



NORDEL™ 6555 OE EPDM

## Two-pass Sponge Weatherstrip Processing Guide

### Product Description

NORDEL™ 6555 OE EPDM is an amorphous grade of ethylene propylene diene terpolymer (EPDM) designed for extruded foam applications. It is ideally suited for extruded sponge profiles requiring fast curing conditions. The combination of high viscosity and low crystallinity allows for good balance of processability, extensibility, low temperature properties, and performance. The NORDEL™ 6555 OE EPDM product features improved mixing and extrusion characteristics, suitable for class A surface manufacturing, with improved shape stability of the green compound.

Main characteristics:

- Amorphous
- High diene
- High molecular weight
- Good low temperature properties
- Complies with U.S. FDA 21 CFR 175.105 (consult regulations for complete details)

Applications:

- Extruded profiles (dense or sponge)
- Coolant hoses

**Table 1:** ASTM & ISO Properties<sup>(1)</sup>

Property	Nominal Value	Units	Test Method
Specific Gravity	0.862	g/cc	ASTM D297
Mooney Viscosity (ML 1+4 at 125°C)	55	MU	ASTM D1646
Ethylene Content	53.0	wt%	ASTM D3900
Ethylidene Norbornene (ENB) Content	8.5	wt%	ASTM D6047
Ash Content	< 0.1	wt%	ASTM D296
Molecular Weight Distribution	Medium		Dow Method
Propylene Content	38.5	wt%	ASTM D3900
Oil Content	20-23	phr	Dow Method
Residual Transition Metal	< 10	ppm	Dow Method
Volatile Matter	< 0.40	wt%	Dow Method

<sup>(1)</sup> Data per tests conducted by Dow. Additional information available upon request. Properties shown are typical, not to be construed as specifications. Users should confirm results by their own tests.

### Model Formulation

NORDEL™ 6555 OE EPDM Rubber was utilized to successfully produce closed cell sponge weatherstrip profiles. Three different sponge profile formulations were developed to enable flexibility in equipment and processing as well as to meet customer regulatory needs. Those three sponge formulations feature the master batch shown in Table 2 and use curing/blowing agent packages based on: (1) 100% Azodicarbonamide (ADC), (2) a blend of ADC and 4-4'-Oxydibenzene-sulfonyl hydrazide (OBSh), and (3) low nitrosamine. The final batch formulations appear in Table 3 (page 2).

**Table 2:** Master Batch Formulation

Material	Formulation (phr)
NORDEL™ 6555 OE	120.0
Sunpar 2280	70.0
Calcium Carbonate	50.0
N-550 Carbon Black	90.0
PEG 4000	2.0
Stearic Acid	1.5
Zinc Oxide	5.0
Total Parts	338.5

**Table 3:** Final Batch Formulations

Material	100% ADC Formulation	ADC + OBSH Blend Formulation	Low Nitrosamine Formulation
	phr	phr	phr
Master Batch	338.50	338.50	338.50
Azodicarbonamide (ADC)	4.50	3.50	4.50
4,4-Oxydibenzenesulfonyl hydrazide (OBSH)	–	1.50	–
Calcium Oxide (80% dispersion)	2.00	2.00	2.00
Sulphur (80% dispersion)	1.88	1.88	1.88
2-2'-Dithiobis(benzothiazole) (MBTS) 70%	1.00	1.00	1.00
Mercaptobenzothiazole (MBT) 80%	1.50	1.50	1.50
Zinc Dibutylthiocarbamate (ZDBC) 80%	3.60	3.60	–
Tetramethylthiuram Disulfide (TMTD) 75%	1.00	1.00	–
Tellurium Diethyldithiocarbamate (TDEC) 80%	0.15	0.19	0.19
TetraBenzyl Thiuram Disulfide (TBzTD) 70%	–	–	1.20
Zinc DiBenzylthiocarbamate (ZnBEC) 70%	–	–	2.00
Zinc Dibutylthiophosphate (ZnBPD) 50%	–	–	2.50
Total Parts	354.13	354.67	355.27

## Mixing Equipment

A rubber internal mixer with a net volume of 135 L equipped with an intermeshing rotor design and hydraulic ram control was used in this evaluation. However, other rubber mixing equipment can be utilized with appropriate mixing procedures and mixing conditions. See list below:

- Rubber internal mixer: intermeshing rotor design
- Rubber internal mixer: tangential rotor design
- Rubber kneader
- Two-roll mill

## Master Batch Mixing Procedures

The following mixer settings and mixing procedure were utilized for master batch mixing:

- Fill factor = 0.73
- Rotor temperature = 120°F (49°C)
- Mixer body temperature = 120°F (49°C)
- Side temperature = 120°F (49°C)

For detailed steps, see Table 4.

**Table 4:** Master Batch Mixing Procedures

Step	Command	Logic	Time (s)	Temp. (°F [°C])	Rotor RPM
1	Raise Ram	None	–	–	30
2	Charge Black/White/Oil	None	–	–	30
3	Charge EPDM	None	20	–	30
4	Close Hopper Door	None	–	–	30
5	Lower Ram	TIME or TEMP	200	194 [90]	30
6	Raise Ram	TIME	10	–	30
7	Lower Ram	TEMP	–	257 [125]	30
8	Discharge Warning	TIME	3	–	30
9	Open Drop Door	TIME	45	–	30
10	Close Drop Door	None	–	–	30

**Table 5:** Final Batch Mixing Procedures

Step	Command	Logic	Time (s)	Temp. (°F [°C])	Rotor RPM
1	Raise Ram	None	–	–	15
2	Auto Charge (Half Master Batch)	None	20	–	15
3	Close Hopper Door	None	–	–	15
4	Lower Ram	TIME	20	–	15
5	Auto Charge (Half Master Batch and Curatives)	None	20	–	15
6	Close Hopper Door	None	–	–	15
7	Lower Ram	TEMP	–	140 [60]	15
8	Raise Ram	TIME	10	–	15
9	Lower Ram	TEMP	–	185 [82]	15
10	Discharge Warning	TIME	3	–	15
11	Open Drop Door	TIME	60	–	20
12	Close Drop Door	None	–	–	20

## Final Batch Mixing Procedures

The following mixer settings and mixing procedures were utilized for final batch mixing:

- Fill factor = 0.72
- Rotor temperature = 73°F (23°C)
- Mixer body temperature = 73°F (23°C)
- Side temperature = 73°F (23°C)

For detailed steps, see Table 5 (page 2).

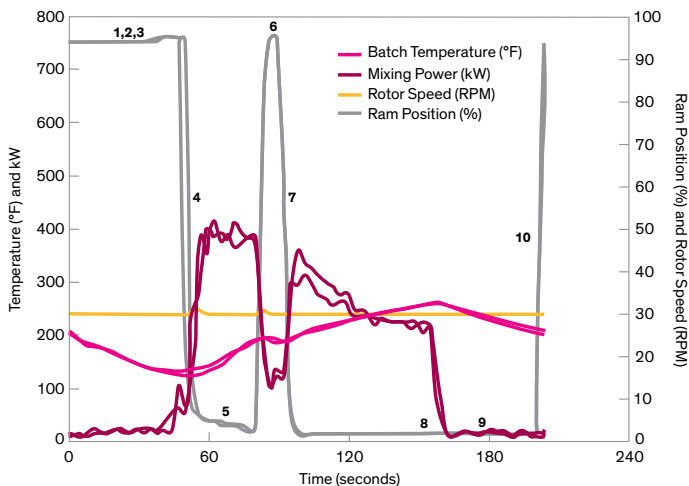
## Master Batch Mixing Curves

Mixing curves for the master batch are included in Figure 1. Fast mixing cycles (<3 min) can be achieved with this model formulation and mixing procedure. Good mixing power (400 kW) was also achieved, enabling good filler dispersion.

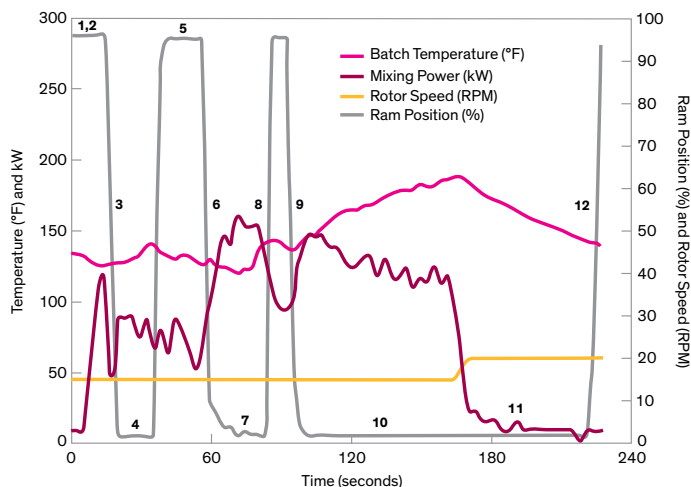
## Final Batch Mixing Curves

Good temperature control and fast mixing were achieved using the model formulations and mixing procedures described above for all final batch formulations (Figures 2-4).

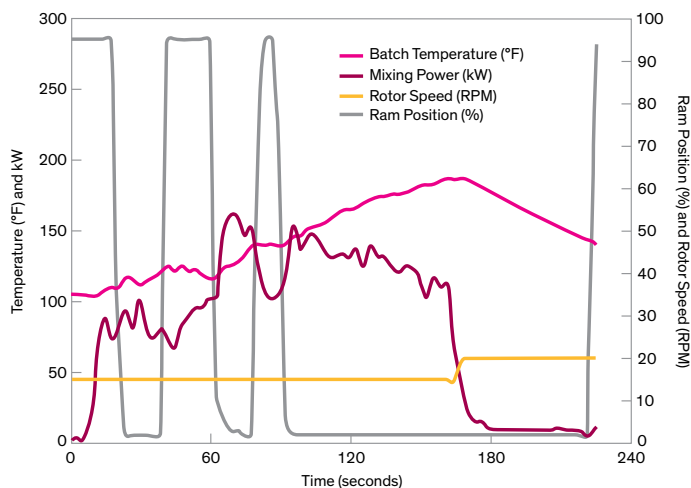
**Figure 1:** Master Batch Mixing Curves



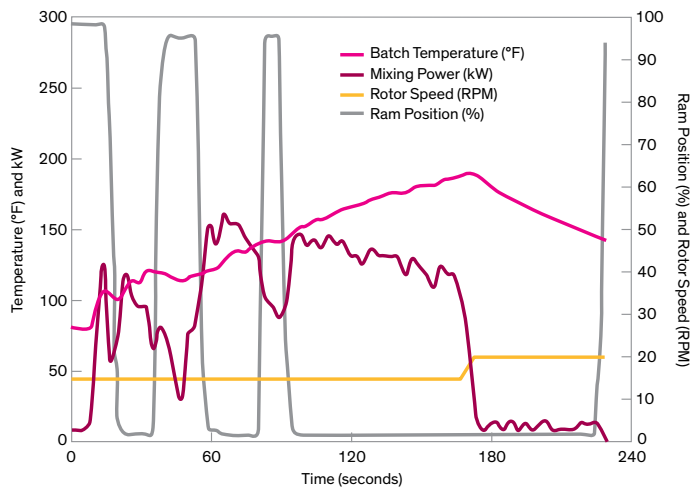
**Figure 2:** Final Batch Mixing Curves for 100% ADC Formulation



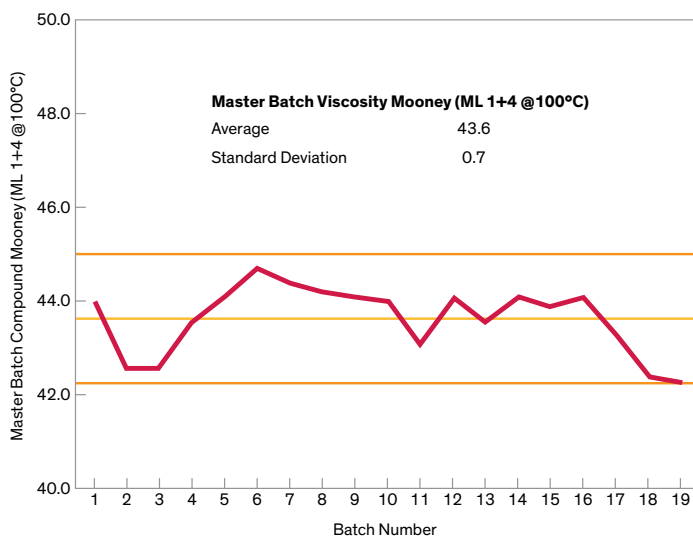
**Figure 3:** Final Batch Mixing Curves for ADC and OBSH Blend Formulation



**Figure 4:** Final Batch Mixing Curves for Low Nitrosamine Formulation



**Figure 5:** Control Chart for Master Batch Compounds



## Master Batch Compound Analysis

The model formulations described were utilized to prepare multiple production master batches with consistent rheological properties. The average Mooney Viscosity for the model formulations (Figure 5) was 43.6 MU.

## Final Batch Compound Analysis

The NORDEL™ 6555 OE EPDM-based sponge compound was designed to have a fast cure rate in order to balance curing and foaming properties during the vulcanization process. The target ts2 at 180°C was approximately 0.4 min. However, the formulation utilizing OBSH as the blowing agent yielded even faster cure rates (ts2 at 180°C <0.4 min). A low nitrosamine cure package was successfully developed to achieve the same target cure rate of 0.4 min (see Table 6).

**Table 6:** Final Batch Compound Analysis

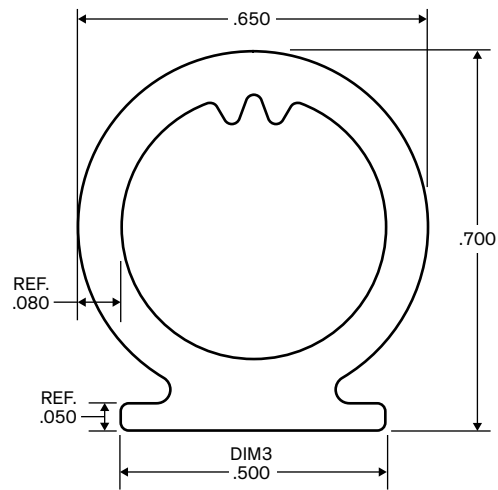
Test Conditions	Properties	Units	100% ADC Formulation	ADC + OBSH Blend Formulation	Low Nitrosamine Formulation
ML @ 275°F (135°C)	ML	dNm	32.10	32.40	32.10
	ts5	min	<b>2.53</b>	<b>2.17</b>	<b>2.46</b>
MDR @ 180°C and 8 min	ts1	min	0.35	0.33	0.32
	ts2	min	<b>0.44</b>	<b>0.39</b>	<b>0.41</b>
	t10	min	0.39	0.36	0.36
	t50	min	<b>1.27</b>	<b>0.85</b>	<b>1.4</b>
	t90	min	<b>4.29</b>	<b>3.22</b>	<b>4.63</b>
	ML	dNm	<b>1.17</b>	<b>1.20</b>	<b>1.22</b>
	MH	dNm	15.78	15.86	15.73
MDR @ 160°C and 8 min	ts1	min	0.66	0.6	0.59
	ts2	min	<b>0.89</b>	<b>0.77</b>	<b>0.82</b>
	t10	min	0.74	0.67	0.64
	t50	min	<b>2.39</b>	<b>1.74</b>	<b>2.59</b>
	t90	min	<b>5.24</b>	<b>5.13</b>	<b>5.73</b>
	ML	dNm	<b>1.32</b>	<b>1.35</b>	<b>1.35</b>
	MH	dNm	14.72	14.86	13.79

## Extrusion and Vulcanization

NORDEL™ 6555 OE EPDM-based sponge compounds were extruded on a 3.5-inch rubber cold feed extruder with a 10:1 L/D ratio to form the desired profile shape shown in Figure 6.

The extruded profile was continuously cured on a continuous vulcanization (CV) line, which is a combination of multiple hot air and microwave ovens. High quality, closed cell sponge profiles were successfully produced via the previously mentioned process. In this particular study, the CV line consists of a total of three 20-foot ovens (see Table 7). The first and third ovens are hot air ovens with adjustable speed, temperature, and air velocity. The second oven is a 20-foot microwave oven with three adjustable power outputs (max power 6 kW) as well as adjustable speed, temperature, and air velocity.

**Figure 6:** Omega Testing Profile Die Utilized for Extrusion



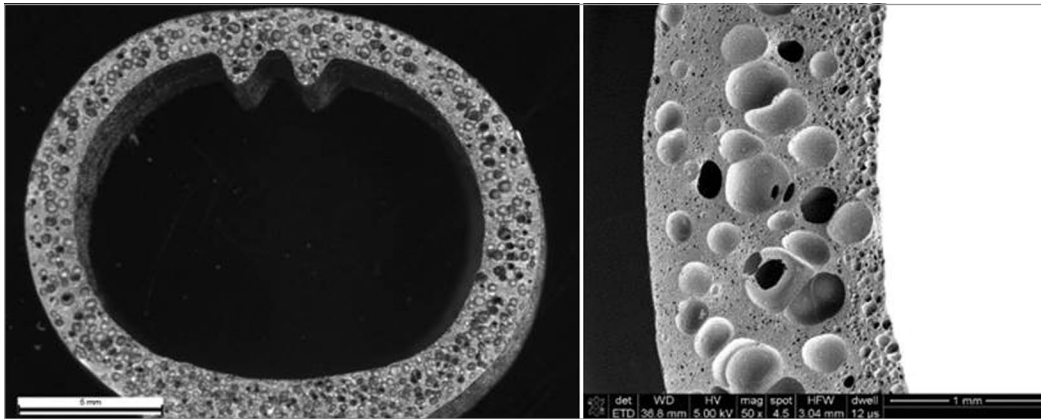
**Table 7:** Extrusion and Vulcanization

Extruder	Units	100% ADC Formulation	ADC + OBSH Blend Formulation	Low Nitrosamine Formulation
Screw Temperature	°F (°C)	125 (52)	125 (52)	125 (52)
Zone 1 Temperature	°F (°C)	150 (66)	150 (66)	150 (66)
Zone 2 Temperature	°F (°C)	150 (66)	150 (66)	150 (66)
Zone 3 Temperature	°F (°C)	150 (66)	150 (66)	150 (66)
Zone 4 Temperature	°F (°C)	150 (66)	150 (66)	150 (66)
Speed	RPM	18	18	18
<b>Hot Air Oven #1</b>				
Oven Length	ft	20	20	20
Temperature	°F (°C)	430 (221)	430 (221)	430 (221)
Speed	fpm	30	30	30
<b>Microwave Oven</b>				
Oven Length	ft	20	20	20
Temperature	°F (°C)	480 (249)	450 (232)	480 (249)
1-Bottom	kW	1.5	0.8	1.7
2-Top	kW	1.4	1.0	1.7
3-Bottom	kW	1.5	1.0	1.7
Speed	fpm	33	35	33
<b>Hot Air Oven #2</b>				
Oven Length	ft	20	20	20
Temperature	°F (°C)	500 (260)	500 (260)	500 (260)
Speed	fpm	37.3	38.5	39.1
<b>Last Belt</b>				
Speed	fpm	40.3	41.2	40

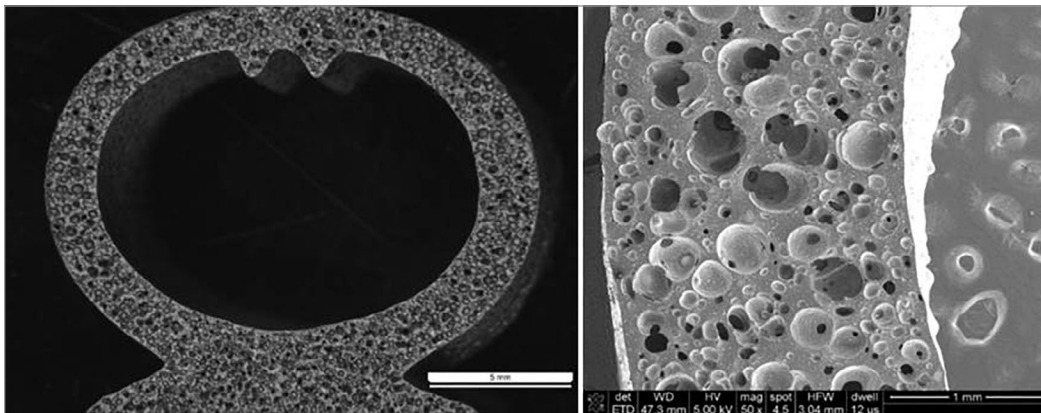
## EPDM Sponge Profile Properties

Good surface quality and uniform closed cell structures were achieved for all three model formulations. Nevertheless, differences in cell morphology were observed across formulations. Most significantly, sponge profiles generated using the ADC/OBSH blend formulation had more cell rupture, more opened cells, and skin that was less dense relative to the 100% ADC and low nitrosamine formulations.

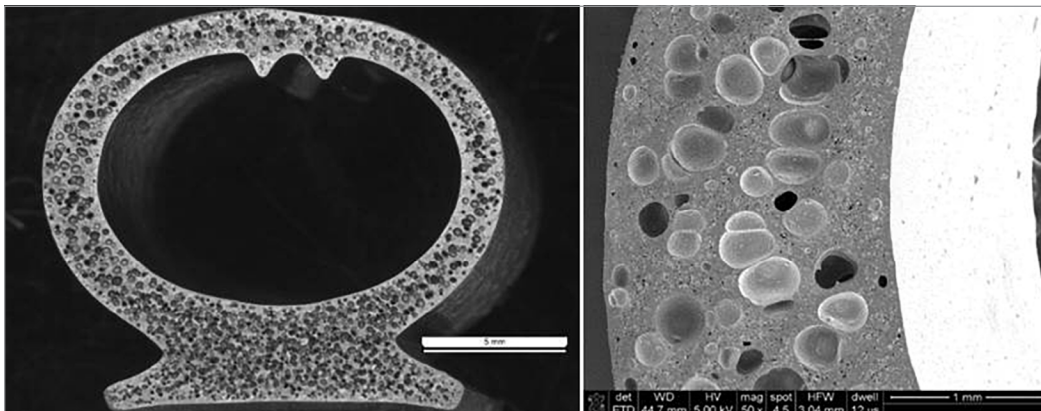
**Figure 7:** Cross-sectional Morphology of EPDM Sponge Profile Based on 100% ADC Formulation



**Figure 8:** Cross-sectional Morphology of EPDM Sponge Profile Based on ADC + OBSH Blend Formulation



**Figure 9:** Cross-sectional Morphology of EPDM Sponge Profile Based on Low Nitrosamine Formulation



All model formulations yielded sponge profiles with low water absorption, low compression set and good surface quality at target densities (see Table 8). Additionally, the tensile and tear properties exceeded specification targets.

**Table 8:** EPDM Sponge Profile Properties<sup>(1)</sup>

Properties <sup>(2)</sup>	Units	Specification <sup>(3)</sup> VW-TL52704 & Chrysler- MS-AK-92/ Sponge Grade 2	100% ADC Formulation	ADC + OBSh Blend Formulation	Low Nitrosamine Formulation
Density	pcf (g/cc)	28-41 (0.45-0.65)	36.7 (0.59)	36.4 (0.58)	36.4 (0.58)
CLD <sup>(4)</sup>	lbf (kgf)	—	0.8 (0.36)	1.6 (0.64)	1.6 (0.64)
CLD <sup>(5)</sup>	lbf (kgf)	—	1.4 (0.64)	2.4 (1.09)	2.7 (1.22)
Compression Set <sup>(6)</sup>	%	—	2.2	2.4	2.8
Compression Set <sup>(7)</sup>	%	—	17.5	19.0	18.1
Water Absorption	%	≤5	0.50	3.50	0.15
Tensile Strength	psi (MPa)	≥435 (≥3)	587.6 (4.1)	487.0 (3.4)	645.4 (4.4)
Tear (Die °C) Strength	lbf/in (kN/m)	≥11.4 (≥2.0)	58.5 (10.2)	59.0 (10.3)	63.4 (11.1)

<sup>(1)</sup> Data per tests conducted by Dow. Additional information available upon request. Properties shown are typical, not to be construed as specifications. Users should confirm results by their own tests.

<sup>(2)</sup> Measurements were taken on fabricated sponge profiles.

<sup>(3)</sup> This term and any corresponding data refers to typical performance in the specific tests indicated and should not be construed to imply these materials meet VW-TL52704 and Chrysler-MS-AK-92/Sponge Grade 2 sponge specifications.

<sup>(4)</sup> Compression Load Deflection: Compress 25% on a 100 mm profile. The profile was pre-flexed three times at 40% deflection.

<sup>(5)</sup> Compression Load Deflection: Compress 40% on a 100 mm profile. The profile was pre-flexed three times at 40% deflection.

<sup>(6)</sup> Compression Set: Compress 50% deflection for 22 hours at room temperature on 100 mm piece and recovery for 24 hours.

<sup>(7)</sup> Compression Set: Compress 40% deflection for 22 hours at 70°C on 100 mm piece and recovery for 2 hours.

<b>North America</b>		<b>Europe/Middle East</b>	00 800 3694 6367	<b>dow.com</b>
U.S. & Canada	1 800 441 4369		00 31 115 672626	<b>dowelastomers.com</b>
	1 989 832 1426	Italy	800 783 825	
Mexico	+ 1 800 441 4369	<b>South Africa</b>	00 800 99 5078	
<b>Latin America</b>		<b>Asia Pacific</b>	+ 800 7776 7776	
Argentina	+ 54 11 4319 0100		+ 603 7965 5392	
Brazil	+ 55 11 5188 9000		+ 86 21 3851 4988	
Colombia	+ 57 1 219 6000	China	+ 400 889 0789	
Mexico	+ 52 55 5201 4700			

The principles of Responsible Care® and Sustainable Development influence the production of printed literature for The Dow Chemical Company ("Dow"). As a contribution towards the protection of our environment, Dow's printed literature is produced in small quantities and on paper containing recovered/post-consumer fiber and using 100 percent soy-based ink whenever possible.

NOTICE: Any photographs of end-use applications in this document represent potential end-use applications but do not necessarily represent current commercial applications, nor do they represent an endorsement by Dow of the actual products. Further, these photographs are for illustration purposes only and do not reflect either an endorsement or sponsorship of any other manufacturer for a specific potential end-use product or application, or for Dow, or for specific products manufactured by Dow.

NOTICE: No freedom from infringement of any patent owned by Dow or others is to be inferred. Because use conditions and applicable laws may differ from one location to another and may change with time, the Customer is responsible for determining whether products and the information in this document are appropriate for the Customer's use and for ensuring that the Customer's workplace and disposal practices are in compliance with applicable laws and other governmental enactments. Dow assumes no obligation or liability for the information in this document. **NO WARRANTIES ARE GIVEN; ALL IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE ARE EXPRESSLY EXCLUDED.**

NOTICE REGARDING MEDICAL APPLICATION RESTRICTIONS: Dow will not knowingly sell or sample any product or service ("Product") into any commercial or developmental application that is intended for:

- long-term or permanent contact with internal bodily fluids or tissues. "Long-term" is contact which exceeds 72 continuous hours;
- use in cardiac prosthetic devices regardless of the length of time involved ("cardiac prosthetic devices" include, but are not limited to, pacemaker leads and devices, artificial hearts, heart valves, intra-aortic balloons and control systems, and ventricular bypass-assisted devices);
- use as a critical component in medical devices that support or sustain human life; or
- use specifically by pregnant women or in applications designed specifically to promote or interfere with human reproduction.

Dow requests that customers considering use of Dow products in medical applications notify Dow so that appropriate assessments may be conducted.

Dow does not endorse or claim suitability of its products for specific medical applications. It is the responsibility of the medical device or pharmaceutical manufacturer to determine that the Dow product is safe, lawful, and technically suitable for the intended use. **DOW MAKES NO WARRANTIES, EXPRESS OR IMPLIED, CONCERNING THE SUITABILITY OF ANY DOW PRODUCT FOR USE IN MEDICAL APPLICATIONS.**

This document is intended for use in North America.

Published December, 2016.

© 2019 The Dow Chemical Company

®™ Trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow

® Responsible Care is a service mark of the American Chemistry Council. Dow is a partner in the American Chemistry Council Responsible Care initiative.

Form No. 265-14001-0219 S2D