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FINAL REPORT

ON

AROCLOR 1248 AS A HEAT TRANSFER MEDIUM IN A LAMONT FORCED CIRCULATION HEATER

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Job No. 2-02-750.01-2957

Monsanto Chemical Company
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INTRODUCTION

Aroclor 1248 has been widely used as a heat transfer medium during the past 15 years. These years of experience have indicated that heater design and fluid flow rates have much to do with the success of the Aroclor heater.

In 1953, the International Boiler Works Company of East Stroudsburg, Pennsylvania and Monsanto agreed to cooperatively sponsor tests on a Lamont type forced circulation boiler to obtain overall heat transfer coefficients, film coefficients and maximum operating temperature limits for Aroclor 1248. These data would allow Aroclor heater manufacturers to design more efficient units using Aroclor 1248.

SUMMARY

An experimental 500,000 BTU heater was built at International Boiler works for the test runs. Two test runs were made at 600°F. and three at 650°F. All runs were of approximately 700 hours or one month duration.

Viscosity of the Aroclor was used as an indication of the degradation of the Aroclor. At 600°F. very little viscosity change was noticed, whereas an increase in viscosity at 650°F. clearly indicated a polymerization of the Aroclor.

CONCLUSIONS

Aroclor 1248 can be used up to four years at 600°F. in a forced circulation heater designed to have rapid turbulent flow in the tubes.

Limited use of the Aroclor 1248 can be made at higher temperatures. Viscosity determinations at intervals will be needed to indicate the proper time to replace the Aroclor.

RECOMMENDATIONS

The data and experience gained in this test will be incorporated into bulletins and handbooks by the Sales Department. With the design data to be furnished by International Boiler Works Company, an excellent booklet on the use of Aroclor 1248 in properly designed heater will be available.

PATENT STATUS

The use of Aroclor as a heat exchange media is not considered patentable.

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REFERENCES

Monsanto Technical Bulletin No. P-130.

Organic Chemicals Division Report on Job No. 117-2060, "Design and Testing of a Portable Aroclor Heating Unit", R. E. Howard, August 1, 1948.

Phosphate Division Report No. 2210, "Efficiency of Aroclor Heater", L. C. Garrett, November, 1947.

EXPERIMENTAL WORK

Using the Lamont type forced circulation heater described below, experiments were planned to give continuous operation at both 600 and 650°F. for extended periods.

As each test progressed samples of the Aroclor were taken to observe the condition of the heating medium. These results are listed with the conditions of each test.

A. Equipment

An International Lamont Boiler, LCF-5, rated at 500,000 BTU per hour was used in these tests. Full requirements were 5 to 6 gallons of oil per hour to give an input of 690,000 to 830,000 BTU per hour. The heating surface of the tubes is 99 square feet.

The boiler tubes are made of No. 83 carbon steel (13 gauge) with 13/16" inside diameter. An arrangement of seven tubes makes two passes through the firebox. Each pass is 27 feet in length to give a total of 380 feet of pipe in the heating area.

The firebox temperature was 2000°F. and the outside tube wall temperature was measured at approximately 730°F.

An automatic temperature controller maintained the temperature of the Aroclor 1248 leaving the heater at 600 or 650°F. as required. A heat exchanger removed heat from the Aroclor so that the temperature differential was about 50°F. A low flame is automatically used in the firebox until the Aroclor temperature in the return line has reached 150°F.

A centrifugal pump, Dean Brothers type with a 5 HP, 1750 rpm motor, was used to pump the Aroclor at the rate of 60 gallons per minute. Orifices in the inlet of the seven tubes from a header insured a balanced high flow in each tube.

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A flow rate of 60 gpm is equal to 231 cu. in. per second. The cross sectional area of the 7 tubes is 3.62 sq. in. so the velocity of the flow through the boiler tubes is 64 in per second or 5.3 ft. per second.

The Lamont type forced circulation boiler used in these tests is standard equipment of International Boiler Works. Similar design is used for heaters of 4,000,000 BTU/hr. size and larger.

B. Analytical Results on Aroclor Samples

Samples of the Aroclor were removed from the heater periodically during each run for checking the condition of the heating medium.

Test I: Aroclor 1248 was used in this run at 600°F. The system was vented to the atmosphere. Dowtherm and a phenyl silicate had been used in the system prior to the Aroclor run so slight contamination from these materials may be evident.

Analyses of the Aroclor samples in use are as follows:

Test I - 600°F.

Sample No.	Date	Hours	Sp. Gr. at 65/15.5°C.	Saybolt Seconds Viscosity at 130°F.
Start	5/19/53	0	1.394	66.5
1	5/25/53	168	1.394	69.1
2	6/3/53	357	1.394	72.1
3	6/9/53	504	1.395	74.4
4	6/16/53	671	1.396	76.8

Test II: The second phase of the Aroclor heater operation was started at 600°F. under 30 psig nitrogen pressure. A failure in the cooling water supply caused the initial run to be halted. For about 20 minutes the Aroclor was heated to 760°F. The Aroclor showed a viscosity increase from 72.8 Saybolt Seconds to 73.3 SUS at 130°F. This slight increase was not considered harmful.

The test was started again with new Aroclor and sampled as the run continued. Analysis of the Aroclor is given below:

Test II - 600°F. - 30 psig Nitrogen Pressure

Sample	Date	Hours	Sp. Gr. at 65/15.5°C.	Viscosity at 130°F.
Initial	7/29/53	0	1.406	72.4
1	8/5/53	168	1.407	73.4
2	8/12/53	322	1.407	73.6
3	8/19/53	479	1.408	74.0
4	8/26/53	647	1.408	74.8

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Test III For this run, the flow rate of the Aroclor was decreased by installing a new set of orifices in the header. Aroclor temperature was maintained at 650°F. with 30 psig nitrogen pressure. Samples were tested at intervals during this run.

Test III - 650°F. - 30 psig Nitrogen Pressure

Sample	Date	Hours	Sp. Gr. at 65/15.5°C.	Viscosity at 130°F.
Initial	10/7/53	0	1.408	73.7
1	10/16/53	216	1.408	81.5
2	10/21/53	336	1.410	90.8
3	10/25/53	500	1.408	102.2
4	11/4/53	668	1.409	117.7

A leak was discovered in the condenser at the end of 336 hours, so the exact pressure during the run up to this point is questionable.

The leak was fixed and 30 psig nitrogen pressure was applied during the remainder of the test.

Test IV: The unit was charged with Aroclor used previously in Test II. The test conditions were the same as Test III except the rate of Aroclor circulation was increased approximately 12%. After two weeks operation it was noticed that the pressure on the system had increased from 30 to 70 psig and at the end of the test the pressure was 90 psig.

Test IV - 650°F. - 30 psig Nitrogen Pressure

Sample	Date	Hours	Sp. Gr. at 65/15.5°C.	Viscosity at 130°F.
Initial	12/23/53	0	1.406	76.3
1	12/30/53	168	1.408	80.8
2	1/13/54	336	1.408	88.5
3	1/20/54	500	1.409	97.3
4	1/27/54	668	1.410	110.4

Test V: This test was run at 650°F. with an imposed pressure of 125 psig nitrogen on the system. Samples were taken during the run for analyses.

Test V - 650°F. - 125 psig Nitrogen Pressure

Sample	Hours	Sp. Gr. at 65/15.5°C.	Viscosity at 130°F.
Initial	18	1.407	74.6
1	174	1.407	77.7
2	342	1.408	81.9
3	510	1.410	87.2
4	678	1.409	94.7

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The results of Tests II, III and V are plotted on Figure 1 to show the increase in viscosity versus time.

Figure 2 shows the life expectancy of Aroclor 1248 when handled properly in a heat transfer unit. The data for this plot are from a Lamont type forced circulation unit located at Crawford Manufacturing Company, Third and Decatur Street, Richmond, Virginia.

After one year's operation at 600°F., the viscosity of the Aroclor had increased to only 83.5 Saybolt seconds at 130°F. It was recommended that the Aroclor be continued in service.

DISCUSSION

The results of these tests indicate that with a properly designed heater to give adequate circulation of the Aroclor 1248 a very long life of the heating medium can be expected at 600°F. At 650°F., the plotted data show a more limited life can be expected from the Aroclor 1248.

Since HCl is evolved on heating at the higher temperatures, a condensation to form high molecular weight and more viscous compounds occurs. Therefore, the viscosity increase was used to indicate the condition of the Aroclor.

Other properties such as color, specific gravity and acidity are not sufficient to tell the condition of the Aroclor. Heating Aroclor in the presence of iron will discolor the material without affecting its properties as a heat transfer medium. There was little change in the density of the Aroclor used in these tests so density is not sensitive enough to indicate the condition of the Aroclor. Acidity indicates some deterioration of Aroclor, but the limited solubility of HCl in Aroclor prevents this test from showing any cumulative degradation. Viscosity was therefore chosen to indicate the condition of the Aroclor in a heating system.

Aroclor 1248 has a viscosity of 73-80 Saybolt Universal Seconds at 130°F. In Test I, some contaminants from previous tests were present so the results are not considered. Test II at 600°F., shows very little change in viscosity so that years of life might be anticipated from the Aroclor.

Tests III, IV and V were all at 650°F. The greater deterioration is noticed in Test III. During this test a leak in the closed expansion tank allowed the pressure to bleed off, so the exact pressure during the first part of the test is unknown.

In Test IV, a change was made in the orifices and pump to increase the flow rate of recirculation by 12%. The pressure on this test was

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started at 30 psig with nitrogen, but rose to 90 psig during the test. This pressure was no doubt due to the HCl gas released in the closed system. Less increase in viscosity was found in a month's test than in the previous test at 650°F. The improved flow rate may have been responsible for the reduced degradation.

For Test V, the pressure on the system was started at 125 psig with nitrogen and remained at this pressure throughout the run. The increase in viscosity was noticeably less than in Tests III and IV. The increased pressure may have shifted the equilibrium to some extent so that the Aroclor was more stable. The faster flow rate used in Test IV also continued in this test and contributed to the lower degradation by reducing the time of Aroclor contact with the heated tubes.

In our opinion 650°F. is too high a temperature for continued Aroclor 1248 use. Eventually it will break down to give a liquid which will be very viscous and would not be pumpable at low temperatures in case of a cold start-up.

The most trouble free use of Aroclor 1248 as a heat transfer medium can be obtained by limiting the maximum temperature to 600°F. in a forced circulation heater.

In addition to the results obtained here on reporting the condition of the Aroclor, engineering data on the use of Aroclor in heat transfer applications is being assembled by International Boiler Works.

An engineering handbook is being prepared jointly by Monsanto and International Boiler Works to enable design engineers to properly design Aroclor heating systems.

Monsanto is writing the portion pertaining to the physical properties of the Aroclor 1248 and the chemical characteristics that concern the stability and life of the Aroclor.

International Boiler Works is supplying the charts on film coefficients, over-all coefficients for heat transfer, pump performance curves, pressure drop in various pipe sizes, flow rate selection curves for pumps and thermodynamic properties of the Aroclor 1248. Table I which is included in this report is the thermodynamic chart for the booklet.

MATERIALS SPECIFICATIONS AND ANALYTICAL PROCEDURES

Aroclor 1248 is produced at both Anniston, Alabama and Monsanto, Illinois plants.

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The standard tests for non-dielectric uses are made to meet these specifications:

Appearance and Color	Colorless to light yellow-green liquid; APHA 100 max.
Condition	Clear
Specific Gravity at 65/15.5°C.	1.405-1.415
Acid Number (mg KOH/gm)	0.010 Max.
Moisture (H_2O)	35 ppm, Max.
Viscosity at 130°F.	73-80 SUS

Viscosity determinations on the condition of the Aroclor 1248 after use was made by using a standard Saybolt viscosimeter and ASTM D-88 at 130°F.

TOXICITY AND HAZARDS

The toxicity of Aroclor 1248 is covered in Monsanto Bulletin O-P115, "The Aroclors". Bulletin P-130 on the Aroclor heater also discusses the toxicity and hazards involved in using Aroclor. The proper equipment to safely handle Aroclor as a heating fluid is also ably discussed.

ACKNOWLEDGEMENT

Mr. P. G. Benignus in charge of Aroclor Sales has been an able proponent of the use of Aroclor as a heat transfer fluid. His efforts in arranging for the tests with International Boiler Works are gratefully acknowledged. Mr. George Stabenow, Chief Engineer, and Mr. Russell Imbt, Jr., Project Engineer, of International Boiler Works have contributed greatly to the demonstration that Aroclor 1248 can be used at 600°F.

APPENDIX

The results on testing Aroclor samples are reported on notebook pages - 99752, 99758, and 99770.

A. M. Ellenburg

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THERMODYNAMIC PROPERTIES OF AROCLOR #1248

TABLE 1

Temperature °F.	Temperature °C.	Enthalpy Btu/lbs.	c_p Spec. Heat Btu/lbs.°F.	Density Lbs./cu.ft.	Lbs./gal.	Specific Gravity	Absolute Viscosity Centipoises
32	0	0.000	0.2695	91.6	12.22	1.47	----
40	4	2.162	0.2711	91.3	12.19	1.46	----
50	10	4.881	0.2727	90.9	12.13	1.455	----
60	16	7.616	0.2743	90.6	12.08	1.45	850
70	21	10.367	0.2759	90.2	12.03	1.445	380
80	27	13.134	0.2775	89.8	12.00	1.40	200
90	32	15.917	0.2791	89.5	11.96	1.432	115
100	38	18.716	0.2807	89.1	11.91	1.425	66
110	43	21.531	0.2823	88.8	11.87	1.420	47
120	49	24.362	0.2839	88.4	11.82	1.414	32
130	54	27.209	0.2855	88.1	11.77	1.409	24
140	60	30.072	0.2871	87.8	11.73	1.404	18
150	66	32.951	0.2887	87.4	11.69	1.400	14
160	71	35.846	0.2903	87.0	11.64	1.493	11
170	77	38.757	0.2919	86.6	11.58	1.387	9.1
180	82	41.784	0.2935	86.2	11.53	1.381	7.5
190	88	44.727	0.2951	85.9	11.47	1.375	6.3
200	93	47.686	0.2967	85.6	11.42	1.370	5.2
210	99	50.661	0.2982	85.2	11.38	1.365	4.4
220	104	53.651	0.2998	84.8	11.34	1.359	3.9
230	110	56.657	0.3014	84.4	11.29	1.353	3.35
240	116	59.679	0.3030	84.1	11.24	1.348	3.00
250	121	62.717	0.3046	83.7	11.18	1.342	2.68
260	127	65.771	0.3062	83.4	11.14	1.336	2.38
270	132	68.841	0.3078	83.1	11.10	1.331	2.08
280	138	71.927	0.3094	82.9	11.06	1.326	1.96
290	143	74.029	0.3110	82.6	11.03	1.321	1.82
300	149	77.147	0.3126	82.3	10.98	1.316	1.68
310	154	80.281	0.3142	81.9	10.94	1.311	1.58
320	160	83.431	0.3158	81.6	10.90	1.305	1.46
330	166	86.597	0.3174	81.2	10.85	1.300	1.38
340	171	89.779	0.3190	80.9	10.81	1.296	1.30
350	177	92.977	0.3206	80.6	10.76	1.291	1.22
360	182	96.191	0.3222	80.2	10.71	1.286	1.15
370	188	99.421	0.3238	79.8	10.67	1.280	1.10
380	193	102.667	0.3254	79.4	10.62	1.274	1.05
390	199	105.929	0.3269	79.1	10.57	1.269	1.00
400	204	109.206	0.3285	78.8	10.53	1.264	0.96
410	210	112.499	0.3301	78.5	10.48	1.259	0.91
420	216	115.808	0.3317	78.2	10.45	1.253	0.87
430	221	119.133	0.3331	77.9	10.39	1.248	0.84
440	227	122.474	0.3349	77.6	10.34	1.243	0.80
450	232	125.831	0.3365	77.2	10.30	1.237	0.76
460	238	129.204	0.3381	76.8	10.25	1.231	0.73
470	243	132.593	0.3397	76.4	10.20	1.225	0.71
480	249	135.998	0.3413	76.1	10.16	1.220	0.68
490	254	139.419	0.3429	75.7	10.11	1.214	0.65
500	260	142.856	0.3445	75.4	10.06	1.208	0.62
510	266	146.309	0.3461	75.0	10.02	1.202	0.60
520	271	149.778	0.3476	74.7	9.98	1.196	0.57
530	277	153.262	0.3492	74.4	9.94	1.191	0.55
540	282	156.762	0.3508	74.1	9.90	1.186	0.53
550	288	160.278	0.3524	73.7	9.85	1.180	0.51
560	293	163.810	0.3540	73.4	9.80	1.175	0.49
570	299	167.358	0.3556	73.0	9.76	1.170	0.47
580	304	170.922	0.3572	72.7	9.71	1.165	0.45
590	310	174.502	0.3588	72.4	9.67	1.160	0.43
600	316	178.098	0.3604	72.0	9.63	1.155	0.42
610	321	181.710	0.3620	71.7	9.58	1.150	0.40
620	327	185.338	0.3636	71.4	9.53	1.144	0.39
630	332	188.982	0.3652	71.0	9.48	1.138	0.37

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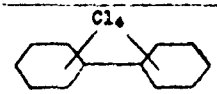
PHYSICAL CONSTANTS OF AROCLOR 1248

COMPILED BY A. M. Ellenburg
DATE August 23, 1955



NAME	Tetrachlorobiphenyl	SOURCE	DATE
Formula	$C_{12}H_6Cl_4$		
Appearance	Yellow tinted oil		
Molecular weight	292 (average)		
Boiling range at 760mm	345-380°C.	Monsanto OP-115	1954
Boiling range at 3 mm	165-210°C.	" "	"
Crystallizing point	None	" "	"
Pour point	-7°C.	" "	"
Solution point			
Specific gravity @ 65/15.5°C.	1.410	Dayton Report 597	1949
Specific gravity @ 300°C.	1.170	" " "	"
Refractive index @ 25°C.	1.6295	Monsanto OP-115	1954
Viscosity 65°C. / 300°C.	14 centipoises / 0.47	Dayton Report 597	1949
Surface tension at 20°C.	44.2 dyne/cm	J.Coll.Sci. 7,166	1952
Solubility in water	Insoluble	Monsanto OP-115	1954
glycerine	Insoluble	" "	"
benzene	Very soluble	" "	"
Solubility in 3A ⅘ alc.	15 gr/100 ml at 25	" "	"
Solubility in CCl_4	Soluble	" "	"
Flash point °F (method) COC	193-196°C.	" "	"
Fire point °F COC	None	" "	"
Heat of combustion			
Heat of formation			
Latent heat of fusion			
Latent heat of vap.			
Specific heat 25°C. / 300°C.	0.277 / 0.356	Dayton Report 597	1949
Critical temperature			
Critical pressure			
Dissociation constant			
Pounds per gal. @ 25°C	12.04	Monsanto OP-115	1954

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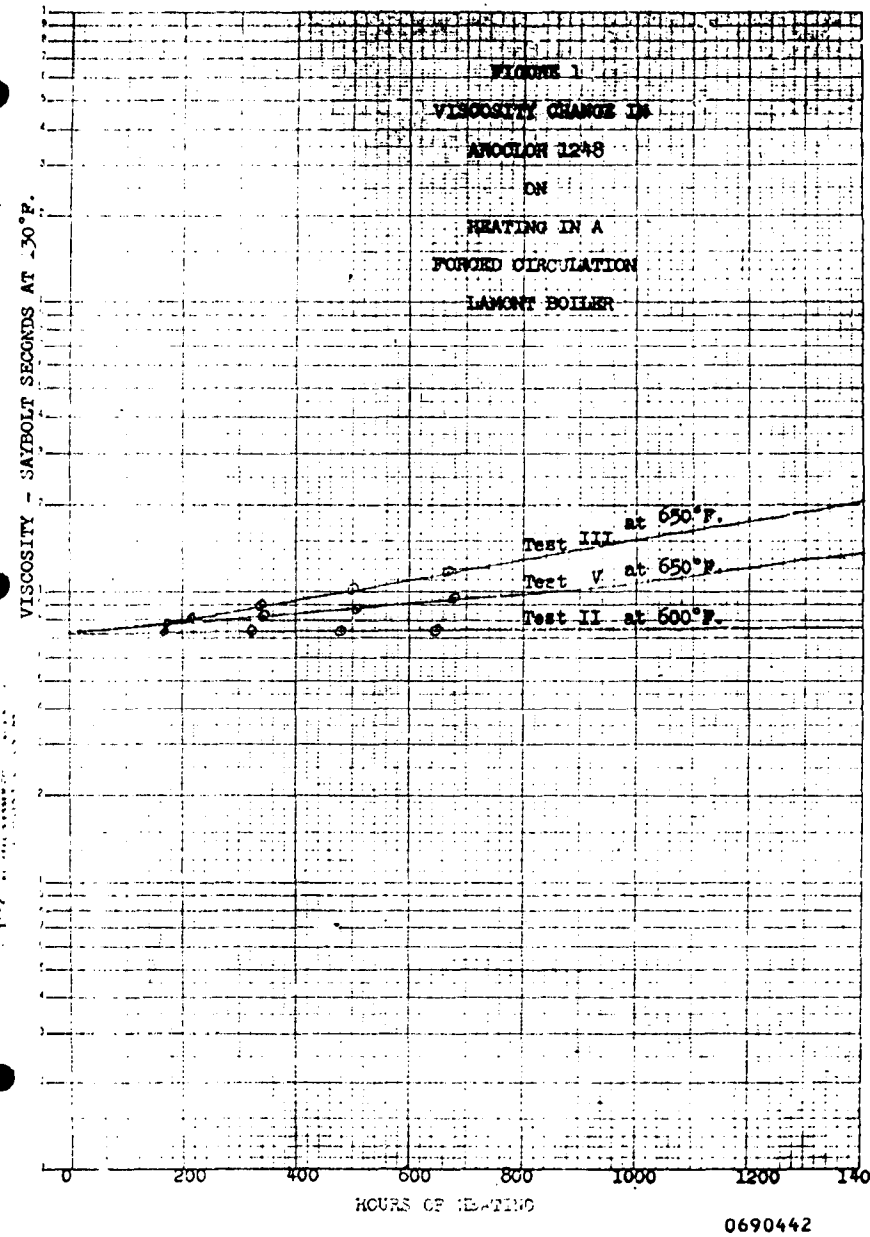

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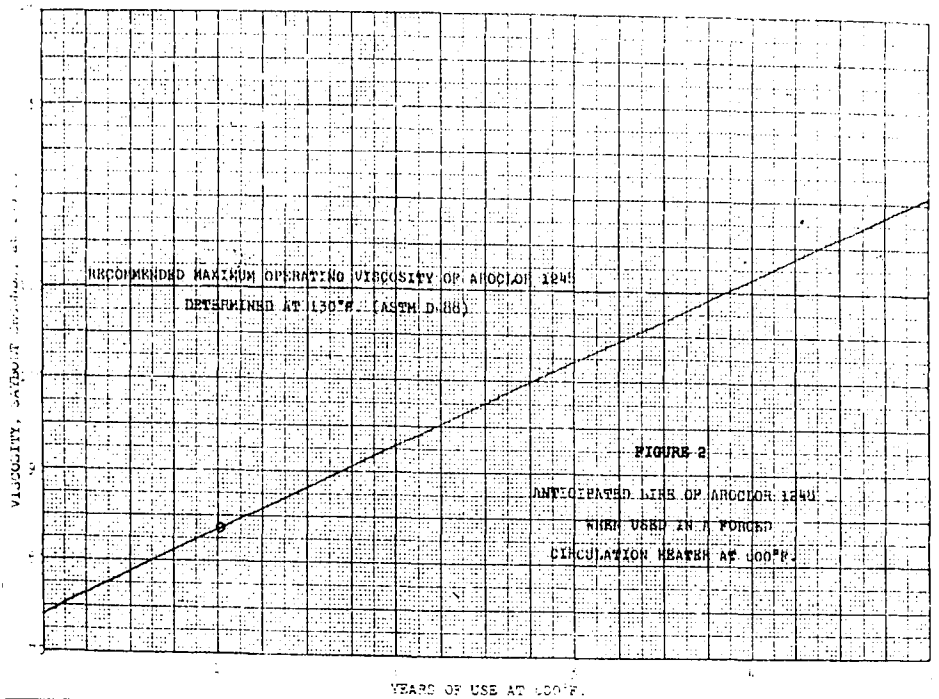

FIGURE 2

ANTICIPATED LIFE OF AROCLOR 1248
WHEN USED IN A FORCED
CIRCULATION HEATER AT 400°F.

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