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Physical Properties of Santoprene Rubber General Purpose Grades

INTRODUCTION

Santoprene® thermoplastic rubber offers a variety of performance and processing advantages over conventional thermoset rubber. This material offers mechanical properties comparable or superior to most vulcanized elastomers, with the economical processability of a thermoplastic. Santoprene rubber is thus suitable for a broad spectrum of automotive, industrial and consumer applications.

This bulletin provides a brief survey of the physical properties of Santoprene rubber, properties which indicate the superior performance of this material. Standard methods (in most cases, ASTM) were used on routine production lots of each grade of Santoprene rubber. The data provided are typical and representative of those obtained on a day-to-day basis. The specific test results given are those most important for utilizing the unique properties of Santoprene rubber. An extensive amount of physical test and applications data has been generated for these materials in a wide variety of end-use applications. Additional test results for specific applications, which complement those in this bulletin, may be obtained.

The values of the physical properties of the general purpose black and colorable grades of Santoprene rubber, for a given hardness, are experimentally the same. Thus, physical measurements for black grades should also be valid for colorable grades and vice versa.

Santoprene rubber, like most thermoplastics, can be anisotropic in its properties. Compared to most commercial thermoplastics, the anisotropic behavior of Santoprene rubber is relatively small. The data in this bulletin was obtained with test specimens cut in the strong tensile direction (i.e., perpendicular to the flow direction) from standard injection molded plaques with dimensions of 101 x 151 x 2 mm (4 x 6 x 0.08 in.), unless noted to the contrary.

Please note: The information contained in this document applies to general purpose grades of Santoprene rubber. Please contact us at (877)-PSI-SEAL (Toll Free) or (860)-282-9100 (in CT) for more information about the physical properties of specialty grades and the Santoprene rubber 8000 series.

Physical Properties of Santoprene Rubber General Purpose Grades

TENSILE PROPERTIES

For the different hardness grades of Santoprene rubber, tensile stress-strain curves are given in Figures 1-7 for temperatures of -40˚C (-40˚F) to 125˚C (257˚F). These curves illustrate the broad temperature range at which these rubbers may be used. In each curve, tensile properties of microbar specimens were measured as a function of temperature. Each curve ends at the ultimate elongation.

Figure 1:
55 Shore A Grades, ASTM D 412

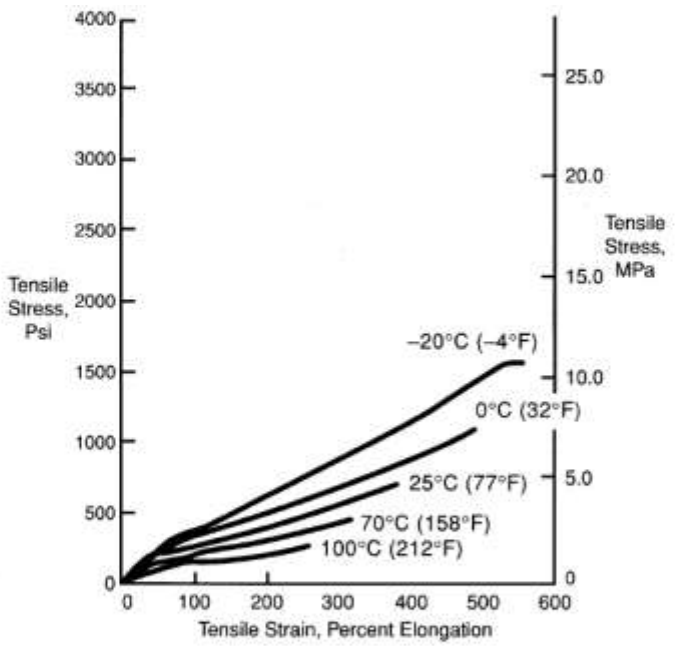


Figure 2:
64 Shore A Grades, ASTM D 412

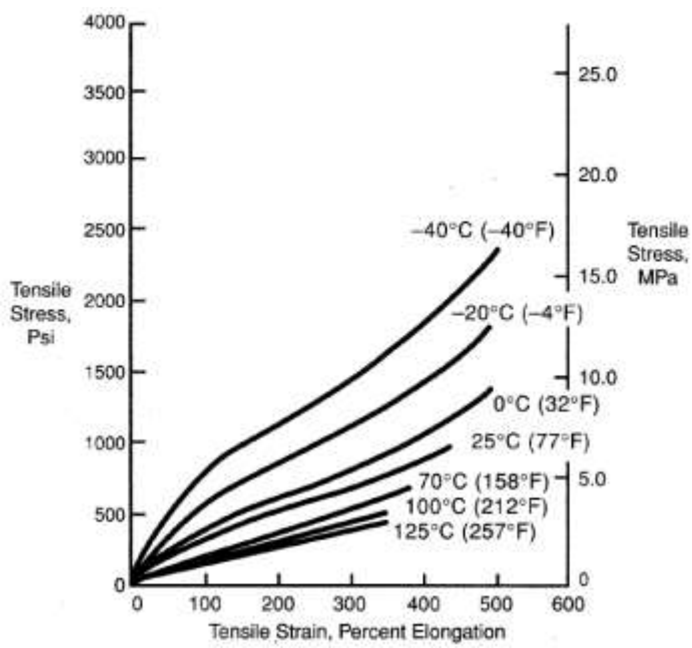


Figure 3:
73 Shore A Grades, ASTM D 412

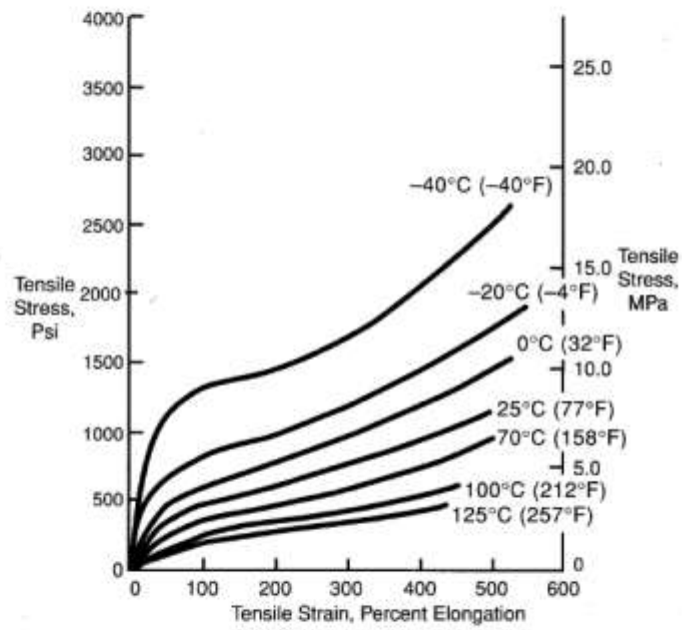
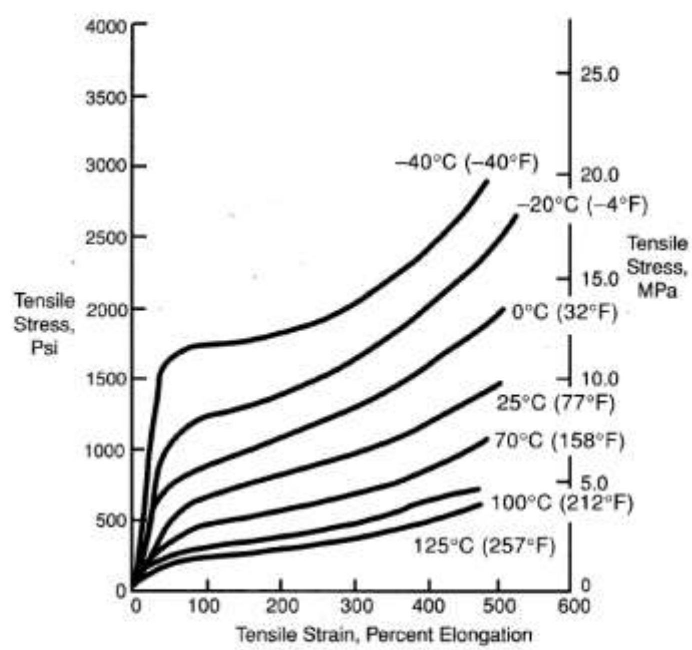


Figure 4:
80 Shore A Grades, ASTM D 412



Physical Properties of Santoprene Rubber General Purpose Grades

TENSILE PROPERTIES CONTINUED

Figure 5:
87 Shore A Grades, ASTM D 412

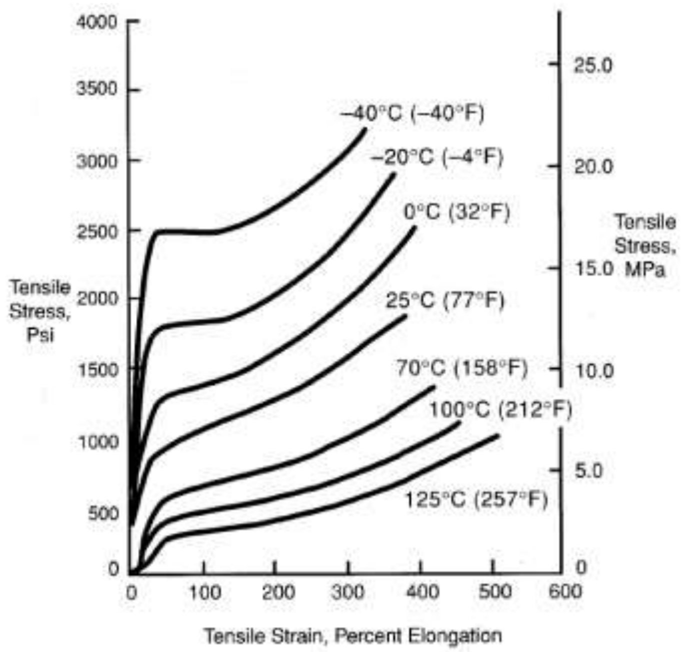


Figure 6:
40 Shore D Grades, ASTM D 412

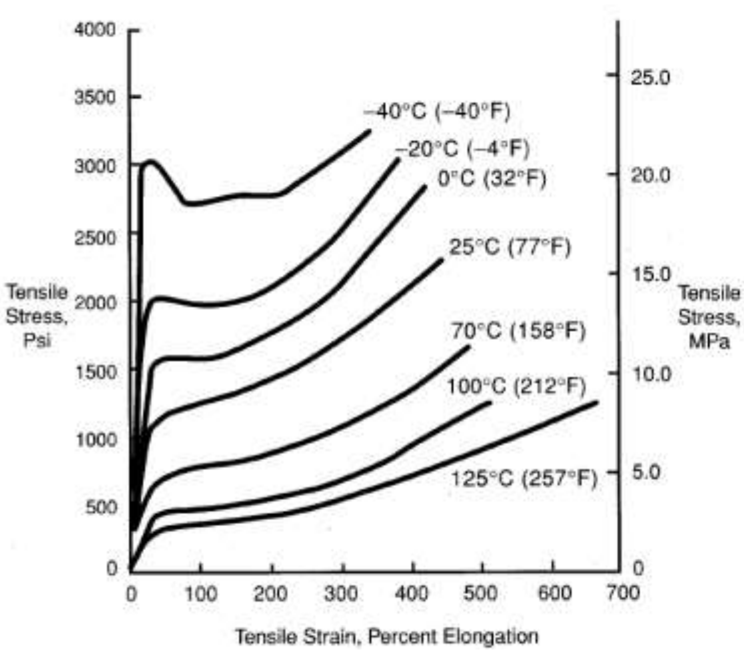
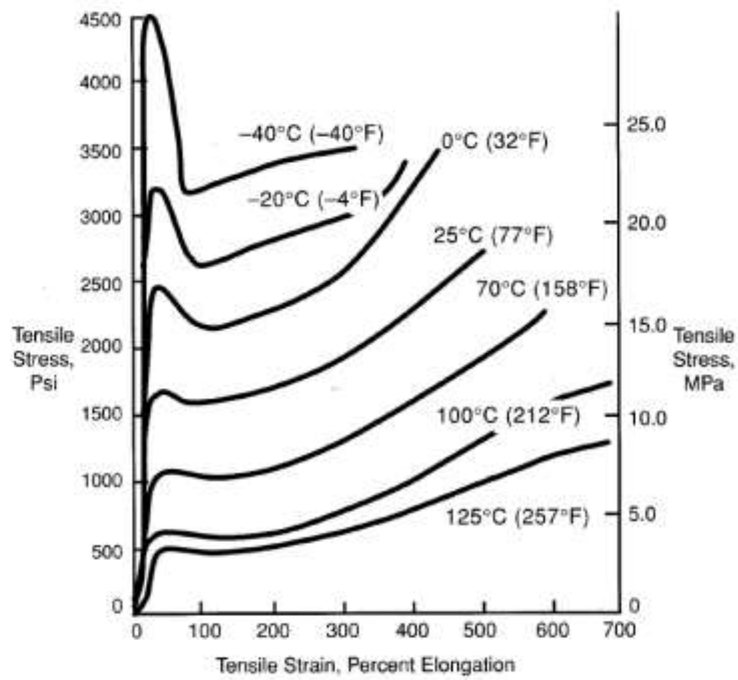


Figure 7:
50 Shore D Grades, ASTM D 412



Physical Properties of Santoprene Rubber General Purpose Grades

KEY PHYSICAL PROPERTIES

Both modulus (tensile stress) and tensile strength decrease with an increase in temperature, whereas, elongation at break tends to increase with temperature. As expected, both tensile stress and tensile strength increase with hardness. The stress-strain curves for the softer grades (55, 64 and 73 Shore A hardness) are typically elastomeric. The harder grades (40 and 50 Shore D hardness) have more of a plateau where very little additional stress gives much elongation. This plateau becomes more pronounced as the temperature is lowered. For these harder grades at the lowest temperatures, an actual yield-point maximum is observed.

Table I gives key physical properties of the different grades of Santoprene rubber. The tensile properties vary by grade, with the harder grades having higher tensile stress, tensile strength and ultimate elongation. The low specific gravity (less than 1.0) of Santoprene rubber gives a definite cost advantage in the many applications where usage is on a volume basis.

The low specific gravity (Table I) of Santoprene rubber compares quite favorably to the higher values of vulcanized specialty elastomers such as polychloroprene (1.4), chlorosulfonated polyethylene (1.4) and EPDM (1.2). Thus on a unit volume basis a much smaller weight (15-30%) of Santoprene rubber would be needed for a specific application.

The flexural and tensile modulus (Young's modulus) values for Santoprene rubber are tabulated in Table II. Both tensile and flexural modulus increase with hardness. As expected, the tensile modulus decreases markedly with temperature.

It is extremely likely that a desired set of elastomeric tensile properties could be closely approximated by a selected mixture of different hardness grades. The key tensile parameters to be duplicated would depend on the specific end-use application.

Physical Properties of Santoprene Rubber General Purpose Grades

KEY PHYSICAL PROPERTIES CONTINUED

TABLE I:
Key Physical Properties of Santoprene Rubber

Properties	ASTM Test Method	Test Temp. ˚C (˚F)	Units	Santoprene Rubber Grades 201-55 101-55	201-64 101-64	201-73 101-73	201-80 101-80	201-87 101-87	203-40 103-40	203-50 103-50
Hardness	D 2240	25 (77)	5 sec. Shore	55A	64A	73A	80A	87A	40D	50D
Specific Gravity	D 792	25 (77)	--	0.97	0.97	0.98	0.97	0.96	0.95	0.94
Tensile Strength	D 412 Die "C"	25 (77)	psi MPa	640 4.4	1000 6.9	1200 8.3	1600 11.0	2300 15.9	2750 19.0	4000 27.6
Ultimate Elongation	D 412	25 (77)	%	330	400	410	450	530	600	600
Stress at 100% Elongation	D 412	25 (77)	psi MPa	290 2.0	340 2.3	470 3.2	700 4.8	1000 6.9	1250 8.6	1450 10.0

Typical properties based on samples tested in a laboratory - injection molded plaques, 101 x 151 x 2 mm (4 x 6 x 0.08 in.) long, with an edge gate.

[2] ASTM D 638 used for tensile measurements on grades 203-50 and 103-50 only.

TABLE II:
Flexural and Tensile Modulus of Santoprene Rubber

Santoprene Grades	Tensile Modulus, [2] psi (MPa) @23˚C (73˚F)	@100˚C (212˚F)	@125˚C (257˚F)	Flexural Modulus, [3] psi (MPa) @23˚C (73˚F)
201-55, 101-55	679 (4.7)	345 (2.38)	211 (1.46)	1,129 (7.8)
201-64, 101-64	1,060 (7.3)	490 (3.4)	--	2,680 (18.5)
201-73, 101-73	2,300 (16)	840 (5.8)	280 (1.9)	3,550 (24)
201-80, 101-80	4,700 (32)	1,380 (9.5)	420 (2.9)	6,620 (46)
201-87, 101-87	16,400 (113)	1,340 (9.2)	790 (5.4)	14,900 (103)
203-40, 103-40	18,100 (125)	1,810 (12.5)	820 (5.7)	20,360 (140)
203-50, 103-50	34,100 (235)	7,280 (50.2)	4,740 (32.7)	50,280 (347)

[2] Young's modulus, ASTM D 797.89.

[3] ASTM D 790, 0.5 in/min. Secant modulus, 1%.

Physical Properties of Santoprene Rubber General Purpose Grades

HEAT AGING STABILITY

Santoprene rubber retains its tensile properties better than most thermoset rubbers after exposure to elevated temperatures for extended periods of time. This capability is of significant value in a great variety of high temperature applications (e.g., under-the-hood automotive).

Tables Ill-IX give heat aging data for general purpose grades of Santoprene at 100, 125 and 150˚C (212, 257 and 302˚F). At 125 and 150˚C (212 and 257˚F), the retention of tensile properties is quite high. Only at 150˚C (302˚F) do the properties show pronounced loss after extended aging (thirty days or more). This leads to the conclusion that Santoprene rubber may be considered for service up to 135˚ C (275˚F) for extended periods and up to 150˚C (302˚F) for short periods.

As expected, extended heat aging causes a loss in tensile strength and elongation. Both modulus and hardness, however, increase progressively as the degree of aging becomes significant.

TABLE III:

55 Shore A Grades, Physical Properties After Heat Aging In Air[2]

Test Temp.	Aging Time,	Stress At 100% Elongation [3]			Tensile At Break [3]			Elongation At Break [3]		Shore A Hardness [4]
˚C (˚F)	Days	psi	MPa	% Change	psi	MPa	% Change	%	% Change	5 Sec., Change
Unaged Control	--	264	1.8	--	653	4.5	--	369	--	--
100 (212)	1	278	1.9	5	653	4.5	0	350	-5	-2
	7	273	1.9	3	660	4.6	1	362	-2	-1
	15	274	1.9	4	689	4.8	6	379	3	-1
	30	272	1.9	3	679	4.7	4	387	5	0
	41.7 (1000 hrs)	272	1.9	3	706	4.9	8	402	9	-1
125 (257)	1	279	1.9	3	628	4.3	-4	325	-12	-2
	7	277	1.9	5	681	4.7	4	373	1	-1
	15	282	1.9	7	669	4.6	2	359	-3	0
	30	273	1.9	3	709	4.9	9	408	11	2
	41.7 (1000 hrs)	277	1.9	5	763	5.3	17	428	16	2
135 (275)	1	279	1.9	2	661	4.6	1	326	-12	-2
	7	274	1.9	4	678	4.7	4	367	-1	0
	15	282	1.9	7	669	4.6	2	362	-2	1
	30	273	1.9	3	686	4.7	5	417	13	3
	41.7 (1000 hrs)	277	1.9	5	738	5.1	13	431	16	3
150 (302)	1	267	1.8	1	603	4.1	-8	318	-14	-3
	7	262	1.8	-1	635	4.4	-3	369	0	-1
	15	247	1.7	-6	606	4.2	-7	391	6	-1
	30	242	1.7	-8	434	3.0	-34	276	-25	-3
	41.7 (1000 hrs)	--	--	--	302	2.1	-54	93	-75	-3

[2] Heating aging in air oven, ASTM D 573.

[3] Stress-strain, ASTM D 412.

[4] Hardness, ASTM D 2240.

Physical Properties of Santoprene Rubber General Purpose Grades

HEAT AGING STABILITY CONTINUED

TABLE IV:

64 Shore A Grades, Physical Properties After Heat Aging In Air[2]

Test Temp. ˚C (˚F)	Aging Time, Days	Stress At 100% Elongation [3] psi	MPa	% Change	Tensile At Break [3] psi	MPa	% Change	Elongation At Break [3] %	% Change	Shore A Hardness [4] 5 Sec., Change
Unaged Control	--	334	2.3	--	870	6.0	--	402	--	--
100 (212)	1	333	2.3	0	890	6.1	2	414	3	0
	7	326	2.2	-2	865	6.0	-1	421	5	0
	15	336	2.3	1	880	6.1	1	412	2	1
	30	338	2.3	1	861	5.9	-9	395	-2	4
	41.7 (1000 hrs)	339	2.3	1	900	6.2	3	424	5	2
125 (257)	1	329	2.3	-1	888	6.1	2	404	0	0
	7	339	2.3	1	934	6.4	7	416	3	0
	15	344	2.4	3	962	6.6	11	427	6	1
	30	359	2.5	7	938	6.5	8	407	1	6
	41.7 (1000 hrs)	347	2.4	4	980	6.8	13	446	11	2
150 (302)	1	320	2.2	-4	894	6.2	3	409	2	0
	7	348	2.4	4	1011	7.0	16	447	11	3
	15	355	2.4	6	959	6.6	10	434	8	2
	30	380	2.6	14	507	3.5	-42	167	-58	8
	41.7 (1000 hrs)	--	--	--	439	3.0	-50	65	-84	9

TABLE V:

73 Shore A Grades, Physical Properties After Heat Aging In Air[2]

Test Temp. ˚C (˚F)	Aging Time, Days	Stress At 100% Elongation [3] psi	MPa	% Change	Tensile At Break [3] psi	MPa	% Change	Elongation At Break [3] %	% Change	Shore A Hardness [4] 5 Sec., Change
Unaged Control	--	450	3.1	--	1120	7.7	--	430	--	--
100 (212)	1	470	3.2	4	1130	7.8	1	410	-5	0
	7	490	3.4	9	1050	7.2	-6	390	-9	0
	15	500	3.4	11	1110	7.7	-1	410	-5	1
	30	480	3.3	7	1090	7.5	-3	400	-7	0
	41.7 (1000 hrs)	490	3.4	9	1030	7.1	-8	360	-16	0
125 (257)	1	480	3.3	7	1090	7.5	-3	390	-9	1
	7	500	3.4	11	1160	8.0	4	400	-7	2
	15	540	3.7	20	1240	8.5	11	410	-5	5
	30	540	3.7	20	1280	8.8	14	400	-7	3
	41.7 (1000 hrs)	540	3.7	20	1310	9.0	17	380	-12	3
150 (302)	1	440	3.0	-2	1110	7.7	-1	390	-9	0
	7	510	3.5	13	1240	8.6	11	370	-14	2
	15	610	4.2	36	1330	9.1	19	340	-21	6
	30	690	4.8	53	1170	8.1	4	280	-35	7
	41.7 (1000 hrs)	770	5.3	71	910	6.2	-19	130	-70	10

[2] Heating aging in air oven, ASTM D 573.

[3] Stress-strain, ASTM D 412.

[4] Hardness, ASTM D 2240.

Physical Properties of Santoprene Rubber General Purpose Grades

HEAT AGING STABILITY CONTINUED

TABLE VI:

80 Shore A Grades, Physical Properties After Heat Aging In Air[2]

Test Temp.	Aging Time,	Stress At 100% Elongation [3]			Tensile At Break [3]			Elongation At Break [3]		Shore A Hardness [4]
˚C (˚F)	Days	psi	MPa	% Change	psi	MPa	% Change	%	% Change	5 Sec., Change
Unaged Control	--	640	4.4	--	1400	9.7	--	430	--	--
100 (212)	1	690	4.8	8	1400	9.7	0	400	-7	1
	7	690	4.8	8	1390	9.6	-1	400	-7	1
	15	700	4.8	9	1490	10.2	6	420	-2	3
	30	690	4.8	8	1290	8.9	-8	370	-14	2
	41.7 (1000 hrs)	690	4.8	8	1440	9.9	3	400	-7	1
125 (257)	1	680	4.7	6	1310	9.0	-6	370	-14	1
	7	710	4.9	11	1530	10.6	9	400	-7	3
	15	750	5.2	17	1520	10.5	9	390	-9	4
	30	750	5.2	17	1450	10.0	4	360	-16	2
	41.7 (1000 hrs)	770	5.3	20	1740	12.0	24	410	-5	4
150 (302)	1	650	4.5	2	1320	9.1	-6	340	-21	3
	7	730	5.0	14	1440	9.9	3	330	-23	3
	15	840	5.8	31	1620	11.2	16	340	-21	5
	30	930	6.4	45	1380	9.5	-1	250	-42	5
	41.7 (1000 hrs)	1000	6.9	56	1110	7.7	-21	130	-70	8

TABLE VII:

87 Shore A Grades, Physical Properties After Heat Aging In Air[2]

Test Temp.	Aging Time,	Stress At 100% Elongation [3]			Tensile At Break [3]			Elongation At Break [3]		Shore A Hardness [4]
˚C (˚F)	Days	psi	MPa	% Change	psi	MPa	% Change	%	% Change	5 Sec., Change
Unaged Control	--	1010	7.0	--	2220	15.3	--	540	--	--
100 (212)	1	1080	7.4	7	2260	15.6	2	540	0	0
	7	1020	7.0	1	2210	15.2	0	540	0	0
	15	1030	7.1	2	2230	15.4	0	540	0	-1
	30	1030	7.1	2	2180	15.0	-2	530	-2	-1
	41.7 (1000 hrs)	1030	7.1	2	2180	15.2	0	530	-2	-1
125 (257)	1	1090	7.5	8	2270	15.7	2	530	-2	0
	7	1080	7.4	7	2180	15.0	-2	500	-7	0
	15	1110	7.7	9	2360	16.0	6	520	-4	0
	30	1140	7.9	13	2440	16.8	10	520	-4	-1
	41.7 (1000 hrs)	1180	8.1	17	2460	17.0	11	490	-9	-1
150 (302)	1	1070	7.4	6	2150	14.8	-3	450	-17	-1
	7	1170	8.1	16	2210	15.2	0	430	-20	0
	15	1260	8.7	25	2210	15.2	0	390	-28	0
	30	1380	9.5	37	1740	12.0	-22	240	-56	0
	41.7 (1000 hrs)	--	--	--	1280	8.8	-42	40	-93	0

[2] Heating aging in air oven, ASTM D 573.

[3] Stress-strain, ASTM D 412.

[4] Hardness, ASTM D 2240.

Physical Properties of Santoprene Rubber General Purpose Grades

HEAT AGING STABILITY CONTINUED

TABLE VIII:

40 Shore D Grades, Physical Properties After Heat Aging In Air[2]

Test Temp.	Aging Time,	Stress At 100% Elongation [3]			Tensile At Break [3]			Elongation At Break [3]		Shore A Hardness [4]
˚C (˚F)	Days	psi	MPa	% Change	psi	MPa	% Change	%	% Change	5 Sec., Change
Unaged Control	--	1330	9.2	--	2690	18.6	--	530	--	--
100 (212)	1	1410	9.7	6	2660	18.3	-1	520	-2	0
	7	1410	9.7	6	2590	17.9	-4	540	0	0
	15	1460	10.1	10	2830	19.5	5	530	0	0
	30	1470	10.1	11	2650	18.3	-1	530	0	2
	41.7 (1000 hrs)	1480	10.2	11	2560	17.7	-5	510	-4	0
125 (257)	1	1450	10.0	9	2760	19.0	3	530	0	1
	7	1490	10.2	12	2730	18.8	1	530	0	1
	15	1580	10.9	19	2650	18.3	-1	490	-8	1
	30	1580	10.9	19	2830	19.5	5	500	-6	4
	41.7 (1000 hrs)	1640	11.3	23	2790	19.2	4	470	-11	5
150 (302)	1	1520	10.5	14	2640	18.2	-2	450	-15	2
	7	1580	10.9	19	2540	17.5	-6	390	-26	6
	15	1720	11.9	29	2580	17.8	-4	390	-26	7
	30	1840	12.7	38	2020	13.9	-25	180	-66	10
	41.7 (1000 hrs)	--	--	--	1650	11.4	-39	10	-98	10

TABLE IX:

50 Shore D Grades, Physical Properties After Heat Aging In Air[2]

Test Temp.	Aging Time,	Stress At 100% Elongation [3]			Tensile At Break [3]			Elongation At Break [3]		Shore A Hardness [4]
˚C (˚F)	Days	psi	MPa	% Change	psi	MPa	% Change	%	% Change	5 Sec., Change
Unaged Control	--	1562	10.8	--	3899	26.9	--	616	--	--
100 (212)	1	1664	11.5	7	3756	27.3	-4	597	-3	0
	7	1669	11.5	9	3903	26.9	0	613	0	0
	15	1752	12.1	12	3886	26.8	0	622	1	0
	30	1763	12.2	13	3913	27.0	0	610	-1	0
	41.7 (1000 hrs)	1771	12.2	13	3921	27.0	1	609	-1	0
125 (257)	1	1769	12.2	13	3758	25.9	-4	557	-10	0
	7	1834	12.6	17	3801	26.2	-3	557	-10	0
	15	1871	12.9	20	3886	26.8	0	572	-7	0
	30	1881	13.0	20	3569	24.6	-8	519	-16	2
	41.7 (1000 hrs)	1925	13.3	23	3759	25.9	-4	546	-11	4
150 (302)	1	1891	13.0	21	3520	24.3	-10	470	-24	0
	7	1968	8.1	26	3291	22.7	-16	427	-31	1
	15	1983	13.6	27	2561	17.7	-34	289	-53	3
	30	--	13.7	--	1627	11.2	-58	61	-90	5
	41.7 (1000 hrs)	--	--	--	--	--	--	--	--	10

[2] Heating aging in air oven, ASTM D 573.

[3] Stress-strain, ASTM D 412 for 40D, ASTM D 638 for 50D.

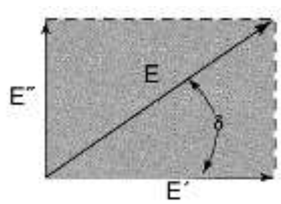
[4] Hardness, ASTM D 2240.

Physical Properties of Santoprene Rubber General Purpose Grades

DYNAMIC MECHANICAL PROPERTIES

In many mechanical uses, rubber is subject to vibrations at one or more frequencies. The basic parameters for assessing the vibrational properties of a specific rubber are the elastic modulus (E'), loss modulus (E") and tangent delta (tan δ). E' is a direct measure of the pure elasticity (Hook's law behavior) and E" a measure of the viscous or hysteresis properties (conversion of mechanical to heat energy).

These parameters are related by the equation E'' / E' = tan δ, and may be represented by the rectangle:



E is the modulus of the material and is related to the elastic and loss moduli by $E = [(E')^2 + (E'')^2]^{(1/2)}$

These parameters are widely used in the design and development of rubbers with specific vibrational properties. Thus, an energy-absorbing rubber would require a large E" and tan δ, whereas, one requiring minimum heat generation would need E" and tan δ as low as possible.

The tensile elastic modulus (E'), loss modulus (E") and tan δ, were determined for Santoprene rubber at temperatures of -80 to 150˚C (-112 to 302˚F) using a Rheovibron*Viscoelastometer at a frequency of 11 Hz. Figures 8 through 14 illustrate the variation of E', E" and tan δ as a function of temperature for all grades. ASTM D 5992.96 describes in detail the general procedure for dynamic mechanical property measurements.

Physical Properties of Santoprene Rubber General Purpose Grades

DYNAMIC MECHANICAL PROPERTIES CONTINUED

Figure 8:
Dynamic Mechanical Properties, 55 Shore A Grades

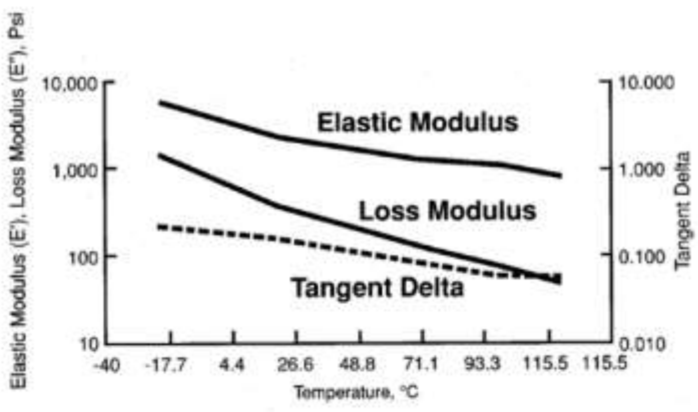


Figure 10:
Dynamic Mechanical Properties, 73 Shore A Grades

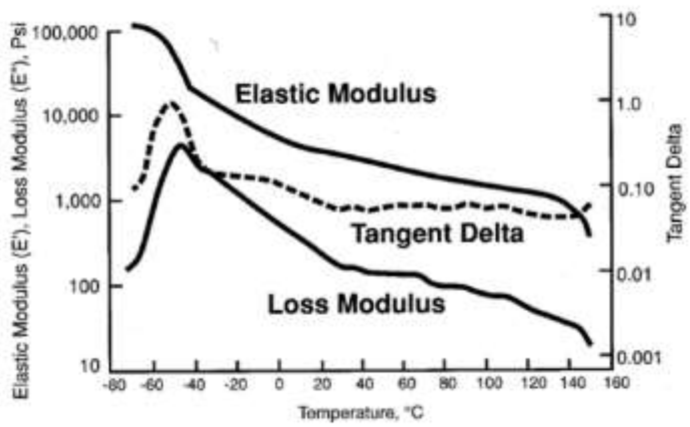


Figure 9:
Dynamic Mechanical Properties, 64 Shore A Grades

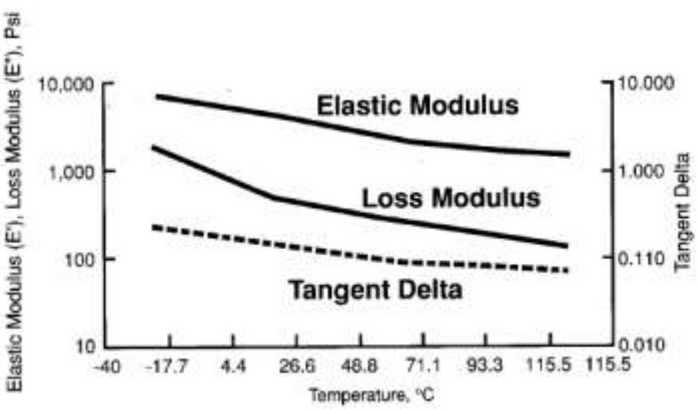
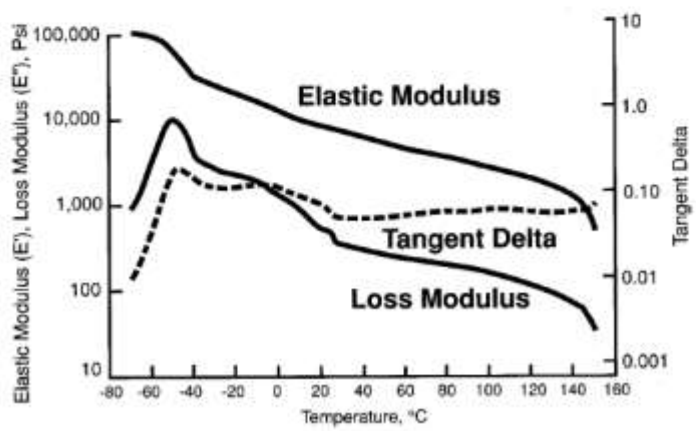


Figure 11:
Dynamic Mechanical Properties, 80 Shore A Grades



Physical Properties of Santoprene Rubber General Purpose Grades

DYNAMIC MECHANICAL PROPERTIES CONTINUED

Figure 12:
Dynamic Mechanical Properties, 87 Shore A Grades

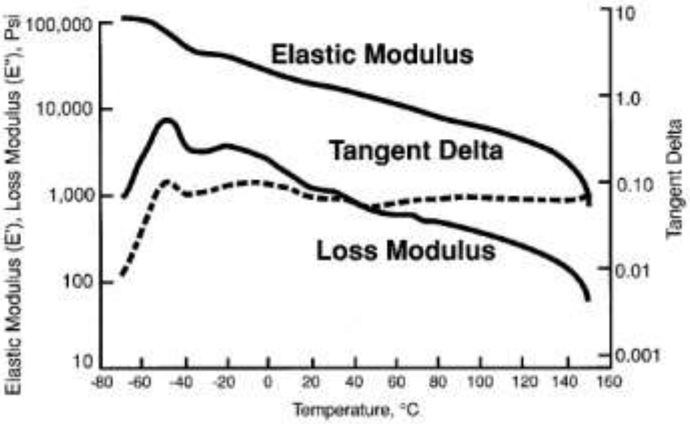


Figure 14:
Dynamic Mechanical Properties, 50 Shore A Grades

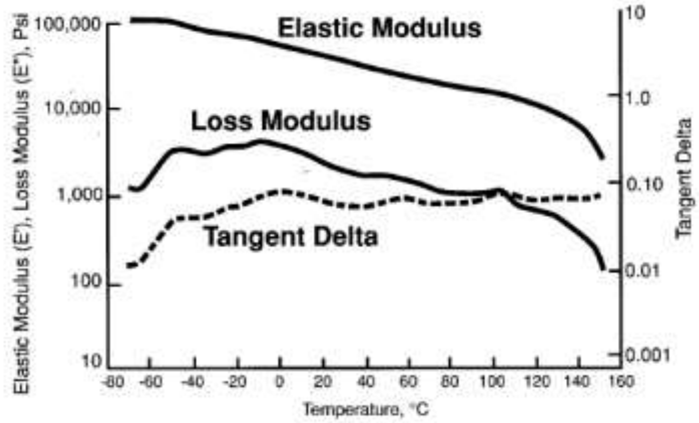
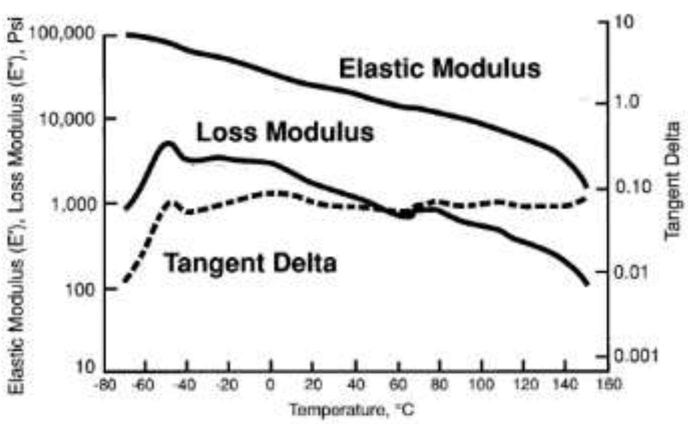


Figure 13:
Dynamic Mechanical Properties, 40 Shore D Grades



Physical Properties of Santoprene Rubber General Purpose Grades

RESILIENCE

In many mechanical applications of rubber, high resilience is a desired and often necessary property. The Lupke and Bashore rebound tests (R.O. Babbit "The Vanderbilt Rubber Handbook," R.T. Vanderbilt Co., Norwalk, Ct., 1978, p. 555) provide a good measure of resilience (elastic behavior). Each of these tests measures the rebound of a specified object after impacting the rubber. A high-resilience rubber will thus have a low loss modulus and tan δ. Table X gives Lupke and Bashore rebound test results for different grades of Santoprene rubber. As expected, the results are essentially equal for a given hardness level. These rebound data show Santoprene rubber to be comparable in resilience to a well-compounded natural rubber stock. Thus, Santoprene rubber merits consideration in those application areas where resilience is of concern. Care should be used in comparing these resilience data to those dynamic mechanical results in Figures 8-14. The resilience properties are the result of a combination of shear and compression strain, whereas, the viscoelastometer data relate to tensile strain at a much higher frequency.

TABLE X:

Lupke and Bashore Resilience Test Results for General Purpose Santoprene Rubber

Santoprene Shore Hardness	1st Lupke Rebound	1st Bashore Rebound, % [2]
55A	--	51
64A	71	46
73A	69	39
80A	65	39
87A	62	41
40D	61	38
50D	59	44

[2] ASTM D 2632.

TEAR STRENGTH

The high tear strength of Santoprene rubber (Table XI) is particularly noteworthy and suggests a number of possible uses. This high tear strength at elevated temperature permits quick, easy removal of hot finished parts from molding equipment, thus permitting rapid, economical molding cycles.

TABLE XI:

Key Mechanical Properties of Santoprene Rubber

Properties	ASTM Test Method	Test Temp. ˚C (˚F)	Units	Santoprene Rubber Grades 201-55 101-55	201-64 101-64	201-73 101-73	201-80 101-80	201-87 101-87	203-40 103-40	203-50 103-50
Tear Strength	D 624	25 (77)	pli	108	140	159	194	278	369	514
			kN/m	19	25	28	34	49	65	90
		100 (212)	pli	42	58	76	75	133	203	364
			kN/m	7.3	10	13	13	23	36	64
Tension Set	D 412	25 (77)	%	6	10	14	20	33	48	61
Compression Set, 22 hrs.	D 395, Method B (Type 1 Specimen)	25 (77)	%	14	22	25	27	35	39	--
		100 (212)	%	17	34	33	39	52	65	--
Brittle Point	D 746	--	˚F	<-76	<-76	-81	-81	-78	-71	-29
			˚C	<-80	<-60	-63	-63	-61	-57	-34

Physical Properties of Santoprene Rubber General Purpose Grades

LOW TEMPERATURE FLEXIBILITY

Santoprene rubber is well suited for temperatures below 0˚C (32˚F). Brittle point data (Table XI) show all but the highest hardness grades (203-50 and 103-50) to have flexibility down to -57˚C (-71˚F). Even 50D grades are flexible to -34˚C (-29˚F). These brittle points compare favorably to those of polychloroprene (-43˚C, -45˚F), nitrile (-40˚C, -40˚F) and other specialty elastomers.

TENSILE AND COMPRESSION SET

The permanent plastic deformation of Santoprene rubber is quite small after the removal of an applied stress. The elastic recovery following compression or tensile stress is shown in Table XI. Tensile set is quite low for all grades of Santoprene rubber after a 100% elongation and subsequent relaxation. Tensile and compression set progressively increase with both hardness and temperature.

Figures 15-18 give compression set curves as a function of time for different hardness grades at temperatures of 23, 70, 100 and 125˚C (73, 158, 212 and 257˚F). All curves were generated using ASTM D 395, method B; 25% deflection, sample thickness of 11.94 mm (0.47 in.). These levels of compression set are very low, especially at the higher temperatures. In contrast to many thermoset rubbers, the compression set at a given temperature is essentially constant after the first 22 hours. The low compression and tensile set of Santoprene rubber permits its use in a variety of application needs now filled by thermoset rubber.

Figure 15:
Compression set at 23˚C (73˚F)

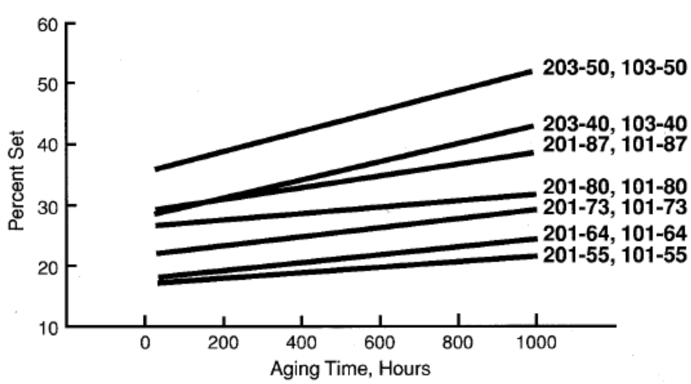


Figure 17:
Compression set at 100˚C (212˚F)

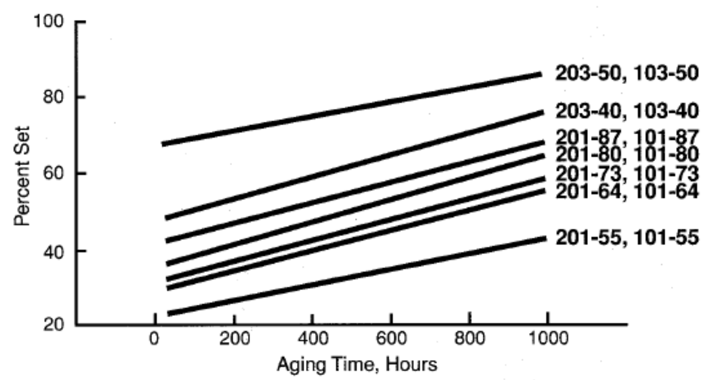


Figure 16:
Compression set at 70˚C (158˚F)

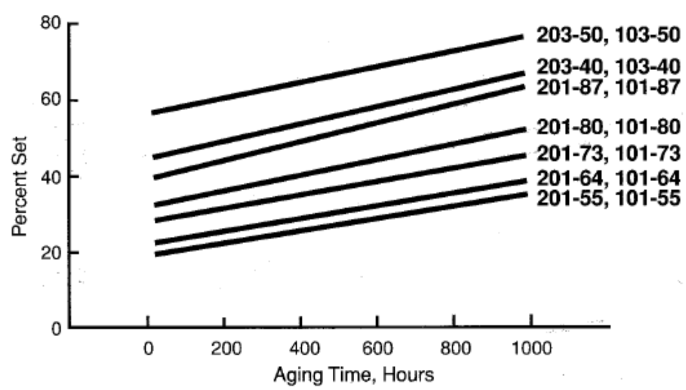
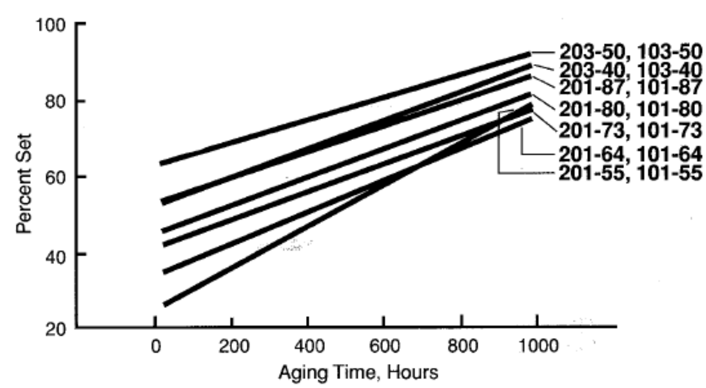


Figure 18:
Compression set at 125˚C (257˚F)



Physical Properties of Santoprene Rubber General Purpose Grades

FATIGUE RESISTANCE

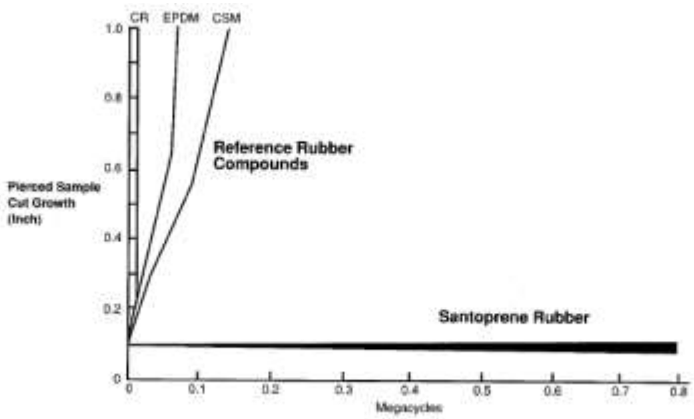
The Ross flex test (ASTM D 1052) measures the formation and propagation of a crack through rubber during flex bending. Two sets of tests were run, using all hardnesses of Santoprene rubber, plus polychloroprene (CR), EPDM and chlorosulfonated polyethylene (CSM), flexing at 100 cycles/minute.

The first test used specimens with no initial cut. After one million cycles of flexing, no failures were reported. Further tests, using specimens with an initial cut of 0.25 cm (0.10 in.), produced substantially different results (Figure 19).

After more than two million cycles of flexing, Santoprene rubber specimens showed no failures; whereas the three thermoset rubbers failed rapidly. This indicates outstanding fatigue resistance for Santoprene rubber. It must be kept in mind that the Ross flex test measures both the fatigue and tear of the rubber, rather than tear per se.

Figure 19:

Fatigue Resistance of Santoprene Rubber and Conventional Thermosets.



Physical Properties of Santoprene Rubber General Purpose Grades

VAPOR PERMEABILITY

The permeability of Santoprene rubber to common gases is essentially the same as that of conventional EPDM thermosets. Table XII gives permeability rates of various gases for the 73A, 87A and 50D) general purpose grades, expressed as the volume of gas passing through a film of rubber, of a given area and thickness, during a specific period of time, with a given pressure difference across the rubber. These vapor permeability values are in the range normally found for conventional thermoset rubbers. Thus, Santoprene rubber merits consideration for applications employing conventional thermosets (such as EPDM) where vapor permeability is of concern.

TABLE XII:
Transmission Rates of Gases Through Santoprene Rubber

	Santoprene Grades		
Gas	**201-73**	**201-87**	**203-50**
Air	31	39	18
Nitrogen	25	34	12
Oxygen	65	56	36
Carbon Dioxide	390	260	170
Argon	67	77	51
Propane	150	430	250

ASTM D 1434. Expressed as cubic centimeters of gas at 0˚C (32˚F) and 0.11 MPa (14.7 psi) pressure transmitted through a 645 sq. cm. (100 sq. in.) area of rubber 0.5mm (0.020 in.) thick, during a 24 hour period, under a pressure differential of 14.7 psi at 23˚C (73˚F).

For many applications, good resistance to moisture permeability is required. Santoprene rubber has been found to exhibit low water permeation rates. The transmission of water vapor through Santoprene rubber has been measured with (a) the rubber in contact with saturated vapor over the water (Procedure A) and (b) in contact with the liquid (Procedure BW). Table XIII summarizes these results for the materials tested. The numbers in Table XIII express the weight of water passing through a film of rubber, of given area and thickness, during a specific time period at room temperature. This permeability to water is comparable (and in many cases superior) to that of most common rubbers and plastics. The liquid contact data suggest that Santoprene rubber may be considered for film material for lining pits and ponds for the retention of water.

TABLE XIII:
Water Vapor Transmission[2] Through Santoprene Rubber

Santoprene Grade	Procedure A[2]	Procedure BW[3]
201-73	0.97	0.45
201-87	0.32	0.45
203-50	0.45	1.61

[2] ASTM 96. Expressed as grams of water passing through one square meter (10.8 sq. ft.) of rubber 0.5 mm (0.020 in.) thick, during 24 hours, at 25˚C (77˚F).

[3] ASTM E 96, Procedure A. Saturated vapor over liquid water contacts the rubber, with 25% relative humidity on the opposite side.

[4] ASTM 96, Procedure BW. Liquid water contacts the rubber, with 75% relative humidity on the opposite side.

Physical Properties of Santoprene Rubber General Purpose Grades

RESISTANCE TO FUNGAL GROWTH AND SOIL BURIAL

Outdoor applications of Santoprene rubber require a knowledge of its resistance to fungi and soil burial. The fungal resistance was evaluated by placing 50 x 50 x 1 mm (2 x 2 x 0.040 in.) sheets of grades of Santoprene rubber into an agar solution inoculated with a mixture of the following fungi:

- Aspergillus niger
- Penicillium funciulosum
- Chretomium globosum
- Trichoderma sporulosum
- Pullularia pullulans
- Aspergillus flavus
- Aspergillus versicolor

After 21 days of incubation under favorable conditions for growth, the culture was rated visually for the extent of fungal growth. Table XIV summarizes these ratings, indicating light to medium fungal growth, the extent of which decreases with increasing hardness.

TABLE XIV:
Fungal Growth on Santoprene Rubber

Santoprene Grade	Fungal Growth
201-73	Light Growth, 10 - 30%
201-80	Medium Growth, 30 - 60%
201-87	Light Growth, 10 - 30%
203-40	Light Growth, 10 - 30%
203-50	Traces of Growth, 0 - 10%
ASTM G 21. Mixture of selected fungi.	

Resistance to soil burial was evaluated by burying Santoprene rubber for 120 days in soil rich in cellulose-destroying microorganisms. At the end of this period, the tensile properties were measured and compared to unaged controls. Table XV shows the retention of tensile properties to be good for all grades. This retention appears to improve as the hardness increases. Under the test conditions used, the soil resistance of Santoprene rubber is quite good.

TABLE XV:
Retention of Tensile Properties After 120 Days Soil Burial

	Santoprene Grades			
Property	201-73	201-80	203-40	203-50
Tensile Strength, % Change	-10	-16	-9	-4
Ultimate Elongation, % Change	-2	-16	-2	0
ASTM D 3083. Soil pH 6.5 - 7.5; moisture content 25 - 30%; 32 - 38˚C (90 - 100˚F). Sheets of rubber 1mm (0.040 in.) thick.				

The data in Tables XIV and XV suggest Santoprene rubber may be considered for a variety of uses on, or in, the ground, e.g., buried electrical cable, hose, and pit and pond liners. Its performance would likely be at least comparable to that of conventional thermoset rubbers. For applications in which Santoprene rubber is buried in the ground for an extended period, the use of a fungicide should be considered.