LUBRICATING COMPOSITIONS FOR BATTERY IMMERSION COOLING

CROSS-REFERENCE TO RELATED APPLICATIONS

[01] This application claims the benefit of U.S. Provisional Application No. 63/565,097, filed March 14, 2024, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[02] This disclosure relates to compositions that can be used as cooling fluid for an immersion cooling system.

BACKGROUND

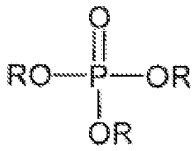
[03] Optimizing battery operating temperatures in electric vehicles is important for a number of reasons including reducing the possibility of thermal runaway reactions and extending the life of modern battery systems.

[04] Direct immersion cooling is one way of optimizing the temperature of battery packs in electric vehicles. Current examples of battery cooling systems in common use involve indirect cooling, such as air-cooling and glycol-water cooling. Although these strategies lead to some sort of temperature control, it is far from optimal, and can lead to the strong possibility of cell degradation and thermal runaway.

[05] The problem with immersion cooling is that there is direct contact with battery anodes, cathodes, wires and other electronic devices within the battery pack. Direct immersion cooling fluids require very low chemical reactivity, high flash and fire points to prevent fire propagation, high autoignition temperatures, low viscosity, to improve circulation to remove excess heat to a heat exchanger.

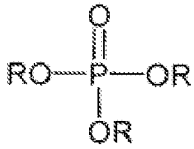
SUMMARY

[06] In one aspect, there is provided a cooling fluid for immersion cooling system comprising: a) ester type base stock or a hydrocarbon base stock or both; and b) phosphate ester having the following formula



where each R is independently C1-C18 alkyl group, unsubstituted phenyl group or C1-C12 alkyl-substituted phenyl group.

[07] In another aspect, there is provided a method of cooling a battery in an electric or hybrid vehicle, comprising: immersing the battery with a cooling fluid comprising: a) a hydrocarbon base stock or an ester type base stock or both; and b) phosphate ester having the following formula



where each R is independently C1-C18 alkyl group, unsubstituted phenyl group or C1-C12 alkyl-substituted phenyl group.

DETAILED DESCRIPTION

[08] It is understood that when combinations, subsets, groups, etc. of elements are disclosed (e.g., combinations of components in a composition, or combinations of steps in a method), that while specific reference of each of the various individual and collective combinations and permutations of these elements may not be explicitly disclosed, each is specifically contemplated and described herein.

[09] The present invention is related to a cooling fluid. More particularly, the present invention is related an immersion cooling fluid that can reduce or regulate temperature of an immersion cooling system, such as ones found in vehicles equipped with battery-operated electric motors. It is generally desirable for immersion cooling fluids to have certain physical characteristics such as low dielectric constants, low kinematic viscosities, high flash points, and/or high auto-ignition temperatures.

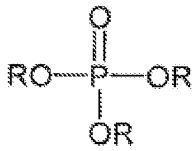
[010] The present invention relates to a cooling fluid comprising a phosphate ester and an ester base stock and/or a hydrocarbon base stock. It has been

discovered that the combination of phosphate ester and ester base stock and/or hydrocarbon base stock surprisingly elevates flash point and/or autoignition temperature while maintaining low kinematic viscosities, resulting in cooling fluid with desirable thermal properties.

[011] It is also contemplated that the immersion cooling fluid may include phosphate ester and water-glycol.

Phosphate Esters

[012] The cooling fluid of the present disclosure includes a phosphate ester given by the following formula:



where each R group is independently C1-C18 alkyl group, unsubstituted phenyl group, or C1-C12 alkyl-substituted phenyl group.

[013] The phosphate ester is present in an amount ranging from about 0.1 wt % to about 95 wt % by total weight of the cooling fluid, such as, from about 0.1 wt % to about 90 wt %, from about 0.1 wt % to about 85 wt %, from about 0.1 wt % to about 80 wt %, from about 0.1 wt % to about 75 wt %, from about 0.1 wt % to about 70 wt %, from about 0.1 wt % to about 65 wt %, from about 0.1 wt % to about 60 wt %, from about 0.1 wt % to about 55 wt %, from about 0.1 wt % to about 50 wt %, from about 0.1 wt % to about 45 wt %, from about 0.1 wt % to about 40 wt %, from about 0.1 wt % to about 35 wt %, from about 0.1 wt % to about 30 wt %, from about 0.1 wt % to about 25 wt %, from about 0.1 wt % to about 20 wt %, from about 0.1 wt % to about 15 wt %, from about 0.1 wt % to about 10 wt %, 0.5 wt % to about 95 wt %, from about 0.5 wt % to about 90 wt %, from about 0.5 wt % to about 85 wt %, from about 0.5 wt % to about 80 wt %, from about 0.5 wt % to about 75 wt %, from about 0.5 wt % to about 70 wt %, from about 0.5 wt % to about 65 wt %, from about 0.5 wt % to about 60 wt %, from about 0.5 wt % to about 55 wt %, from about 0.5 wt % to about 50 wt %, from about 0.5 wt % to about 45 wt %, from about 0.5 wt % to about 40 wt %, from about 0.5 wt % to about 35 wt %, from about 0.5 wt % to about 30 wt %, from about 0.5 wt % to about 25 wt %, from about 0.5 wt % to about 20 wt %, from

about 0.5 wt % to about 15 wt %, from about 0.5 wt % to about 10 wt %, from about 1 wt % to about 95 wt %, from about 1 wt % to about 90 wt %, from about 0.5 wt % to about 85 wt %, from about 1 wt % to about 80 wt %, from about 1 wt % to about 75 wt %, from about 1 wt % to about 70 wt %, from about 1 wt % to about 65 wt %, from about 1 wt % to about 60 wt %, from about 1 wt % to about 55 wt %, from about 1 wt % to about 50 wt %, from about 1 wt % to about 45 wt %, from about 1 wt % to about 40 wt %, from about 1 wt % to about 35 wt %, from about 1 wt % to about 30 wt %, from about 1 wt % to about 25 wt %, from about 1 wt % to about 20 wt %, from about 1 wt % to about 15 wt %, from about 1 wt % to about 10 wt %, from about 5 wt % to about 95 wt % , from about 5 wt % to about 90 wt %, from about 5 wt % to about 85 wt %, from about 5 wt % to about 80 wt %, from about 5 wt % to about 75 wt %, from about 5 wt % to about 70 wt %, from about 5 wt % to about 65 wt %, from about 5 wt % to about 60 wt %, from about 5 wt % to about 55 wt %, from about 5 wt % to about 50 wt %, from about 5 wt % to about 45 wt %, from about 5 wt % to about 40 wt %, from about 5 wt % to about 35 wt %, from about 5 wt % to about 30 wt %, from about 5 wt % to about 25 wt %, from about 5 wt % to about 20 wt %, from about 5 wt % to about 15 wt %, from about 5 wt % to about 10 wt %, from about 10 wt % to about 95 wt %, from about 10 wt % to about 90 wt %, from about 10 wt % to about 85 wt %, from about 10 wt % to about 80 wt %, from about 10 wt % to about 75 wt %, from about 10 wt % to about 70 wt %, from about 10 wt % to about 65 wt %, from about 10 wt % to about 60 wt %, from about 10 wt % to about 55 wt %, from about 10 wt % to about 50 wt %, from about 10 wt % to about 45 wt %, from about 10 wt % to about 40 wt %, from about 10 wt % to about 35 wt %, from about 10 wt % to about 30 wt %, from about 10 wt % to about 25 wt %, from about 10 wt % to about 20 wt %, from about 10 wt % to about 15 wt %, from about 15 wt % to about 95 wt %, from about 15 wt % to about 90 wt %, from about 15 wt % to about 85 wt %, from about 15 wt % to about 80 wt %, from about 15 wt % to about 75 wt %, from about 15 wt % to about 70 wt %, from about 15 wt % to about 65 wt %, from about 15 wt % to about 60 wt %, from about 15 wt % to about 55 wt %, from about 15 wt % to about 50 wt %, from about 15 wt % to about 45 wt %, from about 15 wt % to about 40 wt %, from about 15 wt % to about 35 wt %, from about 15 wt % to about 30 wt %, from about 15 wt % to about 25 wt %, from about 15 wt % to about 20 wt %, from about 20 wt % to about 95 wt %, from about 20 wt % to about 90 wt %, from about 20 wt % to about 85 wt %,

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[014] Suitable phosphate esters include, but are not limited to, 2-ethyl hexyl diphenyl phosphate, trioctyl phosphate, tris(2-butoxyethyl) phosphate, isopropylated triphenyl phosphate, triethyl phosphate, and the like.

[015] The phosphate ester can be prepared by any known method compatible with the present invention. By way of an illustrative example, preparation of triethyl phosphate will be described herein.

[016] In one embodiment, triethyl phosphate can be obtained by reacting phosphorus oxychloride with ethanol. The reaction takes place under reduced pressures and at temperatures ranging from 0 to 50 °C. The reaction produces volatile components which can be condensed by, for example, a reflux condenser. Any remaining volatile components are passed into a scrubber filled with water. The resulting reaction mixture can be separated by distillation. A more detailed

description of the process is described in U.S. Patent No. 6,673,955, which is hereby incorporated by reference.

[017] The cooling fluid may include an ester-type base stock ("organic ester base stock" or "ester base stock) or a hydrocarbon-type base stock or both.

Ester-Type Base Stock

[018] Ester-type base stock are oils that have one or more ester groups and may be natural (natural products) or synthetic.

[019] If present in the cooling fluid, the ester-type base stock is present in an amount ranging from about 1 wt % of about 99 wt % by total weight of the cooling fluid, such as, from about1 wt % to about 95 wt % from about 1 wt % to about 90 wt %, from about 1 wt % to about 85 wt %, from about 1 wt % to about 80 wt %, from about 1 wt % to about 75 wt %, from about 1 wt % to about 70 wt %, from about 1 wt % to about 65 wt %, from about 1 wt % to about 60 wt %, from about 1 wt % to about 55 wt %, from about 1 wt % to about 50 wt %, from about 1 wt % to about 45 wt %, from about 1 wt % to about 40 wt %, from about 1 wt % to about 35 wt %, from about 1 wt % to about 30 wt %, from about 1 wt % to about 25 wt %, from about 1 wt % to about 20 wt %, from about 1 wt % to about 15 wt %, from about 1 wt % to about 10 wt %, from about 5 wt % of about 99 wt %, 5 wt % to about 95 wt % by total weight of the cooling fluid, such as, from about 5 wt % to about 90 wt %, from about 5 wt % to about 85 wt %, from about 5 wt % to about 80 wt %, from about 5 wt % to about 75 wt %, from about 5 wt % to about 70 wt %, from about 5 wt % to about 65 wt %, from about 5 wt % to about 60 wt %, from about 5 wt % to about 55 wt %, from about 5 wt % to about 50 wt %, from about 5 wt % to about 45 wt %, from about 5 wt % to about 40 wt %, from about 5 wt % to about 35 wt %, from about 5 wt % to about 30 wt %, from about 5 wt % to about 25 wt %, from about 5 wt % to about 20 wt %, from about 5 wt % to about 15 wt %, from about 5 wt % to about 10 wt %, from about 10 wt % of about 99 wt %, from about 10 wt % to about 95 wt %, from about 10 wt % to about 90 wt %, from about 10 wt % to about 85 wt %, from about 10 wt % to about 80 wt %, from about 10 wt % to about 75 wt %, from about 10 wt % to about 70 wt %, from about 10 wt % to about 65 wt %, from about 10 wt % to about 60 wt %, from about 10 wt % to about 55 wt %, from about 10 wt % to about 50 wt %, from about 10 wt % to about 45 wt %, from about 10 wt % to about 40 wt %, from about 10 wt %

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90 wt %, from about 75 wt % to about 85 wt %, from about 75 wt % to about 80 wt %, from about 80 wt % of about 99 wt %, from about 80 wt % to about 95 wt %, from about 80 wt % to about 90 wt %, from about 80 wt % to about 85 wt %, from about 85 wt % of about 99 wt %, from about 85 wt % to about 95 wt %, from about 85 wt % to about 90 wt %, from about 90 wt % of about 99 wt %, or from about 90 wt % to about 95 wt %.

[020] Suitable organic ester base stocks include, but are not limited to, monoesters, diesters, polyol esters, pentaerythreitol esters, and the like. The ester-type basestocks are generally considered Group V base stocks, which is a collection of all base oils that do not fall into the Group I-IV base oil categories.

[021] Organic ester base stocks can be derived from animal or vegetable sources. Naturally occurring organic esters are found in animal fats such as sperm oil and lard oil, or in vegetable oils such as rapeseed and castor oil.

[022] Alternatively, organic esters can be synthesized by reacting organic acids with alcohols. For example, monoesters can be prepared by reacting monohydric alcohols with monobasic fatty acids creating a molecule with a single ester linkage and linear or branched alkyl groups. These products are generally very low in viscosity (usually under 2 cSt at 100° C) and exhibit extremely low pour points and high VI's.

[023] Diesters can be prepared by reacting monohydric alcohols with dibasic acids creating a molecule which may be linear, branched, or aromatic and with two ester groups. Diester types include, for example, adipates, azelates, sebacates, dodecanedioates, phthalates, and dimerates. Specific diesters include, for example, di(1-ethylpropyl)adipate, di(3-methylbutyl)adipate, di(1,3-methylbutyl)adipate, di(2-ethylhexyl)adipate, di(isononyl)adipate, di(isodecyl)adipate, di(undecyl)adipate, di(tridecyl)adipate, di(isotetradecyl)adipate, di(2,2,4-trimethylpentyl)adipate, di[mixed (2-ethylhexyl, isononyl)]adipate, di(1-ethylpropyl)azelate, di(3-methylbutyl)azelate, di(2-ethylbutyl)azelate, di(2-ethylhexyl)azelate, di(isooctyl)azelate, di(isononyl)azelate, di(isodecyl)azelate, di(tridecyl)azelate, di[mixed (2-ethylhexyl, isononyl)]azelate, di[mixed (2-ethylhexyl, decyl)azelate, di[mixed (2-ethylhexyl, isodecyl)]azelate, di[mixed (2-ethylhexyl, 2-propylheptyl)]azelate, di(n-butyl)sebacate, di(isobutyl)sebacate, di(1-ethylpropyl)sebacate, di(1,3-

methylbutyl)sebacate, di(2-methylbutyl)sebacate, di(2-ethylhexyl)sebacate, di[2-(2-ethylbutoxy)ethyl]sebacate, di(2,2,4-trimethylbenzyl)sebacate, di(isononyl)sebacate, di(isodecyl)sebacate, di(isoundecyl)sebacate, di(tridecyl)sebacate, di(isotetradecyl)sebacate, di[mixed (2-ethylhexyl, isononyl)]sebacate, di(2-ethylhexyl)glutarate, di(isoundecyl)glutarate, and di(isotetradecyl)glutarate.

[024] Polyol esters can be prepared by esterifying one or more polyols with one or more organic acids (see, e.g., U.S. Pat. No. 6,462,001, the contents of which are incorporated by reference herein). The synthesis of polyol esters from one or more polyols and one or more organic acids can be performed by methods known in the art such as subjecting polyols to dehydrating condensation in the presence of an acid catalyst. The polyols for use in forming the polyol esters can be those having from 2 to about 10 carbon atoms and from two to six hydroxyl groups. One example of a polyol for use herein is a neopentyl polyol having 5 to 10 carbon atoms. The term “neopentyl polyol” as used herein means a polyhydric alcohol having a neopentyl group. Examples of these polyols include, but are not limited to, 1,2-propanediol, 1,3-propanediol, 1,2-butanediol, 1,3-butanediol, 2,3-butanediol, 2-ethyl-1,3-propanediol, 2-ethyl-2-butyl-1,3-propanediol, 1,3-diol, (namely, neopentyl glycol), 2,2,4-trimethyl-1,3-pentanediol, 2,2-diethylpropane-1,3-diol, 2,2-dibutylpropane-1,3-diol, 2-methyl-2-propylpropane-1,3-diol, trimethylolpropane (TMP), pentaerythritol, dipentaerythritol and the like and mixtures thereof.

[025] The organic acids used in synthesis of polyol esters can be those having from 4 to about 24 carbon atoms. Examples of organic acids include, but are not limited to, butanoic acid, isobutanoic acid, pentanoic acid, isopentanoic acid, hexanoic acid, 2-ethylbutanoic acid, cyclohexanoic acid, heptanoic acid, isoheptanoic acid, methylcyclohexanoic acid, octanoic acid, dimethyl-hexanoic acid, 2-ethylhexanoic acid, 2,4,4-trimethyl-pentanoic acid, isooctanoic acid, 3,5,5-trimethylhexanoic acid, nonanoic acid, isononanoic acid, isodecanoic acid, isoundecanoic acid, 2-butyloctanoic acid, tridecanoic acid, tetradecanoic acid, hexadecanoic acid, heptadecanoic acid, octadecanoic acid, 2-ethylhexadecanoic acid, nonadecanoic acid, 2-methyloctadecanoic acid, icosanoic acid, 2-

methylicosanoic acid, 3-methylnonadecanoic acid, docosanoic acid, tetradocosanoic acid, 2-methyltricosanoic acid and the like and mixtures thereof.

[026] The organic acids can also be fatty acids which are a class of compounds containing a long hydrocarbon chain and a terminal carboxylate group and are characterized as unsaturated or saturated depending upon whether a double bond is present in the hydrocarbon chain. An unsaturated fatty acid has at least one double bond in its hydrocarbon chain whereas a saturated fatty acid has no double bonds in its fatty acid chain. Examples of unsaturated fatty acids include, but are not limited to, myristoleic acid, palmitoleic acid, oleic acid, linolenic acid and the like and mixtures thereof. Examples of saturated fatty acids include, but are not limited to, caproic acid, caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachidic acid, behenic acid, lignoceric acid and the like and mixtures thereof.

[027] In another embodiment, the polyol ester is at least one glycerol ester such as a C4 to about C75 fatty acid glycerol ester and preferably a C6 to about C24 fatty acid glycerol ester. The glycerol esters for use herein can be glycerides derived from, for example, natural sources, i.e., those derived from natural sources such as plants or animals; synthetic oils and the like and mixtures thereof. Useful natural oil include, but are not limited to, coconut oil, babassu oil, palm kernel oil, palm oil, olive oil, castor oil, rape oil, corn oil, beef tallow oil, whale oil, sunflower, cottonseed oil, linseed oil, tung oil, tallow oil, lard oil, peanut oil, canola oil, soya oil, and the like and mixtures thereof. Useful synthetic oils include, but are not limited to, synthetic oils derived from the reaction of one or more carboxylic acids with one or more glycerols, e.g., glycerol triacetate, and the like and mixtures thereof. Suitable starting oils will ordinarily contain triacylglycerols (TAGs), which contain three fatty acid chains esterified to a glycerol moiety and can be natural or synthetic. For example, TAGs such as triolein, trieicosenoin, or trierucin can be used as starting materials.

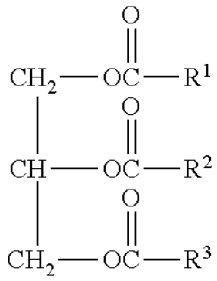
[028] The foregoing glycerol esters can contain from about C4 to about C75 and preferably contain about C6 to about C24 fatty acid esters, i.e., several fatty acid moieties, the number and type varying with the source of the oil. The fatty acid moieties independently can be unsaturated or saturated fatty acids. Examples of unsaturated fatty acids include, but are not limited to, myristoleic acid, palmitoleic

acid, oleic acid, linolenic acid, and the like and mixtures thereof. Examples of saturated fatty acids include, but are not limited to, caproic acid, caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachidic acid, behenic acid, lignoceric acid, and the like and mixtures thereof.

[029] In some embodiments, the acid moiety may be supplied in a fully esterified compound while in other embodiments, the acid moiety may be supplied a partially esterified compound, for example, glyceryl tri-stearate, glyceryl di-laurate and glyceryl mono-oleate, respectively.

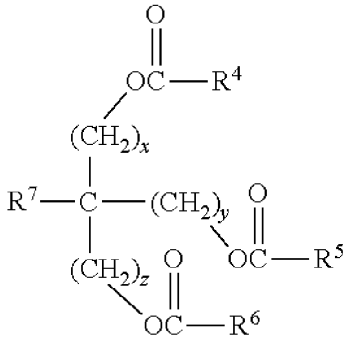
[030] The starting material can be plant derived oils, i.e., vegetable oils. Suitable vegetable oils have a monounsaturated fatty acid content of at least about 50%, based on total fatty acid content, and include, for example, rapeseed (Brassica), sunflower (Helianthus), soybean (Glycine max), corn (Zea mays), crambe (Crambe), and meadowfoam (Limnanthes) oil. Canola oil, which has less than 2% erucic acid, is a particularly useful rapeseed oil. Oils having a monounsaturated fatty acid content of at least 70% are also particularly useful. The monounsaturated fatty acid content can be composed of, for example, oleic acid (C18:1), eicosenoic acid (C20:1), erucic acid (C22:1), or mixtures thereof.

[031] In one embodiment, the polyol esters can be glycerol esters of the following general formula:



wherein R1, R2 and R3 are independently aliphatic hydrocarbyl moieties having 4 to about 75 carbon atoms, preferably 4 to about 24 carbon atoms inclusive, and more preferably wherein at least one of R1, R2 and R3 is a saturated aliphatic hydrocarbyl moiety having 4 to about 10 carbon atoms inclusive and wherein at least one of R1, R2 and R3 is an aliphatic hydrocarbyl moiety having from 11 to about 24 carbon atoms inclusive.

[032] In another embodiment, the polyol esters are compounds of the following general formula:



wherein R4, R5 and R6 are independently aliphatic hydrocarbyl moieties having from 4 to about 24 carbon atoms, R7 is hydrogen or an aliphatic hydrocarbyl moiety having 1 to 10 carbon atoms and x, y and z are the same or different and are integers from 1 to 10. The compounds of formula (II) are known compounds and can be prepared by known procedures and hence readily commercially available. Referring to the R4, R5 and R6 groups, the aliphatic hydrocarbyl moieties may be independently saturated or unsaturated, linear (straight chain) or branched chain and preferably have 4 to about 24 carbon atoms, more preferably 4 to about 16 carbon atoms and most preferably 6 to about 10 carbon atoms. The R7 group can be hydrogen or an aliphatic hydrocarbyl moiety such as, by way of example, a linear or branched chain alkyl group having from 1 to about 10 carbon atoms and preferably 1 to 6 carbon atoms, optionally containing an aromatic or aryl group. Examples of such polyol esters for use herein include, but are not limited to, trimethylolpropane (TMP) esters such as, for example, TMP tri(2-ethyl hexanoate), TMP triheptanoate, TMP tricaprylate, TMP tricaprate, TMP tri(isononanoate) and the like.

Hydrocarbon base stock

[033] The cooling fluid of the present disclosure may include a hydrocarbon base stock.

[034] In some embodiments, the hydrocarbon base stocks can be natural. In some embodiments, the hydrocarbon base stock can be synthetic such as certain Group III or III+ base stocks.

[035] Suitable hydrocarbon synthetic base stocks may include certain base stocks classified as sustainable synthetic base oils, renewable base oils, rerefined base oils, polyakylene glycol (PAG), GTL base oils, base oils prepared from the polymerization of ethylene or from the polymerization of 1-olefins to provide polymers such as polyalphaolefin or PAO oils, or from hydrocarbon synthesis procedures using carbon monoxide and hydrogen gases such as in a Fischer-Tropsch process.

[036] In an embodiment, the hydrocarbon base stock is present in an amount ranging from about 1 wt % of about 99 wt % by total weight of the cooling fluid, such as, from about1 wt % to about 95 wt % from about 1 wt % to about 90 wt %, from about 1 wt % to about 85 wt %, from about 1 wt % to about 80 wt %, from about 1 wt % to about 75 wt %, from about 1 wt % to about 70 wt %, from about 1 wt % to about 65 wt %, from about 1 wt % to about 60 wt %, from about 1 wt % to about 55 wt %, from about 1 wt % to about 50 wt %, from about 1 wt % to about 45 wt %, from about 1 wt % to about 40 wt %, from about 1 wt % to about 35 wt %, from about 1 wt % to about 30 wt %, from about 1 wt % to about 25 wt %, from about 1 wt % to about 20 wt %, from about 1 wt % to about 15 wt %, from about 1 wt % to about 10 wt %, from about 5 wt % of about 99 wt %, 5 wt % to about 95 wt % by total weight of the cooling fluid, such as, from about 5 wt % to about 90 wt %, from about 5 wt % to about 85 wt %, from about 5 wt % to about 80 wt %, from about 5 wt % to about 75 wt %, from about 5 wt % to about 70 wt %, from about 5 wt % to about 65 wt %, from about 5 wt % to about 60 wt %, from about 5 wt % to about 55 wt %, from about 5 wt % to about 50 wt %, from about 5 wt % to about 45 wt %, from about 5 wt % to about 40 wt %, from about 5 wt % to about 35 wt %, from about 5 wt % to about 30 wt %, from about 5 wt % to about 25 wt %, from about 5 wt % to about 20 wt %, from about 5 wt % to about 15 wt %, from about 5 wt % to about 10 wt %, from about 10 wt % of about 99 wt %, from about 10 wt % to about 95 wt %, from about 10 wt % to about 90 wt %, from about 10 wt % to about 85 wt %, from about 10 wt % to about 80 wt %, from about 10 wt % to about 75 wt %, from about 10 wt % to about 70 wt %, from about 10 wt % to about 65 wt %, from about 10 wt % to about 60 wt %, from about 10 wt % to about 55 wt %, from about 10 wt % to about 50 wt %, from about 10 wt % to about 45 wt %, from about 10 wt % to about 40 wt %, from about 10 wt % to about 35 wt %, from about 10 wt % to about 30 wt %, from about 10 wt % to about 25 wt %, from

about 10 wt % to about 20 wt %, from about 10 wt % to about 15 wt %, from about 15 wt % of about 99 wt %, from about 15 wt % to about 95 wt %, from about 15 wt % to about 90 wt %, from about 15 wt % to about 85 wt %, from about 15 wt % to about 80 wt %, from about 15 wt % to about 75 wt %, from about 15 wt % to about 70 wt %, from about 15 wt % to about 65 wt %, from about 15 wt % to about 60 wt %, from about 15 wt % to about 55 wt %, from about 15 wt % to about 50 wt %, from about 15 wt % to about 45 wt %, from about 15 wt % to about 40 wt %, from about 15 wt % to about 35 wt %, from about 15 wt % to about 30 wt %, from about 15 wt % to about 25 wt %, from about 15 wt % to about 20 wt %, from about 20 wt % of about 99 wt %, from about 20 wt % to about 95 wt %, from about 20 wt % to about 90 wt %, from about 20 wt % to about 85 wt %, from about 20 wt % to about 80 wt %, from about 20 wt % to about 75 wt %, from about 20 wt % to about 70 wt %, from about 20 wt % to about 65 wt %, from about 20 wt % to about 60 wt %, from about 20 wt % to about 55 wt %, from about 20 wt % to about 50 wt %, from about 20 wt % to about 45 wt %, from about 20 wt % to about 40 wt %, from about 20 wt % to about 35 wt %, from about 20 wt % to about 30 wt %, from about 20 wt % to about 25 wt %, from about 25 wt % of about 99 wt %, from about 25 wt % to about 95 wt %, from about 25 wt % to about 90 wt %, from about 25 wt % to about 85 wt %, from about 25 wt % to about 80 wt %, from about 25 wt % to about 75 wt %, from about 25 wt % to about 70 wt %, from about 25 wt % to about 65 wt %, from about 25 wt % to about 60 wt %, from about 25 wt % to about 55 wt %, from about 25 wt % to about 50 wt %, from about 25 wt % to about 45 wt %, from about 25 wt % to about 40 wt %, from about 25 wt % to about 35 wt %, from about 25 wt % to about 30 wt %, from about 30 wt % of about 99 wt %, from about 30 wt % to about 95 wt %, from about 30 wt % to about 90 wt %, from about 30 wt % to about 85 wt %, from about 30 wt % to about 80 wt %, from about 30 wt % to about 75 wt %, from about 30 wt % to about 70 wt %, from about 30 wt % to about 65 wt %, from about 30 wt % to about 60 wt %, from about 30 wt % to about 55 wt %, from about 30 wt % to about 50 wt %, from about 30 wt % to about 45 wt %, from about 30 wt % to about 40 wt %, from about 30 wt % to about 35 wt %, from about 35 wt % of about 99 wt %, from about 35 wt % to about 95 wt %, from about 35 wt % to about 90 wt %, from about 35 wt % to about 85 wt %, from about 35 wt % to about 80 wt %, from about 35 wt % to about 75 wt %, from about 35 wt % to about 70 wt %, from about 35 wt % to about 65 wt %, from about 35 wt % to about

60 wt %, from about 35 wt % to about 55 wt %, from about 35 wt % to about 50 wt %, from about 35 wt % to about 45 wt %, from about 35 wt % to about 40 wt %, from about 40 wt % of about 99 wt %, from about 40 wt % to about 95 wt %, from about 40 wt % to about 90 wt %, from about 40 wt % to about 85 wt %, from about 40 wt % to about 80 wt %, from about 40 wt % to about 75 wt %, from about 40 wt % to about 70 wt %, from about 40 wt % to about 65 wt %, from about 40 wt % to about 60 wt %, from about 40 wt % to about 55 wt %, from about 40 wt % to about 50 wt %, from about 40 wt % to about 45 wt %, from about 45 wt % of about 99 wt %, from about 45 wt % to about 95 wt %, from about 45 wt % to about 90 wt %, from about 45 wt % to about 85 wt %, from about 45 wt % to about 80 wt %, from about 45 wt % to about 75 wt %, from about 45 wt % to about 70 wt %, from about 45 wt % to about 65 wt %, from about 45 wt % to about 60 wt %, from about 45 wt % to about 55 wt %, from about 45 wt % to about 50 wt %, from about 50 wt % of about 99 wt %, from about 50 wt % to about 95 wt %, from about 50 wt % to about 90 wt %, from about 50 wt % to about 85 wt %, from about 50 wt % to about 80 wt %, from about 50 wt % to about 75 wt %, from about 50 wt % to about 70 wt %, from about 50 wt % to about 65 wt %, from about 50 wt % to about 60 wt %, from about 50 wt % to about 55 wt %, from about 55 wt % of about 99 wt %, from about 55 wt % to about 95 wt %, from about 55 wt % to about 90 wt %, from about 55 wt % to about 85 wt %, from about 55 wt % to about 80 wt %, from about 55 wt % to about 75 wt %, from about 55 wt % to about 70 wt %, from about 55 wt % to about 65 wt %, from about 55 wt % to about 60 wt %, from about 60 wt % of about 99 wt %, from about 60 wt % to about 95 wt %, from about 60 wt % to about 90 wt %, from about 60 wt % to about 85 wt %, from about 60 wt % to about 80 wt %, from about 60 wt % to about 75 wt %, from about 60 wt % to about 70 wt %, from about 60 wt % to about 65 wt %, from about 65 wt % of about 99 wt %, from about 65 wt % to about 95 wt %, from about 65 wt % to about 90 wt %, from about 65 wt % to about 85 wt %, from about 65 wt % to about 80 wt %, from about 65 wt % to about 75 wt %, from about 65 wt % to about 70 wt %, from about 70 wt % of about 99 wt %, from about 70 wt % to about 95 wt %, from about 70 wt % to about 90 wt %, from about 70 wt % to about 85 wt %, from about 70 wt % to about 80 wt %, from about 70 wt % to about 75 wt %, from about 75 wt % of about 99 wt %, from about 75 wt % to about 95 wt %, from about 75 wt % to about 90 wt %, from about 75 wt % to about 85 wt %, from about 75 wt % to about 80 wt %, from about

80 wt % of about 99 wt %, from about 80 wt % to about 95 wt %, from about 80 wt % to about 90 wt %, from about 80 wt % to about 85 wt %, from about 85 wt % of about 99 wt %, from about 85 wt % to about 95 wt %, from about 85 wt % to about 90 wt %, from about 90 wt % of about 99 wt %, or from about 90 wt % to about 95 wt %.

[037] The hydrocarbon base stock may be derived from natural lubricating oils, synthetic lubricating oils or mixtures thereof. Suitable base oil includes base stocks obtained by isomerization of synthetic wax and slack wax, as well as hydrocracked base stocks produced by hydrocracking (rather than solvent extracting) the aromatic and polar components of the crude.

[038] Useful natural hydrocarbon base stocks include mineral lubricating oils such as, for example, liquid petroleum oils, solvent-treated or acid-treated mineral lubricating oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types, oils derived from coal or shale, animal oils, vegetable oils (e.g., rapeseed oils, castor oils and lard oil), and the like.

[039] Useful synthetic base stocks include, but are not limited to, hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and interpolymerized olefins, e.g., polybutylenes, polypropylenes, propylene-isobutylene copolymers, chlorinated polybutylenes, poly(1-hexenes), poly(1-octenes), poly(1-decenes), and the like and mixtures thereof, alkylbenzenes such as dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di(2-ethylhexyl)-benzenes, and the like, polyphenyls such as biphenyls, terphenyls, alkylated polyphenyls, and the like, alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivative, analogs and homologs thereof and the like.

[040] Other useful synthetic base stocks include, but are not limited to, oils made by polymerizing olefins of less than 5 carbon atoms such as ethylene, propylene, butylenes, isobutene, pentene, and mixtures thereof. Methods of preparing such polymer oils are well known to those skilled in the art.

[041] Additional useful synthetic hydrocarbon base stocks include liquid polymers of alpha olefins having the proper viscosity. Especially useful synthetic hydrocarbon oils are the hydrogenated liquid oligomers of C6 to C12 alpha olefins such as, for example, 1-decene trimer.

[042] Another class of useful synthetic base stocks include, but are not limited to, alkylene oxide polymers, i.e., homopolymers, interpolymers, and

derivatives thereof where the terminal hydroxyl groups have been modified by, for example, esterification or etherification. These oils are exemplified by the oils prepared through polymerization of ethylene oxide or propylene oxide, the alkyl and phenyl ethers of these polyoxyalkylene polymers (e.g., methyl poly propylene glycol ether having an average molecular weight of 1,000, diphenyl ether of polyethylene glycol having a molecular weight of 500-1000, diethyl ether of polypropylene glycol having a molecular weight of 1,000-1,500, etc.) or mono- and polycarboxylic esters thereof such as, for example, the acetic esters, mixed C3-C8 fatty acid esters, or the C13 oxo acid diester of tetraethylene glycol.

Immersion Cooling Fluid

[043] The immersion cooling fluid has a kinematic viscosity at 100°C (KV100) from about 1 cSt. In some embodiments, the hydrocarbon base stock has a kinematic viscosity at 100°C (KV100) from about 1 cSt to about 16.0 cSt such as from about 1 cSt to about 15.0 cSt, from about 1 cSt to about 14.0 cSt, from about 1 cSt to about 13.0 cSt, from about 1 cSt to about 12.0 cSt, from about 1 cSt to about 11.0 cSt, from about 1 cSt to about 10.0 cSt, or from about 1 cSt to about 9.0 cSt.

[044] In some embodiments, the immersion cooling fluid has a kinematic viscosity at 100°C (KV100) from about 1.0 cSt to about 8.0 cSt, 1.0 cSt to about 7.5 cSt, from about 1.0 cSt to about 7.0 cSt, from about 1.0 cSt to about 6.5 cSt, from about 1.0 cSt to about 6.0 cSt, from about 1.0 cSt to about 5.5 cSt, from about 1.0 cSt to about 5.0 cSt, from about 1.0 cSt to about 4.5 cSt, from about 1.0 cSt to about 4.0 cSt, from about 1.0 cSt to about 3.5 cSt, from about 1.0 cSt to about 3.0 cSt, from about 1.0 cSt to about 2.5 cSt, from about 1.0 cSt to about 2.0 cSt, from about 1.5 cSt to about 8.0 cSt, 1.5 cSt to about 7.5 cSt, from about 1.5 cSt to about 7.0 cSt, from about 1.5 cSt to about 6.5 cSt, from about 1.5 cSt to about 6.0 cSt, from about 1.5 cSt to about 5.5 cSt, from about 1.5 cSt to about 5.0 cSt, from about 1.5 cSt to about 4.5 cSt, from about 1.5 cSt to about 4.0 cSt, from about 1.5 cSt to about 3.5 cSt, from about 1.5 cSt to about 3.0 cSt, from about 1.5 cSt to about 2.5 cSt, from about 1.5 cSt to about 2.0 cSt, from about 2.0 cSt to about 8.0 cSt, from about 2.0 cSt to about 7.5 cSt, from about 2.0 cSt to about 7.0 cSt, from about 2.0 cSt to about 6.5 cSt, from about 2.0 cSt to about 6.0 cSt, from about 2.0 cSt to about 5.5 cSt, from about 2.0 cSt to about 5.0 cSt, from about 2.0 cSt to about 4.5 cSt, from about 2.0 cSt to about 4.0 cSt, from about 2.0 cSt to about 3.5 cSt, from about 2.5

cSt to about 3.0 cSt, from about 3.0 cSt to about 8.0 cSt, from about 3.0 cSt to about 7.5 cSt, from about 3.0 cSt to about 7.0 cSt, from about 3.0 cSt to about 6.5 cSt, from about 3.0 cSt to about 6.0 cSt, from about 3.0 cSt to about 5.5 cSt, from about 3.0 cSt to about 5.0 cSt, from about 3.0 cSt to about 4.5 cSt, from about 3.0 cSt to about 4.0 cSt, from about 3.0 cSt to about 3.5 cSt, from about 3.5 cSt to about 8.0 cSt, from about 3.5 cSt to about 7.5 cSt, from about 3.5 cSt to about 7.0 cSt, from about 3.5 cSt to about 6.5 cSt, from about 3.5 cSt to about 6.0 cSt, from about 3.5 cSt to about 5.5 cSt, from about 3.5 cSt to about 5.0 cSt, from about 3.5 cSt to about 4.5 cSt, from about 3.5 cSt to about 4.0 cSt, from about 4.0 cSt to about 8.0 cSt, from about 4.0 cSt to about 7.5 cSt, from about 4.0 cSt to about 7.0 cSt, from about 4.0 cSt to about 6.5 cSt, from about 4.0 cSt to about 6.0 cSt, from about 4.0 cSt to about 5.5 cSt, from about 4.0 cSt to about 5.0 cSt, from about 4.0 cSt to about 4.5 cSt, from about 4.5 cSt to about 8.0 cSt, from about 4.5 cSt to about 7.5 cSt, from about 4.5 cSt to about 7.0 cSt, from about 4.5 cSt to about 6.5 cSt, from about 4.5 cSt to about 6.0 cSt, from about 4.5 cSt to about 5.5 cSt, from about 4.5 cSt to about 5.0 cSt, from about 5.0 cSt to about 8.0 cSt, from about 5.0 cSt to about 7.5 cSt, from about 5.0 cSt to about 7.0 cSt, from about 5.0 cSt to about 6.5 cSt, from about 5.0 cSt to about 6.0 cSt, from about 5.0 cSt to 5.5 cSt, from about 5.5 cSt to about 8.0 cSt, from about 5.5 cSt to about 7.5 cSt, from about 5.5 cSt to about 7.0 cSt, from about 5.5 cSt to about 6.5 cSt, from about 5.5 cSt to about 6.0 cSt, from about 6.0 cSt to about 8.0 cSt, from 6.0 cSt to about 7.5 cSt, from about 6.0 cSt to about 7.0 cSt, from about 6.0 cSt to about 6.5 cSt, from about 6.5 cSt to about 8.0 cSt, from about 6.5 cSt to about 8.0 cSt, from about 6.5 cSt to about 7.5 cSt, from about 6.5 cSt to about 7.0 cSt, from about 7.0 cSt to about 8.0 cSt, from about 7.0 cSt to about 7.5 cSt, or from about 7.5 cSt to about 8.0 cSt.

Additives

[045] The cooling fluid of the present disclosure may contain one or more performance additives that can impart or improve any desirable property of the cooling fluid. Any additive known to those of skill in the art may be used in the cooling fluid disclosed herein.

[046] In general, the concentration of each of the additives in the cooling fluid, when used, may range from 0.001 to 60 wt. % (e.g., 0.01 to 50 wt. %, or 0.05 to 40 wt. %) of the cooling fluid composition. Further, the total amount of additives

in the cooling fluid composition may range from 0.001 to 70 wt. % (e.g., 0.01 to 50 wt. % or 0.1 to 40 wt. %) of the cooling fluid composition.

[047] Suitable performance additives include antioxidants, anti-wear agent, metal detergents, dispersants, friction modifiers, corrosion inhibitors, demulsifiers, viscosity modifiers, pour point depressants, foam inhibitors, and others.

[048] Other performance additives include anti-hydrolysis components (e.g., acid scavengers), anti-static components, fire-retardant components, seal swell agents, plasticizers, and others.

[049] In particular, acid scavengers may be particularly useful for fluids containing phosphate esters. Examples of acid scavengers can be found in US Publication No. 2017158981, which is incorporated by reference.

Antioxidants

[050] Antioxidants retard the oxidative degradation of base oils during service. Such degradation may result in deposits on metal surfaces, the presence of sludge, or a viscosity increase in the lubricant. Useful antioxidants include hindered amines, hindered phenols, aromatic amines, antioxidant metal complexes (e.g., MoDTC, ZDDP), and sulfurized alkylphenols and alkali and alkaline earth metal salts thereof.

[051] The hindered phenol antioxidant may contain a secondary butyl and/or a tertiary butyl group as a sterically hindering group. The phenol group may be further substituted with a hydrocarbyl group and/or a bridging group linking to a second aromatic group. Examples of suitable hindered phenol antioxidants include 2,6-di-tert-butylphenol, 4-methyl-2,6-di-tert-butylphenol, 2,2′-methylenebis(6-tert-butyl-4-methylphenol), 4,4′-bis(2,6-di-tert-butylphenol) and 4,4′-methylenebis(2,6-di-tert-butylphenol). The hindered phenol antioxidant may be an ester or an addition product derived from 2,6-di-tert-butylphenol and an alkyl acrylate, wherein the alkyl group may contain from 1 to 18 carbon atoms.

[052] Suitable aromatic amine antioxidants include diarylamines such as alkylated diphenylamines (e.g., dioctyl diphenylamine, dinonyl diphenylamine), phenyl-alpha-naphthalene and alkylated phenyl-alpha-naphthalenes.

Anti-Wear Agents

[053] Anti-wear agents reduce wear of metal parts. Examples of anti-wear agents include phosphorus-containing anti-wear/extreme pressure agents such as

metal thiophosphates, phosphoric acid esters and salts thereof, phosphorus-containing carboxylic acids, esters, ethers, and amides; phosphonates, and phosphites. The anti-wear agent may be a zinc dialkyldithiophosphate. Non-phosphorus-containing anti-wear agents include borate esters (including borated epoxides), dithiocarbamate compounds, molybdenum-containing compounds, and sulfurized esters, sulfurized fats, or sulfurized olefins.

Metal Detergents

[054] A typical detergent is an anionic material that contains a long chain hydrophobic portion of the molecule and a smaller anionic or oleophobic hydrophilic portion of the molecule. The anionic portion of the detergent is typically derived from an organic acid such as a sulfur acid, carboxylic acid, phosphorous acid, phenol, or mixtures thereof. The counterion is typically an alkaline earth or alkali metal.

[055] In some embodiments, the cooling fluid provided herein comprises at least a neutral or overbased metal detergent as an additive, or additive components. In certain embodiments, the metal detergents in cooling fluid compositions acts as a neutralizer of acidic products within the oil. In certain embodiments, the metal detergent prevents the formation of deposits on the surface of an engine. Depending on the nature of the acid used, the detergent may have additional functions, for example, antioxidant properties. In certain aspects, cooling fluid compositions contain metal detergents comprising either overbased detergents or mixtures of neutral and overbased detergents. The term “overbased” is intended to define additives which contain a metal content in excess of that required by the stoichiometry of the particular metal and the particular organic acid used. The excess metal exists in the form of particles of inorganic base (e.g., a hydroxide or carbonate) surrounded by a sheath of metal salt. The sheath serves to maintain the particles in dispersion in a liquid oleaginous vehicle. The amount of excess metal is commonly expressed as the ratio of total equivalence of excess metal to equivalence of organic acid and is typically in a range of 0.1 to 30.

[056] Overbased detergents may be further characterized as low overbased, medium overbased, or high overbased. Low overbased detergents may be, for example, an overbased salt having a TBN below 100. In one embodiment, the TBN of a low overbased salt may be from about 5 to about 50. In another embodiment,

the TBN of a low overbased salt may be from about 10 to about 30. In yet another embodiment, the TBN of a low overbased salt may be from about 15 to about 20.

[057] Medium overbased detergents, may be, for example, an overbased salt having a TBN from about 100 to about 250. In one embodiment, the TBN of a medium overbased salt may be from about 100 to about 200. In another embodiment, the TBN of a medium overbased salt may be from about 125 to about 175.

[058] High overbased detergents may be, for example, an overbased salt having a TBN above 250. In one embodiment, the TBN of a high overbased salt may be from about 250 to about 550.

[059] Some examples of suitable metal detergents include sulfurized or unsulfurized alkyl or alkenyl phenates, alkyl or alkenyl aromatic sulfonates, borated sulfonates, sulfurized or unsulfurized metal salts of multi-hydroxy alkyl or alkenyl aromatic compounds, alkyl or alkenyl hydroxy aromatic sulfonates, sulfurized or unsulfurized alkyl or alkenyl naphthenates, metal salts of alkanoic acids, metal salts of an alkyl or alkenyl multiacid, and chemical and physical mixtures thereof. Other examples of suitable metal detergents include metal sulfonates, phenates, salicylates (i.e. carboxylates, hydroxybenzoates), phosphonates, thiophosphonates and combinations thereof. The metal can be any metal suitable for making sulfonate, phenate, salicylate or phosphonate detergents. Non-limiting examples of suitable metals include alkali metals, alkaline metals and transition metals. In some embodiments, the metal is Ca, Mg, Ba, K, Na, Li or the like. An exemplary metal detergent which may be employed in the cooling fluid compositions includes overbased sulfurized calcium phenate.

Ashless Dispersants

[060] A dispersant is an additive whose primary function is to hold solid and liquid contaminations in suspension, thereby passivating them and reducing engine deposits at the same time as reducing sludge depositions. For example, a dispersant maintains in suspension oil-insoluble substances that result from oxidation during use of the lubricant, thus preventing sludge flocculation and precipitation or deposition on metal parts of the engine.

[061] Dispersants are usually “ashless”, being non-metallic organic materials that form substantially no ash on combustion, in contrast to metal-containing, and hence ash-forming materials. They comprise a long hydrocarbon chain with a polar

head, the polarity being derived from inclusion of at least one nitrogen, oxygen or phosphorus atom. The hydrocarbon is an oleophilic group that confers oil-solubility, having, for example, 40 to 500 carbon atoms. Thus, ashless dispersants may comprise an oil-soluble polymeric backbone.

[062] A preferred class of olefin polymers is constituted by polybutylenes, specifically polyisobutylenes (PIB) or poly-n-butylenes, such as may be prepared by polymerization of a C4 refinery stream.

[063] Dispersants include, for example, derivatives of long chain hydrocarbon-substituted carboxylic acids, examples being derivatives of high molecular weight hydrocarbyl-substituted succinic acid. A noteworthy group of dispersants is constituted by hydrocarbon-substituted succinimides, made, for example, by reacting the above acids (or derivatives) with a nitrogen-containing compound, advantageously a polyalkylene polyamine, such as a polyethylene polyamine. Typical commercially available polyisobutylene-based succinimide dispersants contain polyisobutylene polymers having a number average molecular weight ranging from 900 to 2500, functionalized by maleic anhydride, and derivatized with polyamines having a molecular weight of from 100 to 350.

[064] Other suitable dispersants include succinic esters and ester-amides, Mannich bases, polyisobutylene succinic acid (PIBSA), and other related components.

[065] Succinic esters are formed by the condensation reaction between hydrocarbon-substituted succinic anhydrides and alcohols or polyols. For example, the condensation product of a hydrocarbon-substituted succinic anhydride and pentaerythritol is a useful dispersant.

[066] Succinic ester-amides are formed by condensation reaction between hydrocarbon-substituted succinic anhydrides and alkanol amines. For example, suitable alkanol amines include ethoxylated polyalkylpolyamines, propoxylated polyalkylpolyamines and polyalkenylpolyamines such as polyethylene polyamines. One example is propoxylated hexamethylenediamine.

[067] Mannich bases are made from the reaction of an alkylphenols, formaldehyde, and a polyalkylene polyamines. Molecular weights of the alkylphenol may range from 800 to 2500.

[068] Nitrogen-containing dispersants may be post-treated by conventional methods to improve their properties by reaction with any of a variety of agents.

Among these are boron compounds (e.g., boric acid) and cyclic carbonates (e.g., ethylene carbonate).

Friction Modifiers

[069] A friction modifier is any material or materials that can alter the coefficient of friction of a surface lubricated by any lubricant or fluid containing such material(s). Friction modifiers include alkoxylated fatty amines, borated fatty epoxides, fatty phosphites, fatty epoxides, fatty amines, borated alkoxylated fatty amines, metal salts of fatty acids, fatty acid amides, glycerol esters, borated glycerol esters and fatty imidazolines. As used herein, the term “fatty” means a hydrocarbon chain having 10 to 22 carbon atoms, typically a straight hydrocarbon chain.

[070] Other known friction modifiers comprise oil-soluble organo-molybdenum compounds. Such organo-molybdenum friction modifiers also provide antioxidant and anti-wear credits to a cooling fluid composition. Suitable oil-soluble organo-molybdenum compounds have a molybdenum-sulfur core. As examples, there may be mentioned dithiocarbamates dithiophosphates, dithiophosphinates, xanthates, thioxanthates, sulfides, and mixtures thereof. The molybdenum compound may be dinuclear or trinuclear.

Corrosion Inhibitors

[071] Corrosion inhibitors protect lubricated metal surfaces against chemical attack by water or other contaminants. Suitable corrosion inhibitors include polyoxyalkylene polyols and esters thereof, polyoxyalkylene phenols, thiadiazoles and anionic alkyl sulfonic acids.

[072] Other suitable corrosion inhibitors include triazoles (e.g., tolytriazole), derivatives of tolytriazoles, benzotriazoles, derivatives of benzotriazoles, imidazolines, carboxylic acids and their salts or esters, and alkanolamines.

Viscosity Modifiers

[073] Viscosity modifiers provide lubricants with high and low temperature operability. These additives increase the viscosity of the oil composition at elevated temperatures which increases film thickness, while having limited effect on viscosity at low temperatures.

[074] Suitable viscosity improvers include high molecular weight hydrocarbons, polyesters and viscosity index improver dispersants that function as

both a viscosity index improver and a dispersant. Typical molecular weights of these polymers are in a range of 1000 to 1,000,000 (e.g., 2000 to 500,000 or 25,000 to 100,000).

[075] Examples of suitable viscosity improvers are polymers and copolymers of methacrylate, butadiene, olefins, or alkylated styrenes. Polyisobutylene is a commonly used viscosity modifier. Another suitable viscosity modifier is polymethacrylate (copolymers of various chain length alkyl methacrylates, for example), some formulations of which also serve as pour point depressants. Other suitable viscosity modifiers include copolymers of ethylene and propylene, hydrogenated block copolymers of styrene and isoprene, and polyacrylates (copolymers of various chain length acrylates, for example). Specific examples include styrene-isoprene or styrene-butadiene based polymers of 50,000 to 200,000 molecular weight.

Pour Point Depressants

[076] Pour point depressants lower the minimum temperature at which a fluid will flow or can be poured. Suitable pour point depressants include C8 to C18 dialkyl fumarate/vinyl acetate copolymers, polyalkylmethacrylates and the like.

Foam Inhibitors

[077] Foam inhibitors retard the formation of stable foams. Examples of suitable foam inhibitors include polysiloxanes, polyacrylates, and the like.

Thickener

[078] A thickener can increase the viscosity of a cooling fluid composition in order to achieve a desired viscosity grade. Any suitable thickener such as polyisobutylene (PIB) may be used. PIB is a commercially available material from several manufacturers. Polyisobutylene is typically a viscous oil-miscible liquid having a number average molecular weight of 800 to 5000 (e.g., 1000 to 2500) and a kinematic viscosity at 100° C. of 200 to 5000 mm^2/s (e.g., 200 to 1000 mm^2/s). The amount of PIB added to the cooling fluid composition will normally be from 1 to 20 wt. % (e.g., 2 to 15 wt. % or 4 to 12 wt. %) of the finished oil.

EXAMPLES

[079] The following non-limiting examples are illustrative of the present invention. Brief descriptions of how the examples were prepared and the test methods used in evaluation of the inventive lubricants are provided.

[080] Bis(2-Ethylhexyl) adipate was blended with various phosphate esters (Table 1) to show improvements in flash point and/or autoignition temperature.

[081] The viscosity data was measured by following ASTM-D445.

[082] Flash points of the cooling fluids were measured via the ASTM D92 method, also known as the Cleveland Open Cup (COC) method. The procedure involves heating a sample in an open cup at a controlled rate. A test flame is applied at specified intervals to the surface of the liquid. The flash point is the lowest temperature at which the vapors above the liquid ignite when the test flame is applied. During testing, some cooling fluids had their “flame extinguished” which means that the open flame used to test the flash point was extinguished before the flash point could be measured. This is likely due to the volatile phosphorous species extinguishing the open flame in the gaseous phase. This is a surprising result which minimizes fire risks associated with low viscosity fluids in contact with electric vehicle batteries.

[083] The ASTM E659 method was used to determine the autoignition temperature of the cooling fluids. The procedure starts by placing the cooling fluid in a glass vessel, which is then heated uniformly in the presence of air at atmospheric pressure. The temperature is gradually increased until the chemical vapors ignite spontaneously. The autoignition temperature is recorded as the lowest temperature at which this ignition occurs.

Table 1

	Ex 1	Ex 2	Ex 3	Ex 4	Ex 5	Ex 6
	Comparative	Inventive	Inventive	Inventive	Inventive	Inventive
Ester A	100%	75%	75%	75%	75%	75%
Phosphate Ester A		25%				
Phosphate Ester B			25%			
Phosphate Ester C				25%		
Phosphate Ester D					25%	

Phosphate Ester E						25%
Flash Point (°C)	207	237	215	219	225	Flame Extinguished
Autoignition Temp (°C)	324	345	333	324	375	369

- Ester A = Bis(2-Ethyl Hexyl) Adipate
- Phosphate Ester A = 2-Ethyl Hexyl Diphenyl Phosphate
- Phosphate Ester B = trioctyl phosphate
- Phosphate Ester C = tris(2-butoxyethyl) phosphate
- Phosphate Ester D = isopropylated triphenyl phosphate
- Phosphate Ester E = triethyl phosphate

[084] Triethyl phosphate ester was blended with various ester base stocks (Table 2) to show improvements in flash point and/or autoignition temperature.

Table 2

	Ex 1	Ex 7	Ex 8	Ex 9
	Comparative	Comparative	Comparative	Comparative
Ester A	100%			
Ester B		100%		
Ester C			100%	
Ester D				100%
Phosphate Ester E				
Flash Point (°C)	207	193	250	236
Autoignition Temp (°C)	324	321	363	387

	Ex 6	Ex 10	Ex 11	Ex 12
	Inventive	Inventive	Inventive	Inventive
Ester A	75%			
Ester B		75%		
Ester C			75%	
Ester D				75%
Phosphate Ester E	25%	25%	25%	25%
Flash Point (°C)	Flame Extinguished	Flame Extinguished	Flame Extinguished	Flame Extinguished
Autoignition Temp (°C)	369	339	384	384

- Ester A = bis(2-ethyl hexyl) adipate
- Ester B = low viscosity, saturated diester base stock
- Ester C = trioctyl trimellitate
- Ester D = dioctyl terephthalate
- Phosphate Ester E = triethyl phosphate

[085] Table 3 shows Improvements in flash point and autoignition temperature with increasing treat rates of phosphate ester into an ester base stock.

Table 3

	Ex 1	Ex 6	Ex 13
	Comparative	Inventive	Inventive
Ester A	100%	75%	25%
Phosphate Ester E		25%	75%
Flash Point (°C)	207	Flame Extinguished	Flame Extinguished
Autoignition Temp (°C)	324	339	384

Example 4

[086] Ester base stocks, hydrocarbon base stock, and phosphate esters were blended and tested as summarized in Table 4.

Table 4

	Ex 1	Ex 2	Ex 3
	Comparative	Comparative	Comparative
Ester A			
Ester B		100%	75%
HC Oil A	100%		25%
Phosphate Ester A			
Phosphate Ester B			
Phosphate Ester C			
Ester to HC Oil	N/A	N/A	3:1
KV100 (cSt)	1.68	1.82	1.77
Density - 20 °C (g/cm^3)	0.79	0.86	0.84

Pour Point (°C)	< -63	-36	-36
Flash Point (°C)	142	193	171
Autoignition Temp (°C)	210	321	279

	Ex 4	Ex 5	Ex 6	Ex 7	Ex 8
	Inventive	Inventive	Inventive	Inventive	Inventive
Ester A			56.3%		
Ester B	56.3%	37.5%		56.3%	56.3%
HC Oil A	18.8%	12.5%	18.8%	18.8%	18.8%
Phosphate Ester A					25%
Phosphate Ester B				25%	
Phosphate Ester E	25%	50%	25%		
Ester to HC Oil	3:1	3:1	3:1	3:1	3:1
KV100 (cSt)	1.31	1.01	1.49	1.56	1.80
Density - 20 °C (g/cm^3)	0.89	0.94	0.89	0.86	0.89
Pour Point (°C)	-42	-42	-42	-42	-42
Flash Point (°C)	Flame Extinguished	Flame Extinguished	Flame Extinguished	181	189
Autoignition Temp (°C)	315	357	354	291	315

- Ester A = bis(2-ethylhexyl) adipate
- Ester B = low viscosity, saurated diester base stock
- HC Oil A = PAO with KV100 of 2 cSt
- Phosphate Ester A = 2-ethylhexyl diphenyl phosphate
- Phosphate Ester B = trioctyl phosphate
- Phosphate Ester E = triethyl phosphate

[087] Ester base stocks, hydrocarbon base stock, and phosphate esters were blended and tested as summarized in Table 5.

Table 5

	Ex 14	Ex 15	Ex 16	Ex 17
	Inventive	Inventive	Inventive	Inventive
Ester A	5%	5%	5%	5%
HC Oil A	93.4%	88.4%	78.4%	73.4%

Phosphate Ester E	1%	1%	1%	1%
Phosphate Ester F		5%	15%	20%
KV100 (cSt)	1.68	1.70	1.72	1.73
Flash Point (°C)	Flame Extinguished	Flame Extinguished	Flame Extinguished	Flame Extinguished
Autoignition Temp (°C)	220	225	252	282

- Ester A = bis(2-ethylhexyl) adipate
- HC Oil A = PAO with KV100 of 2 cSt
- Phosphate Ester E = triethyl phosphate
- Phosphate Ester F = isodecyl diphenyl phosphate

[088] For the sake of brevity, only certain ranges are explicitly disclosed herein. However, ranges from any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may be combined with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited. Additionally, within a range includes every point or individual value between its end points even though not explicitly recited. Thus, every point or individual value may serve as its own lower or upper limit combined with any other point or individual value or any other lower or upper limit, to recite a range not explicitly recited.

[089] Likewise, the term “comprising” is considered synonymous with the term “including.” Likewise whenever a composition, an element or a group of elements is preceded with the transitional phrase “comprising,” it is understood that we also contemplate the same composition or group of elements with transitional phrases “consisting essentially of,” “consisting of,” “selected from the group of consisting of,” or “is” preceding the recitation of the composition, element, or elements and vice versa.

[090] The terms "a" and "the" as used herein are understood to encompass the plural as well as the singular.

[091] Various terms have been defined above. To the extent a term used in a claim is not defined above, it should be given the broadest definition persons in

the pertinent art have given that term as reflected in at least one printed publication or issued patent. Furthermore, all patents, test procedures, and other documents cited in this application are fully incorporated by reference to the extent such disclosure is not inconsistent with this application and for all jurisdictions in which such incorporation is permitted.

[092] The foregoing description of the disclosure illustrates and describes the present disclosure. Additionally, the disclosure shows and describes only the preferred embodiments but, as mentioned above, it is to be understood that the disclosure is capable of use in various other combinations, modifications, and environments and is capable of changes or modifications within the scope of the concept as expressed herein, commensurate with the above teachings and/or the skill or knowledge of the relevant art. While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

[093] It is understood that when combinations, subsets, groups, etc. of elements are disclosed (e.g., combinations of components in a composition, or combinations of steps in a method), that while specific reference of each of the various individual and collective combinations and permutations of these elements may not be explicitly disclosed, each is specifically contemplated and described herein.

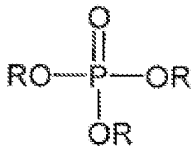
[094] The embodiments described hereinabove are further intended to explain best modes known of practicing it and to enable others skilled in the art to utilize the disclosure in such, or other, embodiments and with the various modifications required by the particular applications or uses. Accordingly, the description is not intended to limit it to the form disclosed herein. Also, it is intended that the appended claims be construed to include alternative embodiments.

CLAIMS

1. A cooling fluid for immersion cooling system comprising:

a) ester type base stock or a hydrocarbon base stock or both; and

b) phosphate ester having the following formula



where each R is independently C1-C18 alkyl group, unsubstituted phenyl group or C1-C12 alkyl-substituted phenyl group.

2. The cooling fluid of claim 1, wherein the ester type base stock is bis(2-ethylhexyl) adipate, saturated diester, trioctyl trimellitate, or dioctyl tetraphthalate.

3. The cooling fluid of claim 1, wherein the phosphate ester is 2-ethylhexyl diphenyl phosphate, trioctyl phosphate, tri(2-butoxyethyl) phosphate, isopropylated triphenyl phosphate, or triethyl phosphate.

4. The cooling fluid of claim 1, wherein the hydrocarbon base stock is present in 1 to 99 wt% based on the amount of the cooling fluid.

5. The cooling fluid of claim 1, wherein the ester type base stock is present in 1 to 99 wt% based on the amount of the cooling fluid.

6. The cooling fluid of claim 1, wherein the phosphate ester is present in about 0.5 to 95 wt% based on the amount of the cooling fluid.

7. The cooling fluid of claim 1, wherein the hydrocarbon base stock is a polyalphaolefin.

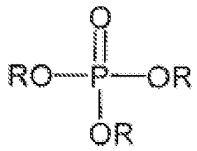
8. The cooling fluid of claim 1, wherein the hydrocarbon base stock has KV100 ranging from 1 cSt to 8 cSt.

9. The cooling fluid of claim 1, further comprising antioxidants, anti-wear agent, metal detergents, dispersants, friction modifiers, corrosion inhibitors, demulsifiers, viscosity modifiers, pour point depressants, foam inhibitors, anti-hydrolysis components, acid scavengers, anti-static components, fire-retardant components, seal swell agents, or plasticizers.

10. A method of cooling a battery in an electric or hybrid vehicle, comprising: immersing the battery with a cooling fluid comprising:

a) a hydrocarbon base stock or an ester type base stock or both; and

b) phosphate ester having the following formula



where each R is independently C1-C18 alkyl group, unsubstituted phenyl group or C1-C12 alkyl-substituted phenyl group.

11. The method of claim 10, wherein the hydrocarbon base stock is a polyalphaolefin.

12. The method of claim 10, wherein the ester type base stock is bis(2-ethylhexyl) adipate, saturated diester, trioctyl trimellitate, or dioctyl tetraphthalate.

13. The method of claim 10, wherein the phosphate ester is 2-ethylhexyl diphenyl phosphate, trioctyl phosphate, tri(2-butoxyethyl) phosphate, isopropylated triphenyl phosphate, or triethyl phosphate.

14. The method of claim 10, wherein the hydrocarbon base stock is present in 1 to 99 wt% based on the amount of the cooling fluid.

15. The method of claim 10, wherein the ester type base stock is present in 1 to 99 wt% based on the amount of the cooling fluid.

16. The method of claim 10, wherein the phosphate ester is present in about 0.5 to 95 wt% based on the amount of the cooling fluid.

17. The method of claim 10, wherein the hydrocarbon base stock is a polyalphaolefin.

18. The method of claim 10, wherein the cooling fluid further comprises antioxidants, anti-wear agent, metal detergents, dispersants, friction modifiers, corrosion inhibitors, demulsifiers, viscosity modifiers, pour point depressants, foam

inhibitors, anti-hydrolysis components, acid scavengers, anti-static components, fire-retardant components, seal swell agents, or plasticizers.