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INTERIM REPORT
ON
FUNCTIONAL FLUIDS; APPLICATION
RESEARCH INDUSTRIAL HYDRAULICS
FEBRUARY 1963 - AUGUST 1966

DATE - August 22, 1966 WRITTEN BY - R W. Stree.

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St. Louis Research Department

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Job No. 2-02-760.01-4290 -4666
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August 22, 1966

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TABLE OF CONTENTS

	Page No.
INTRODUCTION	1
SUMMARY	1
CONCLUSIONS	1
RECOMMENDATIONS	2
PATENT STATUS	2
REFERENCES	2
EXPERIMENTAL WORK AND DISCUSSION	2
I. Low Melting Nuclear Reactor Coolant	2
II. Industrial Fire Resistant Hydraulic Fluids	8
A. Low Cost VI Improved Pydraul A200	8
B. Low Cost Fluid to Compete with Water Based Fluids	10
C. Improved Pydraul 150	26
D. High Viscosity Pydraul 312 Type Fluid	41
E. Factory Mutual Approved Low Cost Fluid	41
F. Low-Low Cost ($0.40-$0.65/gal) Hydraulic Fluid for Coal Mining Machinery	45
G. Low Viscosity Fluid for Canadian Steel Mill Applications	47
III. Miscellaneous	48
A. Reformation of Pydraul 280	48
B. Pydraul 280 Seal Compatibility, Voith Clutches	48
C. Conversion of Straight Phosphate Ester Systems to Pydraul 312	48
D. High Density, High Viscosity Industrial Gear Lubricant	49
E. Special Aroclor 1248/1242 Blend	49
F. Fire Resistance Test Evaluations	49
G. Cavitation Resistant Industrial Fluids	49
DESCRIPTION OF RECOMMENDED PROCESS	49
I. Low Melting Nuclear Reactor Coolant	49
II. Industrial Hydraulic Fluids	50
APPENDICES	

MONS 021153

APPENDICES:

APPENDIX I

Letter from K. L. McHugh to D. B. Hosmer dated 1/10/63, "Reactor Coolants, Successor to Santowax OMP."

Letter from B. O. Severson to R. O. Moody dated 9/25/63, "Production of Santowax WRHD."

APPENDIX II

Letter from J. D. Hinchen to R. W. Street dated 6/25/63, "VI Improved Pydraul A-200."

Properties of MCS 300

APPENDIX III

Field Test Data on MCS 312

Properties of Pydraul 312, Tables I - IV

Underwriters Fire Resistance Test Results on MCS 312, MCS 395 and MCS 404; Issued 3/28/66

APPENDIX IV

Letter from C. L. Early to W. R. Richard dated 12/30/63 concerning Target Properties for Improved Pydraul 150.

Letter from J. D. Hinchen to R. W. Street dated 2/12/64, "Pydraul Blends Via Linear Programming."

Table I - Composition and Physical Properties of Pydraul 312, MCS 404, MCS 395, MCS 370.

Table II - Improved Pydraul 150 (F2747)

Table III - Republic Steel Co. Hydrolytic/Thermal Stability Test

Figures I, II, III

Letter from W. H. Hunt to C. L. Early concerning MCS 395 and MCS 404 Toxicity test results.

APPENDICES (Page 2)

APPENDIX V

Table I - Factory Mutual Approved Candidates
Table II - Bureau of Mines Wick Test Data

APPENDIX VI

Table I - Low Cost Fluids For Coal Mine Machinery
Table II - " " " " " " "
Table III - " " " " " " "
Table IV - " " " " " " "

APPENDIX VII

Table I - Low Cost, Low Viscosity Fluid for Defasco Steel

APPENDIX VIII

Table I-III -Pydraul 280 Reformulation Work

Letter from R. W. Street to R. Davis dated April 27, 1966, "Cellulube 220 Conversion to Pydraul 312."

Letter from R. W. Street to R. Davis dated May 16, 1966, "Cellulube 220 Conversion to Pydraul 312."

Letter from R. W. Street to R. Moody dated 1/13/66, "Special Aroclor 1248/1242 Blend."

Letter from R. W. Street to File dated 12/27/65, "Fire Resistance."

Letter from R. W. Street to L. R. Stark dated 2/28/66, "ASTM - Molten Metal Test Work."

Letter from D. R. Miller to R. W. Street dated 6/7/66, "Pydraul Cavitation Resistance."

Letter from D. R. Miller to C. L. Early dated 3/14/66 on Cavitation.

Letter from D. R. Miller to R. W. Street dated 4/29/66 on Cavitation.

APPENDIX IX

Blend Sheets for MCS 395, MCS 404, MCS 90 and Pydraul 312

APPENDIX X

List of Abbreviations used in report.

INTRODUCTION

Thie report covers certain phasee of reeearch effort on Industrial Hydraulic Fluide over the paet three yeare. In particular, the report discusses the development of several new fire-resistant hydraulic fluide which have been added to the Pydraul line. The program wae undertaken to satisfy the market need for a line of lower cost synthetic hydraulic fluids. In addition, the objectives of the program included reformulating our present Pydraul line to meet the changing requirements of industry.

SUMMARY

Those aspects of Application Research covered in thie report are as follows:

1. Formulation of fluids to meet a set of desired properties.
2. Determination of physical properties of new formulations.
3. Determination of functional properties of new formulations.
4. Determination and evaluation of fire-resistant properties.

CONCLUSIONS

During thie period new hydraulic fluids were defined for six different applications. They were:

1. Pydraul 312 - This low cost fluid was developed to compete with water based fluids. It was transferred to Marketing and is an active product.

2. Pydraul 135, MCS 404, MCS 90 - These fluids were defined to supplement Pydraul 312 in those applications requiring a different viscosity range. Pyraul 135 is intended to fill the need for an improved Steam Turbine control fluid.

3. MCS 300 - This fluid was defined as low cost, VI Improved, Pydraul A200 type fluid. It failed to meet fire-resistant requirements; however, Pydraul 312 now satisfies the market need for this type of fluid.

4. F2828 - This fluid was defined as a low cost Factory Mutual Approved fluid. It offered no particular advantage over Pydraul A200 and was dropped from further consideration.

Research work is continuing on developing a low cost hydraulic fluid for coal mine machinery.

RECOMMENDATIONS

1. Complete the evaluation on fluids F2869 and F2870 for the coal mine application. If there is not a significant difference in the properties of these two fluids consider a field test on F2870. This fluid is the least expensive of the two fluids (about $0.56/gal manufacturing cost less packaging).

2. Evaluate a modified Pydraul 312 type fluid in which TCP is used in place of Santicizer 144. An increase of about 75-100°F in thermal stability would result. This improvement would increase the cost of finished goods about $0.05-$0.06 per gallon.

PATENT STATUS

A patent application, O-2219, was filed on Synergistic Functional Fluid Compositions. This application covers Pydraul 312, Pydraul 135, MCS 404 and related fluids. No further work is pending on this application.

A disclosure, No. 3183, was written on Industrial Gear lubricants. An application covering this disclosure has not been filed.

REFERENCES

1. Development Department Pre-Research Appraisal O.D. 1331
2. " " " " O.D. 1426

EXPERIMENTAL WORK AND DISCUSSION

I. Low Melting Nuclear Reactor Coolant

A project was undertaken in March, 1963 to define a low melting, terphenyl based, nuclear reactor coolant. The intended application was an experimental reactor, WR-1, being built at that time at Whiteshells, Manitoba. Atomic Energy of Canada, Limited was sponsoring the project. The initial requirement for this organic cooled, heavy water moderated reactor was 50,000 lb of a Santowax type material.

Preliminary studies by AECL on Santowax DOM, Santowax HOM and Santowax OM indicated the superior performance of the terphenyl based fluids. The one serious deficiency in the terphenyls, however, was their high melting point. AECL expressed concern over

the high m.p fluids and stated that it would be difficult to charge the coolant system initially with a high melting material. After the system was in operation for a period of time, this was not considered a problem and the fluid make-up could be a higher melting fluid, such as DOM or OM. AECL was also concerned over the possibility of the coolant crystallizing should it become necessary to shut down the reactor prematurely. After a period of time, the coolant degrades and crystallization would probably not occur; however, the early shut-down, before the buildup of high boiler, could cause a serious problem. They stated that the ideal coolant should be a liquid at room temperature.

Of the coolants tested, Santowax OM most closely filled AECL's needs. Since the availability of Santowax OM was limited, Development requested Research to define a similar coolant.

Owing to the relatively small quantity of coolant required, our first approach was to determine if a low melting fluid similar to OM could be derived from a recrystallization or extraction on the readily available Santowax OMP and Santowax R. Improved distillation facilities at Anniston appeared to be the obvious answer to the problem; however, the total needs for Santowax OM were limited and the capital additions required could not be justified. Hence, the less costly approach was explored. The objective of this research was to find the best solvent which would preferentially extract the ortho and meta terphenyl isomers from the high melting para terphenyl. Santowax OMP consists of roughly 10-15% o-terphenyl, 50-60% meta terphenyl and 24-30% para terphenyl. Santowax R contains these isomers in approximately the same proportions plus from 5-12% quaterphenyls and higher boiling polyphenyls.

The solubilities of m-terphenyl and para terphenyl were determined roughly in eleven solvents. The criteria for selecting the solvents were primarily low boiling point and secondarily low cost. Of the solvents examined (Table I), benzene had the greatest ratio of meta to para terphenyl solubility at 30°C. Ortho terphenyl was considerably more soluble than meta terphenyl in these solvents.

A number of recrystallization experiments were run on Santowax OMP and Santowax R using benzene and hexane as solvents. The procedure used was as follows: about 200 g of Santowax was charged to a three neck flask. The minimum amount of solvent to dissolve all of the Santowax at reflux temperature was added. The solution was cooled slowly, with agitation, to 25-30°C and the mixture was filtered. Solvent was then stripped off the filtrate giving the product. G.C. analysis was run to determine the terphenyl isomer distribution

TABLE I

SOLUBILITY OF PARA AND META TERPHENYL IN VARIOUS SOLVENTS

Solvent		g/100 cc at 25°C Para	Meta
methyl ethyl ketone	(about)	0.6	< 16.4
carbon tetrachloride	"	0.6	< 17.5
tetrahydrofuran		> 1.7	-
mono-chlorobenzene		> 1.1	-
chloroform		> 1.0	-
benzene		1.0	< 25.6
cyclohexanone		> 1.1	-
cyclohexane		< 0.4	<< 7.1
n-hexane		< 0.4	< 4.1
trichlorobenzene			
Stoddard solvent			

The following concluaions were drawn from the recrystallization experiments:

(a) The para isomer concentration in Santowax OMP and Santowax R can bs reduced from 25-30% to 4-5% by a one-step rscrystallization and filtration at 30°C.

(b) Thia first recrystallization/filtration will yield about 70% aolubles (product) from Santowax R.

(c) The crystal point of the solubles (product) from OMP is 69-70°C; whereaa the cryatal point of the solubles from Santowax R ranged from 48°C (66.2% yield) to 53°C (69% yield).

(d) The cryatal point of the extracted Santowax R is lower than that of OMP due to the higher concentration of quaterphenyls (oils) in the Santowax R.

(e) A aecond benzene extraction/crystallization/filtration on the product reduced the cryatal point alightly; however, the solution point waa not lowered appreciably.

(f) The single recrystallization of Santowax R to preferentially remove the more soluble ortho and meta terphenyl from the less soluble para terphenyl gave the best product. This material was designated Santowax WR.

Five batches of Santowax WR were produced at Anniston. The properties of these batches are summarized in Table II. The product was made by completely dissolving the Santowax R in a minimum amount of benzene at reflux temperature. The charge of benzene required is 1.8 times the Santowax R charge. After cooling to 30° C. with agitation the mixture is filtered. Benzene is stripped off the filtrate leaving the low melting Santowax WR. The melting point range of WR (Table II) is broad. The solution point is that temperature at which the last crystal melts upon heating. Typical analysis for trace elements is given in Table II. General physical properties are given in Table III.

The objective of developing a terphenyl coolant having a melting point of 125° F. (52° C.) was not achieved. Santowar WR represented an improvement over Santowax OMP and Santowax R; however, it still fell short. A number of experiments were run on the partial reduction of Santowax WR. The objective of this work was to determine the level of saturation required to produce a liquid at room temperature. The reductions were run using a two percent Raney nickel catalyst. Cuts that were drawn off the autoclave and the percent saturation was determined from NMR spectra. It was found that at about 20% saturation a liquid was formed, from which only a small amount (about -2%) of solids precipitated after standing a week at room temperature. By adding 6.5% biphenyl (10 mole percent) the solution point of the fluid was suppressed further. A higher degree of saturation and more biphenyl would have given a product with a still lower solution point; however, at these higher levels formation of gases during use would be excessive. The 20% level and 10 mole percent biphenyl were considered the absolute maximum.

The product formed from the partial reduction of Santowax R was also examined. Anniston provided samples of 8, 15, and 23 minute reduction cuts. The 15 and 23 minute cuts were 21 and 28% saturated, respectively. Extractions using both benzene and Skelly E were run, as previously described. The benzene extractions were more successful; however, a white crystalline precipitate settled out from both 15 and 23 minute stocks. The hydrogenated Santowax WR was superior to these materials because it contained less para terphenyl.

An experimental quantity of Santowax WR HB was produced by the Anniston Plant. A report of this production is given in Appendix I.

Owing to the potential problem of gas evolution in using a partially reduced Santowax WR, AECl finally elected to use Santowax OM as make up, and HB-40 as the initial starting material.

TABLE II

COMPOSITION AND SELECTED PROPERTIES OF SANTOWAX WR

	*Lot AC-1	AC-2	AC-3	AC-4	AC-5
Chlorides	179 ppm	11.0 ppm	8.9 ppm	8 ppm	8 ppm
Color (Gardner)	11.0	12	-	11.0	11.0
Solution Point °C	85	101	104	85.0	91.0
First Crystals °C	69	91	95	76.5	81.0
Biphenyl	0.22	0.11	0.18	0.07	0.07
ortho terphenyl	14.65	14.07	14.74	15.16	11.83
meta terphenyl	68.18	69.82	63.38	74.58	77.45
para terphenyl	4.04	6.81	7.42	4.52	4.98
Hi Boilers (quaterphenyls & high polyphenyls)	12.84	9.2	14.28	5.6	5.6

Notes:

*-Lot AC-1 was made by slurrying the Santowax R and benzene in a Pyranol tank and allowing the insoluble material to settle to the bottom. The benzene solution was decanted and the Santowax WR was recovered by distilling off the benzene.

TRACE ELEMENTS IN SANTOWAX WR LOT AC-4

Element	Method Detection Limit PPM	PPM Found	Specification Limit
Al	0.02	< 0.5	1.0
B	0.04	< 0.25	0.5
Co	0.006	< 0.1	0.1
Mn	0.01	0.1	0.1
Cu	0.5	< 0.5	2.0
As	0.5	< 0.5	0.5
Ba	0.5	< 0.5	2.0
Ca	0.2	0.2-0.6	10.0
Cr	0.005	< 0.005	1.0
Fe	0.02	3-5	10.0
Pb	0.03	0.03-0.3	4.0
Mg	0.3	0.03-0.1	1.0
Mo	0.02	< 0.02	1.0
Ni	0.006	< 0.006	3.0
Si	0.03	< 3	3.0
Ag	0.002	< 0.002	0.1
Sn	0.02	< 0.02	1.0
Ti	0.01	< 0.01	5.0
Zn	0.03	< 0.03	1.0
Na	0.7	< 0.7	0.1
S		11	60.0
P		10	3.0
Na		< 0.1	0.2

MONS 021161

TABLE III

Physical Properties

a. Viscosity

210°F	5.21
364°F	1.21
700°F	0.35

b. Density

300°F	1.0015
450°F	0.910
600°F	0.873
697°F	0.8215

c. Thermal Conductivity & Heat Capacity

Temp. °F	Thermal Conductivity (BTU/hr/ft²/ft/F°)	Heat Capacity (BTU/lb/°F)
200	0.078	0.42
300	0.076	0.46
400	0.073	0.50
500	0.070	0.53
600	0.068	0.56
700	0.065	0.58
750	-	0.595
800	0.063	-

d. Vapor Pressure

Temp. °F	Vapor Pressure (psia)
445	.387
482	.774
521	1.55
565	2.90
619	5.80
665	9.67
700	13.54
800	23.2 (extrapolated)

Flammability

a. Flash Point - 405°F

b. Fire Point - 420°F

c. AIT - 940°F

II. Industrial Hydraulic Fluids

A. Low Cost VI Improved Pydraul A-200

A project was undertaken early in 1963 to develop a low cost, VI Improved Pydraul A200 fluid. The need for this fluid existed particularly in those die casting shops which used Pydraul A200 at temperatures greater than 120° F. The situation was highlighted at the G.M. Central Foundry, Bedford, Indiana. During the previous hot summer months Bedford had experienced difficulty pumping Pydraul A200 and the company had indicated that it was planning a conversion to the higher viscosity, higher VI, HoughtoSafe 1130.

In reformulating Pydraul A200 the initial approach taken was to make maximum use of Aroclor fluids to retain low cost, and utilize FH 139 to effect the needed improvement in VI. Initial screening involved the selection of a satisfactory lubricity additive. Santolube 393, used in Pydraul A200, was disqualified because of reoccurring bad odor. Tricresyl phosphate, and diisopropyl hydrogen phosphate (A88) were examined. A formulation containing 2.0% TCP failed a Vickers 105C pump test due to excessive wear. A similar formulation containing the A88 appeared to pass the pump test; however, close examination of the bronze bushings of the pump indicated heavy stains.

An experimental design was devised to aid us in achieving an optimum fluid based on four major components. The limits of each component were determined by fire resistance requirements, viscosity relationships and cost. The limits chosen were as follows:

Aroclor 1242	66-100%
Aroclor 1221	0-34%
FH-139	2.5-7%
*TCP	5-10%

*Pump failed with 2.0% TCP. MCS 153 contains 10% TCP and passes pump test.

The properties of the desired fluid were specified as follows:

1. Fire resistance equal to competitive fluids and approaching that of Pydraul A200.

2. A 130° F. absolute viscosity equal to that of HoughtoSafe 1130 (22 cs at 130° F.).

3. Pumpability at +40° F. (< 1000 cs. at 40° F.).

4. Low Cost.

5. Performance characteristics equal to or better than Pydraul A200.

Of the fifteen formulations in the design, eight were considered promising. On the basis of viscosities at +40, 100, and 210° F. a near optimum formulation was obtained. The composition of this fluid, F1947, and two alternate formulations are listed below.

	I	II	III
	(F-1947) (F-760)	(F-651) (F-2019)	(F-1949) (F-2018)
Aroclor 12-2	74.8	74.8	81.8
Aroclor 1221	12.4	12.4	5.5
TCP	7.4	7.4	-
Pennzoil 170 SUS Pet. Oil	-	-	7.4
PN-129	5.2	5.2	5.1
BANA	0.1	0.1	0.1
Santolube 70	0.1	-	0.1
DPS acid	-	0.1	-
Dow Corning 200	50 PPM	50 PPM	50 PPM
duPont Oil Blue A Dye	7 PPM	7 PPM	7 PPM

A report on the experimental design is given in a letter from J. D. Hinchen to R. W. Street dated 6/25/63. A copy is included in Appendix II.

Pump tests were run on each of the three candidates. The results of these tests are listed in Table IV.

TABLE IV

LUBRICATION

I. Vickers Hydraulic Pump Test - (1000 hours - 140°F)

	F-760	F-651	F-2019	F-2018	Pydraul A-200
Weight Losses					
Bushings					
2015	0.0168	0.0229	0.0277	0.0023	0.0151
2016	0.0308	0.0210	0.0217	0.0055	0.0217
Ring	0.0061	0.2147	0.0125	3.1418	0.0848
Vanes	0.0022	0.0006	0.0019	0.0456	0.0191
Viscosity					
Initial					
100°F	38.2	38.1	41.11		30.6
210°F	5.66	5.5	5.8		2.89
Final					
100°F	33.2	31.5	36.7		30.4
210°F	4.81	4.60	5.13		2.88
% Change					
100°F	-13.1	-17.3			-0.5
210°F	-15.0	-15.2			-0.4

The results of the pump tests indicated that the lubricity of F760 (same as F1947) was on a par with Pydraul A200. The ring wear on F651 was unaccountably high, 0.2147 g. A retest of this formulation (given as F2019) indicated less ring wear, however, some pitting was observed. The third candidate, utilizing Pennzoil 170 oil as a lubricity additive, failed the pump test. Fluid F760 was considered the best candidate and was designated MCS 300. A complete listing of physical and functional properties of MCS 300 are given in Appendix II.

A field test on MCS 300 was started at Johnson Motors, Waukegan, Ill. Fluid was also sent to Alcoa in Pittsburgh, Pa. The test was discontinued after 375 hrs. when it was learned that MCS 300 did not pass a special fire resistance test originated at Johnson Motors. The test involved igniting a piece of cardboard which had been pre-soaked in MCS 300. The fluid soaked cardboard continued to burn. In similar tests on Pydraul A200 and Cellulube 200 the cardboard did not burn. A modified formulation in which the Aroclor 1221 content was replaced by Aroclor 1242 also failed the test. These failures were attributed to the FH-139 VI Improver.

Work on MCS 300 was stopped. During development of the fluid G. M., Bedford, had decided to convert Pydraul A200 systems to Houghto-Safe 1130. Their interest in MCS 300 at a Pydraul A200 price could not be aroused. The manufacturing cost of MCS 300 was higher than Pydraul A200. It was decided to discontinue this project in favor of a project to develop a low cost fluid which would be competitive with water glycol solutions.

B. Low Cost Fluid to Compete with Water-Based Fluids

A project was started in July of 1963 to develop a low cost ($0.40-$1.00) fire resistant hydraulic fluid which would be competitive with water-based fluids. The needs for such a fluid were outlined in Development Department Pre-Research Appraisal OD 1331. The properties of the optimum fluid were defined generally as being equivalent to Pydraul fluids, and as a minimum somewhat better than water-in-oil emulsions. The specific viscosities outlined in the Appraisal were as follows:

	Viscosity (cs.)			
	0° F.	+40	100	210
Optimum	900	---	75	18
Minimum	---	900	65	7.5

The initial approach taken was to formulate fluids to meet the viscosity specifications above. Unfortunately, none of these formulations had adequate fire resistancy. The following base stock materials were used in these formulations: Shell Mid Continent Bright Stock petroleum oil (HVI 161 SUS at 210° F.) Aroclor 1248; Aroclor 1242; Dioctyl adipate and UCAR G-120. One formulation in particular met the minimum requirements. Its composition was as follows: 29.7% Shell BS oil; 39.6% Aroclor 1248; 19.8% Aroclor 1242; 9.9% Dioctyl adipate and 1% UCAR G-120. The relationship of each of the components in the blend was felt to have the following significance:

1. A reduction in concentration of Bright Stock will improve ultimate fire resistance; however, the 210° F. viscosity will be less than specifications. (Pre-Research Appraisal OD 1331) By increasing the concentration of VI improver, UCARG-120, to make up for the reduction in Bright Stock, the 40° F. viscosity is too high.

2. Aroclors 1248 and 1242 are the only suitable Aroclors. Aroclor 1254 has an unacceptable low temperature viscosity (too high) and Aroclor 1221 is not fire resistant.

3. Dioctyl adipate lowers the 40° F. viscosity of the fluid without sacrificing maximum 210° F. viscosity. Fire resistance does not appear to be sacrificed (molten metal test) and the formulation is non-enterprise at this concentration.

4. UCARG-120 is required in the formulation to boost the 210° F. viscosity and improve the over-all VI.

Owing to the fact that none of the formulations made to OD 1331 viscosity specifications had adequate fire resistancy, another approach was tried. In this case an attempt was made to determine what base stocks were required in what amount, and then make adjustments to satisfy viscosity. The screening tests used were the molten metal test and the high pressure spray test. A large number of tests were run. A summary of the test is given in Table V. Comments on these tests follows.

High Pressure Spray Test.

1. Formulations 1-3 were sprayed at room temperature. Number one possessed better fire resistance than number two or three probably because the viscosity of the fluid was higher and the resulting spray pattern was less dispersed.

Molten Metal Test

1. For all formulations containing oil and Aroclors, the residual oil remaining on the molten metal after the Aroclor had boiled off ignited without a spark. Phosgard 282 is soluble in Aroclors but not soluble in the Bright Stock oils.

2. Formulation 8 was a clear fluid and possessed better fire resistance than straight Aroclor-oil Blends. Formulation 9 was an emulsion owing to the increased percentage of Phosgard 282. The fire resistance of this formulation was considerably better than that of the straight Aroclor-oil blends. Presumably the Phosgard - being less volatile than the Aroclors - imparts fire resistance to the oil-rich residue remaining on the surface of the molten metal.

TABLE V

LOW COST FIRE RESISTANT HYDRAULIC FLUID - FIRE RESISTANT TESTS

No.	Socony Mobil	Penn 150	Gulf 200	Shell 150	Aroclor 1248	Aroclor 1242	BBA	UCAR 0130	Phosgard 282	Visc. 100°F.	High Pressure Spray Test	
											Visc. °F	Fire Resistance
1	100	-	-	-	-	-	-	-	-	415.		Ignited 3 ft from orifice Flame carried downstream about 3 ft
2	89.7	-	-	-	39.8	19.8	9.9	1.8	-	69.1		Ignited 15 inches from orifice Flame carried downstream 15 ft
3	-	89.7	-	-	39.8	19.8	9.9	1.8	-	63.7		Flashed intermittently about 2 ft from orifice Flame carried downstream 8 ft
4	-	-	100	-	-	-	-	-	-	848	135-145	Flashed with difficulty 24-26 inches from orifice
5	-	-	50	50	-	-	-	-	-	700	140	Flashed at 18-22 inches from orifice Flame carried downstream 3 ft
6	-	-	15	15	80	50	-	-	-	approx. 80 SS	135-140	Flashed at 9 inches from orifice Flame carried downstream 15 ft
7	-	-	85	-	15	80	-	-	-	51.2	135-140	Flashed intermittently 8-12 inches from orifice
8	-	-	98	-	-	72	-	-	2	-	145	Did not flash or burn
9	-	-	95	-	-	70	-	-	5	53.3	150	Did not flash or burn

MONS 021167

Since those formulations containing a Phosgard appeared to have greatly improved fire resistance additional phosgard type materials and phosphate esters were examined. Three viscosity grades of petroleum oil were also examined. Again, the screening tests used were the molten metal test and the high pressure spray test. The variables considered were as follows:

1. Type or Structure of Phosphate. Formulations were made consisting of 15% phosphate ester. The ester concentration was restricted to 15% owing to the high relative cost of phosphate esters. In addition, a requirement of this work was to define a non-enterprise fluid. The phosphates examined were: MDP, CDP, Santicizer 144, diphenyl-o-chlorophenyl phosphate, tris-2-chloroethyl phosphate, and decyl diphenyl phosphate. No appreciable difference was observed in the fire resistancy of formulations containing these phosphates. As a class, the alkyl diaryl phosphates gave slightly better fire resistance than the triaryl phosphates in the molten metal test (1250° F.).

2. Viscosity of the Oil. Three oils were examined. A very high viscosity Bright Stock Oil (GUlf 200), a less viscous Shell 150 Bright Stock and a high viscosity neutral oil (Lion lube stream Number 6). Table VI gives the properties and prices of these oils plus all other oils examined from the beginning of this project up to the writing of this report. The Gulf 200 oil was the best oil in terms of viscosity, VI and appearance; however its cost was high. Formulations containing the Gulf oil also exhibited better fire resistance in the high pressure spray test.

3. Type of Chlorine Containing Compound. The Aroclor fluids are the cheapest source of stable organic chlorine compounds. It was found that the combination of both Aroclor and phosphate ester provided a degree of improved fire resistance over formulations containing oil and either one alone. It was also found that no improvement in fire resistancy was realized by using higher weight Aroclors fluids (1254, and 1260); but rather, Aroclor 1242 provided adequate F.R. In addition, by using Aroclor 1242, the formulations had better VI, lower pour point, and lower specific gravity. Trichlorobenzene was also examined. It did not provide a significant increase in fire resistancy to the fluids tested.

TABLE VI

BRIGHT STOCK PETROLEUM OILS

F No.	Name	Viscosities (cs) +100°F	+210	+60	+40	Price/Gal. Tank Car Rate
	Lion Oil Mid-Continent Bright Stock	845.3	33.4	16.000	--	--
F-2682	Lion Oil #6 Lube Stream	498.4	23.57	930 at 50		$0.15
	Socony Mobil 330 St.	415	26.34	3725 at 50		0.255
	Sunray DX 150 Bright Stock	560	325	--	10,020	0.27
	Shell 150 B.S.	586	34.3	--	10,070	0.27
	Gulf 150 M.C. Bright Stock	496.9	31.77	--	8,400	0.27
F-2683	Gulf 200 MC B.S.	848	44.6	--	--	0.2975
	Penn 150 B.S.	519.8	32.70	--	7,940	--
	Humble 2501 Stock	525.9	32.00	--	8,080	0.2600
	Shell 200	1056	46.0	--	--	0.2800
F-2846	Mobil 225 S.R. B.S.	1023	48.3	--	--	0.2500
	Mobil 200 CR BS	1150	43.2	--	--	0.2100
F-2771	Lion #185 Treat.	946	35.2			
F-2867	Kerr McGee G-Stock	1228	45.0	--	--	0.1800
F-2868	Kerr McGee Special M-200	1482	--	--	--	0.1600
F-2874	Champlin 225 B.S.	1048	50.4	--	--	

4. Phosgard Type Materials. Several of the Phosgard type fluids were examined because fire resistance tests indicated that a small amount of very fire resistant, low volatile material would be helpful. Generally, the Phosgards are too expensive and their stability is questionable for this application. Comments on each of the Phosgard type materials tested are as follows:

   a. Phosgard C-22-R available; least expensive ($0.44/lb.); 2% not soluble in Aroclors or oil.

   b. Phosgard C-32-R (propylene oxide analogue of C-22-R) 5% soluble in both Aroclor and oil.

   c. 2XC-20 - chlorine analogue of Phosgard 282. 5% soluble in Aroclor 1242 and 5% insoluble in oil.

d. B-20 - Bis(2-bromoethyl)-2-chloroethyl phosphate. 5% soluble in Aroclor and 5% insoluble in oil.

e. Tris-(2,3-dibromopropyl) phosphate - (Firemaster T23PV Michigan Chemical Corp.). 5% soluble in Aroclor and 5% insoluble in oil.

f. Phosgard 282 - too expensive - about $2.40/lb. 5% soluble in both oil and Aroclor

Formulations		Molten Metal Test (1250°F.) (See Key Table VII)
5% 2XC-20 20% Gulf 200 MBS 75% Aroclor 1242	emulsion - 2XC-20 separates	e - 80
5% Phosgard 282 20% Gulf 200 MBS 75% Aroclor 1242		e - 80
5% C-32-R 25% Gulf 200 70% Aroclor 1242		e - 80 h - 80
5% C-22-R 25% Gulf 200 70% Aroclor 1242	emulsion C-22-R separates	d - 90

The phosgards were not examined further owing to their high cost, low solubility, and hydrolytic instability.

From these investigations two candidate formulations were defined. Both appeared to possess a degree of fire resistancy equivalent to typical water based fluids. Table VII lists the desired properties for the low cost fluid (OD-1331) along with the properties of the candidates; several competitive fluids, and Pydraul fluids. In summary, candidates F-2684 and F-2685 were inferior to the water glycol solution and Pydraul A-200, but superior to Pydraul 150 in the high pressure spray test. On the other hand, both F-2684 and F-2685 appeared to be slightly better than the water based fluids in the molten metal test.

Vickers 105c pump tests were run on both F-2684 and F-2685. Both fluids exhibited exceptional lubricity as evidenced by the very low wear on the pump parts. These fluids were designated MCS 311 and MCS 312 respectively. An additional formulation MCS 313 was defined containing only 25% Bright Stock oil. All three fluids were

TABLE VII

Name or [Gen'l] Origin	Composition	Lbs Water(s) Per Lb.	Specific Gravity	Temperature Range	VI Quality			Fire Hazard Index			
					+90	+300	+210	Vapor Pressure (psia)	Flash	High Temperature Density (lbs. at 0)	
"Desired" Properties (Fire Resistant Hydraulic [illegible])				(81,000 or less, Utility point)	+200 at 0°F	7,	35	Equivalent to Hydrol Fluids			
"Minimum" Properties (Approximal MS 73511)				(31,50 or less Utility point)	900	54	7	Somewhat better than water-in oil emuls ons			
P-2404	45% Lion Al Lube Oil 40.5% Acrawler 1092 14 ml Rustnibar 144 0.5% Ahmes 710 0.1% Rustnibar 70	0.07 0.07481 0.1538 0.25 0.1567	1.1	80.40/gallon	1395	61.6	6.35	(b) (h)-50	30	At 2 feet from orifice flames carried one foot. At 3 feet from orifice flames carried 10 inches. At 4 feet intermittent flashes carried to hood.	
P-2405	40 ml Gulf 200 Bright Stock 35 ml Acrawler 1092 14 ml Rustnibar 144 0.5% Ahmes 710 0.1% Rustnibar 70	0.09 0.07481 0.1538 0.25 0.1567	1.096	80 TI/gallon	741	70.6	7.00	(b) (h)-50	37.)	Same as P-2404.	
Pydraul A-200	Acrawler Based Fluid	0.079	1.48	80.97/gallon	-	30.6	0.82	(b) (r)	-	Flame carried only 6 inches from tip at distance up to 6 feet from orifice. Flashes with great difficulty at all distances from orifice.	
Pydraul 150	Phosphate/Acrawler Based Fluid	0.1648 (200 1b) units)	1.12	80.98/gallon	-	31.9	7.4	(b) (g)	85	At 2 feet from orifice flames carried one foot. At 3 feet from orifice flames carried 2 feet. Intermittent flashes carried to hood. At 4 feet from orifice flame carried continuously flames carried downstream to hood.	
Pyranyltrate Hydrogen	Water-Oil Emulsion	-	-	-	-	-	-	(c)-80 (a)-40	30	Flame carried only 6 inches from tip of torch at distances up to 5-1/2 feet from orifice. No flashes.	
Ucon Hydrolube CF-275	Water-Glycol Fluid	-	-	-	-	-	-	(c)-80 (a)-40		Flame carried only 6 inches at all distances from orifice.	

KEY: MELTED METAL TEST

a) Ignites spontaneously

b) Does not flash or ignite without spark.

c) Flames without spark and burns to completion.

d) Flames without spark and is self-extinguishing.

e) Flashes without spark and burns to completion after after ____# repetitions.

f) Flashes with spark and is self-extinguishing.

g) Flashes with spark and burns to completion.

h) Flashes with spark and is self-extinguishing until ____# repetitions.

STT: HIGH TEST

The number given represents the number of cycles the fluid-covered pipe steamer passed through a bunsen burner flame before combustible burning tubes place

(Rate - 25 ± 2 cycles/min.)

Bureau of Mines Spec. 24 passed.

MONS 021171

submitted to Sam Pollack at the Bureau of Mines for Schedule 30 FR tests. The results of these tests conducted in Pittsburgh and the other bench tests performed in Organic Research are given in Table VIII. During the pump tests the reserve sample of MCS 311 became very turbid and a waxy material gradually formed on the top of the fluid. Owing to this wax separation, MCS 311 was dropped as an active candidate.

MCS 312 passed all of the Bureau of Mines schedule 30 F.R. tests with the exception of the wick test. MCS 312 ran 21.0 cycles whereas the minimum requirement is 24.0 cycles. This deficiency was considered minor and field tests were started on MCS 312 at G. M. Bedford, Budd Corp. in Gary, Indiana, Budd in Philadelphia, and Carter Carburetor. Samples of fluid from the field tests were examined periodically for a change in viscosity and acidity. Logs of this information are given in Appendix III.

The field tests on MCS 312 dramatized its fine lubricity. A slight viscosity increase (2-4%) occurred during the tests and it was decided to modify the formulation to accomodate this increase. Later it was also decided to delete the Admex 710 acid scavenger from the formulation when it was learned that Admex 710 may have been a source of objection to the odor of the fluid. The current composition of MCS 312 (named Pydraul 312) is given in the section VIII, Description of Recommended Process.

The success of MCS 312 in the field tests led to the fluid's promotion to the die casting industry. A composite listing of Physical Properties, Functional Properties and Fire resistance properties may be found in Appendix III.

Considerable work was done toward developing a case upon which a patent application could be filed. The case was defined on the basis of three requirements, fire resistance, synergism in Timken load carrying capacity, and homogeneity at room temperature.

Those ranges in composition of bright stock oil, Aroclor fluids and phosphate esters which satisfied all three requirements were defined and claimed in the application (0-2219). Figure 1 gives the load data for the three component system consisting of Gulf 200 Bright Stock Oil, Aroclor 1242, and Santicizer 144. The general claim of the application is bounded by points ABC in Figure 2. A range of preferred compositions was also defined. The preferred compositions are bounded by curve AFG'G

TABLE VII

PROPERTIES ON LOW-COST FIRE-RESISTANT HYDRAULIC FLUID CANDIDATES

I. Fluid Properties

	MCS 312	MCS 313	Desired OD 1331	Minimum OD 1331
a. Viscosity				
40°F	930	532	900 at 0°F	900
100°F	70.6	39.5	75.	65.
210°F	7.80	5.10	18.0	7.5
b. Viscosity Index	+ 78	+ 38		+ 81
c. Pour Point (extrapolated to 500,000 cs)	- 10°F	-15°F		

II. Fire Resistancy - Desired - Equivalent to Pydraul Fluids
Minimum - Somewhat better than water-in-oil emulsions.

	MCS 312	MCS 313	Penn Hydraqua	UCON Hydrolube 275 CP
a. AIT	940°F .10 cc 5 sec.	-	-	-
b. Flash Point	395	350	-	-
c. Fire Point	545	550	-	-

d. Molten Metal Ignition (1250°F)

MCS 312 - Does not ignite spontaneously. Occasionally flashes without a spark after nearly all of the fluid has vaporized. Flashes with a spark and is self-extinguishing until about half of the fluid has vaporized; then flashes and burns to completion.

MCS 313 - Same as MCS 312.

Pennsylvania Hydraqua - Does not ignite spontaneously. Flashes and burns to completion without spark after water has boiled off. Flashes and burns to completion with a spark after water has boiled off.

Ucon Hydrolube 275 C - Same as Penn Hydraqua.

MONS 021173

TABLE VII (continued)

e. High Pressure Spray Test - Fluids heated to 150°F in reservoir and sprayed at 1000 psi.

MCS 312	- At 2 feet from orifice flames carried one foot. At 3 feet from orifice flames carried 18 inches. At 4 feet from orifice intermittent flashes carried to hood.
MCS 313	- At 3-1/2 feet from orifice flame carried about one foot. At 4-1/2 feet from orifice flame carried about 18 inches. No flashes out to 6 feet from orifice.
Penn Hydragua	- Flame carried only 6 inches from tip of torch at distances up to 5-1/2 feet from orifice. No flashes.
Ucon Hydrolube 275 CP	- Flame carried only 4 inches at all distances from orifice. No flashes.

f. Bureau of Mines Schedule 30 Tests

	MCS 311	MCS 312	MCS 313
AIT (minimum 600°F)	>820°F with 0.05 0.07 & 0.09 ml.	Same	Same
Temp.-Pressure-Spray Ignition Test (150°F, 150 psi)			
(a) cotton waste kerosene soaked	propagation to 6 sec. mark.	no propagation	propagation under 6 sec.
(b) 12,000 volt arc	pass	no propagation	no propagation
(c) Propane torch	propagation to 6 sec. mark.	no propagation	propagation under 6 sec.
(minimum: propagation not exceeding 6 sec. at distance of at least 18" from orifice.)			
Evaporation/ Flammability (Minimum: 24 passes)	18.8	21.	24.4

TABLE VII (continued)

III. Lubricity

	MCS 312	MCS 313
a. Four Ball Wear at 167°F, 1 hour, 620 rpm		
Steel on Steel		
4 Kg	0.24	0.154
10 Kg	0.25	0.23
40 Kg	0.44	0.28
Steel on Bronze		
10 Kg	0.87	

b. Vickers Pump Test (1000 Hours - 140°F)

Weight Losses (g)	MCS 311	MCS 312
Bushings		
2015	0.0017	+0.0081
2016	0.0018	0.0057
Ring	0.0036	0.0013
Vanes	0.0109	0.0021
Viscosity		
Initial		
100	61.6	70.6
210	6.34	7.8
Final		
100	58.7	67.0
210	6.36	7.64
% Viscosity Loss		
100	4.7	5.09
210	-	2.05
Initial Acidity	.13	.13
Final Acidity	.21	.14

c. Timken Load - MCS 312 - Maximum load without seizure 55 lbs.

Pydraul A-200 - 50 lbs.

TABLE VII (Continued)

IV. Performance Tests

a. Foam Test (ASTM D892)

	MCS 312
75°F Tendency, foam after 5 minute air blowing	20 cc
Stability	12 sec.
200°F Tendency	5 cc
Stability	8 sec.
75°F Tendency	0 cc
Stability	0 sec.

b. Rust Test (ASTM D665) - MCS 312 - rust rating 10.0 (no rusting)

c. Emulsion Test (ASTM D1401) - MCS 312 - Complete separation had not occurred after one hour. A clear water layer formed on the top and a water/oil emulsion layer was formed below.

d. Hydrolytic Stability (Coke Bottle Test 48 hrs. 200°F)

Acidity Mg KOH/g.	MCS 312
Initial	.13
Final	.17
Mg NaOH to neutralize water layer	2.0
Copper test specimen appearance	Sl. Dull Cu Color
Wt. loss - mg/cm^2	.04
Viscosity	
Initial	
100	70.6
210	7.80
Final	
100	70.2
210	7.70
% Change	
100	.56
210	1.3

TABLE VII (Continued)

e. Compatibility

1. Elastomer Swell (Oven test 158°F, 168 Hrs.)

	MCS 312		MCS 313
Butyl			
Durometer Hardness			
Initial	67	67	68
Final	46	47	49
Volume Increase (%)	64.0	62.7	78.3
Weight Increase	57.4	56.3	67.5
Silicone			
Durometer Hardness			
Initial	72	73	72
Final	70	68	70
Volume Increase (%)	1.93	1.93	3.72
Weight Increase	3.70	2.82	4.43
Viton			
Durometer Hardness			
Initial	68	67	68
Final	68	66	68
Volume Increase	None	None	0.1
Weight Increase	0.2	0.2	0.4
EPR			
Durometer Hardness			
Initial	71	70	70
Final	54	52	53
Volume Increase (%)	64.7	69.5	59.3
Weight Increase	58.9	62.9	57.8

f. Oxidation and Corrosion Test (250°F, 168 Hrs.)

		MCS 312	MCS 313
Test No. 570		Tube 1	Tube 2
% Viscosity Change			
+100°F		+ 50.7%	+ 58.5%
+210°F		+ 29.2%	+ 34.0%
Metal Wt. Change (gm.)	Al	+ .0003	+ .0003
	Mg	+ .0002	.0000
	Cd	- .0082	- .0140
	Fe	.0000	+ .0001
	Cu	- .0014	- .0016

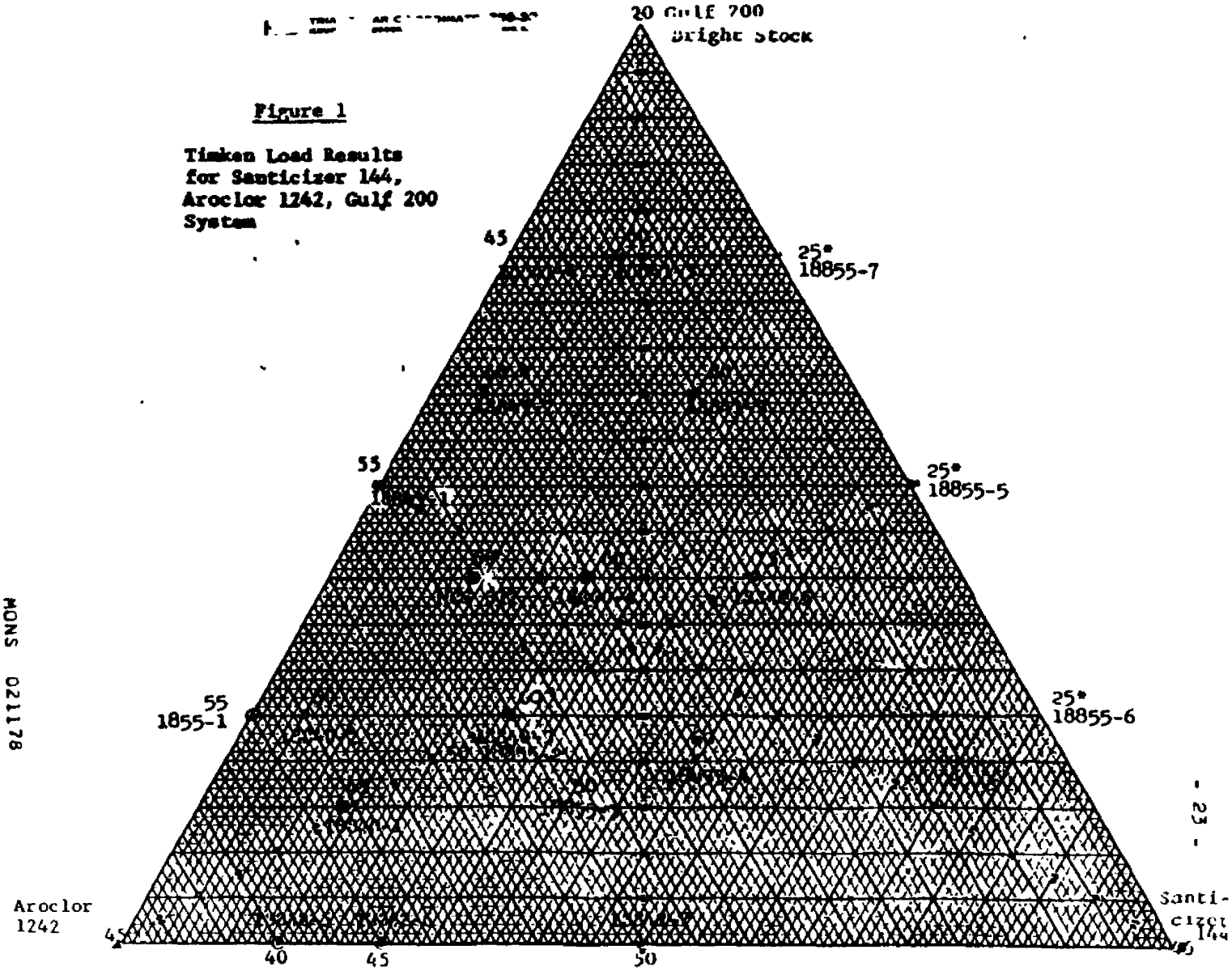

Figure 1

Timken Load Results for Santicizer 144, Aroclor 1242, Gulf 200 System

MONS 021178

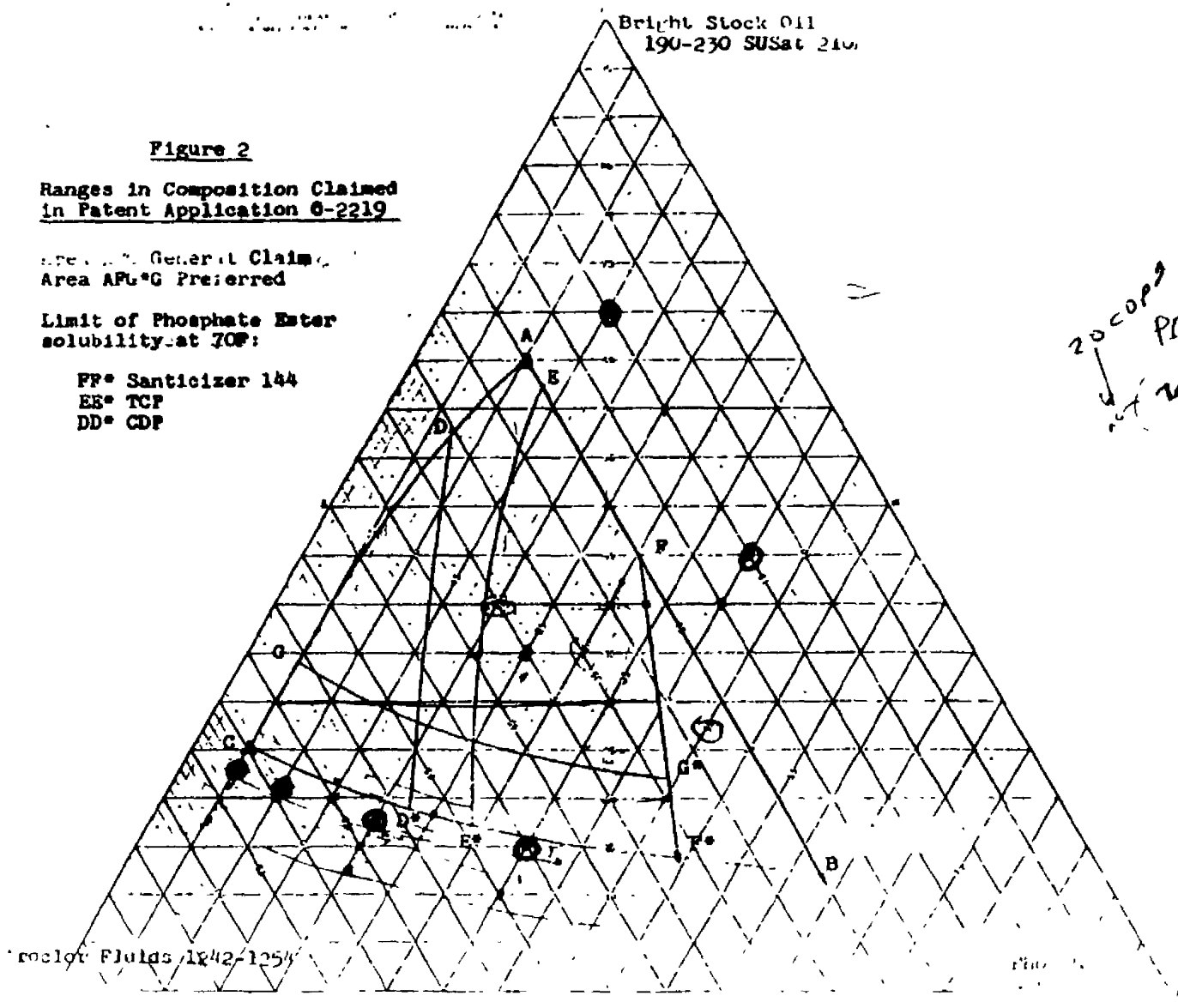

Figure 2

Ranges in Composition Claimed in Patent Application 6-2219

Area APG*G Preferred

Limit of Phosphate Ester solubility at 70F:

FF* Santicizer 144
EE* TCP
DD* CDP

MONS 021179

of Figure 2. These preferred compositions have a viscosity index rating of at least about +20, and when alkyl diaryl phosphate esters are employed viscosity index ratings of at least about +35 are obtained. In Table IX the Timken load results are listed for each of the base stock materials examined, plus MCS 312 and modifications to MCS 312.

MCS 312 suffered one major set back during the field testing stage. The fluid failed the severe Factory Mutual Engineering Division's Hot Channel Iron Test. A number of modifications to MCS 312 were examined and none passed this test. Fluids with as little as 10% bright stock oil failed. Certification by F.M. was desired because this approval would mean that die casting firms would now qualify for lower insurance rates. Moreover, certification by FM carried with it the connotation of a quality product. This set back was partially offset by listing of MCS 312 (Pydraul 312) by Underwriters Laboratories. The report on Pydraul 312, Pydraul 135 and Pydraul 540 from Underwriters is given in Appendix III.

The technology acquired in development of Pydraul 312 was used to define several other viscosity grades. These fluids are MCS 90, MCS 395 (Pydraul 135) and MCS 404 (Pydraul 540). The specifics of their development are discussed later.

TABLE IX

Timken Load on Base Stocks and Formulations

Base Stocks	Max Load Without Seizure
Gulf 200 Bright Stock	20 lbs.
Aroclor 1242	45 lbs.
Aroclor 1221	50 lbs.
TCP	45 lbs.
Santicizer 144	45 lbs.
Santicizer 141	45 lbs.
Methyl diphenyl phosphate (MDP)	15 lbs.
Di-n-butyl phenyl phosphate	15 lbs.
Aroclor 1248	35 lbs.
Formulations	
MCS 312	55 lbs.
MCS 312 - containing TCP instead of Santicizer 144	55 lbs.
MCS 312 - containing Aroclor 1221 instead of Aroclor 1242	70 lbs.
MCS 312 - containing Gulf 220 SUS at 100° F. oil in place of Gulf 200 bright stock	55 lbs.
MCS 312 - containing Gulf 150 bright stock instead of Gulf 200 bright stock	55 lbs.
MCS 312 - containing Santicizer 141 in lieu of 144	50 lbs.
MCS 312 - containing MDP in lieu of 144	45 lbs.
MCS 312 - containing Di-n-butyl phenyl phosphate in lieu of 144	45 lbs.
MCS 312 - containing Aroclor 1248 in lieu of 1242	60 lbs.

II. Industrial Fire Resistant Hydraulic Fluids

C. Improved Pydraul 150

A project was started late in 1963 to develop an improved Pydraul 150 type fluid. The principal objections to Pydraul 150 were shear instability and inadequate thermal stability. These chief complaints came from Europe where the fluid was being used in Brown Boveri steam turbine control systems. This application alone accounted for a large percentage of Pydraul 150 sales.

The initial approach taken was to improve the thermal stability of Pydraul 150 by replacing 2-ethylhexyl diphenyl phosphate with more thermally stable phosphates. Shear stability was to be improved by replacing Acryloid 710 with FH-139. The phosphate esters examined were MDP and TCP. A matrix of 29 formulations consisting of TCP, MDP, Aroclor 1242, FH-139, and diisodecyl adipate was devised.

The formulations were made and compared in terms of viscosity and cost of raw materials. The best formulation appeared to be 18.3% TCP; 36.7% MDP; 25.0% Aroclor 1242; 5.0% FH-139 and 15.0% DIDA. The viscosity data and cost of raw materials for this formulation are given below.

Viscosity (cs)					
-20° F.	-10° F.	0° F.	100° F.	210° F.	Cost
13,390	5080	2190	30.4	5.73	$0.2185/lb.

This approach was abandoned when it was learned that the hydrolytic stability of MDP was poor. Moreover, water solubility of 3.5% in MDP added to the hydrolytic stability weakness.

Development was asked then to provide more definitive target properties for an improved Pydraul 150. A copy of the report from Development is given in Appendix IV. In summary, the desired properties were:

1. Viscosity on "used" fluid

+10° F.	1000 cs (max.)
100° F.	29.5
130° F.	15 maximum
210° F.	4.6

2. Viscosity Index about +64

3. Permanent viscosity loss from shear about 20% max.

MONS 021181

4. Thermal Stability +50° F. greater than current Pydraul 150

5. Compatibility with current Pydraul 150

Later the following additional objectives were stated.

1. Improved rust inhibition

2. Cost not to exceed present Pydraul 150.

With these objectives in mind a second approach to the problem was tried. Use of MDP was ruled out because of inadequate hydrolytic stability. Formulations consisting of TCP, CDP, DIDA, TCB and FH-139 were examined. These formulations are given below. The FH-139 content was held constant at 5.0% because it was known from work on MCS 300 that the viscosity loss in a 1000 Hi pump test would not exceed 20%. Accordingly members 4 and 6 below were considered close to the desired initial viscosity. Unfortunately the costs of these formulations were considerably greater than Pydraul 150. These high costs were caused, in part, by the relatively expensive FH-139 VI Improver.

						Viscosity		
	TCP	CDP	DIDA	TCB	FH-139	100	210	0°F.
114381-1	--	85	--	10.0	5.0	28.16	5.64	1910
-2	--	90	--	5.0	5.0	33.4	6.18	3000
-3	10	75	--	10.0	5.0	29.50	5.72	2180
-4	11	79	--	5.0	5.0	35.03	6.32	3560
-5	11	64	10.0	10.0	5.0	28.95	5.74	1760
-6	15.7	64.3	10.0	5.0	5.0	33.73	6.28	2700

Two higher viscosity triaryl phosphates were made to determine if a non-VI-Improved fluid could be defined. They were Diphenyl-p-tert butylphenyl phosphate and Diphenyl-p-nonyl phenyl phosphate. Linear programming of these potential base stocks along with Aroclor fluids and other base stocks indicated that a non-polymeric VI improved formulation could not be achieved. Next, these base stocks were programmed to yield an optimum viscosity, minimum cost formulation. The +10° F., 100° F. and 210° F. viscosities were specified and the minimum cost formulation was obtained. Formulations were defined having properties as follows:

+10° F.	500-2000 cs
+100° F.	15-21 cs
210° F.	3.0-4.3 cs
Cost	$0.15-0.20/lb.

A report of this linear programming effort is given in Appendix IV in a letter from J. D. Hinchen to R. W. Street dated February 12, 1964.

From information obtained through the linear programming an optimum fluid was defined. This fluid, MCS 290, consisted of the slightly more thermally stable iso-octyl diphenyl phosphate in place of the 2-ethylhexyl diphenyl phosphate. Improvement in Shear Stability was realized, hopefully, by utilizing less VI Improver and higher viscosity basestocks. The MCS 290 formulation less VI Improver has a 100° F. viscosity of about 16 cs; whereas, Pydraul 150 less VI Improver has a viscosity of about 11 cs. Composition of MCS 290 and initial properties are given in Table X.

MCS 290 was the culmination of efforts to define an improved Pydraul 150 fluid from currently available base stock fluids at a cost equivalent to Pydraul 150. Table XI gives the properties of MCS 290, Pydraul 150 and fluid F2747. The major deficiency found in MCS 290 was the permanent viscosity loss after the 1000 hour pump test. It was anticipated that the permanent viscosity loss due to mechanical shear in the pump would be equivalent to that observed in the diesel injector shear test. This, however, was not the case. It was concluded that MCS 290 did not provide a sufficient improvement in shear stability. The fluid did provide improved rust inhibition and a slight improvement in thermal stability.

Owing to the fact that MCS 290 fell short of the needed improvements, new formulations comprised of higher viscosity alkyl diaryl phosphates were examined. It was believed that the only way to completely avoid shear instability problems was to avoid using polymeric VI Improvers. Accordingly this meant using higher viscosity bass stock fluids.

A number of new phosphates and phosphoroamidates were examined. Tables XII and XIII test the viscosities of each. Of these fluids oxo-tridecyl diphenyl phosphate appeared to offer the best combination of high viscosity, high VI and low cost. The range in composition for a system comprised of this phosphate, Aroclor 1242, and Gulf 200 Bright Stock was defined on the basis of the following viscosities:

at 210° F.	4.0-4.5 cs.
at 100° F.	25-30 cs.
at +10° F.	1160-1500 cs.

Key formulations meeting these criteria are listed in Table XIV.

TABLE X

MCS 290

Components	Std. Raw Material Cost
43.9% Santicizer 144	$0.1538/lb.
40.0% Aroclor 1242	0.07681/lb.
10.0% DIDP	0.1503
5.0% Acryloid 710	0.3211
1.0% Admex 710	0.25
0.1% Santolube 70	0.2367
25 PPM DC-200	-
7 PPM Blue Dye	-
2 PPM Black Dye	-

Total Mfg. Cost

$0.1360/lb.

9.70 lbs/gal

$1.32/gal.

Viscosity

-10°F - 7370
+10°F - 1400
+100°F - 33.33
+210°F - 6.35

Pour Point -40°F

Lubricity

Pour Ball Wear
(167°F 1 Hr. 600 Rpm)

Steel on Steel	Wear Scar
4 Kg	0.24 mm
10 Kg	0.28 mm
40 Kg	0.46 mm
Steel on Bronze	
10 Kg	1.94 mm

Fire Resistance

Flash	Fire Pt.	Molten Metal
400°F	510°F	Same as Pydraul 150 (See Table II)

Hot Manifold Test
MIL

Flashes and burns on the tube, burns on leaving the tube and burns intermittently in the pan.

(Same results with Pydraul 150)

Thermal Aging Test

(250°F Oven Test)

Hrs.	MCS 290 (TAN)	Pydraul 150 (TAN)
0	0.07	0.11
90	0.13	0.65
168	0.15	1.30

Rust Test (ASTM D665)

MCS 290

A Version (Distilled Water)

Results: No rusting after 24 hrs.

B Version (Synthetic Sea Water)

Results: No rusting after 24 hours.

Shear Stability

Diesel Injector Shear

Passes	MCS 290 100°F Visc.	MCS 290 % Loss	Pydraul 150 100°F	Pydraul 150 % Loss
0	33.33	-	30.37	-
2	26.62		23.17	
4	25.48		21.74	
6	24.75	25.7	20.90	31.2
8	-		20.36	
10	24.21		20.16	
12	24.05		19.92	
13	-		19.87	34.6
14	24.00	28.0		

Hydrolytic Stability

Coke Bottle Test
(200°F 48 Hours)

MCS 290

Acidity MgHCOH/g.

Initial	0.072
Final	0.24

Mg of NaOH to neutralize water layer 1.40

Copper Test Specimen: No etching or pitting. SL dull Cu color.

Weight Loss 0.14 mg/mm²

Visc. Change (%)

+100	-3.6
+210	-1.6

TABLE XI

IMPROVED PYDRAUL 150

		MCS 290	Pydraul 150	F2747
1.	Fluid Properties			
	a. Viscosity (cs)			
	at -10°F.	7370	1600	
	+10°F.	1400	585	1561
	+40°F.			255.5
	100°F.	33.3	31.0	25.86
	210°F.	6.35	7.4	4.15
	b. Viscosity Index	+144	+170	+43
	c. Pour Point	-40	-55	-30
2.	Neutralization Number	0.07	0.04	0.10
3.	Flammability			
	a. Flash point	400	425	425
	b. Fire point	510	465	535
4.	Lubricity			
	a. Four Ball Wear (167, 1 hr. 600 RPM)			
	S/S			
	4 Kg.	0.24 mm		0.27 mm
	10 Kg.	0.28 mm	0.36 mm	0.32 mm
	40 Kg.	0.46 mm	0.51 mm	0.42 mm
	S/B			
	10 Kg.	0.95 mm	1.10 mm	0.95 mm

Table XI(continued)

	MCS 290	Pydraul 150	F2747
5. **Performance Tests**			
a. Vickers Hydraulic Pump Test (140°F. 1000 psi)		"A" Pump 12/62-2/63	"B" Pump
Weight Losses			
Bushings			
2015	-0.0382	-0.1601	-0.0040
2016	-0.0082	-0.1134	-0.0104
Ring	-0.011	-0.1212	-0.0012
Vanes	-0.0053	-0.0378	-0.0048
Viscosity			
Initial			
100	32.81	29.58	25.86
210	6.32	7.06	4.15
+10	1400.	-	1561.
Final			
100	19.94	19.11	25.62
210	3.70	4.22	4.06
+10	917	-	-
Viscosity Change			
100°F.	-39.2%	-35.4%	-0.93%
210°F.	-41.4%	-40%	-2.2%
Acidity			
Initial	0.072	0.07	0.10
Final	0.18	0.22	0.14

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Table XI (continued)

	MCS 290	F2747
b. Hydrolytic Stability		
Coke Bottle Test (48 Hrs., 200°F.)		
Acidity		
Initial	0.072	0.10
Final	0.24	0.55
Mg NaOH to neutralize water layer	1.40	14.9
TAN of water layer		0.20 mg. NaOH/gm fluid
Copper Test Specimen Appearance	No etching or pitting. S1 dull cu color.	Same
Wt. loss of Copper strip. mg/cm^2	0.14 mg/cm^2	0.74 mg/cm^2
Viscosity		
Initial		
100	32.81	25.86
210	6.32	-
Final		
100	32.10	27.06
210	6.25	-
% Change		
100	-2.2%	+4.64%
210	-1.1%	-

Table XI (continued)

		MCS 290	Pydraul 150	F2747 #1	F2747 #2
c.	Oxidation Corrosion Test (250°F. - 168 Hrs.)				
	Viscosity Change (%)				
	100°F.	+7.7	-2.1	+29.2	+39
	210°F.	+4.6	+3.1	18.7%	+25
	Metal Wt. Loss, mg/cm²				
	Mg.	-0.2	-0.1	-0.01	None
	Al	+0.01	None	+0.01	+0.01
	Cu	+0.13	-3.04	-10.08	-10.26
	Fe	+0.15	-0.15	None	+0.01
	Cd	-0.77	-0.04	-3.05	-2.14
	Acidity (TAN)				
	Initial	0.07	0.096	0.10	0.10
	Final	0.21	0.78	3.51	4.89
d.	Elastomer Compatibility (168 Hrs. - 158°F.)				
	Butyl				
	Durometer "A"				
	Initial	65	67		65
	Final	49	51		52
	Volume Increase (%)	27.7	22.5		23.1
	Weight Increase (%)	27.1	19.8		23.7
	Viton				
	Durometer "A"				
	Initial	67	65		66
	Final	61	64		63
	Volume Inc. (%)	4.2	7.5		1.5
	Wt. Increase (%)	2.6	3.7		0.92

Table XI(continued)

	MCS 290	Pydraul 150	F2747
EPR			
Durometer Hardness "A"			
Initial	70	70	71
Final	55	60	57
Volume Increase (%)	10.0	8.3	31.2
Wt. Increase (%)	10.9	7.8	28.6
Silicone			
Durometer Hardness "A"			
Initial	72	70	70
Final	68	68	67
Volume Increase (%)	4.9	7.3	-0.78
Wt. Increase (%)	4.0	5.3	0.75

The role of each component in the formulations was as follows:

a. The phosphate provides good VI, good low temperature fluidity and a source of fire resistance to the system. By itself, this phosphate is less fire resistant than either Pydraul 150 or Skydrol 500A.

b. The Aroclor possesses a poor VI, but it provides the very important source of inexpensive stable chlorine for synergism with the phosphate to yield fire resistant fluids.

c. The Gulf 200 has a very high VI along with very high viscosity. It serves to boost the viscosity of the formulations to the desired level.

High pressure spray tests were run on Formulations 18802-1,3,5,6 and 7. Only blends 18802-6 and 7 were equivalent to or better than Pydraul 150 in this fire resistance test. Of these two formulations, 18802-6 most closely met the viscosity specifications outlined by Marketing and Development. All of the blends were equivalent to Pydraul 150 in the Molten Metal test.

The phosphoroamidates were found to have higher thermal stabilities than the alkyl diaryl phosphates. Their higher cost, poorer VI, and insolubility in Aroclor 1242/Gulf 200 Bright Stock formulations made them unattractive as base stocks for this application.

Two formulations, 18802-6 and 18802-7, Table XIV, were considered for testing and evaluation; the latter was finally selected owing to its better fire resistancy and lower anticipated cost. With an additive package this fluid was designated F2747. The composition of F2747 is:

57.9% Tridecyl diphenyl phosphate
32.0% Aroclor 1242
9.0% Gulf 200 Bright Stock
1.0% Admex 710
0.1% Santolube 70
20 ppm DCF 200

Properties on F2747 are listed in Table X[I]. The 1000 hour Vickers pump test was run successfully. Very little wear occurred and the fluid proved to be shear stable as expected. In the O&C Test, however, fluid degradation, acid build up and copper attack was pronounced. It was felt that this may have occurred as

TABLE XII
ALKYL DIARYL PHOSPHATES

SL.No.		Viscosity °F -20	0	+10	+100	+210
122021	di-o-chlorophenyl diphenyl phosphate (mixed ether)	-	9,447	-	23.59	3.55
122026	oxo-Tridecyl diphenyl phosphate	-6,015	-	-	19.68	3.68
122028	oxo-Tridecyl diphenyl phosphate (via Santicizer 141 process)	-	-	658	19.72	3.77
-	oxo-Tridecyl diphenyl phosphate Santicizer 141 process - (Tech Lab batch 1)	-	-	617	19.40	3.67
122029	nC_{12}-C_{16} Alkyl diphenyl phosphate (via Santicizer 141 process)	-	434	-	14.40	3.38
122030	nC_{12}-C_{18} Alkyl di(o-chlorophenyl) phosphate	-	-	642	23.57	4.49
122033	nC_{12}-C_{16} Alkyl dicresyl phosphate	-	-	492	21.58	4.13

TABLE XIII
AMIDATES

122036	Mixed phenyl cresyl di dimethylamino phosphoroamidate	-	-	1,470	17.14	2.97
122037	Mixed dicresyl dimethylamino phosphoroamidate	-	-	2,500	20.65	3.22
122035	Mixed diphenyl dimethylamino phosphoroamidate	-	-	630	13.30	2.63
122034	Diphenyl dimethylamino phosphoroamidate	-	-	-	13.40	2.60

TABLE XIV

PYDRAUL 150 REFORMULATION

	Composition	Sp.Gr.	Viscosity -10	Viscosity +10	Viscosity +100	Viscosity +210	Fire Resistancy: Halton Metal	Fire Resistancy: H.P. Spray (150°F)
18802-1	70.0% Tridecyl diphenyl phosphate (TDDPP) 20.0% Arcolor 1242 10.0% Gulf 200		6640	1285	26.02	4.32	Same as Pydraul 150	Flashed at 3 ft. from orifice with balls of flames carrying downstream to hood. At 2 ft. from orifice fluid flashed hesitantly.
-3	70.0% TDDPP 18.0% Arcolor 1242 12.0% Gulf 200			1320	27.55	4.47	Same as Pydraul 150	(Pydraul 150 is better)
-5	65.0% TDDPP 21.0% Arcolor 1242 14.0% Gulf 200		8880	1556	30.08	4.69	Same as Pydraul 150	
-6	62.0% TDDPP 26.0% Arcolor 1242 12.0% Gulf 200			1613	28.43	4.95	Same as Pydraul 150	Fluid flashed occasionally at 4-1/2 ft. from orifice. At 6 ft. from orifice flashed with partially self-extinguishing flames carrying to hood. (Equivalent to Pydraul 150.)
-7	59.0% TDDPP 32.0% Arcolor 1242 9.0% Gulf 200	1.110		1581	25.64	4.12	Same as Pydraul 150	Fluid flashed intermittently at 4-1/2 ft. from orifice. At 5 ft. from orifice flashes occurred more regularly with balls of flames carrying downstream to hood. (Slightly better than Pydraul 150)

a result of a poor quality of the TDDPP. A complete emulsion also resulted in the ASTM D1401 test on F2747 less rust inhibitor. Both hydrolytic stability and O&C tests were rerun using a more-thoroughly washed Tridecyl diphenyl phosphate. Acidity increases were less for the improved matsrial; however copper attack and viscosity increase were appreciable. Results of these tests are listed for comparison in Appendix IV.

Republic Steel Company Hydrolytic Stability Test was run on F2747, Pydraul 150, and several other candidate fluids for other applications. The results given in Table XV show that F2747 had a slower rate of acid increase than Pydraul 150; however its degree of stability over an extended period was about comparable to Pydraul 150. This actually was not surprising because the same mechanism (ester pyrolysis) of decomposition could take place on TDDPP and 2-Ethyl hexyl diphenyl phosphate. The combination of questionable stability, copper attack, and processing difficulties on TDDPP necessitated looking for another answer to the problem.

About this time Republic Steel rsported the need for a lower viscosity Pydraul 312. A number of formulations were derived from a modified Pydraul 312 using fire resistant diluents (TCB, Tritetrachlorobenzene) to obtain improved low temperature viscosity. Fluid F2794 was defined and a complete laboratory evaluation was obtained. The additive version of F2794 was designated MCS 395 which is the current successor to Pydraul 150.

The original composition of MCS 395 along with its properties is given in Appendix IV. In order to qualify for use in the Brown Boveri Steem regulator systems it was necessary to modify the formulation to reduce its specific gravity to less than 1.20 at 20° C. The current composition of MCS 395, now called Pydraul 135, is given in Section VIII, Description of Recommended Process.

A field test on MCS 395 (Pydraul 135) has been running for over eight months at Inland Steel in Chicago. There have been no significant changes in properties in this test. The fluid is shear stable and it has good thermal stability. A Republic Steel Stability test was run and the results are given in Appendix IV. The fire resistance of MCS 395 is comparable to Pydraul 150.

Other combinations of base stock fluids examined included TCP/CDP/Aroclor 1242; TCP/CDP/Aroclor 1248; Bright Stock Oil/Aroclor 1242/TCP/CDP/dibromoethyl benzene; Aroclor 1248/TCP/dibutyl phenyl phosphate; Aroclor 1242/TCP/Dibutyl phenyl phosphate; and Aroclor 1242/Gulf 200 B.S./DBPP.

TABLE XV

Republic Steel Hydrolytic Stability Test

Conditions: Sample containing 0.2% water is placed in an oven at 280° F. Samples taken periodically to determine acidity. When a sample has 1.5 neutralization number it is considered no longer usable. This test was run for only one week in order to compare relative stability. Total Acid Number is given in the table.

	Samples				
Hrs. of Test.	F2747 (new)	HS1010	MCS312	MCS312* (Mod)	Pydraul 150
4	0.08	0.50	0.03	0.05	0.08
8	0.13	0.08	0.05	0.08	0.15
24	0.10	0.10	0.10	0.08	0.71
48	0.10	0.10	0.10	0.10	0.71
96	0.73	0.07	0.12	0.19	2.93**
168	7.43	0.11	0.78	0.24	--
Viscosity (cs.)					
100° F.					
Initial	25.85	25.57	70.50	87.46	31.00
Final	29.35	20.27	95.75	95.77	30.41
Change %	+13.5	-21.0	+35.5	+9.5	-1.9

*Formulation contains 14.0% TCP in place of 14.0% Santicizer 144.

**Sample removed from oven. Final viscosity measured on 96 hr. sample.

From the formulation of the first system mentioned above MCS 370 was defined. The purpose of MCS 370 was to determine if a fluid having a viscosity as low as 18-19 cs at 100° F. would be suitable in turbine control systems. Rather than giving us an out right answer Dr. Thoenes of TUV, Essen, Germany, requested a one gallon sample of the proposed fluid. The answer was affirmative. MCS 370 was defined from cost/property optimization. The viscosity relationship of each component can be seen by referring to Figure I and II of Appendix IV. Properties of MCS 370 are listed in the tables in Appendix IV also.

Several other systems were examined. A system containing Gulf 200 Bright Stock, Aroclor 1242, TCP, CDP, Santicizer 144 and dibromoethyl benzene was examined. In developing formulations based on these components the following restrictions were adhered to:

Gulf 200 Bright Stock:	<30% by wt. owing to fire resistance considerations
Total Phosphate Ester:	not greater than 14% owing to enterprise agreement and limited solubility in the oil
Aroclor 1242:	No restrictions
Dibromoethylbenzene:	<10% by wt. DBEB is expensive; about $0.80-1.00/lb.

The table below gives the viscosities and approximate costs of seven blends:

	Composition (Wt. %)						Viscosities °F(cs)			
OR-No.	Gulf 200	Aroclor 1242	TCP	CDP	Sant. 144	DBEB	+10	+100	+210	Approx. Mfg.Cost cwt.
18866-3	20.	61.0	-	14.0	-	5.0	Emulsion	30.92	4.23	$12.71
-4	15.	66.0	14.0	-	-	5.0	7143	28.86	3.84	13.37
-5	20.	65.0	-	10.0	-	5.0	5520	31.48	-	12.24
-6	20.	62.0	-	11.0	-	7.0	4355	29.45	-	14.80
-7	20.	59.0	-	11.0	-	10.0	3209	26.91	4.0	15.97
-8	25.	56.0	-	-	14.0	5.0	3370	33.97	4.79	12.51
-9	25.	61.0	-	-	14.0	5.0	2976	28.23	4.15	12.89

The $0.80/lb. cost contribution of DBEB to these blends made them excessively high in cost.

Other systems examined were: Aroclor 1248/TCP/dibutylphenylphosphate, and Aroclor 1242/bright stock oil/dibutylphenylphosphate. The viscosity temperature relationship of the first is given in Fig. III, Appendix IV. It was found that those formulations having satisfactory low temp. viscosities also had 100°F. and 210°F. viscosities which were too low. Moreover, it may be noted that the two optimum fluids, Nos. 11890-8 and 11890-9, are roughly equivalent to MCS 370. Owing to the dibutylphenylphosphate they would be expected to be less thermally stable than MCS 370.

Only two formulations of the second system were prepared. Their composition and properties are given below:

Number	Composition			Viscosity °F. (cs.)		
	Aroclor 1242	Gulf 200BS	DBPP	+10	+100	+210
18890-10	61.0	25.0	14.0	2444	29.52	4.31
-11	66.0	20.0	14.0	2281	25.19	3.85

D. High Viscosity Pydraul 312 Type Fluid. A higher viscosity version of Pydraul 312 was developed to satisfy the need for a low cost, fire-resistant fluid having good lubricity. The intended Application was the large metal extrusion and forgoing industry. Heretofore, fire resistant fluids had not been used owing to poor lubricity as claimed by the pump manufacturers. MCS 404 was defined to satisfy this need. Properties of MCS 404 are listed in Appendix IV. About 1000 gallons of MCS 404 were prepared for field testing.

A field test on MCS 404 was run at Dow Metal Products, Madison, Illinois. The fluid was tested in a large Farrell Extrusion Press. No significant change in viscosity or acidity was noted after 6 weeks of one-shift per day operation.

MCS 404 was arbitrarily defined to have a viscosity of about 525 SUS at 210° F. Experience at Dow Metal Products has indicated that this viscosity is too high. A modified MCS 404 to a 450 SUS viscosity at 100° F. has been requested by Development.

E. Factory Mutual Approved Low Cost Fluid. Because MCS 312 did not receive F.M. approval, General Motors Central Foundry, Bedford, Indiana was hesitant to convert to the fluid. Later, after a fire resistance demonstration at Hazelwood Farm, and assurance from Development that MCS 312 would soon be listed by Underwriters, Bedford did start to convert to MCS 312. Budd Company in Philadelphia, however, decided not to convert to MCS 312. The situation at Budd was, for the most part, a question of insurance company approval. In order to obtain low insurance rates it would have been necessary for Budd to install expensive F.M. approved sprinkler systems.

These circumstances prompted us to develop a Factory Mutual Approved Fluid. A Hot Channel Iron Test apparatus was built to FM specifications. Table XVI gives the conditions of the test and results for 14 fluids tested. It was found that fluids containing as little as 5% Bright Stock oil failed the test.

Since bright stock oil could not be used in low cost formulations, a lower cost Pydraul A-200 type fluid was considered. Formulations based on various cuts of crude Aroclor fluids and crude biphenyl chlorinated were examined. Table XVII lists the properties of the crude base stocks obtained from Anniston. Two formulations were defined, F2792 and F2805. The properties of these fluids are given in Appendix V. Both fluids failed the 1000 hour pump test due primarily to insufficient lubricity and secondarily poor viscosity-temperature characteristics. Both of these fluids consisted of crude biphenyl chlorinated and an additive package of 0.2% diphenyl phosphate, 0.1% Santolube 70 - rust inhibitor and 20 ppm. defoamer. G.C. analysis of the material on the pump filters indicated an enrichment of higher boiling material. Accordingly it was felt that if this high boiling material - partially chlorinated terphenyls - could be kept in solution, the filter clogging might not occur. F2817 was formulated utilizing 0.5% Santolube 900, a detergent. The lubricity additive was also changed to A-88, diisopropyl phosphite. The 1000 hr. test was successfully completed. No filter clogging occurred. Wear on the bushings was high, however. It was also noted in the oxidation erosion test on F2817 that the metal specimens remained "Clean", whereas the specimens on previous tests of F2792 and F2805 increased in weight due to a hard deposit. There was one disadvantage, however, in including a detergent in the formulation. In the presence of water contamination, thick marshmallow-like emulsions formed.

Upon learning that crude Aroclor cost was not as low as previously anticipated ($0.035/lb. at high volume), it was decided to concentrate effort on developing a F.M. candidate from the more readily available Aroclor 1142 and Aroclor 1148. These materials were also prepared at Anniston. They were undistilled but treated with CaO and filtered to remove labile chlorides. A product, F2828, similar to Pydraul A200, was formulated using these crude Aroclor fluids. Two unsuccessful pump tests were run. The first pump test failed after 600 hours due to a bearing failure. A second test was started because it was felt that this failure was not related to the hydraulic fluid. It appeared that when the bearing failed, metal debris got into the hydraulic fluid and became lodged between the ring and pressure plate. Abrasion caused a pressure drop and the test was stopped. The second pump test was run for 746 hrs. At this point the test was stopped due to low pressure. It was apparent that at 140° F. the pumping rate could not be maintained due to low fluid viscosity. Several other deficiencies in F2828 were also found. In the hydrolytic stability test, high copper attack was observed. In addition, stable emulsions formed in the ASTM-D1401 emulsion test.

Owing to the increasing acceptance of Pydraul 312, it was decided to terminate work on the F.M. approved alternative fluid. The primary customer for this fluid would have been the Budd Corporation in Philadelphia. Budd was considering replacing Pydraul F9 with water-based fluids. Owing to a special pump design at Budd - small intake ports - the F.M. approved alternate may have been unacceptable due to high specific gravity.

TABLE XVI

Hot Channel Iron Spray Ignition Test

The test fluid is sprayed under 1000 psi N_2 pressure on to a channel iron, mounted at a 30 degree angle to horizontal. The fluid temperature is 140°F. The oil burner nozzle (1.5 gal/hr. at 80°F and 100 psi) provides a fine conical spray. It is positioned about 6-8 inches from the channel iron which has been heated to 1100-1300°F.

In all of the following tests, the spray was aimed at the second thermocouple position. Over-spraying carried to thermocouple positions 3-5. No ignition is a passing result.

	Thermocouple Temperature °F.						
Fluid	T_1	T_2	T_3	T_4	T_5	Fluid Temp.	Results
F2782	850	1340	1030	1210	950	140°F.	No ignition
95% F2782 5% Gulf 200 Bright Stock	810	1310	1030	1280	950	140°F.	No ignition
MCS 312	850	1310	1010	1230	940	140°F.	Burned after short delay
90% F2782 10% Gulf 200 Bright Stock	830	1260	1000	1240	980	140°F.	Burned after short delay
75% F2782 14% CDP 10% Gulf 200	980	1360	1110	1170	1030	140°F.	Burned after short delay
81% F2782 14% CDP 5% Gulf 200	980	1370	1110	1120	1050	140°F.	Burned after a short delay
F2783	940	1340	1110	1270	1010	140-145°F.	Burned after short delay (~5 seconds)
F 2805	940	1290	1140	1110	1020	140-145°F.	No ignition
Pydraul 150	918	1290	1070	1120	960	140-150°F.	No ignition
F2747	945 950	1360 1380	1100 1120	1150 1130	1025 1040	140-150°F. 140°F.	No ignition No ignition
F2794	940	1350	1110	1130	1040	140°F.	Burned after a short delay
F2805	1010	1400	1130	1230	1060	140°F.	Burned after a short delay
Skydrol 500A	1040	1470	1160	1320	1060	140°F.	No ignition
F2792	860	1260	1020	1180	880	140°F.	No ignition

TABLE XVII

Factory Mutual "Approved" Fluids

All of the formulations which are defined to pass the F.M. Fire Resistancy Tests are based on Crude Chlorinated Biphenyl.

Properties of the batches of Crude Chlorinated Biphenyl made to date at Anniston are given below.

Crude Chlorinated Biphenyl Base Stocks

Fluid	Batch	Viscosity (cs.) 40°F.	100°F.	210°F.	Flash Point/ Fire Point	Sp. Gr. 55° C.
F2782	1	8729	54.91	3.59	380/530°F.	1.355
a	2		56.52	3.78	--	
b	3		56.01	3.74	--	1.358
c	4 & 5		48.53	3.69		1.356
d	5 & 6		48.14	3.55		1.355
F2812	7 & 8	2155	32.72	3.08	--	1.330
F2812b	8, 9 & 10		32.72	3.07	--	1.330
F2812a	10 & 11	2498	34.27	3.12	--	1.332

The additive package selected for initial screening was Diphenyl phosphite and Santolube 70. A concentration of 0.1% Santolube 70 was found adequate. The ASTM D565 Rust Test was run on F2782 containing 0.1, 0.3, 0.5% Santolube 70. Ratings were as follows:

0.1% Santolube 70 - No rusting 10.0 Rating
0.3% Santolube 70 - No rusting 10.0 Rating
0.5% Santolube 70 - No rusting 10.0 Rating

Using 0.1% Santolube 70, Shell 4 Ball Tests were run formulations containing various percentages of Diphenyl phosphite. A concentration of only 0.2% diphenyl phosphite gave optimum results.

Shell Four Ball (10 Kg load 1 Hr., 525 RPM, 167° F., Steel on steel)

	Wear Scar (mm)
F2782 (neat)	0.37
F2782 + 0.1% Santolube 70 0.5% Diphenyl phosphite	0.275
F2782 + 0.1% Santolube 70 0.1% Diphenyl phosphite	0.30
F2782 + 0.1% Santolube 70 0.2% Diphenyl phosphite	0.225

F. Low-Low Cost ($0.40-$0.65/gal.) Hydraulic Fluid for Coal Mine Machinery. Development of the low cost fluid to compete with water based fluids (MCS 312) was initially intended to satisfy the needs of the Coal Mining Industry. MCS 312 was well received in principle by Coal Mine operators; however, its cost was prohibitive. Development Department market studies indicated that to gain significant sales in mining equipment application, the fluid had to be priced more competitively with water-oil emulsions ($0.70-$1.00/gal).

As an initial approach to this problem MCS 312 type fluids were defined using cheaper chlorinated biphenyl base stocks. Four candidates were defined and tested. The composition and properties of these fluids are given in Appendix VI, Table I.

Fluid F2803 was the first of the candidates defined. It consisted of crude chlorinated biphenyl (46-47% chlorinated) Bright Stock oil, and Santicizer 144. Its hydrolytic and thermal stability were comparable to Pydraul 312. Its VI was only +22 compared to +75 +78 for Pydraul 312. A lower viscosity batch of crude chlorinated biphenyl (42-43% chlorine) was made enabling definition of F2811. This formulation contained more oil than F2783 and consequently had a higher VI (VI- +58).

F2786 was defined to provide a more thermally stable candidate. It necessarily contains CDP rather than TCP in order to obtain the desired viscosity at 100 and 200° F. Again the lower viscosity crude chlorinated biphenyl enabled improvements realized in F2806. This fluid contained TCP which is more soluble in oil than CDP. Separation does not occur down to the pour point of the fluid; whereas, F2786 becomes cloudy at 35-40° F.

According to Development's recent Pre-Research Appraisal OD 1426, F2811 appeared to satisfy the needs specified.

Two low cost oils were obtained through the Hydrocarbons Division. The anticipated cost of these oils at roughly $0.15/gallon would further reduce costs over the Gulf and Mobil Bright Stocks priced at $0.23-$0.30/gal. These oils were, however, unsatisfactory. MCS 312 type formulations containing these oils did not pass the High Pressure Spray Test. In addition, the oils had a very bad sulfur odor and oxidized readily.

These four fluids were developed along the general lines of Pydraul 312. Low costs over Pydraul 312 were anticipated by using the crude Aroclor fluids as major components in these formulations. The crude Aroclor fluids proved to be technically satisfactory; however, the original

cost estimate of crude biphenyl chlorinated at $0.035/lb. at high volume was too optimistic. Additional cost reductions were necessary to achieve an acceptable product. Later estimates of crude Aroclor cost were $0.0522/lb. on crude biphenyl chlorinated (6-20% terphenyls present), and $0.0560/lb. on crude Aroclor 1142/1148 using a figure of $0.0572/lb. as an Aroclor 1242 base.

Since the crude Aroclor fluids could not be counted upon to provide significant cost reductions, it was decided to explore the feasibility of reducing the phosphate ester concentration in the formulations. The phosphate esters contribute a significant cost to the formulations, even at low concentrations (14%). The phosphates have two important functions. They serve as non-volatile fire-resistant diluents. They also enhance the fire resistancy of the formulations, as measured by the molten aluminum test. It was felt, however, that a reduction in phosphate concentration might be permissable since the sources of ignition associated with mining machinery, and the mines themselves, do not present as great a hazard as diecasting, where Pydraul 312 was gaining acceptance.

All four fluids, F2783, F2811, F2786 and F2806, easily pass two of the three Bureau of Mines Fire-Resistance Tests, The High Pressure Spray and AIT. They barely pass the third test, an evaporation flammability test (Wick). It was decided to study the variables of the Wick test in order to improve the reproducibility of the test, and concurrently determine whether a fluid containing less phosphate ester would pass. The variables examined were burner flame height and weight of the fluid on the wick.

The average number of cycles for several fluids at different flame heights are presented in Appendix V, Table II. Conclusions drawn from these brief tests were:

1. A fluid containing only 10% phosphate ester would pass the test under certain conditions.

2. The most critical variable is burner flame height. The Bureau of Mines procedure prescribes a flame height of about four inches. Considerable difference was noted between total cycles at a four inch flame height and a 4-1/2 inch flame height.

3. Control of the amount of fluid on the wick is also important. The procedure merely calls for draining excess fluid from the wick after soaking two minutes in a petri-dish. It was found that at a given flame height, the more fluid on the wick, the more cycles before sustained burning.

Two formulations containing 10% phosphate ester were then sent to the Bureau of Mines (Sam Polack) for fire resistancy evaluation. They were MCS 396 and MCS 397. Composition andproperties of these fluids are given in Table II, Appendix VI. Both fluids passed the Bureau of Mines Fire Resistancy Tests. MCS 403 was subsequently defined to utilize the more readily available Aroclor 1142/1148 base stocks.

Laboratory evaluation of MCS 403 is finished. Results are given in Table III, Appendix VI. No significant deficiencies were noted.

At the following raw material costs, the estimated total manufacturing cost of MCS 403 is $0.615/gallon. This figure includes $0.50/cwt. conversion costs. Packaging and transportation costs are not included.

Santicizer 141	$0.149/lb.
Bright Stock Oil	$0.034/lb.
Aroclor 1142/1148	$0.0560/lb.

The introduction of MCS 403 was deferred due to the possibility of disrupting the price/sales structure of the other Pydraul fluids, Pydraul 312 in particular. In the meantime work to reduce costs has continued.

Primary effort here has been to obtain and qualify a lower cost bright stock oil. Four new oils were obtained. The viscosities of each are listed in Table VI, Page 14. They were Mobil 200 conventionally refined bright stock, Kerr McGee G-Stock, Kerr McGee Special M-200, and Champlin 225 B.S. The Mobil 200 CR Bright Stock was found to have inadequate fire resistance in a formulation similar to MCS 403. It also appeared to contain considerable wax like material which could be a source of trouble.

Four formulations were defined on the Kerr McGee Oils. They are F2869, F2870, F2871 and F2872. Compositions are properties of these candidates are given in Appendix VI. Pump tests have been started on F2869 and F2870, anticipated costs for F2869 and F2870 are $0.61 and $0.56/gal. respectively. These figures include $0.50/CWT conversion costs. Packaging is not included.

G. Low Viscosity Fluid for Canadian Steel Mill Applications. The need for a slightly lower viscosity fluid than MCS 395 (Pydraul 135)was brought out at Defasco Steel in Toronto, Canada. Fluid F2862 was defined to satisfy these needs. The composition and physical properties of F2862 are given in Appendix VII. The fluid was designated MCS 90 to correspond with its 90 SUS viscosity at 100° F. The functional properties of MCS 90 are expected to be very similar to MCS 395 owing to the

similarity in their composition. Field test quantities of MCS 90 were prepared in the "W" Bldg. The process for MCS 90 is given in Section VIII.

III. Miscellaneous

A. Reformulation of Pydraul 280

In July of 1965 the reformulation of Pydraul 280 was proposed. The objective was to remove the zinc dialkyl phosphorodithioate additive, Santolube 393, from the formulation and reduce the number of Aroclor fluids from three to two. Pydraul 280 was initially defined as 56.2% Pydraul A200 and 43.8% Pydraul 625. Consequently, the lubricity additive was considered redundant. Moreover, Santolube 393 occasionally develops a sulfurous odor which has jeopardized sales of Pydraul 280.

The reformulated version of Pydraul 280 was designated MCS 371. A 1000 hour pump test on MCS 371 was run successfully. Properties on Pydraul 280 and MCS 371 are listed in Appendix VIII. An Amendment to the Tentative Process for Pydraul 280 was issued to reflect these changes.

B. Pydraul 280 Seal Compatibility, Voith Clutches

Pydraul 280 has been used in Voith Company Clutches. These clutches are used in conjunction with mining machinery in Europe and represent a large potential for Pydraul 280. Initial tests using Pydraul 280 indicated a lack of fluid to elastomer seal compatibility. The seals were reported to have failed due to insufficient wettability. Two additive versions of Pydraul 280 have been sent to Voith for evaluation. They are MCS 485 which contains 4.0% Mobil 225 Bright Stock and MCS 489 which contains 0.2% Kel F #3 oil. A report on the performance of MCS 485 and MCS 489 is pending.

C. Conversion of Straight Phosphate Ester Systems to Pydraul 312

Data was obtained to aid customers in converting from straight phosphate ester hydraulic fluids to Pydraul 312. The intermediate fluid used can be either Pydraul A200 or Aroclor 1248. By using these fluids the problem of PE-Pydraul 312 limited solubility is avoided. The intermediate fluid is added as make up until the total composition is roughly 65% intermediate, at which time Pydraul 312 can be added as make up. The composition of the fluid in the system is monitored by specific gravity, viscosity or both. A report of this work is given in Appendix VIII in a letter from R. W. Street to R. Davis dated April 27, 1965 and a letter dated May 16, 1966.

D. High Density, High Viscosity Industrial Gear Lubricant

Two fluids were sent to Bethlehem Steel for evaluation as industrial gear lubricants. They were MCS 458 and MCS 459. Both fluids have specific gravities greater than 1.0 at 25° C. Both have good demulsibility and high Timken loads. They consist of Bright Stock Oil and Aroclor fluids (1254 and 1260).

E. Special Aroclor 1248/1242 Blend

The composition of a special Aroclor blend was defined. This blend was made for FMC Corporation, Nitro, W.Va. for use as a hydraulic fluid component. Blending conditions, specifications and composition are given in Appendix VIII in a letter from R. W. Street to R. Moody dated 1/13/66.

F. Fire Resistance Test Evaluations

Over the past three years considerable work was done in measuring the fire resistancy of various fluids. Letter to file dated December 27, 1965 discussed some pertinent observations involving spray tests. This letter along with a letter concerning ASTM cooperative work are found in Appendix VIII.

G. Cavitation Resistant Industrial Fluids

Several experiments were run to determine the tendency of Pydraul fluids to cause cavitation damage. A report of these tests on MCS 404, Pydraul 312 and several additive versions of these fluids is found in Appendix VIII. Letters from D. R. Miller to R. W. Street and C. L. Early contain information on the simulative tests run.

DESCRIPTION OF RECOMMENDED PROCESS

1. Low Melting Nuclear Reactor Coolant

a. Street, R. W., Tentative Process for Santowax WR, St. Louis Research Report No. P-1248, dated May 7, 1963, Job No. 4009 and Memorandum Correction.

b. Street, R. W., Tentative Process for Santowax WR-HB, St. Louis Research Report No. P-1262, dated July 25, 1963, Job No. 4009.

2. Industrial Hydraulic Fluids

a. Street, R. W., Tentative Process for Blending of MCS 300, St. Louis Research Report No P-1275, dated Oct. 17, 1965, Job No. 4009.

b. Blend Sheets for MCS 395, MCS 404, MCS 90 and Pydraul 312 are found in Appendix IX.

R. W. Street (Author)
F. R. Stark 10/12/66
(Signed and approved by)

10/7/66
RWS

APPENDICES

Appendices I through X (definition of each can be found in the Table of Contents).

APPENDIX I

St. Louis Organic Research

January 10, 1963

REACTOR COOLANTS
SUCCESSOR TO SANTOWAX OMP

M. Mokwa/T. P. Sands-G.O
T. M. Patrick - Res. 1
R. G. Moody - Anniston
W. D. Robinson- Res. 1
J. C. Larkin - Anniston
J. R. McClain - Anniston

D. B. Boomer
B-2-H

As requested by M. Mokwa we have examined the possibility of producing a lower melting terphenyl mixture by extraction of Santowax OMP or Santowax R with benzene. The results of this study are summarized below.

1. Both Santowax OMP and Santowax R were slurried with one and a half times their weight of benzene and the resulting slurry filtered at 30°C. The soluble material was stripped of benzene before determination of their crystallization points. The product from the Santowax OMP had a C.P. of 84.5°C. and the product from Santowax R, obtained in lower yield, had an estimated C.P. of 84-85°C., in spite of the fact that it was more amorphous.

2. The solubility of each of the isomers in the Santowax OMP does not display the same relative increase with temperature. Consequently, filtration at different temperatures should give slightly different isomeric ratios; higher temperatures favoring lower percentages of the para isomer. This is, in fact, observed as shown below.

Filtration Temperature °C.

	30	40	50	60
Weight of OMP (g)	100	100	100	100
Weight of benzene (g)	150	88	44	87
Insolubles, weight (g)	33.3	31.1	36.5	36.4
Solubles, weight (g)	67.0	59.6	57.4	53.6
composition(%)*				
ortho	19.8	18.0	19.8	17.9
meta	75.8	77.6	76.5	78.8
para	4.3	4.2	3.8	3.3

* relative peak areas from VPC.

All four of the materials produced had essentially the same melting point range (ca 85°C.). Consequently, no real advantage can be seen in attempting a high temperature crystallization with the relatively combustible benzene. In addition,

MONS 021206

Lower yields of useable product are realized in the higher temperature operation.

3. Dilution of the product from the 50°C. filtration of Santowax OMP with other aromatic derivatives to further reduce its crystallization point was attempted. The results are as follows:

	Crystallization point °C.	Estimated Pressure @600°F.
Rx Santowax OMP*	84.5	50 psia
" + 10% phenylcyclohexane	66.5	-
" + 10% bicyclohexyl	65.0	-
" + 10% HB-40	65.5	45 psia
" + 5% biphenyl	66.5	52 psia
" + 10% biphenyl	64.0	60 psia

*Calculated vapor pressure @ 600°F - 45 psia.

As can be seen from the vapor pressure data, even the Santowax OMP product is unable to meet the 35 psia maximum requirement. Addition of the biphenyl derivatives increases the vapor pressure at 600°F which is moving in the wrong direction. Aside from the HB-40 mixture, the best of these mixtures appears to be the 5% biphenyl which achieves the relatively largest reduction in C.P. with the smallest increase in vapor pressure. The presence of a cycloaliphatic in the coolant is understood to be somewhat detrimental so that HB-40 is not considered an ideal choice.

If a compromise can be accepted to allow a small amount of cycloaliphatic, the latter might be better be derived from the extracted Santowax OMP. That is, in lieu of adding HB-40, the better course might be to hydrogenate the extracted Santowax OMP. Monsanto informs me that Santowax OM becomes a liquid when hydrogenated to 16% of theory. Since Santowax OM and our extracted product have almost identical C.P.'s it is not inconceivable that it too could be a liquid at that level of saturation.

This is, however, merely speculation. We have now done all that we can in the time allocated to us. We have succeeded only in producing a product equivalent to Santowax OM which contains much less ortho; the learner with the limited availability. At this juncture it's up to Monsanto to tell us which way to go.

E. L. McHugh

pet

MONS 021207

APPENDIX I

MONSANTO CHEMICAL COMPANY *Inter-Office Correspondence*

From LOCATION Anniston, Alabama

DATE September 25, 1963

SUBJECT PRODUCTION OF SANTOWAX WRHD (WRHB)

REFERENCE

TO R. G. Moody

cc: D. B. Curry
O. E. Dolin
J. C. Larkin
M. McEwen - St. Louis
R. W. Street - St. Louis
D. B. Hoemer - St. Louis

This Copy For

Summary

An experimental quantity, 556 lbs., of Santowax WRHD was produced on September 11 in the HB-40 Plant under the direction of Mr. D. B. Curry. Lot AC-1 of Santowax WRHD was hydrogenated to approximately 23% level in the No. 1 autoclave and was produced from Santowax WR Lots AC-4 and 5.

This experimental batch to fill order No. EX-22585-D, 200 lbs., to Atomic Energy of Canada Ltd., Pinawa, Manitoba, was shipped September 24, 1963.

Details

The experimental batch was produced following Organic Research Tentative Process Report for Santowax WRHB, No. D-1262, dated July 25, 1963, by R. W. Street.

Preparation of Equipment

The No. 1 autoclave was heated, the bottom plate removed, and all HB-40 was drained from the reactor. The catalyst reactor was drained, the filter feed tank was drained, and the filter press was cleaned and all lines and pump were drained. Five leaves of the filter press were used.

Charging

Santowax WR, batches AC-4 and AC-5, was placed in the melting shed approximately August 15. The melting shed temperature during this period was about 80°C. On September 5, it was found that material was only partially melted. Additional coils were turned on, the material was placed on benches over the hottest area and was melted by September 11. Hot house temperature by this time was 125°C. The following material was charged to No. 1 autoclave by vacuum:

AC-4 -	120 lbs.
AC-5 -	475 lbs.
Total	595 lbs.

Twelve pounds of unused Raney Catalyst was dug from a drum in a manner that obtained essentially HB-40 free catalyst. This material was mixed with five gallons of the melted Santowax WR and was pulled into the reactor.

MONS 021208

IN 16

Autoclave Operation

The normal batch charge for an autoclave is 1,200 lbs. of Santowax. This charge is therefore approximately one-half normal charge. Santowax WR was heated to 195°C. The reactor was then purged twice with nitrogen and then twice with hydrogen. The hydrogen was applied at 240 lbs. for ten minutes. The following refractive indices were obtained on duplicate samples:

Refractive Index @ 25°C	% Hydrogenation
1.6175	19.9%
1.6177	19.8%

Hydrogen was applied for 30 seconds at 195°C at 250 lbs. pressure. The duplicate samples following this reaction were:

1.6116	22.7%
1.6107	23.1%

Two quart samples of this material from the autoclave were held for future analysis. Molten Biphenyl (41.25 lbs.) was pulled into the autoclave, mixed for 20 minutes, and blown with nitrogen to the batch receiver. The material settled for 10 minutes and was then blown to filter feed tank. The batch was circulated through the press for 10 minutes. After it cleared up, it was filtered through the press into 55 gallon steel unlined drums (HB-40). A sock filter was used to polish material going to the drum. The following drum weights were obtained:

	400 lbs. net
	156 lbs. net
Total	556 lbs.

4 quart samples were taken for analysis and reserve.

Analysis Section

		Lot AC-4	Lot AC-5
Santowax WR -	% of charge	20%	80%
	Chlorides	8 ppm	8 ppm
	Color	11.0 Gardner	11.0 Gardner
	Solution Point	85.0°C	91.0°C
	1st Crystals	76.5°C	81.0°C
	Biphenyl	0.07%	0.07%
	Ortho	15.16%	11.83%
	Meta	74.58%	77.45%
	Para	4.52%	4.98%
	Hi-boilers	5.6%	5.6%

		Lot AC-1
Santowax WRRD		
	Color	70 HAZEN
	Chlorides	10 ppm
	Ref. Index	1.6100

E. O. Severson

BOE/md

MONS 021209

APPENDIX II

St. Louis Org. Res. Dept.

June 25, 1963

K. L. McHugh - Res-2
W. R. Richard, Jr. - Res-1
L. R. Stark - Res-2

VI IMPROVED PYDRAUL A-200

Mr. R. W. Street

ORGANIC RESEARCH - 2

Based on the eight experimental compounds prepared according to the discussed experimental design, the following conclusions may be drawn:

1. Viscosity index increases directly with the amount of FH-139 present.

2. Formulations with a 5/1 ratio of 1242 to 1221 give higher VI values than those with a 10/1 ratio.

3. TCP per se does not appear to affect viscosity index; however, with the 10/1 ratio samples, low VI is associated with low concentrations of TCP. This is not the case in the 5/1 samples.

4. Viscosity at 100°F. and viscosity at 210°F. increase directly with the concentration of FH-139.

5. The samples containing 10/1 ratio of 1242 to 1221 at a given concentration of FH-139 are higher in viscosity than those containing a 5/1 ratio.

6. Concentration of TCP does not appear to affect viscosity.

7. The temperature at which the viscosity of the sample is equivalent to the viscosity of HS-1130 depends on the ratio of the Aroclors and the concentration of FH-139. Again, TCP does not appear to have a significant effect.

8. In order to obtain equivalent viscosities (to HS-1130) at temperatures between 140° and 165°, the following formulations should be satisfactory:

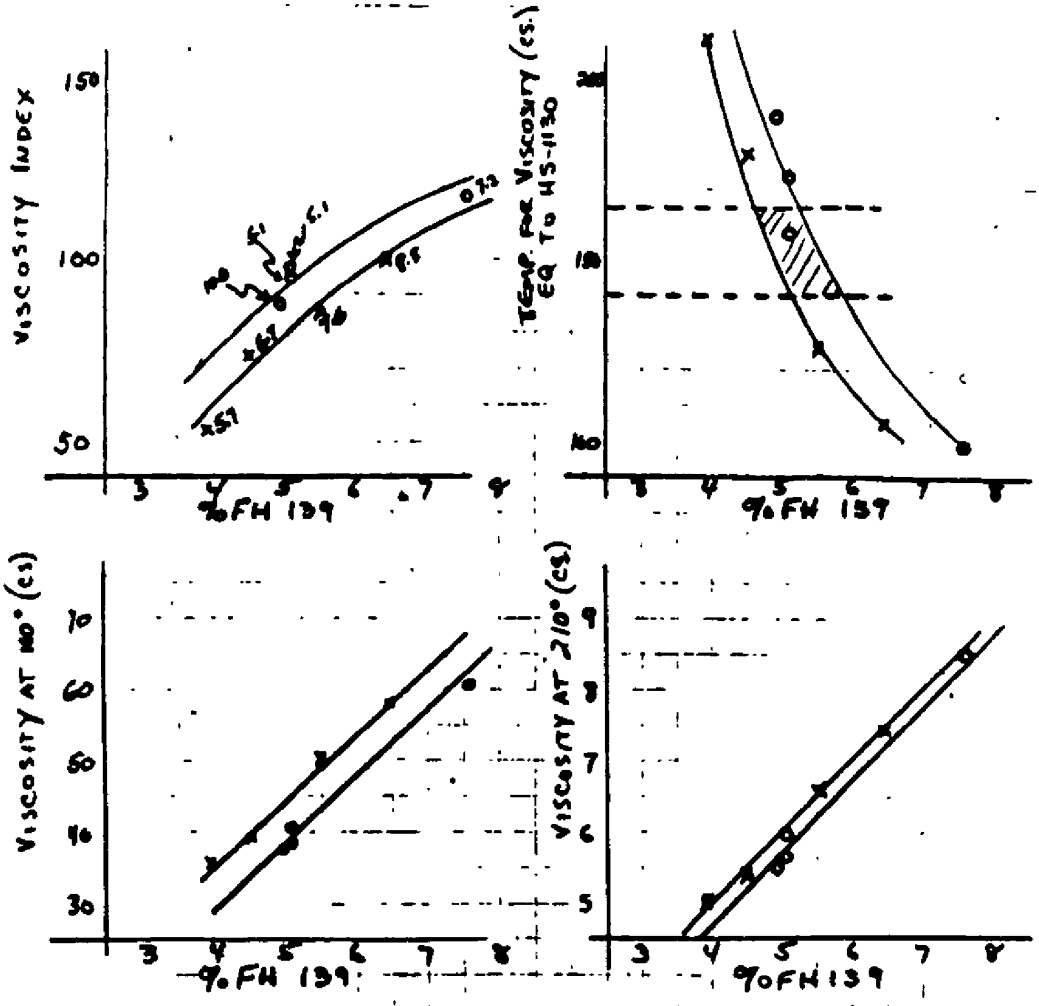
1242/1221 Ratio	5/1	10/1
% FH-139	4.6-5.2	5.0-5.8
% TCP	ca. 7.5	ca. 7.5

The attached charts show the relationships discussed. Per our conversation, optimum formulations can be calculated using Desirability Functions for viscosity index, viscosity at 100° and 210°, and cost. These, of course, are subject to the restriction of sufficient lubricity.

John D. Hinchen

dm
Att.

MONS 021210



LEGEND:

X = 5/1 _____ NUMBERS ON CHART (VI)

X = 10/1 _____ SHOW % FCP

JDH 6/17/63

MONS 021211

APPENDIX II

PROPERTIES OF MCS 300

1. Fluid Properties

Table I lists the pour point along with the viscosities of MCS 300 at various temperatures. Similar data for Pydraul A-200 and Houghto-Safe 1130 are listed for comparison.

TABLE I

a. Viscosity (cs)	MCS 300	Houghto-Safe 1130	Pydraul A-200
at 20°F	5250	-	
at 40°F	779.5	-	1920
at 50°F	381	1004	887
at 70°F	127.6	257	154
at 100°F	42.03	59.11	30.14
at 210°F	6.01	5.07	2.86
c. Viscosity Index	+ 94	- 115	- 450
c. Pour Point	0°F		+ 15°F

2. Quality Tests

	MCS 300	Pydraul A-200
a. Neutralization Number (typical)	0.11	0.80-1.10
b. Water, % by weight maximum	0.05	0.05

3. Physical Properties

a. Density

	MCS 300
at + 32°F	1.335
at + 86°F	1.310
at +140°F	1.280
at +194°F	1.254

b. Thermal Conductivity

at - 32°F	0.063 BTU/Ft/°F/Hr.
at 122°F	0.063 " " " "
at 212°F	0.062 " " " "

c. Specific Heat

at +32°F	0.28 BTU/lb/°F
at +122°F	0.30 " " "
at +212°F	0.32 " " "

d. Heat Capacity

at +77°F	0.29 BTU/lb/°F

e. Coefficient of Thermal Expansion 0.00041/°F for range from 30°F to 150°F

MONS 021212

4. Flammability	MCS 300	Pydraul A-200
a. AIT	1080°F	1220°F
b. Flash Point (COC)	350°F	380°F
c. Fire Point (COC)	590°F	680°F
d. High Pressure Spray Test (AMS 31503)	Does not flash or burn.	Does not flash or burn.
e. Low Pressure Spray Test	Flame brightened.	Flame brightened but did not increase.
f. Molten Metal Ignition Test (molten aluminum alloy at 1150-1250°F)	Does not ignite spontaneously. Flashes by spark and is self-extinguishing. Flashes without spark after most fluid vaporized and then burns to completion.	Does not spontaneously ignite. Flashes by spark.
g. Hot Manifold (MILF-7000) 1300°F	Intermittent flashing and burning on tube. Burns on leaving the tube but does not burn in the pan.	Intermittent flashing on the tube. Does not burn on leaving the tube or in the pan.

5. Lubricity

a. Four Ball Wear

at 167°F, 1 hr.
626 rpm

Steel on Steel

4 Kg	0.21 mm	0.21 mm
10 Kg	0.24 mm	0.29 mm
40 Kg	0.59 mm	0.43 mm

Steel on Bronze

10 Kg	1.06 mm	1.40 mm

b. Timken Wear

MCS 300 - Maximum load without seizure 45 lbs. (18,000 psi)

Pydraul A-200- 50 lbs; (16,340 psi)

6. Performance Tests

a. Vickers Hydraulic Pump Test (140°F, 1000 Hrs., 1000 psi).

Weight Losses	MCS 300	Pydraul A-200
Bushings		
2015	0.0168	0.0151
2016	0.038	0.0217
Ring	0.0061	0.0848
Vanes	0.0022	0.0191
Viscosity		
Initial		
100°F	38.2	30.58
210°F	5.86	2.89
Final		
100°F	33.2	30.44
210°F	4.81	2.88
Viscosity Change (%)		
100°F	-13.1	- .46
210°F	-15.0	- .38
Acidity mg KOH/g		
Initial	0.11	.92
Final	0.16	.92
Foam Test (room temp.) Stability		
Initial	33 sec.	363 sec.
Final	192 sec.	-

c. Shear Stability

Viscosity measurements at 100°F showed that MCS 300 sheared down 2.0% after 12 passes in the diesel injector shear machine. In the pump MCS 300 sheared down about 15%.

c. Oxidation-Corrosion Test (250°F - 168 hrs.)

	MCS 300	Pydraul A-200
Viscosity Change (%)		
100°F	+12.7%	+5.6
210°F	+ 2.5%	+2.4
Metal Weight Loss, mg/cm²		
Mg	None	None
Al	+0.01	+0.01
Cu	+0.07	-0.05
Fe	None	+0.01
Cd	+0.07	-0.01

d. Foam Tests (ASTM D892)

75°F Tendency (foam after 5 min. air blowing)	0 ml.	30 ml.
Stability (time to collapse)	0 sec.	60 sec.
200°F Tendency	10 ml.	8 ml.
Stability	10 sec.	60 sec.
75°F (after cooling from 200°F) Tendency	0 ml.	35 ml.
Stability	0 sec.	60 sec.

e. Rust Test (ASTM D665)

Both MCS 300 and Pydraul A-200 showed no rusting under the conditions of this test. Rust rating, 10.0 after 48 hour test.

f. Emulsion Test (ASTM D1401)

The emulsification property of a fluid is measured by the ability of the formulation to separate from an equal amount of water in half an hour at 135°C, after the mixture has been thoroughly agitated for five minutes at that temperature. MCS 300 was completely emulsified after the one-half hour period described above. This property can sometimes be attributed to the additives present in the fluid, especially VI improvers. It is anticipated that the emulsifying property of MCS 300 will be corrected by using an improved, impurity free FH-139.

g. Hydrolytic Stability (Coke Bottle Test, 48 hr., 200°F)

MCS 300 exhibits excellent hydrolytic stability as indicated in the following table:

	MCS 300	Pydraul A-200
Acidity Mg KOH/g		
Initial	0.00	1.03
Final	0.06	0.72
Mg of KOH to neutralize water layer	1.00	4.424
Copper test specimen appearance	No etching stain, or pitting	Sl. Dull Copper color
wt. loss - mg/cm^2	0.000	1.870
Viscosity		
Initial		
100°F	41.82	30.45
210°F	5.91	2.97
Final		
100°F	39.78	30.29
210°F	5.72	2.92
% Change		
100°F	-4.88	- .52
210°F	-3.21	+1.70

h. Compatibility

(1) Solubility. Solubility experiments showed that MCS 300 is completely soluble in all proportions in Pydraul F-9, Pydraul A-200 and Houghto-Safe 1130.

(2) Elastomer Swell data are listed in the following table. (Static oven test 158°F, 168 hrs.).

	MCS 300 (neat)
Teflon	
Durometer Hardness	
Initial	96
Final	94
Volume Increase (%)	1.2
Weight Increase (%)	0.44

	MCS 300 (neat)
Butyl	
Durometer Hardness	
Initial	59
Final	58
Volume Increase (%)	48.7
Weight Increase (%)	61.1
Silicone	
Durometer Hardness	
Initial	69
Final	62
Volume Increase (%)	4.53
Weight Increase (%)	4.97
Viton	
Durometer Hardness	
Initial	65
Final	63
Volume Increase (%)	5.77
Weight Increase (%)	0.72

APPENDIX III

MONSANTO COMPANY
ORGANIC CHEMICALS DIVISION
ST. LOUIS, MISSOURI

FIELD TEST ON MCS-312

COMPANY CONDUCTING TEST: Carter Carburetor

MACHINE NO. 50

SEALS Viton

PRESSURE 2800-3000

FLUID IN MACHINE PREVIOUS TO THIS TEST

TEMPERATURE OF OPERATION 110°F

PROPERTIES ON SAMPLES

Sampling Date	Approximate Operating Hours	Viscosity, SUS 100°F	Viscosity, SUS 210°F	Neutralization Number	Remarks
/21/64	Drained Pydraul A-200	144	36.0	1.12	
12/21/64	2 Hours	287	-		
12/22/64	24 Hours	288	-	0.16	
12/24/64	72 Hours			0.11	
12/28/64	1 Week	288	48.48		
1/5/65	2 Weeks	288	48.76		
1/1/65	4 Weeks	293	49.15		
2/3/65	6 Weeks	293	49.05		
2/10/65	7 Weeks	293	49.11	0.15	Fluid looks very Good.
2/17/65		294	49.05		
2/24/65		296	49.15	0.14	
3/3/65		296	49.11		
3/10/65		294	49.25	0.12	
3/24/65		295	49.28		
5/26/65	21 weeks	301	49.95	0.16	

MONSANTO COMPANY
ORGANIC CHEMICALS DIVISION
ST. LOUIS, MISSOURI

FIELD TEST ON MCS-312

COMPANY CONDUCTING TEST: General Motors - Bedford

MACHINE NO. 51

SEALS Butyl

PRESSURE 2,000 psi

FLUID IN MACHINE PREVIOUS TO THIS TEST Houghto-Safe 625

TEMPERATURE OF OPERATION 110°F

PROPERTIES ON SAMPLES

Sampling Date	Approximate Operating Hours	Viscosity, SUS 100°F	210°F	Neutralization Number	Remarks
11/18/64	6 (Flushing Fluid)			0.15	Fluid contains ~0. water and 1.8% glycol.
11/24/64	6 (Fresh charge of Test Fluid)	320.7	51.6	0.10	<0.5% glycol
1/4/65	?	327.2	51.7	0.10	
2/5/65	Est. 1 Month Over.	330.9	51.9	0.12	
2/16/65		330.5	51.98	0.14	

MONS 021219

MONSANTO COMPANY
ORGANIC CHEMICALS DIVISION
ST. LOUIS, MISSOURI

FIELD TEST ON MCS-312

COMPANY CONDUCTING TEST: General Motors - Bedford

MACHINE NO. 21

SEALS Viton

PRESSURE 1800 psi

FLUID IN MACHINE PREVIOUS TO THIS TEST Pydraul A-200

TEMPERATURE OF OPERATION 110°F

PROPERTIES ON SAMPLES

Sampling Date	Approximate Operating Hours	Viscosity, SUS 100°F	210°F	Neutralization Number	Remarks
11/18/64	New fluid ex drum	324.4	51.8	0.16	
11/18/64	4	314.0	51.1	-	
11/24/64	?	312.7	50.9	0.16	
1/4/65	?	313.8	50.9	0.10	
2/5/65	?	322	51.4	0.10	
2/16/65		333.5	51.9	0.17	

MONS 021220

MONSANTO COMPANY
ORGANIC CHEMICALS DIVISION
ST. LOUIS, MISSOURI

FIELD TEST ON MCS-312

COMPANY CONDUCTING TEST: General Motors - Bedford

MACHINE NO. 63

SEALS Viton

PRESSURE 1650 psi

FLUID IN MACHINE PREVIOUS TO THIS TEST Houghto-Safe 1130

TEMPERATURE OF OPERATION 110°F

PROPERTIES ON SAMPLES

Sampling Date	Approximate Operating Hours	Viscosity, SUS 100°F	Viscosity, SUS 210°F	Neutralization Number	Remarks
ALL DATE: 12/4/6 1/4/65	25 ?	344.4	50.22	0.10	First Sample Rec'd.
2/5/65	Over 300 hours	332.8	50.32	0.10	Looks Ne:
3/16/65		334.6	51.12	0.04	

MONS 021221

MONSANTO COMPANY
ORGANIC CHEMICALS DIVISION
ST. LOUIS, MISSOURI

FIELD TEST ON MCS-312

COMPANY CONDUCTING TEST: Budd Corporation, Gary, Indiana

MACHINE NO. 2678

SEALS Butyl and Viton

PRESSURE 800 psi

FLUID IN MACHINE PREVIOUS TO THIS TEST Pydraul F-9

TEMPERATURE OF OPERATION 150°F

PROPERTIES ON SAMPLES

Sampling Date	Approximate Operating Hours	Viscosity, SUS 100°F	Viscosity, SUS 210°F	Neutralization Number	Remarks
11/20/64		893.0	49.35	-	After one hour in machine
11/20/64				-	Noon sample
11/20/64		899.0	48.85		3:30 P.M.
11/25/64					3:30 P.M.
11/27/64		899.4	49.78		3:30 P.M.
11/30/64		901.4	50.22	0.13	7:00 A.M.
12/11/64		901.7	49.68	0.10	Friday of 2nd Week
1/8/65	832	903.7	49.75	0.10	-
1/15/65	256	899.5	49.85	0.11	
1/19/65	304	881.5	48.05	0.17	

MONS 021222

MONSANTO COMPANY
ORGANIC CHEMICALS DIVISION
ST. LOUIS, MISSOURI

FIELD TEST ON MCS-312

COMPANY CONDUCTING TEST: Budd Company, Philadelphia, Pennsylvania

MACHINE NO. 28169

SEALS Viton

PRESSURE 800 psi

FLUID IN MACHINE PREVIOUS TO THIS TEST Pydraul F-9

TEMPERATURE OF OPERATION 130°F

PROPERTIES ON SAMPLES

Sampling Date	Approximate Operating Hours	Viscosity, SUS 100°F	Viscosity, SUS 210°F	Neutralization Number	Remarks
12/14/64	1	325.4	(a)	-	
12/14/64	4	326.3	(a)	51.65	-
12/15/64	24	327.7	(a)	51.88	0.05
12/16/64	2 Days	328.1	(a)	51.92	-
12/18/64	4 Days	330.9	51.08	0.11	
12/21/64	1 Week	331.4	52.02	0.16	
12/28/64	2 Weeks	337.9	52.12	-	
1/29/65	3 Weeks	355.9	53.0	0.46	Pump bearings and Motor burned after 2 weeks. 3-week sample smelled of "burned motor."
2/8/65	4-1/2 Weeks(760 hr.)	368.5	53.55	0.82	Oxidised Organic Odor
2/15/65	895 Hours	370.8	53.55	0.83	" "
2/22/65	1042 Hrs	3749	53.23	1.11	

(a) 210°F Viscosity will be run as soon as equipment repair can be made

MONS 021223

APPENDIX III

TABLE I

PROPERTIES OF PYDRAUL 312

FIRE RESISTANCE

A. Autogenous-Ignition-Temperature (AIT) (Procedure given in Bureau of Mines, Schedule 30, Section 35.20)

Results: 940°F

B. Flash Point (COC): 395°F

C. Fire Point (COC): 545°F

D. Molten Metal Ignition: (1250°F)

1. Without a spark: The droplet of fluid does not ignite spontaneously. After nearly all of the fluid has vaporized, the remaining residue occasionally flashes and burns to completion. Otherwise, the droplet evaporates completely with no ignition.

2. With a spark: At first, the droplet flashes and is self-extinguishing. Then after most of the fluid has vaporized, repeated sparking causes the droplet to ignite and burn to completion.

3. Comment: In a similar test on Pydraul 150, the droplet boils off completely and does not flash without a spark. On the other hand, with a spark, Pydraul 150 flashes and burns to completion. Straight alkyl phosphate esters, Cellulube 220, Houghto-Safe 1130, etc., do not flash or ignite without a spark. With a spark they flash and burn momentarily, but are self-extinguishing.

Pydraul A200 does not flash without a spark. With a spark it flashes but is immediately self-extinguishing. MCS 312 is in the Pydraul 150 class of fire resistance in this test.

E. Hot Manifold (MIL F 7100)	(Procedure: During a period of 40-60 seconds, 10 ml. of test fluid is dropped onto an inclined manifold heated to 1300°F)
1. At 1300°F:	Pydraul 312 flashes and burns on the manifold; it does not burn on leaving the manifold or in the pan.
2. At 900-950°F:	Pydraul 312 does not burn on the tube.
3. Comment:	At 1300°F the straight phosphate esters, i.e., Cellulube 220 and Houghto-Safe 1130 also burn on the tube; but at about 1100°F they do not burn on the tube. Pydraul A200 flashes momentarily and gives a faint glow along the bead at 1300°F. Underwriters Labs' "Tests of Behavior in Presence of Hot Metals" is similar to the Hot Manifold Test (See Table II)
F. High Pressure Spray Test: (AMS 3150C)	(Conditions 1000 psi, orifice dia. 0.0145 in. in dia. oxyacetylene torch, fluid temperature 150°F)
1. Fluid Temp. 150°F:	At about 2 feet from the orifice flames will carry about one foot downstream from the tip of the torch. At about 3-5 feet from the orifice flames will carry up to 18 inches.
2. Fluid Temperature -: 88°C	The higher temperature results in more atomization and a finer spray; however, the results are about the same.
3. Comment:	Pydraul 312 can be caused to burn by breaking up the solid stream spray with the tip of the oxyacetylene torch. Straight aryl phosphate esters (Cellulube 220, HS1130) will also burn with flames carrying downstream to the hood when the tip of the torch is inserted into the solid stream so as to break it and atomize it very finely at that point. Pydraul A200 is much more fire resistant; when the torch is held in the manner described, flames carry only 1-2 feet downstream. Water-based fluids: Shell Irus 903 at 60°C (140°F) flashes intermittently at 3-5 feet from the orifice. When the tip of the torch is inserted into the stream it flashes with flames carrying downstream to hood. See Table II for similar UL test.

G. Low Pressure Spray Test: (Conditions fluid/air mixture is sprayed from a paint gun at 50 lbs. over burning kerosene soaked rags. Increase or decrease in flame intensity is noted)

1. Results: Slight increase in flame intensity.

H. Bureau of Mines Title 30 Tests: (Sec. 35.20 - 35.22)

1. AIT Minimum 600°F MCS 312 passed.

2. Temperature Pressure Spray Ignition Test (150 psi, 0.025 in dia. discharge orifice, solid cone spray.

a. Cotton waste, kerosene soaked - MCS 312- no propagation
b. 12,000 volt arc. - MCS 312- no propagation
c. Propane torch - MCS 312- no propagation
d. Minimum requirements: - Propagation not exceeding 6 seconds at a distance of at least 18" from orifice to center of each igniting device.

3. Evaporation/Flammability - (Wick Test) Conditions: Non luminous bunson burner flame ½ in. in height. Cycling device 25±2 cycles/minute.

	No. of Cycles to Self-sustaining flame	
	Min. requirement	MCS 312
a. Phase 1 (new fluid)	24	25-28
b. Phase 2 (Two hours heated 150°F sample evaluation)	18	-
c. Phase 3 (Four hour heated sample, 150°F, evaluation)	12	-

d. Comment: Since Pydraul 312 does not attribute its fire resistance to a volatile snuffer, such as water, Phase 2 and 3 results are similar to Phase 1.

I. Factory Mutual Division Tests: (Conducted at Norwood, Mass.)

1. High Pressure Spray Ignition Test:

a. Procedure: The atomized spray discharging at 1000 psi and 140°F from a 1.5 gph 80° angle nozzle is directed into an open area and an oxyacetylene welding torch flame is introduced into the spray. If ignition is established the torch flame will be moved away from the spray to determine if combustion will continue without presence of the ignition flame.

b. Requirements: When the welding torch is introduced into the spray, there shall be no continuing full spray flame, and no persistent flame, except locally around the igniter when the latter is more than 18 inches away from the nozzle. When the igniter is located at distances of more than 6 inches from the nozzle, the oil spray flame, if established, shall be self-extinguishing within 5 seconds after cutting off the ignition.

c. Results: MCS 312 - Pass

2. Hot Channel Iron Ignition

a. Procedure: A 7-inch steel channel iron, 26 inches long, is supported at a 30° angle. Steel sheets are spot welded vertically along each side to reduce drafts across the surface of the channel. Five thermocouples are mounted along the center line of the channel. The fluid is sprayed at 1000 psi and 140°F from an oil burner nozzle (described above) located 6 inches from the surface of the channel. Flame from two propane type gas burners is directed against the back of the channel to provide a maximum surface temperature of approximately 1300°F. The burners are turned off immediately before the fluid is sprayed on the surface of the channel.

b. Requirements: When the spray is directed at the hot surface of the channel iron, there shall be no ignition of the atomized spray.

c. Results: MCS 312 - Failed test. Fluid ignited on the channel iron after spraying about 5 seconds.

d. Comment: Fluids containing as little as 5% Bright Stock oil fail this test.

J. Ruptured Line/ Mannequin Test: (Memo January 18, 1965, RWS to CIE, attached)

K. Underwriters Labs Tests: Full details are given in a preliminary report from UL to C.L.I. dated June 24, 1965. A brief summary of these results with comments and interpretation is given in Table II.

TABLE II

UL TEST RESULTS ON PYDRAUL 312 and PYDRAUL F9

Test	Pydraul 312	Pydraul F-9	Comment/Interpretation
1. Flash Point - ASTM D93-61	385°F	355°F	Our results were 395°F on the initial batch. Sales specification reads 370°F minimum.
2. Fire Point - ASTM D92-57	580°F		Our results were 545°F on this initial batch.
3. Behavior when heated on a larger scale.	At 398°F-Some flashing 480°F-Burning continuous 549°F-With burner off, application of test flame ignited vapors over entire surfaces. Smoke & initiating fumes.	At 383°F-Some flashing 455°F-Burning continuous. 572°F-With burner and test flame off, burned weakly. Smoke and initiating fumes.	This test is essentially a larger scale fire point test.
4. Ignition Temperature Test, °F.	777	1103	This test is very similar to the AIT test (Our Mines); a smaller Erlenmeyer(160 ml.) is used. Pydraul F9 published AIT is 1110°F.
5. Explosiveness of Vapors in Air.	At 286°F-Flame prop. mod. pressure	At 355°F-Flame prop. Weak press.	Vapors of the test fluid are ignited in a cylindrical tube 6" dia. 36" long, and fitted with asbestos plugs in both ends. Ignition is produced by the discharge of a high voltage spark across a gap of about 1/4" The outside of vessel is heated by gas burners. Pydraul 312 has a lower explosive temp. than Pydraul F9 Test has little significance in normal applications

MONS 021229

TABLE II (Continued)

Test	Pydraul 312	Pydraul F-9	Comment/Interpretation
6. Tests of Behavior in presence of hot metals	At 1022°F - Evaporated or decomposed without ignition of vapors or evidence of hazardous reaction with the metals - steel, hot copper or aluminum and molten zinc.	Same	Similar to molten metal test Drops of test fluid applied to surface of horizontal steel plate heated underneath by gas burners.
7. Flammability of streams and sprays. (Solid stream and spray tests each at 600 and 1000 psi)	Ignites but little prop. No flashing after removal of ignition source No propagation from the igniting source back to the origin of the stream or spray.	Very similar to MCS 312.	Test set-up very similar to MIL F7100. High pressure spray test. For stream test, orifice size 0.0145 in dia. (same as in MIL F7100) For spray tests: 0.025 spray nozzle used. Primary differences: Fluid Temp. 24°C (75.2°F). Gas-air blast burner used instead of oxy-acetylene torch. Solid stream test gave very similar results to our H.P. Spray Test, however in spray test at 1000 psig, MCS 312 was caused to ignite and burn 0.2-0.5 feet from orifice with flames carrying downstream 7 feet.

MONS 021230

TABLE

PROPERTIES OF PYRENOL 312

PHYSICAL PROPERTIES

A.	Viscosity	
	At 210°F	7.50
	130°F	89.5
	100°F	88.5
	40°F	1000
	20°F	4000
B.	Pour Point (ASTM D-97-57)	-10°F
C.	Viscosity Index (ASTM D567-53)	+77
D.	ASTM Slope	
E.	Density (g.cc. at 25°C)	1.105
F.	Moisture (maximum)	0.08%
G.	Boiling Point (Atmospheric)	615°F
H.	Vapor Pressure at 200°F	0.1 mm
I.	Bulk Modulus (Room Temp. 1000-6000 psi.)	365,000
J.	Compressibility ($X10^{-6}$ sq.in./lb.)	2.74

MONS 021231

TABLE III

PROPERTIES ON PYDRAUL 312
(Continued)

K.	Coefficient of Thermal Expansion	-0.00036/F°
L.	Specific Heat (BTU/lb./F° at 77°F)	-0.36
M.	Thermal Conductivity (BTU/hr./ft./°F	-0.069
N.	Neutralization Number (mg. KOH/g. Fluid)	0.10
O.	Compatibility	
	1. Solubility in other fluids Straight phosphate esters: such as, Houghto-Safe 1010, 1130, Cellulube 220,500, 1000.	-10% or less Phosphate Ester in Pydraul 312 is soluble at room temperature
		-15% or more phosphate ester in Pydraul 312 is insoluble at room temperature.
	Pydraul A-200,F9,625,280,150	Soluble in all proportions with Pydraul 312
	Pydraul 60	25% or less Pydraul 60 is soluble in Pydraul 312

2. Elastomer Swell (Oven Test 158°F 168 Hrs.)

Butyl	Sample 1	Sample 2
Durometer Hardness		
Initial	67	67
Final	46	47
Volume Increase (%)	64.0	62.7
Weight Increase	57.4	56.3

MONS 021232

PROPERTIES ON HYDRAUL. 312

2. Elastomer Swell (Continued)

Silicone	Sample 1	Sample 2
Durometer Hardness		
Initial	72	73
Final	70	68
Volume Increase	1.93	1.93
Weight Increase	3.70	2.82
Viton		
Durometer Hardness		
Initial	68	67
Final	68	66
Volume Increase	None	None
Weight Increase	0.2	0.2
EPR		
Durometer Hardness		
Initial	71	70
Final	54	52
Volume Increase	64.7	69.5
Weight Increase	58.9	62.9

TABLE IV

PROPERTIES OF PYDRAUL 312

FUNCTIONAL PROPERTIES

A. Four Ball Wear (167°F, 1 hr., 620 RPM)

		Ave. Wear Scar dia. mm.
Steel on Steel 52-100	4 Kg.	0.24
	10 Kg.	0.25
	40 Kg.	0.44
Steel on Bronze	10 Kg.	0.87

B. Vickers Pump Test V-105-C-10

	1000 Hrs.-140°F	1000 Hrs.-180°F	1000 Hrs.-140°F + 2% H_2O
Weight Losses			
Bushings			
2015	+0.0081	-0.0078	-0.0056
2016	-0.0057	-0.0015	-0.0148
Ring	-0.0013	-0.0008	-0.1339
Vanes	-0.0021	-0.0015	-0.0052
Viscosity			
Initial			
100	70.6	70.26	
210	7.8	7.91	
465 Hours			
100	-	72.24	
210	-	7.97	
Final			
100	67.0	(illegible)	
210	7.64	8.15	
NN Initial	0.13	0.10	0.10
Final	0.14	0.89	0.17

MONS 021234

TABLE IV

PROPERTIES OF PYDRAUL 312 (Continued)

FUNCTIONAL PROPERTIES

C. Timken Load Test
(Max. Load without Seizure) 55 lb.

D. Hydrolytic Stability Test
(Beverage Bottle Test, 48 Hrs., 200°F, 27 g. fluid, 25 g. water, copper strip)

Viscosity		
100°F	Initial	70.6
210°F	Initial	7.80
100°F	Final	70.2
210°F	Final	7.70
100°F	% Change	-0.56
210°F	% Change	-1.3
Acidity		
Fluid Layer (mg.KOH/g.)		
	Initial	0.13
	Final	0.17
Water Layer (mg. NaOH/g. Fluid)		0.027
Copper Specimen		
Appearance		Sl. dull Cu Color
Wt. loss - mg/cm^2		0.04

E. Oxidation Corrosion Test
(250°F, 100 Hrs., 5 l. dry air/hr.)

Metal Attack (Wt. loss/g.)	
Copper	-0.0014
Magnesium	+0.0002
Steel	nil
Aluminum	+0.0003
Cadmium	-0.0082
% Viscosity Change	
100°F	+50.7
210°F	+29.2
Acidity	
Initial	0.10
Final	4.65

F. Rust Test
(ASTM D665) (140°F, Dist. Water) No rust

G. Foam Test
(ASTM D892)

75°F	After 5 min. blowing,	20
	Collapse time, sec.	12
200°F	After 5 min blowing	5
	Collapse time, sec.	8
75°F	After 5 min. blowing	0
	Collapse time, sec.	0

H. Emulsion Test
(ASTM D1401) Partial but not complete separation after one hour.

G E N E R A L

These hydraulic fluids are mixtures of synthetic organic liquids and petroleum fractions, the nature of which are trade secrets and are on file at Underwriters' Laboratories, Inc.

They are intended for use as pressure transmitting media in die-casting machines, hydraulic presses, etc., where accidental release of hydraulic fluid into the surroundings may present a potential fire and explosion hazard.

The object of this investigation was to obtain information relative to the fire and explosion hazards of these products.

This investigation was designed to develop data on the flammable and physical properties of these hydraulic fluids by means of a test program similar in nature and extent to that developed for our investigation of this manufacturer's hydraulic fluid "Pydraul F-9," previously tested and listed, and covered in our Report MH6049 dated May 23, 1955.

As to the underlying principles and the procedure employed in the tests for fire and explosion hazards, reference is made to our earlier Report MH6049 dated May 23, 1955, in which this phase of the work is fully discussed.

For the purposes of comparison, results obtained in tests of a representative hydraulic fluid of the petroleum-base type and included in our Report MH6049 dated May 23, 1955, are referred to in the conclusions section of this Report.

In this investigation representative samples of the products were subjected to physical and chemical tests for the purposes of identification and to establish their general nature.

D E S C R I P T I O N

PRODUCT COVERED:

Hydraulic fluids, "Pydraul 135," "Pydraul 312," and "Pydraul 540."

MARKING:

Listee's name and trade name.

T E S T R E C O R D N O. 1

SAMPLES:

The manufacturer supplied samples of the "Pydraul 135," "Pydraul 312," and "Pydraul 540" for test purposes.

IDENTIFICATION TESTS:

METHODS

Specific Gravity - The specific gravities of the products were determined by means of a pycnometer.

Viscosity - The viscosities of the products were determined by means of a Saybolt Universal viscosimeter in accordance with ASTM Method D88-56.

Qualitative Infrared Analysis - Infrared spectra of each of the products were obtained by means of a double-beam automatic-recording infrared spectrophotometer having a sodium chloride optical system.

RESULTS

Specific Gravity -

Product	Specific Gravity at 15.6 C (60 F) 15.6 C (60 F)
"Pydraul 135"	1.2123
"Pydraul 312"	1.1101
"Pydraul 540"	1.1832

Viscosity -

Product	Saybolt Viscosity, Sec
"Pydraul 135"	138
"Pydraul 312"	308
"Pydraul 540"	542

Qualitative Infrared Analysis - The infrared spectra obtained are considered to be representative of the materials tested. The recorded spectra are being made a part of the permanent records of these products.

FLASH POINT TESTS:

METHOD

The flash points of the products were determined with the Pensky-Martens closed tester in accordance with ASTM Method D93-61.

RESULTS

Product	Flash Point (†)
"Pydraul 135"	140.6 C (285.0 F)
"Pydraul 312"	185.0 C (365.0 F)
"Pydraul 540"	198.9 C (390.0 F)

† - The flash point alone is not necessarily a true measure of the fire hazard of a liquid. In this connection see double dagger note under fire point tests.

FIRE POINT TESTS:

METHOD

The fire point tests of the products were conducted using the Cleveland open cup tester in accordance with ASTM Method D92-57.

RESULTS

"Pydraul 135" ††

This product gave negative results in the fire point test. Intermittent flashes were obtained but the product vapors did not continued to burn. The sample was heated to 385 C (725 F) at which point evidence of decomposition was noted; the test was then discontinued.

"Pydraul 312"

The fire point of this product was 293.3 C (560.0 F).

"Pydraul 540" ††

This product gave negative results in the fire point test. Intermittent flashes were obtained but the product vapors did not continue to burn. The sample was heated to 393.3 C (740 F) at which point evidence of decomposition was noted; the test was then discontinued.

†† - In view of the negative results obtained in fire point tests of "Pydraul 135" and "Pydraul 540," it was considered necessary to conduct the additional flammability tests, "Tests Of Behavior When Heated On A Larger Scale," to obtain additional data for evaluation of the fire hazards of these products.

TESTS OF BEHAVIOR WHEN HEATED ON A LARGER SCALE:

METHOD

A sheet-steel vessel, 1-ft square and 2-1/2 in. deep, was mounted over a gas burner of the ring type. An iron-constantan thermocouple (No. 30 Awg wire) in a small glass protection tube was placed on the interior bottom of the vessel. Approximately 1.2 qt of the product was placed in the vessel, forming a layer 1/2 in. in depth. The samples were heated by the gas burner, and a test flame was applied briefly to the surface of the liquid at intervals during the heating of the products.

RESULTS

The behavior of the products when heated is shown in the following tabulation.

Product	Flashed In Vicinity Of Test Flame At	Ignited On Application Of Test Flame And Continued To Burn At	Flame Characteristics †	Flame Height, In.
"Pydraul 135"	255 C (491 F)	309 C (588 F)	Weak	5 to 11
"Pydraul 312"	202 C (396 F)	238 C (460 F)	Weak	8 to 28
"Pydraul 540"	258 C (496 F)	323 C (613 F)	Weak	8

† - The burning, in all samples, produced a considerable amount of smoke and irritating fumes.

IGNITION TEMPERATURE TESTS:

METHOD

The apparatus employed for this test consists essentially of a combustion chamber surrounded by a molten alloy bath heated by a special electric furnace having low resistance rod-type elements and thermostatic control. The temperature of the bath is measured by means of a calibrated thermocouple provided with a quartz tube for protection of the hot junction.

The combustion chamber consists of a glass flask of conical form with flat bottom 11.4 cm in height, 6.0 cm in diameter at the bottom, and 2.8 cm in diameter at the top. It is of about 160 ml capacity, having a ratio of surface area to volume of about 1.1.

Measured test samples of the product in the liquid phase were introduced into the heated combustion chamber by means of a pipette. Different amounts of liquid were admitted to the heated chamber in successive trials at progressively lower temperatures, in order to determine the minimum temperatures at which the vapor, in any proportion with air, would ignite without application of flame. In some of the tests, air was introduced into the flask by means of a rubber bulb and a bent glass delivery tube. After each trial, the combustion chamber was purged of residual gases and vapors by means of a slow stream of air.

RESULTS

Product	Initial Temperature
"Pydraul 135"	411 C (771.8 F)
"Pydraul 312"	414 C (777.2 F)
"Pydraul 540"	407 C (764.6 F)

DETERMINATION OF HEATS OF COMBUSTION:

METHOD

The heats of combustion were determined by means of an oxygen bomb calorimeter in accordance with ASTM Method D240-64.

RESULTS

Product	Heats of Combustion
"Pydraul 135"	6736 cal per g (12,124 Btu per lb)
"Pydraul 312"	8225 cal per g (14,804 Btu per lb)
"Pydraul 540"	7074 cal per g (12,733 Btu per lb)

TESTS FOR EXPLOSIVENESS OF VAPORS IN MIXTURE WITH AIR:

METHOD

The apparatus consisted of a cylindrical steel vessel 6 in. in diameter (internal) and 26 in. long. It was provided with a small mica window, and an outlet to the atmosphere, this outlet being normally closed by loosely fitted asbestos plugs. Openings were provided halfway between the ends of the vessel to admit electrode terminals connected to the secondary of a high-voltage transformer. The terminals were centrally located in the vessel, and were spaced to give a spark gap of approximately 1/4 in.

The vessel was heated externally by gas burners. A chromel-alumel thermocouple connected to a potentiometer was used for rough measurements of the temperature of the vapor-air mixture inside the vessel.

The electrical discharge used as a source of ignition in the test vessel is produced by a transformer rated 110 v, ac for the primary and 23[illegible],000 v for the secondary. A 0.01 mu f capacitor is connected across the secondary of the transformer.

Samples of the liquid products, ranging in volume from 20 to 50 ml, were introduced into the vessel which had been previously heated to a predetermined temperature. The transformer discharge was passed between the electrodes at intervals of 1/2 min, and observations made as to whether flame propagation occurred.

The residual liquid was drained from the vessel, and residual gases and vapors were displaced by a stream of air, in the interval between tests.

RESULTS

The results of the tests conducted on the products in the cylindrical steel vessel were as shown in the following table.

Sample, Ml	Temp, C	Duration Of Test, Min	Results
			"Pydraul 135"
20	137	1	Propagated flame with moderate pressure effects.
20	124	30	No flame propagation obtained.
30	124	24	Propagated flame with weak pressure effects.
30	115	30	No flame propagation obtained.
50	115	30	No flame propagation obtained.
			"Pydraul 312"
20	154	13	Propagated flame with moderate pressure effects.
20	149	30	No flame propagation obtained.
30	149	10	Propagated flame with weak pressure effects.
30	142	30	No flame propagation obtained.
40	141	10	Propagated flame with moderate pressure effects.
50	129	30	No flame propagation obtained.

(Table Cont'd)

Sample, Ml	Temp, C	Duration Of Test, Min	Results
		"Pydraul 540"	
20	170	1-1/2	Propagated flame with weak pressure effects.
20	163	30	No flame propagation obtained.
30	152	6	Propagated flame with moderate pressure effects.
30	143	30	No flame propagation obtained.
50	134	3-1/2	Propagated flame with moderate pressure effects.
50	123	30	No flame propagation obtained.

SPONTANEOUS HEATING TESTS:

METHOD

In spontaneous heating tests, the products were uniformly distributed over cotton fibers (absorbent cotton) or cotton waste, so that a relatively large area of contact with air was provided. The sample was then placed in a ventilated chamber at a constant temperature, which was somewhat elevated in order to accelerate chemical reactions capable of causing spontaneous heating. During each test, the temperatures of the interior of the sample and of the ambient were recorded. In the spontaneous heating tests conducted, the ambient temperatures were 100 and 110 C (212 and 230 F).

The apparatus used in tests at 100 C (212 F) consists essentially of a cylindrical chamber, 4 in. in diameter and 7 in. in height, which was surrounded by a water bath. Covering the chamber was a lid through which passed two ventilating tubes of unequal height. An opening at the center of the lid was provided for insertion of an iron-constantan thermocouple (No. 28 Awg wire), the hot junction of which was placed in the center of the test sample. A cylinder of wire gauze, 1-1/2 in. in diameter and 6 in. in height, was placed inside the chamber to hold the test sample. The water bath was maintained at boiling temperature for 72 hr.

In preparation of the test samples for use in the above-mentioned apparatus, 14 g of the product were uniformly distributed over 7 g of cotton fibers. The test sample, after preparation, was placed in the wire gauze cylinder in the sample chamber of the apparatus. Observations were made of the maximum temperature obtained in the test sample during the test, and the appearance of the sample after conclusion of the test.

Tests at 110 C (230 F) were conducted in a ventilated thermostatically controlled electric oven of approximately 1.5-cu ft volume. Test samples were prepared as described above and placed in the 1-[illegible] 6-in. wire gauze cylinder near the center of the oven. A test sample consisting of 28 g of the product distributed over 14 g of cotton waste was also included. For temperature measurements, two iron-constantan thermocouples (No. 28 Awg wire) were arranged with the hot junction of one in the center of the test sample, and the other in the ambient air inside the oven. These thermocouples were connected to a recording potentiometer. The test samples were heated in the oven for a duration of 72 hr.

RESULTS

No indication of spontaneous heating was obtained in tests of each of the products in the water heated chamber (ambient temperature 100 C, 212 F) and in the oven (ambient temperature 110 C, 230 F). The temperatures of the samples remained slightly below the respective ambient temperatures throughout the tests.

TESTS OF BEHAVIOR IN THE PRESENCE OF HOT METALS:

METHOD

The apparatus consisted essentially of a horizontal steel plate heated to dull red (about 550 C, 1022 F) by gas burners underneath. Flame and hot gases from these burners were deflected from the upper surface of the steel plate by a thin sheet of steel extending 10 in. horizontally beyond the edges of the plate. This deflector was bolted to the edges of the plate, asbestos gaskets being provided at the joints.

Various amounts of the products were applied as drops to the surface of the heated steel plate and the behavior observed.

The products were also applied as drops to the surface of molten zinc supported by the heated steel plate. In other tests, the products were applied dropwise to compacted fine copper wire or aluminum turnings resting on the steel plate and heated thereby.

RESULTS

The products when applied to hot steel (about 550 C, 1022 F) hot copper or aluminum, and molten zinc, evaporated or decomposed without ignition of the vapors or evidences of hazardous reaction with the heated metals.

FLAMMABILITY TESTS OF STREAMS OR SPRAYS:

METHOD

In these tests, the products were discharged under pressure as a horizontal stream or as a spray of droplets in the presence of a source of ignition.

The apparatus for producing the experimental streams or sprays consisted essentially of a pressurized vessel containing the product, an orifice fitting or a pressure spray nozzle connected to the pressurized vessel by incidental valves and tubing, and a pressure source (cylinder of compressed nitrogen). The pressurized vessel (internal volume 138 cu in., 2.26 l) was constructed from a vertical section of 3-in. extra-strong steel pipe having welded-on forged steel flanges and end plates. Copper tubing (about 1/4-in. OD) was used for connections.

The orifice fitting for the production of streams consisted of 1/8-in. pipe size cap bored with a central straight hole 0.0145 in. in diameter. The pressure spraying nozzle consisted of a small metal chamber having tangential inlet passageways which impart a rotary motion to the flowing liquid before leaving the discharge orifice of the nozzle. The discharge orifice of this nozzle was 0.025 in. in diameter, and the device had a rated capacity of 0.05-gal water per minute at 100-psig operating pressure.

A gas-air blast burner and an electric arc were used as sources of ignition. The gas was burned with considerable air, the length of flame was approximately 10 in. The alternating-current electric arc (198 v, 10 amp) was drawn between 1/8-in. copper electrodes in series with a current-limiting resistance coil.

The source of ignition (flame or arc) was supplied to the stream or spray (droplets) of the product discharged at pressures ranging from 200 to 1000 psig. Applications were made close to the orifice fitting or spray nozzle, and at distances of 1, 2, 3, and 4 ft from the orifice or nozzle. Observations were made as to whether the stream or spray ignited, and the rate of flame propagation either toward or away from the generating orifice or spray nozzle.

RESULTS

The products, when discharged at room temperature under high pressure in the form of a stream or finely divided spray, ignited on contact with flame, but burning did not continue after removal of the test flame.

When discharged at higher temperatures in the form of a spray, the products ignited on contact with flame, and the burning continued after removal of the source of ignition. The flame propagated throughout the spray, and the burning continued until the supply was shut off.

The results of the flammability tests of the products in the form of streams or sprays are summarized in Tables I, II, and III.

BURNING TESTS WHEN DISSEMINATED ON ASBESTOS:

METHOD

Three 3 by 40-in. strips were cut from heavy (52 oz per square yard) woven asbestos cloth approximately 0.08 in. thick and containing 98 per cent asbestos. These strips were weighed, then saturated with the products, and again weighed. The original weight of the individual strips, before saturation, was approximately 137 g. The amounts of product retained on the strips were 195 g for "Pydraul 135," 176 g for "Pydraul 312," and 205 g for "Pydraul 540."

In conducting the burning tests, the specimens were suspended with their long edges vertical in a location free from drafts. An 11-in. high flame produced by a Bunsen burner, having a 3/8-in. diameter tube, was used as the source of ignition. The Bunsen burner flame was applied vertically to the lower end of the test specimen so that the flame overlapped the specimen approximately 7 in.

RESULTS

Sample	Time Required For Ignition, Sec	Maximum Flame Height During Burning, In.	Total Time Of Burning Min	Sec
"Pydraul 135"	120	20	15	45
"Pydraul 312"	42	38	9	15
"Pydraul 540"	120	22	13	55

TABLE I

RESULTS OF FLAMMABILITY TESTS OF "HYDRAUL 135" IN STREAMS AND SPRAYS

Discharge Conditions			Source Of Ignition, Flame Or Electric Arc	Length Of Flame Propagation Ft, With Source Of Ignition At Indicated Distance From Origin Of Stream Or Spray (1)				
				Distance From Origin, Ft				
Form	Pressure, PSIG	Temperature Of Liquid, C (F)		0.1-0.5	1	2	3	4
Stream	600	16 (60.8)	Gas-air (3)	None (5)	None	None	None	0.5
Stream	1000	16	Gas-air	None	None	0.5	0.5	0.7
Stream	200	76 (168.8)	Gas-air	9	0.5	0.7	0.5	0.3
Stream	400	74 (165.2)	Gas-air	8	0.8	1.0	1.0	None
Stream	600	76	Gas-air	8	4	0.6	0.8	0.8
Stream	800	70 (158.0)	Gas-air	9	0.7	0.7	0.8	0.8
Stream	1000	72 (161.6)	Gas-air	8	1.0	1.0	0.8	0.8
Stream	600	68 (154.4)	Copper arc (4)	None	None	None	-	-
Stream	1000	66 (150.8)	Copper arc	None	None	None	-	-
Spray	600	16	Gas-air	1.5	1.1	1.0	0.7	1.0
Spray	1000	16	Gas-air	6	1.2	1.0	1.0	1.0
Spray	600	72	Gas-air	-	5 (2)	3	1.5	1.0

(1) - Length of flame propagation refers to horizontal distance flame traveled from the source of ignition in the direction of the stream or spray. Flame propagation ceased on removal of the source of ignition in all but one of the tests (see Note 2). No propagation from the igniting source back to the origin of the stream or spray (orifice or pressure spray nozzle) was observed.

(2) - Flame propagated throughout the spray. After the ignition source was removed, the burning continued until the supply was shut off.

(3) - Gas-air blast burner.

(4) - Arc between 1/8 in. copper electrodes at 198 v, 10 amp, ac.

(5) - Less than 0.1 ft.

TABLE II

RESULTS OF FLAMMABILITY TESTS OF "PYDRAUL 312" IN STREAMS & SPRAYS

Discharge Conditions			Source Of Ignition, Flame Or Electric Arc	Length Of Flame Propagation Ft, With Source Of Ignition At Indicated Distance From Origin Of Stream Or Spray (1)				
				Distance From Origin, Ft				
Form	Pressure, PSIG	Temperature Of Liquid, C (F)		0.1-0.5	1	2	3	4
Stream	600	24 (75.2)	Gas-air (3)	None (5)	None	0.3	0.5	0.7
Stream	1000	24	Gas-air	0.5	0.5	0.6	0.7	0.7
Stream	200	68 (154.4)	Gas-air	0.7	1.0	0.3	0.7	0.3
Stream	400	68	Gas-air	1.0	0.8	0.7	0.7	0.5
Stream	600	68	Gas-air	0.5	0.5	0.7	0.7	0.7
Stream	800	68	Gas-air	6	3	1.2	1.0	0.7
Stream	1000	68	Gas-air	12 to 14	0.7	1.0	1.2	1.0
Stream	600	73 (163.4)	Copper arc (4)	None	None	None	-	-
Stream	1000	69 (156.2)	Copper arc	None	None	None	-	-
Spray	600	24	Gas-air	1.2	1.5	1.3	1.2	1.2
Spray	1000	24	Gas-air	7	3	0.9	1.0	1.0
Spray	600	60 (140.0)	Gas-air	-	-	7 (2)	4	1.5

(1) - Length of flame propagation refers to horisontal distance flame traveled from the source of ignition in the direction of the stream or spray. Flame propagation ceased on removal of the source of ignition in all but one of the tests (see Note 2). No propagation from the igniting source back to the origin of the stream or spray (orifice or spray nozzle) was observed.

(2) - Flame propagated throughout the spray. After the ignition source was removed, the burning continued until the supply was shut off.

(3) - Gas-air blast burner.

(4) - Arc between 1/8 in. copper electrodes at 196 v, 10 amp, d.c.

(5) - Less than 0.1 ft.

TABLE III

RESULTS OF FLAMMABILITY TESTS OF "PYDRAUL 540" IN STREAMS AND SPRAYS

Discharge Conditions			Source Of Ignition, Flame Or Electric Arc	Length Of Flame Propagation Ft, With Source Of Ignition At Indicated Distance From Origin Of Stream Or Spray (1)				
				Distance From Origin, Ft				
Form	Pressure, PSIG	Temperature Of Liquid, C (F)		0.1-0.5	1	2	3	4
Stream	600	16	Gas-air (3)	None (5)	None	None	None	None
Stream	1000	16	Gas-air	None	None	None	None	-
Stream	200	70	Gas-air	None	None	0.5	0.7	0.7
Stream	400	70	Gas-air	0.8	0.5	0.7	0.7	0.8
Stream	600	70	Gas-air	None	None	0.7	0.7	0.8
Stream	800	66	Gas-air	None	0.2	0.4	0.4	0.5
Stream	1000	63	Gas-air	None	0.2	0.4	0.5	0.5
Stream	600	76	Copper arc (4)	None	None	None	-	-
Stream	1000	74	Copper arc	None	None	None	-	-
Spray	600	16	Gas-air	None	None	None	None	None
Spray	1000	16	Gas-air	None	None	None	None	None
Spray	600	70	Gas-air	6	3	3	1.5	1.5
Spray	1000	72	Gas-air	8	6	4	2	1.5
Spray	600	124	Gas-air	-	5 (2)	4	2	1.0

(1) - Length of flame propagation refers to horisontal distance flame travelled from the source of ignition in the direction of the stream or spray. Flame propagation ceased on removal of the source of ignition in all but one of the tests (see Note 2). No propagation from the igniting source back to the origin of the stream or spray (orifice or pressure spray nozzle) was observed.

(2) - Flame propagated throughout the spray. After the ignition source was removed, the burning continued until the supply was shut off.

(3) - Gas-air blast burner.

(4) - Arc between 1/8-in. copper electrodes at 198 v, 10 amp, ac.

(5) - Less than 0.1 ft.

MONS 021252

JBW

C O N C L U S I O N S

FIRE HAZARD:

With respect to fire hazard, these products are considered to be less hazardous than ordinary petroleum base hydraulic fluids.

The fire hazards of these products are judged to be in a class less hazardous than paraffin oil as determined by the Standard of Underwriters' Laboratories, Inc. for the classification of liquids, the rate of hazard being 5 to 10 in accordance with the following schedule in which:

Ether rates	- 100
Gasoline rates	- 90-100
Alcohol (ethyl) rates	- 50-70
Kerosene (100 F flash) rates	- 30-40
Paraffin oil rates	- 10-20

All three products showed flash points in the closed cup tester: "Pydraul 135," 141.7 C (285.0 F); "Pydraul 312," 185.0 C (365.0 F); and "Pydraul 540," 198.9 C (390.0 F).

"Pydraul 312" showed a fire point in the open cup tester of 293.3 C (560.0 F); "Pydraul 135" and "Pydraul 540" did not show a true fire point in this test. When heated in larger quantities in an open container, the products could be ignited, and continued to burn at temperatures of 309 C (588 F) for "Pydraul 135," 238 C (460 F) for "Pydraul 312," and 323 C (613 F) for "Pydraul 540." The flash point and fire point test, particularly the latter, in the case of the compositions tested, are of limited value as a measure of fire hazard, but are useful for purposes of identification. The practical significance of these tests, in the case of these products, is that their fire hazards are less than those of paraffin oil.

Ignition temperatures recorded in tests of these products were substantially of the same order: 411 C (771.8 F) for "Pydraul 135," 414 C (777.2 F) for "Pydraul 312," and 407 C (764.6 F) for "Pydraul 540." In tests conducted previously, a representative petroleum base hydraulic fluid was found to have an ignition temperature of 285 C (545 F).

The heats of combustion of these products were found to be 6736 cal per g (12,1[illegible] per lb) for "Pydraul 135," 6225 cal per g (14,804 Btu per lb) for "Pydraul 312," and 7074 cal per g (12,733 Btu per lb) for "Pydraul 540." Available data indicate that the heat of combustion for (paraffin) petroleum oil would be of the order of 9779 cal per g (17,600 Btu per lb).

As shown by results of tests for explosiveness of vapors in mixture with air, these products were capable of propagating flame with development of weak to moderate pressure effects.

The temperatures at or above which the products may form flammable mixtures with air were found to be 124 C (255.2 F) for "Pydraul 135," 141 C (285.8 F) for "Pydraul 312," and 134 C (273.2 F) for "Pydraul 540."

The products, when applied to hot steel surfaces (dull red heat, about 550 C, 1022 F), hot copper and aluminum, and molten zinc, evaporated or decomposed without ignition of the vapors, or evidences of hazardous reaction with the heated metals. In tests conducted previously, a representative petroleum base hydraulic fluid, when applied to the same hot metals under the same conditions, ignited readily and burned freely.

When discharged under pressure in the form of a stream at ordinary room temperature and at moderately elevated temperatures, and in the form of a spray at ordinary room temperature, each of these products was found to ignite on contact with a source of ignition, but in each case there was little propagation of flame beyond the zone of contact with the igniting source, and combustion did not continue after removal of the source of ignition. When discharged under pressure in the form of a spray at moderately elevated temperatures, 70 C (158 F) for "Pydraul 135," 60 C (140 F) for "Pydraul 312," and 124 C (255 F) for "Pydraul 540," the spray of each product ignited on contact with a source of ignition with flame propagating throughout the spray, and continued to burn after removal of the source of ignition, until the spray supply was shut off.

In tests conducted previously, a representative petroleum base hydraulic fluid discharged in the form of a finely divided spray at ordinary room temperature, ignited readily on contact with a source of ignition with flame propagating throughout the spray; combustion continued after removal of the source of ignition, until the spray supply was shut off.

These products, disseminated on vertically suspended strips of asbestos cloth, ignited and burned after application of a test flame for periods of from 42 to 120 sec. In each case, the burning continued until all of the fluid retained on the asbestos had been consumed. The burning times and maximum flame heights during burning for the products were 15 min, 45 sec and 20 in. for "Pydraul 135," 9 min, 15 sec and 38 in. for "Pydraul 312," and 13 min, 55 sec and 22 in. for "Pydraul 540." In tests conducted previously, a representative petroleum base hydraulic fluid disseminated on vertically suspended strips of asbestos cloth ignited readily on application of a test flame and the burning continued for 2 min, 50 sec with a maximum flame height of 10 ft. All of the fluid retained on the asbestos was consumed.

The products, when burning, or in contact with flames or hot surfaces, may be decomposed into irritating and corrosive fumes. The life hazards of the products or the fumes evolved during their combustion or decomposition are not covered by this investigation, nor are the effects of such fumes on metals or other materials. Since these fumes are irritants, they not only give definite warning of their presence, even in small concentrations, but cause people to make efforts to escape. Under fire conditions, the toxic hazard presented will depend upon the amount of the product released into the surroundings, and the degree of confinement of the fumes (ventilation). It is to be noted in this connection that petroleum base hydraulic fluids are readily combustible, and that the combustion products may be more or less toxic inasmuch as they include smoke, carbon dioxide, acrid vapors, and in some cases carbon monoxide, depending upon the conditions of burning.

PRACTICABILITY:

It is considered practicable to use these products as pressure transmitting media in die-casting machines, hydraulic presses, etc.

These products are not intended to replace other hydraulic fluids unless equipment is designed for such hydraulic fluids or these products. Due to the fact that some gasket, seal, packing, and hose materials may not be suitable for use with these products, the equipment manufacturer should be contacted with respect to his recommendations in connection with the replacement of such materials.

STABILITY:

The products are reasonably stable and in use are unlikely to undergo decomposition resulting in an increase of fire hazard.

Considerations of the chemical compositions and properties of these products indicate that they are reasonably stable.

These products showed no tendency to heat or ignite spontaneously under test conditions designed to start and accelerate the process.

The corrosive effects of the products, if any, on common metals are not covered by this investigation, but available data indicate that they are not likely to cause corrosion of metals ordinarily used in hydraulic systems.

The products covered by this Report will be listed under Reexamination Service of Underwriters' Laboratories, Inc.

Report by:

J. E. Wallis
J. E. WALLIS
Project Engineer
Chemical Department

Reviewed by:

J. F. Breen
J. F. BREEN
Assoc. Managing Engr.
Chemical Department

JEW:LAR

MONSANTO CHEMICAL COMPANY

APPENDIX IV

FROM St. Louis - General Offices

DATE December 30, 1963

SUBJECT

REFERENCE

cc G. R. Buchanan/R. Davis
R. E. Hatton
M. McEwen/DJM
K. L. McHugh
D. F. Smith
L. R. Stark
R. Street

TO W. R. Richard

At our recent discussion on hydraulic fluids, you requested more definitive target properties for improved Pydraul 150. The viscosity characteristics of current Pydraul 150, used Pydraul 150 from 1000 hour Pump test, a typical TCP, and target viscosity properties for improved Pydraul 150 are given in the table below and in the attached Figures I and II.

	Pydraul 150	Pydraul 150 after 1000 hr Pump Test	TCP	Improved Pydraul 150[b]
Viscosity, cs, + 10°F	240	220	1800	1000 maximum
100°F	30.8	18.0	30.0	29.5
130°F	20.0	10.8	15.0	15 minimum
210°F	8.0	4.1	4.1	4.6
Viscosity Index	173	152	-28[a]	64

a. Cellulube 220 = -27 VI
b. Values given represent target properties for "used" fluid, e.g., after 1000 hour pump test. A minimum viscosity loss during use is desired but some (~ 20% max) could be tolerated. Hence, new fluid viscosities should be higher by a factor necessary to achieve the above values after shear-down.

The important viscosity properties are pumpability at low temperatures (~ -10°F) and adequate viscosity at operating temperatures (~ 130°F) to prevent pump leakage and insure trouble-free operation. As the viscosity data indicate, new or used Pydraul 150 exhibit excellent low-temperature fluidity whereas TCP is borderline in this respect. The viscosity of used Pydraul 150 at 130°F (10.8 cs) is considered too low because of customer complaints but TCP at ~ 15 cs at 130°F is considered satisfactory. On this basis, target viscosity properties for an improved Pydraul 150 are maximum +10°F viscosity of 1000 cs to insure low-temperature pumpability and minimum 15 cs at 130°F after shear-down, to insure satisfactory operation at normal operating temperatures. A plot of these requirements (Figure II) indicates that the 100°F and 210°F viscosities after shear-down are approximately 29.5 cs and 4.6 cs, respectively and the viscosity index is 64 units minimum.

Other desired property requirements are compatibility with current Pydraul 150, approximately -20°F maximum pour point, and thermal stability approximately 50°F greater than that of Pydraul 150 as measured by oven-type tests of your choice.

A trip to Europe to discuss Pydraul fluids is tentatively planned for about mid-April (1964). It would be very helpful for this trip to have an improved Pydraul 150 available for introduction at that time.

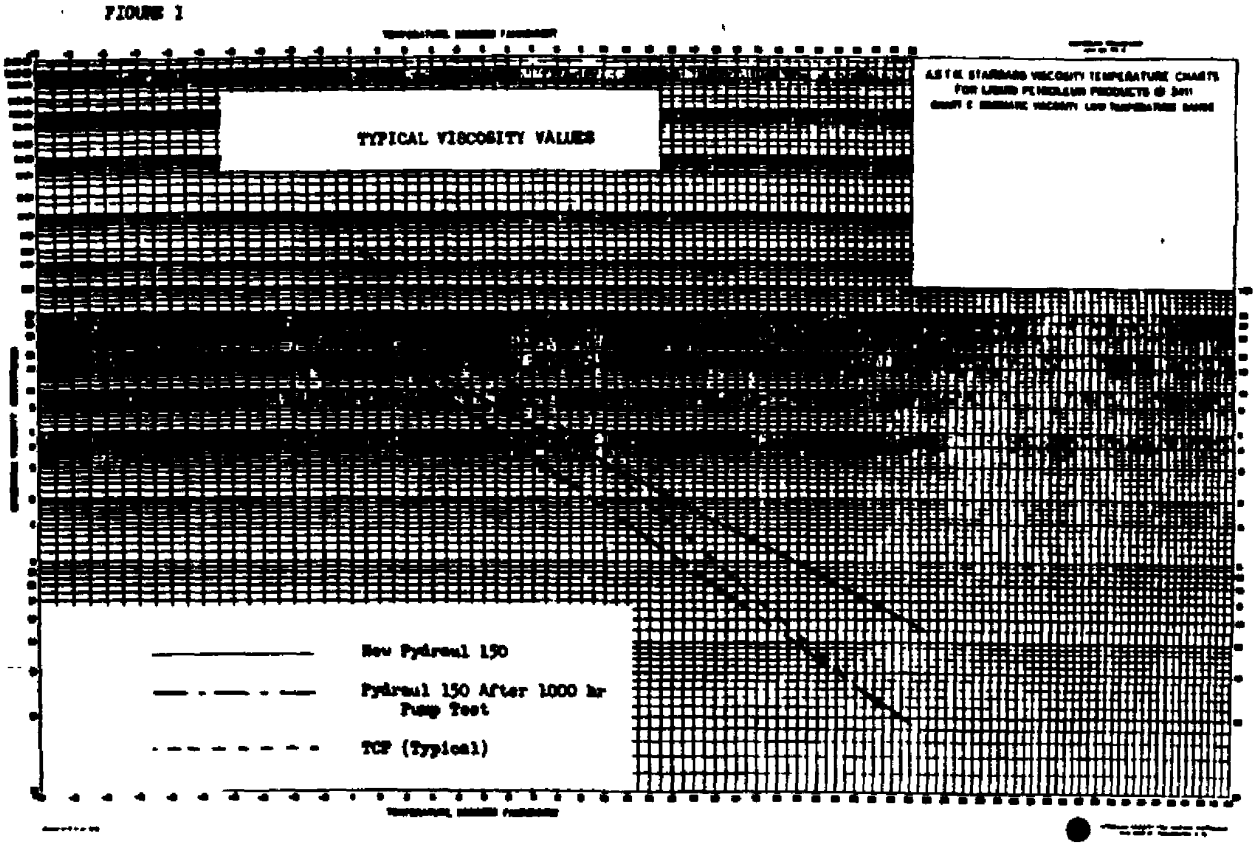
If you have any questions about these target test properties, please let me know.

C. L. Early

D. F. Smith

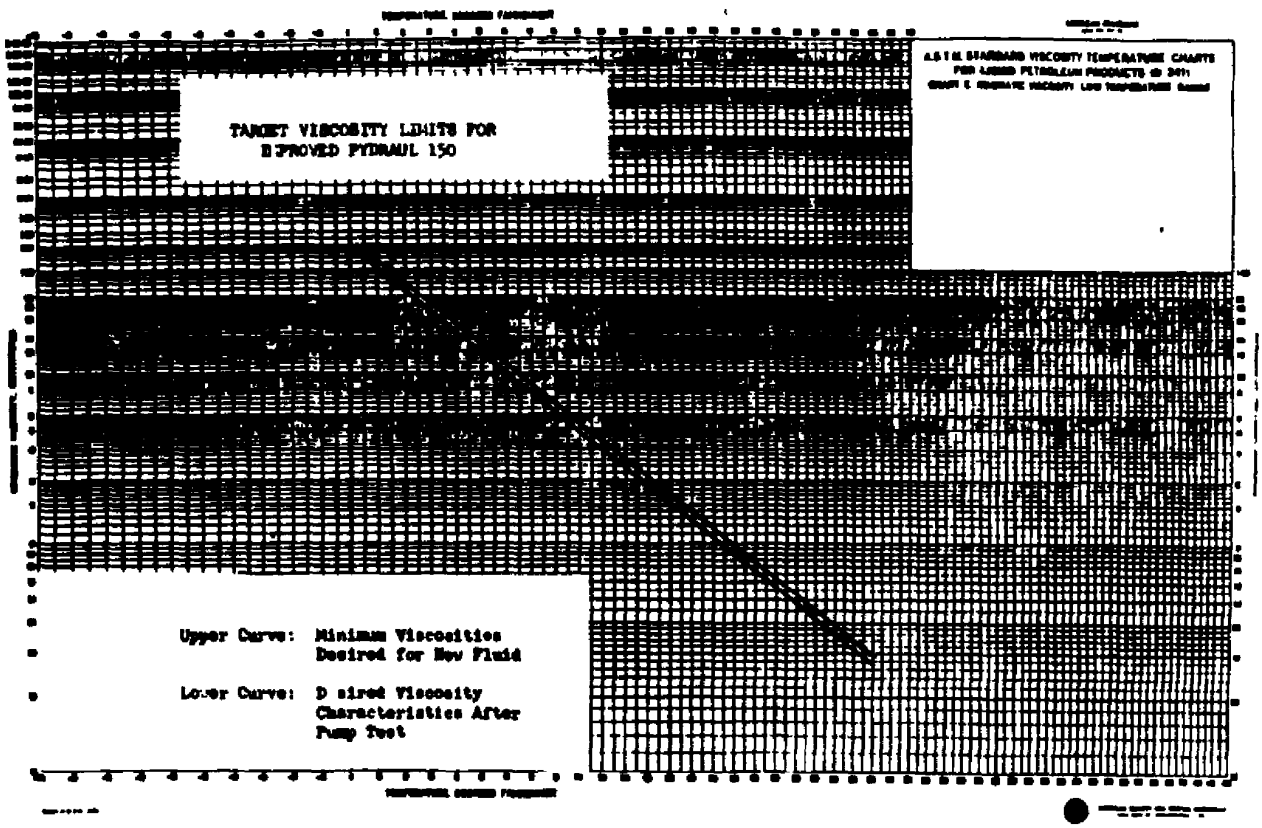
/le

FIGURE 1



MONS 021259

FIGURE II



MONS 021260

APPENDIX IV

St. Louis Org. Res. Dept.

February 12, 1964

PYDRAUL BLENDS VIA
LINEAR PROGRAMMING

J. R. Darby - Res-3
M. W. Farrar - Res-1
H. L. Hubbard - " "
W. E. Koerner - Res-2
K. L. McHugh - " "
W. R. Richard - Res-1

Mr. R. W. Street

ORGANIC RESEARCH - 2

The technique of linear programming is proving to be a feasible method of screening large numbers of possible fluid blends mathematically and selecting the lowest cost formulation which meets certain viscosity requirements. In addition, the program can be handled in such a way that all possible combinations between certain viscosity limits can be calculated and their costs determined.

Based on cost and viscosity information you provided, the following minimum cost formulations were calculated:

	Restrictions	Materials Screened	Formulation	Cost
1.	10°F. visc $\leq$ 500 cs 100°F. visc $\geq$ 17 cs 210°F. visc $\geq$ 3 cs DIDA $\leq$ 15% TCB $\leq$ 15%	TCP CDP DIDA A-1242 TCB	No combination meets requirements. 100° visc $\not<$ 17 cs	----
2.	10°F. visc $\leq$ 750 cs 100°F. visc $\geq$ 17 cs 210°F. visc $\geq$ 3 cs DIDA $\leq$ 15% TCB $\leq$ 15%	Same as above.	TCB 0.144% CDP 80.430% DIDA 15.000% A-1242 4.426%	$0.18436/lb.
3.	10°F. visc $\leq$ 1000 cs 100°F. visc $\geq$ 29.5 cs 210°F. visc $\geq$ 4.6 cs DIDA $\leq$ 15% TCB $\leq$ 15%	Same as above plus TPDBPP A-1232.	No combination meets requirements.	----
4.	Same as above but 10°F. visc $\leq$ 1200 cs	"	"	----
5.	10°F. visc $\leq$ 850 cs 100°F. visc $\geq$ 24.0 cs 210°F. visc $\geq$ 4.0 cs DIDA $\leq$ 15% TCB $\leq$ 15%	"	"	----
6.	Same as above except 10°F. visc $\leq$ 1000 cs	"	"	----

MONS 021261

	Restrictions	Materials Screened	Formulation	Cost
7.	10°F. visc ≤ 750 cs 100°F. visc ≥ 17 cs 210°F. visc ≥ 3 cs DIDA ≤ 15% TCB ≤ 15%	Same as above plus 2 EHDP	A-1242 = 3.843% EHDP = 41.277% TCP = 39.880% DIDA = 15.000%	$0.17840/lb.
8.	10°F. visc ≤ 500 cs 100°F. visc ≥ 17 cs 210°F. visc ≥ 3 cs No restrictions on DIDA and TCB	Same as #1	TCP = 16.864% DIDA = 74.838% A-1242 = 8.298%	$0.16508/lb.

Using a technique called non-parametric programming, the following formulations and properties were obtained. Restrictions on TCB and DIDA were at 15% maximum, and all fluids were screened. Intermediate solutions having viscosities between those specified can be linearly interpolated both in formulation and cost.

		Viscosity at 10°, 100°, 210°	Cost $
9.	A.	(1) ≤ 2000, ≥ 15.0, ≥ 3.0	.15109
		(2) ≤ 2000, ≥ 15.5, ≥ 3.1	.15634
		(3) ≤ 2000, ≥ 21.3, ≥ 4.3	.21304
	B.	(1) ≤ 1500, ≥ 15.0, ≥ 3.0	.15403
		(2) ≤ 1500, ≥ 16.1, ≥ 3.2	.16500
		(3) ≤ 1500, ≥ 20.1, ≥ 4.0	.20723
	C.	(1) ≤ 1000, ≥ 15.0, ≥ 3.0	.15819
		(2) ≤ 1000, ≥ 15.6, ≥ 3.1	.16413
		(3) ≤ 1000, ≥ 19.5, ≥ 3.9	.21047
	D.	(1) ≤ 500, ≥ 15.0, ≥ 3.0	.17049
		(2) ≤ 500, ≥ 17.5, ≥ 3.5	.17651

These formulations are listed below:

9A(1)		9A(2)		9A(3)	
A-1242	31.388%	A-1242	29.187%	TCP	68.053
CDP	48.178%	CDP	55.813%	CDP	16.947%
DIDA	15.000%	DIDA	15.000%	DIDA	15.000%
EHDP	5.434%				

MONS 021262

9B(1)		9B(2)		9B(3)	
A-1242	26.362%	A-1242	21.866%	TCP	50.983%
CDP	47.538%	CDP	63.134%	CDP	34.017%
DIDA	15.000%	DIDA	15.000%	DIDA	15.000%
EHDP	11.100%				

9C(1)		9C(2)		9C(3)	
A-1242	19.278%	A-1242	16.709%	TCP	8.089%
CDP	46.638%	CDP	55.550%	CDP	65.416%
DIDA	15.000%	DIDA	15.000%	DIDA	15.000%
EHDP	19.084%	EHDP	12.741%	DPTBPP	11.495%

9D(1)		9D(2)	
A-1242	2.740%		
CDP	2.213%	CDP	6.133%
DIDA	15.000%	DIDA	15.000%
EHDP	51.756%	EHDP	47.864%
TCP	28.290%	TCP	31.004%

Figure 1, attached, shows how to obtain formulations with properties between those printed. Read the desired combination of viscosities on the horizontal axis, proceed upward to the lines and read the proportion of each ingredient on the left-hand vertical scale, the cost of the formulation on the right-hand scale.

Discussion

This project only scratches the surface of the potential uses of this method. For example, there may be 40 or 50 possible candidate fluids which could be used; properties other than viscosity can be built into the program as restrictions. Alternate costs of ingredients could be tried. In fact, this technique is applicable to any formulation problem where the cost and properties of the ingredients are known, the required properties of the blend can be specified, and the properties are such that they combine linearly.

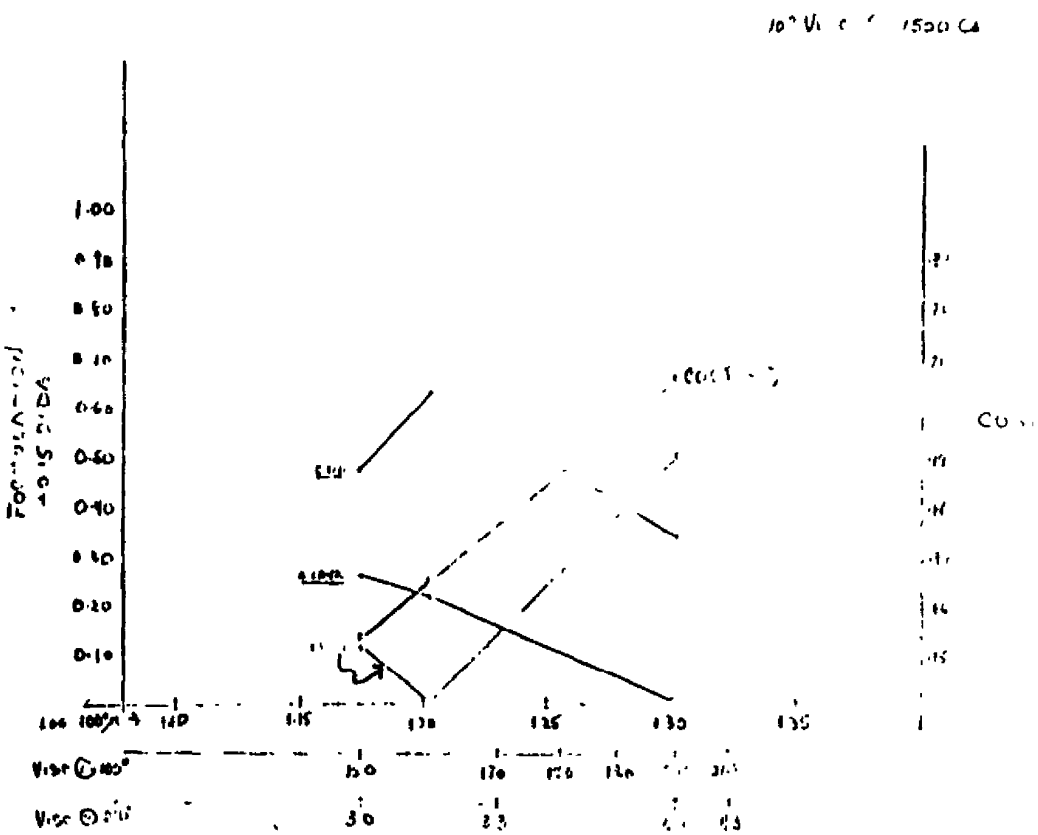
The Applied Math Group at Creve Coeur is now set up to handle these problems routinely.

John D. Hinchen

dm
Att.

MONS 021263

Fig 1
Interpolation between Propeller Characteristics



APPENDIX IV

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Composition WT %	PYDRAUL 312	(HI VISC 312 TYPE) MCS 404	MCS 395	(LOW VISC 312) MCS 370
BRIGHT STOCK 200 SUS 210	38.5	32.0	25.0	-
ARECLOR 1242	46.9	-	42.7	23.0
1248	-	43.7	-	-
1254	-	10.0	-	-
TTCB (49% ENRICHED TETRA)	-	-	18.0	-
SANTICIZER 141	14.0	-	-	-
TCP	-	14.0	14.0	42.7
CDP	-	-	-	34.0
SANTOLUBE 70	0.1	0.3	0.3	0.3
DCF 200 350 cs 40.	0.002	0.002	0.002	0.002
BLUE DYE	0.003	0.003	0.003	0.001
Appearance	DARK BLUE-GREEN FLUID.	DK. BLUE-GREEN	DK. BLUE-GREEN	BLUE
Viscosity (CS) at 210°F	7.50	8.47	4.27	3.32
100°F	66.5	114.7	28.08	21.53
40°F	1000	3415.	-	-
14°F	4000 (20°F)	-	2200	1744
10°F				
Viscosity Index 100-210°F	+77	+13	+31	-78
Pour Point, °F	-10	0	-12	
Density (g/ml at 73°F	1.10	1.1810	12073	1.219
Acidity TAN mg KOH/g.	0.10	0.28	0.20	0.16

Page 1

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	Pydraul 312	MCS 404	MCS 395	MCS 370
Flash Point, COC°F.	395	415	360	430
Fire Point, COC°F.	545	740	> 725	680
Molten Metal Ignition (Aluminum Alloy at 1200-1300°F)				
1. Spontaneous:	1. NO IGNITION	1. NO IGNITION	1. NO IGNITION	1. NO IGNITION
2. Without Spark:	2. OCCASIONALLY IGNITES AND BURNS AFTER MOST OF THE FLUID HAS VAPORIZED.			2. DOES NOT FLASH OR BURN
3. With Spark:	3. SELF EXTINGUISHING UNTIL MOST OF FLUID VAPORIZED. THEN FLASHES AND BURNS TO COMPLETION			3. FLASHES BUT SELF EXTINGUISHING
High Pressure Spray Flammability AMS 3150C. Fluid Temp. 150°F	1. AT ABOUT TWO FEET FROM ORIFICE FLAMES WILL CARRY 6 INCHES TO 1 FOOT DOWNSTREAM FROM THE TIP OF THE TORCH. AT ABOUT 3-5 FEET FROM THE ORIFICE FLAMES CARRY 1- 1/2 FEET			
Hot Manifold (1500°F)	FLUID BURNS ON BURN ON LEAVING	THE TUBE BUT DOES NOT THE TUBE OR IN THE PAN. (AT 900-950°F) DOES NOT BURN ON TUBE	(AT 900-950°F) DOES NOT BURN ON TUBE	BURNS ON THE TUBE DOES NOT BURN ON LEAVING THE TUBE OR IN THE PAN

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	PYDRAUL 312	MCS 404	MCS 395	MCS 370
Pipe Cleaner (Bu Mines Sched. 50)		26.2	27.4	
No. cycles before burning through one complete cycle. AFTER 4 HRS IN OVEN (450°F)		26.0	24.4	
Low Pressure Spray.	SLIGHT INC. IN FLAME INTENSITY			
P. M. Channel Iron Spray Ignition Test				
Fluid Temp: 440 °F				
To 1 °F	850		940	
To 2 °F	1310		1350	
To 3 °F	1010		1110	
To 4 °F	1230		1130	
To 5 °F	940		1040	
Results	IGNITED AND BURNED AFTER A DELAY OF ABOUT 5 SEC.		IGNITED AND BURNED AFTER ABOUT A 5 SEC DELAY.	
AIT	940°F	815°F/0.07/15#	760°F/0.07/15#	

MONS 021267

TABLE 1

PHYSICAL AND FUNCTIONAL PROPERTIES

Hydrolytic Stability.	PYDRAUL 312	MCS 404	MCS 395	MCS 370
(Beverage Bottle Test 200°F 48 Hrs.)				
Viscosity				
100°F Initial	70.6	114.7	28.05	
Final	70.2	113.5	28 32	
% Change	- 0.56	- 1.	+ 1.	
200°F Initial	7.80	847	4.26	
Final	7.70	8.81	4.28	
% Change	- 1.3	+ 4.	nil	
Acidity				
Fluid Layer.				
TAN Initial	0.13	0.28	0.10	
TAN Final	0.17	0.17	0 31	
Change	+ 0.04	- 0 11	+0.21	
Water Layer				
(MgNaOH/g fluid)	0.027	0 0344	0.024	
Wt. loss Copper Specimen (g)	- 0.0054	- 0.0018	- 0.0019	
Appearance of Specimen.	SLIGHT DULL COPPER COLOR	BRIGHT COPPER COLOR	BRIGHT, CLEAR, NO PITTING OR ETCHING	
Solids (Insolubles).	NONE	NONE	NONE	

Page 4

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Oxidation - Corrosion.	PYDRAUL 312	MOS 404	MCS 395	MCS 370
250°F, 168 Hrs.				
Metal Attack mg/cm²				
Copper	-0.10	-0.30	-0.09	-0.22
Magnesium	+0.01	+0.01	∓0.00	0.00
Steel	-0.00	+0.01	-0.02	0.00
Aluminum	+0.02	-0.01	0.00	0.00
Cadmium	-0.61	-0.14	-0.01	-0.01
Viscosity				
100°F Initial		113.5	28.42	20.1
Final		150.8	78.72	21.34
% Change	+50.7	+32.9	+177	+3.1
200°F Initial		9.81	4.26	3.23
Final		10.11	7.54	3.31
% Change	+29.2	+14.8	+77.0	+2.5
Acidity				
Initial, TAN	0.10	0.28	0.20	0.16
Final, TAN	4.65	3.03	1.80	0.15

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	HYDRAULIC	MCS 404	MCS 395	MCS 340
Four Ball Wear 1 Hour, 167°F 600RPM.				
Steel-On-Steel MM.				
4 Kg	0.24	0.19	0.175	
10 Kg	0.243	0.225	0.243	
40 Kg	0 44	0.44	043	
— Kg		—		
Steel-On-Bronze				
10 Kg	0.87	0.43	0.475	
— Kg				
Hydraulic Pump Test (110°F, 1000Hrs., 1000PSI.)				110°F, 1000 Hrs 1000 PSI
Weight Losses				
Pressure Plates				
2015	+0.0081	-0.0012	-0.0211	-0.0052
2016	-0.0057	-0.0053	-0.0114	-0.0018
Ring	-0.0013	-0.0039	-0.0218	-0.0009
Vanes	-0.0021	-0.0010	-0.0016	-0.0043
Viscosity				
100°F Initial	67.0	113.8	27.94	20.70
Final		116.7	31.22	21.01
% Chg.		+1.6		
200°F Initial	7.64	7.52	4.26	3.29
Final		8.67	4.47	3.29
% Chg.				
Acidity, mg KOH/g.				
Initial	0.13	0.28	0.10	0.16
Final	0.14	0.29	0.27	0.16

MONS 021270

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Elastomer Compatibility (158°F 168 Hrs.)	PYDRAUL 312	MCS 404	MCS 395	MCS 370
Butyl				
Durometer "A" Hardness Initial	67	66	65	62
Final	46	52	41	55
Wt. Increase	57.4	43	85	5.7
Volume Increase	64.0	42.9	98	4.8
EPR				
Durometer "A" Hardness Initial	71	69	69	70
Final	54	53	53	66
Wt. Increase	58.9	57.3	73	4.8
Volume Increase	64.7	59.4	90	4.7
Viton				
Durometer "A" Hardness Initial	68	66	68	68
Final	68	64	65	63
Wt. Increase	0.2	5.27	-0.1	2.83
Volume Increase	NIL	0.54	3.4	1.97
Silicone				
Durometer "A" Hardness Initial	72	70		72
Final	70	68		67
Wt. Increase	3.70	3.7%		0.8
Volume Increase	1.93	1.82		1.9
POLYURETHANE				
INITIAL	47	47	46	
FINAL	36	36	35	
WT INC.	61.2	76.3	86	
VOL INC.	59.9	68.7	80.4	

TABLE II

IMPROVED PYDRAUL 150

	PHYSICAL AND FUNCTIONAL PROPERTIES				
	INITIAL TESTS	INITIAL TESTS	SECOND ROUND OF TESTS		
Oxidation - Corrosion.	F2747	F2747	F2747*	F2747	PYDRAUL 150 F2763
___°F. ___ Hrs.					
Metal Attack Mg/cm²					
Copper	-10.08	-10.26	-13.1	-9.91	-4.36
Magnesium	-0.01	NONE	NONE	NONE	NONE
Steel	NONE	+0.01	-0.02	-0.04	-0.04
Aluminum	+0.01	+0.01	-0.02	-0.04	-0.04
Cadmium	-3.05	-2.14	-4.45	-1.39	-0.06
Viscosity					
100°F Initial			25.86	25.92	31.14
Final			36.75	34.88	32.12
% Change	+29.2	+39.0	+42.1	+34.6	+3.5
200°F Initial			4.15	4.17	-
Final			5.29	5.04	7.71
% Change	+18.7	+25.0	+27.5	+18.4	-
Acidity					
Initial, TAN	0.10	0.10	0.10	0.06	0.08
Final, TAN	3.51	4.89	7.77	6.26	1.51

* SAME MATERIALS USED FOR INITIAL TEST (TECHNICAL DIVISION, PURCHASE)

APPENDIX II

MONS 021272

TABLE 1.

IMPROVED PYDRAUL 150

	PHYSICAL AND FUNCTIONAL PROPERTIES			
	INITIAL TESTS		SECOND ROUND OF TESTS	
Hydrolytic Stability.	F2747	F2747	F2747	PYDRAUL 150
(Beverage Bottle Test 200°F 48 Hrs.)				
Viscosity				
100°F Initial	25.76	25.86	25.92	31.14
Final	27.06	26.91	26.60	30.97
% Change	+ 4.64 %	+ 4.06 %	+ 2.63	- 0.55 %
200°F Initial	4.15	4.15	4.17	-
Final	4.17	4.17	4.22	7.38
% Change	+ 0.5 %	+ 0.5%	+ 1.2%	-
Acidity				
Fluid Layer.				
TAN Initial	0.10	0.10	0.06	0.08
TAN Final	0.55	0.42	0.21	0.13
Change	+0.45	+0.32	+0.15	+0.05
Water Layer				
(MgNaOH/g fluid)	0.20	0.21	0.075	0.069
Wt. loss Copper Specimen (gr/m²)	- 0.74	- 0.32	- 0.26	- 0.20
Appearance of Specimen.	Dull Cu color NO PIT OR ETCH	SAME NONE	SAME NONE	SAME NONE
Solids (Insolubles).	NONE			

APPENDIX IV

APPENDIX IV

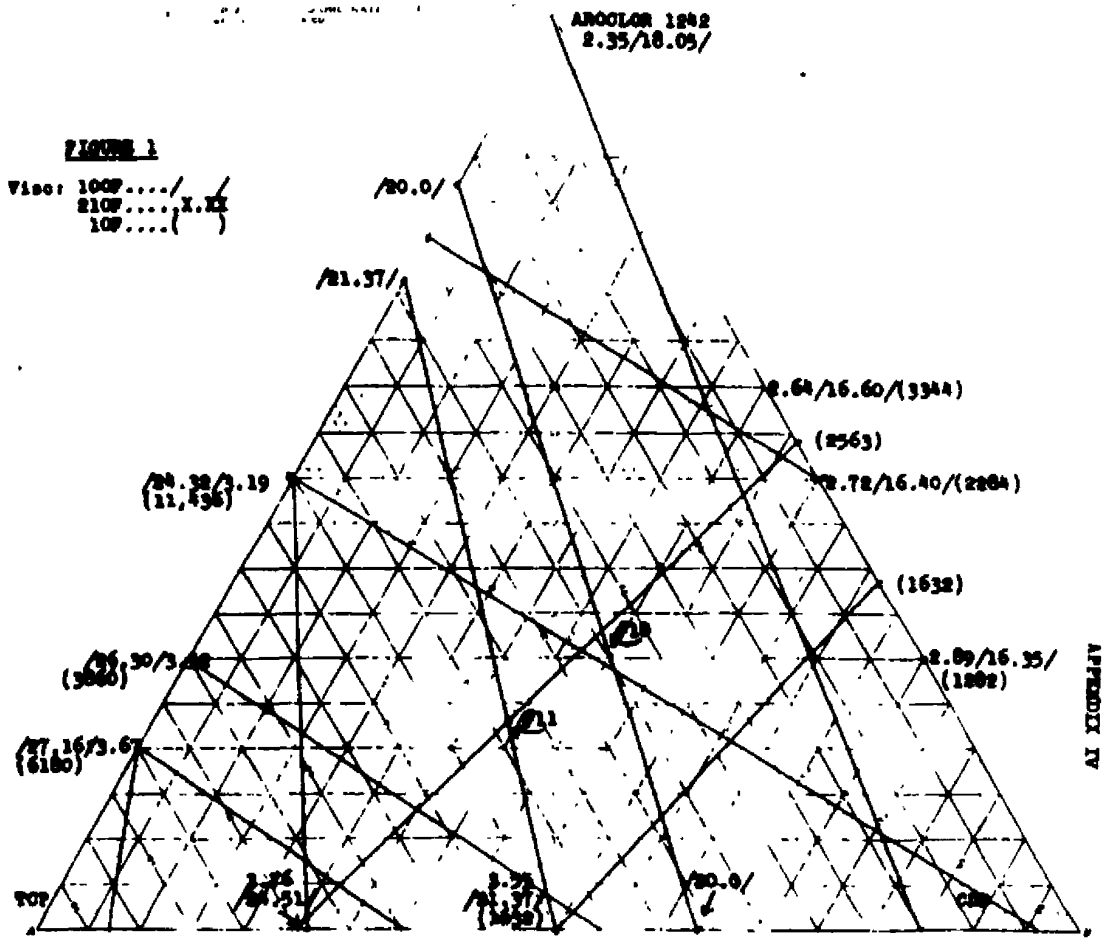
TABLE III

REPUBLIC STEEL CO

HYDROLYTIC / THERMAL STABILITY TEST

(TEMP 280°F, 0.2% H_2O)
(OVEN TEST)

	PYDRAUL 150	HOUGHTO-SAFE 1010	F2744a	MCS 312 QD-2
VN				
INITIAL	0.07	0.02	0.10	0.10
AFTER 24 Hrs	0.46	0.10	0.13	0.15
48 Hrs.	0.73	0.10	0.14	0.24
73 Hrs.	1.40	0.12	0.11	0.14
119 Hrs	4.37	0.14	0.21	0.57
168 Hrs.	-	0.20	0.18	1.21
193 Hrs	-	0.24	0.19	1.78
242 Hrs	-	0.44	0.25	3.42
Final Visc.				
100	NA	20.81	55.5	83.9
210	NA	3.48	6.11	8.63
Initial Visc				
100	29.44	20.36	28.05	69.2
210	7.00	3.45	4.26	7.7
% Increase				
100	-	+ 2.2 %	+ 98.7%	+ 21.2%
210	-	+ 0.8 %	+ 43.5%	+ 11.7%

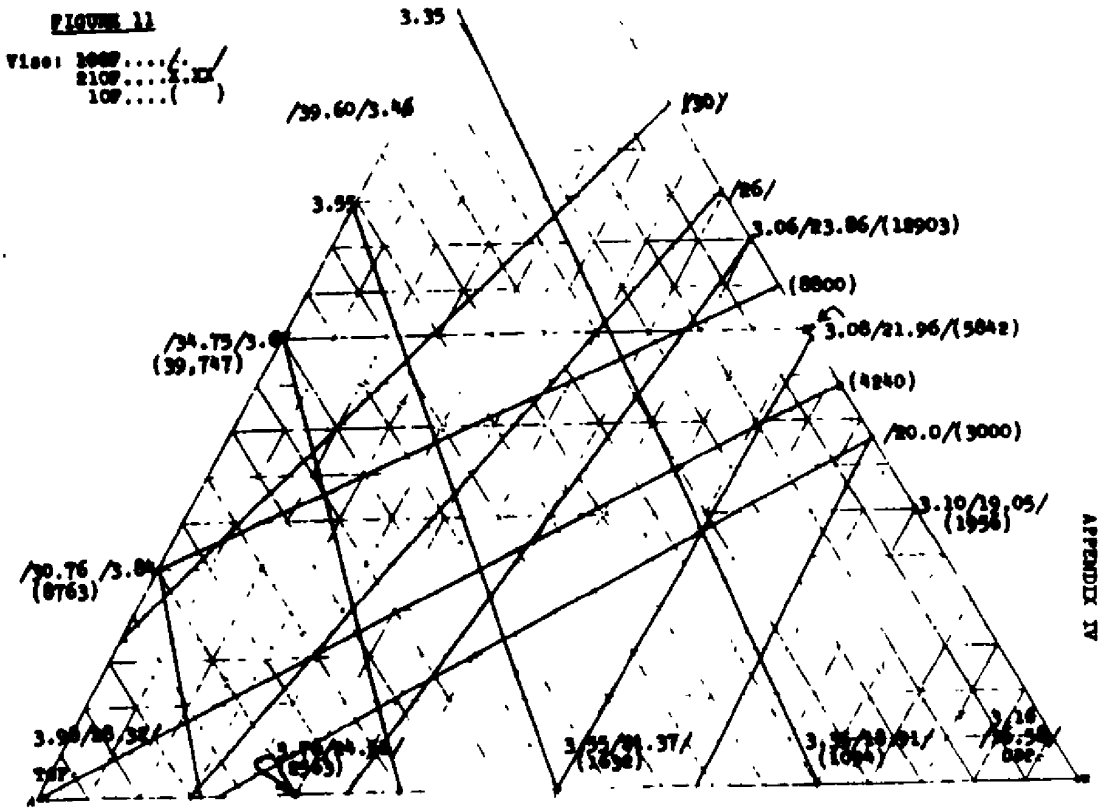


APPENDIX IV

MONS 021275

AROCLOR 1248
3.20/44.06/

FIGURE 11



APPENDIX IV

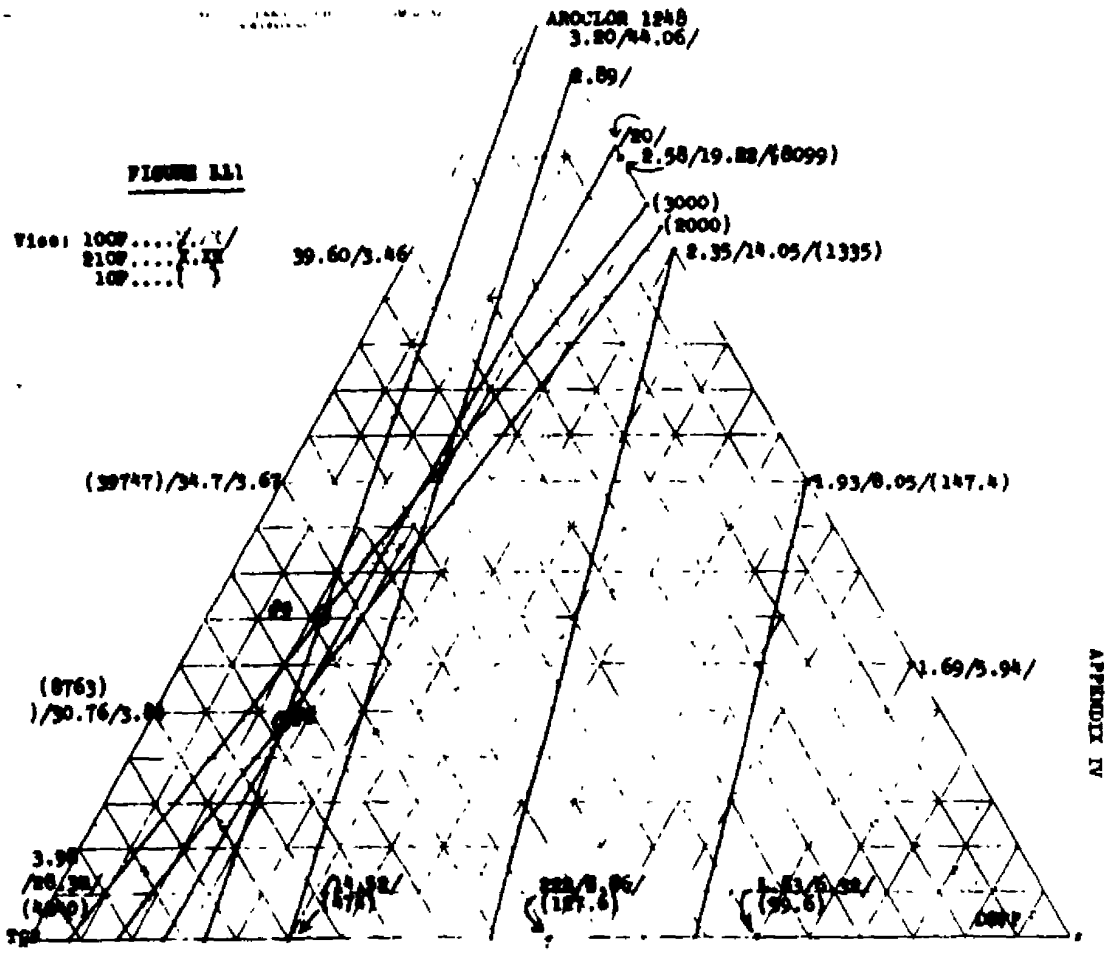


FIGURE III
AROCLOR 1248
3.80/44.06/
8.89/
8.58/19.88/(8099)
(3000)
(2000)
8.35/14.05/(1335)
39.60/3.46/
(39747)/34.7/3.67
1.93/8.05/(147.4)
1.69/5.94/
(8763)
APPENDIX IV

APPENDIX IV

General Offices - St. Louis

January 21, 1966

G. R. Buchanan/RD/DPS
M. McEwen/REH/DJM/KLM
W. R. Richard - Queeny
L. R. Stark
→W. W. Street - Queeny

C. L. Early

Enclosed are copies of the reports from Younger Laboratories showing the results of the toxicity studies on MCS 395 and MCS 404. For those not receiving a copy of the report, the summary is shown below.

SUMMARY - MCS 395

A) Oral LD_{50} (Rats, Mixed Sex)
The Oral LD_{50} for male and female rats was placed at 4615 milligrams per kilogram with lower and upper limits of 4060 to 5260 milligrams per kilogram.

The compound was classed as slightly toxic by oral ingestion in male and female rats.

B) Oral MLD (Rabbits, Mixed Sex)
The Minimum Lethal Oral Dose for male and female rabbits was found to be greater than 1580 milligrams per kilogram and less than 2510 milligrams per kilogram.

The compound was classed as slightly toxic by oral ingestion in male and female rabbits.

C) Skin Absorption MLD (Rabbits, Mixed Sex)
The Minimum Lethal Dose by skin absorption in male and female rabbits was found to be greater than 2510 milligrams per kilogram and less than 3980 milligrams per kilogram.

The compound was classed as slightly toxic by skin absorption in male and female rabbits.

D) Skin Irritation (Rabbits, Mixed Sex)
The compound was classed as non-irritating when applied to the intact skin of male and female rabbits.

E) Eye Irritation (Rabbits, Mixed Sex)
The compound was classed as a slight eye irritant in male and female rabbits.

The average maximum score was 8.3 out of a possible 110 in one hour.

F) Vapor Inhalation (Male Rats)
All animals survived the six hour exposure as well as the following ten day observation period.

It was concluded that the vapors were practically non-toxic

under conditions of the test.

MCS 404

A) Oral LD_{50} (Rats, Mixed Sex)
The Oral LD_{50} for male and female rats was placed at 19,800 milligrams per kilogram with lower and upper limits of 17,030 to 23,165 milligrams per kilogram.

The compound was classed as practically non-toxic by oral ingestion in male and female rats.

B) Oral MLD (Rabbits, Mixed Sex)
The Minimum Lethal Oral Dose for male and female rabbits was found to be greater than 1580 milligrams per kilogram and less than 2510 milligrams per kilogram.

The compound was classed as slightly toxic by oral ingestion in male and female rabbits.

C) Skin Absorption MLD (Rabbits, Mixed Sex)
The Minimum Lethal Dose by Skin Absorption in male and female rabbits was found to be greater than 1000 milligrams per kilogram and less than 1580 milligrams per kilogram.

The compound was classed as mildly toxic by skin absorption in male and female rabbits.

D) Skin Irritation (Rabbits, Mixed Sex)
The compound was classed as a slight skin irritant when applied undiluted to intact skin of male and female rabbits.

The average maximum score was 0.6 out of a possible 8 in twenty-four hours.

E) Eye Irritation (Rabbits, Mixed Sex)
The compound was classed as a slight eye irritant in male and female rabbits.

The average maximum score was 11.6 out of a possible 110 in one hour.

F) Vapor Inhalation (Male Rats)
All animals survived the six hour exposure as well as the following ten day observation period.

It was concluded that the vapors were relatively non-toxic under conditions of the test.

INTERPRETATION OF DATA

Since MCS 395 and 404 are related compounds this interpretation of the toxicity data will combine the two reports and we will for your convenience tabulate the results for Hydraul 312, MCS 395 and 404.

The results from the oral administration of undiluted MCS 395 and 404 to mixed sex rats indicates that 395 is approximately five times more toxic than 404. MCS 395 is classed as slightly toxic, whereas MCS 404 is classed as practically non-toxic.

The results from the oral administration of undiluted MCS 395 and 404 to mixed sex rabbits indicates that the minimal lethal dose for these two preparations is approximately the same. Both are classed as slightly toxic.

When the preparations were applied undiluted to the clipped intact skin of mixed sex rabbits the results indicated MCS 395 was classed as slightly toxic, while MCS 404 was slightly more toxic, being classed as mildly toxic.

The skin irritation studies on rabbits indicated that undiluted MCS 395 was non-irritant while undiluted MCS 404 was classed as a slight skin irritant.

When the undiluted samples were instilled into the rabbit eye both MCS 395 and 404 were classed as slight eye irritants.

Vapor inhalation studies conducted at ambient temperature on rats exposed for 6 hours indicated that both MCS 395 and 404 were non-toxic.

From these data it appears that the same handling, precautions and label as for Hydraul 312 will suffice.

A tabulation of the toxicity data for Pydraul 312, MCS 395 and 404 is as follows:

	Pydraul 312	MCS 395	MCS 404
Oral LD_{50}-Rats	6500 (5460-7735) mg/kg	4615 (4060-5260) mg/kg	19,800 (17030-23165) mg/kg
Oral LD_{50}-Rabbits		1580-2510 mg/kg	1580-2510 mg/kg
Skin Absorption Rabbits MLD	2000-3160 mg/kg	2510-3980 mg/kg	1000-1580 mg/kg
Skin Irritation Rabbits Max. score after	1.3/8 24 hrs.	0/8 24 hrs	0.6/8 24 hrs.
Eye Irritation Rabbit Max. score after	13.0/110 24 hrs.	4.6/130 24 hrs.	7.6/110 24 hrs.
Vapor Inhalation Rats Deaths/number exposed	0/4	0/4	0/4

William E. Hunt, Ph.D.
Toxicologist
Medical Department

[redacted]:cjs

TABLE I

FACTORY MUTUAL APPROVED CANDIDATES

PHYSICAL AND FUNCTIONAL PROPERTIES

Composition	F2792	F2805	F2817	F2828
CRUDE BIPHENYL CHLORINATED (F2782)	99.7	–	99.0	–
CRUDE BIPHENYL CHLORINATED (F2812a)	–	99.7	–	–
AROCLOR 1142 (F2812a)	–	–	–	35.0
AROCLOR 1148 (F2827)	–	–	–	64.2
DIPHENYL PHOSPHITE	0.2	0.2	–	0.0
DIISOPROPYL PHOSPHITE (A88)	–	–	0.2	–
LUBRIZOL 1360	–	–	–	0.5
SANTOLUBE 70	0.1	0.1	0.3	0.3
Appearance DCF 200	0.002	0.002	0.002	0.002
	DARK BROWN-BLACK FLUID			
Viscosity (CS) at 210°F	3.69	3.12	3.81	2.90
100°F	54.9	34.2	56.2	32.16
°F				
+40°F	8729.	2500.	8254.	2670.
°F				
Viscosity Index	-578	-434		-485
Pour Point, °F				
Density (g/ml at 73°F	1.3839	1.3646	1.388	1.426
Acidity TAN mg KOH/g.	0.1	0.1	0.24	0.78

APPENDIX A

Page 1

MONS 021282

TABLE I

FACTORY MUTUAL APPROVED CANDIDATES

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	F2792	F2805	F2817	F2823
Flash Point, COC°F.	360	370	375	385
Fire Point, COC°F.	605	590	620	640
Molten Metal Ignition (Aluminum Alloy at 1200-1300°F)				
1 Spontaneous:	1. DOES NOT FLASH			
2. Without Spark:	2. DOES NOT FLASH OR BURN	SAME	SAME	SAME
3. With Spark:	3. SELF EXTINGUISHING			
High Pressure Spray Flammability AMS 3150C. Fluid Temp. 140°F	FOR ALL FOUR FORMULATIONS NO FLASHES OCCURRED OUT TO SEVEN FEET FROM THE ORIFICE. LOCAL BURNING CARRIED 4-6 INCHES FROM THE TIP OF THE TORCH			
Hot Manifold (1300°F)	SAME FOR ALL FOUR FORMULATIONS FLUID BURNED WITH A VERY SMALL FLAME ON THE TUBE. NO BURNING IN THE PAN.			

Page 2

TABLE I

FACTORY MUTUAL APPROVED CANDIDATES

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	F2792	F2805	F2817	F2842
Pipe Cleaner (Bu Mines Sched. 50)				
No. cycles before burning through one complete cycle.				
Low Pressure Spray.				
F. M. Channel Iron Spray Ignition Test				
Fluid Temp: 140-5°F				
To 1 °F	860	940		
To 2 °F	1260	1290		
To 3 °F	1030	1140		
To 4 °F	1180	1110		
To 5 °F	880	1030		
Results	No Ignition	No Ignition		

AIT

TABLE I

FACTORY MUTUAL APPROVED CANDIDATES

PHYSICAL AND FUNCTIONAL PROPERTIES

Hydrolytic Stability.	F2792	F2805	F2817	F2828
(Beverage Bottle Test 200°F 48 Hrs.)				
Viscosity				
100°F Initial	54.90	34.20	56.2	
Final	56.70	34.09	57.0	
% Change	+3.28	− 0.38	—	
200°F Initial	3.69	3.12	3.81	
Final	3.76	3.14	3.77	
% Change	+ 1.90	+0.6	—	
Acidity				
Fluid Layer.				
TAN Initial	0.56		0.24	
TAN Final	0.05		—	
Change	− 0.51		—	
Water Layer			FLUID EMULSIFIED	
(MgMeOH/g fluid)	0.48	0.47		
Wt. loss Copper Specimen (g)	+0.0014	+0.0011	−0.0070	
Appearance of Specimen.	DULL, NO PITTING OR ETCHING	SAME	SAME	
Solids (Insolubles).	NONE	NONE	EMULSION	

Page 1

TABLE I

FACTORY MUTUAL APPROVED CANDIDATES

PHYSICAL AND FUNCTIONAL PROPERTIES

Oxidation - Corrosion.	F2792	F2805	F2817	F2828
250°F, 168 Hrs.				
Metal Attack Mg/CM²				
Copper	-0.04	-0.33	-0.46	- 0 04
Magnesium	+0.12	+0.16	-0.02	NIL
Steel	+0.13	+0.19	-0.03	- 0 01
Aluminum	+0.18	+0.21	-0.01	NIL
Cadmium	+0.10	+0.10	-0.08	- 0 04
Viscosity				
100°F Initial	54.9	34.2	56 2	32.21
Final	58.8	37 8	60 7	36 22
% Change	+ 7.1	+ 10.5	+ 8.00	12.4
200°F Initial	3.69	3.12	3.81	7 90
Final	3.81	3.24	3 92	3.14.
% Change	+ 3.25	+ 3.84	2.88	5.51
Acidity				
Initial, TAN	0.10	0 10	0 10	0 78
Final, TAN	0.26	0 08	6.40	0 75

MONS 021286

TABLE I

FACTORY MUTUAL APPROVED CANDIDATES

PHYSICAL AND FUNCTIONAL PROPERTIES

Property		F2792	F2805	F2817	F2828
Four Ball Wear 1 Hour, 167°F 600RPM.					
Steel-On-Steel	4 Kg	0.20	0.18	0.17	0.18
	10 Kg	0.23	0.32	0.23	0.24
	40 Kg	0.53	0.66	0.50	0.44
	— Kg	—			
Steel-On-Bronze	10 Kg	0.38	0.38	0.44	0.59
	— Kg				
Hydraulic Pump Test (140°F, 1000Hrs., 1000PSI.)			TEST STOPPED AFTER 326 HRS. DUE TO FILTER CLOGGING, PRESSURE DROP & HIGH WEAR		
Weight Losses (g). Pressure Plates	2015	-0.0128 *		-0.0725	-0.0180 **
	2016	-0.0509 *		-0.0439	-0.1265
Ring		-0.0164		-0.0054	-0.0132
Vanes		-0.0002		-0.0006	-0.0087
Viscosity 100°F	Initial	54.9	34.2	52.65	33.34
	Final	54.4	32.5	52.98	
	% Chg.	-0.9	-4.8	+0.63	
200°F	Initial	3.69	3.12	3.73	
	Final	3.68	3.07	3.68	
	% Chg.	-0.3	-1.6	-0.4	
Acidity, mg KOH/g.					
	Initial	0.10	0.10	0.24	
	Final	0.10	0.13	0.28	

MONS 021287

* ORIGINAL PRESSURE PLATES REPLACED AFTER 415 HRS SECOND SET OF PLATES HAVE 585 HRS RUNNING TIME

** TEST STOPPED AFTER 597 HRS. 900PSI AT < 1.0 GPM.

TABLE I

FACTORY MUTUAL APPROVED CANDIDATES

PHYSICAL AND FUNCTIONAL PROPERTIES

Elastomer Compatibility (158°F 168 Hrs.)	F2792	F2805	F2817		F2828
Butyl					
Durometer "A" Hardness Initial	67	66	65	65	66
Final	50	48	40	46	45
Wt. Increase	48.4	54.2	65.3	65.7	89
Volume Increase	32.8	45.8	56.9	40.7	85
EPR					
Durometer "A" Hardness Initial	70	70	70	70	68
Final	58	58	58	56	47
Wt. Increase	38.1	40.3	44.3	44.5	63
Volume Increase	35.0	36.6	40.4	39.7	66
Viton					
Durometer "A" Hardness Initial	66	65	65	65	67
Final	63	65	63	60	66
Wt. Increase	0.44	2.97	1.17	1.11	0.5
Volume Increase	3.49	3.87	3.27	2.44	2.5
Silicone					
Durometer "A" Hardness Initial					
Final					
Wt. Increase					
Volume Increase					

APPENDIX V

TABLE II

BUREAU OF MINES EVAPORATION FLAMMABILITY (WICK) TEST (PHASE 1)

TEST DATA.

FLUID	FLAME HEIGHT	NO. OF TESTS	AVE. WT OF WICK	AVE WT. BIL	AVE NO. CYCLES	STEAD OF CY'L
MCS 312 QD-2	4 ± IN.	12	0.194 g	0.435 g	21.2	16-23
MCS 312 QD-2	4 IN.	10	0.201 g	0.399 g	23.5	21-25
MCS 396	4 ± IN	8	0.190 g	0 464 g	24 0	23-25
MCS 396	4 IN	10	0 202 g	0.401 g	26 5	24-30
MCS 312 QD-2	4 IN.	8	0.193 g	0 392 g	23 0	22-24
UCON CP 275 (WATER GLYCOL)	4 IN.	9	0.190 g	0.455 g	34.1	28-39
PERMAMUL FR (EMULSION)	4 IN	9	0.190 g	0 387 g	24.1	21-28
OR 18884-3	4 IN	9	0.193 g	0.412 g	27.5	24-31

TABLE I

Low Cost Fluids for Coal Mine Machinery

PHYSICAL AND FUNCTIONAL PROPERTIES

Composition (WT PERCENT)	F2782	F2811	F2786	F2806
CRUDE BIPHENYL CHLORINATED	61.4	—	65.9	—
F2782	—	—	—	61.9
F2782a	—	—	—	—
F2812	—	53.9	—	—
F2812a	—	—	—	—
GULF 200 BRIGHT STOCK	24.0	32.0	20.0	24.0
SANTICIZER 141	14.0	14.0	14.0	—
SANTICIZER 140 (CDP)	—	—	—	14.0
TCP	—	—	—	—
ADMEX 710	0.5	—	—	—
SANTOLUBE 70	0.1	0.1	0.1	0.1
Appearance DCF 200	0.002	0.002	0.002	0.002
	DARK GREEN-BLACK FLUID	SAME	SAME	SAME
Viscosity (CS) at 210°F	6.48	7.09	5.99	6.21
100°F	66.25	67.08	67.3	66.1
+40°F	1439.	1105.	2643.	1900
—°F				
—°F				
Viscosity Index	+22	+58	−16	+3
Pour Point, °F	—	—	—	—
Density (g/ml at 73 °F	1.1783	1.1224	1.1207	1.1802
Acidity TAN mg KOH/g.	0.10	0.03	0.09	0.07

APPENDIX VI

Page 1

MONS 021290

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	F2783	F2811	F2786	F2812
Flash Point, COC°F.	395	370	400	365
Fire Point, COC°F.	555	555	715	630
Molten Metal Ignition (Aluminum Alloy at 1200-1300°F)	ALL FOUR FLUIDS THE SAME. DO NOT IGNITE SPONTANEOUSLY. FLASH OCCASIONALLY WITHOUT A SPARK AFTER NEARLY ALL OF THE FLUID HAS VAPORIZED. FLASHES WITH A SPARK AND IS SELF EXTINGUISHING UNTIL ABOUT ONE-HALF OF THE FLUID HAS VAPORIZED, THEN FLASHES AND BURNS TO COMPLETION.			
Spontaneous:				
Without Spark:				
With Spark:				
High Pressure Spray Flammability AMS 3150C.	ALL FOUR FLUIDS SAME. FLUID DOES NOT FLASH OUT TO SIX FEET FROM ORIFICE. FLAMES CARRY FOUR TO EIGHT INCHES FROM TIP OF TORCH IN LOCAL BURNING.			
Fluid Temp. 140°F				
Hot Manifold (1300°F)	ALL FOUR FLUIDS SAME. FLUID BURNED ON THE TUBE, DID NOT BURN ON LEAVING THE TUBE OR IN THE PAN			

Page 2

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	F2783	F2811	F2786	F280X
Pipe Cleaner (Bu Mines Sched. 50) No. cycles before burning through one complete cycle.	27.6	30.2	-	30 0
Low Pressure Spray:				
F. M. Channel Iron Spray Ignition Test				
Fluid Temp: 140-5F				
To 1 °F	940			1010
To 2 °F	1340			1400
To 3 °F	1110			1130
To 4 °F	1270			1230
To 5 °F	1090			1060
Results	BURNED AFTER A DELAY OF ABOUT 5 SECONDS			BURNED AFTER A DELAY OF ABOUT 5 SECONDS

AIT

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	F2783	F2811	F2806
Four Ball Wear 1 Hour, 167°F 600 RPM.			
Steel-On-Steel			
4 Kg	0.20	0.19	0.18
10 Kg	0.25	0.23	0.20
40 Kg	0.49	0.47	0.52
__ Kg			
Steel-On-Bronze			
10 Kg	1.05	0.79	0.48
__ Kg			
Hydraulic Pump Test (140°F, 1000Hrs., 1000PSI.)			
Weight Losses			
Pressure Plates			
2015	-0.0025	-0.0279	-0.0524
2016	-0.0072	-0.0296	-0.0035
Ring	-0.0011	-0.0030	-0.0026
Vanes	-0.0010	-0.0017	-0.0027
Viscosity			
100°F Initial	64.94	64.61	66.36
Final	72.00	65.85	66.14
% Chg.	+10.9	+1.9	-0.33
200°F Initial	6.50	6.87	6.24
Final	6.80	6.87	6.17
% Chg.	+4.6	-	-1.1
Acidity, mg KOH/g.			
Initial	0.10	0.03	0.07
Final	0.63	0.23	0.27

TABLE 1

PHYSICAL AND FUNCTIONAL PROPERTIES

Hydrolytic Stability.	F2783	F2811	F2786	F2802
(Beverage Bottle Test 200°F 48 Hrs.)				
Viscosity				
100°F Initial	66.25	67 98	67.30	66 10
Final	66.16	67.58	67.09	67 91
% Change	- 0.13	+0.74	0.31	2 74
200°F Initial	6.48	7.09	5 99	6 21
Final	6.52	7 04	6.04	6.25
% Change	+ 0.62	-0.70	+ 0 83	+ 0 64
Acidity				
Fluid Layer.				
TAN Initial	0.09	0 03	0.09	0.07
TAN Final	0.12	0 05	0 12	0 13
Change	+ 0 03	+ 0 02	+ 0 03	+ 0.06
Water Layer				
(MgMeOH/g fluid)	0 008	0.016	0.023	0 021
Wt. loss Copper Specimen (g)	- 0 0151	+ 0 0016	0 0528	0 0019
Appearance of Specimen.	DULL COPPER COLOR NO PITTING OR ETCHING	SAME	SAME	SAME
Solids (Insolubles).	NONE	NONE	NONE	NONE

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Oxidation - Corrosion.	F2783	F2811	F2786	F2806
250°F, 168 Hrs.				
Metal Attack mg/cm²				
Copper	-0.54	-1.50	-0.26	-0.09
Magnesium	-0.03	-0.02	-0.01	-0.02
Steel	NIL	-0.04	NIL	-0.03
Aluminum	-0.05	-0.01	0.01	NIL
Cadmium	-0.34	-0.07	-0.03	-0.03
Viscosity				
100°F Initial	66.25	67.1	66.67	66.1
Final	93.52	79.1	82.20	73.8
% Change	+41.2	+17.9	+23.3	+11.6
200°F Initial	6.48	7.09	5.98	6.21
Final	7.94	7.93	6.74	6.60
% Change	+22.5	+11.8	+12.7	+6.28
Acidity				
Initial, TAN	0.09	0.03	0.09	0.07
Final, TAN	2.56	0.97	0.92	0.54

MONS 021295

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Elastomer Compatibility (158°F 168 Hrs.)	F2783	F2811		F2806
Butyl				
Durometer "A" Hardness Initial	68	63	65	66
Final	53	42	42	46
Wt. Increase	62.1	69	63.8	44.2
Volume Increase	65.8	67.9	69.2	46.2
EPR				
Durometer "A" Hardness Initial	71	68	70	72
Final	50	47	47	55
Wt. Increase	36.6	59.3	57.2	50.0
Volume Increase	45.6	65.4	64.8	54.2
Viton				
Durometer "A" Hardness Initial	66	65	65	67
Final	64	60	62	62
Wt. Increase	0.99	2.32	2.31	0.55
Volume Increase	3.21	4.93	6.31	3.32
Silicone				
Durometer "A" Hardness Initial				
Final				
Wt. Increase				
Volume Increase				

TABLE II

LOW COST FLUIDS FOR COAL MINE MACHINERY

PHYSICAL AND FUNCTIONAL PROPERTIES

Composition (WT. %)	MCS 396	MCS 397		
GULF 200 BRIGHT STOCK	30.0	38.5		
CRUDE BIPHENYL CHLORINATED	59.2	50.7		
AROCLOR 1142	10.0	10.0		
SANTICIZER 141	0.3	0.3		
SANTOLUBE 70	0.5	0.5		
ADMEX 710	25 PPM	25 PPM		
D.C 200 DEFOAMER				
Appearance	BLACK OILY FLUID.	BROWN-BLACK OILY FLUID.		
Viscosity (CS) at 210°F	6.71	7.40		
100°F	65.58	68.52		
40°F	1150.	955.		
—°F				
—°F				
Viscosity Index	+40.5	+68		
Pour Point, °F	—	—		
Density (g/ml at 73°F	1.149	1.1145		
Acidity TAN mg KOH/g.	—	—		

APPENDIX VI Page 1

MONS 021297

TABLE II

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	MCS 396	MCS 397		
Flash Point, COC°F.	385	385		
Fire Point, COC°F.	520	530		
Molten Metal Ignition (Aluminum Alloy at 1200-1300°F)	SAME FOR BOTH FLUIDS.			
1. Spontaneous:	1. DOES NOT IGNITE			
2. Without Spark:	2 IGNITES AND BURNS TO COMPLETION AFTER ABOUT 60-80% OF THE FLUID HAS VAPORIZED.			
3. With Spark:	3. SELF EXTING. UNTIL 60-80% VAPORIZED THEN FLASHES AND BURNS TO COMPL			
High Pressure Spray Flammability AMS 3150C.	DOES NOT FLASH OUT TO SEVEN FEET FROM THE ORIFICE. FLAMES FROM LOCAL BURNING AT TIP OF TORCH CARRY 6-8 INCHES.			
Fluid Temp. 140°F				
Hot Manifold (1300°F)	BURNS ON THE TUBE. DOES NOT BURN ON LEAVING THE TUBE OR IN THE PAN.			

MONS 021298

TABLE III

PHYSICAL AND FUNCTIONAL PROPERTIES

Composition	MCS 403			
Gulf 200 Bright Stock	30.0			
Aroclor 1142	20.0			
1148	39.7			
Santicizer 141	10.0			
Santolube 70	0.3			
DCF 200	0.002			
Blue Dye	0.003			
Appearance	Dark Blue-Black Oil			
Viscosity (CS) at 210°F	6.77			
100°F	69.30			
40°F	1340.			
—°F				
—°F				
Viscosity Index	+31.5			
Pour Point, °F	-9			
Density (g/ml at 72°F	1.182			
Acidity TAN mg KOH/g.	0.80			

APPENDIX VI

Page 1

MONS 021299

TABLE III

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	MCS 403			
Flash Point, COC°F.	395			
Fire Point, COC°F.	515			
Molten Metal Ignition (Aluminum Alloy at 1200-1300°F)	1. NO IGNITION 2. IGNITES AND BURNS AFTER MOST OF THE FLUID HAS VAPORIZED			
1. Spontaneous:				
2. Without Spark:				
3. With Spark:				
High Pressure Spray Flammability AMS 3150C.	2 SAME AS 312 395, 404			
Fluid Temp. 1150°F	SAME AS PYDRAUL 312, 395 404			
Hot Manifold (1300°F)	BURNS ON TUBE DOES NOT BURN ON LEAVING TUBE OR IN THE PAN. (AT 900°F) DOES NOT BURN ON TUBE.			

Page 2

MONS 021300

TABLE III

PHYSICAL AND FUNCTIONAL PROPERTIES

Oxidation - Corrosion.	MCS403			
250°F, 168 Hrs.				
Metal Attack Mg/Cm²				
Copper	-2.23			
Magnesium	+0.01			
Steel	+0.01			
Aluminum	nil			
Cadmium	-0.03			
Viscosity				
100°F Initial	69.85			
Final	83.43			
% Change	+19.4			
200°F Initial	6.78			
Final	7.67			
% Change	+13.1			
Acidity				
Initial, TAN	0.30			
Final, TAN	2.25			

TABLE II

PHYSICAL AND FUNCTIONAL PROPERTIES

Hydrolytic Stability.	MCS 403			
(Beverage Bottle Test 200°F 48 Hrs.)				
Viscosity				
100°F Initial	69.30			
Final	69.85			
% Change	0.8%			
200°F Initial	6.77			
Final	6.78			
% Change	—			
Acidity				
Fluid Layer.				
TAN Initial	0.30			
TAN Final	0.33			
Change	+0.03			
Water Layer				
(MgMeOH/g fluid)	0.0344			
Wt. loss Copper Specimen (g)	-0.0010			
Appearance of Specimen.	Bright copper color			
Solids (Insolubles).	None			

Page 1

TABLE III

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	MC5403			
Four Ball Wear				
___Hour, ___°F				
___RPM.				
Steel-On-Steel				
4 Kg				
10 Kg				
40 Kg				
__ Kg				
Steel-On-Bronze				
10 Kg				
__ Kg				
Hydraulic Pump Test (140°F, 1000 Hrs., 1000 PSI.)				
Weight Losses				
Pressure Plates				
2015	-0.0003			
2016	-0.0058			
Ring	-0.0027			
Vanes	-0.0017			
Viscosity				
100°F Initial	67.21			
Final	70.40			
% Chg.				
200°F Initial	6.74			
Final	6.86			
% Chg.				
Acidity, mg KOH/g.				
Initial	0.21			
Final	0.30			

MONS 021303

TABLE III

PHYSICAL AND FUNCTIONAL PROPERTIES

Elastomer Compatibility (158°F 168 Hrs.)	MCS403			
Butyl				
Durometer "A" Hardness Initial	60			
Final	42			
Wt. Increase	64.4			
Volume Increase	61.2			
EPR				
Durometer "A" Hardness Initial	71			
Final	53			
Wt. Increase	66.7			
Volume Increase	37.4			
Viton				
Durometer "A" Hardness Initial	67			
Final	64			
Wt. Increase	0.76			
Volume Increase	0.37			
Silicone				
Durometer "A" Hardness Initial	71			
Final	67			
Wt. Increase	5.14			
Volume Increase	4.0			

MONS 021304

TABLE IV

Low Cost Hydraulic Fluid for Coal Mine Machinery

PHYSICAL AND FUNCTIONAL PROPERTIES

Composition	F2869	F2870	F2871	F2872
Kerr McGee G-Stock	30.0	30.0	30.0	
Kerr McGee M-200	—	—	—	30.0
Aroclor 1148	7.0	20.0	12.0	14.0
Aroclor 1192	55.7	43.7	50.7	49.7
TCP	7.0	—	—	—
Santicizer 141	—	6.0	—	6.0
Chlorophenyl Diphenyl Phosphate (MS150)	—	—	7.0	—
Silicone 70	0.3	0.3	0.3	0.3
Dow Corning 200	0.002	0.002	0.002	0.002
Inhibitors	0.003	0.003	0.003	0.003
Viscosity (CS) at 210°F	6.04	6.04	6.12	5.90
100°F	64.98	64.21	65.17	62.57
___°F				
___°F				
___°F				
Viscosity Index				
Pour Point, °F	0°F	0°F	+5°F	+5°F
Density (g/ml at 25°C	1.1890	1.1916	1.1950	1.1905
Acidity TAN mg KOH/g.	0.27	0.26	0.28	0.28

APPENDIX VI

MONS 021305

TABLE IV

PHYSICAL AND FUNCTIONAL PROPERTIES

Property		F2869	F2870	F2871	F2872
Flash Point, COC°F.		385	370		370
Fire Point, COC°F.		680	555		710
Molten Metal Ignition (Aluminum Alloy at 1200-1500°F)	①	No ignition →			
① Spontaneous:	②	Ignition delayed. After most of fluid vaporized the residue occasionally flashes and burns to completion			
② Without Spark:	③	Self extinguishing until most of fluid vaporized. Then flashes and burns to completion.			
③ With Spark:					
High Pressure Spray Flammability MIL 31500.		LOCALIZED BURNING 6-12 INCHES FROM TIP OF TORCH AT DISTANCES OF UP TO SEVEN FEET FROM ORIFICE. →			
Fluid Temp. 140-150°F		WHEN VALVE "JOGGED" SO AS TO BREAK UP STREAM AT ORIFICE, FLUID BURNS READILY ½ TO 2 IN. FROM ORIFICE			
Hot Manifold (1500°F)	AT 1200°F		BURNS ON TUBE BUT NOT IN PAN BELOW		
	AT 925°F		DELAYED IGNITION ON TUBE		
	AT 900°F		NO IGNITION.		

MONS 021306

TABLE IV

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	F2869	F2870	F2871	F2872
Pipe Cleaner (Du Nines Sched. 50)	30.4	25.0		29.4
No. cycles before burning through one complete cycle.				
Low Pressure Spray.				
P. M. Channel Iron Spray Ignition Test				
Fluid Temp: ___°F				
To 1 °F				
To 2 °F				
To 3 °F				
To 4 °F				
To 5 °F				
Results				
AIT				

TABLE IV

PHYSICAL AND FUNCTIONAL PROPERTIES

Hydrolytic Stability.	F2869	F2870	F2871	F2872
(Beverage Bottle Test 200°F 48 Hrs.)				
Viscosity				
100°F Initial	64.98	64.21	65.17	62.57
Final	62.98	63.15	6[illegible]	62.33
% Change	—	—	—	—
200°F Initial	6.04	6.04	6.12	5.90
Final	5.91	6.03	6.02	5.92
% Change	—	—	—	—
Acidity				
Fluid Layer.				
TAN Initial	0.27	0.26	0.28	0.28
TAN Final	0.16	0.20	0.30	0.20
Change	−0.11	−0.06	+0.02	−0.02
Water Layer				
(MgMeOH/g fluid)	0.0133	0.0246	0.0160	0.0160
Wt. loss Copper Specimen (g)	−0.0007	−0.0003	−0.0010	−0.0005
Appearance of Specimen.	SL Dull Cu Color	SL. Dull NO PITTING	SL. Dull NO PITTING	SL Dull no pitting
Solids (Insolubles).	NONE	NONE	NONE	NONE

MONS 021308

TABLE I

Low Cost Low Viscosity Fluid For Deaerd Steel

PHYSICAL AND FUNCTIONAL PROPERTIES

Composition	F28.2			
Mobil 225 SR. Bright	22.0			
Arolor 1242	37.7			
Arolor 1232	6.0			
TCB	20.0			
TCP	14.0			
Santowire 70	0.3			
DCF 200	0.002			
Blue Dye	0.003			
Appearance				
Viscosity (CS)				
at 210°F	3.44			
100°F	18.07			
___°F				
0°F	1785.			
___°F				
Viscosity Index	+55			
Pour Point, °F	-25°F			
Density (g/ml at 25°F	1.2055			
Acidity TAN mg KOH/g	0.26			

APPENDIX VII

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Property		F286.2
Flash Point, COC°F.		330
Fire Point, COC°F.		NONE TO BOILING POINT ABOUT 340°F NONE TO 610°F
Molten Metal Ignition (Aluminum Alloy at 1200-1300°F)		
(1) Spontaneous:	(1)	NO IGNITION
(2) Without Spark:	(2)	IGNITION DELAYED. AFTER MOST OF FLUID VAPORIZED THE RESIDUE OCCASIONALLY FLASHES AND THEN BURNS TO COMPLETION.
(3) With Spark:	(3)	SELF EXTINGUISHING UNTIL MOST OF FLUID VAPORIZED THEN FLASHES AND BURNS TO COMPLETION.
High Pressure Spray Flammability AMS 3150C.		LOCALIZED BURNING ONLY OUT TO 50MM FROM ORIFICE. LOCAL BURNING CARRIED 6-12 IN. FROM TIP OF TORCH. WHEN SPRAY BROKEN UP BY TIP OF TORCH, SPRAY IGNITED WITH FLAMES CARRYING DOWNSTREAM TO HOOD.
Fluid Temp. 150-160°F		
Hot Manifold (1300°F)	AT 1300°F	BURNS ON TUBE. DOES NOT BURN IN PAN.
	925°F	DELAYED IGNITION ON TUBE
	900°F	DOES NOT BURN ON THE TUBE

APPENDIX VII

MONS 021310

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Property	F2862			
Pipe Cleaner (Du Nimes Sched. 50)	29.8			
No. cycles before burning through one complete cycle.				
Low Pressure Spray.				
P. M. Channel Iron Spray Ignition Test				
Fluid Temp: ___°F				
To 1 °F				
To 2 °F				
To 3 °F				
To 4 °F				
To 5 °F				
Results				
AIT	840°F			

APPENDIX VII

TABLE I

PHYSICAL AND FUNCTIONAL PROPERTIES

Hydrolytic Stability.	F286.2			
(Beverage Bottle Test 200°F 48 Hrs.)				
Viscosity				
100°F Initial	18.07			
Final	18.75			
% Change				
200°F Initial	3.44			
Final	3.49			
% Change				
Acidity				
Fluid Layer.				
TAN Initial	0.26			
TAN Final	0.29			
Change				
Water Layer				
(MgNaOH/g fluid)	0.0266			
Wt. lose Copper Specimen (g)	-0.0006			
Appearance of Specimen.	SL. Dull Copper No. PIT OR ETCH.			
Solids (Insolubles).	NONE			

APPENDIX VII

TABLE I

PYDRAUL 280 REFORMULATION WORK

PHYSICAL AND FUNCTIONAL PROPERTIES

Composition	"ORIGINAL" COMPOSITION	CHANGE 1 TO LUBRIZOL 1360 ADDITIVE	NEW FORM RECOMMENDED MCS 371
AROCLOR 1260	21.9	SAME	15.90
AROCLOR 1248	37.1		61.90
AROCLOR 1242	18.5		—
TCP	21.85		21.80
SANTOLUBE 70	0.40		0.40
SANTOLUBE 392	0.25	—	—
LUBRIZOL 1360	—	0.25	—
DYE, OIL BLUE A	0.0007	SAME	0.0007
DEFOAMANT DC-200	0.002		0.002
Viscosity (CS) at 210°F	4.02		4.02
100°F	59.80		59.82
°F			2230
°F			
°F			
Viscosity Index	+15		+20
Pour Point, °F			
Specific Gravity (g/ml) at 25/25°C	1.3949		1.3979
Acidity TAN mg KOH/g.	0.65		0.5

MONS 021313

TABLE II

PYDRAUL 280 PUMP TEST DATA

Property	PHYSICAL AND FUNCTIONAL PROPERTIES TEST DATE 5-19-64	TEST DATE 2-2-65	TEST DATE 5-66
	ORIGINAL	REVISED	NEW
Four Ball Wear	COMPOSITION	COMP TO	COMPOSITION
___Hour, ___°F	(56.2% A200	ELIMINATE	ELIMINATE
___RPM.	43.8% 625	ZN DITHIO-	1242
		LUBE ADD	
Steel-On-Steel			
4 Kg			
10 Kg			MCS 371
40 Kg			
___ Kg			
Steel-On-Bronze			
10 Kg			
___ Kg			
Hydraulic Pump Test			
(___°F, 100Hrs., 1000PSI.)	160°F	140°F	140°F
Weight Losses			
Pressure Plates			
2015	-0.0373	-0.0129	-0.0178
2016	-0.0120	-0.0322	-0.0173
Ring	-0.0034	-0.0150	-0.0016
Vanes	-0.0044	-0.0077	-0.0001
Viscosity			
100°F Initial	61.10	57.13	59.82
Final	61.34	—	59.87
% Chg.			
200°F Initial	4.00	—	4.02
Final	4.01	—	4.02
% Chg.			
Acidity, mg KOH/g.			
Initial			
Final			

TABLE III

PYDRAUL 280 SPECIFICATIONS AND LOT PROPERTIES

	KRUMMRICH PLANT SPEC 4596-280.	LOT PROPERTIES. 1964 KD2301	1964 KD2302	1964 KD2303	1965	QUEENEY QD-4	MCS 371
VISCOSITY (CS)							
100°F	56-62	61.8	58.0	61.1	56.06	57.28	59.82
210°F	3.90-4.10	3.91	3.92	3.98	3.95	3.94	4.02
(50°F)	—		2043			2018	2230
SP GR 25/25°C	1.385-1.405	1.405	1.399	1.395	1.460		1.3979
FLASH POINT (°F)	350 MIN	380	415	400	390		415
POUR POINT	+20 MAX	+14	+18	+16	+26		+20
NN (mg KOH/g)	0.5-0.8	0.80	0.60	0.60	0.73		0.5
MOISTURE	0.15 MAX.	0.01	0.01	0.02	0.01		—

APPENDIX VIII

APPENDIX VIII

St. Louis Research Department

April 27, 1966

Cellulube 220 Conversion
to Pydraul 312

R.D. to L.R.S. dated 3/23/66

Richard Davis RDAVI

B-

L.R.Stark
R.G.Cox
L.R.Richard
C.L.Early

The requested laboratory data for converting Cellulube 220 accounts to Pydraul 312 has been obtained.

Two graphs are attached which will give the specific gravity, 25/25°C., and viscosity - 210°F, of mixtures of Cellulube 220 and Aroclor 1248, the transition fluid. These graphs may be used to determine the composition of the customer's fluid during the period in which he adds Aroclor 1248. When the composition of the system reaches 65% Aroclor 1248 and 35% Cellulube 220, Pydraul 312 may be added without oil phase separation. This corresponds to a fluid having a 210°F. viscosity of 39.64 SUS and a specific gravity of 1.3039. At higher concentrations of 220, about 40% and greater, separation may occur.

Lubricity, foam and elastomer swell tests were run on two formulations. F2859 consists of 65% Aroclor 1248 and 35% Cellulube 220. F2860 consists of 50% F2859 and 50% Pydraul 312. The data is given below:

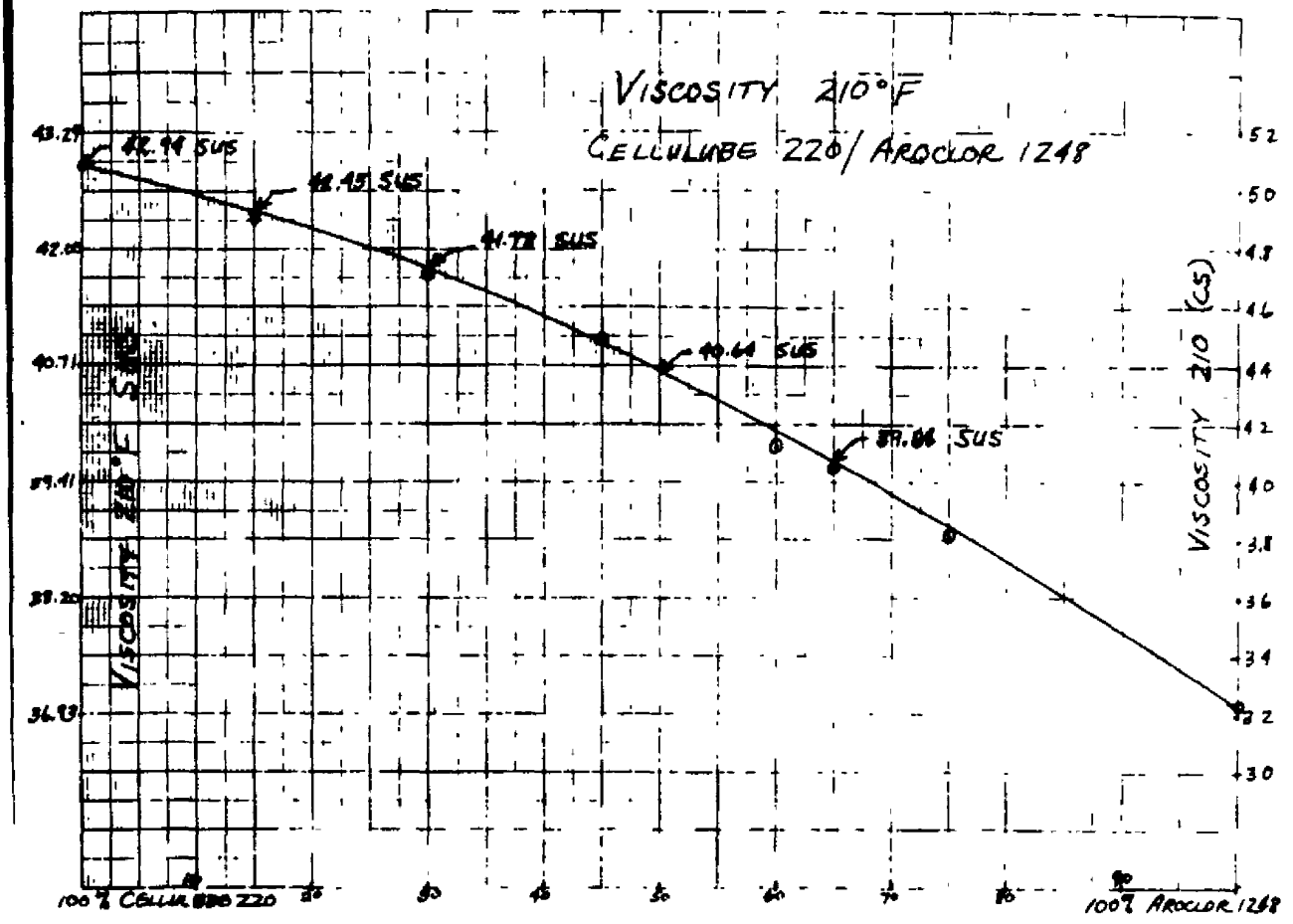
	F2859	F2860
Viscosity - -		
100°F	51.20	55.2
210°F	4.05	5.86
Pour Point	+5°F	0°F
Lubricity - Shell 4 Ball Wear Wear Scar dia. (mm.)		
40 Kg.	0.59	0.54
10 Kg.	0.85	0.22

MONS 021316

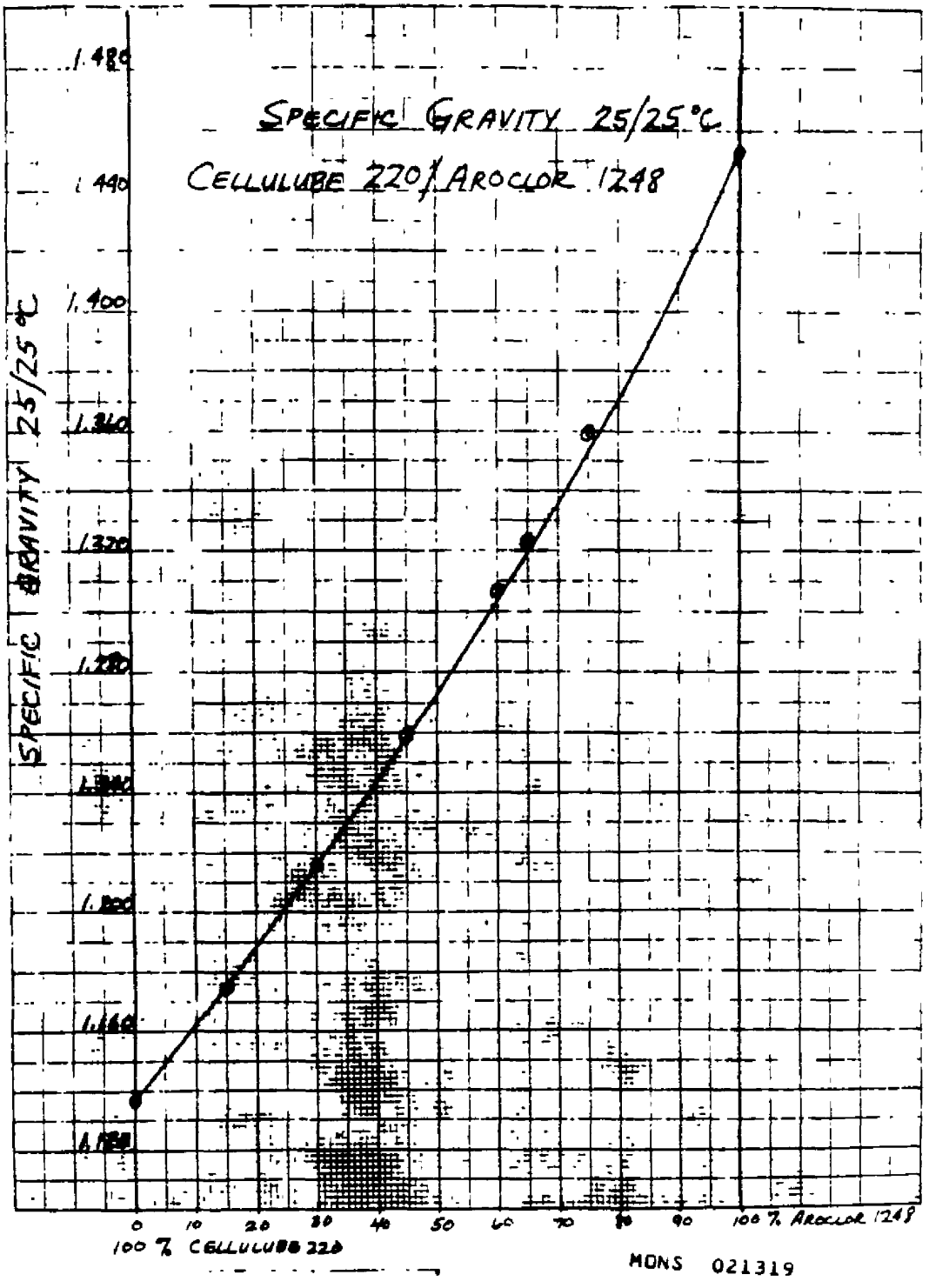
	F285	F2460
Foam Test (ASTM D892) -		
75°F Tendency	60 ml.	0 ml.
75°F Stability	0 ml.	-
200°F Tendency	15 ml.	15 ml.
200°F Stability	0 ml.	0 ml.
75°F Tendency	35 ml.	0 ml.
75°F Stability	0 ml.	-
Elastomer Compatibility (168 Hrs., 150°F Immersion Test)		
Viton		
Durometer "A" Hardness -		
Initial	68	65
Final	64	60
% Volume Increase	0.23	-0.58
% Weight Increase	1.60	1.62
Butyl		
Durometer "A" Hardness -		
Initial	79	79
Final	58	54
% Volume Increase	17.6	50.5
% Weight Increase	23.7	50.5

R. W. Street

MONS 021317


VISCOSITY 210°F
CELLULUBE 220/ AROCLOR 1248
42.94 SUS
42.45 SUS
41.78 SUS
40.64 SUS
39.86 SUS
VISCOSITY 210 (cS)
100% CELLULUBE 220
100% AROCLOR 1248

MONS 021318


SPECIFIC GRAVITY 25/25°C
CELLULUBE 220 / AROCLOR 1248
SPECIFIC GRAVITY 25/25°C
1.480
1.440
1.400
1.360
1.320
1.280
1.240
1.200
1.160
1.120
0
10
20
30
40
50
60
70
80
90
100 % AROCLOR 1248
100 % CELLULUBE 220
MONS 021319

APPENDIX VIII

St. Louis Research Department

May 16, 1966

Cellulube 220 Conversion
to Pydraul 312

R.D. to R.W.S. - 5/3/66

Richard Davis RDAVI
B-2-S

L.R.Stark
R.C.Cox
W.R.Richard
C.L.Early

Here is some additional data which can be used to promote conversion using Pydraul A200 as the intermediate fluid.

Once again, to avoid oil separation the Pydraul A200 content should be 65% or greater before starting to add Pydraul 312. At this level - 65% Pydraul A200, 35% Cellulube 220, F2861, the specific gravity at 25/25°C. is 1.306 and the 210°F. viscosity is 3.73 cs. or 38.60 SUS.

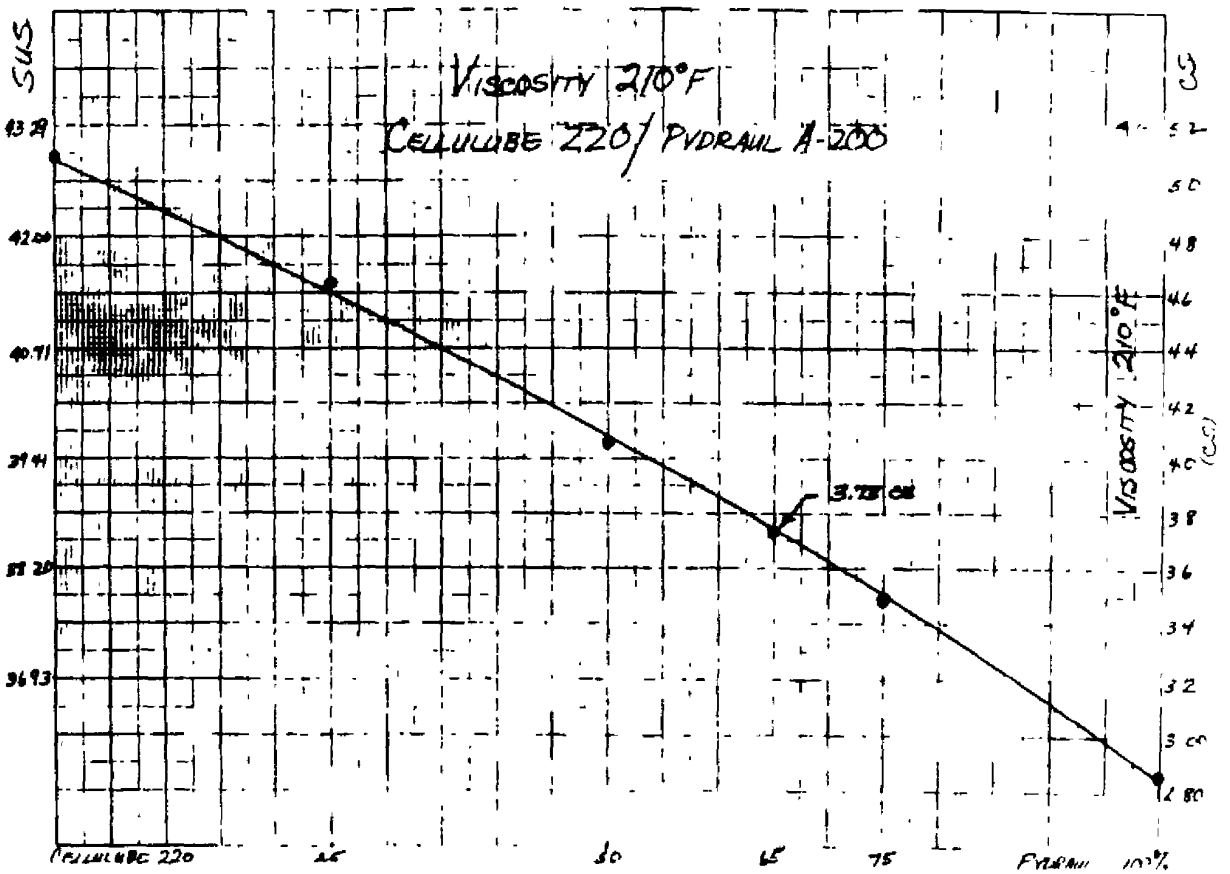
Since the fluid added already contains a defoamer, we would expect no foam problems. The elastomer compatibility is expected to be about the same as F2859 and F2860.

Properties	F2861
Viscosity	
100	40.44
210	3.73
Lubricity Shell 4 Ball Wear Scar dia. (mm)	
40 Kg.	.59
10 Kg.	.25

R. W. Street

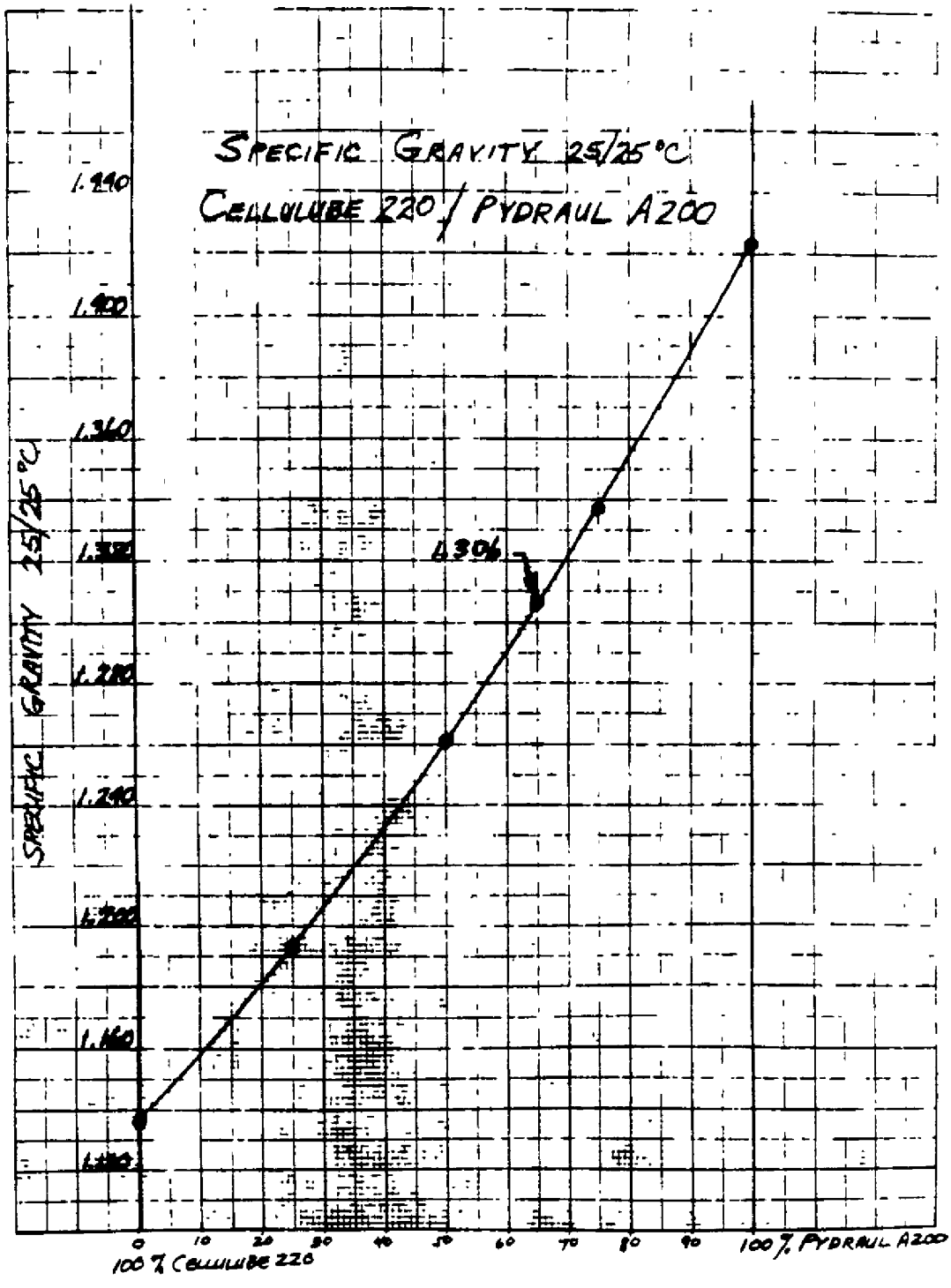
mw

MONS 021320



VISCOSITY 210°F
CELLULUBE 220/ PYDRAUL A-200
SUS
CS
VISCOSITY 210°F
(CS)
3.75 CS
CELLULUBE 220
25
50
65
75
PYDRAUL 100%

MONS 021321


SPECIFIC GRAVITY 25/25 °C
CELLULUBE 220 / PYDRAUL A200
1.440
1.400
1.360
1.320
1.280
1.240
1.200
1.160
1.120
SPECIFIC GRAVITY 25/25 °C
43%
0
10
20
30
40
50
60
70
80
90
100 % CELLULUBE 220
100 % PYDRAUL A200

MONS 021322

[illegible]

R & S

APPENDIX VIII

FROM: S. Louis Research Department

DATE: January [illegible], 1966

SUBJECT: S[illegible] Aroclor 1248/1242 Blend

TO: [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] letter confirms my teletype and also our phone conversation on January [illegible], 1966.

[illegible] for Aroclor 1248/1242 Blend. This product is [illegible] made for [illegible] Corporation, Nitro, West Virginia for use as a hydraulic fluid component.

Composition

		lbs/100 lbs finished goods
Aroclor 1248	Code 81102	72
Aroclor 1242	Code 81101	28

Specifications (Finished Goods)

Property	Tentative Specifications	Typical Property
Viscosity 100°F	150 - 165 SUS	157 SUS
Specific Gravity 25/25°C	1.4335 - 1.4378	1.4355
Color	APHA 100 max.	8
Flash Point (COC)	370°F minimum	[illegible]
Moisture (%)	0.1 max.	0.0[illegible]
Acidity (mg.KOH/g)	0.1 max.	0.001

Blending Conditions

Any suitable vessel can be used. Moderate agitation for 20 minutes at 50°C should insure thorough mixing. Charge of raw materials should not [illegible] more than one percent. In making adjustments, an addition of one percent of either component will change the specific gravity of the blend about 0.0007 units.

Toxicity and Hazards

Usual precautions while working with Aroclors.

R. W. Street

MONS 021323

Monsanto

K W S

APPENDIX VIII

FROM (LOCATION)	St. Louis Research Department	cc	W.R.Richard L.R.Stark J.F.Herber R.E.Hatton/C.L.Early R.Davis/D.F.Smith F.H.Langenfeld/Paul Vance
DATE	December 27, 1965		
SUBJECT	Fire Resistance		
REFERENCE			
TO	File		

The purpose of this memorandum is to discuss some questions which were raised subsequent to Andy Pryor's (Southwest Research Institute) visit to St. Louis. It also seems appropriate at this time to report the results of some recent fire resistance test work.

Several of the questions asked directly or indirectly were:

1. What kind of temperatures are involved in an electrical spark? What degree of fire resistance is required to provide adequate protection against fires caused by an arcing electrical motor?

2. Under what conditions will a spray or stream of 5606 oil ignite and continue to burn after the source of ignition is taken away?

3. What is the effect of preheating a fluid prior to spraying? What is the significance of ambient temperature on the fire resistance of a fluid.

4. What are the explosive limits and temperatures of the Pydraul and Skydrols?

To answer the first question: An electric spark does not have a definable temperature. The word "temperature" implies a measure of average molecular motion. A spark has such a short duration that an equilibrium is not established; consequently, it does not have any one specific temperature. It is obvious that the energy intensity of a welding arc must be high in order to braze two pieces of steel. In this case, it might be reasonable to assume that the molten steel itself constitutes and defines this hazard. It would be an academic question whether a welding arc or the molten steel produced by the arc ignites the fluid since the location of the ignition source is essentially the same.

An electrical spark from a motor is more difficult to discuss. Since a spark usually occurs inside a motor housing and is somewhat confined, the prime hazard appears to be an explosion. The apparatus used by Underwriters in their "Test for Explosiveness of Vapors in Mixture with Air" could be used to measure the degree of protection provided by the fluid. Presently, we do not have this equipment.

Under what conditions will a spray or stream of 5606 oil ignite and continue to burn after removal of the source of ignition? MIL5606 oil ignites and burns readily in our High Pressure Spray Test. The AMS3150C test procedure specifies a nozzle with a straight unbeveled hole, 0.0145 inches in diameter. This orifice gives a solid stream with some overepray developing as the stream breaks up. At 1000 psi fluids usually form a solid stream for about 15 inches before taking on some spray characteristics. Under these conditions 5606 does not continue to burn at the point of ignition after removal of the oxyacetylene torch. One of the affects of heating a fluid is to lower its viscosity giving more spray around the solid stream. Sustained burning does not occur, not even at temperatures of 85-90°C, owing to the high velocity of the stream/spray.

On the other hand, continuous burning takes place when the oil burner nozzle, specified in the Factory Mutual Hot Channel Iron Test, is used. The nozzle gives a very fine 80° solid cone spray pattern. The fluid velocity at 1000 psi is not too great and the oil spray continues to burn until the spray is turned off. In summary, it appears that in order to effect sustained burning the velocity of the stream cannot be too great and the fluid must be predominately a spray or finely divided droplets.

What is the effect of preheating a fluid prior to spraying? One effect, discussed above is a high temperature spray which is more finely divided than a low temperature spray. Moreover, the droplets themselves have a higher temperature; all of which results in easier combustion. A table is attached which presents spray test results for a number of fluids. The fluids are arranged in the table in ascending fire resistance as measured by this test. It may be interesting to note that triaryl phosphates which are self-extinguishing in the molten metal test at 1250°F burn readily when finely divided in a spray. Water oil emulsion fluids seem to be broken by the oil burner nozzle. Shell Irus 902 burns with considerable flames; however, it is not sustained after the torch is removed.

A new spray test under study by a Section VI of TECH N committee of ASTM calls for measuring the flammability of very finely divided sprays produced by the Electr-O-Airless Paint Gun. The source of ignition is a lazy yellow natural gas burner flame. Results of this test are similar to our high pressure spray test modified by the oil burner nozzle.

During Walter Unangst's visit to St. Louis, high pressure spray tests were run on a number of fluids including Hought Safe 1130 - a straight triaryl phosphate ester - and Pydraul 312. The fluids were sprayed at 75°C through the standard straight orifice. Both fluids ignited about - inches from the tip of the orifice when the outer white part of the flame was placed in the stream. Flames carried downstream in intermittent flashes. At further distances from the nozzle, flames did not occur. This phenomena has been observed before, particularly when the flow through the orifice was turbulent. Occasionally the orifice becomes

partially clogged giving a slightly turbulent flow. This was also observed at Underwriters during a test on MCS 404. When the spray-stream was not turbulent, flame propagation downstream did not take place. Whereas, when the stream partially broke up at the nozzle, intermittent flashes carried downstream.

One would expect ambient temperatures to play some role in the results of these spray tests. On a cold day heat diseipation to the atmosphere from a fine spray is likely to be very rapid. Theoretically, if the ambient temperature were greater than the flash point of the fluid, one would expect a flash from even the small flame of a burning match. The AIT can be viewed as that minimum ambient temperature at which a vapor-air mixture will ignite and burn spontaneously. As the ambient temperature becomes lower, the source of ignition must be more intense to produce burning. The following is an example: The high pressure spray (solid stream) of Pydraul F9 ignites with considerable difficulty when an oxyacetylene torch is used. At the most, intermittent flashes carry downstream even when the fluid is heated to 75°C (168°F). When a propane oxygen blast burner is used producing a white bushy 12-15 inch flame, the solid stream burns more readily. Rapid flashes carry down-stream in the spray nine (9) feet to hood. (See Table II)

Pydraul 312 has looked good in our high pressure spray test because its viscosity is high and very little atomization occurs. The very low volatility of the Bright Stock (flash point > 600°F) is also a plus factor in its fire resistance.

In the long range it would be worthwhile knowing the temperatures at which vapor-air mixtures of all the Pydrauls and Skydrols will explode.

Underwriters Testson Pydraul F9 and Pydraul 312 are as follows: Test for Explosiveness of Vapors in a Mixture With Air:

	Pydraul F9	Pydraul 312
Temperature	355°F	285°F

R. W. Street

mw

MONS 021326

TABLE I

MODIFIED HIGH PRESSURE SPRAY TEST (AMS 3150C)

(Oil Burner spray nozzle used - rated at 1.8 gph, 140°F, 100 psi, 80° angle)

Fluid	Temperature	Pressure (psig)	%Cl/%P	Results
1. DTE (Med) Oil	150°F	1000		Spray ignited and burned vigorously. flames carrying downstream 5-6 ft. Burning sustained after removal of the torch.
2. Shell Irus 902	150°F	1000		Spray ignited and burned readily. flames carrying downstream 5 ft. Burning sustained after removal of the torch.
3. Pydraul 312	150°F	1000	19.8/1.23	Spray ignited and burned readily, flames carrying downstream 3-4 feet. Burning sustained 2-5 seconds after removal of the torch.
"	"	600		Same as above, however burning not sustained after removal of torch.
4. HoughtoSafe 1130	150°F	1000 & 600	0/8.0	Same as Pydraul 312, however less smoke.
5. Pydraul 150	150°F	1000 & 600	9.65/6.1	Same as HoughtoSafe 1130; however no sustained burning.
6. MCS 395	150°F	1000	29.2/1.21	Spray ignited and burned readily with flames carrying downstream 2-3 feet. Burning noticeably less intense than Pydraul 312 and HoughtoSafe 1130. Burning not sustained after removal of torch.

TABLE I (Continued)

Fluid	Temperature	Pressure (psig)	%Cl/%F	Results
7. Pydraul F9	150	1000	25.2/3.9	Spray ignited and burned Intermittent flashes carried downstream 3-5 ft, otherwise burning confined to 1-2 feet from tip of torch. Burning not sustained after removal of torch.
8. Pydraul 625	150	1000	30.0/4.4	Same as Pydraul F9.
9. Pydraul AC	150	1000	30.8/3.7	Same as Pydraul F9.
10. MCS 331	150	1000	37.1/1.47	Spray ignited and burned. Intermittent flashes carried downstream 2-3 feet. Otherwise local burning 1-2 feet from tip of torch. No sustained burning.
11. MCS 330	150	1000	40.7/0.88	Same as MCS 331
12. 30% TCP 70% Aroclor 1248	150	1000	33.6/2.6	Spray ignited and burned locally around tip of torch. No flashes. Flames carried one foot and occasionally up to 2 feet from the tip of the torch. More P.R. than Pydraul 625 or Pydraul AC.
13. Pydraul 280	150	1000	38.7/1.88	Spray ignited and burned locally around tip of torch. No flashes.
14. Pydraul A200	150	1000 & 600	46.0/<0.2	Spray ignited and burned locally around tip of torch. Flames carried 4-6 inches
15. Pacemaker Water Glycol	150	1000		Spray did not ignite.

All of the above tests are on film except Nos. 5, 8, 9 and 14.

MONS 021328

TABLE II

MODIFIED HIGH PRESSURE SPRAY TEST (AMS3150C)

(Propane-oxygen blast burner used. White bushy flame 10-12 inches in length)
(Standard nozzle-straight hole. 0.0145 in. dia.)

	Fluid	Temperature	Pressure (psig)	Results
1.	Pydraul 312	140°F	1000	Fluid ignited and burned continuously with flames carrying downstream 9 feet to hood. No sustained burning after removing torch.
2.	HoughtoSafe 1130	122°F	1000	Same as Pydraul 312
3.	Pydraul P9	122°F	1000	Fluid ignited and burned continuously with rapid flashes carrying downstream to hood. Burning less intense than Pydraul 312 or HoughtoSafe 1130.
4.	Pydraul A200	122°F	1000	Only localized burning around tip of torch. Flames carried up to 1-1/2 feet. No flashes.

R. & S.

APPENDIX VIII

FROM (Location) St. Louis Research Department

DATE February 28, 1966

SUBJECT ASTM - Molten Metal Task Work

REFERENCE L. R. Stark's letter dated Sept. 7, 1965

TO L. R. Stark

The tests you described in your letter to the Molten Metal Task Group are finished, and the results are given in the attachment.

The procedure used corresponded closely to that recommended in your letter; however, there were several differences. A Hoskins FD 104 (5 inch dia.) electric furnace was used. The 200 ml. iron crucible (ASTM D189) was supported on a small iron tripod inside the furnace so that the top of the crucible was 1/4 inch above the top of the furnace. An asbestos board (1/4 inch thick) with a 3-1/4 inch dia. hole was placed over the cup to form a collar around the lip of the cup, reduce heat loss, and improve cup stability. All tests were run with the cup supported in the furnace as described. An attempt to remove the cup and run a test without the continuous heating was unsuccessful. The molten metal cooled rapidly to 1100°F and started to solidify within a minute. The temperature of the molten aluminum was measured using a Hoskins Pyrometer Type AH and thermocouple wire. Temperature stability at 1200-1230°F was excellent; however, the heat-up time - 2-1/2 hrs., was much too long.

These tests gave results which are similar to those obtained using the smaller furnace and crucible. The larger crucible has the advantage of much better temperature stability.

R. W. Street

MONS 021330

MOLTEN METAL DROP TEST

Fluid	0.3 ml.	1 ml.	2 ml.
1A1	The fluid ignited after 2-3 seconds and burned to completion.	The fluid ignited after a delay of about 2 seconds. It then burned to completion in 5-6 seconds with flames rising to 10-12 inches high. The burning was intense.	The fluid ignited after 1-2 seconds. It burned intensely for 6-9 seconds with flames rising 10-12 inches high. Black sooty smoke.
2B2	Ignition delayed 20 seconds after which the fluid burned with a lazy yellow flame for an additional 10-15 seconds. Burning was slight to moderate.	Ignition delayed for 20 seconds, after which the fluid ignited and burned with moderate intensity for an additional 30 seconds. Very little smoke.	Same as 1 ml. test
3C1	No ignition, heavy white fumes	Same as 0.3 ml.	No ignition without flame. With a flame the fumes ignited and burned intensely. Fluid continued to burn after the burner was removed
1D2	No ignition, heavy white fumes.	Same as 0.3 ml	No ignition without flame. With a flame the fumes ignited and burned with moderate intensity. The burning stopped when the burner was removed.
501	No ignition, heavy white fumes.	Same as 0.3 ml.	No ignition without flame. With a flame the fumes ignited and continued to burn moderately after the flame was removed.
6K3	Ignition delayed 5-7 seconds. The fluid then ignited and burned with a lazy yellow flame about 5 seconds. Fluid spattered as volatile components boiled off.	Same as 0.3 ml.	Same as 0.3 ml.

Monsanto

APPENDIX VIII

FROM (LOCATION) Organic Research Department
Research Center

DATE June 7, 1966

SUBJECT Pydraul Cavitation Resistance

REFERENCE

cc CEARLy B-2-N
LSTARk W-Bldg.
TMCDOnnell "
WRICHard 2nd, Res.

TO R. W. Street

2nd, Res.

Attached is a summary on cavitation testing of MCS-312 and 404 with additives. As you will note, the ethylene tetrachloride showed a perverse propensity for increasing damage in the sonic probe test at 85°C.

D. R. Miller

cp
att.

85°c - COVERED - MAY 31, 66

FLUID	ADDITIVE	NO RUNS	RUN NO'S	WT LOSS (Mg)	RELATIVE DAMAGE % SKDROL 500A	% BASE
SKYDROL 500A	NONE	2	2805 2810	25.4 26.2	100	194.5
MCS-312	NONE	1	2807	13.2	51.4	100
MCS-312	.2% H_2O	1	2806	9.4	36.4	71.2
MCS-312	.7% ETHYLENE TETRACHLORIDE.	1	2808	13.8	53.4	104.5
MCS-404	.7% ETHYLENE TETRACHLORIDE	1	2809	— 15.7	* 45.0 60.9	* 100 136

* BASED ON PREVIOUS MCS-404 RUN NO'S 2711, 2718

June 3, 66
[signature]

MONS 021333

APPENDIX VIII

Organic Research Department
Research Center - [illegible]-208

March 14, 1966

TMCDOnnell W-102
STARk W-205
WRICHard 2nd, Res.

Ultrasonic Cavitation of Extrusion Machine Fluids

CEARLy

B-2-N

We have tested the samples of Rykon 31, Pydraul 312, and MCS 404 which you submitted. Standard exposure of 45 minutes at 95°C. in covered beakers with nickel tips was employed, with these results:

Fluid	Expt. No.	Gen.	Wt. Loss/gms.	Rel. Rating (Skydrol 500A=100)
Rykon 31	2634	B	.0031	15.4) 18.7 avg.
	2633	B	.0044	21.9)
Pydraul 312	2629	A	.0155	45.2) 41.1 avg.
	2631	A	.0127	37.0)
MCS 404	2630	B	.0096	47.7) 46.0 avg.
	2632	B	.0089	44.4)
Skydrol 500A	2635	A	.0343 (hi)	--
	2636	B	.0201	--

The Pydraul 312 relative rating is probably a little low because of the above average weight loss on reference experiment 2635. A more typical weight loss on generator A with 500A is .0250 gm., which would put 312 in the neighborhood of 56 relative to 500A.

We plan no further work pending your advice.

D. R. Miller

cp

MONS 021334

Monsanto

APPENDIX VIII

FROM (LOCATION) Organic Research Department
Research Center - Q-208

DATE April 29, 1966

SUBJECT Sonic Probe Cavitation of Industrial Hydraulic Fluids

REFERENCE

TO

WRICHard	2nd. Ree.
LSTARk	W-Bldg.
TMCDOnnell	"
CEARLy	B-2-N

RSTREEt

2nd. Ree.

Listed here are our results on MCS 404 and Pydraul A200.

85°C, Gen. B			Relative Damage			
Fluid	No. Expts.	Expt. Nos.	Avg. Wt. Loss Mg	Est. Std. Dev. Mg.	% of Skydrol 500A	% Base Stock
Skydrol 500A	3	2710, 14, 20	17.3	1.2	100	----
MCS 404	2	2711, 18	7.9	.4	45	100
MCS 404 +.25% H_2O	2	2712, 16	1.9	2.5	11	24
Pydraul A 200	1	2722	23.3	-	135	----
67°C. Gen C						
Skydrol 500A	2	2713, 19	26.0	2.6	100	---
MCS 404	1	2715	6.7	-	26	100
MCS 404+.25% H_2O	1	2717	4.0	-	15	60
Pydraul A 200	1	2719	12.6	-	48	---

Nickel tips, 45 minute exposure.

D.R. Miller

cp

APPENDIX IX

MCS 395

Established: March 25, 1966

Composition

		Lbs./
81101	- Aroclor 1242	56.2
81115	- Aroclor 1232	9.0
60820	- Tri-tetrachlorobenzene (49% tetra enriched)	15.0
80071	- Trieresyl phosphate	14.0
44875	- Gulf 200 Bright Stock	25.5
44876*	- Mobil 225 S.R. Bright Stock*	
81787	- Santolube 70	0.3
31100	- Dow Corning 200 Fluid 350 cs.	0.002
20640	- Dye, DuPont Oil Blue A	0.003

*Mobil 225 S.R.Bright Stock may be used interchangeably with the Gulf 200 Bright Stock.

Specifications (4/26/66 tantative)

	Sales	Internal	Procedure
Appearance	Blue green liquid - Free of sediment		16-B
Flash point	330°F min.	340°F min.	50-A
Moisture (By KF in methanol)	0.12% max.	0.08% max.	79-B
Neutralization No. (mg.KOH/g.)	0.50 max.	0.40 max.	80-B
Specific Gravity at 25/25°C	1.1860-1.1920	1.1860-1.1920	116-B
Viscosities:			
at 100°F	26.0 - 31.5	27.5 - 30.5	126-A
at 210°F	4.20- 4.75	4.30-4.65	

Blending Conditions

The total charge of materials should be stirred at a convenient temperature, however, not greater than 60°C.

In bringing batches back into specification, use the following guide:

1. If both specific gravity and viscosity are out of specification, adjust to correct viscosity first. By correcting the viscosity, the specific gravity should fall into place at the same time. If the specific gravity is still off-spec. after viscosity adjustment, proceed to paragraph 2 below.

If the viscosity of the batch is - -

High at 100°F.	Low at 100°F.
Add tri-tetrachlorobenzene 1.0 lbs. 100 lbs./each 1.0 centistoke over 30.0 cs.	Add Bright Stock oil; 1.0 lbs./ 100 lbs./each 1.5 cs. less than 27.5 cs.
at 210°F.	at 210°F.
Add tri-tetrachlorobenzene 1.0 lbs./100 lbs./each 0.1 centistoke over 4.60 cs.	Add Bright Stock oil; 1.0 lbs./ 100 lbs./each 0.1 cs. less than 4.30 cs.

2. If the specific gravity specification is (out-of-specification) low:

   Add a mixture of 35% Aroclor 1242, 65% Aroclor 1248. 1.0 lbs./100 lbs./0.004 units low.

   If the specific gravity is high and the viscosities are within specifications: Add a mixture of 70% TCP, 30% Bright Stock. 1.0%/100 lbs./0.05 units high.

   The viscosity and specific gravity specifications allow for ±1% variation in charge of components - or the equivalent variation resulting in differences in raw materials.

Toxicity and Hazards

Normal Precautions.

Issue #2: April 25, 1966

Replaces Tentative Issue (Memoranda of November 17, 1965 and March 25, 1966)

Developed by: Robert W. Street

Monsanto

APPENDIX IX

Q#.5

FROM (LOCATION): St. Louis Research Department

DEPT: L.R.Stark
W.R.Richard
C.L.Early

DATE: March 2, 1966

SUBJECT: MCS 404 - Change in Composition and Specifications

REFERENCE:

TO: P. N. Biven
R. A. Dykstra
W. J. Hunt

Please make the following change in composition to all future production of MCS 404. When using the Mobil 225 Solvent Refined Bright Stock, the revised charge is 30.0 lbs/100 lbs. finished goods. The total composition for batches made with Gulf 200 Bright Stock is given in the column headed "Original"; the composition for batches made with Mobil 225SR Bright Stock is given in the "Alternate" column.

The specifications for MCS 404 are changed as follows: The viscosity is broadened to 111.0 - 118.0 centistokes at 100°F and 8.20 - 8.90 at 210°F. All other specifications remain the same as before.

Charge adjustments are given in the Blending Instructions below.

Composition

Code	Name	lbs/100 lbs. product Original	Alternate
81102	Aroclor 1248	43.7	45.7
81103	Aroclor 1254	10.0	10.0
44875	Gulf 200 Bright Stock	32.0	-
44876	Mobil 225 SR Bright Stock	-	30.0
80071	Tricresyl phosphate	14.0	14.0
81787	Santolube 70	0.3	0.3
31100	Dow-Corning 200 fluid, 350 cs. grade	0.002	0.002
20640	Dye, DuPont Oil Blue A	0.003	0.003

% Cl calculated
27.3%

MONS 021339

Tentative Specifications

Appearance	Blue green liquid
Moisture	0.08
Flash Point	400°F min.
Neutralization number (mg.KOH/g.)	0.40 max.
Specific gravity 25/25°C	1.16 - 1.20
Viscosity centistokes	
at 100°F	111.0 - 118.0
at 210°F	8.20 - 8.90

Blending Conditions

The total charge of materials should be stirred at a convenient temperature, however, not greater than 60°C. For rapid drumming, the material may be charged to the drums at 50-60°C.

In bringing batches back into specification use the following guide:

1. If both specific gravity and viscosity are out of specification, adjust to correct viscosity first. In bringing the batch back into viscosity specification the gravity should fall into place at the same time. If the specific gravity is still off -spec. after viscosity adjustment, proceed to paragraph (2).

   If the viscosity of the batch is -

High	Low
at 100°F	at 100°F
Add Aroclor 1248. 0.5 lbs/100 lbs/each centistoke over 118 cs.	Add Bright Stock oil 1.0 lbs/100 lbs/each centistoke less than 111 cs.
at 210°F	at 210°F
Add Aroclor 1248 0.5 lbs./100 lbs/each 0.1 cs. over 8.90 cs.	Add Bright Stock oil 1.0 lbs./100 lbs.0.2 cs. less than 8.20 cs.

2. If the specific gravity is (out-of-specification) low: Add - Aroclor 1254. 1.0 lbs/100/lbs/0.003 units low.

   If the specific gravity is high: Add a mixture of 50% Aroclor 1248, 35% Bright Stock oil and 15% TCP. 1.0 lbs. mixture/100 lbs/ 0.003 sp. gr. units high.

R. W. Street

mw

MONS 021340

APPENDIX IX

MCS 90

Established: August 18, 1966

Composition:

			Lbs.
44876	-	Mobil 225 S.R. Bright Stock	22.0
81101	-	Aroclor 1242	37.7
81115	-	Aroclor 1232	6.0
60200	-	Trichlorobenzene	20.0
80071	-	Trioresyl phosphate	14.0
81787	-	Santolube 70	0.3
31100	-	Dow Corning 200 Fluid, 350 cs.	0.002
20640	-	Dye, DuPont Oil Blue A	0.003

Specifications: (Tentative - 8/18/66)

	Sales	Internal	Procedure
Appearance	Blue-green liquid, free of sediment		16-B
Flash Point	320°F min.	325°F min.	50-A
Moisture (By KF in methanol)	0.12% max.	0.08% max.	79-B
Neutralization No.(mg.KOH/g.)	0.50 max.	0.40 max.	80-B
Specific Gravity at 25/25°C	1.1940-1.2100	1.1940-1.2100	116-B
Viscosities (cs.):			
at 100°F	17.40-19.00	17.60-18.70	126-A
210°F	3.15- 3.75	3.25- 3.65	

Blending Conditions:

The total charge of materials should be stirred at a convenient temperature; however, not greater than 60°C.

In bringing batches back into specification, use the following guide:

1. If both specific gravity and viscosity are out of specification, adjust to correct viscosity first. By correcting the viscosity, the specific gravity should fall into place at the same time. If the specific gravity is still off-spec. after viscosity adjustment, proceed to paragraph 2 below.

If the viscosity of the batch is - -

High at 100°F	Low at 100°F
Add trichlorobenzene 0.5 lbs/100 lbs./each 1.0 cs. over 18.70 cs.	Add Bright Stock Oil; 1.0 lbs/100 lbs./each 1.5 cs. less than 17.60 cs.

- Continued -

Blending Conditions: (Continued)

High at 210°F	Low at 210°F
Add trichlorobenzene 0.5 lbs./100 lbs./each 0.1 centistoke over 3.65 cs.	Add Bright Stock oil; 1.0 lbs./100 lbs/each 0.1 cs. less than 3.20 cs.

If the batch is high in viscosity at both 100°F and 210°F, use the adjustment listed for 100°F only.

If the batch is low in viscosity at both 100°F and 210°F, use the adjustment listed for 100°F only.

2. If the specific gravity specification is (out of spec.) low:
   Add a mixture of 95% Aroclor 1242; 5% Aroclor 1248.
   1.0 lbs./100 lbs./0.004 units low.

   If the specific gravity is high and the viscosities are within specification: Add a mixture of 70% TCP, 30% Bright Stock.
   1.0 lbs. mixture/100 lbs/0.05 units high.

   The viscosity specifications allow for approximately ±1% variation in charge of raw materials - or the equivalent variation in differences in raw materials.

Toxicity and Hazards:

Normal Precautions.

Developed by: Robert W. Street

APPENDIX IX

PYDRAUL 312

Established: February 18, 1965

Based On: Tentative Research Process for blending MCS-312, P-1338, Job 4009, of October 8, 1964, and approved amendment #1.

Composition:

		Original lbs.	Alternate lbs.
81101	Aroclor 1242	47.4	47.9
80152	Santicizer 144	14.0	14.0
44875	Oil, Gulf 200 N.C. Bright Stock	38.5	----
44786	Oil, Mobil 225, S.R. Bright Stock	----	38.0
~~10679~~	~~Adnox 710~~	~~0.5~~	~~0.5~~
82113	Santolube 70	0.1	0.1
31100	Dow Corning 200 Fluid, 350 cs	0.002	0.002
20640	Dye, DuPont Oil Blue A	0.003	0.003

Specifications (2-19-65 tentative)

	Sales	Internal	Procedure
Appearance	Blue green liquid	Blue green liquid	16-S
Flash Point	350°F min.	370 to 420	52-A
Moisture (By KF in Methanol)	0.10% max.	0.07% max.	78-S
Neutralization No.	0.30 max.	0.22 max.	80-S
Specific gravity 825/25°C	1.08 to 1.14	1.09 to 1.13	116-A
Viscosities:			126-A
@100°F	63 to 72 cs	64.5 to 71.0 cs	
@210°F	7.1 to 8.0 cs	7.2 to 7.9 cs	

Blending Conditions

Normal. See Process, Section III, Material Mixing

The total charge of materials should be stirred at 45 to 55°C, but not greater than 60°C, to assure thorough mixing and uniformity.

Toxicity and Hazards

Normal precautions.

Issue #1: March 8, 1965 for MCS-312

Issue #2: February 3, 1966 - To show name and composition changes and revised specifications.

Developed By: R. W. Street
Revised By: W. J. Hunt
Approved By: L. J. Stober
L. R. Stark
W. R. Richard

APPENDIX X

ABBREVIATIONS

CDP	-	Cresyldiphenyl phosphate
DBEB	-	Dibromoethylbenzene
DBPP	-	Dibutylphenyl phosphate
DIDA	-	Diisodecyl adipate
DOA	-	Dioctyl adipate
MDP	-	Methyldiphenyl phosphate
PANA	-	Phenyl alpha naphthylamine
TCB	-	Trichlorobenzene
TCP	-	Tricresylphosphate
TDDPP	-	Tridecyldiphenyl phosphate
TPS acid	-	Tetrapropenylsuccinic acid

4009
4290
4666
4667

#8

3557

MONS 021345