

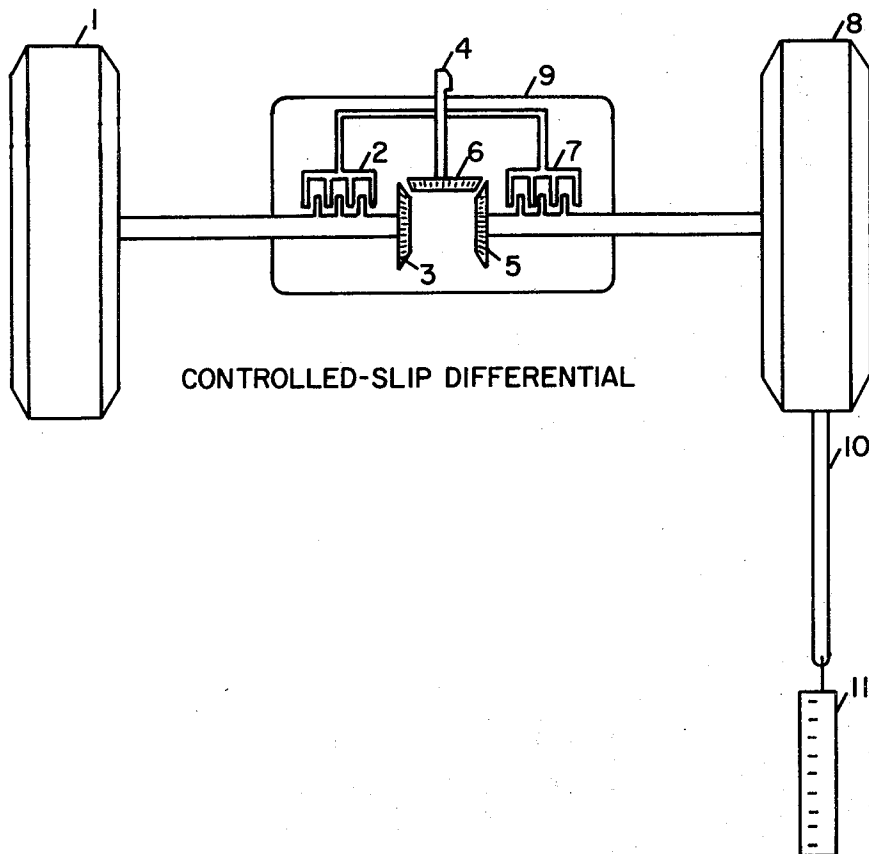
July 23, 1974

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3,825,495

LUBRICANT FOR CONTROLLED-SLIP DIFFERENTIAL

Filed Feb 19, 1971



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LUBRICANT FOR CONTROLLED-SLIP
DIFFERENTIAL

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Filed Feb. 19, 1971, Ser. No. 116,985

Int. Cl. C10m 1/48, 1/38

U.S. Cl. 252—32.7 E

11 Claims

ABSTRACT OF THE DISCLOSURE

An improved method of lubrication of a controlled-slip differential comprises using a lubricant comprising (A) synthetic sulfurized oil consisting essentially of a sulfurized blend of lard oil and a C_{12} - C_{24} monoolefin and (B) a hydrocarbon base stock having a kinematic viscosity at 210° F. in the range of 1.5–200.0 cs. and containing a blend of at least one C_{13} - C_{29} naphthene and from 0.1–20 parts by weight, based on said naphthene of at least one member from at least one of the following groups (a), (b), (c) and (d):

- (a) a synthetic liquid C_3 - C_4 olefin homopolymer copolymer, or terpolymer;
- (b) a member from group (a) above which is at least partially hydrogenated;
- (c) a severely hydrorefined naphthenic lube containing less than 1% of gel aromatic hydrocarbons; and
- (d) a severely hydrorefined paraffinic lube containing less than 1% of gel aromatic hydrocarbons;

and wherein the amount of said blend which is present in said base stock is sufficient to provide a greater coefficient of traction, measured at 600 ft./min., 200° F., 400,000 p.s.i., than would be provided by substitution of the same amount of ASTM Oil No. 3 for said blend in said base stock and wherein said lubricant contains 0.5–10 volumes of synthetic sulfurized oil for each 100 volumes of said base stock. The preferred lubricant also contains an extreme pressure additive (e.g. tricresyl phosphate) and an additive which lowers the static friction of the lubricant (e.g. a surface-active, organic phosphate ester of a linear aliphatic, ethoxylated alcohol).

CROSS REFERENCES TO RELATED
APPLICATIONS

The present application is related to the following listed applications:

Serial No.	Filing date	Title/Inventor(s)
679,834 (now U.S. 3,595,797, issued 7-21-71).	11-1-67	Blending Branched Paraffin Fluids for Use in Traction Drive Transmission—Irl N. Duling-David S. Gates and Marcus W. Haseltine.
679,851 (now U.S. 3,598,740, issued 8-10-71).	11-1-67	Traction Drive Transmission Containing Paraffinic oil as Lubricant—Irl N. Duling-David S. Gates and Thomas D. Newingham.
794,844 (now U.S. 3,608,385 issued 9-28-71).	1-24-69	Friction Drive Fluid—Irl N. Duling and Frederick P. Glazier.
812,516 (now U.S. 3,619,414, issued 11-9-71).	2-19-69	Catalytic Hydrofinishing of Petroleum Distillates in the Lubricating Oil Boiling Range—Ivor W. Mills-Merritt C. Kirk, Jr. and Albert T. Olenzak

In particular, these applications disclose blended hydrocarbon base stocks which can be useful in practice of the present invention, additives which can be added to such a base stock and processes for making individual components of such blends.

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BACKGROUND OF THE INVENTION

As have been reported by R. L. Kostelak in *Lubrication*, vol. 56, No. 4, 1970 (pg. 49 et seq.), the principle of operation of the conventional differential in today's American automobile remains the same as the Pecquer differential, invented in 1827. Although this "conventional differential" generally performs very satisfactory, it has one serious shortcoming; namely, "stalling," which occurs when either rear wheel loses traction. Due to the kinematics of the conventional differential design, the driving torque is divided equally between the two rear wheels and is limited by the wheel with the least traction. Hence, when one wheel loses traction, the vehicle does not move.

To prevent this shortcoming, engineers have developed many ingenious ideas and mechanisms. Each manufacturer has his own descriptive name for his particular mechanism; for example, Chevrolet Positraction, Chrysler Sure-Grip, and Ford Traction-Lok. Generally, however, a differential incorporating one of these mechanisms is called a "locking" or "limited slip" or "controlled-slip" differential.

The limited slip differential used in the American passenger car is essentially the same as a conventional differential except for the incorporation of some form of friction members (e.g. clutch plates or friction cones). The Kostelak article describes the conventional differential and typical controlled-slip differential.

Another pertinent article is "Lubricants for Limited Slip Differentials" by John W. Allen, given at Fuels and Lubricants Meeting, Society of Automotive Engineers, Houston, Tex., Nov. 1–3, 1966.

SUMMARY OF THE INVENTION

In a combination of a controlled-slip differential and a lubricant therefor, we have discovered an improvement wherein said lubricant comprises (A) synthetic sulfurized oil comprising a sulfurized blend of lard oil and a C_{12} - C_{24} monoolefin and (B) a hydrocarbon base stock having a kinematic viscosity at 210° F. in the range of 1.5–200.0 cs., said base stock containing a blend of at least one C_{13} - C_{29} naphthene and from 0.1–20 parts by weight, based on said naphthene, of at least one member from at least one of the following groups (a), (b), (c) and (d):

- (a) a synthetic liquid C_3 - C_8 olefin homopolymer copolymer, or terpolymer;
- (b) a member from group (a) above which is at least partially hydrogenated (preferably, to an iodine number less than 20, more preferably less than 5 and/or having a 195 UVA less than 2.0);
- (c) a severely hydrorefined naphthenic lube containing less than 1% of gel aromatic hydrocarbons; and
- (d) a severely hydrorefined paraffinic lube containing less than 1% of gel aromatic hydrocarbons;

and wherein the amount of said blend which is present in said base stock is sufficient to provide a greater coefficient of traction, measured at 600 ft./min., 200° F., 400,000 p.s.i., than would be provided by substitution of the same amount of ASTM Oil No. 3 for said blend in said base stock. The preferred lubricant has a viscosity in the range of 5–50 cs. at 210° F. (typically 10–20 cs.), has a channel point below 32° F. (more preferred below 10° F., typically 0 to –25° F.) and also contains an extreme pressure (EP) additive (e.g. tricresyl phosphate, zinc dithiophosphate, etc.) and an additive which lowers the static friction of the lubricant (e.g. a surface-active, organic phosphate ester of a linear aliphatic, ethoxylated alcohol).

Preferably, the C_{13} - C_{29} naphthene has a glass transition temperature in the range of –90 to –30° C. and contains as a structural nucleus, a cyclohexyl hydrindan,

di(cyclohexyl) alkane, adamantane, spirodecane, spiro-pentane, perhydrofluorene, perhydrobiphenyl, perhydro-phenyl, decaline, norbornane, perhydroindacene, perhydrohomotetraphthene, perhydroacenaphthene, perhydrophenanthrene, perhydrocrysene, perhydroindane-1-spirocyclohexane, perhydrocaryophyllene, pinane, camphane, perhydrophenylnaphthalene or perhydropyrene.

These blended hydrocarbon base stocks are described in the aforementioned applications of Duling et al. ASTM Oil No. 3 is described, for example, in U.S. 3,598,740. Naphthenic and paraffinic oils are described, for example, in Bruins, P. F. *Plasticizer Technology*, pages 79, 80 and 85, Vol. 1, Reinhold Pub., N.Y. 1965.

BRIEF DESCRIPTION OF THE DRAWING

The accompanying drawing is an illustration of a controlled-slip differential and will be referred to with reference to a test method for comparing the dynamic torque obtained from a given combination of lubricant and controlled-slip differential. The test can be useful in comparing various lubricants in a given differential.

For example, in a limited slip differential (LSD), the contact plates can be surfaced with swirl patterns to produce high friction. When the plate has become worn, the friction drops drastically and the LSD fails to perform any better than a conventional differential. With a high traction-LSD fluid, the friction property is inherent in the fluid itself and is not completely dependent on the patterned contact surfaces. Thus, the lubricated contacts can have high friction (or traction) even when badly worn.

With reference to the Figure, torque measurements are made by attaching a belt 10 around one of the rear wheels 8 and connecting the belt end to a calibrated spring scale 11. The other rear wheel 1 is then turned by hand to slip the differential. The measurement when slip begins is taken as the "break-free torque." A second measurement is determined at approximately 40 r.p.m. (with the wheel 1 being driven by a motor).

The differential in the Figure consists of a ring gear 4, a differential pinion 6 and cross shaft, and a right 7 and a left 2 clutch plate attached to the differential case. The wheels are connected to the differential pinion by the right 5 and left 3 side gears. Clutch plates are also attached to the left and right axle shafts. The differential assembly and the lubricant are contained in a housing 9.

EXAMPLE I

466 g. of a commercial α -methyl styrene polymer, obtained by conventional acid-catalyzed polymerization, is placed in a one-liter round bottomed flask, attached to a one-inch column, and dry-distilled with essentially no reflux or fractionation at a pot temperature of about 290° C., and a vapor temperature of about 210° C. under a vacuum of about 6 millimeters of mercury. 373 g. of distillate are obtained and about 73 grams of material remain in the bottom of the flask at the end of the distillation. The commercial α -methyl styrene polymer has a softening point of 210° F., a Gardner-Holdt viscosity of J-L, a specific gravity of 1.075, a refractive index at 20° C. of 1.61, a molecular weight of 685, an iodine number of 0, an acid number of 0, and a saponification number of 0.

EXAMPLE II

300 g. of the distillation product of Example I is placed in a 316 stainless steel bomb along with 7.5 grams of Raney nickel catalyst and the bomb is pressured to 3000 p.s.i.g. of 100% hydrogen while heat is applied until the temperature in the bomb is 150° C. At that point an exothermic reaction occurs and heating is discontinued. The temperature is allowed to rise to about 220° C. and the hydrogen pressure is maintained at 3000 p.s.i. for 6 hours at which time the bomb is slowly cooled to ambient temperature while maintaining the hydrogen pressure at 3000 p.s.i. in order to avoid dehydrogenation of the hydrogenated product. The resulting perhydrogenated

poly (α -methyl styrene) oil is topped to remove components boiling below 125° C. The remaining perhydrogenated naphthene product has a KV₂₁₀ of 11.07 cs. and a KV₁₀₀° F. of 327.8 cs. Analysis by nuclear magnetic resonance (NMR), shows the oil of this example to contain about 40% of trimers (mostly hydrindan form), and 60% dimers, mainly 1,1,3-trimethyl-3-cyclohexyl hydrindan.

EXAMPLE III

A blend of two commercially available polybutene polymers (i.e. 90 vol. percent Indapol L-100 and 10% Oronite Special 6) is completely hydrogenated to produce a hydrogenated polybutene oil which analyzes 0.5 mole percent olefin by the ultraviolet absorbance method. The hydrogenation is at 200° C., 2000 p.s.i. of 100% hydrogen for 6 hours using Harshaw NI0104P catalyst. The resulting hydrogenated polyolefin oil has a KV₂₁₀° F. of 13.54 cs. and a KV₁₀₀ of 162.8.

EXAMPLE IV

A blended base oil was compounded from 61.0 volumes of the naphthene product of Example II and 33.1 volumes of the hydrogenated polyolefin oil of Example III. Then 5.9 volumes of a commercial "limited slip axle additive" (Lubrizol Company, Anglamol 99LS) was added to the blend to produce a formulated lubricant. Table 1 describes typical properties of Anglamol 99 LS.

TABLE 1

Specific gravity @ 60° F., (15.6° C.)	1.055
Pounds per gallon @ 60° F., U.S.	8.79
Pounds per gallon @ 60° F., IMP.	10.55
Viscosity @ 210° F., (98.9° C.) SUS	60
Viscosity @ 210° F., cst.	10.2
Weight Percent of:	
Sulfur	29.2
Phosphorus	2.0

Similarly, other blended base oils (e.g. comprising synthetic paraffins and naphthenes) and other gear oil additives can be used to formulate such lubricants. Other useful additives are those mentioned by F. G. Rounds, *Journal of Chem. and Eng. Data*, vol. 5, No. 4, October 1960, pp. 504-505.

EXAMPLE V

Another useful lubricant for controlled-slip differential, and which is also useful for lubrication of a traction drive transmission, comprises a blend of the following (all hydrogenations are to at least 98% saturation):

Volume percent	Component	KV ₂₁₀ ° F. (c.s.)	KV ₁₀₀ ° F. (c.s.)
7.0	Hydrogenated Cosden SH06 polybutene	11.04	124
28.0	Hydrogenated Cosden SH15 polybutene	33.5	744
31.6	Hydrogenated poly α -methyl styrene	23	2,468
21.0	do.	4.65	39.6
7.4	Anglamol 93 (E.P. additive)		
3.0	Amoco 9000 (dispersant)		
1.0	Ultraphos 11, (low static modifier)		
1.0	Synthetic sulfurized oil		

The use in this lubricant of high and low viscosity fractions of the naphthene and paraffin is an example of "dumbbell-blending" to improve viscosity index.

The ultraphos 11 additive is a surface-active, organic phosphate ester of a linear aliphatic, ethoxylated alcohol.

The synthetic sulfurized oil is the invention of Alexander D. Rechhuite and will be the subject of a later filed application. This oil can be used as a replacement for sulfurized sperm oil and can be made by heating sulfur and a blend of from 50-95% lard oil and 50-5% of one or a mixture of C₁₂-C₂₄ acyclic monoolefin. For example, 10 weight percent of sulfur was added at 250° F. to 90 weight percent of a blend of 85 volumes of lard oil (extra winter strained) and 15 volumes of Chevron

C₁₅-C₂₀ α -olefin. The sulfur-containing mixture was heated to 375° F. and maintained at that temperature, with stirring, for 2 hours, then cooled to 200° F., and, finally, blown with air for 1 hour.

Another procedure for making the synthetic sulfurized oil is to heat the large oil-olefin blend to about 300° F., and add sulfur (e.g. 5-25%) over a 30 minute period (with agitation), then bring the temperature to 335° F., maintain for ½ hour, raise the temperature to 375° F. and maintain for 1 hour (also with agitation), cool to 200° F. and blow with air (at 200° F.) for 16 hours.

time in a high traction-LSD fluid. This results in longer LSD fluid life before chatter occurs.

EXAMPLE VII

Conventional petroleum-LSD lubricant and the blended "Traction-LSD" lubricant of Example IV were compared in four limited slip differentials, by the previously described test method. The results of these tests are summarized in Table 3. The performance of each differential was improved when lubricated by the blended traction-LSD lubricant.

TABLE 3.—TORQUE THROUGH VARIOUS LIMITED SLIP DIFFERENTIALS

Car	Fluid	Odometer at torque test	Torque, lbs.		Odometer at fluid change
			Break-free	~40 r.p.m.	
Chev., 1969	Original	11,151	20	10	11,151
	Petroleum-LSD	11,437	22-23	12-14	11,437
	Traction-LSD	11,449	25	15-20	
		11,539	20	21-22	
Chev., 1969	Original	12,808	22-25	6-9	12,808
	Petroleum-LSD	13,239	20-25	6-7	13,239
	Traction-LSD	13,274	20	12-14	
		13,309	20	12-14	
Pontiac 1970	Original	5,721	30	21-23	5,721
	Petroleum-LSD	6,578	30-32	20	6,578
	Traction-LSD	6,823	35	28-29	
		6,981	35	30	
Ford, 1968	Original	18,617	90	20	18,617
	Petroleum-LSD	19,145	80-90	22	19,145
	Traction-LSD	19,198	75	40	
		19,244	75	40	

The channel point of a lubricant is determined by drawing a channel with a spatula in a sample of lubricant, at a given temperature, and finding the maximum temperature where the walls of the channel no longer cave-in.

EXAMPLE VI

A well-worn limited slip differential in a 1965 Buick Skylark (driven over 65,000 miles) was used to compare lubricants, by the previously described method.

The used, original fill fluid was replaced with a fresh conventional petroleum-based LDS fluid (e.g. solvent refined paraffinic lube plus Anglamol 99LS). Torque measurements were made periodically for the next 500 miles. For the last 100 miles, a 6 p.s.i. difference in air pressure in the rear tires caused the differential to slip constantly. It was believed that this tire pressure difference caused the fresh fluid to work into the contact areas. At the end of 500 miles, the conventional fluid was replaced with the blended "traction-LSD fluid" of Example IV, which had the same viscosity at 100° F. and the same additive system as the petroleum-LSD fluid. After 40 miles of driving with the 6 p.s.i. air pressure differential in the rear tires, the torque measurement at the low speed dynamic conditions was nearly double that observed when the petroleum-LSD fluid was used. There was little difference in the break-free torque since the static friction is primarily dependent on the additive system. Table 2 presents the test data obtained from this testing.

TABLE 2.—TORQUE THROUGH WORN LIMITED SLIP DIFFERENTIAL

Fluid	Torque (lbs.)		
	Odometer	Break-free	~40 r.p.m.
Original fill	66,055	80	13
Petroleum-LSD fluid charged	66,070		
	66,070	85	13
	66,104	80	12.5
	66,400	92	12
Traction-LSD fluid charged	66,509		
	66,541	90	23
	66,650	90	26
	69,207	95	25

The high dynamic friction also helped reduce chatter. With high dynamic friction, static friction can increase to a higher level before chatter will occur. Thus, low static modifying additives are effective for a longer period of

Any of the usual gear lube additives can be used in the lubricant-differential combination of the present invention; however, especially beneficial results are obtained when 0.25-10% (based on the base stock) Ultraphos 11 (or less preferred, Ultraphos 12) used as one of the additives. Ultraphos 11 is marketed by Witco Chemical Company and has the following typical properties:

KV₂₁₀=23.44 cs.

KV₁₀₀=217.20 cs.

Melting Point=0° C.

Glass Transition Temperature=-62° C.

ASTM-VI=142

VTF-VI=132

Elemental Analysis:

Carbon: 58.16%

Hydrogen: 10.47%

Oxygen: 20.44%

Ash: 1.58%

Phosphorous: 5.77%

Sulfur: 0.4% (Schoniger)

Nitrogen: 0.10%

Chlorine: 10 p.p.m.

Alternatively, Antara LB400 (General Aniline and Film) can be used instead of Ultraphos as a low static modifier.

Another useful, multipurpose additive package which is useful in such lubricants is 2-15% Anglamol 93, which has been previously described and which is a product of Lubrizol Company and comprises a mixture of zinc phosphorodithioate and chlorinated hydrocarbons, a typical analysis being 3% Zn, 3% P, 16.5% Cl and 16.0% S.

The blended fluids and limited slip differential lubricants referred to herein, especially that of Example IV can be used to increase traction between two rolling elements. When traction fluid is used to lubricate high speed ball bearings—for an example, the main shaft bearings in a turbine engine—it reduces ball skidding. Ball skidding is one of the factors limiting shaft speed. Accordingly, such lubricants can be used for high speed and highly loaded bearings. They can also be used for lubrication of overrunning clutches.

During engagement, there is a sliding motion between the cam or rollers and the races in overrunning clutches. Since wear occurs during the engagement period, a lubricant which reduces engagement time will reduce wear

and extend service life. In one test, engagement was reduced from 11 to 2 revolutions simply by replacing the conventional petroleum oil grease with a grease component of a naphthene-paraffin blend similar to that of Example IV. The traction fluid and its grease show the greatest advantage in clutches where load is high enough to elastically deform the rollers or cams.

The invention claimed is:

1. A composition comprising (A) friction improving amounts of a synthetic cosulfurized blend of lard oil and a C_{12} - C_{24} monoolefin and (B) major amounts of a hydrocarbon base stock having a kinematic viscosity at 210° F. in the range of 1.5 to 200.0 cs. and consisting essentially of a blend of at least one C_{13} - C_{29} naphthene and from 0.1 to 20 parts by weight, based on said naphthene, of at least one member from at least one of the following groups (a), (b), (c) and (d):

- (a) a synthetic liquid C_3 - C_8 olefin homopolymer;
- (b) a member from group (a) above which is at least partially hydrogenated;
- (c) a severely hydrotreated naphthenic mineral lube oil containing less than 1% gel aromatic hydrocarbons; and
- (d) a severely hydrotreated paraffinic mineral lube oil containing less than 1% of gel aromatic hydrocarbons;

wherein the amount of said blend of naphthene and member of groups (a), (b), (c) and (d) which is present in said base stock is sufficient to provide a greater coefficient of traction, measured at 600 feet per minute, 200° F., 400,000 p.s.i., than would be provided by substitution of the same amount of ASTM Oil No. 3 for said blend in said base stock, and wherein said composition contains in the range of 0.5 to 10 volume percent of said cosulfurized blend for each 100 volumes of said blended hydrocarbon base stock.

2. The composition of Claim 1 wherein said C_{13} - C_{29} naphthene has a glass transition temperature in the range of -90 to -30° C. and contains, as a structural nucleus, a cyclohexyl hydrindan, di(cyclohexyl)alkane, adamantane, spirodecane, spiropentane, perhydrofluorene, perhydrobiphenyl, perhydroterphenyl, Decalin, norbornane, perhydroindacene, perhydrohomotetraphthene, perhydroacenaphthene, perhydrophenanthrene, perhydrocrysene, perhydroindane - 1 - spirocyclohexane, perhydrocarylophylene, pinane, camphane, perhydrophenylnaphthalene or perhydropyrene, and wherein said synthetic sulfurized oil is a sulfurized blend of 50-90 volume percent lard oil

and 50-5 volume percent of one or a mixture of C_{12} - C_{24} monoolefin.

3. The composition of Claim 2 wherein said synthetic sulfurized oil contains in the range of 5-25 weight percent sulfur.

4. The composition of Claim 1 wherein said lubricant also contains an extreme pressure additive and an additive which lowers the static friction of said lubricant.

5. The composition of Claim 4 wherein said extreme pressure additive contains a chlorinated hydrocarbon, or a zinc phosphorodithioate or a mixture thereof.

6. The composition of Claim 1 wherein said naphthene is the hydrogenated dimers and trimers of alpha-methylstyrene.

7. The composition of Claim 6 wherein said blend contains from 0.1 to 20 parts by weight, based on said naphthene, of a hydrogenated homopolymer of a C_4 monoolefin.

8. The composition of Claim 7 wherein said C_4 olefin consists essentially of isobutylene.

9. The composition of Claim 1 wherein said C_3 - C_8 olefin is at least one C_4 olefin.

10. The composition of Claim 1 wherein said kinematic viscosity at 210° F. is in the range of 5 to 50 cs. and wherein the channel point is at least 10° F.

11. In the art of lubrication of a controlled-slip differential, the improvement wherein the composition of Claim 1 is used as a lubricant.

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WARREN H. CANNON, Primary Examiner

U.S. Cl. X.R.

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