ABSTRACT

A biodegradable compressor oil comprising a biobased hydrocarbon base oil.
Figure 1

Hydrolytic Stability Comparison by ASTM-D2619-09 method

(acidity of water layer, mg KOH/g) vs (copper panel weight loss, mg/cm²)

<table>
<thead>
<tr>
<th>Product</th>
<th>Acidity (mg KOH/g)</th>
<th>Weight Loss (mg/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comm-PAO.3</td>
<td>4.34</td>
<td>0.06</td>
</tr>
<tr>
<td>Comm-Min.3</td>
<td>1.35</td>
<td>0.03</td>
</tr>
<tr>
<td>Comm-PAO.4</td>
<td>3.59</td>
<td>0.03</td>
</tr>
<tr>
<td>Comm-PAG.1</td>
<td>2.40</td>
<td>0.01</td>
</tr>
<tr>
<td>Comm-PAO.1</td>
<td>1.09</td>
<td>0.00</td>
</tr>
<tr>
<td>Comm-PAO.2</td>
<td>2.09</td>
<td>0.03</td>
</tr>
<tr>
<td>Exp-Comp.BL.1</td>
<td>0.20</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Figure 2

Air Release Time from Compressor Oil by ASTM-D3427-12, Standard Test Method for Air Release Properties of Petroleum Oils

![Bar Chart]

- Comm-PAO.3: 10.3 min
- Comm-Min.3: 8.5 min
- Comm-PAO.4: 7.8 min
- Comm-PAG.1: 5.0 min
- Comm-PAO.1: 4.0 min
- Comm-PAO.2: 3.2 min
- Exp-Comp.BL.1: 1.0 min

Air release time (min)
Figure 3

Separation of Compressor Oil from Water by ASTM-D1401-12, Standard Test Method for Water Separability of Petroleum Oils and Synthetic Fluids
Figure 4


```
<table>
<thead>
<tr>
<th>Sample</th>
<th>Average Wear Scar Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comm-PAG.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Comm-PAO.3</td>
<td>0.65</td>
</tr>
<tr>
<td>Comm-PAO.2</td>
<td>0.65</td>
</tr>
<tr>
<td>Comm-PAO.4</td>
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</tr>
<tr>
<td>Comm-Min.1</td>
<td>0.57</td>
</tr>
<tr>
<td>Comm-Min.3</td>
<td>0.55</td>
</tr>
<tr>
<td>Comm-PAO.1</td>
<td>0.45</td>
</tr>
<tr>
<td>Exp-Comp.BL.1</td>
<td>0.49</td>
</tr>
</tbody>
</table>
```

average wear scar diameter (mm)
Figure 5

Comparison of Specific Heat of a biobased base oil based compressor oil with other commercially available compressor oils
Figure 6

Comparison of Biodegradation Curves obtained from OECD 301B method and ISO32 grade Base Oils.

- biobased base oil (34cSt)
- isoparaffinic base oil (37cSt)
- PAO base oil (31cSt)
Figure 7

Biodegradation Curve obtained using Compressor Oil formulated with Biobased Base Oil

from OECD 301B method
COMPRESSOR OIL WITH BIOBASED BASE OIL

[0001] The present invention generally relates to compressor fluids. In one embodiment, the disclosure relates to compressor oil comprising a bio-based hydrocarbon, such as isoparaffinic hydrocarbon derived from hydrocarbon terpenes such as myrcene, ocimene and farnesene.

[0002] Compressed air is vital to modern day industrial operations and its importance is often compared to basic industrial utilities such as electricity, oil, gas, and water. Applications for compressed air include, without limitation, uses in environmental engineering, construction, mining, forging and other uses in foundries, metal working, plastic molding, wood working, automotive manufacturing, chemical manufacturing, food processing, paper manufacturing, textile processing, repair shops, and medical facilities. Compressors consume about 10% of global production of electricity.

[0003] A typical lifetime cost analysis of equipment ownership indicates that more than 75% of the cost comes from electricity cost, 10% comes from maintenance, and only 15% comes from equipment cost. Therefore, industrial operations have been paying great attention to the improvement of mechanical reliability and the enhancement of energy efficiency of compressed air systems.

[0004] Both issues, mechanical reliability and energy efficiency of air compressors, can be tightly linked to the performance of compressor oil. Compressor oil performs five vital functions. It provides lubrication to mechanical parts of compressor, provides protection against physical and chemical damage, provides sealing, provides cooling to internal parts, and removes contaminants.

[0005] No single parameter can provide quantitative and qualitative evaluation of an individual compressor oil’s level of performance in fulfillment of the five vital functions mentioned above. However, industrial standards (such as, for example, DIN 51506 and ISO 6743-3), equipment manufacturers, and end users have been using a combination of many performance parameters to evaluate and compare one compressor oil to another. These parameters are oxidative stability, hydrolytic stability, lubrication at low and high temperatures, wear prevention, rust and corrosion prevention, cooling/heat transfer, separation speed of air from compressor oil, separation speed of water from compressor oil, foam prevention capability, compatibility of oil with material inside a compressor, and fire safety.

[0006] Oxidative stability can be evaluated many different ways. Industrial standards include, for example, ASTM-D2272-11 (Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel), ASTM-D943 (Oxidation Characteristics of Inhibited Mineral Oils), DIN 51352 (determination of ageing characteristics of lubricating oils; Conradson carbon residue after aging by passing air through the lubricating oil in the presence of iron(II)oxide), and other equivalent or similar types of tests.

[0007] Hydrolytic stability can be evaluated using standardized test methods such as, for example, ASTM-D2619-09 (Standard Test Method for Hydrolytic Stability of Hydraulic Fluids, Beverage Bottle Method) or equivalent or similar test methods. Separation speed and degree of separation of air from oil samples can be tested by standardized test methods such as, for example, ASTM-D3427-12 (Standard Test Method for Air Release Properties of Petroleum Oils) or equivalent or similar methods. Separation speed and degree of separation of water from oil samples can be tested by standardized test methods such as, for example, ASTM D1401-12 (Standard Test Method for Water Separability of Petroleum Oils and Synthetic Fluids).

[0008] Foam prevention characteristics of oil samples can be tested by standardized test methods such as, for example, ASTM-D892 (Standard Test Method for Foaming Characteristics of Lubricating Oils) or equivalent methods.

[0009] Lubrication capability of an oil sample is greatly influenced by its viscosity which determines film thickness and film strength of the liquid under various conditions (i.e., temperature, shearing speed, and etc.). Standardized test methods such as, for example, ASTM-D445-12 (Test Method for Kinematic Viscosity of Transparent and Opaque Liquids, and Calculation of Dynamic Viscosity) or equivalent methods are frequently used to report the viscosity of oil samples. Temperature has a great effect on the viscosity of liquids and standardized methods and practices such as ASTM-D2270 (Standard Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100 °C). This method and equivalent methods are used to represent the impact of temperature change on the viscosity of an oil sample.

[0010] Preliminary evaluation of the wear prevention characteristic of an oil sample in sliding contact can be evaluated using standardized test method such as ASTM D4172-94(2010) (Standard Test Method for Wear Prevenitive Characteristics of Lubricating Fluid, Four-Ball Method) or equivalent methods.

[0011] Rust and corrosion prevention capability of an oil sample can be evaluated using standardized test methods such as ASTM-D130-12 (Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test), ASTM-D665-12 (Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water), or equivalent methods.

[0012] The cooling and heat transfer capability of oil samples can be evaluated by determination of their specific heat and thermal conductivity. The specific heat of a liquid sample can be evaluated using standardized test methods such as, for example, ASTM-E1269-12 (Determining Specific Heat Capacity by Differential Scanning Calorimetry), ASTM-E2716-09 (Determining Specific Heat Capacity by Sinusoidal Modulated Temperature Differential Scanning Calorimetry), or equivalent methods. Thermal conductivity can be evaluated using standardized test methods such as, for example, ASTM-E1952-11 (Thermal Conductivity and Thermal Diffusivity by Modulated Temperature Differential Scanning Calorimetry) or equivalent methods.

[0013] In or during the process of compressing air, atmospheric air along with water vapor and atmospheric contaminants (hydrocarbon or chemical vapors), are drawn into the compressor intake. Additionally, the compression chambers of most compressors require oil for lubrication, sealing and cooling. Once compressed, the air flows into an after-cooler to remove the heat of compression. As the air cools in the after-cooler, water and hydrocarbon vapors will condense. Additional condensation takes place as the air is further cooled in the piping and air dryers. This condensed moisture must be removed from the compressed air system to prevent damage to downstream components and processes. Drain valves are installed on moisture separators, coalescing filters, air receivers, air dryers and drip legs to remove this condensate from the compressed air system. The condensate should be piped from automatic drain valves to
Compressor condensate must be either collected or treated prior to disposal. An oil/water separator can be used to remove oil from the condensate. Collection involves the drainage of the condensate into drums or storage tanks, which are then hauled away to an approved disposal facility. Transportation, storage, and disposal costs (TSD) can exceed $500 for a single 55-gallon (208 liter) drum. A typical 25 hp (18 kW) compressed air system will generate approximately 20 gallons (76 liters) of condensate in one day. Eleven 55-gallon (208 liter) drums are required to dispose of the condensate produced in only one month of operation resulting in a cost of about $5,500. Since the condensate is approximately 95% water and 5% oil, oil/water separators have been developed to reduce or eliminate the amount of oil in the condensate. An oil/water separator system, installed on the 25 hp (18 kW) compressed air system example above, can reduce the number of 55-gallon (208 liter) drums from eleven to less than one drum per month, reducing condensate disposal costs by about $5,000 per month.

In either case, whether the oil is separated out or not, a compressed air system yields a significant amount of waste oil as a result of its routine operation, and therefore, environmental performance of compressor oil should be part of the performance matrix of compressor oil.

Reflecting growing concerns from the general public and environmental experts, government agencies and authorities around the world have begun to introduce more stringent regulation requiring usage of environmentally acceptable lubricants (EAL). For example, the US Environmental Protection Agency (EPA) signed the Final National Pollutant Discharge Elimination System (NPDES) General Permit for Discharges Incidental to the Normal Operation of a Vessel (Vessel General Permit or VGP) on March 2013. The VGP authorizes discharges incidental to the normal operation of non-military and non-recreational vessels greater than or equal to 79 feet in length into waters of the United States of America, as defined in 40 CFR 122.2. For purposes of the VGP, products meeting the permit’s definition of being an EAL include those labeled by the following labeling programs: Blue Angel, European Ecolabel, Nordic Swan, the Swedish Standards SS 155434 and 155470, Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) requirements, and EPA’s Design for the Environment (DFE).

In recent years, regulatory agencies have become increasingly concerned about oil spills which can contaminate the ground soil and other areas. A biodegradable oil is especially desirable for electrical apparatuses such as transformers used in populated areas, underground, near water, non-stationary, or other environmentally sensitive areas. In many cases, environmental non-toxicity and biodegradability of lubricants are defining parameters. Both performance parameters are the focus of government regulatory approval processes. Lubricants need to exceed minimum levels of performance in order to obtain approval to be part of the above referenced labeling programs.

Evaluating and predicting the environmental performances of base oils and lubricants is not simple or easy and is still considered a “mature science.” Currently, the most widely employed method of evaluating environmental performance involves testing for biodegradability, environmental toxicity, carbon footprint, carbon neutrality, recyclability, and renewability.

Biodegradability can be determined using one or more standardized test procedures and can provide valuable insight in comparing the potential risk of different lubricant products to the environment. One such guideline and test method has been set by the Organization for Economic Cooperation and Development (OECD) for degradation and accumulation testing.

The OECD has indicated that several tests may be used to determine the “ready biodegradability” of organic chemicals. Among these, aerobic ready biodegradability by the OECD 301B method tests material over a 28-day period and determines biodegradation of the material by measuring the evolution of carbon dioxide from the microbial oxidation of the material’s organic carbon. The carbon dioxide produced is trapped in barium hydroxide solution and is quantified by titration of residual hydroxide with standardized hydrogen chloride. To determine the percent biodegradation, the amount of carbon dioxide produced microbially from the test material is compared to its theoretical carbon dioxide content (the complete oxidation of the carbon in the test material to CO2). Positive controls, using sodium benzoate as a reference material, are run to check the viability of the aerobic microorganisms used in the procedure. Blank controls are also run in parallel. Tests, controls, and blanks are run in duplicate.

Using the OECD 301B or equivalent methods (28 day period), most green labeling programs require more than 60% biodegradation in 28 days. According to historical data, this level of biodegradation is hard to achieve using hydrocarbon base oil (petroleum based or synthetic hydrocarbon based) available in the current market with viscosity of fluid greater than 32cSt at KV40.

Improving oxidative stability of lubricants can contribute to environmental performance indirectly. Improving the oxidative stability of compressor oil can lead to a longer drain interval and to less generation of waste oil. Improving the heat transfer capability of compressor oil, such as its specific heat and thermal conductivity, can reduce the temperature of compressor parts and the lubricating oil in operation, leading to longer lubricant life due to less exposure to harmful thermal history and more energy efficient operation of the compressor.

According to data published by U.S. Energy Information Administration (EIA) on Electric Power Monthly in December 2013, more than 67% of electricity generated in the United States was generated utilizing fossil fuels. Therefore, enhanced energy efficiency in the operation of compressed air systems can contribute to the systems’ environmental performance indirectly.

There continues to be a need for improved compressor oils or lubricants, particularly which offer desired performance and physical properties such as better oxidative stability, low volatility, improved separation of oil from water (and air), and anti-wear properties. There also continues to be a need for an improved compressor oil or lubricant using clean biodegradable alternative hydrocarbon products which have improved environmental performance.
Among the various aspects of the disclosure, therefore, may be noted the provision of a compressor oil offering certain environmental performance characteristics, the provision of a biodegradable compressor oil or lubricant, the provision of a compressor oil comprising a biobased hydrocarbon, and the provision of clean biodegradable alternative hydrocarbon products which have improved environmental performance and/or physical properties such as better oxidative stability, low volatility, improved separation of oil from water (and air), and anti-wear properties.

Briefly, therefore, one aspect of the present disclosure is a compressor oil comprising a biobased hydrocarbon base oil, wherein the biobased hydrocarbon base oil has renewable carbon content greater than 40 wt% as measured by ASTM-D6866-12, and at least one antioxidant wherein the oxidative stability of the compressor oil is at least 1,000 minutes as determined by ASTM-D2272-11.

A further aspect of the present disclosure is a compressor oil having greater than 25% renewable carbon content measured by ASTM-D6866-12 and having the following properties:

- a kinematic viscosity at 40°C in range of 30cSt to 500cSt as measured by ASTM-D445-12 or equivalent method;
- a viscosity index greater than 120;
- an oxidative stability greater than 1,000 minutes as measured by ASTM-D2272-11;
- a flash point greater than 180°C as measured by ASTM-D92-12b;
- a pour point less than and equal to -30°C as measured by ASTM-D97-12, air release speed less than 3 minutes as determined by ASTM-D3427-12; and
- at least one of the following properties:
  - (i) a biodegradability of greater than 60% at 28 days as measured by OECD 301B;
  - (ii) a wear scar less than 0.5 mm as measured by ASTM-D4172-94a (2010);
  - (iii) an acidity of water layer after aging procedure no more than 0.5 mg KOH/g as measured by ASTM-D2619-09;
  - (iv) a copper panel weight loss during aging procedure no more than 0.05 mg/cm² and surface condition better or equal to ‘Shiny 1B’ rating as determined and measured by ASTM-D2619-09;
  - (v) an increase in kinematic viscosity at 40°C less than 0.5% measured by ASTM-D2619-09; and
  - (vi) an oil/water separation time less than 16 min and leaves no emulsion layer after test is done as measured by ASTM-D1401-12.

A further aspect of the present disclosure is a compressor oil having an improved specific heat value of at least 2.3 J/g °K at 50°C as determined by using standardized test methods such as, for example, ASTM-E1269-12 (Determining Specific Heat Capacity by Differential Scanning calorimetry), ASTM-E2716-09 (Determining Specific Heat Capacity by Sinusoidal Modulated Temperature Differential Scanning calorimetry).

A further aspect of the present disclosure is a compressor oil comprising a biobased hydrocarbon base oil having an average molecular weight (weight average) between 300 g/mol and 1500 g/mol, and an additive package, the additive package comprising an anti-oxidant.

A further aspect of the present disclosure is a compressor oil comprising a biobased hydrocarbon base oil, the compressor oil having a biodegradable rate in excess of 60% as determined in accordance with OECD 301B.

A further aspect of the present disclosure is a compressor oil comprising a biobased base oil having the molecular structure:

\[
[B]_n\quad [P]_m
\]

wherein,

- \(B\) is biobased hydrocarbon repeating unit;
- \(P\) is non-biobased hydrocarbon repeating unit;
- \(n\) is greater than 1, and \(m\) is less than 4;
- the stereoscopic arrangement of \([B]\) and \([P]\) repeating unit can be linear, branched, and cyclic;
- the sequential arrangement of \([B]\) and \([P]\) can be block, alternating, or random; and

- the molecular weight is in range of 300 g/mol to 1500 g/mol; and
- the biobased content of the compressor oil is greater than 20%, as measured by ASTM D6866-12.

A further aspect of the present disclosure is a compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil meets DIN 51506-VDL.

A further aspect of the present disclosure is a compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN <2 at 1000 hours as determined in accordance with ASTM D943-04a (2010).e1

A further aspect of the present disclosure is a compressor oil comprising a biobased hydrocarbon base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a pour point of less than -40°C.

A further aspect of the present disclosure is a compressor oil comprising a biobased hydrocarbon base oil, the compressor oil being compatible with and suitable for mixing with a Group I, Group II, or Group III base oil.

A further aspect of the present disclosure is a compressor oil having an ISO viscosity grade of 2 to 46,000 and comprising:

- (a) 1 to 95 wt% of a biobased hydrocarbon base oil containing carbon from a renewable source; and
- (b) 5 to 50 wt% of at least a first basestock selected from Group I base oils having a viscosity range of from 3 cSt to 500 cSt and combinations thereof, Group II and Group III hydroprocessed base oils and combinations thereof, and Group IV PAOs having a viscosity index of about 130 or less and combinations thereof; or
- (ii) 1 to 50 wt% of a second basestock selected from Group V base oils and combinations thereof.

A further aspect of the present disclosure is a compressor oil comprising: (a) a base oil having a weight average molecular weight in the range of 300 to 600 g/mol, a viscosity index greater than 120 and less than 140; and (b) an anti-wear hydraulic oil additive package; wherein the compressor oil has (i) an air release by ASTM D 3427-012 of less than 3 minutes at 50°C, (ii) a Sequence II foam tendency by ASTM D 892-13 of less than 50 ml, and a biodegradability rate of at least 60% as determined by OECD 301B.
[0061] A further aspect of the present disclosure is a compressor lubricated by a compressor oil according to any of the preceding paragraphs.

[0062] A further aspect of the present disclosure is a method of improving efficiency of operation of compressor, compressed gas, and compressed air system using compressor oil according to any of the preceding paragraphs.

[0063] Other aspects, features and embodiments of the present disclosure will, in part, discussed and, in part, apparent in the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0064] FIG. 1 is a pair of bar charts comparing Hydrolytic Stability Comparison by ASTM-D2619-09 method for several compressor oil formulations.

[0065] FIG. 2 is a bar chart comparing Air Release Time from Compressor Oil by ASTM-D3427-12, Standard Test Method for Air Release Properties of Petroleum Oils for several compressor oil formulations.

[0066] FIG. 3 is a bar chart comparing Separation of Compressor Oil from Water by ASTM-D1401-12, Standard Test Method for Water Separability of Petroleum Oils and Synthetic Fluids for several compressor oil formulations.


[0068] FIG. 5 is a graph showing a Comparison of Specific Heat of a biobased base oil based compressor oil with other commercially available compressor oils.

[0069] FIG. 6 is a graph showing a Comparison of Biodegradation Curves obtained from OECD 301B method and ISO32 grade Base Oils.

[0070] FIG. 7 is a Biodegradation Curve obtained using Compressor Oil formulated with Biobased Base Oil from OECD 301B method.

DETAILED DESCRIPTION

[0071] Base oils, and more particularly isoparaffins, derived from biobased hydrocarbon terpenes such as myrcene, ocimene and farnesene, have been described in PCT Patent Application No. PCT/US2012/024926, entitled “Base Oils and Methods for Making the Same,” filed, Feb. 13, 2012 and published as WO 2012/141784 on Oct. 18, 2012, by Nicholas Ohlcer et al., and assigned to Amyris, Inc. in Emeryville, Calif. These base oils have been stated to have utility as lubricant base stocks.

[0072] WO 2012/141784 discloses that terpenes are capable of being derived from isopentyl pyrophosphate or dimethylallyl pyrophosphate and the term “terpene” encompasses hemiterpenes, monoterpenes, sesquiterpenes, diterpenes, sesterterpenes, triterpenes, tetraterpenes and polypolterpenes. A hydrocarbon terpene contains only hydrogen and carbon atoms and no heteroatoms such as oxygen, and in some embodiments has the general formula (C\textsubscript{n}H\textsubscript{2n+2})\r

<table>
<thead>
<tr>
<th>TABLE I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example Biobased Base Oil Specifications</td>
</tr>
<tr>
<td>Properties</td>
</tr>
<tr>
<td>Appearance</td>
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<tr>
<td>Color</td>
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</table>

[0073] Further processing of certain of such biobased base oil stocks has been found to yield highly useful and superior compressor fluids. For example, C15 hydrocarbons containing four double bonds such as Biofen™ β-farnesene, commercially available from Amyris, Inc. (Emeryville, Calif.) may be pre-treated to eliminate impurities and then hydrogenated so that three of the four double bonds are reduced to single bonds. The partially hydrogenated intermediate product is then subjected to an oligomerization reaction with a linear alpha-olefin (LAO) using a catalyst such as BF\textsubscript{3} or a BF\textsubscript{3} complex. A further intermediate product, consisting of a mixture of hydrocarbons ranging from C10 to about C75, results. This oligomeric mixture of hydrocarbons is then hydrogenated to reduce the amount of unsaturation. The saturated hydrocarbon mixture is then distilled to obtain the targeted composition and finally blended to meet desirable base oil product specifications (such as kinematic viscosity at 40°C) for the compressor oil. Desirable examples of biobased base oil specifications that can be used to produce blends suitable for compressor oil formulation for one embodiment are set forth in Table 1.

In some embodiments in this disclosure, a commercially available biobased hydrocarbon base oil called “Partially hydrogenated β-3,7,11-trimethyldodeca-1,3,6,10-tetraene, reaction products with linear C8-C16 alpha-olefin, hydrogenated” (REACH registration number 01-2120031429-59-0000, commercially available from Novii L.I.C, California, United States) is used.
In preparing a compressor oil with the exemplary biobased hydrocarbon base oil of Table I, or another biobased hydrocarbon base oil of the present disclosure, about 20 weight percent (wt %) to about 100 wt % of the biobased hydrocarbon base oil may be used. To this biobased hydrocarbon oil may be added about 1 ppm to about 20 wt % additives, namely one or more antioxidants, anti-wear/Extreme pressure additives, rust and corrosion inhibitors, metal deactivators, thickeners, viscosity index (VI) improvers, pour point depressants, co-solvents, friction modifiers, foam inhibitors, and/or demulsifiers for a compressor oil formulation. A blend component comprising one or more oils or liquids may also be used as the base oil to formulate or complete the compressor oil, or to adjust the viscosity of the fluid or some other desired characteristic. Such additive oils or liquids may be selected from one or more of the following: microbial oils, vegetable oils, seed oils, mineral oils, isoparaffinic hydrocarbon fluids, silicone fluids, synthetic esters, poly-alpha-olefins, polylsioxanes, pentacycitherols esters, poly(-butane) liquids, and combinations thereof. The particular additives and the quantity of each used are selected with desired performances and intended use in mind. Other biobased oils may be used as a base oil in a similar manner, with attention to viscosity as with the biobased hydrocarbon base oil.

As used herein, biobased base oil is understood to mean any biologically derived oil to be used as a base oil in a compressor oil. Such oils may be made, for non-limiting example, from biological organisms designed to manufacture specific oils, as discussed in PCT Patent Application No. PCT/US2012/024926, published as WO 2012/141784, cited above, but do not include petroleum distillate or processed oils such as for non-limiting example mineral oils. A suitable method to assess materials derived from renewable resources is through ASTM D6866-12, “Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis.”

Counts from $^{14}\text{C}$ in a sample can be compared directly or through secondary standards to SRM 4990C. A measurement of 0% $^{14}\text{C}$ relative to the appropriate standard indicates carbon originating entirely from fossils (e.g., petroleum based). A measurement of 100% $^{14}\text{C}$ indicates carbon originating entirely from modern sources. A measurement of $>100\%$ $^{14}\text{C}$ indicates the source of carbon has an age of more than several years. See, e.g., WO 2012/141784, incorporated herein by reference.
have utility as a feedstock is a terminal olefin having a saturated hydrocarbon tail with structure (A1):

\[
\text{\(A11\)}
\]

where \(n=1, 2, 3, \text{ or } 4\).

In some variations, a mono-olefinic alpha-olefin having structure A11 may be derived from a conjugated hydrocarbon terpene wherein the conjugated diene is at the 1,3-position of the terpene. Examples include alpha-olefins derived from a 1,3-diene conjugated hydrocarbon terpene (e.g., a C10-C30 conjugated hydrocarbon terpene such as farnesene, myrcene, ocimene, springene, geranylfiarnesene, neophytadiene, trans-phyta-1,3-diene, or cis-phyta-1,3-diene). Another non-limiting example of an alpha-olefin having the general structure A11 includes 3,7,11-trimethyldodecene having structure A12.

A mono-olefinic alpha-olefin having structure A11 may be prepared from the appropriate conjugated hydrocarbon terpene using any suitable method. In some variations, the mono-olefinic alpha-olefin having structure A11 is produced from primary alcohol of corresponding to the hydrocarbon terpene (e.g., farnesol in the case of farnesene, or geraniol in the case of myrcene). The methods comprise hydrogenating the primary alcohol, forming a carboxylic acid ester or carbamate ester from the hydrogenated alcohol, and pyrolyzing the ester (or heating the ester to drive the elimination reaction) to form the alpha-olefin with a saturated hydrocarbon tail, e.g., as described in Smith, L. E.; Rouault, G. F.; J. Am. Chem. Soc. 1943, 65, 745-750, for the preparation of 3,7-dimethylcoctene, which is incorporated by reference herein in its entirety. The primary alcohol of the corresponding hydrocarbon terpene may be obtained using any suitable method.

Alpha-olefins having the general structure A11 from conjugated hydrocarbon terpenes may be prepared via other schemes. For example, in some variations, the hydrocarbon terpene has a conjugated diene at the 1,3-position, and the conjugated diene can be functionalized with any suitable protecting group known to one of skill in the art in a first step (which may comprise one reaction or more than one reaction). The remaining olefinic bonds can be saturated in a second step (which may comprise one reaction or more than one reaction), and the protecting group can be eliminated to produce an alpha-olefin having the general structure A11 in a third step (which may comprise one reaction or more than one reaction).

Any suitable protecting group and elimination scheme may be used. For example, a hydrocarbon terpene having a 1,3-conjugated diene (e.g., \(\beta\)-farnesene) may be reacted with an amine (e.g., a dialkyl amine such as dimethylamine or diethylamine) in the first step to produce an amine having the formula \(N(R_1)(R_2)(R_3)\), where \(R_1\) and \(R_2\) are alkyl groups such as methyl or ethyl, and \(R_3\) is an unsaturated hydrocarbon originating from the conjugated terpene. In the case of \(\beta\)-farnesene, \(R_3\) is

The resulting amine may be oxidized to the N-oxide using hydrogen peroxide followed by elimination to the aldehyde using acetic anhydride. Hydrogenation of the aldehyde in the presence of a catalyst may be carried out to saturate any remaining olefinic bonds on the aliphatic tail originating from the hydrocarbon terpene, and the aldehyde functionality may be eliminated to produce an alpha-olefin having structure A11. Scheme I below illustrates an example of such a preparation of an alpha-olefin having structure A11 using \(\beta\)-farnesene as a model compound.

Another variation of a method to make an alpha-olefin from a hydrocarbon terpene having a 1,3-conjugated diene follows Scheme II below. Here, the hydrocarbon terpene is reacted with a dialkyl amine (e.g., dimethylamine). The resulting amine has the general formula \(N(R_1)(R_2)\) (where \(R_1\) and \(R_2\) are alkyl groups such as methyl and \(R_3\) is an unsaturated hydrocarbon originating from the hydrocarbon terpene (e.g., in the case of \(\beta\)-farnesene, \(R_3\) is

The amine \(N(R_1)(R_2)(R_3)\) can be hydrogenated (e.g., using an appropriate catalyst), treated with peroxide, and heated to undergo elimination to form an alpha-olefin having structure A11 (e.g., compound A12 if \(\beta\)-farnesene is used as the starting hydrocarbon terpene). Scheme II illustrates this method using \(\beta\)-farnesene as a model compound.
In another variation, a hydrogenated primary alcohol corresponding to a hydrocarbon terpene (e.g., hydrogenated farnesol or hydrogenated geraniol) can be dehydrated using basic aluminum oxide (e.g., at a temperature of about 250°C) to make an alpha-olefin having the general structure A11. Any suitable dehydration apparatus can be used, but in some variations, a hot tube reactor (e.g., at 250°C) is used to carry out a dehydration of a primary alcohol. In one variation, hydrogenated farnesol can be dehydrated using basic aluminum oxide (e.g., in a hot tube reactor at 250°C) to make compound A12, or an isomer thereof.

Other examples of particular species of partially hydrogenated conjugated hydrocarbon terpene that may have utility as a feedstock are mono-olefins having a saturated hydrocarbon tail with structure (A13) or structure (A15):

\[
\text{(-)}-\text{la} \quad \text{(-)}-\text{la} \\
\text{n=1, 2, 3, or 4. A mono-olefin having the general structure A13, A15 or A11 may in certain instances be derived from a conjugated hydrocarbon terpene having a 1,3-diene moiety, such as myrcene, farnesene, springlene, geranylformesene, neophytadiene, trans-phylta-1,3-diene, or cis-phylta-1,3-diene. Here again, the conjugated may be functionalized with a protecting group (e.g., via a Diels-Alder reaction) in a first step, exocyclic olefinic bonds hydrogenated in a second step, and the protecting group eliminated in a third step. In one non-limiting example of a method for making mono-olefins having the structure A13, A15 or A11, a conjugated hydrocarbon terpene having a 1,3-diene is reacted with SO\(_2\) in the presence of a catalyst to form a Diels-Alder adduct. The Diels-Alder adduct may be hydrogenated with an appropriate hydrogenation catalyst to saturate exocyclic olefinic bonds. A retro Diels-Alder reaction may be carried out on hydrogenated adduct (e.g., by heating, and in some instances in the presence of an appropriate catalyst) to eliminate the sulfone to form a 1,3-diene. The 1,3-diene can then be selectively hydrogenated using a catalyst known in the art to result in a mono-olefin having structure A11, A13 or A15, or a mixture of two or more of the foregoing. Non-limiting examples of regioselective hydrogenation catalysts for 1,3-diienes are provided in Jong Tae Lee et al., "Regioselective hydrogenation of conjugated dienes catalyzed by hydridepentacynanoaluminate mon using \(\beta\)-cyclodextrin as the phase transfer agent and lanthanide halides as promoters," J. Org. Chem., 1990, 55 (6), pp. 1854-1856, in V. M. Frolov et al, "Highly active supported palladium catalysts for selective hydrogenation of conjugated dienes into olefins," Reaction Kinetics and Catalysis Letters, 1984, Volume 25, Numbers 3-4, pp. 319-322, in Tungler, A., Hegedus, L., Fodor, K., Farkas, G., Furcht, A. and Karancsi, Z. P. (2003) "Reduction of Dienes and Polyenes," in The Chemistry of Dienes and Polynes, Volume 2 (ed. Z. Rappoport), John Wiley & Sons, Ltd, Chichester, UK, doi: 10.1002/0470857226.ch2, and in Tungler, A., Hegedus, L., Fodor, K., Farkas, G., Furcht, A. and Karancsi, Z. P., "Reduction of Dienes and Polyenes" in Patai’s Chemistry of Functional Groups (John Wiley and Sons, Ltd. published online Dec. 15, 2009, DOI: 10.1002/9780470682531.pat0233), each of which is incorporated herein by reference in its entirety. For example, a catalyst known in the art for 1,4 hydrogen addition to 1,3-diienes results in a mono-olefin having structure A13. In one non-limiting example, \(\beta\)-farnesene can be reacted with SO\(_2\) in the presence of a catalyst to form a Diels-Alder adduct, which is subsequently hydrogenated, and the sulfone eliminated to form a 1,3-diene, which is subsequently selectively hydrogenated using a catalyst known in the art for regioselective hydrogenation additions to 1,3-diienes to form 3,7,11-trimethylundodec-2-ene, 5,7,11-trimethylundodec-1-ene, or 3-methylene-7,11-dimethylundecane, or a mixture of any two or more of the foregoing.

In yet another example of a particular species of partially hydrogenated hydrocarbon terpene that may have utility as a feedstock, a terminal olefin of the general structure A14 may be made from a conjugated hydrocarbon terpene having a 1,3-conjugated diene and at least one additional olefinic bond (e.g., myrcene, farnesene, springlene, or geranylformesene):

\[
\text{(-)}-\text{la} \quad \text{(-)}-\text{la} \\
\text{n=1, 2, 3, or 4. In one non-limiting variation, a compound having the structure A14 may be derived from an unsaturated primary alcohol corresponding to the relevant hydrocarbon terpene (e.g., farnesol in the case of farnesene, or geraniol in the case of myrcene). The unsaturated primary alcohol may be exposed to a suitable catalyst under suitable reaction conditions to dehydrate the primary alcohol to form the terminal olefin A14.}

In one non-limiting example, a stoichiometric deoxyxygenation-reduction reaction may be conducted to form compounds having structure A14 from a primary alcohol (e.g., farnesol or geraniol) of a hydrocarbon terpene. One prophetic example of such a reaction can be conducted according to a procedure described in Dieguez et al., "Weakening C-O Bonds: Ti(III), a New Reagent for Alcohol Deoxygenation and Carbonyl Coupling Olefination," J. Am. Chem. Soc. 2010, vol. 132, pp. 254-259, which is incorporated by reference herein in its entirety: A mixture of titanic acid dichloride (\(\eta^2\)-C\(_2\)H\(_5\))\(_2\)TiCl\(_2\) (C\(_2\)H\(_5\))\(_2\)TiCl\(_2\) (3.88 mmol) and Mn dust (2.77 mmol) in strictly deoxygenated tetrahydrofuran (THF) (7 ml.) can be heated at reflux under stirring until the red solution turns green. Then, to this
mixture can be added a solution of the primary alcohol (e.g., farnesol or geraniol) (1.85 mmol) in strictly deoxygenated THF (4 mL). After the starting materials disappear, the reaction can be quenched with 1N HCl and extracted with tert-butylmethyl ether (t-BuOMe). The organic phase can be washed with brine, filtered and concentrated in vacuo to yield a crude product, which can be purified, e.g., by column chromatography (hexane/t-BuOMe, 8:1) over silica gel column to afford a compound having structure A14 (e.g., 3,7,11-trimethyldec-1,6,10-triene if farnesol is used as the starting material).

[0090] Other reactions may be conducted to form compounds having structure A14 from a primary alcohol (e.g., farnesol or geraniol) of a hydrocarbon terpene. One prophetic example of such a reaction can be conducted according to another procedure described in Diquez et al., “Weakening C-O Bonds: Ti(III),” A New Reagent for Alcohol Deoxygenation and Carbonyl Coupling Olefination,” J. Am. Chem. Soc. 2010, vol. 132, pp. 254-259, which is incorporated herein by reference in its entirety: A mixture of Cp3TiCl (0.639 mmol) and Mn dust (17.04 mmol) in thoroughly deoxygenated THF (8 mL) and under Ar atmosphere can be stirred until the red solution turned green. This mixture can then be heated at reflux and the corresponding trimethylsilyl chloride (TMSCI) (8.52 mmol) may be added. The primary alcohol (e.g., farnesol) (1.92 mmol) in strictly deoxygenated THF (2 mL) may then be added. After the starting materials disappear, the reaction may be quenched with t-BuOMe, washed with 1 N HCl, brine, dried, and concentrated under reduced pressure. The resulting crude may be purified, e.g., by column chromatography (hexane/t-BuOMe, 8:1) on silica gel to afford compound having structure A14 (e.g., 3,7,11-trimethyldec-1,6,10-triene if farnesol is used as the starting material).

[0091] An olefinic feedstock as described herein may comprise any useful amount of the particular species (e.g., alpha-olefinic species having structure A11, A12 or A15, mono-olefinic species having structure A13, or unsaturated terminal olefin species having structure A14), made either by a partial hydrogenation route or by another route, e.g., as described herein. In certain variations, an olefinic feedstock comprises at least about 1° A, at least about 5%, at least about 10%, at least about 20%, at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, or at least about 90% of species having structure A11, A12, A13, A14, or A15. In certain variations, an olefinic feedstock comprises at least about 1° A, at least about 5%, at least about 10%, at least about 20%, at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, or at least about 90% of 3,7,11-trimethyldec-1-ene. In certain variations, an olefinic feedstock comprises at least about 1° A, at least about 5%, at least about 10%, at least about 20%, at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, at least about 90% of 3,7,11-trimethyldec-2-ene. In certain variations, an olefinic feedstock comprises at least about 1° A, at least about 5%, at least about 10%, at least about 20%, at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, at least about 90% of 3,7,11-trimethyldec-2-ene. In certain variations, an olefinic feedstock comprises at least about 1° A, at least about 5%, at least about 10%, at least about 20%, at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, at least about 90% of 3,7,11-trimethyldec-2-ene.

In certain variations, an olefinic feedstock comprises at least about 1° A, at least about 5%, at least about 10%, at least about 20%, at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, or at least about 90% of 3,7,11-trimethyldec-2-ene. In certain variations, an olefinic feedstock comprises at least about 1° A, at least about 5%, at least about 10%, at least about 20%, at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, or at least about 90% of 3,7,11-trimethyldec-2-ene. In certain variations, an olefinic feedstock comprises at least about 1° A, at least about 5%, at least about 10%, at least about 20%, at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, or at least about 90% of 3,7,11-trimethyldec-2-ene. In certain variations, an olefinic feedstock comprises at least about 1° A, at least about 5%, at least about 10%, at least about 20%, at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, or at least about 90% of 3,7,11-trimethyldec-2-ene. In certain variations, an olefinic feedstock comprises at least about 1° A, at least about 5%, at least about 10%, at least about 20%, at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, or at least about 90% of 3,7,11-trimethyldec-2-ene.

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with the compressor oil formulation described in this disclosure. Examples from one class of suitable antioxidants include without limitation butylated hydroxyanisole, dibutyl-paracresol (BHT), alkylated diphenylamines, tocopherol (vitamin-E), β-carotene, sterically hindered alkylthiophenethylphenol, 2-(1,1-Dimethylethyl)-1,4-benzenediol, 1,2-dihydro-2,2,4-trimethylquinoline, ascorbyl palmitate, propyl gallate, and mixtures of these. In embodiments of this disclosure, such an antioxidant in an amount of 0.01 wt % to 2 wt % of the compressor oil may part of the additive package and be added to the bio-based base oil. Compressor oil for an application in the environmentally sensitive areas requires environmental performance of toxicity and biodegradability in addition to improved oxidation stability requirement. Some of the above listed chemistries can meet both requirements along with thiocyclohexyl bis (3,5-di-tert-butyl-4-hydroxyhydrocinnamate). This chemistry is a sterically hindered phenolic antioxidant. This chemistry is excellent for inhibiting oxidation and increasing thermal stability for hydrocarbon base oils. The preferred chemistry has low toxicity to aquatic fish and plants making it ideal for environmental applications.

Other types of phenolic anti-oxidants are available. Here the chemistry preferably contains no (or at least no detectable) or minimal levels of sulfur or phosphorus, to meet toxicity specifications for the formulation. This can allow the treat rate to be larger, up to 5%, preferably <2%, more preferable, <1%. These types of anti-oxidants can be in liquid form and this is the preferred state for ease of manufacturing. Further, octylated/butylated diphenylamine or alkylated phenyl-α-naphthylamine can be used. This amine chemistry can be used alone or in combination with the phenolic anti-oxidants for synergistic effects. Depending on the type of amine chemistry the toxicity effects on the overall formulation may vary. For diphenylamine chemistry the treat rate may be <0.5% versus the naphthylamine which can treat at higher rates and up to 5%. Each of these chemistries contain nitrogen at levels <5% but contain no Sulfur or Phosphorus compounds.

Examples of phenolic antioxidants include 2,6-di-tert-butylphenol, liquid mixtures of tertiary butylated phenols, 2,6-di-tert-butyl-4-methylphenol, 4,4’-methylenebis(2,6-di-tert-butylphenol), 2,2’-methylenebis(4-methyl-6-tert-butylphenol), mixed monochrome-bridged polyaalkyl phenols, 4,4’-thiobis(2-methyl-6-tert-butylphenol), 4,4’-butyldienone-bis(3-methyl-6-tert-butylphenol), 4,4’-isopropylidene-bis(2,6-di-tert-butylphenol), 2,2’-methylene-bis(4-methyl-6-nonylphenol), 2,2’-isobutyldiene-bis(4,6-dimethylphenol), 2,6-di-tert-butyl-4-methylphenol, 2,6-di-tert-butyl-4-ethylphenol, 2,4-dimethyl-6-tert-butylphenol, 2,6-ditert-butyl-1,4-methylenedio, 2,6-dimethyl-1,4-methylenedio-β-creosol, 2,6-dimethyl-4-(N,N'-dimethylinonphenophenol), 4,4’-thiobis(2-methyl-6-tert-butylphenol), 2,2’-thiobis(4-methyl-6-tert-butylphenol), bis (3-methyl-4-hydroxy-5-tet-10-butenyl)-sulfide, bis(3,5-ditert-butyl-4-hydroxybenzyl), 2,2’-methylene-bis(4-methyl-6-cyclohexylphenol), N,N’-di-sec-butylphenylenediamine, 4-isopropylaminodiophenylamine, phenyl-α-naphthyl amine, phenyl-α-naphthyl amine, and ring-alkylated diphenylamines. Examples include the sterically hindered tertiary butylated phenols, bisphenols and cinnamic acid derivatives and combinations thereof. In yet another embodiment, the antioxidant is an organic phosphate having at least one direct carbon-to-phosphorus linkage. Diphenylamine-type oxidation inhibitors include, but are not limited to, alkylated diphenylamine, phenyl-α-naphthylamine, and alkylated-α-naphthylamine. Other types of oxidation inhibitors include metal dithiocarbamate (e.g., zinc dithiocarbamate), and 15-methylbenzenes(dibutylfithio-carbamate). In another embodiment, class of antioxidants suitable for food grade industrial lubricant formulation are also useful in the compressor oil described in the current disclosure. Examples of such antioxidants include, without limitation, butylated hydroxyanisole (BHA), di-buty1-paracresol (BHT), phenyl-α-naphthylamine (PANA), octylated/butylated diphenylamine, tocopherol (vitamin-E), β-carotene, sterically hindered alkylthiophenethylphenol, 2-(1,1-Dimethylethyl)-1,4-benzenediol, 1,2-dihydro-2,2,4-trimethylquinoline, ascorbyl palmitate, propyl gallate, high molecular weight phenolic antioxidants, hindered bis-phenolic antioxidant, and mixtures of these.

In certain embodiments, exemplary phenolic anti-oxidants include: 2-t-butyl-4-heptyl phenol; 2-t-butyl-4-octyl phenol; 2-t-butyl-4-dodecyl phenol; 2,6-di-t-butyl-4-heptyl phenol; 2,6-di-t-butyl-4-dodecyl phenol; 2-methyl-6-di-t-butyl-4-heptyl phenol; and 2-methyl-6-di-t-butyl-4-dodecyl phenol. Examples of ortho coupled phenols include: 2,2’-bis(6-t-butyl-4-heptyl phenol); 2,2’-bis(6-t-butyl-4-octyl phenol); and 2,2’-bis(6-t-butyl-4-dodecyl phenol). Sulfur containing phenolics may also be used to advantage in certain embodiments. The sulfur can be present as either aromatic or aliphatic sulfur within the phenolic antioxidant molecule. 4,4’-methylenebis(6-t-butyl o-creosol), 4,4’-methylenebis(2-tet-aryl o-creosol); 2,2’-methylenebis(4-methyl-6-tert-butylphenol); 4,4’-methylene-bis(2,6-di-tert-butylphenol). In certain embodiments, exemplary aminic anti-oxidants include p,p’-dihexyl-diphenylamine; p,p’-diheptyl-diphenylamine; p,p’-dioctyldiphenylamine; p,p’-dinonyl-diphenylamine; p,p’-distearyldiphenylamine; octyphenyl-β-naphthylamine; t-octylphenyl-α-naphthylamine; phenyl-β-naphthylamine; p-octyl phenyl-α-naphthylamine. In certain embodiments, exemplary sulfur/phosphorous anti-oxidants include n-dodecyl-2-hydroxyethyl sulfide; 1-(t-tetradecylthio)-2-propanol; dibenzyl sulfide, polysulfides, diallyl sulfides, modified thiols, mercaptobenzimidazoles, thiophene derivatives, xanthogenates, and thioglycols, 2-(4-hydroxy-3,5-di-t-butyl benzyl thio)acetate, alkythiocarbamoyl with linear and branched alkyl groups of from 3-30 carbon atoms, alkyl and aryl mono, di, triphosphites with linear or branched alkyl or aryl group from 4-20 carbon atoms, thio and diithiophosphates with linear or branched alkyl or aryl groups from 4-20 carbons, neutralized as a metal salt such as zinc, molybdenum, antimony, bismuth or neutralized with an alkyl or aryl linear or branched amine with groups from 4-20 carbon.

Anti-Wear/Extreme Pressure

In one embodiment, the compressor oil formulation comprises an anti-wear/extreme pressure additive. For example, in one such embodiment the compressor oil formulation may comprise about 0.01-10% anti-wear/extreme pressure additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.01-2% anti-wear/extreme pressure additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.1-1% anti-wear/extreme pressure additive. In each of these embodiments, the anti-wear/extreme pres-
Sure additive may be a single anti-wear/extreme pressure additive or it may comprise a combination of anti-wear/extreme pressure additives. Further, in each of these embodiments, the anti-wear/extreme pressure additive may be selected from among the following compositions:

[0105] (i) mono-di-butyl, hexyl, octyl, decyl, dodecyl, or fatty alcohol acid phosphate salts with long chain (C11-C14) alkylamines, fatty amines, ethoxylated amines, branched amines. Also aromatic phosphates such as cresyl diphenylphosphate;

[0106] (ii) zinc dialkyl dithiophosphate typically containing about 4 to about 12 carbon atoms and, more commonly about 6 to about 12 carbon atoms in each alkyl group. Preferably each alkyl group contains about 8 to about 12 carbon atoms. Examples of suitable alkyl moieties include butyl, sec-butyl, isobutyl, tert-butyl, pentyl, n-hexyl, sec-hexyl, n-octyl, 2-ethylhexyl, decyl and dodecyl;

[0107] (iii) alkyl and aryl mono, di, triphosphites with linear or branched alkyl or aryl group from 4-20 carbon atoms;

[0108] (iv) thio and dithiophosphates with linear or branched alkyl or aryl groups from 4-20 carbons, neutralized as a metal salt such as zinc, molybdenum, antimony, bismuth or neutralized with an alkyl or aryl linear or branched amine with groups from 4-20 carbon;

[0109] (v) triphenyl, butylated triphenyl, nonylated triphenyl phosphorothionates; and

[0110] (vi) sulfurized linear or branched olefins with 4-24 carbons.

[0111] Rust and Corrosion Inhibitors

[0112] A rust inhibitor is an additive that is mixed with a compressor oil base oil to prevent rust in finished compressor oil applications. Examples of commercial rust inhibitors are metal sulfonates, alkylamines, alkyl amine phosphates, alkenyl succinic acids, fatty acids, and acid phosphate esters. Rust inhibitors are sometimes comprised of one or more active ingredients. Examples of applications where rust inhibitors are needed include: internal combustion engines, turbines, electric and mechanical rotary machinery, hydraulic equipment, gears, and compressors. Rust inhibitors work by interacting with steel surfaces to form a surface film or neutralize acids. Rust inhibitors are effective in some embodiments of the compressor oil when they are used in an amount less than 25 weight percent. In some other embodiments, rust inhibitors are effective in an amount less than 10 percent of the total composition. In some other embodiments, rust inhibitors are effective in an amount less than 1 weight percent. Hereinafter, (less than 0.1%).

[0113] In one embodiment, the compressor oil formulation comprises a rust or a corrosion inhibitor additive. For example, in one such embodiment the compressor oil formulation may comprise about 0.01-5% rust and/or corrosion inhibitor additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.01-2% rust and/or corrosion inhibitor additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.1-0.5% rust and/or corrosion inhibitor additive. In each of these embodiments, the rust and/or corrosion inhibitor additive may be a single rust and/or corrosion inhibitor additive or it may comprise a combination of rust and/or corrosion inhibitor additive. Further, in each of these embodiments, the rust and/or corrosion inhibitor additive may be selected from among the following compositions:

[0114] (i) hydrocarbyl amine salts of alkylphosphoric acid, dihydrcarbyl amine salts of alkylphosphoric acid or hydrocarbyl amine salts of hydrocarbyl aryl sulphonic acid, especially reaction product of a C14 to C18 alkylated phosphoric acid with Primene 81R (produced and sold by Rohm & Haas) which is a mixture of C11 to C14 tertiary alkyl primary amines;

[0115] (ii) succinimide derivatives such as the higher alkyl substituted amides of dodecylene succinic acid, higher alkyl substituted amides of dodecyl succinic acid such as the tetrapropenylsuccinic monoesters (commercially available) and imidazoline succinic anhydride derivatives, e.g. the imidazoline derivatives of tetrapropenyl succinic anhydride;

[0116] (iii) alkyl succinic acid half esters of mono or polyalcohols with linear or branch chain length of 3-30 carbons.

[0117] (iv) iso-nonyl phenoxy acetic acid;

[0118] (v) mono-/di-butyl, hexyl, octyl, decyl, dodecyl, or fatty alcohol acid phosphate salts with linear or branched chain from 4-20 carbons alkyl or aryl amines, fatty amines, ethoxylated amines, branched amines;

[0119] (vi) aromatic phosphates such as cresyl diphenylphosphate; and

[0120] (vii) imidazolines, sarcosine derivatives with linear or branched alkyl or aryl chain from 4-20 carbons.

[0121] Metal Deactivators

[0122] In one embodiment, the compressor oil formulation comprises a metal deactivator additive. For example, in one such embodiment the compressor oil formulation may comprise about 0.01-5% metal deactivator additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.01-2% metal deactivator additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.1-0.5% metal deactivator additive. In each of these embodiments, the metal deactivator additive may be a single metal deactivator additive or it may comprise a combination of metal deactivator additives. Further, in each of these embodiments, the rust and/or corrosion inhibitor additive may be selected from among the following compositions: N.N-disubstituted aminomethyl-1,2,4-triazoles, and the N,N-disubstituted amino methyl-benzotriazoles; derivatives of benzotriazoles, benzimidazole, 2-alkylthiobenimidazoles, 2-alkylthiobenzothiazoles, 2-(N,N-diisopropyl carbamoyl)benzotriazoles, 2,5-bis (alkyl-diethyl)-1,3,4-thiadiazoles, 2,5-bis(N,N-dialkyldithiocarbamoyl)-1,3,4-thiadiazoles, and 2-alkylthio-5-mercapto thiadiazoles.

[0123] Thickeners, VI Improvers and Pour Point Depressants

[0124] In one embodiment, the compressor oil formulation comprises a thickener, viscosity index (“VI”) improver or pour point depressant additive. For example, in one such embodiment the compressor oil formulation may comprise about 0.1-25% thickener, viscosity index (“VI”) improver or pour point depressant additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.1-2% thickener, viscosity index (“VI”) improver or pour point depressant additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.5-20% thickener, viscosity index (“VI”) improver or pour point depressant additive. By way of further example, in one such embodiment the compressor oil may comprise about 1-15% thickener, viscosity index (“VI”) improver or pour point depressant additive. In each of these embodiments, the thickener, viscosity index (“VI”) improver or pour point depressant additive may be a single thickener, viscosity index (“VI”) improver or pour point depressant additive.
additive or it may comprise a combination of thickener, viscosity index ("VI") improver or pour point depressant additives. Further, in each of these embodiments, the thickener, viscosity index ("VI") improver or pour point depressant additive may be selected from among the following compositions:

- **[0125]** (i) polyisobutylene, polymerized and co-polymerized alkyl methacrylates, and mixed esters of styrene maleic anhydride interpolymers reacted with nitrogen containing compounds, ethylene-propylene polymers, polyethacrylates and various diene block polymers and copolymers, polyolefins and polyalkylstyrenes, nitrogen-containing esters of carboxylic-containing interpolymers and the oil-soluble acrylate-polymerization products of acrylate esters, block copolymers produced by the anionic polymerization of unsaturated monomers including styrene, butadiene, and isoprene; and

- **[0126]** (ii) esters of maleic anhydride-styrene copolymers, polyethacrylates; polyacrylates; polyacrylamides; condensation products of halolparaffin waxes and aromatic compounds; vinyl carboxylate polymers; and terpolymers of diallyltrimurate, vinyl esters of fatty acids, ethylene-vinyl acetate copolymers, alkyl phenol formaldehyde condensation resins, alkyl vinyl ethers and mixtures thereof.

- **[0127]** Esters and Co-Solvents

- **[0128]** Esters can be considered a co-base oil or additive depending on the degree of environmental performance for the target of the formulation. Typically there can be a renewability requirement on the amount of renewable carbon contained in the overall formulation. The renewable base oil of the disclosure may vary in its amount of renewable carbon. To add additional renewable carbon, fatty acids, esters, glycerine, or other bioderived base oils can be considered. Some of these can be forms of Trimethylolpropanetriolates, Triglycerylces, Trimethylolpropane esters, Polyl complex esters, 2-Ethylhexyl Cocoate, methyl esters, saturated trimethylolpropane ester, trimethylolpropane ester of carboxylic acids, saturated monopentaerythritol branched acids, trimethylolpropane, and complex esters of carboxylic acids.

- **[0129]** In one embodiment, the compressor oil formulation comprises an ester or cosolvent. For example, in one such embodiment the compressor oil formulation may comprise about 0.1-75% ester or cosolvent. By way of further example, in one such embodiment the compressor oil may comprise about 1-70% ester or cosolvent. By way of further example, in one such embodiment the compressor oil may comprise about 3-20% ester or cosolvent. In each of these embodiments, the ester or cosolvent additive may be a single ester or cosolvent or it may comprise a combination of ester or cosolvent. Further, in each of these embodiments, the ester or cosolvent may be selected from among the following compositions (and included as a co-base oil or an additive):

- **[0130]** (i) esters made by dehydration of mono-acids, di-acids, tri-acids with alcohols with mono-, di- or multi-alcohols. Preferred acids include C4-C30 monobasic acids, more preferably 2-ethylhexanoic acid, isohexyl, isopentyl, and capric acids, and di-basic acids, more preferably adipic, fumaric, sebacic, azelaic, maleic, phthalic, and terephthalic acids, dimerized and trimeredized fatty acids. The alcohols can be any of the suitable mono-alcohols or polyols. Preferred examples are glycerol, 2-ethylhexanol, iso-tridecanols, neopentyl glycol, trimethylol ethane, 2-methyl-2-propyl-1,3-propanediol, trimethylol propane, pentaerythritol, and dipentaerythritol, ethoxylated, propoxylated and butoxylated alcohols; and.

- **[0131]** (ii) alkylbenzenes and other alkyl aromatics such as alkyl napthenes

- **[0132]** Friction Modifiers

- **[0133]** In one embodiment, the compressor oil formulation comprises a friction modifier additive. For example, in one such embodiment the compressor oil formulation may comprise about 0.01-5% friction modifier additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.05-5% friction modifier additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.1-2% friction modifier additive. In each of these embodiments, the friction modifier additive may be a single friction modifier additive or it may comprise a combination of friction modifier additives. Further, in each of these embodiments, the friction modifier additive may be selected from among the following compositions: aliphatic amines or ethoxylated aliphatic amines, aliphatic fatty acid amides, aliphatic carboxylic acids, aliphatic carboxylic esters, aliphatic carboxylic esteramides, aliphatic phosphonates, aliphatic phosphates, aliphatic thio phosphonates, aliphatic thiophosphates, etc., wherein the aliphatic group usually contains above about eight carbon atoms so as to render the compound suitably oil soluble. Also suitable are aliphatic substituted succinimides formed by reacting one or more aliphatic succinic acids or alcohols with ammonia. Molybdenum salts such as carbamate, dithiocarbamate or dithiophosphate.

- **[0134]** Foam Inhibitors

- **[0135]** In one embodiment, the compressor oil formulation comprises a foam inhibitor additive. For example, in one such embodiment the compressor oil formulation may comprise about 0.001-1% foam inhibitor additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.005-0.5% foam inhibitor additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.005-0.2% foam inhibitor additive. In each of these embodiments, the friction modifier additive may be a single foam inhibitor additive or it may comprise a combination of foam inhibitor additives. Further, in each of these embodiments, the foam inhibitor additive may be selected from among the following compositions: silicones, polyacrylates, surfactants.

- **[0136]** Demulsifiers

- **[0137]** In one embodiment, the compressor oil formulation comprises a demulsifier additive. For example, in one such embodiment the compressor oil formulation may comprise about 0.001-1% demulsifier additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.005-0.5% demulsifier additive. By way of further example, in one such embodiment the compressor oil may comprise about 0.005-0.2% demulsifier additive. In each of these embodiments, the demulsifier additive may be a single foam inhibitor additive or it may comprise a combination of demulsifier additives. Further, in each of these embodiments, the demulsifier additive may be selected from among the following compositions: derivatives of propylene oxide, ethylene oxide, polyoxymethylene alcohol, alkyl amines, amino alcohols, diamines or polyyamines reacted sequentially with ethylene oxide or substituted ethylene oxides or mixtures thereof. Examples of demulsifiers include trialkyl phosphates, polyethylene glycols, polyeth
ylene oxides, polypropylene oxides, (ethylene oxide-propylene oxide) polymers and mixtures thereof. [0138] In preparing a compressor oil with the biobased hydrocarbon base oil, about 25 weight percent (wt%) up to about 100 wt% of the biobased hydrocarbon base oil may be used. To this biobased hydrocarbon oil may be added between about 1 ppm to about 20 wt% additives, namely one or more oxidation inhibitors (anti-oxidants), corrosion and rust inhibitors, viscosity modifiers, pour point depressants, metal deactivators (anti-foam) agents, friction modifiers, extreme pressure additives, anti-wear agents, commercially available additive packages, and mixtures thereof. A blend component comprising one or more oils or liquids may also be used as the base oil to formulate or complete the compressor oil, or to adjust the viscosity of the compressor oil or some other desired characteristic. Such additive oils or liquids may be selected from one or more of the following: microbial oils, vegetable oils, seed oils, mineral oils, isoparaffinic hydrocarbon fluids, silicone fluids, synthetic esters, poly alpha-olefins, polysiloxanes, pentaoctylthiol esters, poly(butane) liquids and combinations thereof. The particular additives and the quantity of each used are selected with desired performances and intended use in mind. Other biobased oils may be used as a base oil in a similar manner, with attention to viscosity as well as with the biobased hydrocarbon base oil.

[0139] It is well known to those who are skilled art that typical compressor oil composition is engineered to meet typical ISO viscosity grade such as ISO 32, ISO 46, ISO 68, ISO 100, or ISO 150. Table II illustrates the kinematic viscosity limits on such grades at 40°C.

<table>
<thead>
<tr>
<th>ISO viscosity classification common to compressor oil</th>
<th>Minimum, kinetic viscosity at 40°C, cSt</th>
<th>Maximum, kinetic viscosity at 40°C, cSt</th>
</tr>
</thead>
<tbody>
<tr>
<td>name, viscosity grade</td>
<td>mid-point target kinetic viscosity at 40°C, cSt</td>
<td>minimum, kinetic viscosity at 40°C, cSt</td>
</tr>
<tr>
<td>ISO 32</td>
<td>32.0</td>
<td>28.8</td>
</tr>
<tr>
<td>ISO 46</td>
<td>46.0</td>
<td>41.4</td>
</tr>
<tr>
<td>ISO 68</td>
<td>68.0</td>
<td>61.2</td>
</tr>
<tr>
<td>ISO 100</td>
<td>100.0</td>
<td>90.0</td>
</tr>
<tr>
<td>ISO 150</td>
<td>150.0</td>
<td>135.0</td>
</tr>
</tbody>
</table>

[0140] In formulating the synthetic compressor oils of this disclosure, according to one embodiment of this disclosure, the compressor oil composition comprises an anti-oxidant. Antioxidants are typically free-radical traps, acting as free-radical reaction chain breakers. That is, effective antioxidants may be selected from radical scavengers such as phenolic, aminic antioxidants, or synergistic mixtures of these. Sulfurized phenolic antioxidants and organic phosphites are useful as components of such mixtures. Many antioxidant additives that are known and used in the formulation of lubricant products are suitable for use with the compressor oil formulations described in this disclosure. Examples of phenolic antioxidants include 2,6-di-tert-butylphenol, liquid mixtures of tertiary butylated phenols, 2,6-di-tert-butyl-4-methylphenol, 4,4'-methylenediphenyl, 2,4'-methylenediphenyl(4-methyl-6-tert-butylphenol), mixed methylene-bridged polyalkyl phenols, 4,4'-thiobis(2-methyl-6-tert-butylphenol), 4,4'-butylidenebis(3-methyl-6-tert-butylphenol), 4,4'-isopropylidenedi-bis(2,6-di-tert-butylphenol), 2,2'-methylene-bis(4-methyl-6-nonylphenol), 2,2'-isobutylidene-bis(4,6-dimethylphenol), 2,6-di-tert-butyl-4-methylphenol, 2,6-di-tert-butyl-4-ethylphenol, 2,4-dimethyl-6-tert-butylphenol, 2,6-di-tert-1-dimethylamino-1-tert-cresol, 2,6-di-tert-1-(N,N'-dimethylaminomethylphenol), 4,4'-thiobis(2-methyl-6-tert-butylphenol), 2,2'-thiobis(4-methyl-6-tert-butylphenol), bis(3-methyl-4-hydroxy-5-tert-butylbenzyl)-sulfide, bis(3,5-di-tert-butyl-4-hydroxybenzyl), 2,2'-5-methylene-bis(4-methyl-6-cyclohexylphenol), N,N'-di-sec-butylphenylenediamine, 4-isopropylamino diphenylamine, phenyl-alpha-naphthyl amine, phenyl-alpha-naphthyl amine, and ring-alkylated diphenylamines. Examples include the sterically hindered tertiary butylated phenols, biphenols and cinnamic acid derivatives and combinations thereof. In yet another embodiment, the antioxidant is an organic phosphonate having at least one direct carbon-to-phosphorus linkage. Diphénylamine-type oxidation inhibitors include, but are not limited to, alkylated diphenylamine, phenyl-alpha-naphthylamine, and alkylated-alpha-naphthylamine. Other types of oxidation inhibitors include metal dithiocarbamate (e.g., zinc dithiocarbamate), and 15-methylenecis(butylidithiocarbamate). In another embodiment, class of antioxidants suitable for food grade industrial lubricant formulation are also useful in the compressor oil as described in current disclosure. Example of such antioxidants include, without limitation, butylated hydroxyanisole (BHA), di-butyl-paracresol (BHT), phenyl-alpha-naphthylamine (PANA), octylated/butylated diphenylamine, tocopherol (vitamin-E), β-carotene, sterically hindered alkylthiophenol, 2-(1,1-Dimethylcyl)-1,4-benzenediol, 1,2-dihydro-2,2,4-trimethylquinoline, ascorbyl palmitate, propyl gallate, high molecular weight phenolic antioxidants, hindered bis-phenolic antioxidant, and mixtures of these.

[0141] In one embodiment, such an antioxidant in an amount of 0.01 wt% to 0.2 wt% of the compressor oil may be added to the biobased base oil and other additive mixture comprising the compressor oil described in the current disclosure. [0142] Metal deactivators/passivator may also be used in addition to or as an alternative to an antioxidant. In one embodiment, list of useful metal deactivators include imidazole, benzimidazole, pyrazole, benzotriazole, tolutriazole, 2-methyl benzimidazole, 3,5-dimethyl pyrazole, and methylene bis-benzotriazole. Commercial examples used in some embodiments of the disclosure include, without limitation, triazole derivative metal deactivators, such as Liganet® 30 (available from BASF), and tolutriazole derivative metal deactivators, such as Liganet® 39 (available from BASF). An amount of metal deactivators up to about 100 ppm is used in some embodiments. In one embodiment, the metal passivator is food grade and comply with FDA regulations. One of such useful additive is the N-acyl derivative of sarcosine, such as an N-acyl derivative of sarcosine. One example is N-methyl-N-(1-oxo-9-octadecenyl) glycine. This derivative is commercially available from BASF® under the trade name SARKOSYL™ O. Another additive is an imidazole such as Amine O™, also commercially available from BASF®.

[0143] In one embodiment, the compressor oils of the present disclosure comprise a foam inhibitor. Examples of foam inhibitors include but are not limited to alkylpolysiloxanes, dimethyl polycyclohexane and polyacrylates. Commercial examples useful foam inhibitors in some embodi-
ments of the disclosure include, without limitation, PC-1344 (Cytec), PC-1844 (Cytec), PC-2544 (Cytec), PC-3144 (Cytec), HiTec2030 (Afton), AC AMH2 (BASF), 889D (Lubrizol), and mixture thereof.

In one embodiment, the compressor oils of the present disclosure comprise a viscosity modifier/viscosity index improver. Viscosity modifiers (or viscosity index improvers) are polymeric materials, typical examples of these being hydrogenated styrene-isoprene block copolymers, hydrogenated copolymers of styrene-butadiene copolymers of ethylene and propylene, acrylic polymers produced by polymerization of acrylate and methacylate esters, hydrogenated isoprene polymers, polyalkyl styrenes, hydrogenated alkyl arene conjugated diene copolymers, polyolefins, esters of maleic anhydride-styrene copolymers, and polyisobutylene. These polymeric thickeners are added to bring the viscosity of the base fluid mixture up to the required level of ISO viscosity grade according to compressor equipment manufacturer (OEM)’s requirements (please refer to Table II).

In various embodiments, the viscosity modifier/viscosity index improver may be a polymer with linear, radial or star architecture, such as those described in Schober et al., US Patent Application No. 2011/0306529, which is incorporated by reference in its entirety, and in the references cited therein, all of which are incorporated herein in their entirety. Such viscosity modifiers may have a random, tapered, di-block, tri-block, or multi-block architecture and may have weight average molecular weights of about 100,000 to about 800,000. As a non-limiting example, a disclosed embodiment in US Patent Application No. 2011/0306529 is prepared from 50 wt % to about 100 wt % of an alkyl methacrylate, wherein the alkyl group has about 10 to about 20 carbon atoms up to about 40 wt % of an alkyl methacrylate, wherein the alkyl group has about 9 carbon atoms; and up to about 10 wt % of a nitrogen-containing monomer. Other examples of viscosity modifiers that are star polymers include isoprene/styrene/isoprene triblock polymers.

Examples of commercially available viscosity modifier/viscosity index improver for use in some embodiments of the disclosure include, without limitation, TPC1285 (TPC group), TPC175 (TPC group), TPC1105 (TPC group), TPC1160 (TPC group), SV260 (Infineum), SV261 (Infineum), SV265 (Infineum), V554 (Infineum), 7308 (Lubrizol), 7723 (Lubrizol), 87705 (Lubrizol), HiTec5754 (Afton), HiTec5751 (Afton), HiTec5748 (Afton), HiTec5825A (Afton), Viscoatex 8-100 (Evonik), Viscoatex 8-112 (Evonik), Viscoatex 8-200 (Evonik), Viscoatex 8-219 (Evonik), Viscoatex 8-220 (Evonik), Viscoatex 8-251 (Evonik), Viscoatex 8-310 (Evonik), Viscoatex 8-400 (Evonik), Viscoatex 8-407 (Evonik), Viscoatex 8-450 (Evonik), Viscoatex 8-944 (Evonik), Viscoatex 8-954 (Evonik), Viscoatex 10-250 (Evonik), Viscoatex 10-930 (Evonik), Viscoatex 10-950 (Evonik), Viscoatex 7-302 (Evonik), Viscoatex 7-305 (Evonik), Viscoatex 7-310 (Evonik), Viscoatex 7-510 (Evonik), and mixture thereof.

In one embodiment, the compressor oils of the present disclosure comprise a detergents or dispersants which can be anionic, cationic, zwitterionic or non-ionic. Lubricant detergents are metal salts of organic surfactants giving corrosion protection, deposit prevention, and other formulation enhancement. Lubricant dispersants stabilize contaminants during lubrication cycle resulting in protection against problem such as viscosity increase, wear, and filter plugging. The surfactant or dispersant may be used alone or in combination with other types of surfactants or dispersants. Examples include an oil-soluble dispersant selected from the group consisting of succinimide dispersants, succinic ester dispersants, and succinic ester-amide dispersants. In one embodiment, the dispersant is selected from the group of alkenyl succinimides, alkenyl succinimides modified with other organic compounds, alkenyl succinimides modified by post-treatment with ethylene carbonate or boric acid, neoterythritols, phenate-saliclylates and their post-treated analogs, alkali metal or mixed alkali metal, alkaline earth metal borates, dispersions of hydrated alkali metal borates, dispersions of alkaline-earth metal borates, polyamide ashless dispersants and the like or mixtures of such dispersants. Examples of metallic detergents include an oil-soluble neutral or overbased salt of alkali or alkaline earth metal with one or more of the following acidic substance (or mixtures thereof): a sulfonic acid; a carboxylic acid; a salicylic acid; an alkyl phenol; a sulfurized alkyl phenol; and an organic phosphorus acid characterized by at least one direct carbon-to-phosphorus linkage, such as phosphate.

In one embodiment, the compressor oils of the present disclosure further comprise at least one corrosion inhibitor. Examples of suitable ferrous metal corrosion inhibitors are the metal sulfonates such as calcium petroleum sulfonate, barium diol-naphthalene sulfonate and basic barium dioxyxynaphthalene sulfonate, carbonated or non-carbonated. Other examples are selected from thiazoles, triazoles, and thiadiazoles. Examples of such compounds include benzotriazole, tolyltirazole, octyltirazole, decyltriazole, dodecyltriazole, 2-mercapto benzothiazole, 2,5-dimercapto-1,3,4-thiadiazole, 2-mercapto-5-hydroxybenzothiolo-1,3,4-thiadiazoles, 2-mercapto-5-hydroxybenzothio-1,3,4-thiadiazoles, 2,5-bis(hydroxybenzothio)-1,3,4-thiadiazoles, and 2,5-bis(hydroxybenzothio)-1,3,4-thiadiazoles. Suitable compounds include the 1,3,4-thiadiazoles, a number of which are available as articles of commerce, and also combinations of triazoles such as tolurytriazole with a 1,3,5-thiadiazole such as 2,5-bis(alkylthio)-1,3,4-thiadiazole. The 1,3,4-thiadiazoles are generally synthesized from hydrazine and carbon disulfide by known procedures. See, for example, U.S. Pat. Nos. 2,765,289; 2,749,311; 2,760,933; 2,850,453; 2,910,439; 3,665,561; 3,862,798; and 3,840,549.

In one embodiment, the rust or corrosion inhibitors are selected from the group of monoacrylic acid and polyacrylic acids. Examples include octanoic acid, decanoic acid and dodecanoic acid. Suitable polyacrylic acids include dimer and trimer acids produced from acids such as tall oil fatty acids, oleic acid, linoleic acid, or the like. Another useful type of rust inhibitor may comprise alkyl succinic acid and alkyl succinic anhydride corrosion inhibitors, for example, tetrapropenylsuccinic acid, tetrapropenylsuccinic anhydride, tetradecenylsuccinic acid, tetradeceylsuccinic anhydride, hexadecenylsuccinic acid, hexadecenylsuccinic anhydride, and the like. Also useful are the half esters of alkyl succinic acids having 8 to 24 carbon atoms in the alkyl group with alcohols such as the polyglycols. Other suitable rust or corrosion inhibitors include ether amines; acid phosphates; amines; polyethoxylated compounds such as ethoxylated amines, ethoxylated phenols, and ethoxylated alcohols; imidazolines; aminosuccinic acids or derivatives thereof; and the like. Mixtures of
such rust or corrosion inhibitors can be used. Other examples of rust inhibitors include a polyethylene terephthalate phenol, neutral calcium sulfonate and basic calcium sulfonate.

In one embodiment, the compressor oils of the present disclosure further comprise at least a friction modifier selected from the group of succinimide, a bis-succinimide, an alkylated fatty amine, an ethoxylated fatty amine, an amide, a glycerol ester, an imidazole, fatty alcohol, fatty acid, amine, borated ester, other esters, phosphates, phosphites, phosphonates, and mixtures thereof.

Extreme pressure/anti-wear agents useful for present disclosure may be selected from library of molecules deemed suitable/preferable by those who are skilled in art of industrial lubricant formulation. Such molecules and compounds can reduce friction and/or wear by forming protective-film layer between two sliding surfaces. Such compounds include oxygen-containing organic compounds with polar head group, organic sulphur compounds which can form reacted films at surfaces, organic phosphorus compounds, organic boron compounds, organic molybdenum compounds, zinc dialkyldithiophosphates (ZDDP), and mixture thereof. In one embodiment, the compressor oils further comprise at least an extreme pressure/anti-wear agent in the range of from 100 ppm to 1 wt %, based on the total weight of compressor oil composition. Examples of such agents include, but are not limited to, phosphates, carbamates, esters, molybdenum-containing compounds, boron-containing compounds and ashless anti-wear additives such as substituted or unsubstituted thio-phosphoric acids, and salts thereof. In one embodiment, the anti-wear agents are selected from the group of zinc dialkyl-dithiophosphate (primary alkyl, secondary alkyl, and aryl type), diphenyl sulfide, methyl trichlorostearate, chlorinated napthalenes, fluoroalkylpolyisoxanes, lead naphthenate, neutralized phosphates, dithiophosphates, and sulfur-free phosphates. In another embodiment, the anti-wear agent is selected from the group of a zinc dialkyl dithio phosphate (ZDDP), an alkyl phosphite, a trialkyl phosphite, and amine salts of dialkyl and mono-alkyl phosphoric acid. Examples of molybdenum-containing compounds that may serve as anti-wear agents include molybdenum dithiocarbamates, trinuclear molybdenum compounds, for example as described in WO1998/026030, sulphonates of molybdien and molybdenum dithiophosphate. Boron-containing compounds that may be used as anti-wear agents include borated esters, borated fatty amines, borated epoxides, alkali metal (or mixed alkali metal or alkaline earth metal) borates and borated overbased metal salts.

In one embodiment, the additional or additive components to the compressor base oil are added as a fully formulated additive package fully formulated to meet an original equipment manufacturer’s requirements. The package to be used depends in part on the requirements of the specific equipment to receive the compressor oil composition. Some of the above-mentioned additives can provide a multiplicity of effects; thus for example, a single additive may act as a dispersant as well as an oxidation inhibitor. In one embodiment, when the compressor oil contains one or more of the above-mentioned additives, each additive is typically blended into the base oil in an amount that enables the additive to provide its desired function. It may be desirable, although not essential, to prepare one or more additive concentrates comprising additives (concentrates containing at least one of above-mentioned additives sometimes being referred to as “additive packages”) to add to the compressor lubricant composition. The final composition may employ from about 0.001 to 20 wt. % of the concentrate, the remainder being the oil of lubricating viscosity. The components can be blended in any order and can be blended as combinations of components.

Additives used in formulating the compressor oil composition can be blended into the base oil individually or in various sub-combinations to subsequently form the compressor oil. In one embodiment, all of the components are blended concurrently using an additive concentrate (i.e., additives plus a diluent, such as a hydrocarbon solvent). The use of an additive concentrate takes advantage of the mutual compatibility afforded by the combination of ingredients when in the form of an additive concentrate.

In another embodiment, the compressor oil composition is prepared by mixing the base oil with the separate additives or additive package(s) at an appropriate temperature, such as approximately 25–80°C, until homogeneous.

The compressor oils of the present disclosure can be used in various compressor applications including reciprocating compressors as well as screw compressors.

In one embodiment, the compressor oils of the present disclosure are suitable for use in oil injected rotary screw compressors operating at high discharge temperatures (>100°C) and high discharge pressures (>15 bar). In another embodiment, the composition meets the requirements for reciprocating air compressors operating at high discharge temperature (>200°C). In yet another embodiment, the compressor oil composition is suitable for use in stationary and portable compressors, operating at compression temperatures up to 220°C including compressors with oil lubricated pressure space, e.g. single and multistage reciprocating compressors or single or multistage centrifugal compressors.

The disclosure will be further understood by reference to the following examples which are not to be construed as limiting. Those skilled in the art will appreciate that other and further embodiments are apparent and within the spirit and scope of the claims from the teachings of the examples taken with the accompanying specification.

The synthetic compressor oils made with biobased base oils of this disclosure, including for non-limiting examples embodiments employing biobased hydrocarbon base oils, have significant performance advantages. The compressor oils of this disclosure have superior oxidative stability over commercially available synthetic and mineral based compressor fluids. The compressor oils of this disclosure also have superior hydrolytic stability (stability of lubricant in the presence of hot metallic surface and moisture, measured according to standardized test method such as ASTM-D2619-09 or equivalent methods) which in turn provides better protection to internal parts of a compressor system.

Agitation of compressor oil during compressor operation is known to lead to entrainment of air in the oil. Such entrainment of air can ultimately cause reduced lubrication quality, reduced heat dissipation and an accelerated risk of oxidation. However, the compressor oils of the present disclosure provide fast release of air, thus ensuring more continuous lubrication and cooling of internal parts of the compressor system and a reduced risk of foam accumulation. Similarly, the compressor oils of the present disclosure quickly separate from water, avoiding detrimental
sludge filter-plugging, oil breakdown and reduced performance that can occur when oil/water emulsions develop. The compressor oils of the present disclosure also show superior anti-wear performance when compared to commercially available synthetic and mineral compressor oils. Moreover, with the present disclosure, these high performances with the compressor oils of the disclosure can be obtained while still providing environmental compatibility and environmental performance (i.e. biodegradability, renewability, and etc.).

[0160] Referring to Table III, a commercial mineral oil based compressor oil, herein also called “Comm-Min.1” for abbreviation, containing a mineral base oil, showed less than a 150 minutes oxidative stability when tested with ASTM D2272-11. Poly alkylene glycol (PAG) based compressor oil, herein also called “Comm-PAG.1” for abbreviation, showed about 500 minutes oxidative stability. Another mineral oil based compressor oil, herein also called “Comm-Min.2” for abbreviation, and diester based compressor oil, herein also called “Comm-Die.1” for abbreviation, showed slightly more than 1000 minutes oxidative stability. Greater oxidative stabilities were observed from poly alpha-olefin (PAO) based commercially available compressor oil. “Comm-PAO.1”, for abbreviation, had about 1800 minutes oxidative stability and “Comm-PAO.2”, for abbreviation, showed slightly greater than 2000 minutes oxidative stability.

[0161] In contrast, an example formulation of a compressor oil of one embodiment of the present disclosure, called Exp-Comp.BL.1 herein, comprising a biobased hydrocarbon base oil, showed greater than 4000 minutes oxidative stability by ASTM-D2272-11. Table IV shows oxidative stability obtained with various combinations of additives together with chosen biobased hydrocarbon base oil blend. All blends identified in Table IV show much improved oxidative stability than commercially available compressor oils shown in Table III. These observations demonstrated the improved oxidative stability of synthetic compressor oil made with biobased base oil disclosed herein when compared to commercially available compressor oils.

[0162] The hydrolytic stability of a lubricant is measured by testing the stability of the lubricant in the presence of a hot metallic surface and measuring the release of moisture using ASTM-D2619-09 or an equivalent method. Two of the key parameters—acidity of water layer after aging and weight loss of copper panel during aging process—of compressor oil formulated with biobased hydrocarbon base oil are compared to those parameters of commercially available compressor oils (shown on FIG. 1). Increased acidity as a result of compressor oil breakdown can adversely affect the lubricant itself, to induce further breakdown, and the internal part of the compressor, to induce corrosion and rust. Compressor oil formulated with biobased hydrocarbon base oil (Exp-Comp.BL.1) shows much improved/ superior hydrolytic stability compared to commercial compressor oils. Table V compares % viscosity change (comparing before and after the aging procedure prescribed in ASTM-D2619-09) between compressor oils formulated with biobased hydrocarbon base oil and commercially available premium synthetic compressor oil formulated with polyalkylene glycol (Comm-PAG.1). Compressor oils formulated with biobased hydrocarbon show little change (less than 0.5%) while Comm-PAG.1 had 2.64% viscosity increase after 48 hr aging process.
TABLE V

<table>
<thead>
<tr>
<th>Change in kinematic viscosity, measured at 40°C., during aging procedure prescribed by ASTM-D2619-09 method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp-Comp. BL. 7</td>
</tr>
<tr>
<td>% viscosity change</td>
</tr>
</tbody>
</table>

[0163] Agitation of compressor oil during an operation of air compression leads to entrainment of air in the oil. A high amount of entrapped air can adversely affect the compressor oil’s function as a lubricant. For example, lubrication quality is reduced, heat transfer capability is adversely affected, and the contact between air and oil is increased, providing an increased risk of oxidation of the compressor oil. Compressor oil formulated with biobased hydrocarbon (Exp-Comp. BL.1) shows improved speed of separation from air when compared to commercial compressor oil, as illustrated in FIG. 2.

[0164] Quick separation of oil and water is key to uninterrupted and extended operation of a compressor. Emulsification of water and compressor oil can adversely affect the operation of the compressed air system such as to increase the risk of sludge formation, filter plugging, breakdown of oil, and reduced overall performance. Compressor oil formulated with biobased hydrocarbon (Exp-Comp.BL.1) achieves the best possible speed of separation between oil and water, separation time=5 minutes, which is shortest time measurable within the used test method, ASTM-D1401-12 (See FIG. 3).

[0165] Compressor oil formulated with biobased hydrocarbon also provides improved protection against wear of metallic parts inside the compressor. ASTM-D4172-94 (2010) tests wear preventive characteristics of lubricating fluid and compressor oil formulated with biobased oil. The biobased oil showed a smaller size of wear scar than all commercially available compressor oils except Comm-PAO.1 (See FIG. 4).

[0166] The heat transfer capability of fluids can be compared using specific heat (J/g °C) and thermal conductivity (W/m °K). Exp-Comp.BL.4 fluids have greater specific heat (heat capacity per unit mass of liquid) than all fluids compared in FIG. 5. Biobased base oil used in the formulation of compressor oils of this disclosure also exhibit improved thermal conductivity over mineral oils (both mineral base oil and Group III base oil), as shown in Table VI.

TABLE VI

<table>
<thead>
<tr>
<th>Thermal Conductivity of Base Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Conductivity at 50°C. (W/m °K)</td>
</tr>
<tr>
<td>biobased hydrocarbon base oil</td>
</tr>
<tr>
<td>Group III base oil</td>
</tr>
<tr>
<td>mineral base oil</td>
</tr>
<tr>
<td>natural ester</td>
</tr>
<tr>
<td>PAO</td>
</tr>
</tbody>
</table>

[0167] While comparing degree of biodegradation of base oil using OECD 301B method, and comparing the environmental performance of different types of base oil, the effect of the viscosity of the base oil on the degradation behavior should be carefully noted. For example, poly alpha-olefin (PAO), classified as a Group IV base oil by The American Petroleum Institute (API), can achieve greater than 60% of biodegradation in 28 days when the base oil mainly consists of PAO with kinematic viscosity (at 40°C.) of about 3.1cSt. However, PAO base oil can only achieve less than 35% of biodegradation in 28 days when its kinematic viscosity at 40°C. is greater than 31cSt. FIG. 6 compares biodegradability of different types of base oils using the OECD 301B method, which is considered to be part of the environmental performance matrix. In order to provide a fair comparison, base oils with similar kinematic viscosity are compared (31cSt-37cSt at 40°C., noted in FIG. 6). Tests were extended to 40 days to prove long term behavior over the standard period of 28 days. Slightly greater than 10 days of lag phase was observed from the biodegradation of PAO. PAO showed 22% of biodegradation by 21 days and reached a plateau value, 27% biodegradation, by 25 days. Isoparaffinic base oil, classified as Group III base oil according to API classification, showed better biodegradation behavior than PAO. For isoparaffinic base oil, duration of lag phase was less than 6 days, and a plateau value of 56% was reached by 25 days. In contrast, biobased hydrocarbon base oil showed 78% of biodegradation at 28 days, achieved 90% of biodegradation by 40 days time mark, and had not entered the plateau phase (FIG. 6, open circle symbol).

[0168] FIG. 7 plots the results of percentage biodegradation of compressor oil formulated with biobased base oils according to one embodiment of the present disclosure, Exp-Comp.BL.1 over a period of 28 days. Exp-Comp.BL.1 comprised of biobased hydrocarbon base oils, showed about 65% biodegradation at 28 days. Exp-Comp.BL.1 has much higher viscosity (46cSt at 40°C., FIG. 7) than any base oils (about 32cSt at 40°C.) shown in FIG. 6, yet Exp-Comp. BL.1 achieved greater than 60% of biodegradation, demonstrating superior and significantly improved biodegradability.

[0169] The biobased base oils discussed in the test examples comprise a biobased hydrocarbon base oil. However, it is contemplated that other biobased base oils, not necessarily hydrocarbon based, but synthesized to have favorable compressor oil properties, would also have the benefits of the biobased hydrocarbon base oil compressor oils. The foregoing examples demonstrate that the compressor oils disclosed herein provide an environmentally safe electrically insulating fluid that has superior or competitive properties to fluids previously available.

[0170] The present disclosure further includes the following enumerated embodiments.

Embodiment 1

A compressor oil comprising a biobased hydrocarbon base oil, wherein the biobased hydrocarbon base oil has renewable carbon content greater than 40 wt (% as measured by ASTM-D6866-12, and at least one antioxidant wherein the oxidative stability of the compressor oil is at least 1,000 minutes as determined by ASTM-D2272-11.

Embodiment 2

The compressor oil of embodiment 1 wherein the hydrocarbon base oil comprises a biobased terpene selected from the group consisting of myrcene, ocimene, farnesene, and combinations thereof.
Embodiment 3

[0173] The compressor oil of embodiment 1 or 2 wherein the biobased hydrocarbon base oil constitutes about 25 wt% to about 99.999 wt% of the compressor oil.

Embodiment 4

[0174] The compressor oil of embodiment 3 wherein the additive is selected from the group consisting of antioxidants, corrosion and rust inhibitors, viscosity modifiers, pour point depressants, metal deactivators, anti-foaming agents, friction modifiers, extreme pressure additives, anti-wear agents, additive oils and combinations thereof.

Embodiment 5

[0175] The compressor oil of embodiment 4 wherein the additive is an additive oil selected from the group consisting of microbial oils, vegetable oils, seed oils, mineral oils, isoparaffinic hydrocarbon fluids, silicone fluids, synthetic esters, poly alpha-olefins, polyalkylsiloxanes, pentaerythritol esters, poly (butane) liquids, and combinations thereof.

Embodiment 6

[0176] The compressor oil of embodiment 1 wherein air release speed of such compressor oil is less than 3 minutes as determined by ASTM-D3427-12.

Embodiment 7

[0177] The compressor oil of embodiment 1 wherein air release speed of such compressor oil is less than 2 minutes as determined by ASTM-D3427-12.

Embodiment 8

[0178] The compressor oil of any of the preceding enumerated embodiments wherein the oxidative stability of the compressor oil is at least 2,000 minutes as determined by ASTM-D2272-11.

Embodiment 9

[0179] The compressor oil of any of the preceding enumerated embodiments wherein the oxidative stability of the compressor oil is at least 3,000 minutes as determined by ASTM-D2272-11.

Embodiment 10

[0180] The compressor oil of any of the preceding enumerated embodiments wherein the compressor oil has an oil/water separation time of less than 16 min and it leaves no emulsion layer upon completion of the test, as determined in accordance with ASTM-D1401-12.

Embodiment 11

[0181] The compressor oil of embodiment 1 having a hydrolytic stability as measured by ASTM-D2619-09 with acidity of water layer after aging procedure no more than 2.5 mg KOH/g.

Embodiment 12

[0182] The compressor oil of embodiment 1 having a hydrolytic stability as measured by ASTM-D2619-09 with acidity of water layer after aging procedure no more than 1.0 mg KOH/g.

Embodiment 13

[0183] The compressor oil of embodiment 1 having a hydrolytic stability as measured by ASTM-D2619-09 with acidity of water layer after aging procedure no more than 0.5 mg KOH/g.

[0184] Embodiment 14. The compressor oil of embodiment 1 having a hydrolytic stability as measured by ASTM-D2619-09 with copper panel weight loss no more than 0.05 mg/cm².

Embodiment 15

[0185] The compressor oil with biobased base oil of embodiment 1 having a improved hydrolytic stability as measured by ASTM-D2619-09 with no more than 0.5% kinematic viscosity increase wherein kinematic viscosity is measured at 40°C using ASTM-D445-12.

Embodiment 16

[0186] The compressor oil of embodiment 1 having a wear scar less than 0.5 mm as determined by ASTM-D4172-94 (2010).

Embodiment 17

[0187] The compressor oil of embodiment 1 having a compatibility and miscibility with mineral oil or synthetic base fluid, such as poly-alpha-olefin (PAO), such that therefore does not cause gelling, phase separation, low temperature fluidity, negative impact on high temperature thermal stability, and negative impact on long term storage stability when mixed with compressor oil formulated using such base fluid and subjected to temperature between -30°C and 200°C.

Embodiment 18

[0188] The compressor oil of any of the preceding enumerated embodiments having a specific heat value of at least 2.3 J/g °K at 50°C, as determined in accordance with ASTM-E1269-12 (Determining Specific Heat Capacity by Differential Scanning Calorimetry) or ASTM-E2716-09 (Determining Specific Heat Capacity by Sinusoidal Modulated Temperature Differential Scanning Calorimetry).

Embodiment 19

[0189] The compressor oil of any of the preceding enumerated embodiments having a thermal conductivity of at least 0.13 W/m °K at 50°C, as determined by ASTM-E1952-11.

Embodiment 20

[0190] The compressor oil of any of the preceding enumerated embodiments wherein the compressor oil exhibits more than 60% biodegradation at 28 days using the OECD 501B.
Embodiment 21

[0191] The compressor oil of any of the preceding enumerated embodiments wherein the compressor oil exhibits at least 70% biodegradation at 28 days using the OECD 301B.

Embodiment 22

[0192] The compressor oil of any of the preceding enumerated embodiments wherein the compressor oil exhibits at least 80% biodegradation at 40 days using the OECD 301B.

Embodiment 23

[0193] A compressor oil having greater than 25% renewable carbon content measured by ASTM-D6866-12 and having the following properties:

[0194] (a) a kinematic viscosity at 40°C in range of 30cSt to 500cSt as measured by ASTM-D445-12 or equivalent method;

[0195] (b) a viscosity index greater than 120;

[0196] (c) an oxidative stability greater than 1000 minutes as measured by ASTM-D2272-11;

[0197] (d) a flash point greater than 180°C as measured by ASTM-D92-12b;

[0198] (e) a pour point less than and equal to −30°C as measured by ASTM-D97-12, and

[0199] (f) air release speed less than 3 minutes as determined by ASTM-D3427-12

[0200] (g) at least one of the following properties:

[0201] (i) a biodegradability of greater than 60% at 28 days as measured by OECD 301B;

[0202] (ii) a wear scar less than 0.5 mm as measured by ASTM-D4172-94(2010);

[0203] (iii) an acidity of water layer after aging procedure no more than 0.5 mg KOH/g as measured by ASTM-D2619-09;

[0204] (iv) a copper panel weight loss during aging procedure no more than 0.05 mg/cm² and surface condition better or equal to ‘Shiny 1B’ rating as determined and measured by ASTM-D2619-09;

[0205] (v) an increase in kinematic viscosity at 40°C less than 0.5% measured by ASTM-D2619-09; and

[0206] (vi) an oil/water separation time less than 16 min and leaves no emulsion layer after test is done as measured by ASTM-D1401-12.

Embodiment 24.

[0207] The compressor oil of embodiment 23 further comprising at least one additive in an amount ranging from about 100 ppm to about 50 wt %, the additive(s) being selected from the group consisting of oxidation inhibitors/anti-oxidants, pour point depressants, metal deactivators/passivators, foam inhibitor/anti-foam agents, friction modifiers/anti-wear agents, viscosity modifiers/viscosity index improvers, non-biobased hydrocarbon base oils, non-hydrocarbon fluids, additive packages, and combinations thereof.

Embodiment 25.

[0208] The compressor oil of embodiment 24 wherein the compressor oil comprises about 100 ppm to about 5 wt % oxidation inhibitor(s)/anti-oxidant(s).

Embodiment 26.

[0209] The compressor oil of embodiment 24 wherein the compressor oil comprises about 100 ppm to about 5 wt % pour point depressant(s).

Embodiment 27.

[0210] The compressor oil of embodiment 24 wherein the compressor oil comprises about 50 ppm to about 2 wt % foam inhibitor(s)/anti-foam agent(s).

Embodiment 28.

[0211] The compressor oil of embodiment 24 wherein the compressor oil comprises about 10 ppm to about 5 wt % metal deactivator(s).

Embodiment 29.

[0212] The compressor oil of embodiment 24 wherein the compressor oil comprises about 10 ppm to about 5 wt % friction modifier(s)/anti-wear agent(s).

Embodiment 30.

[0213] The compressor oil of embodiment 24 wherein the compressor oil comprises about 10 ppm to about 30 wt % viscosity modifier(s)/viscosity index improver(s).

Embodiment 31.

[0214] The compressor oil of embodiment 24 wherein the compressor oil comprises about 10 ppm to about 50 wt % non-biobased hydrocarbon base oil(s).

Embodiment 32.

[0215] The compressor oil of embodiment 24 wherein the compressor oil comprises about 10 ppm to about 50 wt % biobased non-hydrocarbon base oil(s).

Embodiment 33.

[0216] The compressor oil of embodiment 24 wherein the compressor oil comprises about 0.1 wt % to about 20 wt % additive package(s).

Embodiment 34.

[0217] The compressor oil of embodiment 23 wherein air release speed of such compressor oil is less than 2 minutes as determined by ASTM-D3427-12.

Embodiment 35.

[0218] The compressor oil of embodiment 23 wherein oxidative stability of such compressor oil is at least 2,000 minutes as determined by ASTM-D2272-11.

Embodiment 36.

[0219] The compressor oil of embodiment 23 wherein oxidative stability of such compressor oil is at least 3,000 minutes as determined by ASTM-D2272-11.

Embodiment 37.

[0220] The compressor oil having an improved specific heat value of at least 2.3 J/g °C at 50°C as determined by using standardized test methods such as, for example, ASTM-E1269-12 (Determining Specific Heat Capacity by Differential Scanning Calorimetry), ASTM-E2716-09 (De-
determining Specific Heat Capacity by Sinusoidal Modulated Temperature Differential Scanning calorimetry).

Embodiment 38

[0221] A compressor oil comprising a biobased hydrocarbon base oil having an average molecular weight (weight average) between 300 g/mol and 1500 g/mol, and an additive package, the additive package comprising an antioxidant.

Embodiment 39

[0222] A compressor oil comprising a biobased hydrocarbon base oil, the compressor oil having a biodegradable rate in excess of 60% as determined in accordance with OECD 301B.

Embodiment 40

[0223] A compressor oil comprising a biobased base oil having the molecular structure:

\[ B^n \rightarrow (P^m)_s \]

[0224] wherein,

[0225] [B] is biobased hydrocarbon repeating unit;

[0226] [P] is non-biobased hydrocarbon repeating unit;

[0227] n is greater than 1, and m is less than 4;

[0228] the stereoisomeric arrangement of [B] and [P] repeating unit can be linear, branched, and cyclic.

[0229] the sequential arrangement of [B] and [P] can be block, alternating or random; and

[0230] the molecular weight is in range of 300 g/mol to 900 g/mol; and

[0231] the biobased content of the compressor oil is greater than 20%, as measured by ASTM D6866-12.

Embodiment 41

[0232] A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil meets DIN 51506-VDL.

Embodiment 42

[0233] A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN <2 at 1000 hours as determined in accordance with ASTM D943-04a (2010)e1.

Embodiment 43

[0234] A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN <2 at 2000 hours as determined in accordance with ASTM D943-04a (2010)e1.

Embodiment 44

[0235] A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN <2 at 4000 hours as determined in accordance with ASTM D943-04a (2010)e1.

Embodiment 45

[0236] A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN <2 at 8000 hours as determined in accordance with ASTM D943-04a (2010)e1.

Embodiment 46

[0237] A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN <2 at 16000 hours as determined in accordance with ASTM D943-04a (2010)e1.

Embodiment 47

[0238] A compressor oil comprising a biobased hydrocarbon base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a pour point of less than -40°C.

Embodiment 48

[0239] A compressor oil comprising a biobased hydrocarbon base oil, the compressor oil being compatible with and suitable for mixing with a Group I, Group II, or Group III based compressor oil.

Embodiment 49

[0240] A compressor oil having an ISO viscosity grade of 2 to 46,000 and comprising:

[0241] (a) 1 to 95 wt % of a biobased hydrocarbon base oil containing carbon from a renewable source; and

[0242] (b)(i) 5 to 50 wt % of at least first basestock selected from Group I base oils having a viscosity range of from 3 cSt to 500 cSt and combinations thereof, Group II and Group III hydroprefined base oils and combinations thereof, and Group IV PAOs having a viscosity index of about 130 or less and combinations thereof; or

[0243] (b)(ii) 1 to 50 wt % of a second basestock selected from Group V base oils and combinations thereof.

Embodiment 50

[0244] The compressor oil of embodiment 49 wherein the compressor oil has an absence of any additional polymeric thickeners and viscosity index improvers.

Embodiment 51

[0245] The compressor oil according to embodiment 49 or 50, wherein the biobased hydrocarbon base oil is characterized by a viscosity index (VI) greater than 120, as measured in accordance with ASTM D2270-10e1, and a branch ratio of less than 0.41.

Embodiment 52

[0246] The compressor oil according to any of enumerated embodiments 49 to 51, wherein the compressor oil contains about 2 to 25 wt % of the second basestock.
Embodiment 53

[0247] The compressor oil according to any of enumerated embodiments 49 to 52, wherein the second basestock comprises a Group V base-stock selected from alkylated aromatics, poly alkylene glycols, esters, and mixtures thereof.

Embodiment 54

[0248] The compressor oil according to any of enumerated embodiments 49 to 53, wherein the compressor oil comprises 5 to 50 wt % of the first basestock and 1 to 50 wt % of the second basestock.

Embodiment 55

[0249] A compressor oil comprising: (a) a base oil having a weight average molecular weight in the range of 300 to 600 g/mol, a viscosity index greater than 120 and less than 140; and (b) an anti-wear hydraulic oil additive package; wherein the compressor oil has (i) an air release by ASTM D 3427-01 of less than 3 minutes at 50° C., (ii) a Sequence II foam tendency by ASTM D 892-13 of less than 50 ml, and a biocongruence rate of at least 60% as determined by OECD 301B.

Embodiment 56

[0250] The compressor oil of embodiment 55, wherein the base oil comprises carbon from a renewable source.

Embodiment 57

[0251] The compressor oil of embodiment 55 or 56, wherein the base oil additionally has an average degree of branching in the molecules less than about 8 alkyl branches per 100 carbon atoms.

Embodiment 58

[0252] The compressor oil of embodiment 55, 56 or 57, wherein the base oil comprises at least 5 weight percent molecules with monocyclopentadiene functionality.

Embodiment 59

[0253] The compressor oil of any of the preceding enumerated embodiments, wherein the base oil has a T90-T10 boiling range distribution of less than 180° F.

Embodiment 60

[0254] The compressor oil of any of the preceding enumerated embodiments, wherein the average molecular weight of the base oil is between about 500 and about 900 g/mol.

Embodiment 61

[0255] The compressor oil of any of the preceding enumerated embodiments, wherein the base oil has a Bromine Index <200.

Embodiment 62

[0256] The compressor oil of any of the preceding enumerated embodiments, wherein the compressor oil has an air release at 50° C. of less than 2 minutes.

Embodiment 63

[0257] The compressor oil of any of the preceding enumerated embodiments, wherein the compressor oil has an air release at 25° C. of less than 10 minutes.

Embodiment 64

[0258] The compressor oil of any of the preceding enumerated embodiments, wherein the base oil has an aniline point between 212 and 300° F.

Embodiment 65

[0259] The compressor oil of any of the preceding enumerated embodiments, wherein the compressor oil has a Sequence I foam tendency as determined in accordance with ASTM D892-13 of less than 50 ml.

Embodiment 66

[0260] The compressor oil of any of the preceding enumerated embodiments, wherein the compressor oil has a Sequence II foam tendency as determined in accordance with ASTM D 892-13 of less than 30 ml.

Embodiment 67

[0261] The compressor oil of any of the preceding enumerated embodiments, wherein the compressor oil has a number of minutes to 3 ml emulsion at 54° C. as determined in accordance with ASTM D1401-12 of less than 30.

Embodiment 68

[0262] The compressor oil of any of the preceding enumerated embodiments, wherein the base oil has alkyl branches positioned over various branch carbon resonances as determined in accordance by carbon ~13 NMR.

Embodiment 69

[0263] The compressor oil of any of enumerated embodiments 1 to 30 wherein the compressor oil has a biodegradable rate in excess of 60% according to by OECD 301B.

Embodiment 70

[0264] The compressor oil of any of enumerated embodiments 1 to 69 wherein the compressor oil comprises about 0.2 to about 2 wt % of an additive package.

Embodiment 71

[0265] The compressor oil of any of enumerated embodiments 1 to 33 wherein the compressor oil comprises about 50 wt % to about 99 wt % biobased hydrocarbon base oil and from about 0.2 to about 2 wt % additive package.

Embodiment 72

[0266] The compressor oil of embodiment 70 or 71 wherein the additive package comprises at least one additive selected from the group consisting of anti-oxidants, anti-wear agents, extreme pressure agents, defoamants, detergent/dispersant, rust and corrosion inhibitors, and demulsifiers.
 embodiments and illustrations contained herein. The disclosure includes modified forms of the described embodiments, including portions of the embodiments and combinations of elements of different embodiments. These and other embodiments are within the scope of the following claims.

What is claimed is:

1. A compressor oil comprising a biobased hydrocarbon base oil, wherein the biobased hydrocarbon base oil has renewable carbon content greater than 40 wt % as measured by ASTM-D6866-12, and at least one antioxidant wherein the oxidative stability of the compressor oil is at least 1,000 minutes as determined by ASTM-D2272-11.

2. The compressor oil of claim 1 wherein the hydrocarbon base oil comprises a biobased terpene selected from the group consisting of myrcene, ocimene, farnesene, and combinations thereof.

3. The compressor oil of claim 1 or 2 wherein the biobased hydrocarbon base oil constitutes about 25 wt % to about 99.999 wt % of the compressor oil.

4. The compressor oil of claim 3 wherein the additive is selected from the group consisting of antioxidants, corrosion and rust inhibitors, viscosity modifiers, pour point depressants, metal deactivators, anti-foaming agents, friction modifiers, extreme pressure additives, anti-wear agents, additive oils and combinations thereof.

5. The compressor oil of claim 4 wherein the additive is an additive oil selected from the group consisting of microbial oils, vegetable oils, seed oils, mineral oils, isoparaflinic hydrocarbon fluids, silicone fluids, synthetic esters, polyalpha-olefins, polyisoxanes, pentaerythritol esters, poly (butane) liquids, and combinations thereof.

6. The compressor oil of claim 1 wherein air release speed of such compressor oil is less than 3 minutes as determined by ASTM-D3427-12.

7. The compressor oil of claim 1 wherein air release speed of such compressor oil is less than 2 minutes as determined by ASTM-D3427-12.

8. The compressor oil of any preceding claim wherein the oxidative stability of the compressor oil is at least 2,000 minutes as determined by ASTM-D2272-11.

9. The compressor oil of any preceding claim wherein the oxidative stability of the compressor oil is at least 3,000 minutes as determined by ASTM-D2272-11.

10. The compressor oil of any preceding claim wherein the compressor oil has an oil/water separation time of less than 16 min and it leaves no emulsion layer upon completion of the test, as determined in accordance with ASTM-D1401-12.

11. The compressor oil of claim 1 having a hydrolytic stability as measured by ASTM-D2619-09 with acidity of water layer after aging procedure no more than 2.5 mg KOH/g.

12. The compressor oil of claim 1 having a hydrolytic stability as measured by ASTM-D2619-09 with acidity of water layer after aging procedure no more than 1.0 mg KOH/g.

13. The compressor oil of claim 1 having a hydrolytic stability as measured by ASTM-D2619-09 with acidity of water layer after aging procedure no more than 0.5 mg KOH/g.

14. The compressor oil of claim 1 having a hydrolytic stability as measured by ASTM-D2619-09 with copper panel weight loss no more than 0.05 mg/cm².
15. The compressor oil with biobased base oil of claim 1 having a improved hydrolytic stability as measured by ASTM-D2619-09 with no more than 0.5% kinematic viscosity increase wherein kinematic viscosity is measured at 40°C using ASTM-D445-12.

16. The compressor oil of claim 1 having a wear scar less than 0.5 mm as determined by ASTM-D4172-94(2010).

17. The compressor oil of claim 1 having a compatibility and miscibility with mineral oil or synthetic base fluid, such as poly-alpha-olefin (PAO), such that therefore does not cause gelling, phase separation, low temperature fluidity, negative impact on high temperature thermal stability, and negative impact on long term storage stability when mixed with compressor oil formulated using such base fluid and subjected to temperature between ~30°C. and 200°C.

18. The compressor oil of any preceding claim having a specific heat value of at least 2.3 J/g °C at 50°C. as determined in accordance with ASTM-E1269-12 (Determining Specific Heat Capacity by Differential Scanning Calorimetry) or ASTM-E2716-09 (Determining Specific Heat Capacity by Sinusoidal Modulated Temperature Differential Scanning Calorimetry).

19. The compressor oil of any preceding claim having a thermal conductivity of at least 0.13 W/m °C at 50°C as determined by ASTM-E1952-11.

20. The compressor oil of any preceding claim wherein the compressor oil exhibits more than 60% biodegradation at 28 days using the OECD 301B.

21. The compressor oil of any preceding claim wherein the compressor oil exhibits at least 70% biodegradation at 28 days using the OECD 301B.

22. The compressor oil of any preceding claim wherein the compressor oil exhibits at least 80% biodegradation at 40 days using the OECD 301B.

23. A compressor oil having greater than 25% renewable carbon content measured by ASTM-D6866-12 and having the following properties:

(a) a kinematic viscosity at 40°C. in range of 30cSt to 500cSt as measured by ASTM-D445-12 or equivalent method;

(b) a viscosity index greater than 120;

(c) an oxidative stability greater than 1000 minutes as measured by ASTM-D2272-11;

(d) a flash point greater than 180°C. as measured by ASTM-D92-12b;

(e) a pour point less than and equal to ~30°C. as measured by ASTM-D97-12, and

(f) air release speed less than 3 minutes as determined by ASTM-D3427-12

(g) at least one of the following properties:

(i) a biodegradability of greater than 60% at 28 days as measured by OECD 301B;

(ii) a wear scar less than 0.5 mm as measured by ASTM-D4172-94(2010);

(iii) an acidity of water layer after aging procedure no more than 0.5 mg KOH/g as measured by ASTM-D2619-09;

(iv) a copper panel weight loss during aging procedure no more than 0.05 mg/cm² and surface condition better or equal to 'Shiny 10' rating as determined and measured by ASTM-D2619-09;

(v) an increase in kinematic viscosity at 40°C. less than 0.5% measured by ASTM-D2619-09; and

(vi) an oil/water separation time less than 16 min and leaves no emulsion layer after test is done as measured by ASTM-D1401-12.

24. The compressor oil of claim 23 further comprising at least one additive in an amount ranging from about 100 ppm to about 50 wt %, the additive(s) being selected from the group consisting of oxidation inhibitors/anti-oxidants, pour point depressants, metal deactivators/passivators, foam inhibitor/anti-foaming agents, friction modifiers/anti-wear agents, viscosity modifiers/viscosity index improvers, non-biobased hydrocarbon base oils, non-hydrocarbon fluids, additive packages, and combinations thereof.

25. The compressor oil of claim 24 wherein the compressor oil comprises about 100 ppm to about 5 wt % oxidation inhibitor(s)/anti-oxidant(s).

26. The compressor oil of claim 24 wherein the compressor oil comprises about 100 ppm to about 5 wt % pour point depressant(s).

27. The compressor oil of claim 24 wherein the compressor oil comprises about 50 ppm to about 2 wt % foam inhibitor(s)/anti-foam agent(s).

28. The compressor oil of claim 24 wherein the compressor oil comprises about 10 ppm to about 5 wt % metal deactivator(s).

29. The compressor oil of claim 24 wherein the compressor oil comprises about 10 ppm to about 5 wt % friction modifier(s)/anti-wear agent(s).

30. The compressor oil of claim 24 wherein the compressor oil comprises about 10 ppm to about 30 wt % viscosity modifier(s)/viscosity index improver(s).

31. The compressor oil of claim 24 wherein the compressor oil comprises about 10 ppm to about 30 wt % viscosity modifier(s)/viscosity index improver(s).

32. The compressor oil of claim 24 wherein the compressor oil comprises about 10 ppm to about 50 wt % non-biobased hydrocarbon base oil(s).

33. The compressor oil of claim 24 wherein the compressor oil comprises about 0.1 wt % to about 20 wt % additive package(s).

34. The compressor oil of claim 23 wherein air release speed of such compressor oil is less than 2 minutes as determined by ASTM-D3427-12.

35. The compressor oil of claim 23 wherein oxidative stability of such compressor oil is at least 2,000 minutes as determined by ASTM-D2272-11.

36. The compressor oil of claim 23 wherein oxidative stability of such compressor oil is at least 3,000 minutes as determined by ASTM-D2272-11.

37. The compressor oil having an improved specific heat value of at least 2.3 J/g °C at 50°C. as determined by using standardized test methods such as, for example, ASTM-E1269-12 (Determining Specific Heat Capacity by Differential Scanning Calorimetry), ASTM-E2716-09 (Determining Specific Heat Capacity by Sinusoidal Modulated Temperature Differential Scanning Calorimetry).

38. A compressor oil comprising a biobased hydrocarbon base oil having an average molecular weight (weight average) between 300 g/mol and 1500 g/mol, and an additive package, the additive package comprising an anti-oxidant.

39. A compressor oil comprising a biobased hydrocarbon base oil, the compressor oil having a biodegradable rate in excess of 60% as determined in accordance with OECD 301B.
40. A compressor oil comprising a biobased base oil having the molecular structure:

\[ [B]_n - [P]_m \]

wherein,

[B] is biobased hydrocarbon repeating unit;

[P] is non-biobased hydrocarbon repeating unit;

\( n \) is greater than 1, and \( m \) is less than 4;

the stereospecific arrangement of [B] and [P] repeating unit can be linear, branched, and cyclic;

the sequential arrangement of [B] and [P] can be block, alternating or random; and

the molecular weight is in range of 300 g/mol to 900 g/mol; and

the biobased content of the compressor oil is greater than 20%, as measured by ASTM D6866-12.

41. A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil meets DIN 51506-VDL.

42. A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN < 2 at 1000 hours as determined in accordance with ASTM D 943-04a (2010)e1.

43. A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN < 2 at 2000 hours as determined in accordance with ASTM D 943-04a (2010)e1.

44. A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN < 2 at 4000 hours as determined in accordance with ASTM D 943-04a (2010)e1.

45. A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN < 2 at 8000 hours as determined in accordance with ASTM D 943-04a (2010)e1.

46. A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN < 2 at 16000 hours as determined in accordance with ASTM D 943-04a (2010)e1.

47. A compressor oil comprising a biobased base oil, wherein at least about 20% of the carbon atoms in the biobased base oil originate from renewable carbon sources and the compressor oil has a TAN < 2 at 40000 hours as determined in accordance with ASTM D 943-04a (2010)e1.

48. A compressor oil comprising a biobased base oil, wherein at least 20% of the carbon atoms in the biobased base oil contain carbon from a renewable source; and

49. A compressor oil having an ISO viscosity grade of 2 to 46,000 and comprising:

(a) 1 to 95 wt % of a biobased hydrocarbon base oil containing carbon from a renewable source; and

(b)(i) 5 to 50 wt % of at least a first basestock selected from Group I base oils having a viscosity range of from 3 cSt to 500 cSt and combinations thereof, Group II and Group III hydroprocessed base oils and combinations thereof, and Group IV PAOs having a viscosity index of about 130 or less and combinations thereof; or

(b)(ii) 1 to 50 wt % of a second basestock selected from Group V base oils and combinations thereof.

50. The compressor oil of claim 49 wherein the compressor oil has an absence of any additional polymeric thickeners and viscosity index improvers.

51. The compressor oil according to claim 49 or 50, wherein the biobased hydrocarbon base oil is characterized by a viscosity index (VI) greater than 120, as measured in accordance with ASTM D2270-10e1, and a branch ratio of less than 0.41.

52. The compressor oil according to any of claims 49 to 51, wherein the compressor oil contains about 2 to 25 wt % of the second basestock.

53. The compressor oil according to any of claims 49 to 52, wherein the second basestock comprises a Group V base-stock selected from alkylated aromatics, polyalkylene glycols, esters, and mixtures thereof.

54. The compressor oil according to any of claims 49 to 53, wherein the compressor oil comprises 5 to 50 wt % of the first basestock and 1 to 50 wt % of the second basestock.

55. A compressor oil comprising: (a) a base oil having a weight average molecular weight in the range of 300 to 600 g/mol, a viscosity index greater than 120 and less than 140; and (b) an anti-wear hydraulic oil additive package; wherein the compressor oil has (i) an air release by ASTM D 3427-01 of less than 3 minutes at 50° C., (ii) a Sequence II foam tendency by ASTM D 892-13 of less than 50 ml, and a biodegradability rate of at least 60% as determined by OECD 301B.

56. The compressor oil of claim 55, wherein the base oil comprises carbon from a renewable source.

57. The compressor oil of claim 55 or 56, wherein the base oil additionally has an average degree of branching in the molecules less than about 8 alkyl branches per 100 carbon atoms.

58. The compressor oil of claim 55, 56 or 57, wherein the base oil comprises at least 5 weight percent molecules with monocyclopentadiene functionality.

59. The compressor oil of any preceding claim, wherein the base oil has a T90-110 boiling range distribution of less than 180° F.

60. The compressor oil of any preceding claim, wherein the average molecular weight of the base oil is between about 500 and about 900 g/mol.

61. The compressor oil of any of any preceding claim, wherein the base oil has a Bromine Index <200.

62. The compressor oil of any of any preceding claim, wherein the compressor oil has an air release at 50° C. of less than 2 minutes.

63. The compressor oil of any preceding claim, wherein the compressor oil has an air release at 25° C. of less than 10 minutes.

64. The compressor oil of any preceding claim, wherein the base oil has an aniline point between 212 and 300° F.

65. The compressor oil of any preceding claim, wherein the compressor oil has a Sequence I foam tendency as determined in accordance with ASTM D 892-13 of less than 50 ml.

66. The compressor oil of any preceding claim, wherein the compressor oil has a Sequence II foam tendency as determined in accordance with ASTM D 892-13 of less than 50 ml.
67. The compressor oil of any preceding claim, wherein the compressor oil has a number of minutes to 3 ml emulsion at 54°C as determined in accordance with ASTM D1401-12 of less than 30.
68. The compressor oil of any preceding claim, wherein the base oil has alkyl branches positioned over various branch carbon resonances as determined in accordance by carbon –13 NMR.
69. The compressor oil of any of claims 1 to 30 wherein the compressor oil has a biodegradable rate in excess of 60% according to to OECD 301B.
70. The compressor oil of any of claims 1 to 69 wherein the compressor oil comprises about 0.2 to about 2 wt % of an additive package.
71. The compressor oil of any of claims 1 to 33 wherein the compressor oil comprises about 50 wt % to about 99 wt % biobased hydrocarbon base oil and from about 0.2 to about 2 wt % additive package.
72. The compressor oil of claim 70 or 71 wherein the additive package comprises at least one additive selected from the group consisting of anti-oxidants, anti-wear agents, extreme pressure agents, defoamants, detergent/dispersant, rust and corrosion inhibitors, and demulsifiers.
73. The compressor oil of claim 72 wherein the additive package comprises an anti-wear additive selected from the group consisting of ashless, zinc-free, and zinc-containing anti-wear additives, and combinations thereof.
74. The compressor oil of any preceding claim, wherein the additive package is an ashless additive package.
75. The compressor oil of any of claims 1 to 73 wherein the compressor oil comprises less than 0.11 wt. % sulfated ash derived from the additive package.
76. The compressor oil of any preceding claim, wherein the compressor oil contains between about 0.1 wt % and about 1 wt % of a phenolic anti-oxidant.
77. The compressor oil of any preceding claim, wherein the compressor oil contains an anti-wear additive.
78. The compressor oil of claim 77 wherein the anti-wear additive contains an amine phosphate anti-wear additive and the compressor oil further comprises up to about 1 wt % of the anti-wear additive(s).
79. The compressor oil of any preceding claim, wherein the compressor oil contains a viscosity index improver.
80. The compressor oil of claim 79 wherein the compressor oil contains at least 1 wt % of the viscosity index improver.
81. A compressor lubricated by a compressor oil according to any of the preceding claims.
82. A method of improving efficiency of operation of compressor, compressed gas, and compressed air system using compressor oil according to any of the preceding claims.
83. A method of recycling used compressor oil, the method comprising recycling a compressor oil according to any of the preceding claims.

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