

1 This invention relates to novel lubricating oil
2 additives and lubricating oil compositions containing same
3 which exhibit the desirable properties of being multifunc-
4 tional dispersants and viscosity index improvers for both
5 gasoline and diesel engine formulations. More particularly,
6 the invention relates to amine derivatives of oil soluble
7 hydrocarbon substituted succinic anhydrides which are char-
8 acterized by a macrocyclic or polycyclic polyamine structure
9 resulting from the use of certain 3-aminopropyl compounds in
10 a cyclodehydration reaction or from reaction with certain
11 pre-formed cyclic amino compounds.

12 Lubricating oil additives, especially disper-
13 sants prepared by the reaction of hydrocarbon substituted suc-
14 cinic acid anhydrides with polyamines, to give linear mono-
15 and bis-imides, are well known in the art and representative
16 disclosures include U.S. Patent 3,172,892 issued March 9,
17 1965 to LeSuer et al, U.S. Patent 3,272,746, issued September
18 13, 1966 to LeSuer et al. Patents which disclose a cyclic
19 structure for the dispersant additive include U.S. Patent
20 4,102,798 issued July 25, 1978 to Ryer et al and U.S. Patent
21 4,239,636 issued to Brois which discloses a product con-
22 taining a macrocyclic lactone ester.

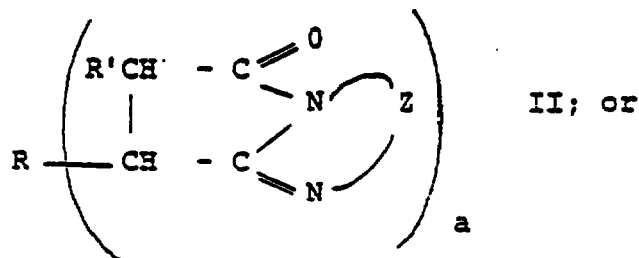
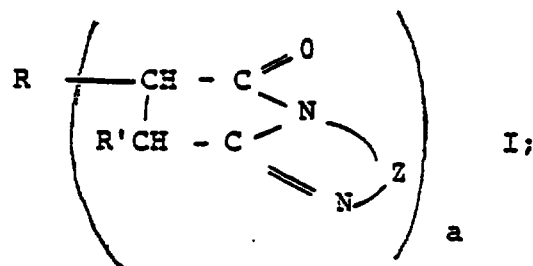
23 Dispersant viscosity index (VI) improvers which
24 result from the grafting of maleic anhydride to an ethylene
25 propylene copolymer with subsequent reaction with polyamines
26 are also known and are disclosed; for example, in U.S.
27 Patent 4,089,794 issued May 16, 1978 to Engel et al and U.S.
28 Patent 4,144,181 issued March 13, 1979 to Elliot et al. The
29 present invention is considered distinguished from the fore-
30 going Engel et al and Elliot et al patents through formation
31 of the characteristic macrocyclic polyamine structure.

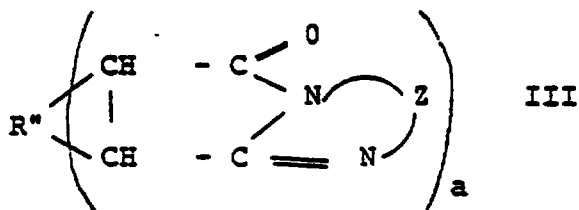
32 U.S. 4,160,739 teaches that in the reaction between
33 polyamines and grafted maleic anhydride polymers, only one
34 reactive amine group must be present in the polyamine to
35 eliminate interfering reactions. U.S. 4,137,185 teaches
36 that, in the reaction between the same materials, alkylene
37 polyamines having two primary amine groups produce linear

amino-imides which can cause adverse increases in viscosity, and, therefore, acylation of NH_2 groups in the amino-imide products with anhydrides is required to prevent chain extension.

One aspect of the present invention is based upon the discovery that certain macrocyclic and polycyclic polyamine compounds possess significant properties as multifunctional dispersant-viscosity index improvers, especially the capability to be a highly effective dispersant in both a gasoline engine lubricating oil formulation and corresponding diesel engine lubricating oil formulations and thereby enable lubricating oils containing these novel additives to pass or exceed the highest qualification standards for such oils.

In accordance with one embodiment of this invention there have been discovered as novel compositions of matter oil-soluble, macrocyclic polyamine compounds being the reaction product, in a cyclodehydration reaction, of a hydrocarbon substituted succinic anhydride with a poly 3-amino propyl amine compound, having 2 to 8 nitrogen atoms, the oil soluble macrocyclic polyamine compound being a member of the group of compounds represented by the following formulas, or mixtures of said compounds:

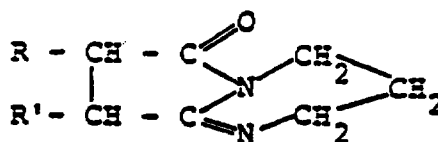




wherein R' is hydrogen or lower C₁-C₁₂ alkyl, R is a hydrocarbon substituent having 2 to 15,000 carbon atoms, R'' is a hydrocarbon substituent of 4 to 15,000 carbon atoms having two of its carbon atoms bonded to the alpha carbon atoms of the cyclodehydrated succinic anhydride moiety, Z may represent -CH₂CH₂CH₂-, -(CH₂CH₂CH₂NH)_nCH₂CH₂CH₂- where n is 1-6 or -(CH₂CH₂CH₂NH)_mCH₂(CH₂)_p(NH-CH₂CH₂CH₂)_{m'}- where m and m' are each at least 1 and m + m' is 2-5, p is 1-4 and a is an integer 1-20.

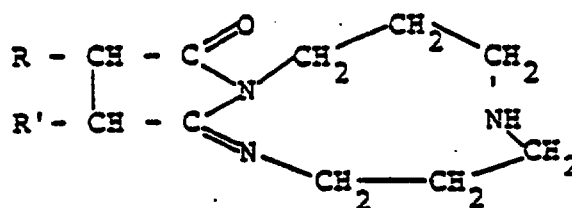
Formulas I and II above are meant only to represent different isomers which will form as result of formation of the hydrocarbon substituted succinic anhydride. A typical product will be a mixture of isomers such as about 50-90% of the Formula I syn-isomer and the balance the Formula II anti-isomer. Formula III would be illustrated by a Diels-Alder type reaction in the preparation of polyisobutenyl succinic anhydride from chlorinated polyisobutylene and maleic anhydride where two reactive sites are provided for bonding the polymer backbone to each of the alpha carbon atoms of the anhydride moiety.

With reference to Formula I above the simplest embodiment would be represented by a formula wherein Z is trimethylene and a is 1:

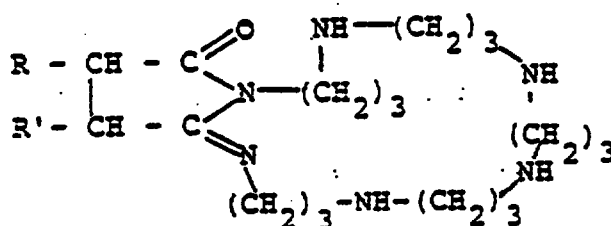


and this compound would therefore be derived from 1,3-propanediamine.

Larger macrocyclic structures can be represented by the structure below wherein Z is -CH₂CH₂CH₂NECH₂CH₂CH₂- and a is 1:

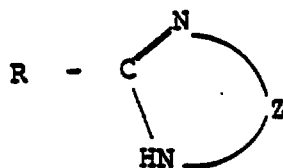


7 and in the next structure below, a is 1, and z is a polyimino
8 alkylene unit of the formula $-(CH_2)_3-NH-(CH_2)_3-NH-(CH_2)_3-$
9 $NH(CH_2)_3NH-(CH_2)_3-$:

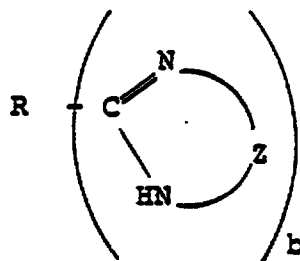


The variation of a between 1 and 20 is intended for numbers greater than 1 to represent multi-site macrocyclic polyamines, that is, those products derived from polyfunctionalized hydrocarbon succinic anhydrides having more than 1 succinic anhydride group per mole of hydrocarbon substituent. Usually, such as for ethylene-propylene copolymer substituted succinic anhydrides, the value of a may vary from about 1 to about 10. The preferred value is about 1 to 8, with multi-site products derived from ethylene propylene copolymers and terpolymers of M_n 10,000 to 200,000 being particularly preferred with a corresponding preferred value for a of from about 2 to 20 since these products have good viscosity modifying or viscosity index improving properties.

29 In another embodiment of the invention macrocyclic
30 polyamine compounds may also be formed in the same cyclode-
31 hydration reaction using the inverse addition process except
32 the intermediate formed is a 1:1 amine carboxylate salt which
33 is subsequently cyclodehydrated utilizing the same
34 category of poly(3-aminopropyl) amine reagents from mono-
35 carboxylic acid to give macrocyclic compounds having the
36 general formula:



wherein R and Z are as described above. Similarly, useful macrocyclic polyamine compound may be prepared from polycarboxylic acids or polymers such as ethylene-propylene graft copolymer with acrylic acid or alternating copolymers of ethylene-acrylic acid or vinyl ether-acrylic acid in accordance with the cyclodehydration reaction process of the invention to give macrocyclic compounds which may be generalized as



wherein b is an integer of 2 or more representing compounds derived from polycarboxylic acids having 2 or more reactive carboxylic groups. The upper limit of b is a value of about 150. R and Z are as previously defined. These embodiments differ structurally from those macrocyclic polyamines derived from the hydrocarbon succinic anhydrides but the cyclodehydration reaction process and poly(3-aminopropyl) amine reagents useful therein are the same.

These embodiments of the present invention depend upon the use of polyamines having terminal 3-amino propyl groups including both simple diamines such as 1,3-propane diamines, 3,3' -imino-bis-propylamine, N,N-bis-(3-amino propyl)ethylene diamine and higher oligomers such as penta-propylene hexamine. Further embodiments include polyamino propyl amines having C-substituents such as C₁₂-C₂₀ alkyl, C₆-C₁₀ aryl, hydroxyl, thiol, cyano, ethoxy, polyoxyethylene and polyoxypropylene having a degree of polymerization of 2-10 and other compatible non-reactive functional groups, but N-substituted polyamines are not suitable reactants in preparing the macrocyclic compounds of this invention in a

1 cyclodehydration reaction. Amines not meeting these re-
2 quirements, such as ethylene, 1,2-propylene amines will,
3 upon aminolysis, give non-cyclic imide type products not
4 within the scope of this invention as opposed to the macro-
5 cyclic structures obtained in accordance with the invention,
6 the cyclic structure being the essential critical aspect of
7 this invention.

8 Suitable amines for the cyclodehydration reaction
9 may be generalized by the formula $\text{NH}_2\text{-Z-NH}_2$, where Z is as
10 described above. The carbon atoms may contain substituents
11 as noted above but the nitrogen atoms must be either -NH or
12 -NH₂. Preferably Z is $-\text{CH}_2\text{CH}_2\text{CH}_2-$, $-(\text{CH}_2\text{CH}_2\text{CH}_2\text{NH})_n\text{CH}_2\text{CH}_2\text{CH}_2-$
13 where n is 1-3 or $\{\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}\}_m(\text{CH}_2\text{CH}_2)(\text{NHCH}_2\text{CH}_2\text{CH}_2-)_m$
14 where m and m' are as described above.

15 Formation of the macrocyclic and polycyclic poly-
16 amine compounds of the present invention proceeds by amino-
17 lysis of the hydrocarbyl substituted succinic anhydride,
18 monocarboxylic acid or polycarboxylic acid using an inverse
19 mode of addition. Such a process will avoid the formation of
20 the prior art non-cyclic, imide products or other products
21 resulting from chain extension. The first step of the
22 synthesis is to slowly add the succinic anhydride or mono- or
23 polycarboxylic acid to the polyamine compound at relatively
24 low temperatures, such as room temperature, that is, about
25 20°C, up to about 100°C in an inert hydrocarbon solvent, such
26 as xylene, toluene, dichlorobenzene or a neutral paraffinic
27 mineral oil. This inverse mode of addition is critical to
28 form the 1:1 amic acid or amine carboxylate salt intermediate
29 and inhibit or prevent formation of imide or bis-imide non-
30 cyclic final products. The reaction temperature during this
31 inverse addition of hydrocarbon succinic anhydride or carboxy-
32 lic acid should be as low as possible, preferably below 100°C,
33 and the optimum temperature will vary somewhat depending on
34 the reactivity and structure of the anhydride compound. The
35 first phase is believed to be the formation of an intermediate
36 and the temperature and rate of addition should be merely
37 sufficient to promote this reaction. Thus at the beginning

1 of the reaction a molar excess of amine relative to moles of
2 succinic anhydride or carboxylic acid groups present is used
3 to minimize any chain extension or bis-imide formation. The
4 formation of an intermediate 1:1 amic acid salt is indicated
5 by the disappearance of carbonyl bands in the infrared
6 spectrum of the anhydride reactant. The formation of the
7 amine carboxylate intermediate is indicated by the appear-
8 ance of a carbonyl based in the infrared spectrum of the
9 product due to carboxylate formation.

10 The second step of the process, the cyclodehydra-
11 tion of the amic acid or amine carboxylate intermediate is
12 effected at a temperature consistent with the reactivity of
13 the intermediate salt, with suitable cyclodehydration tem-
14 peratures ranging from 130°C-250°C, preferably about 140°C
15 to 175°C. Formation of the macrocyclic polyamine structure
16 is indicated by cessation of evolution of water and by the
17 maximization of the C=N absorption band at about the 6 micron
18 range in the infrared spectrum of the reaction product.

19 It is critical to the cyclodehydration process of
20 the present invention that this inverse mode of addition be
21 used to effect the aminolysis of the succinic anhydride or
22 carboxylic acid. Thus the slow addition of hydrocarbon
23 succinic anhydride or carboxylic acid to the well stirred
24 polyamine, preferably in solution, maintained at about 20 to
25 100°C maximizes the formation of the 1:1 intermediate salt
26 which upon further heating at 130°-250°C undergoes cyclo-
27 dehydration to the desired macrobicyclic polyamine product.
28 In contrast to this, the prior art mode of addition, such as
29 adding the polyamine to the hydrocarbon succinic anhydride,
30 produces linear imide products.

31 The yield of macrocyclic polyamine lubricating oil
32 additive products formed in accordance with the cyclode-
33 hydration process of this invention will vary somewhat from
34 about 50% to 90% depending on various parameters including
35 reactants used, temperatures, rate of addition and whether
36 laboratory, pilot or commercial process procedures are being
37 conducted. The balance of the products produced will gen-
38 erally be the bis-imide reaction products which in most cases

1 can be tolerated in the final product since they are known
2 lubricating oil additives, but it is preferred that such by-
3 products not exceed about 30% yield and that the yield of
4 desired macrocyclic polyamine additive be on the order of
5 about 70% or more.

6 A preferred technique for preparing the macro-
7 cyclic and polycyclic polyamine compounds in accordance with
8 this invention and improving the yield thereof comprises the
9 additional step of heat soaking the reaction mixture sub-
10 sequent to the addition of the hydrocarbyl substituted suc-
11 cinic anhydride, mono- or polycarboxylic acid by maintaining
12 the reaction mixture at a temperature of 80° to 130°C for 1
13 to 3 hours and prior to increasing the temperature to effect
14 the cyclodehydration reaction. After the conclusion of the
15 heat soak period, the temperature of the reaction mixture is
16 increased to the cyclodehydration range of 130° to 250°C but
17 at least 20°C higher than the temperature employed during the
18 heat soaking step.

19 For preparation of preferred embodiments of this
20 invention using polyisobutenyl succinic anhydride of Mn
21 about 900 to 2,000, it is preferred to conduct the inverse
22 addition step at a temperature of about 75 to 85°C, such as
23 80°C, then heat soak the reaction mixture at about 80°C to
24 110°C for 3 hours and thereafter effect the cyclodehydration
25 by increasing the reaction mixture to 175° to 180°C and
26 maintaining this temperature for about 10 hours.

27 The use of acid catalysis has also been found to be
28 a preferred process technique for improving the yield of the
29 products of this invention. Preferred are oil soluble strong
30 acids such as alkyl aryl sulfonic acids such as alkyl benzene
31 sulfonic acid of about Mn 300 to 800, a C₂₄ alkyl benzene
32 sulfonic acid being especially preferred. Also suitable are
33 alkyl sulfonic acids, organic phosphoric acids, resin acids
34 as well as the mineral acids such as HCl and H₂SO₄. In general
35 the acid should have a pKa of about -10 to +5. The acid will
36 be employed by adding it to the polyamine prior to inverse
37 addition in mole ratios of 1:1 to 1,000:1 moles of amine per
38 mole of acid.

1 The hydrocarbon substituted succinic anhydrides
2 which are suitable for reaction with the poly 3-amino propyl
3 reagents or pre-formed cyclic amines in accordance with this
4 invention are derived generally from oil soluble hydro-
5 carbons comprising unbranched saturated or unsaturated hy-
6 drocarbon chains of at least 8, preferably at least 50 carbon
7 atoms including both polymeric, oligomeric and nonpolymeric
8 aliphatic chains, particularly polymers of C₂-C₅ olefins.
9 Particularly preferable for use in this invention is thermal
10 polyisobutenyl succinic anhydride of Mn about 900 to 2,000
11 produced in the "ene" reaction by heating together polyiso-
12 butylene and maleic anhydride at about 200°C. Hydrocarbon
13 substituents having from about 8 to 50 carbon atoms, while
14 forming useful oil-soluble products, are less preferable as
15 dispersant viscosity index improvers. They have been found,
16 however, to exhibit desirable properties as antioxidants in
17 oleaginous compositions, such as products of the present
18 invention derived from octadecenyl succinic anhydride.

19 Suitable olefin polymers include polymers com-
20 prising a major molar amount of C₂ to C₅ mono olefins, e.g.,
21 ethylene, propylene, butylene, isobutylene and pentene. The
22 polymers may be homopolymers such as polyisobutylene, as well
23 as copolymers of two or more such olefins such as copolymers
24 of ethylene and propylene, butylene and isobutylene, pro-
25 pylene and isobutylene and the like. Other copolymers
26 include those in which a minor molar amount of the copolymer
27 monomers, e.g., 1-20 mole %, is a C₄ to C₁₈ non-conjugated
28 diolefin, e.g., a copolymer of ethylene, propylene and 1,4-
29 hexadiene, i.e. the EPDM polymers.

30 The olefin polymers will usually have number aver-
31 age molecular weight within the range of about 500 to
32 about 200,000, more usually to about 60,000. Particularly
33 useful olefin polymers for dispersant additives have number
34 average molecular weights (Mn) within the range of about 900
35 to about 2,000 with approximately one terminal bond per
36 polymer chain. Especially useful material in the present
37 invention is polyisobutylene. Polybutene-1 and polypropy-

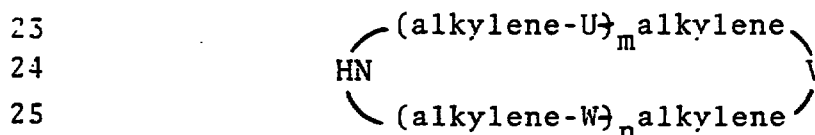
1 lene are also preferred hydrocarbon substituents for pre-
2 paring dispersants.

3 Particularly useful materials, when dispersant-
4 viscosity index improving additives are desired, are derived
5 from ethylene/propylene copolymers, terpolymers and tetra-
6 polymers having a M_n of about 10,000 to 200,000, especially
7 25,000 to 100,000. An example is a copolymer of about 30 to
8 85 mole % ethylene, 15 to 70 mole % C_3 to C_5 mono-alpha-
9 olefin, preferably propylene, and 0 to 20 mole % of a C_4 to
10 C_{14} non-conjugated diene. Preferred examples of such dienes
11 include those of U.S. Pats. 3,790,480; 4,089,794 and
12 4,137,185. Particularly useful dienes are 5-ethylidene
13 norbornene; 1,4-hexadiene; 2,5-norbornadiene and ethyl nor-
14 bornadiene. The latter terpolymers are commercially avail-
15 able under the trademarks VISTALON® an elastomeric terpolymer
16 of ethylene, propylene and 5-ethylidene norbornene, marketed
17 by Exxon Chemical Company and NORDEL® a terpolymer of
18 ethylene, propylene and 1,4-hexadiene, marketed by E. I.
19 DuPont de Nemours and Company The term copolymer as used
20 herein is meant to include terpolymers and tetrapolymers.

21 Other useful hydrocarbon substituents include
22 styrene-isoprene copolymers, styrene-isobutene copolymers,
23 isobutene-butadiene-1,3 copolymers, propene-isoprene co-
24 polymers, isobutene-chloroprene copolymers, isobutene-
25 (para-methyl)styrene copolymers, copolymers of hexene-1
26 with hexadiene-1,3, copolymers of octene-1 with hexene-1,
27 copolymers of heptene-1 with pentene-1, copolymers of 3-
28 methyl-butene-1 with octene-1, copolymers of 3,3-dimethyl-
29 pentene-1 with hexene-1, and terpolymers of isobutene,
30 styrene and piperylene. More specific examples of such
31 interpolymers include copolymer of 95% (by weight) of
32 isobutene with 5% (by weight) of styrene; terpolymer of
33 98% of isobutene with 1% of piperylene and 1% of chloro-
34 prene; terpolymer of 95% of isobutene with 2% of butene-1
35 and 3% of hexene-1; terpolymer of 60% of isobutene with
36 20% of pentene-1 and 20% of octene-1; copolymer of 80% of
37 hexene-1 and 20% of heptene-1; terpolymer of 90% of iso-
38 butene with 2% of cyclohexene and 8% of propylene.

1 Techniques for attaching succinic anhydride
2 groups to the above-described hydrocarbons and polymers are
3 well known in the art and these include, for example, reacting
4 maleic anhydride directly with the polyolefin which may have
5 first been halogenated in the range of about 2 to 5 wt. % prior
6 to the reaction of maleic anhydride. Grafting of maleic
7 anhydride with ethylene propylene copolymers and terpolymers
8 is described in U.S. Patents 4,089,794 and 4,137,185 and
9 represents a particularly preferred embodiment since it
10 provides a multi-site reactant which, upon aminolysis and
11 cyclodehydration in accordance with the invention, results
12 in a lubricating oil additive having especially valuable
13 multi-functional dispersant-viscosity index improving pro-
14 perties and such products are especially useful in improving
15 the dispersancy of diesel engine oil formulations.

16 In another embodiment of the present invention
17 macrocyclic and polycyclic polyamine additives can be pre-
18 pared by condensing the hydrocarbon succinic anhydrides with
19 macrocyclic polyamines (aza crown compound) and polycy-
20 clic polyamines (aza polycycles) in an acylation reaction.
21 Aza crown compounds useful herein are those having at least
22 2 NH groups and may be represented by the formula:

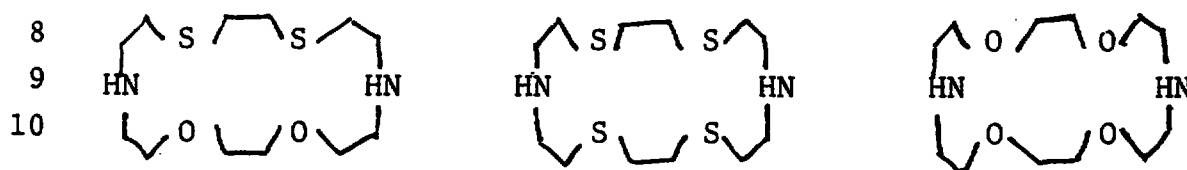


26 wherein U,V and W can be NH, S and/or O, n or m is an integer
27 of 1 to about 4, alkylene is C₂-C₄, usually an ethylene or
28 trimethylene group, and these aza crown compounds include
29 macrocyclic polyamines (U=V=W=NH), polyether amines; U=W=O,
30 V=NH, etc.) and polythioether amines; U=W=S; V=NH).

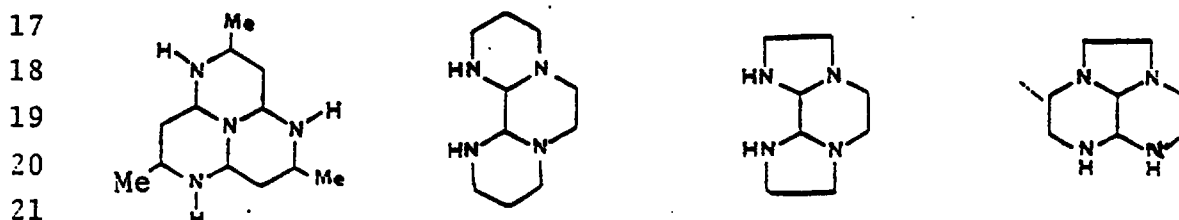
31 Examples within the scope of the foregoing formula
32 are macrocyclic polyamines and their complexes having three
33 to about eight nitrogen atoms, at least one, which is an NH
34 group. Preferred are those having four nitrogen donors in
35 cycles containing about 12 to 16 atoms. Examples of useful
36 macrocyclic polyamines include 1,4,8,11-tetraazacyclo-te-
37 tradecane (cyclam), 1,4,7,10-tetrazacyclododecane, 1,4,7,

1 10-tetraazacyclotridecane, 1,4,8,12-tetraazacyclopenta-
2 decane, 1,5,9,13-tetraazacyclohexadecane, and 1,4,7,10,13,
3 16-hexaazacyclooctadecane (hexacyclen).

4 Also suitable are mixed donor macrocyclic amines
5 containing nitrogen-oxygen, nitrogen-sulfur, and nitrogen-
6 oxygen-sulfur donor groups as depicted below which can be
7 acylated to give useful lubricant additives.



11 Also useful are aza polycyclic ring assemblies
12 (aza polycycles) containing 2 to 3 rings having 5 to 3
13 rings having 5 to 6 atoms in the ring, including 3 or 4
14 nitrogen atoms at least one being an NH group, but pref-
15 erably 2-3 NH groups per molecule are present, which com-
16 pounds can be represented by the formulas:



22 These amino compounds may be acylated by reacting
23 at least a half-mole equivalent up to a 2 mole equivalent of
24 the aforementioned hydrocarbon substituted succinic anhy-
25 drides to yield useful lubricant additives.

26 Further embodiments of the present invention re-
27 side in the formation of metal complexes and other post-
28 treatment derivatives, e.g. borated derivatives, of the
29 novel macrocyclic additives prepared in accordance with
30 this invention. Suitable metal complexes may be formed in
31 accordance with known techniques of employing a reactive
32 metal ion species during or after the reaction of the
33 polyamine and the hydrocarbyl anhydride compound. Complex-

1 forming metal reactants include the nitrates, thiocyanates,
2 halides, carboxylates, phosphates, thio-phosphates, sul-
3 fates, and borates of transition metals such as iron,
4 cobalt, nickel, copper, chromium, manganese, molybdenum,
5 tungsten, ruthenium, palladium, platinum, cadmium, lead,
6 silver, mercury, antimony and the like. Prior art disclo-
7 sures of these complexing reactions may be found in U.S.
8 Patents 3,306,908 and Re. 26,433.

9 Post-treatment compositions include reacting the
10 novel macrocyclic additives of the present invention with
11 one or more post-reacting reagents, usually selected from
12 the group consisting of boron oxide, boron oxide hydrate,
13 boron halides, boron acids, sulfur, sulfur chlorides,
14 phosphorous sulfides and oxides, carboxylic acid or anhy-
15 dride acylating agents, epoxides and episulfides and
16 acrylonitriles. The reaction of such post-treating agents
17 with the novel macrocyclic polyamine compounds of this
18 invention is carried out using procedures known in the
19 art. For example, boration is accomplished in accordance
20 with the teachings of U.S. Patent 3,254,025 by treating
21 the macrocyclic polyamine compound with a boron oxide,
22 halide, ester or acid to provide about 0.1 to 1 atomic
23 proportions of boron for each atomic proportion of nitrogen
24 in the composition. Treatment is carried out by adding
25 about 1-3 wt% of boron compound, preferably boric acid,
26 and heating and stirring the reaction mixture at about 135°C
27 to 165°C for 1 to 5 hours followed by nitrogen stripping and
28 filtration, if desired. Mineral oil or inert organic
29 solvents facilitate the process.

30 A particularly preferred post-treatment technique
31 especially useful for preparation of lubricating oil dis-
32 persants is post-treatment with a polyisobutenyl succinic
33 anhydride. In this embodiment a polyisobutenyl succinic
34 anhydride-poly 3-aminopropylamine macrobicyclic reaction
35 product is first prepared in accordance with the invention,
36 and subsequently treated with about 10 - 50 mole % of
37 additional polyisobutenyl (Mn of about 900-2000) succinic

1 anhydride at elevated temperatures of about 120°C for
2 about one hour or until the reaction mixture shows complete
3 reaction of the free anhydride. Such products are espe-
4 cially useful as dispersants for diesel engine lubricating
5 oil compositions.

6 The products of this invention can be incorporated
7 in lubricating oil compositions, e.g., gasoline or diesel
8 crankcase lubricating oil in active ingredient concentra-
9 tions within the range of about 0.01 to 20 wt% based on the
10 total weight of the lubricating oil composition. Such
11 additives are usually dispensed in the form of concentrates
12 as discussed below.

13 The products prepared according to this invention
14 can be incorporated in a wide variety of lubricants. They can
15 be used in lubricating oil compositions, such as automotive
16 crankcase lubricating oils, automatic transmission fluid,
17 etc., in active ingredient concentrations generally within
18 the range of about 0.5 to 10 wt%, for example, 1 to 5 wt. %,
19 preferably 1.5 to 3 wt. % of the total composition when used
20 only as a dispersant. Conventionally, the dispersants are
21 admixed with the lubricating oils as concentrates which
22 usually contain up to about 50% weight of the additive
23 compound dissolved in mineral oil, preferably a mineral oil
24 having an ASTM D-445 viscosity of about 2 to 40, preferably
25 5 to 20 centistokes at 99°C. The lubricating oil includes not
26 only hydrocarbon oils derived from petroleum but also in-
27 cludes synthetic lubricating oils such as polyethylene oils;
28 alkyl esters of dicarboxylic acids, complex esters of di-
29 carboxylic acid, polyglycol and alcohol; alkyl esters of
30 carbonic or phosphoric acids; polysilicones; fluorohydro-
31 carbon oils; and, mixtures of lubricating oils and synthetic
32 oils in any proportion, et. The term, "lubricating oil" for
33 this disclosure includes all the foregoing. The useful
34 additive of this invention may be conveniently dispensed as
35 a concentrate of 10 to 80 wt. % such as about 49 wt. % of
36 said dispersant in 20 to 90 wt. % of mineral oil, e.g.,
37 Solvent 150 Neutral oil with or without other additives being
38 present.

1 As noted above, such composition or concentrates
2 containing the dispersants of the present invention will also
3 contain other well-known additives such as the zinc dialkyl
4 (C_3-C_8) dithiophosphate anti-wear inhibitors usually present
5 in amounts of from 1 to 5 wt. %.

6 Useful detergents include the normal basic or
7 over-based metal, e.g., calcium magnesium, barium, etc.,
8 salts of petroleum naphthene acids, petroleum sulfonic ac-
9 ids, alkyl benzene sulfonic acids, oil-soluble fatty acids,
10 alkyl salicyclic acids, alkylene bisphenols and hydrolyzed
11 phosphosulfurized polyolefins. Typical amounts are from
12 1-7 wt. % with preferred materials being normal and basic
13 calcium and magnesium sulfonates, phenates and sulfurized
14 phenates.

15 Oxidation inhibitors include hindered phenols,
16 e.g., 2,6-ditert-butyl para-cresol, amines, sulfurized
17 phenols and alkyl phenothiazines, usually present in a-
18 mounts of from 0.001 to 1 wt. %.

19 Pour point depressants usually present in amounts
20 of 0.01 to 1 wt.% include wax alkylated aromatic hydrocar-
21 bons, olefin polymers and copolymers, acrylate and metha-
22 crylate polymers and copolymers.

23 Viscosity index improvers including olefin poly-
24 mers and copolymers such as polybutene, ethylene-propylene
25 copolymers, hydrogenated polymers and copolymers and ter-
26 polymers of styrene with isoprene and/or butadiene, polymers
27 of alkyl acrylates or alkyl methacrylates, copolymers of
28 alkyl methacrylates with N-vinyl pyrrolidone or dimethyl-
29 aminoalkyl methacrylate, post-grafted polymers of ethylene-
30 propylene with an active monomer such as maleic anhydride
31 which may be further reacted with an alcohol or an alkylene
32 polyamine, styrene/maleic anhydride polymers post-treated
33 with alcohols and amines, etc. Such products are used in
34 amounts as required to meet the viscosity grade desired,
35 generally 1-15 wt.% being used.

36 Rust inhibition activity can be provided by the
37 aforementioned metal dihydrocarbyl dithiophosphates and the

1 corresponding precursor esters, phosphosulfurized pinenes,
2 sulfurized olefins and hydrocarbons, sulfurized fatty esters
3 and sulfurized alkyl phenols. Preferred are the zinc di-
4 hydrocarbyl dithiophosphates which are salts of dihydro-
5 carbyl (C₃-C₈) esters of dithiophosphoric acids. Rust in-
6 hibitors are usually used in the range of 0.01 to 1 wt. %.

7 Fuel economy or friction reducing additives may
8 also be present such as dimer acid esters with glycols as
9 disclosed in U.S. Patent 4,105,781 issued to Shaub with the
10 esters of dimerized linoleic acid and diethylene glycol being
11 a preferred material or other effective fuel economy addi-
12 tives such as glycerol esters of C₁₆-C₁₈ fatty acids with
13 glycerol oleate being especially suitable. These additives
14 are present in amounts which vary greatly according to their
15 effectiveness but generally are used in very small pro-
16 portions.

17 Thus, the term lubricating oil composition as
18 used herein is meant to include an oil of lubricating vis-
19 cosity containing in addition to the products of this in-
20 ventions conventional additives in customary amounts as
21 required to provide their normal attendant functions.

22 The macrocyclic polyamine and polycyclic polyamine
23 compounds of this invention may also be used in fuels in
24 amounts sufficient to provide dispersant and detergent
25 properties to the fuel, particularly in preventing and
26 removing deposits from the carburetor and fuel lines---
27 when used preferably in gasoline fuel composition.
28 The compounds of the invention may be used in fuels
29 in amounts ranging from about 0.0001 to about 1 wt. %,
30 preferably about 0.0004 to about 0.1 wt.% based on the
31 weight of the fuel composition. Suitable fuel compositions
32 include normally liquid hydrocarbon fuels such as
33 motor gasoline (ASTM D439-73) diesel fuel or fuel oil
34 (ASTM D-391) and mixtures of such hydrocarbon fuels
35 with non-hydrocarbon materials such as alcohols, ethers,
36 nitro compounds and the like.

37 The invention is further illustrated by the fol-

1 following examples which are not to be considered as limitative
2 of its scope.

3 One aspect of the present invention teaches the
4 aminolysis of succinic anhydride functionality attached to
5 a hydrocarbon or substituted hydrocarbon chain of any length
6 by purposely adding the hydrocarbon succinic anhydride to a
7 3-aminoalkyl substituted amine such as 3-amino-propylamine,
8 3-amino-2-hydroxy-propylamine, N,N'-bis(3-aminopropyl)
9 ethylene-1,2-diamine, or an oligomeric poly-1,3-propylene
10 polyamine. This inverse mode of addition at 0-140°C con-
11 verts the anhydride group into a 1:1 molar succinamic acid
12 amine salt adduct which upon heating neat or in a suitable
13 azeotroping solvent, e.g. xylene, undergoes cyclodehydration
14 to give a hydrocarbon chain bearing bicyclic and/or
15 macrobicyclic polyamine functionality.

16 The following examples in groups (A), (B) and (C)
17 teach the inverse addition route to bicyclic and macro-
18 bicyclic polyamines from (A) low molecular weight hydro-
19 carbon succinic anhydrides (HSA) ranging from nadic anhy-
20 dride to n-octadecenyl anhydride (B) intermediate molecular
21 weight HSA (Mn 500-10,000) such as polyisobutenyl succinic
22 anhydrides useful for dispersant synthesis, and
23 (C) polymers (Mn 10,000 and higher) bearing more than one
24 succinic anhydride per chain useful for designing disper-
25 sant VI improvers.

26 To emphasize the remarkable sensitivity of
27 product composition to mode of addition, the prior art
28 method, i.e. the addition of polyamine to hydrocarbon
29 succinic anhydride (direct addition) is also described to
30 illustrate the formation of linear imide product as taught
31 in the prior art.

32 A. SYNTHESIS OF LOW MOLECULAR WEIGHT MACRO-
33 BICYCLIC POLYAMINES

34 EXAMPLES

35 EXAMPLE A1. 8-OCTADEC-2-ENYL-2,6-DIAZA-BICYCLO-
36 [4.3.0]NON-1-EN-7-ONE VIA AMINOLYSIS OF OCTADE-
37 CENYL-SUCCINIC ANHYDRIDE (OSA) WITH 1,3-PROPANE-
38 DIAMINE (PDA)

1 Approximately 1.5 moles (112g) of PDA was dissolved
2 in a half liter of isopropanol contained in a reactor fitted
3 with a Dean-Stark trap. To the stirred solution at about
4 25°C was added dropwise 1.02 mole (357g) of OSA dissolved in
5 a liter of tetrahydrofuran. Following addition, the sol-
6 vents were distilled off and gradually replaced by xylene.
7 The reaction mixture was refluxed until no more water
8 collected in the Dean-Stark trap (about 8 hours). Upon
9 cooling overnight, solid separated from the xylene solu-
10 tion. Filtration gave a high yield of product which featured
11 an IR spectrum displaying a prominent C=N absorption band at
12 6 microns, and analyzed for 77.15% C, 11.53% H, and 7.06%
13 N. Theory for the title compound (C₂₅H₄₅N₂O) requires
14 77.26% C, 11.41% H and 7.21% N. Attempts to aminate OSA with
15 ethylene diamine in the manner described above gave amino-
16 imide product exclusively.

17 EXAMPLE A2. PREPARATION OF 12-n-OCTYL-2,6,10-
18 TRIAZA-BICYCLO[8.3.0]-TRIDEC-2-EN-11- ONE VIA
19 AMINOLYSIS OF n-OCTYLSUCCINIC ANHYDRIDE WITH 3,3-
20 IMINO-BIS-PROPYLAMINE (IBPA)

21 To a mixture of 14.7g (0.11 mole) of 3,3'-imino-
22 bis-propylamine in 350 ml of refluxing xylene contained in
23 a reactor equipped with a moisture trap was added 21.2g (0.10
24 mole) of n-octyl succinic anhydride in 150 ml of xylene
25 dropwise over a period of six hours. During this period,
26 approximately 2 ml of water were collected in the moisture
27 trap.

28 After refluxing the reaction mixture for about 8
29 hours, an additional 2 ml of water were collected. Removal
30 of the xylene solvent by distillation afforded the title
31 macrobicyclic polyamine product and/or its positional iso-
32 mer isolated in over 80% yield. The liquid product featured
33 an infrared spectrum with a strong absorption band at about
34 6 microns (characteristic C=N stretching frequency) and
35 analyzed for 13.28% N. Theory for the title compound
36 (C₁₈H₃₃N₃O) requires 13.67% N. Attempts to aminate n-

1 octyl succinic anhydride with diethylene triamine in the
2 manner described above afforded linear amino-imide product
3 exclusively.

4 EXAMPLE A3. 15-OCTADEC-2-ENYL-2,6,9-13-TETRA-
5 AZABICYCLO[11.3.0]HEXADEC-1-EN-14-ONE

6 To a mixture of 17.6g (0.101 mole) of 4,7-diaza-
7 decane-1,10-diamine in 200 ml of refluxing xylene was
8 added 35.5g (0.101 mole) of n-octadecenyl-succinic an-
9 hydride (OSA) in 175 ml of xylene dropwise over a period
10 of about four hours. After addition of the OSA reactant,
11 the mixture was refluxed for about two hours. Infrared
12 analysis of the reaction mixture revealed macrobicyclic
13 polyamine formation was progressing as evidenced by an
14 absorption band appearing at 6.0 microns (C=N stretching
15 frequency). After 10 hours of refluxing, 270 ml of
16 xylene were removed. The mixture was again refluxed for
17 four hours at about 150°C. The IR spectrum of the
18 mixture revealed a very strong absorption band at 6.0
19 microns, indicating that macrocycle formation was
20 maximized. The solvent was removed under vacuum, and the
21 residue was sparged with nitrogen at 150°C for about two
22 hours. The title compound and/or its positional isomer
23 (with the n-octadecenyl group at position 16) was isolated
24 in 88% yield (44.7g). The product analyzed for 73.19% C,
25 11.31% H, and 11.38% N. Analysis calculated for C₃₀H₅₇N₄O
26 requires 73.62% C, 11.65% H and 11.45% N.

27 EXAMPLE A4. 16-OCTADEC-2-ENYL-2,6,10,14-TETRA-
28 AZABICYCLO[12.3.0]HEPTA-DEC-1-EN-15- ONE VIA
29 AMINOLYSIS OF n-OCTADECENYL-SUCCINIC ANHYDRIDE
30 (OSA) WITH 4,8-DIAZAUNDECANE-1,11-DIAMINE (DUDD)

31 A sample of DUDD weighing 38.25 g (0.203 mole) was
32 dissolved in 350 ml of xylene and brought to reflux in a
33 reactor fitted with a Dean-Stark moisture trap. To the
34 stirred refluxing solution was added dropwise over six hours
35 71.2g (0.203 mole) of OSA dissolved in 250 ml xylene. After

1 about 8 hours refluxing, a total of 6.6 ml of water was
2 collected. The reaction temperature was increased to 160°C
3 and the remaining solvent was removed by nitrogen sparging
4 for several hours. The macrobicyclic product (96g isolated)
5 showed an IR spectrum with a prominent absorption band at 6
6 microns, and analyzed for 73.65% C, 11.58% H, and 10.63% N.
7 Theory for the title compound (C₃₁H₅₉N₄O) requires 74.0%
8 C, 11.73% H, and 11.13% N.

9
10 EXAMPLE A5. 23-OCTADEC-2-ENYL-2,6,10,13,17, 21-
11 HEXAZA-BICYCLO[19.3.0] TETRACOS-1-EN-22-ONE VIA
12 AMINOLYSIS OF n-OCTADEC-2-ENYL SUCCINIC ANHYDRIDE
13 (OSA) WITH 4,8,11,15-TETRAAZA-OCTADECANE-1,18-
14 DIAMINE(TADD)

15 Crude TADD was distilled through a 30 cm column (1
16 inch O.D.) of glass beads under vacuum. A constant boiling
17 fraction, b.p. 207°C (1mm) was collected. Analysis by mass
18 spectrometry showed the fraction to be 85% TADD, 10% 4,8,11-
19 triazatetradecane-1,14-diamine and 5% 4,8,11,15,19-penta-
20 zadocosane-1,22-diamine. A 30.2g (0.105 mole) sample of
21 this fraction was dissolved in 250 ml of boiling xylene. To
22 the refluxing xylene solution of TADD was added 35g (0.10
23 mole) of OSA dissolved in 250 ml xylene over a period of 9
24 hours. The water of reaction was collected in a moisture
25 trap fitted on the reactor. The mixture was refluxed for
26 about 14 hours, and then concentrated under reduced pres-
27 sure. Sparging the concentrate with nitrogen at 100°C
28 for 2 hours gave 59.2g of product (90% yield of macro-
29 bicyclic polyamine) which featured an IR spectrum having
30 a prominent adsorption band at 6 microns, and analyzing
31 for 72.73% C, 11.69% H, and 14.87% N. Theory for
32 C₃₆H₇₁N₆O requires 71.64% C, 11.77% H and 13.93% N.

33 Treatment of 7.12g (ca. 11.8 millimole) of the
34 title macrobicyclic product dissolved in 50 ml of chloroform
35 with 1.61g (11.8 millimole) of zinc choride gave, after 18
36 hours stirring at room temperature and solvent removal, a
37 brown crystalline solid. The dried product featured a 6.0

1 micron absorption band in the IR, and analyzed for 57.93 C,
2 9.20% H, and 9.73% N. Analysis calculated for $C_{36}H_{71}N_6O-$
3 $ZnCl_2$ complex requires 58.43% C, 9.60% H and 11.36% N. The
4 Zn complex was soluble in chloroform, methanol and xylene,
5 and insoluble in pentane.

6 EXAMPLE A6. SYNTHESIS OF 3,7-DIAZA-TETRACYCLO-
7 [9.2.1.0¹,9.02.7]-TETRADECA- 1,11-DIEN-8-ONE VIA
8 AMINOLYSIS OF NADIC ANHYDRIDE WITH 1,3-PROPANE
9 DIAMINE

10 Eight moles (592g) of 1,3-diamine propane dissolved
11 in liter of xylene were charged into a 5 liter 4-necked re-
12 actor equipped with a moisture trap, and heated to 115°C.
13 Then, 4 moles (656g) of nadic anhydride (5-norbornene-2,3-
14 dicarboxylic anhydride) dissolved in 2 xylene were gradual-
15 ly added to maintain steady refluxing. The mixture was held
16 at reflux until water ceased to collect in the moisture
17 trap. Upon cooling overnight, solid separated from xylene
18 solution. Filtration gave some material characterized as
19 imide product. The supernatant was evaporated to a con-
20 centrate and then mixed with a liter of hexane. The mixture
21 was heated to give a clear solution, which upon standing gave
22 crystals. Filtration gave a substantial yield of crystal-
23 line product which analyzed for 70.18% C, 6.96% H, and
24 13.81 N. IR and ^{13}C NMR spectral data and elemental
25 analysis for the crystalline product are consistent with
26 the title compound.

27 EXAMPLE A7. AMINOLYSIS OF NADIC ANHYDRIDE WITH
28 1,3-PROPANE DIAMINE (PDA) MONO-PARA-TOLUENE-SUL-
29 FONIC ACID SALT.

30 A half mole (37g) of 1,3-propane diamine was
31 acidified with a half mole (95g) of p-toluene sulfonic
32 acid hydrate in 250 ml of ethylene glycol and heated to
33 about 160°C. To the stirred solution was added dropwise

1 over a 2 hour period, a half mole (82g) of 5-norbornene-
2 2,3-dicarboxylic acid anhydride dissolved in 400 ml tetra-
3 hydrofuran (THF). At this temperature (160°C), THF and
4 water of reaction distilled off. After water evolution
5 ceased (ca. 2 hours), the ethylene glycol was removed under
6 vacuum. Addition of 500 ml of acetone to the cooled residue
7 caused the product to precipitate as a white solid.
8 Filtration gave 170g of product which was recrystallized
9 from methylene chloride-ether solution. The crystalline
10 product had an IR and carbon NMR spectra identical with the
11 p-toluene sulfonate salt made from the title product
12 described in Example A6.

13 B. SYNTHESIS OF MACROBICYCLIC POLYAMINE DISPER-
14 SANTS

15 Novel macrobicyclic polyamine dispersants with
16 outstanding sludge and varnish control properties can be
17 designed from a diversity of polyalkenyl succinic anhy-
18 drides including the preferred polyisobutenyl succinic an-
19 hydrides (PIBSA) and heterosubstituted PIBSA reactants.
20 The latter class of acylating agents are obtained by per-
21 oxidizing or sulfenylating the carbon-carbon double bond in
22 PIBSA as taught in U.S. 4,167,514 and 4,302,395 and sub-
23 sequently aminating the heterosubstituted PIBSA reagents
24 according to the process of the present invention.

25 A variety of PIBSA reactants generated by the Ene,
26 Diels-Alder, or free-radical grafting reactions of maleic
27 anhydride with polyisobutene (PIB) and/or chlorinated PIB
28 are readily accessible. The aminolysis of several PIBSA
29 reagents effected by the prior art method and the present
30 invention is elaborated in the example below to show that
31 the mode of addition, i.e. PIBSA to polyamine (present
32 invention) or polyamine to PIBSA will very selectively
33 engender macrobicyclic polyamine or linear imide dispersant
34 product, respectively. Moreover, the macrobicyclic poly-
35 amine dispersants, when compared with the linear imide
36 products feature superior performance in tests designed
37 to measure sludge and varnish control.

1 EXAMPLE B1. MACROBICYCLIC POLYAMINE FORMATION VIA
2 ADDITION OF POLYISOBUTENYLSUCCINIC ANHYDRIDE TO
3 4,7-DIAZADECANE-1,10-DIAMINE

4 About 200g (ca. 0.087 mole) of polyisobutenylsuc-
5 cinic anhydride (PIBSA) prepared via Ene reaction of poly-
6 isobutylene (Mn 1300 by vapor phase osmometry) and maleic
7 anhydride as described by Brois and Gutierrez in U.S. Patent
8 4,239,636, and having a saponification number of 48.5 were
9 dissolved in 200 ml of toluene. The resulting toluene
10 solution was added dropwise to a stirred solution of 15.1g
11 of 4,7-diazadecane-1,10-diamine in 100 ml of toluene at room
12 temperature. This specific mode of addition of anhydride to
13 polyamine selectively affords substantial amounts of amic
14 acid salts as equimolar adducts of anhydride and polyamine.
15 Once polyamine addition was complete, the reaction mixture
16 was heated to refluxing temperature to achieve the cyclo-
17 dehydration of the amic acid salt intermediates. The water
18 of reaction was removed by azeotropic distillation into a
19 moisture trap mounted on the reactor. When water evolution
20 ceased, the toluene was distilled off, and the reaction
21 mixture was then heated to about 175°C and maintained at said
22 temperature for about 9 hours. The reaction mixture was then
23 stripped of residual light ends with a mild stream at
24 nitrogen gas at 175°C for about a half hour, and subsequently
25 filtered. The infrared spectrum of the filtered product
26 showed a strong absorption band at about 6 microns, which is
27 diagnostic of C=N functionality ascribable to the macro-
28 bicyclic polyamine product described in part, as 15-poly-
29 isobutenyl-2,6,9,13-tetraaza-bicyclo [11.3.0] hexadec-
30 1-ene-14-one. Said product analyzed for 1.81% N, and 0.09
31 milliequivalent of primary amine per gram of product.

32 EXAMPLE B2. MACROBICYCLIC POLYAMINE FORMATION VIA
33 ADDITION OF PIBSA TO 4,8-DIAZAUNDECANE-1,11-DI-
34 AMINE

1 About 230 g (ca. 0.1 mole) of the PIBSA described
2 in Example B1 were dissolved in 200 ml of toluene, and
3 transferred to a dropping funnel. The toluene solution of
4 the polyamine was added dropwise to a solution of 18.8g (0.1
5 mole) of 4,8-diaza-undecane-1,11-diamine in 100 ml of tol-
6 uene at room temperature. After anhydride addition was
7 complete, the reaction mixture was heated to refluxing
8 temperature. The water of reaction was collected in a
9 moisture trap mounted on the reactor. When water evolution
10 stopped, the toluene was distilled off, and the reaction
11 temperature reached 175°C.

12 The mixture was stirred at 175°C for about four
13 hours, sparged with gaseous nitrogen for a half hour to
14 remove any remaining volatile components, and finally fil-
15 tered. The filtrate analyzed for 1.97% N, and featured an
16 IR spectrum with a strong absorption band at 6.0 microns
17 which is characteristic of the C=N functionality present in
18 the macrobicyclic polyamine product described in part, as
19 16-polyisobutenyl-2,6,10,14-tetraazabicyclo [12.3.0] hep-
20 tadec-1-en-15-one.

21 LINEAR DISPERSANT SYNTHESIS VIA DIRECT ADDITION ROUTE --
22 COMPARATIVE EXAMPLES B3 AND B4

23 EXAMPLE B3. LINEAR POLYAMINE SUCCINIMIDE FORMATION
24 VIA ADDITION OF 4,7-DIAZA-DECANE-1,10-DIAMINE TO
25 POLYISOBUTENYL-SUCCINIC ANHYDRIDE (1:1 MOLAR RA-
26 TIO)

27 About 200 g (ca. 0.087) mole of the PIBSA described
28 in Example B1 were charged into a reaction flask and heated
29 to 150°C and stirred under a nitrogen atmosphere. About an
30 equimolar quantity (15.1g) of 4,7-diaza-decane-1,10-dia-
31 mine were added dropwise to the neat PIBSA reactant at 150°C
32 over a 15 minute period. After polyamine treatment,
33 the reaction mixture was sparged with nitrogen gas at 150°C
34 for about two hours, and subsequently filtered. The fil-
35 trate featured an infrared spectrum with a strong imide

1 carbonyl absorption band at about 5.9 microns ascribable to
2 linear polyamine imides of PIBSA. The analyses indicate
3 that the product is a mixture of 1(2-polyisobutenylsuc-
4 cinimido)-4,7-diazadecane-10-amine and 1,10-bis-(2-poly-
5 isobutenylsuccinimido)-4,7-diazadecane. The filtered res-
6 idue analyzed for 1.93% N, and 0.24 milliequivalent of
7 primary amine per gram of product.

8 EXAMPLE B4. LINEAR POLYAMINE BIS-IMIDE VIA ADDI-
9 TION OF 4,7-DIAZA-DECANE-1,10-DIAMINE TO POLYISO-
10 BUTENYLSUCCINIC ANHYDRIDE (1:2 MOLAR RATIO)

11 About 200g (ca. 0.087 mole) of the PIBSA described
12 in Example B1 were charged into a reaction flask and heated
13 to about 150°C and stirred under a nitrogen atmosphere.
14 Thereafter, 7.6g (ca. 0.043 mole) of 4,7-diaza-decane-1,10-
15 diamine were added dropwise over a 15 minute period while the
16 reaction temperature was maintained at about 150°C. Once
17 the polyamine addition was complete, the reaction mixture
18 was sparged with gaseous nitrogen for about two hours at
19 150°C, and subsequently filtered. The filtered product
20 featured an infrared spectrum with a dominant imide carbonyl
21 absorption band at about 5.9 microns, analyzed for 1.17% N,
22 and 00.00 meq of primary amine per gram of product. The
23 analytical data are consistent with bis-imide product which
24 can be described mainly as 1,10-bis-(2-polyisobutenylsuc-
25 cinimido)-4,7-diazadecane.

26 A series of macrobicyclic polyamines designed from
27 a representative spectrum of polyisobutenyl succinic an-
28 hydrides using the inverse addition mode of the present
29 invention are described in Table 1. These are Examples B5
30 through B14 in Table 1 below and were prepared following the
31 procedure of Examples B1 and B2. It is noteworthy that the
32 post-treatment of selected macrobicyclic polyamines with
33 metal salts, boric acid, alkylene oxide and additional
34 polyisobutenyl succinic anhydride (PIBSA) also affords ad-
35 ditives having additional multifunctional properties.

36 EXAMPLES B5 AND B6 - USE OF HEAT SOAK PROCESS IN
37 PREPARATION OF MACROCYCLIC POLYAMINES

Example B5

About 228g (~1 mole) of a polyisobutenyl succinic anhydride (PIBSA) of Sap #65 and Mn=1300 obtained via the ene reaction was diluted with solvent 150 neutral mineral to a Sap of 49 were added to 18.8g (~0.1 mole) of 4,8-diazaundecane-1,11-diamine at 80°C for a period of 15 minutes. The reaction mixture was soaked at 100-110°C for 3 hours while stirring under nitrogen blanket. At the end of the third hour the reaction temperature was raised to 175°C and maintained at this temperature for 10 hours. Thereafter, the product was nitrogen stripped at 150°C for one half hour and collected. The final product showed an excellent yield of macrocycle as indicated by the strong absorption at 6.0-6.1 micron of the infrared spectrum and analyzed for 1.96% nitrogen.

Example B6

About 262g of PIBSA of Mn=1300 and Sap No. 103 were added to 31g of 4,8-diazaundecane-1,11-diamine containing 3g of 50% a.i. SA 119 for a period of one half hour at 80°C. When the addition was completed, the reaction mixture was soaked at 80-100°C for 3 hours while stirring under a nitrogen blanket. Thereafter, the temperature was raised to 175-180°C and kept for 10 hours. At the end of the 10th hour, the reaction temperature was lowered to 150°C and the reaction mixture was nitrogen stripped for one half hour. The product showed an intense absorption and had characteristics of macrocyclic materials. It analyzed for 2.58% N.

Table 1

MACROBICYCLIC POLYAMINE DISPERSANTS (MPD)

<u>Example</u>	<u>Polyisobutenylsuccinic anhydride (PIBSA)</u>			<u>Polyamine</u>	<u>MPD</u>
	<u>Type¹</u>	<u>MW²</u>	<u>SAP³</u>		<u>%N</u>
35	Thermal	1300	65	4-azaheptane-1,7-diamine (AHD)	1.46
36	Chloro	1300	103	AHD	

1	B7	Thermal	1300	65	4,7-diazade-	1.98
2					cane 1,10-di-	
3					amine (DADD)	
4	B8	Thermal	1300	65	DADD	1.57
5	B9	Thermal	1300	65	DADD	1.83
6	B10	Grafted	1300	65	DADD	2.31
7	B11	Chloro	2300	67	DADD	—
8	B12	Thermal	1300	65	4,8,11,15-te-	2.54
9					tetraazaocta-	
10					decane-1,18-	
11					diamine	
12					(TAOD mixture) ⁴	
13	B13	Grafted	1300	65	TAOD mixture	—

14 1) The preparation of the requisite PIBSA reactants
15 is described in U.S. Patents 3,306,980; 4,239,636 and U.K.
16 Patent 1,398,000. Grafted PIBSA can be obtained by reacting
17 a polyisobutene (PIB) and maleic anhydride in the presence
18 of an organic peroxide at an elevated temperature according
19 to Example 1 of U.K. Patent 1,398,000. Chloro PIBSA is
20 prepared by heating chlorinated PIB and maleic anhydride
21 together at elevated temperatures according to U.S. Patents
22 3,306,980 and 4,239,636. Thermal PIBSA is produced by
23 simply heating PIB and maleic anhydride together at about
24 200°C according to the procedures outlined in U.S. Patents
25 3,306,908 and 4,239,636.

26 2) MW designates the molecular weights of the PIB
27 reactants determined by vapor phase osmometry (VPO).

28 3) SAP designates the saponification number.

29 4) Commercial TAOD is a product of BASF Wyandotte
30 Corporation, Parsippany, NJ (BASF identifies this product
31 as "N₆-amine mixture"). According to BASF's Technical
32 Bulletin, commercial TAOD consists mainly (over 50%) of
33 4,8,11,15-tetra-aza-octadecane-1,18-diamine (TAOD); addi-

1 tional components include higher and lower homologs. The
2 total nitrogen content is ca 28.5%, comprising 12% primary,
3 15% secondary and 1.7% tertiary nitrogen.

4 C. SYNTHESIS OF BICYCLIC AND MACROBICYCLIC
5 POLYAMINE DISPERSANT VI IMPROVERS

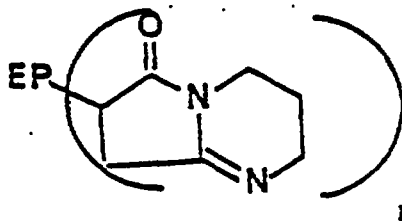
6 Novel compositions of the instant invention having
7 both dispersant and viscosity-index (VI) improving pro-
8 perties are prepared by the addition of polymers function-
9 alized with succinic anhydride groups to the selected
10 polyamines taught in the present invention. Virtually all
11 polymers bearing succinic anhydride groups are responsive
12 to the process of the present invention in generating the
13 corresponding bicyclic and macrobicyclic polyamine derivatives.
14 The following examples are used simply to illustrate the
15 formation of the bicyclic and macrobicyclic polyamines
16 using the readily available maleic anhydride grafted ethyl-
17 ene-propylene copolymer, i.e., ethylene propylene-succinic
18 anhydride (EPSA) as taught in Example 1 of U.S. 4,089,794;
19 4,137,185; and 4,144,181.

20 EXAMPLE C1. SYNTHESIS OF 2,6-DIAZA-7-OXO-BICYCLO-
21 [4.3.0] NON-1-EN-8-YL SUBSTITUTED ETHYLENE PROPY-
22 LENE(EP) COPOLYMER VIA THE AMINOLYSIS OF SUCCINIC
23 ANHYDRIDE SUBSTITUTED EP(EPSA) WITH 1,3,PROPANE
24 DIAMINE (PDA).

25 An 11% mineral oil (Solvent 100 Neutral) solution
26 of EP copolymer of Mn = 50,000 and was grafted with maleic
27 anhydride by heating in the presence of peroxide as shown in
28 Example 1 of U.S. Patent 4,089,794 to provide an EPSA having
29 an acid value of about 0.14 meq. per gram of polymer.

30 About 200gms of this EPSA and grafted oil was
31 dissolved in 100ml xylene and added dropwise to a stirred
32 solution of 10 gms (.135 mol) of PDA and 100ml of xylene at
33 room temperature. The reaction mixture was gradually heated
34 to reflux to distill off the xylene and water of reaction.
35 When water evolution ceased, the mixture was heated to 200°C
36 and sparged with nitrogen for about 2 hours. The IR spectrum

1 of the product had a prominent C = N band at about 6 microns,
2 which is characteristic of the bicyclic polyamine struc-
3 ture. Imide absorption was absent. The product analyzed
4 for 0.34% nitrogen and had a viscosity of 2366cSt. at 100°C.
5 The product is represented below with n being approximately
6 5.



11 **EXAMPLE C2.**

12 A. The product described in Example C1 was prepared
13 by adding the EPSA to a refluxing solution of PDA and xylene
14 until evolution of water ceased. Analyses confirmed that
15 the product was the same as that formed in Example C1.

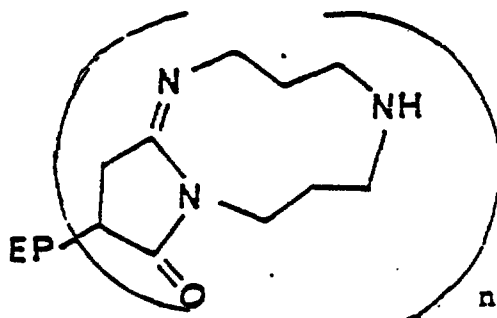
16 B. Example C1 was repeated except that the amine
17 used was replaced with 0.315 mole of 2-hydroxy-1,3-propane-
18 diamine. The resulting hydroxy substituted bicyclic poly-
19 amine product contained 0.38% nitrogen.

20 **EXAMPLE C3. IMIDATION OF EPSA WITH 1,3-PROPANE-**
21 **DIAMINE**

22 This example was carried out for comparative pur-
23 poses and illustrates prior art technique. A solution of 3g
24 PDA in 100ml of xylene was added dropwise to 200gms of EPSA
25 in 100ml of xylene stirred at 160°C. A gel formed but
26 despite gelation, the PDA addition was completed and the re-
27 action mixture stirred at 180°C for about 2 hours. Solvent
28 was removed by nitrogen sparging at 180°C for 2 hours and a
29 thickened polymer solution with an IR spectrum featuring a
30 prominent imide absorption band. The product was too thick
31 for viscosity measurement at 100°C. These data clearly
32 indicate the presence of a linear chain extended product.

1 EXAMPLE C4. ATTACHMENT OF 2,6,10-TRIAZA-11-OXO-
2 BICYCLO[8.3.0]DODEC-1-EN-12-YL FUNCTIONALITY ONTO
3 EP COPOLYMER VIA AMINOLYSIS OF EPSA WITH 4-
4 AZAHEPTANE-1,7-DIAMINE (AHD)

5 200 gms of the EPSA of Example C1 were dissolved in
6 100ml xylene and added dropwise to 1.83gm of AHD in 100 ml
7 of xylene at room temperature. The mixture was gradually
8 heated to reflux. The xylene and water of reaction were
9 distilled from the reaction mixture which was then sparged
10 with nitrogen at 180° for 1 hour. Analysis of the polymer
11 solution by IR revealed macrobicyclic polyamine function-
12 ality (prominent absorption band at about 6 microns as
13 depicted in the formula below. The product contained 0.5
14 weight percent nitrogen; n is approximately 5.



20 EXAMPLE C5. SYNTHESIS OF 2,6,9,13-TETRAAZA-14-
21 OXO-BICYCLO[11.3.0] HEXADEC-1-EN-15-YL SUBSTITUTED
22 EP COPOLYMER VIA AMINOLYSIS OF EPSA WITH 4,7-
23 DIAZA-DECANE-1,10-DIAMINE(DADD)

24 200gms of the EPSA of Example C1 were dissolved in
25 200ml xylene at a dropwise to 6gms (34 millimoles of DADD)
26 in 100 ml of xylene at about 25° under a nitrogen atmosphere.
27 The stirred reaction mixture is heated to 180°C and the
28 xylene together water of reaction were gradually distilled
29 off. The resulting polymer solution in Solvent 150 Neutral
30 mineral oil was sparged with nitrogen and the reaction
31 temperature was maintained at 180°C. The polymer solution

1 featured an IR spectrum with an intense C = N absorption
2 band, analyzed for 0.63 percent nitrogen, and had a kine-
3 matic viscosity of 365 cSt at 100°C.

4 EXAMPLE C6.

5 A product of Example C5 was prepared, except
6 that the EPSA was added to a refluxing xylene solution of the
7 polyamine. Analyses confirmed the preparation of the same
8 product.

9 EXAMPLE C7

10 This example is for comparative purposes. The same
11 reactants were used as in Example C5, except that to a
12 stirred solution of the EPSA in xylene at 160°C was added
13 dropwise 2.1 grams (0.012 mole) of DADD over an hour
14 period. A rapid increase in viscosity was observed and the
15 reaction mixture assumed a gel-like appearance. Heating was
16 continued to distill off the xylene; the residue was heated
17 to 200°C for about 2 hours. The thickened polymer solution
18 showed an IR spectrum with a prominent imide carbonyl
19 absorption band at 5.95 microns, analyzed for 0.62% nitro-
20 gen and had a kinematic viscosity of 1587 cSt at 100°C.

21 EXAMPLES C-8 to C-12

22 Table 2 below contains an additional listing of
23 dispersant - VI improvers derived from various ethylene-
24 propylene (EP) copolymers grafted with maleic anhydride
25 under varying conditions. The EP copolymer was 43 wt%
26 ethylene of varying molecular weight.

TABLE 2

Ex.	Polymer Graft Type	Polymer Mn ($\times 10^{-3}$)	Polyamine	%N
C8	EP - Grafted in dichloro-benzene	54	PDA	0.08
C9	EP - Grafted in polyisobutylene ^a diluent	27	PDA	0.27
C10	EP- Grafted in Oil ^b	50	IBPA	0.48
C11	EP- Grafted in Oil	50	DADD	0.62
C12	EP- Grafted in Oil	50	TAOD	0.92
(a) Mn = 500				
(b) Oil was a Solvent 100 Neutral mineral oil				

D. EXAMPLES OF DISPERSANTS PREPARED VIA AMINATION OF PIBSA WITH AZA CROWN AND AZA POLYCYCLIC COMPOUNDS.

EXAMPLE D1. AMINOLYSIS OF PIBSA WITH 1,4,9,11-TETRA-AZACYCLOTETRADECANE (CYCLAM)
6.5 gms of the PIBSA described in Example B1 and 0.5gm (2.5 millimoles) of cyclam were combined and heated to 150°C; the reaction mixture was stirred for several hours at 150°C and then nitrogen sparged for two hours. The concentrate analyzed for 1.65% nitrogen, and had an IR spectrum with carbonyl absorption characteristic of an acylated cyclam product.

The above procedure was repeated except the amount of PIBSA used was doubled to reflect further acylation of the cyclam compound. The final product analyzed for 1.13% nitrogen.

EXAMPLE D2. AMINOLYSIS OF PIBSA WITH HEXACYCLEN(1,4,7,10,13,16- HEXAAZACYCLOOCTADECANE).

Equimolar amounts of the aza crown compound and the PIBSA of Example B1 were combined and heated at 150°C, the mixture was stirred at this temperature for two hours

1 and nitrogen sparged for 1 hour. The acylated hexacyclen
2 product contained 1.5% nitrogen.

3 The procedure above was repeated except the
4 amount of PIBSA was doubled. The final product contained
5 .85% nitrogen.

6 EXAMPLE D3. AMINOLYSIS OF PIBSA WITH 3,7,11-
7 TRIMETHYL-2,6,10,13-TETRAAZA-TRICYCLO [7.3.1.0^{5,13}]
8 TRIDECANE(TTT).

9 Approximately 115gms (0.05 moles) of the PIBSA
10 of Example B1 and 11.2gms (0.05 moles) of TTT were dis-
11 solved in 100mls xylene. The mixture was refluxed 2
12 hours, nitrogen sparged and filtered to give an acylated
13 aza polycyclic product which analyzed for 1.05% nitrogen.

14 EXAMPLE D4. AMINOLYSIS OF PIBSA WITH 1,4,8,11-
15 TETRAAZATRICYCLO-[8.4.0.0^{4,9}]TETRADECANE (TATT).

16 173gms (0.1 mole) of PIBSA of Example B8 and
17 19.6gms (0.1 mole) of TATT were combined and heated at 180°
18 for 2 hours, nitrogen sparged for 1 hour at 180°C. The
19 acylated aza polycyclic product analyzed for 2.76%
20 nitrogen

21 E. DISPERSANT-VI IMPROVERS VIA AMINATION OF EPSA WITH
22 AZA CROWN AND AZA POLYCYCLIC COMPOUNDS

23 EXAMPLE E1. MODIFICATION OF EPSA WITH 12,12-
24 DIMETHYL-2,6,10-TRIAZABICYCLO[8.3.0] TRIDEC-1-
25 EN-11-ONE(TBT).

26 3.4gms (15.2 millimoles) of TBT was dissolved in
27 100ml of xylene and mixed with 55gms of the EPSA des-
28 cribed in Example C1; the reaction mixture was gradually
29 heated to 150° for 1 hour to distill off xylene and water
30 of reaction, then sparged with nitrogen at 160° for 1
31 hour. The acylated aza crown compound analyzed for
32 0.87% nitrogen.

1 EXAMPLE E2. AMINATION OF EPSA WITH 3,7,11-TRI-
2 METHYL-2,6,10,13-TETRAAZATRICYCLO [7.3.1.0^{5,13}]
3 TRIDECANE(TTT).

4 100gms of EPSA of Example C1 and 3.1 gms (0.014
5 moles) of TTT were combined and heated at 180° for 2
6 hours, nitrogen sparged at 190°C for 1 hour and cooled.
7 The acylated azapolycyclic product analyzed for 0.43%
8 nitrogen.

9 E3. AMINATION OF EPSA WITH 1,4,8,11-TETRAAZATRI
10 CYCLO[8.4.0.0^{4,9}]TETRADECANE(TATT)

11 100 gms of the EPSA of Example C1 were mixed
12 with 2.7 gms (13.8 millimoles) of TATT, heated to about
13 200° and maintained at this temperature for 2 hours with
14 nitrogen sparging. The acylated aza polycyclic product
15 contained 1.05% nitrogen.

16 EXAMPLE E4. AMINATION OF EPSA WITH 1,4,7,9-
17 TETRAAZATRICYCLO[6.3.1.0^{4,12}]-DODECANE (TATD).

18 100gms of the EPSA of Example C1 were mixed with
19 2.4gms (14.3 millimoles) of TATD and gradually heated to
20 200°C. The mixture was maintained at 200°C with nitrogen
21 sparging for 2 hours. The acylated aza polycyclic product
22 analyzed for 1.0% nitrogen.

23 In Tables 3 and 4 below the products of this in-
24 vention were evaluated for sludge and varnish potency in the
25 SIB (Sludge Inhibition Bench Test) and VIB (Varnish Inhi-
26 bition Bench Test). Comparative Tests with prior art
27 products were also conducted. These tests are described
28 below:

29 The SIB test employs a used crankcase mineral lu-
30 bricating oil composition having an original viscosity of
31 about 325 SUS at 37.8°C that has been used in a taxicab that
32 was driven generally for short trips only, thereby causing
33 a buildup of a high concentration of sludge precursors. The
34 oil that was used contained only a refined base mineral oil,

1 a viscosity index improver, a pour point depressant and zinc
2 dialkyldithiophosphate anti-wear additive. The oil con-
3 tained no sludge dispersants. The quantity of such used oil
4 was acquired by draining and refilling the taxicab crankcase
5 at 1,000 - 2,000 mile intervals.

6 The SIB test is conducted in the following manner:
7 The used crankcase oil is freed of sludge by centrifuging for
8 one half hour at about 39,000 gravities (gs). The resulting
9 clear bright red oil is then decanted from the insoluble
10 sludge particles thereby separated out. However, the super-
11 natant oil still contains oil-soluble sludge precursors
12 which under the conditions employed by this test will tend
13 to form additional oil-insoluble deposits of sludge. The
14 sludge inhibiting properties of the additives being tested
15 are determined by adding to portions of the used oil, a small
16 amount of the particular additive being tested. Ten grams
17 of each one being tested is placed in a stainless steel
18 centrifuge tube and is heated at 137.8°C for 16 hours at the
19 presence of air. Following the heating, the tube containing
20 the oil being tested is cooled and then centrifuged for 30
21 minutes at about 39,000gs. Any deposits of new sludge that
22 forms in this step are separated from the oil by decanting
23 supernatant oil and then carefully washing the sludge
24 deposits with 15 ml. of pentane to remove all remaining
25 oils from the sludge. The weight of the new solid sludge
26 that formed in test, in milligrams, is determined by drying
27 the residue and weighing it. The results are reported as
28 milligrams of sludge per ten grams of oil, thus measuring
29 differences as small as one part per ten thousand. The less
30 new sludge formed, the more effective is the additive as a
31 dispersant. In other words, if the additive is effective,
32 it will hold at least a portion of the new sludge that forms
33 on heating and oxidation stably suspended in the oil so that
34 it does not precipitate down during the centrifuging period.

35 In the VIB test, a test sample consisting of ten
36 grams of lubricating oil containing the additive being
37 evaluated is used. The test oil is a commercial lubricating

1 oil obtained from a taxi after two thousand miles of driving
2 with said lubricating oil. Each sample is heat soaked
3 overnight at about 140°C and thereafter centrifuged to
4 remove the sludge. The supernatant fluid of each sample is
5 subjected to heat cycling from about 150°C to room tem-
6 perature over a period of 3.5 hours at a frequency of about
7 two cycles per minute. During the heating phase, a gas -
8 containing a mixture of 0.7 volume percent SO₂, 1.4 volume
9 percent NO and the balance air was bubbled through the test
10 samples and during the cooling phase, water vapor was
11 bubbled through the test samples. At the end of the test
12 period, which testing cycle can be repeated as necessary to
13 determine the inhibiting effect of any additive, the wall
14 surfaces of the test flasks in which the samples were
15 contained are visually evaluated as to the varnish inhi-
16 bition. The amount of varnish imposed on the walls is
17 rated at values of from one to seven with the higher
18 number being the greater amount of varnish. It has been
19 found that this test correlates with the varnish results
20 obtained as a consequence of carrying out ASTM-MS-VC
21 engine tests.

22 EXAMPLE G1. EVALUATION OF DISPERSANTS IN THE SIB
23 AND VIB TESTS

24 A series of SIB and VIB evaluations were carried out
25 comparing macrobicyclic and polycyclic polyamine disper-
26 sants of this invention with non-cyclic linear bis-imide
27 dispersants prepared utilizing the prior art conditions
28 which do not provide the macrocyclic structure.

29 Included in the testing for comparative purposes
30 are two dispersants CD-1 and CD-2 which are representative
31 of current commercially available products and are made
32 by aminating PIBSA of Mn 900 and 1300 respectively with
33 tetraethylene pentamine to give polyisobutenyl succinimide
34 products which are linear bis-imide structures. These
35 results are in the table below.

<u>TABLE - EXAMPLE G1</u>				
		SIB RESULTS		VIB
<u>4</u>	<u>ADDITIVE</u>	<u>TYPE</u>	<u>MG SLUDGE/10.0g Oil</u>	<u>RATING</u>
	<u>EXAMPLE</u>			
5	Ex B-1	M	0.00	3
6	EX B-4	L	2.93	5
7	EX B-8	M	0.21	2
8	EX B-10	M	0.68	3
9	EX B-11	M	0.38	3
10	EX B-12		0.00	2
11	EX D-4	PC	0.48	2
12	CD-1	L	4.54	5
13	CD-2	L	5.29	5
14	' M = macrobicyclic; PC = polycyclic; L = Linear			

EXAMPLE G2. EVALUATION OF DISPERSANT VI IMPROVERS
IN THE SIB AND VIB TESTS.

A number of products of the invention as prepared in the foregoing examples are suitable as dispersant - VI improvers were evaluated in the SIB/VIB tests and compared for activity against a compound representative of current commercially suitable products. These results are tabulated below.

In the table, BC, MBC and PC represent the structural categorization of the products of the invention, i.e., bicyclic, macrobicyclic and polycyclic polyamine dispersant- VI improvers, respectively. CD-3 is a product which qualifies under commercial standards and is made by reaction of EPSA (Ex. C1) and N-(3-aminopropyl) morpholine, and is included for comparative purposes.

TABLE - EXAMPLE G-2

1	ADDITIVE	TYPE(1)	SIB RESULTS MG SLUDGE IN 10.0 g OIL	VIB RATING
2	EXAMPLE	TYPE(1)	SIB RESULTS MG SLUDGE IN 10.0 g OIL	VIB RATING
5	C1	BC	2.04	1.5 - 2
6	C2A	BC	3.97	1.5 - 2
7	C B	BC	2.93	1.5 - 2
8	C5	MBC	1.55	1 - 2
9	C6	MBC	0.42	1.5 - 2
10	C8	BC	4.70	1 - 2
11	C9	BC	2.72	2 - 3
12	C10	BC	1.36	2
13	C11	MBC	1.75	1.5 - 2
14	C12	MBC	2.51	1 - 2
15	E2	PC	1.25	2 - 2.5
16	E3	PC	2.37	2
17	E4	PC	2.09	2
18	CD-3	IMIDE	6.29	5

EXAMPLE H1

Engine tests were carried out using the novel dispersant - V.I. improver multifunctional additives of this invention in the Caterpillar 1H-2 test. Lubricating oil formulations of 10W30 quality were prepared containing the novel bicyclic polyamine additive of the present invention (Example C-2A product) and these were tested in comparison with a "Base" Formulation which contained a borated polyisobutylene (Mn=980) succinic anhydride - alkylene polyamine dispersant and with a "Comparison" formulation which employed a multifunctional commercial dispersant - V.I. improver, "Acryloid 1155" which is available from Rohm & Haas Co., Philadelphia, PA and is a C-vinyl pyridine ethylene copolymer graft. The lubricating oils evaluated also contained, where required, conventional V.I. improver, a rust inhibitor, a metal detergent and a zinc dialkyldithiophosphate in a mineral oil base. These formulated oils were each subjected to engine testing in the

1 "Caterpillar 1H-2" test which is an industry and government
2 accepted test for the dispersancy and overall effectiveness
3 of diesel oil lubricants. The results and explanation of the
4 test are given below:

240 Hour Caterpillar 1H-2 Test		
Formulation	TGF ²	WTD ³
Base ¹	16.6%	189.1
Comparison		195
Example C2A		119
¹ Base	this result is an average data base for comparison in evaluating new diesel formulations and is an average of 25 engine tests.	
² TGF	top groove fill, % deposits in groove	
³ WTD	weighted total demerits	

15 The Caterpillar 1H-2 test is also a U.S. Federal
16 Test Method 791-346 and is used to meet military specifications, such as MIL-L-21260B and industry specifications, such as SAE 183 and General Motors GM 6146M. The purpose of the test is to determine the effect of an oil on ring sticking, wear and accumulation of deposits. The test uses a single cylinder Caterpillar diesel 5 1/8" x 6 1/2".

22 For the 1H-2 test WTD (Weighted Total Demerits)
23 is the principal value and for a 240 hour test, the target specification is a value near the 90-100 range. This is derived from the published specification target for a 480 hour test. WTD is cumulative rating based on observation of deposits in the groove and land areas of the piston and lacquer on piston skirts with all these specific evaluations being weighted according to their relative importance and the final WTD value being calculated in accordance with the test procedure.

32 EXAMPLE H2

33 A lubricating oil composition of 10W40 quality
34 containing macrocyclic polyamine dispersant. Example B12
35 of the present invention together with conventional amounts
36 of other additives to provide their normal attendant func-

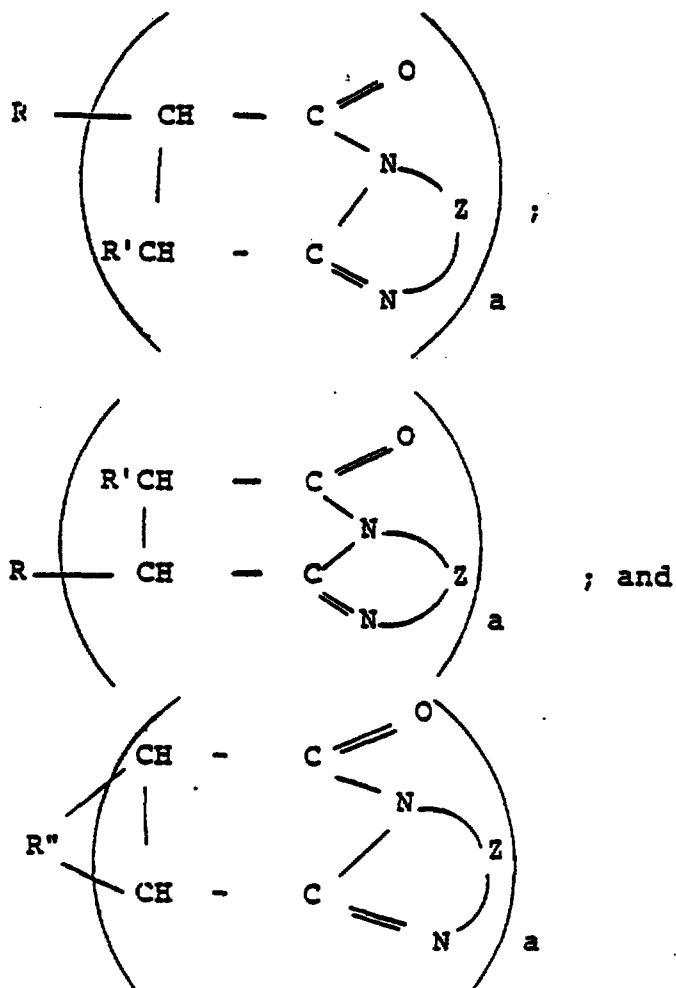
1 tions such as viscosity index improver, rust inhibitor,
2 metal detergent additive, antioxidant, and zinc dialkyl-
3 dithiophosphate anti-wear additives was evaluated in the
4 ASTM VD gasoline engine test. For gasoline engine lube
5 oils to meet the current "SF" designation of the American
6 Petroleum Institute, lubricating oil formulations must
7 equal or exceed certain values in the MS Sequence VD Engine
8 Test (ASTM Special Publication 315). For dispersancy
9 the significant values in this test are a minimum of 9.4
10 sludge, 6.7 piston skirt varnish and 6.6 average varnish.
11 The Sequence VD uses a 1980 Ford 2.3 liter 4-cylinder en-
12 gine and is a 192-hour test comprising the cyclic operation
13 at varying engine speeds and temperature to simulate "stop
14 and go" city driving and moderate turnpike operation. The
15 test is an established industry standard. The lubricating
16 oil of this Example gave the following outstanding results:

17	Sludge	9.49
18	Piston Skirt Varnish	8.18
19	Average Varnish	8.88



CLAIMS:

1. An oil-soluble macrocyclic polyamine compound being a member of the group of compounds and mixtures thereof having the formulas:



where R' is hydrogen or lower C₁-C₁₂ alkyl, R is a hydrocarbon substituent having 2 to 15,000 carbon atoms, R'' is a hydrocarbon substituent of 4 to 15,000 carbon atoms, Z may be -CH₂CH₂CH₂-; -(CH₂CH₂CH₂NH)_nCH₂CH₂CH₂ - where n is 1-6; or (CH₂CH₂CH₂NH)_mCH₂(CH₂)_p(NH-CH₂CH₂CH₂)_{m'} - where m and m' are each at least 1 and m + m' is 1-5, p is 1-4, and a is 1-20.

2. The compound of claim 1 wherein R is a polyisobutylene of Mn 900 to 2,000 and R' is hydrogen.



3. The compound of claim 1 wherein R is an ethylene propylene copolymer or terpolymer of Mn 10,000 to 80,000.

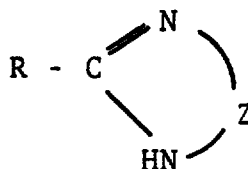
4. The compound of claim 1 wherein Z is $-\text{CH}_2\text{CH}_2\text{CH}_2-$ or $\text{CH}_2\text{CH}_2\text{CH}_2(\text{NHCH}_2\text{CH}_2\text{CH}_2)_n$ wherein n is 1-5.

5. The compound of claim 1 where a is 1-8 and R is an ethylene propylene copolymer or terpolymer of Mn 10,000 to 200,000.

6. The compound of claim 5 wherein R is a styrene isoprene copolymer.

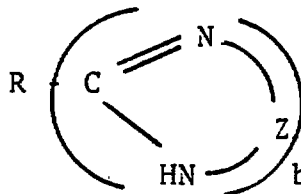
7. A lubricating oil composition comprising a major amount of an oil of lubricating viscosity and 0.01 to 20 wt% of the macrocyclic compounds of claims 1-6.

8. An oil-soluble macrocyclic polyamine compound having the formula



where R is a hydrocarbon having 2 to 15,000 carbon atoms and Z may be $-\text{CH}_2\text{CH}_2\text{CH}_2-$; $(\text{CH}_2\text{CH}_2\text{CH}_2\text{NH})_n\text{CH}_2\text{CH}_2\text{CH}_2-$ where n is 1-6 or $(\text{CH}_2\text{CH}_2\text{CH}_2\text{NH})_m\text{CH}_2\text{CH}_2(\text{NH}-\text{CH}_2\text{CH}_2\text{CH}_2)_{m'}$ wherein $m + m'$ is 1-5.

9. An oil-soluble macrocyclic polyamine compound having the formula:





wherein R is hydrocarbon having 2 to 15,000 carbon atoms, b may be 2 -150, Z may be $-\text{CH}_2\text{CH}_2\text{CH}_2-$; $(\text{CH}_2\text{CH}_2\text{CH}_2\text{NH})_n \text{CH}_2\text{CH}_2\text{CH}_2-$ wherein n is 1-6 or $(\text{CH}_2\text{CH}_2\text{CH}_2\text{NH})_m \text{CH}_2\text{CH}_2(\text{NH}-\text{CH}_2\text{CH}_2\text{CH}_2)_m$, - wherein m + m' is 1-5.

10. A method for preparing in a cyclodehydration reaction an oil-soluble hydrocarbon substituted macrocyclic polyamine compound comprising (i) in a first step reacting a poly 3-aminopropyl amine compound of the formula $\text{NH}_2-\text{Z}-\text{NH}_2$ wherein Z may be $-\text{CH}_2\text{CH}_2\text{CH}_2-$; $(\text{CH}_2\text{CH}_2\text{CH}_2\text{NH})_n \text{CH}_2\text{CH}_2\text{CH}_2-$ wherein n is 1-6 or $(\text{CH}_2\text{CH}_2\text{CH}_2\text{NH})_m \text{CH}_2(\text{CH}_2)_p(\text{NH}-\text{CH}_2\text{CH}_2\text{CH}_2)_m$, - wherein p is 1-4 and m and m' are each at least 1 and m + m' is 1-5 with a $\text{C}_2-\text{C}_{15,000}$ monocarboxylic acid or polycarboxylic acid or $\text{C}_2-\text{C}_{15,000}$ hydrocarbon substituted succinic anhydride, by addition of said carboxylic acid or succinic anhydride to an initial excess of said amine compound at a rate such that there is formed an amic acid salt intermediate from said anhydride or an amine carboxylate salt intermediate from said carboxylate and at a temperature of about 20°C up to about 100°C in an inert solvent and, after said addition is complete (ii) in a second step maintaining the temperature of the reaction mixture at about 130°C to 250°C thereby causing cyclodehydration of said intermediates and formation of the macrocyclic polyamine compound.

11. The method of claim 10 wherein said second step is conducted at a temperature of about 140°C to 175°C .

12. The method of claim 10 which further comprises the step of heat soaking the reaction mixture at a temperature of 80°C to 130°C for 1 to 3 hours prior to increasing the temperature to cause cyclodehydration and formation of the macrocyclic polyamine compound.



13. The method of claim 12 wherein cyclodehydration is conducted at a temperature at least 20°C higher than the temperature of said heat soaking.

14. The method of claims 10-13 wherein the hydrocarbon succinic anhydride is polyisobutenyl succinic anhydride of Mn=900 - 2,000.

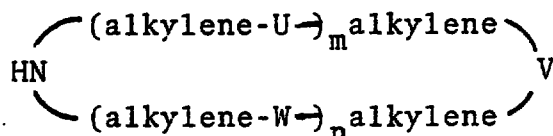
15. The method of claim 14 wherein the heat soaking is conducted at a temperature of 80°C to 110°C and the cyclodehydration is conducted at a temperature of 175°C to 180°C.

16. The method of claim 10 wherein a strong acid catalyst is added to the amine prior to adding said carboxylic acid or succinic anhydride to said amine.

17. The method of claim 16 wherein said acid is an oil soluble alkyl benzene sulfonic acid.

18. A lubricating oil additive concentrate composition comprising a major amount of oil of lubricating viscosity and about 10 to 49 wt% of the macrocyclic polyamine compound of claims 1-9.

19. An oil soluble macrocyclic polyamine compound being the reaction product of a hydrocarbon succinic anhydride or carboxylic acid having 8 to 15,000 carbon atoms with an aza macrocyclic compound having at least 2 NH groups and represented by the formula



where U, V and W may be NH, S or O, n and m are integers of 1 to 4, alkylene is C₂-C₄.