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Characterization of Tensile Strength of Glovebox Gloves

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February 29, 2012

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Characterization of Tensile Strength of Glovebox Gloves

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Characterization of Tensile Strength of Glovebox Gloves

Summary

A task was undertaken to compare various properties of different glovebox gloves, having various compositions, for use in gloveboxes at the Savannah River Site (SRS). One aspect of this project was to determine the tensile strength (TS) of the gloves. Longitudinal tensile samples were cut from 15 different gloves and tensile tested. The stress, load, and elongation at failure were determined. All of the gloves that are approved for glovebox use and listed in the glovebox procurement specification met the tensile and elongation requirements. The Viton® compound gloves are not listed in the specification, but exhibited lower tensile strengths than permissible based on the Butyl rubber requirements. Piercan Polyurethane gloves were the thinnest samples and exhibited the highest tensile strength of the materials tested.

Background

Four vendors provided a total of 15 different gloves for permeation testing, Thermogravimetric Analysis (TGA), Dynamic Mechanical Analysis (DMA), puncture testing, and tensile testing. In the study reported here, gloves from the vendors North, Piercan, Guardian, and Jung have been tensile tested. The composition and thickness of the gloves are listed in Table 1. Butyl gloves are the baseline gloves currently used in the Tritium Facility. These gloves have very good hydrogen and air permeation resistance but suffer from somewhat poor abrasion resistance. The tests reported here were performed to measure the mechanical properties of the gloves.

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				

Experiment

ASTM D412 (1) was used as a guideline for this experiment. Three “dog bone” shaped tensile samples were cut along the sleeve axis from each glove represented. Two sample sizes were used (Figure 1). The longer gauge length sample was used for the majority of the tests, but two glove compounds required the use of a shorter test sample. The die geometry and select dimensions are shown in Figure 1 . The glove material was placed on a piece of Teflon® and cut with a die with the aid of a manual press. The samples were pulled to failure with an Instron Model 4507 test machine including a MTS Systems Renew Package at a constant crosshead rate of 20 inches/ minute. The elongation of each sample was assumed to be the applied elongation of the crosshead (no independent elongation gages were used.) The loads, percent elongation and peak stress were recorded on a computer using Testworks software. A 200 lb capacity load cell calibrated to ASTM E4 (2) was used during this experiment.

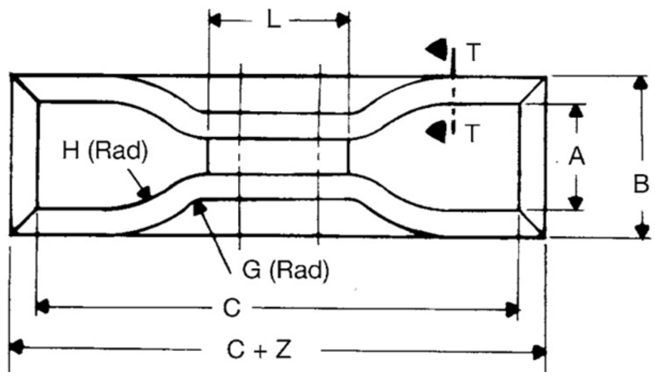


Figure 1. Die geometry for gauge width of 0.5 inch, and L of 3 or 2.25 inches, and C of 6.5 or 5.5 inches for long and short tensile samples, respectively.

Results

Butyl

Typical load-elongation and stress-strain curves are shown in Figures 2 and 3 for 15 mil North Butyl rubber gloves. Note that the load increases with increased time, Figure 2, in a nonlinear manner. Figure 3 shows the results from three tests- the data from separate tests of the same material were quite consistent; this was observed for all of the gloves tested, including the alternatives to pure butyl. The average stress, elongation, and load at failure are presented in Table 2 and the results from the individual tests are tabulated in Appendix A and shown graphically in Appendix B.

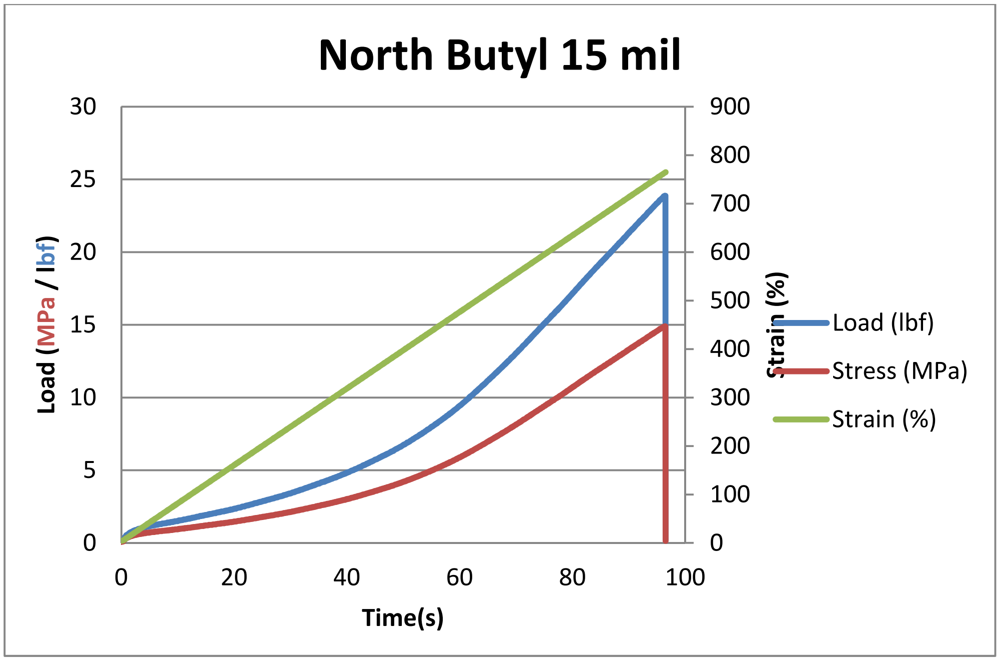


Figure 2. Typical load (lbf), stress (MPa), and strain (%) results for North butyl rubber glove material.

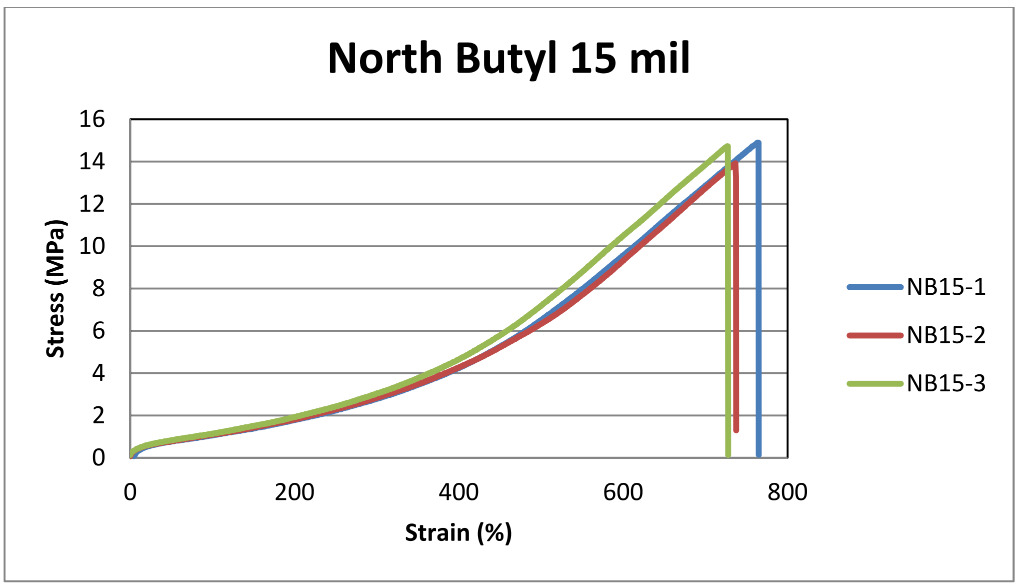


Figure 3. Stress (MPa) versus strain (%) results for three North Butyl rubber gloves.

Table 2. Butyl rubber glove results.

	GB15 Ave.	GB30 Ave.	NB15 Ave.	NB30 Ave.	PB15 Ave.	PB30 Ave.	PESDB15 Ave.	PESDB24 Ave.
Stress (Mpa)	11	12	15	13	11	11	13	13
% Elong	666	726	745	754	714	843	680	746
Load (lbf)	16	27	23	31	15	27	14	19
Thickness (in)	0.020	0.029	0.021	0.034	0.019	0.032	0.015	0.020

These tensile strength (TS) results indicate some scatter for the strength of the butyl rubber gloves but the tensile strength is bounded by 11 to 15 MPa with tensile elongations from 666 to 843%. The determination of the tensile strength, which can be modified by additives, is an important material property, but the load at failure is more applicable information for the product and application within the facility. The failure load is also listed in Table 2 and shown in Figure 3. These data show that the increased thickness results in an increased load for failure, as expected.

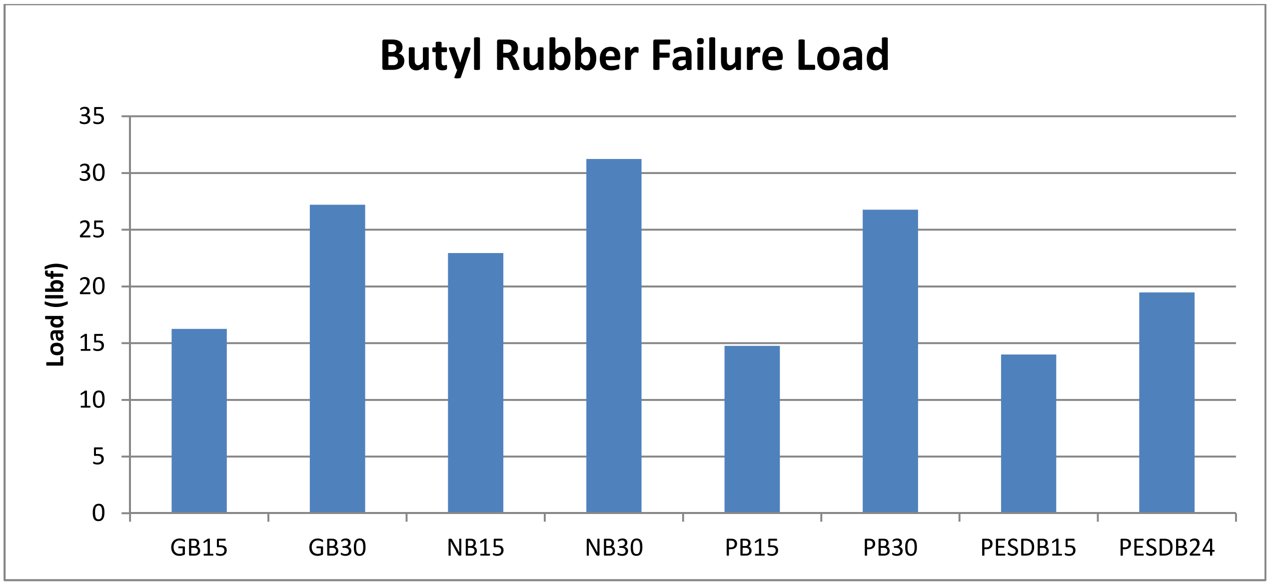


Figure 4. Comparison of tensile load of Butyl rubber gloves.

Other Compound Gloves

The tensile properties of gloves made from compounds other than butyl are listed in Table 3. These data indicate a wider range of tensile strength from 5.4 MPa to 49 MPa. The Viton® glove exhibits the lowest strength at 5.4 MPA for a 31 mil thick glove, the butyl-Hypalon®, butyl-Viton®, and 24 mil Viton® are second lowest with about 8 MPa, with Hypalon® (19 MPa), Hypalon®-Polyurethane (24 MPa) and Polyurethane (49 MPa) completing the rankings. These strengths are both considerably weaker ~ 1/3 TS of Butyl to considerably stronger ~ 3X Butyl.

The load at failure is indicated in Table 3 and Figure 4. The polyurethane and Hypalon® indicate a significant increase in load at failure compared to Butyl of comparable thickness. This result is expected since polyurethane is considered to be tougher than butyl. The Viton® exhibits interesting results. The JV24 and JV31 have thicknesses that vary between 0.025" and 0.039" yet exhibit virtually identical failure loads of 14 and 15 MPa, respectively. A different effect is also apparent from the tensile strength which shows a reduced % elongation value for the thicker gloves compared to the thinner ones.

Table 3. Tensile properties of other glove compositions.

	JBH27 Ave.	JBV20 Ave.	JV24 Ave.	JV31 Ave.	PU15 Ave.	PUY20 Ave.	PY25 Ave.
Stress (MPa)	7.8	8.0	7.6	5.4	49	24	19
% Elong	454	640	545	453	697	603	570
Load (lbf)	16	10	14	15	55	37	30
Thickness (in)	0.045	0.017	0.025	0.039	0.015	0.022	0.021

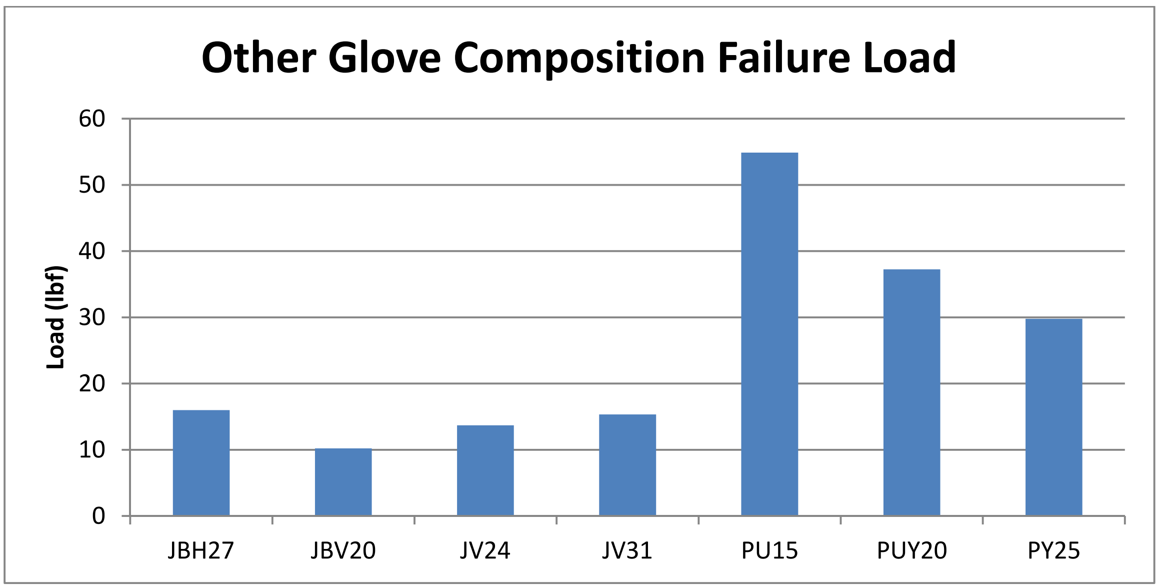


Figure 5. Comparison of load at failure of other glove compositions

Table 4. Property requirements for selected gloves (3).

Material	Min Tensile Strength (psi) / (MPa)	Min Ultimate Elongation (%)
Butyl (B)	1300 / 9.1	550
CSM (Chlorosulfonated Polyethylene (Y)) – Hypalon®	1900 / 13.	500
Polyurethane / CSM (UY) 20 mil 12 mil	 3500 / 24. 2500 / 17.	 450 450
Polyurethane	5000 / 34.	400

Note: No mechanical property data is provided for Viton® based gloves. Literature (4) indicates 500-2000 psi capability (3.4-14 MPa) at 400-500% elongation.

Summary and Conclusions

The glove box glove specification (3) for Savannah River Site (SRS) requires the above properties listed in Table 4 for the gloves included in this study. All of the Butyl gloves meet the requirements of the specification for both tensile strength and elongation. The listed gloves, U, UY, and Y meet the minimum requirements for both tensile strength and elongation, with the PUY just meeting tensile strength minima. Since there are no SRS requirements for Viton® containing gloves these are reported for information only; however, the Jung manufactured gloves exhibited the lowest tensile strengths of the materials tested, with tensile strengths as low as 5.4 MPa, and commonly 8 MPa.

The Piercan Polyurethane gloves were the strongest material tested. They exhibited the highest tensile strength, well over minimum tensile elongation, and the highest load to failure. They were also one of the thinnest gloves tested which may offer improved tactile response.

Acknowledgements

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

References

1. ASTM D412-06, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension, West Conshohocken, PA 19428, 2006.
2. ASTM E4-10, Standard Practices for Force Verification of Testing Machines, West Conshohocken, PA 19428, 2010.
3. SRS Glove Specification, "Gloves for Gloveboxes (U), March 2011.
4. http://www.robinsonrubber.com/pdfs/FKMRubber.pdf , 2005

Appendix A: Raw Data

	GB15-1	GB15-2	GB15-3	GB15 Ave.	GB30-1	GB30-2	GB30-3	GB30 Ave.
Time	82	85	85	84	94	91	101	95
Load	15	17	17	16	31	25	26	27
Stress	11	11.0	11	11	12	12	12	12
% Elong	641	686	670	666	705	721	752	726
Thickness (in)	0.020	0.020	0.020	0.020	0.030	0.029	0.029	0.029
Width (in)	0.501	0.504	0.505	0.503	0.506	0.505	0.507	0.506

	NB15-1	NB15-2	NB15-3	NB15 Ave.	NB30-1	NB30-4[1]	NB30-5[1]	NB30-6[1]	NB30 Ave.
Time	97	96	98	97	109	81	81	78	87
Load	24	22	23	23	38	30	30	28	31
Stress	15	14	15	15	15	12	12	12	13
% Elong	765	743	726	745	831	707	721	758	754
Thickness (in)	0.022	0.022	0.021	0.021	0.034	0.034	0.034	0.033	0.034
Width (in)	0.514	0.510	0.508	0.511	0.502	0.503	0.505	0.500	0.503

	PB15-4	PB15-5	PB15-6	PB15-7[1]	PB15 Ave.	PB30-1	PB30-2	PB30-3	PB30 Ave.
Time	99	96	88	74	89	103	101	101	102
Load	17	16	13	13	15	27	26	28	27
Stress	12	11	10	9.4	11	11	11	11	11
% Elong	781	734	668	674	714	868	820	839	843
Thickness (in)	0.019	0.019	0.018	0.019	0.019	0.033	0.031	0.033	0.032
Width (in)	0.505	0.505	0.505	0.505	0.505	0.502	0.509	0.509	0.507

[1]The long samples did not reach failure so the smaller samples were tested, Figure 1. Small samples tended to fail at transition rather than center of reduced section.

	PESDB15-1	PESDB15-2	PESDB15-3	PESDB15 Ave.	PESDB24-1	PESDB24-2	PESDB24-3	PESDB24 Ave.
Time	90	86	92	89	98	92	97	95
Load	14	14	14	14	20	19	20	19
Stress	12	13	13	13	13	13	14	13
% Elong	711	673	655	680	747	714	778	746
Thickness (in)	0.015	0.015	0.015	0.015	0.020	0.020	0.019	0.020
Width (in)	0.507	0.507	0.505	0.506	0.505	0.512	0.509	0.509

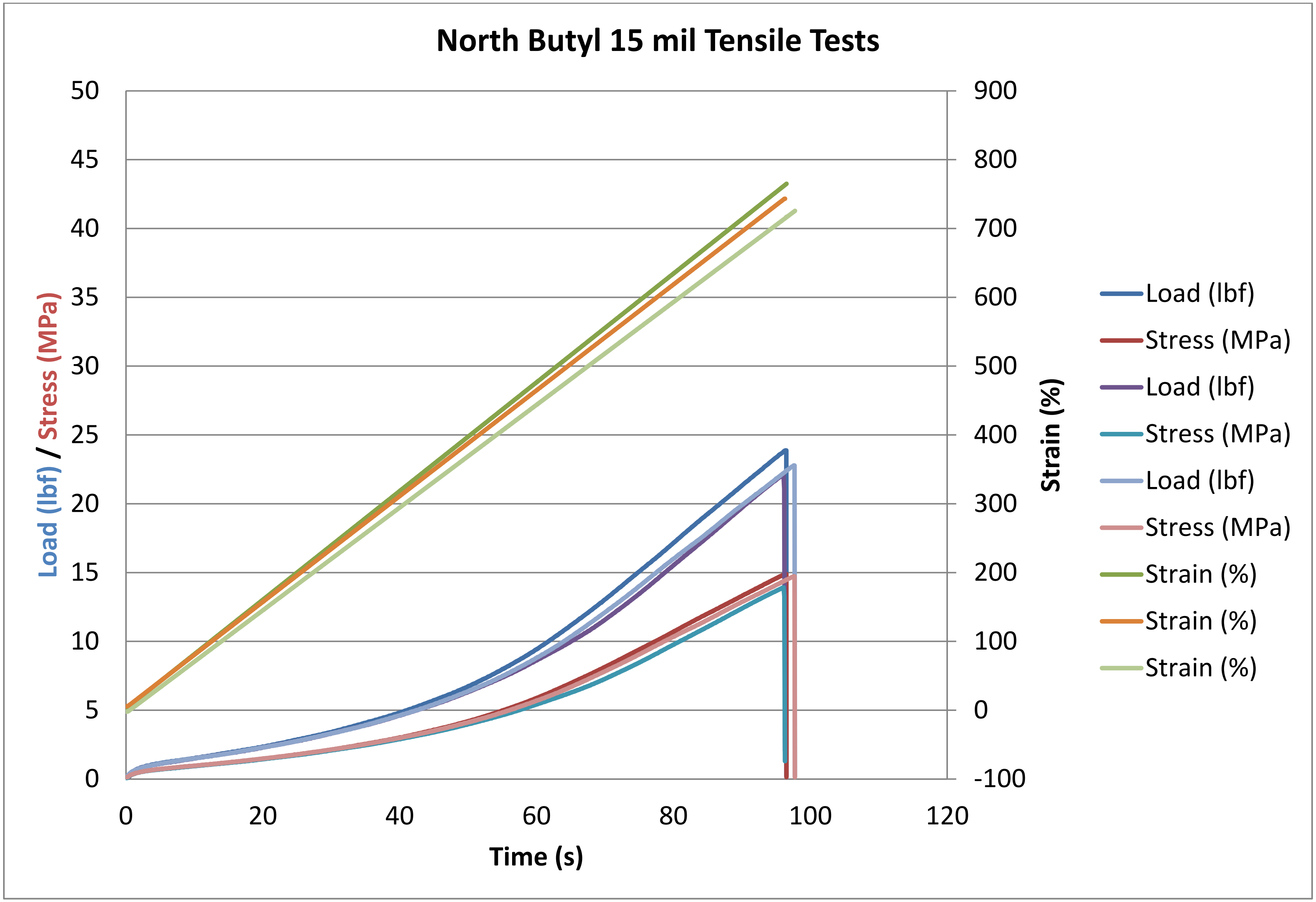
	JBH27-1	JBH27-2	JBH27-3	JBH27 Ave.	JBV20-1	JBV20-2	JBV20-3	JBV20 Ave.
Time	57	56	56	56	83	80	82	82
Load	16	16	16	16	10	10	10	10
Stress	7.9	7.8	7.8	7.8	8.0	8.1	7.9	8.0
% Elong	454	458	451	454	634	643	643	640
Thickness (in)	0.028	0.028	0.080	0.045	0.017	0.017	0.018	0.017
Width (in)	0.506	0.504	0.503	0.504	0.510	0.503	0.505	0.506

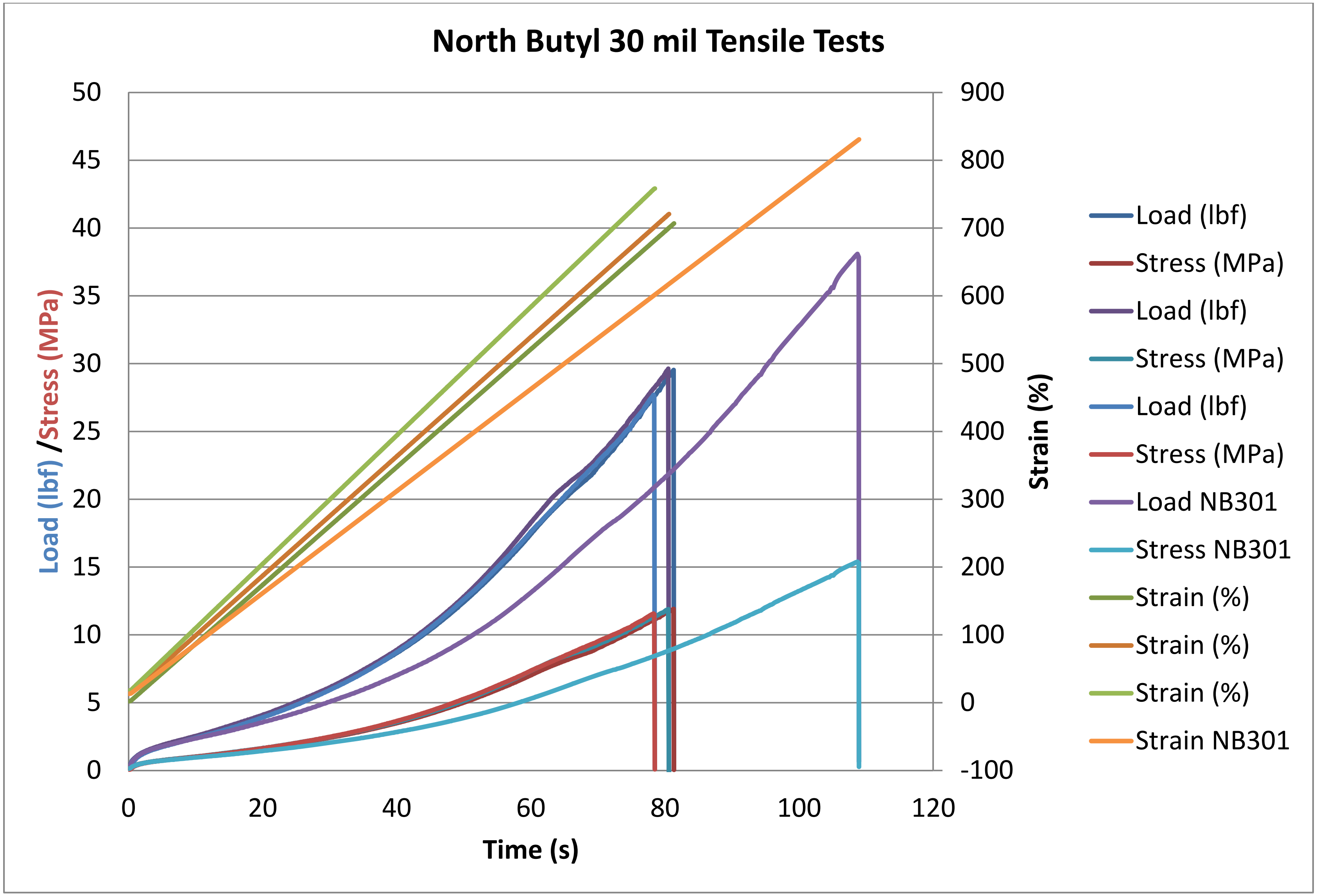
	JV24-1	JV24-2	JV24-3	JV24 Ave.	JV31-1	JV31-2	JV31-3	JV31 Ave.
Time	71	66	71	70	63	56	56	58
Load	14	13	14	14	16	15	15	15
Stress	7.8	7.3	7.7	7.6	5.8	5.1	5.2	5.4
% Elong	559	534	541	545	494	443	423	453
Thickness (in)	0.025	0.025	0.025	0.025	0.039	0.040	0.039	0.039
Width (in)	0.510	0.505	0.506	0.507	0.504	0.505	0.506	0.505

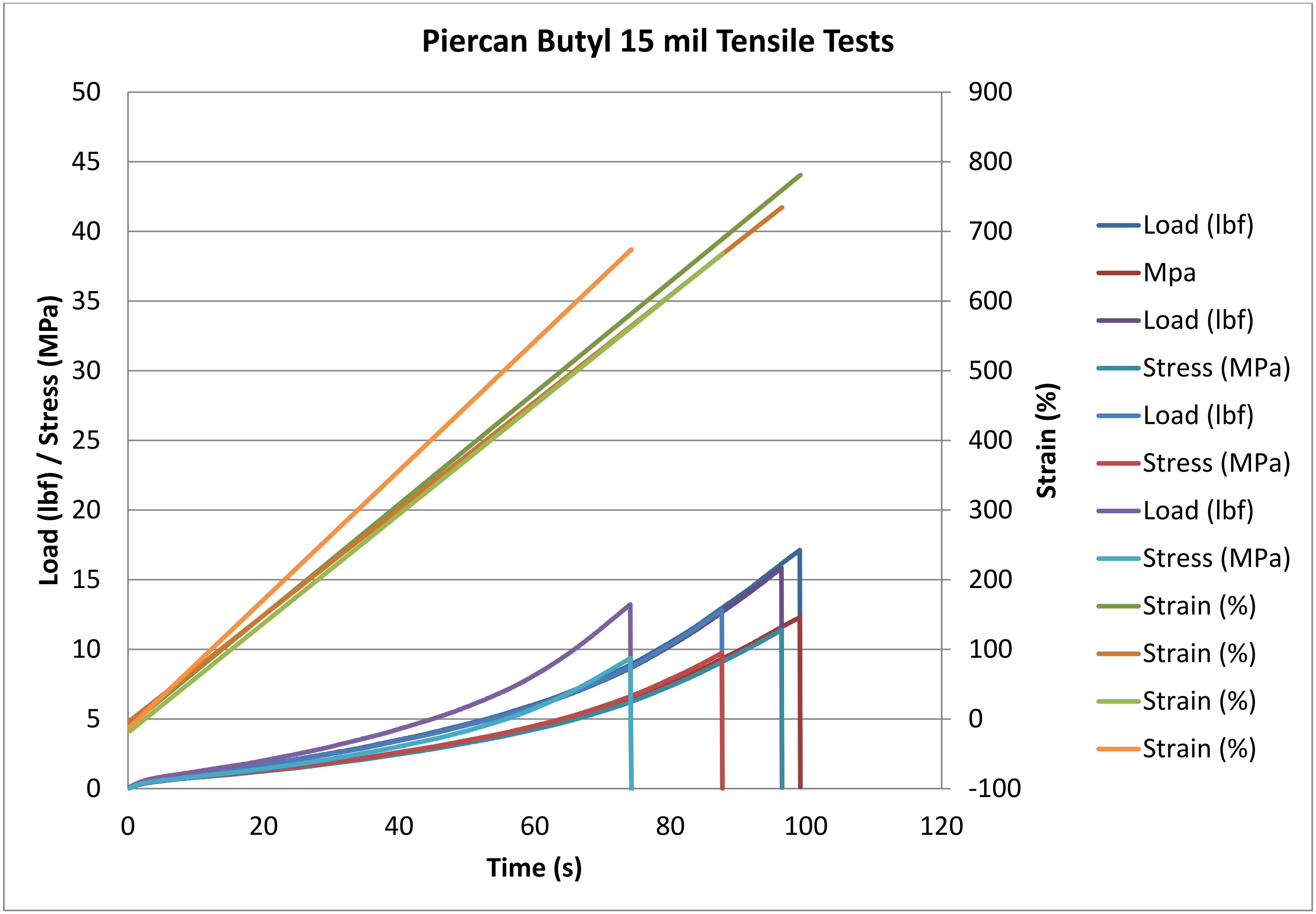
	PU15-1	PU15-2	PU15-3	PU15 Ave.	PUY20-1	PUY20-2	PUY20-3	PUY20 Ave.
Time	87	87	93	89	77	77	77	77
Load	53	55	57	55	38	37	37	37
Stress	47	50	51	49	24	24	22	24
% Elong	674	696	722	697	595	625	588	603
Thickness (in)	0.015	0.015	0.015	0.015	0.021	0.021	0.023	0.022
Width (in)	0.505	0.505	0.515	0.508	0.504	0.508	0.510	0.507

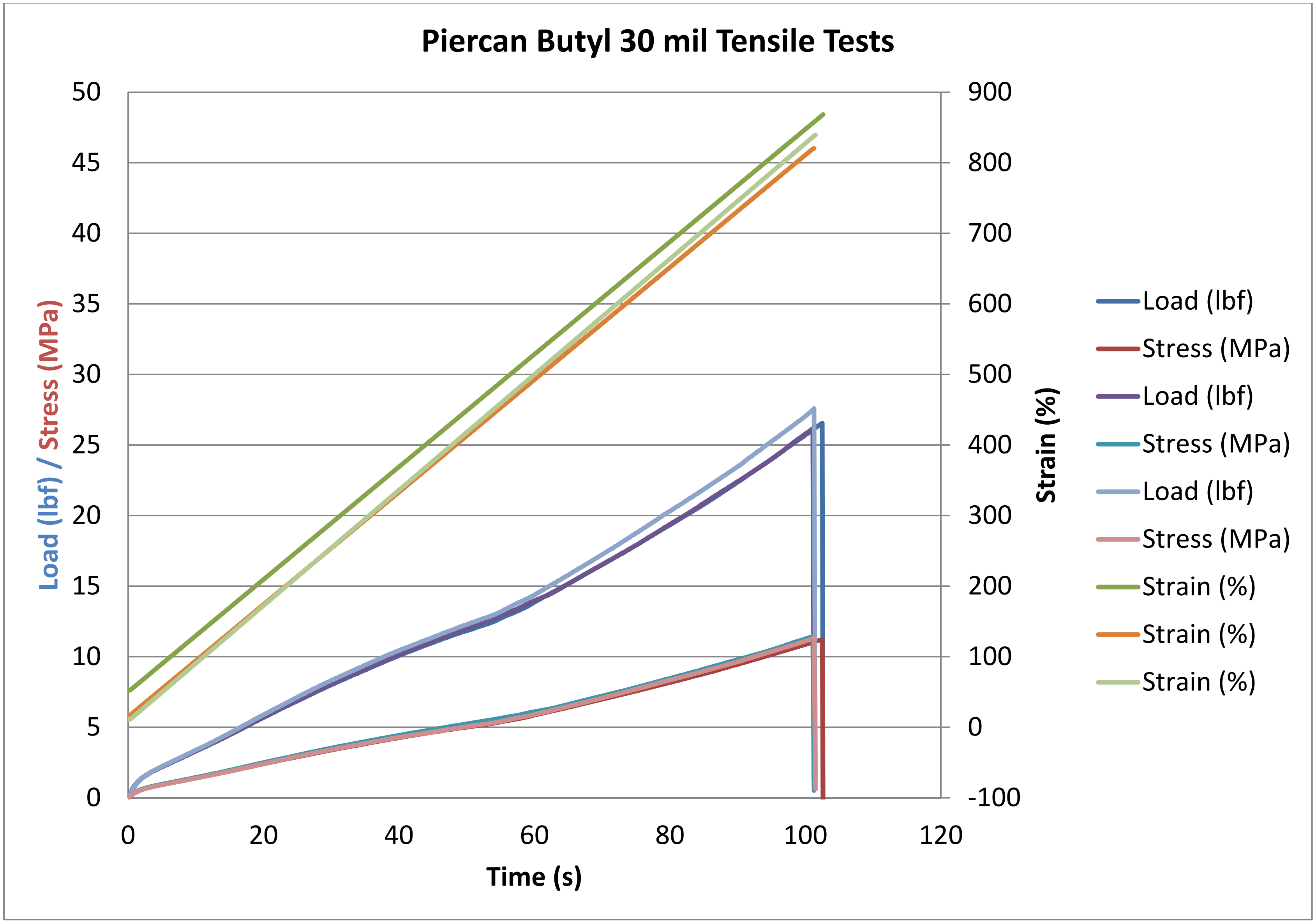
	PY25-1	PY25-2	PY25-3	PY25 Ave.
Time	72	74	72	73
Load	31	31	27	30
Stress	20	20	18	19
% Elong	568	577	564	570
Thickness (in)	0.022	0.021	0.021	0.021
Width (in)	0.505	0.506	0.504	0.505

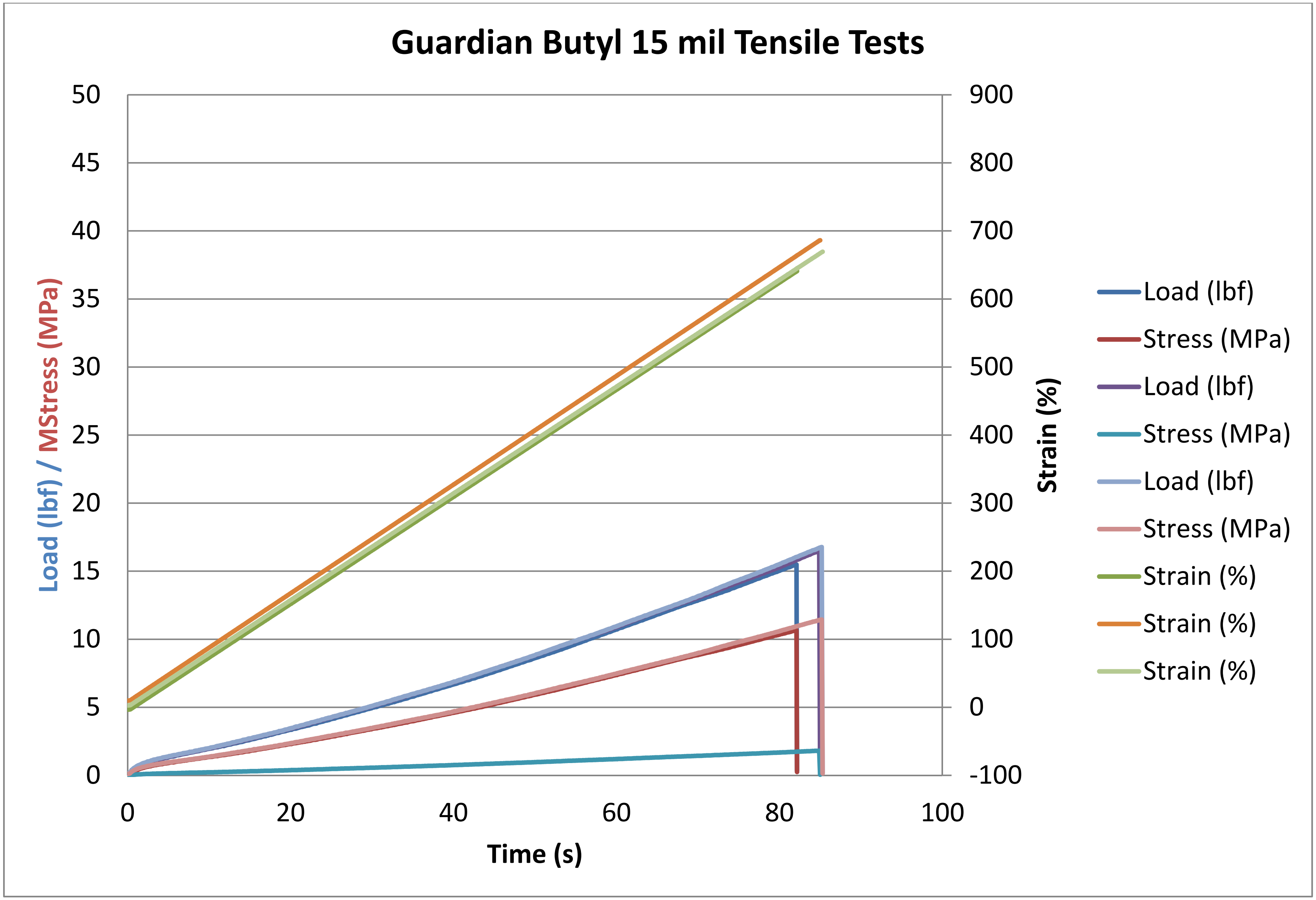
Appendix B: Tensile Charts

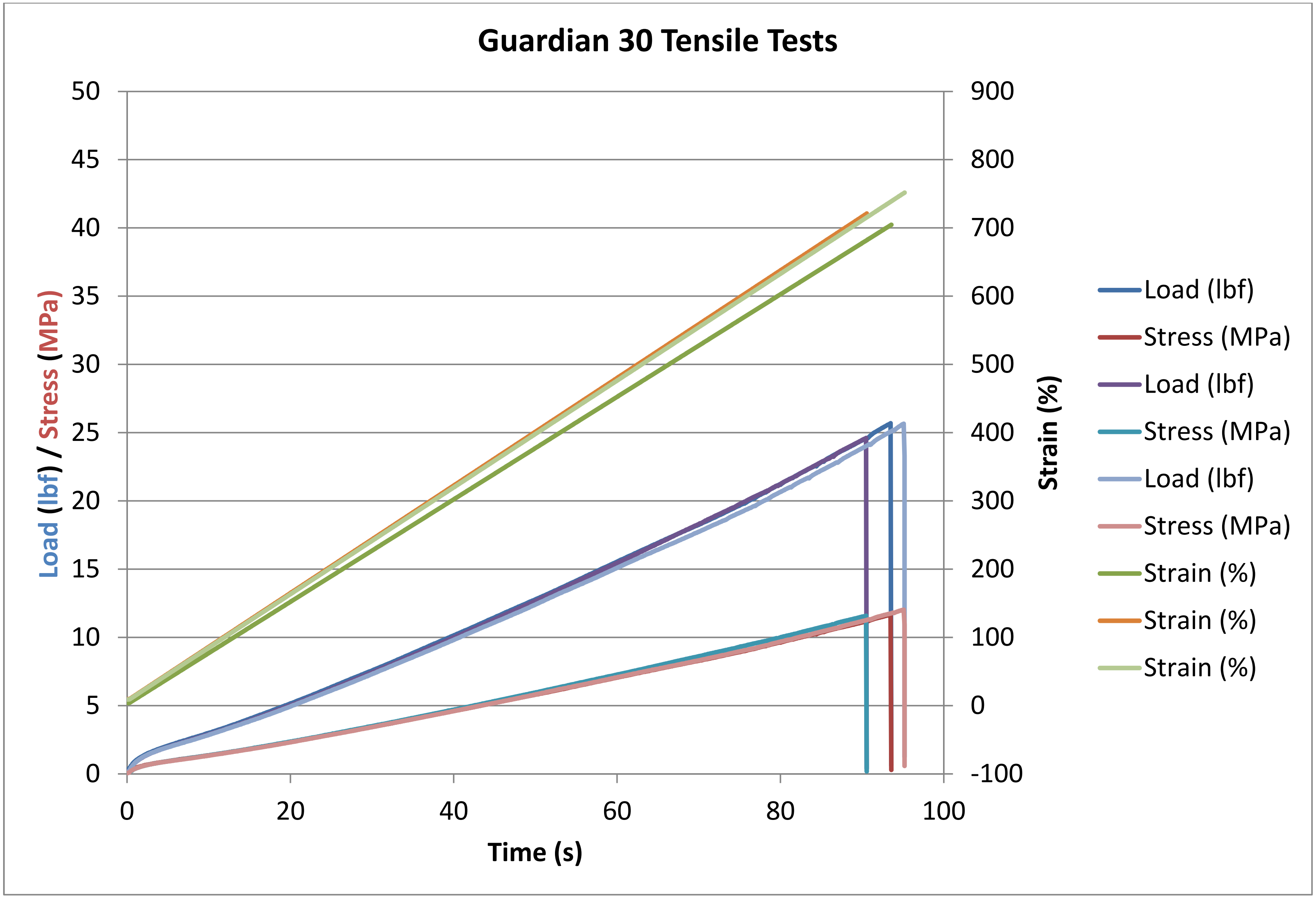


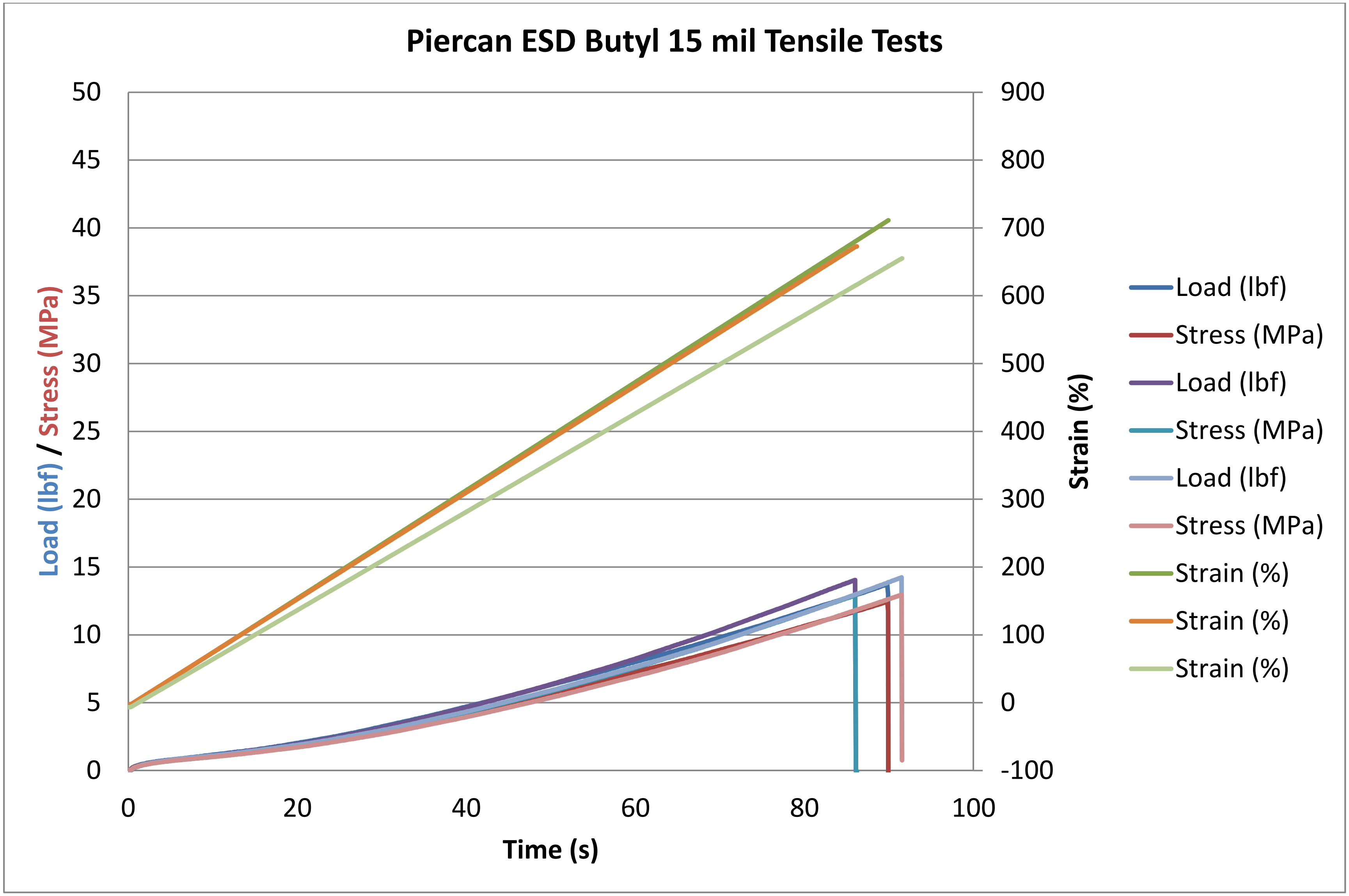

North Butyl 30 mil Tensile Tests
Load (lbf) /Stress (MPa)
Strain (%)
Time (s)
50
45
40
35
30
25
20
15
10
5
0
900
800
700
600
500
400
300
200
100
0
-100
0
20
40
60
80
100
120
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load NB301
Stress NB301
Strain (%)
Strain (%)
Strain (%)
Strain NB301

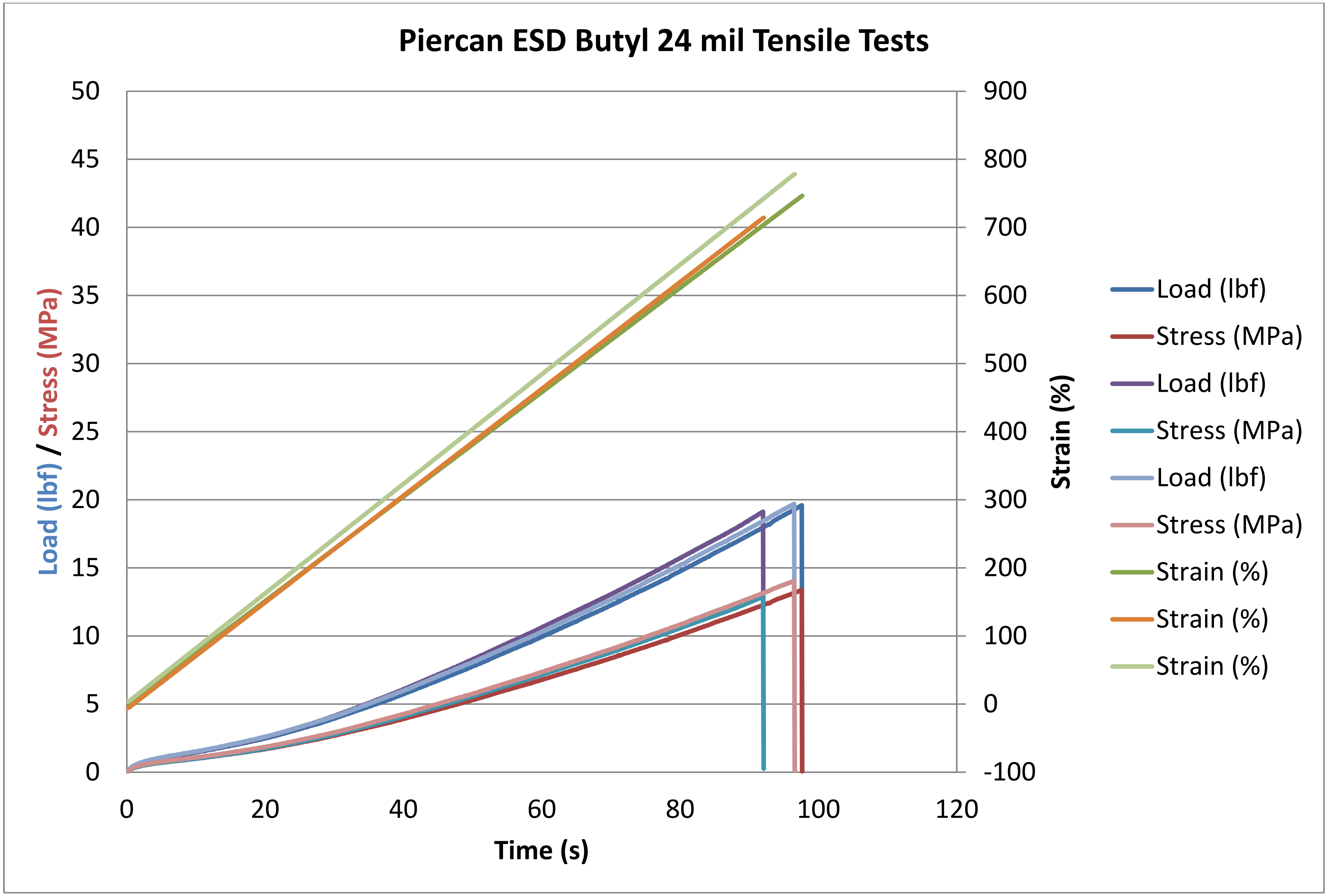

Piercan Butyl 15 mil Tensile Tests
Load (lbf) / Stress (MPa)
Strain (%)
Time (s)
0
5
10
15
20
25
30
35
40
45
50
-100
0
100
200
300
400
500
600
700
800
900
0
20
40
60
80
100
120
Load (lbf)
Mpa
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)
Strain (%)

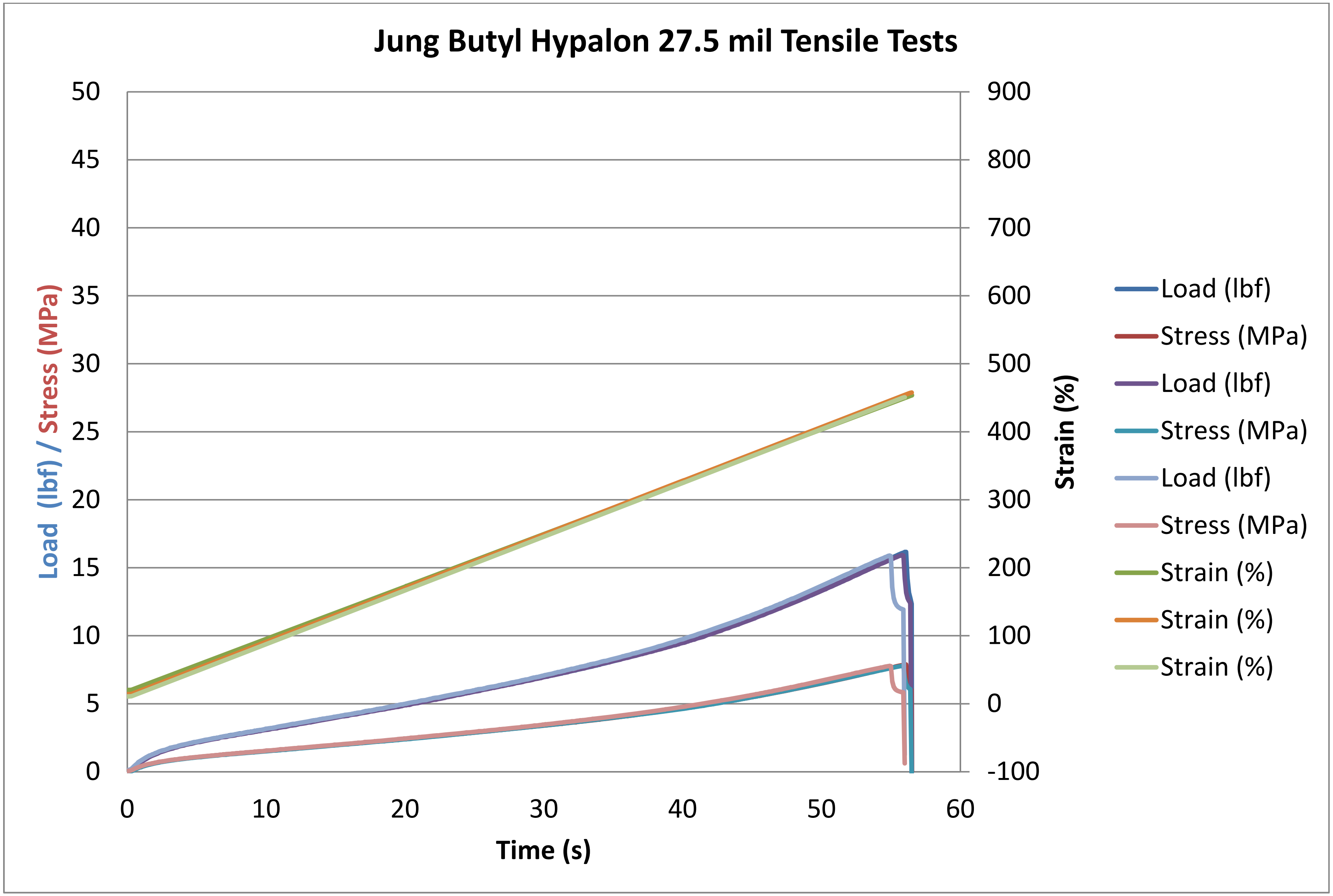

Piercan Butyl 30 mil Tensile Tests
Load (lbf) / Stress (MPa)
Strain (%)
Time (s)
50
45
40
35
30
25
20
15
10
5
0
900
800
700
600
500
400
300
200
100
0
-100
0
20
40
60
80
100
120
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)

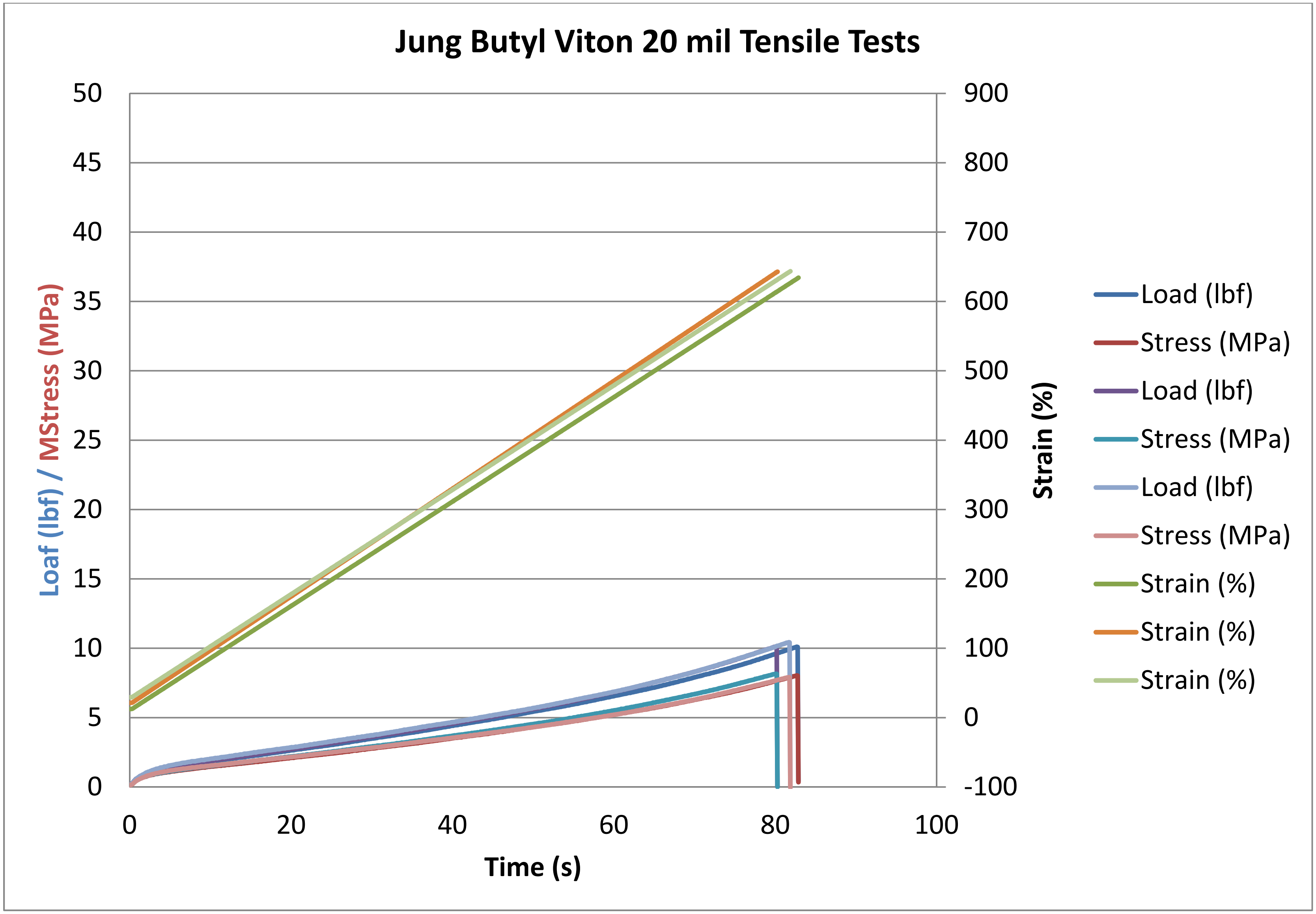

Guardian Butyl 15 mil Tensile Tests
Load (lbf) / MStress (MPa)
Strain (%)
Time (s)
50
45
40
35
30
25
20
15
10
5
0
900
800
700
600
500
400
300
200
100
0
-100
0
20
40
60
80
100
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)

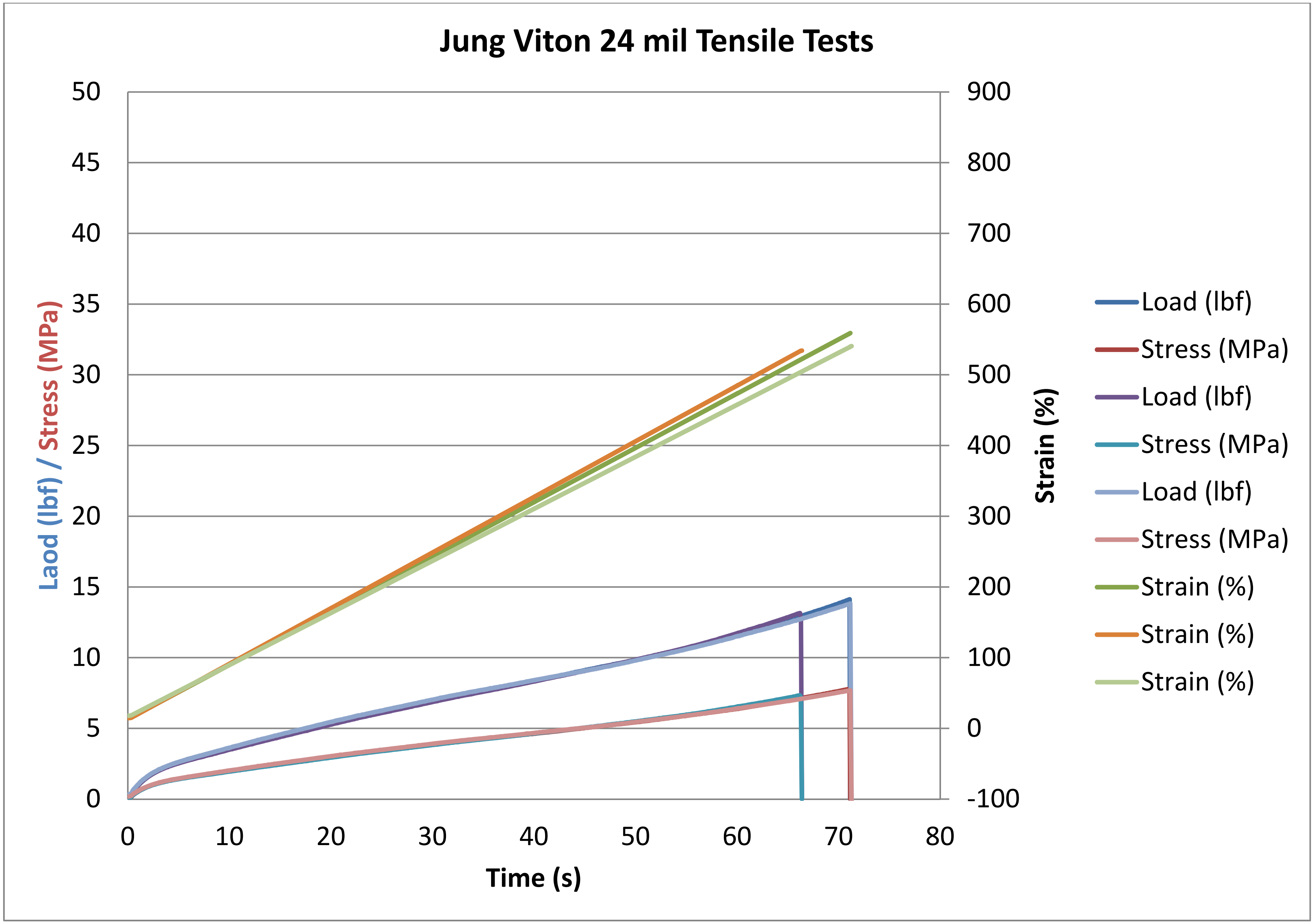

Guardian 30 Tensile Tests
Load (lbf) / Stress (MPa)
50
45
40
35
30
25
20
15
10
5
0
900
800
700
600
500
400
300
200
100
0
-100
Strain (%)
0
20
40
60
80
100
Time (s)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)


Piercan ESD Butyl 15 mil Tensile Tests
Load (lbf) / Stress (MPa)
Strain (%)
Time (s)
0
5
10
15
20
25
30
35
40
45
50
-100
0
100
200
300
400
500
600
700
800
900
0
20
40
60
80
100
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)


Piercan ESD Butyl 24 mil Tensile Tests
Load (lbf) / Stress (MPa)
50
45
40
35
30
25
20
15
10
5
0
Strain (%)
900
800
700
600
500
400
300
200
100
0
-100
0
20
40
60
80
100
120
Time (s)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)


Jung Butyl Hypalon 27.5 mil Tensile Tests
Load (lbf) / Stress (MPa)
Strain (%)
Time (s)
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
40
45
50
-100
0
100
200
300
400
500
600
700
800
900
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)


Jung Butyl Viton 20 mil Tensile Tests
Loaf (lbf) / MStress (MPa)
Strain (%)
Time (s)
0
5
10
15
20
25
30
35
40
45
50
-100
0
100
200
300
400
500
600
700
800
900
0
20
40
60
80
100
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)


Jung Viton 24 mil Tensile Tests
50
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40
35
30
25
20
15
10
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Laod (lbf) / Stress (MPa)
900
800
700
600
500
400
300
200
100
0
-100
Strain (%)
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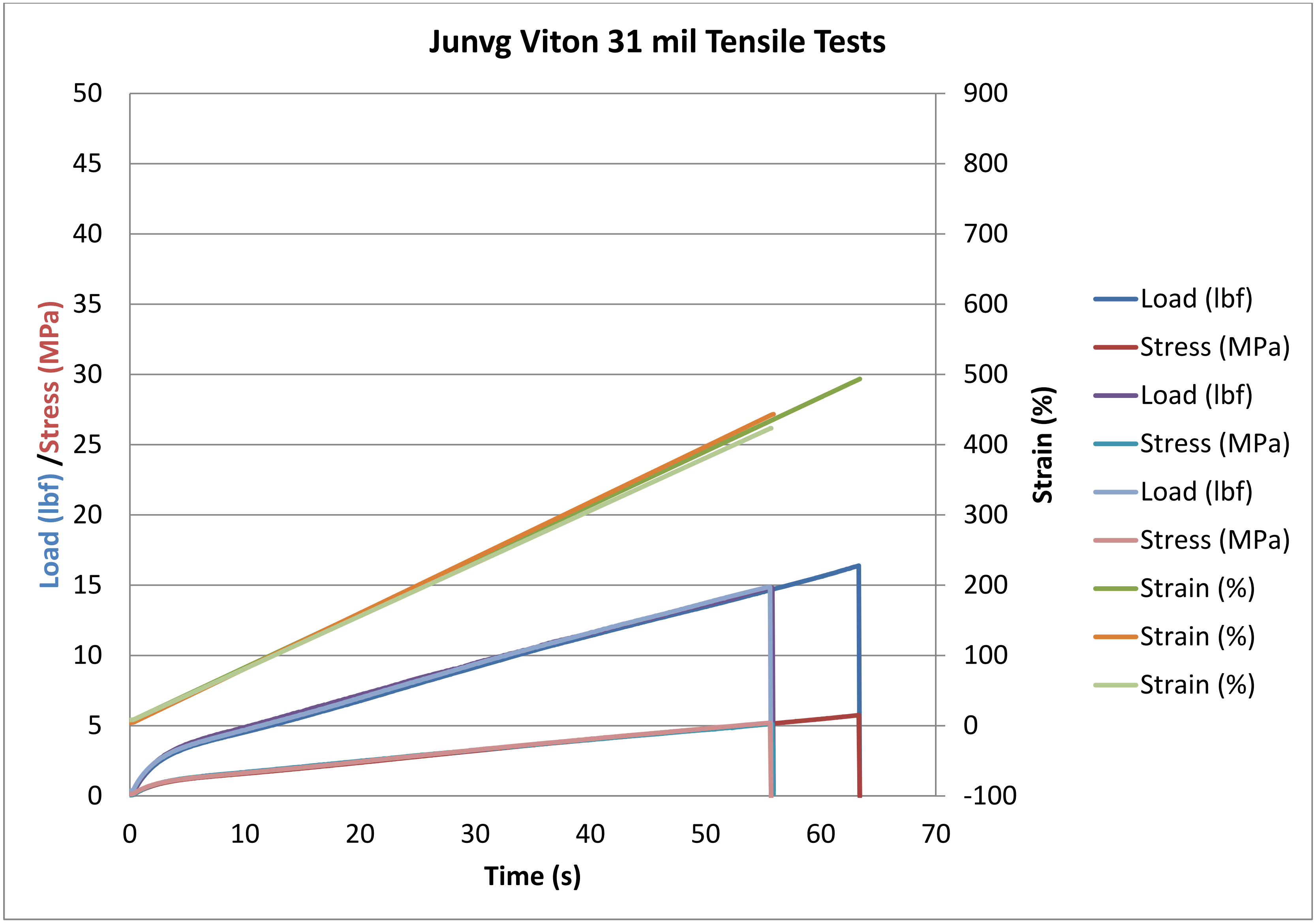
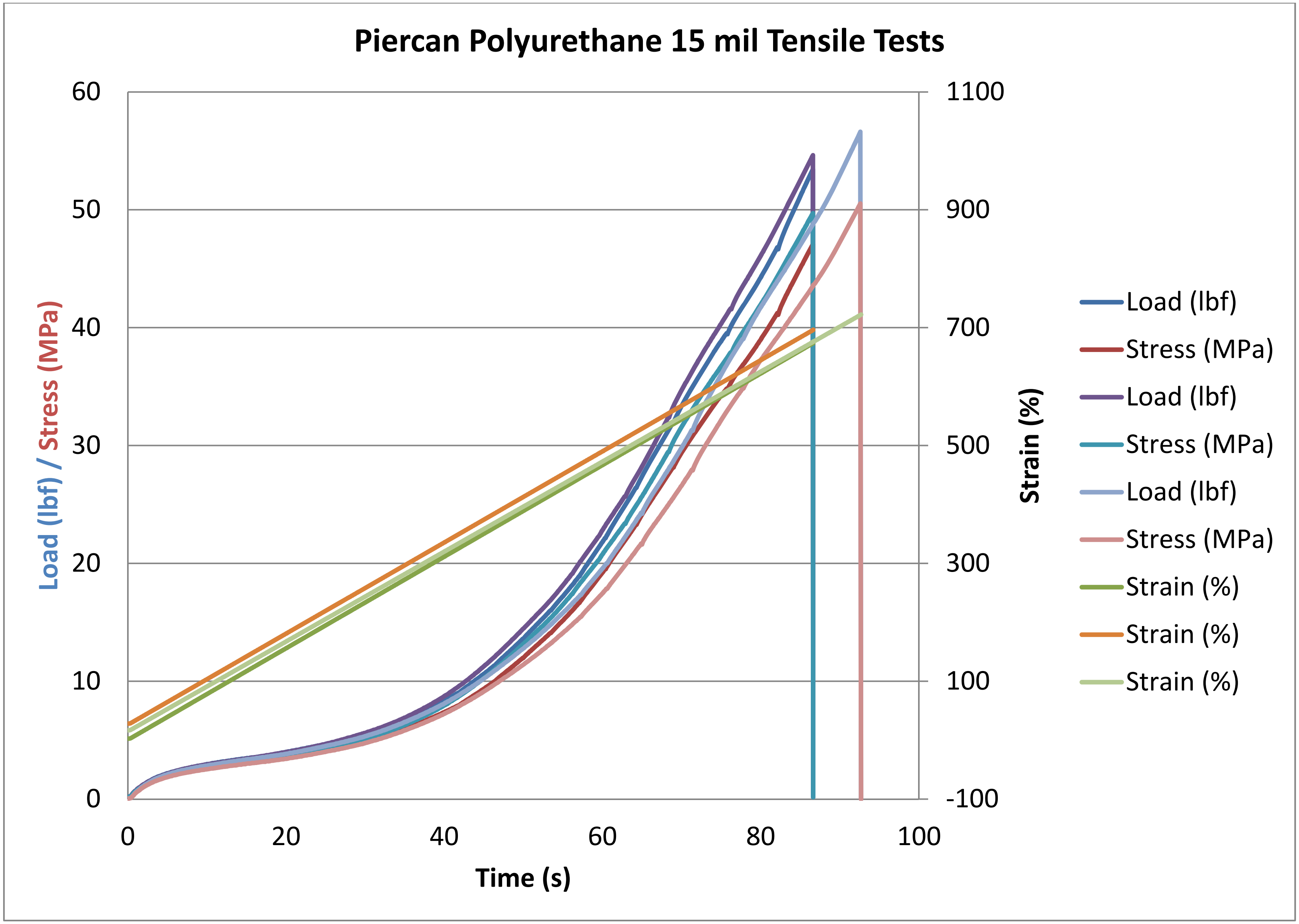
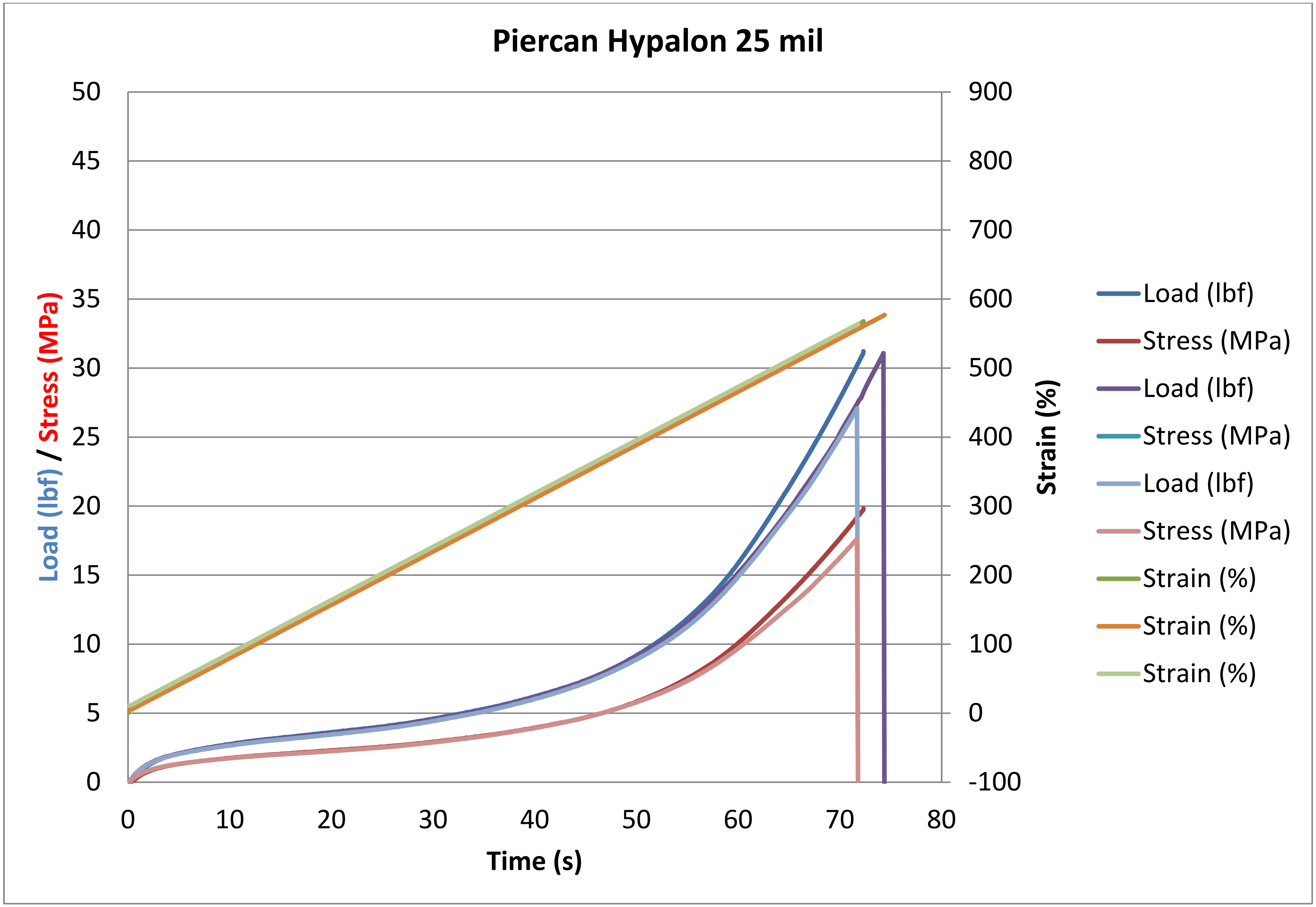
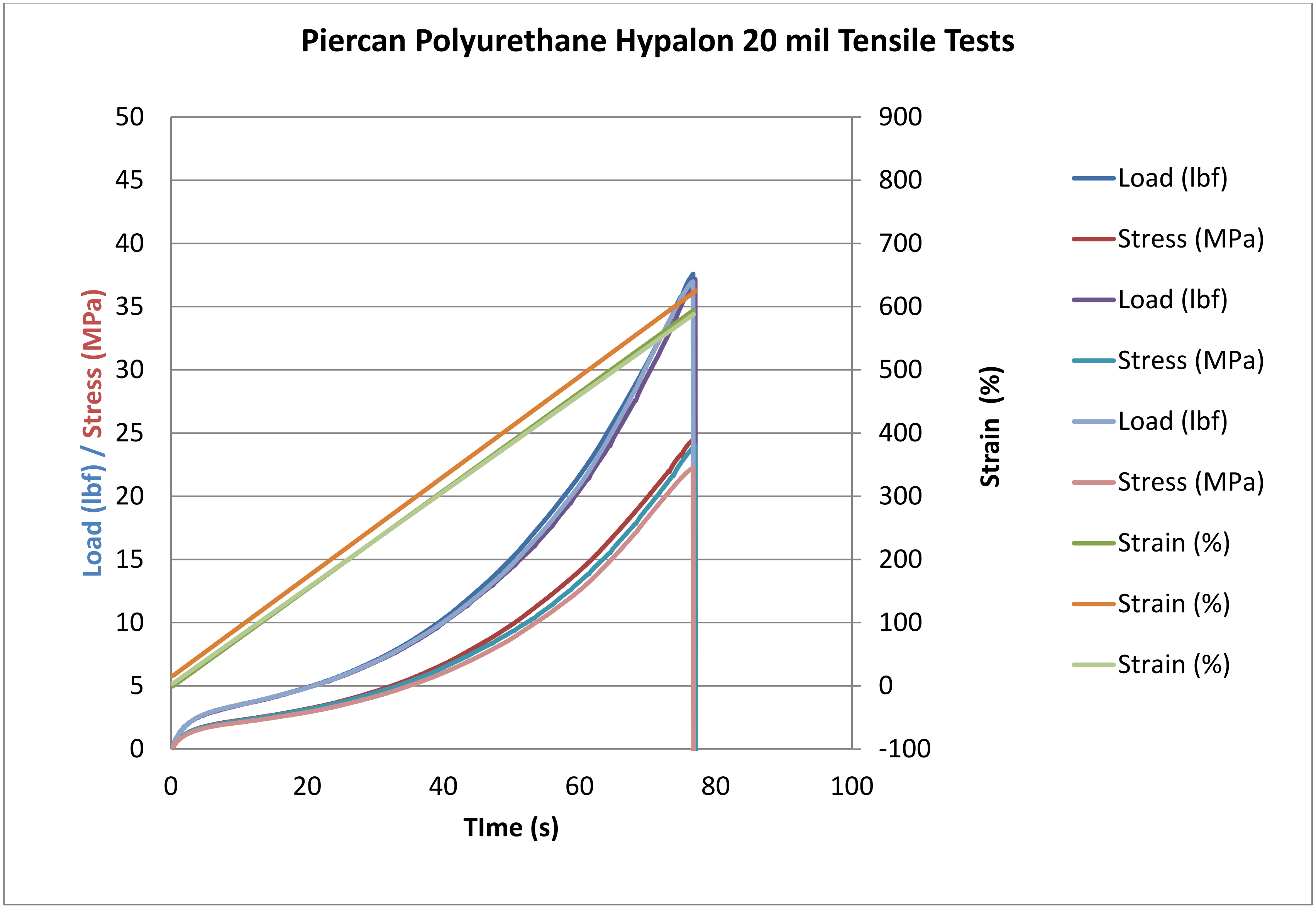
10
20
30
40
50
60
70
80
Time (s)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)


Junvg Viton 31 mil Tensile Tests
Load (lbf) /Stress (MPa)
Strain (%)
Time (s)
50
45
40
35
30
25
20
15
10
5
0
900
800
700
600
500
400
300
200
100
0
-100
0
10
20
30
40
50
60
70
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)


Piercan Polyurethane 15 mil Tensile Tests
Load (lbf) / Stress (MPa)
60
50
40
30
20
10
0
1100
900
700
500
300
100
-100
Strain (%)
0
20
40
60
80
100
Time (s)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)


Piercan Hypalon 25 mil
Load (lbf) / Stress (MPa)
Strain (%)
Time (s)
50
45
40
35
30
25
20
15
10
5
0
900
800
700
600
500
400
300
200
100
0
-100
0
10
20
30
40
50
60
70
80
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)


Piercan Polyurethane Hypalon 20 mil Tensile Tests
Load (lbf) / Stress (MPa)
50
45
40
35
30
25
20
15
10
5
0
900
800
700
600
500
400
300
200
100
0
-100
Strain (%)
0
20
40
60
80
100
TIme (s)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Load (lbf)
Stress (MPa)
Strain (%)
Strain (%)
Strain (%)