

-1-

APPARATUS FOR MAKING CONCENTRATED EMULSIONS**Field of the Invention**

The present invention relates to apparatus for continuously preparing concentrated emulsions, such as
5 a variety of water-in-oil emulsions, particularly those which can be effectively employed as additives for hydrocarbon fuels.

Background of the Invention

Emulsions, including water-in-oil emulsions, for
10 various uses have been prepared by use of a wide variety of equipment. Usually, the equipment has been high shear producing apparatus, such as high speed impellers, mixers, static mixers and the like. Emulsions are usually made in batch operations, but
15 some are made or maintained by continuous operations.

Emulsions made in the apparatus of this invention are of particular interest for fuels. The concept of adding water to a combustion mixture can be traced back as far as about 200 years, while the use of emulsions
20 as fuels can be traced back about 80 years. In particular, it has been found that water-in-oil emulsions can improve the burning characteristics of, e.g., internal combustion engines.

A variety of fuel compositions for use in internal
25 combustion engines and which comprise emulsions of hydrocarbon fuels and water are known in the art. A few representative examples include U.S. Patents

-2-

1,498,340 to Belknap; 1,533,158 to Belknap; 1,701,621 to Kirschbraun; 3,876,391 to McCoy et al.; 4,199,316 to Fung; 4,244,702 to Alliger; and 4,696,638 to DenHerder, the disclosures of which are incorporated herein by
5 reference.

Water-in-oil hydrocarbon fuel emulsions have been produced by a variety of techniques including, e.g., the homogenizing of water and oil together in the presence of surfactants so as to create a final fuel
10 having certain combustion characteristics.

In addition, as discussed in U.S. Patent 1,701,621 to Kirschbraun, the art has recognized the ability to produce an initial concentrated emulsion of water with a heavy hydrocarbon oil and then diluting this initial
15 emulsion into the fuel, e.g., gasoline, so as to obtain the final fuel composition. U.S. Patent 4,696,638 to DenHerder contains a similar disclosure.

In the past, the art has traditionally produced saturated emulsions, i.e., emulsions where the volume
20 of the discontinuous phase exceeds the volume of the continuous phase, in batch processes involving the slow addition of the discontinuous phase into a mixing tank containing the continuous phase. In such a process, emulsifiers can optionally be employed within either
25 the discontinuous or the continuous phase, or in both phases.

However, continuous processes are considered to be more efficient. Thus, it is an object of the present invention in order to provide a continuous process for
30 producing concentrated emulsions, as well as other emulsions.

-3-

This and further objects will become apparent from the specification and claims which follow.

Summary of the Invention

The present invention relates to an apparatus for
5 continuously preparing an emulsion, e.g., a
concentrated water-in-oil emulsion, such as can be
effectively employed as an additive for hydrocarbon
fuels.

In particular, the apparatus comprises a
10 circulating loop vessel which comprises at least two
inlet means, e.g., one inlet means for a discontinuous
phase, and one inlet means for a continuous phase, as
well as at least one outlet means for the emulsion and
a flow circulation means, e.g., a circulating pump.
15 Each of the inlet means, outlet means, and circulating
pump are arranged so as to be capable of producing a
concentrated emulsion when the appropriate
discontinuous and continuous phases are introduced into
the vessel and the circulating means is operated to
20 circulate and emulsify the phases.

Brief Description of the Drawings

Figure 1 is a schematic drawing of the apparatus
according to the present invention; and

Figure 2 illustrates a preferred embodiment of an
25 apparatus according to the present invention.

Detailed Description of the Invention

As discussed above, the present invention relates
to an apparatus for making of an emulsion, particularly

-4-

a concentrated water-in-oil emulsion, which can be employed as additive for hydrocarbon fuels.

Although the apparatus of the present invention will be discussed in terms of the production of a concentrated water-in-oil emulsion fuel additive, those skilled in the art will clearly recognize the applicability of this apparatus to the production of a wide variety of emulsions and concentrated emulsions.

In making the water-in-oil emulsion fuel additive of the present invention, light hydrocarbon fuel is preferably first mixed with at least one surfactant. The light hydrocarbon fuel which can be effectively employed in the present invention includes any light oil, e.g., #2 diesel oil, #1 diesel oil, which is recognized in the art with the choice of a particular oil being dependent on the final application for the fuel emulsion. For example, when the emulsion is to be added to #2 diesel fuel, #2 diesel oil is usually preferred for forming the emulsion additive.

The surfactants which can be employed include any emulsifier or mixture of emulsifiers, which are recognized in the art. Typical emulsifiers include amine alkylbenzene sulfonates, tall oil fatty acids, oleylimidazolinium hydrochloride and mixtures thereof. For example, in an embodiment where a mixture of such additives is to be added to #2 diesel fuel, the mixture can comprise the above three components in a ratio of, e.g., about 45:30:25, respectively.

In forming such an emulsion, it is preferred that water is mixed with the other components in an amount effective to provide an emulsion which is about 40 to about 80% by volume water, preferably about 50 to about

-5-

70%, and more preferably about 55 to about 65%, and in particular about 60% being even more preferred. These guidelines are based on the fact if too much water is present in the emulsion additive, the emulsion may be too viscous to be quickly dispersed when finally added to the hydrocarbon fuel.

The ratio of water to emulsifiers is sufficient to reduce interfacial surface tension so as to achieve the desired size of water droplets. Preferably, the ratio of water to emulsifier(s) is about 5:1 to about 20:1, with about 10:1 being more preferred. In the embodiment employing diesel oil as the hydrocarbon fuel, the ratio of water:hydrocarbon fuel:emulsifier(s) is preferably from about 80:12:8 to 40:56:4, more preferably about 70:23:7 to about 50:45:5, with about 60:34:6 being even more preferred.

The water employed in the present invention can come from any recognized source, e.g., typical city water can be effectively employed.

The emulsion made according to the present invention will have water droplets which are substantially continuously and uniformly distributed therethrough and will have a droplet size or diameter which effectively allows for a "microexplosion" when of the water droplets present in the emulsion additive is added to a hydrocarbon fuel which is combusted.

It is the belief of the inventors that many of the advantages associated with the present invention can be attributed to the "microexplosions" of the water droplets present within the emulsion during the combustion of the final fuel composition. See, for example, the discussion in the article entitled "The

-6-

Application of Emulsified Fuels in Diesel Engine
Designs: Experimental Results and Theoretical
Predictions" by R.V. Thompson et al, Trans. I. Mr.
Engr. (TM), Vol. 97, Paper 10 (1985). However, this
5 invention should not be bound by or limited to this or
any other particular theory.

This droplet size can range from about 0.1 to
about 200 microns. Preferably, this size ranges from
about 0.2 microns to about 100 microns, more preferably
10 about 0.3 to about 70, still more preferably about 1.0
to about 50, with about 5 to about 30 microns being
even more preferred.

The desired water droplet size can be provided by
any means which is recognized in the art, for example,
15 through the amount and type of emulsifier(s) employed,
i.e., the greater the amount of emulsifier employed in
the mixture, the smaller the droplet size in the
emulsion. In addition, the choice of mixing means can
effectively control the size of the water droplets and
20 the uniformity of the droplet size. The apparatus of
the present invention is particularly effective in
producing emulsions of desired droplet size and
uniformity.

Emulsions produced by the present invention can be
25 stable over long periods of time, e.g., months, and
possibly even years, and thus has an adequate shelf
life for, e.g., storage and distribution purposes.

In addition, when the emulsion produced by the
apparatus of this invention is employed as an additive
30 for light hydrocarbon fuels such as diesel fuels, jet
fuels or gasoline, the resulting composition improves
the efficiency of the fuel, i.e., the miles per gallon

-7-

(mpg) associated with the fuel is increased, while also reducing the exhaust gas pollution and particulate emissions associated therewith.

The apparatus according to the present invention is capable of continuously producing a concentrated emulsion. This apparatus for continuous production, which is illustrated schematically in Figure 1, includes suitable means, e.g., three or more metering pumps, 1, 2 and 3, for continuously adding the components to a circulating loop vessel 4. Circulating means, pump 5, produces a circulating flow rate in the loop that is "large" when compared to the discontinuous phase flow rate entering the loop. By "large" it is meant that the circulating flow rate is significantly larger, e.g., no less than about 5 times the flow rate of the discontinuous phase entering the loop. In general, the circulating flow rate within the loop will be between about 5 and about 100 times the flow rate of the discontinuous phase entering the loop, preferably between about 10 and about 40 times, and more preferably in the range of about 15 times.

As further illustrated in Figure 1, components of the continuous phase, i.e., diesel oil at 2.8 gpm (10.6 lpm) and surfactant(s) at 0.5 gpm (1.9 lpm), can be premixed by metering means, pumps 2 and 3, respectively, prior to introduction into the circulating loop 4. Once the circulating loop is fully charged and circulating nominally at about 80 gpm (about 303 lpm), the discontinuous phase, e.g., water, can then be introduced via metering pump 1 at 5 gpm (19 lpm). The emulsion can then be continuously removed from the loop via line 6 at 8.3 gpm (31.4 lpm). Co-surfactants (or water soluble additives) can be premixed with the water if desired using pump 7, or the

-8-

co-surfactant(s) can be added to the final emulsion at outlet 6 of the circulating loop vessel 4.

A preferred apparatus of the present invention for producing emulsions is illustrated in Figure 2. In this apparatus, both the continuous phase, i.e., preferably a premix of the oil and emulsifier(s) 11, and the discontinuous phase, i.e., preferably water, 12 are introduced in the circulating loop via, e.g., suitable means such as pipes 13a and 13b, respectively, into the circulating loop vessel 4. A circulating pump 14, e.g., a centrifugal circulating pump, is employed to circulate the material within the loop. The emulsion is removed via outlet 15, this emulsion can then be further refined for uniformity of product by passing through a suitable mixing means, e.g., a static mixer or a homogenizer 17. Drain 16 is employed to remove all residual material from the loop when needed for cleaning.

Although the present invention is described in terms of the fuel additive emulsion embodiment illustrated above, it is recognized that a number of apparatus and process parameters may be varied according to this invention depending on the nature and quality of a desired emulsion. The apparatus of this invention is useful in making emulsions for food, paint, cosmetics, drugs and other products. The apparatus of this invention is also useful in premixing, mixing or otherwise contacting materials.

In terms of the apparatus, such parameters include overall loop design, e.g., volume, velocity, turbulence and the like; pump selection, and the optional use of a static or other mixing means in connection with the outlet of the loop, as well as point of introduction

-9-

and method of introduction, e.g., co-current or counter-current, spray injection or open ended pipe, for the inlet streams.

In addition to those features relating to the apparatus, process parameters, e.g., the choice and amount of emulsifier(s), temperature, system pressure, circulating pump type and speed and the like, are also selected based upon the characteristics of the desired emulsion, and since this is a continuous process, it does allow for both open loop and closed loop automatic control.

The continuous nature of the process associated with the apparatus of the present invention provides an increased efficiency i.e., reduced labor costs, better quality control and increase ease associated with packaging of such emulsions, as well as change of product properties while on stream.

In order to further illustrate the present invention and the advantages which can be associated therewith, the following specific example is given, it being understood that the same is intended only as illustrative and is in no way limitative of the scope of this invention.

EXAMPLE

A circulating loop vessel using 2 inch (5 cm) size pipe of Fig. 2 is charged with a premixed #2 diesel oil and emulsifier stream. The diesel oil is introduced by a metering pump at the rate of 2.8 gallons per minute (gpm) (10.6 liters per minute) while the emulsifier described in Example 1 is introduced at a rate of 0.5 gallons per minute (1.9 lpm). Once the loop is fully

-10-

charged, and circulating at about 80 gallons per minute (about 303 lpm), water is then introduced via a third metering pump at a rate of 5.0 gallons per minute (19 lpm). The circulating pump was a 3x3x4 centrifugal at 1750 rpm with a semi-open impeller. The resulting concentrated emulsion is passed through a static mixer at a rate of 8.3 gallons per minute (31.4 lpm).

It should be noted, that when first started this loop will obviously produce only pure continuous phase. As the liquid circulates in the loop, however, an increasing amount of discontinuous phase will build up very quickly. For this particular example, only about 30 seconds of running time would be necessary to approach the final 60:34:6 ratio. Once stabilized, the loop can be stopped and restarted to produce final 60:34:6 emulsion immediately at intermittent intervals.

While the invention has been described in terms of various preferred embodiments, the skilled artisan will appreciate the various modifications, substitutions, omissions, and changes which may be made without departing from the spirit thereof. Accordingly, it is intended that the scope of the present invention be limited solely by the scope of the following claims including equivalents thereof.

-11-

**WHAT IS CLAIMED IS:**

1. An apparatus for making a concentrated emulsion which comprises a circulating loop vessel including at least two inlet means, at least one outlet means, and a flow circulating means, and further comprising
5 means for introducing a continuous phase into a first inlet means,
means for introducing a discontinuous phase into a
10 second inlet means, and
means for withdrawing an emulsion from the outlet means,
wherein the inlets means, outlet means and flow circulating means are arranged so as to be capable of
15 producing a concentrated emulsion.
2. The apparatus according to claim 1 wherein said flow circulating means is a circulating pump.
3. The apparatus according to claim 2 wherein the pump is a centrifugal circulating pump.
- 20 4. The apparatus according to claim 2, wherein the pump is a positive displacement pump.
5. The apparatus according to claim 1 wherein each of the continuous phase introducing means and the discontinuous phase introducing means comprises a spray
25 injection means.
6. The apparatus according to claim 5 wherein the introducing means comprises open-ended pipe injection means.

-12-

7. The apparatus according to claim 1 further comprising a mixing means which is in fluid communication with the emulsion outlet means.

5 8. The apparatus according to claim 5 wherein the mixing means is a static mixing means.

9. The apparatus according to claim 5 wherein the mixing means comprises a homogenizer means.

10 10. The apparatus according to claim 1 wherein each of the inlet means is in fluid communication with a respective metering pump.

11. The apparatus according to claim 1 wherein each of the inlet means is at a position relative to the flow in the apparatus which is prior to the flow circulating means.

15 12. The apparatus according to claim 1 wherein each of the inlet means are positioned on either side of the flow circulating means.

13. The apparatus according to claim 1 further comprises another outlet means is an air venting means.

20 14. The apparatus according to claim 1 further comprising another outlet means which is a drain.

