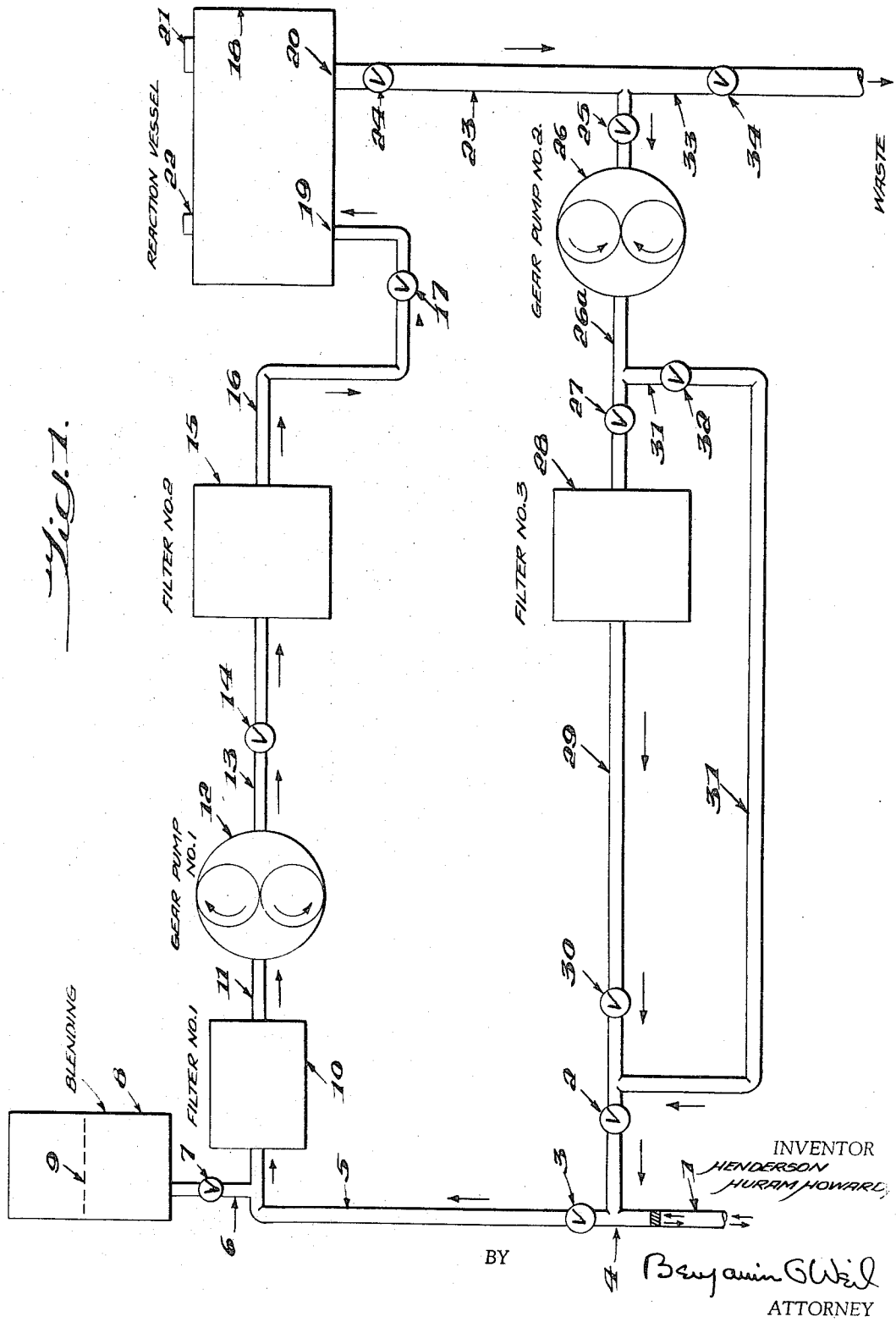
Sept. 12, 1967 H. H. HOWARD 3,341,449

METHOD AND APPARATUS FOR THE PURIFICATION OF HYDRAULIC FLUIDS

Filed May 5, 1964 3 Sheets-Sheet 1



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METHOD AND APPARATUS FOR THE PURIFICATION OF HYDRAULIC FLUIDS

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Fig. 2.

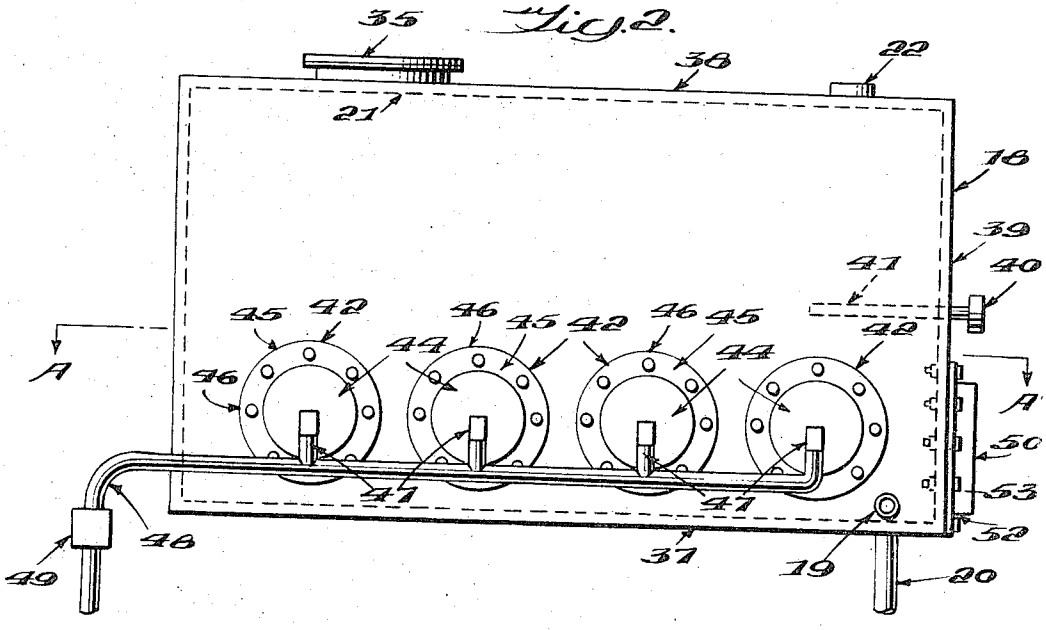
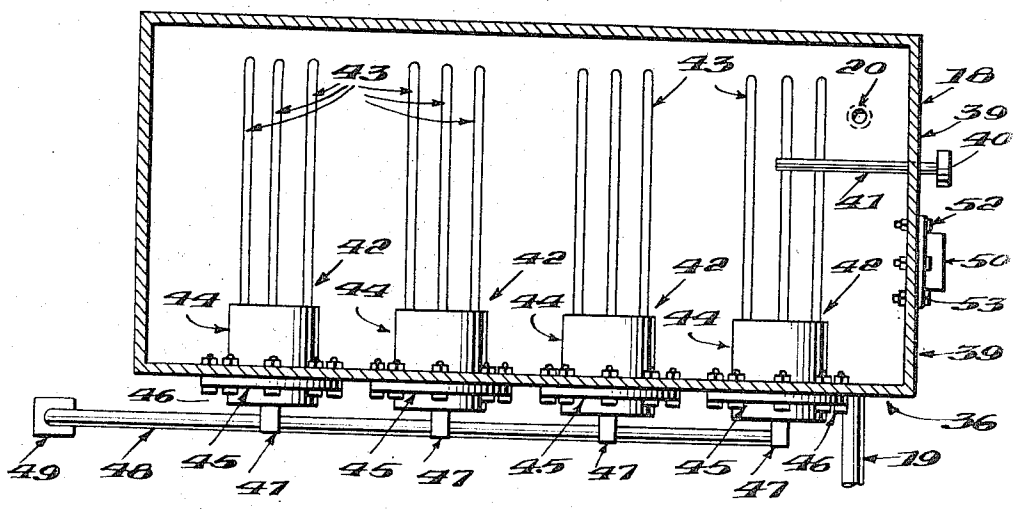


Fig. 3.



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Fig. 4.

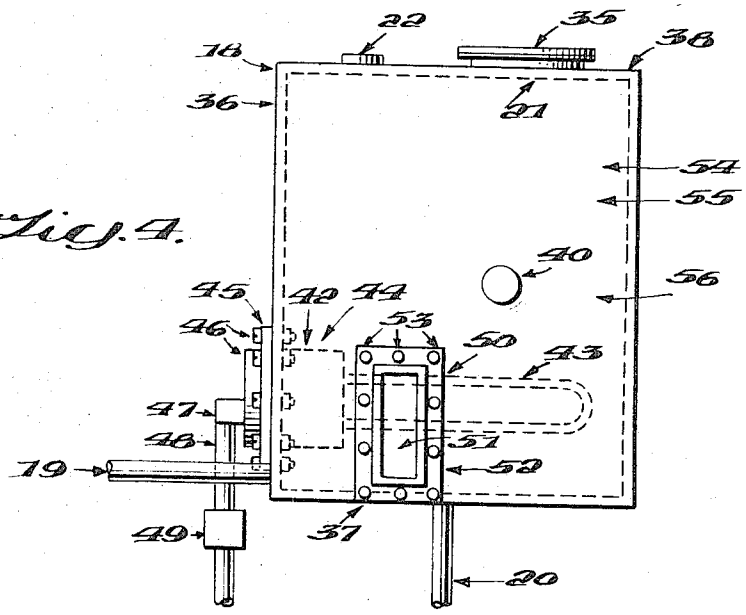


Fig. 5.

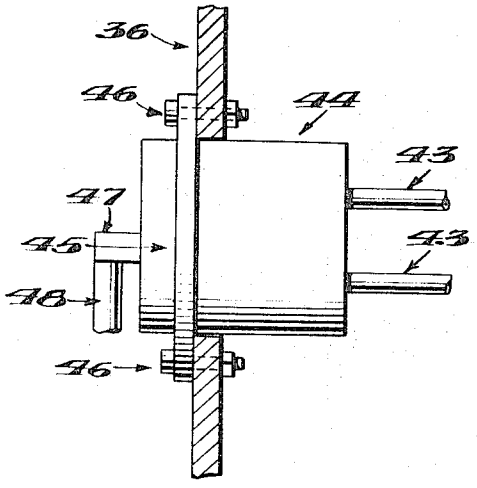
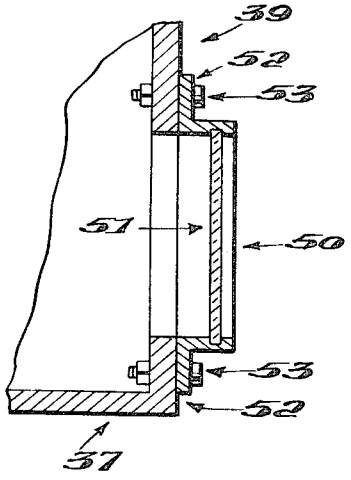


Fig. 6.



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METHOD AND APPARATUS FOR THE PURIFICATION OF HYDRAULIC FLUIDS

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13 Claims. (Cl. 210—44)

The present invention relates generally to water-glycol soultion hydraulic fluid and has particular reference to a method of and apparatus for the removal therefrom of contamination such as mineral oil hydraulic fluid, particles, sludge and other impurities.

In recent years, the fire hazards connected with the use of mineral oil hydraulic fluids has caused grave concern to the users of hydraulic systems employing such fluids. This concern was particlarly acute within the armed services who employ hydraulic systems as subsystems of larger weapons systems on an extensive scale and operate such systems in environments such as ships and missile bases where such fire hazards present risks which are not acceptable. For these reasons, an extensive program has been underway within the armed services to develop and employ fire-resistant hydraulic fluids in place of previously utilized oil fluids.

Among the fluids developed was a type termed water-glycol solution fluid. This type of fluid gives maximum protection against fire and explosion if fluid should escape from the hydraulic system in equipment in military installations, vehicles or naval vessels. For example, such fluids are used in plane launching catapult systems employed by the United States, British and other navies aboard aircraft carriers and in ground support equipment for missile systems.

Such water-glycol solution fluids are composed of a glycol which is usualy ethylene or propylene glycol, water, a water soluble polymer employed as a thickening agent, and a plurality of additives of various natures such as lubricity agents, anti-wear agents, extreme pressure agents and corrosion preventative agents. Fluids of such type are readily available on the open commercial market from multiple sources, among which are fluids sold by Union Carbide under trade names such as Ucon Hydrolube 200N and 300N, by the Celanese Chemical Corporation under the trade name of Cellugard and E. F. Houghton and Company under the trade name of Houghto-Safe 271. Such fluids if used in weapons systems by the U.S. Government must meet Military Specification MIL–H–22072, and Houghto-Safe 271 is a qualified product under this specification.

Mineral oil fluids are very widely available on the open commercial market from most oil companies and many specialty manufacturers. These fluids in many cases meet military specifications and are qualified products for use in weapons systems.

In a substantial number of equipments, defense authorities have directed the replacement of oil fluids with water-glycol fluids to achieve the advantages in the employment of the latter type fluid hereinbefore described. Besides presenting problems of system redesign due to the different physical characteristics of the two fluids serious problems of a chemical nature are present. The water-glycol fluid is not compatible with the oil fluid. Consequently, residual mineral oil fluid has adverse effects on the properties of the water-glycol fluid and reacts with the water-glycol fluid to produce sludge. Inhibiting the activity of important additives and the formation of sludge has serious adverse effects on system operation and reliability. For example, sludge causes valve seats to leak, valves and actuators to stick or to jam; orifices to close and lines to clog, thereby adversely affecting the reliability of the system. Lack of lubricity caused by deactivating the lubricity agent will promote rapid wear on all moving surfaces, inefficient operation of the system, increased load, increased power consumption and destroy precision of movement. It did not prove practicable to remove all the oil fluid prior to refilling the hydraulic system with water-glycol fluid. To do so would require disassembling and thoroughly cleaning each and every part of the system. This would have been clostly, would have deprived the Armed Forces of the use of vital equipment continuously needed for defense purposes for an indeterminate period of time, and would be practically impossible in the case of many fixed installations without structural destruction and reconstruction. As a result, contamination of the replacement water-glycol fluid by the residual oil fluid is invariably encountered.

A demand was therefore created for an apparatus and method for purification of water-glycol hydraulic fluid which had been contaminated by oil fluid.

In addition, hydraulic fluids become contaminated in service use. Such contamination may come from airborne particles, metal particles resulting from component fabrication and wear, sand from castings, oxide scale from fabricating methods, process residues, fibers from filters, elastomers used in seals, aditives which decompose with use and chemical action within the systems. Of particular significance are contamination caused by oxidization and by particles. Numerious oxidization contaminants are possible, including the formation of new compounds which polymerize. They can be classed in two generic groups. These groups are (a) soluble oxidization contaminants and (b) insoluble oxidization contaminants. Soluble oxidization products thicken the fluid and make it sluggish in service. The insoluble oxidization products form sludge with serious disadvantages heretofore described. Particle contamination is at least equally serious in its adverse affects on system performance. Particles cause valves to leak, components to stick or jam, clogging of orifices, internal erosion of system components, and destruction of precision of movement. Particles also cause the formation of foam, sludges, deposits and rust. Such particles are of very small size and are measured in microns, the unit of particle size. One micron is one millionth of a meter or approximately a 39 millionth of an inch. Thus, 25 microns is approximately .001 inch. Just what particle size a system will tolerate varies wtih system design criteria and may in practice range from 5 to 200 microns. From this, it can be seen that these particles are of very minute size and are largely present in the fluid in a state of colloidal suspension. Despite their small size, such particles adversely affect system reliability and accuracy.

For these reasons a demand has also arisen for a method of and apparatus for the removal of general service contamination from hydraulic fluids of the water glycol type.

Separation of suspended contaminants from suspending fluids is conventionally affected by several well-known processes. Such processes are air or gas flotation, settling, centrifuging and filtration.

Air flotation involves the aeration of fluid under treatment which is undesirable in the case of hydraulic fluids as it would affect accelerated oxidization of the fluid with the deleterious results hereinbefore described. The introduction of another gas into the fluid is undesirable as it likewise would be expected to either react with the fluid under treatment to produce chemical changes therein thereby changing its properties, destroying its conformity to required specifications or require expensive equipment for the containment and recapture of the gas utilized.

Settlement is not considered desirable for different reasons. It is the least effective of all methods of separation owing to the slow settling rate of the contaminants. Thus long retention of the fluid is required. This requires either

leaving the system in an inoperative condition due to withdrawal of the fluid which is unacceptable in the case of defense systems required to be in a state of readiness or replacing the withdrawn fluid with fresh fluid. Such a process requires the construction and use of settling tanks and other fluid handling equipment occupying space which is not always available in defense installations. It also would add additional weight which might not be desirable in the case of mobile systems. Such increases in structure and in handling add to the cost of both installation and operation of the system in which the fluid is used.

Centrifuging is not practical in the case of water-glycol fluids as it separates the glycol from the water, thereby thoroughly breaking down the fluid. In addition, this process requires the use of expensive equipment and the high maintenance costs associated with high speed machinery.

Filtering is likewise impractical as colloidally suspended substances do not lend themselves to mechanical filtration processes. "Non-active" mechanical filters are required to be used with water-glycol fluids as substances such as activated earth will remove additives from the fluid, especially anti-corrosive additives.

Because of the ineffectiveness or undesirability of such known processes when used to purify hydraulic fluids in general, it had become standard practice to dispose of hydraulic fluid after it had been contaminated by usage to an extent that mechanical filtration was no longer effective and to replace such fluid with new fluid. This solution to the problem of fluid contamination by disposal of contaminated fluid as waste was economically tolerable in the era of oil fluids which are relatively cheap. However, the advent of synthetic fluids such as glycol-water fluids which cost many times as much as oil fluids caused the development of reluctance to accept the past procedure of disposal of used fluid and the creation of a demand for a process to purify the fluid for reuse. This demand became a requirement when fire resistant water-glycol fluid was specified to be substituted in equipment previously employing oil fluid and the problem of residual contamination of the water-glycol fluid required a solution.

Therefore, it is the general object of the invention to provide an apparatus and a method for the treatment of water-glycol solution hydraulic fluids to remove contamination therefrom.

A primary object of the invention is to effect the removal of mineral oil hydraulic fluid from water-glycol solution hydraulic fluids.

Another primary object of the invention is to remove contamination in the form of suspended colloids from water-glycol solution hydraulic fluids.

Thus, an object of the invention is to provide an apparatus and a process for the removal from water-glycol hydraulic fluids of both oil fluid contamination and contamination in the form of suspended colloids in a single reaction vessel in which the steps of removal of the different contaminants are combined.

Also, it is an object of the invention to provide a process and apparatus that will effect the removal of contamination from water-glycol solution hydraulic fluids without causing the water-glycol fluid to separate, to degradate or impairing the effect of any constituent thereof, thus leaving the water-glycol fluid physically and chemically unchanged.

It is a further object of the invention to provide a process for the removal of contamination from water-glycol hydraulic fluids in which no added chemical agents are utilized to effect the purification of the fluid.

It is another object of the invention to provide a process for the removal of contamination from a water-glycol hydraulic fluid in which no matter of any nature or in any form is added to the mixture being treated in order to effect the separation of such contaminants from the water-glycol fluid.

It is still another object of the invention to provide a system and a process for the removal of contamination from water-glycol hydraulic fluids which will accomplish this result rapidly.

It is yet another object of the invention to provide a process for the removal of contamination from water-glycol hydraulic fluids which does not require the use of expensive and massive equipment or structures or the use of continual expensive maintenance labor.

Other objects will become apparent upon consideration of the detailed description and the claims that follow.

According to the invention, the above objects are attained by providing a process and apparatus in which water-glycol solution hydraulic fluid contaminated by mineral oil hydraulic fluid and by other contaminants is filtered under positive pressure to remove suspended particles in an ordinary state of suspension and other filterable contaminants, then transferring the fluid to a reaction vessel wherein, controlled heat is applied to the mixed fluid which causes an internal reaction resulting in zonal separation of the oil fluid, the other contaminants and the water-glycol hydraulic fluid into three distinct strata, with the water-glycol fluid stratum being lowest, removal of the water-glycol fluid from the reaction vessel by inverted decantation and either optionally passing the purified through a filter under positive pressure to remove residual contamination or returning the fluid directly to its reservoir.

The invention will now be described in detail in connection with the accompanying drawings in which:

FIGURE 1 is a flowsheet of the process utilizing conventional apparatus elements suitable for its performance, except for the reaction vessel.

FIGURE 2 is a front view of an embodiment of a reaction vessel employed in the invention.

FIGURE 3 is a side view of FIGURE 2.

FIGURE 4 is a sectional view of FIGURE 2 taken along the line A—A of FIGURE 2.

FIGURE 5 is an enlarged fragmentary view showing the details of the attachment of the heater illustrated in FIGURES 2 to 4 to the wall of the reaction vessel.

FIGURE 6 is an enlarged fragmentary view showing the details of the sight gauge or visual inspection device provided on the wall of the reaction vessel.

Referring first to FIGURE 1, **1** represents a hose that is connected to a reservoir for water-glycol solution hydraulic fluid in the apparatus in which the fluid is used and serves as an intake and return line for the fluid. In the intake cycle, the fluid is drawn through pipe T-fitting **4** which connects hose **1** with valves **2** and **3**, valve **2** being closed and valve **3** being open during the intake cycle. The fluid then passes through valve **3** and pipe line **5** to filter **10**. Intermediate valve **3** and filter **10**, pipe line **5** is joined to pipe line **6**, running to a reservoir **8** containing a mineral oil hydraulic fluid **9**. Valve **7** located in pipe line **6** is a metering valve serving to control the rate of flow of oil fluid **9**, when added to a water-glycol fluid flowing through pipe line **5**.

Filter **10** is a standard commercial filter selected from a wide variety of in-line filter of the non-active type. This filter is designed to remove foreign matter present in the fluid in an ordinary suspension.

The fluid leaves filter **10** through pipe line **11** connecting filter **10** to the suction side of gear pump **12**. The fluid is discharged from the pressure side of gear pump **12** and passes through pressure relief valve **14** to filter **15**. Pressure relief valve **13** is adjusted to keep a constant positive pressure on filter **15** to minimize clogging of filter **15**.

The maintenance of a constant positive pressure on filter **15** is an important feature of the invention as such constant positive pressure has been found to be a solution to the problem of clogged filters.

Filter **15** is a standard commercial mechanical filter of the non-active type. As previously stated herein, non-active filters should be used with water-glycol hydraulic fluids as activated filters will remove the additives from

fluids of this type. Filter 15, being the second filter, should be a filter capable of removing suspended particles of a smaller size than those removed by filter 10.

Pipe line 16 connects filter 15 and the reaction vessel 18 and is delivered to inlet point 19. Valve 17 is located in line 16 intermediate filter 15 and reaction vessel 18. Valve 17 is open during the intake cycle. Reaction vessel 18 is provided with an outlet 20 located in the bottom thereof to which is connected outlet pipe 23 having located therein outlet valve 24, which is closed during the intake and reaction cycles. The reaction vessel 18 is also provided with a clean-out opening 22 kept covered during the operating cycle and vent means 22 venting vessel 18 to the atmosphere. The reaction vessel 18 may be of varied shapes and capacities, but is preferably rectangular in configuration and it is fabricated from a material compatible with the fluid being treated and having structural capacity to support and contain the weight thereof.

After the batch of fluid being treated is pumped into reaction vessel 18, valve 17 is closed.

The fluid contained in reaction vessel 18 is then heated and an internal reaction takes place, as hereafter described in detail, causing the fluid mixture to separate in three strata, with the purified water-glycol fluid being the bottom layer. The purified water-glycol fluid is then withdrawn from vessel 18 by inverted decantation through outlet 20 located in the bottom of vessel 18, and then through pipe line 23 when valve 24 is opened. When observation of the top level of the water-glycol fluid through sight gauge 50 indicates that substantially all of the purified water-glycol fluid has been withdrawn, valve 23 is closed, leaving the residue in vessel 18.

The purified water-glycol fluid passes through discharge pipe line 23 to the suction side of gear pump 26. Waste pipe 34 is connected to discharge pipe 23 downstream from valve 24. Valve 33 is located in pipe line 34 between its junction with line 23 and its terminus, and is closed during the discharge cycle.

The fluid is then discharged from the pressure side of pump 26 and returned to its source by one of two optional routes. The first route is through filter 28 and then return. The second route is a direct route via filter by-pass line 31. An additional stage of filtration is not always required after the fluid is purified in the reaction vessel and a by-pass route is therefor provided. When the filter route is selected, valves 27 and 30 are opened, and valve 32 in by-pass line 31 is closed. Valve 2 is always open during the discharge cycle and valve 3 is always closed, regardless of which route is chosen. Fluid passes from pump 26 through line 26*a* to filter 28, being delivered to filter 28 under positive pressure. The fluid passes through filter 28 through discharge line 29 through open valves 30 and 2, through pipe T 4 into hose 1 from which it is discharged into the reservoir from which it had been extracted. If the by-pass route is selected, valves 27 and 30 are closed and valve 32 is open. The fluid passes from pump 26, through line 26*a* to the junction of pipe lines 26*a* and 31 located upstream of valve 27, then through line 31 to its junction with line 29, through valve 2 and T 4 to hose 1 from whence the fluid is discharged.

As an alternative arrangement, one pump may be utilized for the purpose of both intake and discharge through the use of readily apparent hydraulic circuitry.

After the purified water-glycol fluid is returned to the apparatus in which it is used, disposition is made of the residue remaining in reaction vessel as waste. Valve 25 is closed and valves 33 and 24 opened, thereby connecting outlet 20 with waste pipe 34, via line 23. The liquid residual content of vessel 18 flows out of waste pipe 34. The remaining coagulants are flushed out of vessel 18, and are discharged as waste from waste pipe 34. Clean-out hole 21 is opened and access is gained to the interior of vessel 18 to scrub and clean it for reuse.

In the foregoing description, all valves to which reference is made are cut-off valves, except valve 7.

A reaction vessel for use in the system and process of this invention is illustrated in detail in FIGURES 2 to 6. Reaction vessel 18 is constructed in a rectangular configuration with a bottom 37, a top 38, a front 36 and a back and sides 39. Vent means 22 is located in the top 38 to vent the interior of vessel 18 to the atmosphere, insuring that the reaction takes place under atmospheric pressure. A clean-out opening 21 is constructed in top 38 which is covered by cover plate 35. A thermometer assembly is mounted on a side 39 of the reactor vessel having a dial indicator 40 outside vessel 18 so that it may be readily observed and a temperature sensing probe 41 extending inside vessel 18 for sensing the temperature of the fluid content, said temperature gauge assembly being mounted in a location where the temperature of the contents 18 can be effectively ascertained and registered.

The level of fluid in vessel 18 is indicated by a sight gauge 50, externally mounted over an opening formed in a side 39, preferably below thermometer dial 40, adjacent to the bottom 37 of vessel 18. As more particularly shown in FIGURE 6, the sight gauge 50 is constructed of a transparent visual inspection plate 51, preferably made of glass, mounted in an annular flange 52, flange 52 being in turn bolted by flange bolts 53 to side 39 of vessel 18. As this assembly must be free from fluid leaks, commercially available sealants and gaskets may be employed in well known manners to achieve this result. The purpose of this sight-gauge 30 is to observe the interface between the stratum of purified water-glycol fluid 56 and the stratum 55 lying directly above it when purified fluid is being discharged from vessel 18. The descent of the interface is observed and when substantially all of the purified fluid is discharged as indicated by the interface closely approaching the bottom 37 of vessel 18, valve 24 is closed to prevent the separated contaminants from being discharged.

A plurality of immersion heaters 42 extending from side wall to side wall in equally spaced relationship along a level horizontal plane are mounted on the front wall 36 of vessel 18 in the lower portion of vessel 18 at a height just above the bottom 37. These heating units employ a plurality of tubular elements 43, formed in a hair pin shape, joined to a junction box 44 having an annular mounting flange 45 formed around the periphery thereof. The heating elements 43 and a portion of junction box 44 are inserted through holes formed in front wall 36 of reaction vessel 18 and bolted to the exterior of wall 18 by flange bolts 46, the flange joint being sealed to prevent leakage of fuel by any of numerous well known methods. The external portion of junction box 44 acts as a terminal box and has mounted thereon an electrical cable connector 47 to which cable 48 is connected. Cable 48 is connected at its other end to an appropriate source of electric energy. Switch 49 is connected between the source of electric energy and the connection of cable 48 to heaters 42 in order to control the electrical input to heaters 42, thereby effecting control over the thermal output of heaters 42. Tubular heating elements 43 are sheathed with a material inert to the action with the fluid being heated, such as copper, and junction box 44 is likewise made from an inert material. Electric immersion heaters of this type are generally available on the open commercial market, being sold by the General Electric Company under the trade name "Cal-rod" and by the Edwin L. Wiegand Company under the trade name "Chromalux." A three element Chromalux heater is depicted herein for illustrative purposes. It should be understood, however, that the use of electric heaters is purely illustrative and the fluid within vessel 18 may be heated by many other methods.

Vessel 18 is provided with an outlet 20 formed in its bottom 37 and with an inlet 19 formed in a side 39. Inlet 19 is located to one side of the line of heaters 42

at a level above the bottom of vessel 18, but adjacent thereto, preferably at a level just below the lower leg of heating element 43.

The operation of the reaction vessel 18 and the practice of the process of this invention will be readily understood from the description that follows.

Water-glycol solution hydraulic fluid contaminated by mineral oil hydraulic fluid and suspended substances is introduced into vessel 18. When vessel 18 is charged by the full quantity of fluid which it is desired to treat, valve 17 is closed and the fluid is ready for treatment. Switch 49 is closed so that electrical energy is transmitted to the heaters 42 causing heat energy to be emitted by heating elements 43.

The fluid is then heated to operating temperature. It must be heated sufficiently for the desired reaction to take place and it must not be heated beyond a temperature where any of its constituents separate from the water-glycol fluid or it otherwise degenerates or the flash point of the oil fluid is reached. This has been found to be a temperature range of from 90° F. to 200° F. Ordinarily, this temperature will be about 160° F. for most effective operation and the fluid mixture is heated to a temperature within a range of 155° F. to 165° F. The term "separation point" is used herein to denote the foregoing reference to the temperature at or above which temperature constituents of a water-glycol fluid tend to separate from each other. This critical temperature is also known in the art as the "separation temperature."

When the fluid reaches the operating temperature desired, electric current to heating elements 42 is cut off by operation of switch 49, thereby de-energizing heating elements 42 so as to end their production of heat. No further thermal energy is imparted to the fluid under treatment.

When the temperature of the fluid mixture under treatment is brought to a temperature of approximately 100° F., thermal agitation is visible within the fluid at a lower level within vessel 18 where the fluid is in relatively close contact with heater elements 43, which level is referred to herein as the heat exchange zone. As the fluid temperature is increased by heating to approximately 120°, gas bubbles commence to form in a level above the heat exchange zone, which level is referred to herein as the gasification zone. These bubbles of gas rise towards the surface of the fluid being treated. As heat is further applied to the fluid mixture, contaminating matter colloidally suspended in the fluid commences to coagulate to form flocs, which coagulation takes place at a level above the gasification zone, but well beneath the surface of the fluid. Flocculation continues to form a spongy agglomerate in which rising gas bubbles are entrapped. Also, entrapped within the agglomerate is non-colloidal matter in ordinary suspension within the fluid, such as particles. This spongy agglomerate acquires positive buoyancy due to the entrapment of gas bubbles therein and rises to the surface of the fluid to form a well-defined surface layer or upper stratum 54. As the spongy agglomerate rises, it entraps further matter in ordinary suspension in the fluid and removes it therefrom, acting in effect as a dynamic filtering means.

The oil hydraulic fluid separates from the water-glycol hydraulic fluid. The purified water-glycol fluid settles to the bottom of the vessel 18 forming a clearly defined lower stratum 56. The oil fluid rises above the water-glycol fluid to form a clearly defined layer or intermediate stratum 55 between the lower stratum of water-glycol fluid 56 and the upper stratum of floating agglomerate 54. The interface between a water-glycol fluid and oil fluid may be more readily defined by the addition of dye substances of contrasting colors which have selective affinity for these fluids, such dyes being well known in the art.

The time required for the purification of the water-glycol fluid varies with the quantity of fluid being treated and the temperature to which it is raised. For example, a volume of 250 gallons of contaminated water-glycol fluid will require approximately 40 minutes of treatment time when heated to 200° F. and 2 hours when heated to 90° F.

The exact nature of the reaction which takes place in fluid in the reaction vessel in response to the action of heat is not known. It is not possible to state positively whether the reaction described herein is physical or chemical in nature or whether it is a combination thereof.

The origin of the gas forming the gas bubbles has not been exactly determined. It may originate from several sources. It may come from air colloidally dispersed or dissolved in the fluid under treatment. It may originate from a change of physical state of one or more substances in the fluid due to the application heat which effected a change to a gaseous state. It may also originate from a thermally produced chemical reaction between substances present in the fluid. It is postulated, however, that, since the gas particles are invisible until the fluid is heated, only thermal agitation is visible in the heat exchange zone and gas bubbles become visible in a zone above the heat exchange zone, the gas is originally present in the form of an organosol or hydrosol. It is further postulated that heat stimulates the Brownian movement of the gas particles, causing small bubbles to coalesce into larger bubbles when they come into contact with each other.

Likewise, the manner in which colloidal dispersion is coagulated at a level above the gasification zone has not been precisely determined. It may be the result of thermal coagulation or it may result from the production of a coagulating agent produced from a heat induced reaction between substances present in the fluid under treatment. It is postulated to probably be the result of both, as it is known, as hereinbefore stated, that the oil fluid and the water-glycol fluid are not compatible and react together to form sludge.

It should be clearly understood, however, that the separation of suspended matter by the coagulation of a spongy agglomerate in which gas is entrapped causing the agglomerate to rise to the surface of the fluid under treatment is not a flotation process in the sense that such a process is defined in the art of chemical engineering. In the flotation process, separation is achieved by the action of surface tensions between an aerophobe liquid and an aerophile substance which is unwetted. The unwetted substances attach themselves to foam bubbles and are carried by these bubbles to the surface in the form of a frothy suspension. The present invention depends on an entirely different principle. It depends on the coagulation of suspended matter in a zone above the production of gas bubbles which bubbles are entrapped in the coagulated material to form a cellular agglomerate having positive buoyancy.

For a further explanation of this invention, a typical example illustrating the separation of a water-glycol hydraulic fluid from contamination by residual oil hydraulic fluid and by matter of other nature is listed below:

EXAMPLE

A quantity of 250 gallons of water-glycol solution was withdrawn from a defense weapon system for purification. The water-glycol fluid was a fluid which met Military Specification MIL–H–22072 and was sold to the Government by E. F. Houghton & Co. under the tradename Houghto-Safe 271. It was contaminated by residual mineral oil hydraulic fluid remaining in the system after the original mineral oil fluid had been replaced with water-glycol fluid, which oil fluid was a fluid in accordance with Military Specification MIL–H–6083B, and with other contaminants. It was passed through a conventional in-line filter for preliminary filtration of relatively coarse suspended particles, and then pumped into a second filter under a positive pressure of approximately 20 p.s.i. After this filtration step, the fluid was led into a reaction vessel

of the type heretofore described. The fluid was heated to a temperature within the range of 155° F. and 165° F., during which heating process separation of the contamination from the fluid commenced. Heating was discontinued when operating temperature was reached. After 55 minutes, separation was complete and approximately 230 gallons of purified water-glycol fluid was removed by inverted decantation. This fluid was then passed through a second filter and then returned to the weapons system from which it had been withdrawn.

A sample of the purified fluid was tested. "Slight traces" of oil fluid were reported, meaning that the percentage of contamination was below that which could be measured as a finite quantity, namely, less than ½ of 1%. The particle contamination requirement of less than 20 microns was likewise met.

In addition, the process and apparatus of the invention may be used to purify water-glycol hydraulic fluids which have not been contaminated by oil hydraulic fluid. This is accomplished by the addition of a metered quantity of oil fluid to the water-glycol fluid prior to its treatment in the reaction vessel **18**. This is accomplished by adjusting blending valve **7** to permit oil fluid **9** to flow from tank **8** through pipe line **6** into pipe line **11** during the time when the fluid to be treated is being drawn through pipe line **11**. Such additive oil fluid is added at a constant volumetric rate in a range of between 5% to 10% of the water-glycol fluid by volume, and preferable at a rate of about 5% by volume. This addition of this quantity of oil fluid will permit the removal of suspended colloidal contaminants as hereinbefore described, which result will not be achieved if water-glycol fluid is heated alone. While the embodiment of the apparatus illustrated and described herein shows introduction of the additive fluid upstream of filter **10**, it may be introduced in the fluid flow at any point between filter **10** and pump **12** with equally benefiicial results.

It will thus be apparent that the process and apparatus of the present invention possess important advantages over the prior art.

The outstanding advantage of the new apparatus and process resides in the provision of a method of and apparatus for the removal of contamination from water-glycol solution hydraulic fluids.

One of the most important applications of the new apparatus and process is to provide for the effective substitution of water-glycol fire resistant fluids in defense weapon systems where the use of the flammable mineral on fluids known to the prior art is undesirable without fear of crippling contamination by residual oil fluid which would render the weapon system unreliable and inaccurate.

One of the more specific advantages of the new apparatus and method is the provision of a simple and inexpensive method and apparatus which will separate both oil fluid contamination and colloidal contamination from water-glycol solution hydraulic fluids and which leaves the water-glycol fluid physically and chemically unchanged so that it may be reused in the apparatus in which it had been previously used.

A further specific advantage is the speed with which the water-glycol fluid can be processed, which is an important advantage in the case of weapon systems vital to our national defense where extended periods of inoperability cannot be tolerated.

Yet a further advantage of the present invention is in the provision of a system which is inexpensive to construct and maintain since its construction does not require the use of expensive and massive construction such as settling tanks nor the use of high speed machinery such as centrifugal separators.

It should be understood that additional embodiments of the invention herein illustrated and described will occur to others and therefore it is intended that the specific embodiment herein illustrated and described is representative only. Accordingly, it is intended that the scope of the invention be limited only by the appended claims and not by the embodiment described hereinbefore.

I claim:

1. A method of separating a water-glycol solution hydraulic fluid from contamination by a mineral oil hydraulic fluid mixed therewith and by other contaminants colloidally suspended therein comprising heating said fluid mixture in a vessel to a temperature within the temperature range of 90° F. to a temperature in excess of 90° F. but not above the separation point of said water-glycol fluid thereby producing gasification, coagulation, and separation of said fluid mixture causing said colloidally suspended contaminants to coagulate and to entrap gas bubbles therein to produce a spongy floatable agglomerate rising to the surface of said fluid to form a surface stratum thereon and causing said water-glycol fluid and said oil fluid to separate from each other, ceasing to heat said fluids when said temperature is reached, permitting said separated oil fluid to rise to a level above said water-glycol fluid to form an intermediate stratum, permitting said water-glycol fluid to settle beneath said oil fluid to form a bottom stratum, and withdrawing said purified water-glycol fluid by inverted decantation.

2. A method as described in claim **1** in which the said fluid mixture is heated to a temperature within the range of 90° F. to 200° F.

3. A method as described in claim **1** in which said mixture is heated to a temperature within the range of 155° F. to 165° F.

4. A method of removing contamination from a water-glycol solution hydraulic fluid contaminated by mineral oil hydraulic fluid mixed therewith and by other contaminants colloidally suspended therein comprising introducing said mixture into the bottom of a reaction vessel, applying heat to said fluid mixture in a zone approximately adjacent to the bottom of said vessel, heating said fluid to a temperature where the colloidally suspended contaminants coagulate into a floc suspended below the surface of said fluid, heating said liquid further until it gasifies at a level below the coagulation zone but above the heat exchange zone forming gas bubbles that rise to become entrapped in said floc so as to change its specific gravity to cause the flotation thereof and until said oil fluid separates from said water-glycol fluid, ceasing the application of heat when said fluids reach a temperature within the temperature range of 90° F. to a temperature in excess of 90° F. but below the separation temperature of said water-glycol fluid, permitting said separated oil fluid to rise above said water-glycol fluid, permitting said water-glycol fluid to settle to the bottom of said vessel and withdrawing said purified water glycol fluid by inverted decantation.

5. A method as described in claim **4** in which the application of heat is ceased when the fluids reach a temperature in the range of 90° F. to 200° F.

6. A method as described in claim **4** in which the application of heat is ceased when the fluids reach a temperature in the range of 155° F. to 165° F.

7. A method of removing contamination from a water-glycol solution hydraulic fluid contaminated by mineral oil hydraulic fluid mixed therewith and by other contaminants contained therein comprising withdrawing said fluid mixture from the apparatus in which it is used, forcing said fluid through a filter under a constant positive pressure to remove relatively large particle contamination not colloidally suspended in said fluid, delivering said filtered fluid to a reaction vessel, applying heat to said fluid in a zone approximately adjacent to the bottom of said vessel, heating said fluid to a point where gas bubbles are formed in said fluid in a zone directly above the heat exchange zone, continuing to heat said fluid until colloidally suspended contaminants coagulate in a zone in which said bubbles are present entrapping said gas bubbles therein to form a spongy agglomerate which rises to the surface

of said fluids and until said water-glycol fluid and said oil fluid separate, ceasing the application of heat to said fluids when the temperature thereon reaches a range withing 90° F. and 200° F. and permitting said separated oil fluid to rise above said water-glycol fluid to form a separate and distinct stratum of oil fluid above a lower stratum of water-glycol fluid, removing said purified water-glycol fluid from said vessel by inverted decantation, and returning the said purified water-glycol fluid back into the apparatus in which it is used.

8. A method as described in claim **7** which comprises cessation of application of heat when the fluids reach a temperature within the range of 155° F. to 165° F.

9. A method as described in claim **8** in which the positive fluid pressure applied to the filter is within a range of 15 p.s.i. to 25 p.s.i.

10. A method of purifying and cleaning water-glycol solution hydraulic fluid from contamination contained therein comprising withdrawal of the dirty fluid from the apparatus in which it is used, mixing it with an oil based hydraulic fluid in an amount of approximately 5% by volume of said water-glycol fluid, forcing said fluid mixture through a filter under a constant positive pressure to remove relatively large particle contamination not colloidally suspended therein, delivering said filtered fluid to a reaction vessel, applying heat to said fluid mixture in a zone approximately adjacent to the bottom of said vessel, heating said fluid to a point where gas bubbles are formed in said fluid in a zone directly above the heat exchange zone, continuing to heat said fluid until colloidally suspended contaminants coagulate in a zone in which bubbles are present entrapping said gas bubbles therein to form a spongy agglomerate which rises to the surface of said fluids and until said water-glycol fluid and said oil fluid separate, ceasing the application of heat to said fluids when the temperature thereof reaches a range between 155° F. and 165° F. and permitting said separated oil fluid to rise above said water-glycol fluid to form a separate and distinct stratum of oil fluid above a lower stratum of water-glycol fluid, removing said purified and cleaned water-glycol fluid from said vessel by inverted decantation, and returning said water-glycol fluid to the apparatus in which said fluid is used.

11. A system for the removal of contamination from a water-glycol solution hydraulic fluid contaminated by mineral oil hydraulic fluid and other contaminants mixed therein comprising a conduit for withdrawing said fluid from the apparatus in which said fluid is used, a positive displacement pump having its suction side connected to said conduit, filter means connected to the pressure side of said pump, said filter serving to remove relatively large particle contamination not colloidally suspended in said fluid and said positive pressure minimizing filter clogging, a reaction chamber connected to said filter means having means therein to heat said fluid to produce the separation of said mixture into a distinct layer of previously suspended contaminants, a distinct layer of oil fluid and a distinct layer of water-glycol fluid, said water-glycol fluid being the lowest of said three layers, means to withdraw said water-glycol fluid through inverted decantation, and a conduit for effecting the return of said purified water-glycol fluid to the apparatus in which said fluid is used.

12. The system as described in claim **11** in which means is included to provide a positive filtration pressure in the range of 15 p.s.i. to 25 p.s.i.

13. A system for the removal of contamination from a water-glycol solution hydraulic fluid comprising a conduit for withdrawing said fluid from the apparatus in which it is used, a containing vessel for mineral oil hydraulic fluid, valve means connected with said vessel and said conduit for adding a metered volume of said oil fluid at a controlled rate to the stream of said water-glycol fluid flowing with said conduit, a positive displacement pump having its suction side connected to said conduit, filter means connected to the pressure side of said pump, said filter serving to remove relatively large particle contamination not colloidally suspended in said fluid mixture and said positive pressure minimizing filter clogging, a reaction chamber connected to said filter means having means therein to heat said fluid mixture to produce the separation of said mixture into a distinct layer of previously suspended contaminants, a distinct layer of oil fluid, and a distinct layer of water-glycol fluid, said water-glycol fluid being the lowest of said three layers, means to withdraw said water-glycol fluid through inverted decantation, and a conduit for effecting the return of said purified water-glycol fluid to the apparatus in which said fluid is used.

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