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LUBRICANT

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The present invention relates to the art of lubrication, and more particularly to the lubrication of surfaces engaging under extreme pressure, as for example, the rubbing surfaces of hypoid gears, free wheeling transmissions, speed reducers and the like.

The general tendency in the design of modern machinery has been toward a higher ratio between power and "dead weight". This is especially true in the automotive industry, and in recent years certain types of gears and other mechanisms have been developed with the operating pressures on the working surfaces so high that ordinary mineral oil lubricants will not provide sufficient lubrication for satisfactory operation.

Heretofore it has been thought that lubrication consists in maintaining a film of oil between the rubbing surfaces, thereby preventing them from coming into contact with one another and thus preventing wear. That this condition exists in well lubricated bearings is well known, but this conception of lubrication does not apply to highly loaded gears. In well lubricated bearings the loads rarely exceed 2000 lbs. per sq. in. projected area and the rubbing speeds are generally high enough to maintain a film of oil which separates the rubbing surfaces. In automobile gears, the pressures between gear teeth reach very high values and even the most viscous oils or greases cannot be retained between the surfaces of the teeth in a sufficiently thick film to prevent metal to metal contact, particularly when operating temperatures of 210° F. or higher are commonly encountered.

It has been known that compounded lubricants such as, for example, mineral oils containing fatty oils, fatty acids, metallic soaps, sulfur or combined chlorine, possess lubricating qualities which render them suitable for use under high operating pressures. These compounded oils function satisfactorily under conditions which would cause failure of an unblended mineral oil, if used alone. It is believed that the successful use of such compounded oils depends upon the adsorption and reaction or union of certain components of these oils with the metal surfaces whereby a film of metallic compound, such as, for example, iron sulfide or chloride is formed.

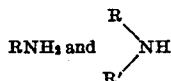
It appears that such a film or plating has a low

coefficient of friction and that satisfactory operation of heavily loaded bearings or gears depends upon the formation and maintenance of such a film, and not upon the retaining of a film of oil between the bearing surfaces. The hydrocarbon oil constituent of an extreme pressure lubricant serves primarily to remove frictional heat, to wash away any solid particles which may result from wear, and to prevent oxidation of the engaging surfaces.

I have discovered that organic compounds of phosphorus and nitrogen, and more particularly the compounds which may be termed, in general, the substituted amides of the phosphorus acids, when admixed with hydrocarbon oils, are of special utility in the field of extreme pressure lubrication. These compounds may be prepared, in accordance with my invention, by the reaction of halogen and/or sulfur derivatives of phosphorus with primary and secondary amino compounds. More particularly, one or more compounds from the group phosphorus trichloride PCl_3 ; phosphorus pentachloride PCl_5 ; phosphorus oxychloride POCl_3 ; phosphorus sulfochloride PSCl_3 ; and the phosphorus sulfides P_2S_3 and P_2S_5 may be reacted with a primary or secondary amino compound to yield products which may be described as the substituted amides of the phosphorus acids.

The amino compounds which I may employ in the preparation of my reaction products comprehend one or a mixture of any of the primary and secondary aliphatic, aromatic, hydroaromatic and heterocyclic amines. The aliphatic amines include, for example, mono- and dimethylamine and their homologues, ethyl-, propyl-, butylamines and the like, as well as the halogen substituted aliphatic amines, for example, chloro-butylamine and chloro-amylamine. The aromatic amino compounds may be represented, for example, by aniline, toluidine, xylidine, phenylene diamine, naphthylamine, anthramine, benzylamine, methylaniline and the like. The hydroaromatic amino compounds include cyclohexylamine, tetrahydro-naphthylamine, methylcyclohexylamine and the like. The heterocyclic amino compounds may be represented, for example, by furfurylamine, piperidine, tetrahydroquinoline, aminopyridine and the like. Other

substituted ammonias containing at least one reactive hydrogen atom, such as phenylhydrazine, may be suitably employed. In general, the primary and secondary amino compounds contemplated have the following formulae:



wherein R and R' are of the group consisting of aliphatic, aromatic, hydroaromatic and heterocyclic radicals, and the substitution products thereof.

Herein, the term "reaction product" is to be understood to comprehend the compounds formed by the reaction of the halogen and sulfur derivatives of phosphorus with primary and secondary amino compounds.

In preparing my lubricant, I add to a suitable mineral oil one or a mixture of two or more of my reaction products in quantity sufficient to improve the value of the oil as a lubricant to any desired extent, depending upon the operating conditions under which the lubricant is to be used. I have found that the quantity of reaction product required, in general, does not exceed substantially 5% by weight of my composition. Quantities as small as 3%, or even 1% or less, have been found to improve lubricating oils to a satisfactory extent. In certain instances, 0.1% to 0.5% by weight of the reaction product was sufficient to improve the lubricating oil to the desired extent. In preparing my lubricant, I may obtain a homogeneous solution or stable suspension of my reaction product in mineral oil by agitating the mixture at normal or elevated temperatures, or I may dissolve the reaction product in a suitable solvent and add the resulting solution to the oil, thereafter removing the solvent by vaporization.

The mechanism by which the reaction products in lubricating oils function to improve the load-bearing ability and other properties thereof is not entirely understood. It appears, however, that the functioning is dependent upon the adsorption of the compounds upon the metal surfaces of the bearings or other lubricated parts, and the reaction or chemical combination of such compounds with the metal under the influence of localized high temperature and pressure to form a coating or plating having a low coefficient of friction which is resistant to seizure under high operating pressures.

The following tables indicate some of the reaction products obtained by the treatment of primary and secondary amines with the phosphorus halides. The treatment may be carried on in the presence of hydroxy and/or mercaptan compounds, whereby other groups are introduced into the reaction products. Or, the initial reaction products may subsequently be reacted with a hydroxy and/or mercaptan compound. The resulting products, more complex in structure, have been found suitable for use as addition agents for hydrocarbon oils. In the formulae given in tables, R, and R' may be the same or different aliphatic, aromatic, hydroaromatic and heterocyclic radicals, while "X" represents halogen, i. e., chlorine, bromine or fluorine. The reaction product may be one or a mixture of compounds, depending upon the ratio of the reacting components, the time and temperature of the reaction, and the completeness of the reaction between the components. The hydroxy and/or mercaptan compounds which may be employed in the reaction include, for example, methyl alcohol and mercaptan and their homologues; phenol and phenyl mercaptan and their homologues; cyclohexanol and cyclohexyl mercaptan and their homologues; and various heterocyclic compounds such as furfuryl alcohol, furfuryl mercaptan, hydroxyquinoline and pyridyl mercaptan.

Table 1

Reaction components		Reaction products		
$\text{RNH}_2 + \text{PX}_3$	$\rightarrow$	RNHPX_3	$\begin{array}{c} \text{RNH} \\ \diagup \\ \text{PX} \\ \diagdown \\ \text{RNH} \end{array}$	$\begin{array}{c} \text{RNH} \\ \diagup \\ \text{RNH}-\text{P} \\ \diagdown \\ \text{RNH} \end{array}$
$\text{RNH}_2 + \text{PX}_3 + \text{R}'\text{OH}$	$\rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \\ \text{RNHP} \\ \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{OR}' \\ \diagup \\ \text{RNHP} \\ \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{RNH} \\ \diagup \\ \text{RNH}-\text{P}-\text{OR}' \\ \diagdown \\ \text{RNH} \end{array}$
$\text{RNH}_2 + \text{PX}_3 + \text{R}'\text{SH}$	$\rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \\ \text{RNHP} \\ \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{SR}' \\ \diagup \\ \text{RNHP} \\ \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{RNH} \\ \diagup \\ \text{RNH}-\text{P}-\text{SR}' \\ \diagdown \\ \text{RNH} \end{array}$
$\text{R}_2\text{NH} + \text{PX}_3$	$\rightarrow$	R_2NXPX_2	$\begin{array}{c} \text{R}_2\text{N} \\ \diagup \\ \text{PX} \\ \diagdown \\ \text{R}_2\text{N} \end{array}$	$\begin{array}{c} \text{R}_2\text{N} \\ \diagup \\ \text{R}_2\text{N}-\text{P} \\ \diagdown \\ \text{R}_2\text{N} \end{array}$
$\text{R}_2\text{NH} + \text{PX}_3 + \text{R}'\text{OH}$	$\rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \\ \text{R}_2\text{NP} \\ \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{OR}' \\ \diagup \\ \text{R}_2\text{NP} \\ \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{R}_2\text{N} \\ \diagup \\ \text{R}_2\text{N}-\text{P}-\text{OR}' \\ \diagdown \\ \text{R}_2\text{N} \end{array}$
$\text{R}_2\text{NH} + \text{PX}_3 + \text{R}'\text{SH}$	$\rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \\ \text{R}_2\text{NP} \\ \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{SR}' \\ \diagup \\ \text{R}_2\text{NP} \\ \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{R}_2\text{N} \\ \diagup \\ \text{R}_2\text{N}-\text{P}-\text{SR}' \\ \diagdown \\ \text{R}_2\text{N} \end{array}$

Table 2

Reaction components	Reaction products		
$\text{RNH}_2 + \text{POX}_3 \rightarrow$	RNHPOX_2	$\begin{array}{c} \text{RNH} \\ \diagup \quad \diagdown \\ \text{POX} \end{array}$	$\begin{array}{c} \text{RNH} \\ \diagup \quad \diagdown \\ \text{RNH}-\text{PO} \end{array}$
$\text{RNH}_2 + \text{POX}_3 + \text{R}'\text{OH} \rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \quad \diagdown \\ \text{RNHP}=\text{O} \\ \diagup \quad \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{OR}' \\ \diagup \quad \diagdown \\ \text{RNHP}=\text{O} \\ \diagup \quad \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{OR}' \\ \diagup \quad \diagdown \\ \text{RNH}-\text{P} \\ \diagup \quad \diagdown \\ \text{RHH} \quad \text{O} \end{array}$
$\text{RNH}_2 + \text{POX}_3 + \text{R}'\text{SH} \rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \quad \diagdown \\ \text{RNHP}=\text{O} \\ \diagup \quad \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{SR}' \\ \diagup \quad \diagdown \\ \text{RNHP}=\text{O} \\ \diagup \quad \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{SR}' \\ \diagup \quad \diagdown \\ \text{RNH}-\text{P} \\ \diagup \quad \diagdown \\ \text{RNH} \quad \text{O} \end{array}$
$\text{R}_2\text{NH} + \text{POX}_3 \rightarrow$	R_2NPOX_2	$\begin{array}{c} \text{R}_2\text{N} \\ \diagup \quad \diagdown \\ \text{POX} \end{array}$	$\begin{array}{c} \text{R}_2\text{N} \\ \diagup \quad \diagdown \\ \text{R}_2\text{N}-\text{PO} \end{array}$
$\text{R}_2\text{NH} + \text{POX}_3 + \text{R}'\text{OH} \rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \quad \diagdown \\ \text{R}_2\text{NP}=\text{O} \\ \diagup \quad \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{OR}' \\ \diagup \quad \diagdown \\ \text{R}_2\text{NP}=\text{O} \\ \diagup \quad \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{OR}' \\ \diagup \quad \diagdown \\ \text{R}_2\text{N}-\text{P} \\ \diagup \quad \diagdown \\ \text{R}_2\text{N} \quad \text{O} \end{array}$
$\text{R}_2\text{NH} + \text{POX}_3 + \text{R}'\text{SH} \rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \quad \diagdown \\ \text{R}_2\text{NP}=\text{O} \\ \diagup \quad \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{SR}' \\ \diagup \quad \diagdown \\ \text{R}_2\text{NP}=\text{O} \\ \diagup \quad \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{SR}' \\ \diagup \quad \diagdown \\ \text{R}_2\text{N}-\text{P} \\ \diagup \quad \diagdown \\ \text{R}_2\text{N} \quad \text{O} \end{array}$

Table 3

Reaction components	Reaction products		
$\text{RNH}_2 + \text{PSX}_3 \rightarrow$	RNHPSX_2	$\begin{array}{c} \text{RNH} \\ \diagup \quad \diagdown \\ \text{PSX} \end{array}$	$\begin{array}{c} \text{RNH} \\ \diagup \quad \diagdown \\ \text{RNH}-\text{PS} \end{array}$
$\text{RNH}_2 + \text{PSX}_3 + \text{R}'\text{OH} \rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \quad \diagdown \\ \text{RNHP}=\text{S} \\ \diagup \quad \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{OR}' \\ \diagup \quad \diagdown \\ \text{RNHP}=\text{S} \\ \diagup \quad \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{OR}' \\ \diagup \quad \diagdown \\ \text{RNH}-\text{P} \\ \diagup \quad \diagdown \\ \text{RNH} \quad \text{S} \end{array}$
$\text{RNH}_2 + \text{PSX}_3 + \text{R}'\text{SH} \rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \quad \diagdown \\ \text{RNHP}=\text{S} \\ \diagup \quad \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{SR}' \\ \diagup \quad \diagdown \\ \text{RNHP}=\text{S} \\ \diagup \quad \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{SR}' \\ \diagup \quad \diagdown \\ \text{RNH}-\text{P} \\ \diagup \quad \diagdown \\ \text{RNH} \quad \text{S} \end{array}$
$\text{R}_2\text{NH} + \text{PSX}_3 \rightarrow$	R_2NPSX_2	$\begin{array}{c} \text{R}_2\text{N} \\ \diagup \quad \diagdown \\ \text{PSX} \end{array}$	$\begin{array}{c} \text{R}_2\text{N} \\ \diagup \quad \diagdown \\ \text{R}_2\text{N}-\text{PS} \end{array}$
$\text{R}_2\text{NH} + \text{PSX}_3 + \text{R}'\text{OH} \rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \quad \diagdown \\ \text{R}_2\text{NP}=\text{S} \\ \diagup \quad \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{OR}' \\ \diagup \quad \diagdown \\ \text{R}_2\text{NP}=\text{S} \\ \diagup \quad \diagdown \\ \text{OR}' \end{array}$	$\begin{array}{c} \text{OR}' \\ \diagup \quad \diagdown \\ \text{R}_2\text{N}-\text{P} \\ \diagup \quad \diagdown \\ \text{R}_2\text{N} \quad \text{S} \end{array}$
$\text{R}_2\text{NH} + \text{PSX}_3 + \text{R}'\text{SH} \rightarrow$	$\begin{array}{c} \text{X} \\ \diagup \quad \diagdown \\ \text{R}_2\text{NP}=\text{S} \\ \diagup \quad \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{SR}' \\ \diagup \quad \diagdown \\ \text{R}_2\text{NP}=\text{S} \\ \diagup \quad \diagdown \\ \text{SR}' \end{array}$	$\begin{array}{c} \text{SR}' \\ \diagup \quad \diagdown \\ \text{R}_2\text{N}-\text{P} \\ \diagup \quad \diagdown \\ \text{R}_2\text{N} \quad \text{S} \end{array}$

The following table presents, in an exemplary manner, a number of reaction products which may be suitably employed as addition agents for lubricants.

Table 4

Hexabutyl phosphorous acid amide
 $[(\text{C}_4\text{H}_9)_3\text{N}]_3\text{P}$
 Tris-cyclopentamethylene phosphorous acid amide
 $(\text{C}_5\text{H}_{10}\text{N})_3\text{P}$
 Isobutylaminephosphonic acid chloride
 $(\text{CH}_3)_2\text{CHCH}_2\text{NHPOCl}_2$
 Isobutylaminephosphonic acid anilide
 $(\text{CH}_3)_2\text{CHCH}_2\text{NHPO}(\text{NH}\cdot\text{C}_6\text{H}_5)_2$
 Isobutylaminephosphonic acid phenylhydrazide
 $(\text{CH}_3)_2\text{CHCH}_2\text{NHPO}(\text{NHNHC}_6\text{H}_5)_2$
 Benzylaminephosphonic acid chloride
 $\text{C}_6\text{H}_5\text{CH}_2\text{NHPOCl}_2$
 Diphenyl benzylaminephosphonate
 $\text{C}_6\text{H}_5\text{CH}_2\text{NHPO}(\text{OC}_6\text{H}_5)_2$

Tetrahydroquinoline-anilinephosphonic acid chloride
 $\text{C}_8\text{H}_{10}\text{NPOCl}(\text{NHC}_6\text{H}_5)$
 Hexaethyl phosphoric acid amide
 $[(\text{C}_2\text{H}_5)_3\text{N}]_3\text{PO}$
 n-Propylaminephosphonic acid chloride
 $\text{C}_3\text{H}_7\text{NHPSCl}_2$
 Diethyl n-propylaminephosphonate
 $\text{C}_4\text{H}_9\text{NHPS}(\text{OC}_2\text{H}_5)_2$
 n-Propylaminephosphonic acid anilide
 $\text{C}_3\text{H}_7\text{NHPS}(\text{NHC}_6\text{H}_5)_2$
 N,N',N''-triethyl-thiophosphoric acid amide
 $(\text{C}_2\text{H}_5\text{NH})_3\text{PS}$
 Dipropylaminephosphonic acid chloride
 $(\text{C}_3\text{H}_7)_3\text{NPSCl}_2$
 Piperidinephosphonic acid chloride
 $(\text{C}_4\text{H}_8\text{N})_2\text{PSCl}$
 Hexaethyl thiophosphoric acid amide
 $[(\text{C}_2\text{H}_5)_3\text{N}]_3\text{PS}$
 n-Propylaminephosphonic acid chloride
 $(\text{C}_3\text{H}_7\text{NH})_2\text{POCl}$
 Phenyl benzylaminephosphinate
 $(\text{C}_6\text{H}_5\text{CH}_2\text{NH})_2\text{PO}(\text{OC}_6\text{H}_5)$

Table 4—Continued

- N,N',N''-tri-n-butyl-phosphoric acid amide
 $(C_4H_9NH)_3PO$
 Diisobutylaminephosphonic acid chloride
 $[(CH_3)_2CHCH_2]_2NPOCl_2$
 5 Diethyl diisobutylaminephosphonate
 $[(CH_3)_2CHCH_2]_2NPO(OC_2H_5)_2$
 Diphenyl diisobutylaminephosphonate
 $[(CH_3)_2CHCH_2]_2NPO(OC_6H_5)_2$
 Diisobutylaminephosphonic acid anilide
 $[(CH_3)_2CHCH_2]_2NPO(NHC_6H_5)_2$
 Tetrahydroquinolinephosphonic acid chloride
 $C_6H_9NPOCl_2$
 10 Chloroanilinephosphonic acid chloride
 $ClC_6H_4NHPOCl_2$

Typical examples of my improved lubricants and methods of preparing the same are as follows:

Example 1

- 0.1 mole of phosphorus oxychloride, $POCl_3$, in ether solution was added to 0.7 mole of mono-n-butylamine in ether solution with stirring. The mixture was refluxed on a steam bath for about 3 hours, removed and cooled, and then washed with dilute HCl solution and finally with water. The ether solution of the reaction product, N, N', N''-tri-n-butyl phosphoric acid amide, was dried over anhydrous K_2CO_3 , the ether then removed by distillation and the reaction product, in the amount of about 1% by weight, was added to a hydrocarbon oil having a Saybolt universal viscosity of 304 seconds at 100° F. and an A. P. I. gravity of 29.5°. This blended oil, when tested in an Almen extreme pressure lubricant testing machine at 200 R. P. M., withstood a pressure of 17,000 lbs./sq. in. projected bearing area before failure, whereas the unblended hydrocarbon oil failed at a pressure of only 4,000 lbs./sq. in. projected bearing area.

Example 2

- 0.1 mole of phosphorus oxychloride, $POCl_3$, in ether solution was added to 0.6 mole of di-n-butylamine in ether solution with stirring. The mixture was refluxed on a steam bath for about 2 hours, and 0.6 mole of mono-n-butylamine was added. The refluxing was continued for about 5 hours, the mixture then removed and cooled, and washed with water. The ether solution of the reaction product, poly-butylphosphoric acid amide, was dried over anhydrous K_2CO_3 , the ether evaporated off and the excess unreacted amine removed from the product by distillation under reduced pressure. The reaction product, in the amount of about 1% by weight was added to the hydrocarbon oil mentioned in Example 1 and the blended oil, when tested under the conditions set forth in Example 1, withstood a pressure of 15,000 lbs./sq. in. projected bearing area before failure, whereas the unblended hydrocarbon oil failed at a pressure of 4,000 lbs./sq. in. projected bearing area.

Example 3

- 0.04 mole of phosphorus oxychloride, $POCl_3$, in benzene solution was added to 0.25 mole of di-n-butylamine in ether solution with stirring. The mixture was refluxed on a steam bath for about 10 hours, removed and cooled, and washed with water. The ether solution of the reaction product, di-n-butylamine-phosphonic acid chloride, was dried over anhydrous K_2CO_3 , the ether evaporated off and the excess unreacted amine removed from the product by distillation under reduced pressure. The reaction product, in the amount of about 2% by weight, was added to the hydrocarbon oil mentioned in Example 1 and the blended oil, when tested under the conditions set forth in Example 1, withstood a pressure of 16,000

lbs./sq. in. projected bearing area before failure, whereas the unblended hydrocarbon oil failed at a pressure of 4,000 lbs./sq. in. projected bearing area.

Example 4

- 0.07 mole of phosphorus sulfochloride, $PSCl_3$, in naphtha solution was added to 0.05 mole of mono-n-butylamine in naphtha solution with stirring. The mixture was refluxed on a steam bath for about 11 hours, removed and cooled, filtered and the filtrate washed with water. The naphtha solution of the reaction product, N, N', N''-tri-n-butyl phosphoric acid amide, was heated to a temperature sufficient to distill off the naphtha. The reaction product, in the amount of about 1% by weight was added to the hydrocarbon oil mentioned in Example 1 and the blended oil, when tested under the conditions set forth in Example 1, withstood a pressure of 17,000 lbs./sq. in. projected bearing area before failure, whereas the unblended hydrocarbon oil failed at a pressure of 4,000 lbs./sq. in. projected bearing area.

Example 5

- 0.1 mole of phosphorus sulfochloride, $PSCl_3$, was added to 0.2 mole of di-n-butylamine with stirring. The mixture was refluxed by means of an oil bath at a temperature of about 240° F. to 265° F. for about 3 hours, and thereafter was steam-distilled to produce a distillate and a residue. The distillate was extracted with ether and the ether extract was then heated to an elevated temperature in order to drive off the ether. The reaction product, di-n-butylamine-thiophosphonic acid chloride in the amount of about 1% by weight was added to the hydrocarbon oil mentioned in Example 1 and the blended oil, when tested under the conditions set forth in Example 1, withstood a pressure of 22,000 lbs./sq. in. projected bearing area before failure, whereas the unblended hydrocarbon oil failed at a pressure of 4,000 lbs./sq. in. projected bearing area.

Example 6

- 0.03 mole of phosphorus trichloride, PCl_3 , in naphtha solution was added to 0.25 mole of di-n-butylamine in naphtha solution with stirring. The mixture was stirred at room temperature for about 2 hours, then filtered, and the filtrate washed with water. The naphtha solution of the reaction product, hexa-n-butyl phosphorus acid amide, was dried over anhydrous K_2CO_3 , the naphtha evaporated off and the excess unreacted amine removed from the product by distillation under reduced pressure. The reaction product, in the amount of about 1% by weight was added to the hydrocarbon oil mentioned in Example 1 and the blended oil, when tested under the conditions set forth in Example 1, withstood a pressure of 22,000 lbs./sq. in. projected bearing area before failure, whereas the unblended hydrocarbon oil failed at a pressure of 4,000 lbs./sq. in. projected bearing area.

It will be seen, from the above examples, that the addition of my reaction products to a hydrocarbon oil improves the lubricating value of such an oil to a marked degree, and imparts to the oil certain properties which render it suitable for use in the lubrication of surfaces engaging under extreme pressure. Under certain conditions, for example in the lubrication of transmissions or gear drives where elevated temperatures are not normally encountered, it has been found that the halogenated, and particularly the chlorinated reaction products are more efficient than the unchlorinated products in their

ability to improve the load-bearing ability of the lubricants.

Furthermore, I have found that my reaction products having as substituents long hydrocarbon chains or substituted hydrocarbon chains, are capable of not only improving the load-bearing capacity of hydrocarbon oils but also effect a lowering of the coefficient of friction, or improve the "oiliness" of the lubricant. The reaction products containing long chain alkyl radicals such as cetyl, lauryl, dodecyl and oleyl, and the substitution products thereof, are representative examples of this type of materials.

In another aspect of my invention, I have found that these reaction products not only improve the load-bearing capacity of hydrocarbon oils but also impart thereto a marked resistivity to oxidation and sludge formation. For example, a lubricating oil containing about 1% by weight of N, N', N''-tri-n-butyl phosphoric acid amide, when subjected to an oxidation test at 340° F. for 96 hours, developed only 18 milligrams of sludge per gram of oil, whereas the unblended lubricating oil, under the same test, produced 40 milligrams of sludge per gram of oil.

Furthermore, the addition of my reaction products to lubricating oils, especially the highly paraffinic oils produced by solvent extraction processes, inhibits and in many cases prevents, the corrosion of copper-silver-cadmium and copper-lead bearings of internal combustion engines lubricated with such oils.

While I have described my invention with reference to the lubrication of gears and bearings operating under heavy loads, I do not intend to limit myself thereto, but contemplate the use of my lubricant in operations such as the cutting and boring of metals, in which conditions of extreme pressure and temperature are normally encountered, and also in the lubrication of mechanisms operating under moderate pressures, as for example, the crankcase bearings and cylinder walls of internal combustion engines. Furthermore, my compounded oil may be utilized as a base in the preparation of thickened oils, i. e., greases, by the addition thereto of soaps or other conventional thickening agents, in order to obtain lubricants of desired viscosity. My compounded oil may also be blended with fatty oils, fatty acids, synthetic esters and the like, or the

reaction products, per se, may be admixed with fatty oils, for the lubrication of mechanisms in which the presence of a fatty oil is desirable.

What I claim is:

1. A lubricant comprising a hydrocarbon oil and a small proportion of a product of reaction of at least one compound from the group PCl_5 , POCl_3 , PSCl_3 , P_2S_3 and P_2S_5 with an aliphatic amine having at least one hydrogen atom directly connected to the nitrogen atom.

2. A lubricant comprising a hydrocarbon oil and a small proportion of a product of reaction of at least one compound from the group PCl_5 , POCl_3 , PSCl_3 , P_2S_3 and P_2S_5 with a butylamine having at least one hydrogen atom directly connected to the nitrogen atom.

3. A lubricating oil composition comprising a relatively large proportion of a lubricating oil of the type which normally tends to rupture at the surface of contact with a bearing-metal under relatively high bearing pressure, and in intimate homogeneous combination therewith a small but sufficient proportion of the oil-miscible, substantially water-insoluble condensation reaction product of phosphorus trichloride and an aryl amine having at least one hydrogen atom attached directly to the nitrogen atom to impart extreme pressure lubricating characteristics to said oil.

4. A lubricant comprising a hydrocarbon oil and a small proportion of a product of reaction of at least one compound from the group PCl_5 , POCl_3 , PSCl_3 , P_2S_3 and P_2S_5 with an amine having at least one hydrogen atom directly connected to the nitrogen atom.

5. A lubricant comprising a hydrocarbon oil and a small proportion of a product of reaction of at least one compound from the group PCl_5 , POCl_3 , PSCl_3 , P_2S_3 and P_2S_5 with an aromatic amine having at least one hydrogen atom directly connected to the nitrogen atom.

6. A lubricant comprising hydrocarbon oil and a small proportion of a product of reaction of at least one compound from the group PCl_5 , POCl_3 , PSCl_3 , P_2S_3 and P_2S_5 with an amine having at least one hydrogen atom directly connected to the nitrogen atom and with a compound from the group consisting of hydroxy and mercaptan compounds.

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