DEVELOPMENT OF RESEARCH TECHNIQUE FOR EVALUATING THE LOW-TEMPERATURE FLUIDITY OF AUTOMATIC TRANSMISSION FLUIDS

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COORDINATING RESEARCH COUNCIL, INC.
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DEVELOPMENT OF RESEARCH TECHNIQUE FOR EVALUATING THE LOW-TEMPERATURE FLUIDITY OF AUTOMATIC TRANSMISSION FLUIDS
(CRC Project No. CM-26-58)

Prepared by the
Low-Temperature Fluidity Panel of the
Power-Transmission and Power-Steering Units and Fluids Group

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Motor Vehicle Fuel, Lubricant, and Equipment Research Committee

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I. OBJECTIVES

The Low-Temperature Fluidity Panel of the CRC-Motor Power-Transmission and Power-Steering Units and Fluids Group was formed to evaluate the Brookfield viscometer technique recommended for measuring the low-temperature fluidity of automatic transmission fluids. This evaluation included:

1. Calibration of Brookfield viscometers with standard reference oils.
2. Determination of the low-temperature fluidity of representative automatic transmission fluids.
3. Statistical evaluation of results to determine repeatability and reproducibility.
4. Preparation of the Research Technique for Evaluating the Low-Temperature Fluidity of Automatic Transmission Fluids (CRC Designation L-45-1262).

II. BACKGROUND

A. Requirements of Automatic Transmissions with Regard to Low-Temperature Fluidity

In all automatic transmissions of the fluid coupling or torque converter type, fluid viscosity has a direct effect on the efficiency of power transmission through the device. Generally, as viscosity increases, efficiency decreases. Moreover, when the fluid is used to control certain operations within the automatic transmission, a very viscous condition may cause retardation or failure of the operation. During the severe winters of 1949 and 1950 in the United States, many stepped-type or shifting automatic transmissions failed in service due to burned clutch plates. This experience led to an effort to find what correlation existed among temperature, viscosity, and transmission failure (Reference 1).

1. Pour Point Test - One of the first properties of automatic transmission fluids investigated was that of pour point (ASTM Method D 97). It was soon evident that although a gross correlation existed between high pour points and transmission failure, transmissions would fail even with some relatively low pour point fluids.

2. Paint Can Pour Test - The pour point test was replaced in 1947 by a Paint Can Pour Test.* In this test, the criterion was the time for the oil to flow to the lip of a half-filled quart paint can at a given temperature when the can was laid on its side. The correlation between test results and transmission failure was better than the pour point test but still not satisfactory.

*Developed by Oldsmobile Division, General Motors Corporation.

II. BACKGROUND (Cont'd)

3. Cold Room Transmission Test - In the process of gathering information on those fluids which would fail or pass at low temperatures in the field, a simulated field test was established in the cold room facilities of one automobile company. It was this test which was used to establish the degree of correlation between transmission failure and various bench tests.

   The test involved placing a car in a cold room for three days at -40°F with a start every morning, followed immediately by a wide open throttle acceleration. The transmission was then disassembled and inspected. The fluid was considered to have failed if there was any burning of the cork-paper clutch plates.

B. Correlation of Cold Room Transmission Failures with Transmission Fluid Viscosity

In an effort to select a means for predicting the low-temperature failure of automatic transmission fluids, one company set up a full-scale cold room test whereby the factors influencing failure were studied. One obviously important fluid property was that of viscosity.

The Brookfield viscometer was selected as a convenient means of analyzing the viscosity of automatic transmission fluids from 0°F to -40°F. The results of this study were recorded in the literature (Reference 2) and showed that correlation was good between viscosity (as determined using the technique involving the Brookfield viscometer) and failure in the one type of transmission studied. A survey of industry at the time indicated that there were no additional field data over and above these data.

III. SUMMARY

CRC cooperative work has resulted in a test technique (Appendix A) using the Brookfield viscometer, which is considered satisfactory with regard to repeatability and reproducibility for the measurement of low-temperature viscosities of automatic transmission fluids. Because there was evidence of systematic error which must be identified by individual laboratories, the use of a reference oil (designated RPTF-11-59)* to standardize instruments is recommended. This fluid was selected because it is Newtonian over the range of temperatures and shear rates used in this technique and remains single phase over this temperature range.

Two series of cooperative tests were conducted with the CRC L-45 technique. The initial series involved viscosity determinations of four reference oils representing three types of petroleum and one synthetic base stock. Five analyses of each reference oil at each of five temperatures, 0, -10, -20, -30, and -40°F, were made by the 13 participating laboratories. Reproducibility studies showed

* Source given in Appendix A; pertinent inspection data on all reference fluids used in test program are given in Appendix B.

III. SUMMARY (Cont'd)

variations in standard deviation of 3% to 16.2% or, at the 95% confidence level, of 9% to 51%. Poorest reproducibility generally was evident for tests made at the lower temperatures and for samples with the highest viscosity.

The second series of tests, based on refinements suggested following the first series, were obtained on a new group of four reference oils. These consisted of three fully compounded automatic transmission fluids and one synthetic oil. The transmission fluids had known cold room failure characteristics. Five results at each of the temperatures of 0, -10, -20, -30, and -40°F for each oil by the 20 cooperating laboratories indicated repeatability at the 95% confidence level in the range of 0°F to -30°F of from 6% to 10%, and at -40°F of 20%. Reproducibility of results at the 95% confidence level from all laboratories in the range of 0°F to -30°F temperature range was relatively constant at approximately 20% and appreciably better than the reproducibility at -40°F of approximately 39%.

The technique is now in general use by industry for measuring the low-temperature fluidity of automatic transmission fluids.

IV. COOPERATIVE TESTS*

A. First Test Series

An initial series of cooperative tests was conducted to determine the reproducibility of the L-45 technique and to determine what refinements could be made in the method. The tests involved Brookfield viscosity determinations of four reference oils by 13 participants. The oils used were paraffinic; naphthenic; an aromatic mineral oil; and a synthetic oil Newtonian to -40°F. The method given in Reference 2 was followed as a procedure guide, although individual variations in technique and equipment were used by the participants.

Five analyses of each reference oil were made by each participant at each of five nominal test temperatures: 0, -10, -20, -30, and -40°F. The actual values of viscosity and temperature were recorded and plotted on semilog graph paper to obtain the interpolated viscosity values at the specified nominal temperatures.

Table I gives the average viscosities reported by each laboratory. Table II presents the standard deviations and calculated reproducibilities among laboratories. In general, the data indicate that the poorest reproducibility was obtained for tests made at the lower temperatures and for samples with the higher viscosities.

* Participating laboratories are listed in Appendix C.

IV. COOPERATIVE TESTS (Cont'd)

Based on the data and comments offered by the participants, some refinements of the test technique were adopted to improve reproducibility. These included:

1. Standardization of the viscometers by running two reference fluids (RPTF-5-59 and RPTF-6-59) at 100°F.

2. Use of two mercury-thallium thermometers of +10°F to -70°F range to measure fluid and cold box temperature accurately.

3. Heating fluids to 120°F for one-half hour and cooling at room temperature one-half hour before starting measurement to remove the thermal history acquired by the sample at low temperature.

4. Use of semilog graph paper to interpolate viscosities at specified temperatures by drawing the best line through the actual data points obtained with each test rather than all the data points for a given fluid.

B. Second Test Series

Following the standardization of the Brookfield viscometers in each participating laboratory, a series of determinations was made with a new group of reference oils (RPTF-8-59, RPTF-9-59, RPTF-10-59, and RPTF-11-59). Three of these oils were fully compounded automatic transmission fluids, the cold room performance of which had previously been determined by one laboratory. The fourth sample (RPTF-11-59) was a synthetic oil.

A tentative revised procedure was used for this test series which incorporated the above changes for improvement as suggested by the participating laboratories. Although multiple samples are normally run, it was agreed that only one average value should be used for further statistical work.

Five analyses of each reference fluid were made by each participant at nominal test temperatures of 0, -10, -20, -30, and -40°F. The actual values of viscosity and temperature were recorded and plotted on standard semilog graph paper. The program thus called for 20 separate semilog plots. From these charts, the values for viscosity at the specified nominal temperatures were interpolated and recorded. Statistical evaluation of the data was based on these interpolated values.

Data from 20 participating laboratories were received in time to be considered in the statistical evaluation. Three separate statistical analyses were made. Table III summarizes the average viscosities reported by each laboratory. Table IV gives the standard deviations, and Table V the percent standard deviation for the nominal viscosities used to compute the averages shown in Table III.

IV. COOPERATIVE TESTS (Cont'd)

During the course of the program, many suggestions were made by the participants for improvements in the test method and the manner in which to plot the data in order to obtain viscosities at nominal temperatures. While a standard semilog graph paper was supplied to all participants, its use involved fitting a best curve to the five points obtained. Variations in the fitting of the curves accounted for some of the variation shown in the data.

Toward the end of the program, one laboratory suggested that the viscosities would plot in a more linear manner between 0°F and -30°F on regular ASTM kinematic viscosity paper. Below -30°F, the plots deviated from a straight line; an additional viscosity at -35°F was required to determine the shape of the curve at the low-temperature end. Despite this drawback, however, it was agreed that this method of data plotting was advantageous since it eliminated curve fitting down to -30°F.

A standard graph paper (CRR-996) for use with this method of plotting data was devised by one of the participating laboratories. It is an enlargement of the low-temperature section of ASTM viscosity-temperature chart. A sample is included in Appendix A to this report.

In the second, and final test series, the viscosities of three typical automatic transmission fluids and a diester (Newtonian) fluid of similar viscosity were determined by 20 independent laboratories at 0, -10, -20, -30 and -40°F using the Brookfield viscometer. The data were analyzed by several statisticians to estimate the repeatability and reproducibility of the method with fluids of this class.

It was found upon analysis of the data that the error was proportional to the viscosity, and a more rigorous analysis could be made with the logarithms of the determined viscosities. Two analyses were performed using the viscosities as determined, and two analyses treated the logarithms of the viscosities. A summary of this work is shown in Tables VI and VII. It is clear from these analyses that over the temperature range of 0°F to -30°F the repeatability and reproducibility of the test method is relatively constant and far better than at -40°F.

V. CONCLUSIONS

1. A technique (CRC Designation L-45-1262) has been established for the measurement of low-temperature fluidity of automatic transmission fluids. This technique correlates with the only field service data known to the CRC Group.

VI. CONCLUSIONS (Cont'd)

2. The precision of the technique is adequate for the measurement of low-temperature fluidity of automatic transmission fluids. However, other viscometric techniques may be more precise for Newtonian fluids.

3. The repeatability of this technique at the 95% confidence level is as follows:

°F	%
0	7
-10	6
-20	8
-30	10
-40	20

4. The reproducibility of this technique at the 95% confidence level is as follows:

°F	%
0	19
-10	20
-20	19
-30	25
-40	39

5. Analysis of the data indicates that the CRC L-45 technique is susceptible to systematic error. This may be minimized by standardizing the equipment with reference fluid RPTF-11-59.

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REFERENCES

1. N. A. Hunstad, T. W. Selby, and R. E. Osborne, "Present Status of Automatic Transmission Fluid, Type A." SAE Journal (November, 1956)) 21-27.

2. T. W. Selby, "Automatic Transmission Fluid Viscosity at Low-Temperature and Its Effect on Transmission Performance," SAE Transactions 68 (1960) 457-467.

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Table I

SUMMARY OF AVERAGE VISCOSITIES*

Oil	Synthetic					Naphthenic					Aromatic					Paraffinic				
Temp, °F	0	-10	-20	-30	-40	0	-10	-20	-30	-40	0	-10	-20	-20	-40	0	-10	-20	-30	-40
Laboratory Number																				
1	250	344	510	836	1450	1760	3290	6650	15,040	38,400	1090	2510	6310	20,000	69,500	1440	3450	10,260	39,300	-
2	230	330	510	840	1520	1910	3550	7170	16,400	45,500	1170	2770	7510	23,600	87,600	1430	3340	9,360	29,000	95,600
3	190	300	480	840	1490	1580	3580	7300	16,800	46,600	1170	2910	8000	24,200	89,200	1580	3850	10,600	34,700	-
4	210	290	470	810	1450	1880	3610	7820	16,540	44,300	1150	2800	7560	23,500	87,500	1690	3680	11,100	38,800	171,000
5	210	310	480	800	1480	1860	3590	7380	16,700	45,100	1170	2760	7376	23,020	90,500	1560	3620	10,600	37,900	-
6	210	310	490	825	1440	1620	3200	6550	15,150	49,000	1045	2370	6550	22,100	81,500	1380	3230	8,950	29,000	-
7	210	330	520	840	1400	1780	3250	6600	15,100	36,000	1100	2600	7100	21,500	68,000	1280	3400	9,000	26,500	110,000
8	260	360	520	820	1470	1760	3160	6050	13,000	34,900	1000	2380	5940	16,700	59,300	1240	3160	8,330	23,500	77,300
9	210	300	470	760	1300	1690	3060	6120	14,000	34,800	1030	2300	5640	16,300	57,600	1380	2930	7,100	17,950[a]	58,000
10	226	338	511	818	1436	2010	3803	7585	15,660	45,773	1305	3028	7795	21,850	88,000	1562	4257	11,817	33,100	-
11	190	290	460	800	1540	1770	3520	7090	17,300	49,100	1090	2590	6830	22,600	95,800	1440	3440	9,070	31,600	133,600
12	200	300	480	790	1400	1820	3340	6660	14,480	42,100	1110	2690[a]	6870	19,200	79,800	1260	2790[a]	8,040	36,700	-
13	210	310	380[a]	600[a]	890[a]	1310[a]	2870[a]	4100[a]	9,580[a]	22,600	710[a]	2020[a]	3430[a]	10,080[a]	34,200[a]	1210[a]	3800[a]	5,020[a]	15,120[a]	56,300
Average, cp	216	316	492	815	1448	1787	3413	6915	15,523	42,628	1119	2642	6957	20,214	79,525	1419	3457	9,519	32,736	-

* Each entry is the average of 5 individual runs and is reported in centipoises.

[a] Not included in average or statistical treatment.

Table II

SUMMARY OF PERCENT STANDARD DEVIATIONS AND REPRODUCIBILITY ANALYSES

Oil	Synthetic					Naphthenic					Aromatic					Paraffinic				
Temp, °F	0	-10	-20	-30	-40	0	-10	-20	-30	-40	0	-10	-20	-30	-40	0	-10	-20	-30	-40
Laboratory Number																				
1	6.00	1.60	1.96	3.54	1.50	1.93	3.54	0.97	1.63	1.71	3.18	1.81	3.64	6.69	3.44	2.37	3.56	13.0	6.23	-
2	3.68	1.37	2.61	1.86	2.36	1.20	1.49	0.94	1.02	2.40	2.36	2.96	1.44	0.46	0.83	2.64	1.73	1.03	0.59	0.91
3	3.21	3.42	4.70	1.26	1.53	3.84	3.04	3.36	10.2	7.70	2.10	2.34	5.48	5.13	6.21	2.97	5.52	7.02	3.42	-
4	10.9	2.44	3.31	3.20	6.13	3.76	2.22	5.90	7.08	3.82	5.43	4.69	5.75	8.30	14.9	5.66	16.9	7.81	7.87	13.3
5	13.3	2.11	7.44	8.94	5.91	3.14	3.46	5.08	4.90	4.98	3.46	5.74	2.64	6.23	8.36	15.0	7.34	3.20	8.59	-
6	0.0	4.55	4.85	4.29	9.80	2.62	15.4	5.56	5.20	2.02	7.54	12.6	3.24	5.12	2.60	15.3	10.5	10.5	4.88	-
7	1.2	3.81	4.10	3.84	6.00	1.38	6.94	8.10	5.01	2.43	4.03	6.22	4.10	7.05	8.95	4.53	3.89	8.28	5.98	-
8	0.0	1.40	3.00	3.70	4.54	1.76	0.74	2.02	1.54	11.03	1.83	2.27	5.07	3.57	9.29	3.42	4.72	7.49	6.58	8.90
9	3.33	1.97	4.24	1.49	0.46	4.82	4.34	4.95	5.57	3.34	3.22	7.93	9.96	10.6	17.2	1.45	9.72	10.3	4.01[a]	26.9
10	9.9	6.1	3.7	2.5	2.3	5.0	4.5	3.1	5.6	1.1	8.4	7.1	5.0	7.4	3.9	5.0	4.8	5.9	8.2	-
11	6.4	5.2	5.9	4.9	6.6	4.7	7.6	9.0	4.6	3.4	3.0	2.8	3.1	6.4	18.5	5.2	5.4	4.7	6.8	10.6
12	13.2	8.95	8.15	7.90	7.38	12.5	9.6	8.3	6.3	15.6	9.74	2.80	10.3	9.69	23.6	17.7	10.3	19.2	18.2	-
13	10.8	5.10	5.97[a]	13.6[a]	10.2[a]	9.00[a]	8.26[a]	7.81[a]	15.4[a]	20.4	12.1[a]	10.6[a]	9.10[a]	18.3[a]	35.6[a]	19.4	12.3	8.31[a]	19.7[a]	42.3
Average Viscosity, $\bar{V}$, cp (from table)	216	316	492	815	1448	1787	3413	6915	15,523	42,628	1119	2642	6957	20,214	79,525	1419	3457	9519	32,736	-
Degrees of Freedom (N-1)	12	12	11	11	11	11	11	11	11	12	11	11	11	11	11	12	12	11	10	-
Between Laboratories Std Dev, S_B, cp	20.8	22.0	21.3	24.4	63.0	121.2	225.9	561.0	1,273	5,293	81.5	225.6	736.8	2,627	12,816	148.3	394.6	1380	5,288	--
% Std Dev	9.6	7.0	4.3	3.0	4.4	6.8	6.6	8.1	8.2	12.4	7.3	8.5	10.6	13.0	16.1	10.4	11.4	14.5	16.2	-
Reproducibility, R_B[b], cp	64	68	66	76	196	377	704	1745	3,959	16,461	253	702	2291	8,170	39,858	457	1215	4292	16,657	-
% R_B	30	22	13	9	14	21	21	25	26	39	23	27	33	40	50	32	35	42	51	-

[a] Not included in statistical treatment.

[b] Reproducibility: $R_B = \sqrt{2}\, tS_B$ with t selected at 95% confidence level. Definition: In 95% of the cases, viscosities reported by any two laboratories will differ by no more than R_B centipoises.

Table II

Table III

SUMMARY OF AVERAGE VISCOSITIES*

Oil	RPTF-8-59					RPTF-9-59					RPTF-10-59					RPTF-11-59				
°F	0	-10	-20	-30	-40	0	-10	-20	-30	-40	0	-10	-20	-30	-40	0	-10	-20	-30	-40
Laboratory Number																				
1	1328	2458	4822	10,200	30,600	1344	2406	4844	11,180	32,800	1808	3710	7798	17,180	49,750	1386	2568	4794	9,440	20,520
2	1394	2470	4762	10,540	31,880	1390	2478	4834	10,560	33,700	1756	3536	7370	16,700	43,900	1334	2436	4538	8,920	19,800
3	1422	2639	4907	10,046	30,940	1397	2638	4922	10,562	25,930	1863	3808	7708	18,360	40,830	1442[b]	2703[b]	4742[b]	9,369[b]	18,311[b]
4	1423	2439	4662	10,570	37,940	1424	2450	4918	11,820	39,500	1904	3628	7940	19,520	52,240	1472	2562	4860	9,940	21,440
5	1437	2640	5050	10,652	30,440	1440	2698	5192	11,418	35,130	1930	3986	8272	18,960	50,090	1448	2696	4956	9,550	20,000
6	1274	2286	4551	9,544	26,368	1257	3365	4597	10,287	28,736	1667	3364	7542	17,812	44,182	1288	2309	4473	9,165	19,496
7	1480	2640	5000	10,700	35,300	1435	2567	5000	11,200	38,900	1875	3810	8070	18,500	50,7000	1445	2548	4625	9,300	22,050
8	1375	2515	4845	10,550	39,200[a]	1377	2590	5152	11,533	36,700[a]	1907	3862	8112	18,850	51,116	1425	2602	4890	9,600	21,030
9	1364	2492	4866	10,660	31,520	1320	2412	4654	10,380	31,560	1746	3502	7360	16,900	46,260	1342	2372	4538	9,310	21,140
10	1480	2729	5414	11,860	34,460	1395	2616	5290	12,000	35,420	1920	3732	8400	20,300	51,240	1486	2616	5050	10,210	21,400
11	1402	2536	4860	10,560	32,900	1344	2552	5110	11,460	35,240	1842	3770	8160	19,640	53,460	1426	2598	4890	9,820	22,260
12	1400	2670	5140	11,270	34,150	1380	2650	5205	11,840	35,450	1845	3705	8700	18,590	52,500	1512	2876	5075	10,308	24,850
13	1300	2484	4820	10,420	31,200	1328	2462	4926	11,660	35,940	1742	3668	7882	19,760	53,540	1366	2526	4730	9,764	21,320
14	1402	2496	4752	10,300	28,840	1390	2506	5018	11,620	34,920	1902	3834	7940	17,920	51,000	1432	2644	5050	8,840	21,140
15	1150	2296	4440	7,810	33,100	1084	2320	4240	8,140	35,100	1560	2610	6740	16,740	38,900	1190	1990	4400	8,880	17,100
16	1244	2272	4310	9,000	30,580	1230	2284	4460	9,212	23,100	1696	3380	7090	16,020	41,360	1306	2352	4376	8,650	18,260
17	1398	2582	5064	11,640	39,420	1338	2478	4878	11,280	41,360	1792	3706	7936	18,100	46,240	1398	2510	4700	9,365	21,500
18	1238	2180	4134	8,392	21,041	1250	2226	4394	9,012	24,503	1614	3117	6512	14,988	38,300	1316	2356	4252	8,592	17,812
19	1350	2510	4950	10,580	30,965	1350	2420	4840	10,940	34,860	1780	3640	8240	20,120	53,600	1420	2520	4840	9,860	21,260
20	1431	2365	4800	11,530	31,200	1459	2422	4912	11,840	33,520	1934	3518	7600	18,800	48,500	1476	2504	4730	9,690	20,480

* Each entry is the average of five individual determinations (Brookfield viscosities in centipoises).

[a] Average of four (two extremely high values excluded).

[b] Missing values, estimated by correcting Laboratory 3's average bias for the other three oils by the ratio of the interlaboratory range on 11-59 to the average range of the other three oils.

Table IV

SUMMARY OF STANDARD DEVIATIONS

Oil °F	RPTF-8-59					RPTF-9-59					RPTF-10-59					RPTF-11-59				
	0	-10	-20	-30	-40	0	-10	-20	-30	-40	0	-10	-20	-30	-40	0	-10	-20	-30	-40
Laboratory Number																				
1	13.0	49.2	47.0	206	696	29.7	72.0	62.7	356	469	8.4	54.8	155	217	1560	27.0	58.0	26.1	54.8	443
2	39.8	53.4	142	527	4296	50.0	39.0	101	391	2620	26.1	86.5	126	100	1294	32.1	37.8	158	325	187
3	45.6	60	191	927	3973	39.9	52.6	220	883	1161	29.9	79.5	379	1325	2500	-	-	-	-	-
4	30.5	43.1	56.3	278	1744	23.1	24.5	38.3	476	1525	30.5	70.2	230	832	2916	42.1	34.9	108	286	727
5	30.3	46.4	58.7	180	378	38.1	49.2	100	312	1139	46.9	81.4	129	148	553	32.7	59.4	116	132	175
6	9.35	58	37	262	524	13.4	82.5	133	376	1020	30	66	154	701	2245	37.3	40	151	234	624
7	30.2	49.0	80.2	242	446	39.5	60.6	269	675	747	53	78	249	353	326	10.9	22.8	194	146	326
8	20.7	51.3	138	524	3736*	15.1	40.0	221	771	5735*	20.6	72.3	354	378	2362	15.2	11.7	83.9	138	137
9	15.2	34.2	85.3	195	2670	35.4	49.2	78.0	278	2251	65	92.3	344	927	3238	50.7	41.5	133	317	1714
10	41.8	35.1	87.9	744	1276	17.3	72.3	78.7	922	1489	74.5	64.1	170	424	1545	36.5	27.0	55.7	256	1122
11	86.6	78.4	167	523	2220	68.1	121	189	456	2375	54.5	189	498	815	1380	60.6	68.0	167	370	488
12	30.0	46.1	38.1	197	840	24.5	53.9	57.7	120	1575	29.7	86.5	158	309	962	13.0	52.7	50.0	363	285
13	12.2	49.3	115	259	1870	21.7	35.6	110	114	1950	29.5	57.6	134	594	2550	25.1	25.1	75.2	254	421
14	36.3	72	156	419	2000	37	31	73	310	1980	41	89	240	512	1900	31	62	250	590	378
15	41.8	8.9	167	114	1782	25.1	27.4	152	54.7	409	22.4	22.4	130	670	548	52.1	22.4	114	179	224
16	11.4	23.9	108	235	2770	14.1	33.6	134	260	539	8.9	57.0	230	890	1450	18.2	47.6	88.8	106	241
17	19	52	132	498	1917	40	64.2	131	482	3650	36	88	220	632	1415	25	53.5	82	242	1509
18	51.6	18.7	65.4	79.1	642	45.0	67	92	321	1020	20.7	61.9	121	41.4	572	33.6	101	67	156	336
19	41	62	107	377	1080	20	56	113	403	1310	59	110	147	460	1560	83	61	103	150	447
20	69.6	65.2	94.1	733	1245	76.7	66.1	242	627	4830	57.3	124	465	1008	1870	43.4	55.9	130	311	1673

* Two abnormally high results excluded.

Table IV

Table V

SUMMARY OF PER CENT STANDARD DEVIATION

Oil	Temp, °F	Laboratory Number																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
RPTF-8-59	0	0.98	2.85	3.21	2.14	2.11	0.73	2.04	1.51	1.11	2.82	6.17	2.14	0.94	2.59	3.64	0.92	1.36	4.18	3.04	4.86
	-10	2.00	2.16	2.28	1.77	1.76	2.54	1.86	2.04	1.37	1.29	3.09	1.73	1.98	2.88	3.88	1.05	2.01	0.86	2.47	2.76
	-20	0.97	2.98	3.89	1.21	1.16	1.91	1.61	2.85	1.75	1.62	3.44	0.74	2.38	3.28	3.76	2.50	2.60	1.58	2.16	6.20
	-30	2.02	5.00	9.23	2.63	1.69	2.75	2.26	4.97	1.83	6.27	4.95	1.75	2.48	4.07	1.46	2.61	4.28	0.94	3.57	6.35
	-40	2.27	13.47	12.83	4.59	1.24	1.99	1.26	9.51*	8.48	3.70	6.74	3.50	6.00	6.93	5.38	9.06	4.86	3.05	3.49	3.99
RPTF-9-59	0	2.21	3.60	2.86	1.62	2.65	1.06	2.75	1.10	2.68	1.24	5.06	1.78	1.63	2.66	2.32	1.15	2.99	3.60	1.48	5.26
	-10	2.99	1.57	2.00	1.00	1.83	3.64	2.36	1.54	2.04	2.76	4.74	2.03	1.45	1.24	1.18	1.47	2.59	3.01	2.34	2.73
	-20	1.29	2.10	4.47	0.78	1.94	2.89	5.38	4.29	1.68	1.49	3.70	1.11	2.23	1.46	3.59	3.00	2.68	2.10	2.34	4.43
	-30	3.19	3.70	8.37	4.03	2.73	3.66	6.03	66.9	2.68	7.68	3.98	1.01	0.98	2.67	0.67	2.82	4.28	3.56	3.68	5.30
	-40	1.43	7.77	4.48	3.86	3.24	3.55	1.92	15.58*	7.13	4.20	6.73	4.44	5.43	5.67	1.16	2.33	8.84	4.16	3.76	14.41
RPTF-10-59	0	0.46	1.49	1.60	1.60	2.43	1.81	2.82	1.08	3.72	3.88	2.95	1.61	1.69	2.16	1.44	0.52	2.01	1.28	3.31	2.95
	-10	1.48	2.45	2.09	1.93	2.04	1.96	2.05	1.87	2.63	1.72	5.01	2.34	1.57	2.32	0.86	1.69	2.38	1.99	3.02	3.52
	-20	1.99	1.70	4.92	2.90	1.56	2.05	3.08	4.36	4.66	2.02	6.10	1.81	1.70	3.02	1.94	3.25	2.77	1.86	1.78	6.12
	-30	1.26	0.60	7.22	4.26	0.78	3.43	1.91	2.01	5.48	2.09	4.15	1.66	3.01	2.86	4.00	5.55	3.49	0.28	2.29	5.36
	-40	3.02	2.95	6.13	5.58	1.10	5.08	0.64	4.62	7.00	3.02	2.59	1.83	4.76	3.72	1.41	3.51	3.06	1.49	2.91	3.86
RPTF-11-59	0	1.95	2.41	-	2.86	2.26	2.90	0.76	1.07	3.77	2.46	4.26	0.86	1.84	2.16	4.38	1.40	1.79	2.56	5.84	2.94
	-10	2.26	1.55	-	1.36	2.20	1.73	0.89	0.45	1.75	1.03	2.62	1.83	0.99	2.34	1.13	2.03	2.13	4.29	2.42	2.23
	-20	0.54	3.49	-	2.23	2.34	3.38	4.20	1.72	2.92	1.10	3.42	0.98	1.59	4.95	2.59	2.03	1.74	1.57	2.13	2.75
	-30	0.58	3.65	-	2.88	1.38	2.55	1.57	1.44	3.40	2.51	3.76	3.52	2.61	6.67	2.02	1.23	2.59	1.82	1.52	3.21
	-40	2.16	0.94	-	3.39	0.87	3.20	1.48	0.65	8.11	5.25	2.19	1.15	1.97	1.79	1.31	1.32	7.02	1.88	2.10	8.16
Individual Laboratory Total		35.05	66.43	75.58	52.62	37.31	53.31	46.87	69.35	74.19	58.15	85.65	37.82	47.22	65.44	48.12	49.44	65.49	46.06	55.65	97.89
Individual Laboratory Average		1.75	3.32	5.04	2.63	1.87	2.67	2.34	3.47	3.71	2.91	4.28	1.89	2.36	3.27	2.41	2.47	3.27	2.30	2.78	4.89

* Two abnormally high results excluded.

Over-all average per cent standard deviation, $\bar{\bar{S}} = \frac{59.54}{20} = 2.98$

From Table II, p. 63, ASTM Manual on Quality Control of Materials, STP 15-C (1951)
Factors B_3 and B_4 for lower and upper 3-sigma limits for the standard deviation chart (lower part of Figure 9), for n = 20 are, respectively, $B_3 = 0.510$ and $B_4 = 1.490$
The limits are therefore set at $0.510\ \bar{S} = 1.52$ and $1.490\ \bar{S} = 4.43$.

Table V

Table VI

REPEATABILITY AND REPRODUCIBILITY OF BROOKFIELD VISCOMETER MEASUREMENTS

Temp °F	Laboratory No. 7* Standard Error S_r	Laboratory No. 7* Repeatability 2.83 S_r	Laboratory No. 18* Standard Error S_r	Laboratory No. 18* Repeatability 2.83 S_r	Laboratory No 7* Standard Error S_r	Laboratory No 7* Reproducibility 2.97 S_r	Laboratory No. 18* Standard Error S_r	Laboratory No. 18* Reproducibility 2.97 S_r
0	2.2	6.2	2.6	7.4	6.5	19.3	6.1	18.1
-10	2.0	5.7	2.2	6.2	6.6	19.6	6.8	20.2
-20	2.5	7.1	2.8	7.9	6.7	19.9	6.0	17.8
-30	2.9	8.2	3.8	10.8	8.5	25.3	8.2	24.4
-40	8.6	24.4	5.3	15.0	14.9	44.3	11.4	33.9

* Statistical analysis.

Repeatability is the greatest difference between two single measurements in the same laboratory expressed as the percentage of the mean of the two measurements that can be considered acceptable at the 95% confidence level.

Reproducibility is the greatest difference between two single measurements in different laboratories expressed as the percentage of the mean of the two measurements that can be considered acceptable at the 95% confidence level.

lbs

Table VI

Table VII

REPEATABILITY AND REPRODUCIBILITY OF THE LOGARITHMS OF BROOKFIELD VISCOMETER MEASUREMENTS

Temp, °F	Laboratory No. 7* Standard Error 6_E	Laboratory No. 7* Repeatability 2.83 6_E	Laboratory No. 14* Standard Error 6_E	Laboratory No. 14* Repeatability 2.77 6_E	Laboratory No. 7* Standard Error, $\sqrt{6_L^2+6_E^2}$	Laboratory No. 7* Reproducibility 2.97 $\sqrt{6_L^2+6_E^2}$	Laboratory No. 14* Standard Error $\sqrt{6_L^2+6_E^2}$	Laboratory No. 14* Reproducibility 2.97 $\sqrt{6_L^2+6_E^2}$
0	0.009725	0.0275	0.01372	0.03800	0.02847	0.08456	0.03282	0.09751
-10	0.008729	0.0247	0.01104	0.03058	0.02860	0.08494	0.03056	0.09076
-20	0.010742	0.0304	0.02204	0.06015	0.02909	0.08640	0.03452	0.10252
-30	0.012727	0.0360	0.01960	0.05429	0.03706	0.11007	0.04373	0.12988
-40	0.037327	0.1055	0.02463	0.06823	0.06480	0.19246	0.05678	0.16920

* Statistical analysis.

Repeatability is the greatest difference betweenthe logarithms of two single and independent measurements in the same laboratory that can be considered acceptable at the 95% confidence level.

Reproducibility is the greatest difference between the logarithms of two single and independent measurements in different laboratories that can be considered acceptable at the 95% confidence level.

lbs

Table VII

APPENDIX A

RESEARCH TECHNIQUE FOR EVALUATING THE LOW-TEMPERATURE FLUIDITY OF AUTOMATIC TRANSMISSION FLUIDS

(CRC Designation L-45-1262)

Prepared by the

Low-Temperature Fluidity Panel

of the

Power-Transmission and Power-Steering Units and Fluids Group

of the

Motor Vehicle Fuel, Lubricant, and Equipment Research Committee

of the

Coordinating Research Council, Inc.

Appendix A.

(CRC Designation L-45-1262)

TABLE OF CONTENTS

Appendix A

RESEARCH TECHNIQUE FOR EVALUATING THE LOW-TEMPERATURE FLUIDITY OF AUTOMATIC TRANSMISSION FLUIDS

(CRC Designation L-45-1262)

A. PURPOSE

This research technique was formulated by the Power-Transmission and Power-Steering Units and Fluids Group of the Motor Vehicle Fuel, Lubricant, and Equipment Research Committee to provide a means of measuring the low-temperature fluidity of automatic transmission fluids.

B. GENERAL OUTLINE

A sample of automatic transmission fluid is cooled and held at the desired temperature in a cold box for an overnight period. The sample is then removed in an insulated carrier and analyzed with a Brookfield viscometer.

C. EQUIPMENT REQUIRED

1. Brookfield viscometer, Model LVT. (Model LVF may be used for viscosities less than 100,000 cp.)

2. Brookfield viscometer stand equipped preferably with rack and pinion adjustment.

3. Number 4 spindle (for LVT and LVF models).

4. Cell (test tube) OD 25 mm, length 100 mm.

5. Insulating cell carrier (Figure 1).

6. Cell wood stopper (Figure 2).

7. Cell rack and turntable to provide any constant speed from 3-35 rpm (Figure 3).

8. Cold box with an air circulation device capable of maintaining a constant temperature to within ± 0.5°F of the desired temperature (Note 1).

(CRC Designation L-45-1262)

C. EQUIPMENT REQUIRED (Cont'd)

9. Two mercury-thallium thermometers* with +10° to -70° F temperature range, or as an alternate, a copper-constantan thermocouple and suitable potentiometer**.

10. Graph paper representing an enlargement of the ASTM viscosity-temperature chart in the temperature range of +10° to -50°F (Figure 4).

11. Reference fluid RPTF-11-59. ***

D. EXPERIMENTAL PROCEDURE

1. Establish constant (±0.5°F) test temperature within ±2.0°F of desired nominal temperature in cold box using one of the mercury-thallium thermometers.

2. Fill cell with approximately 27 ml of the fluid under test.

3. Put stopper on cell and insert spindle.

4. Place cell assembly in rack.

5. Place cell rack in oven at 120°F for a half hour, then remove rack and let stand at room temperature for a half hour.

6. Place rack on turntable and put these and cell carrier in cold box.

7. Put the second mercury-thallium thermometer in a fluid-filled cell either in the rack or near the rack. (Alternative choice is to insert thermocouple in fluid filled cell.)

8. Rotate cell rack at any one speed between 3-35 rpm.

9. Maintain the test temperature for a period of 16 hours. (Six hours is sufficient at 0°F; this allows a complete viscosity-temperature analysis to be completed in a week.)

* H-B Instrument Company Catalogue No. 22403.

** Suggested instrument: Brown Portable Potentiometer No. 126W3.

*** Reference fluid RPTF-11-59 available from Rohm and Haas Company, Oil Additives Laboratory, 5000 Richmond Street, Philadelphia 37, Pennsylvania.

es

D. EXPERIMENTAL PROCEDURE (Cont'd)

10. Read both thermometers to nearest 0.1°F. (Thermometer not in fluid should be read through box window if possible.)

11. Place cell in cell carrier and immediately transfer the unit to the Brookfield viscometer for analysis.

12. Attach spindle and lower the spindle to the midpoint of the immersion neck by observing the spindle through the plastic window of the cell carrier.

13. Center the spindle in the hole at the top of the cell stopper.

14. Select the highest spindle speed possible to analyze the sample.

15. Take dial reading as soon as possible. A time limit of 2 minutes should not be exceeded for any analysis.

16. Read thermometer in fluid at conclusion of analysis to assure that temperature has not changed by more than 0.5°F

17. Follow this procedure for 0, -10, -20, -30, and -40°F temperatures with new samples of the fluid. (One sample may be carried through the complete test if there is no water contamination.)

E. REPORTING RESULTS

1. Record both box and fluid temperatures to nearest 0.1°F before analysis.

2. Record Brookfield viscosity of each sample in centipoise. (0.4 must be subtracted from dial reading at 60 rpm to correct for windage.)

3. Plot the logarithm of viscosity versus fluid temperature on semilogarithmic paper (K and E 359-71). (Data must be plotted even if test temperatures are the same as nominal temperatures.) (Note 2)

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F. REPEATABILITY AND REPRODUCIBILITY

A cooperative test among 20 participating laboratories using four reference fluids (RPTF-8-59, RPTF-9-59, RPTF-10-59 and RPTF-11-59) has established the following precision limits:

Temp, °F	Repeatability %	Reproducibility %
0	7	19
-10	6	20
-20	8	19
-30	10	25
-40	20	39

NOTE 1:

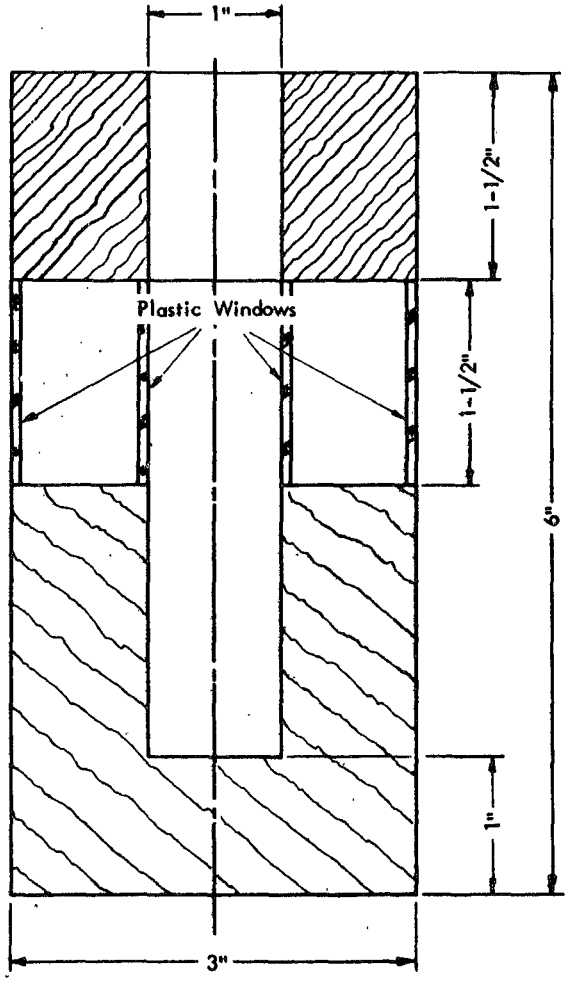
Some laboratories have used liquid baths to obtain cooling and temperature control of the sample. Since the rate of cooling the sample can affect the viscometric properties, a cool-down period of at least 2 hours and preferably 4 hours is recommended. In general, values obtained from samples cooled in liquid baths have been somewhat lower than those obtained from air baths. This anomaly has been attributed to the heat transfered down the exposed stem of the spindle, and the effect has been somewhat diminished by using spindles made of less heat conductive materials.

NOTE 2:

Graph paper based on the ASTM viscosity-temperature chart (on which log-log viscosity in centistokes is used as the ordinate and log absolute temperature in degrees Rankine is used as the abscissa) has been tried successfully. Determined viscosity values for reference fluids RPTF-8-59, RPTF-9-59, RPTF-10-59, and RPTF-11-59 have been plotted linearly down to -30°F. The Low-Temperature Fluidity Panel recommended that such graph paper be used to permit more accurate interpolation and freedom from curve fitting, with the caution that all fluids should not be expected to yield such a linear plot on this paper. Moreover, interpolation below -30°F must be on the basis of the smooth curve obtained on K and E 359-71 semilog paper or else more viscometric data must be obtained between -30°F and -40°F to permit reasonably precise interpolation. A sample of the graph paper representing an enlargement of the ASTM viscosity-temperature chart in the temperature range of +10°F to -50°F is shown in Figure 4.

Appendix A
Figures 1, 2

(CRC Designation L-45-1262)



Section AA

BALSA WOOD
BODY AND TOP

Figure 1

CELL CARRIER

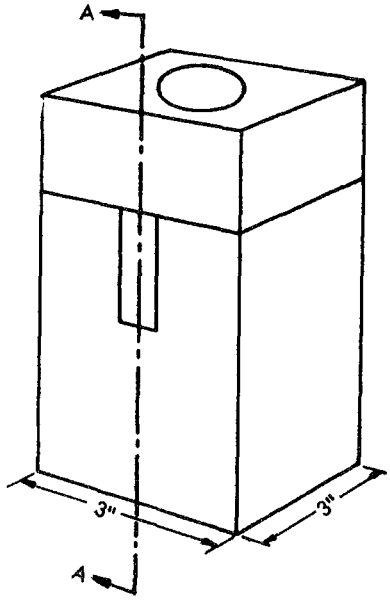
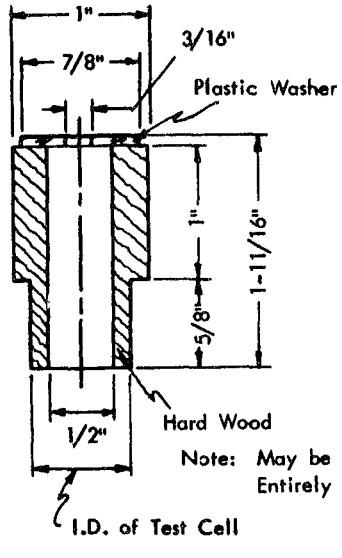


Figure 2

CELL STOPPER

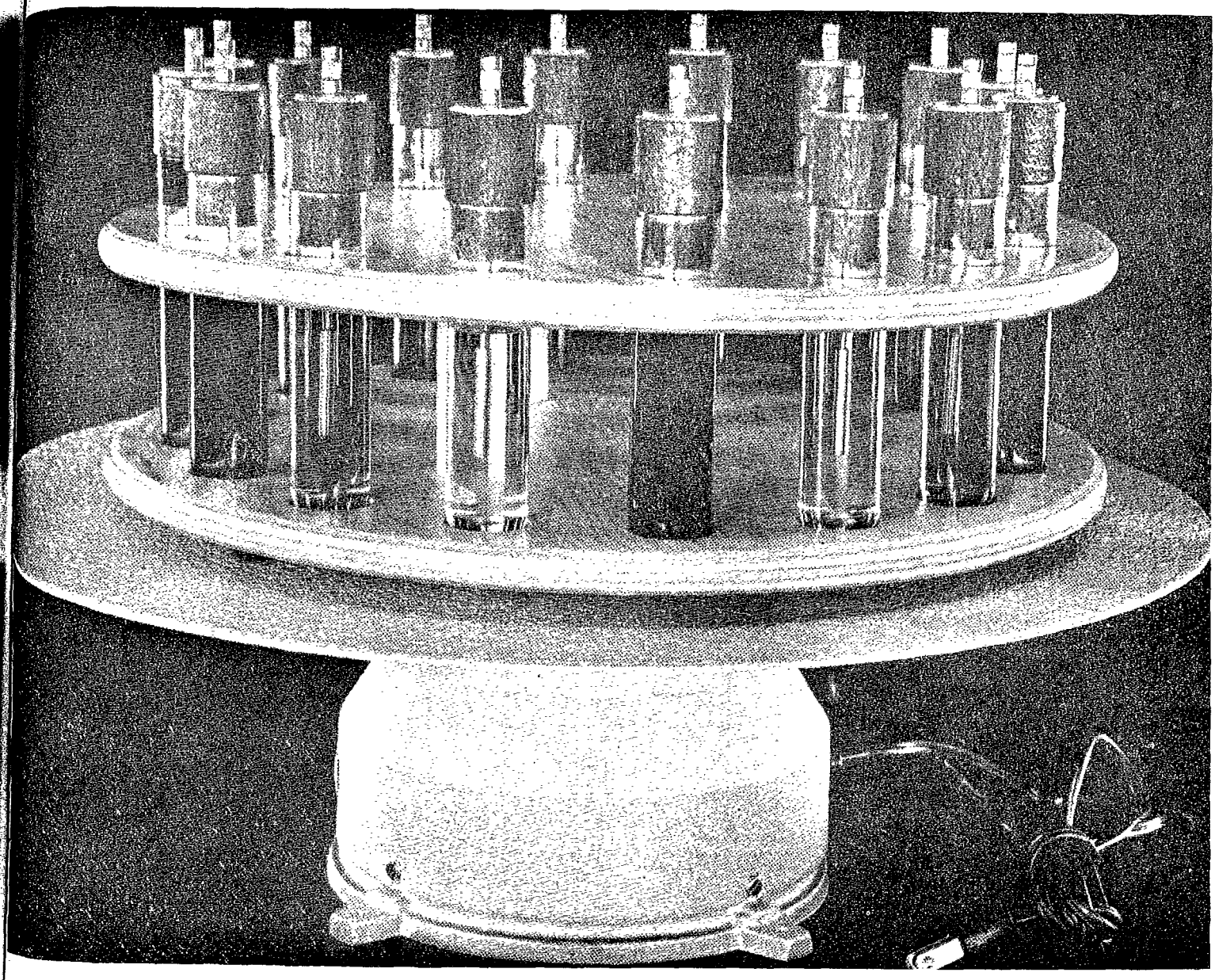


Note: May be Made
Entirely of Plastic

Appendix A
Figure 3

(CRC Designation L-45-1262)

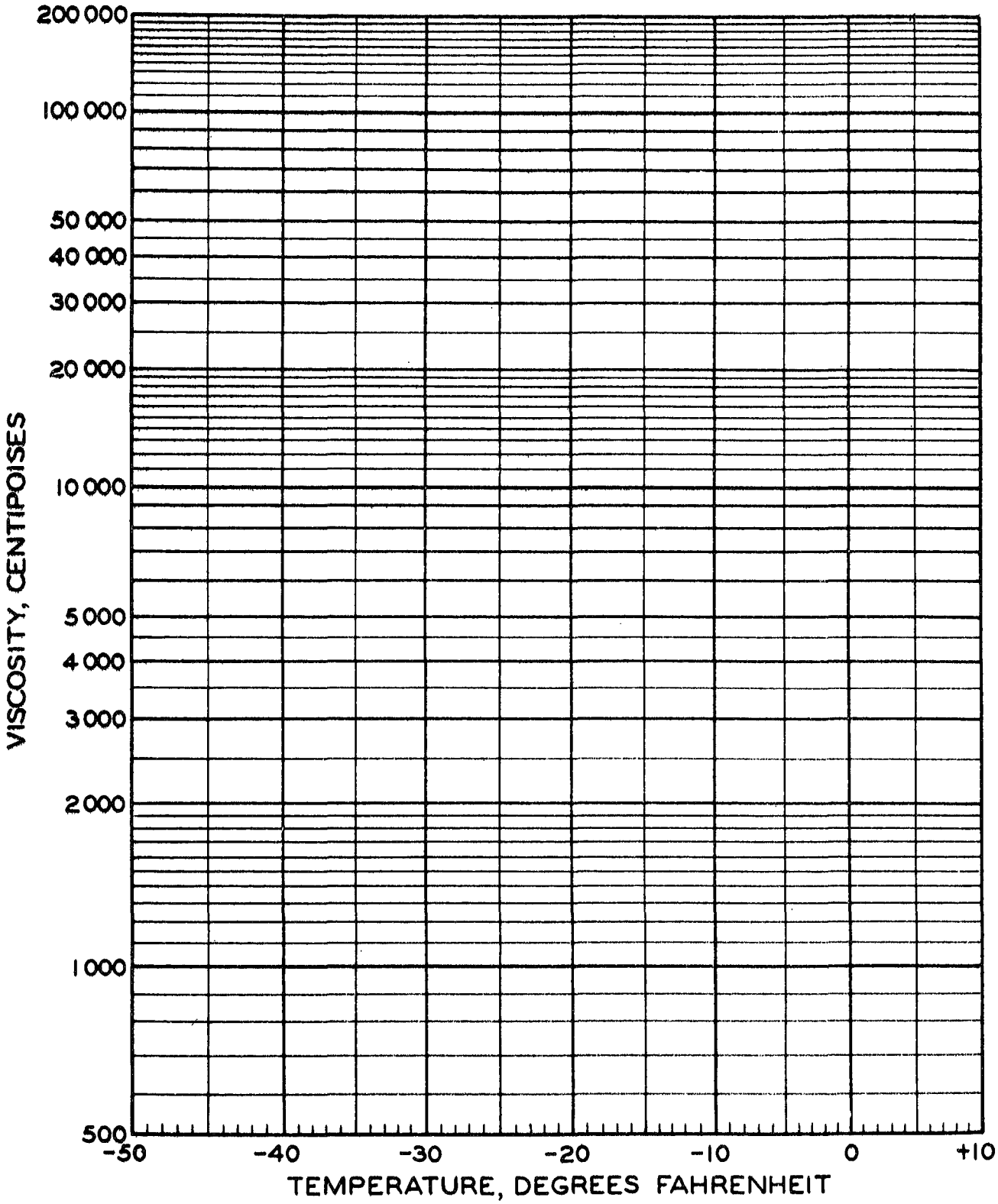
SAMPLE RACK AND TURNTABLE



Appendix A
Figure 4

(CRC Designation L-45-1262)

RECOMMENDED GRAPH PAPER TO PLOT VISCOSITY - TEMPERATURE DATA



APPENDIX B

INSPECTION DATA ON REFERENCE FLUIDS USED IN CRC L-45 TEST PROGRAM

INSPECTION DATA ON REFERENCE FLUIDS USED IN CRC L-45 TEST PROGRAM

A. CALIBRATION FLUIDS RPTF-5-59 and RPTF-6-59

RPTF-5-59

Visc at 100°F	4334 cs
	20087 SUS
Visc at 210°F	138 cs
	644 SUS
Viscosity Index	106
Gravity, °API	23.3

RPTF-6-59

Visc at 100°F	1134 cs
	5256 SUS
Visc at 210°F	54.8 cs
	256 SUS
Viscosity Index	101+
Density at 60°F	0.8735
Density at 100°F	0.8586
Calculated cps at 100°F	974

B. FIRST TEST SERIES

	Synthetic	Naphthenic	Aromatic	Paraffinic
Density at 60°F	0.9084	0.8833	0.9616	0.8734
Viscosity, cs, at 210°F	6.98	7.56	2.57	7.30
at 100°F	39.55	42.32	13.39	36.63

C. SECOND TEST SERIES

	RPTF-8-59	RPTF-9-59	RPTF-10-59	RPTF-11-59
Density at 60°F	0.8812	0.8854	0.8921	-
Viscosity, cs, at 210°F	7.24	7.30	7.17	6.97
at 100°F	39.26	39.46	41.83	39.60

APPENDIX C

PARTICIPATING LABORATORIES

PARTICIPATING LABORATORIES

American Oil Company
California Research Corporation
Cities Service Research and Development Company, Inc.
Dow Chemical Company
DX Sunray Oil Company
Enjay Laboratories
Esso Research and Engineering Company
General Motors Research Laboratories*
Lubrizol Corporation
Monsanto Chemical Company
Olin-Mathieson Chemical Corporation
Phillips Petroleum Company
Pure Oil Company
Richfield Oil Corporation
Rohm and Haas Company, Inc.
Shell Oil Company
Sinclair Research Inc.
Socony Mobil Oil Company, Inc.
Standard Oil Company (Ohio)
Sun Oil Company
Texaco Inc.
Union Carbide Chemicals Company

* Including Fuels and Lubricants Department and Chemistry Department.