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SONIC CLEANING METHOD

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This invention relates to a discovery of an improved method for cleaning articles with fluorinated hydrocarbon solvents and more particularly to a method for cleaning heavily contaminated articles by utilizing the solvent trichlorotrifluoroethane and the cavitation action of sonic energy over a newly discovered range of temperatures.

Fluorinated hydrocarbon solvents have been used for cleaning solutions and have been found effective for mild cleaning purposes. Better cleaning results have been obtained by activating the solvent while maintaining the temperature within a limited temperature range.

Heretofore manufacturers have recommended the use of fluorinated hydrocarbon solvents over a low range of temperatures when used for cleaning purposes and have claimed that the percentage of sonic activity decreases as the solvent temperature approaches its boiling point.

An object of the present invention is to provide an improved method for cleaning whereby a fluorinated hydrocarbon solvent is utilized with cavitation action over a limited range of solvent temperatures.

Another object of the present invention is to provide a method for cleaning whereby the temperature of the fluorinated hydrocarbon solvent is maintained at a high temperature.

Several fluorinated hydrocarbon solvents have been used successfully for cleaning purposes, most noteworthy of these have been trichloromonofluoromethane, tetrachlorodifluoroethane and trichlorotrifluoroethane. These solvents have been used where heavy and tightly bonded contamination appears on the article to be cleaned, but special problems have arisen with the process including the long duration of time required to complete the process. Trichlorotrifluoroethane has been generally recommended for use below 95° F. when used either alone or with sonic energy for cleaning purposes. The solvent has been primarily recommended for use with lightly contaminated articles.

A further object of the present invention is to provide a method for cleaning heavily contaminated articles whereby trichlorotrifluoroethane is used with the cavitation action of sonic energy and is maintained at a temperature of not less than 104° F.

A still further object of the present invention is to provide a method for cleaning heavily contaminated articles whereby cleaning is accomplished in 10 to 30 seconds with trichlorotrifluoroethane and the cavitation action of sonic energy while the temperature is maintained at 104° F. to 117.6° F.

Certain of these objects are realized in the invention by the steps of immersing the contaminated article in a cavitated trichlorotrifluoroethane solution, heating the solution and maintaining the solution at a temperature not less than 104° F.

The foregoing and other objects and advantages of the invention will appear more fully hereinafter from a consideration of the description which follows, the examples set forth herein are for the purpose of illustrating the invention and are not to be construed as limiting the invention.

The present discovery embraces an improved method

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for cleaning the fluorinate hydrocarbon solvents. The present invention provides a method for complete cleaning by providing the proper combination of solvent, temperature, and sonic activation. Solvents, trichloromonofluoromethane, tetrachlorodifluoroethane, and trichlorotrifluoroethane have been found to be more effective for cleaning when used at temperatures close to their boiling point while cavitating the solvents. These solvents include a wide range of boiling points, 74.8° F., 199° F., and 117.6° F., respectively. Trichlorotrifluoroethane solvent has been found to produce the most satisfactory results and has a controllable boiling point of 117.6° F. For the purposes of illustrating the invention trichlorotrifluoroethane will be used but the invention should not be considered to be limited thereto.

The action of the trichlorotrifluoroethane solvent of the invention is augmented and hastened by mechanical agitation. A superior kind of such mechanical agitation is ultrasonic cavitation of the solvent. Those skilled in the art use the term "sonics," "ultrasonics," and "sonic energy" to include sonic frequencies within the range of audible frequencies as well as those beyond that range. The term is used in that sense herein and is not limited to inaudible frequencies.

The trichlorotrifluoroethane solvent is subjected to sonic energy at a frequency and power amplitude to produce cavitation. The term "cavitation" defines several types of action including one in which tiny bubbles or voids present in the liquid and created by other actions are made to collapse. Thus a cavitated solvent experiences these violent pressure changes at myriads of microscopically spaced volumes of microscopic and submicroscopic dimensions. Such pressure changes caused by the cavitating solvent insures its proper action in dislodging the encapsulating material on the article being cleaned, to some extent loosens and removes the contamination on the article, moves the solvent so that fresh solvent reaches the surface to be cleaned, and promotes even and faster cleaning action of the trichlorotrifluoroethane solvent. Therefore, the effect of cavitation of the solvent is to increase the cleaning action of the solvent, to increase the effectiveness and activity of the solvent, and to make the solvent more available to the surface to be cleaned.

A further understanding of sonic energy and sonic energy systems will aid in defining the limits of the invention. A sonic energy system is composed of two basic parts, a generator and a transducer. The function of the generator is to supply electrical energy to the transducer. The transducer converts electrical energy supplied by the generator to mechanical energy in the form of vibrations or sound energy.

When the sound energy is introduced into a liquid under the proper conditions, a secondary phenomenon takes place. This is in the form of pressure differentials which are generated in the liquid by a mechanism technically termed "cavitation."

All liquids contain voids or bubbles. Whether the liquid is a molten metal or water it will still possess bubbles of varying size which range from those easily seen by the naked eye to those which are sub-microscopic. Cavitation is caused by the compression produced in the liquid by the sound wave which passes through it. Sound waves are longitudinal waves which means they are compression waves. They compress the molecules of matter through which they pass. When a sound wave emitting from a sonic energy transducer is passed into a liquid, three important functions occur.

One, energy is imparted to the larger bubbles. They

coalesce, become buoyant, and float to the surface of the liquid and are dispersed. This is termed de-gassing and occurs to most bubbles in the solution which are visible to the naked eye. Thus many air pockets are removed which would have acted as sound absorbers if they remained.

Two, additional bubbles are stabilized in the liquid due to their size. These are not de-gassed and are generally less than 40 microns in diameter. When a sonic compression wave comes in contact with these bubbles, it will compress them, then as the sound wave passes by, the bubbles are expanded due to the resultant rarefaction thus causing a pulsing or vacuuming type of action in the liquid.

Three, many of the bubbles in the solution do not pulse with the compression wave but collapse as pressure is applied. Upon collapse they leave small voids in the solution. These voids collapse violently due to atmospheric and hydrostatic pressures, thus causing implosion.

Thus, the sonic energy system must be sufficiently powered to provide the above effects in the cleaning solution. In order to produce implosion cavitation, the energy input into the solution must be sufficient to overcome the physical forces tending to oppose the bubble rupture. One of the major forces is that of hydrostatic pressure since it is necessary to exceed this pressure prior to producing cavitation.

Sonic energy cavitation can be produced in a solution over a wide range of frequencies. It is well known by those skilled in the art that the lower the frequency, the greater the energy released by the vaporous cavitation or bubble rupture. As frequency is decreased more and more bubbles are available that have the physical requirements for rupture. The effect is that at lower frequencies more energy is available to do the cleaning.

In practice, the degree of cavitation is limited by dispersion of the sonic induced energy by the bubbles or voids acted upon in the cavitation process. After the sonic energy is increased to the threshold level of cavitation, further increase causes relatively low increases in cavitation violence but causes a more wide spread cavitation.

The energy threshold for cavitation in a given liquid, while relatively constant at low frequencies increases rapidly at higher frequencies. The result is that the lower limit for practicing the process is that the sonic energy input must exceed the cavitation threshold of the cavitated liquid in addition to being above the frequency and power at which the cavitation causes significant surface damage to the article being cleaned.

In the invention no lower power limit is imposed but the frequency is maintained above 10 kilocycles per second above which level the forces of cavitation are sufficiently low to preclude significant surface damage to the articles being cleaned due to excessive cavitation. In the invention it has been advantageously found that the upper limit of frequency is the cavitation range of the solution and the solution of the invention has a practical limit of 120 kilocycles per second.

By maintaining the frequency of 20 kilocycles per second the noise of an operating cleaner is kept to a minimum. At such operational frequencies and power as herein described, the apparatus is of minimum size and relatively inexpensive.

Such variables as the pressure at which the invention is practiced and the surface tension and vapor pressure of the cavitated liquid only changes the threshold level of sonic energy required for cavitation. If the sonic frequency is held below 120 kilocycles per second they do not substantially affect the process but are only important to the economics of sonic energy production as long as cavitation is maintained.

It has been found that the method of the invention can be utilized with commercially available apparatus. One type of such apparatus is the sonic cleaner appa-

ratus manufactured by the assignee of the present invention. The container of such apparatus wherein the cavitation occurs is in communication with a recirculating and heating system. The trichlorotrifluoroethane solvent of the invention may be placed in the container. If the solvent is to be mixed with other fluorinated hydrocarbon solvents or other agents such a step may be accomplished in the container and the final solvent solution may be mixed to the degree required before use. Cavitation of a mixture will speed up a mixing process.

The discovery of the present invention requires heating of the solvent to a limited temperature range. This may be advantageously accomplished with the apparatus as described above. Each of the basic elements of the invention, fluorinated hydrocarbon, cavitation, and temperature range, has a specific individual function when used for cleaning purposes and the effectiveness of each of which depends upon the function of the other whereby the invention contemplates a method simultaneously including all steps.

A trichlorotrifluoroethane solvent to which sonic energy is applied will react differently to each temperature range from room temperature to its boiling point of 117.6° F. From room temperature to approximately 95° F. a small amount of activity appears in the conically activated solvent and at approximately 95° F. small ripples will appear on the surface of the solvent. From approximately 95° F. to 100° F. an increase in activity appears in the sonically activated solvent and at approximately 100° F. a mist appears on the solvent surface as the solvent begins to break the surface. From approximately 100° F. to approximately 110° F. increased bubble activity appears indicative of a strong cavitating liquid and at 110° F. a constant ripple appears on the surface of the liquid similar to a slow boiling of a liquid. From approximately 110° F. to the solvent boiling point strong bubble activity occurs with the surfaces of the liquid moving from the appearance of a slow boil to a heavily boiling liquid.

It has been discovered that the acoustical pressure in the cavitated solvent will show a marked increase in pressure as the temperature reached 104° F. This increase in acoustical pressure will occur at all temperatures up to the boiling point of the solvent. Corresponding in the cleaning of heavily contaminated articles a significant increase in soil removal occurs at 104° F. and continued increases in temperature show marked increases in cleaning up to the solvent boiling point.

It has been discovered that for heavy decontamination and cleaning purposes the temperature of the trichlorotrifluoroethane solvents should be maintained within the temperature range of 104° F. to the solvents boiling point of 117.6° F. We have also found that cleaning of normally heavily contaminated articles may be accomplished between 10 and 30 seconds.

The following example is set forth as an illustration of the invention and is not to be considered as limiting the invention.

Example I

The cleaning of a heavy contamination consisting of a baked flux on the surface of an aluminum article is accomplished by immersing said article in a trichlorotrifluoroethane solvent solution while maintaining the temperature of the solvent in the range of 104° F. to 117.6° F. and to cavitate said solvent solution for not less than 10 seconds nor more than 30 seconds by the application of sonic energy at a frequency not less than 10 kilocycles per second.

I claim:

1. The method of cleaning and removing heavy contaminants from surfaces of articles which comprises the steps of immersing said articles in a trichlorotrifluoroethane solution, heating said solution to a temperature from 104° F. to 117.6° F., and cavitating said solution

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for not less than 10 seconds nor more than 30 seconds by the application of sonic energy at a frequency above 10 kilocycles per second.

2. The method of cleaning and removing heavy contaminants from surfaces of articles which comprises the steps of immersing said articles in a trichlorotrifluoroethane solution, heating said solution to a temperature from 104° F. to 117.6° F., and cavitating said solution

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for not less than 10 seconds by the application of sonic energy at a frequency above 10 kilocycles per second.

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