

# Long Term, In-Vehicle Polyurethane Seating Durability Performance

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## **ABSTRACT**

Many millions of road vehicles are built each year in assembly plants around the world. Into every vehicle, new seats containing molded, polyurethane foam parts are installed. These seats are expected and have been found to perform well over the lifetime of a vehicle. Exceptionally, seats have been known to cause problems in service and in many cases these problems are attributed to the molded foam pads inside the seats. Extensive investigations of “failed” seats have found that seat design or misuse is the cause of these complaints. For instance, cushions designed with unsuitable components, e.g. wires with unprotected ends, or a mismatch between the foam pad and the supporting seat frames or pans has been found to cause seat problems/failures. In the vast majority of cases, seats are still intact and functional when the vehicle is removed from the road and sent to a recycling (formerly junkyard) facilities. The purpose of this paper is to demonstrate that seating foam removed from expired vehicles retains both its dimensional integrity and that it has essentially the same properties as when it was produced.

## **Foam Properties of Pads from Recycling Yards**

In this study foam removed from vehicles prior to vehicle shredding, will be considered. Several papers have discussed and reported on the recovery of foam from shredder residues. An excellent summary of the status of ASR foam recovery was reported by Mark and Kamprath<sup>(1)</sup>.

One of the authors of this paper (GRB) was part of a team that examined and tested foam pads from seats removed from recycling yards. In order to establish if there was any difference in the residual quality of foam parts stored in yards exposed to different climatic conditions, seats were removed from vehicles in Ontario, West Virginia and Texas(2) and the foam properties were tested in an ISO17025 accredited testing laboratory in Woodbridge, Ontario ([www.P3Tlab.com](http://www.P3Tlab.com)).

The odometer reading (if available) for each vehicle under study was recorded as was the exposure conditions. For example, most vehicle interiors were completely open to the atmosphere and so foam appearance, discoloration, trim creasing and foam tears and friability were noted. Most molded pads were rated “fair-to-good” in appearance but some parts from Texas had friable or dusty surfaces especially where the foam had been exposed to direct sunlight due to cover ripping, or partial seat disassembly.

Part hardnesses were checked and the values obtained (IFD or IRGL) were compared with the original hardness specifications to which the parts had been targeted. Most parts still met the specification hardnesses but a few were slightly over specification maximum. Some recovered seats and newly-molded ones were evaluated by a seating group but they could not tell which seats were made with old or new foam parts! In most cases the degree-of-support and the “comfort” rating for seats with old or new parts was quite similar.

Most of the vehicles examined in this study had been scrapped-out after high usage, i.e. up to 326K km but some parts from vehicle wrecks had only several thousand kilometers of usage, e.g. 60K km, (2).

The majority of the parts evaluated had core densities of 26-44 kg/m<sup>3</sup>, Table 1. In general, all pads exceeded tensile strength/elongation specifications, passed tear strength and most foams met compression sets, especially after humid aging. None of the set failures were drastic and might be attributed to the influence of atmospheric oxidation of the exposed foam. Some parts were tested for accelerated durability compliance (roller shear as called for by Ford when the parts were produced) and the foam met specification requirements, Table 2. Other parts were subjected to the Urethane Foam Dynamic Fatigue durability test and all pads had quite acceptable performance rating indicating that the foam was still quite durable as predicted by this test, Table 3.

Many parts were subjected to the FMVSS302 flammability test and most were rated SE or SE/NBR in that test. A few parts had burn rates but still satisfied the FMVSS302 maximum burn rate of less than 100mm/min. The foam that burnt came from parts collected in Texas and, as already noted, these had crumbly surfaces; it is well-known that particulates present on flammability test specimens aggravate burn rates. A summary of some of the results obtained is found in Table 1.

From this study, it was concluded that these post-consumer pads from various climatic regions of North America, had maintained their design intent and almost all foam physical properties were retained. Only parts exposed to aggressive storage conditions, e.g. in Texas, exhibit some compression set problems and they had some, but acceptable, burn ratings in the FMVSS302 test, due to the degradation of their surfaces and the presence of dust particles.

Although these parts had acceptable foam properties, it was not possible to correlate foam performance with vehicle odometer readings. It was concluded that the problem was the unknown history of recycling yard vehicles, the absence of occupant weight(s) and driving style(s) and the poor storage conditions, ripped covers, etc. Based on these uncertainties, a more controlled in-vehicle program was initiated and pursued for more than five years of testing.

### **Police Vehicle Durability Study**

Since the data emanating from this study has already been published (3, 4, 5 ), only a brief summary is included here.

Various types of foam and competitive materials were installed in several 1993 Chevrolet Caprice police vehicles. Cushions were manufactured specifically for this evaluation, mostly of various types of PU foam over a range of foam densities. Parts were molded using various isocyanate types (TDI, MDI, etc) and recycled polyols were included in some formulations. Competitive cushioning made with natural or synthetic fibres were included in the study but they did not perform well.

Compete seats (fully trimmed and installed on their frames) were thoroughly evaluated before installation in active vehicles. After several weeks, these seats were removed from the vehicles and a replacement seat installed ready for vehicle re-use an hour or so later. The removed seats were re-evaluated in the laboratory for height and hardness change and any seat creep was noted. After a rest period, seats would be cycled back into the test vehicles until a sufficient number of usage hours for that seat had been achieved. Usually seats were cycled in-and-out till a period of “one vehicle lifetime”, as per the automotive industry, had been achieved. Exceptionally, a seat would be used for up to a period of five years of cycled usage. Only non-urethane seating exhibited failures and had to be rapidly removed from the test vehicles.

After each final in-vehicle cycle, the foam cushioning was extracted from the seats, examined and subjected to physical property determination. A summary of a portion of the data obtained is found in Table 4. There the data shows that foam from (a) as-produced (freshly molded but properly conditioned); (b) one-year fleet-used and (c) stored (without any usage) cushions had essentially the same foam properties. Thus we concluded that good quality PU cushions could all be used for at least one vehicle lifetime of use without property degradation. Cushions with even longer usage lifetimes also had excellent properties and the seats were gauged to be comfortable (in a seat rating study administered to the police officers before and after each seat cycle) and seat durability, e.g. H-point, was maintained throughout usage.

However, since seats and foam types were cycled in-and-out of the vehicles with periods of rest between each usage cycle, we realized that at best, this fleet study could only be considered as a “foam rating test” useful for determining/rating various types of foam cushioning and eliminating either poorly rating PU formulations or other padding materials. Therefore, we accepted the donation of two expired vehicles whose driving histories were at least partially known.

### **Discarded Vehicle Seating Observations**

#### **a) General Motors Chevrolet Lumina**

This vehicle, a 1994 Chevrolet Lumina was discarded recently since it was considered uneconomical to repair its engine. The last owner, a member of the MFIP ([www.moldedfoam-IP.org](http://www.moldedfoam-IP.org)) had owned the vehicle for almost three years and added 119,000 km (74,000 miles) on the odometer. The total odometer reading was 310,054 km (192,700 miles). Based on his comments, this owner drove quite conservatively and certainly did not participate in drag racing. Prior to that, the sedan was owned by a lady considered to drive relatively docilely and she owned the vehicle for at least 30,000 km (20,000 miles). So for about half of the distance travelled by this vehicle it can be considered to have been driven conservatively and hence the seats were probably not subjected to highly-stressed maneuvers! Certainly this car was not scrapped because of any complaints/problems with its seating. The complete seat packages (front and rear assemblies) were unbolted from the interior and the seats were torn down in The Woodbridge Group’s Comfort Laboratory ([mark\\_weierstall@woodbridgegroup.com](mailto:mark_weierstall@woodbridgegroup.com)). Several MFIP members witnessed this disassembly operation. The front seat package consisted of driver and passenger bucket seats with both seats having encapsulated frames in the backs. The rear seat set consisted of a bench cushion and bench back. Date stamps on the parts indicated that the foam parts had been poured in November 1993.

In order to obtain or separate the foam from the coverstock, the latter had to be pulled away from the foam since cover/foam had been bonded together in the assembly process. Thus considerable amounts of foam were lost due to adherence to the covers. The molded cushion was surprisingly quite thin, i.e. 20-25mm thick in the seating area but padded with a 14mm thick laminated coverstock. There was a slight tear in the harder bolster of the back part and similarly a tear on the cushion outboard bolster from

wear and use (ingress/egress). Interestingly, there was a cigarette burn through the cushion trim cover on the inboard side but burning had stopped at the molded foam pad, indicating that the PU formulation that had been used was able to resist cigarette burning.

The rear seat package consisted of the same trim cover package as the front seat combination. Once again, there was a cigarette burn hole through the cushion cover and the laminate foam but burn penetration had stopped at the molded foam skin.

### **Foam Pad Physicals**

Each foam pad was tested separately at the P3T Lab. Since these parts had been produced to meet the now obsolete GM 6293M foam specification, we have evaluated each pad against that specification. In addition, a few additional tests have been done that appear in the newer GMW 15471 specification that was issued in 2008 with assistance from the MFIP. These latter results will be considered separately.

The physical properties found for each of the six parts are shown in Tables 5A, B & C. Also shown in this table are the foam requirements for the three classes (B, C & D) of foam grades listed in GM 6293M. The results may be conveniently divided into cushions (Table 5A) and backs (Table 5B).

In Table 5A, the front seat cushions have core densities of 34.5 and 39.2 kg/m<sup>3</sup> for driver and passenger cushions respectively. Strictly speaking, this would put these cushions in the Class C foam category but it is probable that Class B is the correct class for these parts. Comparing the properties of these cushions against Class B limits, all requirements are met. The rear cushion has a much lower core density at 29.1 kg/m<sup>3</sup> and thus its properties should be compared with Class D foam requirements. This foam easily passes all the requirements of Class D and in fact it meets Class C requirements as well. Apart from a low elongation value and marginally high compression sets, this rear cushion foam does well even when compared with Class B requirements.

In Table 5B, the three back foams can be compared against Class C foam (driver/passenger backs) and Class D foam (rear back). The front seat backs just pass or fail (80%) the Class C elongation requirement of 100% minimum. Also both of these backs have problems meeting the compression set requirements of Class C foam especially at 50% compression. However, both easily meet the set requirements after humid aging. The rear back part easily meets Class D foam requirements and even Class B foam limits as well, even at a core density below 30 kg/m<sup>3</sup>.

All six foam parts satisfy the FMVSS 302 flammability requirements, and also the GM 9070P stricter requirements with one exception, where the maximum burn rate allowed is 63.5 mm/min. Actually these foams had burn rates that were mostly rated SE or SE/NBR, Table 6.

Similarly, all parts pass the GM 9305P fogging requirement as the fogging plates were all clear.

### **Additional Foam Testing**

These parts were additionally subjected to two other foam tests that are contained in the GMW 15471 specification. In this relatively new foam specification, both dry and humid aged compression set requirements are replaced with the more functional Wet Compression Set. Foam specimens are compressed and aged in a chamber held at 50°C/95% RH for 22 hours and any residual set is determined after 30 minutes release from the compressed state. The values found for all six foam parts are shown in Table 5C. When these results are compared against the GM 15471 Type IV requirement of 25% set maximum, two out of the three backs exceed 25% maximum but the passenger back had a surprisingly low set of just 9%. Since it is probable that the driver and passenger back parts were made using the same chemical formulation in production, we are at a loss to explain the large difference between the Wet Sets for the two front backs which have almost the same core densities.

The second property determined in the GMW 15471 spec. is the Die C tear resistance (as opposed to the trouser leg tear called for in GM 6293M). All six Die C tear resistance values greatly exceed the Type IV foam requirement of 450N/m.

### **b. Ford Crown Victoria LTD**

A Second scrapped vehicle with a known driving history was donated by another member of the MFIP. This vehicle was a 1986 Ford Crown Victoria LTD which at the time when the seats were extracted was twenty-four years old but only had 86,656 miles (1389,650 km) registered on the odometer. Thus the seating package can be classified as low usage but well-aged. The drivers who used this vehicle weighed about 136 kg (300 lbs) but the passengers weighed only 50-60 kg (110-130 lbs). The complete seats were in excellent visual condition without any rips or any signs of permanent deformation such as cover sag or staining. In fact, these seats looked as good as originally built almost a quarter of a century previously.

The foam pads were easily removed from their covers and frames. Front seat cushion covers were held in place using plastic J-retainers and a few hog rings. The front backs were hooded and fitted over their respective frames and the covers hog-ringed in place. The rear seat package consisted of a bench cushion and back with the covers hog-ringed to the supporting frames. Both of these parts had metal frames foamed in place.

Examination of the foam pads indicated that three different foam molders had produced these parts. The front seat cushions were made of high resiliency (HR) foam but the front backs were hot molded foam. The rear pads were both HR foam, molded in a captive OEM plant.

Both front cushions were in good visual shape with only minor rips caused by the sharp edges of the frame support cutting into the pad B surface which was unprotected. We also observed that where the underlying spring support assembly had come into contact with a sharp frame edge, that a paper wire spacer (used to maintain the correct spacing distances for the spring support wires) had been sheared apart by the steel support. As far as the pads are concerned, the foam showed permanent deformation where the cover selvedge and the spring support springs had bit into the foam during use.

The hot foam backs were in much poorer condition. Both of the hoods at the top of each part had deep cuts/rips so much so that the hoods were almost separated from the lower portion of the pad. Other areas of these pads exhibited rips/cuts due to the frames cutting into the foam which was unprotected (e.g. with cloth)

The rear pads showed virtually no damage and since both parts had integral frames, no frame rips were found. The rear back exhibited much repairing. Seven areas had been patched by removing unacceptable foam from these areas by cutting and filling with freshly-poured foam right into the resultant holes. After curing, this MDI-based repair foam was trimmed so that the repair patches were flush with the pad “A” surface. During use, these patches remained intact and showed less discoloration (yellowing/browning) than the original, most probably, TDI-based HR foam.

Historical records indicated that the HR foam front seat cushions had been manufactured to pass the Ford foam spec. ESB-M2D221C and the corresponding hot foam backs to meet the ESB-4D113-D spec. The rear parts may have had to pass the ESB-M2D221B spec but in this study we will compare our results to the 221C spec requirements. Since no records are available for the rear parts, or the front seat backs, only the front cushion on the driver’s side has been checked for hardness.

		Original Hardness Specification, mm	
Passenger Cushion:	Thickness	104.3 mm	102-108
IRGL	@ 111 N	84.0 mm	75-85
IRGL	@ 222 N	56.1 mm	49-57

These hardness results indicate that this cushion had maintained its original specification hardnesses for thickness and IRGL values.

**Foam Pad Physicals**

Results are found in Table 7. The front cushions had densities of 30.4 and 31.9 kg/m<sup>3</sup> within the density range called for in Ford ESB-M2D221C spec (221C) of 27-43 kg/m<sup>3</sup>. The corresponding front backs had densities of 26.6 and 21.1 kg/m<sup>3</sup> for the driver and passenger parts respectively. Such low core densities were normal with hot foam chemistry, although at 21 kg/m<sup>3</sup>, this is the lowest density that one of the authors (GRB) has ever found for a molded auto part! The rear parts (HR foam) had densities of 34.1 and 37.2 kg/m<sup>3</sup> for the cushion and back parts. Normally back parts have lower densities than cushions but it is suspected that the mold had problems producing the large thin part with its integral metal frame. This is confirmed by the presence of so many repair patches as indicated before.

All of these parts had tensile strengths and elongations well in excess of the minimum values called for in the Ford specs 221C or 113C. Tear strength resistance measured using the trouser leg type specimen are all very high and meet both Ford specs. Both the elongation and tear strength values for the hot foam backs are considerably higher than for the HR foam parts. This was expected as hot foam chemistry is known to produce foam with excellent elongation and tear values.

In Table 7, the FMVSS302 flammability ratings are included. The numbers in brackets, e.g. (3x), indicate the number of specimens with that rating and foams that were self-extinguishing (SE) or self-extinguishing/burn (SE/B). Both front cushions had zero burns whereas the hot foam backs both had complete burns between 45 and 79 mm/min. The rear parts (HR foam) showed a mixture of non-burns (SE or SE/NBR) and either partial (SE/B) or complete burns (B) with burn rates between 45 and 58 mm/min. All of these parts still satisfy the Ford burn rate criteria. The 221C and the older Ford hot foam spec. (113C) called for dry and humid aged compression sets of 20% (221C) or 25/30% (113C) max and 30 or 25/30% max respectively. All of the HR parts (front cushions, rear cushion and back) easily pass the 221C requirements for both dry and humid aged sets. The front backs also perform well although the passenger back with a 29% HACS is near the 113C spec limit. This may be due to this part having such a low density but it may be noted that both hot parts have higher sets than the HR foam parts and this is contrary to that normally found for hot foam parts.

In addition to measuring most of the foam properties called for in the now-obsolete Ford specs (221C, 113C), we checked these parts for wet compression set and Die C tear resistance (two properties regarded as indicating the functionality of automotive foams). The wet sets were all quite high, i.e. 20-31%. Surprisingly, the hot foam backs have as poor sets as the HR foam parts

but this is almost certainly due to their low densities since it is well-known that wet sets are dependent on foam densities, i.e. lower foam densities have higher set values. The wet sets for all six Ford parts are indeed high and yet as indicated earlier, these seats performance well during the vehicle lifetime.

The tear resistance as measured using Die C-type specimens product very high values easily meeting our MFIP spec minimum value of 450 N/m. Note that, as expected, the hot foam parts, although they are quite low in density, have the highest tear resistances and this can be attributed to the type of polyurethane structure that results from hot foam chemistry.

### **Summary and Conclusions**

With a few exceptions the foam parts extracted from the 1992 Chevrolet Lumina pass the GM 6293M specification requirements including flammability. This indicates that in addition to the parts still looking and behaving well in the vehicle up to the date of scrapping, the foam had held up very well. It is probable that the foam properties have not degraded at all or only marginally since being manufactured in 1993. The burn holes through the seats/laminate foam, but resistance to any burn penetration into the molded foam buns indicates that the inherent flammability resistance of these high resiliency foams serves to cause cigarettes to extinguish burning on contact.

Similarly the foam parts removed from the Ford Crown Victoria LTD have retained their good physical properties. Even back parts made using hot molded foam chemistry have excellent properties although the actual parts had been degraded quite severely during use, i.e. ripping, cutting, indentations. The driver cushion had maintained good properties although it had been used over the vehicle lifetime by relatively heavy drivers. Thus these foam pads still retained their properties and functionality in use after almost a quarter of a century of relatively low occupancy usage, i.e. low distance travelled.

We suggest that our data supports the claim that well-formulated, high resiliency PU foam is a durable and comfortable medium ensuring the long term performance of automotive seating. This most recent data confirms the earlier positive findings for parts obtained from recycling yards and the long term cyclic evaluation of cushions in police vehicles.

**Table 1. Foam Physical Properties of Parts Removed From Recycling Yards**

OEM	Odometer Reading, km	Part Type	Hardness* (Spec)	Density kg/m <sup>3</sup>	Tensile Strength kPa	Elongation %	Tear Resistance N/m	Compression Set			Flammability FMVSS 302 Rating
								50% Def %	75% Def %	Humid Aged %	
FORD	123.4 K	Cushion	49 (44-53) 39 (36-44) 26 (24-32)	44	205	140	354	--	14	12	N.R.
FORD	65,600	Back	62 (63-73) 33 (28-38) 22 (18-23)	34	203	140	N.D.	--	21	26	N.R.
FORD		Cushion	77 (70-78) 61 (60-70) 40 (38-47)	41	242	130	347	--	27	23	N.R.
FORD	51 K	Cushion	150(145-155) 128(115-135) 100 (85-95)	40	193	220	N.D.	--	19	19	SE, SE/NBR B (all pass)
GM	Unknown	Cushion	255(21/-262)	39	143	150	N.D.	15	11	19	N.R.
GM	Unknown	Back	119 (?)	24	157	N.R.	213	21	--	N.R.	SE/NBR

\*mm for Ford parts  
N for GM parts

FORD ESBM2D221C	27-43	83 min	120 min	210 min	20 max	20 max	20 max	30 max
GM 6293M	Class B	40 min	90 min	120 min	220 min	16 max	14 max	30 max
	Class C	32 min	82 min	100 min	200 min	18 max	16 max	30 max
	Class D	24 min	82 min	100 min	180 min	25 max	20 max	30 max

**Table 2. Ford Roller Shear Durability**

<b>Part Type</b>	<b>Odometer Reading, km</b>	<b>Height Loss, %</b>	<b>Hardness Loss %</b>	<b>Core Density, kg/m<sup>3</sup></b>
Cushion	121.6 k	2.5	17.9	40
Back	121.6 k	3.8	23.4	26

**Table 3. Urethane Foam Dynamic Fatigue**

<b>Odometer Reading K km</b>	<b>Hardness Loss, %</b>	<b>Thickness Loss, %</b>	<b>Creep, %</b>	<b>UFD #</b>	<b>Core Density kg/m<sup>3</sup></b>
201	16.7	4.3	9.9	86	42
138	15.9	2.8	11.0	82	N.R.
205	21.0	5.3	10.7	101	40
277	16.3	3.1	9.9	79	35
197	18.0	4.4	9.1	86	43

**Table 4. Physical Properties of Automotive Cushions of Various Types**

Foam Type Foam History Foam Properties	GM 6293M			TDI based foam After Fleet Testing				TDI-based foam containing Recycled Polyol			MDI-based foam		
	Units	Class B	Class C	#7	#4	#1	#6	As- produced	One year fleet use	Aged over one year	As- produced	One year fleet use	Aged over one year
<b>Core Density</b>	kg/m <sup>3</sup>	40 min	32 min	40	43	46	47-48	37	35	36	35-36	35	35
<b>IFD @ 50% Def</b>	N	--	--	373	396	217	411	231	292	309	321-330	289	340
<b>Tensile Strength</b>	kPa	90 min	82 min	237	197-230	190	232-241	179	203	204	153-167	207	215
<b>Elongation</b>	%	120 min	100 min	160	123-152	170	145-161	172	151	143	125-128	127	123
<b>Tear Resistance</b>	N/m	220 min	200 min	368	374-420	301	377-446	303	350	315	242-274	204	189
<b>Compression Set 50% Def</b>	%	16 max	18 max	17	15-17	8	14-15	19	16	21	17-21	30	22
<b>75% Def</b>	%	14 max	16 max	20	10-12	8	11	13	14	8	14-21	16	15
<b>50% Def after Humid Aging</b>	%	25 max	30 max	23	15-18	12	14-15	27	31	26	20-23	28	26
<b>CFD Change after Humid Aging</b>	%	±25 max	±25 max	-9	-5/-6	-4	-15/-17	+13	-14	-9	-8/-11	-24	-9
<b>Hysteresis Loss</b>	%	--	--	29	24	20	24	33	27	28	37	34	35

**Table 5A. Foam Properties of 1992 Chevrolet Lumina Seat Parts (Cushions)**

PROPERTY GM STANDARD GM6293M	UNITS	TOL.	TEST METHOD	CLASS			Driver Cushion	Passenger Cushion	Rear Cushion
				B	C	D			
CORE DENSITY	kg/m <sup>3</sup>	min	ASTM D-3574 (A)	40	32	24	34.5	39.2	29.1
TENSILE STRENGTH	kPa	min	ASTM D-3574 (E)	90	82	85	211.0	162.0	147.0
HEAT AGE TENSILE STRENGTH	%	max	ASTM D-3574 (E,K)	25	25	25	3.0	-7.0	-21.0
ELONGATION	%	min	ASTM D-3574 (E)	120	100	100	133.0	133.0	100.0
TEAR	N/m	min	ASTM D-3574 (F)	220	200	180	269.4	275.2	219.9
COMPRESSION SET A) 50% B) 75%	%	max max	ASTM D-3574 (D) ASTM D-3574 (D)	16 14	18 16	25 20	12.6 9.8	9.0 8.7	17.1 15.5
COMPRESSION SET – (50% H.A.)	%	max change	ASTM D-3574 (D)	30	30	30	14.2	14.3	21.7
HUMID AGE CFD CHANGE	%	max	ASTM D-3574 (D,J1)	30	30	30	9	17.0	15.0
FLAMMABILITY	mm/min	max	GM9070P	63.5	63.5	63.5	Pass	Pass	Pass
FOGGING	fog no.	min	GM9305P	60	60	60	Pass/ Clear	Pass/ Clear	Pass/ Clear

**Table 5B. Foam Properties of 1992 Chevrolet Lumina Seat Parts (Backs)**

PROPERTY GM STANDARD GM6293M	UNITS	TOL.	TEST METHOD	CLASS			Driver Back	Passenger Back	Rear Back
				B	C	D			
CORE DENSITY	kg/m <sup>3</sup>	min	ASTM D-3574 (A)	40	32	24	35.1	34.4	27.8
TENSILE STRENGTH	kPa	min	ASTM D-3574 (E)	90	82	85	172.0	149.0	150.0
HEAT AGE TENSILE STRENGTH	%	max	ASTM D-3574 (E,K)	25	25	25	-1.0	-23.0	-6.0
ELONGATION	%	min	ASTM D-3574 (E)	120	100	100	80	107.0	120.0
TEAR	N/m	min	ASTM D-3574 (F)	220	200	180	201.8	201.0	236.0
COMPRESSION SET A) 50% B) 75%	%	max max	ASTM D-3574 (D) ASTM D-3574 (D)	16 14	18 16	25 20	22.8 16.7	21.7 16.1	13.6 10.5
COMPRESSION SET – (50% H.A.)	%	max change	ASTM D-3574 (D)	25	30	30	23.7	23.5	18.0
HUMID AGE CFD CHANGE	%	max	ASTM D-3574 (D,J1)	30	30	30	29.0	21.0	15.0
FLAMMABILITY	mm/min	max	GM9070P	63.5	63.5	63.5	Pass	Pass	Pass
FOGGING	fog no.	min	GM9305P	60	60	60	Pass/ Clear	Pass/ Clear	Pass/ Clear

**Table 5C. Foam Properties of 1992 Chevrolet Lumina Seat Parts**

PROPERTY GMW 15471 SPEC	UNITS	TOL	TEST METHOD	Type IV	Driver Cushion	Passenger Cushion	Rear Back	Driver Back	Passenger Back	Rear Back
WET COMPRESSION SET	%	max	ASTM D-3574 (D,L)	25	25	30	27.8	27	9	27
TEAR RESISTANCE	N/m	min	ASTM D-624, Die C	450	1026	789	150	709	739	646

**Table 6. 1992 Chevrolet Lumina FMVSS 302 Flammability Details**

SAMPLE TYPE	SE	SEN/NBR	BURN RATE (mm/min)
Driver Cushion	4	0	B79.4
Passenger Cushion	3	2	0
Rear Cushion	3	2	0
Driver Back	3	2	0
Passenger Back	4	1	0
Rear Back	5	0	0

**N.B. Five specimens burnt for each seat part.**

**Table 7. Ford Crown Victoria Parts**

**A) Tested to original specifications**

<b>Part</b>	<b>Units</b>	<b>Driver</b>	<b>Passenger</b>	<b>Driver</b>	<b>Passenger</b>	<b>Rear</b>	<b>Rear</b>		
<b>Property</b>		<b>Cushion</b>	<b>Cushion</b>	<b>Back</b>	<b>Back</b>	<b>Cushion</b>	<b>Back</b>	<b>221C</b>	<b>113C</b>
<b>Core Density</b>	<b>kg/m<sup>3</sup></b>	<b>30.4</b>	<b>31.9</b>	<b>26.6</b>	<b>21.1</b>	<b>34.1</b>	<b>37.2</b>		
<b>Tensile Strength</b>	<b>kPa</b>	<b>160</b>	<b>194</b>	<b>139</b>	<b>137</b>	<b>183</b>	<b>226</b>	<b>83 min</b>	<b>83 min</b>
<b>Elongation</b>	<b>%</b>	<b>150</b>	<b>180</b>	<b>280</b>	<b>240</b>	<b>150</b>	<b>180</b>	<b>120 min</b>	<b>150 min</b>
<b>Tear Strength</b>	<b>N/m</b>	<b>290</b>	<b>275</b>	<b>413</b>	<b>310</b>	<b>264</b>	<b>296</b>	<b>210 min</b>	<b>263 min</b>
<b>75% def Comp Set</b>	<b>%</b>	<b>7</b>	<b>10</b>	<b>10</b>	<b>15</b>	<b>11</b>	<b>11</b>	<b>20 max</b>	<b>25 or</b> <b>30 max</b>
<b>75% def HACS</b>	<b>%</b>	<b>10</b>	<b>13</b>	<b>19</b>	<b>29</b>	<b>10</b>	<b>13</b>	<b>30 max</b>	<b>25 or</b> <b>30 max</b>
<b>Flammability</b>		<b>SE(3X)</b> <b>SE/NBR(3X)</b>	<b>SE(6X)</b>	<b>B52.9</b> <b>B73.6</b>	<b>B45.2</b> <b>B56.4</b> <b>B68.3</b> <b>B78.6</b>	<b>SE/NBR(1X)</b> <b>SE/B 45.2</b> <b>SE/B 46.5</b> <b>SE/B 52.9</b> <b>SE/B 57.8</b>	<b>SE(1X)</b> <b>SE/NBR(1X)</b>		

**B) Additional Foam Properties**

<b>Die C Tear Resistance</b>	<b>N/m</b>	<b>809</b>	<b>816</b>	<b>990</b>	<b>937</b>	<b>725</b>	<b>863</b>	<b>MFIP Spec</b> <b>450 min</b>
<b>Wet Set</b>	<b>%</b>	<b>24</b>	<b>20</b>	<b>21</b>	<b>29</b>	<b>23</b>	<b>31</b>	

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## BIOGRAPHIES

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Ron Blair received his degree in Glasgow Scotland. He continued his studies at the University of British Columbia before joining the Royal Dutch Shell Plastics Laboratory in Holland. During his six years with Shell, Ron worked in various functions including fundamental research, plastics testing and latterly, polyurethanes. In 1976 he joined Monsanto Canada, which became Woodbridge Foam Corporation in 1978. Ron has held various processing and chemistry positions and recently retired from managing the Woodbridge Corporate P3T Lab in Woodbridge, Ontario Canada. Ron is currently a Polyurethane Industry consultant and can be contacted at [ronblair@hotmail.com](mailto:ronblair@hotmail.com)

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