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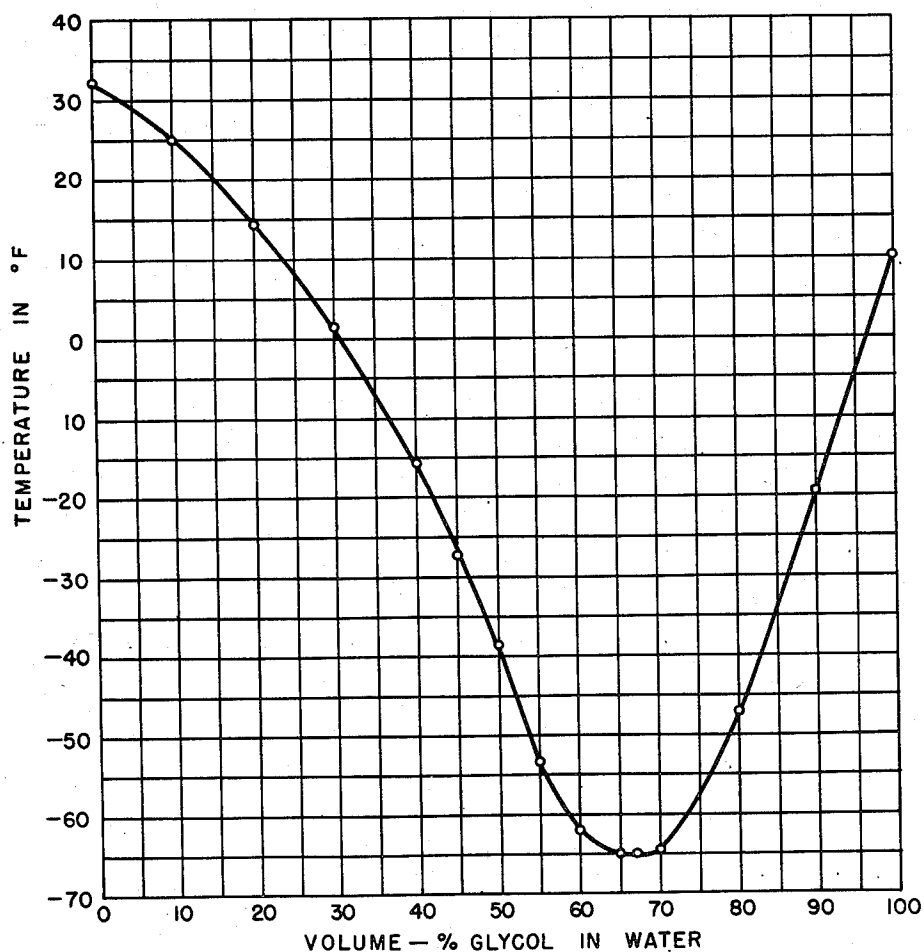
NONINFLAMMABLE HYDRAULIC FLUID AND LUBRICANT

Filed Sept. 23, 1948

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FIG. 1

FREEZING POINTS OF GLYCOL-WATER SOLUTIONS



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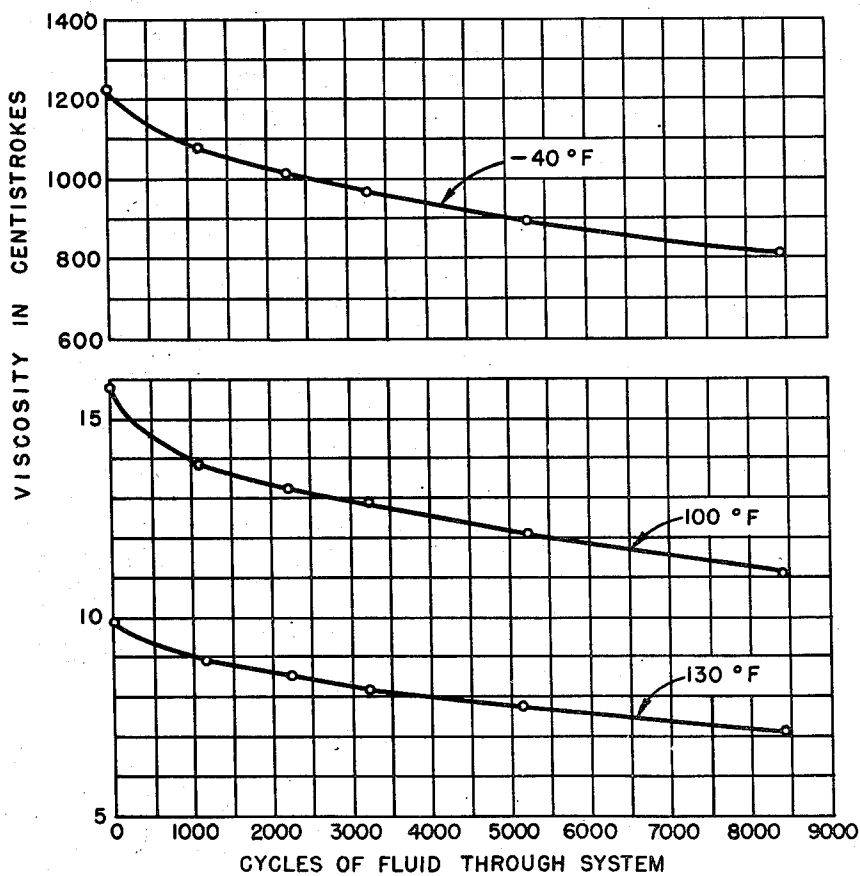
NONINFLAMMABLE HYDRAULIC FLUID AND LUBRICANT

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FIG. 2

SHEAR BREAK OF ACRY SOL G 3650 IN HYDROLUBE A
(HYDRAULIC BENCH TEST—USING PESCO IP349 PUMP)



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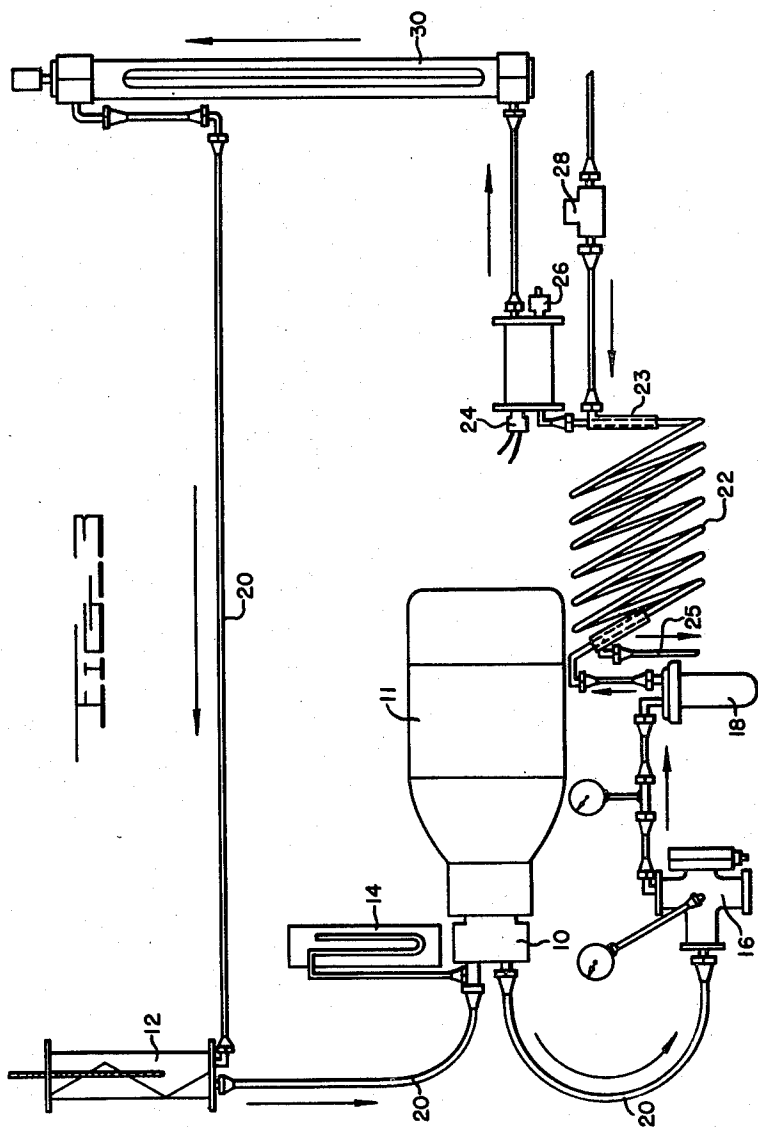
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NONINFLAMMABLE HYDRAULIC FLUID AND LUBRICANT

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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NONINFLAMMABLE HYDRAULIC FLUIDS
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6 Claims. (Cl. 252-76)

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amended April 30, 1928; 370 O. G. 757)

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This invention relates to hydraulic-fluid compositions for use in devices and systems for the transmission of mechanical energy by fluid pressure and to additives for such compositions for the prevention of oxidation, the inhibition of corrosive action and the improvement of wear resisting qualities thereof.

A hydraulic fluid which is essentially an aqueous solution must have a freezing point low enough to avoid any possibility of the separation of solid phases within the system at any temperature to which the fluid may be exposed. In modern military operations, it is not unusual for hydraulic systems, for example, those in aircraft for operation of landing gear, to be exposed for long periods of time to temperatures as low as minus 60° to minus 70° F. Accordingly it is the general object of the invention to provide a hydraulic fluid having an extremely low freezing point to obviate the possibility of solid separation at very low temperatures.

Within any hydraulic system there will be found such metals as iron, brass, solder, bronze, aluminum, zinc, cadmium, copper and other more or less commonly used metals. The presence of several metals in a single hydraulic system presents the possibility of the formation of a large number of electrical couples within the system thereby providing ideal corrosion conditions. Accordingly it is a further object of the invention to inhibit the hydraulic fluid composition against corrosive action so that all metals in the system will be protected therefrom.

Also, within the common hydraulic system, there is always at some point a reservoir for excess fluid. Such a reservoir is never full and, being a closed container, it will define a vapor space above the fluid contained therein. Even within the simplest hydraulic systems, humid corrosion within such space presents a serious problem. In the more complex systems, found in military or commercial aircraft or in naval vessels where service conditions are extremely severe and the system is exceedingly complex, the corrosion problem is correspondingly more difficult. It is therefore a still further object of the invention to provide hydraulic fluid compositions which will inhibit adequately both the humid and contact corrosion of the system.

An additional object of the invention is to

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provide a hydraulic fluid composition to which the above properties have been imparted and which also possesses a viscosity index sufficiently high to make it a desirable hydraulic fluid.

In any military application, a property, in addition to those above mentioned, which a hydraulic fluid should have is that of non-inflammability and, accordingly, it is also an object of the invention to provide a fluid which is substantially non-inflammable.

For the accomplishment of these and other objects of the invention hydraulic compositions are prepared consisting essentially of water as a solvent and flame retarder, a water soluble organic polymeric thickener, a water-miscible freezing point depressant, balancing ingredients in relatively small proportions for the inhibition of corrosion, oxidation and frictional wear and preferably a solublizer for certain wear inhibitors.

The name "Hydrolube" as used in this specification is a generic name for any polymer-thickened, corrosion inhibited aqueous fluid having one or more of the glycols as major constituents. The Hydrolubes herein defined are further identified by the letter "U" which designates fluids thickened with polyalkylene glycol copolymers. Specific examples of such compositions containing various corrosion inhibitors, wear reducing additives, antioxidants and metal deactivators are designated herein below as Hydrolube U-2, Hydrolube U-3, etc.

The water soluble polyhydric alcohols or ethers used as freezing point depressants may be any of the common glycols or glycol ethers having from about 2 to about 14 carbon atoms such as ethylene glycol, diethylene glycol, triethylene glycol, ethylene glycol ethers such as the ethyl, methyl, propyl and butyl ethers thereof, and similar ethers of diethylene and triethylene glycol. In general it is preferred to use the simpler compounds as represented by the polyhydric alcohols such as ethylene glycol, propylene glycol, butylene glycol and diethylene glycol for they are easily obtainable and blend easily with water to give very low-freezing mixtures which form good bases for the fluid compositions. As the basis of the hydraulic fluid composition it is necessary to balance the non-inflammable character of the water component against the low freezing point

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or pour point depressant effect of the polyhydric alcohol which limits the water content to a maximum of about forty-five percent. The relative proportions of the two components are further influenced by the fact that there is a well defined eutectic mixture of glycol and water consisting e. g. in the case of ethylene glycol, of 67% glycol and 33% water. The freezing point of such a mixture is -65°F . It is readily apparent that evaporation of water from this mixture would be attended with a rapid rise in the freezing point and furthermore, that such a relatively low water content would give a mixture which would be inflammable. Reference is here made to Figure 1 of the drawing which is a graph of the freezing points in degrees Fahrenheit for mixtures of glycol and water ranging from 100% water and 0% glycol to 100% glycol and 0% water. The eutectic point is well defined at -65°F . with the composition 67% glycol and 33% water.

The viscosity-temperature characteristics of the 55/45 base stock is as follows:

Temperature in $^{\circ}\text{F}$.	Viscosity in csks.
210	0.79
130	1.74
100	2.60
77	3.75
32	10.0
0	25.0
-20	52.0
-40	134.0

The Bureau of Aeronautics of the Navy Department has specified that the finished aircraft hydraulic fluid should have a viscosity of not less than 10 centistokes (csks.) at 130°F . and not over 2,000 csks. at -40°F . and that the freezing point should be not higher than -50°F . and as low as -65°F . if possible. For use on ships, the Bureau of Ordnance has specified that the viscosity should be not less than 10 csks. at 210°F . and not over 215 csks. at 0°F . while the pour point should be below -40°F .

The preferred, soluble organic polymeric thickener of the hydraulic fluids of this invention consists essentially of a copolymer of ethylene oxide and 1,2-propylene or 1,3-propylene oxide, preferably one containing about 75 mole percent of ethylene oxide and about 25 mole percent of propylene oxide, copolymerized to a thick fluid polymer having an average molecular weight not in excess of about 15,000 to 20,000. This particular polymer thus formed is a fluid designated by the manufacturer, for example, as U-75-H-69,400. The figures 69,400 indicate the viscosity of the pure polymer in Salbolt Universal seconds at 100°F . The effect of this fluid and that of other analogous polymers on the viscosity of the base stock is given in the following table.

TABLE I

Weight percent polymer in glycol-water Base Stock	Viscosity in centistokes				
	210°F .	130°F .	100°F .	0°F .	-40°F .
0.0	0.79	1.74	12.60	25.0	134.0
5.0 U-75-H-90,000	1.93	4.53	-----	86.9	552.1
10.0 U-75-H-90,000	3.66	10.06	-----	223.0	1,500.0
9.8 U-75-H-90,000	-----	10.0	-----	-----	1,470.0
10.7 U-75-H-69,400	-----	9.9	16.3	219.6	1,476.0
20.0 U-75-H-90,000	13.9	35.3	-----	1,007.0	-----
30.0 U-75-H-90,000	34.35	98.95	-----	3,730.0	-----
40.0 U-75-H-90,000	79.1	236.2	-----	-----	-----
50.0 U-75-H-90,000	158.8	498.7	-----	-----	-----

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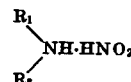
In this table the base stock has a volume ratio of ethylene glycol to water of 55 to 45. The increased effect on the viscosity accomplished by U-75-H-90,000 over that of U-75-H-69,400 is shown by tests 3 and 5 above where the polymer content of the two compositions was very close. By interpolation it is possible to determine the relative proportion of the polymer to the base stock to meet either of the above referenced specifications.

Specific examples of complete hydrolube compositions, based upon the above tests, are given hereinafter.

In general, the greater the average molecular weight of the co-polymer used the less the weight percentage necessary for a given thickening effect. Of course, if the base stock is to be thickened to a higher viscosity at 130°F . a higher concentration of the co-polymer must be used. For instance, to produce from the above base stock a fluid having a viscosity of 20 csks. at 130°F . it is necessary to use 21% of U-75-H-69,400 and 79% of the base stock.

Other properties and characteristics which are essential to hydraulic fluids are: resistance to corrosion of the common metals used in hydraulic systems, stability as to thermal oxidation in the atmosphere, inertness as to effect on rubber or plastic parts in present equipment, resistance to wear of metallic parts exposed to friction, and resistance to break-down of the fluid due to shearing action thereon.

To increase the resistance to corrosive action on the metals commonly present in hydraulic systems or to inhibit the basic hydraulic fluid against corrosion the applicants have found that a class of amine nitrites which can be represented by the following general formula



wherein R_1 and R_2 are any alkyl, aryl, alkaryl or aralkyl organic radicals of which diisopropyl amine nitrite, diisobutyl amine nitrite and dicyclohexyl amine nitrite are typical, possess characteristics which render them ideally adapted to incorporation into corrosion preventing hydraulic compositions. The compounds of low molecular weight, such as the isobutyl, isopropyl and cyclohexyl compounds, have relatively high vapor pressures at ambient temperatures, adsorb strongly onto metal surfaces with which they come into contact and have a sufficient degree of solubility in aqueous organic media to maintain an equilibrium concentration of the amine nitrite vapor in the space above the liquid so that a protective film can be adsorbed onto the metal enclosing such space. Since the solubility of these compounds in aqueous-organic media is limited, adsorption equilibria from dilute solutions are sufficiently favorable to leave on the adsorbent surface a substantially complete layer of adsorbed molecules through a wide range of temperatures without danger of redissolution of the compound, so that the surface once covered thereby is well protected under a wide variety of conditions. In general, the greater the proportion of the organic constituent (e. g. ethylene glycol) in the fluid medium the less soluble the inhibitor and the less that is required.

According to accepted theories of adsorption, when a compound of the nature of a di-substituted amine nitrite, is adsorbed onto a metal sur-

face the nitrite end of the molecule is the one which is adjacent to the surface and attached thereto. The process of attachment to the surface may or may not include actual chemical reaction of the polar end of the molecule with the metal of the surface. When such perpendicular orientation of the molecules takes place, it is apparent that the hydrocarbon ends of the molecules project out from the surface, thereby interposing between the surface and atmosphere or liquid an interface comprising a complete uniform outer layer of contiguous hydrocarbon groups. Since these hydrocarbon groups are hydrophobic, water is prevented from wetting the underlying metallic surface and the latter is thereby inhibited from aqueous corrosion.

Of the vapor phase corrosion inhibitors above given, the applicants have found that diisopropylammonium nitrite is somewhat more effective because of its higher vapor pressure. For that reason the majority of the fluids prepared for service use have contained diisopropylammonium nitrite. In the following compositions it will be referred to as "DIPAN."

For liquid phase inhibition of corrosion of aqueous hydraulic fluids it is necessary that the inhibitor or combinations of inhibitors used be thermally stable to oxidation at temperatures as high as 180° F. They should be effective in small concentrations, e. g. from 0.1% to 5%. They should be soluble in the base fluid at temperatures ranging from below 0° F. to 180° F. depending upon the intended service. They should not interfere either with the thickening action or solubility of the polymer thickener, or give rise on oxidation to detrimental products. Finally, they should not cause the fluid or its vapor to be too toxic for safe use when the fluid leaks out or is spilled in poorly ventilated compartments.

Thus, for reasons of compatibility with and non-interference in the function of the other components of the hydraulic fluid the inhibitor was limited to certain amine salts of which diamylammonium laurate, hereinafter referred to as "DIAL," was found to be the most effective. But this inhibitor was not sufficiently soluble in the base fluid. It produced a turbid solution which was necessary to be made clear by the addition of solubilizing agents, for the reason that in a test pump run of one hundred hours the turbidity became a flocculent precipitate.

As solubilizers of the diamylammonium laurate, salicylal ethanolamine and a combination of butyl Cellosolve (ethylene glycol monobutyl ether) and 2-methyl-2,4-pentanediol were found to be very effective. The function of the 2-methyl-2,4-pentanediol is to hold the diamylammonium laurate in solution at extremely low temperatures, so that it operates to form a hydrophobic film on the metallic surfaces over a range of temperature of about -50° F. to about 160° F. This hydrophobic film not only reduces the corrosion by the base fluid of the metals on which adsorbed but it also reduces the wear loss of the metals which are in frictional engagement with each other.

But this hydrophobic film does not eliminate corrosion of certain of the metals entirely. Copper, copper alloys and 50/50 solder in contact therewith were corroded to some extent. It was found necessary to add a copper deactivator in order to overcome the corrosion of this metal and its alloys. The most effective copper deactivator was found to be sodium mercaptobenzothiazole

which is hereinafter referred to as "MBT." Tests of the base fluid containing from 0.1% to about 0.2% by weight of this additive gave no corrosion of copper. But the final condition of the solution after the test runs was a black discoloration. This discoloration was found to be due to the oxidation of the MBT. This oxidation was eliminated by the use of salicylal ethanolamine as an antioxidant, about 0.2% by weight being sufficient to keep the solution clear and colorless after a relatively long test run.

In the matter of shear breakdown of the polymer thickener the applicants have found that polymers having a molecular weight greater than 15,000 are increasingly subject to shear breakdown or mechanical degradation, this effect becoming very marked where the molecular weights are of the order of 50,000 or more. This means that the viscosity increase and V. I. improvement obtained by the addition of high polymers decreases with time due to the mechanical working of the hydraulic systems. Shear breakdown is indicated by a drop in the viscosity of the fluid which, if it occurs during operation in service, results in great difficulty in maintaining pressure, and faulty operation of the system. Shear breakdown of a polymer thickener is shown graphically in Figure 2 of the drawings. Here the drop in viscosity in centistokes at three fixed temperatures is plotted as a function of the number of cycles of the fluid through an aircraft pump. This particular polymer thickener was "Acrysol G 3667" which is a sodium polymethacrylate resin. The complete composition of Hydrolube A is as follows:

4.8% sodium polymethacrylate
52.6% ethylene glycol
38.8% water
1.6% triethanolamine
0.4% phosphoric acid
1.6% "DIPAN"
0.2% "MBT"

Another desirable property or characteristic of a hydraulic fluid of the type of this invention is that, upon evaporation of the water or ethylene glycol, the residue should not be tacky or hard. There are several instances where threaded connections in the hydraulic system seized and were only disconnected with great difficulty due to the fact that some of the water had evaporated from a hydraulic fluid in which the polymer thickener component was a polymethacrylate resin. Under the same conditions a hydraulic fluid thickened with a polymer used by the applicants leaves a soft waxy residue which does not cause the threaded fittings to seize.

The Hydrolubes of this invention are also superior to the standard petroleum base hydraulic fluid in the matter of their effect on rubber packings. In the following table the effect on rubber packing made by three manufacturers in a seven day immersion test at 158° F. is given. These data show that the percentage volume change is much less for the Hydrolubes than for the petroleum base hydraulic fluid. The complete composition of Hydrolube U-1 is as follows:

10.2% 75-H-69,400
49.7% ethylene glycol
36.4% water
1.5% diethylethanolamine
0.5% phosphoric acid
1.6% "DIPAN"
0.1% "MBT"

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TABLE II

Rubber packing tests
[7 days at 158° F.]

Property	Unaged	Hydrolube U-1	Hydrolube A	Petroleum Base Hydraulic Fluid
Rubber 8¹				
Tensile Strength (lbs./sq. in.)	1,257	1,395	1,435	1,163
Per Cent Elongation	200	150	175	150
Durometer hardness	68	68	68	66
Per Cent Volume change		+7.27	+5.48	+10.6
Rubber 9²				
Tensile Strength	1,688	1,519	1,908	1,295
Per Cent Elongation	242	200	200	175
Durometer hardness	68	68	62	68
Per Cent Volume change		+4.64	+2.18	+17
Rubber 10³				
Tensile Strength	1,860	1,534	1,762	1,980
Per Cent Elongation	242	150	167	233
Durometer hardness	71	70	70	64
Per Cent Volume change		+6.36	+3.76	+11

¹ Rubber 8—Goodyear Rubber Company.² Rubber 9—Arrowhead Rubber Company.³ Rubber 10—Linear Packing Company.

The above data show that the Hydrolubes have a decidedly less effect on the swelling, i. e. the per cent volume change on the three rubber packings tested.

The method of practicing this invention by embodying it in hydraulic fluids will be more completely understood by reference to the following examples which comprise description of specific embodiments typifying preferred hydraulic fluid compositions of the invention.

EXAMPLE I.—HYDROLUBE U-2

Composition percentage by weight	
Polymer 75-H-69,400	10.7
Ethylene glycol	49.9
Water	36.5
Salicylal ethanolamine	0.4
Diamylammonium laurate "DIAL"	0.8
Diisopropylammonium nitrite "DIPAN"	1.6
Sodium mercaptobenzothiazole "MBT"	0.1
	100.0

Temperature in °F.	Viscosity in centistokes
130	10
-40	1,563

Pour point: Below -40° F. Surface tension: 30.6 dynes/cm.

EXAMPLE II.—HYDROLUBE U-3

Composition percentage by weight	
Polymer 75-H-69,400	10.0
Ethylene glycol	38.2
Water	36.9
Butyl Cellosolve	10.0
2-methyl-2,4-pentanediol	2.0
Diamylammonium laurate	1.0
Diisopropylammonium nitrite	1.7
Sodium mercaptobenzothiazole	0.2
	100.0

Temperature in °F.	Viscosity in centistokes
130	10.0
-40	2,310

Pour point: Below -50.

EXAMPLE III.—HYDROLUBE U-4

Composition percentage by weight

Polymer 75-H-69,400	10.0
Ethylene glycol	38.1
Water	36.8
Butyl Cellosolve	10.0
2-methyl-2,4-pentanediol	2.0
Diamylammonium laurate	1.0
Diisopropylammonium nitrite	1.7
Sodium mercaptobenzothiazole	0.2
Salicylaethanolamine	0.2
	100.0

Temperature in °F.	Viscosity in centistokes
130	10.1
-0	244
-40	1,884

Pour point: Below -50° F.

EXAMPLE IV.—HYDROLUBE U-5

[5 csks. at 130° F.]

Polymer 75-H-90,000	4.6
Glycol	41.3
Water	39.0
Butyl Cellosolve	10.0
2-methyl-2,4-pentanediol	2.0
Diamylammonium laurate (DIAL)	1.0
VPI-200 (diisopropylammonium nitrite)	1.7
NaMBT (sodium mercaptobenzothiazole)	0.2
SMEA (salicylaethanolamine)	0.2
	100.0

5 csks. at 130° F. 760 csks. at -40° F.

EXAMPLE V.—HYDROLUBE U-6

[20 csks. at 130° F.]

Polymer 75-H-90,000	14.7
Glycol	35.4
Water	34.8
Butyl Cellosolve	10.0
Hexylene glycol	2.0
DIAL	1.0
VPI-220	1.7
NaMBT	0.2
SMEA	0.2
	100.0

20 csks. at 130° F. 7.6 csks. at 210° F.

EXAMPLE VI.—HYDROLUBE U-7

[30 csks. at 130° F.]

Polymer 75-H-90,000	18.2
Glycol	33.4
Water	33.3
Butyl Cellosolve	10.0
Hexylene glycol	2.0
DIAL	1.0
VPI-220	1.7
NaMBT	0.2
SMEA	0.2
	100.0

30 csks. at 130° F. 11.4 csks. at 210° F.

EXAMPLE VII.—HYDROLUBE U-8

[40 csks. at 130° F.]

Polymer 75-H-90,000	20.8
Glycol	31.9
Water	32.2
Butyl Cellosolve	10.0
Hexylene glycol	2.0
DIAL	1.0
VPI-220	1.7
NaMBT	0.2
SMEA	0.2
	100.0

40 csks. at 130° F. 19.6 csks. at 210° F.

EXAMPLE VIII.—HYDROLUBE U-9

[60 csks. at 130° F.]

Polymer 75-H-90,000	25.2
Glycol	29.4
Water	30.3
Butyl Cellosolve	10.0
Hexylene glycol	2.0
DIAL	1.0
VPI-220	1.7
NaMBT	0.2
SMEA	0.2
	100.0

60 csks. at 130° F. 21.3 csks. at 210° F.

The additives to the base fluid in the above compositions function as follows:

Additive	Function
Salicylal ethanolamine	Antioxidant for the sodium mercaptobenzothiazole.
Diamylammonium laurate	Wear preventer.
Diisopropylammonium nitrate	Vapor phase corrosion inhibitor.
Sodium mercaptobenzothiazole	Copper deactivator.
Butyl Cellosolve and 2-Methyl-2,4-pentanediol.	Solubilizers for the Diamylammonium laurate.

In general, the range in composition of the Hydrolube fluids of the invention, depending upon the particular intended service, will vary within the following limits:

Test run data

TABLE III*Bench tests using "Pesco" gear pumps*

Fluid Hydrolube	Pressure, p. s. i.	Speed, R. P. M.	Temperature, °F.	Time, hrs.	Comments
U-2	1,000	3,600	100	100	Gear weight losses averaged 15 mgs./100 hrs. (1st 100 hrs.); bushing weight losses averaged 10 mgs./100 hrs. (1st 100 hrs.). These weight losses are very low and both the gears and bushings showed very little spalling.
U-3	1,000	3,600	100	100	Gear weight losses averaged 6.3 mgs./100 hrs. bushing weight losses averaged 16 mgs./100 hrs. Special reservoir employed.
U-4	1,500	3,600	140	100	Gear weight losses averaged 103.5 mgs./100 hrs. bushing weight losses averaged 12.3 mgs./100 hrs. (1st 100 hrs.).
A	1,000	1,800	100	400	Gear weight losses averaged 50 mgs./100 hrs. (70 mgs. 1st 100 hrs.); bushing weight losses averaged 2 mgs./100 hrs. (5 mgs. 1st 100 hrs.); viscosity dropped considerably.
AN-VV-O-3665	1,500	3,600	180	100	Gear weight losses averaged 53.3 mgs. 1st 100 hrs.; bushing weight losses averaged 6.3 mgs. 1st 100 hrs.

From about 30% to about 55% by weight of a polyhydric alcohol

From about 50% to about 30% by weight of water

From about 5% to about 20% by weight of a polyalkylene glycol as a thickener for the solution

From about 0.7% to about 2.0% by weight of a wear preventer

From about 0.3% to about 15.0% by weight of solubilizers for said wear preventer

From about 1.0% to about 2.0% by weight of a vapor phase inhibitor

From about 0.1% to about 0.3% of a metal deactivator

From about 0.1% to about 1.0% by weight of an oxidation inhibitor for the metal deactivator

Some of the above described hydraulic fluids were tested in a hydraulic bench system. Reference is here made to Figure 3 of the drawings in which this system, comprised of standard aircraft parts, is shown to include for the gear pump test, Pesco (1P-349N) gear pumps 10 operating at 1800 and 3600 R. P. M. to circulate the fluid, a brass reservoir 12 (approximately 1 gal. capacity), a manometer 14, a line filter 18 having a filter element and hydraulic tubing 20 which usually consisted of 24S-T aluminum or 52S-O aluminum although copper tubing was used in a few runs. After the fluid passed through the pump and was compressed to 1,000 or 1,500 p. s. i., it was passed through a Vickers Model -167-E relief valve 16 and dropped to 25 p. s. i. It then circulated through a copper coil 22 immersed in a thermostated water bath coil (serving as a heat exchanger), through a rotometer 30, and finally flowed back to reservoir 12 where the fluid pressure was again atmospheric. The temperature of the fluid being tested was controlled by thermostatic 24 which cut off motor 11 if temperature exceeded that desired. Thermostatic switch 26 through control of solenoid operated valve 28 regulated the flow of water through water jacket tube 23. Overflow water from tube 23 passed out of the system through outlet tube 25. The entire system contained between three and four gallons of fluid. The thermostat 24 controlling the water bath for the heat exchanger was immersed in the fluid in the reservoir and could be set for any temperature desired. This was usually 100° F., 140° F. or 180° F. The length of the test varied from 50 to 500 hours.

TABLE IV
Bench tests using
Vickers PF9-2713-10ZE Piston Pump

Fluid Hydrolube	Pressure, p. s. i.	Speed, R. P. M.	Temperature, °F.	Time, hrs.	Comments
U-----	1,000	3,600	100	104.5	Ball bearings failed; green deposits on inside of pump; drain line is from pump housing to reservoir instead of through internal relief valve in pump.
U-2----- pH 8.6. Viscosity at 130° F.—10.5 csks.	1,000	3,600	100 140 180	100 100 76	Ball bearings failed; purelator filter element attacked somewhat by fluid; fluid turbid at end of run.
U-2----- pH 8.6. Viscosity at 130° F.—10.5 csks.	1,000	3,600	100	276 648	Ball bearings failed. F8F reservoir (with internal filter) used, as well as drain line from pump housing back to reservoir. Otherwise conditions same as in above run. Fluid turbid at end of run.
U-3----- Viscosity at 130° F.—10.7 csks.	1,000	3,600	140	1,000	Shut down. Pump had not failed. F8F reservoir and drain line used. Fluid circulated through bearings at rate of .33 gal./min.
U-3-----	1,500	3,600	140	382	Pump shut down; ball bearings beginning to fail; F8F reservoir employed; fluid circulated through bearing case at rate of .33 gal./min.
U-4-----	1,500	3,600	140	182	Thrust bearings failed. In this run the polymer thickener was Ucon 75-H-90,000 and the DIAL was Sharple's 120. No pump modifications.
U-4-----	1,500	3,600	140	374	Thrust bearings failed. In this run the polymer thickener was Ucon 75-H-90,000 and the DIAL was Sharple's pilot plant product. This product was of very high purity. No pump modifications.

In the above Vickers pump test runs all runs were carried on to pump failure excepting those runs where non-failure is noted. In none of the tests of the Ucon base fluids was there any significant change in the viscosity of the fluid at the end of the run. There was a noticeable drop in the viscosity of Hydrolube A in which the thickener consisted of a polymethacrylate resin. Also turbidity developed in Hydrolube U-2 fluid in the runs on the Vickers pump. This turbidity reflects the relative insolubility of the diamylammonium laurate in the base fluid. In the fluids where a more efficient solvent for this laurate was used, viz, Hydrolubes U-3 and 4 there was no turbidity developed.

A bench test of the above types of one hundred hours' duration is more than the equivalent of one year's flying time in actual service. This is borne out by the fact that Hydrolube A when tested in the hydraulic system of a Grumman F6F fighter plane operated effectively for a long period of time, viz, after a four months' period and a total of 100 flight hours all of the hydraulically operated parts were still in satisfactory operating condition. Hydrolube U was also tested in the hydraulic systems of ten new Chance-Vought 4-F-U fighter planes and AN-VV-O-366b (petroleum base) aircraft hydraulic fluid was tested in another group of ten planes. These tests were discontinued after a period of fourteen months. There were no mechanical failures attributable to the Hydrolube U fluid. Hydrolube U is therefore suitable for use in fighter planes.

While the bench tests, above given, were carried to pump failure in most cases, it should be noted that these runs were from 100 to as high as 1000 hours' duration. This is equivalent to several years' flying time and in case of the higher times of duration would be more than the normal life expectancy of the plane. Hydrolubes U-2, 3 and 4 are therefore very efficient hydraulic fluids.

The particular compositions given for the different Hydrolubes are merely by way of example since obviously one skilled in the art could vary the percentages slightly from those given without changing the general effect. Such changes are included within the scope of the invention to the extent as defined by the herewith appended claims.

The invention described herein may be manufactured and used by or for the Government of

the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. A non-inflammable hydraulic fluid consisting essentially of from about 30% to about 50% by weight water, from about 30% to about 55% by weight of a freezing point depressant selected from the group consisting of glycols and glycol ethers having from 2 to 14 carbon atoms, from about 4.5% to about 25% by weight of a polyalkylene glycol copolymer having an average molecular weight of from about 15,000 to about 20,000, from about 0.7% to about 2% by weight of diamylammonium laurate, from about 0.3% to about 15% by weight ethylene glycol monobutyl ether, from about 1% to about 2% by weight of a vapor phase inhibitor selected from the group consisting of diisopropyl ammonium nitrite, diisobutyl ammonium nitrite and dicyclohexyl ammonium nitrite, from about 0.1% to about 0.3% by weight of sodium mercaptobenzoethiazole and from about 0.1% to about 1% by weight of salicylaethanolamine.
2. A non-inflammable hydraulic fluid consisting essentially of from about 30% to about 50% by weight water, from about 30% to about 55% by weight of a freezing point depressant selected from the group consisting of glycols and glycol ethers having from 2 to 14 carbon atoms, from about 4.5% to about 25% by weight of a polyalkylene glycol made by copolymerizing about 75 mol percent of ethylene oxide with about 25 mol percent of 1,2-propylene oxide and having an average molecular weight of about 15,000 to about 20,000, from about 0.7% to about 2% by weight of diamylammonium laurate, from about 0.3% to about 15% by weight ethylene glycol monobutyl ether, from about 1% to about 2% by weight of a vapor phase inhibitor selected from the group consisting of diisopropyl ammonium nitrite, diisobutyl ammonium nitrite and dicyclohexyl ammonium nitrite, from about 0.1% to about 0.3% by weight of sodium mercaptobenzoethiazole and from about 0.1% to about 1% by weight of salicylaethanolamine.
3. A non-inflammable hydraulic fluid consisting essentially of about 15% by weight of a copolymer of 75 mol percent ethylene oxide and 25 mol percent 1,2-propylene oxide, having an average molecular weight from about 15,000 to about

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20,000, about 36% by weight ethylene glycol, about 35% by weight water, about 10% by weight ethylene glycol monobutyl ether, 2% by weight hexylene glycol, about 1% by weight diamylammonium laurate, about 0.2% by weight sodium mercaptobenzothiazole, and about 0.2% by weight salicylalethanolamine.

4. A non-inflammable hydraulic fluid consisting essentially of about 10% by weight of a copolymer of about 75 mole percent ethylene oxide and about 25 mol percent 1,2-propylene oxide, having an average molecular weight of about 15,000 to about 20,000, about 38% by weight ethylene glycol, about 37% by weight of water, about 10% by weight of ethylene glycol monobutyl ether, about 2% by weight of 2-methyl-2,4-pentanediol, about 1% by weight diisopropylammonium nitrite, and about 0.2% by weight sodium mercaptobenzothiazole.

5. A non-inflammable hydraulic fluid consisting essentially of about 5% by weight of a copolymer of about 75 mol percent ethylene oxide and about 25 mol percent 1,2-propylene oxide having an average molecular weight of about 15,000 to about 20,000, about 41% by weight ethylene glycol, about 39% by weight water, about 10% by weight ethylene glycol monobutyl ether, about 2% by weight 2-methyl-2,4-pentanediol, about 1% by weight diamylammonium laurate, about 1.7% by weight diisopropylammonium nitrite, about 0.2% by weight sodium mercaptobenzothiazole, and about 0.2% by weight salicylalethanolamine.

6. A non-inflammable hydraulic fluid consisting essentially of from about 30% to about 50% by weight water, from about 30% to about 55% by weight of a freezing point depressant selected

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from the group consisting of glycols and glycol ethers having from 2 to 14 carbon atoms, a highly viscous polyalkylene glycol copolymer having an average molecular weight up to about 20,000 in amount sufficient to thicken the hydraulic fluid, from about 0.7% to about 2% by weight of diamyl ammonium laurate, from about 0.3% to about 15% by weight of ethylene glycol monobutyl ether, from about 1% to about 2% by weight of a vapor phase inhibitor selected from the group consisting of diisopropyl ammonium nitrite, diisobutyl ammonium nitrite and dicyclohexyl ammonium nitrite, from about 0.1% to about 0.3% by weight of sodium mercaptobenzothiazole and from about 0.1% to about 1% by weight salicylalethanolamine.

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