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One-part LSR systems

Producing silicone sponge without chemical blowing agents or VOCs

Structure-property relationships - linear and star-branched macrostructures

Identification of polymers by IR spectroscopy

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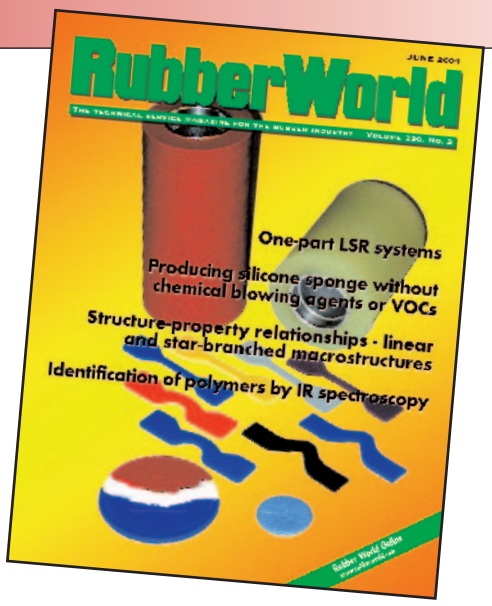

Cover photo: Courtesy of Laur Silicone

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by Paul Kehl and Dan Laur
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Next generation of liquid silicone rubber

Laur Silicone recently revealed the next generation of liquid silicone rubbers. The materials use patent pending Easy Cure technology (EC), which promises to solve some of the problems associated with current two part LSRs. The materials can be furnished fully compounded as a one part system (1P).

Table 1 - physical properties comparison of 40 durometer two-part and 1P systems

	Physical properties			
Materials	*Durometer*	*Tensile MPa (psi)*	*Elongation (%)*	*Tear kN/m (ppi)*
	Press cured 10 minutes at 171°C			
1P, one comp. 40	38.3	6.9 (1,009)	536	55.5 (317)
LSR #1 A+B, 1:1	39.9	9.0 (1,311)	573	19.3 (110)
LSR #2 A+B, 1:1	38.1	9.2 (1,329)	631	60.1 (343)
LSR #3 A+B, 1:1	44.0	9.0 (1,302)	585	40.1 (229)
	Post cured 4 hours at 200°C			
1P, one comp. 40	40.1	8.1(1,181)	572	32.6 (186)
LSR #1 A+B, 1:1	40.2	9.2 (1,341)	533	23.1 (132)
LSR #2 A+B, 1:1	41.4	8.0 (1,159)	516	36.1 (206)
LSR #3 A+B, 1:1	46.2	9.3 (1,353)	528	40.5 (231)

Table 2 - silicone physical properties after heat aging

	Physical properties (70 hrs. @ 225°C)			
Materials	*Durometer*	*Tensile MPa (psi)*	*Elongation (%)*	*Tear kN/m (ppi)*
	Press cured 10 minutes at 171°C			
1P, one comp. 40	46.9	8.2 (1,196)	412	33.8 (193)
LSR #1 A+B, 1:1	40.6	6.9 (1,006)	374	22.8 (130)
LSR #2 A+B, 1:1	45.1	5.3 (768)	236	34.3 (196)
LSR #3 A+B, 1:1	46.7	6.7 (976)	318	28.5 (163)
	Post cured 4 hours at 200°C			
1P, one comp. 40	46.2	8.3 (1,210)	410	33.4 (191)
LSR #1 A+B, 1:1	40.9	6.9 (1,001)	362	20.3 (116)
LSR #2 A+B, 1:1	45.7	4.8 (694)	231	34.0 (194)
LSR #3 A+B, 1:1	47.1	7.1 (1,034)	342	28.0 (160)

Table 3 - press cure and post cure compression set

	Compression set (%) 22 hours @ 177°C	
Materials	*Press cured*	*Post cured*
1P, one comp. 40	24	18
LSR #1 A+B, 1:1	56	38
LSR #2 A+B, 1:1	46	11
LSR #3 A+B, 1:1	16	11

While the system is in the early stages of commercialization, its future looks bright due to the following advantages:

- Fully compounded – no mixing required;
- no off-ratio material;
- no need to purge mixing equipment;
- no material lost to purge cycles;
- good physical properties
  - tensile,
  - elongation,
  - tear,
  - heat aging,
  - compression set;
- long pot life;
- improved scorch times;
- fast cure cycles;
- FDA compliant possible;
- colors possible;
- blending of durometers; and
- testing of material as-used possible.

While LSRs have claimed to be fully compounded, they have, in fact, not been fully compounded. They have been two part systems, having an "A" and a "B", which require mixing prior to use. The pot lives, at room temperature after mixing, are three days or less. In most cases, colorants must be added if pigmented parts are desired. The new EC systems can be furnished as 1P materials with no mixing required. This means that they only need to be pumped into the mold.

Because two part systems need to be mixed prior to use, they are subject to off-ratio mixing. With two part systems, if the pumps are not running correctly, off-ratio material may be produced. Off-ratio mixing can affect the cure cycles and the physical properties of the rubber.

Figure 1 - results of a six month storage test

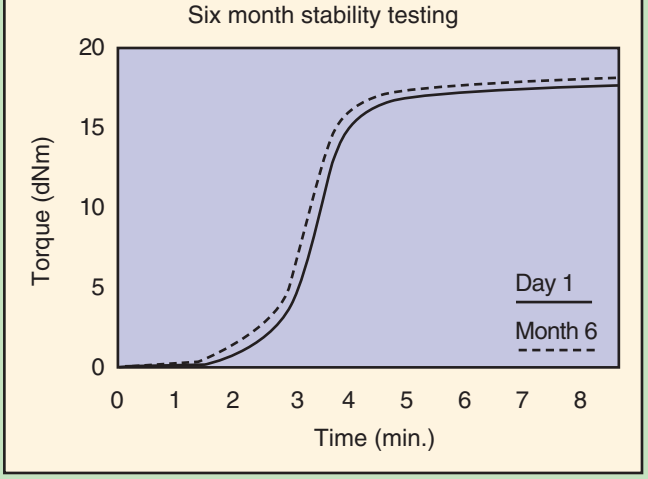

Table 4 - storage test physical properties

Materials	*Durometer*	*Tensile MPa (psi)*	*Elongation (%)*	*Tear kN/m (ppi)*
Before test	63.7	9.2 (1,338)	382	49.0 (280)
After six months	66.3	9.0 (1,298)	344	48.5 (277)

The pot life of mixed two component systems is three days or less. This requires the equipment to be cleaned or purged for long shutdowns. Purging with A or B components leads to off-ratio mixing or wasted material in two part systems. The long pot life of the new EC technology eliminates the need to clean or purge the mixing equipment for long shut downs.

Figure 2 - rheometer curves of material before and after one week at 71°C (160°F)

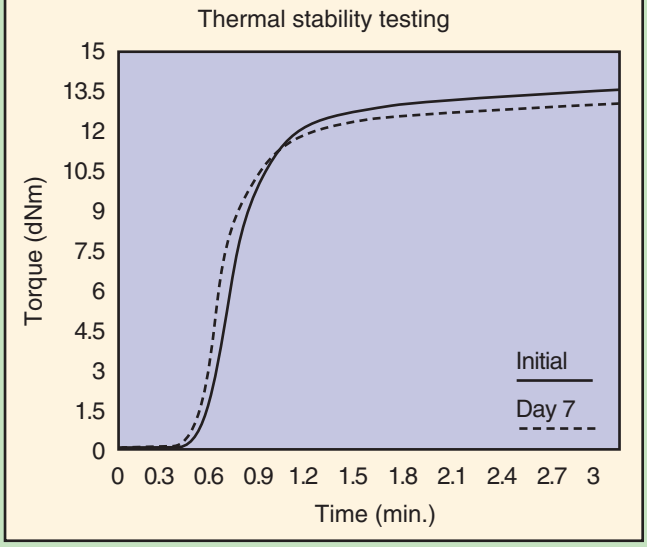

Figure 3 - the rheometer curing of liquid silicones at 171°C (340°F)

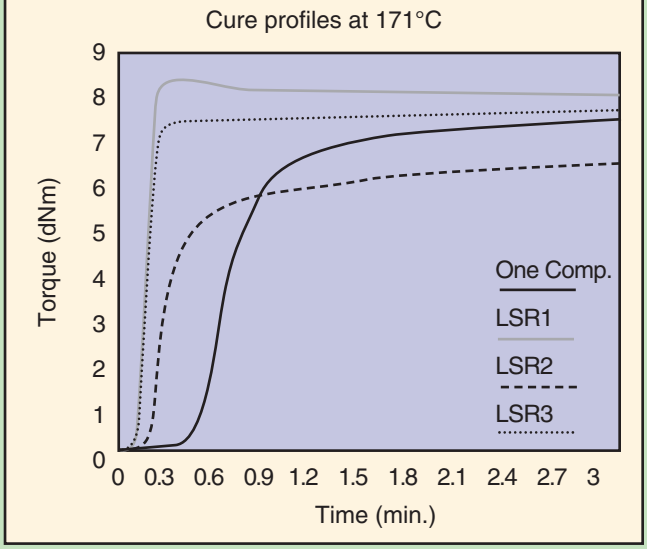

Table 5 - physical properties of thermal stability (71°C) test

Materials	*Durometer*	*Tensile MPa (psi)*	*Elongation (%)*	*Tear kN/m (ppi)*
Before test	56.2	9.2 (1,338)	399	44.5 (254)
After one week	58.6	9.6 (1,390)	408	50.1 (286)

When compared to currently available two component systems, the new 1P materials have similar properties, as is shown in tables 1-3. Not shown in the tables are the viscosities of the new materials, which are also similar to two component silicone viscosities.

Material has been tested after being stored for six months in warehouse conditions. After six months, the cure curves and physical properties had changed little from the original properties (table 4 and figure 1). The stability of the new system was further demonstrated by heating a sample to 71°C (160°F) for one week. Again, properties and cure curves were unchanged (table 5 and figure 2).

The improved stability of the EC technology also has the added benefit of longer scorch times. This provides a more robust process due to longer mold filling times. This should prove beneficial in mold design and with difficult to fill molds.

The total cure time is somewhat longer than two component systems. However, a large part of this is due to the longer scorch times. The rate of cure of the EC systems is comparable to tested two component systems. Figure 3 compares cure curves for a one part material with three different two component materials.

FDA compliant materials are possible. Sample formulations were tested, after post cure, to CFR 171.2600. They have passed the extractability test required for parts intended for long term or repeated contact with food.

Because of the long pot life, it is possible to furnish 1P materials fully compounded. This reduces the chance of mixing errors. It is possible the 1P materials can be furnished colored. This eliminates the need to add colors prior to molding. A simple pump can replace the current meter mix systems.

For fabricators that have meter mix systems, it should be possible to blend high and low durometer materials to give predictable intermediate durometers. This could reduce inventory for smaller users. If only one durometer is desired, both pumps could be used to extend the time between changing pails/drums.

For fabricators not wishing to blend to durometer, full testing of the material as-molded is possible without the need to break into the mixed material lines. This allows materials to be tested prior to placing them into production.

The new EC system is expected to open new markets for liquid silicone rubber. The new one part materials may permit short runs that did not justify the purchase of meter-mix systems. The more robust cure profile is also expected to open new markets.