SPECIFICATION

Lubricating Grease Composition Containing Pyrrolidone Compound(s) as a Grease Thickener

This invention relates to a multipurpose lubricating grease composition having desirable high temperature properties. More particularly, this invention involves a lubricating grease composition comprising a lubricating base oil and an effective amount of one or more defined pyrrolidone compounds as a grease thickener.

A wide variety of thickening agents for greases have been developed over the years. including the alkali salts of fatty acids, clays, polyureas, asbestos, carbon black, silica gels, aluminium complexes, polymers, phthalocyanines, indanthrenes, etc. Despite the number and wide variety of such thickeners, over 90 percent of world-wide grease production uses alkali metal soaps as the thickening agent. The only non-soap thickeners which have achieved commercial importance are the aluminium complexes, clays and polyureas, and then only to a very limited extent.

The soap thickeners which have been mainly used are derived from the saponification of fats and oils by lithium or calcium hydroxides, although the sodium or barium soaps have been used in smaller amounts for special applications. The fats and oils employed are mostly mixtures of C_{16} and C_{18} fatty acid precursors, with the preferred soap being lithium 12-hydroxystearate. This preferred lithium soap currently constitutes the thickener in over 50 percent of all greases manufactured, and in almost all the premium multipurpose greases manufactured. Lithium soap greases are described and exemplified in many patents, for example U.S. Patent Nos. 3,758,407; 3,791,973; 3,929,651.

While a variety of thickeners have been developed, as noted above, they generally do not give equivalent performance to lithium 12-hydroxystearate, particularly in the critical areas of high temperature application, shear stability, water resistance and additive compatibility.

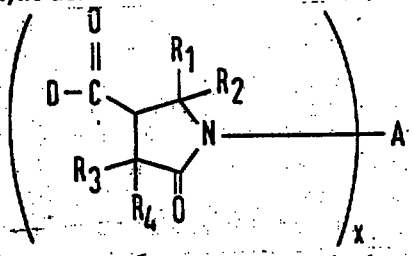
Although 12-hydroxystearic acid is the most desirable fatty acid grease thickening component, it does have some supply and economic problems associated with it. Furthermore lithium, although readily available in many parts of the world, is expensive.

Accordingly, there is need of a new grease thickener system that reduces or eliminates dependence on 12-hydroxystearic acid, reduces or eliminates lithium usage, but still has acceptable performance.

The present invention relates to a lubricating grease composition comprising a lubricating base oil and an effective amount of one or more of the pyrrolidone compounds hereafter defined as a, or the, thickening agent. Although said pyrrolidone compound(s) thickening agent may be employed with any of the previously known thickening agents which are compatible with it, it is preferred that it is employed as the sole thickening agent.

A lubricating grease composition of this invention has one or more improved properties such as shear stability, reduced oil separability, additive compatibility, water resistance and high temperature performance.

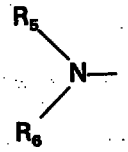
The pyrrolidone compound(s) used in the lubricating grease composition of the invention is/are derived from 2-pyrrolidone-4-carboxylic acid and has/have the following general formula:



where x is 1 to 3, preferably 1 or 2, and most preferably 2; A is a hydrocarbyl group as hereinafter defined of 1 to 50 and preferably 1 to 25 carbon atoms; D is a group as hereinafter defined, there being at least one long chain hydrocarbyl group of at least 12 carbon atoms present in either D or A; and R_1, R_2, R_3 and R_4 are each hydrogen or a hydrocarbyl group of 1 to 6, preferably 1 to 4, carbon atoms.

In the above-described pyrollidone compound the group A is a hydrocarbyl group and this is defined with respect to group A as including hetero oxygen, sulfur and nitrogen atoms. Preferably (a) A is an alkyl, aryl, alkaryl or aralkyl group of 1 to 50, preferably 1 to 25 and more prefereably 1 to 15 carbon atoms when x is 1; (b) A is an alkylene, arylene, alkarylene or aralkylene of 1 to 50, preferably 1 to 25 and more preferably 12 to 22 carbon atoms when x is 2; and (c) A is a trivalent hydrocarbyl radical of 1 to 50, and preferably 1 to 25 carbon atoms when x is 3. It is noted that the unsaturated counterparts of the A groups defined above may be used; however, the saturated groups are preferred.

D is represented by an MO—, a



or an R_7O— group where M is a metal selected from Group I or Group II of the Periodic Table (Mendeleev Table as in Hackh Chemical Dictionary 1969, page 115) or aluminum and more particularly the alkuli metals and the alkaline earth metals, i.e., lithium, sodium, calcium, barium, strontium and magnesium with lithium and sodium being preferred and more preferably lithium. One of R_5 and R_6 can be hydrogen, whilst the other (or both if no hydrogen present) will be hydrocarbyl, which is defined for R_5 and/or R_6 as including alkyl, aryl, alkaryl or aralkyl groups and the unsaturated counterparts thereof of 1 to 50, preferably 1 to 30 and more preferably 1 to 25 carbon atoms, and also includes hetero oxygen or nitrogen atoms interspersed therein. Thus, for example, R_5 and R_6 groups may contain oxyalkylene groups, particularly oxyethylene and oxypropylene and also may contain nitrogen when a polyamine is used to neutralise the acid group. R_7 may be a hydrocarbyl group and more particularly an alkyl, aryl, alkaryl or aralkyl group and the unsaturated counterparts thereof of 1 to 50, preferably 1 to 30, and more preferably 1 to 25 carbon atoms and additionally, R_7 may be hydrogen. The saturated forms of R_5, R_6 and R_7 are particularly preferred. R_1, R_2, R_3 and R_4 in the above structure will preferably be hydrogen or alkyl of 1 to 6 and more preferably 1 to 4 carbon atoms. It is more preferable that such R groups are hydrogen.

It is further understood that branch-chained structures and other isomers thereof are contemplated by the described pyrrolidone structure. The functional D groups may be the same or different when more than one is present. In accordance with the previous description there may be different combinations of the above A and D groups with the proviso that at least one substantially oil-soluble group, i.e. a long chain hydrocarbon group of at least 12 carbon atoms, is present.

The basic pyrrolidone structure used in preparing the grease thickeners of this invention is 1-substituted-2-pyrrolidone-4-carboxylic acid which is obtained by reacting a suitable primary amine with an α-alkylidene substituted carboxylic acid or ester which preferably is itaconic acid. This is a well-known reaction which is used to obtain intermediates for the plastic industry as disclosed in U.S. Patents 2,993,021, issued to A. Bavley et al on July 18, 1961, and 3,395,130, issued to R. McDowell et al on July 30, 1968.

The 1-substituted-2-pyrrolidone-4-carboxylic acid, as described above, is then reacted with suitable amines to form the amide derivative, with an alcohol to form the ester derivative, or with suitable inorganic compounds, e.g. hydroxides, carbonates and alkoxides to yield the metal salt. As indicated above, when there is more than one carboxyl group on the starting pyrrolidone compound, different functional groups, i.e. D as shown on the above-designated formula, may be added to each. This is accomplished by using the appropriate molar proportions of the respective starting materials needed to provide the desired functional groups. One example of this is when a bispyrrolidone made from a diamine and preferably an aromatic diamine is condensed with an amine, preferably a long chain fatty amine to form an amide derivative with one carboxyl group and the other carboxyl group is neutralized with a metal salt.

The amines useful in preparing the pyrrolidone amide derivatives of this invention may be a primary or secondary amine and may be a mono-, di- or polyamine. Illustrative examples of such amines include the following: methylamine, ethylamine, diethylamine, ethylene diamine, n-propylamine, isopropylamine, amylamine, cyclohexylamine, octylamine, dioctylamine, decylamine, dodecylamine, hexadecylamine, octadecylamine, dioctadecylamine, coco amine, dicoco amine, N-coco-trimethylenediamine, tallow amine, dicosylamine, eicosyl-docosylamine, di(eicosyl-docosyl) amine, N-octadecenyltrimethylene diamine, aniline, toluidene, xylidene, N-methylaniline, benzylamine, diphenylamine, amines derived from rapeseed oil, phenethylamine, mixtures of amines such as Primene 81-R (principally t-$C_{12}H_{25}NH_2$ to t-$C_{14}H_{29}NH_2$) and Primene JM-T (principally t-$C_{18}H_{37}NH_2$ to t-$C_{22}H_{45}NH_2$). "Primene" is a Registered Trade Mark. Mixtures of these and other amines may also be employed. Further examples of amines which may be used are disclosed in Kirk-Othmer *Encyclopedia of Chemical Technology*, Second Edition, Vol. 2, 1963, pp 99—138 and 411—426.

Alcohols and other hydroxy compounds useful in preparing the pyrrolidone ester derivative include: ethyl alcohol, butyl alcohol, n-decyl alcohol, cetyl alcohol, stearyl alcohol, eicosonyl alcohol, hentriacontanol, phenol, benzyl alcohol and phenylethyl alcohol. Other useful alcohols are disclosed in Kirk-Othmer *Encyclopedia of Chemical Technology*, Second Edition, Vol. 1, 1963, pp 531—568.

The metal compounds useful in preparing the salt derivative of pyrrolidone include the hydroxides, carbonates and alkoxides of the respective selected metals.

The amines which may be used in preparing the basic or precursor pyrrolidone compound will of course depend on the desired A group in the final pyrrolidone compound. Such amines include phenylamine (aniline), phenylene diamine, phenylene di(methylamine), naphthylene diamine, 4,4'-bisphenylene diamine, 4,4'-thiobisphenylene diamine, 4,4'-oxybisphenylene diamine, 4,4'-methylenebisphenylene diamine, 4,4'-isopropylidene-bisphenylene diamine, octadecylamine, octadecyldiamine, amines of polyisobutylene (up to about 50 carbons) and other amines as described in the earlier description.

The total pyrrolidone thickener content of the grease composition of this invention will normally range from about 1 to about 60 wt% and preferably about 2 to about 50 wt% and more preferably about 5 to about 30 wt% based on the total composition.

The lubricating base oil that is used in preparing the grease compositions of this invention can be any of the conventionally used mineral oils, synthetic hydrocarbon oils or synthetic ester oils. In general, these lubricating oils will have a viscosity in the range of about 35 to 200 SUS at 210°F. Mineral lubricating oil base stocks used in preparing the greases can be any conventionally refined base stocks derived from paraffinic, naphthenic and mixed base crudes. Synthetic lubricating oils that can be used include esters of dibasic acids, such as di-2-ethylhexyl sebacate, esters of poly glycols such as trimethylol propane tricaprylate, pentaerythritol tetraoctanoate, dipentaerythritol tricaprylate tripelargonate, esters of glycols such as a C_{13} oxo acid diester of tetraethylene glycol, or complex esters such as one formed from 1 mole of sebacic acid and 2 moles of tetraethylene glycol and 2 moles of 2-ethylhexanoic acid. Other synthetic oils that can be used include synthetic hydrocarbons such as alkyl benzenes, e.g., alkylate bottoms from the alkylation of benzene with tetrapropylene, or the copolymers of ethylene and propylene; silicone oils, e.g., ethyl phenyl polysiloxanes, methyl polysiloxanes, etc., polyglycol oils, e.g., those obtained by condensing butyl alcohol with propylene oxide; carbonate esters, e.g., the product of reacting C_8 oxo alcohol with ethyl carbonate to form a half ester followed by reaction of the latter with tetraethylene glycol, etc. Other suitable synthetic oils include the polyphenyl ethers, e.g., those having from about 3 to 7 ether linkages and about 4 to 8 phenyl groups. (See U.S. Pat. 3,424,678, col. 3.) Preferably the lubricating base oil will comprise the major amount of the grease composition.

The grease composition of this invention can be prepared in accordance with any of the techniques known in the prior art and such composition may include other additive components, e.g., dyes, antioxidants, anticorrosion agents, lubricity additives, etc., which are conventionally found in grease compositions.

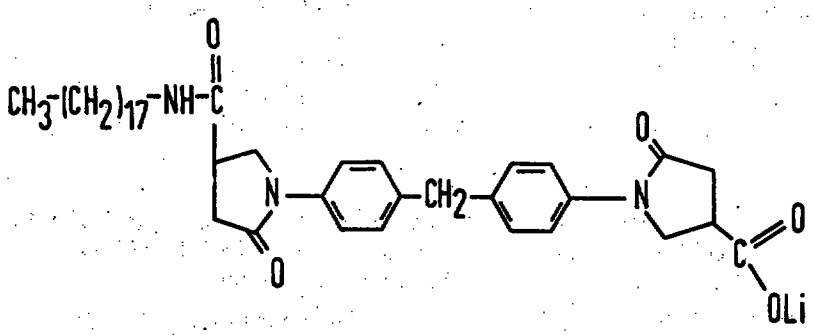
The following examples are set forth to illustrate the invention and should not be construed as limitations thereof.

Example 1

A grease composition was prepared by first mixing 300 grams of solvent 600N oil with 0.25 mole of 4,4'-methylene dianiline (49.5 g; 4.6 wt.%) and 0.5 mole of itaconic acid (65.0 g; 6.04 wt.%) at room temperature to form a slurry. The temperature was raised to 107°C (225°F) and the chemicals reacted to form a sticky mass under the oil. The temperature was raised to 121°C (250°F) with stirring, the water of reaction was driven off and the mass became a granular solid which when the stirring was stopped, settled out. Total reaction time was about 20 minutes and the slurry was stirred for one hour at 121°C (250°F) to ensure complete reaction.

Octadecylamine (0.25 mole—67.4 g, 6.27 wt.%) was added at 121°C (250°F) and the mass began to thicken to a grease-like consistency within 10 to 15 minutes. The temperature was raised to 163°C (325°F) and the mass quickly softened to a fairly smooth thick cream. The temperature was then slowly raised to 204°C (400°F) during which water of reaction was driven off to form a hard soap. An additional 152 g of the oil was added as the mass was cooled to approximately 93°C (200°F).

One-quarter (0.25) mole of $LiOH \cdot H_2O$ (0.98 wt.%) in 100 ml of water was added and the mass slowly raised to 163°C (325°F) for one-half hour to complete dehydration. The temperature was then raised to 218°C (425°F) for a short time to complete cookout during which the mass became quite hard. The mass was cooled and an additional 331 g of oil added to yield a light brown grease. The product was milled and an additional 100 g of oil was added to yield the final product. The total amount of oil used was 883.0 grams (82.11 wt.%). The thickener may be represented by the formula:



The grease produced was evaluated and found to have the following properties:

Color (visual)	light brown
Consistency (visual)	smooth and buttery

Penetration, mm/10, 25°C (77°F), (ASTM D217)	
unworked	282
60 strokes	270
100,000 strokes	299
Dropping point (ASTM 566)	>316°C (600°F)
Rust Test (ASTM D1743)	1,1,1 (Pass)
Water Resistance (100 g grease/100 g water/60 minutes/room temp./ASTM Roller)	
water absorption, g	92
metal adhesion	excellent
change in penetration	−14 mm/10
Wheel bearing test, 163°C (325°F), (ASTM D1263)	
leakage	1.6 g
slump	nil
Wheel bearing test, 163°C (325°F) (ASTM D1263) (containing commercial grease additive package with antiwear, antirust and load-carrying additives)	
leakage	1.1 g
slump	nil
Spindle bearing life, 177°C (350°F) (ASTM 3336) (containing commercial antifriction bearing grease additive package with antioxidants and rust inhibitors)	
running time	271 hours (ave. 3 runs)

Example 2

A grease product similar to Example 1 was prepared in the same manner using a total of 796 g of solvent 600N oil (77.86 wt.%)

0.25 mole of 4,4'-methylene dianiline (49.5 g, 4.84 wt.%),
0.5 mole of itaconic acid (65.0 g, 6.36 wt.%),
0.25 mole octadecylamine (67.4 g, 6.59 wt.%), and
0.25 mole $LiOH \cdot H_2O$ (10.5 g, 1.03 wt.%).

Azelaic acid (0.125 mole, 23.5 g, 2.3 wt.%) was added to the above grease product with an additional equivalent amount of $LiOH \cdot H_2O$ to that noted above added in water to effect neutralization. The temperature was raised to allow dehydration and the mass cooked out at about 232°C (450°F) to improve the grease structure. As the mass cooled, additional oil (part of the total amount stated above) was added and the grease milled at room temperature to yield a fairly smooth light brown product which was evaluated and found to have the following properties:

Penetration, mm/10, 25°C (77°F)	
unworked	261
60 strokes	263
100,000 strokes	306
Dropping point	>316°C (600°F)
Water resistance	
water absorbed	81 g
adhesion	excellent
Δ penetration	−3 mm/10

Example 3

A grease product similar to Example 1 was prepared using 418.1 g (69.69 wt.%) of solvent 600N oil, 49.5 g (8.25 wt.%, 0.25 mole) of 4,4'-methylenedianiline, 65.0 g (10.83 wt.%, 0.5 mole) of itaconic acid and 67.4 g (11.23 wt.%, 0.25 mole) of octadecylamine.

The ingredients were reacted as described in Example 1 and the resultant product was a light brown grease with a free carboxylic acid function rather than the salt derivative as in Example 1 and having the following properties:

Penetration, mm/10, 25°C (77°F)	
unworked	276
60 strokes	283
Dropping Point	278°C (533°F)

Example 4

A grease product similar to Example 1 was prepared using 559.0 g (75.03 wt.%) of solvent 600N oil, 106.5 g (14.30 wt.%, 0.25 mole) of the bispyrrolidone reaction product derived from the reaction of 49.5 g (0.25 mole) of 4,4'-methylenedianiline with 65.0 g (0.50 mole) of itaconic acid and 69.5 g (9.33 wt.%, 0.25 mole of octadecylamine (commercially available as Armeen 18D from Armak Chemical Ltd.). ("Armeen" is a Registered Trade Mark.)

The ingredients were reacted in a similar manner to Example 1. Complete neutralization was accomplished by cooling the mass to 149°C (300°F) and 10.0 g (1.34 wt.%, 0.25 mole) of NaOH in 50 ml of water was slowly added. The temperature was raised to 232°C (450°F) for 15 minutes to complete the reaction and to insure proper dispersion. The product had the following properties:

Penetration, mm/10, 25°C (77°F)	
unworked	268
60 strokes	263
100,000 strokes	306
Dropping point	>316°C (>600°F)
Rust test	1,1,1 (Pass)
Water resistance	
water absorbed	35 g
metal adhesion	fairly good
Δ penetration	−9 mm/10
Wheel bearing test (163°C; 325°F)	
leakage	0.3 g
slump	nil

Example 5

A grease product similar to those previously described in the other examples was prepared using 611.0 g (71.34 wt.%) of solvent 600N oil, 106.5 g (12.43 wt.%, 0.25 mole) of the bispyrrolidone reaction product derived from the reaction of 1 mole of 4,4'-methylenedianiline with 2 moles of itaconic acid and 139.0 g (16.23 wt%, 0.5 mole) of octadecylamine (Armeen 18D). ("Armeen" is a Registered Trade Mark.)

The octadecylamine was dissolved in about one-half of the oil (300 g) at 135°C (275°F) with stirring. The bispyrrolidone reaction product was slowly added and a paste formed. The temperature was raised and at 163°C (325°F) a slurry formed. The temperature was again raised to 177°C (350°F) and the mass thickened as water was driven off over one-half hour. The reaction and dispersion was completed at 204°C (400°F) to give a smooth grease. The mass was cooled to room temperature with oiling to give a product with the following properties:

Penetration, mm/10, 25°C (77°F)	
unworked	281
60 strokes	291
100,000 strokes	286
Dropping point	243°C (470°F)
Water resistance	good metal adhesion

Example 6

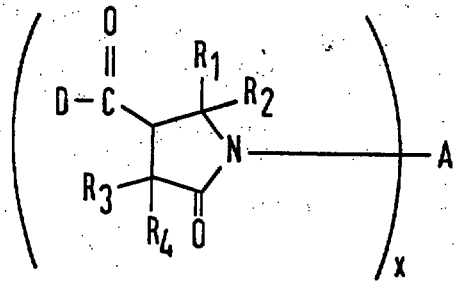
A grease product similar to those previously described in the other examples was prepared using 922.0 g (81.09 wt.%) of solvent 600N oil, 106.0 g (9.32 wt.%, 0.25 mole) of the bispyrrolidone reaction product derived from the reaction of 1 mole of 4,4'-methylenedianiline with 2 moles of itaconic acid, 78.75 g (6.93 wt.%, 0.25 mole) of a commercial grade amine derived from hydrogenated high erucic acid rapeseed soil (Armeen HR) and 30.25 g (2.66 wt%), 0.25 mole) of phenethylamine. ("Armeen" is a Registered Trade Mark.)

The Armeen HR amine was dissolved in 300 g of oil at 121°C (250°F) with stirring. The bispyrrolidone reaction product was slowly added over 1.5 hours as the temperature was raised to 177°C (350°F). The mass was cooled to 93°C (200°F) with oiling (300 g) to yield a product with approximately an NLGI #2 grade consistency. The phenethylamine was slowly dripped in which caused hardening of the mass. Additional oil was added while stirring. The temperature was slowly raised to 204°C (400°F) over a two-hour period before cooling to room temperature with final oiling to yield a smooth buttery grease with the following properties:

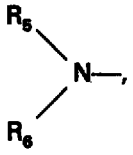
Penetration, mm/10, 25°C (77°F)	
unworked	282
60 strokes	282
100,000 strokes	325
Dropping point	261°C (501°F)
Water resistance	good metal adhesion

Claims

1. A lubricating grease composition comprising a lubricating oil and an effective amount of one or more pyrrolidone compounds as a thickener, said pyrrolidone compound(s) having the formula:



where x is 1 to 3, A is a hydrocarbyl group as herein defined of 1 to 50 carbon atoms, D is an MO—,



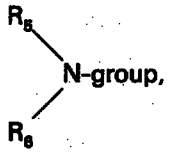
or R_7O— group where M is a metal selected from Group I or II of the Periodic Table herein defined or aluminum, R_5 and R_6 are each a hydrocarbyl group as herein defined of 1 to 50 carbon atoms or one may be hydrogen, R_7 is a hydrocarbyl group of 1 to 50 carbon atoms or hydrogen with the proviso that there is at least one long chain hydrocarbon group of at least 12 carbon atoms present in either D or A, and R_1, R_2, R_3 and R_4 are hydrogen or a hydrocarbyl of 1 to 6 carbon atoms.

2. A lubricating grease composition as claimed in claim 1, wherein x is 1 or 2; A is an alkyl, aryl, alkaryl or aralkyl and the unsaturated counterparts thereof of 1 to 25 carbon atoms when x is 1; and A is an alkylene, arylene, alkarylene or aralkylene and the unsaturated counterparts thereof of 1 to 25 carbon atoms when x is 2; and wherein said thickener is used at a concentration of 1 to 60 weight percent based on the total weight of the composition.

3. A lubricating grease composition as claimed in claim 1 or claim 2, wherein M is a metal selected from lithium, sodium, calcium, barium, strontium, magnesium and aluminum; R_5, R_6 and R_7 are each of 1 to 30 carbon atoms and are an alkyl, aryl, alkaryl or aralkyl group or the unsaturated counterparts thereof; and R_7 and one of R_5 and R_6 may be hydrogen; and said thickener is used in a concentration of 2 to 50 weight percent based on the total weight of the composition.

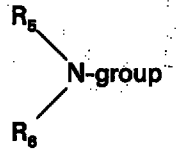
4. A lubricating grease composition as claimed in any preceding claim, wherein M is lithium or sodium, R_5 and R_6 each contain 1 to 25 carbon atoms and one of R_5 and R_6 may be hydrogen, R_7 contains 1 to 25 carbon atoms or is hydrogen.

5. A lubricating grease composition as claimed in claim 4, wherein x is 2, one D is an MO— group and one D is an



and R_1, R_2, R_3 and R_4 are hydrogen.

6. A lubricating grease composition as claimed in claim 5, wherein said



is derived from octadecylamine, tallow amine or an amine of rapeseed oil and A is a 4,4′-methylenebisphenylene radical.

7. A lubricating grease composition as claimed in claim 4, wherein x is 2, one D is derived from octadecylamine and the other D is R_7O—, where R_7 is hydrogen; A is 4,4′-methylenebisphenylene; and R_1, R_2, R_3 and R_4 are hydrogen.

8. A lubricating grease composition as claimed in claim 4, wherein x is 2, both D groups are derived from octadecylamine, and A is a 4,4′-methylenebisphenylene radical.

9. A lubricating grease composition as claimed in claim 4, wherein x is 2, one D group is derived from phenethylamine and the other D group is derived from an amine formed from rapeseed oil.

10. A lubricating grease composition as claimed in Claim 4, wherein x is 2 and A is derived from amines selected from phenylene diamine, phenylene di(methylamine), naphthylene diamine, 4,4′-bisphenylene diamine, 4,4′-thiobisphenylene diamine, 4,4′-oxybisphenylene diamine, 4,4′-methylenebisphenylene diamine, 4,4′-isopropylidene diamine and octadecyldiamine.

11. A lubricating grease composition as claimed in any one of claims 4 to 10, wherein the thickener is used in a concentration of 5 to 30 weight percent based on the total weight of the composition.

12. A lubricating grease composition as claimed in any preceding claim, wherein the pyrrolidone compound(s) is/are the sole thickener.

13. A lubricating grease composition as claimed in claim 1 and substantially as herein described.

14. A lubricating grease composition as claimed in claim 1 and substantially as herein described with reference to any one of Examples 1 to 6.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1983. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained