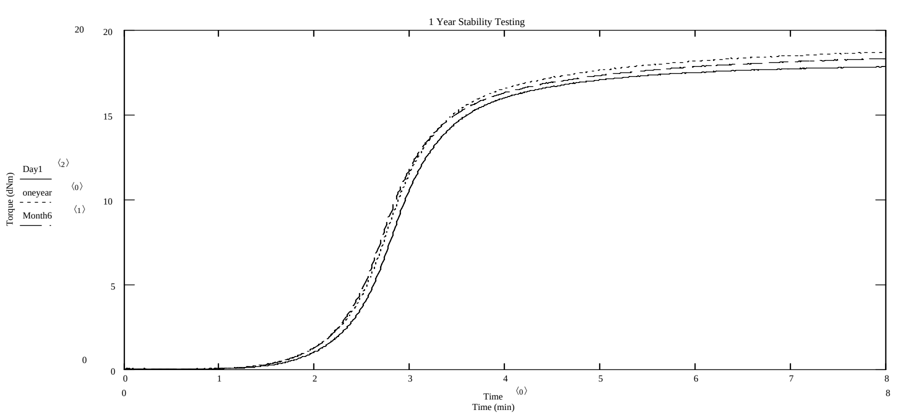
Co-Molding One Part® LSR with Organic Elastomers

By

Michael K. Agodoa

Laur Silicone, Inc. has previously introduced a highly innovative one-component liquid silicone rubber that combines the advantages of liquid silicone rubber with that of high consistency rubber. The One Part® liquid silicone rubber provides viscosity, physical properties, thermal stability, compression set, electrical and other properties comparable to standard heat cured, two-part liquid silicone rubber. Laur Silicone's Easy Cure® system is supplied as a single component, fully compounded, ready-to-use silicone rubber that offers several advantages over the two-part addition cure technology. Laboratory tests at Laur Silicone have shown that this material has a pot life of over one year at room temperature (figure 1).

Figure 1 – One year shelf life rheometer cure curve



One Part® liquid silicone rubber requires a much simpler pumping system to operate. By eliminating the need for precisely mixing equal parts of components "A" & "B", the One Part® LSR can be introduced into cure cavities using a pumping system as simple as a Semco® cartridge and gun. A specially designed LSR molding machine is not required. Any good, high consistency rubber press can be easily converted to run One Part® LSR. This simplicity of molding makes it possible to compression mold One Part® as the material can be easily introduced into cold or hot compression molds, and cured at normal cure temperatures. The Easy Cure® one part system is especially suitable for short runs of small and relatively large molded parts. Long scorch times (see figure 2) allow the material to be introduced into the mold before it begins to cure.

One Part® material is extremely useful in molding silicone rubber rollers that do not have build lines. Due to its resistance to contamination, high physical property profile, long pot life and ease of processing, this material is very suitable for casting seamless rolls in a manner similar to casting of urethane rollers. In fact the same molds used in casting urethane rollers (or slightly modified molds) can be used to make silicone rollers using the One Part® Easy Cure® system. Bonding to the core can be achieved using one of the standard silicone primers.

One Part® is available in durometers ranging from 30 to 65. Lower and higher durometers are being developed. Physical properties of One Part® LS-7010 series are shown in Table 1.

Table 1. Physical properties of LS-7010 series.
Press cured 10 minutes at 171°C

Test Description	LS-7010-30	LS-7010-40	LS-7010-50	LS-7010-60
Durometer, Shore A	31	40	50	60
Tensile Strength, MPa	5.5	6.1	6.7	7.2
Elongation, %	500	450	360	260
Tear, B, kN/m	20	32	34	35
Compression Set, % (Method B, 22/175 C)	24	22	22	18
Specific Gravity	1.08	1.10	1.11	1.12

Rheological properties of One Part® and three commercially available two-part LSR's are shown in figure 2. Using an MDR2000 rheometer, it can be shown that the two-part liquid silicone rubbers have slightly faster cure profiles than the One Part®. The two-part liquids also shows significantly shorter scorch time than One Part®. However, the longer scorch time of the One Part® liquid silicone rubber can be advantageous in filling large and complex molds without significantly sacrificing cure time.

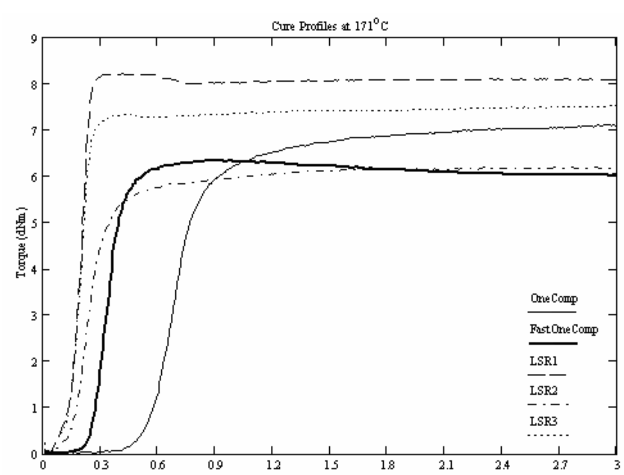


Figure 2. Cure profiles of various liquid silicone rubbers at 171°C.

Those familiar with the chemistry or processing of addition cured liquid silicone rubber are aware of the need to avoid contaminants that can inhibit or "poison" the platinum catalyst. In some severe cases, it is not possible to process two part addition cure silicones within the same facility as organic elastomers. There are reports of contamination in situations where even two buildings sharing the same air system caused inhibition of the platinum catalyst in the case where one of the buildings is being used to mold organic rubbers.

The table below shows some of the common inhibitors of two part, addition curing silicones in comparison to One Part® LSR.

Table 2. Chemicals that may inhibit heat cure rubber

CHEMICALS THAT MAY INHIBIT HEAT CURED SILICONE RUBBER	TWO PART LIQUID SILICONE RUBBER	ONE PART® LIQUID SILICONE RUBBER
Amines, amides, nitriles	Yes	No
Olefinic nitriles	Yes	No
Azides,triazoline diones	Yes	No
Thiols, sulfides, sulfates	Yes	No
Sulfites, thioureas	Yes	No
Triallyl isocyanurate	Yes	No
Tin catalysts	Yes	No
t-Butylhydroperoxide	Yes	No
Acetylenic alcohols	Yes	No
Vinyl acetate	Yes	No
Plasticized PVC	Yes	No
Amine cured epoxy	Yes	No
Neoprene rubber	Yes	No
Natural rubber	Yes	No
Latex rubber	Yes	No

At the International Rubber Conference held in Pittsburgh in 2005, Laur featured samples of One Part® LSR over-molded onto cured buttons of Neoprene, Natural Rubber, hydrogenated nitrile rubber, nitrile rubber, and an NBR/SBR blend. Some of these materials were cured with peroxide and others with sulfur. In all cases Laur demonstrated that the cured rubber did not inhibit the curing of One Part®.

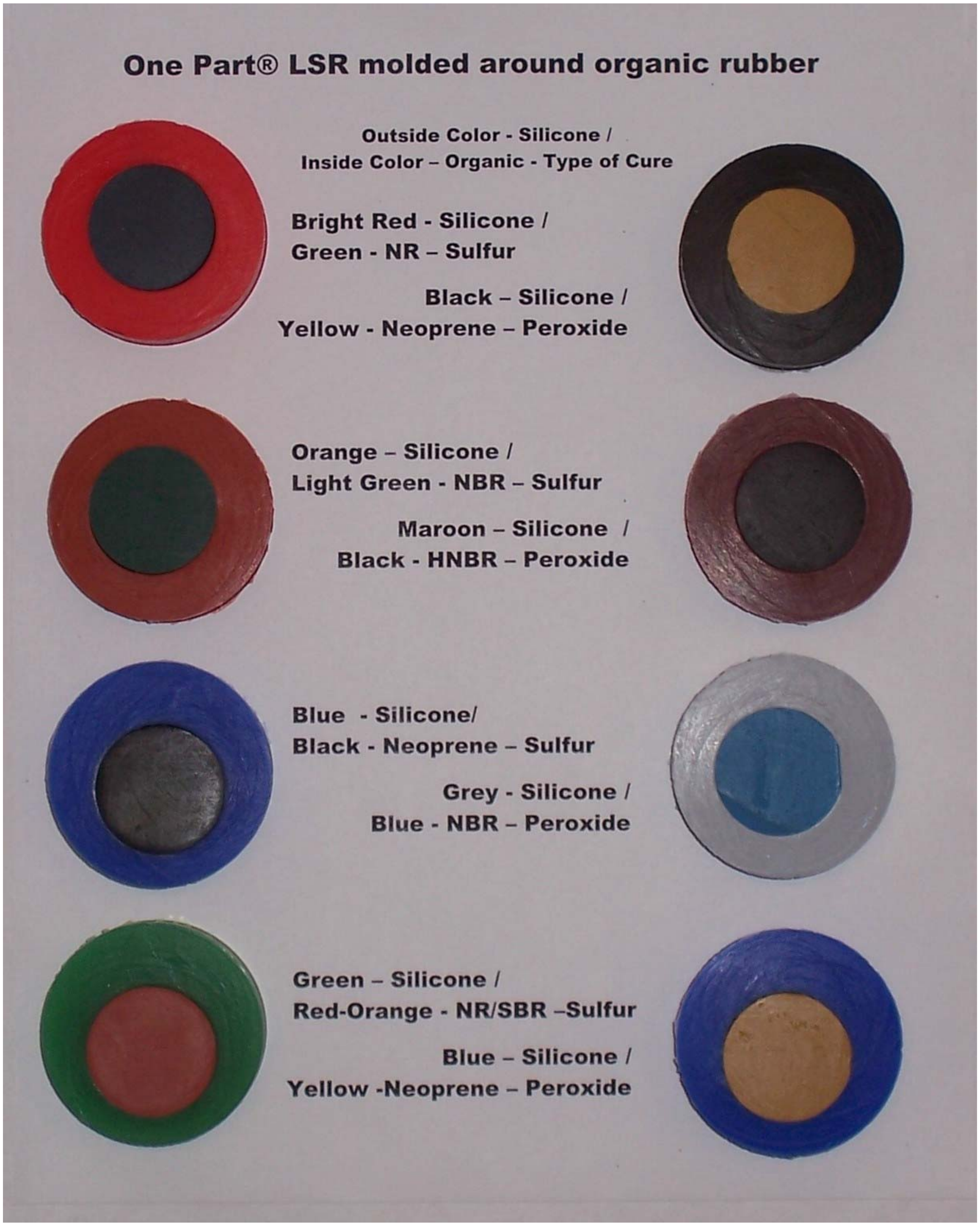


Fig. 3: One Part® LSR molded around cured organic rubber buttons

As previously stated, one of the unique features of Laur Silicone's Easy Cure® liquid silicone rubber technology is that, unlike the typical two part liquid silicone rubber, the cure is much less affected by many of the chemicals that inhibit two part systems.

Many types of organic elastomers can be molded in the same facility as the One Part® with little concern for catalyst inhibition. In many cases, it is possible to mold them together. This opens a wide new area for applications where the combinations of diverse rubber materials can be molded together to attain optimum advantages of the various rubbers.

Possible applications for co-molded silicone/organic rubbers include applications that take advantage of the high strength and resistance to various fluids of organic elastomers combined with the release and high temperature properties of silicone rubber. Some of these include:

- Belting (for food processing)
- Rubber rollers
- Gaskets
- Cloth coating

Current Study

The purpose of this study is to demonstrate that One Part® LSR can be cured simultaneously with various organic elastomers without significant effect on the cure profile of the silicone rubber.

Experimental

Uncured commercial compounds of Natural rubber, Neoprene, Nitrile, SBR, hydrogenated nitrile and EPDM were obtained, courtesy of Graphic Arts Rubber. Each sample was cured in a rheometer using an MDR2000 rheometer at 340 F to establish a baseline rheology curve. Three commercially available two-component, addition cure liquid silicone rubbers were obtained and their baseline rheometer curves established. Next, a 60 durometer, One Part® liquid silicone rubber was run under similar conditions.

A list of materials used in this study.

1. ORGANIC ELASTOMERS:

Material	Description
MG100	50 Duro Urethane/Polyether – Sulfur cure
EP70B	70 Duro EPDM – Peroxide cure
E980BX	80 Duro EPDM – Peroxide cure
CPE80B	80 Duro Hypalon – Sulfur cure
NR970BL	70 Duro Natural Rubber – Peroxide cure
B980B	80 Duro SBR/Nitrile Rubber – Peroxide cure
HT52	65 Duro Chlorobutyl/EPDM/NR – Sulfur cure
CR960W	60 Duro Neoprene – Sulfur cure
B530	40 Duro Nitrile – Sulfur cure
B920CR	20 Duro Nitrile – Sulfur cure

2. TWO COMPONENT LIQUID SILICONE RUBBER

Material	Description
LSR 1	60 Durometer, two-component LSR from Supplier A
LSR 2	60 Durometer, two-component LSR from Supplier B
LSR 3	60 Durometer, two-component LSR from Supplier C

3. ONE PART® LIQUID SILICONE RUBBER

LS7010-60 RED	60 Durometer red one-component LSR from Laur Silicone

Procedure

1. Establish baseline rheometer curves for:
    a. Each Organic Elastomer
    b. LSR 1, LSR 2, and LSR 3.
    c. LS7010-60.

2. Weigh 5 grams of the liquid rubber to be tested onto a small mylar sheet. Weigh 2 grams of the organic rubber, cut it into 3 or 4 pieces, and place into the liquid rubber, cover with another sheet of mylar.
3. Run rheometer curve on this mixture.

Test parameters:

Temperature: 177 C (340 F)
Time: 10 Minutes
Range – auto select.

Results:

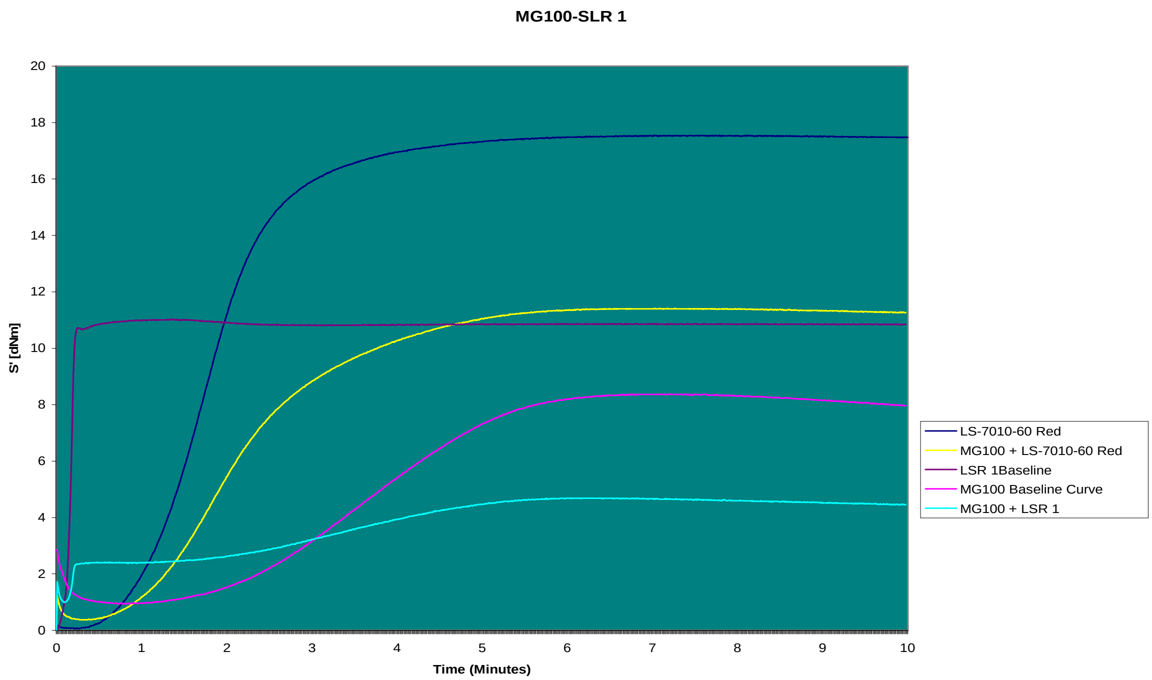


Figure 4. Effect of MG100 on the cure profiles of LS7010-60 RED and LSR 1
(50 Duro Urethane/Polyether blend – sulfur cure)

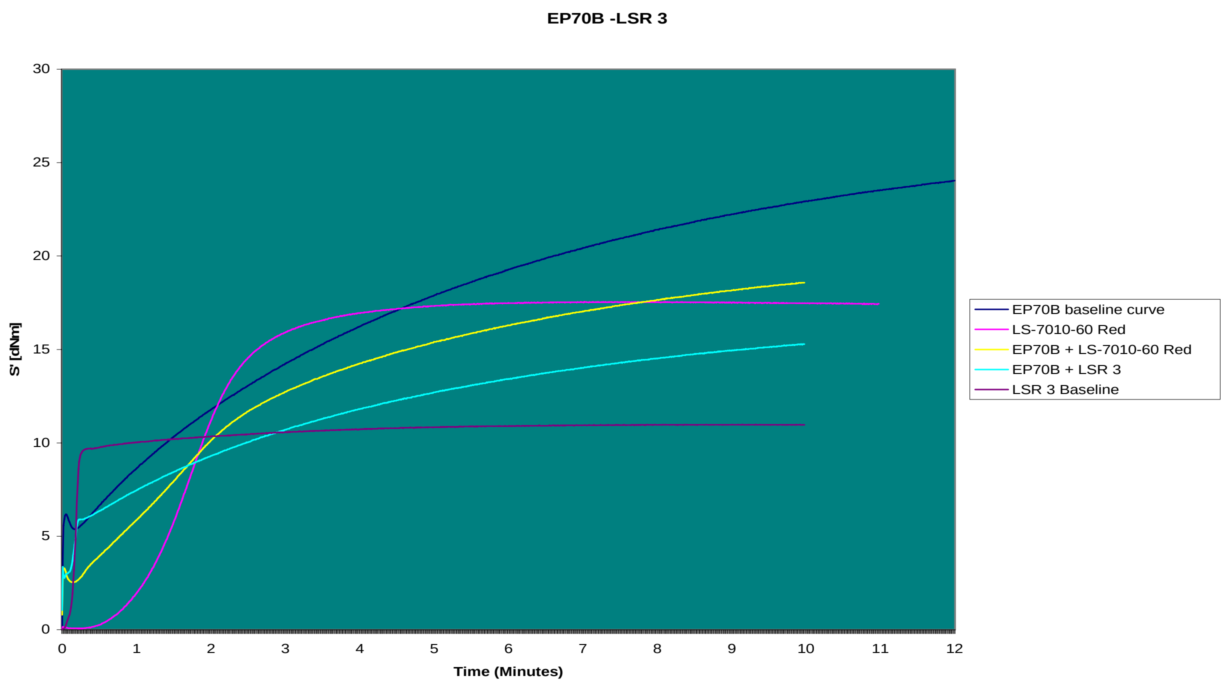


Figure 5: Effect of EP70B on the cure profiles of LS7010-60 RED and LSR 3
(70 Duro EPDM – peroxide cure)

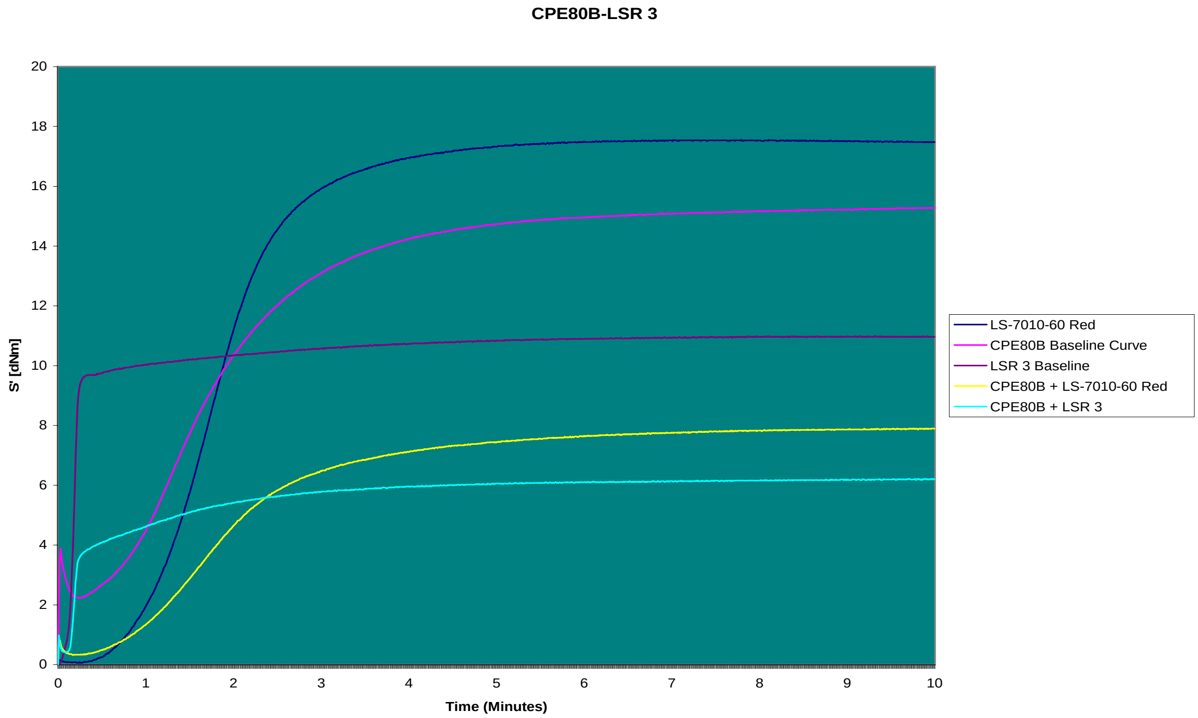


Figure 6: Effect of EP980BX on the cure profiles of LS7010-60 RED and LSR 3
(80 Duro EPDM – peroxide cure)

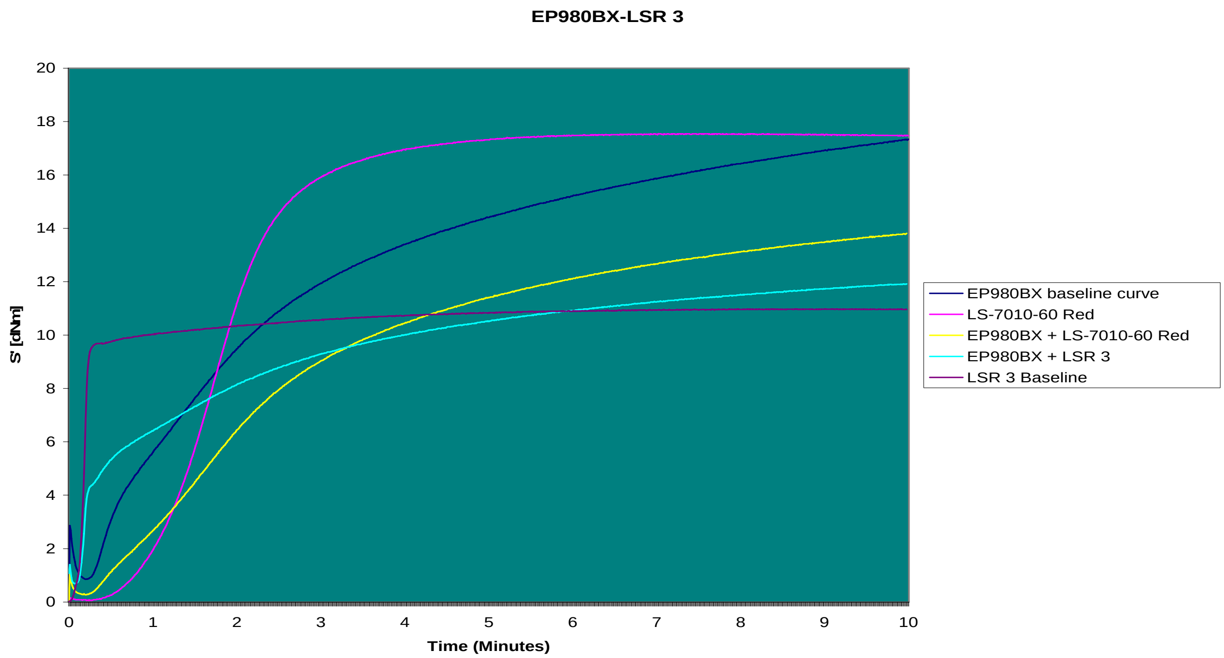


Figure 7: Effect of CPE80B on the cure profiles of LS7010-60 RED and LSR 3
(80 Duro Hypalon – sulfur cure)

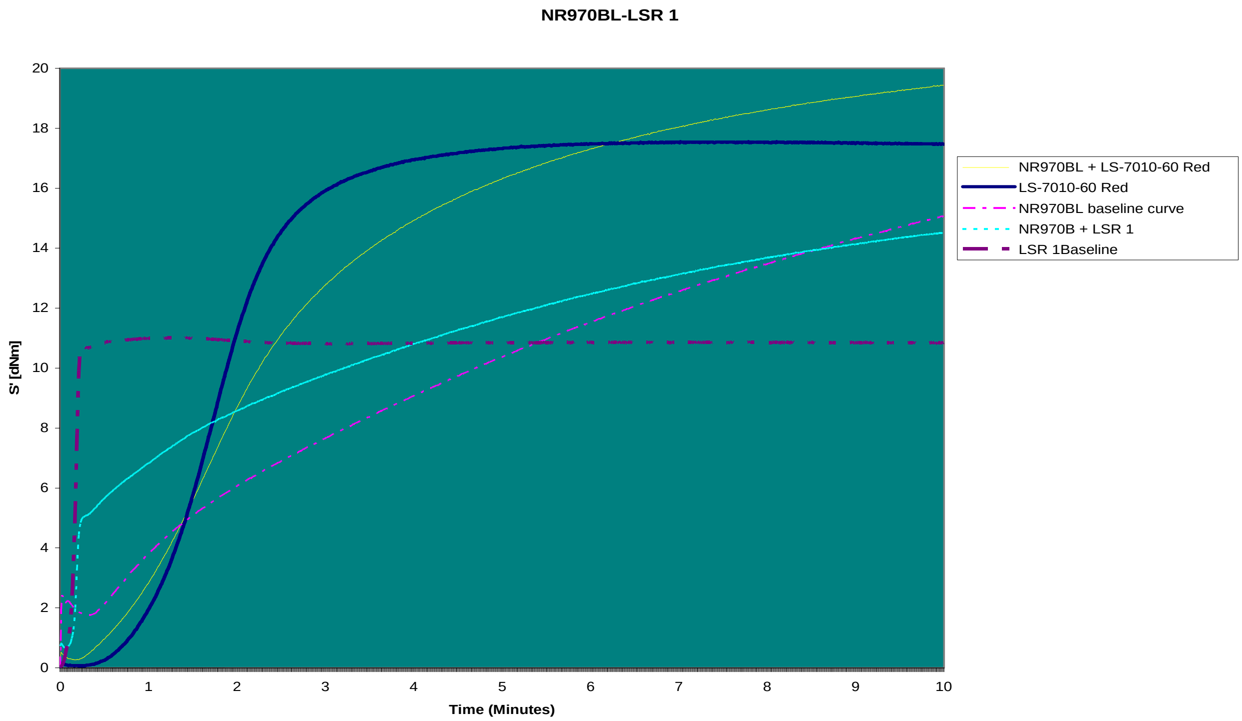


Figure 8: Effect of NR970BL on the cure profiles of LS7010-60 RED and LSR 1
(70 Duro Natural Rubber – peroxide cure)

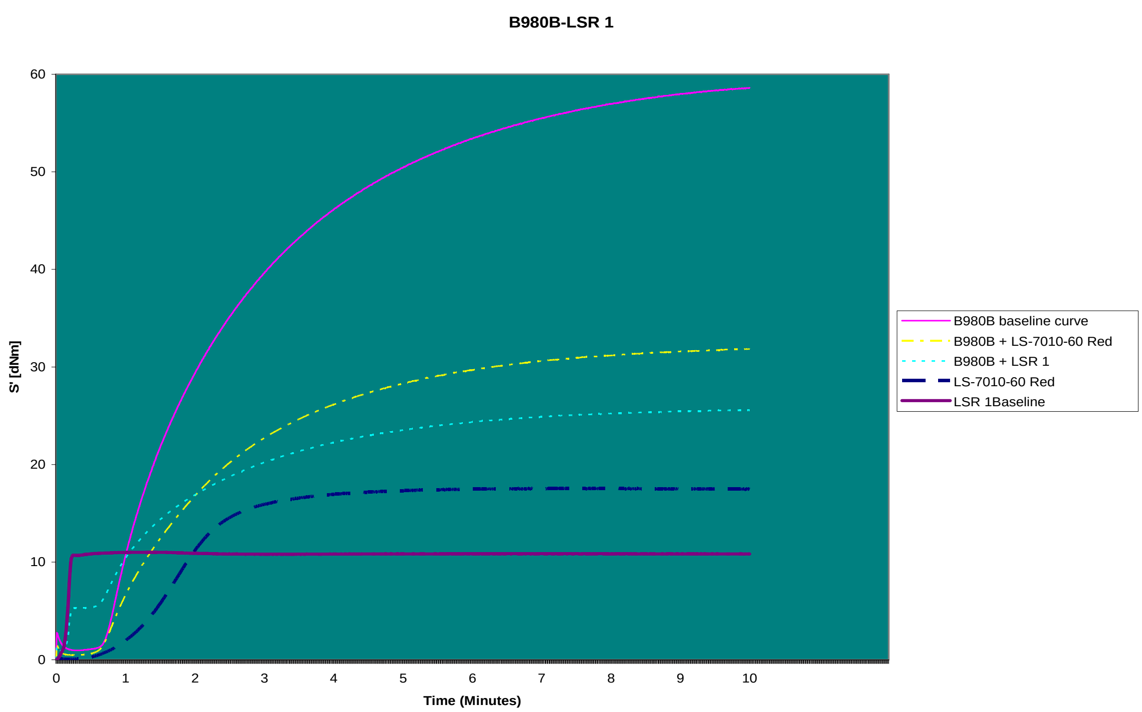


Figure 9: Effect of B980B on the cure profiles of LS7010-60 RED and LSR 1
(80 Duro SBR/Nitrile – peroxide cure)

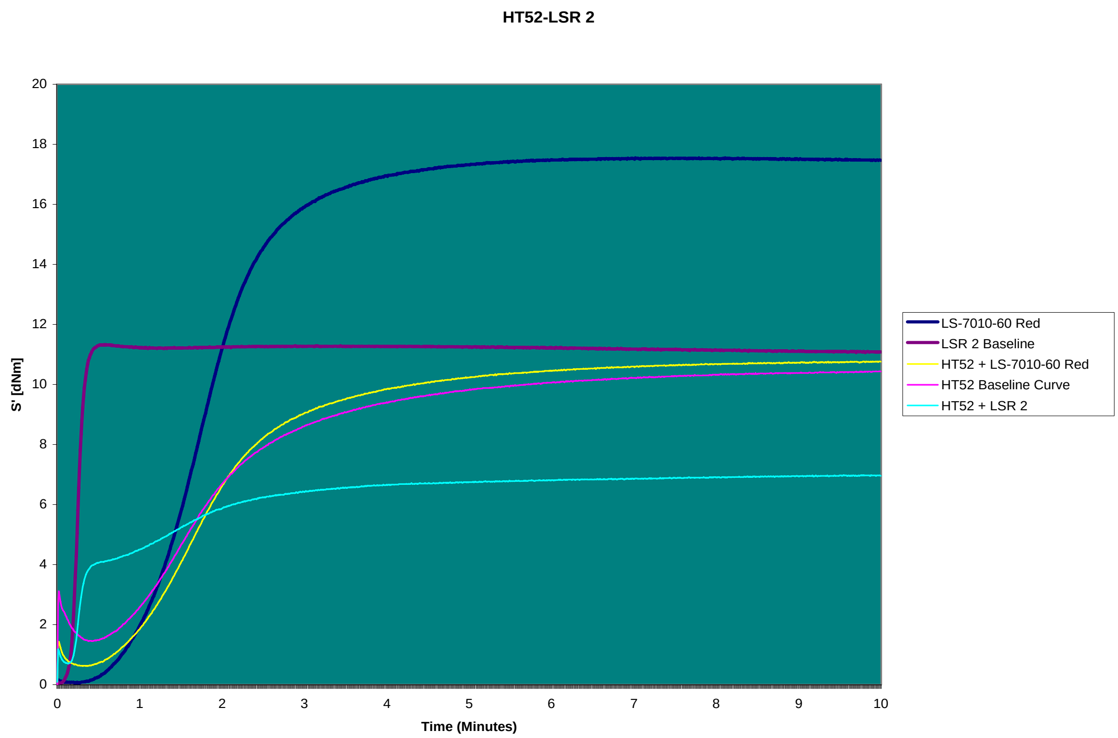


Figure 10: Effect of HT52 on the cure profiles of LS7010-60 RED and LSR 2
(65 Duro Chlorobutyl/EPDM/NR – sulfur cure)

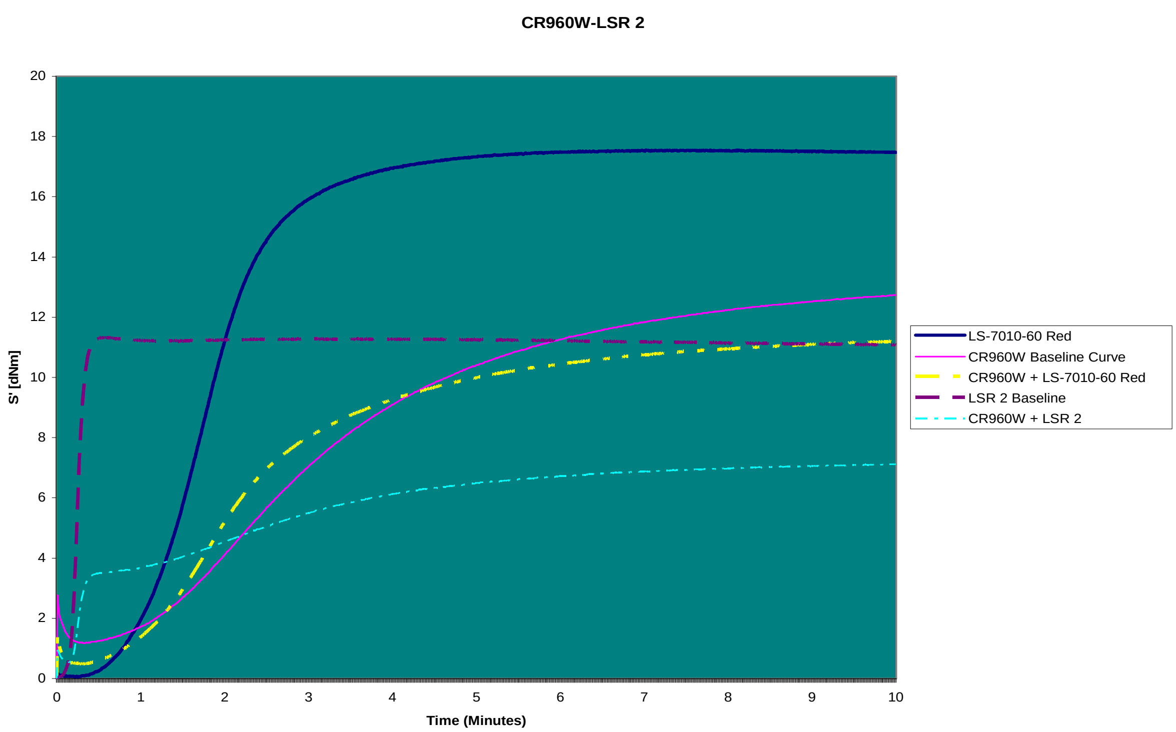


Figure 11: Effect of CR960W on the cure profiles of LS7010-60 RED and LSR 2
(60 Duro Neoprene – sulfur cure)

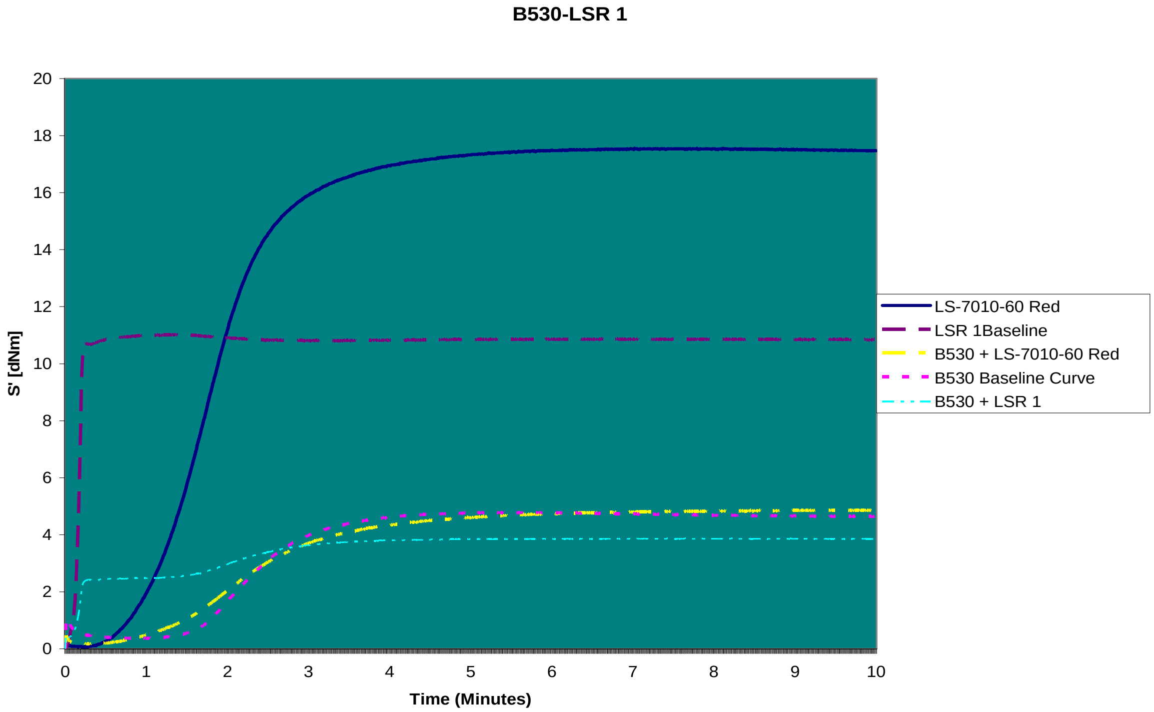


Figure 12: Effect of B530 on the cure profiles of LS7010-60 RED and LSR 1
(40 Duro Nitrile – sulfur cure)

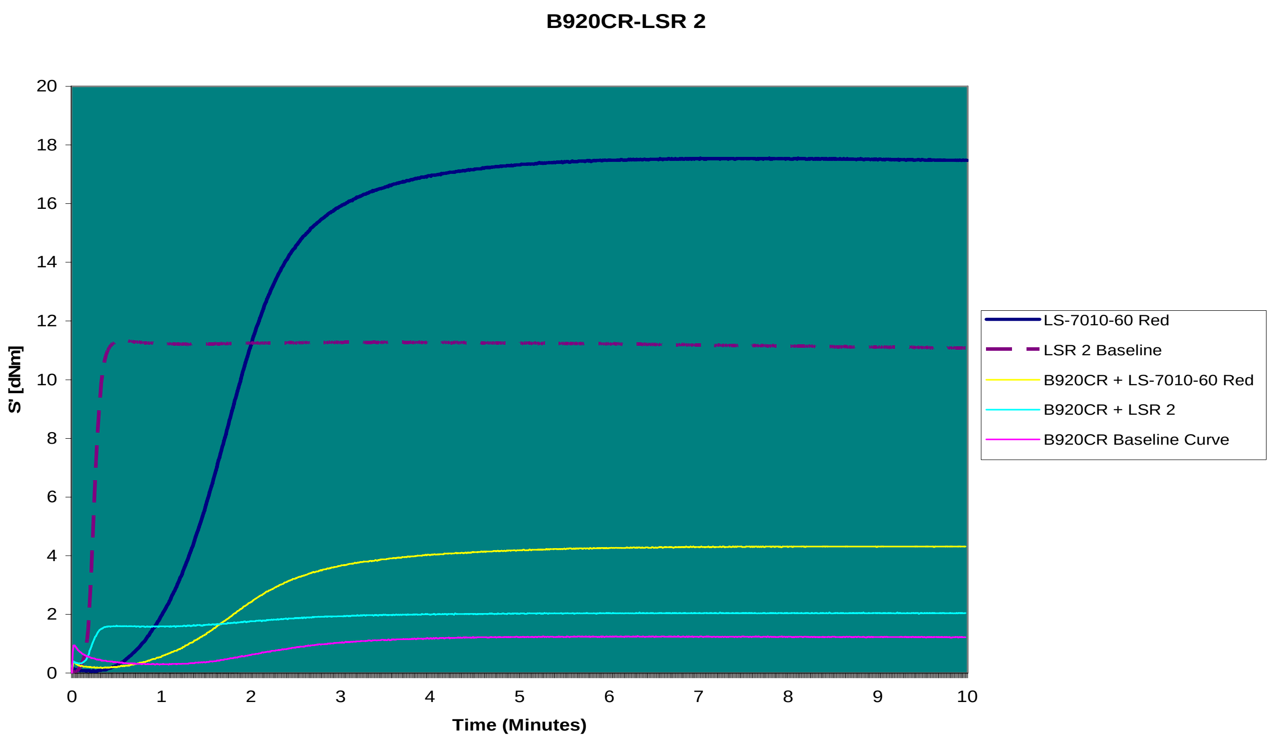


Figure 13: Effect of B920CR on the cure profiles of LS7010-60 RED and LSR 2
(20 Duro Nitrile – sulfur cure)

Discussion of Results

It is clearly evident from the graphs that all of the 10 types of organic elastomers evaluated in this study did not inhibit the curing of One Part® LS7010-60 RED to the same degree as they inhibited the curing of the three two-component LSR's that were evaluated.

In some of the graphs such as CR960W (Fig. 11), B980B (Fig. 9), and NR970BL (Fig.8), the two-part LSR appears to be curing. This is actually a false representation due to the way the test was done. What is actually happening is that, the LSR cure started as the material heated up. But then volatiles from the organic rubber were released and stopped the cure. The torque continued to rise due to the effect of the organic which is uninhibited by the silicone. The organic rubber makes up about 40-50% of the volume of material in the rheometer cavity. Thus a torque rise from the curing organic rubber will appear as if the silicone was curing.

The effect is borne out by actual experience where in most cases the two-part silicone rubber is not always completely inhibited. In most cases, there is some degree of cure depending on how long the rubber has been in contact with the contaminant. In these tests, the contact time between the two-part silicone was rather short, and is limited to the time it takes to weigh the materials and load into the rheometer.

The effect on the LS7010-60 RED on the other hand is minimal. The One Part® undergoes its normal cure but the speed of cure and final torque is affected by the cure of the organic due to the large amount of organic present in the rheometer cavity. It is believed that if a smaller quantity of organic rubber was added to the cavity, the cure curve of the LS7010-60 RED/organic rubber mix will closely match the curve for the pure One Part®. This test provides a simple way to test the effect of different materials for cure compatibility especially in liquid silicone rubber.

An implication for this system is that almost any type of hose can be used to dispense One Part® liquid silicone rubber without concern for catalyst inhibition. Current two-part addition cure technology dictates that certain types of organic elastomer may not be used either as a dispensing hose, or used as gaskets in the pump.

Bonding of Organic and Silicone

Efforts are under way to achieve commercially viable bonds between organic and modified One Part® LSR during co-cure. Some success has been achieved but there is still a long way to go. Three main impediments are getting in the way to achieving a good bond.

1. High strength of the organic rubber compared to silicone
2. Process oils in the organic rubber.
3. Cure mechanism as related to catalyst type and level.

The much higher strength of the organic rubber compared to the silicone means that during the pull test, there is normally rubber failure of the silicone leaving small visible quantities of silicone on the organic rubber. Thus, the test is actually measuring the strength of the silicone “legs” attached to the organic.

The problem with the process oils is quite self-evident. These oils are not compatible with the silicone and tend to interfere at the interface between two polymers thereby preventing bonding.

Finally, cure temperature and mechanism may affect the degree of cure of the various elastomers. The best results have been obtained so far with peroxide cured elastomers of all types. However, peroxide cured EPDM offers the best overall properties.
Samples are being distributed to show the degree of bonding obtained so far.

While there are many applications that can benefit from the improved resistance to cure inhibition that the Easy Cure® technology offers, one that has been demonstrated is, the rubber roller industry. Many roll builders use a wide array of other rubbers. Many of these materials have many ingredients that could inhibit two part LSR’s; one of these is sulfur cure systems. The Easy Cure® technology has made it practical to use LSR in most rubber roll building shops.

This system has been shown to produce rollers with greatly reduced build lines, a property that is important in many high-end rubber roller applications.

The following video demonstrates how easy it is to use LSR to build a roller. The mold systems are modified urethane molds. The pumping system is one half of a standard two-part LSR meter-mix system. Both hot air ovens and autoclaves (hot air and steam) have been used to cure the rollers.