SRNL
SAVANNAH RIVER NATIONAL LABORATORY

Keywords: *Gloveboxes, Polymers, Gloves, Puncture*

Retention: *25 yrs-**10561***

SRNL-STI-2012-00068

Puncture Test Characterization of Glovebox Gloves

P.S. Korinko

Y. Breakiron

G. K. Chapman

February 29, 2012

This Page Intentionally Left Blank

SRNL-STI-2012-00068

Puncture Test Characterization of Glovebox Gloves

Approvals:

Signature on file

2-28-2012

P. S. Korinko, Author
Materials Compatibility and Welding Technology

Signature on file

3-5-2012

Y. Breakiron, Author
Tritium Engineering Intern, Clemson University

Signature on file

3-5-12

G.K. Chapman, Author
Materials Compatibility and Welding Technology

Signature on file

5 March 2012

E. A. Clark, Technical Review
Materials Compatibility and Welding Technology

Signature on file

3/6/2012

T. M. Adams, Manager
Materials Compatibility and Welding Technology

Table of Contents

List of Tables

List of Figures

SRNL-STI-2012-00068

Puncture Test Characterization of Glovebox Gloves

Summary

An experiment was conducted to determine the puncture resistance of 15 gloves that are used or proposed for use in the Tritium Facility at Savannah River Site (SRS). These data will serve as a baseline for characterization and may be incorporated into the glove procurement specification. The testing was conducted in agreement with ASTM D120 and all of the gloves met or exceeded the minimum requirements. Butyl gloves exhibited puncture resistance nearly 2.5 times the minimum requirements at SRS while Polyurethane was nearly 7.5x the minimum.

Background

Currently butyl gloves are used in the facility because of their low permeability; however, butyl is not a particularly tough, puncture resistant, or abrasion resistant glove. To improve the physical and mechanical properties, the butyl gloves may be used with overgloves when exposed to wear applications. The Tritium Facility and SRS glovebox subject matter expert has been working with several vendors to characterize and improve the glove properties. Four vendors: North Piercan, Guardian and Jung, have supplied stock and experimental glove compositions and thicknesses for engineering evaluation. The gloves from these vendors, with the composition and nominal thickness listed in Table 1 have been tested for permeability, tensile, Thermogravimetric, Dynamic Mechanical Analysis and now puncture resistance. The results of the other characterizations are reported separately (1-4). A standard ASTM puncture test methodology (5) was used.

Table 1. Description of gloves and ID used for the testing.

Vendor	Composition	Thickness (mils)	ID		Vendor	Composition	Thickness (mils)	ID
North	Butyl	15	NB15		North	Butyl	30	NB30
Piercan	Butyl	15	PB15		Piercan	Butyl	30	PB30
Piercan	Electrostatic Discharge Butyl	15	PESDB15		Piercan	Electrostatic Discharge Butyl	24	PESDB24
Guardian	Butyl	15	GB15		Guardian	Butyl	30	GB30
Jung	Butyl-Hypalon®	27	JBH27		Jung	Butyl-Viton®	20	JBV20
Jung	Viton®	24	JV24		Jung	Viton®	31	JV31
Piercan	Polyurethane	15	PU15		Piercan	Polyurethane-Hypalon®	20	PUY20
Piercan	Hypalon®	25	PY25					

Experimental

Portions of ASTM D120 (5) were used as a guideline for this experiment. Disk samples were die cut from the hand portion of the glove to simulate the most likely scenario where a sharp will have the opportunity to penetrate a glove in the facility. The sample disk was mounted in a compression holder and probe A was driven into the sample at a cross head speed of 20 in/min. A 200 lb capacity load cell calibrated to ASTM E4 (6) was used for this experiment. The samples were tested to failure with an Instron Model 4507 test machine including a MTS Systems Renew Package. The load and deflection were recorded on a computer using Testworks software. The tests were completed in triplicate rather than 12 times due to time constraints.

Results and Discussion

The average results from the puncture test for butyl rubber gloves are listed in Table 2 and individual test data are listed in Appendix A. These results indicate an average puncture resistance of approximately 240 lbf/in. This value exceeds the 100 lbf/in referred to in ASTM D120 for electrical gloves (5). The data are presented graphically in Figure 2. The standard deviation for the individual three tests is listed in the table; these values show a relative spread of less than 10% that helps justify testing in triplicate. A typical load extension curve for 30 mil North Butyl is shown in Figure 1; individual data plots for the other gloves are presented in Appendix B. All of the pure materials and the PUY samples exhibited similar behavior with monotonic increases in load with extension and a sharp drop in the load on penetration.

Table 2. Results of puncture testing of butyl gloves.

Butyl Gloves Puncture								
Glove	NB15 Ave.	NB30 Ave.	GB15 Ave.	GB30 Ave.	PB15 Ave.	PB30 Ave.	PESDB15 Ave.	PESDB24 Ave.
Extension (in)	0.64	0.65	0.55	0.55	0.66	0.60	0.49	0.53
Load (lbf)	5.1	8.9	6.2	8.6	4.5	11.4	4.3	5.9
Std Dev (lbf)	0.40	0.69	0.31	0.28	0.27	0.35	0.39	0.14
Thickness (in)	0.023	0.038	0.023	0.034	0.025	0.038	0.020	0.025
Punct. Resist. (lbf/in)	222	231	269	257	183	296	221	237

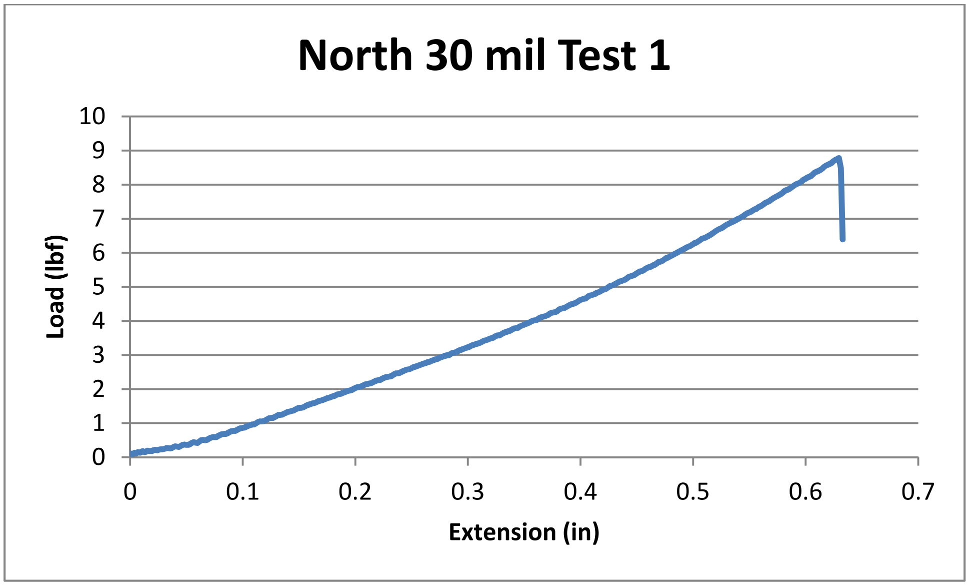


Figure 1. Force-Extension plot for North 30 mil butyl.

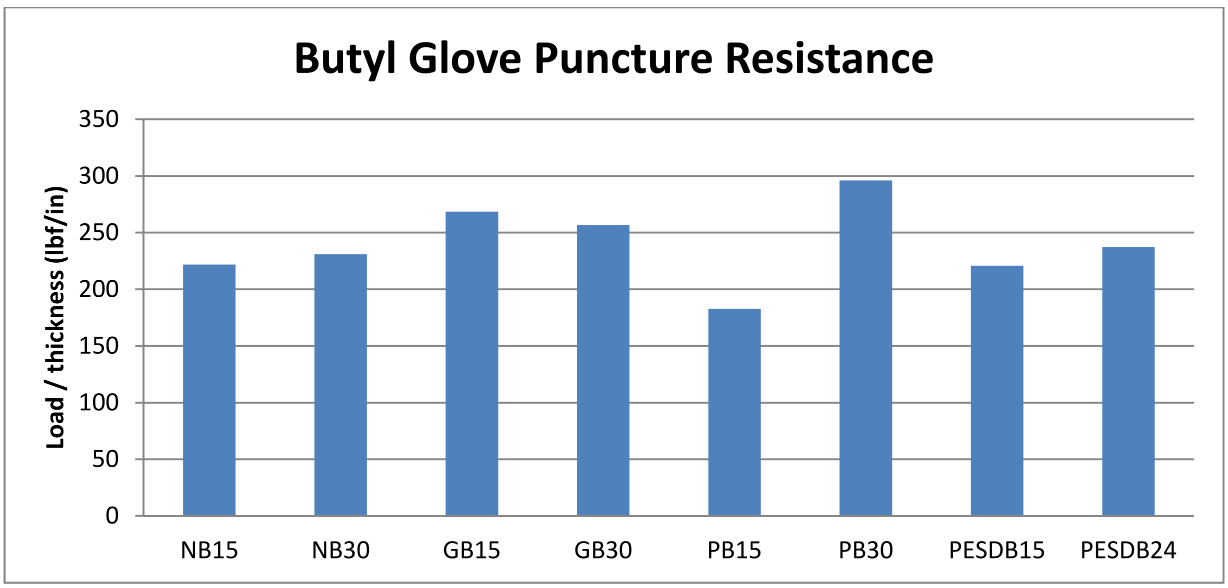


Figure 2. Puncture resistance of Butyl gloves.

The average results from the puncture test for other polymer gloves are listed in Table 3 and graphically in Figure 3. These results indicate a puncture resistance that exceeds 100 lbf/in for all of the gloves that were tested, a minimum value for electrical gloves (5). As was the case for the butyl gloves, the standard deviation for the three tests is listed in the table, these values show a relative spread of less than 10%.

All of the gloves exceed the minimum puncture resistance required for electrical gloves. The SRS specification does not explicitly require puncture testing, so these data are for information and comparison purposes only. The gloves can be ranked from highest to lowest puncture resistance: polyurethane, polyurethane-Hypalon®, Hypalon®, Butyl and Viton®, Butyl-Hypalon® and finally Butyl-

Viton®. The elongation to failure is another indicator of puncture resistance and a similar ranking occurs from this assessment as well.

Table 3. Results for puncture testing other polymer gloves.

Other Polymer Gloves Puncture							
Glove	PU15 Ave.	PY25 Ave.	PUY20 Ave	JV24 Ave.	JV31 Ave.	JBV20 Ave	JBH27.5 Ave.
Extension (in)	0.83	0.61	0.74	0.36	0.40	0.25	0.31
Load (lbf)	14.01	9.4	16.3	5.9	8.5	2.5	5.1
Thickness (in)	0.019	0.023	0.023	0.027	0.044	0.022	0.035
Std Dev (lbf)	0.97	0.35	1.46	0.51	0.24	0.18	0.11
Punct. Resist. (lbf/in)	749	408	697	215	191	115	146

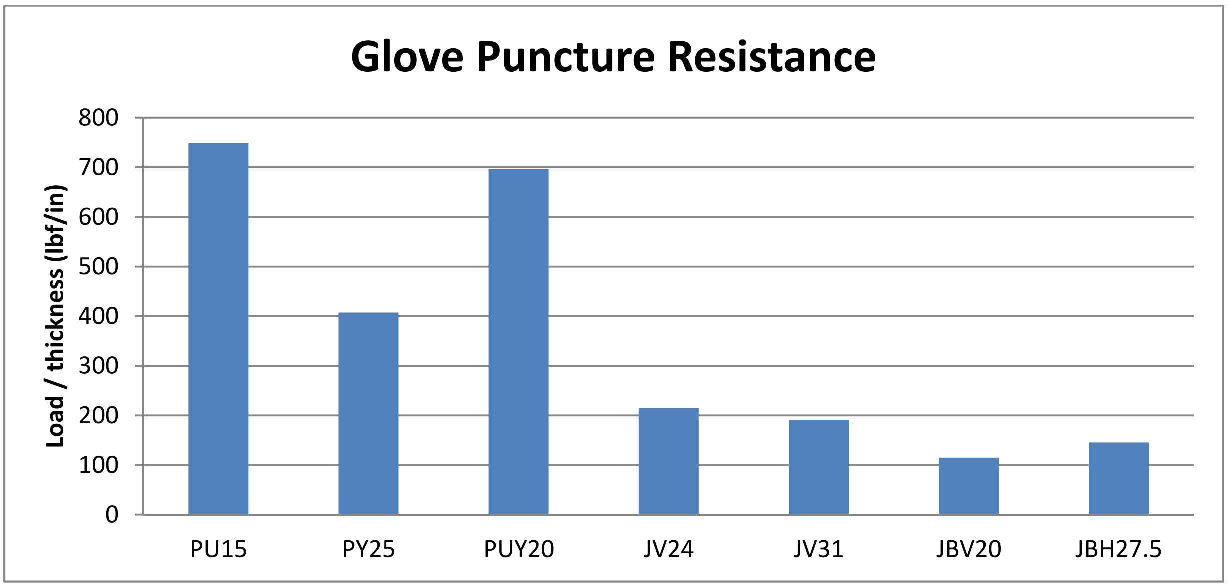


Figure 3. Glove puncture resistance for other polymer gloves.

Figure 4 shows the puncture test data from the Jung butyl-Viton® test. This curve indicates that there were two failure events, with a partial unloading at about 0.18 inch and a complete failure at 0.25 inch extension. These discontinuities are attributed to the butyl failure followed by the Viton® failure. Similar behavior was not observed for the other two layer gloves. The reason for either behavior was not pursued further.

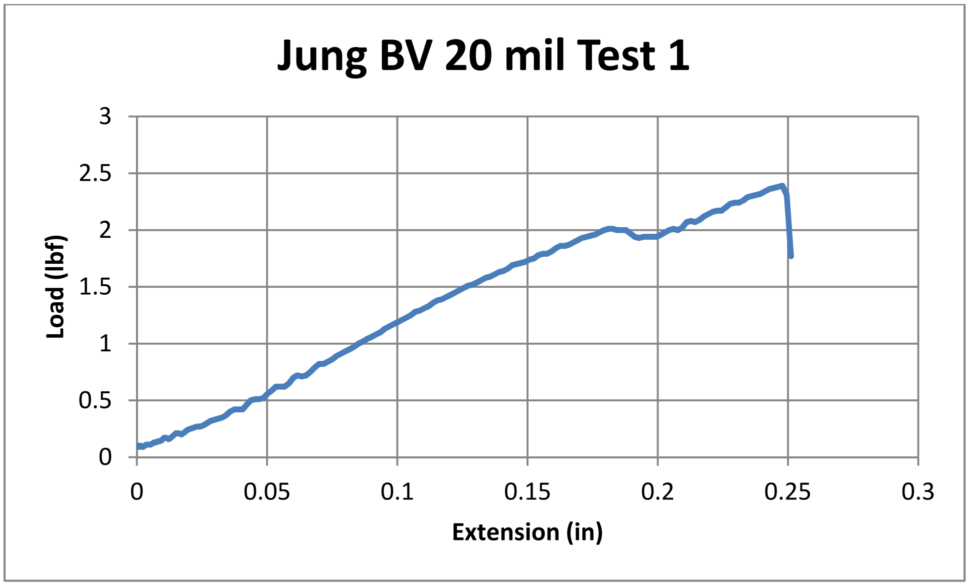


Figure 4. Load extension curve for Jung Butyl Viton.

Conclusions and Summary

All of the gloves meet or exceed the 100 lbf/in requirement stated in ASTM D120 for electrical gloves. The Butyl gloves exhibit puncture resistance in excess of 200 lbf/in and the Polyurethane gloves exhibit the highest puncture resistance with a value of nearly 750 lbf /in. Jung Butyl Viton® glove failed in two stage manner with the lowest puncture resistance.

Acknowledgements

The authors would like to thank Tritium Operations, Tritium Engineering, and Tritium Extraction Facility for technical and financial support.

References

1. SRNL-STI-2012-00030, Thermogravimetric Characterization of Glovebox Gloves, P.S. Korinko, Y. Breakiron, Feb 29, 2012
2. SRNL-STI-2012-00069, Characterization of Tensile Strength of Glovebox Gloves , P.S. Korinko, Y. Breakiron, G. K. Chapman, Feb 29, 2012
3. SRNL-STI-2012-00030, Evaluation of Glovebox Gloves for Effective Permeation Control, P.S. Korinko, Y. Breakiron, Feb 29, 2012
4. SRNL-STI-2012-00070, Dynamic Mechanical Analysis Characterization of Glovebox Gloves, P.S. Korinko, Y. Breakiron, Feb 29, 2012
5. ASTM D120-09, Standard Specification for Rubber Insulating Gloves, West Conshohocken, PA 19428, 2009.
6. ASTM E4-10, Standard Practices for Force Verification of Testing Machines, West Conshohocken, PA 19428, 2010.

Appendix A: Puncture Testing Raw Data

Glove	NB15-1P	NB15-2P	NB15-3P	NB15 Ave.	NB30-1P	NB30-2P	NB30-3P	NB30 Ave.
Extension (in)	0.63	0.64	0.66	0.64	0.63	0.70	0.63	0.65
Load (lbf)	4.85	5.59	4.98	5.14	8.78	9.61	8.23	8.87
Thickness	0.023	0.023	0.023	0.023	0.038	0.038	0.038	0.038
P/t (lbf/in)	209	241	215	222	228	250	214	231

Glove	GB15-1P	GB15-2P	GB15-3P	GB15 Ave.	GB30-1P	GB30-2P	GB30-3P	GB30 Ave.
Extension (in)	0.55	0.54	0.56	0.55	0.56	0.55	0.54	0.55
Load (lbf)	6.55	6.14	5.94	6.21	8.50	8.93	8.41	8.61
Thickness	0.023	0.023	0.023	0.023	0.034	0.034	0.034	0.034
P/t (lbf/in)	283	266	257	269	253	266	251	257

Glove	PB15-1P	PB15-2P	PB15-3P	PB15 Ave.	PB30-1P	PB30-2P	PB30-3P	PB30 Ave.
Extension (in)	0.63	0.68	0.67	0.66	0.59	0.60	0.61	0.60
Load (lbf)	4.35	4.83	4.39	4.52	10.97	11.45	11.64	11.35
Thickness	0.025	0.025	0.025	0.025	0.038	0.038	0.038	0.038
P/t (lbf/in)	176	195	178	183	286	299	304	296

Glove	PESDB15-1P	PESDB15-2P	PESDB15-3P	PESDB15 Ave.	PESDB24-1P	PESDB24-2P	PESDB24-3P	PESDB24 Ave.
Extension (in)	0.48	0.50	0.50	0.49	0.54	0.51	0.53	0.53
Load (lbf)	3.95	4.72	4.33	4.33	6.03	5.79	5.77	5.86
Thickness	0.020	0.020	0.020	0.020	0.025	0.025	0.025	0.025
P/t (lbf/in)	201	241	221	221	244	234	234	237

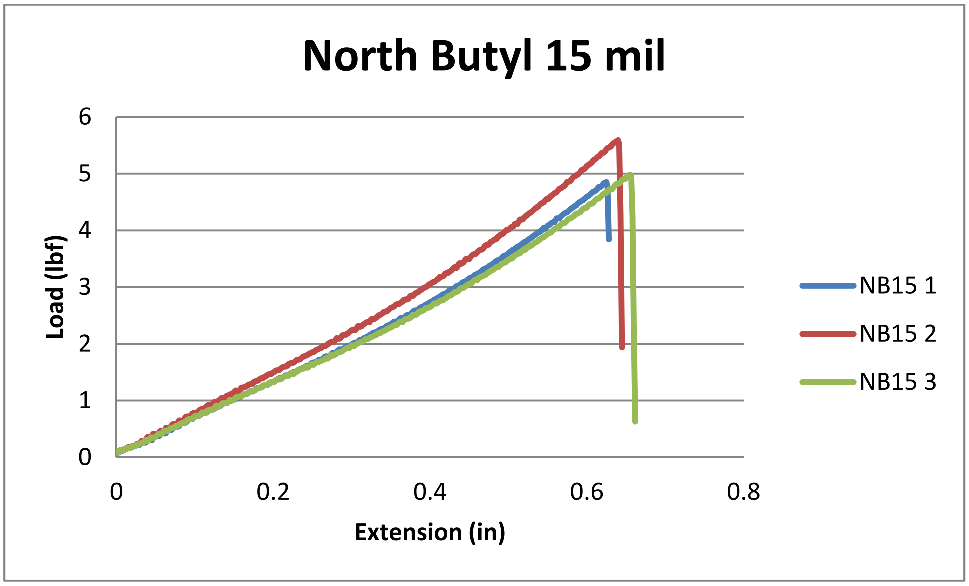
Glove	JV24-1P	JV24-2P	JV24-3P	JV24 Ave.	JV31-1P	JV31-2P	JV31-3P	JV31 Ave.
Extension (in)	0.39	0.35	0.34	0.36	0.39	0.40	0.41	0.40
Load (lbf)	6.41	5.76	5.40	5.86	8.17	8.62	8.56	8.45
Thickness	0.027	0.027	0.027	0.027	0.044	0.044	0.044	0.044
P/t (lbf/in)	235	211	198	215	185	195	194	191

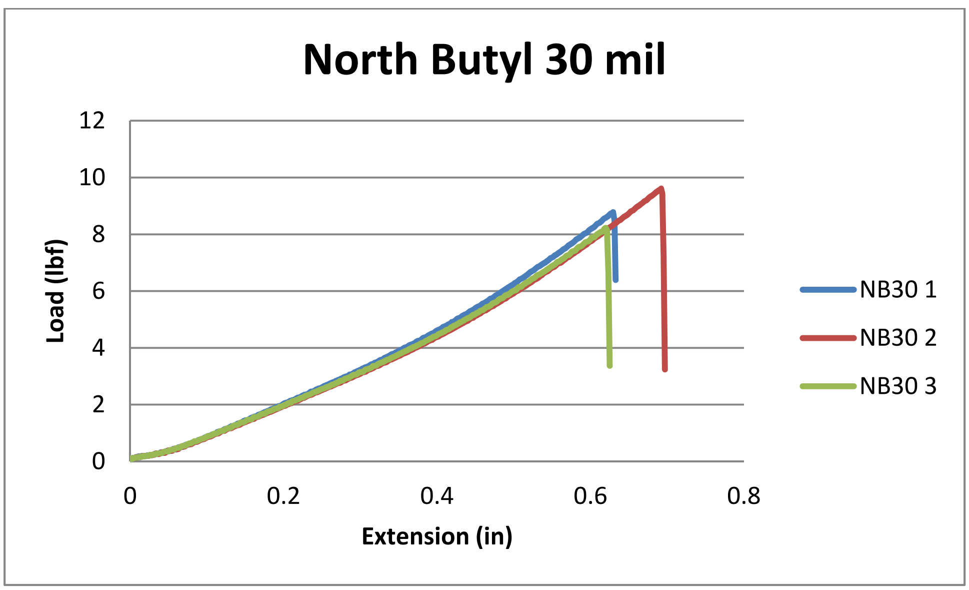
Glove	PU15-1P	PU15-2P	PU15-3P	PU15-4P	PU15 Ave.	PY25-1P	PY25-2P	PY25-3P	PY25 Ave.
Extension (in)	0.75	0.80	0.87	0.83	0.83	0.62	0.59	0.64	0.61
Load (lbf)	12.04	13.22	15.09	13.72	14.01	9.46	9.04	9.74	9.41
Thickness	0.019	0.019	0.019	0.019	0.019	0.023	0.023	0.023	0.023
P/t (lbf/in)	644	707	807	734	749	410	391	422	408

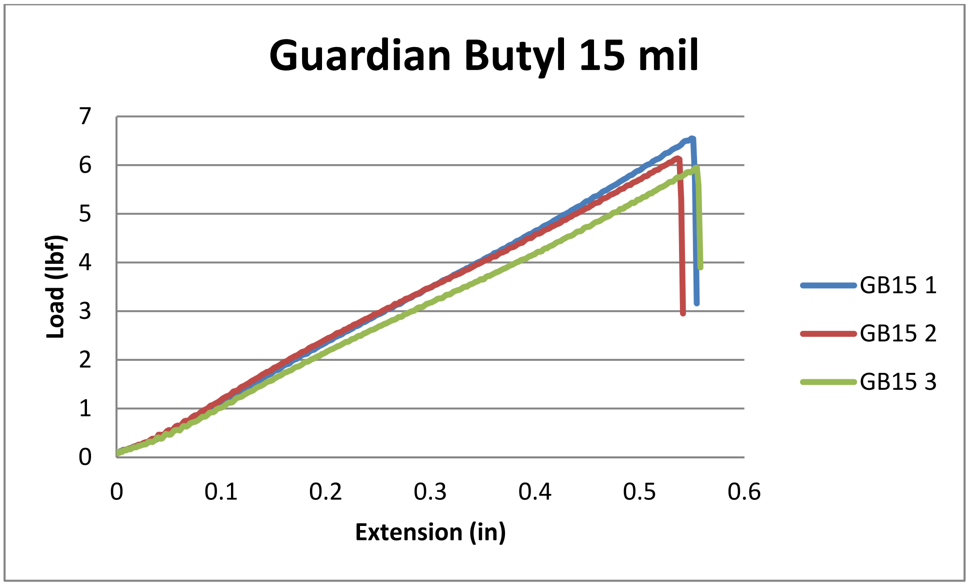
Glove	JBV20-1P	JBV20-2P	JBV20-3P	JBV20 Ave	JBH27.5-1P	JBH27.5-2P	JBH27.5-3P	JBH27.5 Ave.
Extension (in)	0.25	0.24	0.27	0.25	0.31	0.30	0.31	0.31
Load (lbf)	2.39	2.44	2.72	2.52	5.20	5.21	5.02	5.14
Thickness	0.022	0.022	0.022	0.022	0.035	0.035	0.035	0.035
P/t (lbf/in)	109	112	124	115	147	147	142	146

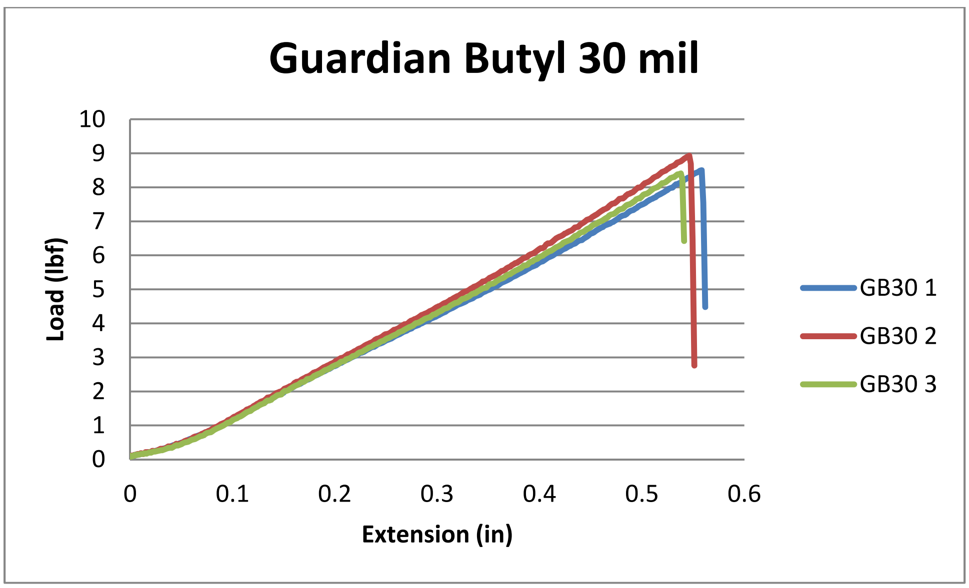
Glove	PUY20-1P	PUY20-2P	PUY20-3P	PUY20 Ave
Extension (in)	0.71	0.76	0.75	0.74
Load (lbf)	14.68	16.65	17.53	16.29
Thickness	0.023	0.023	0.023	0.023
P/t (lbf/in)	628	712	750	697

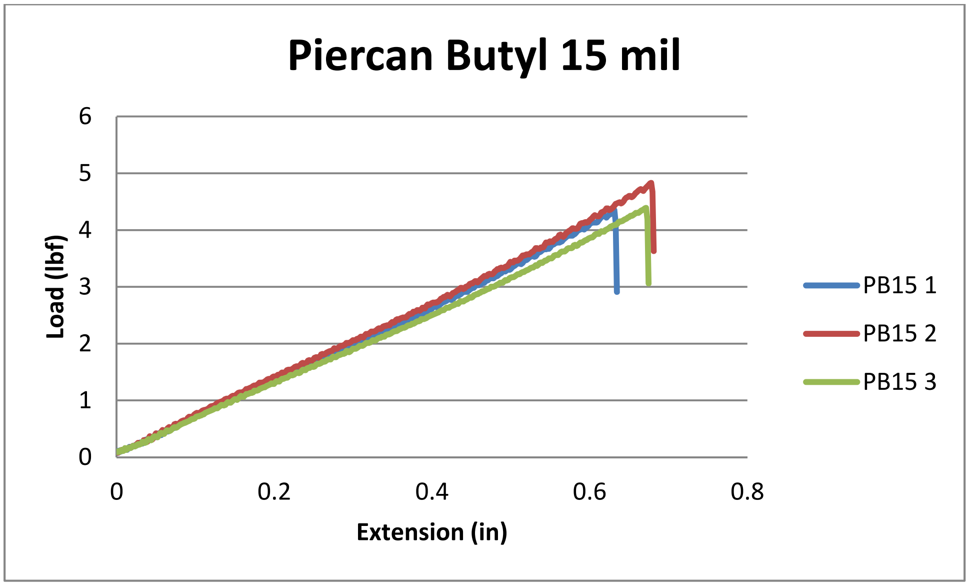
Appendix B: Puncture Testing Charts

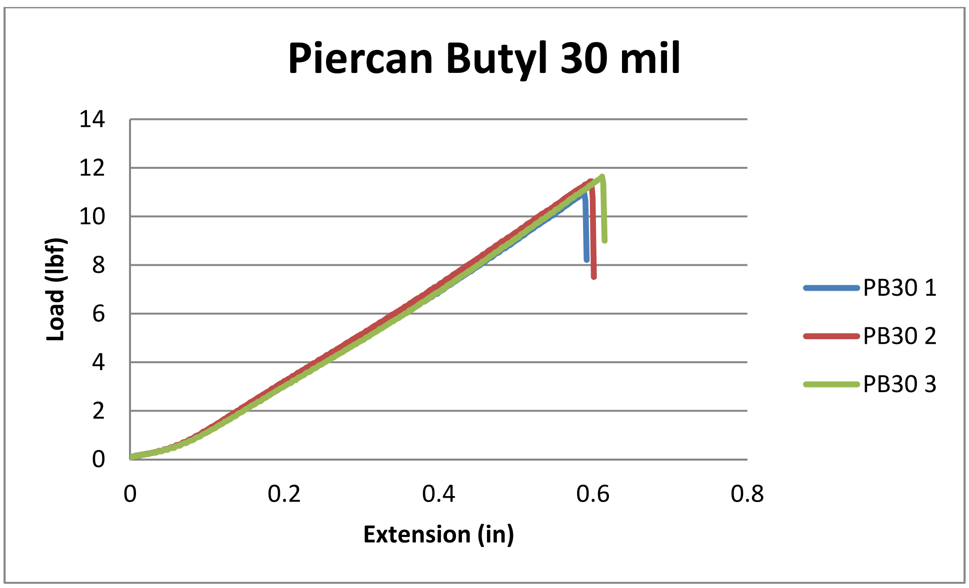


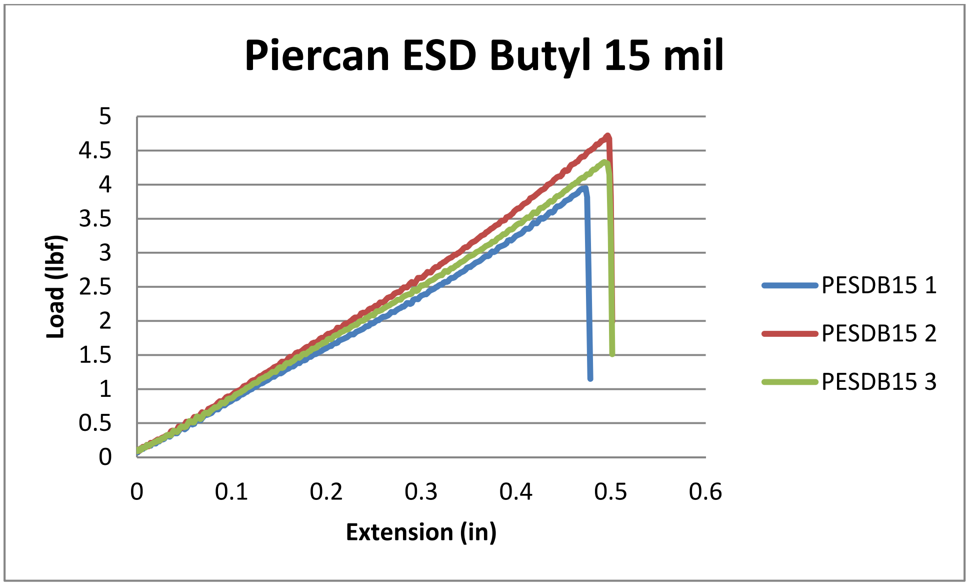


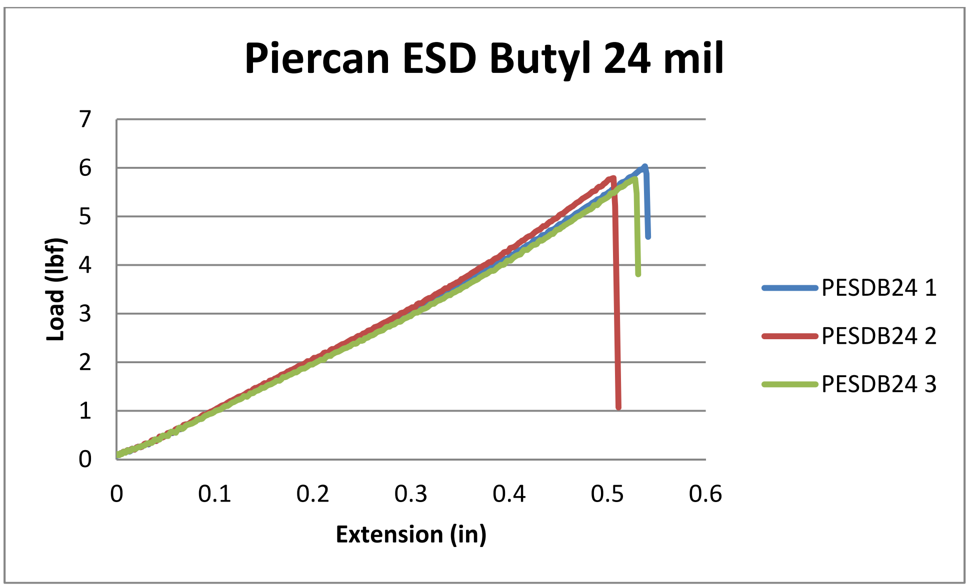

Guardian Butyl 15 mil
Load (lbf)
Extension (in)
0
1
2
3
4
5
6
7
0
0.1
0.2
0.3
0.4
0.5
0.6
GB15 1
GB15 2
GB15 3

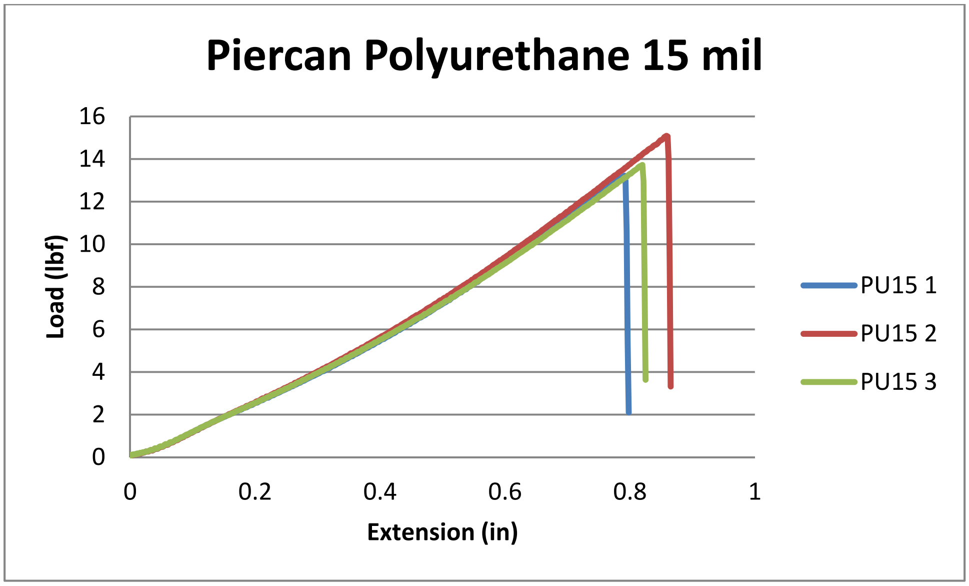

Guardian Butyl 30 mil
Load (lbf)
Extension (in)
0
1
2
3
4
5
6
7
8
9
10
0
0.1
0.2
0.3
0.4
0.5
0.6
GB30 1
GB30 2
GB30 3

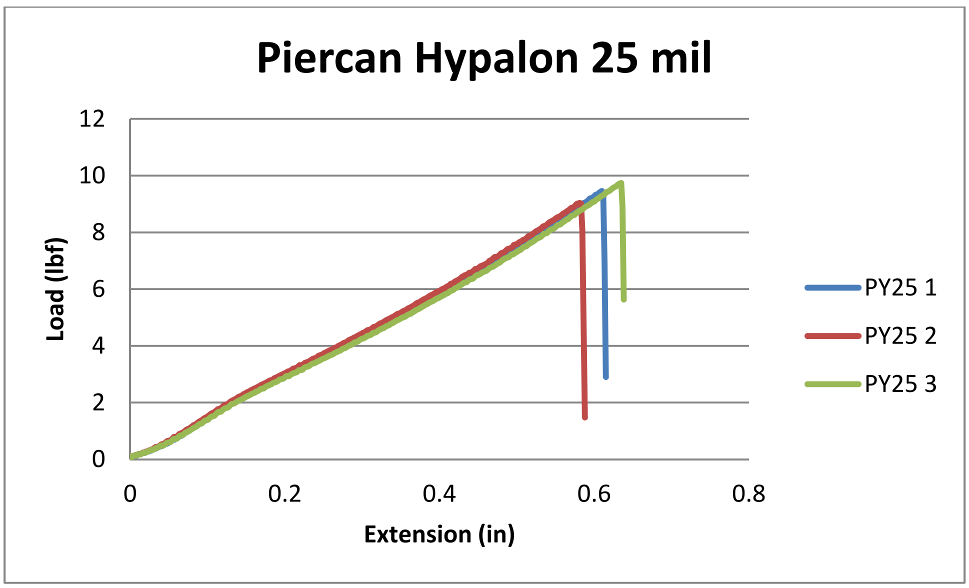

Piercan Butyl 15 mil
Load (lbf)
Extension (in)
0
1
2
3
4
5
6
0
0.2
0.4
0.6
0.8
PB15 1
PB15 2
PB15 3

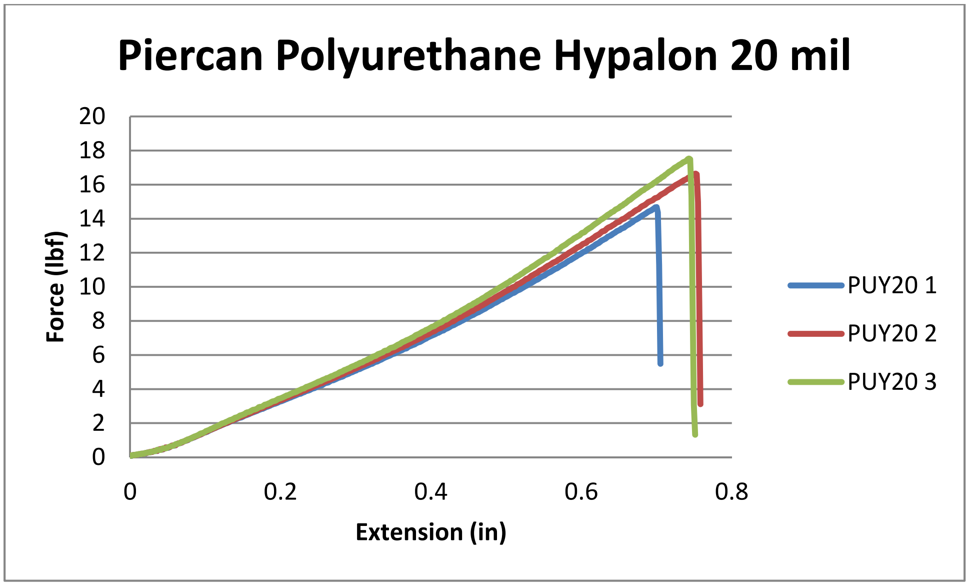

Piercan Butyl 30 mil
Load (lbf)
Extension (in)
0
2
4
6
8
10
12
14
0
0.2
0.4
0.6
0.8
PB30 1
PB30 2
PB30 3

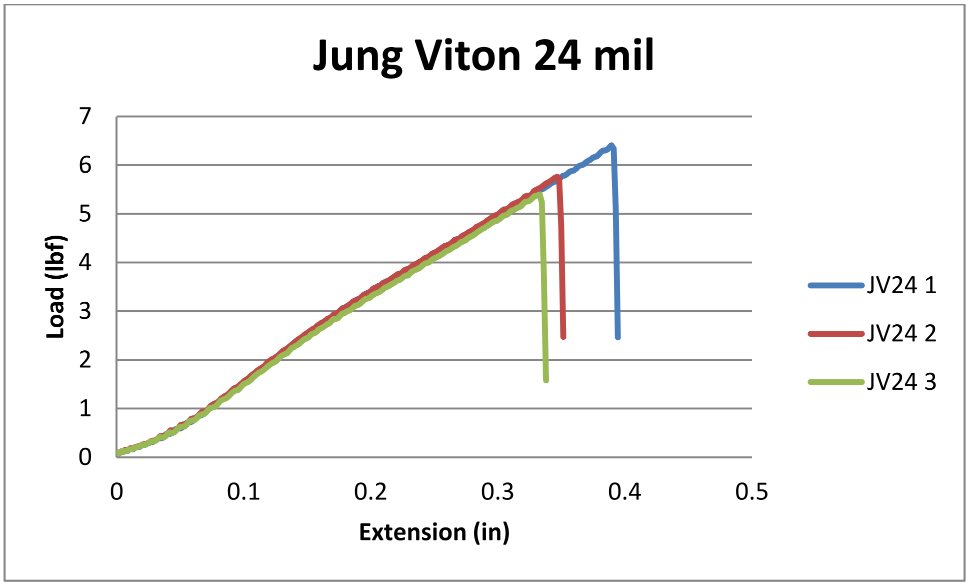

Piercan ESD Butyl 15 mil
Load (lbf)
Extension (in)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
0.1
0.2
0.3
0.4
0.5
0.6
PESDB15 1
PESDB15 2
PESDB15 3

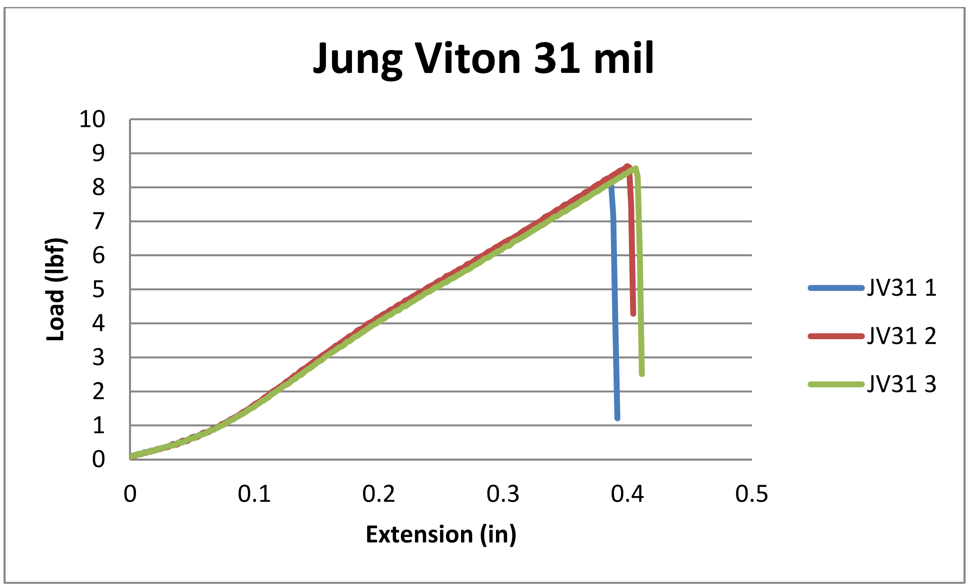

Piercan ESD Butyl 24 mil
Load (lbf)
Extension (in)
0
1
2
3
4
5
6
7
0
0.1
0.2
0.3
0.4
0.5
0.6
PESDB24 1
PESDB24 2
PESDB24 3

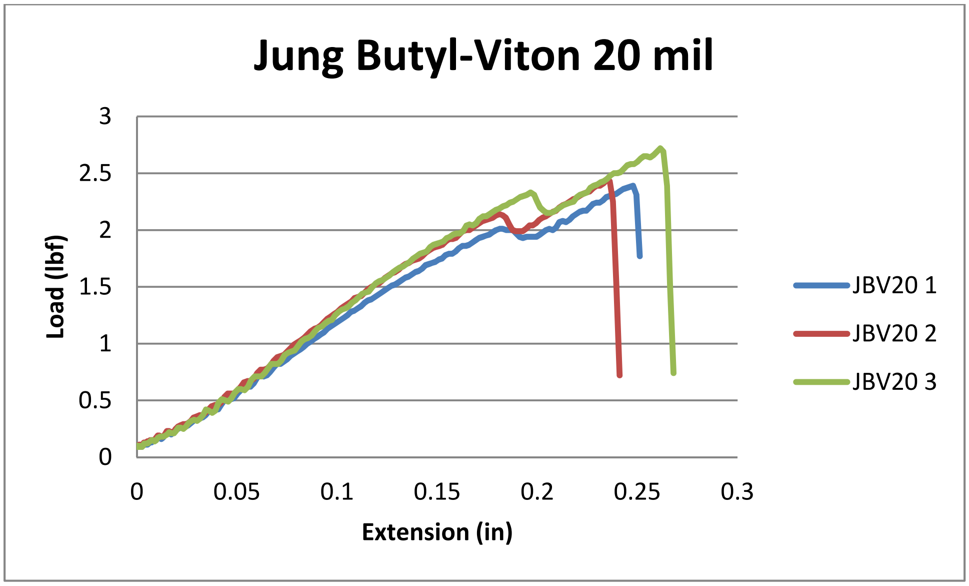

Piercan Polyurethane 15 mil
Load (lbf)
16
14
12
10
8
6
4
2
0
0
0.2
0.4
0.6
0.8
1
Extension (in)
PU15 1
PU15 2
PU15 3

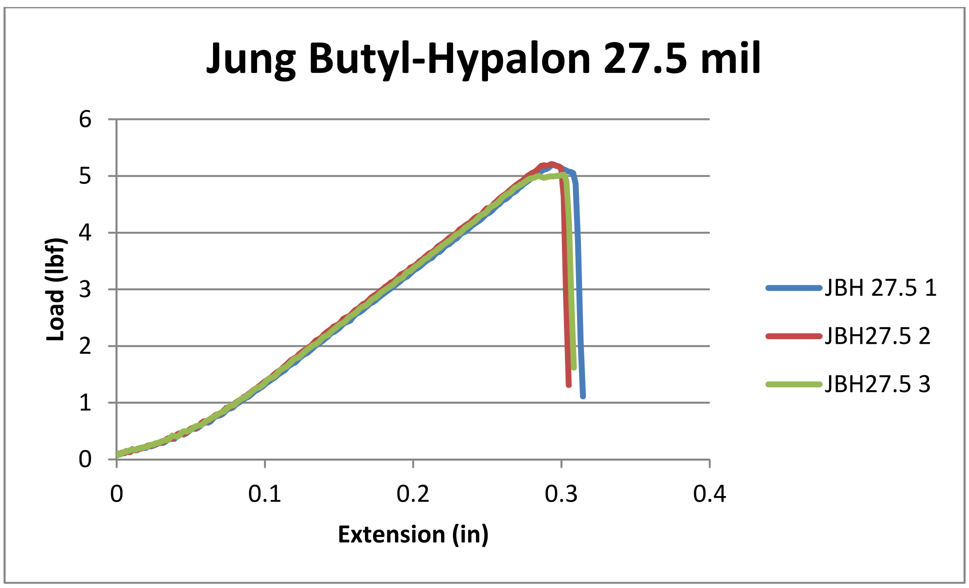

Piercan Hypalon 25 mil
Load (lbf)
12
10
8
6
4
2
0
0
0.2
0.4
0.6
0.8
Extension (in)
PY25 1
PY25 2
PY25 3


Piercan Polyurethane Hypalon 20 mil
Force (lbf)
20
18
16
14
12
10
8
6
4
2
0
0
0.2
0.4
0.6
0.8
Extension (in)
PUY20 1
PUY20 2
PUY20 3


Jung Viton 24 mil
7
6
5
4
3
2
1
0
Load (lbf)
0
0.1
0.2
0.3
0.4
0.5
Extension (in)
JV24 1
JV24 2
JV24 3


Jung Viton 31 mil
10
9
8
7
6
5
4
3
2
1
0
Load (lbf)
0
0.1
0.2
0.3
0.4
0.5
Extension (in)
JV31 1
JV31 2
JV31 3


Jung Butyl-Viton 20 mil
Load (lbf)
3
2.5
2
1.5
1
0.5
0
0
0.05
0.1
0.15
0.2
0.25
0.3
Extension (in)
JBV20 1
JBV20 2
JBV20 3


Jung Butyl-Hypalon 27.5 mil
Load (lbf)
6
5
4
3
2
1
0
0
0.1
0.2
0.3
0.4
Extension (in)
JBH 27.5 1
JBH27.5 2
JBH27.5 3