ENGINEERING RESEARCH INSTITUTE
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

Final Report

A STUDY OF SYNTHETIC RUBBERS FOR USE AS VIBRATION DAMPERS

L. M. Hobbs
Supervisor and Associate Professor of Materials Engineering

R. G. Craig
Principal Investigator and Associate Research Engineer

C. W. Burkhart
Research Assistant

Project 2509

SIMPSON MANUFACTURING COMPANY
LITCHFIELD, MICHIGAN

July 1957

ACKNOWLEDGMENTS

We express our appreciation to H. P. Arnt of the Simpson Manufacturing Company for his helpful suggestions and cooperation in testing the assembly properties of the experimental gaskets and to D. Brott of the Simpson Manufacturing Company for his assistance and profitable discussions. We also wish to thank H. Jacober of the Baldwin Rubber Company for his helpful discussions concerning the compounding of rubber and the preparation of experimental compounds on a commercial scale, S. D. Gehman of The Goodyear Tire and Rubber Company for his stimulating discussion of the dynamic measurements, and R. G. Smith for his assistance in determining the dynamic properties.

TABLE OF CONTENTS

	Page
LIST OF ILLUSTRATIONS	iv
ABSTRACT	v
OBJECTIVE	vi
INTRODUCTION	1
EXPERIMENTAL RESULTS	3
PRELIMINARY EXPERIMENTS	3
TENSILE PROPERTIES	4
TEAR RESISTANCE	13
COMPRESSION SET	13
OIL RESISTANCE	14
DYNAMIC PROPERTIES	14
COMMERCIAL SCALE PREPARATION OF EXPERIMENTAL COMPOSITIONS	16
SUMMARY AND CONCLUSIONS	16

LIST OF ILLUSTRATIONS

Table		Page
I	Properties of Vulcanizates	5
II	Appraisal of Rubber Vulcanizates for Automotive Vibration Dampers	12

Figure		
1	Assembled vibration damper.	2
2	Effect of temperature on the dynamic modulus of various unaged vulcanizates.	6
3	Effect of temperature on the internal friction of various unaged vulcanizates.	7
4	Effect of temperature on the resilience of various unaged vulcanizates.	8
5	Effect of temperature on the dynamic modulus of vulcanizates aged in air for 3 days at 250°F.	9
6	Effect of temperature on the internal friction of vulcanizates aged in air for 3 days at 250°F.	10
7	Effect of temperature on resilience of vulcanizates aged in air for 3 days at 250°F.	11

ABSTRACT

A number of compositions of commercially available synthetic rubbers have been prepared and examined for use in crankshaft-vibration damping assemblies for automotive engines. The suitability of the materials was appraised in terms of tensile properties, hardness, age resistance, tear resistance, compression set, oil resistance, dynamic properties, and change of dynamic properties with temperature and with age.

Several types of synthetic rubber were found to be satisfactory for use in vibration dampers designed for current automobiles. Certain compositions were identified which will function satisfactorily in the assemblies designed for future engines operating under more stringent conditions of speed and environment.

Specifically, it was found that for the conditions of operation now employed, satisfactory gaskets could be prepared from SBR-1500 ("cold rubber"), SBR-1707 and 1711 (oil extended "cold rubbers"), Neoprene, nitrile and Philprene VP-15 (butadiene-vinyl pyridine) rubbers, the compositions being vulcanized in the normal fashion. For operation at moderately high temperatures in air, SBR-1500 and nitrile rubbers cured with dicumyl peroxide and Neoprene cured in the normal way can be employed. For operation at moderately high temperatures in the presence of oil, the nitrile rubber vulcanized with peroxide is recommended. For operation temperatures above 250°F, silicone and Viton A (a copolymer of perfluoropropylene and vinylidene fluoride) are superior, and if at high temperature oil resistance is also required, then the fluorocarbon rubber should be used.

Among the various compositions which had been prepared in the laboratory, a few were selected for commercial scale preparation. The properties of the products from the two scales of operation agreed satisfactorily. In a few cases minor modifications in the compositions were necessary to reduce the temperature of the commercial mixing operation.

OBJECTIVE

The objective of this research was to study the design, preparation, and properties of vulcanized rubber gasket compositions for use as automotive vibration dampers that would operate under normal and extreme conditions. A further purpose of the work was to obtain basic, general information concerning rubber gasket materials for use in designing vibration dampers for future automotive engines.

INTRODUCTION

The crankshaft-vibration damping assembly shown in Fig. 1 is generally similar to types being used on current automobiles. It consists of a pulley member and an inertia member, the two being connected by means of a rubber gasket. As the whole assembly rotates with the crankshaft, the inertia or floating member is free to oscillate in response to vibration of the crankshaft, and in the process the rubber, being imperfectly elastic, absorbs vibrational energy which is dissipated as heat.

The factors which determine the performance of a rubber in this application are (1) the design of the assembly, which in turn determines the dynamic characteristics required of the rubber, the rate of heat dissipation, and the proportion of exposed rubber; (2) fabrication requirements; and (3) environmental conditions, including temperature of operation and the presence of air, oil, or solvents.

Commenting on these factors briefly, with a given design of the damping assembly and of the motor, then the dynamic characteristics of the rubber (including dynamic modulus, heat build-up, internal friction and resilience) and the change of the dynamic properties with temperature become the controlling features. The dynamic properties of most rubbers change markedly with temperature, and accordingly it is desirable to select the rubber composition in terms of the dynamic properties which it will possess at the temperature which it will maintain in normal operation.

The fabrication requirements of the rubber can be stringent. In one fabrication process a doughnut-shaped gasket, 1/8 in. thick, 4 in. inner diameter, and 7 in. outer diameter, is wetted with oil and forced by means of a circular blade into the annular space between the pulley and inertia members. In the process the rubber is compressed some 30-50%. Thus the material must have reasonably good tear resistance for the assembly operation and it must have reasonably good dimensional stability to perform its function continually.

The environmental conditions of temperature of operation and degree of exposure to air and oil are determined largely by the design of the damper and the engine. The current trends in motor design point to higher speeds and temperatures of operation and consideration is being given to designs which may result in continuous exposure to oil.

Thus the purposes of the work were to (1) develop from available synthetic rubbers new formulations for use in present dampers to give greater flexibility to current manufacturing operations, and (2) develop rubber formula-

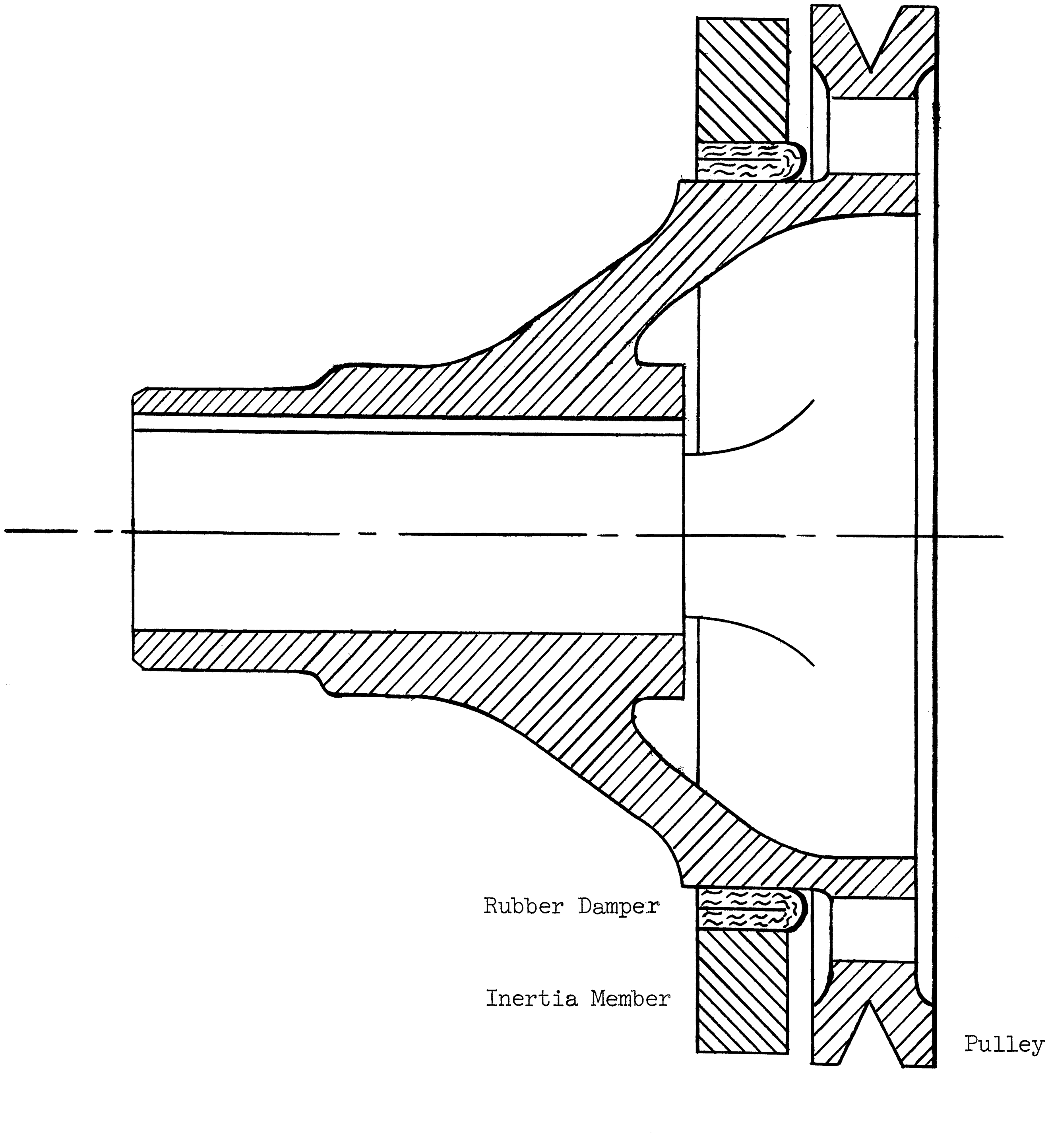

Fig. 1. Assembled vibration damper.

tions which will perform satisfactorily in damping assemblies operating at the higher speeds and under the more stringent conditions of environment that are anticipated to be required in the next few years.

After some preliminary work, it was determined that the desirable information describing rubber compositions for the application included general physical properties, age resistance, tear resistance, oil resistance, compression set, dynamic properties over the temperature range of 25-100°C, and the effect of age on the dynamic properties.

It is the purpose of this report to summarize briefly the overall results of the study.

In brief, it was found that formulations of several commercial synthetic rubbers are satisfactory for use in the current damping assemblies and that compositions of certain rubbers will be satisfactory for the conditions of operation which are expected to be required in the next few years.

It should be emphasized that in the monthly status reports and in this report we have compared the miscellaneous properties, such as strength, oil resistance, age resistance, etc., of very specific compositions prepared for a specific purpose. When we refer to one rubber possessing a better, greater, or more desirable value of a property than another rubber, we are referring to the specific composition for the specific purpose. We are not referring to the potential value of that property which might be developed with the given rubber and other compositions and compounding procedures.

EXPERIMENTAL RESULTS

PRELIMINARY EXPERIMENTS

On the basis of simple analyses, the approximate composition and physical properties of gaskets being used by the Simpson Manufacturing Company in April, 1956, are shown in the following.

Probable Rubber Composition

Ingredient	PHR
SBR 1711 (37.5% aromatic oil cold rubber)	100
Carbon black	75-90
Clay	20
Zinc oxide	5-6
Antioxidant	1-2
Stearic acid	1-2
Sulfur	2
Accelerator	2

Physical Properties: Stresses at 100 and 300% elongation were 290 and 1280, respectively; ultimate tensile and elongation were 1490 psi and 340%, respectively; and durometer hardness (Shore A) was 60.

Gaskets which were considered unsatisfactory at that time possessed essentially the same composition and physical properties but appeared to be 2-3 durometer units harder; they also possessed slightly lower tensile and elongation values and somewhat higher values of stress at 100, 200, and 300% elongation.

The classification of a gasket material as satisfactory rests upon: (a) assembly properties, (b) deflection test by which rubber having suitable stiffness in shear is defined for the specific assembly, and (c) a vibration-energy-absorption measurement in which the ability of the rubber in the specific damping assembly to absorb energy at the vibrational frequencies of the motor is observed.

After some study it was apparent that no single property of the rubber as such could be used to predict the behavior of the material in a specific damping assembly but that optimum behavior could be expected by the selection of a balance of rubber properties chosen in terms of the assembly requirements and the operating conditions.

A number of compositions of commercially available rubbers were formed into experimental gaskets and the properties measured. The compositions and the assembly and physical property information for selected materials are summarized in Table I and the dynamic data are presented in Figs. 2-7. In the following sections brief summary comments are listed regarding the various properties and a qualitative summary appraisal of the various rubbers is given in Table II.

TENSILE PROPERTIES

The rubber compositions containing carbon were compounded to about 60 Shore A hardness. The tensile strengths ranged from 780-2700 psi. The stress at 100% elongation varied between 170 and 460 psi, the stress at 300% elongation was 550-1550 psi and the ultimate elongation varied from 290 to 750%.

The silicones were not compounded to 60 hardness but rather to maximum tear strength which was actually a condition of undercure, and then, after assembly, the curing was completed by placing the whole damping device in an oven at 480°F.

The properties of the acrylic and fluorocarbon rubbers were also improved by subsequent heating at 300 and 400°F, respectively.

TABLE I

PROPERTIES OF VULCANIZATES

Vulcanizate No.		SBR (Oil Extended)					SBR				Neoprene					Butyl				Nitrile				Acrylic[c]			Fluorocarbon[d]	Silicone			Philprene VP-15
		205	211	216	228	242	213	220	222	226	225	229	234	238	247	217	218	232	233	257	258	259	297	243	249	250	265	260	261	280	292
Unaged General Physical Properties	Stress at 100% E, psi	280	250	290	210	230	250	360	320	190	260	650	310	270	230	270	310	300	290	330	210	260	200	230	160	460	170	260	330	80	190
	Stress at 300% E, psi	1080	990	1030	1060	1030	1030	1550	1270	780	1060	---	1690	1110	720	900	910	800	830	1510	1080	1290	1250	820	380	1520	610	--	--	270	550
	Tensile, psi	1750	1450	1590	1610	1550	2060	2220	2430	1440	1840	2640	2700	1690	1530	1630	1410	1170	1210	2040	1910	2050	2250	1200	970	1580	790	780	840	1350	1830
	Elongation, %	500	480	530	470	480	590	430	530	590	530	260	460	500	600	540	510	490	460	420	440	450	480	510	750	310	390	290	290	730	700
	Hardness, Durometer Shore A	59	60	59	59	58	59	60	60	60	60	64	59	60	58	60	63	60	61	62	62	60	60	58	58	60	60	60	70	48	60
Aged[a] General Physical Properties	Stress at 100% E, psi	690	360	420	260	--	520	--	--	--	320	690	310	330	270	350	340	330	350	380	330	370	--	320	240	690	300	--	--	90	360
	Stress at 300% E, psi	--	1290	1220	1100	--	--	1450	1450	1150	1460	--	1840	1350	1050	1230	1100	820	950	--	--	--	--	1130	990	--	800	--	--	380	1050
	Tensile, psi	1380	1470	1480	1500	--	1940	1970	2620	1650	1870	2810	2620	1780	1550	1620	1450	1010	1190	1870	1440	1780	--	1370	1190	1200	1140	--	--	1410	1750
	Elongation, %	190	380	420	460	--	280	400	420	500	440	270	420	420	450	400	470	400	400	300	260	300	--	370	400	170	270	--	--	680	490
	Hardness, Durometer Shore A	72	63	62	60	--	70	61	61	61	62	69	60	65	62	62	65	60	64	65	65	65	--	59	59	70	67	--	--	46	65
Tear Resistance	lb, in. (ASTM Die C)	--	--	--	230	--	260	--	190	150	--	140	--	180	--	--	230	--	--	--	--	--	215	130[e] 70[f]	--	--	140[e] 110[f]	70	175[e] 80[f]	182[f]	172
Compression Set	% (ASTM D395-53T-B)	61	60	55	26	22	52	21	29	27	37	30	29	27	26	69	69	77	73	--	75	59	--	--	--	65	74[e] 44[f]	22	25	--	45
Oil Immersion	Wt % Charge after 70 hr at 300°F in ASTM No. 1 oil	--	--	--	+21.7	--	--	--	--	--	--	+55	--	--	--		disintegrated			-5.1	-5.4	-3.5	--	--	+1.7	--	+0.3	+4.2	+4.0	--	--
	Wt % Charge after 70 hr at 300°F in ASTM No. 3 oil	--	--	--	+82.5	--	--	--	--	--	--	+146	--	--	--		disintegrated			+4.2	+3.9	+11.0	--	--	+12.5	--	+1.6	+30.2	+26.7	--	--
Assembly Oil		SDX[g]	SDX	SDX	SDX	SDX	SDX	SDX	SDX	SDX	SDX	SDX	SDX	SDX	SDX	SDX	SDX	SDX	SDX	TCP[h]	TCP	TCP	TCP	CS[i] or PG[j]	CS or PG	CS or PG	CSA[11] or PG	No. 3[k]	No. 3	No. 3	CS or PG
Assembly[b] Characteristic	Deflection (0.001 in.)	240	280	290	--	240	250	170	180	210	120	80	85	--	--	280	240	--	--	--	--	--	--	cut on assembly		--	--	cut	250[e]	300	200
	Break	--	--	--	--	Fair	Good	Good	Good	Good	--	Very Good	Good	--	--	none	none	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Frequency (calculated)	2225	2160	2190	--	2120	2190	2520	2520	2430	2200	2640	2150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1510[e] 1630	1470- 1510	2530
Basic Composition	Rubber	1711	1711	1711	1707	1707	1500	1500	1500	1500	W[l]	W	W	WRT[l]	WRT	GR-I[m] 217	GR-I 217	GR-I 217	GR-I 217	Hycar[n] 1042	Hycar[n] 1001	Hycar[n] 1041	Hycar 1042	Hycar[n] 4021	Hycar 4021	Hycar 4021	Viton A[l]	UCC6[o]	UCC7[o]	GE[p]	VP-15[q]
	Reinforcing Agents	TMX[r] EPC[s] Clay	TMX EPC Clay	TMX EPC Clay	TMX EPC	TMX EPC Clay	SRF[t]	MAF[u]	MAF	MAF TMX	P-33[v]	MAF	SRF	P-33	P-33	MAF	MAF SRF	MAF TMX	MAF SRF	MAF TMX	MAF TMX	MAF TMX	MAF	SRF	MAF	MAF	P-33	--	--	--	TMX
	Plasticizers	--	--	--	--	--	--	--	--	--	--	--	SDX	SDX	SDX	--	--	--	--	118A[w] G-25[x]	118A G-25	118A G-25	F-26[y]	--	--	--	118A	--	--	--	118A SDX
	Curing System	S[z]-SC[1]	TMTD[2]- MBT[3]	S- TMTD- DMBT[4]	DCP[5]- TMTD	MBT- TMTD	S-SC	DCP	DCP- TMTD	DCP- TMTD	ZnO- MgO- NA-22[6]	ZnO- MgO- NA-22	ZnO- MgO- NA-22	ZnO- MgO- NA-22	ZnO- MgO- NA-22	S- TMTD- DMBT	S- TMTD- DMBT	S- TMTD DMBT	S- TMTD DMBT	S- DMBT	S- DMBT	S- DMBT	DCP	S- TETA[7]	S- TMTD- TETA	DMBT- TETA	S- TETA	ACC[8]	ACC	AGE[9]	DMBT- TMTD- BTC[10]

a. Samples were aged in air for 3 days at 212°F.
b. Measurements were made by Mr. Harold P. Arnt.
c. Compounds were cured for 30 min at 310°F and heat-treated 24 hr at 300°F.
d. Compounds were cured for 60 min at 300°F and heat-treated 16 hr at 400°F.
e. Measurements made before heat treatment.
f. Measurements made after heat treatment.
g. SDX, Sundex 53.
h. TCP, Tricresyl phosphate.
i. CS, Cellosolve.
j. PG, Polyglycol.
k. No. 3, ASTM No. 3 oil.
l. E. I. du Pont de Nemours and Co., Inc.
m. Esso Standard Oil Company, Inc.
n. B. F. Goodrich Chemical Company.
o. Union Carbide Corporation silicone rubbers 1046R and 1047R.
p. General Electric Company silicone 81716U.
q. Phillips Chemical Company; butadiene/vinyl pyridine rubber.
r. TMX, Thermax carbon black.
s. EPC, EPC carbon black.
t. SRF, SRF carbon black.
u. MAF, Philblack A.
v. P-33, P-33 carbon black.
w. 118A, Plasticizer 118A.
x. G-25, Paraplex G-25.
y. F-26, Flexol 26A.
z. S, Sulfur.
1. SC, Santocure.
2. TMTD, Methyl Tuads.
3. MBT, Captax.
4. DMBT, Altax.
5. DCP, DiCup 40C.
6. NA-22, NA-22 Accelerator.
7. TETA, Triethylene tetramine.
8. ACC, Luperco ACC.
9. AGE, Luperco AGE.
10. BTC, benzotrichloride.
11. CSA, Cellosolve acetate.

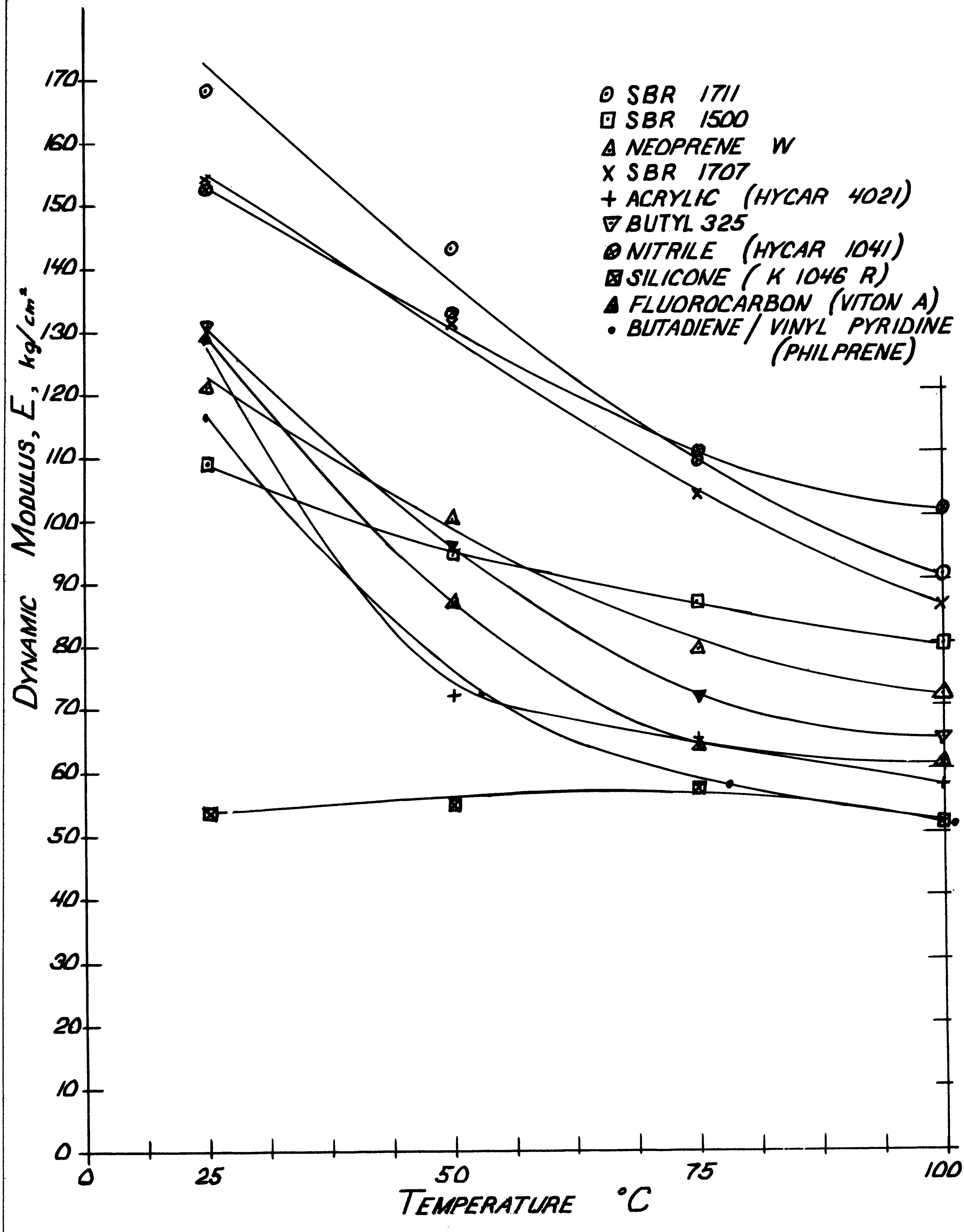

Fig. 2. Effect of temperature on the dynamic modulus of various unaged vulcanizates.

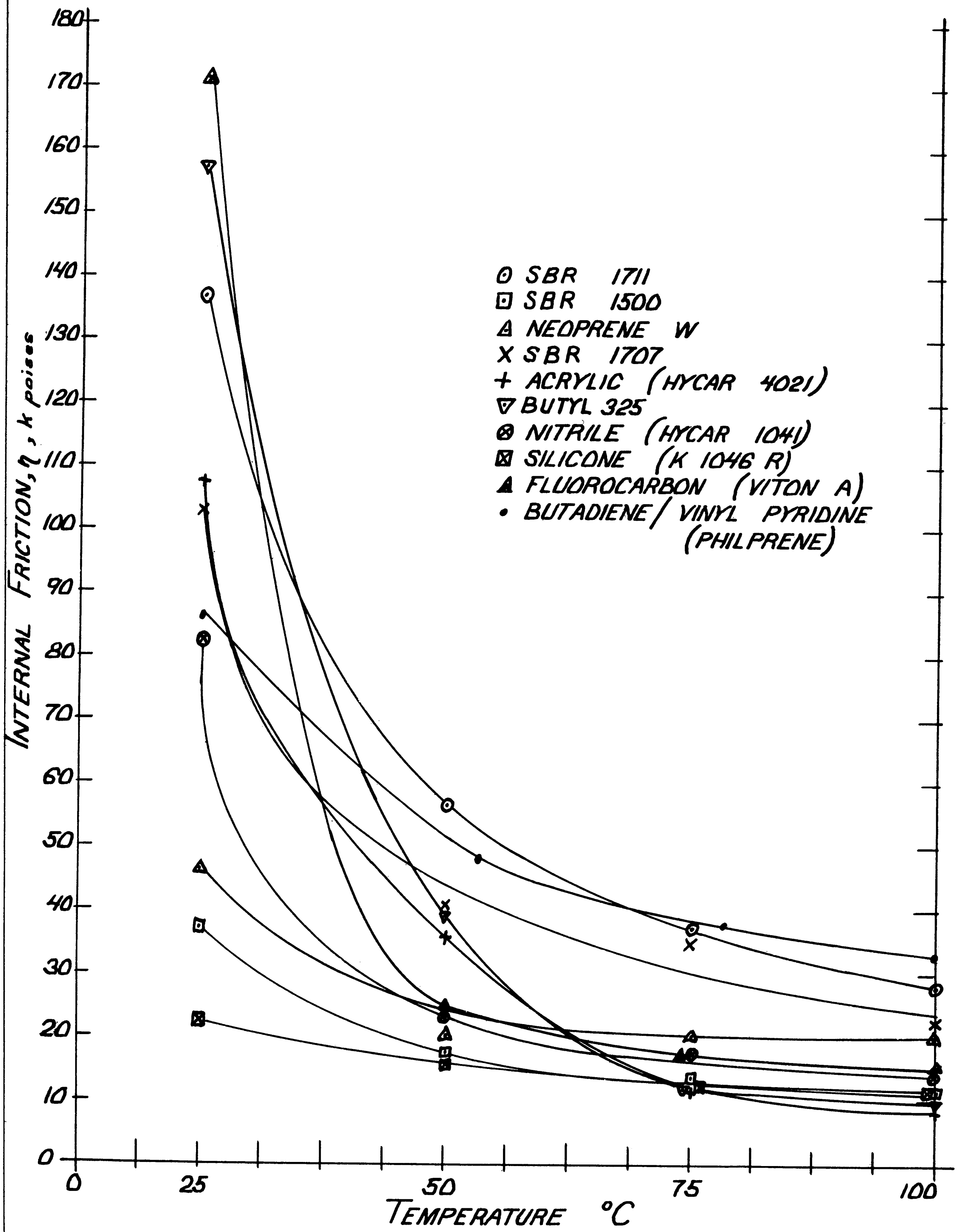

Fig. 3. Effect of temperature on the internal friction of various unaged vulcanizates.

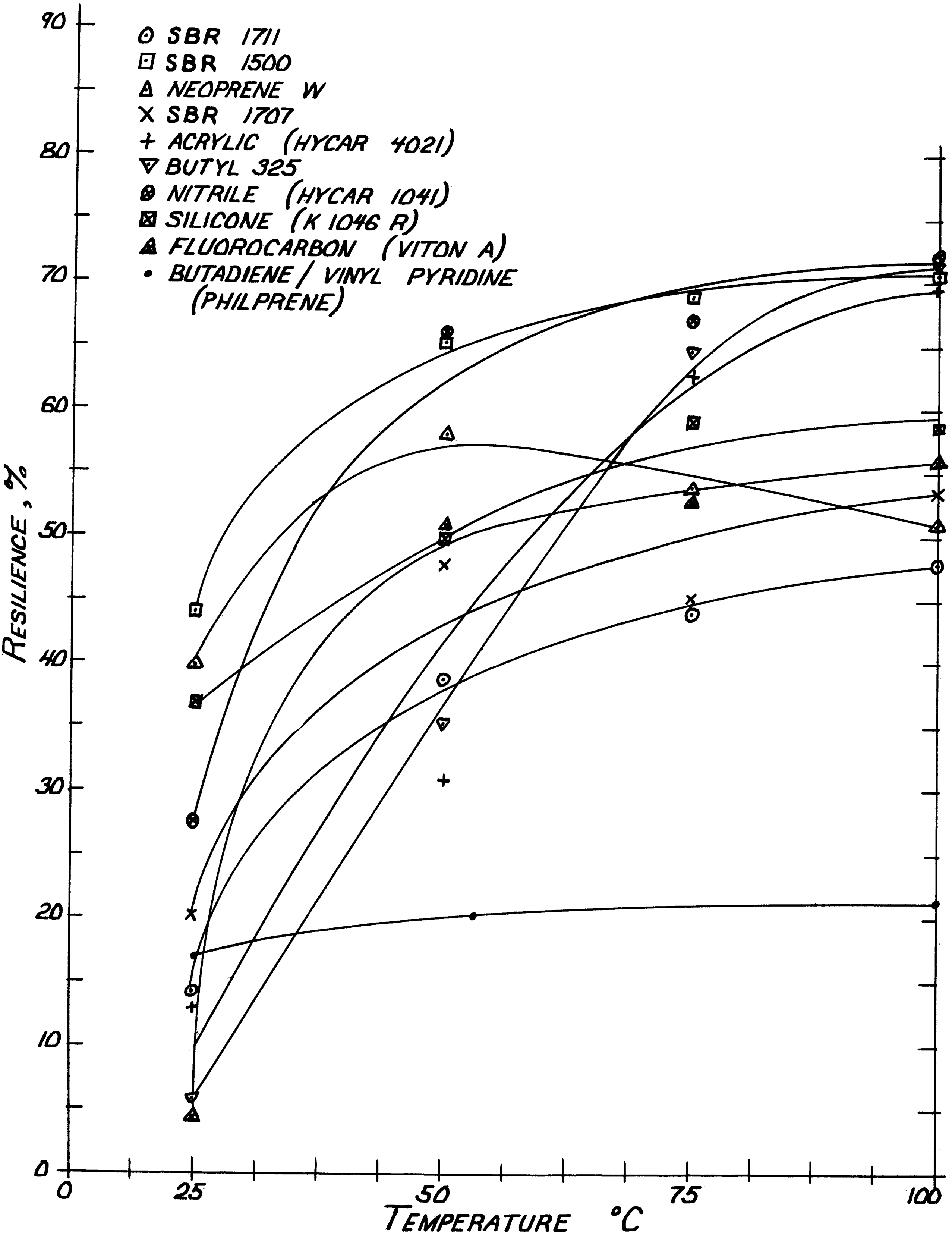

Fig. 4. Effect of temperature on the resilience of various unaged vulcanizates.

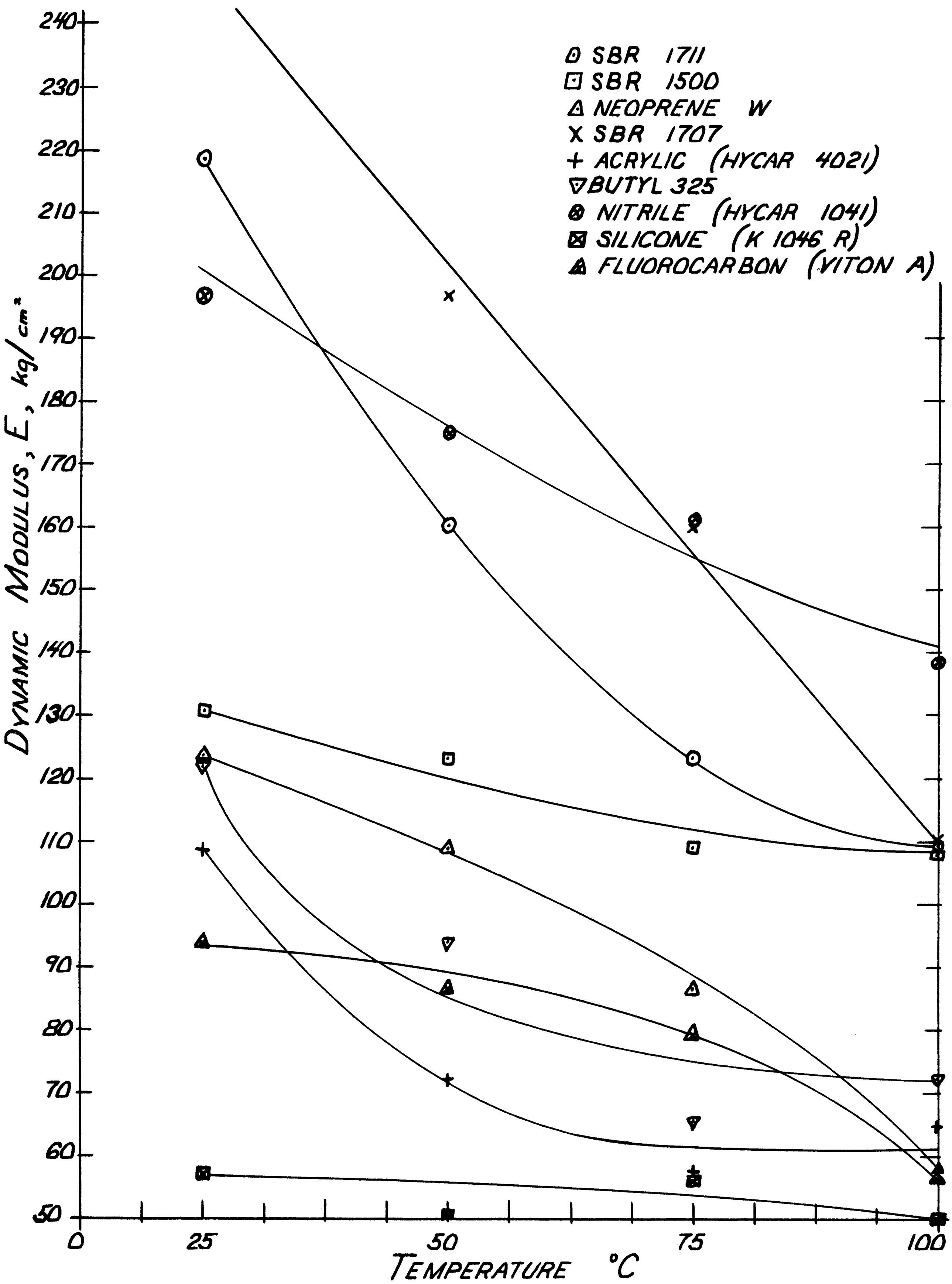

Fig. 5. Effect of temperature on the dynamic modulus of vulcanizates aged in air for 3 days at 250°F.

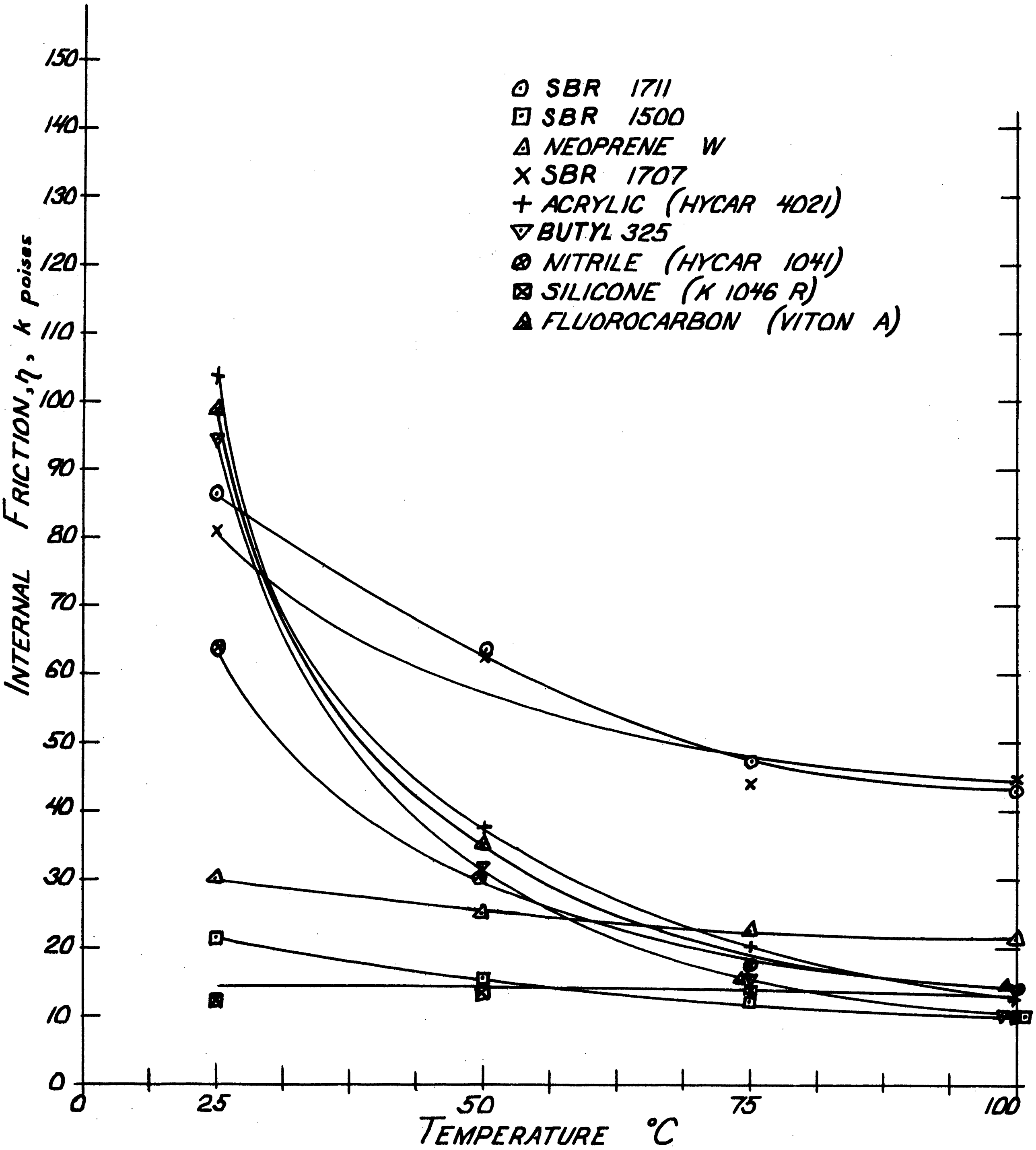

Fig. 6. Effect of temperature on the internal friction of vulcanizates aged in air for 3 days at 250°F.

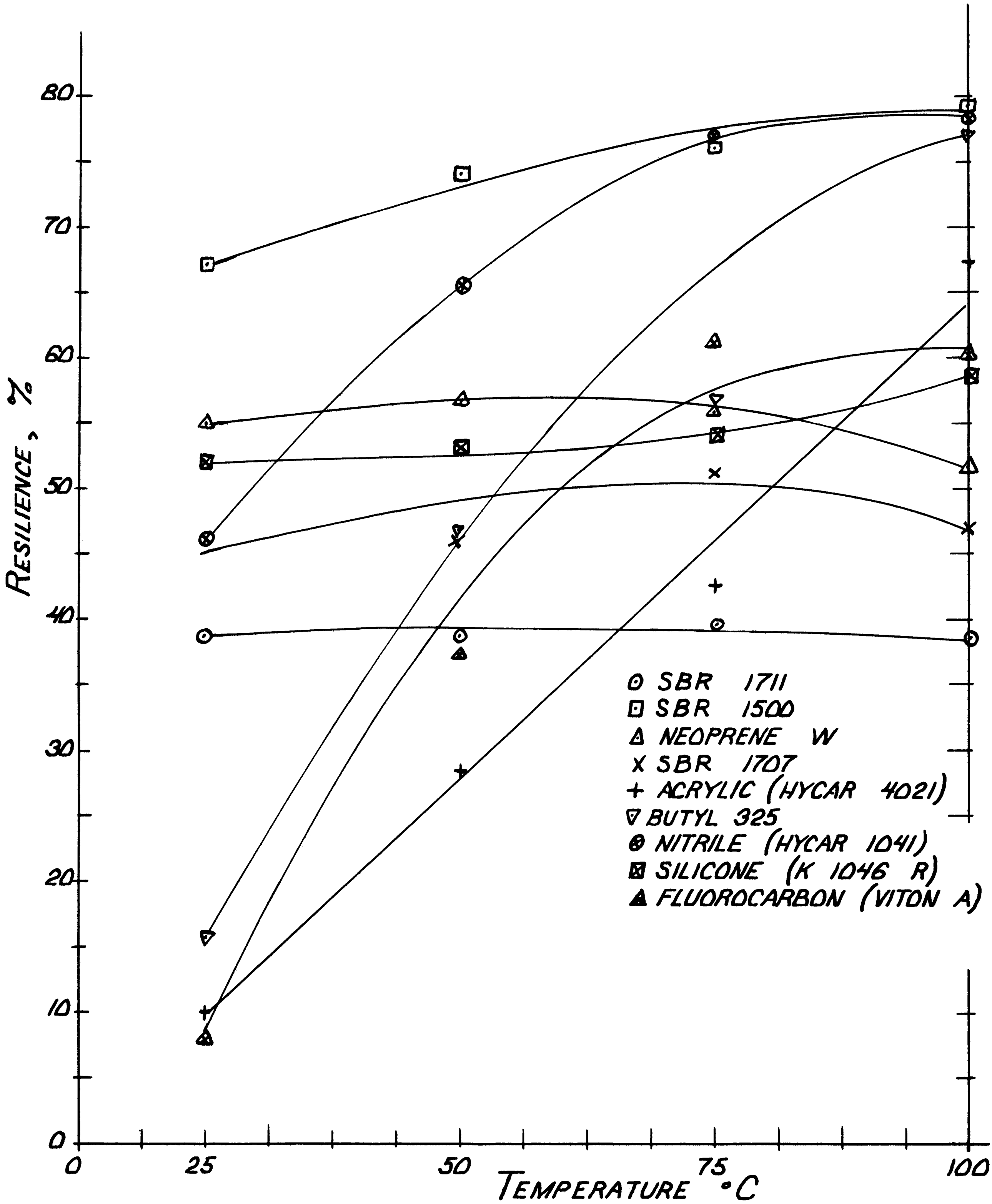

Fig. 7. Effect of temperature on resilience of vulcanizates aged in air for 3 days at 250°F.

TABLE II

APPRAISAL OF RUBBER VULCANIZATES FOR AUTOMOTIVE VIBRATION DAMPERS

	Tensile Properties		Tear Resistance lb/in.	Compression Set %	Oil Resistance	Dynamic Properties	
	Unaged	Aged				Change with Temp.	Change with Age
SBR 1707, 1711 (oil extended)	high	medium[a]-high[b]	good	low[b]-high[a]	fair	moderate-large	large
SBR 1500	high	medium[a]-high[b]	fair-good	low[b]-high[a]	fair	small	small
Neoprene	very high	high	fair-good	low	poor	small	small
Butyl	high	high	good	high	very poor	large	moderate
Nitrile	high	medium[a]-high[b]	good	low[b]-high[a]	very good	moderate	small
Acrylic	high	very high	poor	high	very good	moderate	small
Fluorocarbon (Viton A)	medium	exceptionally high	borderline	medium-high	excellent	large	moderate
Silicone	medium	exceptionally high	very poor-good	low	good	very small	very small
Butadiene/ vinyl pyridine	high	medium-high	good	medium	very good	moderate	small

a. Cured with sulfur plus accelerator.
b. Cured with dicumyl peroxide.

The effect of aging in an air oven at 212°F on the physical properties of several rubbers is shown in Table I. Due to the special heat treatments given the acrylic, fluorocarbon, and silicone rubbers (except No. 280), the aging results for these materials in Table I refer to changes in properties at 300, 400, and 480°F, respectively.

The tensile properties of rubbers are quite sensitive to the effects of aging, and on the basis of these results the various rubbers may be classified in three groups: (1) the fluorocarbon, silicone, and acrylic rubbers showed exceptional age resistance; (2) Neoprene, Butyl, and SBR 1500 cured with dicumyl peroxide showed good resistance to aging; and (3) SBR 1500 (cured with sulfur), nitrile, and Philprene VP-15 exhibited fair resistance to aging in air.

The fluorocarbon, silicone, and acrylic rubbers showed the greatest stability of properties above 250°F.

TEAR RESISTANCE

The gaskets which were cut or torn in assembly possessed tear resistance values of 70-140 lb/in. (specimen from ASTM Tear die C), whereas those which were assembled successfully possessed tear values greater than 150 lb/in. It was concluded that the minimum tear resistance of the rubber should be 150 lb/in. and that the value 170 lb/in. would be desired.

As mentioned above, the acrylic, fluorocarbon, and silicone rubbers have relatively low tear resistance in the fully cured state. However, the optimum values of various properties such as compression set and stiffness and the desired stability of properties are not achieved until the materials are completely cured. In the partially cured condition these rubbers, particularly the silicones, have their maximum tear strengths and can undergo the assembly operation satisfactorily. Accordingly, the procedure selected involved the assembly of the partially cured gaskets and the completion of the curing by treating the whole assembled damping device in an oven at the appropriate temperature.

COMPRESSION SET

As previously indicated, the assembled gasket is under some "30-50% compression," that is, its thickness in the assembly is some 50-70% of the thickness of the original rubber. The "compression set" value in percent represents the permanent deformation resulting after the rubber is held under a certain degree of compression under specified conditions of time and temperature.

In the compression-set measurement used in this work, the sample was held under 30% compression (70% of its original thickness) for 70 hr at 212°F.

If, after the completion of the test, the rubber returned to its original thickness, the compression-set value was listed as 0%, and if it remained at the compressed thickness after the test was complete, the compression-set value was listed as 100%.

Neoprene, silicone, SBR 1707, and SBR 1500 cured with peroxide showed low values of compression set. SBR 1711, SBR 1500 cured with sulfur, Butyl, and nitrile cured with sulfur had somewhat higher values. The partially cured (nonheat-treated) fluorocarbon rubber had the high value of 74% but after 16 hr at 400°F at no stress its compression set was reduced to 44%.

The compression set has an intimate relationship with the deflection test mentioned above. A rubber which possesses a low value of compression set will in general also show a low value in the deflection test, which means that it possesses a greater stiffness in the assembly.

There appears to be considerable latitude in acceptable values of compression set since some commercial gaskets which function successfully have values as high as 50-70%. It is clear, however, that a rubber formulation possessing low stiffness must have a high value of compression set to be satisfactory.

OIL RESISTANCE

The oil absorption by the various rubber compositions immersed in ASTM No. 1 and No. 3 oils was measured. On a relative basis, fluorocarbon rubber showed the highest resistance; nitrile and acrylic rubbers had good resistance and silicone rubber showed good resistance to No. 1 oil and fair resistance to No. 3 oil. SBR rubbers possessed fair resistance and Neoprene and Butyl rubbers lower resistance to both oils. These results are presented in detail in Status Report No. 7.

The highly oil-resistant rubbers require the use of special oils as assembly aids. Oils which satisfactorily lubricate the surfaces of these rubbers are identified in Table I.

DYNAMIC PROPERTIES

The dynamic properties of various compositions were measured with a Goodyear Vibrotester according to directions given in Status Report No. 4. The rubber specimen consisted of a vulcanized sample 1/2 in. in height and 1/2 in. in diameter. The measurements were made in the condition of resonance adjusted (by added weights) to approximately 60 cps. The vibration amplitude was 0.0164 cm. The instrument was located in a constant temperature-humidity room held at 25°C and 50% relative humidity. Measurements at 50, 75, and 100°C were obtained by passing heated air through the chamber in which the sample was mounted.

The results were expressed in terms of (1) dynamic modulus in force per unit area, a value which is related to the stiffness of the rubber; (2) the internal friction in kilopoise which is indicative of friction involved when internal portions of the rubber slide past one another; (3) the heat build-up, the amount of heat developed per cycle at a specific vibrational amplitude; and (4) the resilience, the percentage of vibrational energy remaining in the second of two successive vibrations.

The results for the unaged vulcanizates and those aged in air for 3 and 7 days at 250°F are summarized in Status Report No. 9. Data for the unaged products are shown below in Figs. 2-4, and for those aged for 3 days at 250°F in Figs. 5-7. (Curves for the heat build-up are not included since they are similar to those for the internal friction, Figs. 3 and 6.)

From these results it may be seen that, in general terms, temperature has a pronounced effect on the dynamic properties. The effect of temperature is the inverse of the effect of frequency. At high temperatures and/or low frequencies the materials are the more rubbery and at low temperatures and/or high frequencies the materials are stiffer.

For most of the rubbers,the dynamic properties change markedly with temperature. To obtain optimum performance it would be necessary to select the composition which possesses the desired combination of dynamic properties at the temperature which the rubber will maintain in the operation. That temperature is determined by the heat build-up of the rubber, the rate of heat loss from the assembly, and the ambient temperature (the latter two being functions of the design of the motor and of the damping assembly).

The dynamic properties of most of the rubbers changed less with temperature in the 50-100°C range than in the 25-50°C range.

With many rubbers the dynamic properties showed the same type of variation after aging; however, the properties of certain compositions were very little affected by aging.

Some of the specific observations are enumerated in the following paragraphs.

1. The silicone vulcanizate showed the least change of general dynamic properties with changes in temperature; SBR 1500 and Neoprene evidenced some change; and the oil-extended SBR (1707 and 1711), acrylic, Butyl, Philprene VP-15, and fluorocarbon (Viton A) rubbers exhibited pronounced changes with temperature.

2. The dynamic properties of silicone, Butyl, acrylic, and fluorocarbon products changed very little upon aging the samples; the properties of Neoprene changed somewhat more; and the dynamic properties of the SBR and nitrile rubbers were substantially changed by aging the samples.

The more theoretical aspects of the effect of temperature and age on the dynamic properties of the various vulcanizates are being prepared for publication and will appear in Rubber World in a few months.

COMMERCIAL SCALE PREPARATION OF EXPERIMENTAL COMPOSITIONS

Compositions 218 (Butyl), 223 (Neoprene), 226 (SBR 1500), 228 (SBR 1707), and 229 (Neoprene) were prepared by the Baldwin Rubber Company. The entire compounding operation was carried out using Banbury mixers in contrast to the 3- by 8-in. mill used in the laboratory preparation. The Neoprene compounds 223 and 229 scorched during preparation due to the higher compounding temperatures. After adjustment of the compositions to include 10 PHR of Sundex 53 oil, which helped keep the temperature down, the commercial procedures were satisfactory.

To compare laboratory with commercial preparation, the Baldwin Rubber Company supplied uncured compositions 218, 226, and 228, which were cured and tested according to laboratory procedures. In general, considering the differences in equipment and procedures, satisfactory physical property checks were obtained (see Status Report No. 5, Table I; and No. 7, Table I).

SUMMARY AND CONCLUSIONS

In Table II qualitative ratings of the properties of the various rubbers are listed. High unaged and aged tensile properties, high tear resistance, low compression set, high oil resistance, and small changes of dynamic properties with temperature and aging have been selected as desirable qualities in rubber vulcanizates to be used as vibration dampers.

It is apparent from the ratings reported in Table II that no one rubber is superior to all others in terms of all properties. If the rubbers are compared in terms of one property at a time, the following orders of preference may be listed.

1. Tensile Properties—Neoprene, SBR 1500, nitrile, Philprene VP-15, SBR 1707 and 1711, acrylic, Butyl, fluorocarbon (Viton A), and silicone.

2. Air Age Resistance—fluorocarbon, silicone, acrylic, Butyl, Neoprene, SBR and nitrile cured with peroxide, SBR 1500, 1707 and 1711, and Philprene VP-15.

3. Tear Resistance—SBR, Butyl, nitrile, Neoprene, silicone (special heat treatment), Philprene VP-15, fluorocarbon, and acrylic.

4. Compression Set—Silicone, Neoprene, SBR and nitrile cured with peroxide, fluorocarbon (heat-treated), SBR, Philprene VP-15, nitrile, and Butyl.

5. Oil Resistance—Fluorocarbon, Philprene VP-15, acrylic, nitrile, silicone, SBR, Neoprene, and Butyl.

6. Change of Dynamic Properties with Temperature—Silicone, SBR 1500, Neoprene, Philprene VP-15, nitrile, acrylic, SBR 1707 and 1711, Butyl, and fluorocarbon.

7. Change of Dynamic Properties with Age—Silicone, acrylic, fluorocarbon, Butyl, Neoprene, Philprene VP-15, nitrile, and SBR 1500, 1707 and 1711.

From this study it has been concluded that for current conditions of operation satisfactory gaskets may be prepared from SBR 1500, 1707, and 1711, Neoprene, nitrile, and Philprene VP-15 rubbers, the compositions being vulcanized in the normal fashion. For operation at moderately high temperatures and exposure to air, SBR 1500 cured with dicumyl peroxide and Neoprene cured in the normal way can be employed. For operation at moderately high temperatures and exposure to oil, the nitrile rubber vulcanized with peroxide is recommended. For operation at temperatures above 250°F the silicone and fluorocarbon rubbers are superior, and if at the high temperature oil resistance is also required, then the fluorocarbon rubber is recommended.