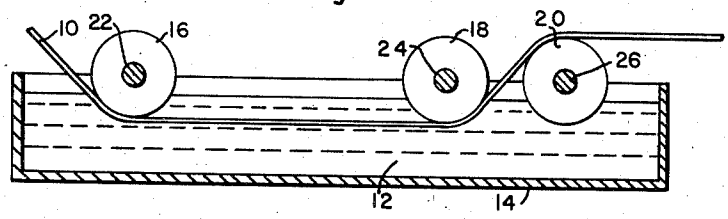
March 11, 1958 J. B. MURTLAND, JR 2,826,539

METHOD OF CLEANING METAL STRIP

Filed Dec. 5, 1956

Fig.1



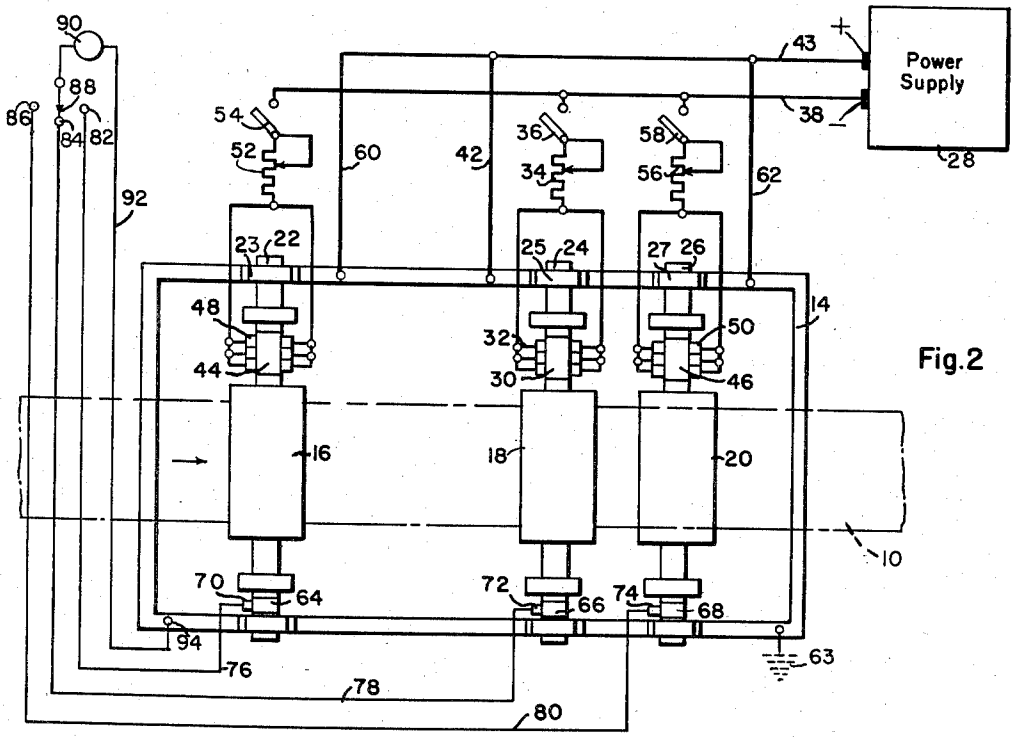


Fig.2

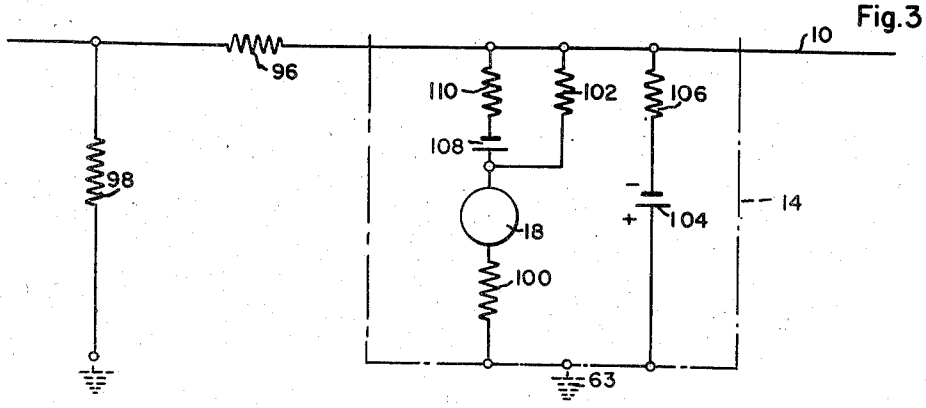


Fig.3

United States Patent Office 2,826,539 Patented Mar. 11, 1958

2,826,539

METHOD OF CLEANING METAL STRIP

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Application December 5, 1956, Serial No. 626,506

8 Claims. (Cl. 204—141)

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 pickling 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 for removing oxides from the surfaces of strip formed from refractory metals of the class of titanium, titanium base alloys, zirconium and zirconium base alloys while preventing electrolytic 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 by immersing the strip in a heated caustic bath and 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:

Figure 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 salt 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 formed of 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 disposed to be connected in an electrical circuit 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 **22**, **24** and **26** is provided with a commutator sleeve **64**, **66** and **68**, respectively, each commutator sleeve having a sliding 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 contact 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_L shown at **96** and a combined leakage resistance R_S 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_K 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_C 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. 3 by the battery **104** which has an internal resistance R_B shown at **106** which is assumed to be of the same magnitude as the bath resistance R_K. A slight battery action is also probably present between the roll **18** and strip **10** as illustrated by the battery **108** and the internal resistance R_B 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 .092 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 potential E as represented by the battery **104** was found to be about 1.1 volts. The battery resistance R_B 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 **10** in each direction from the roll **18** is insufficient, having been computed to be only 0.108 ampere in each direction, to cause electrolytic burning of the strip **10**, the resistance R_L of the strip **10** and the combined leakage resistance R_S of the strip to ground can be ignored in the theroetical 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

$$I \text{ total} = \frac{E_{R_B}}{R_B} = \frac{0.7}{0.005} = 140 \text{ amps.}$$

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,

$$R_C + R_K = \frac{0.4}{70} = 0.0057 \text{ ohm}$$

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 and resistance R_K 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_K 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 so 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 necessary potential 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

fed into the molten caustic bath 12 beneath the submersion 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 or 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 and the tank 14 connected as previously 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 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 88 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 completely 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 alkali metal caustic bath and the oxides of the strip 10 of refractory metal of the class of titanium, titanium base alloys, zirconium and zirconium base alloys without 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 cleaning of the surfaces of the rolls with the result that there are no high points thereon 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 on the iron base 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 replacing 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 shutdowns 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 10 as 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 hereinbefore, 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 insufficient reaction 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 effected or the oxides are removed from the strip, the method of this invention must be practiced, although from a practical operational viewpoint all three of the rolls are actually connected in circuit relation to provide the differences in potential described so as to effectively insure 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 hereinbefore it will be apparent that broadly this invention is applicable where 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 the rolls 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 effected to produce a potential difference therebetween which will be substantially equal to the potential difference between the tank and the strip to in 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 the 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 hold-down 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 metal strip and iron-base roll and iron-base tank normally having a difference in potential therebetween with the strip having a polarity that is normally negative with respect to the roll 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 effect a difference in potential therebetween substantially equal to the normal difference in potential between the strip and iron-base tank and impart to the iron-base roll a polarity that is negative with respect to the tank to decrease current flow between the iron base roll and the metal strip and thereby 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 hold-down 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 metal strip and iron-base roll and iron-base tank normally having a difference in potential therebetween with the strip having a polarity that is normally negative with respect to the polarity of the roll 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 through the heated caustic bath therebetween to effect a difference in potential therebetween substantially equal to the normal difference in potential between the strip and the tank and impart to the iron-base roll a polarity of the same order as that of the metal strip with respect to the iron-base tank to prevent arcing between the roll and the strip.

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 hold-down 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 metal 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 current to effect a flow of current therebetween through the heated caustic bath to impart to the iron base roll a potential different from that of the iron-base tank and substantially equal to the normal potential of the metal strip to thereby substantially eliminate the difference in potential between the metal strip and the iron-base roll 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 hold-down 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 metal 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 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 thereby substantially eliminate any difference in potential between the iron-base roll and the metal strip and prevent electrolytic pitting of the metal strip as the caustic reacts with the oxides of the 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 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 heated caustic bath by passing the strip beneath a rotatable hold-down 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 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 therebetween through the heated caustic bath to effect a difference in potential therebetween 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 reacts with the oxides of the strip in the heated causic bath.

6. 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 and iron-base tank 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 current to effect a difference in potential therebetween substantially 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 effect 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 rotatable iron-base rolls having portions thereof immersed in the caustic bath, the iron-base rolls being electrically insulated from the iron-base tank, the metal strip and the iron-base tank and iron-base rolls normally having a difference in potential therebetween 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 therebetween 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 electrolytic pitting of the metal strip in the caustic bath.

8. 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 an electrolyte which will react with the oxides of the strip, the electrolyte being contained in a tank formed of metal dissimilar with respect to the metal of the strip, maintaining the metal strip immersed in the electrolyte by means of a rotatable hold-down roll formed of a metal having the same base as that of the metal of the tank, and having at least a portion thereof immersed in the electrolyte, the roll being electrically insulated from the metal of the tank, the metal strip and metal roll and metal tank normally having a potential difference therebetween, connecting the roll and tank to the negative terminal and the positive terminal, respectively, of a supply of current to effect a flow of current therebetween through the electrolyte to impart a potential difference therebetween substantially equal to the potential between the strip and tank and a polarity to the roll of the same sign as the strip is with respect to the tank to thereby decrease the potential difference between the strip and roll and decrease the current flow between the roll and the strip to prevent electrolytic pitting of the metal strip in the reacting electrolyte.

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