METHOD OF CLEANING METAL STRIP

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This invention relates to the cleaning of metal strip material and in particular to the cleaning of metal strip formed from refractory metal of the class of titanium, titanium base alloys, zirconium and zirconium base alloys. In producing strip metal of refractory metal of the class of titanium, titanium base alloys, zirconium and zirconium base alloys, it is necessary in processing the metal into strip of commercial quality to remove oxides, scale and the like therefrom. Attempts have been made in the past to effectively remove the oxides from such metal strip by continuously passing the strip through a heated alkali metal caustic bath formed of molten salts such as the commercially available Virgo and Kolene salts, and thereafter picking the treated strip in a suitable acid bath. While such procedure has been effective in the production of stainless steel strip, it has not proven to be successful in the cleaning of metal strip formed of the refractory metals of the class of titanium, titanium base alloys, zirconium and zirconium base alloys in that although the oxides are removed, the resulting cleaned strip is so severely burned or electrolytically pitted that a large amount of rejected strip material is produced. This problem has been present in the industry for a considerable period of time and in fact, ever since strip material of the refractory metals has been produced commercially, and while many attempts have been made heretofore to eliminate such electrolytic pitting, such attempts have been without success.

An object of this invention is to provide a method of removing oxides from the surfaces of strip formed from refractory metal of the class of titanium, titanium base alloys, zirconium and zirconium base alloys while preventing electrolytically pitting of the cleaned strip.

Another object of this invention is to provide a method of removing oxides from the surface of strip formed from refractory metal of the class of titanium, titanium base alloys, zirconium and zirconium base alloys while maintaining the strip immersed by means of at least one rotatable iron-base roll, there being a difference in potential between the iron-base tank containing the caustic bath and the strip metal immersed therein with the strip metal having a negative polarity with respect to the tank, and for effecting a flow of current between the tank and the roll to develop a difference in potential therebetween substantially equal to the difference in potential between the tank and the strip whereby the roll is maintained at the same potential and polarity with respect to the tank as the strip to decrease current flow between the roll and the strip to prevent electrolytic pitting of the strip.

Other objects of this invention will become apparent from the following description when taken in conjunction with the accompanying drawing in which:

Fig. 1 is a view in section of a cleaning tank employed in practicing this invention;

Fig. 2 is a schematic diagram illustrating connections and equipment embodying the teachings of this invention, and

Fig. 3 is a schematic diagram of an equivalent circuit representing the electrical conditions encountered in the use of a tank such as is shown in Fig. 1, only one roll being shown in the equivalent circuit.

Referring to the drawing, and in particular to Fig. 1 thereof, this invention is illustrated by reference to the immersion of a strip 10 of refractory metal of the class of titanium, titanium base alloys, zirconium and zirconium base alloys in a heated alkali caustic metal bath 12 usually having a sodium base and which is in a molten state, the caustic bath being contained in an iron-base tank 14. Associated with the iron-base tank 14 and usually supported on the edges thereof are a number of rolls formed of an iron base and having at least the lower edges thereof immersed in the heated caustic bath 12. As illustrated, three rolls are shown, rolls 16 and 18 being submersion rolls and roll 20 being a wiper roll, the metal strip 10 being passed beneath the rolls 16 and 18 and over the roll 20. Each of the rolls 16, 18 and 20 is suitably mounted on shafts 22, 24 and 26 which have the ends thereof supported in suitable bearing housings 23, 25 and 27, respectively, which are electrically insulated from the iron-base tank 14 so as to completely insulate the rolls 16, 18 and 20 from the tank 14. Each shaft is suitably connected to a prime mover, such as a motor (not shown), to be driven thereby.

The alkali metal caustic bath may be any of the well-known commercial caustic baths which usually have a sodium base and are preferably heated, and in use are preferably maintained at a temperature in the neighborhood of 875 to 975°F. so that the salt bath is in a molten state and will readily react with the oxides normally contained on the surface of the strip 10 as the strip is admitted to the tank beneath the roll 16. While many variations in the composition of the caustic bath are possible, a typical example of a suitable caustic bath is that of the commercially known Virgo salts having about 88.55% sodium hydroxide, about 7.66% sodium nitrate, 1.72% sodium chloride and 0.53% sodium carbonate, with traces of manganese dioxide present. The Kolene salts or alkali metal hydroxides, nitrates and chlorides as described in Patent No. 2,458,661 are also effective for use in removing the oxides from the metal strip 10.

In accordance with this invention the submersion roll 18 near the exit end of the tank 14 and usually the other submersion roll 16 and the wiper roll 20 are disadvantageously connected in an electrical circuit in relation with the tank 14 and to a suitable source of power supply represented by the rectangle 28 in Fig. 2 so as to impart a difference in potential between the iron-base tank 14 and the iron-base roll 18 as well as the iron-base tank 14 and the iron-base rolls 16 and 20 if desired. Thus, the shaft 24 of the roll 18 is provided with a commutator sleeve 30 on which sliding brush contact members 32 ride, the brush contact members 32 being connected through an adjustable resistor 34 and a manually operable switch 36 to conductor 38 which is connected to the negative terminal of the power supply. The tank 14 is connected as through conductors 42 and 43 to the positive terminal of the power supply. In a similar manner the shafts 22 and 26 of the rolls 16 and 20 may be provided with commutator sleeves 44 and 46, respectively, having sliding contact brushes 48 and 50, respectively, in engagement therewith. The contact brushes 48 are connected through adjustable resistor 52 and manually operable switch 54 to the conductor 38 and the contact brushes 50 are similarly connected through adjustable resistor 56 and conductor 58 to the conductor 38. The portions of the tank 14 associated closely with the rolls 16 and 20 are also connected as through conductors 60 and 62, respectively, to conductor 43. In practice the tank 14 may be considered as being connected to
ground as through the supporting structure thereof or the like as represented at 63.

In order that a visual observation may be made as to the difference in potential between the tank 14 and any one of the rolls 16, 18 and 20, each of the shafts 23, 24 and 26 is provided with a commutator sleeve 64, 66 and 68, respectively, each of the commutator sleeves having a slipper contact member 70, 72 and 74, respectively, in engagement therewith for cooperating therewith in making an electrical connection. The brushes 70, 72 and 74 are connected as by conductors 76, 78 and 80, respectively, to fixed conductive members 82, 84 and 86, respectively, which are disposed to be engaged by a movable contact member 88 connected to one terminal of a voltage meter 90. The other terminal of the voltage meter 90 is connected as by conductor 92 to the tank 14 as at 94.

Referring to Fig. 3 of the drawing, the reason for the electrical connections illustrated in Fig. 2 will become apparent when the equivalent circuit for one of the rolls, as for example, roll 18, is considered. In Fig. 3, the strip 10 is illustrated as having a line or strip resistance $R_s$ shown at 96 and a combined leakage resistance $R_k$ shown at 98 of the strip through the supporting structure to ground. The tank 14 contains the molten caustic bath with the insulated roll 18 being at least partially immersed in the bath. The roll 18 is connected in series with a resistance $R_b$ shown at 100 which represents the resistance of the molten caustic bath between the tank 14 and the roll 18. Likewise, in series with the roll 18 and connected to the strip 10 is a resistance $R_e$ shown at 102 which represents the contact resistance of the strip 10 as the strip passes beneath the roll 18. In a similar manner it will be appreciated that there is an open circuit potential $E$ between the strip 10 and the iron-base tank 14 caused by a battery action in the bath, such open circuit potential $E$ being represented in Fig. 2 by the battery 104 which has an internal resistance $R_i$ shown at 106 which is assumed to be of the same magnitude as the bath resistance $R_b$. A slight battery action is also probably present between the roll 18 and the strip 90 as illustrated by the battery 108 and the internal resistance $R_k$ of the battery as shown at 110 in series connection between the roll 18 and the strip 10.

From measurements of potential between a strip of titanium base alloy having a thickness of .021 inch and an average width of about 40 inches and the iron-base tank 14, it was found that a very small leakage current between the strip and the different rolls may be present, which leakage current flows out of the strip to the reel (not shown) and back to the tank 14 through the structural members of the assembly. When the strip 10 is cut at the end, a difference in potential between the tank and the strip at the point of the cut is found which is substantially equal to the normal measured difference in potential of the tank 14 and the strip 10 at the tank. For this reason the effect of the leakage currents can be dismissed in the theoretical consideration of the equivalent circuit.

From actual measurements observed, the resistance $R_k$ of the molten caustic bath between the insulated submersion roll 18 and iron-base tank 14, that is, resistance 100, was found to vary from .005 to .010 ohm depending upon the temperature of the bath, whereas the open circuit voltage $E$ as represented by the battery 104 was found to be about 1.1 volts. The battery resistance $R_i$ shown at 106 may be considered, as stated hereinbefore, to be of the same magnitude as the resistance $R_k$ of the bath, that is, of from .005 to .010 ohm. Since the normal current flow in the strip in each direction from the tank 14 is insufficient, having been computed to be only 0.108 amperes in each direction, electrolytic burning of the strip 10, the resistance $R_k$ of the strip 10 and the combined leakage resistance $R_{k+b}$ of the strip to ground can be ignored in the theoretical consideration of the circuits. Likewise the effect of the cell represented by the battery 108 and battery resistance $R_b$ shown at 110 between the roll 18 and the strip is so slight that it can also be ignored.

With such assumptions it is possible to calculate the approximate current and voltage necessary to effect a difference in potential between the tank 14 and the iron-base roll 18 which will be substantially equal to the difference in potential normally found between the tank 14 and the strip 10 immersed in the caustic bath 12 in the tank 14. In effecting actual voltage measurements between the tank 14 and the strip 10 prior to effecting a flow of current between the iron-base tank and the roll 18, it is found that there is a difference in potential of .4 volt with the strip being of negative polarity with respect to the tank 14. Since the open circuit potential $E$ as represented by the battery 104 measures 1.1 volts, then the potential drop across the internal resistance $R_b$ of the battery as represented by the resistance 106 must be the difference between the open circuit potential of 1.1 volts and the actual measured difference in potential of .4 volt or .7 volt. Thus the current flow I (total) from the tank 14 to the strip 10 can be calculated by dividing the potential drop across the resistance 106 by the resistance 106, or

$$I = \frac{E_{rb}}{R_b}$$

Since there are two of the submersion rolls 16 and 18 in the bath, this would represent a flow of current of 70 amperes at each submersion roll if divided equally therebetween. As stated hereinbefore, the difference in potential between the tank 14 and the strip 10 as the strip passes therethrough is equivalent to .4 volt, so therefore the total resistance represented by the resistors 100 and 102 representing the resistance $R_k$ of the caustic bath and the contact resistance $R_c$ of the strip to roll, respectively, can be determined by dividing the difference in potential by the current at each submersion roll, that is,

$$R_{c+b} = \frac{E_{rb}}{I} = \frac{0.7}{70} = 0.005 \text{ ohm}$$

Since it is known from actual measurements that the resistance $R_k$ of the caustic bath between the tank and the roll 18 is equal to .005 ohm, then it is evident that the contact resistance $R_c$ at 192 is only .0007 ohm. Since the open circuit voltage E as measured is 1.1 volts, then the current required for the two submersion rolls, assuming that the contact resistance $R_c$ of the caustic bath are equally divided between the rolls, can be calculated by dividing the open circuit voltage 1.1 by one-half of the total resistance $R_{c+b}$ of the caustic bath or .0025 for a total of 440 amperes or the equivalent of a maximum of 220 amperes per roll to impart to the roll a negative polarity with a difference in potential between the tank 14 and the roll substantially equal to the difference in potential between the tank 14 and the strip 10 immersed in the caustic bath 12.

In practice it is found that the actual current required is not quite as high as the current calculated, since certain assumptions tending toward a higher current were made in the calculations. Actually where the rolls 16 and 18 are well insulated from the tank, a flow of current of a value of about 150 amperes is effective for causing a sufficient difference in potential between the iron-base tank 14 and the iron-base submersion rolls where such rolls have a diameter of 24 inches and a length of 5 feet, to do decrease the current flow between the roll and the strip 10 as to effectively eliminate all electrolytic pitting of the strip. Of course, if the insulation of the rolls is not sufficient, then more current is required to create the potential $E$ as a difference to prevent arcing between the submersion roll and the strip 10.

In operation, the strip 10 of refractory metal of predetermined thickness, as for example 0.92 inch thick, and predetermined width, as for example 40 inches wide, is
3,836,589 5 fed into the molten caustic bath 12 beneath the immersion roll 16 and the submersion roll 18 and over the wiper roll 20 and from thence to a suitable acid pickling, annealing and heat treating equipment (not shown). As the strip 10 enters the molten caustic bath 12, the strip is usually coated with oxides, as for example, in the case of titanium base alloys, a coating of titanium dioxide is present on, although not uniformly distributed over, the surface of the strip. Because of the presence of the film of titanium dioxide on the strip as it enters the molten caustic bath and is held therein by reason of the submersion roll 16, there is normally little current flow between the roll 16 and the strip 10. As the strip continues through the molten caustic bath, the molten caustic reacts with the oxides and changes them or removes portions thereof with the result that as the strip comes into contact with the submersion roll 18, an increase in the current flow between the roll 18 and the strip 10 will be effected as well as between the wiper roll 20 and the strip 10. Thus arcing to cause electrolytic pitting of the strip is usually found in the area of the submersion roll 18 and the wiper roll 20, the zones of the higher flow of current, as opposed to the area of contact with the submersion roll 16. In practice with the rolls 16, 18 and 20 without any shutdowns by reason of the described, the manually operable switch 36 is actuated to a circuit closing position to effect a flow of current from the tank 14 to the roll 18, such current flow being controlled by adjusting the adjustable resistor 34 in circuit relation therewith so as to create the difference in potential between the tank 14 and the roll 18, and the tank 14 necessary to substantially equal the difference in potential between the tank 14 and the strip 10 with the polarity of the roll 18 being negative with respect to the tank 14. The potential difference can be readily determined by moving the contact member 85 to the fixed contact member 84 to obtain a reading on the voltage meter 90 of the potential between the roll 18 and the tank 14. Under such conditions any current flow between the iron-base roll 18 and the strip 10 is so decreased or completely eliminated as to prevent arcing therebetween with the result that electrolytic pitting or burning of the strip 10 is consequently eliminated.

In practice, it has been found that usually the connection to effect the flow of current from the tank 14 to the roll 18 in the manner just described is sufficient to prevent the electrolytic pitting of the strip 10. However, to insure the complete elimination of the electrolytic pitting, the electrical connections previously described for the rolls 16 and 20 can be effected by actuating the manually operable switches 54 and 58, respectively, to their circuit establishing positions and controlling the flow of current from the tank 14 to the rolls 16 and 20 as by adjusting the adjustable resistors 52 and 56, respectively, so as to definitely effect a flow of current from the tank 14 to each of the rolls 16 and 20 to a degree effective for creating a difference in potential between the tank 14 and each of the rolls 16 and 20 substantially equal to the difference in potential between the tank 14 and the strip 10 to thereby prevent any arcing between the rolls 16 and 20 and the strip 10 in the area of contact of each of the rolls 16 and 20 with the strip 10. The potential difference between the tank 14 and each of the rolls 16 and 20 can be readily determined by actuating the movable contact member 88 to selectively engage the fixed contact members 82 and 86, respectively, to thereby obtain a reading on the voltage meter 90 of such potential differences.

The method of this invention is effective for permitting the reaction between the molten alkaline metal caustic bath and the oxides of the strip 10 of refractory metal of the class of titanium, titanium base alloys, zirconium and zirconium containing any accompanying electrolytic pitting or burning previously encountered, with the result that untold savings are obtained in that treated strip material is no longer rejected on the basis of electrolytic pitting or burning. In addition, another advantage has been obtained in that a longer life of the rolls 16, 18 and 20 is obtained as there is no longer a build-up of oxides and the like on the face of the rolls. Instead, it is found that there is an actual cleaving of the surfaces of the rolls with the result that there are no high points thereof to promote arcing. The reasons for this latter cleaning of the rolls are not understood, as one would normally expect a build-up on the rolls under such operating conditions. It is possible that the flow of current to the rolls removes the surface protective films or oxides normally present only on those rolls which are at a negative polarity with respect to the tank with the result that the caustic more vigorously attacks such metal and keeps it clean. Regardless of the reason, the fact remains that the rolls are actually cleaned with a measurable amount of removal of metal therefrom with the result that no shutdown time is required for replaacing the rolls with clean rolls such as was previously encountered in prior practice. Instead, where the previous systems had to be shut down, usually during or at the end of a 24-hour run, the present method makes it possible to continuously clean strip supplied to the bath without any repairs by reason of changing rolls and without making any corrections to prevent electrolytic pitting. The first installation utilizing the method of this invention was run continuously for six weeks without any strip material cleaned thereby being rejected because of electrolytic pitting or burning and without the necessity of replacing any of the rolls utilized in the molten caustic bath, the line being shut down after such period only for the purpose of making an inspection to examine the equipment, which was found to be in excellent condition. Further, it is to be noted that no electrical connections or contacts are made directly to the strip, but it is being processed other than through the face of the rolls 16, 18 and 20 so that there is no complication of normal production procedure. Another advantage is that the flow of current to the rolls can be initially set at the beginning of a run and will not need to be adjusted during the run, although as a precautionary measure, readings are usually taken periodically on the voltage meter 90 to determine if operating conditions are being maintained. As will be understood, with the rolls 16, 18 and 20 completely insulated from the tank 14, the current required will be maintained at a substantially constant value, and in practice ranges from about 125 to 150 amperes depending upon the temperature of the molten caustic bath 12 in the tank 14, for as the temperature increases the current requirements increase.

While the electrical connections have been described with reference to hold-down rolls 16 and 18 and the wiper roll 20, as has been indicated hereinafore, the method of this invention is operative where the electrical connections are maintained for only the hold-down roll 18. It is essential that such electrical connections be maintained at all times to the hold-down roll 18. Thus, with the switch 36 in the open circuit position and the switch 54 in the circuit establishing position, it is found that the caustic reacts with the film of oxides present on the strip 10 of refractory metal as the strip passes beneath the roll 16 to dissolve, change or remove the oxides from the strip as the strip approaches the roll 18. At this point the difference in potential between the roll 18 and the strip 10 is sufficient to effect a flow of current therebetween to cause electrolytic pitting or burning of the strip with the result that the strip must necessarily be rejected as unsuitable for commercial applications. On the other hand, if the switch 36 is in circuit establishing position and the switch 54 is in an open circuit position, it is found that there is insulation between the caustic and the film of oxides on the strip 10 as the strip approaches and passes beneath the roll 16 to sufficiently change or remove the oxides with the result...
that such film provides sufficient insulation as the strip is in contact with the roll 16 to prevent noticeable electrolytic pitting or burning of the strip. It is thus apparent that once the reaction between the caustic and the oxides is arrested, the oxide is removed from the strip, the method of this invention must be practiced, although from a practical viewpoint all the rolls of the rolls are actually connected in circuit relation to provide the differences in potential described so as to effectively insulate against contact arcing and electrolytic pitting of the strip in the neighborhood of any one of the rolls which are partially immersed in the caustic bath.

From the description given hereinafter it will be apparent that broadly this invention is applicable whether the strip material being treated is of a metal having a base dissimilar to the base metal from which the rolls 16, 18 and 20 and the tank 14 are formed. The caustic bath in which the strip 10 is immersed is in effect an electrolyte which will react with the oxides present on the surface of the strip. It will therefore be apparent that this invention can be utilized where the strip is immersed in an electrolyte and there is a potential difference normally between the strip and roll and tank of metal dissimilar to the strip. Thus in accordance with this invention a flow of current between the tank and the roll of like metals is produced to effect a potential difference therebetween which will be substantially equal to the potential difference between the tank and the strip to effect decrease the potential difference between the strip and the roll, and thereby minimize any current flow between the roll and the strip to prevent electrolytic pitting of the strip as it is in the bath of the reacting electrolyte.

The method of this invention is relatively simple and can be readily practiced by anyone skilled in the art. Standard equipment is utilized, the only change over from existing practice being the necessity of insuring that the hold-down rolls and wiper roll are completely insulated from the tank containing the caustic bath and that suitable commutator sleeves and sliding contact members are provided for connecting the roll into circuit relation to the suitable source of power.

I claim:

1. In the method of cleaning oxides from metal strip formed from titanium, titanium base alloy, zirconium and zirconium base alloy, the steps comprising, immersing and passing the metal strip through a heated caustic bath in an iron-base tank to effect a reaction between the caustic and the oxides, maintaining the metal strip immersed in the heated caustic bath by means of a rotatable and roll of iron-base roll disposed in engagement therewith and having a portion thereof immersed in the heated caustic bath, the iron-base roll being electrically insulated from the iron-base tank, the strip in the heated caustic bath normally being at a potential different from that of the iron-base roll and iron-base tank, connecting the iron-base roll and iron-base tank to the negative terminal and the positive terminal, respectively, of a supply of current to effect a flow of current therebetween through the heated caustic bath to impart to the iron-base roll a polarity different from that of the iron-base tank and substantially equal to the normal potential of the iron-base tank and the iron-base roll is substantially equal to the normal potential of the iron-base tank and the metal strip to thereby substantially eliminate any difference in potential between the iron-base roll and the metal strip and prevent electrolytic pitting of the metal strip in the heated caustic bath.

2. In the method of cleaning oxides from metal strip formed from titanium, titanium base alloy, zirconium and zirconium base alloy, the steps comprising, immersing and passing the metal strip through a heated caustic bath in an iron-base tank to effect a reaction between the caustic and the oxides, maintaining the metal strip immersed in the heated caustic bath by means of a rotatable and roll of iron-base roll having a portion thereof immersed in the heated caustic bath, the iron-base roll being electrically insulated from the iron-base tank, the strip in the heated caustic bath normally being at a potential different from that of the iron-base tank and iron-base tank, connecting the iron-base roll and iron-base tank to the negative terminal and the positive terminal, respectively, of a supply of current to effect a flow of current therebetween through the heated caustic bath to impart to the iron-base roll a polarity different from that of the iron-base tank and having a portion thereof immersed in the heated caustic bath, the iron-base roll being electrically insulated from the iron-base tank, the strip in the heated caustic bath normally being at a potential different from that of the iron-base roll and iron-base tank, connecting the iron-base roll and iron-base tank to the negative terminal and the positive terminal, respectively, of a supply of current to effect a flow of current therebetween through the heated caustic bath to impart to the iron-base roll a polarity different from that of the iron-base tank and substantially equal to the normal potential of the iron-base tank and the iron-base roll is substantially equal to the normal potential of the iron-base tank and the metal strip to thereby substantially eliminate any difference in potential between the iron-base roll and the metal strip and prevent electrolytic pitting of the metal strip in the heated caustic bath.

3. In the method of cleaning oxides from metal strip formed from titanium, titanium base alloy, zirconium and zirconium base alloy, the steps comprising, immersing and passing the metal strip through a heated caustic bath in an iron-base tank to effect a reaction between the caustic and the oxides, maintaining the metal strip submerged in the heated bath by means of a rotatable and roll disposed in engagement therewith and having a portion thereof immersed in the heated caustic bath, the iron-base roll being electrically insulated from the iron-base tank, the strip in the heated caustic bath normally being at a potential different from that of the iron-base roll and iron-base tank, connecting the iron-base roll and iron-base tank to the negative terminal and the positive terminal, respectively, of a supply of current to effect a flow of current therebetween through the heated caustic bath to impart to the iron-base roll a polarity different from that of the iron-base tank and substantially equal to the normal potential of the iron-base tank and the iron-base roll is substantially equal to the normal potential of the iron-base tank and the metal strip to thereby substantially eliminate any difference in potential between the iron-base roll and the metal strip and prevent electrolytic pitting of the metal strip in the heated caustic bath.

4. In the method of cleaning oxides from metal strip formed from titanium, titanium base alloy, zirconium and zirconium base alloy, the steps comprising, immersing and passing the metal strip through a heated caustic bath in an iron-base tank to effect a reaction between the caustic and the oxides, maintaining the metal strip submerged in the heated caustic bath by means of a rotatable and roll disposed in engagement therewith and having a portion thereof immersed in the heated caustic bath, the iron-base roll being electrically insulated from the iron-base tank, the strip in the heated caustic bath normally being at a potential different from that of the iron-base roll and iron-base tank, connecting the iron-base roll and iron-base tank to the negative terminal and the positive terminal, respectively, of a supply of current to effect a flow of current therebetween through the heated caustic bath to impart to the iron-base roll a polarity different from that of the iron-base tank and substantially equal to the normal potential of the iron-base tank and the iron-base roll is substantially equal to the normal potential of the iron-base tank and the metal strip to thereby substantially eliminate any difference in potential between the iron-base roll and the metal strip and prevent electrolytic pitting of the metal strip in the heated caustic bath.

5. In the method of cleaning oxides from metal strip formed from refractory metal of the class of titanium, titanium base alloys, zirconium and zirconium base alloys, the steps comprising, immersing and passing the metal strip through a heated caustic bath in an iron-base tank to effect a reaction between the caustic and the oxides, maintaining the metal strip immersed in the heated caustic bath, the iron-base roll being electrically insulated from the iron-base tank, the metal strip and iron-base roll and iron-base tank normally having a difference in potential therebetweem with the strip having a polarity that is normally negative with respect to the iron-base tank and the tank, connecting the iron-base roll and iron-base tank to the negative terminal and the positive terminal, respectively, of a supply of current to effect a flow of current therebetween through the heated caustic bath to impart to the iron-base roll a polarity different from that of the iron-base tank whereby the potential between the iron-base tank and the iron-base roll is substantially equal to the normal potential between the iron-base tank and the metal strip to the iron-base roll and the metal strip and thereby prevent electrolytic pitting of the metal strip in the heated caustic bath.
the iron-base roll being electrically insulated from the
iron-base tank, the metal strip and the iron-base roll and
iron-base tank normally having a difference in potential
therebetween with the metal strip having a negative
polarity with respect to the polarity of the iron-base tank
and iron-base roll, connecting the iron-base roll and iron-
base tank to the negative terminal and the positive
terminal, respectively, of a supply of current to effect a
flow of current theretwixt through the heated caustic
bath to effect a difference in potential theretwixt
substantially equal to the normal difference in potential
between the strip and the iron-base tank and impart to the
iron-base roll a polarity that is negative with respect to the
polarity of the iron-base tank to decrease current
flow between the iron-base roll and the metal strip and
thereby prevent electrolytic pitting of the metal strip as
the caustic react with the oxides of the strip in the heated
caustic bath.

3. In the method of cleaning oxides from metal strip
formed from refractory metal of the class of titanium,
titanium base alloys, zirconium and zirconium base
alloys, the steps comprising, immersing and passing the
metal strip through a molten alkali metal caustic bath in
an iron-base tank to effect a reaction between the caustic
and the oxides of the metal strip, maintaining the metal
strip immersed in the caustic bath by means of a hold-
down iron-base roll having a portion thereof immersed
in the caustic bath, the iron-base roll being electrically
insulated from the iron-base tank, the metal strip and iron-
base roll normally having a difference in potential
therebetween with the strip having a polarity in the bath that is negative with respect to the
iron-base tank and iron-base roll, connecting the iron-
base tank and iron-base roll to the positive terminal and
the negative terminal, respectively, of a supply of cur-
rent to effect a difference in potential theretwixt sub-
stantially equal to the normal difference in potential
between the strip and the tank and impart a polarity to the
iron-base roll that is negative with respect to the iron-base
tank to thereby decrease a decrease in current flow between the iron-base roll and metal strip in the caustic bath and
prevent electrolytic pitting of the metal strip as the caustic
reacts with the oxides of the strip in the caustic bath.

7. In the method of cleaning oxides from metal strip
formed from refractory metal of the class of titanium,
titanium base alloys, zirconium and zirconium base
alloys, the steps comprising, immersing and passing the
metal strip through a molten alkali metal caustic bath in
an iron-base tank, controlling the immersion and exit of the
metal strip with respect to the caustic bath by means of
a plurality of spaced rotateable iron-base rolls having por-
tions thereof immersed in the caustic bath, the iron-base
rolls being electrically insulated from the iron-base tank,
the metal strip and iron-base rolls normally having a difference in potential theretwixt with the metal strip having a polarity that is negative with respect to the iron-base tank and iron-base rolls, connecting the iron-base tank and each of the iron-base rolls to the positive terminal and the negative terminal, respectively, of a supply of current to effect a flow of
current through the caustic bath between the iron-base
tank and each of the iron-base rolls to produce a difference
in potential theretwixt substantially equal to the normal difference in potential between the strip and iron-
base tank and impart a polarity to each of the iron-
base rolls that is negative with respect to the iron-base
tank whereby current flow between each of the iron-base
rolls and the metal strip is decreased to prevent electro-
lytic pitting of the metal strip in the caustic bath.

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