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CROSS REFERENCE, H2SO4 EXAMINER
aqueous acid sol
cont bisulfate
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# 3,216,857
# PROCESS FOR REMOVAL OF CARBONACEOUS DEPOSITS

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This invention relates to the removal from metal parts of high temperature deposits, particularly hard carbonaceous deposits, of the type produced in gas turbine-type engines. By the expression "deposits of the type produced in gas turbine-type engines" is meant any difficult to remove hard carbonaceous deposits formed by the pyrolysis of organic materials that are similar in nature to the deposits produced in the hot sections of gas turbine-type engines such as airplane jet engines.

Gas turbine-type engines are most commonly employed at present as turbojet and turboprop power plants for modern aircraft and are constructed from stainless steel and other special heat resistant alloys. In general terms, the jet engine consists basically of two sections: the cold section which consists of the forward part of the engine, comprising its compressor and other components and the hot section comprising the aft section of the engine which comprises the combustion chambers, the turbine wheels and blades, tail cone, combustion chamber shroud, etc. The stainless steels and other high temperature alloys employed in construction of the hot sections of gas turbine-type engines are principally those alloys of chromium-nickel, chromium-nickel-iron, chromium-nickel-cobalt or chromium-nickel-cobalt-iron which exhibit adequate oxidation resistance at the temperatures involved. To be classified as a "high temperature alloy," it is generally necessary that the metal be designed to provide high strength as well as oxidation resistance at temperatures of 1300 to 1500° F. or higher. The stainless steels are those alloys which likewise exhibit high strength and oxidation resistance under high temperature conditions, but generally do not have as high a strength as the "high temperature alloys."

In the hot section, temperatures range, on an average, between 400° F. and 1600° F. For example, the turbine shaft will generally experience 400° F.; the turbine wheel itself, 1200° to 1300°, and the turbine buckets on the outer extremity of the wheel 1600° or higher in newer engines. The combustion chambers themselves will operate at temperatures running almost continually in the 1500 to 1600° F. range, with intermittent temperatures as high as 2300° F.

At these high operating temperatures, two principal occurrences affect the metal components, namely, the oxidation of the metals themselves to form what is generally termed a heat scale or oxide film, and the accumulation of carbonaceous coke-like deposits formed from the combustion of engine fuels. The heat scale is to be distinguished from ordinary rust produced by corrosion of mild steel and iron in its physical and chemical nature and is much more refractory and difficult to remove.

The fuels normally encountered in jet engines are aliphatic hydrocarbons in nature, very similar to common kerosene. In earlier engines, some aviation gasoline was frequently used containing lead which further complicated the cleaning procedure. The carbonaceous coke-like deposits which form in gas turbine-type engines as a result of fuel combustion generally overlay the heat scale, are very hard and primarily all carbon with small proportions of binders of asphaltene, resin, etc. As a result of the high temperatures the deposits are drier, harder, and higher in carbon content and thus are more difficult to remove than the conventional carbonaceous deposits



found in reciprocating engines. These carbonaceous deposits are of such a nature that common carbon removers of the organic solvent type will not remove them.

For proper maintenance of the engines, overhaul procedures must be applied during which the engine components are completely and safely cleaned of heat scale or oxide film deposits, carbonaceous deposits and any other contamination which may be present. One of the most important reasons for removing the foreign matter and scale deposits is to provide clean metal surfaces which are suitable for inspection for flaws by standard techniques. Inspection is especially important for jet engine parts which are highly stressed, such as nozzle guide vanes and turbine buckets.

Conventional procedures for cleaning jet engine hot section components during overhaul are based on a combination of inadequate chemical cleaning methods plus mechanical cleaning, which includes grit blasting and liquid honing (or vapor blasting). Thus, for example, a conventional procedure may include use of a chlorinated solvent, either hot or cold, followed by a caustic dip, then a permanganate treatment, and finally vapor or sand blasting. However, these procedures possess certain inherent disadvantages. The carbon deposits formed during engine operation are hard adherent deposits which overlay the heat scale and which are not removed by conventional methods using chlorinated solvent-type carbon removers or hot tank alkaline cleaners. Permanganate, when used as a cleaning agent on parts carrying carbon, precipitates a brown deposit which adds to the carbon deposits and heat scale and which makes cleaning of the part even more difficult. It is believed that this is due to the reducing action of the residual carbon. As a result, the resistant and highly refractory heat scale also is not removed whereby subsequent mechanical cleaning treatment is required which is time consuming, expensive in both material and manpower and has the effect of wearing away the surface of the parts which is detrimental since the size and shape of gas turbine engine-type parts is very critical. Further, as a result of the foregoing and other deficiencies, the procedures frequently fail to provide clean surfaces for inspection since fine cracks are filled with abrasive or cold flow of metal which may seal a crack, thus preventing detection during an inspection cycle.

From the above discussion, it will be seen that it is necessary to remove the carbonaceous deposits in order to expose the underlying oxide heat scale to the action of the next treating step such as contacting the parts with an alkaline permanganate solution. Unless the carbonaceous deposits are removed before introduction into the alkaline permanganate solution, the very expensive permanganate is consumed in the oxidation of carbon and it is physically blocked from immediate effective action on the metal oxide heat scale, thereby retarding such action.

In accordance with prior art practice, drastic agents such as nitric acid-hydrofluoric acid pickling baths were employed to remove the carbonaceous deposits. One of the earliest baths was composed of ferric sulfate and hydrofluoric acid in hot aqueous solutions. The employment of such agents provides adequate decarbonizing and descaling but suffers from the drawback of being highly corrosive. One of the most important and stringent requirements for a jet engine cleaning process is a minimum of corrosion attack on the underlying metal surface. Due to the extreme precision nature of most of the parts, the corrosion loss that is normally considered acceptable in the steel industry cannot be tolerated in jet engine overhaul.

Perhaps the most widely used prior art process involves the use of a highly alkaline sodium hydroxide tri-

ethanolamine composition which requires the use of high temperatures on the order of 235 to 300° F. for suitable performance. This composition has certain inherent disadvantages due to excessive expense of the ingredients, coupled with the fact that it operates very slowly. Further, the high temperatures employed and the nature of the solution are hazardous to operating personnel.

Accordingly, it is the purpose of this invention to remove from metal parts, particularly stainless steel and high temperature alloy parts, high temperature deposits, and particularly hard coke-like carbonaceous deposits, of the type produced in gas turbine-type engines, wherein corrosion of the base metal during treatment is eliminated or substantially reduced and which is economical and may be used in low concentrations at relatively low temperatures.

The method embodying the principles of this invention for removing from metal parts the hard coke-like carbonaceous deposits of the type produced in gas turbine-type engines comprises contacting the parts with an aqueous acidic solution containing ions selected from the group consisting of bisulfate ions, sulfamate ions and mixtures thereof. The solution may be prepared by dissolving any water-soluble bisulfate compound in water, such as, for example, sodium bisulfate, potassium bisulfate, calcium bisulfate, ammonium bisulfate or sulfamic acid. The solution may also be prepared by dissolving any water-soluble sulfate or sulfamate compound in water, together with the chemically equivalent amount of sulfuric acid, to form bisulfate ion or sulfamic acid by chemical reaction in situ, such as, for example, sodium sulfate, potassium sulfate, calcium sulfate, ammonium sulfate and an equal molar amount of sulfuric acid, or sodium sulfamate, potassium sulfamate, calcium sulfamate, ammonium sulfamate and an equal molar amount of sulfuric acid. In general, the solution should have a pH of from 0 to about 2.

This aqueous solution has been found to be effective in almost all proportions, the weaker solutions merely requiring greater treatment times. However, for practical purposes an aqueous solution containing from about 0.15 to 1.00 mol per liter of bisulfate or sulfamate ions or mixtures thereof may be employed although greater or smaller concentration may be employed if desired. A preferred solution contains from about 0.25 to 0.75 mol per liter of bisulfate ions or sulfamate ions or mixtures thereof.

In general, the aqueous solution should be heated and a practical temperature range is from about 140 to 200° F. although higher or lower temperatures may be employed if desired. In general, the metal parts are immersed in a bath of this aqueous solution until the carbonaceous deposit has been removed, after which the metal parts are removed from the solution. In most instances, it is necessary to maintain the parts in the bath for a period of at least about one-half hour. While there is no upper limit to the immersion time, generally the parts are completely cleaned in about 1½ hours and, accordingly, immersion for a greater period of time is unnecessary. Thus, it is preferred to maintain the parts in the bath for a period of about 1½ hours and a practical maximum time period is about 4 hours, although immersion for longer periods of time may be employed if desired.

While the above-described solution is generally satisfactory in most applications, in order to insure minimum corrosiveness it has been found desirable for many applications to include corrosion inhibitors. In general, any well-known corrosion inhibitor effective with sulfuric acid solutions employed for treating steel is satisfactory for this purpose. Examples of such inhibitors are as follows: butyl sulfide, o-tolylthiourea, p-tolylthiourea, butyl disulfide, amyl mercaptan, ethyl selenide, propyl sulfide, phenylthiourea, butyl methyl sulfide, diethylthiourea, dibutyl thiourea, butyl mercaptan, p-thiocresol, i-butyl mercaptan, triamyl amine, m-thiocresol, trihexyl amine, ethyl sulfide, valerophenone, 2-thionaphthol, o-thiocresol, propyl mercaptan, methyl sulfide, crotonaldehyde, aldol (2-OH-butyraldehyde), phenylmorpholine, formaldehyde, ethyl mercaptan, o-tolualdehyde, m-tolualdehyde and p-tolualdehyde. Preferred inhibitors for this purpose are the thioureas. In general, even a very small amount of corrosion inhibitor may be effectively employed. For practical purposes, the minimum amount of inhibitor is about $5\times10^{-7}$ mols per liter of solution. Almost any larger amount of inhibitor may be employed, generally with no detrimental effect other than the expense involved in using greater amounts than necessary. A practical maximum amount of inhibitor would be about $2\times10^{-2}$ mols per liter of the solution although larger amounts may be employed if desired. The use of more than one inhibitor substance may be desirable in many instances.

Since the parts being cleaned frequently have oil or other soils which might interfere with the contact of the solution, it is desirable to incorporate a wetting agent or a plurality of wetting agents in the solution. Any nonionic, anionic, cationic or amphoteric wetting agent may be employed in this solution, with the exception of the soap types which do not retain their wetting properties in acidic solutions.

Exemplary of wetting agents which can be used are (1) alkylarylpolyethers, such as the oxyethylated adducts of nonyl phenol having an oxyethylene content in the range of about 65 to about 85 weight percent of the total molecule and the oxyethylated adducts of tertiary octyl phenol having an exyethylene content in the range of about 65 to about 75 percent by weight of the molecule, and (2) the polyoxyethylene-polyoxypropylene-polyoxyethylene (EPE) block polymer type of nonionics (see U.S. Patent No. 2,674,619, Lundsted), wherein the molecular weight of the polyoxyethylene base is in a range from 800 to about 2500 and the oxyethylene content is from about 30 to about 80 weight percent of the total molecule, which wetting agents are well known in the art. Further examples of wetting agents which can be employed in the compositions of the invention include (3) the well-known alkylarylsulfonates such as sodium alkylbenzenesulfonate wherein the alkyl group has from about 10 to 18 carbon atoms, (4) the alkylsulfates such as sodium laurylsulfate, and (5) the ethylene oxide condensation products of primary fatty amines.

The amount of such wetting agent employed may be very small and still be effective and there is no detrimental effect in the use of large amounts other than the undue expense of employing greater amounts than needed. It has been found that an amount of wetting agent as low as 0.01 weight percent of the solution may be employed. A practical maximum amount is 0.5 weight percent of the solution, although larger amounts may be employed if desired. Also, a plurality of wetting agents may be employed.

It has also been found that oxalate ions may be added to the solution with beneficial results in further reduction of corrosion rate and improved cleaning. The oxalate ion may be supplied by adding to the solution any water-soluble oxalate compound such as sodium oxalate, potassium oxalate, calcium oxalate, ammonium oxalate, oxalic acid, etc. or mixtures thereof. A very small amount of the oxalate ion may be added and it has been found that an amount as small as $5.0\times10^{-3}$ mols per liter of the solution may be employed effectively. In general, any larger amounts may be employed without detrimental effect; however, the desired effectiveness decreases as the amount increases. A practical maximum amount of oxalate ion has been found to be about 0.12 mol per liter of the solution.

The above-recited limits in regard to temperature, time, etc. for the aqueous solution containing only bisulfate ion or sulfamic acid are equally applicable to the modified

solutions including the additional substances, i.e. inhibitors, wetting agent and oxalate ions.

An example of a preferred method for removing carbonaceous deposits from jet engine parts comprises contacting the parts at a temperature ranging from about 160 to 180° F. with a composition which consists essentially of, by weight, of dry ingredients 90.1% sodium bisulfate, 5.0% sodium oxalate, 2.4% of an 85% active sodium alkylbenzenesulfonate, 2.0% of 1,3-diethylthiourea and 0.5% of di-o-tolylthiourea dissolved in water to form a 9 to 12 percent by weight aqueous solution of these ingredients. The contact time ranges from about 30 minutes to 2 hours.

The above-described method of treatment is effective for removing undesirable hard coke-like carbonaceous deposits from the above-described types of metal parts and in many instances will completely clean the desired parts. Where it does not completely clean the desired metal parts of heat scale, etc., the remaining deposit may be removed with various other solutions. A particularly effective treatment for removing all high temperature deposits of the type produced in gas turbine-type engines has been found to consist of immersing the parts in the above-described solution of bisulfate ions or sulfamic acid or mixtures thereof for a period of time sufficient to remove all or a major portion of the undesirable carbonaceous deposits, after which the parts are immersed in an aqueous alkaline permanganate solution. In general, very small amounts or very large amounts of alkaline permanganate solution may be employed, there being no criticality in these limitations, the weaker solutions generally requiring longer periods of time. It has been found that an alkaline permanganate solution containing from about 0.1 to 0.4 mol per liter of permanganate ion and from about 3.0 to 6.0 mols per liter of hydroxyl ion is effective for this purpose although larger or smaller amounts of permanganate and/or hydroxyl ion may be employed if desired. A preferred solution would contain from about 0.15 to 0.25 mol per liter of permanganate ion and from about 4.0 to 5.0 mols per liter of hydroxyl ion. It is preferred to supply the permanganate ion in the form of potassium permanganate or sodium permanganate although any water-soluble permanganate compound may be employed. Any water-soluble alkaline agent containing hydroxyl ions may be employed in such solutions, although sodium and potassium hydroxide are preferred for this purpose.

In general, it is preferred to pressure rinse the parts in water between the two treatments, preferably in warm water, i.e. around 100° F., although heated water is not necessary. The temperature of the potassium permanganate solution is not critical; however a good practical operating range is from about 160 to 220° F. In general, the metal parts are immersed in the permanganate solution for a time period sufficient to completely clean the parts. At least 60 minutes is generally required to clean the parts and there is no maximum time limit since there is no particular disadvantage to long immersions other than that inherent in employing unnecessary excessive amounts of time. A practical maximum period of time is about 6 hours, although longer time periods may be employed if desired. A preferred treatment for removing all deposits comprises immersing or contacting the parts in the solution of bisulfate ion or sulfamic acid or mixtures thereof for about 1½ hours, followed by immersion or contact with the alkaline permanganate solution for about 3 hours.

Another particularly effective treatment for removing all high temperature deposits of the type produced in gas turbine-type engines has been found to consist of immersing the parts in the above-described solutions of bisulfate ions or sulfamic acid, followed by immersing the parts in the above-described alkaline permanganate solution, after which the parts are immersed in an acid pickling bath usually consisting of an aqueous solution of inhibited mineral acids. By the use of this treatment, the time of immersion in the above-described alkaline permanganate solution can be shortened to the time required for a sufficient chemical modification of the heat scale or oxide film, by the oxidizing action of the alkaline permanganate, which thereby renders the heat scale or oxide film acid soluble, rather than continuing treatment with the above-described alkaline permanganate until the parts are completely free of heat scale or oxide film. The over-all processing time may thereby be materially reduced with the subsequent economic advantages. The composition of the acid pickling solution is not critical, any acid solution commonly known in the art to be suitable for pickling metal heat scales being useful. An example of a preferred pickling solution would be a 25% by volume aqueous solution of nitric acid in which the parts are immersed for a period of 15–30 minutes at room temperature. The above-described solutions of bisulfate ions or sulfamic acid or mixtures thereof of this invention may also be employed for the third step in this treatment.

The following examples are provided to illustrate the application of the principles of this invention.

## EXAMPLE I

A series of fifteen 3-liter aqueous solutions having compositions as indicated in Table 1 below are prepared by dissolving the compounds indicated in Table 1 in water. Each solution is provided in a 7.5 x 6.0 inch diameter open top, stainless steel, cylindrical container or tank and the solution heated to the temperature indicated in Table 1 below and subjected to continuous stirring action by means of laboratory stirring equipment. Fifteen identical groups of jet engine parts coated with hard coke-like carbonaceous deposits and heat scale are immersed in the solutions indicated in Table 1 below for the periods of time indicated. Each group includes a turbine bucket, a combustion chamber interliner section and a turbine nozzle and each group is treated in one of the fifteen solutions as indicated in Table 1 below.

*Table 1*

| Parts Group No. | Solution No. | Bisulfate or Sulfamic Acid | Concentration, Mols/Liter | Oxalate | Concentration, Mols/Liter | Wetting Agent | Weight Percent of Solution | Inhibitor | Concentration, Mols/Liter | T., ° F. | Time (Hrs.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Sodium bisulfate. | 0.50 | | | | | | | 180 | 1½ |
| 2 | 2 | do | 0.15 | Sodium oxalate. | 0.025 | Sodium dodecyl benzene sulfonate. | 0.1 | Di-o-tolyl-thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 180 | 4 |
| 3 | 3 | do | 0.50 | do | 0.025 | do | 0.1 | Di-o-tolyl-thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 180 | 1½ |
| 4 | 4 | do | 1.00 | do | 0.025 | do | 0.1 | Di-o-tolyl-thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 180 | 1½ |
| 5 | 5 | Potassium bisulfate. | 0.50 | do | 0.025 | do | 0.1 | Di-o-tolyl-thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 180 | 1½ |

*Table 1*—Continued

| Parts Group No. | Solution No. | Bisulfate or Sulfamic Acid | Concentration, Mols/Liter | Oxalate | Concentration, Mols/Liter | Wetting Agent | Weight Percent of Solution | Inhibitor | Concentration, Mols/Liter | T., ° F. | Time (Hrs.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 6 | Ammonium bisulfate. | 0.50 | Sodium oxalate. | 0.025 | Sodium dodecyl benzene sulfonate. | 0.1 | Di-o-tolyl thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 180 | 1½ |
| 7 | 7 | Calcium bisulfate. | 0.50 | do | 0.025 | do | 0.1 | Di-o-tolyl thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 180 | 1½ |
| 8 | 8 | Sulfamic acid. | 0.50 | do | 0.025 | do | 0.1 | Di-o-tolyl thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 180 | 1½ |
| 9 | 9 | Sodium bisulfate. | 0.50 | Oxalic acid | 0.025 | do | 0.1 | Di-o-tolyl thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 180 | 1½ |
| 10 | 10 | do | 0.50 | Potassium oxalate. | 0.025 | do | 0.1 | Di-o-toly thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 180 | 1½ |
| 11 | 11 | do | 0.50 | Sodium oxalate. | 0.025 | do | 0.1 | Di-o-tolyl-thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 140 | 2 |
| 12 | 12 | do | 0.50 | do | 0.025 | do | 0.1 | Di-o-tolyl-thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 200 | 1½ |
| 13 | 13 | do | 1.00 | do | 0.025 | do | 0.1 | Di-o-tolyl-thiourea. 1,3-diethyl-thiourea. | $2\times10^{-3}$ $9\times10^{-3}$ | 180 | ½ |
| 14 | 14 | do | 0.50 | do | 0.025 | do | 0.1 | Dibutyl thiourea. | $5\times10^{-3}$ | 180 | 1½ |
| 15 | 15 | do | 0.50 | do | 0.025 | do | 0.1 | Phenyl-thiourea. | $5\times10^{-3}$ | 180 | 1½ |

After treatment for the period of time indicated in Table 1, followed by rinsing and drying, all parts are substantially free of the undesirable carbonaceous deposits and in many cases a significant amount of the heat scale is also removed without appreciable corrosion of the parts.

Three 3-liter solutions of bisulfate compounds or sulfamic acid plus other ingredients of this invention are made up having the compositions of solutions Nos. 1, 3 and 8 shown in Table 1 above. These solutions are provided in containers and stirred, all as described in Example I, and 10 groups of the same three kinds of parts as described in Example I are respectively immersed for 1½ hours in solutions of one of these three compositions, as indicated in Table 2 below. These solutions are maintained at a temperature of 180° F. and stirred in the same manner as for the solutions of Example I. Each group of parts is then removed from its respective bisulfate or sulfamic acid solution, pressure rinsed with water at a temperature of 77° F. and immersed in a 3-liter alkaline permanganate solution provided in the same kind of container as that employed for the bisulfate or sulfamic acid solution. The compositions of the permanganate solutions are indicated in Table 2 below. The permanganate solutions are maintained at the temperatures indicated in Table 2 and immersed for the period of time indicated in Table 2.

*Table 2*

| Parts Group No. | Bisulfate or Sulfamic Acid Solution No. | Alkaline Permanganate Solution | | | | | T., ° F. | Time, hrs. |
|---|---|---|---|---|---|---|---|---|
| | | Solution No. | $MnO_4$ | Mols/Liter | $OH^-$ | Mols/Liter | | |
| 1 | 1 | 1 | $KMnO_4$ | 0.20 | NaOH | 4.5 | 190 | 3 |
| 2 | 3 | 2 | $KMnO_4$ | 0.20 | NaOH | 4.5 | 190 | 3 |
| 3 | 8 | 3 | $KMnO_4$ | 0.20 | NaOH | 4.5 | 190 | 3 |
| 4 | 3 | 4 | $KMnO_4$ | 0.10 | NaOH | 4.5 | 190 | 3 |
| 5 | 3 | 5 | $KMnO_4$ | 0.40 | NaOH | 4.5 | 190 | 3 |
| 6 | 3 | 6 | $KMnO_4$ | 0.20 | KOH | 4.5 | 190 | 3 |
| 7 | 3 | 7 | $KMnO_4$ | 0.20 | NaOH | 4.5 | 160 | 3 |
| 8 | 3 | 8 | $KMnO_4$ | 0.20 | NaOH | 4.5 | 220 | 3 |
| 9 | 3 | 9 | $KMnO_4$ | 0.20 | NaOH | 6.0 | 220 | 1 |
| 10 | 3 | 10 | $NaMnO_4$ | 0.20 | NaOH | 4.5 | 190 | 3 |

After treatment in the permanganate solution for the time period indicated in Table 2, followed by pressure rinsing with water at 77° F., all parts are substantially cleaned of all deposits without evidence of appreciable corrosion.

## EXAMPLE III

A 3-liter solution having a composition of solution No. 3 of Example I is made up and placed in the type of container described in Example I, heated to and maintained at a temperature of 180° F. and stirred as described in Example I. A group of the same three kinds of parts as described in Example I is immersed in the solution for a period of 1½ hours. A 3-liter solution having a composition of alkaline permanganate, solution No. 1 of Table 2, is prepared as described above in Example II and placed in the same kind of container and stirred. After expiration of a 1½ hour period of time, the parts are removed from the sodium bisulfate solution, pressure rinsed in water of about 100° F. for two minutes, and immersed in the permanganate solution. The parts are maintained in the permanganate solution for a period of 60 minutes, removed and pressure rinsed as before. The parts are then immersed in a 25% by volume aqueous solution of nitric acid at about 77° F. temperature for a period of 30 minutes, removed, rinsed in water at about 100° F. and dried. After this treatment, the parts are substantially cleaned of all deposits without evidence of appreciable corrosion of the metal.

While there have been shown and described hereinabove the preferred embodiments of this invention, it is to be understood that various changes, alterations and modifications can be made thereto without departing from the spirit and scope thereof as defined in the appended claims.

I claim:

1. The method of removing from metal parts carbonaceous deposits of the type produced in gas turbine-type engines comprising immersing said parts for a period of from about 30 minutes to 2 hours at a temperature ranging from about 160° to 180° F. in a composition consisting essentially of, by weight of dry ingredients, 90.1% sodium bisulfate, 5.0% sodium oxalate, 2.4% of an 85% active sodium alkylbenzenesulfonate wherein the alkyl group has from about 10 to 18 carbon atoms, 2.0% of 1,3-diethylthiourea and 0.5% of di-o-tolylthiourea dissolved in water to form a 9–12% by weight aqueous solution of said dry ingredients, balance water.

2. A method of removing from metal parts carbonaceous deposits of the type produced in gas turbine-type engines comprising immersing said parts in an aqueous solution selected from the group consisting of sodium bisulfate, potassium bisulfate, calcium bisulfate and ammonium bisulfate, aqueous solutions wherein at least about 0.15 mole per liter of bisulfate ions are present in the solution.

3. The method of claim 2 wherein about 0.15 to 1.0 moles per liter of bisulfate ions are present in the solution.

4. The method of claim 2 wherein about 0.25 to 0.75 moles per liter of bisulfate ions are present in the solution.

5. The method of claim 2 wherein said aqueous solution has a pH of from 0 to about 2.

6. A method of removing from metal parts carbonaceous deposits of the type produced in gas turbine-type engines comprising immersing said parts in an aqueous sodium bisulfate solution wherein at least about 0.15 mole per liter of bisulfate ions are present in the solution.



7. A method of removing from metal parts carbonaceous deposits of the type produced in gas turbine-type engines comprising immersing said parts in an aqueous potassium bisulfate solution wherein at least about 0.15 mole per liter of bisulfate ions are present in the solution.

8. A method of removing from metal parts carbonaceous deposits of the type produced in gas turbine-type engines comprising immersing said parts in an aqueous calcium bisulfate solution wherein at least about 0.15 mole per liter of bisulfate ions are present in the solution.

9. A method of removing from metal parts carbonaceous deposits of the type produced in gas turbine-type engines comprising immersing said parts in an aqueous ammonium bisulfate solution wherein at least about 0.15 mole per liter of bisulfate ions are present in the solution.


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