ORGANIC CHEMICALS DIVISION RESEARCH Report

St. Louis Research Report No. 2557

Final Report

on

Pydraul Fluids

Monsanto

ST. LOUIS, MO.

DSW 622240

MONSANTO CHEMICAL COMPANY

ORGANIC CHEMICALS DIVISION

St. Louis Research Department

St. Louis Research Report No. 2557

Final Report

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Pydraul Fluids

Application Research

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INTRODUCTION

The objective of this research was to provide an application program to maintain and to expand Monsanto's industrial functional fluid product line. This report presents the application research studies completed during the period January 1959 through December 1959.

SUMMARY

Appropriate application tests were performed to screen new base stocks and additives, to prepare new fluid formulations, and to service some existing fluid formulations. Future work of this nature will continue under a new job number, 2-02-760.01-4009.

I. Screening of Fluids and Additives

Sixteen experimental base stocks submitted for screening as fire resistant fluids included several aryl phosphate esters and some Pirum compounds (phosphono-phosphites). Of these, the tertiary butyl triaryl phosphates and a special batch of electrical grade tricresyl phosphate exhibited the most promise for further evaluation.

A poly alkylbenzene high boiler from the dodecylbenzene process was given brief consideration as a refrigeration compressor lubricant base. This fluid's poor viscosity characteristics coupled with a lack of activity in this type of fluid resulted in no further work.

Seventeen potential lubricating additives were screened in an Aroclor base stock. Of these eight exhibited antiwear activity and will be referred to in the future as required for Aroclor type formulations.

Several commercial materials and an experimental additive were screened as viscosity index improvers in Aroclor 1242 and tricresyl phosphate base stocks. It was concluded that the high molecular weight Ucons (believed to be ethylene and propylene glycol polymers) are good viscosity index improvers but should be modified to decrease or prevent severe emulsion and water solubility problems.

II. Fluid Formulations

Formulation work toward industrial type functional fluids included a blend based on cresyl diphenyl phosphate to provide a fluid with relatively good low temperature properties and thermal stability better than Pydraul 60, addition of snuffer diluents to Pydraul 150 for liquid oxygen fire resistance, and a brief study of air compressor lubricant low temperature improvement.

OS-127, the cresyl diphenyl phosphate based fluid, was prepared and submitted to a customer for testing.

Several halogenated snuffer diluents were screened in Pydraul 150 to provide improved fire resistance in liquid oxygen contact and in oxygen rich atmospheres. Work on the snuffered Pydraul 150 was not completed during this report period.

Preliminary estimates of Aroclor-dicresyl phenyl phosphate and Aroclor-tricresyl phosphate blends indicated these mixtures may offer some low temperature viscosity advantage over Pydraul AC. However, these blends suffer losses in viscosity at higher temperatures.

III. Existing Formulation Servicing

The industrial gas turbine lubricant application of OS-81 prompted several laboratory studies. These included high lead babbitt bearing compatibility, hydrogen sulfide and monoethanolamine compatibility, and suggestions for a fire resistant air filter fluid.

An experimental Aroclor (chlorination intermediate between Aroclor 1242 and Aroclor 1248) was given a preliminary evaluation as an OS-81 raw material.

The phosphate ester based preservative fluid, OS-100, was further evaluated for physical and chemical properties and the formulation clarified and defined for patent purposes.

Several Pydraul A-200 production lots were checked for correlation of pour points with low temperature viscosity.

Studies were conducted on contaminated Pydraul F-9 and contaminated Pydraul 625, to guide their further use.

IV Miscellaneous

At the Development Department's request a sample of OS-98, a synthetic automotive fluid candidate, was prepared and sent to General Motors. OS-115 and OS-116, experimental phosphate ester based preservative fluids were prepared and sent to the U.S. Naval Engineering Experiment Station.

DISCUSSION AND EXPERIMENTAL WORK

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I. Screening of Fluids and Additives

A. Fire Resistant Base Stocks

Experimental base stocks submitted for screening as fire resistant fluids included several aryl phosphate esters and some Birum compounds (phosphono-phosphite). The Birum compounds exhibited gross thermal instability and corrosive

tendencies. Of the phosphate esters checked, the tertiary butyl triaryl phosphates and a special batch of electrical grade tricresyl phosphate exhibited the most promise for further evaluation. During the period of this report it was not decided which of these latter materials would be considered for further formulation work.

A list of the specific materials evaluated follows:

Tri(X-2 Aryl*) phosphate
Triaryl phosphate from A Grade cresylic acid and o-phenyl phenol
37% alkylated triaryl phosphate from Eastman tert. butyl phenol and phenol.
Alpha cumyl phenyl diphenyl phosphate
Alpha cumyl phenyl dicresyl phosphate
37% alkylated tert. butyl-triaryl phosphate, unpermanganated and from pilot plant tert. butyl phenol
37% alkylated tert. butyl-triaryl phosphate, permanganated and from pilot plant tert. butyl phenol
34% alkylated tert. butyl-triaryl phosphate, permanganated and from pilot plant tert. butyl phenol
Diphenyl m-phenoxyphenyl phosphate
Tris (m-phenoxyphenyl) phosphate
Tricresyl phosphate (experimental electrical grade)
Bis (2-chloroethyl) (1-hydroxyethyl) phosphonate, bis (2-chloroethyl) phosphite, CP-14894-3
Bis (2-chloropropyl) (1-hydroxyethyl) phosphonate, bis (2-chloropropyl) phosphite, CP-30974-3
Bis (2-chloroethyl) 2-hydroxybenzyl) phosphonate, bis (2-chloroethyl) phosphite, CP-14893-3

*Kopper's X-2 cresylic acid

Phosphonate from PCl_3, ethylene oxide, and acetaldehyde heated at 200°C, CP-31156-2
Phosphonate from PCl_3, propylene oxide, and acetaldehyde heated at 200°C, CP-31160-2

Primary screening procedures included a 250°F, 168 hour, oxidation-corrosion test, Shell Four-Ball Wear Test, and viscosity property measurements. Fluids exhibiting very poor results in any one of these were not evaluated further. Those fluids exhibiting better results were subjected to hydrolytic stability and emulsion tests. Promising candidates were then subjected to remaining Mil-H-19457 specification tests since one of the current objectives called for the formulation of a suitable fire resistance fluid for this Navy requirement.

Oxidation-corrosion test results appear in Table I. Tricresyl phosphate values are included for comparison. Of the various phosphate esters evaluated the tertiary butyl triaryl phosphates appeared to be the best. Of these the ones which had been treated with permanganate during preparation had higher copper losses. The Birum compounds (phosphonate, phosphites) were very corrosive and suffered extreme viscosity increases during the oxidation-corrosion testing. Heat treated versions of these compounds failed to increase the thermal and corrosive stability.

Four-ball wear test results for several of the fluids screened appear in Table II. In addition, various other phosphate esters as well as some commercial fluids are included. It is noted that steel-on-steel wear for the experimental esters is higher than for the commercial fluids, that steel-on-bronze is lower, and that they are equivalent to other similar phosphate esters. In general, alkyl phosphates have the best antiwear properties with wear increasing for the other esters in the order: mixed alkyl aryl phosphates, alkylated aryl phosphates, and aryl phosphates.

These oxidation-corrosion and four-ball wear results indicated the tert. butyl-triaryl phosphates prepared from pilot plant tert.butyl phenol to be nearly equivalent to tricresyl phosphate. Mil-H-19457 (Navy fire resistant hydraulic fluid) tests were then run on these esters. The 37% pilot plant No. 2 alkylated, unpermanganated material is preferred over the permanganated versions of these fluids since it met all the Mil-H-19457 specifications checked. The permanganated fluid had a high water layer acidity in the hydrolytic stability test and a higher than specification evaporation loss. These test results appear in Table III.

A sample of laboratory prepared tricresyl phosphate (sample number C-3783) reported to have good electrical properties had viscosity and emulsion characteristics which would make it a Mil-H-19457 fluid candidate. Since the particular sample had a higher than normal acidity it was suggested that further preparations be made for additional functional testing.

During the period of this report no further work was done on the electrical grade tricresyl phosphate or the tert. butyl-triaryl phosphates pending a decision on the best base stock approach for the Mil-H-19457 application.

Diphenyl m-phenoxyphenyl phosphate (NBP-32381) had favorable viscosity characteristics for the Mil-H-19457 application. Four-ball wear for this fluid was very high and the scar irregular and ridged. Subsequently, it was found that this material solidifies at room temperature. Four-ball wear and viscosity determinations of several tricresyl phosphate and diphenyl m-phenoxy phenyl phosphate mixtures indicated no unusual viscosity index behavior or antiwear property improvements. These properties appear to be additive. Also, antiwear values for the phenoxy phenyl

derivative were not appreciably improved at higher temperatures.

As was previously mentioned, the Birum compounds (phosphonate, phosphites) exhibited gross thermal instability and corrosive tendencies. However, two of these materials (CP-14894-3 and CP-30974-3) exhibited good fire resistance properties in the high and low pressure spray flammability tests. No other more stable modifications of these compounds were studied during the period of this report.

B. Refrigeration Compressor Lubricant

Polyalkylbenzene high boiler from the dodecylbenzene process was suggested as a refrigeration compressor lubricant base and especially for Freon 22 service. A sample of this material, although considerably more viscous, exhibits lubricating properties equivalent to or better than a commercially available refrigeration lubricant (Sun Oil Co., Suniso 3G). No further work was done with this material during this report period.

Four-ball wear and viscosity values for the polyalkylbenzene highboiler, Suniso 3G, and Mobil DTE medium appear below.

		Polyalkylbenzene highboiler from DDB Process, S-145	Suniso 3G S-187	Mobil DTE Medium S-100
Viscosity				
100°F		107 cs	33.8 cs	--
210°F		7.79	4.58	--
Four-Ball Wear(167°F, 1 hour, 600 rpm):				
Steel-on-Steel	10Kg -	0.48	0.53	0,24
	40Kg -	0.62	0.57	0.38
Steel-on-Bronze	10Kg -	1.44	2.38	1.48
	40Kg -	3.22	--	--

C. Lubrication Additive Screening

Several potential lubricating additives were screened in a 1 to 2 weight mixture of Aroclor 1242 and Aroclor 1248. The four-ball wear test at 167°F, 620 rpm, one hour, steel-on-steel, and steel-on-bronze was used for screening purposes. Compounds exhibiting anti-wear activity in the Aroclor base stock are tabulated below.

dioctyl hydrogen phosphite
polyisobutylene-P_2S_5 reaction product (SL-13556)
o-tolyl-α,α,α-trifluoro-m-tolyl sulfide (SL-14996)
Santolube 31
tricresyl phosphate
di(o-chlorophenyl) phenyl phosphate
tri(o-chlorophenyl) phosphate
di(p-chlorophenyl) phenyl phosphate

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It was observed that the additive concentration was critical in some cases. These favorable additives will be referred to in the future as required for Aroclor type formulations.

Four-ball wear results for the additives screened appear in Table IV.

D. Viscosity Index Improver Screening

Several commercial viscosity index improvers and an experimental additive were screened as viscosity index improvers in Aroclor 1242 and tricresylphosphate (TCP) base stocks. The experimental material (Pluronic L-61 diperlargonate, NBP:21549) apparently was of too low molecular weight to be effective. The acryloid type material are effective in Aroclor 1242 but have very poor shear stability; whereas, the Ucon type materials of higher molecular weight are both effective and shear stable. The Ucon materials were also effective and shear stable in TCP. Emulsion tests of the Ucon type improvers indicate a very severe emulsion problem in both TCP and Aroclor 1242.

Table V presents effectiveness and shear stability results for several commercial viscosity index improvers in Aroclor 1242 and TCP. Table VI presents emulsion results for some of the Ucon viscosity index improvers in the Aroclor and TCP base stocks.

Of the additives screened in Aroclor 1242 only two, Ucon 75-H-90,000 and Ucon 50-HB-35,000 were both effective (increased viscosity index greater than 0) and shear stable (less than 20% viscosity loss at 210° F upon shearing and final viscosity index greater than 0). Rohm and Haas HF-855 and Ucon 50-HB-25,000 were next with viscosity indices near 0 and less than 20% shear loss but with final viscosities less than 0. All of the other additives were either ineffective or very shear unstable.

Only a few of the Ucon additives and none of the Rohm and Haas materials were checked in TCP. It is expected that relative shear losses would be the same for a particular additive in both Aroclor and TCP but that effectiveness might be considerably different. Ucon LB-1715 appears to be effective in TCP whereas it was not effective in Aroclor 1242.

Although the higher molecular weight Ucons, 75-H-90,000 and 50-HB-50,000 are both effective and shear stable in the TCP and Aroclor base stocks they cause a severe emulsion problem. Ucon LB-1715 results in only little emulsification problem.

The general conclusion on these additives is that the high molecular weight Ucons (believed to be ethylene and propylene glycol polymers) are good viscosity index improvers but should be modified to decrease or prevent a severe emulsion problem.

II FLUID FORMULATIONS

A. OS-127-Low Viscosity, Thermally Stable Fluid

A project was initiated to rust inhibit and dye cresyl diphenyl phosphate (OS-109) to meet the requirements of a specific customer (Alcoa). This was done to provide a fluid with relatively good low temperature properties and thermal stability better than for Pydraul 60. This formulation, designated OS-127, follows:

Cresyl diphenyl phosphate	99.7% (w)
Santolube 70	0.3% (w)
DuPont Oil Blue A	7 ppm
DC 200-350 cs.	50 ppm

Physical and functional tests indicated this fluid to be satisfactory for use and a sample was prepared for customer testing.

The minimum Santolube 70 necessary to rust inhibit OS-109 (cresyl diphenyl phosphate) was found to be 0.3% (w). Lower concentrations allowed rusting in the ASTM D-665 24 hour test with distilled water. The rust inhibited OS-109 exhibited considerable foaming tendency and some foam persistence (450 ml foam, 10 ml. at 10 minutes) which was improved by the addition of DC 200 antifoam fluid.

Both of the dyes tested (DuPont Oil Blue A and Alizarine Irisol NPDR) retained their color after nine (9) weeks exposure at 150°F. On the basis that the color of the DuPont Oil Blue A containing blend nearly matched that of Pydraul 60 it was chosen for further study and was subsequently designated OS-127. An oxidation-corrosion test of this blend indicated it was considerably better than Pydraul 60 with respect to metal attack, acidity increase, and viscosity increase. Oxidation-corrosion results appear in Table VII.

Four-ball wear of the rust inhibited and dyed fluids were not appreciably changed from OS-109.

	Four-Ball Wear*			
	Steel-on-Steel			Steel-on-Bronze
	4 Kg.	10 Kg.	40 Kg.	10 Kg.
OS-109	0.38	0.41	0.65	0.86
OS-109 + 0.3% Sant. 70	0.30	0.39	0.63	0.81
OS-109 + 0.3% Sant. 70 + 7 ppm DuPont Oil Blue A	--	0.34	0.62	0.76
OS-109 + 0.3% Sant. 70 + 7 ppm Alizarine Irisol NPDR	--	0.34	0.64	0.77

* 1 Hr., 620 rpm, 167°F.

B. PYDRAUL 150 - SNUFFER DILUENTS

A fluid fire resistant in oxygen rich atmospheres was desired for a missile launching application (American Machine and Foundry). Three potential snuffers (perchloroethylene, Freon 113, Kel-F Oil No. 1) were blended with Pydraul 150 to approximate viscosity requirements specified by AMF. Oxidation-corrosion tests, flash and fire points, autogeneous ignition temperatures, and molten metal ignition tests of these blends indicated no particular choice. On the basis of cost and availability, it was recommended that the perchloroethylene and Freon 113 versions be submitted for appropriate liquid oxygen flammability tests. These tests were not completed during this report period and further work on the snuffered Pydraul 150 is continued under job number 4009.

It was requested that a Pydraul type fluid containing a halogenated snuffer be prepared to provide imprpved fire resistance in an oxygen rich atmosphere (memo R. Davis to H. S. Litzsinger, October 28, 1959). The following viscosity limits were specified:

160°F	58 SUS, Min.	(9.67 cs.)
100°F	145 SUS, Min.	(30.6 cs.)
0°F	2450 SUS, Max.	(532 cs.)
35°F	13000 SUS, Max.	(2830 cs.)

A plot of these points indicated not all conditions could be met by a Pydraul type fluid. The 0°F maximum and 160°F minimum values appeared to be the most realistic. Formulation work was done with Pydraul 150 since its viscosity level was slightly higher than that desired. Potential snuffers considered were low melting, medium volatility halogenated materials having viscosities lower than Pydraul 150. Materials which appeared to fit these requirements but which were subsequently eliminated for reasons of toxicity, volatility, availability, solubility, or cost follows:

Carbon tetrachloride

Methylene chloride

Ethylene trichloride

1,2,4 Trichlorobenzene

Fluorotrichloroethylene

Fluorochemical FC-75

Fluorochemical FC-101

Freon 213

Materials chosen for further evaluation were:

Kel-F Oil No. 1 (M. W. Kellogg chlorotrifluoroethylene polymer)

Perchloroethylene

Freon 113 (trifluoro trichloro ethane)

The Kel-F version was subsequently eliminated due to its excessive cost.

Flash point, fire point, A.I.T., and viscosity values for Pydraul 150 containing perchloroethylene, Freon 113, and the Kel-F oil appear in Table VIII. Oxidation-corrosion tests of the three blends indicate they are comparable to Pydraul 150 alone. These data appear in Table IX.

C. Air Compressor Lubricant - Low Temperature Improvement

Pydraul AC suffers definite low temperature limitations. Some preliminary estimates were made of Aroclor-tricresyl phosphate and Aroclor-dicresyl phenyl phosphate blend viscosity properties. These calculations indicated that Aroclor 1248-tricresyl phosphate (TCP), Aroclor 1254-cresyl diphenyl phosphate (CDP), and Aroclor 1248-CDP mixtures may offer some low temperature viscosity advantage over Pydraul AC when these are blended on an equivalent phosphate ester basis. However, these fluids suffer losses in high temperature

viscosity. Calculated values for various phosphate ester-Aroclor mixtures appear in Table X. No formulation was done pending a better definition of lower temperature air compressor lubricant philosophy and outline of more specific requirements.

III Existing Formulation Servicing

A. OS-81-Gas turbine Lubricant Application

1. Texas Eastern Transmission-Used OS-81

Used OS-81 samples from Texas Eastern Transmission Corporation's industrial gas turbine equipment were evaluated. The data obtained indicated the fluids from three different pumping stations had viscosity, specific gravity, moisture, acidity, and 4-ball wear equivalent to new OS-81. Flash and fire points, A.I.T., and molten metal ignition tests run on certain selected samples indicated no apparent decrease in fire resistance. Various used samples exhibited increased foam tendency and persistence. Use history for these OS-81 samples is not accurately known and it is estimated that they represent 4 to 6 months service in the gas turbine application.

One of the Texas Eastern Stations (Armagh) experienced a seal break (no details given) which resulted in contamination of the OS-81 lubricant. The fluid contained a fine black material not readily removed by filtration. Functional and physical properties of this fluid were considered equivalent to new OS-81 both before and after filtration treatments. A subsequent sample from the Armagh Station which had been further filtered to remove the black suspended contaminant was found to be equivalent to new OS-81.

2. High Lead Babbitt Bearing Compatibility

A high lead babbitt bearing was exposed to OS-81 in a modified ASTM D-943 Steam Turbine Oil Oxidation test. This was done to provide General Electric Company with information for application of OS-81 in their large gas turbines. General comments on this test are that the babbitt was not attacked appreciably until after 1200 hours exposure, the acidity of the fluid remained less than 0.02 mg. KOH per gm. through 1500 hours; and the steel exhibited rusting at 840 hours. Tests of typical OS-81 in the unmodified D-943 test have exhibited sporadic rusting at about 700 hours in the past.

The high lead babbitt bearing from General Electric Company was exposed to OS-81 in a modified D-943 oxidation test as specified in a procedure from General Electric's Large Steam Turbine-Generator Department. The principal test modifications are the placing of a doughnut shaped bearing specimen on the holder below the copper-steel catalyst coil separated with a glass spacer, the use of 30 ml. of water instead of 60 ml., and the periodic removal of the bearing for a weight check.

Table XI presents the results of this test. It is noted that the bearing weight didn't change appreciably until after 1200 hours and that the steel didn't start rusting until about 800 hours. Sporadic rusting of the steel is considered normal at about 700 to 800 hours for OS-81 in the unmodified test.

3. Hydrogen Sulfide and Momoethanolamine Compatibility

OS-81 does not appear to be adversely affected on exposure to hydrogen sulfide and monoethanolamine with water present. This information was obtained to answer questions pertaining to the proposed application of OS-81 by El Paso Natural Gas Company.

Table XII contains physical and functional properties for OS-81 treated with water, water and hydrogen sulfide, and water and monoethanolamine. In each case 450 cc. of OS-81 in a watch glass covered 600 ml. beaker were placed in a 150°F oven. The first day 5 cc of water was stirred into each. The second day 5 cc of water was stirred into each, hydrogen sulfide bubled through one for 15 minutes with a coarse sintered glass bubbler and 1 cc of monoethanolamine added to another. The same treatment as the second day was repeated three more days and then the samples were held in the oven at 150°F three days without treatment.

4. Air Filter Application

A fire resitant fluid was desired to replace a petroleum fluid in air filters at the Texas Eastern Transmission Gas Turbine installations using OS-81. Viscosities of the petroleum fluid (Viscosine), OS-81, Santicizer 140, and OS-104 tabulated below indicate Santicizer 140 to be the best fire resistant candidate.

Fluid	Viscosity, cs.		Pour Point, of
	210°F	100°F	
Viscosine	3.797	22.55	--40°F
Santicizer 140	3.26	17.81	--
OS-81	3.073	33.33	--
OS-104(70/30:S-140/TCP)	3.53	20.32	--

B. OS-81 Raw Material Revision

OS-81 prepared from Aroclor 1246.4 (chlorination intermediate between Aroclor 1242 and Aroclor 1248) appears to be equivalent to typical OS-81 prepared from the individual Aroclors 1242 and 1248. Since this special Aroclor may provide some process advantages over the current method of blending, it was recommended that it be more completely evaluated in the OS-81 formulation. No further work was done on this project in this report period pending preparation of additional Aroclor. The special Aroclor was blended with TCP to form an OS-81 type material. Blended in the given proportions of Aroclor and TCP, the viscosity was slightly higher than specification OS-81; however, this could be easily adjusted on future batches. Table XIII contains viscosity, specific

gravity, foam, 4-Ball Wear, and ASTM D-943 steam turbine oil oxidation information for this special OS-81, and Table XIV presents 250°F, 168 hour oxidation-corrosion results. The steam turbine oil oxidation results on the special OS-81 were the only results not considered completely equivalent to those of OS-81. It is noted, however, that results for OS-81 in this test have varied considerably in the past.

C. OS-100 Phosphate Ester Based Preservative Fluid

Additonal functional, physical, and chemical properties were determined on the OS-100 preservative fluid formulation. Also, work was done to define and clarify this formulation for patent information purposes.

Properties determined to supplement previously reported OS-100 values (Special Report: OS-100, St. Louis Research Report No. 2257, March 4, 1959) follow:

Acidity, ASTM D-664, T. A. N. - 10.3 mg. KOH/gm.

Pour Point - 15°F.

High Pressure Spray Flammability (SAE-AMS-3150) - does not ignite

Low Pressure Spray Flammability (SAE-AMS-3150) - flame does not increase or decrease.

Molten Metal Ignition (Aluminum Alloy at 1100°F) - does not flash or burn spontaneously; burns to completion when vapors are ignited by flame or spark.

Pour Point of TCP was found to be -30°F. at the time this value was obtained.

TCP tested at the same time did not flash or burn spontaneously and flashing occured when vapors were ignited by flame or spark. Flame was not self-sustaining.

A question of component separation prompted a storage test. No separation was observed for OS-100 exposed for one year at 0°F and -30°F with occasional warming to room temperature. Likewise, no separation was observed in a sample stored at room temperature for one year. The fluid gradually darkens to an opaque purple color. This is believed to be due to the presence of the phenyl-- napthylamine additive.

Additional work done to define and clarify the OS-100 formulation indicates that RT-67-A (dilinoleic acid) alone at 5% (wt.) concentration is sufficient to provide 30 days humidity cabinet protection. The use of a small quantity of RT-53-A in conjunction with RT-67-A appears to enhance the preservative action of the RT-67-A slightly. Minimum total inhibitor concentration (RT-67-A and RT-53-A) was found to be between 3% and 5%.

Cresyl diphenyl phosphate used in place of TCP in a OS-100 formulation had protective capability equivalent to the TCP formulation; whereas, a formulation based on dibutyl phenyl phosphate was less effective. Table XV presents humidity cabinet results for variations of the OS-100 formulation and for some similar formulations based on dibutyl phenyl phosphate and cresyl diphenyl phosphate.

D. Pydraul A-200 - Pour Point

Production lots of Pydraul A-200 were reported to have pour points higher than expected. Viscosities at 50°F were run to compare with pour points reported for various Pydraul A-200 lots. These viscosities do not appear to correlate well with the pour points. This is attributed to the poor reproducibility of apparent pour points obtained on fluids which do not have a true pour point as do paraffin containing petroleum oils. Viscosity and pour point values for various lots representing the range of pour points from +5°F to +15°F are presented in Table XVI.

E. Pydraul F-9 - Contaminated

A sample of contaminated Pydraul F-9 from a J.F.Q. Plant Dept. 53 centrifugal hydraulic control system was found to have about 4% water present and a total acid number of 0.22. The water layer had an acid number of about 2.0 (reported possible contamination with fumaric, maleic, hydrochloric, nitric acids). Four ball wear was abnormally high (0.45 vs 0.28 at 10 Kg for new Pydraul F-9).

Pydraul F-9 was put in this system some years ago to gain full scale application information. Since such information is not being obtained currently it was recommended that the F-9 be replaced with an appropriate petroleum oil. The contamination problem and its elimination will still exist.

F. Pydraul 625 - Contaminated

A batch of Pydraul 625 contaminated with tetrapropenylsuccinic anhydride had an initial total acid number of 11.6. After a 2% NaOH treatment the acidity had been reduced to 1.5 TAN. Further caustic treatment and washing reduced the acidity to 0. This washed fluid was adjusted in viscosity with Aroclor 1260. The required amount of Aroclor 1260 was determined to be 5% (v), 6.7% (w).

Subsequent 4-Ball Wear tests indicated this reworked material to be inferior to normal Pydraul 625. On the basis of this result and the excessive washing necessary to reclaim this material it was recommended that it be discarded.

	Viscosity	
	100°F	210°F
Pydraul 625 spec. limits	5.9-6.1 cs.	132-138 cs.
Reclaimed Pydraul 625	5.77	112.7
Reclaimed Pydraul 625 + 4% (v) Aroclor 1260 (5.4% wt.)	5.95	129.5
Reclaimed Pydraul 625 + 6% (v) Aroclor 1260 (7.95% wt.)	6.06	140.9

It is estimated that 5% (v), 6.7% (w) Aroclor 1260 would be required to bring the viscosity within specifications. Shell 4-Ball Wear values on the washed and viscosity adjusted material follow:

Shell 4-Ball Wear, 1 Hr., 620 RPM, 167°F

	Reclaimed Pydraul 625	Normal Pydraul 625
Steel-on-Steel, 10 Kg	0.43	0.28
40 Kg.	0.75	0.61
Steel-on-Bronze, 10 Kg.	0.83	0.98

Foaming for this reclaimed fluid was not excessive as determined by the ASTM D-892 foam procedure.

IV Miscellaneous

A. Sample Supply

A 5-gallon sample of OS-98, a synthetic fluid for automotive use, was prepared and sent to General Motors at the Development Department's request. This sample of OS-98 (lot S-193) had an acidity (TAN) of 1.92 compared to 0.95 reported for a previous sample. A blend of the diisodecyl adipate with M-437 at the concentration of OS-98 had an acidity of 1.83 with a neat adipate acidity of 0.10. The previous OS-98 batch (Lot B-2299) was checked by the currently used method of this laboratory and was found to be 1.86. It is believed that this erratic acidity behavior is due to the M-437 additive and the various acidity procedures used.

	OS-98 Lot B-2299	OS-98 Lot S-193
Viscosity: 210°F	7.96	8.39
100°F	37.45	40.53
Specific Gravity: 25/25°C	0.9338	0.9372
Acidity	0.95	1.92(TAN, ASTM-
Moisture	0.13	-- (D-664)

One gallon samples of OS-115 and OS-116 were prepared and sent to tl U. S. Naval Engineering Experiment Station at the Development Department's request. OS-115 and OS-116 to be evaluated by the Navy as preservative fluids are, respectively, 95% tricresylphospha (TCP), 4.5% RT-67-A, 0.5% RT-53-A and 95% TCP, 5% N-7797.

TABLE I

OXIDATION-CORROSION: 250°F, 168 HRS. PER FS-791-5308.4

	ALPHA CUMYL PHENYL DIPHENYL PHOSPHATE	ALPHA CUMYL PHENYL DICRESYL PHOSPHATE	BIS(2-CHLOROETHYL) (1-HYDROXYETHYL) PHOSPHONATE, BIS (2-CHLOROETHYL) PHOSPHITE, CP-14894-3	BIS(2-CHLOROPROPYL) (1-HYDROXYETHYL) PHOSPHONATE, BIS (2-CHLOROPROPYL) PHOSPHITE, CP-30974-3
METAL ATTACK, mg/cm²				
ALUMINUM	0	+0.01	ALL METALS EXCEPT	0 SL. PITTING
MAGNESIUM	0 V. SL. ETCH	+0.01	COPPER ETCHED BEYOND RECOGNITION.	−1.7 ETCHED
COPPER	−2.28 ETCHED	−0.93 V. SL. ETCH, BROWN ST.	ONE COMPLETELY GONE; OTHERS WITH	−13.1 SEVERE ETCH
STEEL	+0.02	0 V. SL. ETCH	BLACK AND COPPER COLORED COAT	−0.02 SL. PITTING
CADMIUM PLATE	−0.55 SL. ETCH, COPPER ST.	−0.07 V. SL. ETCH, GREY ST.		−1.23 SL. ETCH
ACIDITY; INITIAL, TAN	0.68	0.62	—	—
FINAL, TAN	1.02	1.08	—	—
VISCOSITY; 100°F INITIAL	455 cs	191 cs	—	681. cs
100°F FINAL	448 cs	205 cs	—	3080.
210°F INITIAL	—	—	—	21.1
210°F FINAL	—	—	—	94.9
FLUID CONDITION;	—	—	WAXY WHITE TO VIOLET COLORED SOLID	EXTREMELY VISCOUS GREY CLEAR

TABLE I

OXIDATION-CORROSION: 250°F, 168 HRS. PER FS-791-5308.4

	BIS(2-CHLOROETHYL) (α-HYDROXY BENZYL) PHOSPHONATE, BIS (2-CHLOROETHYL) PHOSPHITE, CP-14893-3	PHOSPHONATE FROM PCl_3, ETHYLENE OXIDE AND ACETALDEHYDE HEATED AT 200°C CP-31156-2	PHOSPHONATE FROM PCl_3, PROPYLENE OXIDE AND ACETALDEHYDE HEATED AT 200°C CP-31160-2	
METAL ATTACK, mg/cm²:				
ALUMINUM	+0.23 ETCHED	-0.03 SL. ETCH	+0.01 SL. CU. STAIN	
MAGNESIUM	-11.95 SEVERE ETCH	-53.2 SEVERE ETCH	-29.6 SEVERE ETCH	
COPPER	-10.5 SEVERE ETCH	-11.5 SEVERE ETCH	-13.5 SEVERE ETCH	
STEEL	-2.72 ETCHED	-11.3 ETCHED	-2.70 ETCHED	
CADMIUM PLATE	-7.48 ETCHED	-20.9 ETCHED	-9.8 SEVERE ETCH	
ACIDITY: INITIAL, TAN	—	—	—	
FINAL, TAN	—	—	—	
VISCOSITY: 100°F INITIAL	332. cs	449. cs	2,010. cs	
100°F FINAL	2536.	13,860. cs	16,100. cs	
210°F INITIAL	16.02	—	—	
210°F FINAL	48.6	—	—	
FLUID CONDITION	VERY VISCOUS DARK GREY TRANSLUCENT	SL. TURBID VISCOUS	SL. TURBID VISCOUS	

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TABLE I

OXIDATION-CORROSION: 250°F, 168 HRS. PER FS-791-5308.4

	TERT. BUTYL TRI-ARYL PHOSPHATE, 37% PILOT PLANT #2 ALKYLATED, UNPERMANGANATED S-156	TERT. BUTYL TRI-ARYL PHOSPHATE, 37% PILOT PLANT #2 ALKYLATED, PERMANGANATED S-157	TERT. BUTYL TRI-ARYL PHOSPHATE, 34% PILOT PLANT #1 ALKYLATED, PERMANGANATED S-158	
METAL ATTACK, mg/cm²:				
ALUMINUM	-0.01	0	0	
MAGNESIUM	0	0	0	
COPPER	-0.04 V.SL. PITTING	-0.17 V.SL. ETCH	-0.13	
STEEL	-0.02	0	0	
CADMIUM PLATE	-0.02	0	0	
ACIDITY: INITIAL, TAN	0.01 TBN	0.01	0.01	
FINAL, TAN	0.01 TBN	0.03	0.02	
VISCOSITY: 100°F INITIAL	46.8 cs	47.1 cs	41.98 cs	
100°F FINAL	47.1	47.5	42.3	
210°F INITIAL	5.43	5.46	5.16	
210°F FINAL	5.45	5.48	5.18	
FLUID CONDITION:	ALMOST CLEAR NEARLY UNCHANGED FROM NEW	CLEAR RED-BROWN NEARLY UNCHANGED FROM NEW	CLEAR RED-BROWN NEARLY UNCHANGED FROM NEW	

TABLE I

OXIDATION - CORROSION: 250°F, 168 HRS. PER FS-791-5308.4

	TRI ARYL PHOSPHATE (A GRADE CRESYLIC AND o PHENYL PHENOL	TRI ARYL PHOSPHATE (EASTMAN t-BUTYL PHENOL)	TRI ARYL PHOSPHATE (KOPPER'S X-2 CRESYLIC ACID)	TRICRESYL PHOSPHATE LOT 8-32
METAL ATTACK, mg/cm²:				
ALUMINUM	+ 0.02	+ 0.05	- 0.01 V. SL. PITTING	0
MAGNESIUM	- 0.05 GREY COAT, SL. ETCH	+ 0.02	- 0.01 V. SL. PITTING	0 V. SL. PITTING
COPPER	- 0.12 LT. GREEN	- 0.09 MULTI-COLOR	- 0.02 V. SL. PITTING	0 V. SL. PITTING
STEEL	+ 0.03	+ 0.02	- 0.01	0
CADMIUM PLATE	0 LT. GREY STAIN	+ 0.03 SL. YELLOW STAIN	0	- 0.01
ACIDITY: INITIAL, TAN	0.06	0.02	0.10	0.18
FINAL, TAN	0.03	0.02	1.01	0.40
VISCOSITY: 100°F INITIAL	168.7 cs	49.6	53.3	34.8
100°F FINAL	170.1 cs	50.2	59.8	35.7
210°F INITIAL	—	—	5.11	4.34
210°F FINAL	—	—	5.68	4.40
FLUID CONDITION:	MEDIUM AMBER, CLEAR	LIGHT AMBER, CLEAR	LT. AMBER, CLEAR	MED. AMBER, CLEAR

TABLE II

FOUR-BALL WEAR*
FIRE RESISTANT FLUID SCREENING

	STEEL-ON-STEEL	STEEL-ON-BRONZE
TRIARYL PHOSPHATE FROM KOPPERS X-2 CRESYLIC ACID	0.46	0.73
TRIARYL PHOSPHATE FROM A-GRADE CRESYLIC & o PHENYL PHENOL	0.45	0.79
37% ALKYLATED TRIARYL PHOSPHATE FROM EASTMAN TERT. BUTYL PHENOL & PHENOL	0.51	0.84
ISOPROPYL TRIARYL PHOSPHATE	0.43	0.66
ALPHA CUMYL PHENYL DIPHENYL PHOSPHATE	0.41	0.89
ALPHA CUMYL PHENYL DICRESYL PHOSPHATE	0.30	0.72
37% ALKYLATED t-BUTYL TRIARYL PHOSPHATE, PERMANGANATED & FROM PILOT PLANT t-BUTYL PHENOL	0.46	0.71
37% ALKYLATED t-BUTYL TRIARYL PHOSPHATE, UNPERMANGANATED & FROM PILOT PLANT t-BUTYL PHENOL	0.45	0.67
34% ALKYLATED t-BUTYL TRIARYL PHOSPHATE, PERMANGANATED & FROM PILOT PLANT t-BUTYL PHENOL	0.57	0.70
DIPHENYL-m-PHENOXYPHENYL PHOSPHATE	0.55	—
2-ETHYLHEXYL DIPHENYL PHOSPHATE	0.31	0.91
DIBUTYL PHENYL PHOSPHATE	0.39	—
DICRESYL PHENYL PHOSPHATE	0.39	—
TRICRESYL PHOSPHATE	0.38	—
CRESYL DIPHENYL PHOSPHATE	0.42	—
TRIPHENYL PHOSPHATE	0.44	—
AROCLOR 1242	0.38	0.90
AROCLOR 1248	0.39	0.80
PYDRAUL F-9	0.28	1.18
CELLULUBE 220	0.33	0.81
SOCONY MOBIL DTE MEDIUM	0.24	1.48

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* 630 RPM, 1 HR., 167°F, 10 Kg.

TABLE III

HYDROLYTIC STABILITY PER MIL-H-19457

	TERT. BUTYL TRI-ARYL PHOSPHATE, 37% ALKYLATED, P.P. #2 UNPERMANGANATED S-156	TERT. BUTYL TRI-ARYL PHOSPHATE, 37% ALKYLATED, P.P. #2 PERMANGANATED S-157	TERT. BUTYL TRI-ARYL PHOSPHATE, 34% ALKYLATED, P.P. #1 PERMANGANATED S-158	MIL-H-19457 SPECS.
ACIDITY:				
FLUID LAYER, INITIAL	0.01 (BASE)	0.01	0.01	0.1, MAX.
FLUID LAYER, FINAL	0.02	0.04	0.04	—
FLUID LAYER, CHANGE	- 0.01	+ 0.03	+ 0.03	0.2, MAX.
WATER LAYER	2.85	7.10	3.90	5.0, MAX.
VISCOSITY:				
INITIAL, 100°F, cs	46.79	47.05	41.91	43 - 50
FINAL, 100°F, cs	42.11	42.09	37.46	—
CHANGE, 100°F, %	- 10.0	- 10.5	- 10.6	+5 TO -15%
METAL ATTACK:				
WT. LOSS, mg/cm²	0	- 0.17	- 0.15	0.3, MAX.
APPEARANCE	NO ETCH COPPER BROWN TO SLIGHT PURPLE STAIN	NO ETCH, MED. CU-BROWN COLOR	NO ETCH. MED. CU-BROWN COLOR	NO ETCH, PIT OR BLACK OR GREY STAIN
INSOLUBLES, %	0	0	0	0.5%, MAX.

Table IV

LUBRICATING ADDITIVE SCREENING

Additive in 66.5% (w) Aroclor 1248, 33.5% Aroclor 1242 Mixture	Four-Ball Wear 167°F, 620 RPM, 1 Hr. Steel-on-Steel 10 Kg.	Steel-on-Steel 40 Kg.	Steel-on-Bronze 10 Kg.
No additive	0.36 mm	0.46 mm	1.11 mm
0.1% N-7797 (tetra propenyl succinic anhydride and 2 methyl-2,4-pentanediol R.P.)	0.53	--	--
0.5% N-7797	0.48	--	--
0.2% Dicotyl hydrogen phosphite (DOHP)	0.25	--	--
0.1% N-7797, 0.2% DOHP	0.24	--	--
1.0% Santolube 31	0.25	--	--
2.0% Tricresyl phosphate	0.27	--	--
.0% Triphenylphosphine sulfide (SL-14979)	0.39	0.49	1.66
0.2% Triphenylphosphine sulfide (SL-14979)	0.38	--	1.54
0.5% Alox 350 (Alox Corp., Niagara Falls, N. Y.)	0.45	--	--
0.5% Polysiobutylene-P_2S_5 R. P. (SL-13556)	0.28	--	--
0.5% Oleic acid	0.52	--	--
0.1% Phenyl alpha napthylamine	0.38	--	--
0.2% o-Tolyl-α,α,α-trifluoro-m-tolyl sulfide (SL-14996)	0.43	--	0.78
1.0% SL-14996	0.33	0.47	0.84
0.2% o-Tolyl-α,α,α-trifluoro-m-tolyl sulfoxide (SL-26761)	0.29	--	1.34
1.0% SL-26761	0.35	0.51	1.40
0.2% Phenyl-bis-m-tolylphosphine oxide (SL-26758)	0.53	--	1.38

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Table IV - (Cont'd)

LUBRICATING ADDITIVE SCREENING

Additive in 66.5% (w) Aroclor 1248 33.5% Aroclor 1242 Mixture	Four-Ball Wear 167°F, 620 RPM, 1 Hr. Steel-on-Steel 10 Kg.	Steel-on-Steel 40 Kg.	Steel-on-Bronze 10 Kg.
1.0% SL-26758	0.55	0.64	1.49
0.2% Phenyl-bis-m-tolylphosphine sulfide	0.48	--	1.02
1.0% SL-26759	0.43	0.51	1.38
0.2% Phenyl-bis-m-tolylphosphine selenide (SL-26762)	0.54	--	1.34
1.0% SL-26762	0.52	0.83	1.58
1.0% Di(o-chlorophenyl) phenyl phosphate	0.30	0.56	1.03
0.2% Di(o-chlorophenyl)phenyl phosphate	0.32	--	--
1.0% tri(o-chlorophenyl)phosphate	0.50	0.84	0.93
0.2% tri(o-chlorophenyl)phosphate	0.25	--	--
0.2% Di(p-chlorophenyl)phenyl phosphate	0.33	0.54	1.12

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Viscosity Index Improvers in Aroclor 1242

Additive, wt %	Viscosity, cs				Viscosity Index	
	210°F		100°F			
	Initial	Sheared (1)	Initial	Sheared (1)	Initial	Sheared
Aroclor 1242	2.46	----	18.06	----	-248	----
4% Rohm and Haas (R&H) Acryloid 618	5.76	3.01	42.97	22.20	75	-156
4% R&H Acryloid 710 (A-813)	5.60	3.40	40.63	26.12	77	-126
4% R&H Acryloid 763 (A-927)	5.43	3.19	40.47	24.36	65	-151
4% R&H Acryloid 763 (A-945)	5.67	3.30	43.41	25.67	67	-146
4% R&H HF-825 (SA-3)	3.55	3.34	28.50	26.64	-132	-156
3% R&H HF-855 (SA-2)	4.64	3.97	34.19	29.71	20	- 51
4% R&H HF-855 Lot #1790	4.09	3.48	30.20	26.01	33	-102
4% R&H HF-860 (SA-5)	4.58	3 63	33.96	27.17	14	- 85
4% R&H HF-871	4.43	3.43	33.42	25.95	- 8	-114
4% R&H HF-882 + DCF	4.26	3.51	31.45	26.56	- 16	-105
4% R&H HF-8125 (SA-6)	3.93	3.33	29.28	25.05	- 53	-123
4% R&H R-580	5.67	3.30(2)	43.41	25.67(2)	67	-146
6% R&H R-580 + DCF	6.46	3.98	48.91	30.85	87	-67
4% R&H R-582	5.16	3.30(2)	38.34	25.66(2)	54	-146
4% R&H R-3876X + DCF	3.72	3.07	28.86	23.71	- 94	-175
4% R&H PL-272	3.93	3.14	32.45	25.30	-105	-191
4% Ucon 75-H-90,000	5.32	5.33	47.20	47.6	10	10
4% Ucon F-90	5.66	3.50	45.63	27.64	54	-130
4% Ucon D	4.95	3.56	38.79	30 53	25	-170
4% Ucon LB-1715	3.23	3.22	25.7	25.3	-170	-173
4% Ucon 50-HB-5100	3.83	3.83	31.0	30.8	-105	-102
4% Ucon 50-HB-25,000	4.78	4.78	39.4	39.4	- 7	- 7
4% Ucon 50-HB-35,000	5.18	5.18	43.2	42.9	21	23

(1) After 12 passes through REL Diesel Injector Shear machine.
(2) After 5 passes through shear machine, excessive foaming.

TABLE V CONT'D.

Viscosity Index Improvers in Tricresylphosphate

Additive, wt. %	Viscosity, cs				Viscosity Index	
	210°F		100°F			
	Initial	Sheared (1)	Initial	Sheared (1)	Initial	Sheared (1)
Tricresylphosphate	4.34	----	34.8	----	-43.5	----
4% Ucon LB-1715	5.22	5.25	42.1	42.7	34	33
4% Ucon 50-HB-5100	5.78	5.87	47.6	48.2	53	57
4% Ucon 50-HB-35,000	7.24	7.27	59.8	60.6	85	84
4% Ucon 50-HB-50,000	7.56	7.66	62.6	64.2	90	89
4% Ucon 75-H-90,000	7.98	----	65.99	----	95	----

(1) After 12 passes through REL Diesel Injector Shear Machine.

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TABLE VI

Emulsion Test, FS-791, Method 3201.5

Fluid	ml. Emulsion	ml H_2O	ml Fluid
TCP + 4% Ucon 50-HB-5100	44 ml	36 ml	0
TCP + 4% Ucon 50-HB-25,000	79 ml	1 ml	0
TCP + 4% Ucon 50-HB-35,000	61 ml	22 ml	0
TCP + 4% Ucon 50-HB-50,000	80 ml	0	0
T[illegible] + 4% Ucon LB-1715	3 ml	39 ml	38
Aroclor 1242 + 4% Ucon 50-HB-5100	3	39 ml	38
Aroclor 1242 + 4% Ucon 50-HB-25,000	80 ml	0	0
Aroclor 1242 + 4% Ucon 50-HB-35,000	68 ml	12 ml	0
Aroclor 1242 + 4% Ucon 50-HB-50,000	74 ml	6 ml	0
Aroclor 1242 + 4% Ucon LB-1715	0 ml	40 ml	40 ml

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Table VII

OXIDATION-CORROSION, 250°F, 168 HR.

Metal Attack: mg/cm²	Pydraul 60	OS-127
Aluminum	+ 0.01 Slight etching	-0.01 Slight etching and pitting
Magnesium	+ 0.01 Slight etching and pitting	+0.01 Slight etching
Copper	-11.59 Very heavy etching and pitting	-0.63 Heavy etching
Steel	0 Heavy etching	+0.01 Heavy etching
Cadmium Plate	-0.01 Moderate etching	-0.01 Moderate etching
Acidity:		
Initial, TAN	0.23	0.32
Final, TAN	3.10	0.29
Change	+ 2.87	-0.03
Viscosity:		
100°F, Initial, cs.	9.891	17.23
Final, cs.	10.40	17.36
210°F, Initial, cs.	2.423	3.234
Final, cs.	2.514	3.258
Fluid Condition	Brown liquid (Low viscosity)	Brown liquid (Low viscosity)

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TABLE VIII

Pydraul 150 - SNUFFER DILUENTS

	Viscosity, cs.					Fire Resistance		
	210°F	160°F	10°°F	0°F	-35°F	Flash Point	Fire Point	AIT
AMF viscosity requirements	---	9.67 Min.	30.6 Min.	532 Max.	2830 Max.	---	---	---
Pydraul 150	7.9	13	32	900	20,000	425	460	970
Pydraul 150 with 8.5% (w) Perchloroethylene OS-132	6.0	10	22	470	8,000	445	465	915
Pydraul 150 with 10.62% (w) Freon 113	6.2	9.8	21	450	6,000	440	485	975
Pydraul 150 with 29.1% (w) Kel-F Oil No. 1 OS-133	5.5	9.4	23	700	15,000	445	465	975
Pydraul 150 with 10% (w) Freon 213	6.64	12	27	950	15,000	---	---	---

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TABLE IX

OXIDATION-CORROSION, 250°F, 168 HOURS

	Pydraul 150	Pydraul 150 + 8.5% (w) Perchloro-ethylene	Pydraul 150 + 10.62% (w) Freon 113	Pydraul 150 + 29.1% (w) Kel-F Oil No. 1
Metal Attack: mg/cm²				
Aluminum	0	-0.01	-0.01 Clear	0
Magnesium	-0.51	-0.28 Moderate etching	-0.1.. Heavy etching and pitting	-0.02 Very slight pitting
Copper	-6.45	-1.5 Slight etching	-12.14 Heavy etching	-4.2 Heavy etching
Steel	-0.04	0	0	-0.01 Clear
Cadmium Plate	-0.04	-1.8 Moderate etching	-1.17 Moderate etching	-7.2 Heavy etching
Acidity:				
Initial, TAN	0.15	0.28	0.26	0.20
Final, TAN	1.61	0.81	0.76	1.39
Change	+1.46	+0.53	+0.50	+1.19
Viscosity				
100°F, Initial, cs.	32.71	21.81	19.20	22.46
Final, cs.	---	31.91	31.83	24.88
210°F, Initial, cs.	7.83	6.02	Fluid	5.47
Final, cs.	---	7.61	Boiled	5.82
Fluid Condition	---	Amber color, clear	Amber color slight amount flake-like sediment	Medium brown, clear

TABLE X

AROCLOR - PHOSPHATE ESTER MIXTURE VISCOSITIES

Temperature	Pydraul AC (1)	Aroclor Tricresyl phosphate (2)	Aroclor 1248 Cresyl diphenyl phosphate (2)	Aroclor 1254 Cresyl diphenyl phosphate (2)	Low Viscosity	Medium Viscosity	High Viscosity
210°F	5.1 cs	4.4 cs	3.8 cs	4.3 cs	5 cs	10 cs	25 cs
130°F	28.	17.	14.	23.	17	40	130
100°F	90.	41.	30.5	70.	32	90	320
60°F	1,400.	685.	175.	1,100.	100	280	2,000
30°F	20,000.	5,000.	2,000.	900,000.	300	1,800	11,000
Low temperature improvement, °F over Pydraul AC	---	18°F	0 °F	35°F	55°F	35°F	10°F
High temperature loss °F below Pydraul AC	---	12°F	15°F	25°F	0°F	-50°F	-100°F

(1) Approximately 50/50 volume mixture of Aroclor 1254 and TCP

(2) 50/50 volume mixture

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TABLE XI

OS-81 - High Lead Babbitt Bearing

Exposure, Hours	Bearing		Catalyst Appearance		Fluid Acidity, TAN
	Weight	Appearance	Copper	Steel	
0	45.7257 gm.	----	----	----	----
336	----	----	Bright	Bright	----
504	45.7260	Slight dull grey	Bright	Bright	0.02
840	45.7264	Slight dull grey	Slight dull	Rust 5% of area	----
1026	----	----	Slight dull	Rust 5% of area	----
1218	45.7265	Light dull grey	Light rust	Rust 20% of area	0.02
1530	45.71[illegible]	Grey stain	Rust color	Rust 35% of area	0.01

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Table XII

OS-81 Evaluation

	OS-81 Typical	OS-81 Water Treated(1)	OS-81 H_2S and Water Treated(2)	OS-81 Monoethanolamine and water Treated (3)
Viscosity				
100°F	35.2 cs	34.8 cs	34.1 cs	34.8 cs
210°F	3.18	3.13	3.21	3.14
Neut. No.				
Initial pH	---	6.4	8.6	8.7
Strong acid No.	---	none	none	none
Total acid No.	0.05	0.03	1.02	0.03
Foam at room temperature				
tendency	20 ml.	10 ml.	3 ml.	5 ml.
collapse	1. min.	20 sec.	30 sec.	20 sec.
Moisture, %	0.05	0.05	0.31	0.07
4-Ball Wear, 167°F., 1 hr., 620 rpm				
Steel-on-Steel.				
10 Kg	0.27 mm.	0.44 mm.	0.36 mm.	0.40 mm.
40 Kg	0.55	0.65	0.77	0.65
Steel-on-Bronze				
10 Kg	1.25	1.28	0.65	1.20

(1) 7 day heat test at 150°F., 20 ml. water added.
(2) 7 day heat test at 150°F., 20 ml. water and H_2S gas.
(3) 7 day heat test at 150°F., 20 ml. water and 4 ml. monoethanolamine added.

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TABLE XIII

	OS-81 from Aroclor 1246.4	Typical OS-81
Viscosity, cs. at 100°F	36.7	34.9
cs. at 210°F	3.15	3.12
Specific Gravity 25/25°C	1.4052	1.4019
Foam, ASTM D-892		
75°F	0 ml.	20 ml. (30 sec. collapse)
200°F	0 ml.	---
75°F	0 ml.	---
Steam Turbine Oil Oxidation ASTM D-943		
Total Acid No.		
Initial	0.13	---
Final	0.08(1)	---
Final Coil Appearance:		
Steel-	Dull slight (1) overall rusting	Occasional scattered (2) rust spots
Copper-	Dull copper color (1)	Generally clear, few rust-like deposits(2)
Final Fluid Appearance:	Slight yellow(1) transparent	Slight yellow transparent (2)

(1) Test terminated at 1530 hours.
(2) Test terminated at 1200 hours.

TABLE XIV

Oxidation-Corrosion
250°F, 168 Hours, Per FS-791-5308.4

	OS-81 from Arcclor 1246.4	Typical OS-81
Viscosity:		
Initial 100°F	36.7	34.9
Final 100°F	37.5	35.6
Change, %	+2.0	+2.0
Initial 210°F	3.15	3.12
Final 210°F	3.20	3.15
Change, %	+1.6	+1.6
Acidity		
Initial, TAN	0.13	0.06
Final, TAN	0.18	0.11
Fluid Condition	Light amber, clear	Medium amber, clear
Metal Attack, mg/cm²		
Aluminum	0 (Clear)	0 (clear)
Magnesium	0 (Clear)	-0.01 (Slight dull)
Copper	-0.10 (Very slight etching)	-0.08 (Very slight pit)
Steel	-0.02 (Clear)	0 (Clear)
Cadmium Plate	-0.01 (Very slight etching dull Cu-grey streaks)	-0.10 (Very slight etching)

TABLE XV

HUMIDITY CABINET

JAN-H-792, 120°F, 100% Rel. Humidity

Base Stock	Inhibitor Concentration, % wt. RT-67-A	RT-53-A	PAN*	Days Protection
OS-100 (tricresyl phosphate)	2.37	2.37	0.5	>30
tricresyl phosphate (TCP)	0	0	0	<1
TCP	0.25	0	0	<1
TCP	1.0	0	0	5 to 6
TCP	3.0	0	0	25 to 31
TCP	5.0	0	0	>30
TCP	0	5.0	0	15 to 25
TCP	0	0	0.5	<1
TCP	0.9	0.1	0	6 to 7
TCP	1.5	1.5	0	9 to 19
TCP	2.0	1.0	0	8 to 12
TCP	2.7	0.3	0	>30
TCP	3.6	0.4	0	21 to 30
TCP	4.5	0.5	0	>30
TCP	4.7	0	0.5	>30
TCP	0	5.0	0.5	13 to 19
Dibutylphenyl phosphate	1.0	0	0	<1
Dibutylphenyl phosphate	2.7	0.3	0	8
Cresyl diphenyl phosphate	1.0	0	0	3 to 4
Cresyl diphenyl phosphate	2.7	0.3	0	>30

* Phenyl alpha napthylamine

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Table XVI

PYDRAUL A-200 VISCOSITY AND POUR POINT

	Viscosity at 210°F*	Viscosity at 100°F*	Viscosity at 50°F*	Pour Point**
OS-95 Org. Drum Batch S-59	2.865 cs	30.12 cs	765.2 cs	+ 5°F
PR. Lot C-07	2.886 cs	31.04 cs	809.2 cs	+ 5°F
PR. Lot C-12	2.876 cs	29.92 cs	776.6 cs	--
PR. Lot C-16	2.878 cs	30.46 cs	795.5 cs	+ 5°F
PR. Lot C-22	2.872 cs	30.40 cs	784.5 cs	+10°F
PR. Lot C-52	2.908 cs	30.45 cs	801.6 cs	+10°F
PR. Lot C-23	2.917 cs	30.67 cs	825.9 cs	+10°F
PR. Lot C-25	2.915 cs	31.38 cs	847.3 cs	+10°F
PR. Lot C-27	2.932 cs	31.32 cs	852.9 cs	+10°F
PR. Lot C-54	2.899 cs	30.83 cs	814.4 cs	+15°F
PR. Lot C-62	2.901 cs	31.28 cs	863.6 cs	+15°F
PR. Lot C-46	2.981 cs	32.34 cs	938.1 cs	+15°F

* Results from Engine Lab
** Results from Analytical Lab

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