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Development of Additional SAE J2643 Standard Reference Elastomers

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ABSTRACT

The first set of SAE J2643 Standard Reference Elastomers (SRE) was developed in 2004. It was composed of a group of 10 compounds covering multiple elastomer families. Since then, more advanced materials from many elastomer families have been introduced to the automotive industry. The purpose of this study is to add a few more reference compounds to SAE J2643, to enhance the portfolio on FKM, AEM and ACM to reflect advancements in elastomer technology, and make it suitable for a variety of fluids, such as transmission fluid and engine oil.

Fourteen standard elastomer compounds were involved in this study, covering various materials currently used in automotive powertrain static and dynamic sealing applications. Participants include OEMs, major rubber manufacturers, a fluid additive company and an independent lab. Manufacturers of each test compound provided formulations, designated ingredients from defined sources, and detailed mixing and molding procedures. All fourteen compounds were molded at Akron Rubber Development Lab (ARDL), the only approved mixing facility for SAE J2643 SRE compounds. Testing specimens were also die-cut by ARDL to minimize sample preparation variation.

Two fluids were utilized for the study: ASTM SF105 fluid and GM DEXRON®-VI automatic transmission fluid (ATF). Elastomer specimens were aged in the designated fluids per ASTM D471. This paper only reports test results for the ASTM SF105 fluid. The DEXRON®-VI results will be reported internally within GM.

INTRODUCTION

Ethylene acrylic copolymer (AEM), polyacrylate (ACM), fluorinated elastomers (FKM), nitrile rubber (NBR) and hydrogenated nitrile rubber (HNBR) are popular automotive industry elastomeric materials, especially for powertrain applications. New material technologies have been introduced to the automotive industry since the establishment of the first set of Standard Reference Elastomers (SRE) per SAE J2643 in 2004. Those advancements include low temperature flexible FKM materials, AEM and ACM cured with environmental friendly curative package - free of dio-tolylguanidine (DOTG), etc.

Historically, automotive industries tend to use production rubber compounds molded by rubber part manufacturers for the development of engine oils or transmission fluids, if there is no Standard Reference Elastomer (SRE) available. The manufacturing process of molded slabs is usually not controlled and certified to a level required for standard reference. Large property variation of testing slabs is always a big concern during fluid development. An even worse situation is that a reference compound would be obsolete if the compound is out of production. There is a high demand from automotive fluid industries to develop new Standard Reference Elastomers (SREs) representing new material technologies that are commonly used in engine and transmissions. Those SREs shall be well controlled to avoid batch to batch variation, readily available with stabilized supplying source, and good traceability for slab quality monitoring.

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This study is aimed to developing additional SREs to SAE J2643 to enhance the portfolio on FKM, AEM and ACM to reflect advancements in elastomer technology, and make the elastomers set suitable for a variety of fluids. To achieve these goals, a team was formed involving experts industry wide. Participants include automobile original equipment manufacturers (OEMs), raw material manufacturers, a fluid additive company and a certified independent lab. A total of 14 compounds were defined by the team to cover elastomers used in automotive industries representing new technologies developed since 2004. Akron Rubber Development Laboratory (ARDL), the only approved source for mixing SAE J2643 SREs, was pointed as the compounder for this study. The candidate compounds are mixed per formulas and mix procedures provided by the compound owners using designated ingredients from designated sources. In order to minimize variation from sample preparation, ARDL also die cut all the test specimens per ASTM requirements.

MATERIALS AND TESTS

ELASTOMERS

This study involved fourteen (14) elastomers covering five material families from four manufacturers as detailed in table 1. The current SAE J2643 only specifies a bisphenol cured terpolymer fluoroelastomer (Viton B600, FKM Type 2 per ASTM D1418) from DuPont as the FKM Standard Reference Elastomer (SRE). Four more types of FKM materials that are currently used in automotive industries were studied as possible additions to SAE J2643. Those materials cover the traditional bisphenol cured dipolymer FKM, peroxide cured terpolymer FKM, intermediate base resistance FKM, base resistance FKM and the most advanced low temperature flexible FKM.

The current SAE J2643 AEM SRE is DuPont VAMAC G compound cured with dio-tolylguanidine (DOTG) - diamine curative system. Three additional AEM SRE candidates were evaluated in this study covering the three major VAMAC sub-categories: G (regular grade), GLS (low volume swell grade) and DP (dipolymer without post cure grade). Those compounds were all cured with environmental friendly curative system -- DOTG free curative packages.

For ACM, the more advanced Zeon AR12 with new cure technology was evaluated as an addition to the current SAE J2643 that uses a traditional ACM material from Zeon as ACM SRE. Four current SAE J2643 SREs from Zeon (ACM, NBR-1, NBR-2 and HNBR) were also tested in this study. Table 1 shows the elastomer types, curative systems, and technology suppliers.

Table 1. Materials Involved in This Study

Compound ID	Material Family	Sub-category and Compounds		
		ASTM D-1418		Compounds
ES-1	FKM	Type 1	Bisphenol AF 66%	**DuPont**, A401C, Tg -16°C
ES-2		Type 2	PO 68%	**DuPont**, GBL 600S, Tg -17°C
ES-3		Type 3	Low temp, Tg at -40°C	**Dyneon**, LTFE 6400
ES-4			Low temp, Tg at -30°C	**Solvay**, PL855 64% F
ES-5		Type 4	Intermediate BRE	**Dyneon**, BRE 7231, Tg -9°C
ES-6		Type 5	Intermediate BRE	**Solvay**, BR 9151
ES-7	AEM	G	**DuPont**, with 10 phr TP759, EM08A49-2	
ES-8		GLS	**DuPont**, with 10 phr TP759, EM08A49-4	
ES-9		DP	**DuPont**, with no plasticizer, EM08A49-5	
ES-10	ACM	Traditional	ACM-1, SAE J2643, **Zeon**	
ES-11		AR 12	ACM-2, New cure technology, **Zeon**	
ES-12	NBR	S cured	NBR-1, SAE J2643, **Zeon**	
ES-13		PO cured	NBR-2, SAE J2643, **Zeon**	
ES-14	HNBR		HNBR-1, SAE J2643, **Zeon**	

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PREPARATION OF TESTING SPECIMENS

The formulation of each compound (ES-1 through ES-14) was provided by the corresponding base polymer manufacturer with clearly defined grade and source of each ingredient, along with detailed mixing procedure, cure and post cure conditions. Please refer to Appendix I for detailed formulation of each compound.

All fourteen compounds were mixed in accordance with SAE J2643 at Akron Rubber Development Lab (ARDL). Four batches were mixed using Size B Banbury mixes and blended, effectively yielding 7.5 - 10 kg uncured material per lot of each SRE. ARDL followed the detailed mixing procedure provided by material manufacturer for each compound, under the guidelines in Section 5 of ASTM D3187.

Thirty-five (35) ASTM standard sheets/slabs were vulcanized at ARDL per conditions provided by the corresponding material manufacturer for each compound. The sheets meet ASTM D3182 Figure 1 mold cavity dimensions measured to ASTM D3767, with thickness of each sheet measured. One test sheet from each lot was tested for the specified properties for compliance with the tolerances if specified. The molded sheet was inspected visually to be free of any surface defects or internal voids.

Each sheet was marked along one edge with the ASTM D1418/ ISO 1629 nomenclature letters with ES formulation number (will be replaced with SRE number per SAE J2643 designation after approved by SAE CARS, mix number, lot number, and grain direction (arrow), using mold marks/visible or durable ink. Each portion of the nomenclature was separated with a slash mark.

Example: SAE J2643 SRE ES-1/Mix-2/Lot 1

ES-1 will be replaced with SRE number after approval from SAE CARS, such as FKM-2

The documentation for the materials followed portions of ASTM D4678 Section 7. This included a full report that included the name of the material, the ES formulation number, ARDL's organizational name, date of preparation or manufacture and testing, any special preparation or processing steps, and specific conditions for storage and any further pertinent information.

All testing specimens were die cut by ARDL using reference die cutters with sharp edges to ensure specimen quality to minimize specimen preparation variation from multiple labs. Sufficient number of prepared test specimens was shipped to each of the round robin participants along with ARDL's certification after QC review. Any remaining test sheets were stored at ARDL in accordance with ISO 2230.

FLUID

A drum (55 gallons) of ASTM SF105 fluid was ordered by GM from ASTM Test Monitoring Center, well mixed and distributed fluid samples to all seven participating labs, in order to eliminate testing variation due to fluid samples.

FLUID AGING AND MATERIAL PROPERTY MEASUREMENT

Elastomer specimens were aged in the ASTM SF105 fluid per ASTM D471 at each participating lab with the following modifications recommended:

1. Use heat blocks or oil baths for better temperature control

2. Use testing tube of 38mm (dia) × 300 mm (length), or 340 cm^3 filled with 200 cm^3 fluid

3. Place three tensile test dumbbells and three volume specimens into each testing tube, (specimens were separated properly to prevent contact during aging period).

4. Age all elastomers at 150°C except NBR (125°C for NBR) for 70 hours and 168 hours

5. Monitor changes of tensile strength, modulus at 50% elongation, elongation, Shore A hardness and volume swell

Test three (3) specimens per condition per compound, per ASTM standards (D412, D2240, D471)

Test in direction of grain

Report instant Shore A hardness reading (within 1+/− 0.1 second)

RESULTS

Material properties were reported prior to and after the designated fluid aging periods (70 and 168 hours). Since SAE J2643 specifies the 168 hour aging condition, this study will only discuss the 168 hour test results. Labs were requested to report each individual measurement in metric units. For aged properties, the residual values were required. Test results of all fourteen ES compounds, along with detailed formulations are shown in Appendix I of this paper.

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DISCUSSION

STATISTICAL ANALYSIS

Among the seven participating laboratories, the tensile properties from Lab F showed significant higher elongations on all ES compounds tested. The tensile properties: tensile strength, 50% modulus (tensile stress at 50% elongation) and elongation from Lab F were excluded from statistical calculation. Shore A hardness and volume were in line with other labs, therefore included. A few outliers from other laboratories were also eliminated.

The data were calculated using spread sheets set up per ASTM E691. Table 2 shows an example of statistical calculation of compound ES-1. Test results from individual laboratory are not provided in this table due to space limitation. Table 3 provides an example of the detailed calculation of data from lab A. Data from other labs were calculated exactly the same way. Statistical terms are explained in equations 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11.

Table 2. Example of statistical calculation of compound ES-1

ES-1 Statistical Calculation Summary													
	Avg of Cell Avg	Std Dev of Cell Avg	Repeatability Std Dev	Reproducibility Std Dev	90% Repeatability Limit	90% Reproducibility Limit	ES-1 Results from Lab A	ES-1 Results from Lab B	ES-1 Results from Lab C	ES-1 Results from Lab D	ES-1 Results from Lab E	ES-1 Results from Lab F Tensile properties were not used due to outliers	ES-1 Results from Lab G
	X1	sx	Sr	SR	r	R							
Basic Requirements													
Orig. Durometer	76	1.23	0.83	1.44	1.65	2.87							
Tensile Strength, MPa	15.42	0.84	1.61	1.67	3.23	3.34							
50% Modulus, MPa	3.18	0.14	0.12	0.17	0.23	0.34							
Elongation, %	202	10.58	19.46	20.37	38.92	40.74							
Percent Change -- Fluid Resistance Service Fluid 105 - ASTM D471 168 Hours at 150°C (125°C NBR)													
Durometer Change, Points	6	0.39	0.43	0.55	0.86	1.10							
Tensile Strength Change, %	-67.85	2.25	0.90	2.39	1.81	4.79							
50% Modulus Change, %	40.20	11.71	5.05	12.55	10.10	25.11							
Elongation Change, %	-67.32	4.51	2.44	5.01	4.88	10.02							
Volume Change, %	0.62	0.07	0.17	0.17	0.34	0.33							

Table 3. Example of ES-1 results from Lab A as referenced in Table 2

Properties	ES-1 Results from Lab A							
	Indivudual Test Result x			Cell Avg	Cell Std Dev	Cell Dev		
	1	2	3	X	s	d	h	k
Basic Requirements								
Orig. Durometer	74	74	76	74	1.04	-1.17	-0.95	1.26
Tensile Strength, MPa	15.54	15.91	15.42	15.62	0.26	0.20	0.24	0.16
50% Modulus, MPa	3.10	3.13	3.16	3.13	0.03	-0.04	-0.32	0.27
Elongation, %	198	201	204	201	3.00	-0.55	-0.05	0.15
Fluid Resistance Service Fluid 105 - ASTM D471 168 Hours at 150°C (125°C NBR)								
Durometer Change, Ponits	7	6	6	6	0.50	3.12	1.05	1.16
Tensile Strength Change, %	-68.69	-68.55	-69.21	-68.82	0.35	-0.97	-0.43	0.38
50% Modulus Change, %	39.00	32.18	38.12	36.43	3.71	-3.77	-0.32	0.73
Elongation Change, %	-66.67	-63.68	-66.67	-65.67	1.73	1.65	0.37	0.71
Volume Change, %	0.57	0.48	0.50	0.52	0.05	-0.23	-1.49	0.28

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Individual test results X

Cell Average

$$X = \sum_{1}^{n} x/n \quad (1)$$

n is the number of test results per cell (per lab)

Average of Cell Average

$$X1 = \sum_{1}^{p} X/p \quad (2)$$

p is the number of participating labs

Cell Standard Deviation

$$s = \sqrt{\sum_{1}^{n} (x-X)^2/(n-1)} \quad (3)$$

Cell Deviation

$$d = X - X1 \quad (4)$$

Standard Deviation of Cell Average

$$s_X = \sqrt{\sum_{1}^{p} d^2/(p-1)} \quad (5)$$

Repeatability Standard Deviation

$$s_r = \sqrt{\sum_{1}^{p} s^2/p} \quad (6)$$

Reproducibility Standard Deviation

$$s_R = \sqrt{\sum_{1}^{p} (s_x)^2 + (s_r)^2 (n-1)/n} \quad (7)$$

Between Laboratory Consistency Statistic

$$h = d / s_x \quad (8)$$

Within Laboratory Consistency Statistic

$$k = s / s_r \quad (9)$$

90% Repeatability

$$r = 2 s_r \quad (10)$$

90% Reproducibility

$$R = 2 s_R \quad (11)$$

The minimum and maximum values were determined based on 2 sigma -- 90% confidence level at the available degrees of freedom (DF) of each compound. Table 4 shows an example of maximum & minimum value calculation for compound ES-1. For fluid aged properties, the percent changes were recorded.

$$\text{Min} = \text{Ave} - t * \text{Std Dev} = X1 - t * S_X = X1 - R \quad (12)$$

$$\text{Max} = \text{Ave} + t * \text{Std Dev} = X1 + t * S_X = X1 + R \quad (13)$$

Range is defined as the difference between maximum and minimum.

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Table 4. Example of maximum & minimum calculation for ES-1

ES-1		Original		168 hrs at 150°C in SF105 fluid	
		Properties	Units	Property Changes	Units
Shore A hardness	Ave	75.6	Points	5.7	%
	Min - Ave. - t*Std. Dev	72.7		4.6	
	Max = Ave + t* Std Dev	78.5		6.8	
	Range	5.8		2.2	
	Range as a % of Ave.	7.7			
Tenslie Strength	Ave	15.15	MPa	-67.8	%
	Min - Ave. - t*Std. Dev	11.55		-72.59	
	Max = Ave + t* Std Dev	18.75		-63.01	
	Range	7.20		9.58	
	Range as a % of Ave.	47.52			
50% Modulus	Ave	3.18	MPa	40.2	%
	Min - Ave. - t*Std. Dev	2.84		15.09	
	Max = Ave + t* Std Dev	3.52		65.31	
	Range	0.68		50.22	
	Range as a % of Ave.	21.38			
Elongation	Ave	202	%	-67.32	%
	Min - Ave. - t*Std. Dev	161		-77.52	
	Max = Ave + t* Std Dev	242		-57.12	
	Range	81		20.4	
	Range as a % of Ave.	40			
Volume Swell	Ave			0.62	%
	Min - Ave. - t*Std. Dev			0.29	
	Max = Ave + t* Std Dev			0.95	
	Range			0.66	

For original properties, the range as a percentage of average value is also calculated to normalize the effect of different average values for different compounds. This is not needed for fluid age calculation because all changes are based on the same 0 to 100% scale.

Figure 1 compares the Range % of shore A hardness of the six (6) FKM compounds with the current SAE J2643 FKM-1 and FEPM. Range % is used to normalize the impact of different average values for different compounds. All 6 FKM ES compounds showed much lower lab to lab variation compared to the current fluorinated SRE s.

$$\text{Range as a percent of the average (Rang \%)} = 100 * (\text{Range} / \text{Average}) \quad (14)$$

ORIGINAL PROPERTIES

Average, minimum, maximum, Range and Range % are summarized in Table 5, Table 6, Table 7 for FKM, AEM/ACM and NBR/HNBR correspondingly. The current SAE J2643 SREs with similar chemical structure to the ES compounds are listed next to the corresponding ES compound(s) for reference and highlighted in light green columns. Among the five (5) material categories analyzed, FKM, ACM, AEM, NBR and HNBR, the current allowed maximum Range % for original properties, allowed maximum Range for SF105 fluid aged properties are also listed and highlighted in bright blue colored cells.

Similar comparison is conducted for the original tensile strength, 50% modulus and elongation, which are presented in Figures 2, 3, 4. The 50% modulus of all 6 ES compounds demonstrated smaller lab to lab variation. Tensile strength and elongation, however, exhibited mixed results - Some ES compounds showed lower lab to lab variation, others showed higher variation.

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Table 5. Summary of Original Properties of FKM Compounds

Properties	FKM or FEPM								Current J2643 allowed max
	ES-1	ES-2	ES-3	ES-4	ES-5	ES-6	J2643 FKM -1	J2643 FEPM	
Original Shore A Hardness									
Ave	76	72	69	68	73	71	73	69	
Min	73	69	68	67	71	69	68	63	
Max	79	74	71	69	75	72	79	75	
Range	6	5	3	2	4	3	11	12	
Range %	8	6	4	3	5	4	15	18	
Original Tenslie Strength, MPa									
Ave	15.15	21.28	13.29	21	13.79	19.17	11.14	16.74	
Min	11.55	18.8	10.93	19.05	11.75	15.02	10.26	15.45	
Max	18.75	23.76	15.65	22.95	15.83	23.32	12.03	18.97	
Range	7.2	4.96	4.72	3.90	4.08	8.3	1.77	3.52	
Range %	47.5	23.3	35.5	18.6	29.6	43.3	15.89	20.00	**33/NBR**
Original 50% Modulus, MPa									
Ave	3.18	2.01	2.27	1.9	3.1	2.09	2.03	2.12	
Min	2.84	1.69	1.83	1.56	2.72	1.71	1.91	1.69	
Max	3.52	2.33	2.71	2.24	3.48	2.47	2.15	2.56	
Range	0.68	0.64	0.88	0.68	0.76	0.76	0.24	0.87	
Range%	21.4	31.8	38.8	35.8	24.5	36.4	12.00	41.00	**50.5/AEM**
Original Elongation, %									
Ave	202	324	164	251	165	217	320	309	
Min	161	280	143	206	139	179	292	292	
Max	242	368	185	296	192	255	348	326	
Range	81	88	42	90	53	76	56	35	
Range %	40	27	26	36	32	35	17	11	**28/AEM**
Range %: Range as a % of Average									

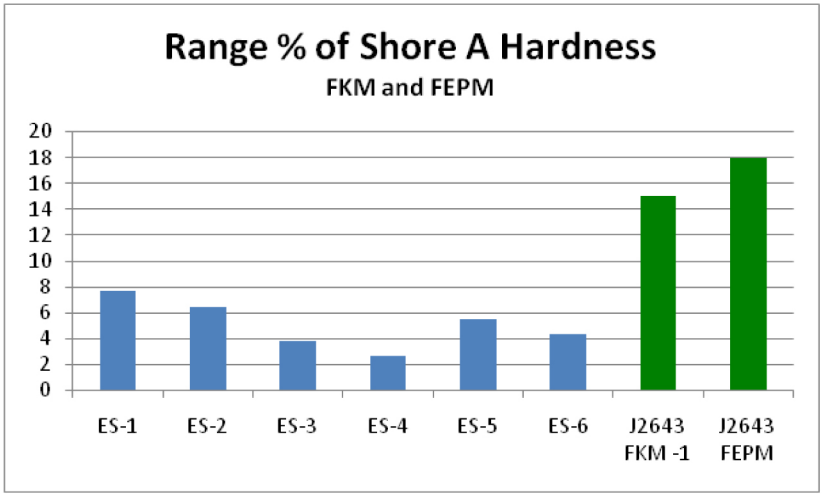


Figure 1. Range % of Original Shore A Hardness for FKM Compounds

The current SAE J2643 maximum allowable Range % is also shown in those pictures highlighted in a red bar. Tensile strength and elongation of ES-1 are considerably higher than the SAE J2643 allowed maximum value.

Figures 5, 6, 7, 8 summarize the Range % of original properties for AEM and ACM compounds, and comparing with the current SAE J2643 SRE s. Similar to FKM compounds, both AEM and ACM compounds exhibited significant better lab to

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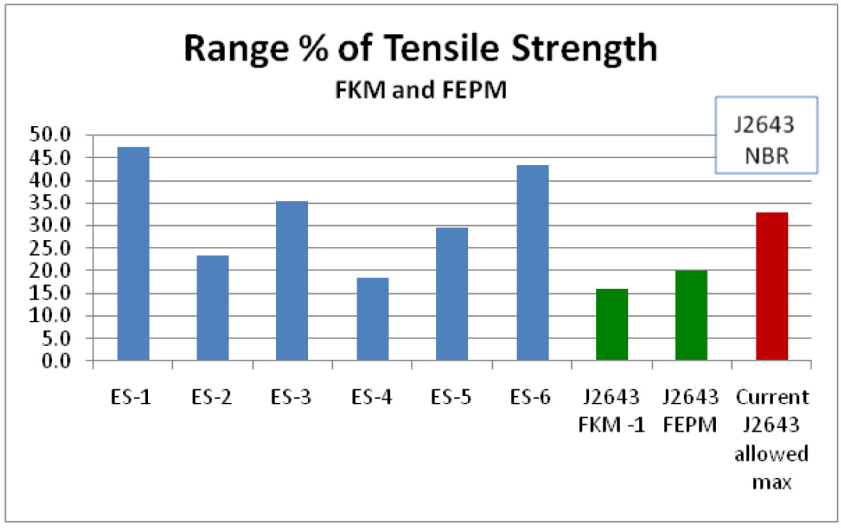


Figure 2. Range % of Original Tensile Strength for FKM Compounds

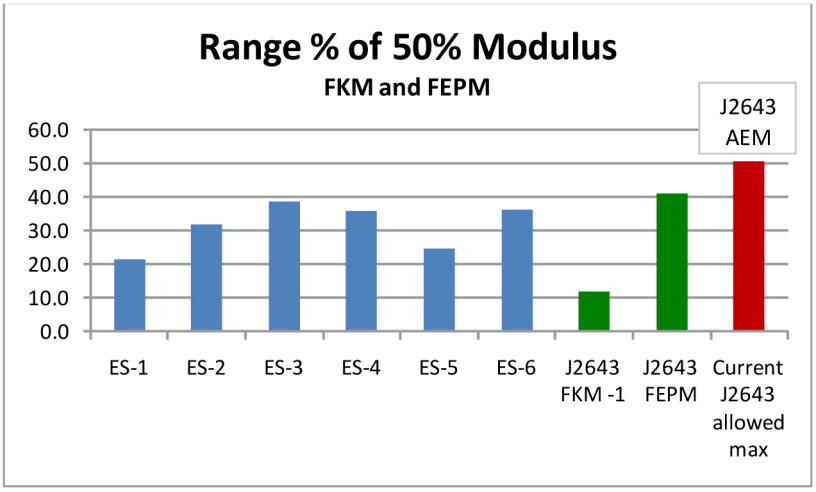


Figure 3. Range % of Original 50% Modulus for FKM Compounds

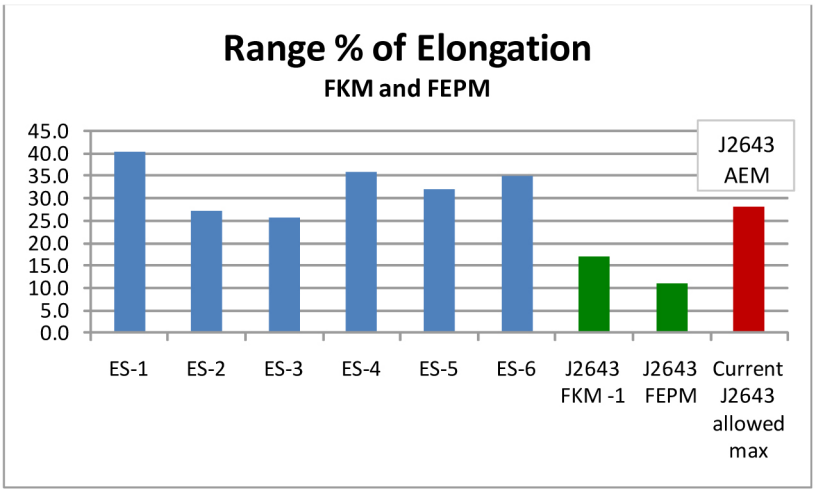


Figure 4. Range % of Original Elongation for FKM Compounds

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lab consistency as shown in Figure 5 The Range % of both tensile strength and elongation for all AEM and ACM compounds were lower than the current SAE J2643 maximum allowed value, which are demonstrated in Figures 6 and 7.

Figure 8 presents Range % of elongation for AEM and ACM compounds. Except ES-10, all other compounds showed similar lab-to-lab consistent results when compared the current SAE J2643 maximum allowed value. ES-10 is a retest of the current SAE J2643 ACM SRE with a previously reported Rang % of 12 versus the reported value of 53 from this study.

Table 6. Summary of Original Properties of AEM and ACM Compounds

Properties	AEM				ACM			Current J2643 allowed max
	ES-7	ES-8	ES-9	J2643 AEM	ES-10*	ES-11	J2643 ACM	
Original Shore A Hardness								
Ave	67	71	73	75	71	60	67	
Min	64	67	70	70	69	58	60	
Max	70	74	75	81	74	63	74	
Range	6	7	5	11	6	5	14	
Range %	9	9	7	15	8	8	21	
Original Tenslie Strength, MPa								
Ave	16.11	16.57	15.36	18.82	8.82	10.10	11.97	
Min	14.95	14.63	14.42	17.96	8.31	9.00	11.14	
Max	17.27	18.51	16.30	19.68	9.33	11.20	12.80	
Range	2.32	3.88	1.88	1.72	1.02	3.00	1.66	
Range %	14.40	23.42	12.24	9.00	11.56	29.70	14.00	**33/NBR**
Original 50% Modulus, MPa								
Ave	2.02	2.31	2.42	3.05	2.31	1.30	2.33	
Min	1.69	2.09	1.80	2.31	1.93	1.09	1.75	
Max	2.35	2.53	3.04	3.85	2.69	1.51	2.91	
Range	0.66	0.44	1.24	1.54	0.76	0.42	1.16	
Range%	32.67	19.05	51.24	**50.5**	32.90	32.31	49.79	**50.5/AEM**
Original Elongation, %								
Ave	290	260	220	261	151	260	169	
Min	262	221	197	224	110	226	150	
Max	318	300	243	297	193	294	188	
Range	56	78	45	73	82	67	22	
Range %	19	30	21	**28**	54	26	13	**28/AEM**
Range %: Range as a % of Average				ES-10 is the same as J2643 ACM				

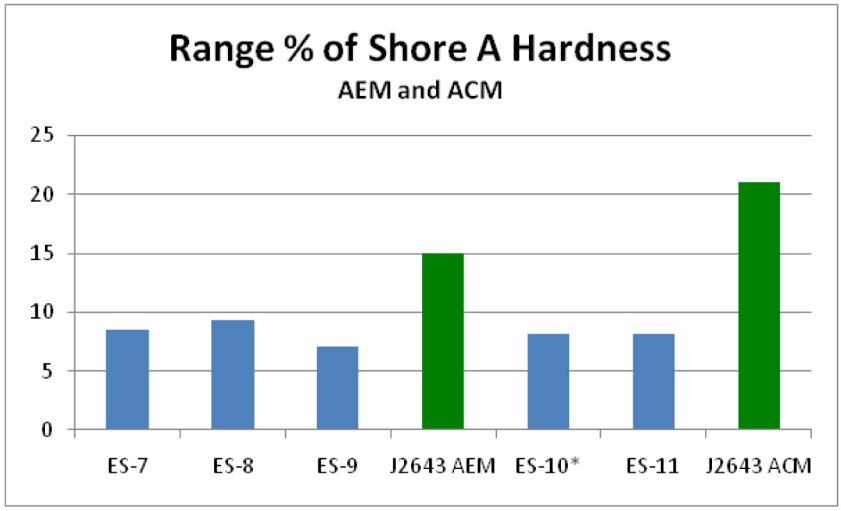


Figure 5. Range % of Shore A Hardness for AEM and ACM Compounds

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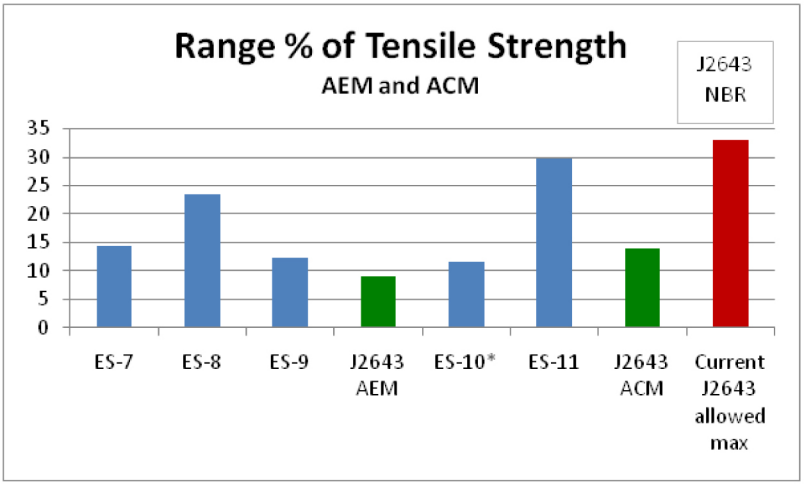


Figure 6. Range % of Tensile Strength for AEM and ACM Compounds

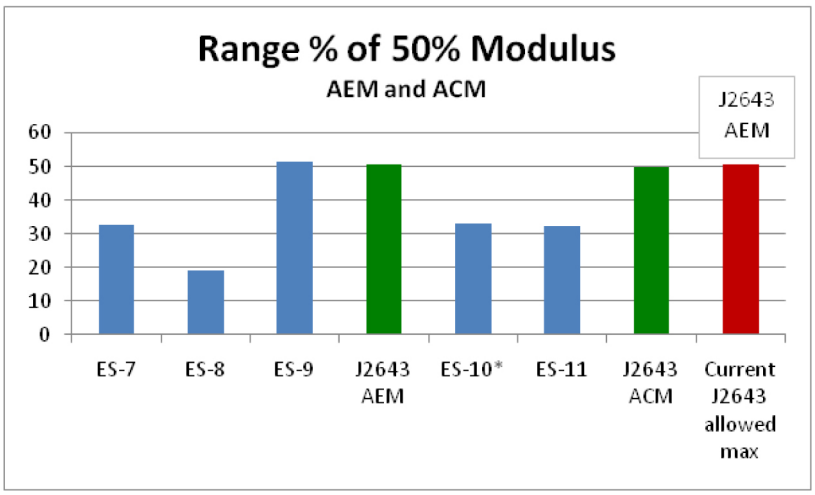


Figure 7. Range % of 50% Modulus for AEM and ACM Compounds

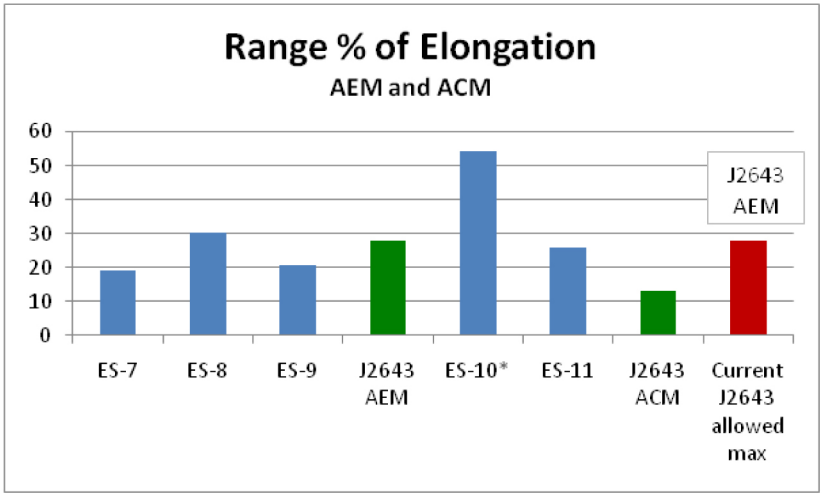


Figure 8. Range % of Elongation for AEM and ACM Compounds

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The Range % for NBR and HNBR compounds are shown in Figures 9, 10, 11, 12. All three (3) compounds are current SAE J2643 SREs and retested for reference purpose. The test results of all 3 compounds exhibited good lab to lab consistency, with the exception of ES-13. This compound showed a higher Range % compared with the result from the previous study: 36 for ES-13 versus 18 for J2643 NBR-2, even though they are really the same compound -- formulated by the same company Zeon Chemicals using the exact ingredients and mixed by the same mixing facility ARDL.

Table 7. Summary of Original Properties of NBR and HNBR Compounds

Properties	NBR				HNBR		Current J2643 allowed max
	ES-12*	J2643 NBR-1	ES-13*	J2643 NBR-2	ES-14*	J2643 HNBR	
Original Shore A Hardness							
Ave	69	69	71	68	66	71	
Min	65	63	68	64	64	65	
Max	72	75	75	73	69	77	
Range	6	12	7	9	5	12	
Range %	9	18	10	13	8	17	
Original Tenslie Strength, MPa							
Ave	17.92	17.30	19.80	16.50	27.30	26.40	
Min	16.83	16.10	17.90	13.70	24.70	24.62	
Max	19.01	18.50	21.70	19.10	29.90	28.18	
Range	2.18	2.45	3.80	5.40	5.20	3.56	
Range %	12.17	14.00	19.19	**33**	19.05	13.50	**33/NBR**
Original 50% Modulus, MPa							
Ave	1.95	1.95	2.41	2.06	1.80	1.99	
Min	1.58	1.76	2.06	1.83	1.61	1.87	
Max	2.32	2.14	2.76	2.29	1.99	2.11	
Range	0.74	0.38	0.70	0.46	0.38	0.24	
Range%	37.95	19.50	29.05	22.30	21.10	12.00	**50.5/AEM**
Original Elongation, %							
Ave	373	400	242	225	368	412	
Min	320	380	197	204	319	352	
Max	426	421	287	247	416	451	
Range	106	41	90	43	97	75	
Range %	29	10	37	19	26	19	**28/AEM**

Range %: Range as a % of Average

ES-12 is the same as J2643 NBR-1

ES-13 is the same as J2643 NBR-2

ES-14 is the same as J2643 HNBR

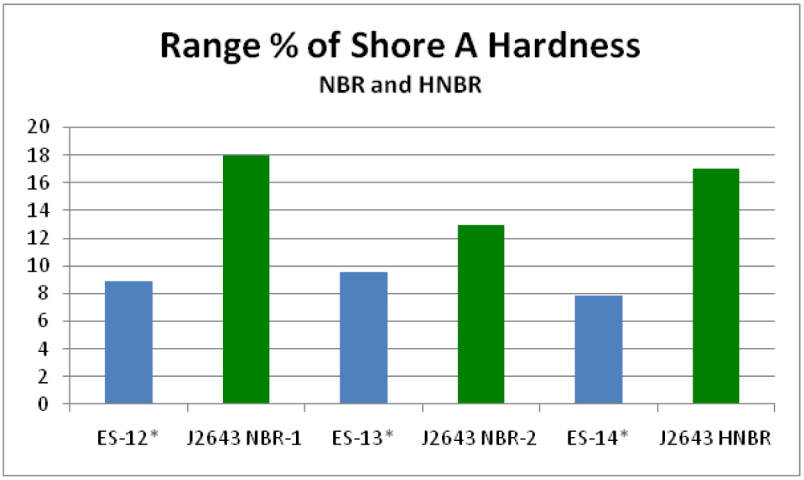


Figure 9. Range % of Shore A Hardness for NBR and HNBR Compounds

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