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# Evaluation of the Use of Processing Aids in Silicone Elastomers and Cellular Silicones

W. E. Cady, E. S. Jessop

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May 23, 1982

Lawrence Livermore National Laboratory


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# Glossary

| | |
|---|---|
| Banbury intensive mixer | Mixer produced by Farrel-Birmingham Co., Inc., Ansonia-Derby, CT. |
| BKC | The Bendix Corporation, Kansas City Division, Kansas City, MO. |
| Cabosil Grade MS7 | A grade of silicon dioxide made by the Cabot Corporation, Boston, MA. |
| Cadox BS | Fifty percent benzoyl peroxide in a dimethylsilicone oil. A curing agent produced by the Chemical Department, McKesson and Robbins, Inc., New York, NY. |
| Cadox TS50 | Fifty percent paste of 2,4-dichlorobenzoyl peroxide in dimethylsilicone oil. A curing agent produced by the Chemical Department, McKesson and Robbins, Inc., New York, NY. |
| $\Delta$ area | The hysteresis loop between the third cycle load and unload curves of load-deflection. |
| $\Delta$t | Difference in starting thickness between the first and third cycles of the load-deflection curves as measured by the Instron test machine. |
| DMS | Dimethylsiloxane repeating unit in our silicone polymers. |
| DPS | Diphenylsiloxane repeating unit in our silicone polymers. |
| DuPont | E. I. DuPont de Nemours and Co., Wilmington, DE. |
| EEMCO rubber mill | Two-roll mill produced by the Erie Engine and Manufacturing Co., Erie, PA. |
| Esperox 497XL | Tertiary butyl per-2-methylbenzoate at 40% concentration on calcium carbonate. A peroxide curing agent produced by Witco Chemical Corporation, U.S. Peroxygen Division, Richmond, CA. |
| Fisher | Fisher Scientific Co., Pittsburgh, PA. |
| GE | General Electric Co., Silicone Products Department, Waterford, NY. |
| GPC | Gel permeation chromatography. |
| Haake intensive mixer | One-pound mixer, System 80, produced by Haake, Inc., Saddle Brook, NJ. |
| Hi Sil 233 | A grade of silicon dioxide produced by Pittsburgh Plate Glass Industries, Inc., Pittsburgh, PA. |
| Instron Test Machine | Universal test machine produced by the Instron Corporation, Canton, MA. |
| L60VB | Vinyl-end-blocked, block-polymerized silicone gum produced by LLNL. |
| L97KVB | Vinyl-end-blocked, equilibrium-polymerized silicone gum produced by LLNL. |
| L1668 | Intermediate reinforced silicone gum produced by LLNL. |
| L3219 | Heat-stripped L1668 produced by LLNL. |
| L3223 | Molding compound of L3219, temporary filler and curing agent or cellular silicone cushion produced from the molding compound by LLNL. Nominal cushion density of 0.63–0.65 $Mg/m^3$. |
| L3260 | Like L3223 but with a nominal density of 0.52–0.55 $Mg/m^3$. |
| LLNL | Lawrence Livermore National Laboratory, Livermore, CA. |
| Luperco 101XL | 2,5-dimethyl-2,5 bis (t-butyl peroxyl) hexane at 50% concentration on an inert filler. A peroxide curing agent produced by Lucidol Division, Pennwalt Corporation, Buffalo, NY. |
| $M_n$ | Number-average molecular weight from GPC measurements based on polystyrene equivalents. |
| MN60VB | Commercial equivalent of L60VB silicone polymer produced by McGhan-NuSil Corporation, Carpenteria, CA. |
| MW | Molecular weight. |
| $M_w$ | Weight-average molecular weight from GPC measurements based on polystyrene equivalents. |
| MWD | Molecular weight distribution, or the ratio of $M_w/M_n$. |

| | |
|---|---|
| MVS | Methylvinylsiloxane repeating unit in our silicone polymers. |
| n | Number of samples tested. |
| NMR | Nuclear magnetic resonance. |
| Pasadena Hydraulics press | Molding press made by Pasadena Hydraulics, Inc., El Monte, CA. |
| % C of V | Coefficient of variation; (S/av)100. |
| Rex O | Durometer Hardness Tester, Type O, Model 1600, made by Rex Gage Co., Glenview, IL. |
| RT | Room temperature. |
| S | Standard deviation. |
| SE33 | A grade of silicone polymer produced by GE and used as a carrier for the other components of GE's SE4210 processing aid. |
| SE54 | A grade of silicone polymer produced by General Electric's Silicone Products Department, Waterford, NY. |
| SE4210 | Processing aid for use in compounding silicone gum produced by General Electric's Silicone Products Department, Waterford, NY. |
| Sherritt-Gordon Mines | Sherritt-Gordon Mines, Ltd., Fort Saskatchewan, Alberta, Canada. |
| Shore A | Durometer Hardness Tester, Type A, made by Shore Instrument and Manufacturing Co., Jamaica, NY. |
| TGA | Thermal gravimetric analysis. |
| UCC | Union Carbide Corporation, Silicone Rubber, New York, NY. |
| U/L ratio | Ratio of 3rd cycle unload to load values at the same deflection. |
| $V/V_o$ | Equilibrium swell ratio or ratio of swollen polymer volume to original polymer volume. A measure of degree of crosslinking. |
| Y1587 | Ethoxy-end-blocked, dimethylsiloxane fluid produced by UCC. |

# Evaluation of the Use of Processing Aids in Silicone Elastomers and Cellular Silicones


## Abstract

We evaluated two processing aids, UCC's Y1587 and GE's SE4210, in GE's SE54, type 97, and type 60 silicone gums. We tested uncured L1668 reinforced gums, cured L3219 elastomers, and L3223 and L3260 cellular silicones. In the new type 97KVB and type 60VB silicone gums, Y1587 produces a softer cushion than SE4210. The type of processing aid has no significant effect on uncured L1668 and has no effect on the compression set of the higher density L3223. For lower density L3260 cushions, Y1587 produces a significantly lower compression set than SE4210. If compression set is not a big consideration, or if cushion density is high, the choice of a processing aid can be used to control cushion stiffness along with the amount of reinforcing $SiO_2$, vinyl content, and porosity. Y1587 is preferred for all silicone gums, and it is important that it be used in the 97KVB and 60KVB gums.


## Introduction

Lawrence Livermore National Laboratory has used cellular silicones as support materials and space fillers in weapons for two decades. Our sole commercial source of these materials has ceased production of both the silicone gum and filled molding compounds. Therefore, we have developed a silicone technology to both synthesize gums and compound them to cellular materials. We are in the process of developing replacement gums and compounding them to equivalent or better cellular silicone than we have had in the past.

The gums we are evaluating include GE's SE54 silicone gum; our L97KVB gum[1] which we hope is an improved version of the commercial gum we have been using; and our L60VB[2] which is an improved alternating block copolymer.

In the first of the series of compounding steps, silicone gum is mixed with two grades of $SiO_2$ and a processing aid to create a reinforced gum, L1668. The L1668 is bin aged at RT for about one month and then heat stripped to the base gum, L3219. The L3219 is filled with a temporary filler and activated with a peroxide curing agent to create a molding compound, e.g. L3223 or L3260. The molding compound is compression-die molded and cured, water washed to remove temporary filler, dried, and post cured to create our product.

With our original commercial gum (UCC's W97), UCC's Y1587, an ethoxy-end-blocked dimethylsiloxane fluid, was used as the processing aid. We have also used Y1587 in all our replacement gums. General Electric recommends that their SE4210 processing aid be used with their SE54 gum. We have also used SE4210 in all our replacement gums in order to compare the two processing aids. We made one comparison of the use of Y1587 with no use of a processing aid.

This report evaluates the use of Y1587, SE4210 or no processing aid on the properties of uncured and cured L1668, cured L3219 elastomer, and cellular silicones, L3223 and L3260.

## Experimental

### Materials

We used two lots of SE54 gum (161 and 167); one lot of L97KVB, one lot of MN97KVB, one lot of L60VB, and several experimental lots of MN60VB in our comparison of processing aids. The SE54 gums were obtained from General Electric Co. Our L97KVB was synthesized in-house to be a random equilibrium terpolymer of dimethyl-, diphenyl-, methylvinylsiloxane containing 0.7

**Table 1. Properties of uncured silicone gums by gum and identification number.**

| | SE 54 | | L97KVB | MN97KVB | L60VB | MN60VB | | |
|---|---|---|---|---|---|---|---|---|
| | Lot 161[a] | Lot 167 | TJ150 | TJ164 | TJ154 | DR115 | DR114 | RD001VR26 |
| Molecular weight[b] | | | | | | | | |
| $M_w$ | 514,000 | 745,000 | 590,000 | 514,150 | 478,000 | 671,350 | 418,700 | 320,750 |
| $M_n$ | 146,000 | 333,500 | 250,000 | 192,400 | 182,500 | 204,000 | 151,300 | 127,750 |
| MWD | 3.52 | 2.24 | 2.38 | 2.67 | 2.62 | 3.30 | 2.77 | 2.51 |
| Wt% MVS[c] | 0.29[d] | 0.27 | 0.7 | 0.69 | 0.80 | 0.67 | 0.69 | 0.71 |
| Wt% DPS[c] | 14.3[e] | 14.3 | 9.6 | 8.52 | 9.64 | 9.70 | 10.1 | 9.45 |

[a] Bendix data, Reference 3.

[b] By GPC, based on polystyrene equivalents.

[c] By NMR except as noted.

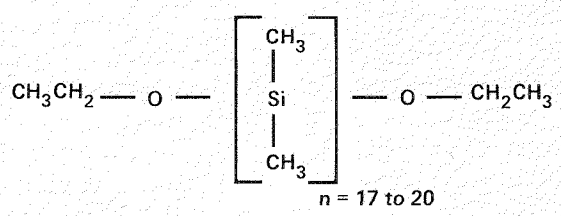
[d] By iodine monochloride titration.

[e] By pyrolysis gas chromatography.

wt% methylvinylsiloxane and 9 wt% diphenylsiloxane. The MN97KVB gum was synthesized in a 200-lb batch by McGhan-NuSil under our guidance to duplicate L97KVB. Both L97 and MN97 were vinyl-end-blocked. The L60VB was synthesized in-house to be an alternating block condensation terpolymer of DMS, DPS, and MVS with the same MVS and DPS contents as L97KVB. The MN60VB's were small scale experimental attempts by McGhan-NuSil to produce our L60VB. All condensation polymers were also vinyl-end-blocked. SE54 is an equilibrium terpolymer of much lower MVS and higher DPS contents than L97 and L60. Data for the polymer lots are listed in Table 1.

To prepare L1668 we normally add 32 parts of Cabosil MS7 $SiO_2$ and 6 parts of HiSil 233 $SiO_2$ plus a processing aid to the silicone gum. We have varied MS7 over the range of 25 to 38 parts and HiSil 233 at 6 parts or none at all. We used only one commercial lot each of MS7 and HiSil 233 in our experiments. The other ingredient in L1668 is the processing aid. Because we do not understand the interaction among silicone gum, $SiO_2$, and the processing aid we had no way of knowing the optimum amount of either processing aid to use, and we had no way of judging equivalent amounts of the two processing aids (Y1587 and SE4210) to be used for comparison. For our standard formulations we used 10 or 11 parts of Y1587 per hundred parts of gum, by weight as was done by UCC; for SE4210 we used 5 or 6 parts as presumably is done by GE with SE54 gum. For amounts of MS7 above 32 parts we increased the amount of SE4210 and for amounts of MS7 below 32 parts we decreased the amount of Y1587 (see Table 5). We did not adjust the amount of either processing aid for the absence of HiSil 233.

Only one lot of UCC's Y1587 (355022178) has been used to date. For SE4210, lot HF230 was used in L1668 TJ82 and thereafter lot JE240 was used. BKC analytical data on SE4210, Y1587, and SE33, the major component of SE4210, are shown in Table 2. Thermal gravimetric analyses of both processing aids are shown in Table 3; these were run at a heating rate of 10°C/min in a nitrogen atmosphere. Y1587 is much more volatile than SE4210 and the excess is probably much more effectively stripped during the conversion of L1668 to L3219 and during the long post cure than it is for SE4210. Table 4 shows the component composition of SE4210 as determined by BKC. SE33, the major component of SE4210, is a GE commercial gum consisting primarily of dimethylsiloxane and a small amount of methylvinylsiloxane, but containing no phenylmethylsiloxane or diphenylsiloxane. Y1587 is probably an ethoxy-end-blocked dimethylsiloxane fluid with a structure as follows[6]:




Y1587 apparently contains small amounts of octamethylcyclotetrasiloxane and oligomers of the above structure where n = 4, 8, 12, and 16.

To cure L3219, we activated L3219 with one of the following peroxide curing agents:

Cadox TS50
Cadox BS
Luperco 101XL
Esperox 497XL

Table 2. Analyses of the two processing aids and the major component of SE4210, SE33.[4,5,6]

| | Y1587 | SE4210 | SE33 |
|---|---|---|---|
| $SiO_2$, wt% | – | 13.0 | – |
| Hydroxyl content, wt% | 0.12 | 0.50 | – |
| Vinyl content, wt% as MVS | – | 0.13[a] | 0.23[a] |
| | – | 0.10[b] | 0.20[b] |
| MW by GPC | | | |
| $M_w$ | ~2000 | 594,000 | 533,000 |
| $M_n$ | 1500-1700 | 300,000 | 270,000 |
| MWD | – | 1.98 | 1.98 |

[a] By the iodine monochloride method.

[b] By gas chromatography.

The curing agent used in a L3219 was the same that we used for the following molding compound but the concentration was not always the same. All curing agents were purchased from commercial sources.

To prepare the molding compound we filled L3219 either with urea and activated it with TS50, BS or 497XL or with $NH_4Cl$ and activated it with 101XL. We used two ureas; one was supplied to us by BKC and was purchased by them from Sherritt-Gordon Mines; the other was our own supply which we had obtained from DuPont. The $NH_4Cl$ was supplied by Fisher and handground by us. All fillers were screened to −25 to +40 mesh, U.S. Sieve Nos.

## Compounding

For preparing L1668's we have established a standard addition sequence for the gum, MS7, HiSil 233, and the processing aid. L1668's TJ81, TJ82, TJ113, and TJ114 were made prior to the adoption of this standard technique. Later formulations in which we varied the amounts of ingredients followed the standard procedure as closely as possible. In all cases, comparative pairs of formulations were made by the same procedure. Most mixings were made in our 1-lb size Banbury intensive mixer but some of the later mixings were made in our new Haake intensive mixer. Comparative formulations mixed in different mixers will be so noted. Mixing times in the Banbury totaled 5 min and in the Haake they totaled 7 min. Final blending and sheeting of all L1668's were done on our EEMCO 2-roll rubber mill. The 6 mm thick sheets (approx) of L1668 were bin aged at RT for at least 28 days and then were heat stripped in an air-circulating oven at 171° to 177°C for 18 h to produce L3219 base gums. Curing agents were added to L1668's and 13219's on the rubber mill. Activated L1668's and L3219's were molded into about 2 mm thick sheets in a flat-slab steel mold at an appropriate time and temperature in a Pasadena Hydraulics press; the sheets were then post cured at an appropriate time and temperature.

Table 3. TGA analyses of the two processing aids. Losses are expressed as wt%.

| | Y1587[a] | SE4210[b] |
|---|---|---|
| Onset of weight loss, °C | 75 | 88 |
| Cumulative loss, wt% | | |
| at 100°C | 1.1 | 1.5 |
| at 200°C | 20.4 | 10.8 |
| at 300°C | 66.1 | 20.0 |
| at 400°C | 76.1 | 25.4 |
| at 500°C | 80.0 | 50.8 |
| at 600°C | – | 87.0 |

[a] LLNL analysis.

[b] BKC analysis, Reference 4.

Table 4. Component composition of SE4210.[7]

| Component | Wt% | Measurement Method |
|---|---|---|
| $SiO_2$ | 15 | TGA |
| SE-33 | 50 | GPC |
| Silanol (MW ~ 1500) | 23 | By difference |
| $D_4$ and $D_5$ cyclics | 12 | GPC |

L3223 and L3260 molding compounds were prepared by our standard technique. Curing agent was added to L3219 on the 2-roll mill. Temporary filler was added to the activated L3219 either in the Banbury mixer or in the Haake mixer. Comparative formulations made in different mixers will be noted. Final mixing and sheeting were done on the 2-roll mill.

Molding compounds were converted to cellular silicones in a series of steps. Flat sheets were molded in a flat-slab steel mold at an appropriate time and temperature in a Pasadena Hydraulics press to a nominal 2.6 mm thickness except for earlier formulations (TJ108-111, TJ113A, and TJ114) which were 2.0 mm thick as noted. All comparative formulations are of the same nominal thickness. The press-cured sheets of molding compound were washed in about 90°C water in a washing machine using our standard washing sequence. The washed cushions were dried at RT for 16 h and then oven dried at 149°C for 4 h. Dried cushions were post cured for 24 h at 249°C.

## Testing

All cured L3219 elastomers were tested for tensile properties and all L3223 and L3260 cushions were tested for load-deflection properties on an Instron test machine with a cross head speed of 1.25 mm/min at RT. Disks of L3219, L3223, and L3260 were weighed, measured, and their densities calculated. The compression sets on L3223's and L3260's were measured by our confined-die test. A 31.7 $cm^2$ disk of material was compressed to the appropriate percentage of original free height in a closed die and placed in an air oven at 149°C for 24 h. After cooling to RT under compression, the sample was removed from the die and its free height measured as a function of time at RT. Compression set was calculated from height at 1 h recovery.

# Results

## SE54 Silicone Gum

### L1668's

The compositions of all L1668's made for this study are listed in Table 5. The data for the two pairs of uncured L1668's made from the two lots of SE54 are listed in Table 6. Y1587 produces a softer reinforced gum for both lots of SE54. Using Y1587, both lots of SE54 lose more weight on bin aging and have more extractables than with SE4210. Properties of cured L1668's from SE54 lot 167 are shown in Table 7. Y1587 produces a softer reinforced elastomer with higher extractables and higher swell ratio ($V/V_o$) which indicates less crosslinking with Y1587. The ultimate tensile strength with Y1587 seems to be slightly higher and the ultimate elongation is much greater than with SE4210.

**Table 5. Compositions of L1668's, parts by weight.**

| Sample | Gum | | $SiO_2$ | | Processing Aid | |
|---|---|---|---|---|---|---|
| Identification | Identification | Parts | MS7 | HiSil 233 | Y1587 | SE4210 |
| TJ81 | SE54 lot 161 | 100 | 38 | 6 | 10 | – |
| TJ82 | SE54 lot 161 | 100 | 38 | 6 | – | 7 |
| TJ113 | SE54 lot 167 | 100 | 38 | 6 | 10 | – |
| TJ114 | SE54 lot 167 | 100 | 38 | 6 | – | 8 |
| TJ115 | SE54 lot 167 | 100 | 32 | 6 | 11 | – |
| TJ116 | SE54 lot 167 | 100 | 32 | 6 | 11 | – |
| TJ117 | SE54 lot 167 | 100 | 32 | 6 | – | – |
| TJ150 | L97KVB-TJ150-Blend | 100 | 32 | 6 | 10 | – |
| TJ150-2 | L97KVB-TJ150-Blend | 100 | 32 | 6 | 10 | – |
| TJ150SE | L97KVB-TJ150-Blend | 100 | 32 | 6 | – | 6 |
| TJ172 | L97KVB-TJ150-Blend | 100 | 25 | 0 | 8 | – |
| TJ168 | L97KVB-TJ150-Blend | 100 | 25 | 0 | – | 5 |
| TJ164 | MN97KVB-RD004-067 | 100 | 32 | 6 | 10 | – |
| TJ175 | MN97KVB-RD004-067 | 100 | 32 | 6 | 10 | – |
| TJ176 | MN97KVB-RD004-067 | 100 | 32 | 6 | – | 6 |
| TJ154 | L60VB-III-49-Blend | 100 | 32 | 6 | 10 | – |
| TJ177 | L60VB-III-49-Blend | 100 | 32 | 6 | – | 6 |
| TJ173 | L60VB-III-49-Blend | 100 | 25 | 0 | 8 | – |
| TJ169 | L60VB-III-49-Blend | 100 | 25 | 0 | – | 5 |
| TJ159I | MN60VB-DR115 | 100 | 32 | 6 | 10 | – |
| TJ159II | MN60VB-DR115 | 100 | 32 | 6 | – | 5 |
| TJ160I | MN60VB-DR114 | 100 | 32 | 6 | 10 | – |
| TJ160II | MN60VB-DR114 | 100 | 32 | 6 | – | 5 |
| TJ161I | MN60VB-RD001VR26 | 100 | 32 | 6 | 10 | – |
| TJ161II | MN60VB-RD001VR26 | 100 | 32 | 6 | – | 5 |

**Table 6. Properties of uncured L1668's made from SE54 silicone gums and Y1587 or SE4210 processing aid.**

| Property | SE54 lot 161 | | SE54 lot 167 | |
|---|---|---|---|---|
| | Y1587 TJ 81 | SE4210 TJ 82 | Y1587 TJ113 | SE4210 TJ114 |
| Hardness, Rex O, after aging | | | | |
| 0 day | 34 | 36 | 22 | 27 |
| 1 day | 42 | 50 | 29 | 35 |
| 6 days | 43 | 53 | – | – |
| 7 days | – | – | 31 | 44 |
| 14 days | 47 | 58 | 37 | 48 |
| 21 days | – | – | 40 | 49 |
| 23 days | 50 | 60 | – | – |
| 28 days | – | – | 41 | 49 |
| 80 days | 53 | 62 | – | – |
| Aging loss, wt%, after aging | | | | |
| 23 days | 1.22 | 0.95 | – | – |
| 28 days | – | – | 0.46 | 0.23 |
| $CHCl_3$ extractables, wt%, after aging | | | | |
| 1 day | 47.2 | 37.6 | 32.4 | 44.6 |
| 30 days | – | – | 33.7 | 19.9 |
| 37 days | 37.9 | 15.5 | – | – |
| 83 days | 38.6 | 10.3 | – | – |
| Swell ratio ($V/V_0$) in chlorobenzene after aging | | | | |
| 1 day | – | – | 4.54 | 4.36 |
| 30 days | – | – | 4.11 | 5.66 |

Comparative properties of SE54 lot 167 with and without Y1587 are shown in Table 8. These L1668's do not compare to T113 of Table 6 because of the difference in the MS7 contents and the switch to the now standard addition sequence. TJ115 and TJ116 are duplicates and they agree well in properties. Omission of Y1587 from SE54 produced a much harder reinforced gum; there is very little weight loss on bin aging and extractables are greatly reduced.

### L3219's

The compositions and cure cycles of all L3219's made for this evaluation are shown in Table 9. The properties of the two pairs of cured L3219's made from lot 161 of SE54 and the pair made from lot 167 are listed in Table 10. The two comparative pairs from lot 161 show higher weight loss on post cure, higher $V/V_0$, slightly greater ultimate elongation and perhaps greater ultimate tensile strength for Y1587. For lot 167, the Y1587 formulation shows higher weight loss on post cure, higher extractables, higher swell ratio and both higher elongation and tensile strength. Y1587 produces a slightly softer elastomer with greater tensile strength and elongation and less crosslinking.

Properties of the two L3219's made from SE54 lot 167 gum and cured with 101XL peroxide with and without Y1587 are shown in Table 11. Omission of Y1587 results in a harder elastomer with reduced tensile strength and greatly reduced elongation. Without Y1587, crosslinking is slightly greater and extractables are reduced.

### L3223's

The composition and cure cycles of all L3223's relative to the comparison of Y1587 and SE4210 are listed in Table 12. The load-deflection properties of the cushions made from SE54 lot 161 are shown in Table 13. No comparison can be made because both formulations utilizing SE4210 could not be processed into L3223 cushions. With lot 167 of SE54 we were able to produce cushions so the load-deflection data are tabulated in Table 14. The confined compression-set results for both lots of SE54 gums are shown in Table 15. Use of Y1587 produces a much softer cushion with greater resiliency then does use of SE4210. The type of processing aid used has no effect on compression set although final recovery is better with Y1587.

Load-deflection and set properties of the L3223 cushions made from SE54 lot 167 with and

**Table 7. Properties of cured L1668's made from SE54 silicone gum (lot 167) and Y1587 or SE4210 processing aid.**

| | Y1587 TJ113 | SE4210 TJ114 |
|---|---|---|
| Composition, parts by weight | | |
| L1668 | 100 | 100 |
| Cadox TS50 | 1.5 | 1.5 |
| Cure, | | |
| Temperature, °C | 116 | 116 |
| Time, min | 15 | 15 |
| Post cure | | |
| Temperature, °C | 249 | 249 |
| Time, hr | 16 | 16 |
| Properties | | |
| Hardness, Shore A | | |
| Cured | 35 | 49 |
| Post cured | 38 | 64 |
| Loss on post cure, wt% | 6.21 | 4.7 |
| $CHCl_3$ extractables, wt% | 3.53 | 2.34 |
| $V/V_0$ in chlorobenzene | 3.62 | 2.73 |
| Density, $Mg/m^3$ | 1.192 | 1.200 |
| Ultimate tensile strength | | |
| n | 5 | 5 |
| Av, kPa | 6233 | 5440 |
| S, kPa | 683 | 683 |
| Ultimate elongation | | |
| Av, % | 468 | 266 |
| S, % | 43 | 27 |

without Y1587 are shown in Tables 16 and 17 respectively. TJ115 and 115 CBA are duplicates except for a slight difference in the amount of $NH_4Cl$ used in the molding compounds. The duplicates are not statistically alike in load-deflection but they are similar. The difference may be due to the density difference as the denser cushion is stiffer. For set, the duplicates are very different and we have no explanation for the difference. Without Y1587 the L3223 cushion is stiffer than either of the duplicates; it is stiffer than TJ115 CBA which it matches more closely in density even though it should not be, based on the amount of $NH_4Cl$ used in the molding compounds. The confined compression set and ultimate recovery without Y1587 match that of TJ115 CBA with Y1587. Elimination of Y1587 produces a stiffer cushion but has no effect on compression set.

## Type 97 Silicone Gums

### L1668's

**A. L97KVB gum.** Properties of all uncured L1668's from our L97KVB silicone gum are listed

**Table 8. Properties of uncured L1668's made from SE54 lot 167 silicone gum and Y1587 processing aid or no processing aid.**

| Property | Y1587 TJ115 | Y1587 TJ116 | None TJ117 |
|---|---|---|---|
| Hardness, Rex O, after aging | | | |
| 0 day | 12 | 20 | 22 |
| 1 day | 19 | – | – |
| 4 days | 25 | – | – |
| 5 days | – | 27 | 34 |
| 7 days | – | – | 36 |
| 11 days | 27 | – | – |
| 14 days | 25 | 30 | 47 |
| 21 days | 26 | 30 | 50 |
| 28 days | 26 | 30 | 50 |
| Aging loss, wt%, after 28 days | 0.59 | 0.68 | 0.06 |
| $CHCl_3$ extractables, wt%, after aging | | | |
| 1 day | 61.0 | 52.5 | 32.3 |
| 28 days | – | 43.4 | 20.4 |
| 32 days | 44.7 | – | – |
| $V/V_0$ after aging | | | |
| 1 day | 3.12 | 3.09 | 3.95 |
| 32 days | 3.45 | – | – |

in Table 18. Formulations TJ150, TJ150-2, and TJ150SE were compounded with our standard amounts of 32 parts of MS7 $SiO_2$ and 6 parts of HiSil 233 $SiO_2$. TJ150 and TJ150-2 are duplicates. Formulations TJ168 and TJ172 were attempts to produce an improved cushion by reducing the MS7 to 25 parts to increase the resiliency of the elastomer and by eliminating HiSil 233, which appears to be a useless ingredient. The processing aids in these two formulations were adjusted proportionally to the MS7 contents but not to the HiSil 233 contents.

The duplication with Y1587 is good. Results with SE4210 are very much like those with Y1587. Type of processing aid has no effect on the properties of standard L1668's.

For the modified formulations, processing aids do have an effect; Y1587 produces a harder uncured L1668.

**B. MN97KVB gum.** Properties of standard uncured L1668's from MN97KVB, the commercial equivalent of our L97KVB gum, are shown in Table 19. TJ164 and TJ175 are excellent equivalents. The type of processing aid has no effect on the uncured L1668's.

### L3219's

**A. L97KVB.** Properties of all relevant cured L3219's from L97KVB gum are listed in Table 20.

## Table 9. Compositions and cure cycles of L3219's.

| Sample Ident. | Gum Ident. | L1668 Ident. | Curing Agent | | Cure Cycle | | Post-Cure Cycle | |
|---|---|---|---|---|---|---|---|---|
| | | | Ident. | Parts[a] | min | °C | h | °C |
| TJ81a | SE54 lot 161 | TJ81 | TS50 | 1.5 | 15 | 113 | 24 | 249 |
| TJ81b | SE54 lot 161 | TJ81 | BS | 1.5 | 15 | 113 | 24 | 249 |
| TJ82a | SE54 lot 161 | TJ82 | TS50 | 1.5 | 15 | 113 | 24 | 249 |
| TJ82b | SE54 lot 161 | TJ82 | BS | 1.5 | 15 | 113 | 24 | 249 |
| TJ113 | SE54 lot 167 | TJ113 | TS50 | 1.5 | 15 | 116 | 16 | 249 |
| TJ114A | SE54 lot 167 | TJ114 | TS50 | 1.5 | 15 | 116 | 16 | 249 |
| TJ115B | SE54 lot 167 | TJ115 | 101XL | 0.5 | 10 | 171 | 16 | 249 |
| TJ117C | SE54 lot 167 | TJ117 | 101XL | 0.5 | 10 | 171 | 16 | 249 |
| TJ150E | L97KVB-TJ150 | TJ150 | 497XL | 2.1 | 60 | 125 | 16 | 249 |
| TJ150-2E | L97KVB-TJ150 | TJ150-2 | 497XL | 2.0 | 60 | 125 | 16 | 249 |
| TJ150SEE | L97KVB-TJ150 | TJ150SE | 497XL | 2.0 | 60 | 125 | 16 | 249 |
| TJ172E | L97KVB-TJ150 | TJ172 | 497XL | 2.0 | 60 | 125 | 16 | 249 |
| TJ168E | L97KVB-TJ150 | TJ168 | 497XL | 2.0 | 60 | 125 | 16 | 249 |
| TJ164E | MN97KVB-RD004-067 | TJ164 | 497XL | 2.0 | 100 | 125 | 16 | 249 |
| TJ175E | MN97KVB-RD004-067 | TJ175 | 497XL | 2.0 | 60 | 125 | 16 | 249 |
| TJ176E | MN97KVB-RD004-067 | TJ176 | 497XL | 2.0 | 100 | 125 | 16 | 249 |
| TJ154E | L60VB-III49 | TJ154 | 497XL | 2.0 | 60 | 125 | 16 | 249 |
| TJ177E | L60VB-III49 | TJ177 | 497XL | 2.0 | 100 | 125 | 16 | 249 |
| TJ173E | L60VB-III49 | TJ173 | 497XL | 2.0 | 60 | 125 | 16 | 249 |
| TJ169E | L60VB-III49 | TJ169 | 497XL | 2.0 | 60 | 125 | 16 | 249 |
| TJ159-IIE | MN60VB-DR115 | TJ159-II | 497XL | 2.0 | 60 | 125 | 16 | 249 |
| TJ160-IE | MN60VB-DR114 | TJ160-I | 497XL | 2.0 | 60 | 125 | 16 | 249 |
| TJ160-IIE | MN60VB-DR114 | TJ160-II | 497XL | 2.0 | 60 | 125 | 16 | 249 |
| TJ161-IIE | MN60VB-RD001VR 26 | TJ161-II | 497XL | 2.0 | 60 | 125 | 16 | 249 |

[a] Parts of curing agent per hundred parts of L3219, by weight.

## Table 10. Properties of cured L3219's made from SE54 silicone gums and Y1587 or SE4210 processing aid.

| | SE54 lot 161 | | | | SE54 lot 167 | |
|---|---|---|---|---|---|---|
| | TS50 | | BS | | TS50 | |
| | Y1587 | SE4210 | Y1587 | SE4210 | Y1587 | SE4210 |
| Property | TJ81a | TJ82a | TJ81b | TJ82b | TJ113 | TJ114A |
| Hardness, Shore A | | | | | | |
| Cured | 45 | 45 | 55 | 54 | 42 | 52 |
| Post cured | 40 | 45 | 51 | 53 | 39 | 57 |
| Loss on post cure, wt% | 2.5 | 1.4 | 2.0 | 1.7 | 3.21 | 2.72 |
| Density, $Mg/m^3$ | 1.198 | 1.190 | 1.190 | 1.184 | 1.193 | 1.199 |
| $CHCl_3$ extractables, wt% | 3.7 | 3.4 | 2.2 | 2.2 | 3.05 | 2.27 |
| $V/V_0$ in chlorobenzene | 3.42 | 3.06 | 2.85 | 2.66 | 3.19 | 2.60 |
| Tensile properties | | | | | | |
| n | 5 | 5 | 5 | 5 | 5 | 5 |
| Ultimate tensile strength, kPa | | | | | | |
| Av | 5888 | 4137 | 5599 | 5123 | 6364 | 5668 |
| S | 586 | 186 | 745 | 358 | 462 | 221 |
| % C of V | 9.95 | 4.50 | 13.3 | 7.00 | 7.26 | 3.89 |
| Ultimate elongation, % | | | | | | |
| Av | 376 | 278 | 212 | 178 | 360 | 226 |
| S | 31 | 13 | 27 | 15 | 16 | 9 |
| % C of V | 8.24 | 4.68 | 12.7 | 8.43 | 4.44 | 3.98 |

**Table 11. Properties cured L3219's made from SE54 lot 167 silicone gum and Y1587 processing aid or no processing aid.**

| Property | Y1587 TJ115B | None TJ117C |
|---|---|---|
| Hardness, Shore A | | |
| Cured | 42 | 55 |
| *Post cured* | 43 | 57 |
| Loss on post cure, wt% | – | 2.1 |
| Density, $Mg/m^3$ | 1.172 | 1.184 |
| $CHCl_3$ extractables, wt% | 2.8 | 1.97 |
| $V/V_o$ in chlorobenzene | 3.23 | 2.86 |
| Tensile properties | | |
| n | 5 | 3 |
| Ultimate tensile strength, kPa | | |
| Av | 6736 | 5688 |
| S | 228 | 103 |
| % C of V | 3.38 | 1.81 |
| Ultimate elongation, % | | |
| Av | 416 | 213 |
| S | 11 | 6 |
| % C of V | 2.64 | 2.82 |

TJ150E and TJ150-2E are considered duplicate standard formulations even though TJ150 contained 5% more curing agent and was made from a L1668 that was heat stripped after one week of bin aging instead of after four weeks of bin aging. TJ150SEE is also a standard formulation. TJ168E and TJ172E are modified formulations with reduced MS7 and no HiSil 233. These formulations contain less equivalent weights of 497XL curing agent than do the TJ150's because they contain more L97KVB gum by weight in the L1668's. All formulations were cured and post cured identically.

In spite of the differences between TJ150E and TJ150-2E, the duplication is good. L3219 with SE4210 is similar to the duplicate L3219's with Y1587; tensile strengths are the same but elongation, swell ratio and $CHCl_3$ extractables are slightly less with SE4210. These differences are probably not significant. For the modified formulations the type of processing aid has no effect on properties of the cured L3219's.

**Table 12. Composition and cure cycles of L3223 molding compounds and cushions.**

| Sample | Gum | L3219 | Filler | | | Curing Agent | | Cure Cycle | | Post-cure Cycle | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ident. | Ident. | Ident. | Type | Source | Part[a] | Type | Parts[a] | min | °C | h | °C |
| TJ108 | SE54 lot 161 | TJ81 | Urea | LLNL | 100 | TS50 | 4.5 | 15 | 113 | 24 | 249 |
| TJ109 | SE54 lot 161 | TJ81 | $NH_4Cl$ | LLNL | 105 | BS | 3.0 | 15 | 113 | 24 | 249 |
| TJ110 | SE54 lot 161 | TJ82 | Urea | LLNL | 100 | TS50 | 4.5 | – | – | – | – |
| TJ111 | SE54 lot 161 | TJ82 | $NH_4Cl$ | LLNL | 105 | BS | 3.0 | – | – | – | – |
| TJ113A | SE54 lot 167 | TJ113 | Urea | LLNL | 100 | TS50 | 4.5 | 15 | 113 | 24 | 249 |
| TJ114 | SE54 lot 167 | TJ114 | Urea | LLNL | 100 | TS50 | 4.5 | 15 | 113 | 24 | 249 |
| TJ115C | SE54 lot 167 | TJ115 | $NH_4Cl$ | BKC | 105.5 | 101XL | 0.5 | 10 | 171 | 24 | 249 |
| TJ115CBA | SE54 lot 167 | TJ115 | $NH_4Cl$ | BKC | 110 | 101XL | 0.5 | 10 | 171 | 24 | 249 |
| TJ117CBA | SE54 lot 167 | TJ117 | $NH_4Cl$ | BKC | 105.5 | 101XL | 0.5 | 10 | 171 | 24 | 249 |
| TJ150EBU | L97KVB-TJ150 | TJ150 | Urea | BKC | 100 | 497XL | 2.0 | 60 | 125 | 24 | 249 |
| TJ150-2EBU | L97KVB-TJ150 | TJ150-2 | Urea | BKC | 100 | 497XL | 2.0 | 60 | 125 | 24 | 249 |
| TJ150SEEBU | L97KVB-TJ150 | TJ150SE | Urea | BKC | 100 | 487XL | 2.0 | 60 | 125 | 24 | 249 |
| TJ172EBU | L97KVB-TJ150 | TJ172 | Urea | BKC | 100 | 497XL | 2.0 | 60 | 125 | 24 | 249 |
| TJ168EBU | L97KVB-TJ150 | TJ168 | Urea | BKC | 100 | 497XL | 2.0 | 60 | 125 | 24 | 249 |
| TJ164ELU | MN97KVB-RD004-067 | TJ164 | Urea | LLNL | 100 | 497XL | 2.0 | 100 | 125 | 24 | 249 |
| TJ176EBU | MN97KVB-RD004-067 | TJ176 | Urea | BKC | 100 | 497XL | 2.0 | 100 | 125 | 24 | 249 |
| TJ154EBU | L60VB-III49 | TJ154 | Urea | BKC | 100 | 497XL | 2.0 | 100 | 125 | 24 | 249 |
| TJ177EBU | L60VB-III49 | TJ177 | Urea | BKC | 100 | 497XL | 2.0 | 100 | 125 | 24 | 249 |
| TJ173EBU | L60VB-III49 | TJ173 | Urea | BKC | 100 | 497XL | 2.0 | 60 | 125 | 24 | 249 |
| TJ169EBU | L60VB-III49 | TJ169 | Urea | BKC | 100 | 497XL | 2.0 | 60 | 125 | 24 | 249 |
| TJ159-IIEBU | MN60VB-DR115 | TJ159-II | Urea | BKC | 100 | 497XL | 2.0 | – | – | – | – |
| TJ160IEBU | MN60VB-DR114 | TJ160-I | Urea | BKC | 100 | 497XL | 2.0 | 100 | 125 | 24 | 249 |
| TJ160IIEBU | MN60VB-DR114 | TJ160-II | Urea | BKC | 100 | 497XL | 2.0 | – | – | – | – |
| TJ161IIEBU | MN60VB-RD001VR26 | TJ161-II | Urea | BKC | 100 | 497XL | 2.0 | – | – | – | – |

[a] Parts per hundred parts of L3219, by weight.

**Table 13. Load-deflection properties of L3223 cushions from SE54, lot 161, silicone gum and Y1587 processing aid. Formulations using SE4210 could not be processed into L3223 cushions, so no comparison can be made with L3223 using Y1587.**

| | TS50 and Urea | | | | | | BS and $NH_4Cl$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Y1587 TJ108 | | | SE4210 TJ110[a] | | | Y1587 TJ109 | | | SE4210 TJ111[a] | | |
| Property | n | Av | S | n | Av | S | n | Av | S | n | Av | S |
| 3rd cycle load, kPa, at deflections of | | | | | | | | | | | | |
| 5% | 5 | 34.1 | 2.36 | | – | | 5 | 28.0 | 0.66 | | – | |
| 10% | 5 | 64.7 | 2.47 | | – | | 5 | 57.7 | 0.97 | | – | |
| 20% | 5 | 121.3 | 2.88 | | – | | 5 | 103.1 | 3.15 | | – | |
| 30% | 5 | 220.1 | 5.51 | | – | | 5 | 167.3 | 7.70 | | – | |
| 40% | 5 | 602.6 | 18.3 | | – | | 5 | 391.2 | 21.4 | | – | |
| 3rd cycle unload, kPa, at deflections of | | | | | | | | | | | | |
| 5% | 5 | 18.3 | 1.95 | | – | | 5 | 16.4 | 0.64 | | – | |
| 10% | 5 | 40.8 | 1.74 | | – | | 5 | 39.6 | 0.31 | | – | |
| 20% | 5 | 79.1 | 1.58 | | – | | 5 | 73.1 | 1.07 | | – | |
| 30% | 5 | 151.8 | 5.07 | | – | | 5 | 119.6 | 6.03 | | – | |
| 40% | 5 | 494.1 | 24.5 | | – | | 5 | 318.3 | 21.2 | | – | |
| 3rd cycle U/L at deflections of | | | | | | | | | | | | |
| 10% | 5 | 0.632 | 0.0098 | | – | | 5 | 0.686 | 0.0097 | | – | |
| 20% | 5 | 0.652 | 0.0077 | | – | | 5 | 0.710 | 0.0132 | | – | |
| 30% | 5 | 0.689 | 0.0088 | | – | | 5 | 0.715 | 0.0056 | | – | |
| 3rd cycle hysteresis loop (Δ area) | 5 | 248.6 | 30.5 | | – | | 5 | 171.3 | 27.6 | | – | |
| Thickness, mm | | | | | | | | | | | | |
| 1st cycle | 5 | 2.11 | 0.028 | | – | | 5 | 2.03 | 0.008 | | – | |
| 3rd cycle | 5 | 2.05 | 0.026 | | – | | 5 | 1.99 | 0.007 | | – | |
| Δt | 5 | 0.073 | 0.0060 | | – | | 5 | 0.039 | 0.0015 | | – | |
| Density, $Mg/m^3$ | 7 | 0.6738 | 0.0027 | | – | | 6 | 0.6353 | 0.0037 | | – | |

[a] Could not be processed.

**B. MN97KVB.** Properties of the cured L3219's from MN97KVB gum are shown in Table 21. All three are standard formulations and TJ164E and TJ175E are duplicates but TJ175E was press cured only 60 min instead of 100 min. The duplicates are very much alike; they have equal $V/V_o$'s indicating equal crosslinking in spite of the difference in time of press cure. Results with SE4210 are like the duplicates with Y1587. Again type of the processing aid has no effect on the properties of cured L3219's.

### L3223's

**A. L97KVB.** The load-deflection properties of standard-formulation L3223's made from L97KVB gum are listed in Table 22 and the modified formulations are shown in Table 23. Corresponding confined-compression-set data are shown in Tables 24 and 25. All five formulations contain the same parts by weight of BKC urea and 497XL curing agent and were cured and post cured alike. The modified formulations contain less urea and less curing agent per gram of L97KVB gum than do the standard formulations because of the reduction of $SiO_2$ fillers.

The standard duplicate L3223's have similar load-deflection properties. The cushion with SE4210 is much stiffer and less resilient than the duplicates with Y1587. The duplicate cushions with Y1587 have the same compression set and ultimate recovery. The L3223 with SE4210 has greater set than duplicate L3223's with Y1587, but the same ultimate recovery. For the modified formulations SE4210 produces a slightly stiffer cushion with slightly greater resilience than does Y1587 but does not effect compression set or 7-day recovery. We found a 7-day recovery to be

**Table 14. Load-deflection properties of L3223 cushions from SE54, lot 167, silicone gum and Y1587 or SE4210 processing aid.**

| | TS50 and Urea | | | | | |
|---|---|---|---|---|---|---|
| | Y1587 TJ113A | | | SE4210 TJ114 | | |
| Property | n | Av | S | n | Av | S |
| 3rd cycle load, kPa, at deflections of | | | | | | |
| 5% | 5 | 39.8 | 1.68 | 4 | 68.4 | 1.87 |
| 10% | 5 | 74.6 | 2.94 | 4 | 123.6 | 2.36 |
| 20% | 5 | 126.8 | 5.57 | 4 | 208.0 | 4.95 |
| 30% | 5 | 200.0 | 6.39 | 4 | 327.2 | 9.26 |
| 40% | 5 | 468.0 | 19.5 | 4 | 762.4 | 45.1 |
| 3rd cycle unload, kPa, at deflection of | | | | | | |
| 5% | 5 | 31.9 | 1.54 | 4 | 45.0 | 0.96 |
| 10% | 5 | 60.8 | 2.62 | 4 | 87.7 | 1.68 |
| 20% | 5 | 98.8 | 4.55 | 4 | 147.3 | 3.19 |
| 30% | 5 | 153.4 | 3.76 | 4 | 234.8 | 7.37 |
| 40% | 5 | 400.6 | 12.5 | 4 | 626.7 | 43.4 |
| 3rd cycle U/L at deflections of | | | | | | |
| 10% | 5 | 0.816 | 0.0038 | 4 | 0.709 | 0.0063 |
| 20% | 5 | 0.779 | 0.0026 | 4 | 0.708 | 0.0042 |
| 30% | 5 | 0.767 | 0.0087 | 4 | 0.718 | 0.0026 |
| 3rd cycle hysteresis loop (Δ area) | 5 | 170.5 | 46.1 | 4 | 367.0 | 12.7 |
| Thickness, mm | | | | | | |
| 1st cycle | 5 | 2.44 | 0.042 | 4 | 2.43 | 0.047 |
| 3rd cycle | 5 | 2.14 | 0.040 | 4 | 2.35 | 0.047 |
| Δt | 5 | 0.047 | 0.0040 | 4 | 0.072 | 0.0096 |
| Density, $Mg/m^3$ | 5 | 0.6541 | 0.0038 | 5 | 0.6477 | 0.0048 |

**Table 15. Confined-compression-set properties at 35% compression of L3223 cushions made from SE54 silicone gums and Y1587 or SE4210 processing aid.**

| | Lot 161 Y1587 | | | | | | Lot 167 TS50 and Urea | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BS and $NH_4Cl$ TJ109 | | | TS50 and Urea TJ108 | | | Y1587 TJ113A | | | SE4210 TJ114 | | |
| Property | n | Av | S | n | Av | S | n | Av | S | n | Av | S |
| Original thickness, mm | 4 | 2.00 | 0.028 | 4 | 2.03 | 0.046 | 4 | 2.17 | 0.037 | 4 | 2.34 | 0.053 |
| Density, $Mg/m^3$ | 4 | 0.6320 | 0.0058 | 4 | 0.6708 | 0.0019 | 4 | 0.6460 | 0.0027 | 4 | 0.6405 | 0.0011 |
| Compression, % | 4 | 34.97 | 0.100 | 4 | 34.95 | 0.081 | – | – | – | – | – | – |
| Set, % | 4 | 23.17 | 2.17 | 4 | 34.26 | 1.45 | 4 | 10.85 | 1.54 | 4 | 10.55 | 0.49 |
| Recovery, % of original thickness after | | | | | | | | | | | | |
| 2 min | 4 | 88.45 | 2.37 | 4 | 81.88 | 1.15 | 4 | 93.05 | 1.53 | 4 | 95.33 | 0.36 |
| 1 hr | 4 | 91.85 | 0.77 | 4 | 88.03 | 0.49 | 4 | 96.20 | 0.54 | 4 | 96.30 | 0.16 |
| 24 hrs | 4 | 93.55 | 0.30 | 4 | 91.08 | 0.43 | 4 | 97.30 | 0.37 | 4 | 96.78 | 0.21 |
| 7 days | 4 | 94.30 | 0.42 | 4 | 93.10 | 0.27 | 4 | 98.03 | 0.51 | 4 | 97.23 | 0.30 |
| 28 days | 4 | 95.40 | 0.36 | 4 | 94.18 | 0.54 | 4 | 98.73 | 0.41 | 4 | 97.88 | 0.47 |

**Table 16. Load-deflection properties of L3223 cushions made from SE54, lot 167, silicone gum with Y1587 processing aid and with no processing aid.**

| | Y1587 | | | | | | None | | |
|---|---|---|---|---|---|---|---|---|---|
| | TJ115C | | | TJ115CBA | | | TJ117CBA | | |
| Property | n | Av | S | n | Av | S | n | Av | S |
| 3rd cycle load, kPa, at deflections of | | | | | | | | | |
| 5% | 5 | 41.0 | 0.58 | 3 | 37.2 | 1.04 | 3 | 45.3 | 0.62 |
| 10% | 5 | 71.2 | 1.38 | 3 | 62.8 | 1.65 | 3 | 81.8 | 1.01 |
| 20% | 5 | 119.4 | 2.13 | 3 | 105.7 | 4.10 | 3 | 142.4 | 1.57 |
| 30% | 5 | 198.4 | 2.98 | 3 | 180.1 | 12.9 | 3 | 239.1 | 2.23 |
| 40% | 5 | 519.1 | 7.33 | 1 | 498.2 | – | 3 | 637.8 | 10.2 |
| 3rd cycle unload, kPa, at deflections of | | | | | | | | | |
| 5% | 5 | 26.8 | 0.26 | 3 | 22.6 | 0.45 | 3 | 29.3 | 0.71 |
| 10% | 5 | 49.5 | 0.73 | 3 | 41.7 | 0.89 | 3 | 57.8 | 0.89 |
| 20% | 5 | 84.0 | 0.95 | 3 | 72.1 | 0.52 | 3 | 103.8 | 1.32 |
| 30% | 5 | 141.8 | 1.86 | 3 | 127.2 | 5.82 | 3 | 178.7 | 1.63 |
| 40% | 5 | 449.5 | 9.14 | 1 | 442.5 | – | 3 | 587.8 | 17.5 |
| 3rd cycle U/L at deflections of | | | | | | | | | |
| 10% | 5 | 0.696 | 0.0063 | 3 | 0.664 | 0.0205 | 3 | 0.707 | 0.0046 |
| 20% | 5 | 0.703 | 0.0060 | 3 | 0.683 | 0.0219 | 3 | 0.729 | 0.0026 |
| 30% | 5 | 0.715 | 0.0025 | 3 | 0.707 | 0.0196 | 3 | 0.748 | 0.0021 |
| 3rd cycle hysteresis loop (Δ area) | 5 | 221.0 | 10.7 | 3 | 201.5 | 26.2 | 3 | 232.9 | 12.8 |
| Thickness, mm | | | | | | | | | |
| 1st cycle | 5 | 2.76 | 0.035 | 3 | 2.62 | 0.016 | 3 | 2.67 | 0.026 |
| 3rd cycle | 5 | 2.70 | 0.035 | 3 | 2.52 | 0.015 | 3 | 2.58 | 0.023 |
| Δt | 5 | 0.067 | 0.0034 | 3 | 0.101 | 0.0104 | 3 | 0.088 | 0.0032 |
| Density, $Mg/m^3$ | 5 | 0.6687 | 0.0015 | 4 | 0.660 | 0.0111 | 4 | 0.6625 | 0.0037 |

**Table 17. Confined-compression-set properties at 35% compression of L3223 cushions made from SE54, lot 167, silicone gum with Y1587 processing aid and with no processing aid.**

| | Y1587 | | | | | | None | | |
|---|---|---|---|---|---|---|---|---|---|
| | TJ115C | | | TJ115CBA | | | TJ117CBA | | |
| Property | n | Av | S | n | Av | S | n | Av | S |
| Original thickness, mm | 4 | 2.75 | 0.038 | 3 | 2.62 | 0.018 | 3 | 2.73 | 0.046 |
| Density, $Mg/m^3$ | 4 | 0.6671 | 0.0047 | 3 | 0.6392 | 0.0073 | 4 | 0.6435 | 0.0029 |
| Compression, % | 4 | 35.02 | 0.014 | – | – | – | – | – | – |
| Set, % | 3 | 10.38 | 0.58 | 3 | 4.83 | 2.04 | 4 | 4.99 | 0.65 |
| Recovery, % of original thickness after | | | | | | | | | |
| 2 min | 3 | 88.87 | 2.24 | 3 | 97.87 | 0.60 | 4 | 97.71 | 0.64 |
| 1 hr | 3 | 96.36 | 0.21 | 3 | 98.29 | 0.73 | 4 | 98.25 | 0.22 |
| 24 hrs | 2 | 97.45 | 0.071 | 3 | 98.68 | 0.65 | 4 | 98.56 | 0.062 |
| 7 days | 4 | 97.85 | 0.55 | 3 | 98.62 | 0.62 | 4 | 98.73 | 0.16 |
| 28 days | 4 | 98.10 | 0.48 | 3 | 98.87 | 0.65 | 4 | 98.98 | 0.29 |

**Table 18. Properties of uncured L1668's made from L97KVB silicone gum and Y1587 or SE4210 processing aid.**

| Property | Y1587 | | SE4210 |
|---|---|---|---|
| | TJ150-2 | TJ150 | TJ150SE |
| Hardness, Rex O after aging | | | |
| 0 days | 44 | 46 | 40 |
| 4 weeks | 60 | 60 | 61 |
| After aging 4 weeks | | | |
| Loss, wt% | 4.47 | 5.1 | 5.50 |
| $CHCl_3$ extractables, wt% | 20.67 | 17.10 | – |
| $V/V_0$ in chlorobenzene | 6.09 | 6.09 | – |
| Stripping loss, wt% | 7.13 | 8.69 | 7.95 |
| | TJ172 | | TJ168 |
| Hardness, Rex O, after aging | | | |
| 0 days | 34 | | 22 |
| 28 days | 50 | | – |
| 33 days | – | | 42 |
| Loss, wt%, after aging | | | |
| 28 days | 6.78 | | – |
| 33 days | – | | 6.54 |
| Stripping loss, wt% | 11.3 | | 9.42 |

as useful a measurement as a 28-day recovery so we ceased measuring 28-day recoveries.

For L97KVB, SE4210 produces a stiffer cushion than Y1587 but has no significant effect on compression set. Its effect on resiliency is variable and depends upon the amount of $SiO_2$ present.

**B. MN97KVB.** TJ164ELU and TJ176EBU are standard formulations comparable to the L3223's from L97KVB but they were both press cured for 100 min instead of 60 min. Also TJ164ELU was filled with LLNL urea instead of BKC urea; the urea source is not considered a significant variable.

The molding compound for the L3223 with Y1587 was compounded in the Banbury mixer and that with SE4210 was compounded in the Haake mixer. We do not consider the mixer to be a significant variable but we are still evaluating this difference. Load-deflection results for the standard L3223's from MN97KVB are listed in Table 26 and their set properties are shown in Table 27. Again, as with the standard formulations from L97KVB, SE4210 produces a much stiffer and less resilient cushion but does not effect compression set on 7-day recovery.

**Table 19. Properties of uncured L1668's made from MN97KVB silicone gum and Y1587 or SE4210 processing aid.**

| Property | Y1587 | | SE4210 |
|---|---|---|---|
| | TJ164 | TJ175 | TJ176 |
| Hardness, Rex O, after aging | | | |
| 0 days | 55 | 51 | 50 |
| 28 days | 73 | 70 | 76 |
| Loss, wt%, after aging 28 days | 6.39 | 6.26 | 5.81 |
| Stripping loss, wt% | 10.6 | 10.7 | 8.7 |

### L3260's

All of our early work was done with L3223 which is defined by a nominal cushion density of 0.65 $Mg/m^3$ corresponding to ~45% porosity because that was the material of weapon interest. Later the interest shifted to a softer, lower density material such as L3260 which is defined by a nominal density of 0.50 $Mg/m^3$ (~57% porosity) so we began to build up a body of knowledge on L3260. The compositions and cure cycles of all L3260's relevant to the processing aid study are shown in Table 28.

**A. L97KVB.** We attempted to prepare L3260 from our modified formulations with Y1587 (TJ172) and SE4210 (TJ168) but could not mill either formulation into a useful molding compound.

**B. MN97KVB.** TJ175ELU and TJ176EBU are standard formulations but there are differences. TJ175 used LLNL urea and was compounded in the Banbury mixer and TJ176 used BKC urea and was compounded in the Haake mixer. These differences are not considered to be significant.

**Table 20. Properties of cured L3219's made from L97KVB silicone gum and Y1587 or SE4210 processing aid.**

| | 32 parts MS7 6 parts HiSil 233 | | | 25 parts MS7 No parts HiSil 233 | |
|---|---|---|---|---|---|
| | Y1587 | | SE4210 | Y1587 | SE4210 |
| Property | TJ150-2E | TJ150E[a] | TJ150SEE | TJ172E | TJ168E |
| Hardness, Shore A | | | | | |
| Cured | 65 | 69 | 69 | 62 | 65 |
| Post cured | 68 | 71 | 75 | 62 | 63 |
| Loss on post cure, wt% | 3.14 | 1.83 | 2.31 | 1.89 | 1.33 |
| Density, $Mg/m^3$ | 1.193 | 1.193 | 1.198 | 1.141 | 1.143 |
| $CHCl_3$ extractables, wt% | 1.48 | 1.16 | 1.04 | 1.07 | 0.91 |
| $V/V_o$ in chlorobenzene | 2.34 | 2.26 | 1.94 | 2.51 | 2.47 |
| Tensile properties | | | | | |
| n | 5 | 5 | 5 | 5 | 5 |
| Ultimate tensile strength, kPa | | | | | |
| Av | 3516 | 3179 | 3509 | 1717 | 1641 |
| S | 359 | 207 | 221 | 193 | 117 |
| % C of V | 10.2 | 6.51 | 6.30 | 11.3 | 7.13 |
| Ultimate elongation, % | | | | | |
| Av | 90 | 74 | 60 | 70 | 66 |
| S | 10 | 2 | 7 | 10 | 5 |
| % C of V | 11.1 | 2.70 | 11.7 | 14.3 | 7.58 |

[a] Heat stripped L668 after 1 week bin aging.

**Table 21. Properties of cured L3219's made from MN97KVB silicone gum and Y1587 or SE4210 processing aid.**

| | Y1587 | | SE4210 |
|---|---|---|---|
| Property | TJ164 | TJ175 | TJ176 |
| Hardness, Shore A | | | |
| Cured | 68 | 70 | 69 |
| Post cured | 68 | 70 | 71 |
| Loss on post cure, wt% | 2.41 | 3.77 | 2.13 |
| Density, $Mg/m^3$ | 1.187 | 1.191 | 1.200 |
| $CHCl_3$ extractables, wt% | – | 1.09 | 0.97 |
| $V/V_o$ in chlorobenzene | 2.30 | 2.29 | 2.21 |
| Tensile properties | | | |
| n | 5 | 5 | 5 |
| Ultimate tensile strength, kPa | | | |
| Av | 3082 | 2903 | 3206 |
| S | 200 | 186 | 379 |
| % C of V | 6.49 | 6.41 | 11.8 |
| Ultimate elongation, % | | | |
| Av | 80 | 76 | 70 |
| S | 10 | 5 | 7 |
| % C of V | 12.5 | 6.58 | 10.1 |

**Table 22. Load-deflection properties of L3223 cushions made from L97KVB silicone gum and Y1587 or SE4210 processing aid.**

| | Y1587 | | | | | | SE4210 | | |
|---|---|---|---|---|---|---|---|---|---|
| | TJ150-2EBU | | | TJ150EBU | | | TJ150SEEBU | | |
| Property | n | Av | S | n | Av | S | n | Av | S |
| 3rd cycle load, kPa, at deflections of | | | | | | | | | |
| 5% | 4 | 78.5 | 1.92 | 5 | 72.8 | 0.99 | 4 | 100.2 | 1.95 |
| 10% | 4 | 145.1 | 2.58 | 5 | 134.3 | 1.59 | 4 | 182.8 | 4.03 |
| 20% | 4 | 258.2 | 3.73 | 5 | 239.0 | 2.92 | 4 | 336.3 | 9.57 |
| 30% | 4 | 417.6 | 5.82 | 5 | 378.0 | 5.06 | 4 | 590.2 | 24.3 |
| 40% | 4 | 969.2 | 23.4 | 5 | 831.1 | 10.4 | — | — | — |
| 3rd cycle unload, kPa, at deflections of | | | | | | | | | |
| 5% | 4 | 61.0 | 1.88 | 5 | 55.6 | 2.01 | 4 | 65.2 | 0.51 |
| 10% | 4 | 115.8 | 2.46 | 5 | 106.3 | 2.52 | 4 | 130.6 | 1.66 |
| 20% | 4 | 202.7 | 3.57 | 5 | 186.4 | 2.97 | 4 | 250.4 | 6.42 |
| 30% | 4 | 333.7 | 6.16 | 5 | 300.6 | 0.89 | 4 | 460.9 | 20.6 |
| 40% | 4 | 890.7 | 34.4 | 5 | 763.1 | 13.9 | — | — | — |
| 3rd cycle U/L at deflections of | | | | | | | | | |
| 10% | 4 | 0.798 | 0.0031 | 5 | 0.791 | 0.0119 | 4 | 0.715 | 0.0079 |
| 20% | 4 | 0.785 | 0.0026 | 5 | 0.780 | 0.0054 | 4 | 0.745 | 0.0040 |
| 30% | 4 | 0.799 | 0.0035 | 5 | 0.795 | 0.0044 | 4 | 0.781 | 0.0032 |
| 3rd cycle hysteresis loop (Δ area) | 4 | 314.1 | 4.33 | 5 | 285.2 | 15.6 | 4 | 424.7 | 16.3 |
| Thickness, mm | | | | | | | | | |
| 1st cycle | 4 | 2.77 | 0.037 | 5 | 2.73 | 0.033 | 4 | 2.84 | 0.034 |
| 3rd cycle | 4 | 2.72 | 0.029 | 5 | 2.67 | 0.030 | 4 | 2.77 | 0.028 |
| Δt | 4 | 0.047 | 0.0086 | 5 | 0.058 | 0.0168 | 4 | 0.069 | 0.0066 |
| Density, $Mg/m^3$ | 5 | 0.6559 | 0.0006 | 5 | 0.651 | 0.005 | 5 | 0.6573 | 0.0021 |

Load-deflection results for these standard L3260's from MN97KVB are listed in Table 29. For L3223, we load to a minimum of 40% deflection but for lower density L3260 we load to a minimum of 45% deflection. Compression-set properties of the two cushions made from MN97KVB are shown in Table 30. Again, because of the density difference we compress L3223 to a nominal 35% of original thickness and L3260 to a nominal 40%. The cushion with SE4210 is slightly stiffer but also has a higher density which could account for the increase in stiffness at higher compressions. The density difference may be due to the use of different mixers, a weighing error, or to the use of different processing aids. SE4210 produces a considerably less resilient cushion than does Y1587 and this is probably not related to the density difference. SE4210 increases set significantly.

## Type 60VB Silicone Gums

### L1668's

**A. L60VB.** The properties of the three standard uncured L1668's and two modified L1668's made from our L60VB silicone gum are listed in Table 31. Duplicate batches of TJ154 with Y1587 were prepared and tested and then combined before stripping to produce one large batch of L3219. The duplication of the two batches of TJ154 is very good. SE4210 produces a harder uncured gum than Y1587, but otherwise the two L1668's are alike. For the modified formulations SE4210 produces a softer uncured gum and has less weight loss on stripping than Y1587.

**B. MN60VB experimental gums.** Data for the McGhan-NuSil 60VB formulations are included to

**Table 23. Load-deflection properties of L3223 cushions made from L97KVB silicone gum and Y1587 or SE4210 processing aid, and containing 25 parts of MS7 and no HiSil 233.**

| Property | Y1587 TJ172EBU n | Av | S | SE4210 TJ168EBU n | Av | S |
|---|---|---|---|---|---|---|
| 3rd cycle load, kPa, at deflections of | | | | | | |
| 5% | 3 | 56.3 | 1.57 | 4 | 62.4 | 1.76 |
| 10% | 3 | 111.3 | 3.57 | 4 | 122.9 | 2.72 |
| 20% | 3 | 192.4 | 7.52 | 4 | 214.4 | 3.95 |
| 30% | 3 | 292.8 | 11.6 | 4 | 327.9 | 6.45 |
| 40% | 3 | 605.3 | 31.6 | 4 | 695.8 | 25.3 |
| 3rd cycle unload, kPa, at deflections of | | | | | | |
| 5% | 3 | 44.6 | 0.89 | 4 | 52.7 | 1.82 |
| 10% | 3 | 94.1 | 2.61 | 4 | 106.8 | 2.98 |
| 20% | 3 | 162.3 | 5.85 | 4 | 181.5 | 3.79 |
| 30% | 3 | 244.4 | 7.26 | 4 | 275.6 | 5.47 |
| 40% | 3 | 541.2 | 9.67 | 4 | 622.7 | 26.2 |
| 3rd cycle U/L at deflections of | | | | | | |
| 10% | 3 | 0.846 | 0.0037 | 4 | 0.868 | 0.0055 |
| 20% | 3 | 0.843 | 0.0027 | 4 | 0.847 | 0.0029 |
| 30% | 3 | 0.835 | 0.0084 | 4 | 0.841 | 0.0010 |
| 3rd cycle hysteresis loop (Δ area) | 3 | 200.0 | 31.0 | 4 | 201.1 | 9.82 |
| Thickness, mm | | | | | | |
| 1st cycle | 3 | 2.81 | 0.023 | 4 | 2.80 | 0.039 |
| 3rd cycle | 3 | 2.77 | 0.024 | 4 | 2.77 | 0.033 |
| Δt | 3 | 0.028 | 0.026 | 4 | 0.028 | 0.021 |
| Density, $Mg/m^3$ | 5 | 0.6424 | 0.0068 | 5 | 0.6449 | 0.0033 |

**Table 24. Confined-compression-set properties at 35% compression of L3223 cushions made from L97KVB silicone gum and Y1587 or SE4210 processing aid.**

| Property | Y1587 TJ150-2EBU n | Av | S | Y1587 TJ150EBU n | Av | S | SE4210 TJ150SEEBU n | Av | S |
|---|---|---|---|---|---|---|---|---|---|
| Original thickness, mm | 3 | 2.74 | 0.038 | 4 | 2.69 | 0.0094 | 3 | 2.81 | 0.048 |
| Density, $Mg/m^3$ | 3 | 0.6456 | 0.0012 | 4 | 0.6434 | 0.0024 | 3 | 0.6542 | 0.0009 |
| Compression, % | 3 | 34.98 | 0.023 | 3 | 35.04 | 0.12 | 3 | 35.02 | 0.12 |
| Set, % | 3 | 5.66 | 0.38 | 3 | 5.53 | 0.44 | 3 | 6.46 | 0.22 |
| Recovery, % of original thickness after | | | | | | | | | |
| 2 min | 3 | 97.83 | 0.14 | 3 | 97.84 | 0.25 | 3 | 97.53 | 0.09 |
| 1 hr | 3 | 98.02 | 0.13 | 3 | 98.06 | 0.16 | 3 | 97.74 | 0.08 |
| 24 hrs | 3 | 98.15 | 0.14 | 3 | 98.29 | 0.04 | 3 | 98.04 | 0.13 |
| 7 days | 3 | 98.42 | 0.14 | 3 | 98.54 | 0.16 | 3 | 98.25 | 0.19 |
| 28 days | 3 | 98.63 | 0.09 | 3 | 98.53 | 0.22 | 3 | 98.48 | 0.10 |

**Table 25. Confined-compression-set properties at 35% compression of L3223 cushions made from L97KVB silicone gum and Y1587 or SE4210 processing aid, and containing 25 parts of MS7 and no HiSil 233.**

| | Y1587 TJ172EBU | | | SE4210 TJ168EBU | | |
|---|---|---|---|---|---|---|
| Property | n | Av | S | n | Av | S |
| Original t, mm | 3 | 2.76 | 0.030 | 4 | 2.78 | 0.029 |
| Density, $Mg/m^3$ | 3 | 0.6360 | 0.0038 | 4 | 0.6445 | 0.0034 |
| Compression, % | 3 | 35.09 | 0.14 | 4 | 34.97 | 0.059 |
| Set, % | 3 | 5.85 | 0.83 | 3 | 5.29 | 0.59 |
| Recovery, % of original thickness after | | | | | | |
| 1 hr | 3 | 97.95 | 0.30 | 3 | 98.15 | 0.21 |
| 7 days | 3 | 98.19 | 0.21 | 3 | 98.53 | 0.17 |

**Table 26. Load-deflection properties of L3223 cushions made from MN97KVB silicone gum and Y1587 or SE4210 processing aid.**

| | Y1587 TJ172EBU | | | SE4210 TJ168EBU | | |
|---|---|---|---|---|---|---|
| Property | n | Av | S | n | Av | S |
| 3rd cycle load, kPa, at deflections of | | | | | | |
| 5% | 5 | 62.5 | 0.51 | 3 | 82.9 | 1.41 |
| 10% | 5 | 119.9 | 0.75 | 3 | 152.5 | 2.53 |
| 20% | 5 | 217.9 | 1.47 | 3 | 288.6 | 4.73 |
| 30% | 5 | 344.6 | 1.84 | 3 | 520.6 | 8.53 |
| 40% | 5 | 742.1 | 6.23 | 1 | 1503.6 | – |
| 3rd cycle unload, kPa, at deflections of | | | | | | |
| 5% | 5 | 48.3 | 0.70 | 3 | 60.2 | 1.11 |
| 10% | 5 | 96.7 | 0.61 | 3 | 117.9 | 1.89 |
| 20% | 5 | 173.2 | 1.00 | 3 | 226.6 | 3.69 |
| 30% | 5 | 274.8 | 2.14 | 3 | 416.3 | 7.64 |
| 40% | 5 | 647.8 | 15.3 | – | – | – |
| 3rd cycle U/L at deflections of | | | | | | |
| 10% | 5 | 0.806 | 0.0034 | 3 | 0.773 | 0.0035 |
| 20% | 5 | 0.795 | 0.0024 | 3 | 0.785 | 0.0021 |
| 30% | 5 | 0.797 | 0.0044 | 3 | 0.800 | 0.0028 |
| 3rd cycle hysteresis loop (Δ area) | 5 | 273.4 | 18.6 | 3 | 346.4 | 5.80 |
| Thickness, mm | | | | | | |
| 1st cycle | 5 | 2.75 | 0.013 | 3 | 2.76 | 0.032 |
| 3rd cycle | 5 | 2.72 | 0.015 | 3 | 2.70 | 0.033 |
| $\Delta t$ | 5 | 0.031 | 0.015 | 3 | 0.053 | 0.0022 |
| Density, $Mg/m^3$ | 5 | 0.6565 | 0.0016 | 5 | 0.6721 | 0.0018 |

Table 27. Confined-compression-set properties at 35% compression of L3223 cushions made from MN97KVB silicone gum and Y1587 or SE4210 processing aid.

| | Y1587 LLNL Urea Banbury Mixer TJ164ELU | | | SE4210 BKC Urea Haake Mixer TJ176EBU | | |
|---|---|---|---|---|---|---|
| Property | n | Av | S | n | Av | S |
| Original thickness, mm | 3 | 2.72 | 0.033 | 5 | 2.71 | 0.038 |
| Density, $Mg/m^3$ | 3 | 0.6572 | 0.0025 | 5 | 0.6695 | 0.0023 |
| Compression, % | 3 | 34.99 | 0.075 | 3 | 34.95 | 0.12 |
| Set, % | 3 | 5.91 | 0.70 | 3 | 5.61 | 0.64 |
| Recovery, % of original thickness after | | | | | | |
| 2 min | 3 | 97.95 | 0.34 | – | – | – |
| 1 hr | 3 | 97.92 | 0.26 | 3 | 98.04 | 0.22 |
| 24 hrs | 3 | 97.96 | 0.046 | – | – | – |
| 7 days | 3 | 98.11 | 0.093 | 3 | 98.38 | 0.27 |
| 28 days | 3 | 98.40 | 0.093 | – | – | – |

illustrate the complexity of the interaction of gum, $SiO_2$ and processing aid and our lack of understanding of it. The only measured property of the MN60VB's that shows any significant variation is molecular weight which ranges over a factor of two, yet the processability of these three gums varied widely. Properties of the three pairs of formulations that we tried to make are shown in Table 32. Both the high and low molecular weight gums could be processed only with SE4210. For DR114 SE4210 produces a harder uncured gum with less weight loss on aging and less weight loss on stripping than does Y1587.

### L3219's

**A. L60VB.** Properties of the two pairs of cured L3219's from the standard and modified formulations of L60VB are listed in Table 33. TJ177E was cured for 100 min instead of 60 min like the rest. For both the standard and modified formulations the type of processing aid has no significant effect on the properties of cured L3219 elastomer.

**B. MN60VB experimental gums.** The four formulations that were processable into L1668's were cured to L3219 elastomers with the properties shown in Table 34. For the only comparison of Y1587 and SE4210 that can be made (gum DR114), there is no major difference in processing aids. All four L3219's are much alike.

### L3223's

**A. L60VB.** The load-deflection properties of L3223 cushions made from standard formulations of L60VB are shown in Table 35 and their

Table 28. Compositions and cure cycles of L3260 molding compounds and cushions.

| Sample Ident. | Gum Ident. | L3219 Ident. | Filler | | | Curing Agent | | Cure Cycle | | Post cure cycle | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Type | Source | Pts[a] | Type | Pts[a] | Min | C° | hrs | C° |
| TJ172EBU | L97KVB-TJ150 | TJ172 | Urea | BKC | 170 | 497XL | 2.0 | – | – | – | – |
| TJ168EBU | L97KVB-TJ150 | TJ168 | Urea | BKC | 170 | 497XL | 2.0 | – | – | – | – |
| TJ175ELU | MN97KVB-RD004067 | TJ175 | Urea | LLNL | 170 | 497XL | 2.0 | 100 | 125 | 24 | 249 |
| TJ175EBU | MN97KVB-RD004067 | TJ176 | Urea | BKC | 170 | 497XL | 2.0 | 100 | 125 | 24 | 249 |
| TJ154EBU | L60VB | TJ154 | Urea | BKC | 170 | 497XL | 2.0 | 100 | 125 | 24 | 249 |
| TJ177EBU | L60VB | TJ177 | Urea | BKC | 170 | 497XL | 2.0 | 100 | 125 | 24 | 249 |
| TJ173EBU | L60VB | TJ173 | Urea | BKC | 170 | 497XL | 2.0 | 60 | 125 | 24 | 249 |
| TJ169EBU | L60VB | TJ169 | Urea | BKC | 170 | 497XL | 2.0 | – | – | – | – |

[a] Parts per hundred parts of L3219, by weight.

Table 29. Load-deflection properties of L3260 cushions made from MN97KVB silicone gum and Y1587 or SE4210 processing aid.

| | Y1587 Banbury Mixer LLNL Urea TJ175ELU | | | SE4210 Haake Mixer BKC Urea TJ176EBU | | |
|---|---|---|---|---|---|---|
| Property | n | Av | S | n | Av | S |
| 3rd cycle load, kPa, at deflections of | | | | | | |
| 5% | 5 | 34.8 | 0.63 | 4 | 35.2 | 1.03 |
| 10% | 5 | 63.5 | 1.23 | 4 | 66.3 | 3.20 |
| 20% | 5 | 108.5 | 2.94 | 4 | 123.3 | 6.89 |
| 30% | 5 | 161.1 | 4.88 | 4 | 202.4 | 11.7 |
| 40% | 5 | 266.3 | 9.77 | 4 | 383.2 | 24.9 |
| 3rd cycle unload, kPa, at deflections of | | | | | | |
| 5% | 4 | 29.5 | 0.62 | 4 | 25.0 | 0.89 |
| 10% | 4 | 54.5 | 1.14 | 4 | 50.4 | 2.72 |
| 20% | 4 | 91.0 | 2.86 | 4 | 96.0 | 5.63 |
| 30% | 4 | 134.3 | 4.85 | 4 | 159.2 | 1.59 |
| 40% | 4 | 229.7 | 10.6 | 4 | 313.9 | 21.7 |
| 3rd cycle U/L at deflections of | | | | | | |
| 10% | 4 | 0.854 | 0.0036 | 4 | 0.760 | 0.0058 |
| 20% | 4 | 0.837 | 0.0030 | 4 | 0.779 | 0.0041 |
| 30% | 4 | 0.832 | 0.0022 | 4 | 0.787 | 0.0026 |
| 3rd cycle hysteresis loop (Δ area) | 4 | 127.6 | 9.52 | 4 | 220.2 | 11.0 |
| Thickness, mm | | | | | | |
| 1st cycle | 4 | 2.72 | 0.021 | 4 | 2.70 | 0.008 |
| 3rd cycle | 5 | 2.68 | 0.019 | 4 | 2.65 | 0.017 |
| Δt | 4 | 0.033 | 0.0036 | 4 | 0.055 | 0.017 |
| Density, $Mg/m^3$ | 5 | 0.5226 | 0.0052 | 5 | 0.5507 | 0.0048 |

Table 30. Confined-compression-set properties at 40% compression of L3260 cushions made from MN97KVB silicone gum and Y1587 or SE4210 processing aid.

| | Y1587 Banbury Mixer LLNL Urea TJ175ELU | | | SE4210 Haake Mixer BKC Urea TJ176EBU | | |
|---|---|---|---|---|---|---|
| Property | n | Av | S | n | Av | S |
| Original thickness, mm | 3 | 2.68 | 0.023 | 6 | 2.68 | 0.047 |
| Density, $Mg/m^3$ | 3 | 0.5205 | 0.0046 | 6 | 0.5461 | 0.0061 |
| Compression, % | 3 | 40.46 | 0.39 | 3 | 39.93 | 0.079 |
| Set, % | 3 | 4.59 | 0.68 | 3 | 7.29 | 0.65 |
| Recovery, % of original thickness after | | | | | | |
| 1 hr | 3 | 98.31 | 0.41 | 3 | 97.09 | 0.26 |
| 7 days | 3 | 98.29 | 0.18 | 3 | 97.84 | 0.10 |

**Table 31. Properties of uncured L1668's made from L60VB silicone gum and Y1587 or SE4210 processing aid.**

| Property | Y1587 TJ154 Batch 1 | Y1587 TJ154 Batch 2 | SE4210 TJ177 |
|---|---|---|---|
| Hardness, Rex O, after aging | | | |
| 0 days | 37 | – | 38 |
| 1 day | – | 45 | – |
| 28 days | 52 | 53 | 65 |
| After aging 28 days | | | |
| Loss, wt% | 1.91 | 1.90 | 1.86 |
| $CHCl_3$ extractables, wt% | 33.0 | 25.6 | – |
| $V/V_0$ in chlorobenzene | 4.87 | 5.06 | – |
| Stripping loss, wt% | 4.45[a] | | 4.42 |

| Property | TJ173 | TJ169 |
|---|---|---|
| Hardness, Rex O, after aging | | |
| 0 days | 27 | 15 |
| 28 days | 41 | – |
| 33 days | – | 33 |
| Loss, wt%, after aging | | |
| 28 days | 2.49 | – |
| 33 days | – | 2.29 |
| Stripping loss, wt% | 6.86 | 4.67 |

[a] Combined batches.

**Table 32. Properties of uncured L1668's made from experimental MN60VB silicone gums and Y1587 or SE4210 processing aid.**

| Property | DR-115 Y1587 TJ159-I[a] | DR-115 SE4216 TJ159-II | DR-114 Y1587 TJ160-I | DR-114 SE4210 TJ160-II | RD001VR26 Y1587 TJ161-I[a] | RD001VR26 SE4210 TJ161-II |
|---|---|---|---|---|---|---|
| Hardness, Rex O, after aging | | | | | | |
| 0 days | – | 43 | 33 | 32 | – | 32 |
| 28 days | – | 54 | 49 | 59 | – | 53 |
| Loss, wt%, after aging 28 days | – | 0.84 | 0.81 | 0.57 | – | 1.56 |
| Stripping loss, wt% | – | 3.59 | 4.70 | 2.71 | – | 4.07 |

[a] Cannot be processed.

**Table 33. Properties of cured L3219's made from L60VB silicone gum and Y1587 or SE4210 processing aid.**

| Property | Standard Formulation[a] | | Modified Formulation[b] | |
|---|---|---|---|---|
| | Y1587 TJ154E | SE4210 TJ177E | Y1587 TJ173E | SE4210 TJ169E |
| Hardness, Shore A | | | | |
| Cured | 63 | 65 | 63 | 60 |
| Post cured | 63 | 68 | 63 | 59 |
| Loss on post cure, wt% | 2.67 | 1.97 | 1.73 | 1.53 |
| Density, $Mg/m^3$ | 1.178 | 1.180 | 1.123 | 1.123 |
| $CHCl_3$ extractables, wt% | 1.18 | 0.96 | 0.85 | 0.78 |
| $V/V_0$ in chlorobenzene | 2.28 | 2.25 | 2.50 | 2.55 |
| Tensile properties | | | | |
| *n* | 5 | 5 | 5 | 5 |
| Ultimate tensile strength, kPa | | | | |
| Av | 3144 | 2834 | 1434 | 1413 |
| S | 496 | 317 | 110 | 90 |
| % C of V | 15.8 | 11.2 | 7.67 | 6.37 |
| Ultimate elongation, % | | | | |
| Av | 52 | 74 | 58 | 68 |
| S | 11 | 11 | 5 | 4 |
| % C of V | 21.2 | 14.9 | 8.62 | 5.88 |

[a] Thirty-two parts of MS7 and six parts of HiSil 233.

[b] Twenty-five parts of MS7 and no HiSil 233.

**Table 34. Properties of cured L3219's made from experimental MN60VB silicone gums and Y1587 or SE4210 processing aid.**

| Property | DR115[a] | DR114 | | RDOOIVR26[b] |
|---|---|---|---|---|
| | SE4216 TJ159-IIE | Y1587 TJ160-IE | SE4210 TJ160-IIE | SE4210 TJ161-IIE |
| Hardness, Shore A | | | | |
| Cured | 65 | 65 | 65 | 68 |
| Post cured | 67 | 67 | 68 | 69 |
| Loss on post cure, wt% | 1.10 | 1.67 | 1.39 | 1.45 |
| Density, $Mg/m^3$ | 1.175 | 1.163 | 1.180 | 1.183 |
| $CHCl_3$ extractables, wt% | 0.90 | 1.10 | 0.90 | 0.62 |
| $V/V_0$ in chlorobenzene | 2.20 | 2.31 | 2.19 | 2.14 |
| Tensile properties | | | | |
| n | 5 | 5 | 5 | 5 |
| Ultimate tensile strength, kPa | | | | |
| Av | 2130 | 1986 | 2110 | 2199 |
| S | 165 | 97 | 255 | 207 |
| % C of V | 7.75 | 4.88 | 12.1 | 9.41 |
| Ultimate elongation, % | | | | |
| Av | 48 | 62 | 46 | 42 |
| S | 4 | 4 | 5 | 8 |
| % C of V | 8.33 | 6.45 | 10.9 | 19.0 |

[a] L1668 with Y1587 from this gum (TJ160-IIE) could not be processed.

[b] L1668 with Y1587 from this gum (TJ161-I) could not be processed.

compression-set properties are listed in Table 36. Corresponding data for modified formulations are listed in Tables 37 and 38. The two standard formulations were made in different mixers. The standard SE4210 cushion has a greater density and also is stiffer and less resilient than the standard Y1587 cushion. SE4210 results in a significant increase in compression set.

For the modified formulations, Y1587 produces a slightly softer cushion than SE4210 but resiliency is the same. The type of processing aid has no effect on compression set or 7-day recovery of the modified formulations.

**B. MN60VB experimental gums.** Of the four processable L1668's from the three experimental MN60VB's only the one L1668 based on lot DR114 and Y1587 could be processed into L3223. Load-deflection and set properties of this single L3223 (TJ160-IEBU) are listed in Tables 39 and 40 respectively. Although SE4210 allowed all three gums to be processed through the cured L3219 stage compared to one gum for Y1587, the only formulation to be successfully molded into an L3223 cushion was based on Y1587. Y1587 seems to have more versatility in accommodating the vagaries of silicone gums than does SE4210.

### L3260's

**A. L60VB.** The load-deflection properties of L3260 cushions made from standard formulation L60VB are shown in Table 41 and those of L3260 from modified formulations are listed in Table 42. Corresponding compression set data are shown in Table 43. The SE4210 standard cushion is denser and stiffer at higher compressions, is less resilient, and has considerably higher compression set than the Y1587 cushion. The modified formulation could not be processed with SE4210.

**Table 35. Load-deflection properties of L3223 cushions made from L60VB silicone gum and Y1587 or SE4210 processing aid.**

| | Y1587 Banbury Mixer TJ174EBU | | | SE4210 Haake Mixer TJ177EBU | | |
|---|---|---|---|---|---|---|
| Property | n | Av | S | n | Av | S |
| 3rd cycle load, kPa, at deflections of | | | | | | |
| 5% | 5 | 60.5 | 2.85 | 3 | 67.9 | 1.07 |
| 10% | 5 | 116.4 | 5.57 | 3 | 132.7 | 0.67 |
| 20% | 5 | 209.4 | 10.8 | 3 | 264.5 | 1.68 |
| 30% | 5 | 329.8 | 17.7 | 3 | 485.6 | 6.14 |
| 40% | 5 | 703.1 | 43.4 | 3 | 1451.7 | 35.3 |
| 3rd cycle unload, kPa, at deflections of | | | | | | |
| 5% | 5 | 50.9 | 2.47 | 3 | 53.3 | 0.58 |
| 10% | 5 | 100.7 | 5.26 | 3 | 109.3 | 0.27 |
| 20% | 5 | 176.2 | 9.39 | 3 | 219.1 | 2.03 |
| 30% | 5 | 275.5 | 15.1 | 3 | 404.2 | 7.03 |
| 40% | 5 | 639.8 | 40.9 | 3 | 1429.0 | 74.6 |
| 3rd cycle U/L at deflections of | | | | | | |
| 10% | 5 | 0.864 | 0.0044 | 3 | 0.824 | 0.0039 |
| 20% | 5 | 0.842 | 0.0022 | 3 | 0.828 | 0.0029 |
| 30% | 5 | 0.835 | 0.0026 | 3 | 0.832 | 0.0041 |
| 3rd cycle hysteresis loop (Δ area) | 5 | 198.1 | 13.8 | 3 | 243.1 | 24.2 |
| Thickness, mm | | | | | | |
| 1st cycle | 5 | 2.77 | 0.027 | 3 | 2.70 | 0.030 |
| 3rd cycle | 5 | 2.73 | 0.022 | 3 | 2.66 | 0.029 |
| Δt | 5 | 0.041 | 0.0061 | 3 | 0.044 | 0.0109 |
| Density, $Mg/m^3$ | 5 | 0.6466 | 0.0020 | 5 | 0.6812 | 0.0038 |

**Table 36. Confined-compression-set properties at 35% compression of L3223 cushions made from L60VB silicone gum and Y1587 or SE4210 processing aid.**

| Property | Y1587 Banbury Mixer TJ175ELU | | | SE4210 Haake Mixer TJ176EBU | | |
|---|---|---|---|---|---|---|
| | n | Av | S | n | Av | S |
| Original thickness, mm | 3 | 2.71 | 0.036 | 6 | 2.70 | 0.060 |
| Density, $Mg/m^3$ | 3 | 0.6442 | 0.0040 | 6 | 0.6771 | 0.0064 |
| Compression, % | 3 | 35.03 | 0.13 | 4 | 35.04 | 0.20 |
| Set, % | 3 | 3.84 | 0.29 | 4 | 6.97 | 0.33 |
| Recovery, % of original thickness after | | | | | | |
| 2 min | 3 | 98.22 | 0.021 | – | – | – |
| 1 hr | 3 | 98.65 | 0.10 | 4 | 97.56 | 0.11 |
| 24 hrs | 3 | 98.78 | 0.18 | – | – | – |
| 7 days | 3 | 98.93 | 0.24 | 4 | 98.08 | 0.16 |
| 28 days | 3 | 99.29 | 0.23 | – | – | – |

**Table 37. Load-deflection properties of L3223 cushions made from L60VB silicone gum and Y1587 or SE4210 processing aid, and containing 25 parts of MS7 and no HiSil 233.**

| Property | Y1587 TJ173EBU | | | SE4210 TJ169EBU | | |
|---|---|---|---|---|---|---|
| | n | Av | S | n | Av | S |
| 3rd cycle load, kPa, at deflections of | | | | | | |
| 5% | 4 | 55.6 | 0.69 | 5 | 60.0 | 2.27 |
| 10% | 4 | 110.5 | 1.22 | 5 | 117.9 | 4.18 |
| 20% | 4 | 190.4 | 3.69 | 5 | 205.1 | 7.50 |
| 30% | 4 | 282.2 | 6.83 | 5 | 311.6 | 12.4 |
| 40% | 4 | 575.2 | 25.6 | 5 | 639.8 | 41.7 |
| 3rd cycle unload, kPa, at deflections of | | | | | | |
| 5% | 4 | 51.5 | 0.41 | 5 | 55.4 | 2.23 |
| 10% | 4 | 113.1 | 1.12 | 5 | 110.3 | 3.94 |
| 20% | 4 | 172.0 | 3.17 | 5 | 186.6 | 3.62 |
| 30% | 4 | 251.6 | 5.33 | 5 | 279.2 | 3.76 |
| 40% | 4 | 537.7 | 19.1 | 5 | 589.2 | 35.2 |
| 3rd cycle U/L at deflections of | | | | | | |
| 10% | 4 | 0.933 | 0.0047 | 5 | 0.935 | 0.0028 |
| 20% | 4 | 0.903 | 0.0015 | 5 | 0.910 | 0.0032 |
| 30% | 4 | 0.891 | 0.0031 | 5 | 0.896 | 0.0039 |
| 3rd cycle hysteresis loop (Δ area) | 4 | 112.0 | 9.43 | 5 | 119.2 | 12.9 |
| Thickness, mm | | | | | | |
| 1st cycle | 4 | 2.78 | 0.0371 | 5 | 2.84 | 0.0310 |
| 3rd cycle | 4 | 2.73 | 0.0248 | 5 | 2.81 | 0.0274 |
| Δt | 4 | 0.049 | 0.0183 | 5 | 0.030 | 0.0056 |
| Density, $Mg/m^3$ | 5 | 0.6233 | 0.0030 | 5 | 0.6334 | 0.0045 |

Table 38. Confined-compression-set properties at 35% compression of L3223 cushions made from L60VB silicone gum and Y1587 or SE4210 processing aid, and containing 25 parts of MS7 and no HiSil 233.

| Property | Y1587 TJ175ELU | | | SE4210 TJ176EBU | | |
|---|---|---|---|---|---|---|
| | n | Av | S | n | Av | S |
| Original thickness, mm | 3 | 2.74 | 0.031 | 5 | 2.80 | 0.040 |
| Density, $Mg/m^3$ | 3 | 0.6200 | 0.0013 | 5 | 0.6302 | 0.0024 |
| Compression, % | 3 | 35.17 | 0.26 | 5 | 35.04 | 0.12 |
| Set, % | 3 | 3.69 | 0.43 | 5 | 3.21 | 0.10 |
| Recovery, % of original thickness after | | | | | | |
| 1 hr | 3 | 98.70 | 0.15 | 5 | 98.88 | 0.032 |
| 7 days | 3 | 98.74 | 0.21 | 5 | 99.21 | 0.24 |

Table 39. Load-deflection properties of L3223 cushions made from experimental MN60VB silicone gum, DR114, and Y1587 processing aid.

| Property | TJ160-IEBU | | |
|---|---|---|---|
| | n | Av | S |
| 3rd cycle load, kPa, at deflections of | | | |
| 5% | 4 | 61.5 | 4.79 |
| 10% | 4 | 123.2 | 7.78 |
| 20% | 4 | 222.5 | 15.9 |
| 30% | 4 | 362.9 | 33.8 |
| 40% | 4 | 813.8 | 128.4 |
| 3rd cycle unload, kPa, at deflections of | | | |
| 5% | 4 | 53.3 | 3.86 |
| 10% | 4 | 109.5 | 6.13 |
| 20% | 4 | 192.5 | 12.4 |
| 30% | 4 | 312.1 | 26.5 |
| 40% | 4 | 739.5 | 108.7 |
| 3rd cycle U/L at deflections of | | | |
| 10% | 4 | 0.885 | 0.0098 |
| 20% | 4 | 0.866 | 0.0080 |
| 30% | 4 | 0.861 | 0.0091 |
| 3rd cycle hysteresis loop (Δ area) | 4 | 184.1 | 18.7 |
| Thickness, mm | | | |
| 1st cycle | 4 | 2.76 | 0.0244 |
| 3rd cycle | 4 | 2.73 | 0.0279 |
| Δt | 4 | 0.0236 | 0.0043 |
| Density, $Mg/m^3$ | 5 | 0.6461 | 0.0157 |

Table 40. Confined-compression-set properties at 35% compression of L3223 cushions made from experimental MN60VB silicone gum, DR114, and Y1587 processing aid.

| Property | TJ160-IEBU | | |
|---|---|---|---|
| | n | Av | S |
| Original thickness, mm | 3 | 2.73 | 0.025 |
| Density, $Mg/m^3$ | 3 | 0.6521 | 0.0194 |
| Compression, % | 3 | 34.97 | 0.075 |
| Set, % | 3 | 3.82 | 0.54 |
| Recovery, % of original thickness after | | | |
| 2 min | 3 | 98.55 | 0.20 |
| 1 hr | 3 | 98.66 | 0.19 |
| 24 hrs | 3 | 98.91 | 0.22 |
| 7 days | 3 | 98.64 | 0.04 |
| 28 days | 3 | 98.69 | 0.17 |

**Table 41. Load-deflection properties of L3260 cushions made from L60VB cellular silicone gum and Y1587 or SE4210 processing aid.**

| Property | Y1587 Banbury Mixer TJ154EBU | | | SE4210 Haake Mixer TJ177EBU | | |
|---|---|---|---|---|---|---|
| | n | Av | S | n | Av | S |
| 3rd cycle load, kPa, at deflections of | | | | | | |
| 5% | 5 | 33.5 | 0.68 | 3 | 30.7 | 0.18 |
| 10% | 5 | 60.8 | 1.60 | 3 | 56.3 | 0.76 |
| 20% | 5 | 101.5 | 3.03 | 3 | 104.1 | 2.61 |
| 30% | 5 | 145.5 | 4.77 | 3 | 171.1 | 6.81 |
| 40% | 5 | 229.1 | 9.49 | 3 | 339.6 | 8.10 |
| 3rd cycle unload, kPa, at deflections of | | | | | | |
| 5% | 5 | 28.7 | 0.40 | 3 | 25.0 | 0.28 |
| 10% | 5 | 52.9 | 0.89 | 3 | 47.2 | 0.58 |
| 20% | 5 | 86.5 | 1.86 | 3 | 87.7 | 2.26 |
| 30% | 5 | 123.2 | 3.22 | 3 | 145.4 | 6.82 |
| 40% | 5 | 198.7 | 7.47 | 3 | 294.6 | 35.7 |
| 3rd cycle U/L at deflections of | | | | | | |
| 10% | 5 | 0.869 | 0.0076 | 3 | 0.839 | 0.0049 |
| 20% | 5 | 0.852 | 0.0062 | 3 | 0.843 | 0.0057 |
| 30% | 5 | 0.846 | 0.0083 | 3 | 0.849 | 0.0129 |
| 3rd cycle hysteresis loop (Δ area) | 5 | 112.8 | 12.8 | 2 | 127.9 | 13.3 |
| Thickness, mm | | | | | | |
| 1st cycle | 5 | 2.69 | 0.014 | 3 | 2.66 | 0.008 |
| 3rd cycle | 5 | 2.66 | 0.010 | 3 | 2.61 | 0.003 |
| Δt | 5 | 0.031 | 0.0094 | 3 | 0.047 | 0.011 |
| Density, $Mg/m^3$ | 5 | 0.5027 | 0.0026 | 5 | 0.5391 | 0.0059 |

**Table 42. Load-deflection properties of L3260 cushions made from L60VB silicone gum, Y1587 processing aid, and containing 25 parts of MS7 and no HiSil 233. The modified formulation with SE4210 could not be processed.**

| Property | Y1587 TJ173EBU | | | SE4210 TJ169EBU[a] | | |
|---|---|---|---|---|---|---|
| | n | Av | S | n | Av | S |
| 3rd cycle load, kPa, at deflections of | | | | | | |
| 5% | 5 | 30.4 | 0.67 | – | – | – |
| 10% | 5 | 56.6 | 1.15 | – | – | – |
| 20% | 5 | 87.8 | 2.17 | – | – | – |
| 30% | 5 | 119.0 | 2.78 | – | – | – |
| 40% | 5 | 179.1 | 3.95 | – | – | – |
| 3rd cycle unload, kPa, at deflections of | | | | | | |
| 5% | 5 | 28.3 | 0.68 | – | – | – |
| 10% | 5 | 52.9 | 1.19 | – | – | – |
| 20% | 5 | 79.9 | 2.01 | – | – | – |
| 30% | 5 | 106.9 | 2.55 | – | – | – |
| 40% | 5 | 162.3 | 3.83 | – | – | – |
| 3rd cycle U/L at deflections of | | | | | | |
| 10% | 5 | 0.936 | 0.0021 | – | – | – |
| 20% | 5 | 0.910 | 0.0015 | – | – | – |
| 30% | 5 | 0.898 | 0.0015 | – | – | – |
| 3rd cycle hysteresis loop (Δ area) | 5 | 60.1 | 1.87 | – | – | – |
| Thickness, mm | | | | | | |
| 1st cycle | 5 | 2.79 | 0.039 | – | – | – |
| 3rd cycle | 5 | 2.76 | 0.027 | – | – | – |
| Δt | 5 | 0.038 | 0.0170 | – | – | – |
| Density, $Mg/m^3$ | 5 | 0.4807 | 0.0037 | – | – | – |

[a] Could not be processed.

**Table 43. Confined-compression-set properties at 40% compression of L3260 cushions made from L60VB and Y1587 or SE4210 processing aid.**

| Property | 32 parts MS7, 6 parts HiSil 233 | | | | | | 25 parts MS7, no HiSil 233 | | |
|---|---|---|---|---|---|---|---|---|---|
| | SE4210 Haake Mixer TJ177EBU | | | Y1587 Banbury Mixer TJ154EBU | | | Y1587 Banbury Mixer TJ173EBU | | |
| | n | Av | S | n | Av | S | n | Av | S |
| Original thickness, mm | 4 | 2.61 | 0.014 | 3 | 2.63 | 0.020 | 3 | 2.73 | 0.051 |
| Density, $Mg/m^3$ | 4 | 0.5356 | 0.0050 | 3 | 0.5129 | 0.0182 | 3 | 0.4798 | 0.0006 |
| Compression, % | 3 | 40.09 | 0.17 | 3 | 39.99 | 0.12 | 3 | 40.23 | 0.41 |
| Set, % | 3 | 7.02 | 0.65 | 3 | 3.30 | 0.63 | 3 | 2.61 | 0.55 |
| Recovery, % of original thickness after | | | | | | | | | |
| 2 min | – | – | – | 3 | 98.33 | 0.35 | – | – | – |
| 1 hr | 3 | 97.18 | 0.27 | 3 | 98.68 | 0.25 | 3 | 98.95 | 0.23 |
| 24 hrs | – | – | – | 2 | 98.85 | – | – | – | – |
| 7 days | 3 | 97.89 | 0.24 | 3 | 98.90 | 0.05 | 3 | 99.12 | 0.13 |
| 28 days | – | – | – | 3 | 99.00 | 0.06 | – | – | – |

# Conclusions

## L1668's

The interpretation of results is aided by a tabulation of results for a specific property such as uncured hardness of L1668 after bin aging in Table 44.

For SE54 gum with 38 parts of MS7 and 6 parts of HiSil 233, Y1587 produces a softer uncured reinforced gum with higher extractables and greater weight loss on bin aging than does SE4210. Elimination of the processing aid from SE54 with 32 parts of MS7 and 6 parts of HiSil 233 greatly increases the uncured hardness and significantly reduces the weight loss on bin aging and the extractables. Since there is no excess processing aid or the by-product ethanol to be eliminated by aging or extraction, the results on weight loss and extractables are to be expected.

For type 97 gums with 32 parts MS7 and 6 parts HiSil 233, the type of processing aid has no effect on the properties of uncured L1668.

For type 60 gums with 32 parts MS7 and 6 parts HiSil 233, Y1587 produces a softer uncured gum.

For modified L97KVB and L60VB with 25 parts of MS7 and no HiSil 233, Y1587 produces a softer uncured L1668.

The type of processing aid has no profound effect on the properties of uncured reinforced gum (L1668) and the effects it does have are probably of no consequence.

## L3219's

Comparative data for extractables and the swell ratio which relates to the extent of crosslinking are shown in Table 45. Strength properties for which we have statistics are listed in Tables 46 and 47.

For SE54 gum Y1587 produces higher ultimate tensile strength and elongation than SE4210 or no processing aid. Y1587 also causes a slightly higher density and probably less hardness in the post-cured elastomer. Y1587 results in higher extractables, a higher $V/V_o$ which indicates a lesser degree of crosslinking, and a greater weight loss on post cure. In SE54 gum Y1587 produces a lower density and post-cured hardness, higher extractables and higher $V/V_o$ than no processing aid at all.

In all other gums the type of processing aid has no effect on ultimate tensile strength or post-cure hardness of both standard and modified formulations and has a variable, but probably not significant, effect on elongation. Y1587 produces a lower density in the standard formulation of all gums except SE54 and does not effect density in the modified formulations of L97KVB and L60. Y1587 causes higher extractables and higher weight loss on post cure for all gums and all formulations. Y1587 yields a higher $V/V_o$ for standard formulations of all gums, but does not effect the $V/V_o$ in L97KVB and L60 modified formulations.

**Table 44. Comparisons of the hardness, Rex O, of uncured L1668 after one month bin aging.**

| Gum | Parts by weight MS7 | Parts by weight HiSil 233 | Rex O Y1587 | Comparison | Rex O SE4210 |
|---|---|---|---|---|---|
| SE54 lot 161 | 38 | 6 | 50 | < | 60 |
| SE54 lot 167 | 38 | 6 | 41 | < | 49 |
| L97KVB | 32 | 6 | 60 | = | 61 |
| L97KVB | 32 | 6 | 60 | = | |
| L97KVB | 25 | 0 | 50 | > | 42 |
| MN97KVB | 32 | 6 | 73 | = | 76 |
| MN97KVB | 32 | 6 | 70 | = | |
| L60VB | 32 | 6 | 52 | < | 65 |
| L60VB | 32 | 6 | 53 | < | |
| L60VB | 25 | 0 | 41 | > | 31 |
| MN60VB lot DR114 | 32 | 6 | 49 | < | 59 |
| | | | Y1587 | | None |
| SE54 lot 167 | 32 | 6 | 26 | < | 50 |
| SE54 lot 167 | 32 | 6 | 30 | < | |

## Table 45. Comparison of extractables and swell ratio of cured L3219 elastomers.

| Gum | Parts by weight MS7 | Parts by weight HiSil 233 | $CHCl_3$ Extractables, wt% Y1587 | Comparison | $CHCl_3$ Extractables, wt% SE4210 | $V/V_o$ Y1587 | Comparison | $V/V_o$ SE4210 |
|---|---|---|---|---|---|---|---|---|
| SE54 lot 161 | 38 | 6 | 3.7 | ≥ | 3.4 | 3.42 | > | 3.06 |
| SE54 lot 161 | 38 | 6 | 2.2 | = | 2.2 | 2.85 | > | 2.66 |
| SE54 lot 167 | 38 | 6 | 3.05 | > | 2.27 | 3.19 | > | 2.60 |
| L97KVB | 32 | 6 | 1.16 | ≥ | 1.04 | 2.26 | > | 1.94 |
| L97KVB | 32 | 6 | 1.48 | > | | 2.34 | > | |
| L97KVB | 25 | 0 | 1.07 | > | 0.91 | 2.51 | = | 2.47 |
| MN97KVB | 32 | 6 | – | | 0.97 | 2.30 | > | 2.21 |
| MN97KVB | 32 | 6 | 1.09 | > | | 2.29 | > | |
| L60VB | 32 | 6 | 1.18 | > | 0.96 | 2.28 | ≥ | 2.25 |
| L60VB | 25 | 0 | 0.85 | ≥ | 0.78 | 2.50 | ≤ | 2.55 |
| MN60VB lot DR114 | 32 | 6 | 1.10 | > | 0.90 | 2.31 | > | 2.19 |
| | | | Y1587 | | None | Y1587 | | None |
| SE54 lot 167 | 32 | 6 | 2.8 | > | 1.97 | 3.23 | > | 2.86 |

## Table 46. Comparisons of the ultimate tensile strength of cured L3219 elastomers, kPa.

| Gum | Parts by weight MS7 | Parts by weight HiSil 233 | Y1587 n | Y1587 Av | Y1587 S | Comparison[a] | SE4210 n | SE4210 Av | SE4210 S |
|---|---|---|---|---|---|---|---|---|---|
| SE54 lot 161 | 38 | 6 | 5 | 5888 | 586 | > | 5 | 4137 | 186 |
| SE54 lot 161 | 38 | 6 | 5 | 5599 | 745 | = | 5 | 5123 | 358 |
| SE54 lot 167 | 38 | 6 | 5 | 6346 | 402 | > | 5 | 5668 | 221 |
| L97KVB | 32 | 6 | 5 | 3179 | 207 | = | 5 | 3509 | 221 |
| L97KVB | 32 | 6 | 5 | 3516 | 359 | = | | | |
| L97KVB | 25 | 0 | 5 | 1717 | 193 | = | 5 | 1641 | 117 |
| MN97KVB | 32 | 6 | 5 | 3082 | 200 | = | 5 | 3206 | 379 |
| MN97KVB | 32 | 6 | 5 | 2903 | 186 | = | | | |
| L60VB | 32 | 6 | 5 | 3144 | 496 | = | 5 | 2834 | 317 |
| L60VB | 25 | 0 | 5 | 1434 | 110 | = | 5 | 1413 | 90 |
| MN60VB | 32 | 6 | 5 | 1987 | 97 | = | 5 | 2110 | 255 |
| | | | Y1587 | | | | None | | |
| SE54 lot 167 | 32 | 6 | 5 | 6736 | 228 | > | 3 | 5688 | 103 |

[a] By Student's t test.

## Table 47. Comparisons of the ultimate elongation of cured L3219 elastomers, %.

| Gum | Parts by weight MS7 | Parts by weight HiSil 233 | Y1587 n | Y1587 Av | Y1587 S | Comparison[a] | SE4210 n | SE4210 Av | SE4210 S |
|---|---|---|---|---|---|---|---|---|---|
| SE54 lot 161 | 38 | 6 | 5 | 376 | 31 | > | 5 | 278 | 13 |
| SE54 lot 161 | 38 | 6 | 5 | 212 | 27 | = | 5 | 178 | 15 |
| SE54 lot 167 | 38 | 6 | 5 | 360 | 16 | > | 5 | 226 | 9 |
| L97KVB | 32 | 6 | 5 | 90 | 10 | > | 5 | 60 | 7 |
| L97KVB | 32 | 6 | 5 | 74 | 2 | > | | | |
| L97KVB | 25 | 0 | 5 | 70 | 10 | = | 5 | 66 | 5 |
| MN97KVB | 32 | 6 | 5 | 80 | 10 | = | 5 | 70 | 7 |
| MN97KVB | 32 | 6 | 5 | 76 | 5 | = | | | |
| L60VB | 32 | 6 | 5 | 52 | 11 | < | 5 | 74 | 4 |
| L60VB | 25 | 0 | 5 | 58 | 5 | < | 5 | 68 | 4 |
| MN60VB | 32 | 6 | 5 | 62 | 4 | > | 5 | 46 | 5 |
| | | | Y1587 | | | | None | | |
| SE54 lot 167 | 32 | 6 | 5 | 416 | 11 | > | 3 | 213 | 6 |

[a] By Student's t test.

Except for the effect on tensile strength and elongation of cured L3219's from SE54, the type of processing aid has no significant effect on the properties of cured L3219's from a variety of silicone gums.

## L3223's

For cushion use, the most significant property of the material is its load-bearing capacity as indicated by its load-deflection curve. Retention of load with time is also of great importance but we cannot test for this conveniently. We do test for short-term, elevated-temperature compression set and use the percentage of set as a measure of the worth of cushion materials (i.e., lower set is better). We also measure density and thickness of cushions because load is a function of density and at lower densities it is also a function of thickness. Comparative data for density are shown in Table 48. Compression set data are listed in Table 49. Various data on load-deflection are shown in Tables 50, 51, 52, 53, and 54.

Y1587 may produce a lower density in type 97 and type 60 gums but the difference is small and not significant.

Type of processing aid has no effect on the compression set of L3223's from any silicone gum. Elimination of the processing aid reduces set in SE54 gum.

The major definition of L3223's is the load and unload-deflection properties. These values at 30% deflections are compared in Tables 50 and 51. For all gums, Y1587 produces a distinctly softer cushion. The effect is reduced for the modified formulations. Y1587 also produced a softer cushion than no processing aid at all.

Another property of cushion that may be important is the resiliency of the material. We consider the ratio of the unload values to the load values at the same deflection and the hysteresis in the 3rd cycle unload and load curves as measures of resiliency and show the data for these in Tables 52 and 53; we assume that they both measure the same characteristic of the material. For SE54, Y1587 produces a more resilient cushion. For type 97 and type 60 gums, the type of processing aid has little or no effect. Removal of the processing aid increases resiliency. The correlation of the U/L ratio to the hysteresis loop is not at all clear.

The shift in starting thickness of L3223 from the first to third load cycle is being monitored to see if it is a useful indicator of cushion value. The data are shown in Table 54. The type or amount of processing aid has no apparent effect on $\Delta t$.

The major effect of the type of processing aid on L3223 cellular silicone is that Y1587 produces a significantly softer cushion than SE4210.

## L3260's

Interest had shifted from L3223's to lower density cushions so we began to collect information on L3260's which is shown in Table 55. The data are complicated by a switch from the Banbury mixer to the Haake mixer. This variable is not considered significant except perhaps for its effect on density as shown in the table; the Haake mixer may produce a lower density than the Banbury. Again Y1587 produces a softer cushion than SE4210 but the difference is not so pronounced as it is with L3223. Y1587 does produce considerably less set than SE4210; this effect had not been observed with the higher density L3223.

**Table 48. Comparisons of the density of the load-deflection disks of L3223 cellular silicone, $Mg/m^3$.**

| | Parts by weight | | Y1587 | | | | SE4210 | | |
|---|---|---|---|---|---|---|---|---|---|
| Gum | MS7 | HiSil 233 | n | Av | S | Comparison[a] | n | Av | S |
| SE54 lot 167 | 38 | 6 | 5 | 0.6541 | 0.0038 | > | 5 | 0.6477 | 0.0048 |
| L97KVB | 32 | 6 | 5 | 0.6559 | 0.0006 | = | 5 | 0.6573 | 0.0021 |
| L97KVB | 32 | 6 | 5 | 0.651 | 0.005 | < | | | |
| L97KVB | 25 | 0 | 5 | 0.6424 | 0.0068 | = | 5 | 0.6449 | 0.0033 |
| MN97KVB | 32 | 6 | 5 | 0.6565 | 0.0016 | < | 5 | 0.6721 | 0.0018 |
| L60VB | 32 | 6 | 5 | 0.6466 | 0.0020 | < | 5 | 0.6812 | 0.0038 |
| L60VB | 25 | 0 | 5 | 0.6233 | 0.0030 | < | 5 | 0.6334 | 0.0045 |
| | | | Y1587 | | | | None | | |
| SE54 lot 167 | 32 | 6 | 5 | 0.6687 | 0.0015 | = | 4 | 0.6625 | 0.0037 |
| SE54 lot 167 | 32 | 6 | 4 | 0.660 | 0.011 | = | | | |

[a] By Student's t test.

**Table 49. Comparisons of the confined-compression set of L3223 cellular silicones, %.**

| | Parts by weight | | Y1587 | | | | SE4210 | | |
|---|---|---|---|---|---|---|---|---|---|
| Gum | MS7 | HiSil 233 | n | Av | S | Comparison[a] | n | Av | S |
| SE54 lot 167 | 38 | 6 | 4 | 10.85 | 1.54 | = | 4 | 10.55 | 0.49 |
| L97KVB | 32 | 6 | 3 | 5.66 | 0.38 | = | 3 | 6.46 | 0.22 |
| L97KVB | 32 | 6 | 3 | 5.53 | 0.44 | = | | | |
| L97KVB | 25 | 0 | 3 | 5.85 | 0.83 | = | 3 | 5.29 | 0.59 |
| MN97KVB | 32 | 6 | 3 | 5.91 | 0.70 | = | 3 | 5.61 | 0.64 |
| L60VB | 32 | 6 | 3 | 3.84 | 0.29 | < | 3 | 6.97 | 0.33 |
| L60VB | 25 | 0 | 3 | 3.69 | 0.43 | = | 5 | 3.21 | 0.10 |
| | | | Y1587 | | | | None | | |
| SE54 lot 167 | 32 | 6 | 3 | 10.38 | 0.58 | > | 4 | 4.99 | 0.65 |

[a] By Student's t test.

**Table 50. Comparisons of the 3rd cycle load at 30% deflection of L3223 cellular silicone, kPa.**

| | Parts by weight | | Y1587 | | | | SE4210 | | |
|---|---|---|---|---|---|---|---|---|---|
| Gum | MS7 | HiSil 233 | n | Av | S | Comparison[a] | n | Av | S |
| SE54 lot 167 | 38 | 6 | 5 | 200.0 | 6.39 | < | 4 | 372.2 | 9.26 |
| L97KVB | 32 | 6 | 4 | 417.6 | 5.82 | < | 4 | 590.2 | 24.3 |
| L97KVB | 32 | 6 | 5 | 378.0 | 5.06 | < | | | |
| L97KVB | 25 | 0 | 3 | 292.8 | 11.6 | < | 4 | 327.9 | 6.45 |
| MN97KVB | 32 | 6 | 5 | 344.6 | 1.84 | < | 3 | 520.6 | 8.53 |
| L60VB | 32 | 6 | 5 | 329.8 | 17.7 | < | 3 | 485.6 | 35.3 |
| L60VB | 25 | 0 | 4 | 282.2 | 6.83 | < | 5 | 311.6 | 12.4 |
| | | | Y1587 | | | | None | | |
| SE54 lot 167 | 32 | 6 | 5 | 198.4 | 2.98 | < | 3 | 239.1 | 2.23 |
| SE54 lot 167 | 32 | 6 | 3 | 180.1 | 1.29 | < | | | |

[a] By Student's t test.

**Table 51. Comparisons of the 3rd cycle unload at 30% deflection of L3223 cellular silicone, kPa.**

| | Parts by weight | | Y1587 | | | | SE4210 | | |
|---|---|---|---|---|---|---|---|---|---|
| Gum | MS7 | HiSil 233 | n | Av | S | Comparison[a] | n | Av | S |
| SE54 lot 167 | 38 | 6 | 5 | 153.4 | 3.76 | < | 4 | 234.8 | 7.37 |
| L97KVB | 32 | 6 | 4 | 333.7 | 6.16 | < | 4 | 460.9 | 20.6 |
| L97KVB | 32 | 6 | 5 | 300.6 | 0.89 | < | | | |
| L97KVB | 25 | 0 | 3 | 244.7 | 7.26 | < | 4 | 275.6 | 5.47 |
| MN97KVB | 32 | 6 | 5 | 274.8 | 2.14 | < | 3 | 416.3 | 7.64 |
| L60VB | 32 | 6 | 5 | 176.2 | 9.39 | < | 3 | 219.1 | 2.03 |
| L60VB | 25 | 0 | 4 | 251.6 | 5.33 | < | 5 | 279.2 | 3.76 |
| | | | Y1587 | | | | None | | |
| SE54 lot 167 | 32 | 6 | 5 | 141.8 | 1.86 | < | 3 | 178.7 | 1.63 |
| SE54 lot 167 | 32 | 6 | 3 | 127.2 | 5.82 | < | | | |

[a] By Student's t test.

**Table 52. Comparisons of the 3rd cycle unload-to-load ratio at 30% deflection of L3223 cellular silicones.**

| Gum | Parts by weight MS7 | Parts by weight HiSil 233 | Y1587 n | Y1587 Av | Y1587 S | Comparison[a] | SE4210 n | SE4210 Av | SE4210 S |
|---|---|---|---|---|---|---|---|---|---|
| SE54 lot 167 | 38 | 6 | 5 | 0.767 | 0.0087 | > | 4 | 0.718 | 0.0026 |
| L97KVB | 32 | 6 | 4 | 0.799 | 0.0035 | > | 4 | 0.781 | 0.0032 |
| L97KVB | 32 | 6 | 5 | 0.795 | 0.0040 | > | | | |
| L97KVB | 25 | 0 | 3 | 0.835 | 0.0084 | = | 4 | 0.841 | 0.0010 |
| MN97KVB | 32 | 6 | 5 | 0.797 | 0.0044 | = | 3 | 0.800 | 0.0028 |
| L60VB | 32 | 6 | 5 | 0.835 | 0.0026 | = | 3 | 0.832 | 0.0041 |
| L60VB | 25 | 0 | 4 | 0.891 | 0.0031 | = | 5 | 0.896 | 0.0039 |
| | | | Y1587 | | | | None | | |
| SE54 lot 167 | 32 | 6 | 5 | 0.715 | 0.0025 | < | 3 | 0.748 | 0.0021 |
| SE54 lot 167 | 32 | 6 | 3 | 0.707 | 0.0196 | < | | | |

[a] By Student's t test.

**Table 53. Comparisons of the 3rd cycle hysteresis loop of L3223 cellular silicones.**

| Gum | Parts by weight MS7 | Parts by weight HiSil 233 | Y1587 n | Y1587 Av | Y1587 S | Comparison[a] | SE4210 n | SE4210 Av | SE4210 S |
|---|---|---|---|---|---|---|---|---|---|
| SE54 lot 167 | 38 | 6 | 5 | 170.5 | 46.1 | < | 4 | 367.0 | 12.7 |
| L97KVB | 32 | 6 | 4 | 314.1 | 43.3 | < | 4 | 424.7 | 16.3 |
| L97KVB | 32 | 6 | 5 | 285.2 | 15.6 | < | | | |
| L97KVB | 25 | 0 | 3 | 200.0 | 31.0 | = | 4 | 201.1 | 9.82 |
| MN97KVB | 32 | 6 | 5 | 273.4 | 18.6 | < | 3 | 346.4 | 5.80 |
| L60VB | 32 | 6 | 5 | 198.1 | 13.8 | < | 3 | 243.1 | 24.2 |
| L60VB | 25 | 0 | 4 | 112.0 | 9.43 | = | 5 | 119.2 | 12.9 |
| | | | Y1587 | | | | None | | |
| SE54 lot 167 | 32 | 6 | 5 | 221.0 | 10.7 | = | 3 | 232.9 | 12.8 |
| SE54 lot 167 | 32 | 6 | 3 | 201.5 | 26.2 | = | | | |

[a] By Student's t test.

**Table 54. Comparisons of the difference between 1st cycle and 3rd cycle starting thicknesses of L3223 cellular silicones, mm.**

| Gum | Parts by weight MS7 | Parts by weight HiSil 233 | Y1587 n | Y1587 Av | Y1587 S | Comparison[a] | SE4210 n | SE4210 Av | SE4210 S |
|---|---|---|---|---|---|---|---|---|---|
| SE54 lot 167 | 38 | 6 | 5 | 0.047 | 0.0040 | < | 4 | 0.072 | 0.0096 |
| L97KVB | 32 | 6 | 4 | 0.047 | 0.0086 | < | 4 | 0.069 | 0.0066 |
| L97KVB | 32 | 6 | 5 | 0.058 | 0.0168 | = | | | |
| L97KVB | 25 | 0 | 3 | 0.028 | 0.026 | = | 4 | 0.028 | 0.0021 |
| MN97KVB | 32 | 6 | 5 | 0.031 | 0.015 | = | 3 | 0.053 | 0.0022 |
| L60VB | 32 | 6 | 5 | 0.041 | 0.0061 | = | 3 | 0.044 | 0.0109 |
| L60VB | 25 | 0 | 4 | 0.049 | 0.0183 | = | 5 | 0.030 | 0.0056 |
| | | | Y1587 | | | | None | | |
| SE54 lot 167 | 32 | 6 | 5 | 0.067 | 0.0034 | < | 3 | 0.088 | 0.0032 |
| SE54 lot 167 | 32 | 6 | 3 | 0.101 | 0.0104 | = | | | |

[a] By Student's t test.

**Table 55. Comparisons of the properties of L3260 cellular silicones from MN97KVB and L60VB silicone gums.**

| | MN97KVB | | | | | | | L60VB | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Y1587 LLNL Urea Banbury Mixer | | | | SE4210 BKC Urea Haake Mixer | | | Y1587 BKC Urea Banbury Mixer | | | | SE4210 BKC Urea Haake Mixer | | |
| | n | Av | S | Comparison[a] | n | Av | S | n | Av | S | Comparison[a] | n | Av | S |
| Density of L/D disks, $Mg/m^3$ | 5 | 0.5226 | 0.0052 | < | 5 | 0.5507 | 0.0048 | 5 | 0.5027 | 0.0026 | < | 5 | 0.5391 | 0.0059 |
| 3rd cycle | | | | | | | | | | | | | | |
| Load at 30% deflection, kPa | 5 | 161.1 | 4.88 | < | 5 | 202.4 | 11.7 | 5 | 145.5 | 4.77 | < | 3 | 171.1 | 6.81 |
| Unload at 30% deflection, kPa | 4 | 134.3 | 4.85 | < | 4 | 159.2 | 1.59 | 5 | 123.2 | 3.22 | < | 3 | 145.4 | 6.82 |
| Unload/load ratio at 30% deflection | 4 | 0.832 | 0.0022 | > | 4 | 0.787 | 0.0026 | 5 | 0.846 | 0.0083 | = | 3 | 0.849 | 0.0129 |
| Hysteresis loop (Δ area) | 4 | 127.6 | 9.52 | < | 4 | 220.0 | 11.0 | 5 | 112.8 | 12.8 | = | 2 | 127.9 | 13.3 |
| Δt, mm | 4 | 0.033 | 0.0036 | = | 4 | 0.055 | 0.017 | 5 | 0.031 | 0.0094 | = | 3 | 0.047 | 0.011 |
| Set, % | 3 | 4.59 | 0.68 | < | 3 | 7.29 | 0.65 | 3 | 3.30 | 0.63 | < | 3 | 7.02 | 0.65 |

[a] By Student's t test.

The major effect of the type of processing aid on L3260 cellular silicone is that Y1587 produces a significantly lower compression set than SE4210. Also Y1587 produces a slightly softer cushion than SE4210.

## Summary

We have evaluated two processing aids; UCC's Y1587 and GE's SE4210 in different silicone gums: GE's SE54, type 97 gums (L97KVB and MN97KVB), and type 60 gums (L60VB and MN60VB). We tested uncured L1668 reinforced gums, cured L3219 elastomers, and L3223 and L3260 cellular silicones.

The type of reinforcing aid has no significant effect on uncured L1668. In L3219 from SE54, Y1587 produces higher ultimate tensile strength and elongation than does SE4210. For all the other silicone gums, the type of processing aid has no effect on the properties of cured L3219 elastomer.

For L3223 cellular silicone, Y1587 produces a significantly softer cushion for all gums. Type of processing aid has no effect on the compression set of L3223. For L3260 cellular silicone, Y1587 produced a slightly softer cushion for all gums and it results in significantly lower compression set in type 97 and type 60 gums.

If compression set is not a primary concern or if cushion density is high, the choice of a processing aid can be used to control cushion stiffness along with vinyl content of the gum, amount of reinforcing $SiO_2$ in the L1668 gum, and the porosity of the cellular silicone.

Y1587 is the preferred processing aid for all silicone gums, and it is important that it be used in the new type 97KVB and 60VB gums.

## Recommendations

In the new silicone gums of types 97KVB and 60VB, UCC's Y1587 processing aid produces a softer cushion than does GE's SE4210. This softening effect decreases as cushion density decreases (porosity increases). The type of processing aid has no effect on the compression set of the higher density L3223. For lower density L3260 cushions, Y1587 produces a significantly lower compression set than does SE4210. Our experience with difficult-to-process type 60 gums indicates that Y1587 is more versatile in accommodating to unknown gum variables than SE4210. For these new gums, the Y1587 processing aid should be used.

Although data for GE's SE54 silicone gum is less complete and less conclusive, we recommend that Y1587 be used with SE54 also.

If compression set is not a big consideration, or if cushion density is high, type of processing aid can be used as a tool to manipulate load properties of a cushion along with the amount of reinforcing $SiO_2$, vinyl content and porosity.

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