

PATENT SPECIFICATION

(11) 1 530 690

1 530 690

- (21) Application No. 14594/76 (22) Filed 9 April 1976
(31) Convention Application No. 566926
(32) Filed 10 April 1975 in
(33) United States of America (US)
(44) Complete Specification published 1 Nov. 1978
(51) INT CL² B01D 33/02 21/10
(52) Index at acceptance

BID 107 121 154 165 195 196 197 205 208 211 213 310 313 331
332 335 343 353 356 500 520 531 544 545 602 637 701
709 711 716 761



(54) METHOD AND APPARATUS FOR COALESCING

(71) We, MARINE CONSTRUCTION & DESIGN CO., a Corporation of the State of Washington, of 2300 West Commodore Way, Seattle; Washington 98199, United States of America, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to separation of the components of immiscible liquid mixtures, such as oil and water, wherein one of the liquids (the oil) is finely dispersed in the other liquid. More particularly, the present invention is directed to improved processes and apparatus making novel use of the combined effects of specific gravity differences of the immiscible liquids, substantially static conditions maintained with the pores of a mixture holding and transport matrix, and the "catalytic" effect of the pore surfaces selectively attractive to the liquid to be coalesced. The resultant mixture thus transported by the matrix to a point of discharge while coalescence is occurring is thereby conditioned for separation of the coalesced first liquid from the second liquid by other physical processes and apparatus known in the art.

Environmental protection efforts in recent years have yielded various proposals for separating oil from water. Most techniques operated on the assumption that the oil is already stratified, i.e., either floating as a layer on the water or existing in sizable globules readily settled out of suspension or readily contacted by filter element surfaces. Most of the floating oil existing in that condition can be recovered by any of different techniques including skimming, decanting, contact filtration or contact absorption.

In many situations, however, oil pollution of water exists wherein the oil is dispersed in droplets of such minute size that bulk or stratified oil separation techniques are ineffective. Typical of these are waste or by-product water discharged from

manufacturing facilities such as oil refineries, oil/water mixtures pumped centrifugally against substantial heads and resulting in oil dispersion, engine cooling water discharge, industrial or commercial establishment run-off water where oil is present, ships bilge water and ships ballast water. Under the increasingly rigid anti-pollution policies of industry and government, even the slightest traces of oil are objectionable; for example, as little as 10 parts million of oil in water. This is true not only with oil spills on open bodies of water but often in fixed installations wherein large volumes of water containing small traces of oil must be purified economically. Chemical treatment to precipitate the oil or to convert it into an acceptable material is usually not economical. Flow-through filters act too slowly and are not effective to coalesce minute oil particles.

For example, in seemingly quiescent settling ponds or tanks, naturally occurring thermal convection or other disturbances, however, small, tend to keep the particles or droplets continuously in motion. Those that settle to the surface of the water are extremely slow to coalesce. The relatively very high surface tension acting upon such small oil droplets tends to keep the droplets apart and thwarts coalescence.

Flow-through filter type coalescers are also of limited effectiveness. The light, minute oil droplets are extremely "motile" i.e., motion-reactive to the slightest pressure gradients in the surrounding water and thereby avoid contact with surfaces. Viscous boundary layer forces attending flow, however slow, along the filter matrix surfaces tend to keep the oil droplets away from the surfaces owing to velocity gradients and attendant pressure gradients. Further, matrix surface irregularities causing adjacent flow path curvature force the lighter oil droplets away from the intended coalescing surfaces through centrifugal force effects. Since these are both velocity-dependent effects, attempts

(15) (16)

5 to increase mixture processing rates in conventional flow-through coalescing filters are counter-productive. Capacity increase effected through increased filter element cross-sectional dimensioning, or by adding banks of filters, adds undesirably to the bulk and cost of the apparatus as a whole. Flow-through filters with matrix channels smaller than oil droplets diameter can effectively coalesce oil, but tend to plug up so as to require frequent cleaning or replacement of filter elements.

10 A further object herein is to overcome the problems described, and to devise a coalescer apparatus which is essentially self-reconditioning, continuously and reliably operable unattended substantially over long time periods, and relatively non-critical in terms of operating capability as affected by particle size or mixture proportions.

15 A further object hereof is to achieve the stated objectives with process and apparatus concepts that offer versatility in selecting the overall physical size and shape of equipment to suit varying installation and operation requirements. Thus scaling up or scaling down the size to vary the volumetric capacity proportionately may be done without adversely affecting operating efficiency or effectiveness.

20 According to one aspect the invention provides a process of coalescing droplets of a first liquid suspended in an immiscible mixture thereof with a second liquid comprising ingesting the mixture into the voids of a porous resiliently compressible and expansible matrix immersed in the compressed state in the mixture, such ingestion occurring as the matrix expands from the compressed state while immersed in the mixture, holding the ingested mixture in the matrix in a quiescent state until all or substantially all of the droplets have settled and coalesced in the voids of the matrix and thereafter discharging the ingested liquids from the matrix by pressure applied to the matrix.

25 According to a further aspect the invention provides apparatus for coalescing droplets of a first liquid suspended in an immiscible mixture thereof with a second liquid comprising an endless circulatory matrix of porous, resiliently compressible and expansible material, enclosure means having space therein formed to contain a body of the mixture and a length portion of the matrix immersed in such mixture, and means for compressing said length portion of the matrix prior to immersion in the mixture, operating means, mounting, guiding and moving the circulatory matrix progressively in an endless circulation path which in part extends through the enclosure

means space and causes successive length portions of the matrix passing through the body of mixture to ingest such mixture into its pores, and means for applying pressure to the matrix to purge ingested mixture liquids therefrom.

70 In the preferred and illustrated embodiment the matrix, formed as an endless belt moved circuitously, ingests mixture to be processed in passing through a body thereof, holds such mixture through an interval during which quiescent settling conditions are maintained in the matrix pores, transports the liquid away from the body of mixture to a discharge point, and finally is purged of the liquid at such point. Preferably the matrix belt or band is of a resiliently compressible open-pore polymeric or similar "foam" material. Purging it of liquids is accomplished by squeezing. Reexpansion of the matrix as it reenters the body of mixture causes it to ingest more mixture to start another operating cycle. As a pump the coalescer matrix moves large amounts of liquids while coalescence occurs, whereas in flow-through coalescence filters the liquids can be moved only extremely slowly.

75 As a further feature, the belt is shielded from external disturbances during its holding run by a shielding cover. By moving the band in a horizontal plane hydraulic level remains substantially constant throughout the holding interval, i.e., the matrix remains effectively immersed during its travel, even though the ingestion and discharge chambers are effectively sealed by the belt end associated elements. There is thus no tendency for the quiescently held liquids to drain out of the matrix during the transport-holding interval, impairing the settling action.

80 While there may be slight circulatory motion within each individual pore space due to the changing orientation of the pore walls as the matrix moves in its orbital path of circulation, such motion is so very slight and occurs in a plane at right angles to the direction of settling that it does not impair settling rates or efficiency and thereby can be ignored as negligible under intended operating conditions as herein described.

85 Preferably the matrix is mounted as a jacket surrounding an upright rotary cylindrical support. The support comprises part of the enclosure means and provides a backing surface against which the jacketing matrix is compressed by compression means such as an upright roller that accomplishes purging of the matrix at the end of the coalescence interval, and preparation of the matrix for reingestion of mixture liquids by expansion as it reenters the original body of mixture, and also serves as part of a sealing barrier separating

70

75

80

85

90

95

100

105

110

115

120

125

130

the enclosure compartments from each other which contain the first and second bodies of mixture.

These and other features, objects and advantages of the invention will become more fully evident from the following description thereof by reference to the accompanying drawings in which:—

Figure 1 is a process diagram of the invention.

Figure 2 is an isometric view, Figure 3 is a plan view, Figures 4 and 5 are elevation views from different sides showing the improved coalescer in one form, with parts broken away to reveal certain details; and Figure 6 is an isometric view of the coalescer matrix band and support drum removed from the unit and partially sectioned to reveal structural details.

Figure 7 is an oil droplet settling velocity graph.

Figure 8 is a settling (coalescence) time graph.

Figure 9 is an isometric view of a modified coalescer employing principles of the first described embodiment in a unit of different configuration.

In the schematic diagram of Figure 1 the main process steps are illustrated in sequence together with the relationship between smallest size droplet diameter, settling motion velocity, maximum dimension of the matrix voids and minimum settling time attainable under idealized conditions.

In carrying out the process as indicated by the diagram of Figure 1, the matrix traverses a path of movement in a direction indicated by the arrowed line during which it becomes immersed in the immiscible mixture of droplets of a first liquid (e.g. oil) suspended in a second liquid (e.g. water). Ingestion takes place and during continuing movement of the matrix the ingested liquid is retained in a quiescent state for a time period sufficient to permit all or substantially all of the droplets to settle and coalesce in the voids of the matrix, the matrix then being purged of the ingested liquids by applying pressure to the matrix.

The approximate period of time for retaining the ingested liquid in the quiescent state can be obtained from the following formula:

$$t \geq \frac{D-d}{r}$$

wherein

t=time period

D=matrix void dimension in direction of settling

d=diameter of droplets

r=settling velocity of droplets.

In Figure 7 the graph illustrates droplet velocity (in settling motion under gravity

conditions) as a function of droplet radius. In Figure 8, settling time of different size droplets in reticular foam matrixes of different pore diameters is illustrated assuming a fully reticulated foam matrix and matrix pores of substantially uniform size in the matrix. Comparison of the numerical values in Figures 7 and 8 will show that actual settling time takes into account the necessity of the average droplet to move through a distance of more than one pore diameter before it contracts and settles upon a pore strand, this being due to the openness factor of a fully reticulated foam matrix or network used as the settling medium.

In Figure 2 et seq the coalescer comprises an outer tank or container 10 of cubical shape. The tank bottom 12 is reinforced by stiffener channels 14. A hollow circular cylindrical drum 16 is mounted within the tank on a support shaft 18 maintained in vertical position by upper and lower end mounting journals 20 and 22 so as to be rotatable about a vertical axis. The rotary drum 16 is sealed by top and bottom walls 24 and 26 and reinforcing intermediate partitions 28. Encircling the drum from top to bottom is a polyvinylchloride jacket 30 bonded to the drum's exterior surface. Surrounding the PVC jacket is a polyurethane reticulated foam sleeve or jacket 32 in turn bonded to the PVC. The jacketing band 32 serves as the coalescer matrix according to the invention. The upper end of the drum shaft 18 fixedly supports a drive sheave 34 which is driven by a belt 36 engaging a pulley 38 driven by a motor unit 40.

Typically with polyurethane reticulated foam material in the matrix of the order of 60 to 100 pores per inch the motor drive unit will be operated to turn the drum at a speed of up to approximately four revolutions per minute, which affords a settling interval of about fifteen seconds or longer.

The lower edge of drum 16 moves in sliding substantially sealed contact with a shoe or sheet of polyvinyl chloride 42 supported on a platform plate 44 elevated about the tank bottom upon a supporting frame 46 (Figure 3). The lower drum shaft journal 22 is mounted within the base frame 46. Plate 44 is circular in form and comprises the supportive base of a circular cylindrical shield 48 extending between the tank bottom 12 and the tank top 50. The matrix 32 is fitted to be slidably received within the sleeve, such that the resiliently compressible polyurethane foam matrix is in slight compression from the shield throughout. The shield 48 is open circumferentially to the extent of about 60 degrees of arc starting from the vertical edge 52 and extending to the outturned

18

1,530,690

4
vertical edge 54. Intermediate the edges 52
and 54 is located a squeeze roller 64
engaged by a sealing, scraper blade 56
mounted on a partition 58 extending
5 vertically from top to bottom of the tank
and projecting laterally inward from the
adjacent side wall of the tank. In
cooperation with other elements to be
described the partition 58 and blade 56
10 engaging the squeeze roller divide the
adjacent region of the tank into a mixture
receiving compartment 60 and a mixture
discharge compartment 62.

15 Squeeze roller 64 is mounted at top and
bottom on swinging arms 66 so as to turn
freely on a vertical axis at the ends of such
arms. The base ends of the arms on an
upright shaft 68 carried in bottom and top
journals 70 and 72. A worm and wheel drive
20 74 operated by a hand crank 76 (or power
driven unit if desired) can be turned so as to
move the squeeze roller 64 toward and from
the adjacent side of the drum matrix sleeve
32, between the solid-line and broken-line
25 positions of the roller shown in Figure 3. In
its broken-line position the retracted
squeeze roller 64 is out of contact with the
coalescer matrix band 32 whereas in its
solid-line position the squeeze roller has
30 compressed the band 32 firmly against the
opposing solid wall of the matrix carrier
drum 16 as shown. In the roller's latter
position the wiper or scraper 56 presses
against the PVC coated surface of the roller
35 and forms a fluid-tight seal against that
surface extending between the bottom wall
sheet 42 and top of the container.

The remaining closure elements sealing
off the receiving chamber 60 so that
40 unprocessed mixture liquids may not seep
into the discharge chamber 62 include the
squeeze roller itself, the matrix band 32
compressed against the drum 16 by the
roller, the sealing frictional contact
45 interface between the shield 48 adjacent to
and extending circumferentially from the
shield's entrance edge 54, and the frame
channel 70 which supports the shield 48 and
spans between the shield and the adjacent
50 container side wall as shown. An infeed
pipe 73 delivers mixture into the receiving
compartment 60 for processing in the
coalescer.

55 With the drum rotated in the direction
of the arrow shown in Figure 3 by power
unit 40, and with the squeeze roller 64
positioned in its solid position shown in the
same figure, the resiliently compressible
polyurethane matrix band 32 progressively
60 reexpands upon entering the receiving
chamber 60 and advancing toward the
shield entrance (at 54), and it thereby
ingests mixture liquids into its pores. By the
time any given portion of the matrix
65 previously compressed reaches the

entrance edge 54 of shield 48 it is fully
expanded and is full of mixture liquids.
Matrix liquids thus ingested are held in the
small matrix cells or pores under quiescent
conditions as the matrix continues to
70 advance in its travel within the shield 48.
Under these conditions, when held constant
for a sufficient time interval, opportunity is
afforded for the minute droplets of oil or
other liquid particles suspended in the
75 initial mixture to settle out upon the matrix
strands or pore surfaces and thereby
coalesce. When the band has completed its
circuit within the shield 48 and returned to
the squeeze roller 64 compression of the
80 matrix by the latter expels the mixture
liquids into the discharge compartment 62
through the gap in the shield between edge
52 and the roller 64. Such compression of
the matrix band thus serves the dual
85 function of purging the matrix of liquids
and simultaneously conditioning it for the
ingestion and processing of additional
liquids as it thereupon reenters the
receiving chamber 60.

90 In the case of oil-water separation
systems wherein the present invention is
utilized to coalesce minute oil droplets into
a stratified or bulk condition suitable for
separation by other means, the mixture
95 liquids discharged into chamber 62 will
comprise the same water and oil as
contained in the initial mixture. But at this
stage the oil will be discharged coalesced
into large globules or droplets that will rise
100 rapidly to the surface of the body of water
in the chamber 62. While the surfacing oil
may be removed by any suitable means, in
the example shown, when the level of this
stratified oil rises to a certain height in
105 chamber 62 it will decant out through the
discharge pipe 80. Water collecting in the
discharge chamber 62 passes beneath the
lower edge 84a of a septum 84 extending
across the end of chamber 62 opposite the
110 squeeze roller, and flows through the outlet
86 when operating level is reached and
maintained during normal operation of the
system. If separation of the coalesced oil
and water is to occur in chamber 62 the size
115 and dimensioning of chamber 62 should be
such as to allow surfacing and stratification
of the coalesced oil to occur fully before
the water reaches the outflow pipe 86. With
a small size chamber special baffling or
120 other arrangements to minimize eddying
effects may be desirable to facilitate this
separation. Alternatively the mixture as a
whole may be removed directly and the two
liquids separated externally; or other
125 specialized separator devices may be
operated in the chamber or in physical
association with it.

In operation, rotation of the drum 16
carrying the coalescer matrix 32 is effected 130

(19) (18)

at such a speed, usually the maximum permissible, as to allow settling and coalescence of the oil particles on the matrix strands in the operation cycle. With practical dimensioning of the matrix as to diameter, thickness and height it will be appreciated that relatively large quantities of mixture liquid can thus be processed over a given period of time, the matrix acting essentially as a pump having a volumetric capacity proportional to matrix volume and matrix rotational speed. Matrix volume for this purpose represents nearly the full geometric volume of the matrix body because the solid material making up the strands and interconnecting nodes comprises on the order of five percent of the matrix volume in a fully reticulated polyurethane foam body. Pumping of mixture liquids by the rotating matrix band results in hydraulic head or liquid level in the discharge compartment 62 slightly higher than that in the receiving compartment 60. The inlet and outlet levels in the tank compartments are placed accordingly. Moreover, it will be evident that the apparatus may be provided with suitable float switches, controls and alarms to assure maintaining desired operating levels, and that various external or remote control systems for adjusting and regulating operation of the apparatus can also be furnished. The device is essentially self-conditioning and over long operating periods requires little or no operator attention. The resiliently compressible matrix of expanded polyurethane reticular foam is itself durable and even in small pore sizes does not tend to plug up or foul with oil residues or foreign matter. In that regard the aspirating technique of ingesting and expelling oil and water provides a self-cleaning effect due to the injection occurring through one face of the matrix and expulsion of the oil and water, together with any associated sediment, out of the same face.

Because the open-pore matrix extends between receiving and discharge compartments below the liquid levels therein, the matrix remains essentially immersed through its rotation cycle. It is therefore in hydraulic pressure communication with the body of liquids in the two compartments 60 and 62 throughout its transit around the drum path, so that mixture in the matrix pores undergoes only the slightest change of hydraulic head during the holding or transport interval when coalescence occurs. Accordingly, hydraulic head changes do not occur which otherwise could result in flow and thus present a disturbance in the quiescent state of the mixture liquids during settling.

Compression of the matrix band 32 between the squeeze roller 60 and the drum wall 16, as shown in Figure 3, expresses first the water and then, as the more tenaciously held oil is squeezed between the strands, forces out the oil. Nevertheless, a slight coating of oil is left on the matrix strands priming them as desired for maximum attractability to oil particles on the subsequent cycle. A liner (not shown) of polyvinylchloride or other suitable material on the inside wall of the shield 48 also becomes primed with oil and helps in turn to keep the matrix outer wall surfaces primed, as does a polyvinylchloride layer on the exterior of the squeeze roll 64.

In the embodiment shown in Figure 9 the container 100 is of elongated proportions in plan, and the matrix 102 is in the form of an endless belt encircling a driven roller 104 and opposing idler roller 106. An internal shield body 107 occupying the space surrounded by the belt 102 and rollers 104 and 106 presses the belt with slight pressure against the outer tank walls to effect a seal therewith as did the shield in the preceding embodiment.

The roller 104 drives the matrix belt 102. This roller in turn is driven by a belt and pulley drive 108 and a motor unit 110. Squeeze roller 112 is pressed against the matrix to squeeze it against the roller 104. Squeeze roller position is established by a worm and wheel actuator 112 as in the previous embodiment. Mixture liquids are fed into a receiving compartment 114 through an inlet pipe 116. Mixture liquids expelled or purged from the matrix belt 102 by roller 112 are discharged into a discharge chamber 118 as in the previous embodiment, and the floating stratified oil is tapped off by an outlet 120 whereas the water, after passing through screening partitions 122, and beneath the lower edge of a septum 124, flows out through the pipe 126 as before. A coalescer in this elongated, narrow configuration can be placed in spaces, such as in bilge spaces of ships not readily suited to a more cubically shaped coalescer of equal capacity.

Suitable matrix materials that can be produced in reticulated foams and which are both oleophilic and hydrophobic, include a number of the synthetic polymers such as polyurethane, polypropylene, polystyrene and polyvinylchloride. As previously indicated, priming of the surfaces within these foams by wetting with oil enhances their oleophilic, hydrophobic properties as desired.

From the foregoing, and by way of general summary, it will be appreciated that gravitational settling may be effected whether the suspended droplet liquid has greater or lower specific gravity than the

70

75

80

85

90

95

100

105

110

115

120

125

130

44 20

suspension medium liquid, in one case the droplets rising and in the other case descending into contact with the matrix or network elements. Droplet size and specific gravity, and the viscosity, specific gravity and temperature of the suspension liquid affect settling velocity. The actual rate of coalescence in the matrix is a function of settling velocity, liquid surface tensions, wetting characteristics of the matrix pore surfaces, and matrix pore openness, i.e., average ratio of open area through which rising droplets may pass at the interfaces between adjacent pores to the solid area occupied by the stands and nodes making up the interfaces. Here a compromise is involved because openness is a function of the ratio of void region volume to solid region volume within the matrix, and also determines volumetric holding capacity of the matrix. Hence, openness within the pore labyrinth increases volumetric holding capacity but decreases settling rate and to some extent attainable degree of quiescence through full isolation of the minute pockets of the held mixture. Ideally, total isolation of these small quantities of mixture held within the respective individual pore spaces is desirable for most efficient settling of the minute particles of oil or other liquids to be settled out of a mixture. In practice, however, it is found that a fully reticulated polyurethane foam provides a good compromise achieving practical settling rates, effective total settling and high volumetric capacity within the matrix body.

With the improved and novel coalescing system of this invention, oil droplets which are so small and have such high motility and surface tension as to avoid coalescence using former techniques will coalesce readily on the matrix surfaces herein due to the effective "catalytic" or coalescence-promoting properties of those surfaces. Each droplet, enabled by the smallness of the pore spaces to contact such a surface within a reasonable short time period, tends to be absorbed on and thus spread out along that surface and thus become joined with other droplets similarly affected. The process continues during the quiescent holding interval in the matrix until accumulation of coalesced droplets or globules of oil occur on the strands and their connecting nodes. When the matrix is compressed to a greatly reduced volume, first the water and later the more tenaciously held oil is forced out of the voids. As previously stated, this leaves the matrix strands and nodes wetted slightly with a film of oil, primed for a subsequent cycle of operation.

The present invention applies primarily to coalescence of oil or other liquid

droplets ranging in size from about 5 microns to about 100 microns radius. It will be appreciated that oil in droplets of larger size, and even globules or layers of oil dumped into the receiving compartment in the coalescer will also be ingested into the matrix and eventually purged with mixture water into the receiving compartment together with oil that is coalesced therewith from minute droplets also contained in the initial mixture. The system is thus not critical in terms of the condition of the oil in the mixture processed thereby, since it will coalesce the minute suspended particles of concern even when occurring in the presence of large globules. In order to effectively and efficiently process the mixture as desired, the matrix pores should be in the size range of from about 100 pores per inch as a minimum size to about ten pores per inch as a maximum. Preferably the pores are of about the same size throughout the matrix in order to maximize production rate capacity of the system.

It has been stated that quiescent conditions within the matrix pores are maintained during the holding interval while the ingested mixture is being transported from the point of ingestion to the point of discharge. This condition is achieved by the small size and isolating effect of the matrix pores, the retention of substantially constant hydraulic head throughout the transport interval during which the matrix is effectively "immersed" in the mixture medium, and preferably the protective presence of the surrounding shield 48 isolating the rotating matrix from the effects of external disturbances or temperature gradients. Such quiescent holding conditions and the smallness of the holding pores providing a short settling distance for the particles to negotiate in a brief holding interval, assures substantially complete settling and coalescence of oil particles in a short time, so much so that discharge water can be produced at high "pumping" rates and will be essentially pure or free of particulate oil, i.e., for example, containing as little as five parts per million of oil remaining uncoalesced from an original mixture of five hundred parts per million.

Moreover, it will be evident that different shapes and sizes of coalescers practicing the invention are readily attainable by design to suit different applications. Scaling up or scaling down the apparatus does not adversely affect the operating performance thereof to any material degree because the factors producing efficient coalescence are essentially independent of size. For example, large coalescers having a thick and wide matrix band or belt having proportionately larger cross-sectional area,

70

75

80

85

90

95

100

105

110

115

120

125

130

hence volume per unit of length, are capable of processing at high "pumping" rates for a given travel velocity of the band or belt. By lengthening the belt or band and thereby the physical distance of travel between point of ingestion and point of discharge of mixture liquids in a design, it is also possible to increase volumetric processing rate directly, because the belt or band may be moved faster in a lineal sense without reducing the total cyclic holding interval during which coalescence is allowed to occur within the matrix.

These and other features, aspects and embodiments of the invention will be evident to those skilled in the art based upon an understanding of the foregoing disclosure of the presently preferred embodiment thereof.

WHAT WE CLAIM IS:—

1. A process of coalescing droplets of a first liquid suspended in an immiscible mixture thereof with a second liquid comprising ingesting the mixture into the voids of a porous resiliently compressible and expansible matrix immersed in the compressed state in the mixture, such ingestion occurring as the matrix expands from the compressed state while immersed in the mixture, holding the ingested mixture in the matrix in a quiescent state until all or substantially all of the droplets have settled and coalesced in the voids of the matrix and thereafter discharging the ingested liquids from the matrix by pressure applied to the matrix.

2. A process as claimed in Claim 1, wherein the mixture is ingested into the matrix at a first location, movement of the matrix is effected to bring the ingested liquids to a discharge location under conditions wherein the ingested liquids are subject to a steady settling force effecting settling and resultant coalescence of said particles in the voids of the matrix during the time the matrix is moving to said discharge location, the ingested liquids being otherwise maintained substantially motionless relative to the matrix during such time, and ingested liquids are discharged from the matrix at said discharge location.

3. A process according to Claim 1 or 2 including the step of separating the coalesced droplets of the first liquid from the second liquid after the ingested mixture is discharged from the matrix.

4. A process according to Claim 1, 2 or 3, wherein pressure is applied to the matrix to compress the same, the mixture being ingested during expansion of the matrix from the compressed state.

5. A process as claimed in Claim 4, wherein the discharge of ingested liquids

from the matrix is effected by reapplying pressure to the matrix. 65

6. A process as claimed in any one of the preceding claims wherein the matrix, comprising an endless band, is recirculated through the mixture. 70

7. A process as claimed in Claim 6, wherein the endless band is wide in relation to its thickness and moves in a substantially horizontal path with its wide dimension disposed vertically or substantially vertically. 75

8. A process as claimed in Claim 6 or 7 as appendant to Claim 5, wherein the reapplication of pressure to the matrix to discharge ingested liquids therefrom provides the compressed state of the matrix from which it expands to reingest mixture liquids. 80

9. A process as claimed in any one of the preceding claims wherein the liquids discharged from the matrix are collected in a space sealed from the mixture by the matrix. 85

10. A process as claimed in any one of the preceding claims wherein the mixture comprises water polluted by unstratified, uncoalesced droplets of oil, the mixture being ingested into a porous matrix of oleophilic, hydrophobic material the water and coalesced oil discharged from the matrix being delivered into a body of water wherein coalesced oil stratifies itself on the surface, the stratified oil then being separated from the water. 90

11. Apparatus for coalescing droplets of a first liquid suspended in an immiscible mixture thereof with a second liquid comprising an endless circulatory matrix of porous, resiliently compressible and expansible material, enclosure means having space therein formed to contain a body of the mixture and a length portion of the matrix immersed in such mixture, and means for compressing said length portion of the matrix prior to immersion in the mixture, operating means mounting, guiding and moving the circulatory matrix progressively in an endless circulation path which in part extends through the enclosure means space and causes successive length portions of the matrix passing through the body of mixture to ingest such mixture into its pores, and means for applying pressure to the matrix to purge ingested mixture liquids therefrom. 95

12. Apparatus as claimed in Claim 11, wherein the circulatory matrix is guided and moved in a generally horizontal circulation path and the enclosure means is formed to maintain hydraulic pressure communication between the matrix and the mixture in said space during such transport thereby to avoid substantial pressure head changes in the matrix during transport. 100

65

70

75

80

85

90

95

100

105

110

115

120

125

hence volume per unit of length, are capable of processing at high "pumping" rates for a given travel velocity of the band or belt. By lengthening the belt or band and thereby the physical distance of travel between point of ingestion and point of discharge of mixture liquids in a design, it is also possible to increase volumetric processing rate directly, because the belt or band may be moved faster in a lineal sense without reducing the total cyclic holding interval during which coalescence is allowed to occur within the matrix.

These and other features, aspects and embodiments of the invention will be evident to those skilled in the art based upon an understanding of the foregoing disclosure of the presently preferred embodiment thereof.

WHAT WE CLAIM IS:—

1. A process of coalescing droplets of a first liquid suspended in an immiscible mixture thereof with a second liquid comprising ingesting the mixture into the voids of a porous resiliently compressible and expansible matrix immersed in the compressed state in the mixture, such ingestion occurring as the matrix expands from the compressed state while immersed in the mixture, holding the ingested mixture in the matrix in a quiescent state until all or substantially all of the droplets have settled and coalesced in the voids of the matrix and thereafter discharging the ingested liquids from the matrix by pressure applied to the matrix.

2. A process as claimed in Claim 1, wherein the mixture is ingested into the matrix at a first location, movement of the matrix is effected to bring the ingested liquids to a discharge location under conditions wherein the ingested liquids are subject to a steady settling force effecting settling and resultant coalescence of said particles in the voids of the matrix during the time the matrix is moving to said discharge location, the ingested liquids being otherwise maintained substantially motionless relative to the matrix during such time, and ingested liquids are discharged from the matrix at said discharge location.

3. A process according to Claim 1 or 2 including the step of separating the coalesced droplets of the first liquid from the second liquid after the ingested mixture is discharged from the matrix.

4. A process according to Claim 1, 2 or 3, wherein pressure is applied to the matrix to compress the same, the mixture being ingested during expansion of the matrix from the compressed state.

5. A process as claimed in Claim 4, wherein the discharge of ingested liquids

from the matrix is effected by reapplying pressure to the matrix.

6. A process as claimed in any one of the preceding claims wherein the matrix, comprising an endless band, is recirculated through the mixture.

7. A process as claimed in Claim 6, wherein the endless band is wide in relation to its thickness and moves in a substantially horizontal path with its wide dimension disposed vertically or substantially vertically.

8. A process as claimed in Claim 6 or 7 as appendant to Claim 5, wherein the reapplication of pressure to the matrix to discharge ingested liquids therefrom provides the compressed state of the matrix from which it expands to reingest mixture liquids.

9. A process as claimed in any one of the preceding claims wherein the liquids discharged from the matrix are collected in a space sealed from the mixture by the matrix.

10. A process as claimed in any one of the preceding claims wherein the mixture comprises water polluted by unstratified, uncoalesced droplets of oil, the mixture being ingested into a porous matrix of oleophilic, hydrophobic material the water and coalesced oil discharged from the matrix being delivered into a body of water wherein coalesced oil stratifies itself on the surface, the stratified oil then being separated from the water.

11. Apparatus for coalescing droplets of a first liquid suspended in an immiscible mixture thereof with a second liquid comprising an endless circulatory matrix of porous, resiliently compressible and expansible material, enclosure means having space therein formed to contain a body of the mixture and a length portion of the matrix immersed in such mixture, and means for compressing said length portion of the matrix prior to immersion in the mixture, operating means mounting, guiding and moving the circulatory matrix progressively in an endless circulation path which in part extends through the enclosure means space and causes successive length portions of the matrix passing through the body of mixture to ingest such mixture into its pores, and means for applying pressure to the matrix to purge ingested mixture liquids therefrom.

12. Apparatus as claimed in Claim 11, wherein the circulatory matrix is guided and moved in a generally horizontal circulation path and the enclosure means is formed to maintain hydraulic pressure communication between the matrix and the mixture in said space during such transport thereby to avoid substantial pressure head changes in the matrix during transport.



8 22

1,530,690

8

13. Apparatus as claimed in Claim 11 or 12, wherein the circulatory member comprises a band which is wide in relation to its thickness.
- 5 14. Apparatus as claimed in any one of Claims 11 to 13, wherein the operating means comprises a circular cylindrical support rotatably driven on an upright axis, and wherein the circulatory matrix
- 10 comprises a hollow cylindrical jacket surrounding and mounted on said support to rotate therewith.
- 15 15. Apparatus as claimed in Claim 14, including sealing means comprising a stationary shield of arcuate shape in sliding contact with the jacket substantially over its vertical width and surrounding the jacket
- 20 along a circular arc extending from said enclosure means space in the direction of the rotary motion.
- 25 16. Apparatus as claimed in Claim 14 or 15, wherein the jacket comprises resiliently compressible material, the pressure applying means applying pressure to the jacket and said means being maintained in substantially sealed relationship with the enclosure means and disposed for compressing the jacket against the cylinder
- 30 along substantially the full vertical width of the jacket at a location adjacent said enclosure means space, whereby advancement of successive portions of the jacket against said compression means
- 35 squeezes mixture liquids out of the pores compressed thereby and continuation of such advancement releasing portions to reexpand upon entering the body of mixture causes ingestion of mixture again into said pores.
- 40 17. Apparatus as claimed in Claim 16, wherein the pressure applying means comprises a member maintained in rolling contact with the jacket, said apparatus further comprising additional enclosure
- 45 means having walls including a continuation of the arcuate shield, the latter terminating short of the pressure applying means.
18. Apparatus as claimed in any one of Claims 11 to 17, wherein the pressure applying means purges successive portions of the matrix of mixture liquids before reentering the mixture and permits reexpansion of the matrix as it reenters the mixture to cause further ingestion of mixture by the matrix.
19. Apparatus as claimed in any one of Claims 11 to 13, wherein the matrix comprises an endless belt-like member and the operating means comprises means guiding and moving the belt-like member in a generally horizontal path.
20. Apparatus as claimed in Claim 19, wherein the pressure applying means is maintained in rolling pressure contact with the matrix as it enters the mixture body and releases the matrix to permit expansion thereof while in such mixture body.
21. A process of coalescing particles of a first liquid out of an immiscible mixture of that liquid with a second liquid substantially as described hereinbefore with reference to the accompanying drawings.
22. A process of clarifying water polluted by unstratified, uncoalesced oil droplets substantially as described hereinbefore with reference to the accompanying drawings.
23. Apparatus for coalescing particles of a first liquid out of an immiscible mixture of that liquid with a second liquid substantially as described hereinbefore with reference to the accompanying drawings and as illustrated in Figures 2 to 6 or Figure 9 of the accompanying drawings.

For the Applicants:
F. J. CLEVELAND & COMPANY,
Chartered Patent Agents,
40-43 Chancery Lane,
London, WC2A 1JQ.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1978
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from
which copies may be obtained.

