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(54) **Method for removing sludge and deposits from the interior of a heat exchanger vessel.**

(57) Method for removing sludge and deposits (32) from the interior of a heat exchanger vessel (1). The method includes the steps of filling the interior of the secondary side (5) of the heat exchanger vessel (1) with an aqueous solution of a cleaning agent formed from at least one of the group consisting of surfactants, dispersants, thixotropes and flotation agents, recirculating the aqueous solution within the secondary side (5) while simultaneously filtering it to remove sludge and deposits (32) entrained within the solution, and draining the aqueous solution from the secondary side (5) while continuously introducing a succession of pressurized pulses of gas into the solution during the filling, recirculation and draining steps in order to create shock waves in the solution which loosen and fluidize sludge and deposits (32) present within the secondary side (5).

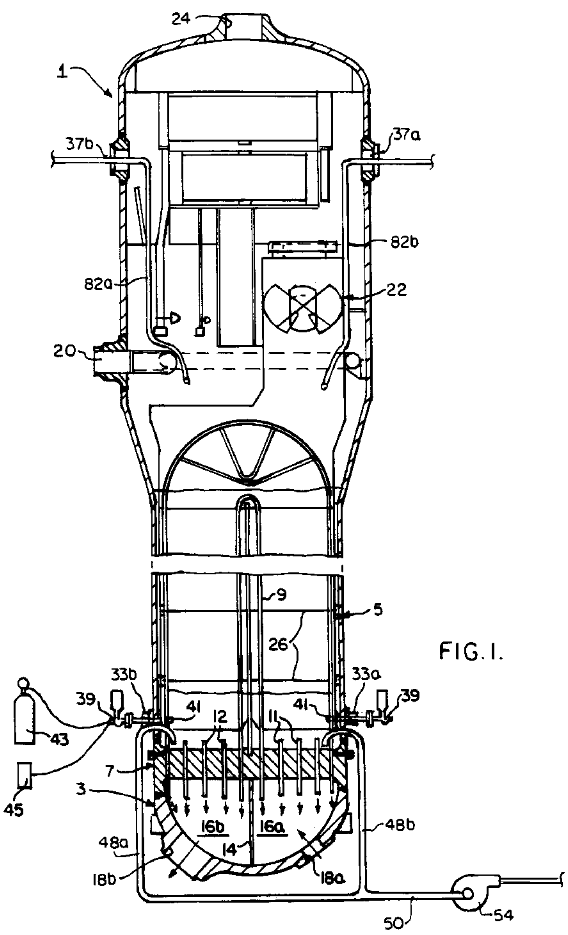

FIG. 1.

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This invention generally relates to a method for removing sludge and deposits from the interior of a heat exchanger vessel and more particularly relates to a method for removing sludge and deposits from the secondary side of a nuclear steam generator.

Both pressure pulse and chemical methods for cleaning the interior of heat exchanger vessels such as the secondary sides of nuclear steam generators are known in the prior art. However, before the purpose and operation of such cleaning methods may be understood, some basic understanding of the structure and maintenance associated with nuclear steam generators is necessary.

Nuclear steam generators generally comprise a bowl-shaped primary side through which hot, radioactive water from the reactor core is circulated, a secondary side disposed on top of the primary side into which non-radioactive water is fed, and a tubesheet which includes a number of U-shaped heat exchanger tubes disposed between the primary and secondary sides of the generator for thermally connecting but hydraulically insulating the primary and secondary sides so that heat from the radio-actively contaminated water in the primary side would be conducted to the non-radioactive water in the secondary side, thereby causing it to boil and to create non-radioactive steam.

The U-shaped heat exchanger tubes are contained within the secondary side of said steam generators. Each such heat exchanger tube in inverted, with its open ends mounted in the tubesheet and its legs and bent portion extending into the secondary side. A plurality of vertically spaced-apart support plates are provided in the secondary side for laterally supporting the legs of each heat exchanger tube. The legs of the U-shaped heat exchanger tubes extend through bores present in the support plates. Small, annular spaces are present between these heat exchanger tubes and the bores in the support plates and tubesheet through which these tubes extend. These annular spaces are known in the art as "crevice regions". Such crevice regions provide only a very limited flow path for the water that circulates within the steam generator, which in turn can cause the water entering these regions to boil completely away, thereby causing these regions to dry-out. This chronic drying-out causes impurities in the water to plate out and collect in these crevice regions. These impurities may promote the formation of deposits and cause corrosion on the exterior surfaces of the tubes. The resulting corrosion products and sludges can, over time, accumulate in the crevice to the point where they can actually dent the heat exchanger tubes. Even though the heat exchanger tubes are made from corrosion-resistant Inconel® 600, if the resulting impurities and sludges are not removed, sufficient corrosion and stress can occur in the crevice region areas of these tubes to ultimately cause them to crack unless some sort of maintenance operation is undertaken. Since a cracked heat exchanger tube can cause radioactive fluids from the primary side to contaminate the non-radioactive water in the secondary side of the generator, it is important that maintenance operations be implemented to prevent such corrosion and subsequent cracking from occurring.

Chemical cleaning methods were developed in the prior art to dissolve such sludge accumulations, and to ameliorate corrosion. In one of the most common of these methods, the nuclear steam generator is first taken out of service and completely drained of water from both the primary and the secondary sides. Next, as most of the corrosion products contained within the crevice regions are iron oxide and copper that have become tightly ensconced in the crevice regions or on the surfaces of heat exchanger tubes, chelate-containing iron removable solvents and copper removable solvents are sequentially introduced into the interior of the secondary side to dissolve and remove them. The iron removal solvents are typically circulated within the interior of the secondary side at a temperature of about, 93.3°C, while the copper removal solvents are circulated at a temperature of about 37.8°C.

While such copper and iron solvents have proven to be effective in removing iron oxide and copper from the interior of the secondary side of such generators, they may be capable of promoting new corrosion within the steam generator despite the use of an inhibitor, particularly among the carbon steel and low alloy steel components of the generator. To minimize these corrosive effects, these solvents are typically provided with low concentrations of their active chelate ingredients. Despite the use of such low concentrations, it is now believed that such chemicals may still be capable of inducing a significant amount of corrosion on the metallic components within the generator. Moreover, the use of such low concentrations protracts the time it takes for these agents to work, and often necessitates exposing the interior of the secondary side to multiple solvent baths. For example, it may be necessary to introduce and to remove an iron solvent twice within the steam generator, and to introduce and remove a copper solvent as many as six times. Such multiple solvent baths, along with the various rinse cycles which they necessitate, can cause a single chemical cleaning of a steam generator to last 120 hours or more. As a utility may loose one million dollars (U.S.) in revenues for each day of downtime of a nuclear steam generator, it can readily be appreciated that the cost of such a state-of-the-art cleaning operation is quite high, particularly when one considers that the total price of such an operation must also include the cost of the chemicals, the setting up of recirculation and heating equipment, and the disposal of the large volume of the spent iron and copper solvents and rinse solutions that are removed from the radioactive interior of the secondary side of the generator.

Pressure pulse cleaning provides a completely mechanical way to clean the interior of a steam generator. In this type of cleaning method, the generator is taken off-line, drained, and then filled with demineralized water up to the top of the bundle of heat exchanger tubes that are disposed within the secondary side. Pressurized pulses of gas are then continuously introduced into this demineralized water near the tubesheet of the generator as the generator is being filled. These pulses of gas create shock waves in the demineralized water within the secondary side which tend to loosen, dislodge and even fluidize the sludge and deposits present on the heat exchanger tubes, the support plates, the tubesheet and in the crevice regions of the secondary side. The dislodged and fluidized sludge and deposits are removed from the demineralized water by recirculating them through a filter during the pressure pulsing operation. Preferably, the pulses of pressurized gas responsible for the generation of the debris-removing shock waves are continuously introduced into the demineralized water not only during the recirculation step, but also during the time that the demineralized water is introduced into and drained from the secondary side.

Because pressure pulse cleaning induces no new, unwanted corrosion on the metallic surfaces within the secondary side of the steam generator, it represents a substantial advance in the art, and is rapidly gaining acceptance in the nuclear power industry as an alternative to chemical cleaning methods. But, while pressure pulse cleaning is capable of removing a great deal of the sludge and deposits present in many of the secondary sides of such steam generators, it is rarely effective in removing all of the tightly ensconced deposits that accumulate in the crevice regions of the generator. Applicants believe that one of the factors that limits the effectiveness of pressure pulse cleaning is that the intensity of the shock waves generated by the pulses of pressurized gas is curtailed by the limited hydraulic flow path presented by these regions. Sludge lancing is often performed on the tubesheet regions'prior to pressure pulsing to remove the large accumulations of sludge and deposits on top of the tubesheet. Sludge lancing is also performed after the pressure pulsing operation has been completed to remove loosened deposits that have fallen out of solution onto the tubesheet. Unfortunately, such sludge lancing adds to both the time and expense of the pressure pulsing cleaning operation.

Clearly, there is a need for improved cleaning method which maintains all of the advantages associated with known pressure pulse and chemical cleaning techniques, but which avoids the disadvantages associated with both. Ideally, such a cleaning method would be relatively simple and inexpensive to implement, and would be capable of effectively cleaning the interior of the secondary side of the generator in a short period of time and with the generation of a minimum amount of liquid radioactive waste. It would further be desirable if the cleaning method induced no new corrosion within the generator, and obviated the need for sludge lancing.

In its broad form, the invention resides in a method for removing sludge and deposits from the interior of a heat exchanger vessel, characterized by the steps of introducing a liquid into the interior of the vessel, said liquid including a cleaning agent formed from at least one of the group consisting of surfactants, dispersants, thixotropes and flotation agents to promote fluidization and to inhibit re-settling of said sludge and deposits, and introducing a succession of pressurized pulses of gas into the liquid to generate shock waves that loosen and remove said sludge and deposits from said heat exchanger interior.

In the preferred method of the invention, the aqueous solution is formed from a combination of surfactant to promote penetration of the solution into the crevice regions within the secondary side, and a dispersant to promote the fluidization of the loosened sludge and deposits. The surfactant is preferably formed from at least one of the group consisting of Immunol 236 (a combination of alkylphenoy ethoxylate, ethylene oxide, and fatty alkanol amide), Surfynol 104 (tertiary acetylenic diol), Triton-X100 (octyphenorypoly ethoxyethanal) and Hamposyl-L (lauroyl sarcosine), while the dispersant is formed from at least one of the group consisting of polyacrylates, acrylic polymers, polypropyloxy quarternium ammonium acetate, imidazoline acetate and aminedodecylbenzine sulfonate. To minimize the chance that the aqueous solution will induce any unwanted corrosion within the interior of the steam generator, the concentration of the cleaning agents within the water component of the solution is preferably maintained to between about 0.1 and 0.5 weight percent.

In the preferred method of the invention, the secondary side of the steam generator is filled with the aqueous solution of cleaning agent up to the top of the bundle of heat exchanger tubes which is contains. The aqueous solution is then recirculated through a filtration system to remove sludge and deposits that have been dislodged and loosened by the shock wave generated by the pressurized pulses of gas that are continually introduced into the solution. The solution is then drained out of the interior of the secondary side of the generator.

The introduction of the pressurized pulses of gas into the solution may commence shortly after the solution is first introduced into the interior of the secondary side, and may further continue throughout the draining step. The pressure of the gas used to create the pulses is increased from about 2.76 to 6.21 MPa as the secondary side is filled with the solution, and maintained at between about 5.52 and 6.21 MPa during the recirculation step, and then is reduced from about 6.21 to 2.76 MPa when the solution is drained from the interior of the secondary side. Preferably, the pressurized pulses are generated at a frequency of between about 10 and 60 seconds.

To obviate the need for sludge lancing after the secondary side has been drained, the draining step of the method may be halted when the level of the solution within the secondary side is about the same as the lowermost support plate, and the recirculation of the solution may be recommenced through the filter means while pulses of pressurized gas continue to be discharged into the solution until the density of the sludge and deposits entrained in the solution reaches a selected low level, whereupon the draining step is finally completed. During recirculation, the solution is pumped at a flow rate of preferably over at least 94.64 litres per minute in order to help maintain the entrainment of sludge and deposits within the solution as it flows into the filter means.

The chemically enhanced pressure pulse cleaning method of the invention is more effective than pressure pulse cleaning methods alone and about as effective as chemical cleaning methods without inducing the unwanted corrosion associated with the cleaning agents used in prior art chemical cleaning methods. It further obviates the need for the post cleaning sludge lancing associated with prior art pressure pulse cleaning methods, and is faster and easier to implement than prior art chemical cleaning techniques since there is no need to heat the cleaning solutions, and further generates less in the way of radioactive liquid wastes since multiple baths of cleaning agent are unnecessary.

Figure 1 is a cross-sectional side view of the type of nuclear steam generator that the enhanced pressure pulse cleaning method of the invention may be applied to;

Figure 2A is a cross-sectional side view of one of the heat exchanger tubes used in the steam generator illustrated in Figure 1, showing how this tube extends through a bore in a support plate, and how sludge and corrosion products accumulate in the annular space between the tube and the bore in the support plate;

Figure 2B is a plan view of the heat exchanger tube illustrated in Figure 2A along the line 2B-B, and

Figure 3 is a schematic diagram of the recirculation system used to implement the method of the invention.

With reference now to Figure 1, the enhanced pressure pulse cleaning method of the invention is particularly useful in cleaning the interior of a nuclear steam generator 1. Such generators 1 include a bowl-shaped primary side 3 at their bottom portions, and a cylindrically shaped secondary side 5 in their middle portions which are hydraulically separated by means of a tubesheet 7. Heat is conducted from the primary side 3 to the secondary side 5 through a number of heat exchanger tubes 9, each of which is shaped like an inverted U. Each tube 9 includes an inlet end 11 and an outlet end 12 which are mounted in bores in the tubesheet 7. A divider plate 14 divides the bowl-shaped primary side 3 into two quadrispherical chambers known as channel heads 16a,b in the art. The inlet ends 11 of all of the heat exchanger tubes 9 communicate with the right-hand channel head 16a, while the outlet ends 12 of all of these tubes 9 communicate with the left-hand channel head 16b. Manways 18a,b afford access to the channel heads 16a,b respectively. In the secondary side, a feed water inlet 20 is provided for admitting non-radioactive and purified water over the bundle of U-shaped heat exchanger tubes 9 so as to immerse the same. Disposed above these tubes 9 is a steam drying assembly 22 which captures and returns water vapor entrained in the steam created by the generator 1 back into the feed water that immerses the heat exchanger tubes 9. An outlet port 24 at the top of the steam generator 1 conducts dry steam to the blades of a turbine that is connected to an electrical generator (not shown). Finally, a number of vertically spaced support plates 26 are disposed along the length of the secondary side 5 of the steam generator 1 for laterally supporting the legs of the U-shaped heat exchanger tubes 9.

As is best seen in Figures 2A and 2B, each of these support plates 26 includes a plurality of bores 28 through which the heat exchanger tubes 9 extend.

In operation, hot radioactive water from the reactor core (not shown) is admitted into the channel head 16a, and from thence flows upwardly into the inlet ends 11 of each of the heat exchanger tubes 9. This hot water flows upwardly through the inlet legs of each of the tubes 9 (known as hot legs in the art), continues flowing around the bend of each of the tubes 9, and from there flows down through the outlet legs (known as cold legs) and from thence out through the outlet ends 12 of the heat exchanger tubes 9 and into the outlet channel head 16b, where it is ultimately recirculated back to the core of the reactor.

The hot, radioactive water from the primary side transfers much of its heat through the walls of the heat exchanger tubes 9 and into the non-radioactive water that surrounds these tubes 9. This causes the non-radioactive water to boil, and to create the steam which is ultimately conducted out of the outlet port 24 of the steam generator 1.

The manner in which sludge and corrosion products accumulate in the crevice regions of the steam generator 1 is best understood with reference to Figures 2A and 2B. Between the heat exchanger tubes 9 and the bores 28 in the support plates 26 is a narrow, annular space 30. This annular space 30 provides a relatively constricted flow path for the non-radioactive water that is in a constant state of circulation around these tubes 9 during the operation of the steam generator 1. The resulting limited circulation can allow water to boil out of the space faster than the surrounding ambient water can re-envelope the heat exchanger tube 9. As a result of this "dry boiling", any impurities present in the water in the secondary side are plated out onto the surfaces of this narrow annular space 30, forming sludge and deposits 32. As these sludge and deposits 32 accumulate, recirculation through the annular space 30 is further retarded, which in turn accelerates the accumulation of even more sludge and deposits 32 in this region. Ultimately, such sludge and deposits 32 can completely fill the annular space 30. Chemical analysis has shown that the primary components of the sludge and deposits 32 include magnetite (Fe_3O_4), elemental copper, and copper oxide. Such sludge and deposits can promote the occurrence of corrosion in the outer walls of the heat exchanger tubes 9 in the vicinity of the support plates 26, which in turn may cause these tubes 9 to crack, thereby contaminating the non-radioactive water of the secondary side 5 with the hot, radioactive water from the primary side 3 of the generator 1. The same destructive phenomenon can also occur in the annular spaces (not shown) between the bores in the tubesheet 7, and the outer walls of the heat exchanger tubes 9 that extend through these bores.

One of the principal purposes of the enhanced pressure pulse cleaning method of the invention is to remove such sludge and deposits 32 from crevice regions such as the annular space 30, along with the products of any corrosion which this debris might have started. To this end, the method of the invention involves the generation of pressure pulses in an aqueous solution of a surfactant, dispersant, thixotrope, and/or a flotation agent introduced into the secondary side 5 of the steam generator 1 in order to loosen, dislodge and fluidize such sludge and deposits 32.

Figures 1 and 3 illustrate the best mode of implementing the method of the invention, wherein both pressure pulse generators 33a,b and a solution recirculation system 34 are installed within the lower hand holds 35a,b and upper manways 37a,b of the nuclear steam generator 1. More specifically, a pressure generator 33a,b having a nozzle 41 for emitting a pressurized pulse of gas is detachably secured within each of the lower hand holes 35a,b. A source of pressurized gas 43, which may be a compressed bottle of nitrogen or air, is connected to each of the pressure pulse generators 33a,b, as is a pulser control unit 45 which periodically actuates the pulser generators 33a,b to discharge a volume of compressed nitrogen through the nozzle 41. In the preferred method, each of the pressure pulse generators 33a,b includes a pulser control unit 45 which periodically actuates the pulser generators 33a,b to discharge a volume of compressed nitrogen through the nozzle 41. In the preferred method, each of the pressure pulse generators 33a,b is a PAR 600 B air gun manufactured by Bolt Technology Inc. located in Norwalk, Connecticut, U.S.A., and the pulser control unit 45 is a model FC100 controller manufactured by the same corporate entity. Additionally, while the nozzles 41 are schematically illustrated as being horizontally oriented, they are more preferably canted at a 30 angle with respect to the upper surface of the tubesheet 7 so as to minimize the momentary forces that the shock waves created by the pulses of gas apply to the heat exchanger tubes 9 nearest the open ends of the nozzle 41. Preferably, the firing cylinder of each of the pressure pulse generators 33a,b contains between 1229 and 1638 cubic cms. of pressurized gas.

With reference now to both Figures 1 and 3, the recirculation system 34 that is preferably used to implement the method of the invention includes a pair of suction conduits 48a,b which extend through the hand holes 35a,b, respectively. A mounting plate (not shown) allows both the nozzles 41 of the pressure pulse generators 33a,b and the suction conduits 48a,b to be mounted in water-tight engagement over the hand holes 35a,b. The open ends of these suction conduits 48a,b are each located in close proximity to the upper surface of the tubesheet 7. In the preferred embodiment, each suction conduit 48a,b has an internal diameter of approximately 76.2 cm or more in order to easily conduct the preferred flow rate of cleaning solution out of the steam generator 1 of 946.4 litres per minute. These conduits 48a,b may be formed from either a durable plastic such as polyvinylchloride, or stainless steel pipes.

With specific reference now to Figure 3, both of the suction conduits 48a,b converge into a main recirculation conduit 50. Conduit 50 has an in-line strainer assembly 52 that is disposed upstream of the intake of suction pump 54. The purpose of the strainer assembly 52 is to prevent large particles of sludge and other debris entrained in the solution exiting the steam generator 1 from damaging the blades of the suction pump 54, which is preferably an impeller-type pump having a capacity of about 1135.6 litres per minute.

Downstream of the suction pump 54 is a filtration system 56 for removing fine particles of sludge and deposits from the aqueous cleaning solution being recirculated through the secondary side 5 of the steam generator 1. This filtration system 56 has an upstream filter bank 58 formed from filter units 60a,b, and a downstream filter bank 62 formed from filter units 64a,b. Each of the filter banks 58 and 62 are connected parallel with respect to one another so that one filter bank may be completely isolated from both the main conduit 50 and the other filter bank when it becomes necessary to change the filter elements in the units of either of the banks 58,62. To this end, various pairs of isolation valves 66a,b; 68a,b; 70a,b and

72a,b are provided both upstream and downstream of filter units 60a, 60b, 64a, and 64b, respectively. In the preferred embodiment, filter units 60a,b are bag-type filters, while filter units 64a,b are cartridge-type filter units. The filter elements (not shown) in each of the filter units 60a,b and 64a,b are each preferably sized to remove particulate matter having a diameter of one 0.001 mm or more.

Downstream of the filtration system 56 is a resin bed 74 which is formed from a plurality of ionexchange columns hydraulically connected in parallel. As will be described more specifically hereinafter, the resin bed 74 does not normally come on-line until the cleaning operation has been completed, as the purpose of the bed 74 is to remove all of the chemical cleaning agents and other ionic species which are present in the aqueous solution exiting the generator 1 in order to convert it back to demineralized water. Three isolation valves 76a,b,c are provided so that cleaning solution leaving the filtration system 56 may be forced through the resin bed 74 at the end of the cleaning operation. An optional return conduit (illustrated in phantom) may be provided which connects the outlet of the resin bed 74 back to the main conduit 50. Such an optional conduit is provided when it is desired to circulate the cleaning solution through the bed 74 to remove dissolved, radioactive ionic species from the solution. However, if this mode of operation is desired, it will be necessary to select resins for the ion-exchange columns that will not remove the dissolved cleaning agents present in the solution, but only the radioactive ionic species. An isolation valve 77 is provided in the optional return conduit to isolate the flow of solution through the main conduit from any contact with the resin bed 74 when the bed 74 is not is use.

Downstream of the resin bed 74 is a holding tank 78. In the preferred embodiment, the tank 78 has a capacity of about 1892.7 litres. The purpose of the tank 78 is to insure that a sufficient amount of solution is present throughout the recirculation system 34 at all times to avoid the introduction of air either into the inlet of a solution-introduction pump 80 (located down-stream of the tank 78), or in any other critical junction within the system 34.

The impeller-type solution introduction pump 80 is located downstream of the holding tank 78. The purpose of this pump 80 is to drive the filtered cleaning solution through the balance of the main conduit 50 so that it is forceably discharged through the two inlet conduits 82a,b that are connected to the terminus of the conduit 50. Preferably, the outlet ends of the inlet conduits 82a,b are located just above the bundle of heat exchanger tubes 9. During the draining step of the method of the invention (which will be specifically described presently), the inlet conduits 82a,b effectively hose-down sludge and debris that would otherwise settle on the top surfaces of the support plates 26 so that this sludge and debris is ultimately entrained in cleaning solution flowing over the top surface of the tubesheet 7 which in turn is ultimately sucked up by the suction conduits 48a,b. The technique of vertically recirculating a cleaning liquid throughout the secondary side 5 of a steam generator 1 is an inventive concept described and claimed in U.S. patent application serial number 07/456,436 filed December 26, 1989, the entire specification of which is expressly incorporated herein by reference. Finally, it should be noted that an inlet valve 84 that is connected to an inlet conduit 86 joins with the main conduit 50 just upstream of the holding tank 78. The purpose of the inlet conduit 86 is to introduce cleaning solution from a reservoir (not shown) connected to conduit 86.

In the first step of the preferred method of the invention, the steam generator 1 is taken off-line, and all of the water in the secondary side 5 is then completely drained. Depending upon the condition of the steam generator 1, sludge lancing may or may not be necessary at this juncture. If the sludge and deposits on the tubesheet 7 and support plates 26 are relatively light (i.e., not thick), no sludge lancing is necessary and the recirculation system 34 illustrated in Figure 3 is then hydraulically connected to the secondary side. If, however, these deposits are several centimeters thick, sludge lancing in accordance with known prior art techniques is carried out for two reasons. First, such sludge lancing expedites the entire cleaning operation by quickly removing what might amount to up to 453.6 Kg of sludge and debris that, while loosely deposited on the tubesheet 7 and other areas of the generator 1, would tend to hydraulically insulate crevice regions such as the annular spaces 30 between the bores 28 ;in the support plates 26 and the heat exchanger tubes 9 from the penetrating and cleaning action of any surrounding cleaning agent. Secondly, such sludge lancing reduces the number of times that the various filter units 60a,b and 64a,b of the filtration system 56 must be back-washed or changed during the pressure pulse cleaning phase of the method. In either case, the next step of the method is to install the mounting plates (not shown) which secure the nozzles 41 of the pressure pulse generators 33a,b and the suction conduits 48a,b the hand holes 35a,b, and to further install the inlet conduits 82,b through the upper manways 37a,b into position over the bundle of heat exchanger tubes 9.

In the next step of the method, inlet valve 84 is opened to admit a flow of cleaning solution into the holding tank 78 from a reservoir (not shown). As soon as the holding tank 78 is substantially filled with this cleaning agent, the solution introduction pump 80 is actuated to spray this solution through the inlet conduits 82 over the heat exchanger tubes 9 to begin to fill the secondary side 5 with solution.

The cleaning solution is an aqueous solution of de-mineralized water containing a surfactant, a dispersant, a thixotrope, and/or a flotation agent. In order to minimize the chances that the cleaning agents will induce any corrosion or other unwanted chemical reactions on the metallic surfaces within'the secondary side 5, the concentration of the cleaning agent within the de-mineralized water is preferably no more than 0.5 weight percent, and may be as little as 0.1 percent. Additionally, the surfactants, dispersants, thixotropes and flotation agents forming the active ingredients within the cleaning solution are selected so as to be substantially free from either sodiumchloride, or sulfate ions which can render the cleaning solution either undesirably alkaline or acidic. These cleaning agents are further selected so as to be substantially free from phosphates which can form unwanted encrustations within the crevice regions 30 and hence impair the cleaning operation, as well as halides which are known to promote the occurrence of unwanted corrosion.

Examples of surfactants which are suitable for use in the method of the invention include Immunol 236 available from the Harry Miller Company located in Philadelphia, Pennsylvania, U.S.A., Surfynol 104, available from Air Products located in Allentown, Pennsylvania, U.S.A., Triton X100 available from Rohm & Haas located in Philadelphia, Pennsylvania, U.S.A., and Hamposyl L, which is available from the W. R. Grace Company located in Nashua, New Hampshire, U.S.A. Stated more generically, surfactants whose primary active ingredients include either a combination of alkylphenoy ethoxylate, ethylene oxide and fatty alkanol amide, or tertiary acetylenic diol, or octyphenoxypoly ethoxyethanol, or lauroyl sarcosine are suitable for use in the method of the invention. Of all the aforementioned exemplary surfactants, Surfynol 104 is the most preferred because it has proven to be virtually non-foaming when subjected to the near-explosive burst of pressurized gas generated by the pressure pulse generators 33a,b.

Dispersants which may be used in conjunction with the method of the invention include tannic acid, Wayplex 55-S, Wayplex 55-A, Indulin C, Indulin AT, polyocrylic acid and lignin in the form of Reax 68 W. Stated more generically, dispersants whose active ingredients include polyacrylates, acrylic polymers, polypropyloxy quarternium ammonium acetate, imidazoline acetate and aminedodecylbenzine sulfonate are suitable for use in the method of the invention. Each of the aforementioned dispersants works by coating the small particles of sludge and other debris dislodged and fluidized within the cleaning solution by the pressure pulse generator 33a,b so that they do not agglomerate with one another.

Flotation agents which may be used in conjunction with the method of the invention include Emersol 221, or a mixture of Emersol 221 plus triethanolamine. Emersol 221 may be obtained from Emery Industries located in Cincinnati, Ohio, U.S.A. More generically, flotation agents whose active ingredients are comprised mostly of 9-octadecenoic acid may be used in the method.

While a cleaning solution including one or more of the group of the aforementioned surfactants, dispersants, thixotropes and flotation agents may be used in the method of the invention, a mixture of only a surfactant and a dispersant is the most preferred mode of implementing the method of the invention. While flotation agents help to keep particles of sludge and debris in suspension, they also tend to drive a disproportionate amount of the particulate sludge and other debris near the surface of the cleaning agent present within the interior of the secondary side 5, and hence far away from the suction conduits 48a,b. While thixotropes help to keep such particulate matter in suspension by thickening the cleaning agent; they also impair the ability of the cleaning agent to penetrate small crevice regions such as the annular space 30 between the heat exchanger tubes 9 and the bores 28 in the support plate 26.

As soon as a sufficient amount of cleaning solution has accumulated within the secondary side 5 to completely submerge the nozzles 41 of the pressure pulse generators 33a,b, these generators are actuated to commence the introduction of pressurized pulses of gas into the solution in order to generate shock waves that effectively loosen and dislodge sludge and other debris from the metallic surfaces within the secondary side 5. Initially these shock waves are induced by pulses of gas pressurized to about 2.76 MPa. However, as the level of the cleaning solution rises, the pressure of these gas pulses is proportionately increased to a maximum of about 6.21 MPa until the level of cleaning solution is about the same level as the uppermost bent portions of the heat exchanger tubes 9. This proportionate increase in the pressure of the gas pulses counteracts the tendency of the gradually increasing level of the hydrostatic pressure of the solution at the bottom of the secondary side 5 to reduce the intensity of the shock waves generated by the pressure pulse generators 33a,b. The frequency of the pressure pulses generated by the pressure pulses generators 33a,b takes place at intervals of between 10 and 60 seconds, and is preferably one pulse every ten seconds.

While the filling step may be implemented with a flow rate through the inlet conduits 82a,b of as little as 94.64 litres per minute, a relatively fast flow rate of 946.4 litres per minute is preferred in order to shorten the total amount of time required for the method to be completed.

Even before the filling step has been completed, the recirculation step of the method may be commenced by actuating the suction pump 54. Of course, if this particular mode of operation is followed, the flow rate of the suction pump 54 is adjusted so that it is less than that of introduction pump 80 until the level of cleaning solution is about even with the height of the bundle of heat exchanger tubes 9, whereupon the rate of solution introduction and the rate of solution withdrawal are made equal. The recirculation of the cleaning solution preferably takes place at a rate of between approximately 283.9 to 946.4 litres per minute. All during this step, the recirculated solution is continuously filtered by the filter units 60a,b, 64a,b of the filtration system 56. The fluidization of the sludge and other deposits within the secondary side 5 by the pressure pulse generators 33a,b, in combination with the increased penetration and dispersant properties of the solution afforded by the surfactants and dispersants present therein and the relatively fast flow rate of this solution during the recirculation step all coact to effectively entrain the sludge and deposits into the solution exiting the secondary side 5 through the suction conduits 48a,b, where it is ultimately removed from the solution by the filtration system 56. While a recirculation step of only about one hour may be used to clean a generator with only light deposits of sludge and debris, the recirculation of the cleaning solution along with continuous pressure pulsing is between 16 and 24 hours to insure that the bulk of the sludge and other deposits initially present within the secondary side 5 is removed. Of course, the filter bags and cartridges present in the filter units 60a,b are replaced as necessary during this step.

After the recirculation step of the method has been completed, the secondary side 5 is drained by either de-actuating the introduction pump 80 or by reducing the flow rate of the introduction pump 80 relative to the suction pump 54. During this step, the state of the isolation valves 76a,b,c is changed so that the net amount of cleaning solution drained from the secondary side 5 is forced to flow through the resin bed 74 to remove the dissolved ionic species and active cleaning agents from the solution and render it back into de-mineralized water. This draining step continues until the level of cleaning solution within the secondary side 5 is about the same as the level of the lowermost support plate 26, whereupon the state of the isolation valves 76a,b,c is again reversed, and the rate of flow of the introduction pump 80 is again made equal to the rate of flow of the suction pump 54 to induce a second recirculation step. At this juncture, nearly all of the remaining dislodged sludge is concentrated into a relatively small volume of rapidly circulated cleaning solution, which again is filtered through the filtration system 56 to remove all particulate sludge and deposits. Samples of the cleaning solution exiting through the suction conduits 48a,b are regularly taken in order to determine the density of fluidized sludge and deposits within the cleaning solution. When the density of such fluidized sludge and deposits reaches a level which indicates that substantially all suspended material has been removed from the secondary side 5, the rate of flow of the introduction pump 80 is set lower than that of the suction pump 54, and the state of the isolation valves 76a,b,c is again reversed to continue the draining step. The draining step is then continued until substantially all of the cleaning solution is removed from the interior of the secondary side 5.

It should be noted that the efficacy of the second recirculation step in completely removing all dislodged and fluidized sludge and debris from the cleaning solution advantageously obviates the need for a second sludge lancing, which was often necessary in prior art pressure pulse cleaning operations which utilized only de-mineralized water as a cleaning medium.

Claims

1. A method for removing sludge and deposits (32) from the interior of a heat exchanger vessel (1), characterized by the steps of:

   introducing a liquid into the interior of the vessel (1), said liquid including a cleaning agent formed from at least one of the group consisting of surfactants, dispersants, thixotropes and flotation agents to promote fluidization and to inhibit re-settling of said sludge and deposits (32), and

   introducing a succession of pressurized pulses of gas into the liquid to generate shock waves that loosen and remove said sludge and deposits (32) from said heat exchanger interior.

2. A method for removing sludge and deposits (32) as defined in claim 1, wherein said cleaning agent further includes an anti-foaming agent.

3. A method for removing sludge and deposits as defined in claim 1, wherein said cleaning agent forms less than one weight percent of said liquid.

4. A method for removing sludge and deposits as defined in claim 1, wherein said cleaning agent is free from sodium, phosphates, halides and sulfates.

5. A method for removing sludge and deposits as defined in claim 1, wherein said cleaning agent forms between about 0.1 to 0.5 weight percent of said liquid.

6. A method for removing sludge and deposits as defined in claim 1, further characterized by the step of recirculating said liquid through a filtration system (56) as said succession of pressurized pulses of gas is introduced into the liquid in order to remove sludge and deposits (32) entrained within the liquid.

7. A method for removing sludge and deposits (32) as defined in claim 6, further characterized by the step of recirculating said liquid through an ion exchange medium (74) to remove dissolved sludge and deposits from said liquid.

8. A method for removing sludge and deposits (32) as defined in claim 1, further characterized by the sequential steps of substantially filling said vessel (1) with said liquid, recirculating said liquid within the vessel interior, and draining said liquid from said vessel (1) while continuously introducing said succession of pressurized pulses during said fill, recirculation and drain steps.

9. A method for removing sludge and deposits as defined in claim 8, wherein the pressure of the gas used to create said pulses is increased from about 2.76 to 6.21 MPa as the vessel is filled with said liquid, maintained at about 6.21 MPa during said recirculation step, and reduced from about 6.21 to 2.76 MPa when said liquid is drained.

10. A method for removing sludge and deposits as defined in claim 1, wherein the frequency of said pressurized pulses is one pulse between about every 10-60 seconds.

11. A method for removing sludge and deposits (32) as defined in claim 1, wherein said liquid is formed from a combination of a surfactant to promote penetration of said solution into crevice regions within said heat exchanger vessel (1) and a dispersant to promote fluidization of said sludge and deposits (32).

12. A method for removing sludge and deposits (32) as defined in claim 1, wherein said dispersant is at least one of the group consisting of polyacrylates, acrylic polymers, polypropyloxy quarternium ammonium acetate, imidazoline acetate and aminedodecylbenzine sulfonate.

13. A method for removing sludge and deposits (32) as defined in claim 1, wherein said surfactant is at least one of the group consisting of alkylphenoy ethoxylate, ethylene oxide, and fatty alkanol amide, tertiary acetylenic diol, octyphenoxypoly ethoxy-ethanol, and lauroyl sarcosine.

14. A method for removing sludge and deposits (32) as defined in claim 1, wherein said flotation agent is 9-octadecenoic acid.

15. A method for removing sludge and deposits (32) as defined in claim 1, wherein said thixotrope is a cross-linked polyacrylate.

16. A method for removing sludge and deposits (32) as defined in claim 6, wherein said liquid is recirculated at a flow rate of between about 94.6 to 567.8 litres per minute in order to maintain the entrainment of said sludge and deposits (32) within said liquid as it flows toward said filtration system (56).

17. A method for removing sludge and deposits (32) as defined in claim 8, wherein said draining step is halted when the level of the liquid within said heat exchanger (1) reaches a selected level, and wherein recirculation of said liquid is recommenced until the density of sludge and deposits (32) entrained in said liquid reaches a selected level, whereupon said draining step is recommenced.

18. A method for removing sludge and deposits (32) as defined in claim 1, wherein the total weight percent of said agent relative to the water component of the liquid is between about 0.1 to 0.5 percent.

19. A method for removing sludge and deposits (32) as defined in claim 6, wherein said recirculation step lasts between 1 and 30 hours.

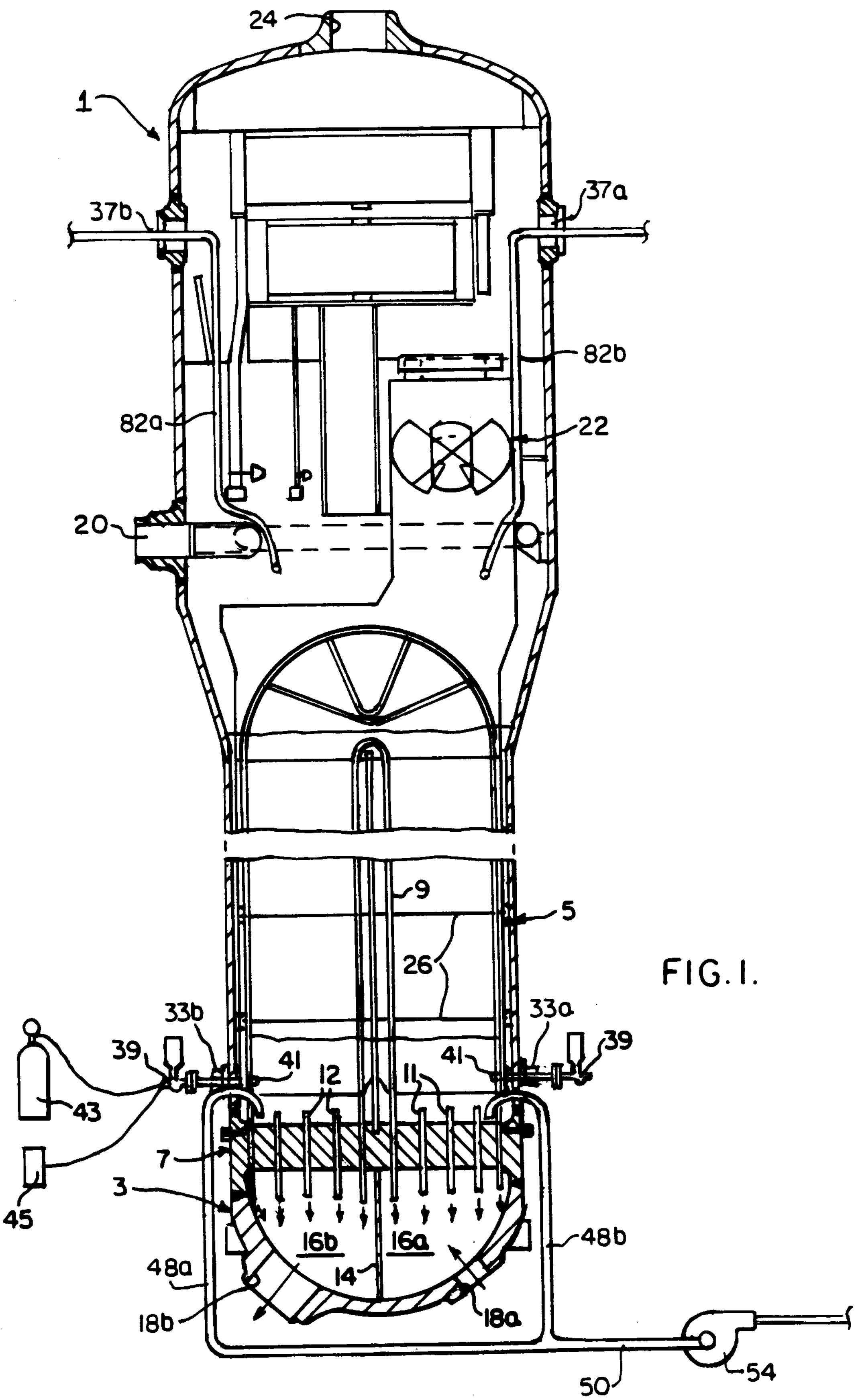
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FIG.1.

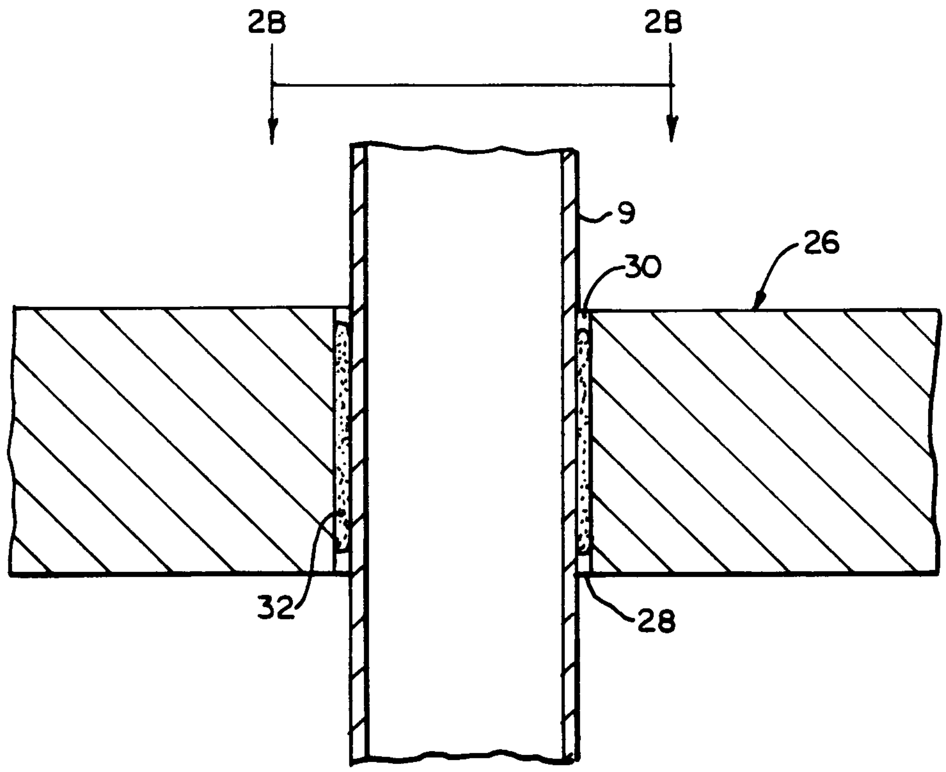


FIG. 2A.

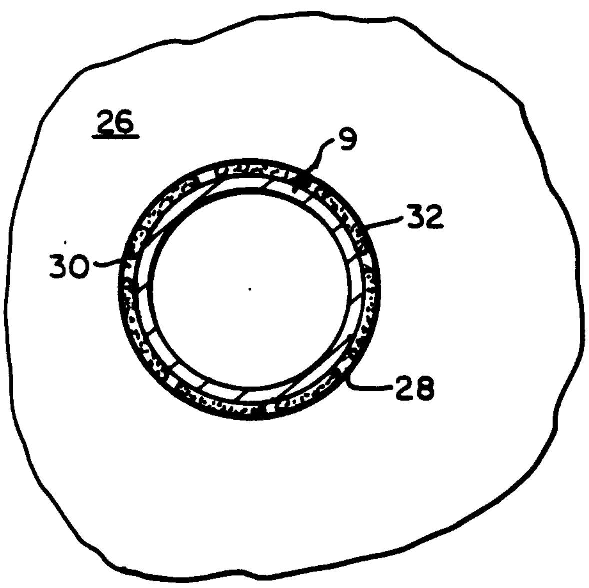
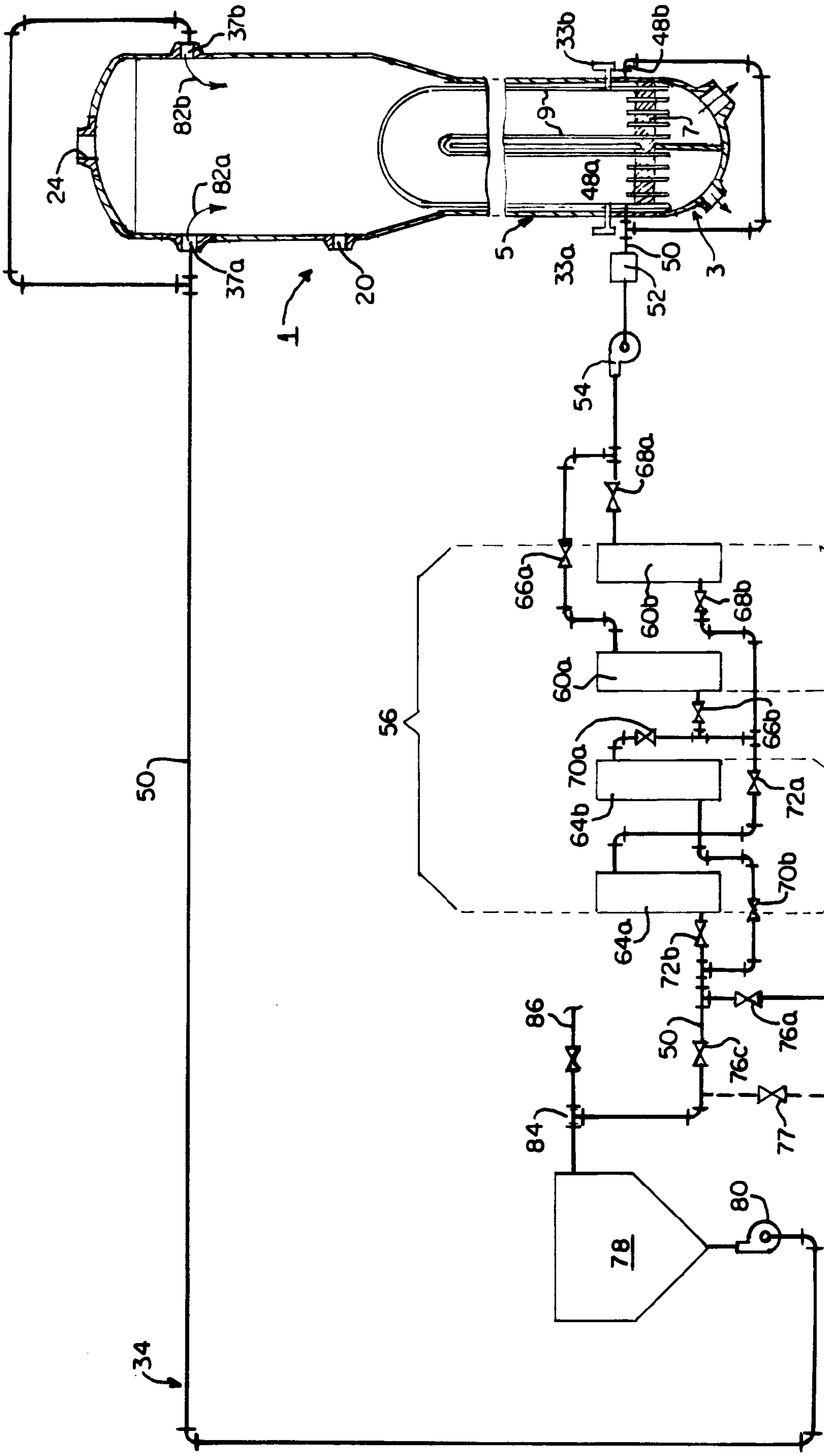


FIG. 2B.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64a
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66b
68a
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76c
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82b
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FIG. 3.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 30 9816

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	US-A-4 320 528 (SCHARTON) * column 8, line 43 - column 11, line 10; figures *	1	F22B37/48 F28G7/00 F28G9/00
A	EP-A-0 339 289 (WESTINGHOUSE) * abstract; figures *	1	
E	EP-A-0 458 533 (WESTINGHOUSE) * page 5, line 28 - page 11, line 47; figures *	1,3-6, 8-10,18, 19	
A	US-A-3 447 965 (TEUMAC)		
A	EP-A-0 155 568 (WESTINGHOUSE)		
A	EP-A-0 198 340 (KRAFTWERK UNION)		
A	FR-A-2 419 118 (MITSUBISHI)		
A	PATENT ABSTRACTS OF JAPAN vol. 6, no. 50 (M-120)(928) 3 April 1982 & JP-A-56 165 900 (SHINKOU KAWADA) 19 December 1981 * abstract *		TECHNICAL FIELDS SEARCHED (Int. Cl.5) F22B F28G B08B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	31 JANUARY 1992	VAN GHEEL J.U.M.

CATEGORY OF CITED DOCUMENTS

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