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CHEMICAL CLEANING OF METAL SURFACES EMPLOYING STEAM

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The invention is concerned with cleaning of equipment, especially with cleaning the interior of metal vessels employed to confine fluids, e.g., ducts, pipes, coils, tanks, and the like used to transfer, circulate, and store fluids, and particularly to the removal of coatings, scale, films, and residue of a more-or-less adherent character from the interior of such vessels which do not lend themselves readily either to mechanical scraping or to accommodating large volumes of liquid for chemical dissolution and removal of such scale or residue.

Solids usually accumulate on the walls of vessels employed to confine fluids due to deposition of substances carried along in the fluid as suspensions or solutions. Such substances deposit on the walls of the confining vessels for a number of reasons among which are reduction in velocity, temperature, and turbulence, and altered direction of flow of the fluid; sharpness, frequency, and general pattern of bends and turns of the confining vessel; character and variations in the surface of the walls in contact with the fluid; chemical reactions between suspended or dissolved substance in the fluid and/or between such substances and the metal in the walls of the vessel. The scale or residue formed from either liquids or gases confined in a vessel often forms a cementitious type of material which adherers tenaciously to the walls of the vessel and shows persistent resistance to removal therefrom. Such deposits are seldom a substantially pure material but are generally a mixture of a number of substances which appear to supplement one another to result in a particularly cementitious and adherent material.

Methods of removing scale, coatings, and residues from the interior of walls of vessels used to confine liquids and gases include mechanical scraping of such vessels and chemical dissolution and flushing of such vessels. Mechanical scraping or cutting away of adhering scale and residue is tedious and relatively expensive and often such scale and residue are often inaccessible to mechanical devices for the removal thereof. Aqueous or organic solutions of substances which chemically attack the scale and thereby loosen it and aid in its removal are more extensively used than mechanical scraping or cutting away of the scale or residue. Because the scale is composed of different materials, a solvent which will attack the scale as a whole is often difficult to obtain. It is sometimes necessary to employ different chemical solvents in series to consummate an acceptable cleaning operation. Some chemical solvents have the particular disadvantage of being non-removable from non-drainable portions of a line or coil, often referred to as hair-pin turns, such as are found in many steam-generating units and heat exchangers. A particular disadvantage associated with the use of known liquid cleaning solvents for metal surfaces has been the difficulty in maintaining a sufficiently high temperature and solvent action together with sufficient velocity of the cleaning composition to remove, forcefully, the scale as it is dissolved and dislodged or at least shortly thereafter. Another disadvantage associated with liquid cleaning solvents is the weight thereof which puts an undesirable and sometimes destructive burden on supporting structures of pipes and lines. A still further disadvantage is the large weight of material that must be provided when a liquid cleaner is employed entailing appreciable handling and material costs.

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Since the employment of various types and shapes of vessels for confining fluids is extensive in both domestic and industrial operations, the need for an improved method of removing scale and residue from such vessels is great.

The principal object of the invention is to provide an improved method of cleaning the interior of vessels employed for the confinement of fluids, i.e., liquids and/or gases. A particular object of the invention is to provide a method which employs a material in a substantially vaporous state, usually containing suspended or entrained liquid as droplets, for use in the removal of scale and residue from fluid-confining vessels which has particular application to vessels which are not sufficiently well supported to permit the use of conventional liquid solvents. Illustrative of such vessels are overhead transfer lines used to transfer gases, light-weight liquids, or liquids which customarily do not completely fill the vessel. A further object of the invention is to provide a cleaning composition which has sufficiently high turbulence, temperature, and solvent action to dissolve and loosen adhering scale and sufficient velocity and force to dislodge the dissolved and loosened scale and residue from the walls of the vessels, maintain the thus-dislodged scale and residue in the more-or-less suspended manner and carry them along in the direction of the outlet of the vessel being cleaned.

The way by which these and related objects of the invention are attained will be made clear in the ensuing description and is defined concisely in the appended claims.

The method consists of introducing steam containing an entrained chemical therein into a vessel having scale or residue on the walls thereof, which scale is reactive with or solubilizable by said chemical at a steam pressure sufficiently great to force it through said vessel and out an exit therein, for the purpose of removing said scale and residue, at a temperature sufficiently high to effect solvent action of the entrained chemical thereon and at a velocity sufficiently great to dislodge and carry along, dissolved or suspended therein, the scale and residue thus attacked or solubilized by the entrained chemicals, until the scale and residue have been substantially all removed. Any type of scale or residue, therefore, may be removed by the practice of the invention for which a solvent therefor is known and available and which solvent can be carried in steam. The term "solubilizable" as used in the description and claims means any action of a treating chemical which aids in loosening or dislodging a scale including erosion and undercutting the scale by action on the wall of the vessel itself.

By the term steam, herein is meant water vapor and includes both superheated or dry steam, that is water vapor at a temperature above its saturation point, and wet steam or saturated steam as well as mist which is water vapor containing entrained or suspended droplets of liquid water or condensate. The steam after injection comes into contact with the walls of the vessel being cleaned, is cooled and a part, thereby, is condensed, forming some water before the remaining water vapor leaves the vessel at the exit thereof.

The method of the invention has application to a vessel through which a positive flow of a gaseous material comprising water vapor can be maintained. In other words, the vessel must have an inlet and an outlet therein which permits a movement of gas or vapor therethrough. The walls of the vessel should also be cooler than the temperature of the steam injected thereinto. Any chemical having appreciable solvent action on the scale or corrosive material to be removed from the vessel may be employed. Among the chemicals employed are citric acid, formic acid, phosphoric acid, nitric acid, sulfuric acid, hydrochloric acid, sulfamic acid, chromic acid, sodium acid sulfate, the Versene acids such as ethylenediamine tetra-acetic acid, and the acid anhydrides of such acids. A conventional type inhibitor to the corrosive attack of the acid on the metal of the vessel may be employed generally by admixing it with an aqueous solution of the chemical. In the practice of the invention the acid anhydride is usually admixed with water to prepare an acid thereof prior to intermixing with the steam. A surfactant to increase the wetting properties of the aqueous acid may be also employed.

In the practice of the invention, the steam is injected directly from a source thereof, e.g., a steam generator, into the vessel to be cleaned. The chemical solvent to be entrained in the steam may be introduced as a gas, liquid, or finely-divided solids, directly into the steam prior to or shortly after it enters the vessel being cleaned in a number of ways. To illustrate, steam may be started through the vessel to be cleaned from a conventionally located steam boiler and the chemical solvent then bled or otherwise forced, either into the steam line or into the vessel to be cleaned, preferably at a location close to the place of entrance of the steam. One type of apparatus used for this purpose is known as an eductor and permits the chemical to be fed as a fluid into the line and there picked up and carried along, as a gas or as suspended droplets by the steam. If desired, the chemical as a fluid may be pumped by conventional pumping means into the steam line or directly into the vessel to be cleaned, preferably near the steam entrance, where it is picked up and carried along by the steam similarly as when an eductor is used. Other modes of practicing the invention include passing steam through a body of the chemical as a liquid where it picks up and carries along with it appreciable amounts of the liquid chemical through which it passes. A modification of this mode is to pass air or an inert gas through a body of the chemical as a liquid or fine powder where it picks up the chemical as a mist or dust. The air or inert gas, thus laden with the chemical, is then directed into a steam line leading into the vessel to be cleaned or directly into the vessel simultaneously with steam injection. A further modification is to intermix a gas, reactive with the scale or residue in the presence of steam, with air or an inert gas, and pass the resulting diluted gaseous mixture into a steam line leading to a vessel to be cleaned or directly into the vessel simultaneously with steam being injected thereinto. The chemical to be employed may also be intermixed with a body of water and the water thereafter be converted to steam provided that the chemical is of such nature that it volatilizes at a temperature not greater than that employed in the conversion of the water to steam. If desirable, air, nitrogen, or an inert gas may be injected along with the steam as a diluent of the steam-chemical solvent vaporous mixture or to provide added turbulence thereto or for better control of the temperature thereof by heating or cooling the air or inert gas, as desired. The invention also contemplates the injection of both water and air into the vessel being cleaned, heating the mixture thus formed and introducing from a separate line the entrained solvent for the scale therein which then mixes with the steam and air so mixed.

The temperature of the steam is such that at the pressure existing within the vessel being cleaned some condensate is formed on the walls of the vessel. As aforesaid, superheated steam may be used but similar to saturated or wet steam is at least partially converted to condensate as the pressure is lessened and as it contacts the cooler walls of the vessel. The temperature is usually between the boiling point of the water and about 250° F. but may be as high as 350° F. or more.

If desired, the invention may be practiced by merely dislodging the scale adhering to the walls of a vessel and thereafter blowing it out of the vessel with air or other gas or, if the size and shape of the vessel permits, e.g., a storage tank, removing the dislodged scale by mechanical means, e.g., a dragline or shovel.

The invention is not to be construed as being dependent upon any theory or explanation. However, it is thought that among the reasons to which the highly effective results of the invention are attributed is the fact that the steam in the vessel to be cleaned is a gas which thereafter, upon contacting the cooler walls of the vessel being cleaned, undergoes a reduction in pressure and loss of temperature and some of the steam condenses. By so doing, the steam performs two valuable functions in addition to that of a carrying agent: (1) it serves to form a liquid or wet vaporous medium for the ionization of the solvent employed so that its reactivity is greatly enhanced and (2) by being converted to a liquid it gives up great quantities of heat, due to the heat of vaporization, which is released when a gas is converted to a liquid. The steam thereby serves as an agent to provide both reactive ions and high heat at the area most needed, viz., the interface between the cleaning composition and the walls of the vessel being cleaned.

The amount of the chemical solvent to employ in the steam is not highly critical so long as sufficient chemical is provided therein to insure some action on the surface of the scale contacted thereby as the steam containing the chemical passes through the vessel. Any amount between that which is barely perceptibly effective and an amount that provides a stoichiometric quantity of the chemical with the reactive portions of the scale thus contacted is satisfactory in the practice of the invention. It is recommended that the chemical be introduced into the steam in an amount sufficient to provide a continuous appreciable solvent action on the adhering scale on the walls of the vessel being cleaned or descaled. When more solvent is provided than that which can react with the exposed scale, unnecessary waste of the chemical results.

The velocity of the steam carrying the entrained chemical solvent for the scale or residue is not highly critical so long as there is a positive forward movement of the steam carrying the entrained chemical through the vessel being cleaned. Best results are obtained when the velocity is sufficiently high to maintain an appreciable turbulence in the steam-solvent mixture in the vessel. It is inherent in the practice of the invention for the velocity to be greater in that portion of the body of steam-solvent mixture which is in contact with the walls of the vessel. This inherent condition serves a useful purpose in that the condensing steam containing the chemical reactive with the scale or residue is allowed to remain in contact with the scale or residue a sufficient length of time to dissolve the exposed areas thereof while the interior of the body of steam and chemical reactant is moving forward and carrying with it the dissolved and dislodged scale or residue. The dislodged particles of scale or residue are not only thereby carried away thus exposing fresh areas of relatively unattacked scale or residue and ultimately expelled from the vessel being cleaned, but the thus suspended dislodged particles of scale or residue have an erosive effect upon the scale of the vessel being cleaned and physically loosen and erode some of the scale and residue by the effect of the impinging particles of dislodged scale.

In practicing the invention an aqueous solution of an acid is usually employed as the entrained chemical solvent for the scale. The acid most commonly used is formic, citric, acetic, or hydrochloric because these acids are not only excellent solvents for iron compounds which form a substantial part of all scale and residue in vessels of iron or steel employed to confine fluids therein, but are sufficiently volatile at the temperature employed in the invention to be readily removed from hair-pin bends and other type of tortuous lines such as are found in confining vessels, e.g., heat exchangers and certain types of steam boilers. An acid of this type may be completely removed therefrom merely by continuing to pass steam or a heated gas through the vessel. Chromic acid is particularly suitable for use in the practice of the invention where a scale is to be removed which is loosened by the action of an oxidizing agent, e.g., scales containing organic material.

In the preferred practice of the invention, the vessel to be descaled is usually first blown with steam alone and then subjected to the action of an alkaline cleaner such as an aqueous solution of sodium carbonate, sodium hydroxide, or a mixture of the two, preparatory to introducing the chemical solvent for the scale. Preferably the alkaline solution is blown through the vessel to be cleaned with steam in a similar manner to that by which the chemical solvent is subsequently blown therethrough. The alkaline steam treatment as a preparatory step is employed to remove a film of oil, grease, or organic substances which are often found on the surface of a vessel to be cleaned. Thereafter the steam and the chemical solvent to be entrained therein, e.g., formic acid, citric acid, hydrochloric acid, or ethylenediamine tetra-acetic acid, is blown into one end of the vessel and out the other until the effluent steam, carrying with it spent solvent and dislodged scale, no longer shows an appreciable percentage of scale therein and/or an examination of the interior of the vessel shows that substantially all the scale has been loosened and removed.

It is preferred, in the practice of the invention, to blow the vessel being cleaned with steam alone for a period, following subjecting the scale to the combined action of the entrained solvent and steam, to remove therefrom substantially all remaining loosened scale and dilute any of the chemical solvent remaining in the vessel. If desired, a mixture of an alkaline material, such as soda ash or caustic soda and steam may be blown through the vessel being cleaned following the treatment thereof with the solvent and steam in a similar manner to that followed when the alkaline material was blown through the vessel just prior to its treatment with the solvent and steam. It is also recommended that the vessel being cleaned be ultimately blown with substantially dry and inactive gas, e.g., flue gases, nitrogen, inert gases, or air to remove water therefrom which has condensed on the interior of the vessel.

The following examples are illustrative of the practice of the invention.

EXAMPLE 1

A cooling assembly including supply lines thereto and effluent lines therefrom consisting essentially of a cooler, 900 feet of 4-inch line, 1100 feet of 3-inch line, and 1400 feet of 2-inch line, exposed to the normal ambient atmosphere, was to be cleaned in accordance with the invention. The cooling assembly was a newly constructed unit which had not been used. However, the surface thereof including the interior of the pipes and coils was coated with mill scale acquired during tempering and shaping. The cooling assembly was to be used for passing hot liquid wax therethrough for the purpose of applying the wax to heavy paper. The paper thus treated was to be used for food containers. Therefore, any contamination, discolorations, or stains thereon were objectionable.

The lines and coils of the assembly were cleaned accrding to the invention as follows:

Part 1 of Example 1

The coils of the cooler were cleaned first. A 2" steam hose was connected to the inlet end of the cooler coils. Steam was blown into the inlet and through the cooler and out the outlet thereof to remove any loose debris that was present therein and heat up the lines to be cleaned. The time taken for the steam blowing step was about 10 minutes. A solution of soda ash and a surfactant (prepared by condensing 10 moles of ethylene oxide per mole of di-secondary-butyl phenyl) was prepared by admixing the soda ash, surfactant and water in a ratio of 4 pounds of soda ash, two ounces of the surfactant and sufficient water to make 5 gallons of the solution. While continuing to blow steam through the cooling unit, the soda ash solution was pumped gradually into the line and carried therethrough by the force of the steam, which also kept the unit hot while permitting some condensation. The purpose of the soda ash solution was to remove adhering grease and oil which customarily is found on construction steel prior to use, e.g., the residue of cutting oils and perservative oils. The soda ash injection was then discontinued and steam continuously blown through the line for a time thereafter until the soda ash was substantially out of the cooler as determined by testing the pH of the effluent condensate until it showed a pH of about 7. The injection and removal of the soda ash solution required about 40 minutes.

After that time, the injection of steam was resumed and an aqueous solution which was prepared by admixing citric acid, an inhibitor to corrosion, the surfactant employed above, and water in a ratio of 6 ounces of the acid, 4 ounces of the inhibitor, 2 ounces of the surfactant, and sufficient water to make 5 gallons of the citric acid solution, was educted into the cooler near the place of entrance of the steam. The solution thus educted was carried along through the coils of the cooler by the steam, and spued from the outlet thereof, carrying substantial amounts of dissolved and dislodged scale therewith. It was a yellow-to-brown color and contained some condensate which was present therein both as dispersed droplets and as a trickle forming a continuous liquid phase. The pH of the effluent condensate from the outlet of the cooler showed a pH value of about 5 during treatment indicating that some of the acid was being carried completely through the system. Both the steam and citric acid solution were injected into the system at a more-or-less uniform rate for a period of about 45 minutes during which 20 gallons thereof were used.

The interior surfaces of the cooler coils were then neutralized by passing steam therethrough into which was injected an aqueous alkaline solution containing the surfactant prepared as above. The steam was then discontinued, an air line was hooked to the cooler, and air under pressure admitted by which the condensed water from the steam remaining therein was blown out, leaving the coils of the cooler dry.

Part 2 of Example 1

Thereafter the 2- and 4-inch lines of the cooling assembly were cleaned as follows: Steam was started through the lines and a degreasing solution, consisting of the soda ash and the surfactant in the proportions employed above, was pumped into the steam line connected to the lines and the resulting vaporous mixture blown therethrough to remove any grease or oil film therefrom. Thereafter an aqueous solution was prepared by admixing formic acid, an inhibitor to corrosive attack of an acid on metal, a surfactant, and water in the proportions of 6 gallons of formic acid, a gallon of the corrosion inhibitor, ½ gallon of the surfactant prepared as above, and enough water to make 100 gallons of the aqueous formic acid solution. The solution thus made was pumped into the lines and the steam injection into the lines resumed until the 100 gallons of the formic acid solution were thus used. Thereafter, 50 gallons of citric acid solution, prepared as above described (except no inhibitor to corrosion was added) were pumped into the lines while steam injection was continued. During the injection of the steam and formic or citric acid solutions, yellow-brown effluent vapor and liquid spued out the ends of the 2" and 4" lines, in a similar manner to that which occurred during cleaning of the cooler, until the vapors and liquid effluent became clear indicating removal of substantially all scale therefrom. Thereafter steam only was again passed through the lines for a short time then an additional amount of the soda ash solution was fed into the steam in lines and forced therethrough by the steam to neutralize any residual acid therein. Thereafter air was blown through the lines, as above, to dry them.

Part 3 of Example 1

The 3-inch line was then treated by first injecting steam into and through the line, and then, simultaneously with continued steam injection, educting into the 2-inch line, near the steam entrance, thereof, ethylenediamine tetra-acetic acid until a total of 100 gallons of the ethylenediamine tetra-acetic acid was used. The time taken for the acid-steam injection was 1½ hours. Thereafter, the lines were neutralized with the aqueous caustic soda solution and steam employed as above, and then blown dry by air, as above. The amount of time necessary to blow the lines dry with air was about 5 minutes.

Inspection of the lines and cooler showed them all to be perfectly clean and free of all scale and residue.

EXAMPLE 2

Part 1 of Example 2

The interior of two 6-inch, more-or-less, horizontally positioned metal pipes serving as vents or escape lines for fly ash which was produced incidental to the operation of a boiler in a power plant, were heavily coated with a tenaceously adhering hard scale. Fly ash is the name used to refer to suspended particles, chiefly inorganic matter intermixed with some unburned carbonaceous material contained in smoke and gases produced during the combustion of fuels, particularly soft coal. The gases, smoke, and fly ash form scale on the walls of confining vessels, such as smoke stacks and venting ducts, which is particularly difficult to remove therefrom. The fly ash lines to be cleaned were each 1500 feet long, making a total of 3000 feet of 6-inch line having a total volume of about 600 cubic feet.

The interior of the fly ash lines showed a greater thickness of scale deposit along the lower section thereof than along the upper section thereof and a progressively increasing thickness of scale from the inlet end (near the fire box in the basement of the boiler house) to the outlet ends of the lines.

Each of the two 1500-foot sections were cleaned separately. The first section to be cleaned, designated fly ash line No. 2, had been out of use for more than two weeks prior to being cleaned, in accordance with this example. The scale in line No. 2 near the inlet end thereof measured 5/16 inch thick at the upper section and 3/8 inch thick at the lower section. At a number of points along the line toward the outlet including the outlet end itself, the thickness of the scale was measured and showed a more-or-less continuous increase in thickness measuring at the outlet end 1 7/16 inches in the upper section and 2 inches in the lower section. It was estimated that there were about 160 cubic feet of scale in line No. 2 to be removed therefrom. It was also estimated that at least about 14,000 gallons of a 15 percent by weight aqueous solution, e.g., of HCl, would have been required to remove satisfactorily the scale from fly ash line No. 2.

Six thousand gallons of a 28 percent by weight aqueous solution of HCl were prepared in a suitable mixing tank mounted on a mobile unit and placed in a position to be pumped into the fly ash line in the basement of the power house.

A 2-inch steam line was then connected to the No. 2 fly ash line near the inlet end thereof in the basement of the boiler house. Steam was then injected into the fly ash line at a pressure of 500 p.s.i.g. for about 10 minutes to remove loose material from the interior of the line and to wet and heat the interior surface of the line. After passing steam therethrough for about 10 minutes, the 28 percent HCl solution was started into the line near the point of injection of the steam. The average rate of injection of the HCl solution was between 10 and 12 gallons

per minute. Steam containing dislodged scale therein and having a yellow-brown color, spued from the opposite end of the fly ash line to a distance of between about 20 and 30 feet. Some condensate continued also to trickle from the exit end of the fly ash line.

After a thousand gallons of the 28 percent acid had been used, the line was blown with substantially pure steam for about an hour. Thereafter, the tank containing the remaining 28 percent HCl solution was moved down and connected to the fly ash line at a distance of about 500 feet from the inlet. The same procedure as was employed at the first injection was repeated. Injection was at about the same rate as was formerly employed and was continued until another 1000 gallons had been injected into the fly ash line No. 2 while the steam was being forced therethrough under a pressure of about 50 p.s.i.g. The injection of the HCl solution was then stopped and substantially pure steam was again blown through the line for about an hour.

Thereafter the tank containing the remaining 28 percent HCl solution was moved another 500 feet along the No. 2 line, i.e., to a distance of about 1000 feet from the entrance end thereof, and 1100 gallons of the acid injected at about the same rate as earlier used at this point while the steam was continued to be passed therethrough at the same pressure as formerly employed. The fly ash line was hammered lightly by a hand hammer particularly toward the outlet end thereof to aid in loosening the scale, and preventing redeposition of some of that already loosened aiding in its being carried along and out the end thereof. 4100 gallons of liquid solvent had been used over a total cleaning period of 8 hours.

Thereafter, the pumping of the acid was discontinued and steam only forced through the line for about an hour. The steam injection was then discontinued and the line examined at a number of points. The line appeared to be completely free of adhering scale except for traces thereof which appeared in the last 50 feet of the line and did not exceed 1/16 of an inch at any place.

Part 2 of Example 2

The other fly ash line, designated fly ash line No. 1 was then cleaned. It had been in continuous use right up to the cleaning thereof in accordance with this example. The scale deposit in fly ash line No. 1 was not quite so hard nor so firmly bonded to the interior surface of the line as in the case of fly ash line No. 2. The deposits, as in fly ash line No. 2, were heaviest near the outlet end and at the bottom portion of the line. They varied from 1/8 inch thick at the top section of the line near the ash pit in the boiler house to 9/16 inch thick in the bottom section of the line near the exit end thereof.

Line No. 1 was cleaned substantially according to the same method as was line No. 2 of Part 1 of this example. Steam was first passed through followed by 500 gallons of the 28 percent HCl acid gradually injected near the steam entrance and borne along by the steam. Thereafter, the point of injection was moved 500 feet from the steam entrance and another 500 gallons injected into the steam at that point. The point of liquid injection was then moved another 500 feet along line No. 1 and another 300 gallons injected at that point making a total of 1300 gallons over a total period of 2 hours. Six hundred gallons of the total of 6000 gallons of cleaning solvent prepared were, therefore, unnecessary for use in Example 2.

The No. 1 line was then flushed with steam and examined. It was found to be completely clean throughout.

An examination of the examples show that a cooling assembly or unit comprising a cooler and hundreds of feet of line leading to and away from the cooler unit were satisfactorily cleaned by the practice of the invention. It also shows that fly ash lines containing hard adhering scale on the interior thereof were satisfactorily cleaned by the practice of the invention.

A number of advantages are to be realized by the practice of the invention, among which are: equipment comprising vessels through which fluids are passed or stored, may be readily cleaned by employing a relatively inexpensive but highly efficient composition; units which are difficult to fill or generally inaccessible for cleaning by the use of conventional liquid cleaners may be easily cleaned by the practice of the invention; a unit to be cleaned, which is not sufficiently strong to withstand the weight of a quantity of liquid ordinarily required for filling and cleaning by conventional methods, may be now adequately cleaned by the practice of the invention; sloughed or partially dissolved deposits, which heretofore have resisted removal from circuitous or serpentine coils and vessels may now be forced therefrom by the composition of the invention employing steam pressure; large capacity units may now be cleaned by employing relatively small weights of cleaning solvent, which entails notable reductions in costs of materials, transportation, and handling; in most instances the effluent steam-solvent mixture carrying suspended and dissolved therein the scale, is blown completely clear of the unit being cleaned and there may be readily disposed of as by a tank of a caustic solution or moving stream of water which conveniently carries away the spent solvent and removed scale.

Having described the invention, what is claimed and desired to be protected by Letters Patent is:

1. The method of removing an adhering substance selected from the class consisting of mill scale and fly ash, from the inner surface of a vessel adapted to confine a fluid and being provided with at least two openings, at least one of which serves as an inlet and at least one of which serves as an exit to permit forward movement of fluid introduced into the inlet and through the vessel without objectionable build-up of back pressure which method comprises: contacting said adhering substance with steam containing entrained therein a sufficient amount of a solubilizing agent for the adhering scale selected from the class consisting of formic acid, citric acid, acetic acid, hydrochloric acid, nitric acid, alkylene polyamine-carboxylic acids, the anhydride form of such acids, and water-soluble acid salts thereof and mixtures of such acids and salts, to attack and loosen said adhering substance, said contacting steam having a temperature above the boiling point of water and below about 250° F., the walls of said vessel being at a temperature lower than that of the steam, and said steam contacting said adhering substance at sufficient pressure to provide turbulent action adjacent said surface and a positive movement of said steam containing the solubilizing agent to dislodge and carry along, dissolved and suspended therein, the dislodged substance until at least a substantial portion of said adhering substance is dislodged and removed from the vessel.

2. The method according to claim 1 wherein said solubilizing agent is a gas reactive with said adhering substance.

3. The method according to claim 1 wherein a substantially unreactive gas, selected from the class consisting of air, nitrogen, flue gas, and the inert gases is passed into the vessel simultaneously with the steam containing the solubilizing agent entrained therein.

4. The method according to claim 1 wherein a substantially dry gas, selected from the class consisting of air, nitrogen flue gas and the inert gases is passed into said vessel following solubilizing and dislodging said adhering substance to blow a substantial portion thereof out the exit of the vessel.

5. The method according to claim 4 wherein added substantially dry gas is continued to be passed through said vessel until it is substantially dry.

6. The method of removing adhering scale from the interior surface of a vessel adapted to confine a fluid and provided with at least two openings, at least one of which serves as an inlet and at least one of which serves as an exit, to permit forward movement of fluids introduced into the inlet through the vessel without objectionable build-up of back-pressure which comprises injecting steam containing an alkaline degreasing ingredient into and through the vessel; injecting into and through the vessel steam having entrained therein an acidic solubilizing agent for the adhering scale until said scale is substantially solubilized and dislodged from the surface and the thus injected steam leaves the exit of the vessel at a pH value of less than 7; and injecting steam into and through the vessel to remove substantially all the dislodged scale.

7. The method according to claim 6 wherein said acidic solubilizing agent is selected from the class consisting of formic acid, citric acid, acetic acid, hydrochloric acid, nitric acid, alkylene polyaminecarboxylic acids, the anhydride form of such acids, and water-soluble acid salts thereof and mixtures of such acids and salts.

8. The method according to claim 6 wherein the steam injected to remove substantially all the dislodged scale contains an alkaline substance entrained therein to neutralize the residual acid in the vessel being treated.

9. The method according to claim 8 wherein the injection of said degreasing ingredient is followed by injecting steam substantially free of any substance entrained therein into and through the vessel prior to injecting the steam containing a solubilizing agent for the adhering scale.

10. The method according to claim 8 wherein steam substantially free of entrained substances is injected into and through the vessel as a preparatory step to heat, soften, and moisten said scale, prior to injecting the steam containing an alkaline degreasing agent.

11. The method according to claim 8 wherein the steam containing the acid solubilizer for said scale contains also a surface active agent.

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