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FINAL REPORT

PROPERTIES OF ASPHALT CEMENT USED IN VIRGINIA AND THEIR EFFECTS ON PAVEMENT PERFORMANCE

by

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Virginia Highway & Transportation Research Council
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ABSTRACT

This is a summary report that along with the two previous reports listed as references 1 and 2 constitute the final report of the project.

No unusual properties were found in any of the AC-20 asphalt cements supplied to the Virginia Department of Highways and Transportation for use in highway construction projects in 1983. This finding and the summary of effects of chemical composition on the physical properties and specifications for asphalt cements reported in reference 2 lead to the conclusion that, other than the possible addition of a requirement for a maximum ash content of 0.40 percent, no significant modification of the Department's asphalt cement specifications is needed at this time. However, from the standpoint of regional simplification of industry requirements, future consideration should be given to eliminating present differences between the Department's specification and the equivalent specification of the American Association of State Highway and Transportation Officials.

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PREVIOUSLY REPORTED WORK

This summary report and two previously published interim reports constitute the final report of the cooperative study supported by the U. S. Department of Transportation and the Virginia Highway and Transportation Research Council. The interim report for Task 1 on the evaluation of asphalt characteristics included the results of tests on 30 samples of AC-20 asphalts supplied for use by the Virginia Department of Highways and Transportation in 1983.(1) These results are reproduced in Table 1 of the Appendix of this report. They include the usual tests for specification compliance and special tests to show viscosity-temperature susceptibility and ductility-penetration relationships. These indicate that from the standpoint of physical or engineering properties all of the products would be expected to give satisfactory performance when used in properly designed and placed mixtures. However, at the time that interim report was published any possible differences in asphalt-aggregate adhesion or loss of strength from moisture had not been assessed. Such tests have now been made on mixtures containing a siliceous type aggregate (quartzite) and are reported in a subsequent section of this report.

The report on Task 2 of the study was a synthesis of information concerning the chemical composition of asphalt and the relation of such composition to the physical properties of the asphalt and its performance as a binder in asphaltic pavements.(2) An attempt was made in that report to present accepted concepts without necessarily covering all the details of the complex chemistry involved. It is believed that the data presented and relationships discussed demonstrate that there is no simple "cook book" approach to specifying the characteristics of asphalt cements that will guarantee trouble-free mixtures with all types of aggregates. It is indicated that, even if possible, it would not be desirable from an economic or technological standpoint to write specifications for asphalt cements based on close control of their chemical composition.

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Increased national interest in new research efforts concerning the properties of asphalt cement, including their composition and means of modifying properties to improve performance, has led to widespread distribution of the two interim reports. Both reports were distributed by the FHWA to its Division Offices and to all state highway agencies. In addition, the report on the relation of asphalt chemistry to physical properties and specifications was presented by title only at the 1985 meeting of the Association of Asphalt Paving Technologists (AAPT). A shortened version of the report will be published in the AAPT Proceedings for 1985. Finally, a report stemming from the literature search made in preparing the report on chemical composition was prepared and presented at the 1985 convention of the National Asphalt Pavement Association. It presented a brief review of major research efforts resulting in significant specification requirements for asphalt cements. It also summarized needed additional research.(3)

TESTS FOR ASPHALT-AGGREGATE BOND

Although it is generally considered that the properties of the aggregate affect the asphalt-aggregate bond to a greater extent than do the properties of asphalts of the same grade, significant variation because of differences in asphalt properties have been encountered. To determine if any of the asphalts being supplied to Virginia had significantly different adhesive characteristics, a typical asphalt from each supplier was selected and tested for susceptibility of the asphalt-aggregate bond to water damage using the Virginia Test Method for Stripping of Bituminous Concrete VTM-62.(4) This procedure is a modification of one developed by Lottman.(5) It consists of comparing the average indirect tensile strength of a series of test specimens tested dry with the average indirect tensile strength of a series of test specimens made from the same asphalt mix but conditioned by vacuum saturation with water, freezing, and then soaking in a 140°F (60°C) water bath for a prescribed period. The temperature of the specimens is then adjusted to 77°F (25°C) for determination of the indirect tensile strength by applying a compressive load along the diameter of the specimen. The average result for the conditioned specimens divided by the average result for the dry specimens is reported as the tensile strength ratio (TSR). An asphalt mix having a TSR of 0.75 or greater is considered to have adequate resistance to moisture damage. Values less than 0.75 are taken as an indication that an antistrip additive is needed to give the most satisfactory resistance to water damage.

For these tests a quartzite aggregate identified as Sylvatus stone was selected. This is a borderline material that sometimes requires the use of an antistrip additive with the asphalt, but at other times does not. Thus, it was selected since it was thought to be sensitive to differences in asphalts should they be encountered. The results of the tests are shown in Table 1. As indicated, only small differences in the TSR were obtained. The range from the lowest to the highest is from 0.51 to 0.64. The average was 0.55 and the standard deviation 0.04. The within laboratory repeatability of the test (range for duplicate specimens) is generally considered to be 0.08. Thus, it can be concluded that differences between asphalts for this series of tests were not significant. It is noted that all of the asphalts would require an antistrip additive when used with this stone.

As a measure of the potential response of the asphalt-aggregate mixtures to an antistrip additive, three asphalts were tested using 0.3% additive. As indicated the TSR for all three asphalts was increased to an acceptable level (>0.75)

Table 1

Retained Tensile Strength Ratio
for Selected Asphalts

Asphalt No. No Additive	Producer Identification	Indirect Tensile Strength, lbf/in^2, Average of 6 Specimens: Dry	Conditioned	TSR
110	A	86	48	0.56
105	B	70	37	0.53
102	C	77	42	0.55
111	D	78	48	0.58
121	D	69	44	0.64
108	E_1	65	33	0.51
118	E_2	65	35	0.54
116	F_1	86	45	0.52
117	G_2	72	39	0.54
129	G_3	65	37	0.57
			Average	0.55
			Standard Deviation	0.04
0.3 % antistrip additive added to asphalt				
108	E_1	63	51	0.81
102	C	77	64	0.83
121	D	77	61	0.79

Note: See VTM-62 in reference 4 for detailed description of test method and conditioning of specimens.

1 lbf/in^2 = 6.895 kPa

SIGNIFICANCE OF DIFFERENCES IN VISCOSITY-TEMPERATURE SUSCEPTIBILITY

As discussed in reference 1, the lowest penetration at 77°F (25°C) measured for asphalts in the study was 63 and the highest was 100. Recent changes in the asphalt specifications by the Virginia Department of Highways and Transportation inserted a requirement that the penetration of AC-20 asphalt be no greater than 100, thereby establishing 60 to 100 as the range for suitable materials. Thus, the materials submitted for this evaluation cover essentially the full permitted range. It was also noted in reference 1 that 18 of the materials tested would be graded as 85-100 under the penetration system and 5 would be graded as 60-70. Nine asphalts had penetration values between these two grades.

To obtain additional insight as to the practical significance of the differences in viscosity-temperature susceptibility, the maximum and minimum viscosities obtained at 275°F (135°C), 140°F (60°C), and 77°F (25°C) were plotted using the principle of the ASTM standard viscosity chart for asphalts (D2493). In this chart the logarithm of the logarithm of viscosity is plotted against the logarithm of the absolute temperature in degrees Rankine. The results approach a straight line for many asphalts. Values for viscosity at 77°F (25°C) were estimated by the equation

$$\log. \text{ viscosity} = 10 - 2 \log \text{ penetration.}$$

This equation represents the "average" of several such equations developed by different authors and provides good general estimates, but not necessarily precise values, for all asphalts.

The shaded area in Figure 1 includes all the asphalts tested for this study. As is shown, even though the acceptable range of penetration at 77°F (25°C) of 60 to 100 may appear relatively large if the temperatures at which equiviscous conditions are attained at several significant viscosity levels, the differences noted appear considerably smaller and may have no practical significance for a construction project. The dotted line above the shaded area and the solid line below the shaded area represent the theoretical boundaries of minimum and maximum viscosity-temperature susceptibility permitted under the Virginia specification, assuming a straight line is attained on the chart in between the viscosity range from 77°F (25°C) to 140°F (60°C) and that extrapolation to higher temperatures is valid.

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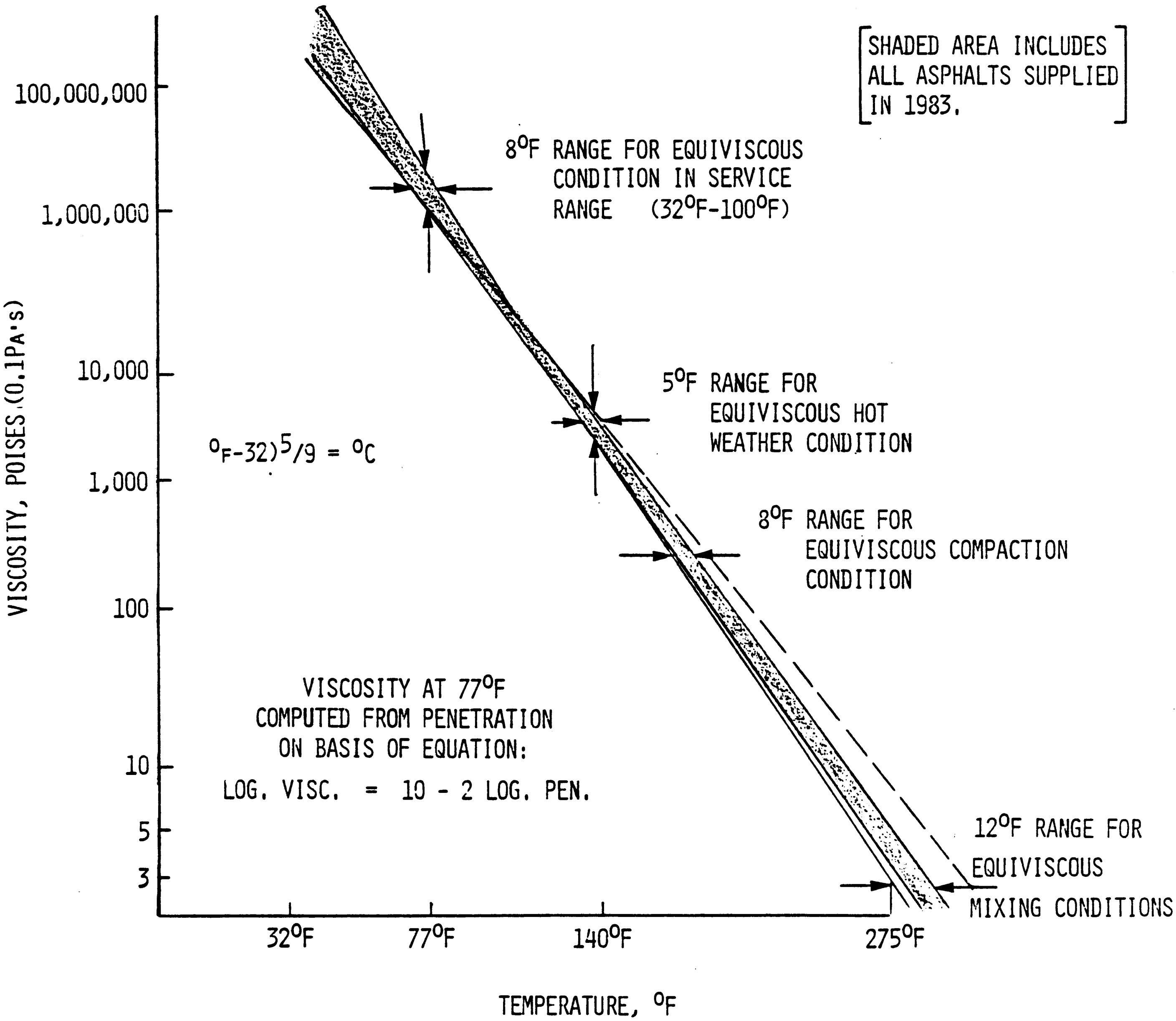

Figure 1. Approximate ranges of temperatures for equiviscous conditions for asphalt supplied to the Virginia Department of Highways and Transportation.

A summary of the temperature ranges shown on Figure 1 is as follows:

Ranges for equiviscous conditions:

1. Normal ambient temperatures (32°-100°F) - - - - - -
   8°F (3.6°C)
   Example: Hardest AC-20 has penetration of 75 at 80°F (26.7°C)
   Softest AC-20 has penetration of 75 at 72°F (22.2°C)

2. Hot summer temperatures (140°F [60°C] pavement temp.) - -
   5°F (2.8°C)
   Example: AC-20 at upper limit of specification has 2,000 poise (200 Pa's) viscosity at 143°F (61.7°C)
   AC-20 at lower limit of specification has 2,000 poise (200 Pa's) viscosity at 138°F (58.9°C)

3. Compaction temperatures - - - - - - - - - - 8°F (3.6°C)
   Example: Hardest AC-20 has 200 poise (20 Pa's) viscosity at 175°F 79.4°C)
   Softest AC-20 has 200 poise (20 Pa's) viscosity at 183°F (84.0°C)

4. Mixing temperatures - - - - - - - - - - - --- 10°F (5.6°C)
   Example: Hardest AC-20 has 3 poise (0. 3 Pa's) viscosity at 283°F (139.4°C)
   Softest AC-20 has 3 poise (0. 3 Pa's) viscosity at 293°F (145.0°C)

Since normal variations of temperature during construction and in service are so much greater than the approximate ranges shown above, it is concluded that differences in viscosity-temperature susceptibilities of asphalts supplied to Virginia in 1983 were not significant from the standpoint of either construction operations or performance conditions.

ADEQUACY OF SPECIFICATIONS

Control of Asphalt Composition

It has been established that nationwide very few refiners use a single source of crude petroleum to manufacture asphalt cements. As a result, some consumer personnel have suggested that consideration be given to establishing specification limitations on composition to assure that unsatisfactory materials meeting physical requirements are not marketed.

The information provided by the asphalt suppliers in Virginia is consistent with the national trend. All reported that they use blends of several crudes and that the percentages of the crudes in the blends will vary significantly depending on cost and availability factors beyond the refiners' control. The synthesis report, reference 2, demonstrates the complexity of chemical composition and the high degrees of overall variability among crude petroleums. On a national basis it has been established that materials of significantly different chemical composition can provide good service in asphalt pavements if used properly.

As demonstrated by the tests on the asphalt supplied to Virginia in 1983, the variability is considerably less than that possible on a national basis, and the limitations on composition inherent in the established physical requirement indicate that under present state of the art "compositional" requirements are not needed. The problem of proper blending of crude sources and obtaining satisfactory materials is a problem of the asphalt producer.

As discussed in reference 2, the three major attributes needed for an asphalt cement are:

1. Proper mechanical properties -- It must have the right consistency (viscosity or penetration) to provide proper fluidity at mixing temperatures and, after compaction, pavements able to withstand the expected traffic without rutting at high temperatures or cracking at low temperatures.

2. Good durability -- Although some change is inevitable, high quality asphalts must have good resistance to changes such as hardening and loss of adhesive qualities during the lifetime of the pavement.

3. Proper adhesive characteristics -- The asphalt must form a good bond with aggregates and not be displaced or degraded by moisture.

As indicated by the discussions in reference 2, present specifications depend on viscosity or penetration grading to establish suitable grades for application under different ambient temperature conditions and different expected traffic situations. Control of the viscosity-temperature susceptibility is attained in standard American Association of State Highway and Transportation Officials and ASTM viscosity graded specifications by a minimum penetration at 77°F (25°C) and a minimum viscosity at 275°F (135°C). AASHTO and ASTM penetration graded specifications do not contain controls of viscosity-temperature, although some states and Canadian provinces using penetration grading place a minimum value on the viscosity at 275°F (135°C).

AASHTO specifications use the thin-film oven test with requirements for the maximum viscosity and minimum ductility for the residue from the test as the primary measure of durability. This test adequately measures the effects of heat and air (oxygen) on the asphalts. Variations in long-term chemical changes may be possible for asphalts having the same response to the thin-film oven test, but the significance of such differences, if they occur, to performance in a pavement is not known.

Asphalt specifications do not contain a direct measure of adhesive properties and the effects of moisture on such properties. Some states require measures of the effects of water on asphalt-aggregate bond by stripping tests or ratios of the strength of specimens tested after conditioning to that of specimens tested dry. As discussed in reference 2, the long-term effects of moisture in pavement mixtures need further research, but the problem is one of asphalt-aggregate combinations rather than asphalt alone.

Requirement for Low Temperature Ductility

Wide variations in ductility results at temperatures lower than 77°F (25°C) are sometimes cited as indicating a need for minimum ductility requirements at low temperatures. The analysis of the data previously reported was based on the ductility-penetration relationship rather than the ductility-temperature relationship. It was concluded that the ductility-penetration relationship was satisfactory for all asphalts in the study. Thus, the variations noted in ductility values at low temperatures for these asphalts result from differences in consistency of the asphalts, and the low ductility values shown are not considered as being indicative of poor quality asphalt. It is concluded that a low temperature ductility requirement is not needed in the Virginia asphalt specification.

Ash Content

Because of a known instance in another state of pavement distress caused by excessive stripping during construction when the asphalt contained an appreciable amount of sodium organic salts, it was recommended in reference 1 that a limitation on the amount of ash in an asphalt cement be added to the present Virginia specifications. The recommended maximum is 0.40% ash. This recommendation was made as a safeguard measure to avoid a significant amount of sodium salts in the asphalts which would be present in the ash as sodium carbonate. None of the asphalts tested in this study had ash contents greater than 0.40%; thus, there was no opportunity to examine ash contents of the type likely to be indicative of asphalts with an unusual propensity to strip with certain aggregates. Should an asphalt having greater than 0.40% ash content be submitted for use in Virginia, tests should be conducted to determine whether such ash contains appreciable amounts of water soluble salts (sodium or potassium carbonate, or both).

RECOMMENDATION

Except, as discussed, for inclusion of a limit on ash content, no change in specifications for asphalt cements is needed at the present time. However, future consideration should be given to the need for differences between the AASHTO specification and the Virginia Department of Highways and Transportation specification, since the use of a single region-wide specification is advantageous to the asphalt supplier and may result in an economic advantage to the state.

REFERENCES

1. Halstead, W. J., "Properties of Asphalt Cement Used in Virginia and Their Effects on Pavement Performance - Interim Report on Task 1. Evaluation of Asphalt Characteristics," VHTRC 84-R48, Virginia Highway and Transportation Research Council, Charlottesville, Va.

2. _______, "Relation of Asphalt Chemistry to Physical Properties and Specifications," VHTRC 84-R45, Virginia Highway and Transportation Research Council, Charlottesville, Va., May 1984.

3. _______, "A Review of Research Pertaining to Asphalt Composition and Its Relation to Quality," VHTRC 85-R16, Virginia Highway and Transportation Research Council, Charlottesville, Va., December 1984.

4. Virginia Department of Highways, "Virginia Test Methods Manual, Materials Division," July 1984.

5. Lottman, R. P., "Predicting Moisture-Induced Damage to Asphaltic Concrete." NCHRP Report 192, Transportation Research Board, Washington, D. C., 1978.

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APPENDIX

CHARACTERISTICS OF ASPHALTS USED BY VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION IN 1983
(From Reference 1)

Producer Code	Sample No.	Viscosity at: 140°F., V_o, poises	Viscosity at: 275°F. centistokes	Thin-film Oven Test: Viscosity Residue at 140°F., V_{tf}, poises	Thin-film Oven Test: Ratio V_{tf}/V_o	Softening Point °F.	Specific Gravity at 77°F.	Penetration at: 77°F.	Penetration at: 60°F.	Penetration at: 50°F.	Penetration at: 45°F.	Penetration at: 39.2°F.	Ductility 5 cm./min. at: 50°F., cm.	Ductility 5 cm./min. at: 45°F., cm.	Ductility 5 cm./min. at: 39.2°F., cm.	Ash %
A	100	1959	409	8788	4.5	123.7	1.029	70	25	14	12	9	9.7	6.2	B[a]	0.03
	110	1904	392	5257	2.8	124.5	1.030	66	26	14	11	8	9.2	6.2	B[a]	0.09
	123	-	-	-		124.7	1.027	64	25	14	11	8	9.5	6.2	B[a]	0.10
B	101	2258	514	3580	1.6	121.2	1.035	91	36	19	14	11	142	9.7	8.0	0.03
	105	2316	513	6479	2.8	120.2	1.033	93	35	19	15	12	135	9.7	6.7	0.08
	109	1942	379	3908	2.0	123.2	1.028	80	31	18	12	9	117	7.0	B[a,b]	0.09
	120	-	-	-	-	119.7	1.032	97	37	20	16	11	131	14.7	7.5	
C	102	1911	409	4726	2.5	122.2	1.026	78	30	17	13	9	13.7	7.2	B[a]	0.03
	103	1886	406	4380	2.3	121.2	1.027	75	29	16	12	9	22.2	6.5	B[a]	0.00
D	104	1937	397	-	-	122.2	1.028	77	29	15	14	9	18.2	7.0	5.0	0.01
	111	1775	300	3732	2.1	121.7	1.027	75	28	15	12	9	43	7.2	B[a]	0.09
	121	-	-	-		118.2	1.023	84	29	17	12	9	136	36.5[cl]	7.2	0.10
El	107	2004	419	-	-	122.2	1.029	73	27	14	12	8	45	7.2	B[a,d]	0.02
	108	2050	468	-	-	120.2	1.033	100	38	22	16	11	26	10.5	6.7	0.34
	113	2254	377	5326	2.4	121.2	1.033	96	37	20	16	11	148	10.5	7.5	0.28
	119	1874	414	6588	3.5	121.7	1.028	78	29	17	13	9	58	9.0	B[a,e]	0.12

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APPENDIX (continued)

Producer Code	Sample No.	Viscosity at: 140°F., V_o, poises	Viscosity at: 275°F., centistokes	Thin-film Oven Test: Viscosity Residue at 140°F., V_{tf}, poises	Thin-film Oven Test: Ratio V_{tf}/V_o	Softening Point °F.	Specific Gravity at 77°F.	Penetration at: 77°F.	Penetration at: 60°F.	Penetration at: 50°F.	Penetration at: 45°F.	Penetration at: 39.2°F.	Ductility 5 cm./min. at: 50°F., cm.	Ductility 5 cm./min. at: 45°F., cm.	Ductility 5 cm./min. at: 39.2°F., cm.	Ash %
E2	115	1687	397	5148	3.1	119.7	1.031	92	36	21	18	12	44	9.2	6.7	0.01
	118	1805	402	5383	3.0	122.2	1.032	91	35	21	16	12	67	9.5	6.5	0.02
	125	1805	402	5383	3.0	121.7	1.032	88	36	20	16	12	36	9.7	6.0	0.19
F1	116	1895	393	5796	3.1	122.0	1.026	69	24	14	11	8	36	8.2	B[a]	0.04
	126	2238	471	5137	2.3	122.2	1.033	88	34	18	14	9	146	13.0	7.0	0.04
2	128	1742	372	3739	2.1	122.2	1.025	71	24	13	10	6	26	7.0	B[a]	0.09
	130	1957	399	4007	2.0	123.7	1.028	63	21	12	7	7	12.5	8.0	6.2	0.04
G1	106	1760	407	4570	2.6	119.2	1.030	88	35	19	15	11	45	8.2	5.7	0.23
	112	1741	312	4826	2.8	120.2	1.033	95	38	21	16	13	77	10.5	7.5	0.16
	114	2069	450	5506	2.7	120.2	1.029	88	33	19	16	11	56	9.0	6.2	0.24
	122	-	-	-	-	120.7	1.030	91	37	21	16	12	62	9.5	5.7	0.16
2	117	2130	448	5998	2.8	122.0	1.034	86	33	20	15	11	88	7.2	6.0	0.05
	124	1928	427	5211	2.7	123.0	1.032	86	35	20	16	12	53	7.7	5.5	0.21
3	127	1736	413	-	-	120.5	1.032	97	37	22	17	11	48	13.0	7.0	0.10
	129	1656	400	5749	3.5	[illegible]	1.031	96	37	21	16	10	40	10.5	6.7	0.22
	131	1796	422	4913	2.7	121.7	1.034	94	35	21	16	10	46	8.0	6.2	0.19
	Max.	2258	514	8788	4.5	124.7	1.035	100	38	22	18	13	148	36.5	8.0	0.34
	Min.	1656	300	3580	1.6	118.2	1.023	63	21	12	7	6	12.5	7.0	B[a]	0.00

a1 - Specimens broke at approximately 0.25 cm.
b1 - Ductility at 41°F. = 4.2 cm.
c1 - Average of 4 tests
d1 - Ductility at 41°F. = 40 cm.
e1 - Ductility at 41°F. = 6.7 cm.