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- 1 -

METHOD AND APPARATUS FOR OIL-WATER SEPARATION
BY COALESCENCE

This invention is related to a method and device for oil/water separation by coalescing the oil particles to separate the oil effectively from oil contaminated water which contains finely divided and dispersed oil or oil in an emulsified state.

Conventional methods for separating oil from oil contaminated water include gravity separation methods, filtration methods, adsorption methods, cohesion deposition methods, air flotation methods, microbiological processes, electrolytic methods, physical chemistry methods and coalescence methods.

The gravity method is only applicable for oil droplets, and is unsuitable for the separation of finely divided oil while filter clogging occurs in the filtration method and requires large-sized equipment for back flushing. However, difficulties are still encountered in the complete prevention of such clogging. The air flotation method also requires a large system and it is impossible to separate finely divided oil. The micro-biological method requires large sized equipment and is time consuming, and the electrolytic or physical chemistry method is accompanied by secondary processing, thus offering problems in connection with the size of installation involved and the procedures of processing. The coalescence method now available is an ideal method for oil removal. However, it cannot be applied for the range of emulsion type particles of a dimension smaller than 10 micrometres except when combined with precision filtration or ultrafiltration. The ultrafiltration can only be used for specific cases, because the equipment is large and expensive and the running cost is also high. On the other hand, an oil adsorbent, depending on its lipophilic nature,

requires a high cost and a great deal of manpower for replacing it at saturation point due to its adsorption limit. This is a major drawback due to impediment of oil flow in the case of high oil concentrations and high viscosity oil. The method of using an oil adsorbent for coalescence of oil particles smaller than 10 micrometres is impractical, and therefore this method is not adequate for the separation of emulsified materials. No practical small-sized equipment for economically performing separation by coalescence of oil with particles smaller than 10 micrometres is available at the present time.

The present invention is based upon recognition of these difficulties, and extensive studies have resulted in a method and apparatus to efficiently separate high concentration and/or high viscosity oil or emulsified oil. According to one aspect of the present invention there is provided a method for oil-water separation by coalescence comprising the steps of producing a coalescing layer having oil-resisting and repelling properties as well as water transmitting and absorbing properties on at least one surface of a porous member by forming thereon a water-insoluble hydrous gel layer while maintaining the porous nature of said member to obtain a coalescing element; subjecting said coalescing element in a coalescing unit to a flow of an oil-contaminated water such that said oil contaminated water passes through the porous material to catch and coalesce emulsified oil particles upon said at least one surface, said oil-contaminated water being passed alternately in opposite directions through the coalescing element; and then separating the thus coalesced oil and the water from each other.

According to another aspect of the present invention, there is provided an apparatus for oil-water separation by coalescence comprising a coalescing apparatus for use in oil-water separation by coalescence comprising a
5 coalescing element having a coalescing layer exhibiting oil- resisting and repelling properties, said element being produced by forming a water-insoluble hydrous gel on at least one side of a porous member while maintaining the porous nature thereof; a casing
10 accommodating said coalescing element; inlet and outlet means provided in said casing; and means for reversing flow through said coalescing element so as to permit oil-contaminated water to flow through the coalescing element alternately in opposite directions.

15 The present invention enables removal of oil droplets having a particle size of smaller than 10 micrometres which has been desirable for a long time, and is a considerable advance in a field in which numerous research and developments project have been performed
20 without success. The invention is of great significance in that it will enable the 15 ppm requirement to be realised for the marine use of an onboard oil/water separator as specified in the Sea Pollution Prevention Act in accordance with the IMCO
25 Convention.

In the coalescing process of the present invention, an oil-water separating element consisting of a specific porous material is used. It is important that a water-insoluble hydrous gel layer is formed on at least
30 one of the surfaces of the porous member to come in contact with oil contaminated water and/or to the liquid passage surface. For example, various types of synthetic fiber, inorganic fiber, natural fiber, natural pulp, synthetic pulp, etc., are used to form a

porous member, on which a specific water insoluble hydrous gel layer is formed as a coalescence layer.

The types of water insoluble hydrous gel or its means of formation are not specifically limited to the
5 following examples, and can be selected and exemplified

in a wider range. For example, the following methods can be used to form a hydrous gel:-

- 1) A method in which an aqueous solution of a mixture of a water-soluble monomer such as acrylamide, calcium acrylate or sodium acrylate, with methylene bisacrylamide or N-methylolacrylamide, added with a polymerization catalyst such as ammonium persulfate or sodium persulfate, potassium persulfate, hydrogen peroxide and a condensation catalyst such as ammonium chloride or mono ammonium phosphate, is prepared, and such a solution is adhered to the porous sheet by means of immersion, painting, spraying, etc., and is then dried at a temperature of about 80 - 110°C to effect polycondensation, thereby obtaining a water-insoluble hydrous gel layer;
- (2) a method comprising the steps of applying an aqueous solution of a material having a positive ion charge (compounds having a cation charge such as pyridine or quaternary ammonium group) on a porous sheet, and applying an aqueous solution of a material having a negative charge (compounds having an anion charge such as a carboxyl group or a sulfone group) on the sheet, whereby such materials are ionically coupled to each other at the surface or in the interior of the sheet to form a so-called ion complex;
- (3) a method in which a gel compound is obtained by the coupling reaction of a water-soluble polymeric substance such as carboxymethyl cellulose, a polyphosphate, a polyphosphoric acid salt, sodium polyacrylate, with a polyvalent metallic salt such as magnesium sulfate or calcium chloride, i.e. by previously applying an aqueous solution of polyvalent metallic salt on a porous sheet by way of immersion, coating, spraying, etc., then adding an aqueous solution of the above-stated water soluble polymeric compound capable of being crosslinked with a metal,

followed by intermediary action of polyvalent metallic ions; (4) a method for making a natural or synthetic hydrophilic polymeric substance insoluble without losing its water-absorbing characteristics, i.e.

5 wherein a porous sheet is previously applied with a crosslinker such as chromium alum, potash alum, formalin, zinc chloride, boric acid or magnesium chloride, and a gel compound is formed through a chemical crosslinking reaction by adding a gelatinizer
10 such as gelatin, polyvinyl alcohol, alginic acid, mannan, or cellulose compound; and (5) a method of utilizing a material which absorbs water and swells to form a water insoluble hydrous gel, for example, a method of applying a crosslinked polyethylene oxide
15 (soluble in an organic solvent) to a porous sheet by way of immersion, coating, or spraying or a method of adding lower-substituted carboxymethylated cellulose or polyvinyl fiber by mix spinning or mix weaving.

20 In the present invention, the layer which is insoluble in water and capable of absorbing water as mentioned above is preferably applied on the surface of a porous sheet and/or the surface of a liquid passage to come in contact with oil-containing water; however, it is of importance that there is no lowering of the porosity of
25 the porous sheet filter after formation of the water-absorbing gel layer. In the selection of one or a mixture of filter materials (having a sufficient porosity), the porosity must be taken into account. If the amount of water transmitted is too large, the
30 efficiency of oil-water separation drops with an increase in the amount of water leached out. When the amount of water transmitted is too small, on the other hand, the rate of oil-water separation drops sharply.

In the present invention, it is desirable to provide a further process for enhancing and maintaining the effect of the oil separation function such as an oil-repelling function, oil-collecting function, coalescing ability for oil drops, as well as forming the water-absorbing gel. For example, a lipophilic agent such as a fluorine compound or chromium fluorine compound, lipophilic agent or oil collecting agent such as stearic acid compound, silicone base compound, wax compound, surface tension-reducing agent or oil collecting agent such as a higher alkyl alcohol, silicone alkylene oxide or fluorine surfactant are added to the water insoluble hydrous gel layer. Alternatively, the porous sheet will be treated with such an agent by coating, immersing or spraying before or after forming the water absorbing gel. The porous sheet may have a lipophilic portion formed with the water absorbing gel layer. For example, an oil-separating effect by oil collection, growth and separation can be improved by constructing a filter material by means of mixed making or mixed spinning of polyolefin fiber or pulp, synthetic fiber or glass fiber.

In this invention, any material having characteristics sufficient for use as a filter, i.e. material having water permeability, water resistance, pressure resistance and durability, can be widely used as the porous sheet without any restriction. For example, board, non-woven fabric, paper or foam sheet can be used. Non-woven materials such as paper or non-woven fabric made mainly of cellulose fiber such as cotton, rayon or acetyl cellulose may be used after being given the characteristics of water resistance, pressure resistance, durability, etc., by reinforcing treatment such as described in Japanese Patent No. 659628. With

a porous sheet made of woven fabric such as filter cloth, the aforesaid reinforcement can be omitted as the material itself has characteristics required for filtering, such as water resistance, pressure resistance; however, the reinforcement process is preferably applied. Use may be made of other methods such as those comprising the steps of making a non-woven porous sheet by forming a mixture of heat melting synthetic pulp (polyolefin, nylon, polystyrene, etc.), and applying synthetic pulp thereto by a heating process, or applying a crosslinking compound such as urea - formalin condensate, melamine - formalin condensate, epichlorohydrin compound, methanol group-containing compound, divinyl sulfone compound, etc., to the porous sheet by coating, immersing, spraying, etc., so that the filter function will not be lost.

On the other hand, the porous sheet of the present invention can be made of synthetic fiber material such as polyethylene, polypropylene, phenolic resin thread, polyester, polyamide or of inorganic fibers such as glass fiber, ceramic fiber, asbestos, or of a composite of such various fiber mixtures.

In a preferred embodiment of the invention, use is made of a fixing process in order that specific water absorbing gel layer will not separate from the porous sheet. For example, this process is implemented by using cation fixing agent such as polyethylene amine, epichlorohydrin polyamide, dicyanidiamide - formalin condensate, or an anion fixing agent such as urea - formalin condensate, melamine - formalin condensate in dependence upon the type of the porous sheet, and applying it on the porous sheet by way of coating, immersing, spraying before and after formation of the

gel layer or impregnating it into the gel layer.

The element for the embodiment of the present invention is advantageously of small size. For example, the porous materials may simply be arranged in multiple stages. However, it is most preferable to make structures having a number of small passages formed by a stack of alternate flat and corrugated cardboard sheets, forming an array of alternate inlet and outlet passages separated by porous cardboard or similar structures of the porous material.

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Fig. 1 is a general view of the oil contaminated water processing system in one embodiment of the method of the present invention;

Fig. 2 is a sectional side view of the suction port equipment in the system;

Fig. 3 is a sectional side view of a first example of a coalescing unit.

Fig. 4 is a sectional plan of Fig. 3;

Fig. 5 is a perspective view of a second example of the element used in this invention;

Fig. 6 is a plan view illustrating one end of the element shown in Fig. 5;

Fig. 7 is a plan view of the element of Fig. 5 explaining the condition of oil contaminated water permeating the element;

Fig. 8 is a sectional side view of the embodiment of the element shown in Figs 5 to 7.

Fig. 9 is a schematic drawing indicating another embodiment of implementation of the present invention; Figs. 10(a), (b) and (c) are views explaining the process of coalescence to form a larger drop of oil in the oil contaminated water through the element;

Fig. 11 shows a further embodiment of the present invention;

Fig. 12 shows one example of the element used in the embodiment of Fig. 11;

Fig. 13 is a side view of a conventional oil-water separator;

Figs. 14 - 16 are side views of alternative constructions of oil-water separators which may be mounted on top of and connected to any one of the settling tanks shown in Figs. 11 and 17;

Fig. 17 shows a still further embodiment of the invention;

Fig. 18 is a side view of the ^(coalescing unit) ~~element~~ used in the embodiment of Fig. 17;

Fig. 19 shows a still further embodiment of the invention;

Fig. 20 is a side view of the element used in the embodiment of Fig. 19; and

Fig. 21 is a plan view illustrating one end of the element of Fig. 20.

Fig. 1 is a general outline of the embodiment of this invention, in which numeral 101 is a crude water tank to store oil contaminated water. The oil contaminated water 102 is taken out through a suction port equipment 103. The suction port equipment 103 is constructed as shown in Fig. 2, by which outer cylinder 105 is joined with take-out tube 104 to the bottom and fixed at an appropriate place below the liquid level in the crude water tank 101; inside this outer cylinder 105, is a weir cylinder 107 having a float 106. The weir

cylinder 107 is freely and vertically movable such that the brim of the weir cylinder is positioned slightly below the liquid level. The weir cylinder 107 provides communication with the take-out tube 104. This brim of the weir cylinder 107 may be formed so as to be flat, but unevenness 108 of a saw edge type or notch type is preferable. The suction port equipment 103 enables automatic absorption of the high oil concentration part at the surface of the oil contaminated water 102 in the crude water tank 101, and is constructed to allow oil contaminated water 102 to flow in from the upper end of the weir cylinder 107 which moves in accordance with changes of the height of the liquid surface by way of the function of a float.

The purpose of suction port equipment 103 is to move the suction port in accordance with the change of the fluid level so that the oil contaminated water will be continuously sucked in from the high oil concentrated surface part, as the fluid level of the crude water tank varies about 100 to 300 mm up and down when items to be washed are put into or removed from the crude water tank 101.

The take-out tube 104 of the suction port equipment 103 passes through pipe line 109 outside the crude water tank 101 and is connected to a strainer 110. The strainer is mainly provided to remove foreign elements in the oil contaminated water, and the strainer 110 is selected from conventional known products.

The oil contaminated water from the strainer 110 passes through a pipe 111, a pump 112 and a pipe 113 and enters into a first flotation tank 144. High concentration oil and high viscous oil are removed here. A first flotation tank providing as high a coalescent effect as

possible will be used. The oil contaminated water is sent to a coalescing unit 114 in the form of a reduced oil charge, as much of the high concentration and high viscosity oil is removed as the oil contaminated water passes through the first flotation tank 144. If there is no possibility in yielding high concentration or high viscosity oil in the oil contaminated water, the first flotation tank 144 can be eliminated and the oil contaminated water from the pump 112 may directly be sent to the coalescing unit 114.

Fig. 3 is a longitudinal section side view of the coalescing unit 114, and Fig. 4 is a cross-sectional plan view of the same equipment. Unit 114 has a middle floor 117 at the bottom of a cylindrical case 115 to form a passage chamber 118. An opening 119 is formed in the center portion of the middle floor and an element chamber 120 is formed over the middle floor 117, with chamber 120 accommodating a coalescing element 121 which has porous material 124 on which a specific coalescing layer having water permeable and absorbing function is formed. The structure of element 121 is the same as that of a conventional element. That is, a round cylinder 123, which is formed with many through holes 122, at the center part thereof, porous material 124 is formed in a zigzag shape and the cylinder 123 is positioned over the opening 119 of the middle floor, and the upper end of the case 115 is covered with a lid 116 to which an element holder 125 is installed to fix element 121. Also, an appropriately wide space is formed to the peripheral side and upper portion of the element 121.

Further in this apparatus, each end of the inlet tubes 127a and 127b which are connected to a changeover valve 126 and are attached to open into the inside of element

chamber 120 and the passage chamber 118, and similarly each end of the outlet tubes 129a and 129b, which are connected to a changeover valve 128, which opens into the pipe line 131 such that when in use the changeover valves 126 and 128 are opened so that either tubes 127a and 129a or tubes 127b and 129b are open at the same time the other respective inlet and outlet tubes being closed. The inlet side changeover valve 126 is attached to a pipe line 130 from the pump 112, and the outlet side changeover valve 128 is attached to a pipe line 131 which leads to a flotation tank 132.

In the unit 114, oil contaminated water from the pipe line 130 flows into the unit 114 either from branch tube 127a or 127b according to the operation of the changeover valve 126, such that flow out from the upper branch tube 129a occurs only when flow occurs in from the lower branch tube 127a, and in the contrary situation outflow occurring from the lower branch tube 129b only while flow occurs in through the upper branch tube 127b. By virtue of the operation of the changeover valves 126 and 128, the oil contaminated water passing in from lower branch tube 127a flows as shown by a solid arrow from the passage chamber 118 through the opening 119, the holes 122 of the cylinder 123, permeating through the material 124, through the branch tube 129a and exists to pipe line 131. Also, when changeover valves 126 and 128 are shifted to pass the oil holding water from the branch tube 127b, it flows as shown by the dotted arrow mark to permeate through the material 124 from the outer side and enter into the cylinder 123, through the opening 119, the passage chamber 118 and lower branch pipe 129b and passes out to the piping. In other words, by changing the flow-in and flow-out position with respect to the unit 114 by the operation of changeover valves 126 and

128, the direction of oil contaminated water permeating through the element 121 is reversed.

When oil contaminated water flows into the unit 114 and permeates through the element 121, not only the
5 coalesced oil content but also finely divided and scattered oil of the size less than 10 micrometres is positively caught and collected by the oil separation function of the action of element material 124 which is formed with a coalescing layer providing a water
10 permeating and absorbing function, and the oil collection grows into a coarse oil particle which can automatically float, and is separated out due to this floating characteristic as well as due to the oil separation function of the gel layer on the porous
15 material 124. Moreover, by permeating through the element, by virtue of its special function, emulsion type oil drops which were hitherto considered unable to be separated, grows from a coarse particle to a coarse sized drop which can be removed.

20 Oil contaminated water thus permeating through the element 121 is removed as water and coarse oil particles through branch tube 129a or 129b and the pipe line into the next stage flotation tank 132.

Now, in the oil contaminated water, many types of
25 admixtures (SS) such as suspension and small dust are generally included. Therefore, the element will be choked so as to cause reduction of function during servicing. In many conventional systems, operation of the equipment was stopped in such case to wash the
30 element so as to recover its function, and this resulted in a reduction of processing ability to a marked degree. This invention has solved this deficiency splendidly, so as to enable the equipment to

- 15 -

be operated continuously without stopping accompanied with cleaning effect of the element.

The equipment can be operated with the manipulation of changeover valves 126 and 128 to divert the inflow
5 between the branch tubes 127a and 127b, and the outflow between the branch tubes 129a and 129b. The manipulation of these changeover valves causes the flow of oil contaminated water to be reversed as shown by solid line arrow mark and dotted line arrow mark in
10 Fig. 3. This reversal flow causes SS attached to the face opposite to the flow of the porous material 124 to be removed. Moreover coarse particles, and enlarged oil drops which are attached to this surface will also be removed and separated by this reversal of flow.
15 Both sides of the element serve equally for coalescence and enlargement of oil drops notwithstanding the direction of the flow of oil contaminated water.

The manipulation of the changeover valves 126 and 128 may be performed manually after an established time,
20 after collection of an established amount, or by the increase of feed water pressure; however, automatic operation can be adopted by interlocking the operation of the valves 126 and 128 with a timer, a flow meter, or a feed water pressure gauge. In the so-called
25 reverse washing operation which will be performed by reversing the direction of flow of oil contaminated water, removal of oil particles from the element is effective as well as is the pressure loss at one element so as to be as low as about 0.1 - 0.4 kg/cm², which results in a good water permeating efficiency and
30 therefore allows water feeding under low pressure.

Generally, in oil water separation, oil will be finely divided to reduce coarse particulation separation as

the feeding water pressure increases; however, in this invention a lower pressure can be used as stated before, so as to prevent oil from being finely divided, and result in a synergistic effect for better coarse
5 particulation of oil particles.

Fig. 5 through Fig. 8 indicates another example of the embodiment of the element and the coalescing equipment in the form of a stack of alternate flat and corrugated cardboard sheets to form arrays of alternate inlet and
10 outlet passages separated by porous cardboard are used as the element as shown in Fig. 5.

This element 121 is made of plain boards 140, which are made of porous material formed with a coalescing layer having a water permeable and water absorbing function
15 and the corrugated boards 141 of the same material are placed alternately to form laminated structure, making many fine tubular passages 142, being positioned between those plain board and the corrugated board. Either the top or the bottom end of respective fine
10 tubular passages 142 formed as noted above are plugged by elements 143 as shown in Fig. 6, to allow each neighboring passage to be oppositely plugged. Consequently, the oil contaminated water coming into
15 each passage 142 is caused to flow only by permeating either plain board 140 or corrugated board 141. The plugging 143 can be accomplished by an arbitrary method such as pressed adhesion using adhesive, or filling the opening with adhesive filler, etc.

Fig. 8 indicates coalescing equipment accommodating the elements as shown in above Fig. 5, in which many
20 through holes 134 are formed in the middle floor 117 located on the bottom of the cylindrical case 115. The elements 121 are placed on this middle floor 117, and a

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434.

5 cavity 133 is formed above the elements 121. Branch
tubes 127a, 127b and 129a, 129b are respectively opened
to the passage chamber 118 and the cavity 133. The oil
contaminated water flowing in from either branch tube
127a or 127b enters into the passages 142, the ends of
which are opened respectively as shown by the solid
line arrow mark or the dotted line arrow mark, enters
into the neighboring passages permeating the plain board
140 or the corrugated board 141, enters into the
10 passage chamber 118 or the cavity 133 through the
opened ends of the passages, and flows through the branch
tube 129a or 129b.

15 The structure of the flute type element 121 as shown by
Fig. 5 through Fig. 7 is more efficient than the
conventional common structure as shown in Fig. 3 and
Fig. 4, and their application as shown in Fig. 8 is
easier to make smaller equipment, and the use of this
type is more practical. Specially such smaller
20 configuration is indispensable in the case of limited
installation space as in the case of marine
application, and this invention can comply with such a
stringent installation condition.

25 As stated above referring to Fig. 1, oil contaminated
water is treated such that coarse particles are
separated and float in the water through operation of
coalescing unit 114 and flows into the next flotation
tank 132 through the pipe line 131.

30 The flotation tank 132 can be of any known type. In
this example, physically enlarged oil particles
naturally float to the upper portion of the tank 132 by
means of their difference in density, and are taken
into an oil collecting cylinder 136 from the upper part
of the tank 132 through a pipe 135 or discharged

outside. At this stage, the treated water is led to the crude water tank 101 or discharged outside.

The above example indicates a basic oil water separation system as a unit of the coalescing equipment of the present invention. However, multistage water flow by series installation of a plurality of the coalescing units and flotation tanks may in many cases lead to effective results according to the concentration and viscosity of the oil included. With such a multistage water flow system, coarse particulated oil is removed prior to the next coalescing, interim resistance of oil in the next process being positively reduced and the oil separation rate improved. Therefore, adoption of such multistage water flow system is desirable as far as the installation area permits it.

Fig. 9 indicates the outline of this multistage water flow system, in which oil contaminated water from the crude oil tank 101 passes through the first flotation tank 144, then passes through a water flow system of serially and multistaged coalescing units and flotation tanks in the order of the first coalescing unit 114a - the first flotation tank 132a - the second coalescing unit 114b - the second flotation tank 132b, and feeds almost completely separated oil into the oil collecting cylinder 136. In this case the oil from the upper part of the second flotation tank 132b is fed into the oil collecting cylinder 136 automatically or manually, and the processed water from the lower part of the second flotation tank 132b flows into the crude water tank 101 for the case of circulating use, and is otherwise discharged.

This system is not only adequate for the efficient

transient processing of oil contaminated water, but also demonstrates an especially superior effect in the processing of emulsified finely divided oil contaminated water including oil particles smaller than 1 micrometre by the effect of a surface active element, which could not be attained by conventional technique. For example, it has been experimentally confirmed that the water containing 250,000 ppm of light oil can be processed to leave the oil content less than 5 ppm under the test specification of ship's equipment in accordance with the IMCO-Convention, and that 5 ppm oil content which is determined as the limit for industrial waste water for environmental protection can perfectly be attained.

This invention has especially novel features in permitting separation of not only the finely divided oil but also the emulsified oil content, because of the formation of the specific layer mainly consists of water insoluble hydrous gel layer having an oil water separation function as well as an oil resisting and oil repelling function.

Although the theoretical base for this is not sufficiently clear, the following reason can easily be surmised from its structural characteristics. The abstract of the oil separation process is shown in Fig. 10. When oil contaminated water permeates through the element material 124 from one side, oil particles or emulsified oil particles in the oil contaminated water attach lightly onto the surface of the material 124 due to its oil resisting and oil repelling function to form multiple coalesced oil a, and when oil in the continuously inflowing oil contaminated water are formed as particles in the other part, some of them are caught in the coalesced oil a, and grow to become a

large oil particle b. Eventually the grown oil particles, b, b, will contact each other to grow and form a large oil drop c as shown by the dotted line. This enlarged oil drop c will be separated from the surface of the material 126 by the repelling action of the material 124, and is transformed to have a floating condition due to the self floating function in the oil contaminated water as shown by the arrow mark and begins to float. And many of these growing oil particles or drops easily adsorb SS, and can remove SS as well as oil from the oil contaminated water.

Another special feature of this invention is that, because of its desirable SS removing performance stated above, the strainer 110 placed prior to enter in the coalescing unit 114 is not required to have such a fine straining mesh to collect even fine SS. For the requirement to catch relatively large SS only, a strainer of above 30 to 40 mesh will be sufficient for the purpose.

The conventional method requires use of as fine mesh as possible to catch and remove SS there, and oil drops are finely divided there because of the effect of pressure caused by passing the fine strainer, and the fine oil particles were thus emulsified to make removal of oil more difficult. On the contrary, by this invention pressure resistance of the strainer is lower, does not cause emulsification and results in easier oil separation in the coarse particulating equipment 114, which enables almost perfect removal of emulsified oil which is prevented from being further emulsified. Further, high pressure water feeding for high viscosity oil to a strainer causes a deficiency in intensifying emulsification; however, the invention does not require high pressure water feeding equipment, does not

5 cause any impediment thereof, and because of simultaneous discharge of SS entrapped in the oil particle at the surface of the element, results in efficient removal of SS simultaneously with oil separation.

10 Referring to Fig. 11 there is shown a flow charge of the method according to the present invention, wherein reference numeral 221 stands for an element, 214 a coalescing unit including element 221, 251 an oil
15 extractor equipped with a motor 252 and an extracting pump 253, 226 a main changeover valve, 212 a main pump, 244 a first flotation tank, 232 a second flotation tank, and 254 an oil matter discharge pipe.

15 A feed of oil contaminated water is passed through pre-treatment device such as a strainer and the like, pumped into the coalescing unit element 221 via the
20 pump 212, the first flotation tank 244 and the main changeover valve 226.

20 Fig. 12 is a longitudinal section of the coalescing unit 214. The coalescing unit 214 includes a coalescing cylinder 215 provided at its lower portion with a middle flooring 217 to form a passage chamber
25 218. An opening 219 is formed in the central portion of the flooring 217 over which is mounted an element chamber 220. The chamber 220 is incorporated with the coalescing element including a porous material 224 on
30 which is applied a specific coalescing layer capable of absorbing and transmitting water therethrough. The element 221 may be identical in construction with the widely available element. More specifically, the porous material 124 treated as mentioned above is corniced around a cylindrical member 223 having a number of through holes 222, 222 at the center. The

member 223 is positioned in alignment with the opening 219 in the flooring 217 and fixed thereon. There is then left an appropriate space 233 around and above the element 221.

5 The coalescing unit 214 is also formed with inlet (outlet) pipes 227a, 229a in communication with the changeover valve 226 and with a pipe 227b for connecting a plurality of cylinders 215 with each other, if applied. It is noted that, where the
10 coalescing cylinder 215 is of a single stage arrangement, the process liquid returns from the connecting pipe 227b to the changeover valve 226. The oil contaminated water fed by the main pump 212 is passed through the changeover valve 226 as indicated by
15 the solid lines in Fig. 12, enters the element chamber 220, permeates through the porous material 224, and enters an element chamber 220 of the next coalescing cylinder 215 from the outlet pipe 227b via the opening 219 in the middle flooring 217. A material flow
20 similar to that in the first cylinder 215 is also formed in the second cylinder 215. This flow is fed to the changeover valve 226 via the element chamber 220 and the element 221, from which it is supplied into the second flotation tank 232.

25 As the oil contaminated water enters the coalescing unit 214 and permeates through the element 221, a dispersion with fine oil droplets having a size of at most 10 microns being dispersed, to say nothing of the coalesced oil, is positively collected owing to the
30 oil-absorbing function under the action of the porous material 224 on which is applied the specific layer capable of separating oil from water due to its water-transmitting and absorbing properties. The thus collected oil grows into a larger oil drops which are

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spontaneously floatable, and ^{are} ^a separated out due to floatage as well as the oil separating function provided by the (oil-repelling) gel layer on the porous material 224. With the element 221 having such a unique function, it has now been found that oil drops in the emulsion form can grow into larger drops and be separated off, despite the fact that they have been considered unable to be isolated.

The oil reaching the top of coalescing unit 214 shown in Fig. 12 is positively extracted as occasion arises or at regular intervals by the pump 253 incorporated in the extractor 251, and is fed into the second flotation tank 232. Especially where a plurality of coalescing units 214 are arranged in multistage manner, an extractor is provided for each coalescing unit. With this arrangement, the liquid mixture having a high oil concentration serves to reduce a load applied on the surface layer of element 221 in the next coalescing unit 214 in the course of coalescing, thus making marked improvements in the efficiency and durability of coalescing units 214.

It has been found that the provision of extractors results in considerable reductions in the number of coalescing units 214.

The concentrated oil matter thus fed to the second floating tank 232 is further fed to an oil-water separator which automatically separates the oil from the water by use of different levels resulted from the different specific gravities.

A typical conventional separator by specific gravity is illustrated in Fig. 13. A water reservoir 362 into which is introduced a feed of oil contaminated water is

provided at its lower portion with an inlet portion 364 for a water discharge pipe 363, which extends vertically from the inlet portion 364 and terminates in an outlet port 365 positioned outside of the reservoir 362. The reservoir 362 is also provided at its inner upper portion with an inlet port 369 for an oil discharge pipe 368 terminating in an outlet port located outside of the reservoir 362. The inlet port 369 for the oil discharge pipe is then positioned at a level higher than the outlet port 365 for the water discharge pipe. Such a level difference is shown at H_d .

On the other hand, oil matter built up in the upper portion of a flotation tank 332 is slowly pumped into the reservoir 362 by adjustment of a valve 332₁' mounted on an oil-ascending pipe. Only the highly concentrated oil matter is separated from the oil contaminated water in the reservoir 362, and automatically forms an oil layer in the upper portion thereof. Upon the oil layer reaching at its uppermost surface the inlet portion 369 for the oil discharge pipe, only the oil matter is automatically discharged through the inlet port 369 to the outside. The treated water free from oil matters of high concentrations enters from the inlet portion 364 provided in the bottom of water reservoir 362 into the water discharge pipe 363, and is discharged through the outlet port 365 to the outside. It is noted that, since there is a level difference H_d between the inlet port 369 for the oil discharge pipe and the outlet port 365 for the water discharge pipe, only the treated water is automatically discharged with no removal of the oil matters until the thickness of the oil layer amounts to H_d . No automatic discharge of the oil matters takes place through the outlet port 369 until the oil layer has a thickness amounting to H_d . The oil level is always maintained at a level higher than the water

level due to the difference in specific gravity between the oil and water parts. The prior art oil-water separator illustrated is characterized in that, by making use of such a level difference H_d , an oil matter
5 can be removed through an oil discharge pipe only after an oil layer is surely formed, having a thickness amounting to at least H_d .

The conventional arrangement of Fig. 13, although functioning satisfactorily in a stationary state, has a
10 disadvantage in that it cannot follow a tilting movement. That is to say, a level difference H_d varies in an inclined state with resultant discharge of ~~water~~ water through the inlet port 369 for the oil discharge pipe, since there is a distance between the outlet port
15 365 for the water discharge pipe and the inlet port 369.

The following apparatus provides an oil-water separator which is free from the above-mentioned drawbacks, and can sufficiently be used in, for example, shipping experiencing tilting and rolling movements.

20 Referring to Fig. 14 which is a sectional view of one embodiment of the present invention, a water reservoir 362 is provided at its lower portion with an inlet 364 for a water discharge pipe, and at its central upper portion with an outlet 365 for the water discharge
25 pipe, which is positioned vertically. Above the outlet 365, there is an opening space 367 which is covered with a water discharge pipe sleeve 366 positioned at a level sufficiently higher than a liquid level. The water treated is discharged through the pipe 366. An
30 inlet port 369 for an oil discharge pipe is provided around the sleeve 366. The oil discharge pipe inlet 369 is positioned at a level higher than the water discharge pipe outlet 365 (with a level difference H_d),

whereby an oil matter is separated from oil contaminated water and constantly discharged in an automated manner. The arrangement of Fig. 14 is different from that of Fig. 13 in the following

5 points. In accordance with the Fig. 14 embodiment, the water discharge pipe outlet 365 and the oil discharge pipe inlet 369 are located at the center portion of the water reservoir and positioned in proximity to each other with a level difference H_d , and the opening 367

10 in the water discharge pipe sleeve 366 applied on the port 365 is positioned at a level sufficiently higher than a liquid level. With such an arrangement, there is no virtual variation in the level difference H_d between the outlet port 365 and the inlet port 367,

15 even in an inclined state. Consequently, only an oil matter can be discharged through the oil discharge pipe inlet 369, even when the arrangement is out of the perpendicular. There is also no possibility that an oil matter may enter the water discharge pipe 366 due

20 to tilting or rolling, since the opening 367 in the sleeve 366 is positioned considerably above a liquid level. Namely, the separator of the present invention is not affected by tilting or rolling, and can constantly effect automated separation of oil matters from oil contaminated water, and discharge of the oil

25 matters and the treated water. As shown in Fig. 14, the ^(angular) ~~angular~~ disposition of the oil discharge pipe 368 and the water discharge pipe 366 assures satisfactory discharge of oil and water even in a state where the

30 separator is out of the perpendicular. The device explained in the foregoing is suited for a ship which is subjected to vibration or tilt. In order to prevent waves from being created on the liquid surfaces oil-resistant and net-shaped structure may be provided

35 below the surface of the liquid shown in Fig. 14. In such an example, it is preferably that the structure

has a predetermined thickness and extend from the water discharge pipe 366 and the oil discharge pipe inlet 369 to cover the entire liquid surface such as to meet the minimum tilting requirement of 25 degrees in all directions stipulated in the Ocean Pollution Prevention Law according to the IMCO Convention.

Another example of oil-water separator will be explained referring to Fig. 15. In a water reservoir 362, a water discharge pipe 363, an oil discharge pipe 368 and a water discharge pipe sleeve 366 are ^(provided) at their middle portions with flexible pipe members 363', 368' and 366'. A plurality of floating rods 372 extend sideways from the pipe 368, and are provided with floats 373. The floating rods 372 are also formed at the distal ends with float guides 374 which serve to maintain a water discharge pipe outlet 365 and an oil discharge pipe inlet 369 at the center of reservoir 362, when the separator is out of the perpendicular. In the embodiment as illustrated in Fig. 16, the float guide comprises a radially extending L-shaped lever 374₁ pivotable around its apex, a balance weight 374₂ attached to its inside and a guide 374₃ attached to its outer end.

With such an arrangement, the water discharge pipe outlet 365 and the oil discharge pipe inlet 369 can follow a tilt of the associated vessel, i.e., an inclination of the water reservoir. The water discharge pipe outlet 365 and the oil discharge pipe inlet 369 are maintained at the central position of the water reservoir 362 under that action of the guides 374. That is to say, when a tilt is given to the reservoir 362 to form the liquid surface into an ellipitical shape, the balance weight 374₂ in correspondence with the major axis thereof descends and

forces out the guide 374₃, so that the outlet 365 and the inlet 369 are always maintained at the central position of the reservoir 362. The embodiment of Fig. 14 can sufficiently follow a tilt of the reservoir 362, provided that the oil discharge pipe inlet 369 has sufficiently small diameter relative to the reservoir 362. When it is required to increase the diameter of the inlet 369 for attachment to a large-sized vessel, however, there is a risk that a portion of water below the oil layer may possibly enter the oil discharge pipe inlet 369 of Fig. 14 by an inclination thereof. The example of Fig. 15 is characterized in that it can completely follow a tilt of the liquid surface since the diameter of the oil discharge pipe inlet 369 is relatively large. Thus, this example provides an automated oil discharge device which, if applied to a large-sized vessel, can function satisfactorily without being affected by a tilt of the vessel. An automated discharge device using an electric sensor is known but is presents malfunction problems when used with a creamy oil matter having a large content of water. This is the reason why the separator according to the present invention is developed.

As mentioned above, the separator can automatically separate and discharge oil matters from oil contaminated water without being affected by tilting and rolling movements of a vessel to which it is attached, and can be best suited for use in shipping with good performance, thus meeting the above mentioned IMCO requirements.

Further, it is preferable that a coalescer is provided in the reservoir 362 and/or the flotation tank 332 to prompt the oil particles to float in a shortest possible time. As shown in Fig. 16, there is provided

a coalescer 370 in the flotation tank 332, which coalescer includes a plurality of slanting plates 371 maintaining predetermined spacings.

5 It is known in general that the larger the diameters of oil particles dispersed in the water are, the quicker those particles float on the water surface. If the tank 332 is partitioned by the slanting plates, the particles reach the plates in a shorter time than they float onto the water surface where no coalescer is
10 provided. Thus, even if the diameters of the particles are small, they reach the slanting plates one after another to coalesce each other to become larger-sized oil particles. Those oil particles ascend along the plates 371 to reach the liquid surface. This is known
15 as coalescence effect. The coalescer may be provided not only in the form of the example shown in Fig. 16 but may be provided in the reservoir 362. Moreover, if it is provided in the flotation tank 144, 244, or 232 in the embodiments of Figs. 1, 9 and 11, the efficiency
20 of oil-water separation of the entire system shows remarkable improvement.

Referring to Fig. 17, there is shown a flow ^(chart) ~~change~~ of another embodiment, wherein reference numeral 421 stands for an element, ^(For 2) 414 coalescing unit including
25 therein element 421, 451 an oil extractor equipped with a driving device 452 and an extracting pump 455, 456 an extraction tank, 426 changeover valve, 430 a water supply pipe, 458 a discharge pipe, 412 a main pump, 444 a first flotation tank 432 a second flotation tank, and
30 459 an automated oil matter discharge device.

A feed of oil contaminated water is passed through a pretreatment device such as a strainer and the like, and pumped into the coalescing unit 414 having element

421 via the pump 412, the first flotation tank 444 and the changeover valve 426.

Fig. 18 is a longitudinal section of the coalescing unit 414. The coalescing unit 414 includes a
5 coalescing cylinder 415 provided with a middle flooring 417 to form a passage chamber 418. An opening 419 is formed in the central portion of the flooring 417 which defines an element chamber 420. The chamber 420 is
10 incorporated with the coalescing element including a porous material 424 on which is applied a specific coalescing layer capable of absorbing and transmitting water therethrough. The element 421 which takes a
horizontal position may be identical in construction with the widely available element. More specifically,
15 the porous material 424 treated as mentioned above is corniced around a cylindrical member 423 having a number of through holes 422, at the center. The member 423 is positioned in alignment with the opening 419 in the flooring 417 and fixed thereon. There is then left
20 an appropriate space 433 around and above the element 421.

The coalescing unit 414 is also formed with inlet (outlet) pipes 427a, 429b, 427b in communication with the changeover valve 426. The mechanism 451 for
25 extracting oil matters built up in the coalescing unit 414 is connected with the coalescing unit 414 by an inlet (outlet) pipe 429b. The oil matters are extracted in the upper portion of the tank 456, and the water from which the oil matters have been separated in
30 the tank 456 is returned to the next coalescing unit 414 or the changeover valve 426 via the pipe 427a or 427b. The oil contaminated water fed is by the pump 412 through the changeover valve 426 as indicated by the solid lines in Figs. 18 and 19, enters the passage

chamber 418, permeates through the porous material 424 of the element 421, and is forcibly fed into the extraction tank 456. The oil matters extracted in the upper portion of the mechanism 451 is extracted via the extraction valve 455, and is supplied into the second flotation tank 432. The water treated is returned to the changeover valve 426 via the pipe 427b, and forcibly supplied into the second flotation tank 432 via the discharge pipe 431.

10 As the oil-containing water enters the coalescing unit 414 and permeates through the element 421, a dispersion with fine oil droplets having a size of at most 10 micrometres, to say nothing of the coalesced oil matter, is positively collected owing to the
15 oil-absorbing function under the action of the porous material 424 on which is applied the specific layer capable of separating oil from water due to its water-transmitting and absorbing properties. The thus collected oil matter grows into a larger oil drop which
20 is spontaneously floatable, and is separated out due to floatage as well as the oil-separating function provided by the (oil-repelling) gel layer on the porous material 424. With the element 421 having such a
25 unique function, it has now been found that oil drops in the emulsion form can grow into a larger drop and being separated off, despite the fact that they have been considered unable to be isolated.

The oil matters coalesced by the coalescing unit 414 is accumulated in the upper portion of the tank 456, and
30 positively extracted as occasion arises or at regular intervals by the extraction valve 455 of the mechanism 451 operable by the driving mechanism 452. The oil matters are then supplied into the second flotation tank 432. Especially where a plurality of coalescing

units 414 are arranged in multistage manner, an extractor is provided for each coalescing unit. With this arrangement, the oil matter having a high oil content and/or a high oil concentration serves to
5 reduce a load applied on the surface layer of element 421 in the next coalescing unit 414 in the course of coalescence thus making marked improvements in the efficiency and durability of coalescing units 414.

10 It has been found that the provision of extractors 451 results in considerable reductions in the number of coalescing units 414. In general, the oil-containing water is contaminated with many kinds of impurities (SS) such as suspended matters and fine dust. For this
15 reason, clogging of the element 421 takes place during use with resultant lowering of the efficiency thereof. In such a case, most of conventional systems were shut down to wash the element for the purpose of recovering their function, leading to a reduction of processing
20 ability to a marked degree. The present invention offers a skillful solution to this problem, and enables the apparatus to be operated in a continuous manner without shutdown, while the element is washed.

In the present invention, the direction of material flow is changed by the operation of the changeover
25 valve 426 to cause reversal of the flow before clogging of the element 421 occurs. The manipulation of the changeover valve causes the flow of oil contaminated water to be reversed as shown by solid line arrows and dotted line arrows in Fig. 18. This reversal flow
30 causes removal of SS deposited onto the face of the porous material 424 opposite to the flow. Moreover, oil droplets of smaller and larger sizes which are deposited onto this face will also be removed and separated by this reversal of the flow. Both sides of

the element serve equally for the coalescence and growth of oil drops notwithstanding the direction of the flow of oil contaminated water. The operation of the changeover valve 426 may be performed manually
5 independently upon the given duration of operation, the given throughput and the increase in feed pressures. Alternatively, the changeover valve may be automatically operated in cooperation with a timer, a flow meter or a feed water pressure gauge.

10 In the alternating operation according to the present invention wherein the direction of material flow is altered, successful removal of oil particles from the element is attained with attendant pressure loss amounting to as low as about 0.1 to 0.4 Kg/cm², so that
15 the element 421 is of high water permeability. Such a high water permeability, coupled to the extraction of oil matters, enables the element 421 to coalesce an oil matter having a high viscosity at lower pressures.
20 This offers one of the characteristic features of the present invention.

In the oil-water separator systems, it is generally said that the higher the feed pressure, the lower will be the separation efficiency because of fine
25 coalescence of oil. In the present invention, however, a lower pressure can be applied as discussed above, so that such fine coalescence of oil is avoided. This has a synergistic effect that assures satisfactory coalescence of oil drops in the present invention.
30 These considerations lead to the realization of the present invention.

While the foregoing explanation implies a case where a plurality of element cylinders 414 are arranged in multistage manner, whether the apparatus is of a single

stage or multistage arrangement may be dependent upon the throughput of oil contaminated water, and the concentration and viscosity of an oil matter. Alternatively, it may be possible to operate only parts of the multistage apparatus under normal conditions, the apparatus being operated in its entirety only under severe conditions.

An automatic oil discharge section 459 may be provided on top of the further flotation tank 432. The oil discharge section 459 may be of the type shown in any of Figs. 14 to 16.

Referring to Fig. 19 which schematically shows the method of the present invention, a feed of oil-contaminated water is fed into a changeover valve 526 via a first flotation separation tank 544. Crude oil matters are eliminated by an oil matter removing device 559 in the first flotation separation tank 544. A flow direction changeover mechanism 577 for the oil contaminated water comprises a motor 575 and a changeover valve 526 for effecting flow direction changeover of the oil contaminated water. Such changeover may be accompanied by reversal of the predetermined tilt of an element column 523 by putting the valve in operable association with a mechanism 576 for preventing a build-up of oil matters. Referring to the case where a feed of oil contaminated water is guided in the direction as indicated by the solid lines in Fig. 19, it is fed into a passage chamber 518 in the element column 523 having therein an element 521, and directed into an oil matter extractor 551 via the element 521 and an element chamber 520.

Fig 20 is a longitudinal section of the element column 523, and Fig. 21 is a partial cross-section of the element 521, illustrative of the flow direction of oil

contaminated water. The element 521 may be identical in construction with the widely available element. More preferably, however, the element is in the form of flat and corrugated cardboard sheets to form arrays of alternate inlet and outlet passages 542 separated by the porous cardboard. The elongated passages 542 as shown in Fig. 20 have one end 539 opened and the other end 543 closed as depicted in Figs. 20 to 21, so that the oil contaminated water permeates through adjacent passages 542 by way of the above-mentioned specific layers. The oil matter extractor 551 comprises a motor 575, an extraction valve 555 and an extraction column 556, and is operated manually or automatically depending upon operating time or pressure to extract the oil matters which are then fed into a second flotation separation tank 532.

The water thus treated by extraction is passed into the next element column 523. It is noted that, with the element column 523 of a single stage arrangement, the water treated returns from the extraction column 556 to the changeover valve 526. This is true of the case where the oil contaminated water is passed in the direction as indicated by the dotted lines in Fig. 19 by changeover of the valve 526 and opposite to that as indicated by the solid dotted lines. The treated water leaving the final stage extraction column 556 returns to the changeover valve 526, from which it is fed into the second flotation tank 532.

As the oil contaminated water permeates through of the unique layer of the element 521, a dispersion with fine oil particles having a size of at most 1 micrometre being dispersed, to say nothing of the coalesced oil matter, is positively collected owing to the oil-absorbing function under the action of the porous

material on which is applied the specific layer capable of separating oil from water due to its water-transmitting and absorbing properties. The thus collected oil matter grows into a larger oil particle which is spontaneously floatable, and is separated out due to floatage as well as the oil-separating function provided by the (oil-repelling) gel layer on the porous material. With the element 521 having such a unique function, it has now been found that oil drops in the emulsion form can grow into a larger particles and be separated off, despite the fact that they have previously been considered unable to be isolated.

The oil matter reaching the top of the element column 523 is positively extracted by an extractor 551. Especially where a plurality of element columns 523 are arranged in multistage manner, an extractor is provided for each coalescing unit. With this arrangement, the oil matter having a high oil content and/or a high oil concentration serves to reduce a load applied on the surface layer of element 521 in the next element column 523 in the course of coalescence, thus making marked improvements in the efficiency and durability of coalescing units.

The embodiment is further characterized in that the mechanism 576 is provided for the prevention of a build-up of the oil matters coalesced in the element 521 and element column 523. Referring to the embodiment of Fig. 19, the element column 523 is inclined at an angle A_1 , and is disposed for pivotal movement that is caused by the motor 575 such that the open ends of the elongated passages 542 functioning as outlets normally take raised positions. With the aforesaid angle is set A_1 , a flow of oil-contaminated water is passed in the direction indicated by the solid lines. For reversal of the

flow, the column is inclined at an angle A_2 .

As mentioned above, reversal of the angle of tilt of the element column causes the oil matters coalesced in the elongated passages 542 of element 521 and the
5 element column 523 to ascend and reach the upper extractor 551 without discontinuities, thus resulting in considerable increase in the efficiency of separation and removal of oil matters.

It has been found that the provision of extractors 551
10 results in considerable reductions in the number of element columns 523. In general, the oil contaminated water is contaminated with many kinds of contaminants or impurities (SS) such as suspended matters and fine dust. For this reason, clogging of the element 521
15 takes place during use with resultant lowering of the efficiency thereof. In such a case, most of conventional systems were shut down to wash the element for the purpose of recovering their function, leading to a reduction of processing ability to a marked
20 degree. The present invention offers a skillful solution to this problem, and enables the apparatus to be operated in a continuous manner without shutdown, while the element is washed.

It has now been confirmed that the above-mentioned two
25 requirements, i.e., prevention of accumulation of the oil matter in both the element 521 and the element column 523 and changeover of material flow, have a synergistic effect in maintaining the efficiency of the apparatus for a very extended period of time and even
30 when it is used with an oil matter a high viscosity.

In the present invention, the direction of material flow is changed by the operation of the changeover

valve 526 to cause reversal of the flow before clogging of the element 521 occurs. The manipulation of the changeover valve causes the flow of oil contaminated water to be reversed as shown by solid line arrows and dotted line arrows in Fig. 19. This reversal flow causes removal of SS deposited onto the face of the porous material opposite to the flow. Moreover, oil particles of smaller and larger sizes which are deposited onto this face will also be removed and separated by this reversal of the flow. Both sides of the element 521 serve equally for the coalescence and growth of oil drops notwithstanding the direction of the flow of oil contaminated water. The operation of the changeover valve 526 may be performed manually independent upon the given duration of operation, the given throughput and the increase in feed pressures. Alternatively, the changeover valve may be automatically operated in cooperation with a timer, a flow meter or a feed water pressure gauge.

In the alternating operation according to the present invention wherein the direction of material flow is altered, successful removal of oil particles from the element is attained with attendant pressure loss amounting to as low as about 0.1 to 0.5 Kg/cm², so that the element 521 is of high water permeability. Such a high water permeability, coupled to the forced extractor 551 for oil matters, enables the element 521 to coalesce an oil matter having a high viscosity at low pressures. This offers one of the characteristic features of the present invention.

In the oil-water separator systems, it is generally said that the higher the feed pressure, the lower will be the separation efficiently because of fine coalescence of oil. In the present invention, however,

a lower pressure can be applied as discussed above, so that such fine coalescence of oil is provided. This has a synergistic effect that assures satisfactory coalescence of oil drops in the present invention. These considerations lead to the realization of the present invention.

While the foregoing explanation implies a case where a plurality of element columns 523 are arranged in multistage manner, whether the apparatus is of a single stage or multistage arrangement may be dependent upon the throughput of oil contaminated water, and the concentration and viscosity of an oil matter. Alternatively, it may be possible to operate part of the multistage apparatus under normal conditions, the apparatus being operated in its entirety only under severe conditions.

This system is not only adequate for the batchwise processing of oil contaminated water, but also demonstrates an especially superior effect in the processing of emulsified finely divided oil contaminated water including oil particles made smaller than 1 micrometre by the effect of a surface active agent, which could not be attained by conventional technique. For example, it has been confirmed by experiment that the water containing 250,000 ppm of light oil can be processed to less than 5 ppm under the test specification of ship's equipment in accordance with the IMCO-Convention, and that 5 ppm determined as the limit for industrial waste water for environmental protection can perfectly be attained.

This invention has especially novel features in permitting separation of not only the finely divided oil but also the emulsified oil matter, because of the

89

- 40 -

formation of the specific layer mainly consists of water insoluble hydrous gel layer having an oil water separation function as well as oil-resisting and oil-repelling function .



CLAIMS:

1. A method for oil-water separation by coalescence comprising the steps of producing a coalescing layer having oil-resisting and repelling properties as well
5 as water transmitting and absorbing properties on at least one surface of a porous member by forming thereon a water-insoluble hydrous gel layer while maintaining the porous nature of said member to obtain a coalescing element; subjecting said coalescing element in a
10 coalescing unit to a flow of an oil-contaminated water such that said oil contaminated water passes through the porous material to catch and coalesce emulsified oil particles upon said at least one surface, said oil-contaminated water being passed alternately in
15 opposite directions through the coalescing element; and then separating the thus coalesced oil and the water from each other.
2. A method as claimed in claim 1, further including
20 prior to said subjecting step a step of gravity separating an oil matter from said oil-contaminated water in a flotation tank.
3. A method as claimed in claim 1 or 2, wherein said separating step after the subjecting step is effected by gravity.
- 25 4. A method as claimed in claim 1 or 3, wherein said subjecting and separating steps are performed as a plurality of consecutive alternating stages.



5. Coalescing apparatus for use in oil-water separation by coalescence comprising a coalescing element having a coalescing layer exhibiting oil-resisting and repelling properties, said element being produced by forming a water-insoluble hydrous gel on at least one side of a porous member while maintaining the porous nature thereof; a casing accommodating said coalescing element; inlet and outlet means provided in said casing; and means for reversing flow through said coalescing element so as to permit oil-contaminated water to flow through the coalescing element alternately in opposite directions.

6. An apparatus as claimed in claim 5, further including a flotation tank to receive oil-contaminated water prior to its flow into said casing.

7. An apparatus as claimed in claim 6, further including a reservoir provided on top of said flotation tank to receive the oil contaminated water from said flotation tank; a water discharge pipe having an inlet at its lower end and extending vertically upwards from a central portion of the bottom of said reservoir to a predetermined level below the surface of the oil contaminated water; a water discharge pipe sleeve surrounding an upper end portion of the water discharge pipe to separate the upper end portion from the oil-contaminated water, the upper end of said discharge pipe allowing overflow discharge water into said sleeve, the sleeve extending higher than the water surface and being adapted to discharge the water separated from the oil from the reservoir; and



an oil discharge pipe surrounding a portion of the water discharge pipe sleeve and having an inlet port slightly below the level of the oil contaminated water and above the upper end of the water discharge pipe such that the oil separated from the water is discharged from the reservoir by use of the difference of levels of oil and water due to the different specific gravities of the oil and the water.

8. An apparatus as claimed in claim 7, further including coalescer means within at least one of the said flotation tank and said reservoir.

9. An apparatus as claimed in claim 5, wherein said coalescing element is in the form of a stack of alternate flat and corrugated cardboard sheets to form arrays of alternate inlet and outlet passages separated by porous cardboard.

10. An apparatus as claimed in claim 9, wherein said alternate inlet and outlet passages have ends thereof closed and open alternately.

11. An apparatus as claimed in any one of the claims 5, 9 and 10, further including means for extracting a build-up of concentrated oil-contaminated water within said casing.

12. An apparatus as claimed in claim 11, further including a flotation tank to store the concentrated oil-contaminated water extracted by said extracting means; a reservoir provided on top of the flotation tank and into which said concentrated oil-contaminated water is passed from the flotation tank; a water discharge pipe having an inlet at its lower end and extending vertically upwards from a central portion



of the bottom of said reservoir tank to a predetermined level below the water surface of the concentrated oil-contaminated water; a water discharge pipe sleeve surrounding an upper end portion of the water discharge pipe to separate the upper end portion from the oil-contaminated water, an upper end of said water discharge pipe allowing overflow discharge water into said sleeve, said sleeve extending higher than the water surface, and being adapted to discharge the water separated from the oil from the reservoir; and an oil discharge pipe surrounding an upper end portion of the water discharge pipe sleeve and having an inlet port slightly below the liquid level and above the upper end of the water discharge pipe such that the oil separated from the water is discharged from the reservoir by use of the difference of levels of oil and water due to the different specific gravities of the oil and the water.

13. An apparatus as claimed in claim 12, further including coalescer means within at least one of the said flotation tank and reservoir.

14. An apparatus as claimed in claim 12, wherein intermediate portions of said water discharge pipe, said water discharge pipe sleeve, and said oil discharge pipe are flexible, said oil discharge pipe having a plurality of floating rods radially extending therefrom, each of said floating rods carrying a respective float and a respective L-shaped lever, each float being positioned at an intermediate portion of its respective rod and each lever being pivoted at its apex on an end of its respective rod, one end of the lever carrying a balance weight and the other end of the lever carrying a guide which engages an inside wall of the reservoir.



24

15. An apparatus as claimed in claim 9, wherein said coalescing element takes a position such that said inlet and outlet passages are oriented vertically.

5 16. An apparatus as claimed in claim 9, wherein the coalescing element is adapted for pivotal movement so that the open ends of the elongated passages functioning as outlets always take raised positions.

10 17. An apparatus for oil-water separation by coalescing comprising a plurality of coalescing elements, each element having thereon a coalescing layer having oil-resisting and repelling properties, each said element being produced by forming a
15 water-insoluble hydrous gel on at least one side of a porous member while maintaining the porous nature thereof; each coalescing element being accommodated in a respective casing; inlet and outlet means provided in each of said casings; and means for reversing flow
20 through each of said coalescing elements so as to permit oil-contaminated water to flow through said coalescing elements alternately in opposite directions.

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18. An apparatus as claimed in claim 17, further including means for extracting built-up oil in said casings.

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25 19. An apparatus as claimed in claim 5 or 17 further including a storage tank to store the oil-contaminated water which is to be admitted into the ^{or a said} casing and suction means for sucking oil contaminated water having a high oil content from the surface of the
30 oil-contaminated water stored in said storage tank and delivering said oil contaminated water having a high oil content to the casing.

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65



20. An apparatus as claimed in claim 19, wherein said suction means includes an outer cylinder having a take-out tube at a bottom thereof and positioned below the liquid level, and a weir cylinder vertically
5 movable within the outer cylinder and adapted to keep a brim thereof positioned slightly below the liquid level and providing communication with said take-out tube.

21. An apparatus as claimed in claim 20, wherein said brim is of saw-edge configuration.
