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ORGANIC CHEMICALS DIVISION RESEARCH Report

St. Louis Research Report No. 2397

FINAL REPORT
on
FUNCTIONAL FLUIDS SALES
APPLICATION RESEARCH

JOB No. 2-02-750.01-3486

October 8, 1952 Reported by: J. R. Stark

Monsanto

ST. LOUIS, MO.

DSW 621826

STLCOPCB4095857

MONSANTO CHEMICAL COMPANY
Organic Chemicals Division
St. Louis Research Department

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Reported by: L.R. Stark

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INTRODUCTION

The objective of this research was to provide technical sales information to aid in retaining Monsanto's current sales position and in acquiring new business in the functional fluids field. This report presents the sales service application studies completed during the period May 1957 through December 1958.

SUMMARY

Appropriate application tests were performed on the Pydraul and Skydrol fluids as requested by the Sales Department. Some competitive fire resistant fluids were also evaluated. Various physical properties and bench scale performance properties were determined. Results of these tests appear in the Discussion section.

CONCLUSION

Appropriate sales service application studies requested by the Sales Department were completed during the period May 1957 through December 1958. Future work of this nature will continue under a new job number.

DISCUSSION

A. Pydraul Fluids

1. "Pydraul F-9" from Pydraul 600

Pydraul 600 was replaced as a sales item by the more shear stable Pydraul 625 leaving a relatively large quantity of the Pydraul 600 in stock. By adjusting the Pydraul 600 viscosity (primarily by the addition of Aroclor 1242) a blend with physical properties nearly identical to Pydraul F-9 was obtained. Bench scale lubrication and oxidation-corrosion tests on this "Pydraul F-9" from Pydraul 600 with and without 0.3% Santolube 70 added as a rust inhibitor indicated these fluids to be equivalent to regular Pydraul F-9 with and without Santolube 70 added. Shell 4-Ball Wear values appear in Table II, Almen E.P. values in Table III, and oxidation-corrosion in Table IX. Pydraul 600 stocks were converted to Pydraul F-9 and the resulting fluid sold.

2. Pydraul AC - NaOH Treatment

A potential Pydraul AC customer wished to use this fluid in an air compressor with a caustic scrubber between stages. Antiwear properties of Pydraul AC were improved by treatment with 15% NaOH for 27 hours at 105°C. No other functional properties were determined. Four-ball wear values for Pydraul AC before and after NaOH treatment appear in Table II.

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3. Pydraul 625- Santolube 70 Foaming Characteristics

Rust inhibited Pydraul 625 containing 0.3% (wt.) Santolube 70 prepared for a specific customer (Aluminum Company of America) was found to have a severe foaming tendency. The addition of 50 ppm DCF-200 returns the inhibited fluid foam level to approximately the same as uninhibited fluid. This formulation change was adopted. Foam values for these fluids appear in Table VIII.

4. Pydraul F-9 Rust

A static rusting test (Research Engine Laboratory Procedure F-101 with 75cc fluid, 3cc water and steel strip in 4 oz. bottle) indicated that new Pydraul F-9 is equal or better than a SAE 10 base oil in rusting tendencies in the air space and Pydraul layer. The water layer rating was much worse with the Pydraul F-9 than on the base oil (Sohio SAE 10 solvent refined midcontinent, neutral, viscosity at 100°F - 217.8 SUS; at 210°F - 45.9 SUS; V.I. - 101.2; Research Engine Laboratory Inventory 2157). Rust ratings for fluids in this test appear in Table VI.

A hydraulic machine at Westinghouse Electric Corporation, Lima, Ohio using Pydraul F-9 reported rusting in valves in May 1957. Subsequently the fluid was replaced with Santolube 70 rust inhibited fluid about the last of July 1957. In May 1958 rust - like deposits again appeared.

A sample was evaluated for rusting tendencies. The total acid number of the sample as received was found to be 0.62 with an initial pH of 2.5. Santolube 70 concentrations of 0.25, 0.5, and 1.0% were not sufficient to rust inhibit the Westinghouse sample of Pydraul F-9. Although the higher Santolube 70 eliminated the massive rusting, a dark stain was noted on the steel rust, specimens. Subsequent microscopic examination of the stained specimens revealed what appeared to be many small pits on the surface. It was recommended that the fluid be discarded or treated in some manner to remove the high acidity.

Further D-665 rust tests on new and thermally aged Pydraul F-9 indicate a wide variance in antirust properties as indicated in Table VII. The Pydraul F-9 rusting mechanism and its means of prevention will be studied in the future.

5. Pydraul 150 - Seal Compatibility

A seal specimen furnished by the Galland Henning Manufacturing Company appears to be unchanged on exposure to Pydraul 150 for 168 hours (1 week) at 70°C (158°F).

The specimen had no significant dimensional change and less than 1% weight increase. The slight weight increase might be accounted for by absorption of Pydraul into the pourous edges of the seal.

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6. Pydraul Lubricating Properties

Timken load values were obtained for Pydrauls 60, 150, 625, 600, F-9, and A.C. Almen Wear values were obtained for Pydraul 150, Pydraul 625, and Pydraul F-9 and Almen Load values for Pydraul 60 and Pydraul F-9. Timken load and Almen wear and load values appear in Table III. Shell 4-Ball Wear values for Pydrauls 60, 150, 625, and F-9 appear in Table II.

7. Pydraul Fire Resistance Properties

Hot manifold flammability, high pressure spray flammability, low pressure spray flammability, molten metal ignition, and flash and fire points were run on Pydrauls F-9 and 625. A hot manifold value was obtained for Pydraul 150. These fire resistance test results appear in Table IV and V.

8. Pydraul Foam Properties

ASTM D-892 foam values for Pydrauls 60, 150, and F-9 appear in Table VII.

B. Skydrol Fluids

Miscibilities and viscosities of Skydrol 500 and Skydrol 7000 mixtures were determined for sales information purposes. Skydrols 500 and 7000 were found to be miscible in volume ratios of 90:10, 75:25, 50:90 and 25:75. Viscosity determinations at 210°, 100°, 0°, -40°, and -65°F for both Skydrols and each mixture appear in Table I. Values at 160°F and 70°F were interpolated from determined values.

C. Competitive Fluid Evaluation

1. Nyvac 20

A laboratory scale comparison of new and used Nyvac 20 (Socony Mobil Oil Co. water based fluid) was made with Pydraul F-9 as a sales service to Johnson Motors to help protect our sales position with them. The more significant results are summarized as follows:

a. Used Nyvac 20 (no history was given with the samples from Johnson) is nearly equivalent to new Nyvac in all tests conducted. The used fluid had oily or waxy clumps of foreign material floating on the surface and considerable sediment at the bottom.

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b. Almen and Timken load values indicate that the Nyvac fluid has very poor E.P. properties in comparison with Pydraul F-9. On the Almen Wear Test it was necessary to reduce the load to prevent seizure with the Nyvac. Almen Wear at these reduced loads was light as was the wear with Pydraul F-9 with the standard load, Four-ball Wear using Nyvac 20 was about double that with with Pydraul F-9 on the steel ball on steel ball tests, but the steel on bronze values were nearly equivalent for the two fluids.

c. Nyvac 20 has good anti-rust characteristics which were not destroyed by heating at 200°F for 144 hours. Pydraul F-9 has poor anti-rust qualities when free water is present. Heat treated F-9 etched the steel slightly at the water phase, leaving a clean surface with the rust going into the fluid rather than adhering to the surface as with new Pydraul. Also, there was an improvement in the vapor and fluid phase rusting.

d. Nyvac 20 exhibits considerable foaming tendencies. However, only the used fluid had foam which did not settle within 10 minutes after the initial 75°F blowing period.

e. Nyvac 20 exhibits a very high evaporation loss. The ASTM D-972 evaporation at 200°F for 22 hours resulted in a loss of 86%, indicating that components other than the water are being lost. Pydraul F-9 had a 1.6% loss under the same conditions. Water content of Nyvac 20 by a benzene extrusion was found to be approximately 46%(w). A static oven test at 200°F for 144 hours resulted in 50% (vol.) loss of the Nyvac 20; whereas, the Pydraul F-9 had no appreciable loss.

Acidity and viscosity values for Nyvac 20 appear in Table I, Almen load and wear and Timken load in Table III, 4-ball wear in Table II, hot manifold flammability in Table V, foam in Table VIII, and static rust test results in Table VI.

2. Bayer Leverkusen CA-9031 and CA-9032

The German manufactured competitive fluids, Bayer Leverkusen's CA-9031 and CA-9032 have viscosities comparable to Pydrauls F-9 and 60 respectively. Both fluids are essentially shear stable, both have slightly less antiwear capabilities than the corresponding Pydrauls, and CA-9031 is equivalent to Pydraul F-9 in the Almen load test while CA-9032 is inferior to Pydraul 60 in this test. Viscosity values for the Bayer fluids appear in Table I, Almen load in Table III, and 4-ball wear in Table II.

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D. Miscellaneous

Included in the various tables mentioned above are functional and physical properties obtained during the period of this report but not specifically requested. This information on Pydraul fluids, Skydrol fluids, and several competitive fluids is included for record purposes and future use.

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TABLE I

VISCOSITY AND ACIDITY

Fluid	Viscosity, cs							Acidity	
	210°F	160°F*	100°F	70°F*	0°F	-40°F	-65°F	TAN mg.KOH per gm.	pH
Pydraul F-9, lot Z-81	5.82	---	56.1	---	---	---	---	0.08	4.6
Pydraul 60, lot Z-64	2.44	---	9.95	---	---	---	---	---	---
Skydrol 500	3.93	5.80	11.7	18.5	99.6	533	2555.	---	---
Skydrol 500:7000, 90:10**	3.94	5.90	11.96	19.5	108.	629.8	3298.	---	---
Skydrol 500:7000, 75:25	3.95	6.05	12.5	21.1	127.	865	5530.	---	---
Skydrol 500:7000, 50:50	3.98	6.25	13.4	24.0	174.	1489	13,710.	---	---
Skydrol 500:7000, 25:75	4.00	6.40	14.5	27.5	256	2810	34,900.	---	---
Skydrol 7000	4.03	6.55	15.96	31.0	402	7390	122,300.	---	---
Nyvac 20	***	---	69.9	---	---	---	---	13.6T.B.N.	8.8
Bayer Leverkusen CA-9031	7.02	---	60.3	---	---	---	---	---	---
Bayer Leverkusen CA-9032	3.09	---	11.4	---	---	---	---	---	---
Cellulube 220	4.77	---	47.0	---	---	---	---	---	---
Houghtosafe 1010	3.92	---	25.7	---	6,870	---	---	---	---

* Interpolated
** Volume Ratio
*** Water Evaporation too rapid to obtain 210°F viscosity.

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TABLE II

SHELL FOUR-BALL WEAR

Shell 4-Ball Wear, 630 rpm, 1 hr., 167°F

	Steel-on-Steel				Steel-on-Bronze			
	1 Kg.	4 Kg.	10 Kg.	40 Kg.	1 Kg.	4 Kg.	10 Kg.	40 Kg.
Pydraul F-9 lot Z-81	0.15	0.21	0.28	0.67	---	---	1.18	1.28
"Pydraul F-9" from Pydraul 600	---	0.21	0.31	0.66	---	---	0.89	---
"Pydraul F-9" from Pydraul 600 + 0.3%(wt.) Santolube 70	---	0.23	0.26	0.55	---	---	0.81	---
Pydraul AC	---	---	0.38	0.80	---	---	---	---
Pydraul AC after NaOH treatment	---	---	0.24	0.56	---	---	---	---
Pydraul 60	0.28	---	0.36	0.53	0.52	---	0.91	1.34
Pydraul 150	0.26	---	0.36	0.51	0.44	---	0.80	1.58
Pydraul 625	0.15	---	0.24	0.72	0.54	---	1.10	1.19
Nyvac 20	0.33	---	0.72	0.91	0.62	---	1.18	1.41
Bayer Leverkusen CA-9031	---	0.22	0.32	0.80	---	1.07	1.01	1.52
Bayer Leverkusen CA-9032	---	0.40	0.45	0.57	---	1.24	1.47	1.87

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TABLE III

ALMEN WEAR, ALMEN LOAD AND TIMKEN LOAD

	Almen Wear		Almen Load		Timken Load	
	Loss mg.	Load psi	Load psi	Torque pounds	Passing Load, pounds	Film strength, psi
Pydraul F-9 lot Z-81	2.0	4000	25,000	48	45	18,000
"Pydraul F-9" from Pydraul 600	---	---	25,000	44	--	---
"Pydraul F-9" from Pydraul 600 + 0.3% Santolube 70	---	---	25,000	46	--	---
Pydraul 60, S-9	---	---	25,000	43	10	6,900
Pydraul 150, S-10	3.9	4000	----	--	40	17,100
Pydraul 600, S-11	---	---	----	--	45	20,100
Pydraul 625, S-12	2.2	4000	----	--	55	20,000
Pydraul AC, S-13	---	---	----	--	50	23,200
Nyvac 20	2.0	2500	3,000	11	10	5,200
Bayer Leverkusen CA-9031	---	---	25,000	42	--	---
Bayer Leverkusen CA-9032	---	---	17,000	29	--	---

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TABLE IV

FIRE RESISTANCE

	High Pressure Spray Flammability AMS-3150B	Low Pressure Spray Flammability AMS-3150B	Molten Metal Ignition*
Pydraul 150	Flashed at 2-1/2 ft., self extinguishing	Slight flame increase	Does not spontaneously ignite, burns by spark until fluid consumed
Pydraul F-9	Will not ignite	No increase in flame	Does not spontaneously ignite, flashes by spark
Pydraul 625	Will not ignite	Very slight brightening of flame	-------
OS-81	Will not ignite	Slight brightening of flame	-------
Skydrol 500	Flashed with difficulty at 3 ft.	Some increase of flame	-------
Skydrol 7000	Flashed with difficulty at 3 ft.	Some increase of flame	-------
Cellulube 220	-------	No increase in flame	-------
Houghto-Safe 1010	Will not ignite	Slight flame increase	Small flash at end of fluid evaporation burns by spark but self extinguishing
MIL-O-5606 Fluid	Flashes and burns readily, partly self sustaining	Large flame increase	-------

* Aluminum Alloy at approximately 1150 to 1200°F.

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TABLE V

FIRE RESISTANCE

	Flash Point, C.O.C., °F	Fire Point, C.O.C., °F	Hot Manifold, 1300°F
Pydraul 60	425	465	Intermittent flashing and burning on tube, does not flash or burn after leaving tube.
Pydraul 150	420	470	Intermittent flashing and burning on tube, does not flash or burn after leaving tube.
Pydraul F-9	435	655	Does not flash or burn on tube or after leaving tube.
Pydraul 600	430	720	Does not flash or burn on tube or after leaving tube.
Pydraul 625	470	745	Does not flash or burn on tube or after leaving tube.
Pydraul AC	450	745	Does not flash or burn on tube or after leaving tube.
Skydrol 500	---	---	Intermittent burning on tube, does not flash or burn after leaving tube.
Skydrol 7000	---	---	Intermittent burning on tube, does not flash or burn after leaving tube.
OS-81	---	---	Does not flash or burn on tube or after leaving tube.
OS-58-1	---	---	Does not flash or burn on tube or after leaving tube.

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TABLE V (CONT'D)

FIRE RESISTANCE

	Flash Point, C.O.C., °F	Fire Point, C.O.C., °F	Hot Manifold, 1300°F
Nyvac 20	---	---	Does not flash or burn on tube or after leaving tube.
Cellulube 220	---	---	Does not flash or burn on tube or after leaving tube.
Houghto-Safe 1010	525	575	Does not flash or burn on tube or after leaving tube.
Houghto-Safe 1055	---	---	Does not flash or burn on tube or after leaving tube.
Shell Irus 902	---	---	Intermittent flashing on tube, does not burn on tube or after leaving tube.
Ucon 150 cp	---	---	Does not flash or burn on tube or after leaving tube.
Franklin Fluid-200	---	---	Intermittent flashing on tube, does not burn on tube or flash and burn after leaving tube.
MIL-O-5606 Fluid	---	---	Flashes and burns on tube and in pan.
MIL-L-7808C Fluid	---	---	Burns on tube and droplets falling, does not flash or burn in pan.

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TABLE VI

RUST TEST

	Static Rust*						ASTM D-665	
	4 Hour Metal Strip Rating			24 Hour Metal Strip Rating			Rust Rating	
	Vapor	Water	Fluid	Vapor	Water	Fluid	1 Hr.	24 Hrs.
Pydraul F-9	9.5	3.0	5.0	8.0	3.0	5.0	10.0	5.5
Pydraul 150	---	---	---	---	---	---	1.0	---
Pydraul 625	---	---	---	---	---	---	10.0	8.0
Petroleum Oil**	6.0	5.0	8.0	8.0	5.0	8.0	----	---
Nyvac 20	---	---	---	10.0	---	10.0	10.0	10.0
Cellulube 220	---	---	---	---	---	---	10.0	5.5
Houghto-Safe 1010	---	---	---	---	---	---	10.0	3.5

* REL F-101: 75 cc fluid, 3 cc water, 3/4" x 3" x 1/16" steel strip, room temperature 20/23 REL M-400 Rust Rating, 10 = perfect, 0 = 100% rusted.

** Sohio SAE 10 solvent refined mid-continent, neutral, 100°F viscosity 218. SUS, 210°F viscosity 45.9 SUS.

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TABLE VII

PYDRAUL F-9 D-665 RUST

Pydraul F-9 Source	ASTM D-665 Rating* 1 hr	24 hr	Acidity TAN mg KOH/gm	pH
New lot W-100(1954)	5.5	---	0.13	4.0
New lot Y-76 (1955)	10.0	6.5	0.05	4.4
New lot Z-81 (1956)	10.0	5.5	----	---
New lot A-71 (1957)	5.5	---	0.13	3.8
Lab Prepared (1955)	1.0	---	----	---
Z-81 + 0.001% Santolube 70	10.0	5.0	---	---
Z-81 + 0.01 % Santolube 70	10.0	5.5	---	---
Z-81 + 0.10 % Santolube 70	10.0	5.5	---	---
Z-81 + 0.20 % Santolube 70	10.0	6.0	---	---
Z-81 + 0.25 % Santolube 70	10.0	8.5	---	---
Z-81 + 0.30 % Santolube 70	10.0	10.0	---	---
Z-81 + 0.35 % Santolube 70	10.0	10.0	---	---
Westinghouse May 1957	1.0	---	0.39	---
Westinghouse July 1958	0.0	---	0.62	2.5
Westinghouse 1958 + 0.25% Santolube 70	10.0	4.5	---	---
Westinghouse 1958 + 0.5% Santolube 70	10.0	4.5	---	---
Westinghouse 1958 + 1.0% Santolube 70	10.0	5.0	---	---

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TABLE VIII

FOAM, ASTM D-892

Fluid	Tendency, ml. at 5 min. 75°F	200°F	75°F	Collapse, seconds to 0 ml. 75°F	200°F	75°F
Pydraul 60	20	12	39	53	34	63
Pydraul 150	12	15	15	48	30	56
Pydraul F-9	40	8	40	0*	0*	0*
Pydraul 625	10	14	10	0*	0*	0*
Pydraul 625 + 0.3% Santolube 70	622	560	604	560*	5*	555*
Pydraul 625 + 0.3% Santolube 70 + 50 ppm DCF 200	25	---	---	0*	-	---
Nyvac 20	250	380	150	0*	0*	0*

* ml at 10 minutes

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TABLE IX

OXIDATION-CORROSION, 250°F, 168 Hr.

	Pydraul F-9 lot Z-81	Pydraul F-9 +0.3% (wt.) Santolube 70	"Pydraul F-9" from Pydraul 600 +0.3% Sant. 70
Metal Attack: mg/cm²			
Copper	-0.16 sl. etch and pit	-0.24 sl. etch	-0.24 v. sl. etch
Magnesium	0 clear	0 clear	0 clear
Steel	0 clear	0 clear	0 clear
Aluminum	0 clear	0 clear	0 clear
Cadium Plate	0 clear	0.07 clear	0.01 clear
Acidity: Initial TAN	0.09	0.30	0.25
Final TAN	0.17	0.25	0.14
Viscosity: Initial 100°F	56.7	57.0	54.4
Final 100°F	58.6	58.6	57.0
Initial 210°F	5.51	5.54	5.30
Final 210°F	5.61	5.67	5.38
Fluid Condition:	0.5% loss yellow clear	0.6% loss brown-clear	0.7% loss brown-clear

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