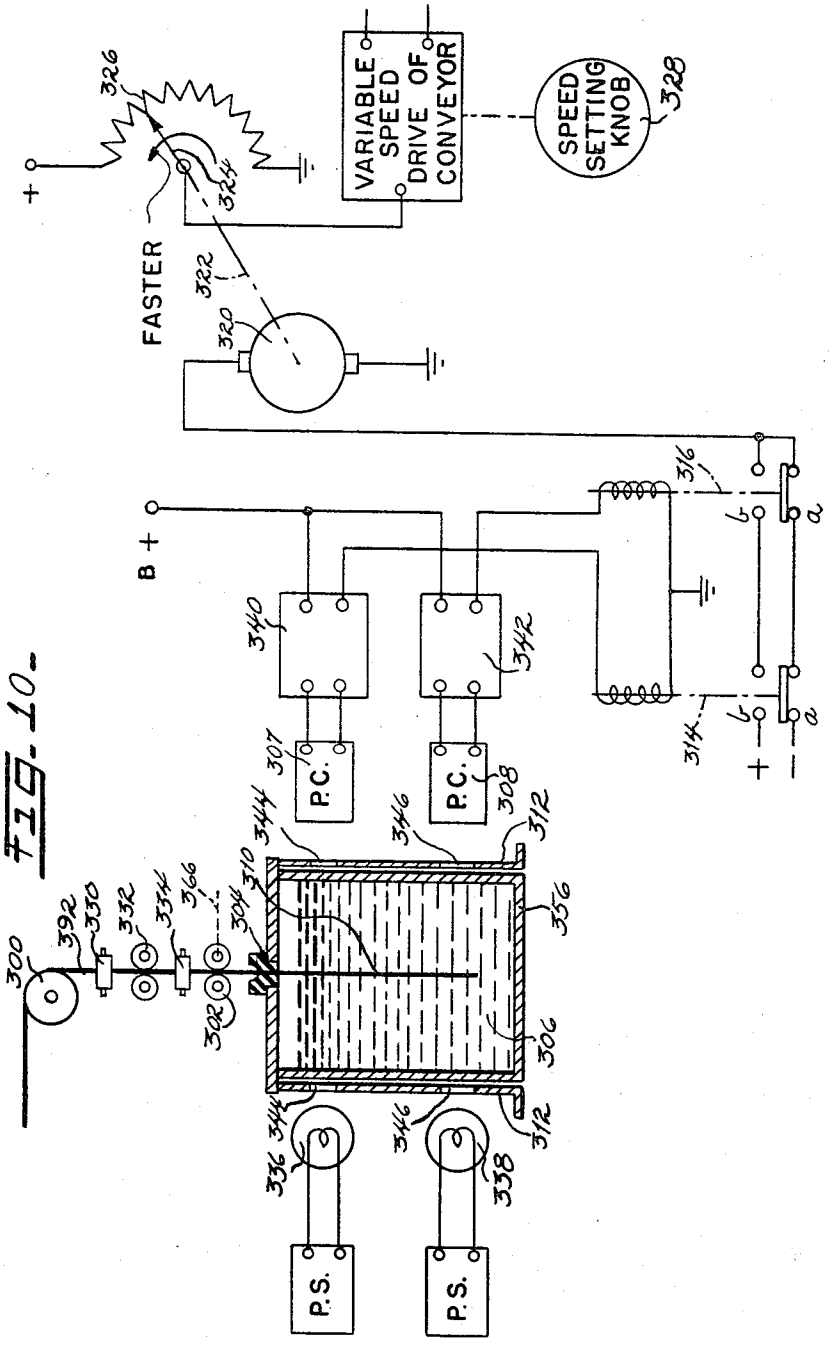

FIG. 10.

INVENTOR.
ROBERT C. BENTON
BY John W. Baines
ATT'Y

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3,419,446

METHOD AND MEANS FOR CONTINUOUS CONTROL OF ETCHING RATE

Robert C. Benton, State College, Pa., assignor to Chemcut Corporation, a corporation of Pennsylvania

Filed Feb. 15, 1965, Ser. No. 432,475
17 Claims. (Cl. 156—3)

This application relates to the etching of metal from a continuously conveyed series of articles. It more particularly relates to a method and apparatus for coordinating the rate of movement of the articles and the etch rate strength of the etchant. Precise coordination of these rates insures that the moving articles pass sufficiently fast through the length of an etching zone to prevent overetching and, at the same time, insures against excessive speed which would prevent removal of enough metal to yield articles of satisfactory quality.

In a continuous etcher, the objects being etched are fed through the etching zone in a series, either in closely spaced apart relation with the objects separate, or in a continuous web form from which the individual objects are, at an appropriate stage, separated from the web and from one another. The objects so etched include many industrial articles such as thin metal grids, flat springs, and perforated masks and sheets of which the unwanted portions are etched completely through from opposite sides of the metal, usually concurrently. The etching leaves intact all desired portions. The desired portions according to the practice are those portions which have been pre-coated with an etch resist in registering patterns on the opposite sides, thereby being fully protected from attack by the etchant.

Other objects etched include printed wiring articles such as single sided and double sided work in the printed, etched circuit field. Printed circuit boards are panels manufactured for this purpose by bonding copper as a film or foil to one or both sides of a backing of insulating base material. Here again, metal in the places where it is desired to be removed from the article is attacked by the etchant because the metal film is left exposed in those places, whereas the balance or image area of the film is protected by a pattern of resist conforming to the circuits desired so that, beneath the resist, the same pattern is retained in the metal film.

An object of my invention is to provide, in a continuous etcher for articles such as the foregoing: a variable speed conveyor moveable over a path in the etcher for carrying the articles through and past the etching zone; wire feeding means for simultaneously feeding a control wire in a path exposing the wire to the etchant of the etcher, the wire feeding means being driven at a speed at all times proportionate to conveyor speed; and speed control means for sensing a dimension of the control wire under attack by the etchant, the speed control means being connected to the conveyor for adjusting same in a speed decreasing direction in response to a decrease in the etch rate of the etchant, and in a speed increasing direction in response to an increase in the etch rate. The wire makes a convenient form of the metal to employ in the speed control means, being readily controlled, readily handled, readily measurable, and easily propelled by conventional feeding means. The reference to metal wire, simply as a term of convenience, means any feedable elongate control element of the metal, such as backed or unbacked foil, sheet material, wire gauze, or other form which can be trained to move into contact with an etchant effective to dissolve same at exposed points.

An unforeseen result of providing automatic control for the conveyor in an etching machine is that it obviates

a major difficulty encountered in continuous etching and materially reduces human error. In the example of one of the common metal etch solutions in use, I have observed that its metal removal or etch rate increases when the temperature of the solution rises; more particularly, a temperature increase of the solution from room temperature to its preferred etching temperature necessitates roughly a 2:1 increase in conveyor speed. The difference in effectiveness of the same etching solution, first, when fresh and, second, after a sustained period of etching of three hours necessitates a 1:5 decrease in conveyor speed. Initial etchant concentration, the rate and method of application of the etchant to the work, and presence of impurities and/or additives in the etchant are further variables which reflect themselves by changing the etch rate.

While overetching to a degree is desired, it is appreciated that the latitude allowed for overetching can become extremely critical. In other words, the attendant lateral attack, also known as undercutting, may not be particularly severe in certain printed etched circuits which can accommodate 50% to perhaps 100% or more overetching without impairment; whereas a much lower percentage of overetching may be all that can be tolerated in other articles wherein one one-thousandth of an inch or more of undercut of the metal edges immediately below the margins of the resist would provide a final product of unsatisfactory quality.

It becomes highly advantageous to maintain an average speed of articles passing through the etching zone which is proper for the then-current condition, thus confining the percentage of overetching to within a precise range.

It is another object of my invention to provide, in the etching of metal from articles passing through the etching zone of a spray etcher, an improved process comprising: setting the articles in movement at a given rate of speed over a path in a spray etcher leading through the etching zone; simultaneously feeding a control wire in a path exposing the wire to the etchant of the etcher whereby, under sustained attack of the etchant on said wire, a wire dimension changes as a measure of the etch rate strength of the etchant; sensing such dimension of the wire in comparison to a reference value; and adjusting the rate of movement of the articles and the wire rate of feed in a speed decreasing direction in response to the dimension of the control wire increasing to the reference value, and in a speed increasing direction in response to the wire dimension being undervalue.

An additional object of the invention is the provision of a process as above, wherein the sensing is photoelectric.

A further object is to provide such a process, wherein the sensing is accomplished electromechanically.

While primarily adapted as a control for use in connection with pressure induced spray etching work, my invention equally applies to paddle induced spray etching procedure in which the moving articles are splashed, or immersed for a portion of the path of transit through the etching zone, or immersed throughout the path completely, either with or without being additionally subjected to immersed jets or forced currents of the bath while so immersed.

Further features, objects, and advantages will either be specifically pointed out or become apparent when, for a better understanding of my invention, reference is made to the following written description taken in conjunction with the accompanying drawings, which show certain preferred embodiments thereof and in which:

FIGURE 1 is a view in front elevation of a continuous conveyor type etcher embodying the present invention;

FIGURE 2 is an enlarged fragmentary showing of a detail of the conveyor in plan view, based on FIGURE 1;

FIGURE 3 is a schematic diagram of a two-state elec-

tromechanical embodiment of the control system for the conveyor;

FIGURE 4 is a fragmentary view in front elevation of a detail of FIGURE 3 shown to enlarged scale;

FIGURE 5 is a speed-time curve showing the conveyor performance;

FIGURE 6 is a schematic view of a two-state photoelectric embodiment of the control system;

FIGURES 7, 8 and 9 are a series of sequence views in side elevation of a detail of FIGURE 6; and

FIGURE 10 is a schematic view of a three-state photoelectric embodiment of the control system.

More particularly in FIGURE 1 of the drawings, a continuous etching machine is shown having a loading end station **20** and an unloading end station **22**. Unetched articles **24** are introduced at the loading station onto a variable speed, roller conveyor **26**. They are conveyed thereby through the etching zone of a spray chamber **28**, through one or more rinse spray chambers **30**, and thence to the unloading end station **22** from which the etched articles **32** are removed and collected for further processing. Front and rear groups **34** of upper spray nozzles in the chamber **28** discharge downwardly in the plane of the rollers, and front and rear groups **36** of lower spray nozzles discharge upwardly in the plane of the rollers; the latter nozdles are used in the case of work requiring etching from both sides. Preferably, two electric pump units **38** and **40** are employed to supply the etchant, enabling the upper nozzle groups **34** to have a separately controllable source of supply from the lower groups **36**, in case single sided work is to be processed.

From a pool **42** of etchant collected in a tank in the bottom of the etching chamber **28**, the electric pump units **38** and **40** draw the etchant through individual filters **44** into the suction side **46** of the pumps. The pumps of the units are preferably centrifugal pumps incorporating an acid-resistant plastic rotor, and the discharge side **48** of each pump communicates through an output conduit **50** leading to the manifold of the nozzles of one of the respective groups of nozzles. The output is split so that a portion of the etchant goes from the output conduit **50** through a branch line **52** leading to a sample tank or cell **54**. An overflow conduit **56** connects the column of each electric pump unit and the tank of the etching chamber **28**, and another overflow conduit **58** connects the sample tank **54** and the tank of the etching chamber **28**.

A variable speed drive for the conveyor **26** comprises a speed control included in a control box **60**, and further comprises an electric drive motor **62** mounted on an upright portion of the frame of the etching machine at a point slightly below the loading end station **20**. The shaft of the motor **62** carries a small sprocket which is connected by a chain **64** to drive the roller conveyor **26**, and carries another sprocket which operates a chain and sprocket drive **66** for feeding a control wire into the sample tank **54** for reasons to be explained.

The control box **60** is connected by conventional electrical circuits to control the electric pump units **38** and **40**, the motor **62** as already noted, a series of solenoid controlled cooling coils, not shown, which are located in the bottom of the tank of the etching chamber **28**, and an electric heating coil **68** located in the bottom of the tank. If copper is the metal being etched from the articles, one suitable etchant in the tank is an aqueous ferric chloride solution; for best results, the temperature is regulated by the cooling coils or heating coil as appropriate.

Sets of manually adjustable baffles **70** carried in the etching chamber **28** can be extended into blocking positions immediately below the upper groups **34** of nozzles so as to equalize the etching rates between the upper groups and the lower groups of nozzles when double sided work is being processed. Suitable labyrinth seals or traps, not shown, are fitted around the conveyor **26** at the inlet to the etching zone, and in the covered bridge **72** between the etching zone and the spray rinse chambers **30** to prevent escape of the etchant. Similarly, a seal or trap, not shown, is provided on the exit sides of the spray rinse chambers **30** to prevent carry-over of the rinse water which otherwise might spill from the etching machine.

Two panels, not shown, are located at the front of the machine. The panels are slidable on longitudinal, horizontally extending tracks to provide access both to the baffles **70** and to the articles within the machine, and they are appropriately sealed to prevent leakage. Preferably, the panels are made of a transparent, etchant resistant plastic allowing both the article movement and the spray nozzle action to be observed while the machine is in operation.

In FIGURE 2, the roller conveyor **26**, in the longitudinal direction, is provided with a succession of transverse rows of rollers **74** and is further provided with a pair of full length walking beams **76** disposed one on each side of the conveyor. The walking beams **76** are supported at points along their length by cross shafts including the two cross shafts **78**, **80**, and others, not shown, each carrying a pair of cranks **82** rigid therewith at the opposite ends and with the throw journalled in a hole in the walking beam **76** at that end. As viewed along the axis of the shafts **78**, **80**, etc., the cranks **82** of each pair are offset or phased at 90 degree angularity to one another to insure unidirectional movement of the walking beams in a curved path. The motor driven chain **64** and a meshing sprocket carried by the shaft **78** rotate the shaft **78**, whose cranks **82** force the walking beams **76** to move each one in a path closing on itself and circular in nature. The cross shaft **80** similarly rotates due to movement of the walking beams.

Roller carrying shafts **84** have cranks **86** provided at one end only and are connected to the walking beam **76** at that end so that the shafts **78**, **80** and **84** all rotate in unison; the throw of the cranks **86** at the end of the shafts **84** has the same phase angularity and radius as the cranks **82** which drive the walking beam **76**. The roller carrying shafts **84** therefore form live axles for all rollers **74** and the rollers convey articles on the roller tops in the direction of material movement indicated by an arrow in FIGURE 2. The shafts are journalled for rotation on fixed axes by means of a longitudinally extending pair of spaced apart rails **87** forming the side rails in a stationary frame or table of the conveyor **26**.

The rollers **74** are made of a plastic resisting the action of the etchant and they are fast to the shafts **84**, which are made of a metal also resistant to etchant attack. Each of the rollers **74** has a bevelled periphery **88**, which is formed with a set of teeth **90** effective to engage and lift the leading, downwardly warped edge of any warped article so as to prevent it from hanging up on the conveyor table. The roller table is the same one described in my copending U.S. Patent No. 3,082,774.

In FIGURE 3, the sample tank **56** is the center of an electromechanical mechanism for feeding a control wire **92** in a path exposing the wire to the etchant of the etching machine. The wire **92** forms part of an operable circuit having respective upper and lower branches **94** and **96** and serving to actuate the referred to conveyor speed control included in the control box **60**. The composition of the wire **92** is preferably the same as the composition of metal being etched from the articles, so that the rate at which the wire is consumed by etchant will be a measure of the removal rate of metal from the articles. Copper is the wire used, for example, when printed etched circuit boards of copper are being etched.

The wire **92** is stored in a coil on a freely rotatable spool **98**, and passes over an idler roller **100** and between a pair of drive rolls **102**. The sprocket and chain drive **66** from the conveyor motor **62** turns the drive rolls **102** at a proportionate speed to the conveyor, drawing the wire from the spool **98** and feeding it through a seal **104** into a body **106** of etchant which is slightly turbulent due to

circulation of the fluid and which is within the sample tank **56**.

Etchant circulates in the branch line **52** from the pump, through a flow regulating valve **108** into the tank **56**, and from the tank the etchant is returned through the overflow conduit **58** to the tank within the spray chamber of the etcher, not shown. Etchant eats the portion of the wire **92** which is below the surface of the body **106** into a stub **110**, the stub being continually fed by the drive rolls **102** toward a conductive metal plate **112** which lies flat adjacent the bottom of the tank **56**.

The upper branch **94** of the actuating circuit, which may be grounded for safety, is connected to a contact tube **114** through which the wire passes at some point between the idler roller **100** and the drive rolls **102**. Suitable straightening rolls may also be provided at this point to remove residual camber from the wire, although straightening rolls are not essential. The lower branch **96** of the actuating circuit includes an electromagnetic relay **116** and connects the relay on one side to a source of current and on the other side to the plate **112**. In the position shown, the wire stub **110** acts as a current conducting means to the extent of allowing small current flow to the plate **112**, owing to the conductivity of certain etchants, such as ferric chloride. The relay **116** however is pre-calibrated to respond only to substantial current, and substantial current flows only when the stub length increases to a point where the stub **110** bridges over and contacts the conducting plate **112**.

The relay **116** controls a motor **120** which reverses its rotation with change in polarity. The motor **120** has a mechanical connection **122** to the slider **124** of a potentiometer **126** for controlling the speed control. A speed setting knob **128** provides an over-riding adjustment for setting the speed control independently of the potentiometer **126**.

When the relay **116** is unactuated due to the wire stub **110** being shorter than a reference value, a lower set of relay contacts *a* connects the motor **120** to a positive source of current, and the motor slowly rotates the slider **124** counter-clockwise as viewed in FIGURE 3, thus gradually reducing the speed setting of the speed control. When the relay **116** is actuated due to bottoming and curling of the wire stub **110** against the plate **112**, an upper set of contacts *b* connects the motor **120** to negative source of current, thus reversing the drive connection **122** and causing the slider **124** to rotate clockwise in the faster speed direction. The speed control has a power connection **128'** to the conveyor motor **62** and according to its two functions is either increasing or decreasing the speed of the motor **62**.

More specifically as seen in FIGURE 4, the reference value referred to for the wire stub **110** is indicated at *s*. The wire etches away as a stub with gradually decreasing thickness from its point of introduction into the body of etchant to a point of discontinuity at the terminal tip. The actuating circuit just discussed serves as a comparison circuit of the actual stub length compared to the reference value *s*. As long as the stub **110** is spaced apart from the plate **112**, the conveyor motor **62** will continue gradually to increase speed. When the length of the stub **110** exceeds the reference value *s*, the stub buckles against and rests upon the plate **112** so as to close the circuit, and substantial current flows and causes the conveyor gradually to decrease speed.

In FIGURE 5, the ideal conveyor speed plotted against time is indicated by a chain line curve. The curve happens to slope down (negative) as illustrated, which is the general performance characteristic as the etchant becomes spent in its strength. The direction of slope however is not critical and, during warm up of an etching machine as the etchant increases in temperature, the curve of ideal conveyor speed during that period has positive slope. The serrated solid line **130** in FIGURE 5 illustrates the actual conveyor speed under automatic control of the system of FIGURE 3 preceding. The speed of the conveyor motor **62** constantly increases until the stub of wire bottoms, whereas the speed of the motor constantly decreases until such point at which the wire stub **110** loses direct contact with the plate **112**.

In the embodiment of FIGURE 6, the mechanical aspects of the electromechanical control system are modified somewhat, and the electrical circuits are changed so as to employ a photosensitive device **208** to sense the stub length.

The control wire **292** is drawn from a coil, not shown, over an idler roller **200** where it passes through a straightener and between drive rolls **202**. The straightener is schematically illustrated as a series of opposed straightening rolls **230**, **232**, and **234**. The drive rolls **202** feed the wire **292** through a seal **204** and into the etchant where, as in the preceding embodiment of the invention, the wire etches away as a stub **210** with gradually decreasing thickness from its point of introduction into the body **206** of etchant to a point of discontinuity at the terminal tip. The body **206** stays slightly turbulent due to being continually replenished by an inflow of the fluid through the branch **252**, the overflow leaving via the conduit **258**.

The tank **256** is transparent. A power source PS energizes a lamp **236**.

Light from the lamp **236** located on one side of the tank **256** passes through the body **206** of solution and through a mask **212** so as to fall upon the photosensitive device **208**. The stub **210** registers or not with the mask **212** so as to allow the light to pass or not, depending upon stub length.

A filter **240** connected in the output of the photosensitive device **208**, is in circuit with a pre-calibrated relay **216**, which maintains an actuated condition while illumination falls on the device **208**.

The relay **216** controls a motor **220** which reverses its rotation with change in polarity. The motor **220** has a connection **222** to the slider **224** of a potentiometer **226** for operating the potentiometer **226** to control the variable speed drive of the conveyor. A speed setting knob **228** provides an over-riding adjustment for setting the variable speed drive independently of the potentiometer **226**.

Etching away of the wire, so that the stub **210** becomes shorter than the reference value, enables light from the lamp **236** to illuminate the photosensitive device **208**, with the result that the relay **216** is actuated. When the relay **216** is actuated, its upper set of relay contacts *b* connects the motor **220** to a negative source of current and the motor slowly rotates the slider **224** clockwise as viewed in FIGURE 6, thus gradually reducing the speed setting of the variable speed drive. When the relay **216** is deactivated due to the photosensitive device **208** being dark, a lower set of contacts *a* of the relay **216** connects the motor **220** to a positive source of current, thus reversing the drive connection **222** and causing the slider **224** to rotate counter-clockwise in a faster speed direction as viewed in FIGURE 6. Under these two operating conditions it is seen that the variable speed drive is progressively either gradually decreasing the speed of the conveyor, not shown, or gradually increasing the speed of the conveyor.

The showing of FIGURE 6 is predominantly schematic and, in practice, transparent guides for the wire stub **210** can be provided if desired, so as to keep the wire aligned in a vertical plane with a V-notch formed in the mask **212**.

In FIGURE 7, the wire stub **210** is shown in an operative position behind and slightly above an upwardly open V-notch **238** formed in the mask **212** appearing in the foreground. The wire stub defines a light gate, allowing the pasage of sufficient light through the notch to actuate the device **208** of FIGURE 6. As already indicated, the variable speed drive of the conveyor progressively slows down.

In FIGURE 9, the wire as shown has undergone an increase in length due, for example, to higher speed of the drive, so that the stub occupies the dotted line position shown by the dotted lines **210**. In that case, the device **208** remains in the dark, causing a progressive decrease in the speed of the drive.

In FIGURE 8, the stub **210** is shown at a point where its profile coincides with the margin of the V-notch **238**, that point representing the transition that occurs when the changing stub length either opens the light gate or closes it. The photoelectric control using gating according to FIGURE 8, and similarly the control using electromechanical contact according to FIGURE 4 are each a two state system.

A three state system to coordinate article speed and etch rate can be provided in accordance with FIGURE 10. In one state, the conveyor in the system operates at gradually decreasing speed in response to the stub length exceeding a maximum reference value. In a second state in which the wire stub has a length between the maximum and a minimum reference value, the conveyor operates at constant speed. In a third state in which the wire stub is shorter than the minimum reference value, the conveyor in the system operates with gradually increasing speed.

More particularly in FIGURE 10, the control wire **392** is uncoiled and fed through the mechanism by passing it over an idler roller **300**, through wire straightening means e.g., straightening rolls **330**, **332**, and **334**, between drive rolls **302** having a drive **366** from the conveyor motor, not shown, through a seal **304** for the sample tank **356**, and into a slightly turbulent body **306** of etchant within the tank. Fluid circulates through the tank **356** in the way previously described, entering through a pump branch line, not shown, and discharging from an overflow conduit, not shown.

Transparent wire guides, not shown, can be provided within the tank **356** so as to keep the wire stub **310** straight along a vertical line. The stub **310** registers with two opposed vertically extending upper slits **344** and with two opposed vertically extending lower slits **346** which are formed in a pair of masks **312** disposed outside of and on opposite sides of the tank **356**. The tank **356** is transparent.

A lamp **336** supplied with alternating current from a power source PS is located at the level of one of the upper slits **344** so as to shine light in the direction of a photosensitive device **307** located at the level of the other one of the upper slits **344**. A lamp **338** is supplied with alternating current from a power source PS and is disposed at the level of one of the lower slits **346** so as to shine light in the direction of a photosensitive device **308** disposed at the level of the other of the lower slits **346**. These slits are very narrow and can be of uniform width although preferably, they each decrease in width from the top to the bottom.

The wire stub **310** defines a light gate, allowing the passage of light through the lower slits **346**, or through both the lower slits **346** and the upper slits **344** so as to actuate the devices **308** and **307** at the appropriate times.

The photosensitive device **307** is connected, by means of a filter **340**, in circuit with a precalibrated, speed-up relay **314** and the device **308** is connected, by means of a filter **342**, in circuit with another pre-calibrated relay **316** which completes a circuit for gradually slowing down the etcher conveyor. The relays **314** and **316** cooperate to control a motor **320** which reverses its rotation with change of polarity and which holds a fixed position when deenergized. The motor **320** has a mechanical connection **322** to the slider **324** of a potentiometer **326** for operating the potentiometer to control the variable speed drive of the conveyor. A speed setting knob **328** provides an overriding adjustment whereby the operator sets the variable speed drive independently of the speed called for by the potentiometer **326**.

When the length of the wire stub **310** is in excess of the maximum reference value determined by the location of the lower slits **346**, the speed-up relay **314** and the other relay **316** are deactivated due to the photosensitive devices **307** and **308** being dark. The lower contacts *a* of the relays **314** and **316** are closed in a series circuit connecting the motor **320** to a negative source of current, and the motor slowly rotates the slider **324** counterclockwise as viewed in FIGURE 10, thus gradually reducing the speed setting of the variable speed drive. When the stub length etches away to a value shorter than the maximum reference value, light from the lamp **338** illuminates the photosensitive device **308**, with the result of actuating the relay **316**. The relay **316** when actuated opens the lower contacts *a* so as to interrupt the circuit and closes the upper contacts *b* so as to prepare another circuit leading to the motor **320**. The motor **320** is deenergized holding the potentiometer **326** fixed and establishing continuous speed in the varibale speed drive.

Etching away of the wire, so that the stub **310** becomes shorter than the minimum reference value, enables light from the lamp **336** to illuminate the photosensitive device **307**, with the result that the speedup relay **314** is actuated. When the speed-up relay is actuated, its upper set of contacts *b* connects the motor **320** through the other circuit referred to, to a positive source of current, and the motor slowly rotates the slider **324** counterclockwise as viewed in FIGURE 10 in the faster speed direction. The converse is equally true, and thus the relays **314** and **316** cooperate to maintain gradually decreasing speed, constant speed, or gradually increasing speed of the conveyor when the wire stub **310** is less than the minimum reference value, exceeds the minimum reference value, or exceeds both the minimum and maximum reference values, respectively. In all three states, the rate of etching away of the wire stub is analagous to and a measure of the rate of metal removal from the articles in the spray zone of the etching chamber.

Following is an example of the characteristics of the components for the embodiments of the invention described.

A make of photosensitive device found entirely satisfactory, as indicated at PC in the drawings, in a Clairex photoresistor. The Clairex type 2P and other types have provided the right performance. The photoresistor when darkened offers high resistance in a circuit, whereas with increasing illumination, the photoresistor allows the current to increase up to the point where the photoresistor saturates at maximum current flow.

The filters in the output of the photoresistors pass the AC light frequency of the illuminating lamps. Preferably the power source PS for each lamp supplies alternating current at a nonstandard frequency and each filter is adjusted to pass frequencies only in the immediate range of that frequency. Thus stray light falling on the photoresistors from ambient standard illuminating frequency lamps will have minimal effect in confusing the present control system.

As herein disclosed, the wire feeding mechanism directs the control wire in a path in which it is eaten into a conical shape and is completely consumed within the sample tank. It is evident that the wire can be passed in a loop through the body of etchant in the tank, from a point at one side thereof leading below the surface of the etchant body and emerging from the surface at a point on the opposite side of the tank. Immersion and movement of the wire at proportionate conveyor speed in the path between those two points will progressively reduce the wire thickness to a measurable extent which can be sensed by conventional thickness gage means in comparison to a predetermined reference value. The conveyor speed can then be automatically increased or reduced, depending upon whether the emerging wire sensed has under thickness or over thickness compared to the reference value. So also, the invention is shown embodied

in a continuous spray etcher but, self evidently, the control system hereof is applicable to continuous etchers of the type already indicated in which the articles are immersed in a bath of the etchant through the complete path or through a portion of the path while they progress through the etching zone.

Variations within the spirit and scope of the invention described are equally comprehended by the foregoing description.

What is claimed is:

1. In the etching of metal simultaneously from a succession of articles, arranged in a continuous series through the etching zone of an etcher, the improved steps comprising:

setting the articles in movement at a given rate of speed over a path in the etcher leading through and past the etching zone;

feeding a portion of a continuous control element of metal into a path of exposure to the etchant of the etcher whereby, under sustained attack of the etchant, the etchant dissolves the metal of the control element until a point of discontinuity is reached as a measure of the each rate strength of the etchant;

sensing the point of discontinuity in comparison with the point at which the discontinuity is attained corresponding to a reference rate of attack; and

automatically adjusting the movement of the articles in a speed decreasing direction in response to sensing that the point of discontinuity is being reached at a point corresponding to a rate of attack slower than the reference value.

2. In the etching of metal from articles passing in a continuous series through the etching zone of an etcher, the improved steps comprising:

setting the articles in movement at a given rate of speed over a path in a spray etcher leading through and past the etching zone;

simultaneously feeding a control wire in a path exposing the wire to the etchant of the etcher whereby, under sustained attack of the etchant upon said wire, a wire dimension changes as a measure of the etch rate strength of the etchant;

sensing said dimension of the wire in comparison to the reference value; and

adjusting the rate of movement of the articles and the wire rate of feed in a speed decreasing direction in response to said dimension of the control wire increasing to the reference value.

3. The invention of claim 2, said sensing being photoelectric.

4. The invention of claim 2, said sensing being by electromechanical contact.

5. In the etching of metal from articles passing in a continuous series through the etching zone of an etcher, the improved process comprising:

setting the articles in movement at a given rate of speed in an etcher leading through and past the etching zone;

simultaneously feeding a control wire in a path exposing the wire to the etchant of the etcher whereby, under sustained attack of the etchant on said wire, a wire dimension changes as a measure of the etch rate strength of the etchant;

sensing said dimension of the wire in comparison to a reference value; and

adjusting the rate of movement of the articles, and the wire rate of feed, in a speed decreasing direction in response to said dimension of control wire increasing to the reference value, and in a speed increasing direction in response to the wire dimension being under value.

6. In the etching of metal from articles passing in a continuous series through the etching zone of an etcher, the improved process comprising:

setting the articles in movement at a given rate of speed through the etching zone in the etcher;

simultaneously feeding a control wire in a path exposing the wire to the etchant of the etcher whereby, under sustained attack of the etchant on said wire, the wire etches away to a stub of which the length tends to vary in inverse relation to the etch rate strength of the etchant;

continuously sensing the stub length from a fixed point for determining whether it is relatively excessive or deficient compared to that point along the path; and

adjusting the rate of movement of the articles, and the wire rate of feed, in a speed decreasing direction in response to excessive length of said wire stub, and in a speed increasing direction in response to a deficiency in length.

7. For use in a production line etching operation having:

etcher spray chamber means for simultaneously etching a succession of articles being continuously conveyed generally in a series therethrough; and

horizontal mechanical conveying means associated therewith, by which those series aligned articles being etched are, in the unetched state, moved-in continuously and in closely spaced apart relationship at one end of the chamber means and conveyed out in etched state at the other end of the chamber means:

the improvement of an etch-responsive speed control therefor operative in a separate chamber provided for testing, and with feed means provided therein;

said feed means effective to define a path for a portion of a continuous elongate metal control element fed thereby for exposure to etchant in that path which is in the last said chamber separate from the chamber means, and further effective to determine the point at which discontinuity is reached from etchant on such exposed portion in comparison with the point at which the discontinuity is attained corresponding to a reference rate of attack of and degree of metal removal by etchant from the articles; and

means in the separate chamber for directing etchant in a path of direct application against the exposed portion of the control element;

said speed control including means coupled thereto for applying output therefrom to the conveying means of the etcher, and providing an output for adjusting the movement at which the articles are advancing, in a speed decreasing direction in response to determining that the point of discontinuity is being reached at a point corresponding to a rate of attack slower than the reference value.

8. A continuous spray etcher effective for the removal of material from articles to be etched and a control element, said etcher having:

inlet and outlet stations;

spray chamber means operatively located therebetween;

a drive motor to operate a conveying means for said articles to advance them between said stations;

separate feed means for said control element to advance said element, which is in the form of a continuous elongate control element, into a path of exposure to the etchant of the etcher; and

sensing means for automatically sensing the degree of removal of material from the exposed portion of the control element by the etchant applied thereto in said path;

said sensing means being connected to said article conveying means to regulate its speed in response to the degree of the material removal sensed by regulating the speed of the drive motor.

9. The invention of claim 8, characterized by:

said sensing means having operable means in the con-

nection to the conveying means automatically operable in a manner, when the sensed degree of material removal is indicative of decreasing effectiveness of the etchant attack, to cause the drive motor to decrease running speed of the conveying means, and vice versa.

10. The invention of claim **9**, the control element material which is fed by the feed means and which is sensed by the sensing means characterized by essentially the same composition as the material being etched from the continuously advancing articles.

11. The invention of claim **10**, characterized by means for directing etchant in a path of direct application against the exposed portion of the control element to cause therein a point of discontinuity comparable to the point at which discontinuity is attained corresponding to a reference rate of attack, whereby the drive motor is caused by the sensing means to decrease the conveying speed when the sensing means senses that the point of discontinuity is being reached at a point corresponding to a rate of attack slower than the reference value.

12. The invention of claim **11**, the sensing by the sensing means characterized by photosensitivity.

13. The invention of claim **11**, the sensing by the sensing means characterized by electromechanical contact.

14. The invention of claim **11**, characterized by the control element path of exposure and the etchant path of direct application to the control element being included in an etch cell entirely separate to and spaced apart from the spray chamber of said chamber means.

15. The invention of claim **8**, characterized by transmission means individual to the conveying means and to the separate feed means and each having an input side;

said drive motor being connected in common to the input sides of both transmission means for driving the conveying means and feed means at a fixed speed ratio to one another.

16. The invention of claim **10**, wherein the sensed characteristic of the control element indicative of the degree of material removal therefrom is a dimensional characteristic of the control element.

17. The invention of claim **16**, wherein the sensed dimension consists of the length of unremoved material remaining in the exposed portion of the control element.

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JACOB H. STEINBERG, *Primary Examiner.*

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134—57; 156—345

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,419,446 December 31

Robert C. Benton

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 26, "nozdles" should read -- nozzles --. Column 5, li 45, before "negative" insert -- a --; line 41, cancel "counter"; line 42, "reducing" should read -- increasing --; lines 47 and 48, "clockwise in th faster" should read -- counterclockwise in the slower --. Column 6, line 49, "negative" should read -- positive --; line 50, "clockwise" should rea -- counterclockwise --; line 51, "reducing" should read -- increasing --; line 55, "positive" should read -- negative --; line 57, "counterclockwise should read -- clockwise --; line 58, "faster" should read -- slower --; line 60, cancel "progressively"; line 75, "slows down" should read -- increases speed --. Column 8, lines 8 and 9, "counterclockwise" should read -- clockwise --; lines 30 and 31, "decreasing" should read -- increas --; line 31, "increasing" should read -- decreasing --; line 38, after "chamber." insert -- The reasons are the similarities of the material (i.e composition) of, the feed speed (at fixed ratio) of, and the etchant appli (same etchant) to, the stub of control element and the etched portion of t articles. So any change of condition as it would affect the etch rate of a article to be treated in the machine is exactly reflected by an appropriat change in respect of the control element, including a change of the common etchant fluid for the article and for the control element. --; line 43, "i second occurrence, should read -- is --. Column 9, line 23, "each" should read -- etch --; line 44, "the reference" should read -- a reference --.

Signed and sealed this 17th day of March 1970.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER,
Commissioner of Pate