

UNITED STATES PATENT OFFICE

2,372,599

ELECTROLYTIC CLEANING AND PICKLING
OF METAL SURFACES

John S. Nachtman, Pittsburgh, Pa.

Application March 29, 1940, Serial No. 326,632

6 Claims. (Cl. 204—141)

This invention relates to the cleaning of metal surfaces; it involves the washing of the metal surface with liquid, ordinarily water or an aqueous solution; and consists in the establishment of conditions of electrolysis, under which the washing proceeds. In the electrolytic arrangement the water-flooded sheet may be the cathode, it may be the anode, or, though neither cathode nor anode, it may yet be immersed in the electrolyte, and in either case the effect of electrolytic action will be to render the cleaning process more effective. The invention finds practical application in the cleaning of steel strip, and in that application I shall describe it.

In the accompanying drawing Fig. I is a diagrammatic view in vertical and longitudinal section of apparatus for cleaning steel strip, in the operation of which this invention may be practised. Figs. II and III are like views of other cleaning apparatus: Fig. II, specifically, of pickling apparatus; Fig. III of electro-plating apparatus. Fig. IV is an enlarged diagrammatic view showing the electrical connections to one of the sprays and to one of the brushes.

Referring to Fig. I, the apparatus there shown is designed and intended for the removal of grease from the surface of the strip. It consists of hot-water scrubber A, drier B, cleaner C, hot-water rinse D, and drier E. These several pieces of apparatus are arranged in succession, end to end, and the strip S to be cleaned advances through them from left to right, in continuous course.

The hot-water scrubber A is provided to remove the heavier part of the coating of grease, oil, and dirt that fouls the strip. It consists of a tank 1, provided with a hood 2 and an exhaust 3. Exhaust 3 may be understood to be connected to an exhaust system, not shown. Within tank 1 are mounted rotating metallic brushes 4 (preferably of stainless steel and driven by individual motors), backing-up rolls 5, hot-water sprays 6 (100 pounds pressure at 180–210° F.), and squeegee rolls 7. The brushes 4 are preferably provided, as here shown, in plurality (the number will depend upon the speed of the strip), and arranged to engage successively both surfaces of the advancing strip; the backing-up rolls 5 are severally paired, each with a brush 4, and are adapted to sustain the strip while the brush scours its opposite surface; the hot-water sprays also plays upon both surfaces of the strip. The jets from the sprays may be directed obliquely to the surface of the strip, and successive jets may be oppositely inclined, as the drawing shows. The

squeegee rolls are paired and set to engage simultaneously and to exert pressure upon the strip as it advances between them. Brushes 4 are rotated to give a speed of approximately 3000 f. p. m. brushing speed on the strip, and they are preferably rotated in a direction contrary to the advance of the strip. Backing-up rolls 5 and squeegee rolls 7 are driven at strip speed, and in the direction of strip progress. Sprays 6 receive hot water under pressure from compartment 33 (presently to be described) through a pipe connection 39. The waste water from tank 1 with its burden of fouling material is carried to the sewer by drain-pipe 8.

In case the sewer capacity is not sufficient to take care of the grease and oil removed in the scrubber A, they may be separated out in a settling tank, as shown. The discharge from pipe 8 is secured in a tank 50. It is essentially a mixture of grease and water. Due to the low velocity of the oily mixture through the tank, the oil and grease will rise to the surface and pass over partition 51, and escape through passageway 53 to a place suitable for disposal. The water collecting in tank 50 passes beneath baffle 56 to compartment 51, and then over partition 58, through passageway 52 to the sewer.

The splash from the brushes 4 is caught by baffles 20 and 21 and directed to tank 1, thereby leaving the strip relatively dry when it enters the squeegee 7. The squeegee 7 attenuates the water film upon the strip, so that it can be quickly dried in the drier B. This feature will be the better understood when it is remembered that the strip is still coated with an oil film, and water will not adhere to its surface.

The drier B consists of tank 9, hood 10, and exhaust 11, heated rolls 12, and a hot-air supply (not shown) for circulating hot air around the heated rolls 12. The purpose of this drier is, by removal of water from the strip, to prevent dilution of the cleaning solution in the tank 13. Rolls 12 are provided in pairs; there is advantageously a plurality of pairs of them; they engage the strip advancing between them; they are driven in the direction of strip progress, and preferably at strip speed; and may be heated in convenient manner, as by gas, steam, or electricity.

The mechanical cleaner, water rinse, and solution-recovery system C, D is an integral unit and includes a tank 13 with hood 14 and exhaust 15. Tank 13 is divided into two compartments 27 and 33, by partition 22. Concentrated cleaning solution is maintained in compartment 27, while the concentration in compartment 33 will be

very much less, as will be made plain in the following description. Within tank 13 are mounted rotating metallic wire brushes 16, 17, and 18, with backing-up rolls 19. As shown, the axes of rotation of these brushes are in planes parallel to the strip so that the brushes brush the strip tangentially. These brushes are preferably of stainless steel and are driven by individual motors to give a brushing speed of approximately 3000 f. p. m. rotating against the travel of the strip. The backing-up rolls are driven at strip-speed and in the direction of strip advance. The organization is that already described, of the brushes 4 and their backing-up rolls 5, in scrubber A.

Concentrated cleaning solution, essentially alkaline, maintained in compartment 27, is kept constantly in circulation. It is withdrawn through drain 28 and is pumped by pump 29 through filter 30, heater 31, and pipe 32 back to sprays 23. The sprays 23 (of greater number) are arranged toward the intake end of the cleaner C, while other sprays 24 (less in number), presently to be described, are arranged toward the delivery end. All the sprays are advantageously arranged to deliver their jets obliquely upon the surfaces of the strip, and successive sprays may deliver oppositely directed jets. The sprays deliver their jets from above and below upon the strip as it advances, and the solution collects in compartment 27. The strip advances in horizontal course, at higher level than the surface of the pool of solution in compartment 27. The discharge from sprays 23 is in continuous stream at a pressure of 1 to 15 pounds. The pressure is as high as is permissible without undue foaming.

Baffles 20 and 21, similar to those already described, catch the splash from the brushes and direct the solution back to the pool in compartment 27 for recirculating and reheating.

The sprays 24, arranged toward the delivery end of cleaner C, receive through pipe 33 and from a source presently to be described, hot water under pressure in quantity sufficient to make up for dragout and evaporation, and to maintain the level of the pool of cleaning solution in compartment 27. The amount of water so supplied under pressure to sprays 24 is controlled by float valve 38A. The sprays 24 deliver hot water on the strip in a high-pressure atomized spray that dilutes the solution of the film upon the strip. This diluted film is picked up by other brushes 17 and thrown against other baffles 20 and 21 and diverted back to pool-compartment 27.

Yet other sprays 25, arranged adjacent the path of progress of the strip, beyond the partition 22 that defines the compartment 27, and within the portion of the apparatus indicated by the letter D and termed the rinse, receive hot water under high pressure from pipe 57. Jets from sprays 25 directed both rearwardly and forwardly, as shown, impinging upon the strip from above and from below, thoroughly wash the strip, and, in cooperation with the scrubbing action of brushes 18, remove all cleaning solution from the strip and replace the film of solution upon the strip with a film of water. The water collecting in compartment 33 is recirculated by means of drain-pipe 34, pump 35, filter 36, heater 37 and pipes 38, 39, and 57. The discharge from 38 is through sprays 24, the discharge from 57 is through sprays 25, and the discharge from 39 is through sprays 6 in scrubber A. Additional baffles 20 and 21 catch the splash from the last-

mentioned brushes 18 and direct the water back to compartment 33 without rewetting the strip.

The sprays 25 are arranged toward the intake end of rinse D. Other sprays 26, less in number than sprays 25, are arranged within the rinse toward the delivery end. Sprays 26 are supplied with fresh, hot water under pressure from a source not shown, and deliver jets of fresh, hot water under pressure upon the strip to rinse it completely. The rinse water is largely removed by the squeegee rolls 47. The rinse water gathers in a pool or compartment 33 and excess is discharged through an overflow pipe 40.

The drier E is similar to B, and consists of tank 41, heated rolls 44, hood 42, and stack 43. The strip at this point, free of oil, is filmed over with water, and is on that account more difficult to dry completely. The drier E may, therefore, be desirably of larger capacity than drier B.

In size the units are suited severally to the speed of operation and the nature of the steel that is being cleaned. In some cases it may be desirable to omit units A and B. In the case of strip stock that has been annealed; or, again, in the case of skin-rolled dry or hot-rolled stock that has been flattened or annealed; the surface does not carry heavy grease. It is in such cases as these that scrubber and drier may be omitted. In other cases, as, for example, when the strip is being prepared for electro-plating, the strip is kept wet, to prevent the filming over of the cleaned surface; and the wet strip is advanced directly into the electro-plating bath. In such case the drier E will be omitted.

It is to apparatus so constructed and organized that my invention may be added, and the method of cleaning that is accomplished in the operation of that apparatus, carried out under the conditions of my invention, will be found to be in greater degree efficacious.

I provide a low-voltage generator. The sprays will be understood to be metallic (and, accordingly, electrically conducting) nozzles that deliver jets of liquid (also electrically conducting) upon the surface of the strip (which also is electrically conducting). I preferably connect one terminal of the generator G to the sprays 23, and the other terminal to the rotating brushes 16. I obtain fastest cleaning when I connect the positive terminal to the sprays 23 and the negative terminal to the brushes 16 as shown in Fig. IV. I preferably employ a current density of 3000 to 5000 amperes per square foot of jet cross-section. Under these conditions there is a rapid evolution of hydrogen on the strip where the spray strikes the strip, and a rapid evolution of both hydrogen and oxygen adjacent the portion of strip that is being brushed, with result that the film of oil is removed almost instantly and is turned to soap by the cleaning solution.

As shown in Fig. IV, the shaft of each rotating brush 16 may have a current collecting drum 204 at one end with a contact brush 205 slidably contacting the same for conducting current from a generator G to the brush.

The electrolytic condition may be imposed upon the cleaning operation by other arrangements of the current connections, but such other arrangements will, however, be less effective in producing an electrocleaning action. For example, half of the sprays 23 may be connected with the positive terminal of the generator, and the other half with the negative terminal; or, again, the backing-up rolls 19 within the extent of the compartment 27 may be connected with one terminal

and either the jets 23 or the cooperating brushes 16 with the other terminal. In some cases it will be desirable to electrify the metallic brushes 4 in the scrubber A by connecting them to one or the other terminal of the generator. Half of the brushes 16 may, for example, be connected to the positive terminal of the generator and half to the negative terminal; and other such permutations may be made.

Alternating current may be used, or alternating current may be superposed on direct current.

The essential characteristic is the rapid evolution under electrolytic action of gas at the surface of the strip and in the area that is under the mechanical action of spray or brush. Thus the cleansing effect is intensified. If it be hydrogen gas, generated at the surface of the strip, it will be effective not only in aiding the mechanical removal of material that fouls the surface; it will tend also to reduced oxide that may be rolled into the surface and in that respect also to improve the surface.

The cleaning apparatus that is shown in Fig. II is, specifically, apparatus for the pickling of metallic strip, and like the cleaning apparatus of Fig. I, it is designed for operation upon strip as it advances in continuous course. In the operation of this apparatus of Fig. II also the invention may be practised. The apparatus consists of a cold-water spray F, a scale breaker G, a scrubber H, a pickler I, a rinse J, and a drier K. These pieces of apparatus are organized to stand in successive positions, that the strips of material moving from left to right may progress in continuous course through them. The pickling apparatus will be described for the pickling of strip steel.

In the present methods of manufacture of strip steel the steel is hot rolled to a thickness of approximately 0.070" to 0.125", and is then coiled before being further processed. During the hot rolling and cooling a heavy scale of iron oxide forms upon the surface; and, before the strip can be further reduced by cold rolling, it is necessary that the scale be removed. In the practice that now is usual the coil is unwound and the strip is passed through pickling apparatus that includes a long tank of acid solution, in which the strip is submerged for several minutes. Because of the length of the tank, the tension upon the strip is necessarily very high, and the machinery must be quite massive. In the practice of the present invention the scale may be removed much more rapidly and in such a manner that the strip need be under no tension and the machinery may be relatively light. The apparatus here shown is designed with the expectation that it will receive the strip directly after the hot rolling and while the strip is still in the form of a long flat sheet; but I desire to make the fact plain that the apparatus may be associated with uncoilers and other necessary mechanism for straightening out a coil of strip and for feeding it into this pickling machine. In such case, as will be understood, the invention will be practised upon strip that has been coiled after passing through the hot rolling mill.

From the hot mill (in preferred procedure) the strip is run out on a cooling table and cooled to a temperature that will permit the strip to be sprayed with water. The leading end of the strip is then caused to advance first through unit F. Unit F consists of a suitable chamber, within which the advancing strip is subject to sprays of

cold water at high pressure from nozzles 60 and to the flexing action of passing between rolls 61, which are adjustable in the vertical direction and are driven at strip speed. The length of unit F is sufficient to reduce the temperature of the strip to approximately 200° F. The strip then advances through the scale breaker G, where it is bent back and forth to loosen the adhering scale.

From the scale breaker the strip advances to the scrubber H. As the strip enters H it is flooded with acid pickling solution from nozzles 62 and is scrubbed by rotating metallic wire brushes 63 against backing-up rolls 64. Rolls 64 are driven at strip speed, and brushes 63 are driven to give a brushing speed of approximately 3000 f. p. m. while rotating in the same direction with that of strip travel. (When the material under treatment is in the form of discontinuous sheets, the control will be so arranged as to stop the brushes as the end of the sheet is approached.) The brushes perform two mechanical functions: first, they remove scale; and, second, they remove the spent acid, so that fresh acid from succeeding sprays 62 may come into immediate contact with the strip surface. Squeegee rolls 65 attenuate the acid film and render more effective the electrified sprays 66 of the pickler I.

The pickler I consists of a tank 67, a hood 68, a chimney 69, and the enclosed apparatus. The strip advances in horizontal course through the tank and at higher level than the surface of the pool of pickling solution that collected in the tank—all as indicated in the drawing.

When the strip has left scrubber H and entered pickler I, it is sprayed with electrified-acid sprays 66 and flexed back and forth by rolls 70 which are driven at strip speed. The spray nozzles 66 are preferably connected to the positive terminal of an electric generator and either the rotating brushes 71 or the rotating brushes 63 in the scrubber H or both may be connected to the negative terminal; and a current of approximately 3000 amperes per square foot of spray cross-section is caused to flow. Under such conditions the strip becomes the cathode of an electrolytic cell and hydrogen gas is generated at its surface.

In some cases it may be advisable to connect also the acid sprays 62 within the scrubber H to the positive terminal of the generator, so that hydrogen gas forms on the surface of the strip while scale is being removed by the brushes 63. Such an enlargement of the number of the sprays that are electrified results in more rapid pickling.

As in the case of the cleaning procedure described with reference to Fig. I, other arrangement of current connections are permissible—though I have described that which I believe to be best. For example, half of the sprays 66 may be connected to the positive terminal of the generator and the other half to the negative terminal; the sprays 62 may be connected to one terminal and the sprays 66 to the other; and other arrangements are permissible—it being requisite only that gas be evolved electrolytically at the strip surface, in the area being sprayed upon or scrubbed.

I have found that alternating current, or alternating current superimposed upon direct current, is effective in accelerating the speed of pickling.

The solution ordinarily will be acidic; but other chemically effective cleaning operations, using solutions that are non-acidic, are known to the metal-cleaning industry; and, manifestly, the invention here described is of general ap-

plicability, and is not conditioned by nor limited to association with an acidic solution.

Pickling solution is supplied under pressure to sprays 62 and 66 through pipe 72. The solution caught in tank 67 is withdrawn, as in the apparatus of Fig. I already described, and is circulated by pump 73 through filter 74 and heater 75 to pipe 72, and thence back to the sprays. Recirculated water, through pipe 76, is sprayed on the strip by sprays 77 that are situated within the pickler I toward the delivery end. They direct their jets upon the strip after it has passed beneath the sprays 66. These water sprays 77 dilute the acid film on the strip before it is acted upon by brushes 71. These brushes engage, one the upper, the other the nether, surface of the strip before the strip passes from the pickler I, and the strip when it is made subject to the action of the successive brushes is backed by a co-operating roll 93. Baffles 95 and 96 catch the splash from brushes 71 and return it to tank 67.

The amount of water supplied to sprays 77 is controlled by a float valve 78 to make up for evaporation and dragout. The temperature of the pickling solution should be maintained at approximately 120° to 180° F. The density of current applied to sprays 66 and 62 should vary inversely with the temperature.

The rinse J consists of a tank 81, a hood 82, a chimney 83, and the enclosed apparatus. The strip enters it from the pickler I and advances through it in horizontal course and at a higher level than the surface of the pool of water that collects in the tank—all as indicated in the drawing.

In rinse J the strip is washed by water delivered through sprays 79 and scrubbed by rotating metallic wire brushes 80 (with cooperating backing rolls 94) to remove all traces of acid and metallic salts from the strip. Fresh hot water from a source not shown is supplied to sprays 84 that are arranged toward the delivery end of the rinser, and in an amount to keep the contents of the tank 81 sufficiently diluted. A constant level is maintained in tank 81 by an overflow pipe 85, through which the excess is passed to the sewer. From the pool in tank 81 water is drawn through a pipe 86 and driven by a pump 87 through a filter 88 and a heater 89, and is delivered through two leads: through lead 76 (which as has been explained is valve controlled) to the sprays 77 in the pickler I, and through the lead 90 to sprays 79 in the rinse J. Of these two sets of sprays the set 79 delivers its jets first upon the advancing strip, and afterward the set 84. Baffles 97 and 98 catch the splash from brushes 80 and return it to tank 81.

Squeegee rolls 91 at the delivery end of the rinse attenuate the water film on the strip, so that it can be quickly removed by the heated rolls 92 in drier K. The strip as it emerges from drier K is oiled and coiled in the usual manner and stored for further processing.

If the strip to be pickled is cold (as it would be if taken from storage in a coiled form) the high-pressure water sprays 61 will not be employed and heated rolls will be used in place of rolls 61, to bring the strip to the approximate temperature of 200° F.

Strip pickled in the manner described is in better condition for further processing than strip pickled the old way, because it is free of foreign matter such as carbon, smudge, etc., and is in ideal condition for cold reducing or for coating

with a protective coating—as by electroplating, hot dipping with zinc, etc.

A distinct advantage of the pickling operation, carried out with the employment of my invention as described, is that most of the scale, mechanically removed from the strip, will be carried by the circulating stream of the pickling solution to the filter. It will there be separated, so that the solution will not continue to react with it; and, in consequence, the life of the solution for its intended useful purpose will be prolonged.

A third case, illustrative of the practice of my invention, is the case of the hot-dip coating of steel strip—as, for example, galvanizing. In slow-speed continuous hot-dip coating, the strip is advanced successively through a fluxing tank and a hot-coating tank. The invention is practiced by arranging in the line of advance of the strip as it approaches the fluxing tank such a unit as that indicated at A, Fig. I. The solution used in the sprays 6 may be acid, alkaline, or neutral, depending on the type of flux used and on the condition of the surface as it comes to be treated. The electrolytic evolution of gas at the surface of the strip advancing through the unit A may be brought about by connections such as those already specified. Within the unit A, in the manner already described, the strip is prepared for fluxing. It is important that the surface cleaned in unit A be not permitted to dry between the cleaning and the fluxing steps of the operation. As long as the surface is kept wet, no superficial film will form to interfere with fluxing. Tests show that, when the surface of the strip has been prepared in the manner indicated, a higher quality is achieved in the coated plate. The coating will be more uniform and more closely adherent. In consequence, deeper drawing of the coated strip becomes possible without peeling or cracking of the coating. Incidentally, speed of operation may be increased.

The use of rotating brushes of stainless steel wire has peculiar value in this association. Cold-rolled strip carries rolled into its surface (as elsewhere herein explained) the products of oil broken down by heat. Cleaning mechanism in common use in this association leaves the surface inadequately cleaned and the consequence is a product whose quality admits of improvement. I find that with the scrubbing mechanism of unit A arranged as last described, and particularly by virtue of the scrubbing effect of brushes of stainless-steel wire, the strip goes to the fluxing bath in singularly clean condition, and, in consequence, the quality of the product is improved. The invention described in association with galvanizing procedure is applicable generally to hot-dipping procedures, as in the making of tin-plate and terne-plate.

The invention may be practised in association with the electro-plating of sheet; and when so associated, the cleaning current and the plating current may be derived from a common source. This is illustrated in Fig. III. In this figure a strip S that may be understood to be a strip of steel advances in continuous course through a plating bath within a tank. Anodes 101 are arranged within the bath in suitable position with relation to the advancing strip. The strip itself becomes the cathode. The electro-plating circuit may be completed through the brushes 102 that scour the sheet as it advances to the tank 100; and if, in the manner already described, the sprays 103 that direct their jets upon the sheet as it approaches the scouring brushes 102 be con-

connected with the positive terminal of the source of electric energy (with which terminal the anodes 101 also within the electro-plating tank are connected), it is manifest that from the same source of energy may be derived both the gas-generating current that aids in cleaning the strip and the electro-plating current that effects the deposit of metal upon the strip. In some cases it will be desirable to connect the anodes to the positive terminal of a voltage source different from that which supplies the current for the sprays 103, in order that the two currents, for plating and for cleaning, may be independently adjusted. The contact through which the strip is brought into circuit may be through the brushes 102 or through the backing-up rolls 104, or through both.

In the bluing of strip, as distinguished from electro-plating, the strip may be made the anode in an electrolytic bath, and in such case the positive terminal of source of electric energy supplied for both the cleaning operation and the bluing operation will be connected with the strip and the gas generated at the strip surface both for the initial cleaning and the succeeding bluing will be oxygen.

In all of the procedures that I have described—the cleaning operation performed by the apparatus of Fig. I, the pickling operation performed by the apparatus of Fig. II, the dipping operation, and the plating and bluing operations last described—superficial fouling material is removed from the surface of the metal. In one case this fouling material is grease, in another it is scale, in yet another it is rolled in hydrocarbon pollution. In each case the cleaning operation involves the flushing of the fouled surface with liquid, and, specifically, aqueous liquid—acid, alkaline, or neutral. The invention is applicable to all these situations, in virtue of the fact that the fouled surface is flushed with liquid. The invention lies primarily in applying, in these circumstances, an electrical circuit—in causing the liquid as it flushes the fouled surface to become the electrolyte of an electrolytic cell. The fouled sheet is immersed in the electrolyte; preferably it is an electrode, most advantageously the cathode, of the cell; but in any case, through electrolysis, water is decomposed, gas is evolved at the metal surface, and gas evolution aids in and renders more effective the removal of the fouling material from the metal surface. Ancillary features of invention are found in the conservation of the metal-treating liquid by washing it from the advancing sheet and returning it to effectual circulation, and in the unique value of brushes of stainless-steel wire, not only for circuit-making contact but also for efficacy in removing inrolled defilement from the strip surface.

The cleaning and pickling processes, rendered more effective by the aid of my invention, as herein described, are suitable for the preparation of metallic surfaces generally—whether prior to annealing; after annealing; after rolling and prior to plating, hot coating, painting, enameling, or other chemical or electro-chemical treatment—indeed, wherever a chemically clean surface is desired. In the cold-rolling of strip at high speed, lubricant is used to keep the stock cool; but the heat generated in rolling may effect some breaking-down of the lubricant and the heavier products of such breaking-down may be rolled into the surface of the strip; again, the strip having already been pickled by a process such as those commonly in use, ferric and ferrous salts

remaining on the strip may in the ensuing rolling operation be rolled into the surface, and in such cases as these the invention is effective, to afford more adequate and complete removal of the surface-fouling material.

I have found by actual test that brushes formed of stainless-steel wire will be effective, under the conditions brought about in the practice of the invention described, to remove most films that under prevalent rolling-mill practice are rolled into strip surfaces. This is due to the high tensile strength, the elasticity, and the non-corrosive character of stainless steel.

In all operations such as those described, where strip is being propelled at high speed and liquid is in contact with the surface of the strip, the liquid is set in motion and carried along with the strip; and, unless preventive means be provided, the dragout of the liquid (which ordinarily is a solution of some relatively costly salt) results in a loss that may be such that in particular cases operation ceases to be profitable. Indeed, in conventional cleaning operations, this dragout of cleaning solution is the major item of expense. With this observation in mind, it will be remarked of the apparatus that has been described that in each case rotating wire brushes are set toward the delivery end of the tank, and that the strip as it approaches these brushes is sprayed upon with limited quantities of water; and baffle plates are added, against which the brush-thrown solution impinges, and by which the solution is directed back to the pool within the tank. These brushes, rotating as they do in direction opposite to that of strip advance, have stiffness sufficient to arrest the liquid in its advance. The quantity of water sprayed upon the strip as it approaches these brushes at the delivery end of the tank is so controlled as to make good the evaporation and (reduced) drag-out losses, and to maintain the surface of the pool within the tank at proper level. This solution-recovering system is manifestly applicable to chemical and electro-chemical processes generally.

In the cleaning or pickling of some metallic surfaces it may be desirable to use brushes of other metal than stainless steel. The type of metallic wire brush to be used will depend upon the speed of strip travel, the nature of the metal being cleaned, etc. For soft strip metals the brush may be made of a metal softer than stainless steel.

I claim as my invention:

1. The method of continuously cleaning the surface of a moving metal strip to remove foreign material therefrom, which consists in applying an aqueous liquid to said strip, tangentially brushing the liquid-carrying surface of said strip with a rotating metallic brush electrically connected to one terminal of an electric generator, and passing a current from the other terminal of the generator through said liquid and brush for rapidly evolving gas electrolytically at the brushed surface.

2. The method of cleaning the surface of a metal strip to remove foreign material therefrom, which consists in passing an aqueous liquid through a jet-forming electrode connected to one terminal of an electric generator, moving the strip past the liquid jet to impinge the jet on the surface of said strip, tangentially brushing the jetted surface with a rotating metallic brush electrically connected to the other terminal of said generator, and passing a current

through said jet electrode, strip and brush for rapidly evolving gas electrolytically at the surface of the strip.

3. The method of continuously cleaning the surface of a moving metal strip to remove foreign material therefrom, which consists in jetting an aqueous liquid against the surface of said strip, tangentially brushing the jetted surface with a rotating metallic brush connected to one terminal of an electric generator, and passing an electric current from the strip through the liquid jet to the other terminal of the generator for rapidly evolving gas electrolytically at the jetted surface of the strip.

4. The method of continuously cleaning a metal strip, which includes passing the strip over a tank containing cleaning solution, jetting said cleaning solution against the surface of said strip, tangentially brushing the jetted surface with a rotating metallic brush connected at one terminal of an electric generator, and passing an electric current from the strip through the liquid jet to the other terminal of the generator, said current having a current density per square foot of jet cross section area sufficient to produce a

rapid electrolytic evolution of gas at the jetted surface of the strip, all while the strip is passing over the tank.

5. The method of continuously cleaning the surface of a moving metal strip to remove foreign material therefrom, which consists in applying aqueous liquid to said strip, tangentially brushing the liquid-carrying surface of said strip with a rotating metallic brush electrically connected to one terminal of an electric generator, and passing an electric current from said brush to the strip.

6. In a method of cleaning a moving metallic surface to remove oil, dirt, carbon and oxides, the steps of jetting a continuous stream of aqueous electrolyte from a jet forming electrode through the atmosphere against said moving metallic surface, and passing electric current from said jet forming electrode through said jet of electrolyte to said moving metallic surface, said electric current being at sufficient current density to cause rapid evolution of gas by electrolysis at the moving metallic surface in the area of said jet impingement.

JOHN S. NACHTMAN.