

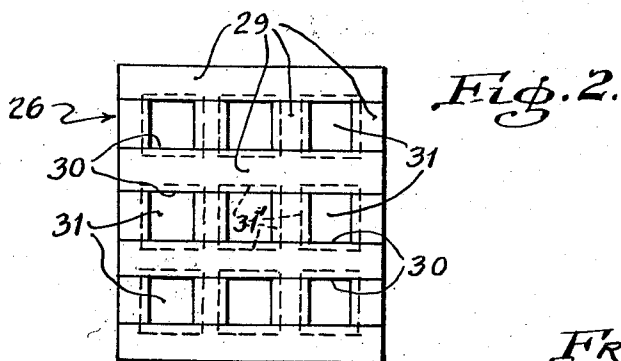
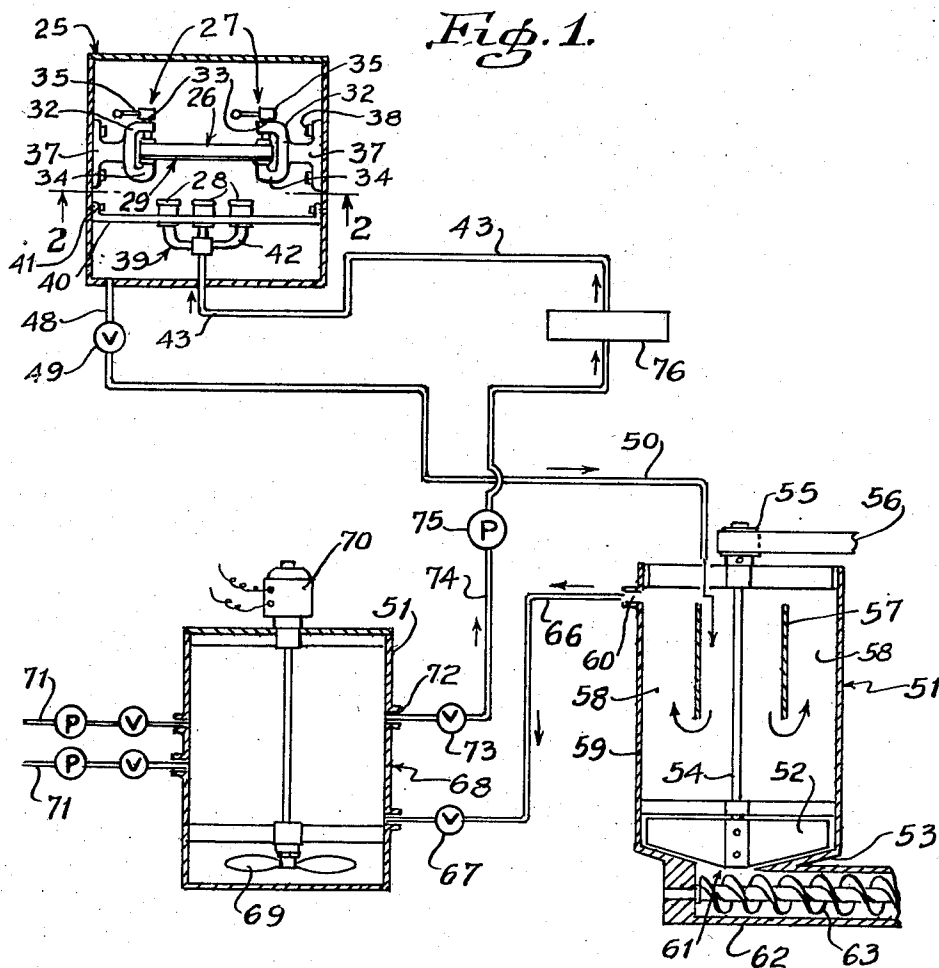
July 21, 1959

F. E. CLARK
APPARATUS AND METHOD FOR REMOVING METAL
FROM THE SURFACE OF A METAL OBJECT

2,895,814

Filed Feb. 4, 1955

5 Sheets-Sheet 1



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Fig. 5.

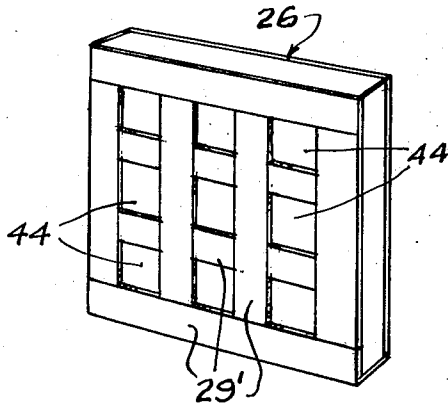


Fig. 4.

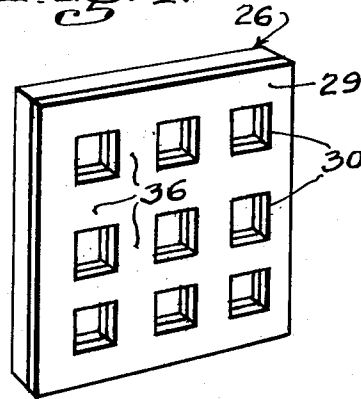


Fig. 6. Fig. 7.

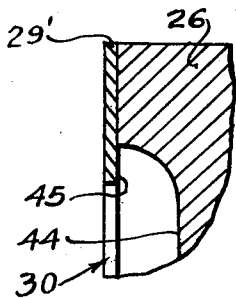
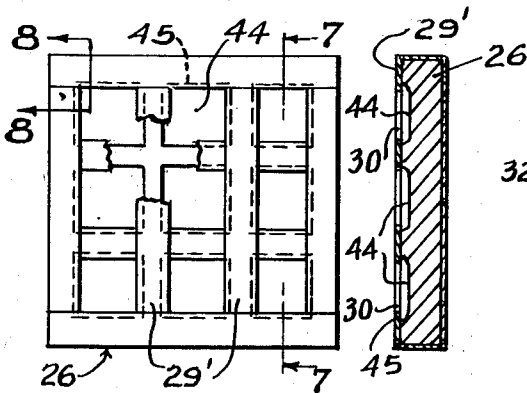
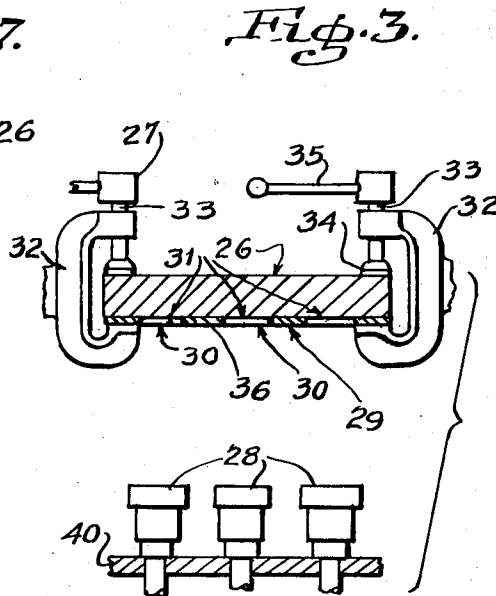


Fig. 8.



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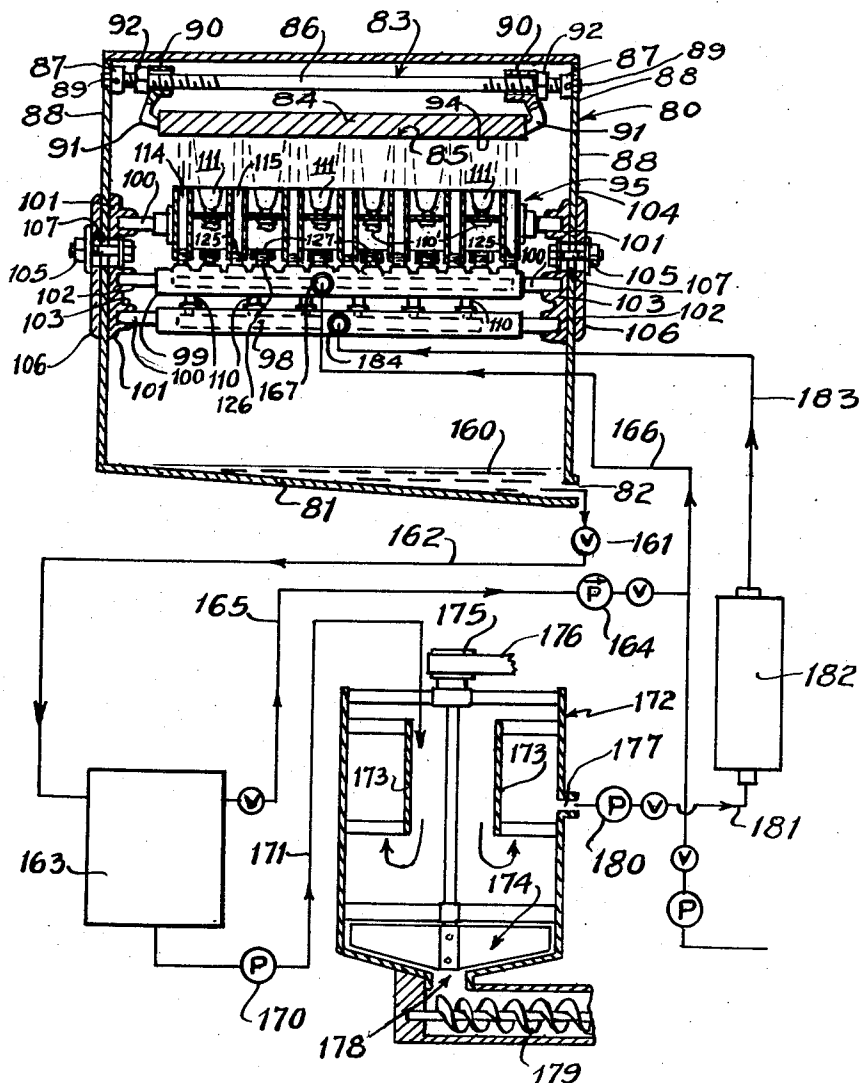
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Fig. 9.



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Fig. 11.

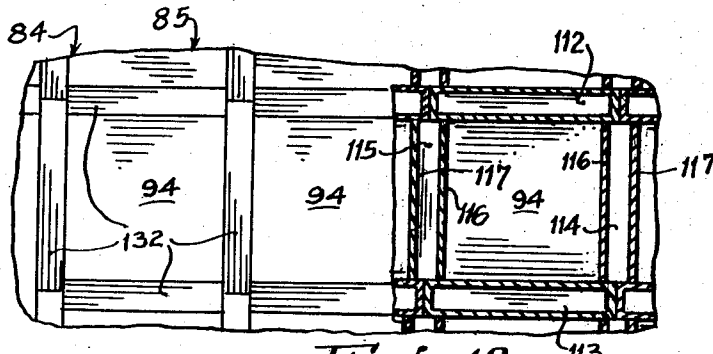


Fig. 10.

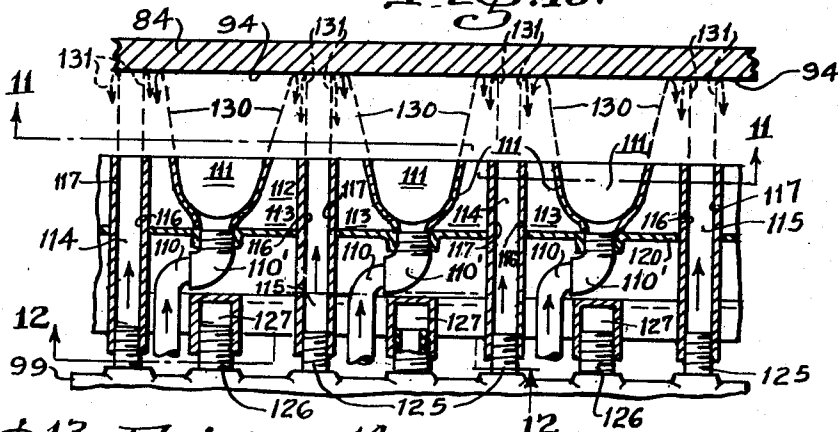


Fig. 13. Fig. 12.

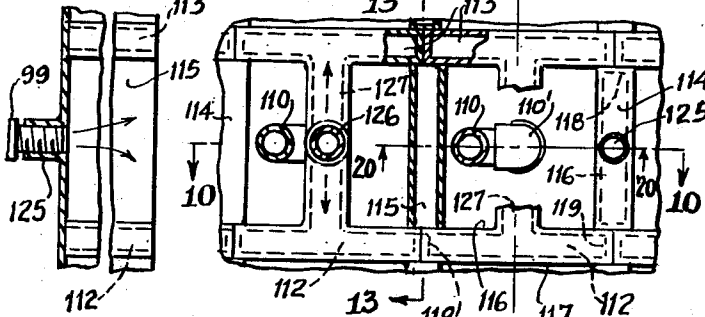


Fig. 14.

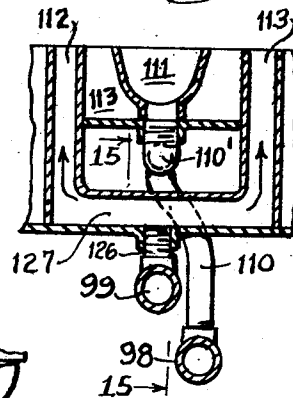
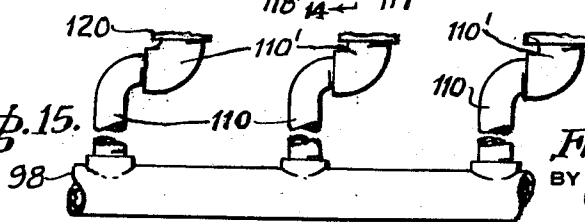


Fig. 15.



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Fig. 16.

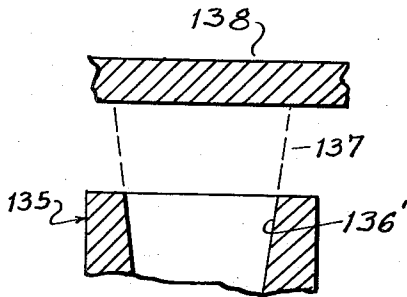
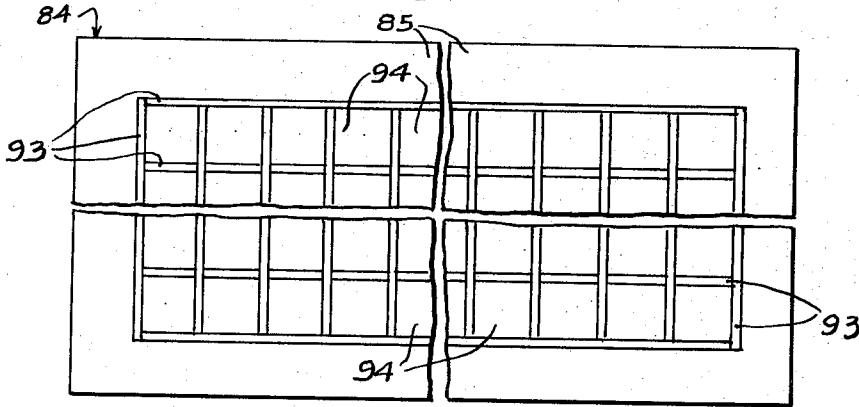


Fig. 17.

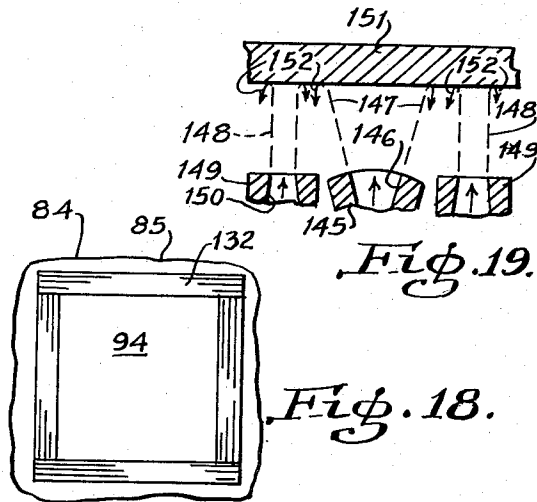


Fig. 18.

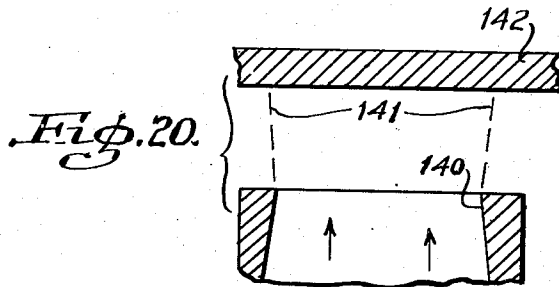


Fig. 20.

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APPARATUS AND METHOD FOR REMOVING METAL FROM THE SURFACE OF A METAL OBJECT

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Application February 4, 1955, Serial No. 486,195

9 Claims. (Cl. 41—43)

This invention relates to the etching or the removal of metal from the surface of a metal object, e.g., one composed of iron, nickel, titanium, magnesium, zinc, aluminum, or their alloys. More particularly, the invention is concerned with novel apparatus and procedure for this purpose, especially for the treatment of aluminum and its alloys.

It is known to etch acid soluble metals such as magnesium, zinc, and their alloys with an acid solution such as aqueous nitric acid. It is also known to etch alkali soluble metals such as aluminum and its alloys with a solution having a solvent action on the aluminum or alloy surface, such as a hot aqueous alkali solution, e.g., one containing sodium hydroxide. One method of carrying out the etching process employing acids is to immerse the metal part to be etched in the etching bath, while another is to splash the solution contained in a bath against the work, the surface of which is to be etched or dissolved away. The prior art method for etching alkali soluble metals such as aluminum or its alloys is by immersion. However, the use of the conventional immersion or splash methods for etching metal parts often produces non-uniform etching, is difficult to control, and is time consuming.

Moreover, where aluminum and its alloys are to be etched, conventional procedures have proven unsatisfactory because of the formation of a precipitate of aluminum hydroxide and/or alumina in the solvent or etching bath, particularly when the concentration of alkali in the solution is reduced due to the reaction of the alkali with the metal. The formation of such precipitate not only interferes with the action of the etching solution on the work but tends to form a scale on the etching tank or equipment which becomes most difficult to remove.

If the tanks are heated by coils, this precipitate in the form of a hard scale, deposits on the coils and also on the surface of the etching tanks; additionally, by depositing on the walls, the scale reduces the volumetric capacity of the tank and if allowed to continue will fill the tank. In order to prevent or reduce the formation of hard adherent scale, it has been proposed to add to the alkaline etching solution, agents which are said to prevent the reversion of the aluminate to form the aluminum hydroxide and alumina, and to cause the precipitate which is formed to be granular and non-adherent.

However, even in the above cases, the granular precipitate tends to fill the tank and must be removed periodically. Also, the strength of the solution gradually decreases and the etching solution must be revitalized by addition of fresh amounts of alkali.

One object of this invention is to devise novel apparatus and procedure for readily dissolving or removing metal in a controllable manner from the surface of a metal object, e.g., iron, nickel, titanium, aluminum, magnesium, zinc, and the like or their alloys.

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Another object is to provide apparatus and procedure for the controlled etching of a work piece.

Another object is the provision of apparatus and procedure for the simultaneous production of a plurality of geometrical etches or etching configurations in a work piece such as a metal plate.

Still another object is to provide apparatus and procedure of the foregoing type especially suited for the etching of aluminum or its alloys.

Another aim of the invention is to afford a device and procedure for the deep etching of a metal, especially aluminum or an alloy thereof.

Another object of the invention is the provision of apparatus and procedure for enabling the production of a plurality of etched configurations in a metal work piece without the application of a mask to the surface of the work piece.

Another object is to design novel apparatus and procedure particularly adapted for the uniform, controlled etching or removal of metal from the surface of a work piece composed of aluminum or its alloys.

A still further object of the invention is the provision of novel apparatus and procedure for the efficient controlled removal of metal from the surface of an aluminum or aluminum alloy part using a nozzle to emit a stream of etchant having a definite geometrical cross sectional configuration.

Another object is to provide apparatus and procedure of the foregoing type including means for maintaining the solvent or etching fluid substantially free of solids or precipitate which may become suspended in the solvent etchant solution.

Yet another object is to provide novel apparatus and procedure for the efficient etching or removal of metal from the surface of an aluminum or aluminum alloy work piece by controllably directing an alkali solution or etchant stream through nozzles against said work piece, and including means for the rapid removal of the solids formed in the etching reaction, from said bath, and for maintaining the strength of said solution.

A still further object is the provision of apparatus and procedure for the removal or etching of metal from the surface of a metal work piece such as aluminum or an aluminum alloy to form a plurality of separate etch configurations of definite geometrical pattern.

Other objects and advantages will become apparent from the following description of the invention.

According to one embodiment of the invention, metal solvent or etching solution is emitted from a specially designed nozzle upon a work piece suitably mounted for this purpose so as to form an etch pattern of a specific geometrical shape. The etch stream is discharged from the nozzle with sufficient kinetic energy and is of cross sectional form to give on impingement against the metal work piece a cross sectional area of impingement corresponding to the etch configuration to be formed in the work piece. Preferably, the apparatus hereof includes a plurality of such nozzles, to form a series of the same or different geometrical patterns simultaneously in one or more work pieces.

I may also incorporate means to confine the etchant streams delivered by the above-mentioned specially designed nozzles or by conventional nozzles, so as to produce a particular etch pattern in the work piece. Such means also permits the elimination of the masks ordinarily used in etching, and confines the etchant spray in such a manner as to produce desired etch patterns, e.g., of a specific geometrical configuration, even when conventional nozzles are used. Said last-mentioned means preferably includes a plurality of additional nozzles positioned with respect to the first-mentioned nozzles and of such a shape as to emit a confining wall of fluid which

surrounds the etchant streams so that they impinge upon only those areas of the work piece which it is desired to etch, thus forming the desired etch configurations and resulting in a minimum of undercutting by the etchant fluid.

The metal part to be etched may be coated, if desired, on selected portions of the surface with a protective masking coating to inhibit or prevent attack by the etching agent while adjacent portions are available for such attack. The etched work piece may be used in the decorative arts or in structures or machine parts.

Specially designed equipment is provided for circulating etching liquid to the nozzles for emitting the etchant streams and also to circulate fluid to the aforementioned additional nozzles, when employed, for confining or retaining the streams of etching liquid in their preselected paths so as to obtain the proper geometrical shape of etch patterns on the work piece. The apparatus is housed in a tank designed so that the etching reaction is carried out in the presence of air. The surface of the metal is thus corroded by the etching solution in the desired or unmasked areas of the work piece, and aeration of such solution during impingement thereof against the work piece produces a scouring effect against the surface thereof. Thus, particularly where the work piece being processed is aluminum or an alloy thereof, such scouring action aids in the removal of so-called smut often formed on the surface of the work piece during aluminum etching, and also of any adherent aluminum compounds such as the oxide or hydroxide. Smut appears on surfaces of aluminum alloys, particularly when aluminum is alloyed with elements, such as for example, copper, iron, silicon, and carbon, etc. Such aluminum alloys when etched with caustic soda, produce a film which is black and highly adherent to the surface. These smuts are insoluble in water and most acids. They are soluble in HNO_3 , mixtures of HNO_3 and H_2SO_4 and in mixtures of chromic and sulfuric acids. Such acids are extremely hazardous to use industrially.

The blast of the etchant solution against the surface of the work piece also functions to sweep away the blanket of hydrogen foam, as well as the aforementioned smut and the tenacious aluminum oxide, all of which have a masking effect which interferes or blocks the etching reaction. The solvent solution, after impinging on the work piece, drops back into the tank, carrying with it the aforementioned solids and gaseous foam.

A portion of the spent liquid mixture from the tank and containing solids or precipitate such as aluminum hydroxide and/or alumina formed in the etching reaction and suspended in the bath, is removed to a second zone maintained at a lower temperature, wherein the solids are settled out of the mixture and removed, and the remaining clear liquor is withdrawn. Such liquor may be recirculated directly to the bath, but is first preferably conducted to a third zone in which make-up liquid (water, alkali, or other components of the bath) can be added to the solution, if desired, to replenish or revitalize the main etching or solvent bath. The resulting solution can then be heated to the proper temperature and recirculated to the etching bath in the first zone. The process of removal of solids and recirculation of liquor to the bath may be carried out either intermittently or continuously, preferably the latter.

When a second immiscible confining liquid is used and discharged from the above-mentioned additional nozzles, the resulting spent liquid mixture is first passed to a separator wherein etch solution and the immiscible confining liquid are separated. The latter is recycled to the system, and the alkali etch liquor containing suspended solids is then treated in the foregoing manner to remove solids, and then recirculated.

The invention will be more clearly understood by reference to the following description of certain embodiments, taken in connection with the accompanying drawings wherein:

Fig. 1 is an essentially schematic assembly view of the apparatus of the invention according to one embodiment, shown partly in section;

Fig. 2 is a plan view of a work piece having a plurality of geometric etch patterns therein produced according to the invention;

Fig. 3 is an enlarged partial sectional view of certain structural features of the invention;

Fig. 4 is a perspective view of the front of a work piece etched according to the invention;

Fig. 5 is a perspective view showing a work piece having a mask thereon for the production of a plurality of geometric etch patterns by the invention process;

Fig. 6 is a front elevation of the work piece of Fig. 5;

Fig. 7 is a sectional view on line 7—7 of Fig. 6;

Fig. 8 is a fragmentary section taken on line 8—8 of Fig. 6;

Fig. 9 is an essentially schematic view of another embodiment of the invention;

Fig. 10 is an enlarged partially sectional view of certain portions of the device shown in Fig. 9;

Fig. 11 is an irregular section taken on line 11—11 of Fig. 10;

Fig. 12 is a section taken on line 12—12 of Fig. 10;

Fig. 13 is a section taken on line 13—13 of Fig. 12;

Fig. 14 is a section taken on line 14—14 of Fig. 12;

Fig. 15 is a view on line 15—15 of Fig. 14;

Fig. 16 is a plan view of a work piece to be etched by the device of Fig. 9;

Fig. 17 is a fragmentary cross section of one form of nozzle according to the invention;

Fig. 18 is an enlarged view of one of the square etch patterns formed according to the invention, particularly illustrating the peripheral area around the etch pattern which is contacted by the confining sprays;

Fig. 19 is a fragmentary sectional view showing the position of the spray nozzles with respect to the nozzles emitting the confining spray; and

Fig. 20 is a fragmentary cross section of a nozzle similar to that of Fig. 17.

Numeral 25 in Fig. 1 represents an enclosed but aerated tank in which a metal work piece 26 is mounted in a clamping means 27 and etched or subjected to the solvent action of a solution emitted in the form of streams from a number of nozzles 28 mounted in proper position in spaced relation to the work piece (see also Fig. 3). Where the work piece is an acid soluble metal such as magnesium, zinc, or their alloys, the solvent solution can be of suitable acid composition such as aqueous nitric acid. According to the preferred embodiment of the invention for etching or removing metal from an aluminum or aluminum alloy material, which is alkali soluble, a hot aqueous solution is employed containing an alkali such as sodium or potassium hydroxide, trisodium phosphate, soda ash or the like, or mixtures thereof. Preferably a sodium hydroxide solution is used. Temperature of the solution in the etching tank is generally maintained in a range say from 100° F. to about boiling during treatment, although lower temperatures may be used. Generally, the alkali concentrations employed in such solutions range from 0.1 to 10 normal, e.g., 1 to 3 normal.

In order to prevent or reduce the formation of hard, adherent scale, there may be added to the alkaline etching solution agents which keep the precipitate flocculent. If sludge modifiers are used, they may be employed in amounts sufficient to produce a non-adherent sludge or precipitate, as for example 0.5% to 10% by weight of the alkali.

Work piece 26, which in the instant embodiment is aluminum or an aluminum alloy, has a mask 29 coated on the surface thereof, e.g., in the form of an alkali resistant resin, such mask having a plurality of square apertures 30 therein. Hence, the surface of the metal work piece 26 to be coated is uncovered by mask 29 in those areas 31 facing the apertures 30 in the mask.

The work piece 26 is preferably mounted horizon-

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tally in tank 25 with the mask 29 facing downward, as seen in Fig. 1. Work piece 26 is held in position by the clamping means 27 including curved clamp members 32 contacting and supporting the opposite masked lower ends of the work piece, and adjustable screws 33 received in the opposite ends of clamp members 32, screws 33 having members 34 at their ends for contacting the work piece. Handles 35 are provided for adjusting screws 33. The clamp assembly 27 is mounted on brackets 37 connected to the walls of the tank 25 by bolts 38.

Nozzles 28 are aligned with the apertures 30 in the mask so that each of these nozzles will emit a stream directly into the oppositely positioned aperture and into contact with the bare metal surfaces 31 of the work piece uncovered by such apertures. The nozzles 28 in this embodiment are each designed to direct a stream having a cross section in the form of a square, and such nozzles are positioned from the work piece such that the cross section of the stream from each nozzle will just cover the area of bare metal 31 of the work piece left open by each of the apertures 30 on impingement of the streams against the work piece under the pressure employed, substantially without impinging on the portions 36 of the mask adjacent the apertures therein. The structure of nozzles 28 for producing a stream of square cross section, as well as other nozzles producing streams having other geometrical cross sectional configurations such as circular, are known. Nozzles of this type, for example, are marketed by Spraying Systems Company of Bellwood, Illinois, and described, e.g., in U.S. Patents Nos. 2,247,897, and 2,305,210.

A manifold 39 having the equally spaced nozzles 28 connected thereto is mounted below the clamping means 27 and the work piece 26 held thereby, on a bracket 40 connected to the inside wall of tank 25 by bolts 41. The manifold is positioned on bracket 40 so that the nozzle outlets are in a plane parallel to the work piece and the respective nozzles are aligned with the apertures in the work piece mask 29 as aforesaid. Each of the nozzles is connected to the manifold 39 by means of feeder lines 42, with etching liquid being introduced into the manifold by means of a line 43 passing through the bottom of tank 25.

As previously indicated, etching solution fed to the nozzles via manifold 39, is directed by the nozzles substantially entirely against the square surfaces of bare metal 31 uncovered by the square apertures 30 in mask 29, i.e., the kinetic energy of these streams is such that the cross sectional configurations of the etch streams striking the work piece retain this shape and these streams impinge practically entirely on the metal within the uncovered square areas 31 of the metal surface. The solution which impinges on the work reacts therewith to etch the same, and the resulting liquid carrying solids and foam drains off the work pieces and back into the body of solution in the lower portion of the tank. The amount of liquid and the velocity of the etchant streams leaving each of the nozzles and striking the various surfaces 31 of the bare metal can be maintained constant, as is the direction of such streams. In other words, these parameters can be maintained substantially constant during the entire treatment. Since a uniform amount of etching liquid is directed substantially in a constant direction against the respective unmasked areas 31 of the work piece, a uniform quantity of fresh solution is constantly in contact with the work piece, bringing about a controlled and uniform rate of attack of the metal on each unmasked portion of the work piece. The impinging liquid in the various streams from the nozzles strikes the surface of the metal almost normal thereto, and sweeps across the surface of the metal carrying with it deposited material such as aluminum hydroxide (where aluminum or its alloys is being treated), and the resulting reaction fluid, including smut and foam, then drains back into the main body of liquid in the tank. This procedure applies

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also to treatment of acid soluble metals, except that in this case no precipitate is formed in the etching reaction.

As seen in Figures 5, 6, 7, and 8, instead of employing a mask such as 29 in the form of a resist for blocking out the areas of the work piece which it is not desired to etch, strips of masking tape 29' may be applied to the surface of the work piece, leaving uncovered the portions which are to be etched. The action of the etching liquid on the uncovered or unmasked areas of the work piece form square etch configurations 44 of substantially uniform depth, and since essentially all of the etchant liquid leaving the nozzles strikes the bare metal with only traces, if any, impinging on the mask or resist bordering the apertures, essentially all of the solution leaving the nozzles is available for reaction with the metal, thus increasing the rate and efficiency of the etching reaction, as well as avoiding the wearing away of portions of the resist or mask as result of the impinging force of any etchant spray undesirably directed thereagainst. It is noted, as seen most clearly in Fig. 8, that some undercutting of the edges of the mask 29' takes place as at 45, due to the lateral corroding action of the stream of the etching solution as it sweeps laterally across the surface and toward the sides of the etch cavity after making contact with the metal. A similar undercutting takes place during etching of the unmasked areas 31 of the work piece of Figs. 1 and 3. However, the position of the work piece in the tank with the surface thereof being etched facing downwardly, enables rapid drainage of the major portion of spent etch solution from the surface of the metal after impingement thereon, downwardly into the bottom of tank 25. Also, the impingement of uniform streams of etchant liquid on the work piece in a constant direction essentially normal thereto, causes such undercutting to be substantially uniform about the entire periphery of the mask adjacent each of the square apertures 30 therein.

To remove from the body of etching solution in tank 25 suspended solids in the form of aluminum hydroxide and/or alumina, resulting from the reaction of the alkali with the aluminum or aluminum alloy work piece 26, as previously described (see Fig. 1), a portion of the liquid mixture is continuously removed by means of the tank outlet 48 and is passed via valve 49 by gravity through a pipe 50 to a settling vessel 51. Vessel 51 has a scraper 52 positioned adjacent the bottom 53 of the vessel, the scraper being rotatably supported on a central shaft 54, which is rotated by a pulley 55 driven by a belt 56 from a motor (not shown). Pipe 50 discharges into a cylindrical baffle 57 suitably mounted axially within vessel 51, causing flow of discharged fluid and solids downwardly into the vessel. The fluid then rises from the bottom of the vessel 51 through the annular space 58 between the baffle 57 and the side wall 59 of the vessel, and overflows through outlet 60 of vessel 51. The path of fluid flow is indicated by the arrows in Fig. 1. In this manner the suspended solids in the liquid mixture entering vessel 51 are deposited at the bottom of the vessel, and substantially clear liquor flows from outlet 60.

Rotation of scraper 52 maintains the solids in a thick suspension at the bottom of vessel 51, a portion of such solids being continuously discharged through the outlet 61 of vessel 51 into a hopper or conveyor 62 having a driven screw feed 63 therein for discharge of solids from the system.

The clear solution passing through outlet 60 is conveyed by a pipe 66 through valve 67 to make-up tank 68. Here the solution is agitated by an agitator 69 driven by a motor 70, while make-up liquid may be pumped through valved pipes 71. The make-up liquid can be water and/or additional alkali solution to replenish that lost in the main tank 25.

The solution in tank 68 is discharged from outlet 72 via valve 73 into pipe 74 and to the intake of pump 75 which pumps the liquid first through a heater 76 to

bring the solution up to the desired temperature and then circulates the heated liquid through pipe 43 connected to the manifold 39 which discharges to the nozzles 28.

Referring now to Figs. 9 to 21 of the drawings illustrating a preferred embodiment of the invention, numeral 80 represents a tank having a sloping bottom 81 and an outlet 82 adjacent the lower end of bottom 81. Mounted in horizontal relation on a work support 83 near the top of the tank, is a work piece 84, the surface 85 of which is to be etched to form a series of spaced square etch patterns similar to those formed in work piece 26, each of the square etch patterns being bounded on all four sides by unattacked areas of metal. Work support 83 comprises a shaft 86 journaled at opposite ends in the upper portions of end walls 88 of the tank 80, and held against longitudinal movement by means of collars 87 having set screws 89 therein. Brackets 90 are slidably mounted on shaft 86, each of brackets 90 having a clamp 91 suspended therefrom for contacting the sides of the work piece 84 to maintain same in fixed position in the tank. Nuts 92 are positioned adjacent brackets 90 for adjustment thereof along shaft 86. The surface 85 of the work piece may have masking strips 93 arranged thereon, as seen in Fig. 16, or, if desired, these masking strips may be omitted.

Below work piece 84 and the supporting structure 83 therefor is a system of nozzles for emitting etching fluid and for emitting streams of confining fluid to limit the direction of the etchant spray so that it impinges substantially entirely on the desired areas, i.e., the squares 94 on the work piece 84, which squares may be enclosed by the masking strips 93. All of the nozzles are mounted on a framework 95, and such framework, along with a pair of hollow tubular manifolds 98 and 99, the function of which will be described more fully hereinafter, are supported by the tank end walls 88. Framework 95 and manifolds 98 and 99 each have a pair of opposite end members 100 which are connected to brackets 101, e.g., by friction fit into apertures 102 formed on bosses 103 of the brackets 101. It is noted that the manifolds are disposed horizontally in tank 80, in vertically spaced relation to each other. Brackets 101 are in engagement with the inner surfaces of the end walls 88 of tank 80 and are secured in position by means of bolt and nut assemblies 105 passing through vertical slots 107 in the walls 88 of the tank, and an outer plate 106 for providing greater rigidity. The manifolds 98 and 99, brackets 101, and outer plates 106 are vertically adjustable by manipulating the fasteners 105 in the vertical slots 107.

Referring particularly to Figs. 10 to 15, connected at spaced intervals along manifold 98 and communicating with the interior thereof is a series of short pipes 110 which are curved at their upper ends for connection with elbows 110', which communicate with a series of nozzles 111 having an upwardly flared throat 111'. These nozzles are each disposed approximately in the center of four rectangular hollow chambers 112, 113, 114, and 115, each having vertically disposed confining side walls 116 and 117, and end walls 118 and 119. Nozzles 111 are supported at their ends on horizontal members 120 attached at opposite ends to the inner side walls 116 of chambers 114 and 115. Chambers 112, 113, 114, and 115 form, in effect, nozzles, as will be more fully pointed out below.

At spaced intervals along manifold 99 are a series of short pipes 125 connecting the interior of manifold 99 with each of the chambers or nozzles 114 and 115, and between each of the pipes 125 is positioned a series of pipes 126 also connecting with the interior of manifold 99, but each communicating at their upper ends with a header 127. Each of the headers 127 is in the form of a horizontal chamber disposed below nozzles 111 and extending parallel to chambers 114 and 115, and com-

municating at its ends with hollow chambers 112 and 113.

It is seen that etching solution, e.g., sodium hydroxide solution contained in manifold 98 is delivered via pipes 110 to each of the central nozzles 111, and that fluid or liquid contained in manifold 99 is delivered via pipes 125 to each of side chambers or nozzles 114 and 115, and via pipes 126 and headers 127 to each of side chambers or nozzles 112 and 113. The fluid delivered from manifold 99 to each of the four side chambers is preferably a liquid which is immiscible with the etchant, e.g., caustic alkali, solution discharged from nozzles 111. Liquids of this type may be, for example, fatty amines, polyglycols, kerosene, or mixtures thereof. The liquid discharged from the four side chambers 112 to 115 should preferably be inert or non-reactive with respect to the etchant solution emanating from nozzles 111, and with the metal of which the work piece is composed.

In practice, the work piece 84 is positioned or suspended above the nozzles so that the surface 85 thereof to be attacked by the etching solution is substantially parallel to the ends of the nozzles, as seen in Fig. 10, with those square portions 94 of the work piece to be etched located directly above and centrally of nozzles 111. As seen in the dotted lines 130 in Fig. 10, the trajectory of the outer periphery of the etchant streams is such that the droplets of liquid in the outer streams strike the work piece near the border of the areas 94 of the work piece being etched. The etchant streams have sufficient kinetic energy and are of cross sectional configuration so as to strike the work piece only in those areas 94 to be etched. The etchant liquid impinging on the work piece is then swept across the surface thereof, carrying reaction products therewith, including, for example, hydrogen foam and solid precipitate from the reaction where the metal etched is aluminum or an alloy thereof. The spent solution then drops back to the bottom 81 of the tank.

During the emission of etchant spray from nozzles 111, walls or streams of immiscible liquid contained in chambers 112 to 115 are discharged vertically into the air as indicated by dotted lines 131 in Fig. 10, forming a square wall of confining liquid corresponding to the square configuration formed by chambers or nozzles 112 to 115 in Figs. 11 and 12, and strike the surface 85 of work piece 84 between the areas 94 of the surface being etched, forming a border 132 of inert material separating each of the etched portions 94, the particles of inert liquid, after contacting the surface of the work piece, dropping back into the bottom of tank 80 with the spent etchant fluid.

It is seen that the walls 131 of immiscible liquid produced by discharge thereof from nozzles 112 to 115, confine the etchant stream from each of the nozzles 111 so that such stream impinges on the work piece only in the square areas 94 defined by the border 132 (see Figs. 11 and 18) formed by impingement on the work piece of the square wall of confining fluid 131. Accordingly, where masking tape strips such as 93 are used to cover those areas of the work piece not to be etched, the wall of fluid 131 will impinge on such strips. However, the main advantage of the instant embodiment resides in the complete elimination of the need for masks or masking tapes, the walls of confining fluid 131 functioning in place of such masks to confine the action of the etching fluid stream 130 to certain selected portions only of the surface of the work piece. It is noted that in place of an immiscible liquid, a gas such as nitrogen or the like may be used to form the confining wall of inert fluid to control the areas of the work piece being subjected to etching treatment.

It is noted that in practice the pressure of the confining fluid 131 is generally somewhat greater than the pressure of the etchant liquid 130 so that the etchant liquid is thereby confined only to those areas of the work piece which it is desired to etch by forcing such

etchant liquid to remain within the confines of the exposed areas 94 bounded by nozzle walls 116 to 119 after impingement of the etchant liquid on the surface of the work piece. Hence, as seen in Fig. 10, the particles of etching fluid in the outer edges of the etchant stream 130 strike the exposed metal surface near the edges of the confining wall of liquid 131, and as the etchant and confining liquids contact each other near the outer edges of the exposed areas 94, they lose their energy and drop down into the bottom of tank 80.

In Fig. 17 is shown a modification of the form of the nozzles which may be used for discharging both the etchant and confining sprays. Thus, the nozzles, e.g., the etchant nozzles 135, may have an outwardly divergent throat 136' designed to emit a stream of liquid the outer periphery of which, as shown by dotted lines 137, spreads prior to impingement of the stream on the work piece 138 but not to the extent of the spreading produced by nozzles 111. In Fig. 20 is shown another nozzle modification having an outwardly converging throat 140, which discharges a body of liquid having an outer periphery 141 which spreads only a small amount before impinging against work piece 142.

Referring to Fig. 19, there is shown still another modification of the nozzles. As seen in this figure, the etchant spray nozzle 145 has a convexly flared throat 146 which emits a stream having an outwardly divergent trajectory 147. The confining streams 148 are discharged from nozzles 149 of a shape similar to the nozzle shown in Fig. 20, i.e., having an outwardly converging throat 150. The function of the nozzle structure of Fig. 19 is similar to that previously described with relation to Fig. 10. Thus, the stream from nozzle 145 impinges on the surface of work piece 151 which it is desired to etch, sweeps across the surface thereof carrying reaction products therewith, and falls back into the bottom of the tank as indicated by arrows 152. When the etchant solution makes contact with the wall of confining liquid 148, the confining liquid impinging on work piece 151 also drops back into the tank with the spent etchant liquid.

If desired, geometrical etch configurations other than square, e.g., circular, elliptical, doughnut shaped, or the like, can be provided by employing nozzles giving a fluid stream having a cross section corresponding to the etch pattern desired, and particularly where a mask is not used, by designing the nozzles which discharge the confining wall of liquid or gas of a shape so as to emit a wall of confining fluid which corresponds to the outlines of the desired etch patterns, e.g., circular, elliptical, or the like. It is thus noted that a desired etch configuration may also be obtained according to the invention by employing conventional nozzles for discharging the etching liquid, the area of impingement of such liquid against the metal work piece being controlled to produce a desired etch pattern by the use of additional nozzles emitting a wall of confining fluid or liquid as aforesaid, said wall of fluid being so shaped by proper design of said additional nozzles as to confine the etching liquid only to those areas to be etched.

Referring to Fig. 9, the mixture 160 at the bottom 81 of the tank 80 is recirculated to manifolds 98 and 99 for re-use in the system. For removal of suspended solids from the solution 160 at the bottom of tank 80, where the metal part etched is composed of aluminum or its alloys and an alkali etch solution is utilized, and to separate the alkali etching solution from the immiscible confining liquid, a portion of the liquid mixture 160 is continuously removed by means of tank outlet 82, and is conveyed via valve 161 and pipe 162 to a separator 163. Where the immiscible confining fluid is lighter than the alkali solution, which is often the case, the lighter immiscible liquid is drawn off near the top of the separator and returned by means of pump 164 through valved lines 165 and 166 to an inlet 167 in manifold 99. The heavier alkali solution in which practically all of the

solid material is suspended is then pumped by means of a pump 170 through line 171 to a settling vessel 172 similar to vessel 51, having therein a fluid diverting cylindrical baffle 173, a scraper 174 driven by a pulley 175 and a drive belt 176, and a liquid outlet 177. Solids deposited at the bottom of vessel 172 are discharged through a bottom opening 178 into a screw conveyor 179 for final removal of the solids from the system.

The clear solution passing through outlet 177 is conducted by means of pump 180 through a valved line 181 into a heater 182 to bring the alkali solution up to the proper temperature for etching, and the heated solution is then circulated through line 183 to an inlet 184 in manifold 98. If desired, make-up liquid, either alkali or immiscible confining liquid, may be added, e.g., in separator 163, to the system to replenish any of such materials.

While I have described a particular embodiment of my invention for the purpose of illustration, it should be understood that various modifications and adaptations thereof may be made within the spirit of the invention as set forth in the appended claims.

I claim:

1. A process for the removal of metal from a metal work piece which comprises directing a stream of liquid etchant against said work piece, directing a stream of confining fluid against said work piece adjacent said stream of liquid etchant, said fluid producing an etchant stream of predetermined geometric cross-sectional configuration and confining the area of impingement of said etchant liquid on said work piece, forming said predetermined geometric etch configuration in said work piece, and withdrawing spent etchant liquid and confining fluid from said work piece.
2. A process as defined in claim 1, wherein said fluid is a liquid which is immiscible with said etchant liquid, and is non-reactive with the metal of said work piece.
3. A process for the removal of metal from the surface of a metal work piece which comprises directing a first stream and a second stream against said surface, said first stream comprising an etchant liquid and said second stream comprising a confining fluid, said confining fluid being inert with respect to said etchant liquid and to said metal work piece, said first etchant stream having sufficient kinetic energy and being of a predetermined geometric cross sectional form to give on impingement against said work piece a cross sectional area of impingement corresponding to the etch configuration to be formed in said surface, said second stream confining said etchant liquid substantially to the area of said work piece defined by said etch configuration, the pressure of said second stream being greater than the pressure of said first stream, removing metal from said work piece in the area of impingement by said etchant stream, and withdrawing the spent etchant liquid from said surface of the work piece.
4. A process for producing an etch having a geometric pattern in a metal work piece, which comprises directing a stream of liquid etchant against said work piece, simultaneously directing a wall of confining liquid against said work piece, said confining liquid being immiscible with said liquid etchant, said confining liquid completely surrounding said etchant stream and producing an etchant stream of predetermined geometric cross-sectional configuration and confining impingement thereof on said work piece substantially to the area of said geometric etch pattern, forming said etch pattern in said work piece, and withdrawing spent etchant liquid and confining liquid from said work piece.
5. A process for producing an etch pattern in the surface of a metal work piece, said etch pattern being composed of a plurality of geometric etch configurations, which comprises directing a plurality of streams of liquid etchant against said surface, said streams each having sufficient kinetic energy and being of a predetermined

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geometric cross sectional form to give on impingement against said work piece a cross sectional area of impingement matching one of said etch configurations, simultaneously directing a wall of confining liquid against said surface, said confining liquid being immiscible with said liquid etchant, said confining liquid completely surrounding each of said liquid etchant streams and confining impingement thereof on said work piece substantially to the area of its matching configuration, forming said etch pattern in said work piece, and withdrawing spent etchant liquid and confining liquid from said work piece.

6. A process for the removal of metal from a metal work piece, which comprises directing a stream of liquid etchant against said work piece in a first zone, directing a stream of confining liquid against said work piece adjacent said stream of liquid etchant, said confining liquid being immiscible with respect to said liquid etchant and producing an etchant stream of predetermined geometric cross-sectional configuration and confining the area of impingement of said etchant liquid on said work piece, forming an etch configuration in said work piece, recovering from said work piece a liquid mixture including spent etchant liquid containing suspended solids and spent confining liquid, separating said last-named liquid from said spent etchant liquid containing suspended solids in a second zone, settling said solids out of said last-named liquid, recovering clear etchant liquid, recirculating said separated confining liquid and said clear etchant liquid to said first zone, and directing said recirculated etchant liquid and said recirculated confining liquid against said work piece as aforesaid.

7. A device for forming an etch pattern in a metal work piece, said etch pattern being composed of a plurality of geometric etch configurations, which comprises a tank, means for supporting a work piece in a substantially horizontal downwardly facing position in said tank, a plurality of nozzles for emitting a plurality of liquid etchant streams against said work piece, means for mounting said nozzles below and spaced from said supporting means for said work piece, said nozzles being positioned to discharge said etchant streams upwardly toward said supporting means, a source of liquid etchant, means connecting said source with said nozzles, said tank being positioned to receive impinged liquid etchant draining downwardly from said work piece, means positioned adjacent and completely surrounding each of said first-mentioned nozzles for discharging streams of confining fluid against said work piece, said last named means each being shaped at its discharge end so that said streams of fluid completely surround each of said etchant streams and produce etchant streams of predetermined geometric cross-sectional configurations and confining impingement thereof on said work piece substantially to the areas of said etch configurations, a source of said fluid, and means connecting said last-named source with said means for discharging said fluid.

8. A device for the removal of metal from a metal work piece, which comprises a tank, means for supporting a work piece in horizontal downwardly facing position in said tank, a nozzle for emitting a liquid etchant stream against said work piece, said nozzle being mounted in said tank adjacent and below said supporting means for said work piece, and positioned to discharge said etchant streams upwardly toward said supporting means, a source

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of liquid etchant, means connecting said source with said liquid etchant stream, said last named means being nozzle, said tank being positioned to receive impinged liquid etchant draining downwardly from said work piece, separate means positioned adjacent said nozzle for discharging fluid upwardly against said work piece adjacent shaped at its discharge end so that said fluid produces an etchant stream of predetermined cross-sectional configuration, a source of said fluid, and means for connecting said last-named source with said fluid discharge means, means in a separate zone for separating said fluid from a mixture also including spent etchant liquid and suspended solids in said tank, means for recirculating said separated fluid to said means for discharging same in said tank, means to permit settling of solid material from a liquid mixture containing etchant liquid recovered in said separate zone, and means for recirculating resulting clear etchant liquid to said nozzle.

9. A device for forming an etch pattern in a metal work piece, which comprises a first tank, means for supporting a work piece in a substantially horizontal downwardly facing position in said tank, a plurality of nozzles for emitting a plurality of liquid etchant streams against said work piece, means for mounting said nozzles below and spaced from said supporting means and a work piece supported thereby, said nozzles being positioned to discharge said etchant streams upwardly against said supporting means, a source of liquid etchant, means connecting said source with said nozzles, nozzle means positioned adjacent each of said first-mentioned nozzles for discharging streams of confining liquid upwardly against said work piece, said nozzle means each being shaped at its discharge end so that said streams of said confining liquid surround each of said etchant streams and produce etchant streams of predetermined geometric cross-sectional configurations and confining impingement thereof on said work piece substantially to the areas of said etch configurations, a source of said confining liquid, means connecting said last-named source with said nozzle means, an outlet in said tank, a second tank for separating said confining liquid from a mixture also including spent etchant liquid and suspended solids in said first tank, means connecting said outlet with said second tank, a third tank, means connecting said second tank with said third tank, means for recirculating said separated confining liquid from said second tank to said nozzle means in said first tank, means in said third tank to permit settling of solid material from a liquid mixture containing etchant liquid withdrawn from said second tank, means for drawing off clear etchant liquid from said third tank, and means for conducting said clear etchant liquid from said third tank to said nozzles in said first tank.

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