

**CYCLOALKANE BASE OILS, CYCLOALKANE-BASE DIELECTRIC LIQUIDS
MADE USING CYCLOALKANE BASE OILS, AND METHODS OF MAKING SAME**

The application relates to "cycloalkane" base oil(s), to
5 cycloalkane-base dielectric liquid(s) made using the
cycloalkane base oil(s), to methods of making the cycloalkane
base oil(s) and to the cycloalkane-base dielectric liquid(s).

Dielectric liquids typically are manufactured from a gas
oil fraction derived at atmospheric pressure from naphthenic
10 crudes. Dielectric liquids manufactured using other
feedstocks are desirable.

The present application provides cycloalkane base oil
comprising a quantity of isoparaffins and from 50 wt.% to 70
wt.% cycloalkanes having the formula C_nH_{2n} wherein n is from
15 15 to 30, said quantity of isoparaffins being less than 50
wt.% of said cycloalkane base oil (as measured by mass
spectroscopy).

The application also provides a cycloalkane-base
dielectric liquid comprising:

20 cycloalkane base oil comprising a quantity of
isoparaffins and from 50 wt.% to 70 wt.%
cycloalkanes having the formula C_nH_{2n} wherein n is
from 15 to 30, said quantity of isoparaffins being
less than 50 wt.% of said cycloalkane base oil (as
25 measured by mass spectroscopy); and,
one or more antigassing agent selected from the group
consisting of non-phenolic alkyl substituted or
partially saturated aromatic compounds comprising
at least one labile hydrogen atom and diaryls, said
30 quantity being effective to reduce the gassing
tendency of the dielectric liquid.

The application provides a method for making a
cycloalkane base oil comprising:

refining crude under refining conditions effective to
produce aromatic vacuum gas oil boiling at a
temperature in the range of from about 371 °C to
about 538 °C, the aromatic vacuum gas oil
5 comprising carbonaceous materials, a majority of
the carbonaceous materials being selected from the
group consisting of cycloalkanes and aromatics;
contacting the aromatic vacuum gas oil with
hydrocracking catalyst under hydrocracking
10 conditions effective to produce hydrocracking
product;
subjecting hydrocracking product to stripping conditions
effective to increase the content of cyclic
hydrocarbons selected from the group consisting of
15 cycloalkanes, cycloalkenes, and combinations
thereof and removing hydrogen sulfide and ammonia
and producing stripped hydrocracking product;
contacting stripped hydrocracking product with
isomerization/dewaxing/hydrogenation (IDH) catalyst
20 comprising a metal selected from the group
consisting of platinum, palladium, and combinations
thereof, under IDH conditions effective to
saturate aromatics to cycloalkanes, reduce normal
paraffins, and to produce IDH product comprising
25 greater than 50 wt.% of one or more cyclic
hydrocarbons selected from the group consisting of
cycloalkanes and cycloalkenes;
without solvent extracting, contacting IDH product with
hydrotreating catalyst under hydrotreating
30 conditions effective to produce hydrotreated
product comprising greater than 50 wt.%
cycloalkanes (as measured by mass spectroscopy);
and,

separating from said hydrotreated product cycloalkane
base oil comprising less than 50 wt.% isoparaffins
and 50 wt.% or more cycloalkanes (as measured by
mass spectroscopy), said cycloalkane base oil
5 boiling at a temperature in the range of from about
260 °C to about 371 °C.

A method for making a cycloalkane base dielectric liquid
comprising:

processing aromatic vacuum gas oil and recovering
10 cycloalkane base oil comprising a quantity of
isoparaffins and from 50 wt.% to 70 wt.%
cycloalkanes having the formula C_nH_{2n} wherein n is
from 15 to 30, said quantity of isoparaffins being
less than 50 wt.% of said cycloalkane base oil (as
15 measured by mass spectroscopy); and,
adding to said cycloalkane base oil one or more agent
selected from the group consisting of an amount of
antigassing agent effective to reduce gassing
tendency of the cycloalkane base oil and a quantity
20 of one or more antioxidant effective to reduce
sludge formation and total acid number in mg of
KOH/g (TAN) under oxidation conditions.

The present application provides cycloalkane base oil(s)
for producing cycloalkane-base dielectric liquid(s).

25 A "cycloalkane base oil" is produced from an aromatic
base oil feedstock, preferably an "aromatic vacuum gas oil"
produced from the refining of crude oil. Substantially any
crude oil may be used as the source of the aromatic vacuum
gas oil. Suitable crudes include, but are not necessarily
30 limited to: Arabian Light, Arabian Medium, Arab Heavy,
Orienta, Kuwati, Isthmus, Maya, Oman, Brent, and combinations
thereof.

A majority of the carbonaceous materials in suitable "aromatic vacuum gas oils" are selected from the group consisting of cycloalkanes and aromatics. Aromatic vacuum gas oil generally comprises the following distribution of carbonaceous materials, in descending order of concentration: aromatics >cycloalkanes >isoparaffins >normal paraffins.

Suitable aromatic vacuum gas oils boil at a temperature in the range of from about 260 °C (500 °F) to about 538°C (1000 °F), preferably from about 371 °C (700 °F) to about 538°C (1000 °F). The aromatic content of suitable aromatic vacuum gas oils is from about 40 wt.% to about 60 wt.% (as measured by mass spectroscopy). In preferred embodiments, the aromatic content of the aromatic vacuum gas oils is from about 50 to about 60 wt.%, more preferably from about 55 wt.% to about 60 wt.% (as measured by mass spectroscopy).

Aromatic vacuum gas oils also typically comprise from about 20 wt.% to about 30 wt.% cycloalkanes, from about 10 wt.% to about 15 wt.% isoparaffins, from about 5 wt.% to about 15 wt.% normal paraffins (as measured by mass spectroscopy).

The aromatic vacuum gas oils also may be mixed with other base oil feedstocks, including, but not necessarily limited to solvent extracted raffinates, soft wax, slack wax, lube boiling range product from a Fischer-Tropsch conversion of gas-to-liquids, and combinations thereof.

In order to produce cycloalkane base oil, aromatic vacuum gas oil is subjected to hydroprocessing conditions. In a preferred embodiment, the hydroprocessing conditions comprise: contacting the aromatic vacuum gas oil with hydrocracking catalyst under hydrocracking conditions effective to produce hydrocracking product; subjecting the hydrocracking product to stripping conditions effective to remove hydrogen sulfide and any ammonia and to produce stripped hydrocracking product; contacting the stripped

hydrocracking product with isomerization/dewaxing/
hydrogenation ("IDH") catalyst under conditions effective to
saturate aromatics to produce cycloalkanes and to reduce
normal paraffins to produce an IDH product comprising
5 carbonaceous molecules, a majority of the carbonaceous
molecules comprising one or more cyclic hydrocarbons selected
from the group consisting of cycloalkanes and cycloalkenes;
contacting IDH product with hydrotreating catalyst under
hydrotreating conditions effective to produce hydrotreated
10 product comprising greater than 50 wt.% cycloalkanes (as
measured by mass spectroscopy); and subjecting the
hydrotreated product to separation conditions effective to
separate a cycloalkane base oil comprising a fraction boiling
at a temperature of from about 260 °C to about 371°C.

15 The cycloalkane base oil may be analyzed for content by
a number of methods, a preferred method being mass
spectroscopy. A preferred method of mass spectroscopy uses
the AutospecQ, a MICROMASS® high resolution magnetic sector
mass spectrometer, commercially available from Waters
20 Corporation, Milford, Massachusetts. In this embodiment,
the ionization mode is Field Ionization Mass Spectrometry
(FIMS), which produces primarily molecular ions with little
or no fragmentation for the various hydrocarbon types
associated with the oils. FIMS data is processed using
25 Poly32, a PC based software package which processes mass
spectral list files in order to generate size exclusion
chromatography (SEC) type data and other computations. Poly
32 is commercially available from Sierra Analytics, Modesto,
California. The SEC data includes molecular weight moments
30 and polydispersity calculations. They are calculated from M,
mass in Daltons, and n, number of moles over the mass range
of interest. The software also will calculate percentages of
oligomer series defined by mass and repeating or monomer

units such as CH₂ groups. In the case of hydrocarbon analysis, a table is generated with percentages of each carbon number and each Z series (where Z is defined by the generalized formula for hydrocarbons C_nH_{2n+Z}). Z series
5 descriptors for saturates are based on the assumption that the oils contain insignificant amounts of aromatics. Therefore, trace aromatics and contaminants are removed by column chromatography (ASTM D 2549) prior to analysis by FIMS.

10 **Hydrocracking Conditions**

In order to produce the cycloalkane base oil, the aromatic vacuum gas oil is subjected to hydrocracking conditions generally comprising hydrocracking catalyst. Substantially any hydrocracking catalyst effective to
15 increase the rate of desired hydrocracking is suitable. The hydrocracking catalyst generally comprises a suitable hydrocracking metal on a carrier.

Suitable hydrocracking metals include, but are not necessarily limited to sulfided catalysts comprising one or
20 more metals selected from the group consisting of cobalt, chromium, molybdenum, tungsten, magnesium, rhenium, iron, ruthenium, iridium, nickel, palladium, platinum, and combinations thereof. In one embodiment, the hydrocracking metal is one or more metal selected from the group consisting
25 of Ni/W, Ni/Mo, and Co/Mo. In a more preferred embodiment, the hydrocracking metal is one or more metal selected from the group consisting of Ni/W and Co/Mo.

The hydrocracking catalyst comprises substantially any carrier which provides sufficient surface area and does not
30 interfere with hydrocracking. Examples of suitable carriers include, but are not necessarily limited to metal oxides and molecular sieves. In one embodiment, the carrier is selected

from the group consisting of alumina and crystalline aluminosilicates.

Suitable hydrocracking conditions comprise:

hydrocracking temperatures of from about 200 °C. and about
5 450 °C.; hydrocracking hydrogen gas pressures of greater than
atmospheric, preferably about 30 atmospheres or more;
hydrocracking hydrogen circulation rates of from about 400
SCF/B (standard cubic feet per barrel) to about 15,000 SCF/B;
and hydrocracking liquid hourly space velocities of from
10 about 0.1 hr⁻¹ to about 20 hr⁻¹. Generally, the hydrocracking
conditions are effective to convert polynuclear aromatics in
the heavy aromatic gas oil into smaller partially
hydrogenated aromatic and hydrogenated species, to convert
some normal paraffins to isoparaffins and to convert sulfur
15 and nitrogen present in the heavy aromatic gas oil to
hydrogen sulfide and ammonia.

Stripping Conditions

The hydrocracking product is subjected to stripping
conditions effective to remove hydrogen sulfide and ammonia
20 and to produce a stripped hydrocracking product. Suitable
stripping conditions comprise a temperature of from about 200
°C to about 300 °C and an effective stripping pressure,
preferably greater than atmospheric pressure. In a more
preferred embodiment, the stripping pressure is substantially
25 the same as the hydrocracking pressure, most preferably about
30 atm or greater. Preferably, stripping gas is hydrogen
essentially free of hydrogen sulfide and ammonia.

Isomerization/Dewaxing/Hydrogenation (IDH) Conditions

The stripped hydrocracking product is subjected to
30 hydroprocessing conditions, preferably isomerization/
dewaxing/hydrogenation ("IDH") conditions, effective to
increase the content of hydrogenated and partially
hydrogenated cyclic hydrocarbons selected from the group

consisting of cycloalkanes, cycloalkenes, and combinations thereof. The hydroprocessing conditions, preferably IDH conditions, also typically increase the content of isoparaffins by isomerizing normal and near normal paraffins to isoparaffins. In a preferred embodiment, the hydroprocessing conditions are effective to produce about 20 wt.% or more isoparaffins, more preferably from about 20 wt.% to less than 50 wt.% isoparaffins, most preferably from about 20 wt.% to about 40 wt.% isoparaffins (as measured by mass spectroscopy).

The IDH conditions generally comprise contacting the stripped hydrocracking product with one or more IDH catalyst at an IDH temperature, an IDH pressure, and an IDH hydrogen flowrate effective to increase the content of cyclic hydrocarbons selected from the group consisting of cycloalkanes, cycloalkenes, and combinations thereof. The IDH conditions also generally are effective to increase the content of isoparaffins.

Suitable IDH catalysts comprise one or more IDH metal, including but not necessarily limited to cobalt, chromium, molybdenum, tungsten, magnesium, rhenium, iron, ruthenium, iridium, nickel, palladium, platinum, and combinations thereof. Preferred IDH metal(s) include, but are not necessarily limited to platinum, palladium, and combinations thereof.

The IDH metal generally is disposed on a suitable IDH metal carrier. Suitable IDH metal carriers include, but are not necessarily limited to molecular sieves and metal oxides. Suitable molecular sieves include, but are not necessarily limited to zeolites and silicoaluminophosphate molecular sieves. Suitable metal oxides include, but are not necessarily limited to alumina. A preferred IDH metal carrier comprises silicoaluminophosphate molecular sieves.

Suitable zeolites are intermediate pore size zeolites. Preferred intermediate pore size zeolites have a pore diameter of from about 0.35 to about 0.8 nm. Specific examples of suitable zeolites include, but are not

5 necessarily limited to zeolite Y, zeolite beta, zeolite theta, mordenite, ZSM-3, ZSM-4, ZSM-5, ZSM-11, ZSM-12, ZSM-18, ZSM-20, ZSM-22, ZSM-23, ZSM-35, ZSM-38, ZSM-48, SSZ-32, offretite, ferrierite, zeolite alpha, and mixtures thereof. Because of their isomerization selectivities, preferred
10 zeolites include, but are not necessarily limited to ZSM -12, ZSM-23, ZSM-22, SSZ-32, and combinations thereof.

Suitable silicoaluminophosphate molecular sieves include, but are not necessarily limited to SAPO-11, SAPO-31, SAPO-41, and combinations thereof. A preferred
15 silicoaluminophosphate molecular sieve is SAPO-11. See also the following U.S. Patents, which are hereby incorporated by reference: 6,090,989; 4,500,417; 4,906,350; 4,943,672; 5,059,299; 5,135,63; 5,282,958, 5,306,860, 5,362,378; and European Patent No. 0 776 959 A2.

20 Suitable IDH conditions comprise: IDH temperatures of from about 250 °C to about 390 °C; IDH gas pressures greater than atmospheric, preferably substantially the same as the hydrocracking pressure, which is preferably about 30 atm or more; IDH hydrogen circulation rates of from about 400 to
25 about 15,000 SCF/B; and, IDH liquid hourly space velocities of from about 0.1 hr.⁻¹ to about 20 hr.⁻¹.

Hydrotreating

In a preferred embodiment, the hydroprocessing product is hydrotreated. Hydrotreating comprises contacting the IDH
30 product with hydrotreating catalyst under hydrotreating conditions effective to convert unsaturated bonds and remaining aromatics, in particular multi-ring aromatics, in

the IDH product into saturated bonds and cycloalkanes, respectively.

Suitable hydrotreating conditions comprise: hydrotreating temperatures of from about 190 °C to about 340 °C; hydrotreating pressures greater than atmospheric, preferably substantially the same as the hydrocracking and IDH pressure, which preferably is about 30 atm or more; hydrogen circulation rates of from about 400 to about 15,000 SCF/B.

Suitable hydrotreating catalyst comprises hydrotreating metal effective to increase the rate of hydrogenation of unsaturated bonds and aromatics in the IDH product. Suitable hydrotreating metal(s) include but are not necessarily limited to cobalt, chromium, molybdenum, tungsten, magnesium, rhenium, iron, ruthenium, iridium, nickel, palladium, platinum, and combinations thereof. Preferred hydrotreating metals are selected from the group consisting of Ni, Pt, Pd, and combinations thereof.

The hydrotreating metal generally is on a suitable support which has sufficient surface area and does not interfere with the hydrotreating process. Suitable hydrotreating catalyst supports include, but are not necessarily limited to metal oxides and molecular sieves. Preferred hydrotreating catalyst supports comprise dispersed zeolite effective to increase saturation of remaining aromatic molecules.

Recovery of cycloalkane base oil

The resulting hydrotreated product boils at a temperature in the range of from about 38 °C (100 °F) to about 538 °C (1000 °F). The hydrotreated product is subjected to separation conditions effective to separate cycloalkane base oil, preferably cycloalkane base oil boiling at a temperature in the range of from about 260 °C to about 371°C.

Any suitable separation conditions may be used as long as they are effective to separate cycloalkane base oil boiling at a temperature in the range of from about 260 °C to about 371°C from the portion of the hydrotreated product (a)

- 5 boiling at a temperature greater than 700 °F (371 °C), and
(b) boiling at a temperature less than 500 °F (260 °C).

In a preferred embodiment, the hydrotreated product is subjected to fractionation conditions comprising removing hydrotreated product boiling at a temperature of greater than
10 371 °C (700 °F) as a bottoms, and removing hydrotreated product boiling at a temperature of less than 260 °C (500 °F) as an overhead.

A majority of carbonaceous molecules in the cycloalkane base oil comprise cycloalkanes, preferably alkyl-substituted
15 cycloalkanes. Preferably, the cycloalkane base oil comprises a content of cycloalkanes, preferably alkyl-substituted cycloalkanes, of 50 wt.% or more, more preferably about 60 wt.% or more, even more preferably about 66 wt.% or more, as measured by mass spectroscopy.

20 Cycloalkanes generally have the formula C_nH_{2n} where n is the total number of carbon atoms. In a preferred embodiment, the base oil comprises cycloalkanes wherein n is from about 15 to about 30.

In a preferred embodiment, a majority of the
25 cycloalkanes comprise alkyl-substituted cycloalkanes. Preferably, about 70 wt.% or more, more preferably about 80 wt.% or more, even more preferably about 90 wt.% or more, and most preferably about 99 wt.% or more of the cycloalkanes comprise alkyl-substituted cycloalkanes, as measured by mass
30 spectroscopy.

The cycloalkane base oil comprises less than 50 wt.% isoparaffins, preferably from about 20 wt.% to less than 50 wt.% isoparaffins, more preferably from about 20 wt.% to

about 40 wt.% isoparaffins, as measured by mass spectroscopy. The cycloalkane base oil also preferably comprises about 15 ppm sulfur or less, according to Test Method D1274 (incorporated herein by reference).

5 **Production of cycloalkane-base dielectric liquid(s)**

The cycloalkane base oil of the present application has a variety of uses, including but not necessarily limited to use as a base oil in cycloalkane-base dielectric liquids. In a preferred embodiment, the cycloalkane base oil is used to
10 produce cycloalkane-base dielectric liquids meeting the requirements of ASTM D 3487 ("Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus," incorporated herein by reference). Most preferably the cycloalkane base oil is used to produce dielectric liquids
15 suitable for use as transformer oil.

Many types of conventional electrical equipment contain a dielectric fluid for dissipating the heat generated by energized components, and for insulating those components from the equipment enclosure and from other internal parts
20 and devices. Examples of such equipment include, but are not necessarily limited to transformers, capacitors, switches, regulators, circuit breakers, cables, reclosers, and x-ray equipment.

A transformer transfers electric power from one circuit
25 to another electromagnetically. Transformers are used in the transmission of electrical power.

Larger transformers generally require insulation of coils and/or conductors in order to protect the transformer at normal operating voltages, during temperature
30 overvoltages, and also during transient overvoltages, which may result from lightning strikes or switching operations. When insulation fails, an internal fault or short circuit may occur. Such occurrences could cause the equipment to fail,

typically leading to system outages and possibly endangering persons in the vicinity of the equipment.

In order to effectively transfer heat away from a transformer core and coil assembly and to maintain an acceptable operating temperature, conventional transformers use relatively large volumes of dielectric fluid as insulation.

In the past, dielectric liquids made from paraffinic oils tended to have inherently poor low temperature viscometric properties and generally did not exhibit low gassing performance, as required by ASTM D 3487.

The gassing tendency of the cycloalkane-base dielectric liquid is a measure of the rate of absorption or desorption of hydrogen into or out of the dielectric liquid under prescribed laboratory conditions. Low gassing performance is important because, if hydrogen is evolved due to electrical stress, a liquid having low gassing tendency tends to absorb the evolved hydrogen and thereby reduce the chances of an explosion.

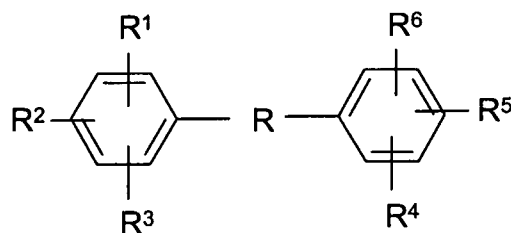
The cycloalkane-base dielectric liquids of the present application exhibit both low temperature viscometric properties and low gassing tendency.

Gassing tendency is reduced by adding one or more anti-gassing agent(s). Preferably, the anti-gassing agent(s) reduce the gassing tendency of the dielectric liquid to +30 $\mu\text{L}/\text{min.}$ or less, preferably 15 $\mu\text{L}/\text{min.}$ or less, more preferably 5 $\mu\text{L}/\text{min.}$ or less, preferably 0 $\mu\text{L}/\text{min.}$ or less, according to ASTM Test Method D2300.

The antigassing agent(s) generally are antigassing aromatic(s) other than phenolic compounds either comprising one or more labile hydrogen atom or comprising diaryls, which may or may not comprise one or more labile hydrogen atoms. Examples of suitable antigassing agents include, but are not

necessarily limited to diaryls and agents having from 9 to 11 carbon atoms selected from the group consisting of alkyl-substituted aromatic compounds, alkyl substituted, partially saturated aromatic compounds, and combinations thereof.

5 Suitable diaryls have the following general structure:



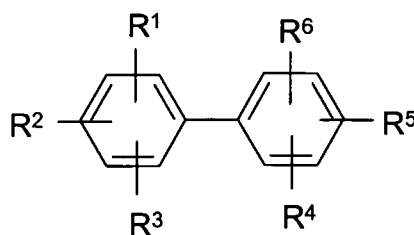
wherein

R is selected from the group consisting of a single

10 continuous bond (making the diaryl a biphenyl) and
alkylene groups having from about 1 to 4 carbon atoms
(making the diaryl a diaryl alkane); and

R^1 - R^6 independently are selected from the group consisting of
nothing and alkyl groups having from about 1 to about
15 2 carbon atoms.

Where R represents a single bond ($R=0$), the diaryl is a biphenyl having the following general structure:



wherein R^1 - R^6 independently are selected from the group
20 consisting of nothing and alkyl groups having from about 1 to
about 2 carbon atoms. In a preferred embodiment, R^1 - R^6 are
selected from the group consisting of methyl groups. In
another preferred embodiment, the biphenyl is unsubstituted,
wherein R^1 - R^6 are nothing. In another embodiment, the
25 biphenyl is dimesityl, wherein R^1 - R^6 are methyl groups.

Examples of suitable anti-gassing agents include, but are not necessarily limited to diaryls, dihydrophenanthrene, phenyl ortho xylyl ethane, alkylated benzenes, including diethylbenzenes, tetrahydro-5-(1-phenylethyl)-naphthalene, acenaphthene, tetrahydro-naphthalene, alkylated tetrahydronaphthalenes, and tetrahydroquinoline.

Generally, the one or more anti-gassing agent(s) are added to the cycloalkane-base oil in an amount of about 5 wt.% or less, more preferably about 2 wt.% or less, even more preferably from about 0.5 wt.% to about 1 wt.%, most preferably about 1 wt.%, based on the volume of the base oil.

In one embodiment, the antigassing agent comprises about 80 wt.% 1,5-dimethyl naphthalene and about 20 wt.% isomeric dimethyl naphthalenes.

In another embodiment, the base oil comprises 2 wt.% or less, preferably 1 wt.% or less, more preferably preferably less than 1 wt.% of antigassing agent(s) selected from the group consisting of alkyl substituted or unsubstituted biphenyl and alkyl substituted or unsubstituted diaryl alkanes. Preferred antigassing agent(s) are selected from the group consisting of biphenyl (unsubstituted) and dimesityl.

In a preferred embodiment, antioxidant (described above) also is added the cycloalkane base oil to improve oxidation stability of the cycloalkane-base dielectric liquid, thereby minimizing the development of oil sludge and acidity during storage, processing, and service. Minimizing oxidation minimizes electrical conduction and metal corrosion, maximizes system life, maximizes electrical breakdown strength, and ensures satisfactory heat transfer.

Preferably, when subjected to the acid sludge test (ASTM D2440), the cycloalkane-base dielectric liquid produces a % sludge by mass at 72 hours of 0.15 or less and a 72 hour

"total acid number" or "TAN" of 0.5 or less (mg of KOH/g). The cycloalkane-base dielectric liquid also preferably produces a % sludge by mass at 164 hours of 0.5 or less and a TAN of 0.6 or less.

5 Generally, antioxidant is added in order to minimize sludge and TAN. In a preferred embodiment, the dielectric liquid comprises from about 0.01 wt. % to about 1.0 wt. % antioxidant, preferably from about 0.07 wt. % to about 0.30 wt. % antioxidant based on the weight of the dielectric
10 liquid.

Substantially any antioxidant accepted for use in the particular type of dielectric fluid is suitable. Preferred antioxidants for use in electrical oils are hindered phenols, cinnamate type phenolic esters, and alkylated diphenylamines.
15 More preferred antioxidants, particularly for use in transformer oils, are selected from the group consisting of 2,6-ditertiary-butyl para-cresol, 2,6-ditertiary butylphenol, and combinations thereof. A most preferred antioxidant is a combination of 2,6-ditertiary-butyl para-cresol and 2,6-
20 ditertiary butylphenol.

If desired, a quantity of one or more pour point depressants may be added to the cycloalkane base oil to depress the pour point of the product to about -30 °C or less, preferably to about -40°C or less. A variety of pour
25 point depressants may be used. Suitable pour depressants include, but are not necessarily limited to pour point depressants based on polymethacrylate chemicals. If pour point depressant(s) are added, the quantity of pour point depressant typically is from about 0.01 wt % to about 0.2 wt
30 % based on the weight of the cycloalkane base oil.

The cycloalkane-base dielectric liquids meet specifications required for a variety of applications, including but not necessarily limited to electrical oils. A

preferred use for the cycloalkane-base dielectric liquids is transformer oil(s).

In addition to oxidation resistance and low gassing tendency, the cycloalkane-base dielectric liquids preferably have a number of other properties, including but not necessarily limited to electrical resistance and thermal stability. In a most preferred embodiment, the cycloalkane-base dielectric liquids meet relevant specifications for physical, electrical, and chemical properties for electrical oils provided by ASTM D 3487. In a preferred embodiment, the cycloalkane-base dielectric liquid also meets other relevant standards, incorporated herein by reference, including, but not necessarily limited to: National Electrical Manufacturers Association (NEMA) TR-P8-1975; U.S. Government Military Specification VV-I-530A and Amendment 2 for Class I and Class II fluids (Type I and Type II, respectively)-supersedes the Department of the Navy specification OS-1023; NATO symbol S-756, British Standard BS 148.

The ASTM physical property requirements for electrical oils include, but are not necessarily limited to: a color of about 0.5 or less, as measured using Test Method D1500; a flash point of about 145 °C or greater, as measured using Test Method D92; an interfacial tension of about 40 dynes/cm or more at 25 °C, as measured using Test Method D971; a pour point of about -40 °C or less, as measured using Test Method D92; a relative density of 0.91 or less, according to Test Method D 1298; a visual examination of clear and bright, according to Test Method D1524; and, a viscosity of about 76 cSt or less at 0°C, about 12.0 cSt or less at 40°C, and from about 3.0 cSt or less at 100°C, as measured by Test Method D445.

The cycloalkane-base dielectric liquid also preferably meets the electrical property requirements for electrical

oils, including but not necessarily limited to the ASTM requirements of: a dielectric breakdown voltage of 30 kV or more at 60 Hz by disc electrodes, according to Test Method D877; a dielectric breakdown voltage of 20 kV or more at 60
5 Hz and a 1.02 mm (0.040-inch) gap using new oil by D1816 (incorporated herein by reference); a dielectric breakdown voltage impulse of about 145 kV or more at 25 °C using a needle-to-sphere grounded 25.4 mm (1-inch) gap, according to Test Method D3300, and, a power factor at 60 Hz of 0.05% or
10 less at 25 °C, and of 0.30% or less at 100 °C, using Test Method D924.

The cycloalkane-base dielectric liquid also preferably meets chemical property requirements for electrical oils, including but not necessarily limited to the ASTM
15 requirements of: an oxidation inhibitor content for Type I oils of 0.08 wt.% or less, and for Type II oils of 0.3 wt.% or less, as measured using Test Method D2668, or, where the oxidation inhibitor is 2,6-ditertiary butyl cresol, as measured using Test Method D1473; a low content of elemental
20 sulfur and thermally unstable sulfur-bearing compounds to prevent corrosion of certain metals such as copper and silver in contact with the dielectric liquid, according to Test Method D1274; 35 ppm or less water according to Test Method D1533; a neutralization number of 0.03 mg KOH/g or less,
25 using Test Method D974; and, a non-detectible polychlorinated biphenyl (PCB) content, or a content of less than 1 ppm, as measured using Test Method D4059.

In a preferred embodiment, the cycloalkane-base dielectric liquid has a color of about 0.5 or less, as
30 measured using ASTM D1500; a flash point of about 145 °C or greater, as measured using ASTM D92; an interfacial tension of about 40 dynes/cm or more at 25 °C, as measured using ASTM D971; a relative density of 0.91 or less, according to ASTM D

1298; a visual examination of clear and bright, according to ASTM D1524; a viscosity, as measured by ASTM D445, of about 76 cSt or less at 0°C, about 12.0 cSt or less at 40°C, and from about 3.0 cSt or less at 100°C; about 35 ppm or less
5 water according to ASTM D1533; a content of less than 1 ppm polychlorinated biphenyl (PCB), as measured using ASTM D4059; a dielectric breakdown voltage of 30 kV or more at 60 Hz by disc electrodes, according to ASTM D877; a dielectric
breakdown voltage of 20 kV or more at 60 Hz and a 1.02 mm
10 (0.040-inch) gap using new oil by ASTM D1816; a dielectric breakdown voltage impulse of about 145 kV or more at 25 °C using a needle-to-sphere grounded 25.4 mm (1-inch) gap, according to ASTM D3300; a power factor at 60 Hz of 0.05% or less at 25 °C, and of 0.30% or less at 100 °C, according to
15 ASTM D924.

The application will be better understood with reference to the following examples, which are illustrative only:

Example 1

A cycloalkane base oil produced as described above was
20 analyzed and determined to have the following properties:

API	31.6
Specific Gravity g/cc	0.8676
Pour Point, °C (°F)	-42.8 (-45)
Cloud Point, °C (°F)	-30.5 (-22.9)
Viscosity @ 40 °C mm ² /s (cSt)*	9.172
Viscosity @ 100 °C mm ² /s (cSt)	2.397
Viscosity Index	68.7

*The viscosity measurements were performed using an automatic Cannon CAV4 instrument. Viscometer according to ASTM D 445, incorporated herein by reference.

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Example 2

A cycloalkane base oil produced as described above was analyzed and determined to have the following properties:

API	32.4
Specific Gravity g/cc	0.8633
Pour Point, °C (°F)	-47 (-52.6)
Cloud Point, °C (°F)	-38 (-36.4)
Cleveland Open Cup (COC) Flash Point, °C (°F)	157.8 (316)
Viscosity @ 40 °C mm ² /s (cSt)	7.471
Viscosity @ 100 °C mm ² /s (cSt)	2.112
Viscosity Index	70.7
UV Aromatics	
Monoaromatics (wt.%)	0.97
Diaromatics (wt.%)	1.06
tri + aromatics (wt.%)	0.7
Total (wt.%)	2.73

Example 3

A cycloalkane base oil produced as described above was analyzed. Simulated distillation by gas chromatography was performed to determine the temperatures (°C) at which 5 wt.% and 95 wt.% of the base oil vaporized. ASTM D 6352 "Standard Test Method for Boiling Range Distribution of Petroleum Distillates in Boiling Range from 174 to 700 Degrees C by Gas Chromatography," incorporated herein by reference. The results are given in the following Table, along with the physical properties of the base oil:

5% vaporization temperature, °C(°F)	267.8(514)
95% vaporization temperature, °C(°F)	400.6(753)
Viscosity @ 40 °C mm ² /s (cSt)	9.9
Viscosity @ 100 °C mm ² /s (cSt)	2.5
VI	53
Density, g/ml@15.6°C (60°F)	0.854
API Gravity	34.1
Pour Point, °C (°F)	-45 (-49)
Pensky-Martens Closed Cup (PMCC) Flash, °C	148
UV Aromatics, mmol/100g	6
Sulfur, ppm	1
Nitrogen, ppm	1

Example 4

Cycloalkane base oil from Example 3 was mixed with either 0.075 wt.% or 0.28 wt.% butylated hydroxytoluene (BHT), obtained from CRI Fine Chemicals, Inc. Samples were prepared containing no added aromatic oil, containing 2.0 wt.% C9-C11 alkylbenzenes ("AB"), containing 0.5 wt.% C9-C11 alkylbenzenes, containing 0.5 wt.% dimethyl naphthalenes (DMN), containing 1 wt. % added DMN, and containing 2.0 wt.% biphenyl. The resulting mixture was oxidized at a bath temperature of 110 °C, in the presence of a copper catalyst coil, by bubbling oxygen through duplicate test specimens for 72 and 164 h, respectively. The cycloalkane base oil was evaluated at the end of each aging period by measuring the amount of sludge and acid formed. The test specimen was diluted with n-heptane and the solution filtered to remove the sludge. The sludge was dried and weighed. The sludge free solution was titrated at room temperature with 0.01 N potassium hydroxide to the end point indicated by the color change (green-brown) of the added p-naphtol-benzein solution. ASTM D 2440, incorporated herein by reference. Test Method D2300 Procedure B, incorporated herein by reference, was performed using a gassing cell assembly and buret assembly to determine the resulting gassing tendency.

The samples were mixed with an acidified, aqueous solution of methylene blue and treated with chloroform to extract hydrophobic ion pairs. The combined chloroform extracts were washed with an acid solution to remove the less hydrophobic ion pairs (having low partition coefficients).

The intensity of the blue color remaining in the chloroform extract was measured at a wavelength of maximum absorption near 650 nm. The results are given in the following Table:

	72 hr. sludge	72 hr. TAN	164 hr. Sludge	164 hr. TAN	Gassing Tendency
D3487 specification	0.15 max	0.5 max	0.3 max	0.6	30 max
Cycloalkane base oil	0.01	0.01	0.01	0.01	49
Cycloalkane base oil	0.01	0.01	0.03	0.13	45
Cycloalkane base oil + 0.28 wt.% BHT + 2.0 wt.% AB	<0.01	<0.1	0.01	<0.01	-56
Cycloalkane base oil + 0.075 wt.% BHT + 0.5 wt.% AB	0.01	0.11	0.03	0.3	-7
Cycloalkane base oil + 0.075 wt.% BHT + 0.5 wt.% DMN	0.02	0.01	0.05	1.74	23
Cycloalkane base oil + 0.075 wt.% BHT + 2.0 wt.% Biphenyl	0.03	<0.01	0.02	0.05	-36
Cycloalkane base oil + 0.075 wt.% BHT + 1 wt.% DMN	0.01	0.01	0.01	0.01	-5

With 0.28 wt.% BHT and 2.0 wt.% AB, the sample performed well exhibiting a negative gassing tendency. With 0.28 wt.% BHT and 0.5 wt.% AB, the sample performed well exhibiting a negative gassing tendency. With 0.075 BHT, the samples containing 0.5 wt.% DMN and 1.0 wt.% DMN performed well. The sample containing 2.0 wt.% AB, 0.5 wt.% AB, 1.0 wt.% DMN, and 2.0 wt.% biphenyl performed exceptionally well, exhibiting a negative gassing tendency. The 164 hour TAN result is believed to be due to experimental error.

Persons of ordinary skill in the art will recognize that many modifications may be made to the foregoing without departing from the spirit and scope thereof. The embodiment described herein is meant to be illustrative only and should

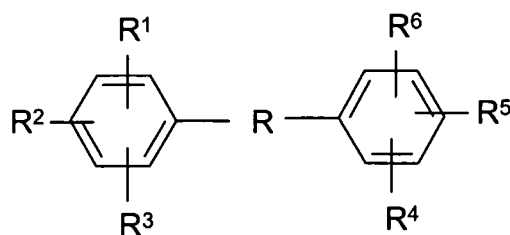
not be taken as limiting the invention, which is defined in the following claims.

C L A I M S

1. A cycloalkane base oil comprising a quantity of
5 isoparaffins and from 50 wt.% to 70 wt.% cycloalkanes
having the formula C_nH_{2n} wherein n is from 15 to 30, said
quantity of isoparaffins being less than 50 wt.% of said
cycloalkane base oil.
2. A cycloalkane base oil according to claim 1 comprising
10 from about 20 wt.% to about 40 wt.% isoparaffins.
3. A cycloalkane base oil according to claims 1 or 2
wherein a majority of the cycloalkanes comprise alkyl-
substituted cycloalkanes.
4. A cycloalkane base oil according to any one of claims 1-
15 3 boiling at a temperature in the range of from about
260 °C (500 °F) to about 371 °C (700 °F).
5. A cycloalkane base oil of claim 3 wherein 70 wt.% or
more, preferably 80 wt.% or more, more preferably 90
wt.% or more, of the cycloalkanes comprise said alkyl-
20 substituted cycloalkanes.
6. A cycloalkane-base dielectric liquid comprising
cycloalkane base oil according to any one of claims 1-5;
and,
one or more antigassing agent selected from the group
25 consisting of non-phenolic alkyl substituted or
partially saturated aromatic compounds comprising
at least one labile hydrogen atom and diaryls, said
quantity being effective to reduce the gassing
tendency of the dielectric liquid.
- 30 7. A cycloalkane-base dielectric liquid of claim 6 further
comprising an amount of one or more antioxidant selected
from the group consisting of hindered phenols, cinnamate
type phenolic esters, and alkylated diphenylamines, said
amount being effective to reduce sludge formation and

total acid number in mg of KOH/g (TAN) under oxidation conditions.

8. A cycloalkane-base dielectric liquid of according to claims 6 or 7 comprising about 60 wt.% cycloalkanes or more.
9. A cycloalkane-base dielectric liquid according to claims 6-8 wherein a majority of the cycloalkanes comprise alkyl-substituted cycloalkanes, preferably 70 wt.% or more of the cycloalkanes comprise alkyl-substituted cycloalkanes.
10. A cycloalkane-base dielectric liquid according to any one of claims 6-9 having gassing tendency of +30 $\mu\text{L}/\text{min}$. or less, more preferably +15 $\mu\text{L}/\text{min}$. or less, more preferably +5 $\mu\text{L}/\text{min}$. or less.
11. A cycloalkane-base dielectric liquid according to any one of claims 6-10 wherein the antigassing agents are selected from the group consisting of diaryls, dihydrophenanthrene, phenyl ortho xylyl ethane, alkylated benzenes, tetrahydro-5-(1-phenylethyl)-naphthalene, acenaphthene, tetrahydro-naphthalene, alkylated tetrahydronaphthalenes, and tetrahydroquinoline.
12. A cycloalkane-base dielectric liquid according to any one of claims 6-11 wherein the antigassing agents are selected from the group consisting of diaryls have the following general structure:



wherein

R is selected from the group consisting of a single continuous bond and alkylene groups having from about 1 to 4 carbon atoms; and

R¹-R⁶ independently are selected from the group consisting of nothing and alkyl groups having from about 1 to about 2 carbon atoms;

alkyl-substituted aromatic compounds, alkyl substituted, partially saturated aromatic compounds, and combinations thereof having from 9 to 11 carbon atoms; and,

a combination comprising 80 wt.% 1,5-dimethyl naphthalene and 20 wt.% isomeric dimethyl naphthalenes.

13. A cycloalkane-base dielectric liquid according to any one of claims 6-12 wherein the quantity of anti-gassing agent is about 5 wt.% or less, preferably 2 wt.% or less, based on the weight of the dielectric liquid.

14. A cycloalkane-base dielectric liquid according to claim 6 comprising about 2 wt.% or less antigassing agent(s), based on the weight of the dielectric liquid, wherein the antigassing agent(s) are selected from the group consisting of:

biphenyl and dimesityl;

alkyl-substituted aromatic compounds, alkyl substituted, partially saturated aromatic compounds, and combinations thereof having from 9 to 11 carbon atoms; and, a combination of 80 wt.% 1,5-dimethyl naphthalene and 20 wt.% isomeric dimethyl naphthalenes.

15. A cycloalkane-base dielectric liquid according to any one of claims 6-14 wherein a % sludge by mass at 72 hours of 0.15 or less and a 72 hour TAN of 0.5 or less,

and to produce a % sludge by mass at 164 hour TAN of 0.6 or less.

16. A cycloalkane-base dielectric liquid according to any one of claims 6-15 comprising a pour point of about -40 °C or less, as measured using ASTM D92.

17. A method for making a cycloalkane base oil according to claim 1 comprising:

refining crude to produce aromatic vacuum gas oil

boiling at a temperature in the range of from 371

°C to 538 °C, the aromatic vacuum gas oil

comprising carbonaceous materials, a majority of the carbonaceous materials being selected from the group consisting of cycloalkanes and aromatics;

hydrocracking the aromatic vacuum gas oil with a

hydrocracking catalyst to produce hydrocracking product;

stripping the hydrocracking product to increase the

content of cyclic hydrocarbons selected from the

group consisting of cycloalkanes, cycloalkenes, and

combinations thereof and removing hydrogen sulfide

and ammonia and producing stripped hydrocracking product;

contacting stripped hydrocracking product with

isomerization/dewaxing/hydrogenation (IDH) catalyst

comprising a metal selected from the group

consisting of platinum, palladium, and combinations

thereof, to saturate aromatics to cycloalkanes,

reduce normal paraffins, and to produce IDH product

comprising greater than 50 wt.% of one or more

cyclic hydrocarbons selected from the group

consisting of cycloalkanes and cycloalkenes;

without solvent extracting, contacting IDH product with

hydrotreating catalyst to produce hydrotreated

- product comprising greater than 50 wt.%
cycloalkanes; and,
separating from said hydrotreated product cycloalkane
base oil comprising a quantity of less than 50 wt.%
5 isoparaffins and 50 wt.% or more cycloalkanes, said
cycloalkane base oil boiling at a temperature in
the range of from about 260 °C to about 371 °C.
18. A method according to claim 17 comprising separating
from said hydrotreated product cycloalkane base oil
10 comprising from 50 wt.% to 70 wt.% cycloalkanes having
the formula C_nH_{2n} wherein n is from 15 to 30.
19. A method according to claims 17 or 18 wherein the IDH
step is carried out at:
IDH temperatures of from about 250 °C to about 390 °C;
15 IDH gas pressures greater than atmospheric;
IDH hydrogen circulation rates of from about 400 to
about 15,000 SCF/B; and,
IDH liquid hourly space velocities of from about 0.1
hr.⁻¹ to about 20 hr.⁻¹.
20. A method according to any one of claims 17-19 wherein
the hydrocracking is carried out at a pressure greater
than atmospheric pressure, the stripping is carried out
at a stripping pressure greater than atmospheric
pressure, and IDH is carried out at an IDH pressure of
25 greater than atmospheric.