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F. W. HIGHTOWER ETAL

3,033,710

METHOD OF SURFACE CLEANING USING ULTRASONIC ENERGY

Filed March 12, 1957

2 Sheets-Sheet 1

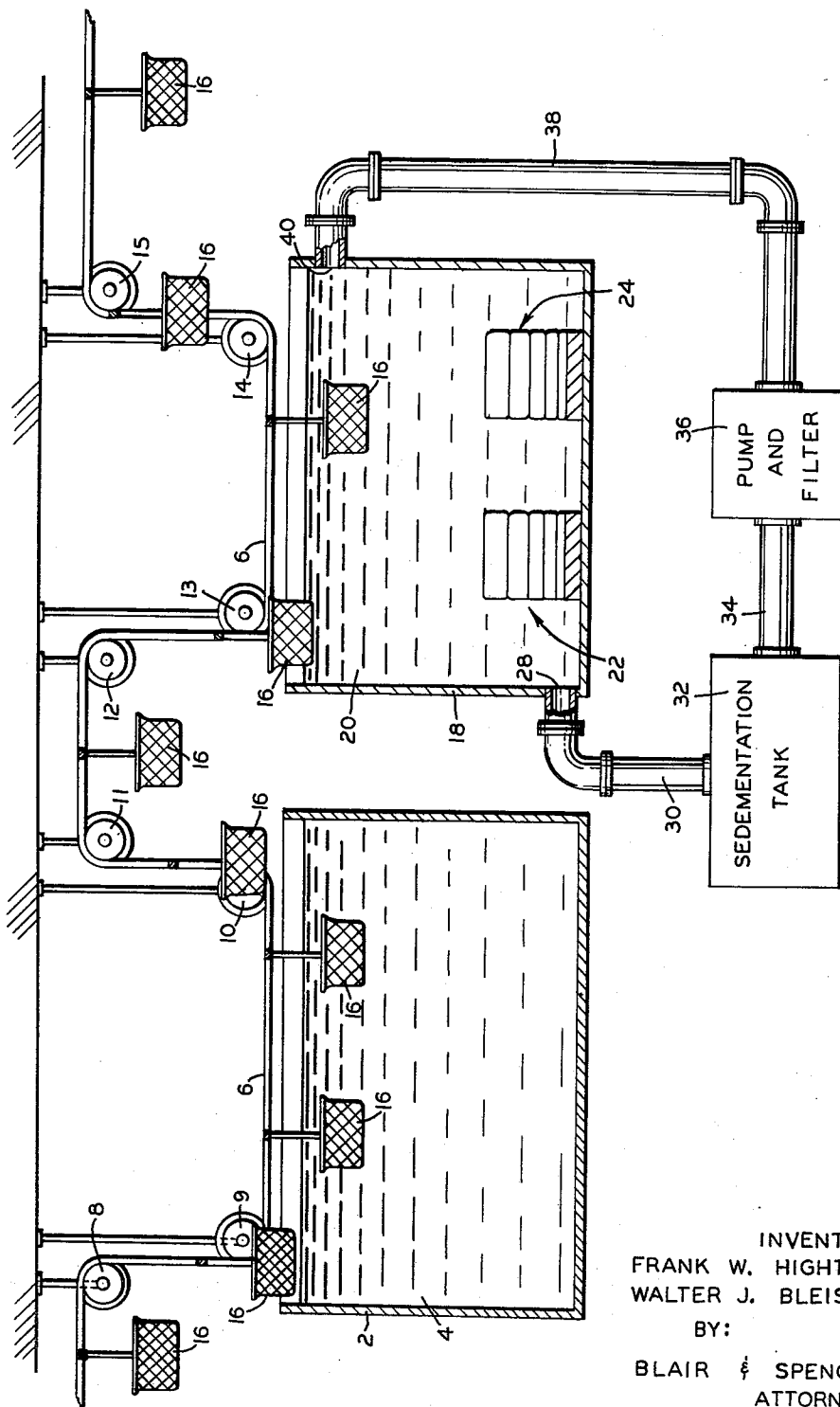


FIG. 1

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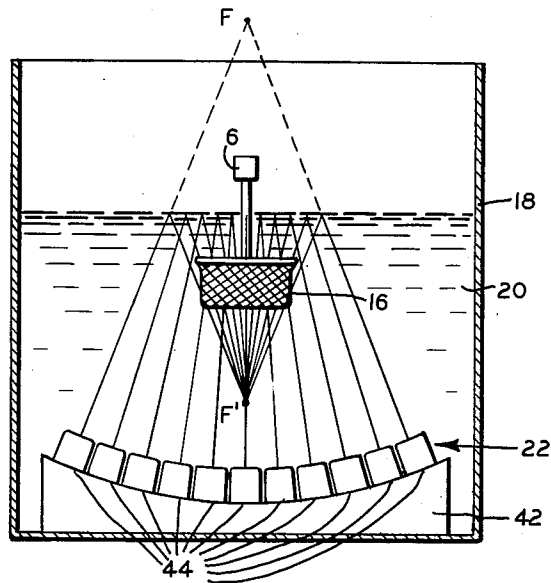
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2 Sheets-Sheet 2

FIG. 2



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METHOD OF SURFACE CLEANING USING ULTRASONIC ENERGY

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Darien, Conn., assignors, by mesne assignments, to
Branson Instruments, Incorporated
Filed Mar. 12, 1957, Ser. No. 645,477
23 Claims. (Cl. 134-1)

Our invention relates to an improved method of cleaning the surfaces of objects by use of ultrasonic energy. More specifically, it relates to a method which greatly increases the speed and efficiency of removal of scale, rust, dirt, and other contaminants from the surfaces of metal, plastic, and ceramic articles.

The art of cleaning objects by placing them in a liquid bath and transmitting ultrasonic waves through the bath to impinge thereagainst is well known. Thus, a piezoelectric transducer is excited from a radio frequency generator at a frequency substantially above that of ordinary sound. These transducers are made from quartz or pre-polarized barium titanate, for example. One face of the transducer is in engagement with the cleaning fluid and sets up alternate compression and rarefaction waves therein at the excitation frequency. These waves in turn create cavitation at the surface of the object to be cleaned which results in a gentle scrubbing action to remove surface contaminants. Cavitation is the result of the formation of bubbles within the cleaning liquid wherever there are imperfections such as microscopic nuclei or absorbed air therein. These bubbles expand in the rarefaction or tension portion of the energy wave and contract during the compression portion. If the size after expansion exceeds a critical ratio to the initial size, the bubble will burst and "crash," thus producing this scrubbing action at the surface of the material to be cleaned. By using ultrasonic cleaning in a suitable liquid, objects having irregularly shaped surfaces and crevices can be cleaned very rapidly, and certain types of surface contaminants which are removed with difficulty or not at all by other cleaning processes may be readily removed. In some cases, however, the amount of ultrasonic equipment required to clean the surface of an object in a given time is large and therefore expensive. For this reason ultrasonic equipment has not been used in certain production applications.

Another method heretofore used in cleaning metal, plastic, and ceramic objects consists of dipping the part in an acidic or basic solution which attacks the surface contaminant. This method is economical, requiring simple equipment such as dipping tanks and conveying equipment. It is used in removing heat treating scale and rust, in the pickling of steel, and in many other industrial applications. However, it is time consuming and does not always clean crevices and holes in the objects being so processed. It has, therefore, been suggested that ultrasonic cleaning which does an efficient cleaning job, even on crevices and holes, etc., and the chemical cleaning method be combined to improve the speed and efficiency of chemical cleaning and reduce the cost of ultrasonic cleaning. However, the combining of these two methods has given rise to additional problems. For example, the continuous operation of transducers for generating ultrasonic energy with attendant cavitation at the surface of the transducer as well as at the surface of the object being cleaned results in considerable transducer wear in a strongly acid bath; indeed, the housing of these transducers is subject to attack even in a neutral cleaning bath. The effect is, of course, greater in an acid bath, reducing considerably the useful life of the transducer. Another problem encountered when combining these methods is in the chemical cleaning bath itself, which may have an

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undesirable attenuating effect on the ultrasonic energy produced by the transducer. Because of such attenuation, greater amounts of transducer input power are required for a given cleaning effect. This increased power in turn causes increased cavitation at the surface of the transducer to further reduce its useful life. Despite these difficulties, ultrasonic cleaning has been used with chemical cleaning methods, resulting in better cleaning and some reduction in cleaning time. However, this time reduction has only been achieved by using a relatively large amount of ultrasonic cleaning equipment in production lines.

Accordingly, it is a general object of our invention to provide an improved method for cleaning the surface of metal, plastic, or ceramic parts which combines both chemical and ultrasonic cleaning methods. A more particular object of our invention is to provide a method of the type described which combines chemical cleaning processes utilizing acidic or basic baths and ultrasonic cleaning. A still further object of our invention is to provide a method of the above character which is substantially faster and less time consuming than the methods heretofore used. Another object of our invention is to provide an improved method of the above character which provides substantially improved surface and crevice cleaning as compared to prior methods. A still further object of our invention is to provide an improved method of the above character in which the ultrasonic transducers are protected from the destructive effects of the chemical cleaning bath. Still another object of our invention is to provide a method of the above character wherein the ultrasonic transducer may operate in a bath which is closely "matched" to its impedance. Still another object of our invention is to provide a method of the above character for combining ultrasonic and chemical cleaning which minimizes the amount of ultrasonic equipment required for satisfactory cleaning. A final stated object of our invention is to provide apparatus for carrying out the methods described. Other and further objects will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others as exemplified in the following detailed disclosure. The scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of our invention, reference should be had to the following detailed description taken in connection with the accompanying drawings in which:

FIGURE 1 is a schematic vertical section illustrating apparatus for cleaning the surfaces of small individual parts according to the method of our invention, and

FIGURE 2 is a vertical section taken along the line 2-2 of FIGURE 1.

In general, in practicing the method of our invention, the objects to be cleaned are first immersed in a chemical cleaning bath which is acidic or basic depending upon the contaminants to be removed. They are allowed to remain therein long enough for the acid or base to penetrate the contaminant to the ultimate surface and perhaps loosen the contaminant. After this the object to be cleaned is removed from the first bath and placed in a second neutralizing bath which may include a detergent. In certain instances a neutral bath may be used alone or with a detergent, although a neutralizing bath is preferred. The object is subjected to ultrasonic cleaning of the type described while in the second bath at the same time the neutralizing action is taking place, and this results in rapid contaminant removal in a very short time. The scale or contaminant seems to "explode" from the surface of the object, leaving it very clean in a very short period.

The apparatus required to achieve this cleaning consists of a first tank or bath for chemical cleaning and a conveyor to move the objects therefrom to the second tank. The second tank contains a bath which has either an opposite pH to that of the first bath or which is neutral; the ultrasonic transducers are in this second bath.

By using the method and apparatus generally described above, very rapid contaminant removal is obtained. This two-stage cleaning requires substantially less ultrasonic equipment than is necessary where such equipment is used in the initial cleaning bath. The surface contaminants are removed not only from flat and rounded surfaces but also from blind holes and crevices therein. A proper cleaning fluid can be selected for operation with the ultrasonic transducer, since the chemical cleaning bath and the neutralizing or neutral bath are separate. Further, the transducer does not operate in the strong chemical cleaning bath with resulting damage thereto. Thus, the method described herein represents a substantial advance over merely operating the ultrasonic transducers in a chemical cleaning bath.

More specifically, in the method of our invention the objects to be cleaned are, as previously described, first subjected to a chemical cleaning bath. This bath may be either acidic or basic depending on the nature of the contaminant to be removed. For example, if the object to be cleaned is made of metal from which rust, heat treating scale, or the like is to be removed, baths of hydrochloric, nitric, chromic, sulfuric acid or phosphoric acid may be used or mixtures thereof. If it is desired to remove "smog" deposits or the like from ceramic insulators, strongly alkaline baths such as those prepared from sodium hydroxide, tri-sodium phosphate, or the like are preferred. The immersion time in the chemical acid bath depends upon the thickness of the contaminant and the particular reaction which takes place. For thin surface contamination such as rust or heat treating scale, we have found that times ranging from a few seconds to five to ten minutes are satisfactory, while for thick surface contamination the chemical reaction sometimes takes thirty minutes or longer. The desirable temperatures for such chemical cleaning baths usually range from 160° F. to 200° F., although higher or lower temperatures may be used. The important requirement of this step is to insure that the chemical cleaning fluid penetrates the scale completely to the ultimate surface.

After completion of the chemical cleaning step described, the object is removed from the first bath. It may be washed prior to insertion in the neutralizing or neutral solution. However, it is preferable to have the material go directly from the chemical cleaning bath to the second bath where it is subjected to ultrasonic cleaning.

While the second bath may be neutral, it preferably has a pH which is opposite to the chemical cleaning bath. For example, if the chemical cleaning bath is acidic, i.e., has a pH lower than seven, the second ultrasonic cleaning bath should be basic, i.e., have a pH higher than seven. Conversely, if the chemical cleaning bath is basic, the ultrasonic cleaning bath should be acidic. While solutions which are either basic or acidic are preferable for the second bath, neutral solutions such as water may also be used in the ultrasonic cleaning step; detergents may be added to the ultrasonic cleaning fluid if desired.

The ultrasonic cleaning apparatus includes a bank of transducers usually of quartz or a piezoelectric ceramic such as barium titanate. While these transducers may be operated at frequencies from above the level of audible sound up to approximately 400 kilocycles, they are preferably operated at about 40 kilocycles, since at this frequency ultrasonic cleaning is relatively efficient at low power levels. Barium titanate crystals are in general preferred in ultrasonic cleaning, although quartz crystals are sometimes used. The transducer is supplied with sufficient energy from a radio frequency generator to accom-

plish cleaning in the time desired while avoiding transducer damage.

After chemically pretreating the object to be cleaned as described, the period of ultrasonic cleaning may be shortened to a few seconds in some cases. The surface contaminant may thus be removed very rapidly; it has been found that little additional ultrasonic cleaning is accomplished by longer immersion. The effectiveness of cavitation decreases as the volatility of the cleaning fluid increases, and tends to increase as its density increases. Both of these factors tend to decrease the effectiveness of cavitation as the temperature of the ultrasonic cleaning fluid approaches the boiling point. Thus we have found that for most water solutions a temperature of approximately 140° F. is preferred for ultrasonic cleaning. If the parts to be cleaned have deep channels or blind holes that might entrap air, it is usually desirable to rotate the work in the ultrasonic cleaning solution to permit air to escape. This is essential, because if no cleaning liquid is in contact with the object to be cleaned, there can be no surface cavitation and hence no cleaning.

While the reasons for the extremely rapid contaminant removal in the ultrasonic cleaning bath as described are not readily apparent, it is believed that neutralization of the chemical cleaning agent used in the first step provides cavitation nuclei deep in the contaminant. The bubbles which form on these cavitation nuclei grow and implode, thus forcing the scale loose from the surface of the object to be cleaned. This apparently is true not only where the chemical bath is neutralized during ultrasonic cleaning, but even where a neutral solution is used, although to a lesser extent.

In any event the process which we have described results in rapid contamination removal and extreme surface cleanliness with crevices and re-entrant cavities such as blind holes, etc. also effectively cleaned. The high speed achieved with such a combination of chemical and ultrasonic cleaning techniques reduces to a minimum the amount of ultrasonic equipment required and thus reduces expense. Finally, in many applications, especially where the chemical cleaning step is acidic, the transducers operate in either a neutral or a basic bath. These baths do not attack the transducer housing as would an acid, and thus the transducers are not damaged.

The following examples illustrate specific applications of our invention and are, of course, illustrative only.

Example I

A panel of AISI 420 stainless steel was heat treated at 1825° for approximately half an hour and then cooled to room temperature. It was then tempered at 600° F. for three hours. As a result of this treatment, the panel was covered with a thin dull grey scale. The panel was pickled in a solution of 25 percent nitric acid plus 3 percent hydrofluoric acid by volume at 100° F. for 10 minutes. After this pickling the panel was immersed for a period of 10 seconds in a strong caustic solution which was ultrasonically cavitated. The resulting panel was clean, bright, and all scale had been removed therefrom.

By comparison, when the panels were pickled as above and then neutralized in a strong caustic solution without ultrasonic treatment, the scale was attacked and loosened to some extent but not removed to leave a bright, shiny surface.

Example II

Heat treating scale was removed from steel castings in the following manner. The castings covered with scale were first placed in a 20 percent solution of phosphoric acid by volume at 160° F. The material used to provide the phosphoric acid is sold under the trademark "Phos-It." The castings were allowed to remain in the solution for about 5 seconds. They were then placed immediately without washing in a solution of 10 percent by volume of sodium hydroxide at about 160° F. which was cavitated with ultrasonic equipment for 15 or 20 seconds. Substan-

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tially complete scale removal from all parts including blind holes, etc. resulted.

Scale removal from the same parts was also accomplished by an initial bath in "Deoxidine 670" at 180° F., a chemical compound believed to contain about 70 percent of phosphoric acid. The castings were then immersed between 36 seconds and 1 minute in a 10 percent solution of sodium hydroxide at 160° F. which was cavitated with ultrasonic equipment. The latter procedure also resulted in substantial scale removal, but apparently not as complete as the first procedure.

Example III

Ceramic insulators which had been exposed to the weather and had substantial carbon deposits on them were cleaned in the following manner. The insulators were placed in a 10 percent solution of sodium hydroxide and allowed to remain therein at a temperature of about 160° F. for about 5 to 10 minutes. They were then removed from this chemical bath and placed in an ultrasonically cavitated solution of 12 to 15 percent by volume of sulfuric acid at a temperature of approximately 135 to 140° F. for a period of 25 to 30 seconds. When removed from the acid solution, the insulators were completely free from the carbon deposit. Prior to the use of this method, the only known way to remove carbon deposited on insulators of this type was by manual application of abrasives.

In the drawing we have illustrated apparatus for practicing the method of our invention. As shown therein, such apparatus includes a first chemical cleaning tank 2 which is filled with an appropriate chemical cleaning fluid 4. A conveyor 6, which may be of the chain or belt type and may be either an indexing or continuously moving type, is threaded over the pulleys or sprockets 8 through 15. A plurality of the articles to be cleaned are placed in open mesh metal baskets, which in turn are suspended from the moving belt or chain of the conveyor.

Experimentation has shown that a fine mesh placed between a part to be cleaned and a source of ultrasonic energy substantially reduces the cleaning effect of the ultrasonic energy. It has also been shown that the finer the mesh, the less effective is the ultrasonic cleaning for a given amount of ultrasonic energy. Accordingly, the baskets 16 should be made of a mesh which is as coarse as possible, consistent with their function of holding the parts therein which are to be cleaned. It has also been found that a solid thin metal sheet placed between the source of ultrasonic energy and the part to be cleaned has relatively little effect on the cleaning process. Accordingly, that portion of the basket which is interposed between the ultrasonic source and the parts to be cleaned is preferably made from a thin solid sheet. In the apparatus shown, the bottoms of the baskets 16 would be such thin solid sheets, since, as hereinafter explained, the ultrasonic transducers are located in the bottom of the ultrasonic cleaning tank. If the transducers were located along the sides of the tank, then the sides of the basket would preferably be solid, while the bottoms would be open mesh.

It is to be understood that while this figure illustrates apparatus for cleaning small parts placed in mesh baskets, large pieces such as sheets of material or larger parts might be suspended directly from the conveyor 6.

A second cleaning tank 18 is provided which is filled with the neutralizing or neutral solution 20. Two focused banks of ultrasonic transducers generally indicated at 22 and 24 are located in tank 18 to ultrasonically cavitate the fluid 20 therein. Pulleys 11 and 12 are spaced upwardly so that the conveyor moves the baskets 16 up from tank 2 and down into tank 18. In addition, tank 18 is provided with an outlet 28 from which the solution 20 flows through the conduit 30 to a sedimentation tank 32 and via conduit 34 to a pump and filter 36. In some instances the fluid from the sedimentation tank is distilled to remove dissolved contaminants in addition to or as a substitute for the filtering. After passing through the

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pump and filter or suitable distilling apparatus (not shown), it is conducted via the conduit 38 to fluid inlet 40 of tank 18. This continuous flow assures substantial removal of contaminants from the fluid 20 so that the ultrasonic cleaning operation may be carried on efficiently.

It will be noted that no washing step is introduced between the chemical cleaning in tank 2 and the ultrasonic cleaning and neutralizing action in the tank 18, since as previously described this is usually undesirable, especially where neutralizing action is to take place.

The lengths of the tanks 2 and 18 depend upon the time the objects being cleaned are to remain in each bath and the speed of the conveyor. It is also to be understood that various types and arrays of the transducer banks can be used. In the apparatus illustrated, we have shown an array adapted to "focus" the ultrasonic energy from the transducers, to form a zone of intense ultrasonic energy. In this zone the ultrasonic energy approaches from all directions, thus insuring that all surfaces of the object to be cleaned are exposed to the ultrasonic cleaning action.

As shown in FIGURE 2, the bank of ultrasonic transducers generally indicated at 22 (the bank 24 being substantially identical) is mounted on a support 42 having a concave upper surface. A plurality of transducers 44 are mounted on this surface and, when energized as described, will transmit energy generally towards the focus F, which is located above the upper surface of the bath 20 as shown by the full and dotted lines. However, when the energy reaches the surface of fluid 20, it will be reflected back into the fluid toward the inverted focus F'. There will thus be a zone or region of extremely high energy at the location of the basket 16 in FIGURE 2. In this region energy will impinge on the bottom and sides of the basket directly from the transducer bank, while reflected energy from the fluid surface will impinge on the top and sides, the larger amounts impinging on the top and bottom thereof. Thus a zone of high intensity ultrasonic energy is provided in which the impinging energy approaches the zone from multiple directions to prevent "shadowing." This and other arrays to concentrate ultrasonic energy are more fully disclosed in the now abandoned co-pending application filed in the name of Norman G. Branson entitled "Method and Apparatus For Ultrasonic Cleaning" (filed May 1, 1956, Serial No. 581,980), and assigned to the same assignee as the present application. While we have described an array for use with the apparatus of our invention, it is to be understood that such an array is not required for its proper operations and the transducers could be located in the side walls of the tank 18 if desired. Thus transducers might be arranged in a flat bank in one side, or if greater speed is desired, banks of transducers might be arranged facing each other. Also, the articles to be cleaned might be passed through a separate tank from the bath which encloses the transducers as disclosed in the co-pending application filed in the name of Norman G. Branson entitled "Ultrasonic Cleaning Apparatus" (Serial No. 601,661, filed August 2, 1956, now Patent No. 2,845,077), and also assigned to the same assignee as the present application.

In some instances it may be desirable to combine with the automatic equipment shown in the drawing vapor de-greasing apparatus and automatic washing and drying apparatus.

It will thus be seen that we have provided an improved method for removing contaminants from the surfaces of metal, ceramic, or plastic objects or the like by first subjecting the objects to chemical cleaning and then subjecting them to treatment with ultrasonic energy in a separate cleaning bath; the second bath preferably neutralizing the chemical bath at the same time. By the use of this method substantially improved cleaning is obtained over that which is possible or practical by using either chemical or ultrasonic cleaning exclusively. Fur-

ther, because of the high speed of the ultrasonic cleaning step, the amount of ultrasonic equipment required is substantially reduced. Further, the life of the ultrasonic transducers is greatly increased. We have also disclosed apparatus by which the process of our invention may be carried out automatically on a production line basis to provide substantially improved surface cleaning as compared to that heretofore available.

Thus the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in carrying out the above method and the construction set forth without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described our invention, what we claim as new and desire to secure by Letters Patent is:

1. The method of surface cleaning objects which comprises, in combination, the steps of immersing an object to be cleaned in a first bath having a pH less than 7, removing the object from said first bath and immersing said object while having a residual amount of said first bath thereon in a second bath having a pH greater than 7, and ultrasonically cavitating said second bath while said object is immersed therein.

2. The method of surface cleaning objects which comprises, in combination, the steps of immersing an object to be cleaned in a first bath having a pH greater than 7, removing the object from said first bath and immersing said object while having a residual amount of said first bath thereon in a second bath having a pH less than 7, and ultrasonically cavitating said second bath while said object is immersed therein.

3. A method for cleaning the surfaces of objects which comprises, in combination, the steps of immersing said object in an acidic bath, removing said object from said acidic bath and immersing it in a basic bath while some residual acid from said first bath remains thereon, and ultrasonically cavitating said second bath while said object is immersed therein.

4. The method of cleaning the surfaces of objects comprising, in combination, the steps of immersing an object to be cleaned in an alkaline bath, removing the object from said alkaline bath and immersing it in an acidic bath while having a residual amount of the alkaline bath thereon, and ultrasonically cavitating said second bath while said object is immersed therein.

5. A method for cleaning the surfaces of an object having a contaminant thereon which comprises, in combination, the steps of immersing said object in a first bath, said first bath containing an acid which attacks said contaminant, for a time sufficient to permit said acid to penetrate through and adhere to said contaminant on said object, removing said object from said first bath and immersing it in a second bath while residual first bath liquor adheres to said object, said second bath being basic to thereby neutralize the acid solution adhering on said object from said first bath, and ultrasonically cavitating said second bath while said object is immersed therein.

6. A method for cleaning the surfaces of an object having a contaminant thereon which comprises, in combination, the steps of immersing said object in a first bath, said first bath containing a caustic solution which attacks said contaminant, said first immersion continuing for a time sufficient to permit said caustic solution to penetrate through and adhere to said contaminant on said object, removing said object from said first bath and immersing it in a second bath while residual caustic solution adheres to said object, said second bath being

acidic to thereby neutralize the caustic solution adhering to said object from said first bath, and ultrasonically cavitating said second bath while said object is immersed therein.

7. A method of cleaning the surface of a metallic object to remove oxides, scale and other contaminants, which comprises the steps of immersing said object to be cleaned in a first chemical cleaning bath having a pH other than 7 to adhere solution to said object, removing said object from said first bath and immersing it in a second bath while residual chemical cleaning bath solution adheres to said object, said second bath having a sufficient pH and sufficient concentration to neutralize the residual portion of said first bath adhering to the surface of said object, and causing ultrasonic energy to impinge upon said object in said neutralizing second bath from a plurality of directions.

8. A method for cleaning the surface of an object having a contaminant thereon which comprises, in combination, the steps of immersing said object in a first bath, said first bath containing an acid which attacks said contaminant for a time sufficient to permit said acid to penetrate through and adhere to said contaminant on said object, removing said object from said first bath and immersing it in a second bath while residual first bath liquor adheres to said object, said second bath being basic to thereby neutralize the acid solution adhering on said object from said first bath, and causing said object to pass through a zone of high intensity ultrasonic energy which enters said zone from a plurality of directions while in said second bath.

9. A method for cleaning stainless steel objects, said objects being covered with a heat treating scale which comprises, in combination, the steps of pickling said objects in an acid solution, immersing said objects having some residual acid thereon in a caustic solution, and ultrasonically cavitating said caustic solution while said objects are placed therein.

10. The method defined in claim 9 in which said acid solution comprises 25 percent by volume of nitric acid and 3 percent by volume of hydrochloric acid.

11. The method defined in claim 9 in which said acid solution is at a temperature of substantially 100° F. and said objects are allowed to remain therein for a period of approximately 10 minutes.

12. The method defined in claim 9 in which said objects are allowed to remain in said second bath for a period of only 10 seconds.

13. A method for removing heat treating scale from steel castings which comprises, in combination, the steps of placing said castings in a phosphoric acid solution, removing said castings from said solution and placing them while having some residual acid thereon in a sodium hydroxide solution, and subjecting said sodium hydroxide solution to ultrasonic cavitation while said castings remain therein.

14. The method defined in claim 13 in which said phosphoric acid solution comprises 20 percent by volume of phosphoric acid.

15. The method defined in claim 13 in which said castings are allowed to remain in said phosphoric acid solution for approximately 5 seconds, and said solution is at a temperature of approximately 160° F.

16. The method defined in claim 13 in which said second bath is a 10 percent solution by volume of sodium hydroxide.

17. The method defined in claim 13 in which said sodium hydroxide solution is at a temperature of 160° F., and said castings are allowed to remain in said solution for between 15 and 20 seconds while said solution is being ultrasonically cavitated.

18. A method for removing carbon deposits from the surfaces of ceramic objects which comprises, in combination, the steps of placing said objects in a solution of sodium hydroxide for a period of not less than 5 minutes,

and removing said objects from said sodium hydroxide solution and placing them while having some residual sodium hydroxide solution thereon in an ultrasonically cavitated solution of sulfuric acid, to thereby neutralize said sodium hydroxide solution and ultrasonically clean said objects simultaneously.

19. The method defined in claim 18 in which said sodium hydroxide solution is at a temperature of about 160° F.

20. The method defined in claim 18 in which said ultrasonically cavitated solution contains between 12 and 15 percent of sulfuric acid by volume, and said parts remain therein for between 20 and 30 seconds.

21. The method of cleaning an object for the removal of contaminants therefrom, comprising in combination the steps of immersing the object to be cleaned in a first bath solution selected from a group consisting of acidic and basic solutions to adhere said solution to said object, removing said object from said first bath and immersing it in a second bath while residual first bath solution adheres to said object, said bath having a substantially opposite pH value to that of the first bath for neutralization of the residual solution of said first bath adhering to said object, and ultrasonically activating said second bath during said neutralization immersion whereby cavitation proximate to said object is increased.

22. The method of cleaning the surface of an object for the removal of contaminants therefrom combining the steps of immersing said object in an acid solution to ad-

here said acid solution to said object, removing said object from said acid solution and immersing it in an alkaline solution while residual acid solution adheres to said object to neutralize the residual acid solution adhering to said object, and ultrasonically activating said object and said alkaline solution during neutralization whereby the co-action of neutralization and ultrasonic activation effect increased cavitation proximate to said contaminants and said surface.

23. The method of cleaning an object comprising the steps of immersing the object in a first bath solution selected from a group consisting of acidic and basic solutions to adhere said solution thereto, then immersing the object in a second bath having opposite pH characteristics while residual first bath solution adheres to said object and subjecting said second bath to ultrasonic activation.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

May 8, 1962

Patent No. 3,033,710

Frank W. Hightower et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 9, line 21, after "said", second occurrence,
insert -- second --.

Signed and sealed this 16th day of October 1962.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents