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(71) **Applicant** *(for all designated States except US)*: **NU-RITCHEM, L.L.C. A LA (USA) LIMITED LIABILITY COMPAGY** [US/US]; Attn. Gordon K. Goldman, 4805 Avron Blvd., Metairie, LA 70006 (US).

(72) **Inventor; and**
(75) **Inventor/Applicant** *(for US only)*: **GOLDMAN, Gordon, K.** [US/US]; Nuritchem, L.L.C., 4805 Avron Blvd., Metairie, LA 70006 (US).

(74) **Agent: PUGH, Emmett, C.**; Pugh/Associates, 82 N. Main Street, Suffield, CT 06078-2102 (US).

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(54) **Title:** LIQUEFACTION AND DISPERSION OF PARAFFIN WAXES, ASPHALTENES AND COKE IN OIL

(57) **Abstract:** Chemical additive comprising selected surfactants, dispersants, and degreasers that liquefy, disperse, demulsify, degrease, inhibit corrosion and scale formation, lower pour-point/cloud-point of petroleum, coal, Fischer-Tropsch synthesized, or naturally occurring paraffin-based wax and asphaltene, comprising preferably mixture of oil soluble, surface active polyethoxylated compounds; organic solvents (non-hydrocarbon) used as degreasing agents, pine oil, and butyl cellusolve; a mixture of oil/water-soluble dispersing copolymers of partially sulfonated, maleic anhydride and polystyrene with molecular weight ranging from 2,000 to 2,000,000; and saturated higher fatty acids and alkyl-phenolic based compound acting as corrosion inhibitors; capable of converting crystalline wax (paraffin) in slop oil into amorphous form at room temperature, allowing the wax to be dissolved and maintained in solution in crude oil without heating, reducing wax build-up in pipelines, processing and transportation equipment, recovery of hydrocarbons in slop oil, resulting in final crude oil blends with B.S. & W. (wax or asphaltene separation) of 0.00%.

Description

LIQUEFACTION AND DISPERSION OF PARAFFIN WAXES, ASPHALTENES AND COKE IN OIL

Technical Field

The present invention relates generally to converting crystalline wax, as, for example, exists in slop oil, to an amorphous form of wax, causing it to be dissolvable in, for example, crude oil at, for example, ambient temperature and maintained in a dissolved state for a prolonged period of time at ambient temperature, and more particularly, in its preferred, exemplary embodiment, to the use preferably of a chemical composition of surfactants, polymeric dispersants and corrosion & scale formation inhibitors that can, for example, recover waste hydrocarbon products (paraffin waxes, asphaltenes, and coke) from both naturally-occurring and synthetic sources, and more particularly to recover these waste hydrocarbon products for use as energy sources and to reduce environmental pollution. A number of other applications is also disclosed and claimed.

Background Art

Waxy materials present in crude oils and in the high boiling fractions are considered to be crystalline throughout but under certain conditions may behave like a colloid. Certain wax solutions of refined products such as petrolatum, when agitated or mixed for long periods near or at the crystallizing temperature, will form a completely transparent jelly. But the same solution, when chilled rapidly with moderate agitation will precipitate a wax that can be centrifuged.

It was observed many years ago in the sweating of solid paraffins at the petroleum refinery that three crystalline forms (manifestations) of hydrocarbons are involved. These are known as "plate", "malcrystal", and "needle" [note, for example, *The Chemistry and Technology of Waxes* by Albin H. Warth, published by Reinhold Publishing Corp. (New York, 1947), p. 239]. It was recognized that the relative proportion of these types of crystals not only has a relationship to the source of the crude but also to the process of handling the wax.

The members of each series crystallize similarly as either plates, malcrystals, or needles. If one type is present (plate, mal, or needle), the crystal form remains the same regardless of such factors as the amount and kind of solvent.

When crude oil is pumped from the ground and transported through pipelines, transported by ocean tankers, or stored in storage tanks on land or offshore, a large amount of heavy material separates and comes out of solution. The main component of this residue is high molecular weight paraffin waxes. In some cases the wax represents as much as 90 percent of the deposited residues.

The amounts of wax present in crude oil are to a large extent an indicator of its origin, whether the crude originated in Venezuela, Mexico, or Malaysia, *etc.*

This mixture of wax or asphaltene,, oil, sand, and water is referred to as "slop oil," or just "slop," in the petroleum industry. The percentage of slop oil varies according to the type of crude and the conditions under which it has been transported. Usually the amount of slop oil ranges from a low of about 0.5% to a high of about 10% or even about 40%; but, typically, it is in the range of about 2% to 5%.

For the last century and until today the only way to keep slop oil from separating from crude oil is to heat the slop oil while it is being transferred into mixing tanks with crude oil. The cost of keeping slop oil mixed with crude oil is a function of many variables such as temperature, solvent diluents, and residence time of the crude in a tank or pipeline.

The petroleum industry is plagued with the problem of having to deliver crude oil to refineries in a timely and economic manner. If a pipeline becomes plugged up or clogged because of paraffin wax precipitating out during the pumping operation, a crisis can arise. Numerous pipelines worldwide are clogged daily or monthly due to wax precipitating out of the crude oil. Daily, about 50,000,000 barrels of crude oil are pumped from the ground worldwide (as of May, 1999). If, for example, 5% of the heavy residues come out of the crude oil being transported, whether by pipeline or tanker, the amount of slop oil or crude residue would be about 2,500,000 barrels per day. This amounts to about 912,000,000 barrels per year. If, for example, 70% of this slop oil is useable crude which can be processed to refine production, then the amount of recoverable hydrocarbon equals over 640,000,000 barrels per year. At a cost of, for example, $10.00/barrel of crude oil, this would amount to the recovery of about $6.4 billion per year of useable hydrocarbon as either energy or petrochemical feedstock.

Another important factor in the transportation of crude oil is the corrosion of pipelines, storage tanks, and marine tankers. One of the main sites of corrosion in pipelines and storage tanks is at the point of buildup of the paraffin wax. At this site corrosion-causing chemicals become embedded in the wax and migrate to the metal surfaces. Pipelines with intrinsically large wax buildup or settling have many more corrosion problems than pipelines where the oil moves swiftly without deposition occurring. This results in increased maintenance cost and in some cases pipelines have to be shut down and crude must be rerouted to new lines as a result of both the clogged lines and corrosion. One of the main maintenance tools used to unclog crude oil pipelines is pigging the line. In this process a small device shaped like a pig with a series of scrapers on its sides is shot through the line to remove all the wax. This wax is then collected at traps located along the line and shipped to pipeline pumping stations for storage.

In storage tanks the problems associated with wax settling out are tremendous and present an extremely challenging task to refiners and terminal operators.

When crude oil remains idle and cold in a storage tank, a heavy residue forms that, over time, accumulates at the bottom of the tank and reduces useable tank volume. This residue, known as slop oil (or slop), consists of heavy paraffinic waxes and asphaltenes which solidify in crystalline form. Slop oil is extremely difficult to remove from tanks and presents a very costly disposal problem for the refinery and terminal operator.

Traditional tank cleaning methods use a combination of heat (*e.g.*, about 60 to 75 degrees C or greater) and mechanical agitation to force the slop oil back into solution with crude oil, so the mixture can be pumped out of the tank. In order to keep the waxes and asphaltenes in solution with the crude oil, the mixture must be kept at, for example, 75 degrees C or greater and, in most cases, continuously circulated. The tremendous amounts of energy required to heat and circulate large volumes of dense crude oil to these elevated temperatures over long periods of time increase handling costs dramatically.

After pumping out the slop oil containing paraffin waxes and asphaltenes, the slop oil mixture must be kept hot or the wax will separate from solution, and the problems associated with slop oil will recur.

This need to use heat results in great energy cost and losses.

The preferred, exemplary chemical compound mixture described herein will perform, *inter alia*, the following functions:

1. Converts the wax in, for example, the slop oil from a crystalline to an amorphous material;
2. Disperses the amorphous material (wax) into a diluent solvent;
3. Acts as a demulsifier which separates any water present in the slop oil;
4. Acts as a degreaser and works at a very low activity, *e.g.*, 0.025%;
5. Acts as a pour point depressant;
6. Disperses asphaltene into crude oil;
7. Acts as a cloud point depressant for lube oil based stocks; and
8. Acts as a sludge breaker for slop oil emulsions.

Since it acts as a wax liquefier and converts the wax to a less crystalline and more amorphous form, the slop oil waxes are readily dispersible into the crude oil medium. Thus a colloid is formed consisting of heavy paraffin wax and asphaltene compounds dispersed in crude oil. Since the preferred, exemplary composition of matter described herein also acts as a demulsifier, all water present in the slop oil mixture separates out, as well as the sand or grit present. The heavy paraffin wax and asphaltenes are dispersed as hydrocarbon into the crude oil and can be, for example, transported to the refinery for processing or to a marine tanker or other transport for shipment, for example, at ambient temperature, even resulting in a B.S.&W. (wax or asphaltene separation content) of 0.00%, as, for example, measured in a centrifuge, measurement tube. The B.S.&W. ("bottoms, sediment & water"; see ASTM D 4007-81) percentage content in the oil industry for the wax or asphaltene interface is often referred to as the visible "rag" and refers to the intermediate, interface separation (typically of wax or asphaltene, but also possibly containing some oil, water & solids) that exists between the top, oil or hydrocarbon layer and the lower, middle, water layer, which in turn is above the solids layer at the bottom of the measuring tube. For a B.S.&W. of 0.00% (see Test #9 below), there is no rag, and all of the hydrocarbons are in solution together above the water layer in the top, hydrocarbon layer, that is, there is no wax or asphalatene interfacing separation seen in the measuring tube between the top, hydrocarbons layer. and the middle, water layer.

The use of the preferred, exemplary composition of matter described herein, when, for example, injected into crude oil pipelines at, for example, the production source, is capable of keeping the heavy wax and asphaltenes dispersed in the crude oil. Having the wax and asphaltenes dispersed 100% into the crude oil will accomplish at least the following:

1. Lower maintenance costs by reducing the need to use costly pigging operations on pipelines, which requires at least a partial shut-down of the pipeline;

2. Lower maintenance costs by reducing the problems associated with corrosion in pipelines; with both items "1" and "2" reducing the number of downtime stoppages in the pipeline;

3. Increased throughput and flow rate of crude oil through pipelines; and

4. Lower hydrocarbon (wax/asphaltene) separation, thus increasing the amount of available hydrocarbon.

The main goal and objective of a crude oil pipeline company is, for example, to deliver to their customers a fixed amount of crude on an agreed-to, set schedule; every day that schedule is not met because of technical problems, the company loses money.

If the preferred, exemplary composition of matter described herein is mixed with crude oil loaded on, for example, marine tankers, the problems associated with wax deposits will be at least greatly inhibited, if not prevented from occurring, namely, slop oil residues will be greatly reduced and indeed prevented from forming. In, for example, oceangoing marine tankers the problems are twofold. At the end of many journeys the tankers have to go into drydock for maintenance due to corrosion caused by slop oil settling out and coating the walls of the tanks.

The benefits of the preferred, exemplary chemical composition described herein can be realized in, for example, the following ways:

1. Recovery of at least 640,000,000 barrels per year of hydrocarbons (based on a daily production of 50,000,000 barrels), which results in a yearly recovery value of approximately $6.4 billion at a world crude oil price of $10.00/barrel. At a world crude oil price of $20.00/barrel the yearly recovery value would be $12.8 billion;

2. The projected cost for use of the composition of matter described herein as a wax and asphaltene dispersant, liquefying agent, and demulsifier would range in price at 1999 costs from a low of about $0.05/barrel to a high of about $0.42/barrel, depending on the injection rate; and

3. The overall maintenance costs associated with pipeline transport, marine tanker transport, and storage tank cleaning could be as much as $0.10/barrel of crude oil produced or $2.0 billion per year.

In addition to the exemplary application of use with crude oil, there are many other applications of the principles and teachings of the present invention, as detailed and exemplified below, all with great utilitarian benefits.

For general background, "prior art" information pertinent to the invention, reference is had to:

The Chemistry and Technology of Waxes by Albin H. Warth, published by Reinhold Publishing Corp. (New York, 1947), p. 239 *et al* (cited above);

Petroleum Refinery Engineering by W.L. Nelson, published by McGraw-Hill Book Co. (New York, 4th Ed., 1958), particularly Chapter 12 "DeWaxing" (pp. 374-75 *et seq.*);

Physical Chemistry by Walter J. Moore, published by Prentice-Hall, Inc. (New York, 1955), particularly Chapter 16 "Surface Chemistry" (p. 498 *et seq.*); and

chemical and process technology encyclopedia edited by Douglas M. Considine, published by McGraw-Hill Co. (New York, 1974), particularly its sub-section on "Waxes" (p. 1167 *et seq.*).

General Summary Discussion of Invention

The invention described herein in a very important aspect relates to the use of a composition of matter and an associated mixture that act as, for example, a paraffin and asphaltene liquefying and dispersing agent and as a dispersing agent for coke and coal fines. The dispersing medium can be, for example, a petroleum-based product (such as crude oil or any refined petroleum product), a Fischer-Tropsch-based product (such as liquid hydrocarbon products derived from natural gas and byproducts of natural gas), coal, town gas, waste gases derived from animal and vegetable wastes, oils and organic solvents derived from agricultural sources (such as, for example, edible oils, furfural, alcohols, and other organic liquids) and water.

The source of the paraffin being liquefied and dispersed can be from, for example, petroleum, petrochemical, Fischer-Tropsch synthesis (including natural gas, natural gas liquids, coal, coal byproducts – peat, *etc.*), agricultural sources (carnauba-palm leaves, *etc.*), and animal sources (*e.g.*, beeswax). The source of the asphaltene being liquefied and dispersed can be, for example, from petroleum, petrochemical, Fischer-Tropsch synthesis, coal, and shale.

In accordance with this aspect of the invention a method for liquefying and dispersing paraffin waxes and asphaltene containing, for example, petroleum products, can be dispersed into, for example, crude oil, refined petroleum products (such as diesel, fuel oil, *etc.)* and other solvents such as water at room temperature. The dispersions remain stable at ambient temperatures over a long period of time. The preferred process of carrying out this invention includes, for example, the simple mixing of waste paraffin waxes and asphaltenes in the presence of crude oil or any refined petroleum product mixed with the product described herein at a concentration ranging from about 50 to about 100,000 ppm, at either, for example, ambient temperature or at an increased temperature, *e.g.*, the melt temperature of the paraffin wax, if so desired, with the optimum concentration ranging from about 250 to 1,500 ppm.

The dispersion of the paraffin wax and asphaltenes tend to disperse more easily at higher temperatures using lower concentrations of chemical dispersant. The ultimate result of mixing the wax and asphaltene with the diluent is the same whether it is mixed at ambient temperatures (*e.g.*, 21 degrees C) or at higher temperatures (*e.g.*, about 60 to about 120 degrees C, or higher, if so desired), namely that the wax and asphaltene are dispersed in the diluent, whether for example, crude oil or other refined products, and stays in solution for at least six (6) months, based on current tests, which are still on-going, if not longer.

Additional advantages of this preferred, exemplary application of the invention, as well as other applications, will become apparent from the description which follows.

In other diluents, such as water, it was found that the wax in grease that has oxidized for over, for example, three (3) years, can be instantly liquefied and dispersed in water. The dispersion of the grease in water was passed through a water filtering system, with the end result being water of a quality acceptable for reuse.

The principles and teachings of the present invention have broad applicability, and a number of other, exemplary applications are listed below.

It is thus an object of the invention to convert crystalline wax to an amorphous form by, for example, reducing its surface tension.

It is a further an object of the invention to convert crystalline wax to an amorphous form suitable for being dissolved in a desired or available diluent, for example, in crude oil or other hydrocarbon, when dealing with, for example, slop oil for, for example, recovery of the hydrocarbons in the slop oil and for enhanced transportation and pipeline movement of crude oil.

It is a still further object of the invention to provide a particularly efficacious dispersant for wax or paraffin, while also preferably providing corrosion and scale formation inhibition, demulsifying and degreasing, with preferably a homogeneous mixture.

It is a still further an object of the invention to provide enhanced cleaning of objects having, for example, a build-up of wax-containing substance(s).

It is a still further an object of the invention to provide cloud point lowering of, for example, lube oil and the like, *i.e.*, dehazing.

It is a still further an object of the invention to provide pour point lowering of, for example, lube oil and the like.

It is a still further an object of the invention to provide a product or composition of matter and associated method for converting crystalline-wax-containing substances to an amorphous form in one or more of the applications detailed below.

For a further understanding of the nature and objects of the present invention, reference should be had to the foregoing and the following detailed description.

Exemplary Modes for Carrying Out the Invention

- Exemplary Composition of Matter or Product -

The currently preferred, exemplary composition of matter/mixture or exemplary, currently preferred, wax liquefier and dispersant product of the invention is a homogeneous mixture (preferably pure solution, one phase) of –

– about 25% to about 99.5% by weight of surface active agent as the primary active component,

– about 15% to about 35% or about 45% by weight butyl cellosolve, for a degreasing agent, when used in the product mixture, and

– about 5% to about 15% by weight of pine oil and a specially mixed catalyst solution made of saturated higher fatty acids, an alkyl phenol (corrosion inhibitor) and an oil-water soluble copolymer of partially sulfonated, maleic anhydride and polystyrene with a molecular weight ranging from about 2,000 to about 2,000,000. The catalyst mixture normally is present in a range of about 0.5% to 5% or even about 10% compared to the pine oil, with all percentages being "by weight" percentages. In some instances, for example, for altering the cloud point or dehazing of processed lube oil, only the catalyst is added to the primary active component, if so desired, (as in Test #7 below). The pine oil works as a degreaser and as a surface tension reducing agent and provides a synergistic effect with the butyl cellosolve.

One particularly preferred, exemplary mixture includes 50% surface active agent as the primary active component in the form of a nonionic polyethoxylated compound, *e.g.*, one derived from polyethylene oxide, which has a H.L.B. ("hydrophile-lipophile-balance") number of 11.0, with 40% of butyl cellosolve and 10% of the pine oil and mixed catalyst solution, with the catalyst solution being present at 5% compared to the pine oil (all percentages by weight). This is the composition or product mixture used in the tests below, except for Test #7 which was modified as indicated above.

As is known in the surfactant art, an H.L.B. number represents a fundamental property of a nonionic surfactant that correlates with both physical properties and surface active effects. The H.L.B. number is a measure of the hydrophilic and lipophilic (hydrophobic) characteristics of the surfactant molecule. In a series of surfactants prepared by the ethoxylation of an alcohol or amine, for example, the ratio of hydrophilic to lipophilic portions increases with the increasing degree of ethoxylation. This corresponds to an increase in hydrophilic character – or water solubility – of the molecule. The H.L.B. number of the surfactant determines the type of emulsion produced as well as the stability of the emulsion. A water-in-oil (W/O) type of emulsion requires emulsifiers of low H.L.B. number, *e.g.*, about four (4) [100% water insoluble-non-dispersible in water)], while an oil-in-water (O/W) type requires emulsifiers with higher H.L.B. numbers, *e.g.*, nine to sixteen (9-16). Surfactants with H.L.B. numbers near thirteen (13) are detergents, and those of fifteen to sixteen (15-16) are stabilizers. The surface active agents in the currently preferred, exemplary product preferably have a H.L.B. number ranging from about ten to about eleven and a half (10-11.5) and are considered to be good re-wetting agents (low contact angle) and are good emulsifying and dispersing agents for oils and solids.

Another factor to be considered is the addition of a surface tension depressant. In order to enhance the effectiveness of the surface active agent, for example, a fluorocarbon alcohol is added to lower the surface tension of the composition of matter. Normally the amount added is, for example, 0.01%. Therefore, the surface active agent consists of a nonionic surfactant that is made up of, for example, about 99.99% of a preferably commercially available, nonionic polyethoxylate surfactant and, for example, about 0.01% of a surface tension depressant in the form of, for example, a flouronated hydrocarbon alcohol. The range of surface tension for the final composition of matter ranges from about 10 to about 48 dynes/cm and more preferably from about 15 to about 32 dynes per cm..

The by-weight percent of the nonionic surface active agent is preferably about 48%, with about 32% butyl cellosolve and about 17% pine oil (with both of these latter components acting as a degreaser), about 3% of a mixture containing about 70% higher fatty acids, about 29% a copolymer of partially sulfonated, maelic anhydride and polystyrene, and about 1% of catechol (serving as a corrosion inhibitor).

Other surface active agents, which may be used in place of or in combination with the exemplary polyethylene-oxide-based, nonionic surfactant, are outlined below.

- Types of Nonionic Surfactants -

	H.L.B.#
1. Ethonylated Alcohols	
tridecyl alcohol ethoxylate (6 EO) (where EO is ethlyene oxide)	11.4
tridecyl alcohol ethoxylate (9 EO)	13.3
tridecyl alcohol ethoxylate (12 EO)	14.5
tridecyl alcohol ethoxylate (15 EO)	15.3
Witco Chemicals' tridecyl alcohol ethoxylate	12.4
Stepan Chemicals' tridecyl alcohol ethoxylate	12.4
alcohol ethoxylate (3 EO)	8.0
alcohol ethoxylate (6 EO)	11.8
alcohol ethoxylate (8 EO)	13.2
alcohol ethoxylate (10 EO)	14.1
C_8-C_{10} alcohol ethoxylate (6 moles)	12.5
C_8-C_{10} alcohol ethoxylate (8 moles)	13.6
2. Reactions of Cocoacid + Polyethylene Glycol (PEG)	
PEG30 – glyceryl cocoate	15.9
PEG80 – glyceryl cocoate	18.0
PEG30 mixture – glyceryl cocoate	15.9
PEG20 – glyceryl tallowate	13.0
PEG80 – glyceryl tallowate	18.0
PEG200 – glyceryl tallowate	19.0
PEG2 cocamine	6.2
PEG5cocamine	11.0
PEG10 cocamine	13.8

PEG15cocamine	15.4
PEG15cocamine mixture	15.4

It is noted that, as the amount of ethoxylation increases, the H.L.B. # increases, and the cationic character changes to more nonionic.

PEG2 tallow amine	5.1
PEG2 tallow amine mixture	5.1
PEG5 tallow amine	9.2
PEG10 tallow amine	12.6
PEG15 tallow amine	14.4
PEG15 tallow amine mixture	14.4
PEG20 tallow amine	15.4

3. Other Commercially Available, Nonionic Surfactants

Nonylphenol (5 EO)	6.8
Nonylphenol (10 EO)	11.0
Nonylphenol (12 EO)	12.2
Nonylphenol (15 EO)	13.5
Nonylphenol (18 EO)	19.5

3. Other Currently Non-Commercially Available, Nonionic Surfactants

a. nonionic surfactant formed from α-diol condensation products;

b. polyhydroxyl nonionic compounds;

c. nonionic surfactant formed by the reaction of an ethoxylated Schiff base with a methyl alkyl ketone;

d.i-alkyl-polyethylene – polyamines reacted with maleric acid semiamide – nonionic compound with antibiocide properties;

e. nonionic surfactant derived from polyethoxylated alcohols + vinyl-alkyl ethers;

f. biodegrdeable glycidol surfactant (nonionic), *e.g.*, alcohol + glycidol (with catalyst) producing nonionic surfactant (biodegradable);

g. multiblock polyacetal copolymer surfactants, *e.g.*, poly-propylene oxide or poly-ethylene oxide + dialkyl ether;

h. urea-ethoxamer nonionic inclusion compounds, *e.g.*, urea + polyethoxylated long chain alcohols; and

i. polyglycol ethers + polyglycol$_{6000}$ + epichlorohydrine derived nonionic surfacts; *etc.*

- Exemplary Applications -

Some exemplary applications of the principles and compositions of the present invention are listed below:

1. Cleaning crude oil and petrochemical storage tanks;
2. Injection into crude oil pipelines to prevent wax or "slop" separation;
3. Add to crude oil in oceangoing vessels to prevent wax or "slop" separation;

4. As a dispersant in base lube oil stocks to lower the cloud point, namely as a dehazing compound;

5. As a wax liquefier and dispersant in base lube oil stocks to lower the pour point;

6. As a dispersant in gasoil to lower the cloud point, namely as a dehazing compound;

7. As a wax liquefier and dispersant in gasoil to lower the pour point;

8. As a demulsifier for crude oil in pipelines and storage tanks;

9. As a wax liquefier in downhole operations in the production of crude oil;

10. As a dispersant and degreaser in crude oil storage tanks;

11. As a dispersant and degreaser in petrochemical storage tanks;

12. As an additive in engine lubricating oil for the purpose of dispersing lubricating oil sludge;

13. As a method of measuring the true value of crude oil by demulsifying the water in the crude oil; this will allow for a more accurate measurement of the actual amount of crude oil being purchased;

14. As a dispersant and wax liquefier in hydrocarbon liquids derived from natural gas processing, *i.e.*, condensates;

15. As a dispersant for napthenic acids in fuel oils;

16. As a dispersant for sludge in processing units such as catalytic crackers;

17. As a dispersant for waste wax residue derived from polyethylene plants for the purpose of dispersing the wax into fuel oil;

18. As a dispersant for wax in cutting and cooling fluids used in machining operations;

19. As a dispersant for wax in heavy fuel oils such as, for example, "Bunker C" and Fuel Oil No. 6 (heating oil);

20. As a wax liquefier and degreaser in heat exchangers in various petroleum refining process units (*e.g.*, furfural lube oil extraction plants);

21. As a dispersing agent for coke and carbon fines into hydrocarbon liquids and/or water;

22. As a dispersant for cleaning machine parts;

23. As a liquefier and dispersant for wax into hydrocarbon liquids derived from Fischer-Tropsch synthesis;

24. As a dispersant for wax in edible oils;

25. As a dispersant for wax in organic solvents;

26. As a dispersant for asphalt in various hydrocarbon solvents;

27. As a dispersant in cutting oil emulsions;

28. As a dispersant for naturally-occurring waxes in various hydrocarbon media and water;

29. As a liquefier and dispersant for wax used as a protective coating;

30. As a dispersant and liquefier for wax for oil recycling processes;

31. As a dispersant for highly-paraffinic organic compounds into various organic solvents;

32. As a liquefier and dispersant additive in gasoline and fuel oil;

33. As a degreaser for removing asphalt from concrete surfaces;

34. As a neutral metal degreaser for metal parts in dip tanks;

35. As a liquefier for wax derived from pipeline pigging operations;

36. As a dispersant in oil for extreme pressure additives (E.P.A.);

37. As a dispersant in oil for anti-wear additives;

38. As a dispersant in lube oil to provide dispersion of products of degradation and combustion;

39. As a dispersant for fuel oil (*e.g.* "Bunker C"), diesel and gasoil;

40. As a dispersant for wax in solvent dewaxing processes;

41. As a dispersant for metals and sludge in petroleum waste products (*e.g.* oil/water separators);

42. As an additive for drilling muds to enhance their dispersion and surface active activity (contact) during drilling operations;

43. As an additive in petroleum production to enhance the flow of crude in secondary and tertiary production;

44. As a wax liquefier and dispersant in the production of –

  a. floor coverings and polishes,
  b. adhesives,
  c. cosmetics,
  d. electrical insulation,
  e. leather finishes,
  f. matches,
  g. treated paper products,
  h. molding and coating processes,
  i. printing inks and varnishes,
  j. dental materials,
  k. explosives,
  l. crayons,
  m. textile finishes,
  n. candles,
  o. rubber antioxidants,
  p. corrosion inhibitors, *etc.*;

45. As a surface active agent and dispersion in descaling formulations;

46. As a surface active agent and dispersion in acid de-rusting formulations;

47. As a wax liquefier and dispersant in high-heat distillates (*e.g.* lignitic tar-lignite paraffins);

48. As a dispersant for asphalt and/or tar on surface coating such as, for example, roofing paper;

49. As a cleaning chemical in the cleaning of ship ballast tanks;

50. As a wax liquefier and dispersant in emulsions used in automobile and other vehicular care products (*i.e.*, transportation cleaners);

51. As a biodegradable dispersant for agricultural fertilizers for trees and plants;

52. As a wax liquefier and dispersant in the manufacture of grease;

53. As a dispersant for inorganic compounds in water, such as tailings from mining;

54. As a dispersant and demulsifier for waste oil in oil production, exploration, transportation and refineries (A.P.I. separators);

55. As a dispersant for wax in commercial car products to help in the self-rinsing applications; *etc.*; and

56. As a sludge-breaker and demulsifier for slop oil emulsions in crude oil tank bottoms.

- Exemplary Method for Recovering Slop Oil Tank Bottoms -

At ambient temperature (e.g., 75 degrees Fahrenheit, 24 degrees Celsius), slowly add 0.13 kg (0.286 lb.) of the exemplary composition to 10kg (22 lb.) of slop oil under intense and vigorous mixing. Mix the two components throughly. After a homogeneous mixture has been achieved, immediately add 30 kg (66 lb.) of crude oil to the mixture of slop oil and the preferred composition. Continue mixing until a completely homogeneous mixture is obtained. This should take no longer than fifteen (15) minutes using the amounts specified.

During the mixing process water and sand will be observed separating from the mixture. The crude oil must be added with vigorous agitation even if water is separating during mixing. After a completely homogeneous mixture is obtained, cease agitation and allow the mixture to stand for three to four (3-4) hours.

After allowing the mixture to stand for three to four (3-4) hours, a separation layer of water and sand will be observed on the bottom of the tank; the mixture of crude oil and the composition will remain on top. The viscosity of the new hydrocarbon fraction will be low and the layer will be completely homogenous; there should be no lumps or pieces of paraffin floating in the hydrocarbon fraction.

Separate the water/sand layer from the mixture by, for example, pumping. The crude oil mixture may then be transferred to a storage tank and on to further processing.

- Tests -

A number of tests have been run showing the efficacy of the present invention, with the first six (6) tests using the preferred composition or combination described above as preferred.

Test #1 The addition of 2% of the invention's currently preferred dispersant to one (1) barrel of slop oil/tank bottoms under rapid mixing at 80 degrees C (176 degrees F), followed by the addition of three (3) barrels of crude oil (at ambient temperature) resulted in a crude oil blend that was stable (no wax precipitates) for well over nine (9) months.

Test #2 Three (3%) percent of the invention's currently preferred dispersant was added to one (1) barrel of slop oil/tank bottoms at 40 degrees C (104 degrees F) under constant rapid mixing, followed by the addition of two (2) barrels of crude oil (at ambient temperature). The resulting product was a homogeneous and viscous blend of crude oil and slop oil/tank bottoms that showed no separation of the slop oil/tank bottoms component from the blend. The blend continues to remain homogeneous and viscous at ambient temperature for a period so far of well over (9) months.

Test #3 A small sample (50 grams) of heavy waxy slop oil was taken from an old storage tank; the slop oil had been in the tank for over 10 years. The slop oil was melted into a liquid mass at a temperature of approximately 80 degrees C and stirred to obtain a homogeneous mixture. Two (2) ml of the invention's currently preferred dispersant was added to the liquefied wax and the resulting blend was stirred for two (2) minutes at approximately 75 degrees C.

After it was determined that the dispersant was thoroughly dispersed throughout the liquefied wax, 150 ml of crude oil tank bottoms (an extremely viscous liquid oil fraction) was added to the mixture and the resultant blend was stirred for an additional ten (10) minutes at 75 degrees C to obtain a homogeneous mixture. The mixture was removed from the heat and allowed to cool down to ambient temperature (25 to 30 degrees C). After reaching ambient temperature the mixture was separated into two halves and poured into glass bottles for observation. Each sample indicated two layers – a clear, oil-free water layer on the bottom that contained suspended solids (sand, *etc.*) and an upper layer of oil.

The samples were allowed to sit for a period of 120 days during which time it was observed that the oil layer remained completely homogeneous. There was no separation of any solid wax material. One of the samples was centrifuged at ambient temperature and three (3) layers were formed: a layer of sand and grit (3%); a layer of water (27%); and a layer of oil (70%). The oil layer remained homogeneous for a period of over seven (7) months; there was no separation of any solid paraffin. The oil layer remains homogeneous with no separation.

Test #4 To a reactor containing 10 kg of slop oil was added 30 kg of heavy Arabian crude oil containing 0.5 kg of the invention's currently preferred dispersant. The mixture was agitated to a thoroughly homogeneous state for a period of 1 ½ hours. At the end of this period 38 kg of the crude + slop hydrocarbon was pumped out. The resulting mixture remained homogeneous for two (2) weeks; a layer of sand and water separated out of solution. The sand was pumped off and cleaned using the dispersant.

Test #5 In this test a steel machine gear heavily encrusted with hardened grease and dirt was immersed in a solution of the invention's currently preferred dispersant and water. This gear had been stored outside, fully exposed to the elements, and had not been handled or moved for at least five (5) years. After being allowed to soak in the solution for a short time, the grease and dirt softened until only slight finger pressure would remove it. The solution was agitated for a few minutes and the grease and dirt completely dispersed into the solution. The gear was removed from the solution and the solution was allowed to stand. The grease remained suspended in the dispersant solution.

Test #6 A 50 gm sample of wax residue from a polyethylene production plant was heated to 120 degrees C. To this heated sample was added 0.5gms of the invention's currently preferred dispersant. The mixture was agitated until complete homogeneity was observed at 120 degrees C. To the heated mixture of polyethylene waste wax plus compound was added 200 gms of fuel oil (#6 fuel). The fuel oil was added to the mixture at 120 degrees C. This mixture was stirred until complete homogeneity was observed at 120 degrees C. When a homogeneous mixture was observed, the heat was taken away and the mixture was allowed to cool down to room temperature. After the mixture reached room temperature, it was observed that no wax separated out of solution. After a period of two (2) months, still no separation of wax was observed.

Test #7 To check for its dehazing or cloud point lowering capabilities, to a sample of processed lube oil was added a modified mixture of the currently preferred dispersant, namely, only the surface active agents (namely, polyalkylethoxylated alcohol plus nonylphenol plus a flourinated polyethoxylated alcohol) and a dispersing agent polymer derived from a copolymer of partially sulfonated, maleic anhydride and polystyrene, with the surface active agent and the dispersing agent being present in a ratio of 200:1, namely 99.5% to 0.5% by weight, was used.

At a concentration of 500 parts per million (ppm) the cloud point of the lube oil was reduced from +15 degrees C to +3 degrees C. This test was repeated at a concentration of 250 ppm and then of 1,000 ppm. The cloud point was reduced to +6 degrees C and +3 degrees C, respectively. The results are summarized in the following table:

Concentration (ppm)	**Reduced Cloud Point (degrees C) from +15° C**
250	6
500	3
1,000	3

Test #8 A test was performed, whereby coke from a delayed coker unit at a refinery was treated with the preferred composition of matter in a heated water mix, and the following results were obtained.:

Water plus 0.5% by weight of the preferred dispersant of the invention were mixed together and heated to about 200 degrees F, with the coke in chunk form dropped into the stirred hot water and composition of matter mix. All of the coke treated was found to be completely dispersed in the heated mixture. Such dispersal would not have occurred without the presence of the added composition of matter of the invention.

The coke used in the test was from a stub tower and the blow-down tower from the delayed coker unit. The test showed that, with the coke being in the dispersed state, the coke could be easily removed from the unit as a dispersion in water and thus easily removed from the site.

Test #9 A slop oil tank with 3,000 barrels of aged wax emulsion slop oil tank bottoms (estimated at 66% hydrocarbon) was treated with a mixture of a 0.15% by volume of the preferred dispersant of the invention and 0.45% of a polycarboxylic acid (pH ranging from 3.0 to 5.0) in the presence of an equal amount of water (3,000 barrels) and the mixture heated to 90°C. After the mixture was treated for a period of 30 minutes, 3,000 barrels of light crude oil (A.P.I. quality of 32 to 35) was added and mixing continued for an additional 45 minutes. After cooling to room temperature, the resulting mixture separated into three (3) distinct layers – oil (crude oil + wax + slop oil recovered), clear water and clean solids. The resulting mixture of added crude oil plus recovered wax and oil yielded a final crude oil blend of 4,980 barrels of crude oil. The final blend had a B.S.&W. of 0.00% (using the test/measurement methodology set forth in ASTM D 4007-81), that is zero rag, with a pour point of 10°C (using the test/measurement methodology set forth in ASTM D 97-96A).

It is noted that the formulations, compositions, and applications described herein generally and/or in detail were for exemplary purposes and are, of course, subject to many variations. Because many varying and different embodiments may be made within the scope of the inventive concept(s) herein taught, and because many modifications may be made in the embodiments herein detailed in accordance with the descriptive requirements of the law, it is to be understood that the details herein are to be interpreted as illustrative and not in a limiting sense.

Claims

1. A method of liquefying and dispersing crystalline wax, comprising the steps of (a) chemically treating the crystalline wax to reduce the surface tension of the crystalline wax, converting it to an amorphous form of wax; and (b) dispersing the amorphous wax in a diluent.

2. The method of **Claim 1**, wherein there is further included in step "a" the step of treating the crystalline wax with a surface active agent having a surface tension in water in the range of about 10 to about 48 dynes per cm, reducing the crystalline wax's surface tension.

3. The method of **Claim 1**, wherein there is further included in step "a" the step of treating the crystalline wax with a surface active agent having a surface tension in water in the range of about 15 to about 32 dynes per cm, reducing the crystalline wax's surface tension.

4. The method of **Claim 1**, wherein the crystalline wax is contained in slop oil, and there is further included in step "b" the step of using crude oil as the diluent, producing a B.S.&W of about 0.00% in the final crude oil blend.

5. The method of **Claim 4**, wherein there is further included the step of: mixing the slop oil with its wax in amorphous form and the crude oil together, forming a homogeneous mixture.

6. The method of **Claim 2**, wherein the crystalline wax is contained in slop oil, and there is further included in step "b" the step of using crude oil as the diluent.

7. The method of **Claim 6**, wherein there is further included the step of mixing the surface active agent, the slop oil and the crude oil together at ambient temperature, forming a homogeneous mixture.

8. The method of **Claim 7**, wherein there is further included the step of maintaining the homogenous mixture of the surface active agent, the slop oil and the crude oil together at ambient temperature.

9. The method of **Claim 8**, wherein there is further included the step of transporting the homogenous mixture of the surface active agent, the slop oil and the crude oil together at ambient temperature.

10. The method of **Claim 6**, wherein there is further included the step of concurrently mixing in a degreaser in the combined amorphous wax and diluent.

11. The method of **Claim 6**, wherein there is further included the step of concurrently mixing in a corrosion and scale formation inhibitor in the combined amorphous wax and diluent.

12. The method of **Claim 6**, wherein in step "b" the diluent is a refined petroleum product, and in step "b" there is further included the step of using said surface active agent as a cloud point lowering, dehazer in the combined amorphous wax and refined petroleum product.

13. The method of **Claim 6**, wherein in step "b" the diluent is a refined petroleum product, and in step "b" there is further included the step of using said surface active agent as a pour point lowering agent in the combined amorphous wax and refined petroleum.

14. The method of **Claim 1**, wherein the diluent is crude oil, and wherein and there is further included the steps of treating the crystalline wax with a treatment chemical to reduce the surface tension of the crystalline wax producing the amorphous wax; and mixing the amorphous wax and crude oil, and retaining the treatment chemical in the mix to inhibit the formation of slop oil out of the crude oil.

15. The method of **Claim 14**, wherein there is further included the step of transporting the mixture of the treatment chemical, the amorphous wax and the crude oil together at ambient temperature.

16. The method of **Claim 14**, wherein there is further included in step "a" the step of concurrently mixing in with the surface active agent at least one further agent from the group consisting of – a degreaser, a demulsifier, a corrosion inhibitor, and a scale formation inhibitor – with the treatment chemical in the combined amorphous wax and crude oil mixture.

17. The method of **Claim 14**, wherein there is further included the step of using the surface active agent as either a cloud point or a pour point depressant.

18. The method of **Claim 14**, wherein there is further included the step of mixing the treatment chemical with the crystalline wax and crude oil at the crude oil production source.

19. The method of **Claim 2**, wherein there is further included the step of using as the surface active agent a homogeneous mixture including about 25% to about 99.9% by weight the surface active agent.

20. The method of **Claim 19**, wherein there is further included the step of including with the surface active agent in a homogeneous mixture of about 15% to about 45% by weight butyl cellosolve, and about 5% to about 15% by weight of pine oil and a mixed catalyst solution made of saturated higher fatty acids, an alkyl phenol and an oil-water soluble copolymer of partially sulfonated, maleic anhydride and polystyrene with a molecular weight ranging from about 2,000 to about 2,000,000.

21. The method of **Claim 20**, wherein there is further included the step of using a catalyst mixture in a range of about 0.5% to about 5% by weight.

22. The method of **Claim 19**, wherein there is further included the step of using as the surface active agent a nonionic polyethoxylated compound.

23. The method of **Claim 22**, wherein there is further included the step of using as the surface active agent a product derived from polyethylene oxide.

24. The method of **Claim 23**, wherein the surface active agent is a nonionic surfactant, and wherein there is further included the step of using, as a composition of matter mixture, a by-weight percent of the nonionic surface active agent of about 48%, with about 32% butyl cellosolve and about 17% pine oil acting as degreaser, about 2% of a mixture containing about 70% higher fatty acids, about 29% a copolymer of maelic anhydride and polystyrene, and about 1% of catechol serving as a corrosion inhibitor.

25. The method of **Claim 1**, wherein steps "a" & "b" are used in association with one of the applications from the group consisting of:

1. Cleaning crude oil and petrochemical storage tanks;
2. Injection into crude oil pipelines to prevent wax or "slop" separation;
3. Add to crude oil in oceangoing vessels to prevent wax or "slop" separation;
4. As a dispersant in base lube oil stocks to lower the cloud point, namely as a dehazing compound;
5. As a wax liquefier and dispersant in base lube oil stocks to lower the pour point;
6. As a dispersant in gasoil to lower the cloud point, namely as a dehazing compound;
7. As a wax liquefier and dispersant in gasoil to lower the pour point;
8. As a demulsifier for crude oil in pipelines and storage tanks;
9. As a wax liquefier in downhole operations in the production of crude oil;
10. As a dispersant and degreaser in crude oil storage tanks;
11. As a dispersant and degreaser in petrochemical storage tanks;
12. As an additive in engine lubricating oil for the purpose of dispersing lubricating oil sludge;
13. As a method of measuring the true value of crude oil by demulsifying the water in the crude oil; this will allow for a more accurate measurement of the actual amount of crude oil being purchased;
14. As a dispersant and wax liquefier in hydrocarbon liquids derived from natural gas processing, *i.e.*, condensates;
15. As a dispersant for napthenic acids in fuel oils;
16. As a dispersant for sludge in processing units such as catalytic crackers;
17. As a dispersant for waste wax residue derived from polyethylene plants for the purpose of dispersing the wax into fuel oil;
18. As a dispersant for wax in cutting and cooling fluids used in machining operations;
19. As a dispersant for wax in heavy fuel oils such as, for example, "Bunker C" and Fuel Oil No. 6 (heating oil);
20. As a wax liquefier and degreaser in heat exchangers in various petroleum refining process units (furfural lube oil extraction plants and the like);
21. As a dispersing agent for coke and carbon fines into hydrocarbon liquids and/or water;
22. As a dispersant for cleaning machine parts;
23. As a liquefier and dispersant for wax into hydrocarbon liquids derived from Fischer-Tropsch synthesis;
24. As a dispersant for wax in edible oils;
25. As a dispersant for wax in organic solvents;
26. As a dispersant for asphalt in various hydrocarbon solvents;
27. As a dispersant in cutting oil emulsions;
28. As a dispersant for naturally-occurring waxes in various hydrocarbon media and water;

29. As a liquefier and dispersant for wax used as a protective coating;

30. As a dispersant and liquefier for wax for oil recycling processes;

31. As a dispersant for highly-paraffinic organic compounds into various organic solvents;

32. As a liquefier and dispersant additive in gasoline and fuel oil;

33. As a degreaser for removing asphalt from concrete surfaces;

34. As a neutral metal degreaser for metal parts in dip tanks;

35. As a liquefier for wax derived from pipeline pigging operations;

36. As a dispersant in oil for extreme pressure additives (E.P.A.);

37. As a dispersant in oil for anti-wear additives;

38. As a dispersant in lube oil to provide dispersion of products of degradation and combustion;

39. As a dispersant for fuel oil ("Bunker C" and the like), diesel and gasoil;

40. As a dispersant for wax in solvent dewaxing processes;

41. As a dispersant for metals and sludge in petroleum waste products (oil/water separators and the like);

42. As an additive for drilling muds to enhance their dispersion and surface active activity (contact) during drilling operations;

43. As an additive in petroleum production to enhance the flow of crude in secondary and tertiary production;

44. As a wax liquefier and dispersant in the production of one of the products from the group consisting of – a. floor coverings and polishes, b. adhesives, c. cosmetics, d. electrical insulation, e. leather finishes, f. matches, g. treated paper products, h. molding and coating processes, i. printing inks and varnishes, j. dental materials, k. explosives, l. crayons, m. textile finishes, n. candles, o. rubber antioxidants, and p. corrosion inhibitors;

45. As a surface active agent and dispersion in descaling formulations;

46. As a surface active agent and dispersion in acid de-rusting formulations;

47. As a wax liquefier and dispersant in high-heat distillates (lignitic tar-lignite paraffins and the like);

48. As a dispersant for asphalt and/or tar on surface coating such as roofing paper and the like;

49. As a cleaning chemical in the cleaning of ship ballast tanks;

50. As a wax liquefier and dispersant in emulsions used in automobile and other vehicular care products (*i.e.*, transportation cleaners);

51. As a biodegradable dispersant for agricultural fertilizers for trees and plants;

52. As a wax liquefier and dispersant in the manufacture of grease;

53. As a dispersant for inorganic compounds in water, such as tailings from mining and the like;

54. As a dispersant and demulsifier for waste oil in oil production, exploration, transportation and/or refining (A.P.I. separator);

55. As a dispersant for wax in commercial car products to help in self-rinsing applications; and

56. As a sludge-breaker and demulsifier for slop oil emulsions in crude oil tank bottoms.

26. A chemical composition of matter, comprising a by-weight percent of a nonionic surface active agent of about 48%, with about 32% butyl cellosolve and about 17% pine oil, about 2% of a mixture containing about 70% higher fatty acids, about 29% a copolymer of maelic anhydride and polystyrene, and about 1% of catechol.

27. The chemical composition of **Claim 26**, wherein said nonionic surface active agent is a nonionic polyethoxylated compound.

29. The chemical composition of **Claim 26**, wherein said nonionic polyethoxylated compound is a product derived from polyethylene oxide.

30. A chemical composition of matter, comprising wax, originally in crystalline form, but converted to an amorphous form due to the presence of an additive including a nonionic surface active agent.

31. The chemical composition of **Claim 30**, wherein said nonionic surface active agent is a nonionic polyethoxylated compound.

32. The chemical composition of **Claim 31**, wherein said nonionic polyethoxylated compound is a product derived from polyethylene oxide.

33. The chemical composition of **Claim 30**, wherein said surface active agent represents about 48% by weight; and there is further included: about 32% butyl cellosolve and about 17% pine oil, about 2% of a mixture containing about 70% higher fatty acids, about 29% a copolymer of maelic anhydride and polystyrene and about 1% catechol.

34. A method of liquefying and dispersing crystalline wax, comprising the steps of (a) chemically treating the crystalline wax with a surface active agent of a nonionic surfactant that is made up of up to about 99.9% by weight of a nonionic surfactant and down to about 0.1% by weight of a surface tension depressant, thereby converting the crystalline wax to an amorphous form of wax; and (b) dispersing the resultant amorphous wax in a diluent.

35. The method of **Claim 34**, wherein there is further included in step "a" the step of using a nonionic polyethoxylate surfactant as the nonionic surfactant.

36. The method of **Claim 34**, wherein there is further included in step "a" the step of using a flouronated hydrocarbon alcohol as the surface tension depressant.

37. The method of **Claim 34**, wherein there is further included in step "a" the step of using a nonionic surfactant having a H.L.B. number ranging from about ten to about eleven and a half.

38. The method of **Claim 34**, wherein there is further included in step "a" the step of using a nonionic surfactant having a surface tension in water in the range of about 10 to about 48 dynes per cm, reducing the crystalline wax's surface tension, causing it to be converted to amorphous wax.

39. The method of **Claim 35**, wherein there is further included in step "a" the step of using a nonionic polyethoxylated compound as the nonionic surfactant.

40. The method of **Claim 39**, wherein there is further included in step "a" the step of using a product derived from polyethylene oxide as the nonionic polyethoxylated compound.

41. The method of **Claim 35**, wherein there is further included in step "a" the step of also adding with said nonionic polyethoxylated compound in a homogeneous mixture of about 15% to about 45% by weight butyl cellosolve, about 5% to about 15% by weight of pine oil and a mixed catalyst solution made of saturated higher fatty acids, an alkyl phenol, and an oil-water soluble copolymer of partially sulfonated, maleic anhydride and polystyrene with a molecular weight ranging from about 2,000 to about 2,000,000.

42. The method of **Claim 34**, wherein the crystalline wax is contained in slop oil, and there is further included in step "b" the step of using crude oil as the diluent.

43. The method of **Claim 34**, wherein there is further included in step "a" the step of concurrently mixing in with the surface active agent at least one additional agent from the group consisting of – a degreaser, a demulsifier, a corrosion inhibitor, and a scale formation inhibitor, – with the treatment chemical in the combined amorphous wax and crude oil mixture.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/14167

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :CO8L 91/08
US CL : 106/271, 272
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 106/271, 272

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST
search terms: slop oil

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 409296162 A [OKURA et al] 18 November 1997, see abstract	1-20, 22, 23, 25, 28-32, 34-40, 42 and 43
Y, P	US 6,000,412 A [CHAN et al] 14 December 1999, see entire document.	1-20,22, 23, 25 ,28-32, 34-40, 42 and 43
Y	US 5,525,201 A [DIAZ-ARAUZO et al] 11 June 1996, see entire document.	1-20, 22, 23, 25, 28-32, 34-40, 42 and 43

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be of particular relevance
"E"	earlier document published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search

11 AUGUST 2000

Date of mailing of the international search report

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Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer
DAVID M. BRUNSMAN

Telephone No. (703) 308-0661

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/14167

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,551,239 A [MERCHANT et al] 05 November 1985, see entire document.	1-20, 22, 23, 25, 28-32, 34-40, 42, 43
Y	US 4,477,337 A [RONDEN et al] 16 October 1984, see entire document.	1-20, 22, 23, 25, 28-32, 34-40, 42, 43