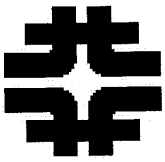


Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG-103 Date: 3/22/06

Project Internal Reference:

Project: SNAP

Title: CROGENIC MECHANICAL PROPERTIES OF THREE ADHESIVES

Author(s): Herman Cease, Paul Derwent, Tom Diehl, Jim Fast, David Finley

Reviewer(s):

Key Words: SNAP, ADHESIVE, SILICON

Abstract Summary:
Material testing of an adhesive for bonding Silicon to a substrate is presented. Tracon-F113, Epotek 301-2, and Hysol 9361 epoxies were tested. Tests results include Young's Modulus, Poisson's Ratio, and Coefficient of Thermal Expansion. Test temperatures ranged from room temperature to 100K.

Applicable Codes:
ASTM D-638 for Tensile Testing, and ASTM E831 for CTE Testing

Introduction:

Tensile tests and CTE measurements were performed on Tracon-F113, Epotek 301-2, and Hysol 9361 epoxies. Tensile tests at five different temperature from 295K to 100K were performed by Precision Measurements and Instruments Corporation. The Fermilab Material Testing Lab performed a Tensile Test on samples at 295K as verification of the results from the Vendor. CTE measurements were performed in house. A continuous measurement of the CTE from 295K to 77K is reported.

Epoxy Properties Supplied by the Manufacturer:

Epoxy Name	Modulus	Viscosity	R.T. CTE
Hysol 9361*	723 MPa	1,000 Pa.s	Not Stated
Tra-Con F113	Not Stated	180 cps @25C	55 ppm C
Epotek 301-302**	Not Stated	225-425 cps	37 ppm C

* Hysol sets in 24 hrs, full cure in 7 days at room temp.
** Epotek has a specification on residual ions (salts) in the resin which is important for silicon bonding applications

Tensile Tests:

Tensile tests were performed by Precision Measurements and Instruments Corporation and also the Fermilab Material Testing Group.

PMIC:
Tensile Tests were performed by Precision Measurements and Instruments Corporation. The samples are dogbone shaped and were machined out of cast plates of Epoxy. The epoxies were degassed to minimize the number and size of air bubbles in the sample. Results are presented in a report attached as an Appendix. Tables of Modulus, Poisson's ratio, Maximum strain and Maximum Stress applied to the sample are displayed included in the Report. The Vendor calculated the sample Modulus using Secant Method at a 0.68% strain, or the highest strain achieved.

FERMILAB:
Fermilab also performed a tensile measurement at room temperature as a confirmation of the data from PMIC. Fermilab reported the steepest slope over a series of ranges to calculate the Modulus. The Crosshead pull speed was greater than 0.05 inches/min.

CTE Tests:

CTE Measurements were performed by Fermilab. The measurement was performed in the spirit of ASTM-E831. The temperature ramp and range did not follow the ASTM guideline. The sample size was approximately 8mm x 8mm x 20 mm. The sample was cast in a mold and then machined to length. During the casting process, the sample was vacuum degassed to minimize the size and number of trapped gas bubbles. The CTE of a sample is measured by placing the sample in holder inside the cryostat. Liquid Nitrogen is poured into the cryostat. Once the sample temperature is 77K, a heater is used to ramp the temperature to 295K over a 3 hour period. A LVDT at the top of the sample holder measures the change in sample length. Both the sample temperature and sample length is recorded as the sample cools down and warms up.

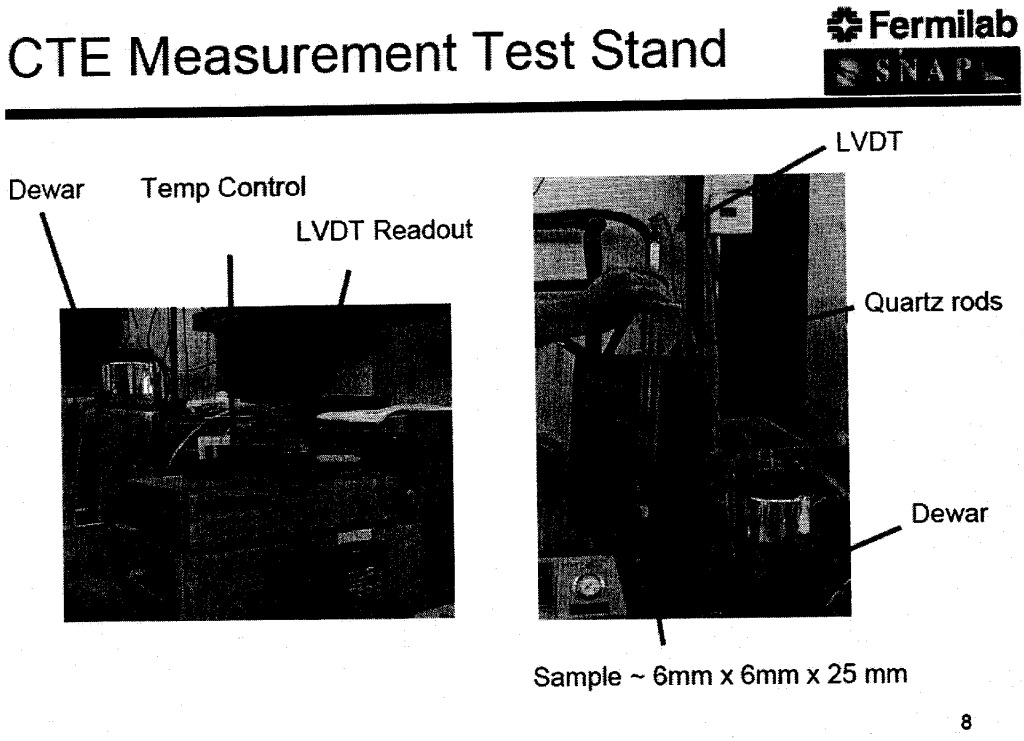


Figure 1, Illustration of the CTE Measurement Test Equipment.

Appendixes

1) PMIC Report, Elastic Property Measurements of Epoxy Specimens.
2) Fermilab Room Temperature Tensile Test Summary Chart and Summary Table.
3) Fermilab CTE Measurements, Summary Chart and Summary Table.

FERMILAB

PURCHASE ORDER NUMBER 565015

ELASTIC PROPERTY MEASUREMENTS OF EPOXY SPECIMENS

February 28, 2006

HERMAN CEASE
MECHANICAL ENGINEER
TEL: 630-840-6453

FERMILAB
500 Wilson Road
Batavia, IL 60510

TESTING SERVICES PROVIDED BY

PRECISION MEASUREMENTS AND INSTRUMENTS CORPORATION
3665 SW Deschutes Street
Corvallis, OR 97333 USA

TEL: 541-753-0607
FAX: 541-753-0610

ELASTIC PROPERTY MEASUREMENTS OF EPOXY SPECIMENS

WORK CONDUCTED FOR FERMILAB
PURCHASE ORDER NUMBER 565015

February 28, 2006

Precision Measurements and Instruments Corporation measured the elastic properties of 75 epoxy resin specimens. Coupons were prepared for Modulus testing and Poisson's Ratio testing. Testing was conducted at 100K, 150K, 200K, 250K and ambient temperatures. Testing was performed per ASTM method D-638. Results are presented in the attached tables. A brief description of the test procedure, data analysis and comments on the results follow.

Specimen Description

Fermilab provided the following specimens:

Quantity	Description	Length	Width	Thickness
35	Tracon F113	8.0"	1.0"	0.125"
35	Epo-Tek 301-2	8.0"	1.0"	0.125"
33	Hysol ES 9361	8.0"	1.0"	0.125"

Test Procedure

- Specimen Check-In

The specimens were received on December 19th, January 11th and January 12th, via Federal Express. The specimens were inspected for damage. No damage was observed. However, it was noted that the Hysol specimens had bubbles visible on the machined surfaces. The specimens were stored at room temperature prior to measurement. A complete list of the specimens is located at the end of the report.

- Specimen Preparation

The specimen preparation and strain gage attachment procedures suggested by the strain gage supplier were followed. Micro-Measurements CEA-06-125UT-350 strain gages were used for both axial and lateral strain measurement on the specimens. Strain gages were bonded to each side of the specimen at corresponding positions, using Micro-Measurements M-Bond AE-10 adhesive. The specimens were clamped and cured for 6+ hours at ≤95°F. Each gage was then wired in series to the corresponding gage on the opposite surface to account for specimen bending. In a few cases the strain gages were shifted axially on the specimen to avoid placing them close to the bubbles.

- Test Procedure

The tensile test machine crosshead speed was set to 0.10 inch/minute. 2 VDC strain gage excitation was used. The specimens were first secured in the machine with the top wedge grip, centered and aligned with the direction of force. For the low temperature tests thermocouples

were placed at three points in the vicinity of the strain gages. The gauge portion of the specimen was enclosed in an insulated chamber. Liquid nitrogen was used to achieve cooling for the 100 K, 150 K, 200 K and 250 K tests. The cryogen was directed close to the proximity of the specimens on either side by dual spray bars. Approximately 20-60 minutes was allowed for the specimens to equilibrate at the desired temperatures. At this point the strain gage conditioning circuitry was balanced, the lower wedge grip tightened and the test started. The load was applied to the specimens by movement of the upper grip until the limits of the strain gage were reached, failure occurred, or the specimens began to yield outside of the gauge section. Load, strain and temperature data were recorded every half second.

- Analysis

The various elastic properties were calculated over certain strain ranges selected to coincide with a level obtained by all, or nearly all, specimens. The first data point used for all calculations was generally the first positive point after all slack was removed. The last data point was generally the limit of the axial strain gage/electronics, ~6800 μ-strain. In some cases the last point was limited by breakage or yielding outside of the temperature controlled zone. In a few cases the endpoints were shifted somewhat due to unusual temperature fluctuations. The secant modulus was calculated by taking the change in axial stress divided by the change in axial strain between the chosen endpoints. Poisson's Ratio was calculated by using the change in transverse strain divided by the change in axial strain at the same endpoints. The nominal dimensions were used in all of the calculations.

Test Results

The results are presented in tabular format in **Table 1**. The stress and strain of the maximum endpoint at which each property is calculated are listed with the results. The properties may be determined for other strain ranges. The raw stress and strain data is being supplied to the requesting engineer.

Some of the specimens broke during the test. The location of the break was always in the area of the specimen held by the upper grip or right beneath it. All but two of the broken specimens were in the Hysol group. In this group, three out of five of the 100 K specimens broke, all of the 150 K specimens broke, and one of the ambient specimens broke. This could have been due to bubbles which were visible in these specimens. In every case of a break, a bubble could be seen in the fractured surfaces. In one of the Hysol specimens the strain gage was slightly offset vertically in order to avoid a bubble. This specimen did not break. In addition, one of the Epo-Tek specimens broke, at 200 K, and one of the Tracon specimens broke, at 100 K.

Possible sources of error include the presence of bubbles in the specimens, the impact of the strain gages on the material and temperature gradients. Digital control of the cryogen flow also induced some degree of temperature fluctuation, which is evident in some of the strain data.

Please contact our technical staff at (541) 753-0607 if you have any questions or require additional information regarding these measurements.

Submitted by:

Don Schneider
Project Engineer

Ann Gaidos-Morgan
Test Technician

Precision Measurements and Instruments Corporation hereby claims that test results are obtained by techniques based on relevant ASTM standards, calibrations with NIST standard reference materials and/or published procedures. Thus, we accept no liability for test results beyond the cost of the contract rendered.

TABLE 1, ELASTIC MODULUS AND POISSON'S RATIO

Ambient (295 K)				
Specimen ID	Elastic Modulus psi	Poisson's Ratio	Maximum Strain %	Maximum Stress psi
TB_5_5	327,203	0.394	0.68	2,324
TB_6_5	369897	0.407	0.69	2,637
TB_8_5	390047	0.405	0.69	2,771
TB_9_5	369262	0.403	0.68	2,611
TB_11_5	328019	0.396	0.69	2,353
ave	**356,886**	**0.401**		
st dev	**28,002**	**0.006**		
ET_1_5	541511	0.353	0.69	3,808
ET_2_5	537859	0.358	0.69	3,791
ET_7_5	542696	0.360	0.69	3,852
ET_19_5	510312	0.359	0.69	3,596
ET_20_5	524758	0.358	0.69	3,708
ave	**531,427**	**0.358**		
st dev	**13,787**	**0.003**		
HS_14_5	155524	0.452	0.69	1,158
HS_15_5	159339	0.434	0.68	1,175
HS_16_5	150281	0.408	0.68	1,122
HS_17_5	155573	0.433	0.68	1,162
HS_18_5	152674	0.439	0.69	1,149
ave	**154,678**	**0.433**		
st dev	**3,413**	**0.016**		

250 K				
Specimen ID	Elastic Modulus psi	Poisson's Ratio	Maximum Strain %	Maximum Stress psi
TB_5_4	513,054	0.369	0.67	3,479
TB_6_4	522,770	0.356	0.68	3,591
TB_8_4	545,348	0.373	0.67	3,463
TB_9_4	555,162	0.383	0.69	3,924
TB_11_4	460,474	0.378	0.67	3,179
ave	519,361	0.372		
st dev	37,000	0.010		
ET_1_4	637,210	0.365	0.67	4,355
ET_2_4	571,547	0.364	0.69	4,013
ET_7_4	604,671	0.359	0.69	4,239
ET_19_4	568,324	0.357	0.68	3,973
ET_20_4	597,763	0.379	0.69	4,046
ave	595,903	0.365		
st dev	28,020	0.009		
HS_14_4	233,015	0.442	0.68	1,669
HS_15_4	225,696	0.425	0.69	1,644
HS_17_4	249,646	0.446	0.69	1,812
HS_18_4	245,975	0.438	0.70	1,813
HS_16_6	241,877	0.424	0.68	1,744
ave	239,242	0.435		
st dev	9,782	0.010		

TABLE 1, ELASTIC MODULUS AND POISSON'S RATIO

200 K				
Specimen ID	Elastic Modulus psi	Poisson's Ratio	Maximum Strain %	Maximum Stress psi
TB_5_3	607,451	0.367	0.69	4258
TB_6_3	613,755	0.370	0.68	4295
TB_8_3	651,835	0.371	0.68	4559
TB_11_3	522,938	0.359	0.68	3550
TB_9_6	681,959	0.374	0.67	4698
ave	**615,588**	**0.368**		
st dev	**59,943**	**0.006**		
ET_1_3	634,469	0.344	0.68	4421
ET_7_3	678,932	0.358	0.68	4738
ET_19_3	608,731	0.333	0.68	4181
ET_20_3	654,185	0.351	0.68	4374
ET_2_3+	667,985	0.357	0.68	4642
ave	**648,860**	**0.349**		
st dev	**27,910**	**0.010**		
HS_14_3	603,769	0.347	0.69	4229
HS_15_3	536,650	0.351	0.69	3734
HS_16_3	561,845	0.366	0.69	3901
HS_17_3	561,774	0.369	0.68	3870
HS_18_3	539,892	0.351	0.69	3825
ave	**560,786**	**0.357**		
st dev	**26,780**	**0.010**		

150 K				
Specimen ID	Elastic Modulus psi	Poisson's Ratio	Maximum Strain %	Maximum Stress psi
TB_5_2	873,958	0.355	0.68	5880
TB_6_2	911,669	0.365	0.69	6262
TB_8_2	939,767	0.358	0.69	6384
TB_9_2	968,010	0.399	0.68	6393
TB_11_2	736,770	0.356	0.69	4994
ave	**886,035**	**0.367**		
st dev	**90,402**	**0.019**		
ET_1_2	825,968	0.327	0.68	5364
ET_2_2	869,247	0.351	0.68	5795
ET_7_2	852,639	0.319	0.69	5932
ET_19_2	785,872	0.322	0.69	5501
ET_20_2	832,372	0.352	0.69	5814
ave	**833,220**	**0.334**		
st dev	**31,505**	**0.016**		
HS_14_2	781,235	0.322	0.59	4616
HS_15_2	858,394	0.365	0.54	4596
HS_16_2	817,672	0.394	0.59	4885
HS_18_2	849,032	0.365	0.54	4709
HS_17_6	806,935	0.338	0.55	4398
ave	**822,654**	**0.357**		
st dev	**31,467**	**0.028**		

TABLE 1, ELASTIC MODULUS AND POISSON'S RATIO

100 K				
Specimen ID	Elastic Modulus psi	Poisson's Ratio	Maximum Strain %	Maximum Stress psi
TB_5_1	1,115,620	0.361	0.69	7518
TB_6_1	1,084,636	0.351	0.69	7671
TB_8_1	1,176,787	0.331	0.69	7982
TB_9_1	1,190,017	0.352	0.69	7777
TB_11_1	962,414	0.344	0.45	4514
ave	**1,105,895**	**0.348**		
st dev	**91,153**	**0.011**		
ET_1_1	1,002,227	0.359	0.69	6360
ET_2_1	1,022,622	0.326	0.69	6570
ET_7_1	1,062,459	0.375	0.69	7327
ET_20_1	1,009,726	0.347	0.69	6865
ET_19_1	974,514	0.343	0.69	6794
ave	**1,014,310**	**0.350**		
st dev	**32,164**	**0.018**		
HS_14_1	1,095,470	0.367	0.39	4223
HS_15_1	1,121,990	0.314	0.39	4479
HS_16_1	1,177,256	0.317	0.41	4789
HS_17_1	1,141,779	0.394	0.31	3602
HS_18_1	1,123,786	0.374	0.40	4033
ave	**1,132,056**	**0.353**		
st dev	**30,190**	**0.036**		

The following table is a listing of the Tracon test specimens.

1) Tracon F113 TB_5_1 (100K) 8" X 1" X 0.13"	18) Tracon F113 TB_8_4 (250K) 8" X 1" X 0.13"
2) Tracon F113 TB_5_2 (150K) 8" X 1" X 0.13"	19) Tracon F113 TB_8_5 (300K) 8" X 1" X 0.13"
3) Tracon F113 TB_5_3 (200K) 8" X 1" X 0.13"	20) Tracon F113 TB_9_1 (100K) 8" X 1" X 0.13"
4) Tracon F113 TB_5_4 (250K) 8" X 1" X 0.13"	21) Tracon F113 TB_9_2 (150K) 8" X 1" X 0.13"
5) Tracon F113 TB_5_5 (300K) 8" X 1" X 0.13"	22) Tracon F113 TB_9_3 (200K) 8" X 1" X 0.13"
6) Tracon F113 TB_5_6 (Spare) 8" X 1" X 0.13"	23) Tracon F113 TB_9_4 (250K) 8" X 1" X 0.13"
7) Tracon F113 TB_5_7 (Spare) 8" X 1" X 0.13"	24) Tracon F113 TB_9_5 (300K) 8" X 1" X 0.13"
8) Tracon F113 TB_6_1 (100K) 8" X 1" X 0.13"	25) Tracon F113 TB_9_6 (Spare) 8" X 1" X 0.13"
9) Tracon F113 TB_6_2 (150K) 8" X 1" X 0.13"	26) Tracon F113 TB_11_1 (100K) 8" X 1" X 0.13"
10) Tracon F113 TB_6_3 (200K) 8" X 1" X 0.13"	27) Tracon F113 TB_11_2 (150K) 8" X 1" X 0.13"
11) Tracon F113 TB_6_4 (250K) 8" X 1" X 0.13"	28) Tracon F113 TB_11_3 (200K) 8" X 1" X 0.13"
12) Tracon F113 TB_6_5 (300K) 8" X 1" X 0.13"	29) Tracon F113 TB_11_4 (250K) 8" X 1" X 0.13"
13) Tracon F113 TB_6_6 (Spare) 8" X 1" X 0.13"	30) Tracon F113 TB_11_5 (300K) 8" X 1" X 0.13"
14) Tracon F113 TB_6_7 (Spare) 8" X 1" X 0.13"	31) Tracon F113 TB_11_6 (Spare) 8" X 1" X 0.13"
15) Tracon F113 TB_8_1 (100K) 8" X 1" X 0.13"	32) Tracon F113 TB_12_1 (Spare) 8" X 1" X 0.13"
16) Tracon F113 TB_8_2 (150K) 8" X 1" X 0.13"	33) Tracon F113 TB_12_2 (Spare) 8" X 1" X 0.13"
17) Tracon F113 TB_8_3 (200K) 8" X 1" X 0.13"	34) Tracon F113 TB_12_3 (Spare) 8" X 1" X 0.13"
	35) Tracon F113 TB_12_4 (Spare) 8" X 1" X 0.13"

The following table is a listing of the Epo-Tek 301-2 specimens.

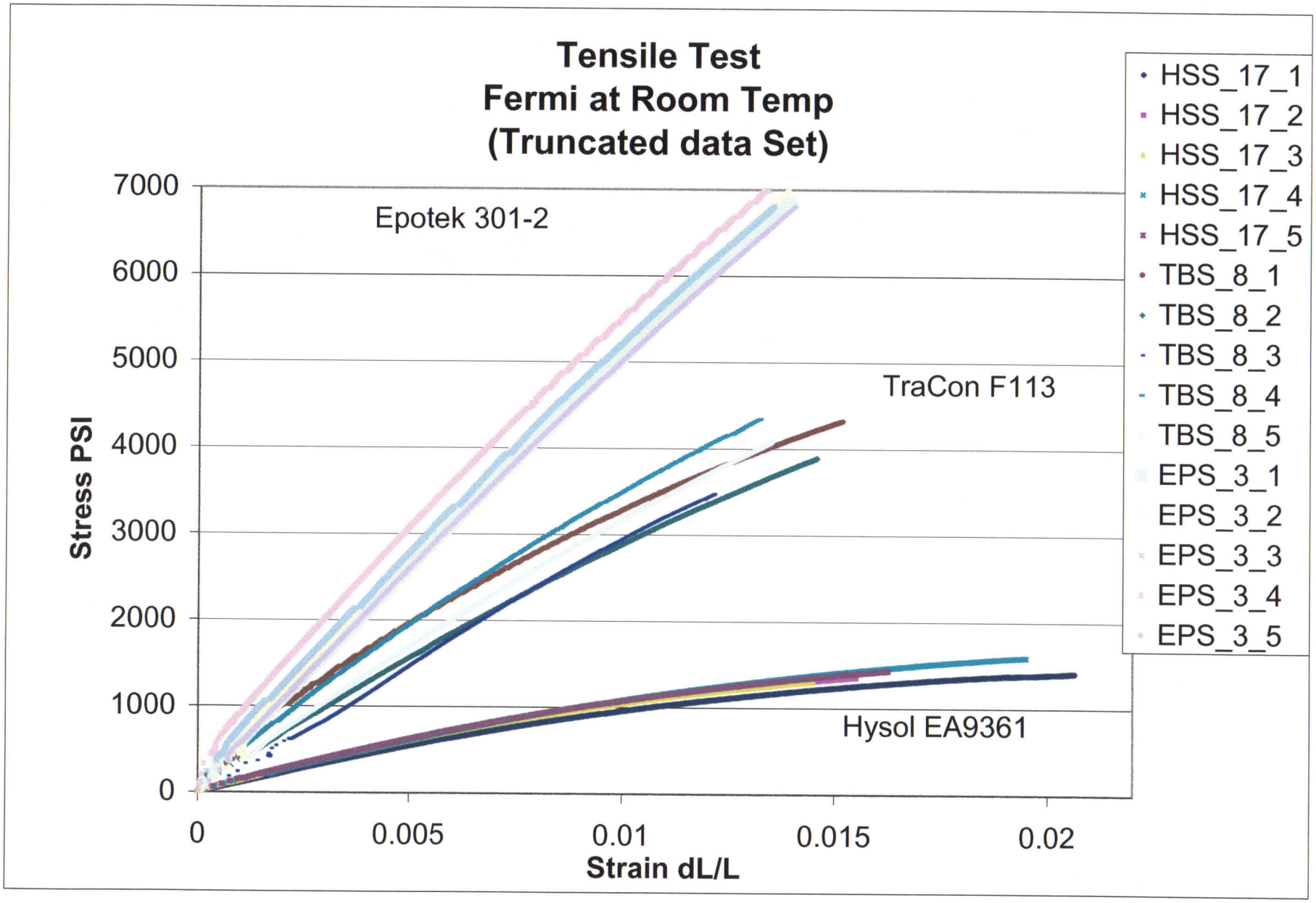
36) Epo-Tek 301-2 ET_1_1 (100K) 8" X 1" X 0.13"	53) Epo-Tek 301-2 ET_4_2 (Spare) 8" X 1" X 0.13"
37) Epo-Tek 301-2 ET_1_2 (150K) 8" X 1" X 0.13"	54) Epo-Tek 301-2 ET_7_1 (100K) 8" X 1" X 0.13"
38) Epo-Tek 301-2 ET_1_3 (200K) 8" X 1" X 0.13"	55) Epo-Tek 301-2 ET_7_2 (150K) 8" X 1" X 0.13"
39) Epo-Tek 301-2 ET_1_4 (250K) 8" X 1" X 0.13"	56) Epo-Tek 301-2 ET_7_3 (200K) 8" X 1" X 0.13"
40) Epo-Tek 301-2 ET_1_5 (300K) 8" X 1" X 0.13"	57) Epo-Tek 301-2 ET_7_4 (250K) 8" X 1" X 0.13"
41) Epo-Tek 301-2 ET_2_1 (100K) 8" X 1" X 0.13"	58) Epo-Tek 301-2 ET_7_5 (300K) 8" X 1" X 0.13"
42) Epo-Tek 301-2 ET_2_2 (150K) 8" X 1" X 0.13"	59) Epo-Tek 301-2 ET_19_1 (100K) 8" X 1" X 0.13"
43) Epo-Tek 301-2 ET_2_3 (200K) 8" X 1" X 0.13"	60) Epo-Tek 301-2 ET_19_2 (150K) 8" X 1" X 0.13"
44) Epo-Tek 301-2 ET_2_4 (250K) 8" X 1" X 0.13"	61) Epo-Tek 301-2 ET_19_3 (200K) 8" X 1" X 0.13"
45) Epo-Tek 301-2 ET_2_5 (300K) 8" X 1" X 0.13"	62) Epo-Tek 301-2 ET_19_4 (250K) 8" X 1" X 0.13"
46) Epo-Tek 301-2 ET_2_6(Spare) 8" X 1" X 0.13"	63) Epo-Tek 301-2 ET_19_5 (300K) 8" X 1" X 0.13"
47) Epo-Tek 301-2 ET_3_1 (Spare) 8" X 1" X 0.13"	64) Epo-Tek 301-2 ET_19_6 (Spare) 8" X 1" X 0.13"
48) Epo-Tek 301-2 ET_3_2 (Spare) 8" X 1" X 0.13"	65) Epo-Tek 301-2 ET_20_1 (100K) 8" X 1" X 0.13"
49) Epo-Tek 301-2 ET_3_3 (Spare) 8" X 1" X 0.13"	66) Epo-Tek 301-2 ET_20_2 (150K) 8" X 1" X 0.13"
50) Epo-Tek 301-2 ET_3_4 (Spare) 8" X 1" X 0.13"	67) Epo-Tek 301-2 ET_20_3 (200K) 8" X 1" X 0.13"
51) Epo-Tek 301-2 ET_3_5 (Spare) 8" X 1" X 0.13"	68) Epo-Tek 301-2 ET_20_4 (250K) 8" X 1" X 0.13"
52) Epo-Tek 301-2 ET_4_1 (Spare) 8" X 1" X 0.13"	69) Epo-Tek 301-2 ET_20_5 (300K) 8" X 1" X 0.13"
	70) Epo-Tek 301-2 ET_20_6 (Spare) 8" X 1" X 0.13"

The following table is a listing of the HYSOL 9361 HS Specimens.

71) HYSOL 9361 HS_14_1 (100K) 8" X 1" X 0.13"	89) HYSOL 9361 HS_16_6 (Spare) 8" X 1" X 0.13"
72) HYSOL 9361 HS_14_2 (150K) 8" X 1" X 0.13"	90) HYSOL 9361 HS_16_7 (Spare) 8" X 1" X 0.13"
73) HYSOL 9361 HS_14_3 (200K) 8" X 1" X 0.13"	91) HYSOL 9361 HS_17_1 (100K) 8" X 1" X 0.13"
74) HYSOL 9361 HS_14_4 (250K) 8" X 1" X 0.13"	92) HYSOL 9361 HS_17_2 (150K) 8" X 1" X 0.13"
75) HYSOL 9361 HS_14_5 (300K) 8" X 1" X 0.13"	93) HYSOL 9361 HS_17_3 (200K) 8" X 1" X 0.13"
76) HYSOL 9361 HS_14_6 (Spare) 8" X 1" X 0.13"	94) HYSOL 9361 HS_17_4 (250K) 8" X 1" X 0.13"
77) HYSOL 9361 HS_15_1 (100K) 8" X 1" X 0.13"	95) HYSOL 9361 HS_17_5 (300K) 8" X 1" X 0.13"
78) HYSOL 9361 HS_15_2 (150K) 8" X 1" X 0.13"	96) HYSOL 9361 HS_17_6 (Spare) 8" X 1" X 0.13"
79) HYSOL 9361 HS_15_3 (200K) 8" X 1" X 0.13"	97) HYSOL 9361 HS_18_1 (100K) 8" X 1" X 0.13"
80) HYSOL 9361 HS_15_4 (250K) 8" X 1" X 0.13"	98) HYSOL 9361 HS_18_2 (150K) 8" X 1" X 0.13"
81) HYSOL 9361 HS_15_5(300K) 8" X 1" X 0.13"	99) HYSOL 9361 HS_18_3 (200K) 8" X 1" X 0.13"
82) HYSOL 9361 HS_15_6 (Spare) 8" X 1" X 0.13"	100) HYSOL 9361 HS_18_4 (250K) 8" X 1" X 0.13"
83) HYSOL 9361 HS_15_7 (Spare) 8" X 1" X 0.13"	101) HYSOL 9361 HS_18_5 (300K) 8" X 1" X 0.13"
84) HYSOL 9361 HS_16_1 (100K) 8" X 1" X 0.13"	102) HYSOL 9361 HS_18_6 (Spare) 8" X 1" X 0.13"
85) HYSOL 9361 HS_16_2 (150K) 8" X 1" X 0.13"	103) HYSOL 9361 HS_18_7 (Spare) 8" X 1" X 0.13"
86) HYSOL 9361 HS_16_3 (200K) 8" X 1" X 0.13"	
87) HYSOL 9361 HS_16_4 (250K) 8" X 1" X 0.13"	
88) HYSOL 9361 HS_16_5 (300K) 8" X 1" X 0.13"	

Fermilab Room Temperature Tensile Test

Summary Chart
and
Summary Table


Tensile Test
Fermi at Room Temp
(Truncated data Set)
Epotek 301-2
TraCon F113
Hysol EA9361
Stress PSI
7000
6000
5000
4000
3000
2000
1000
0
0
0.005
0.01
0.015
0.02
Strain dL/L
HSS_17_1
HSS_17_2
HSS_17_3
HSS_17_4
HSS_17_5
TBS_8_1
TBS_8_2
TBS_8_3
TBS_8_4
TBS_8_5
EPS_3_1
EPS_3_2
EPS_3_3
EPS_3_4
EPS_3_5

FERMI ROOM TEMP TENSILE TEST

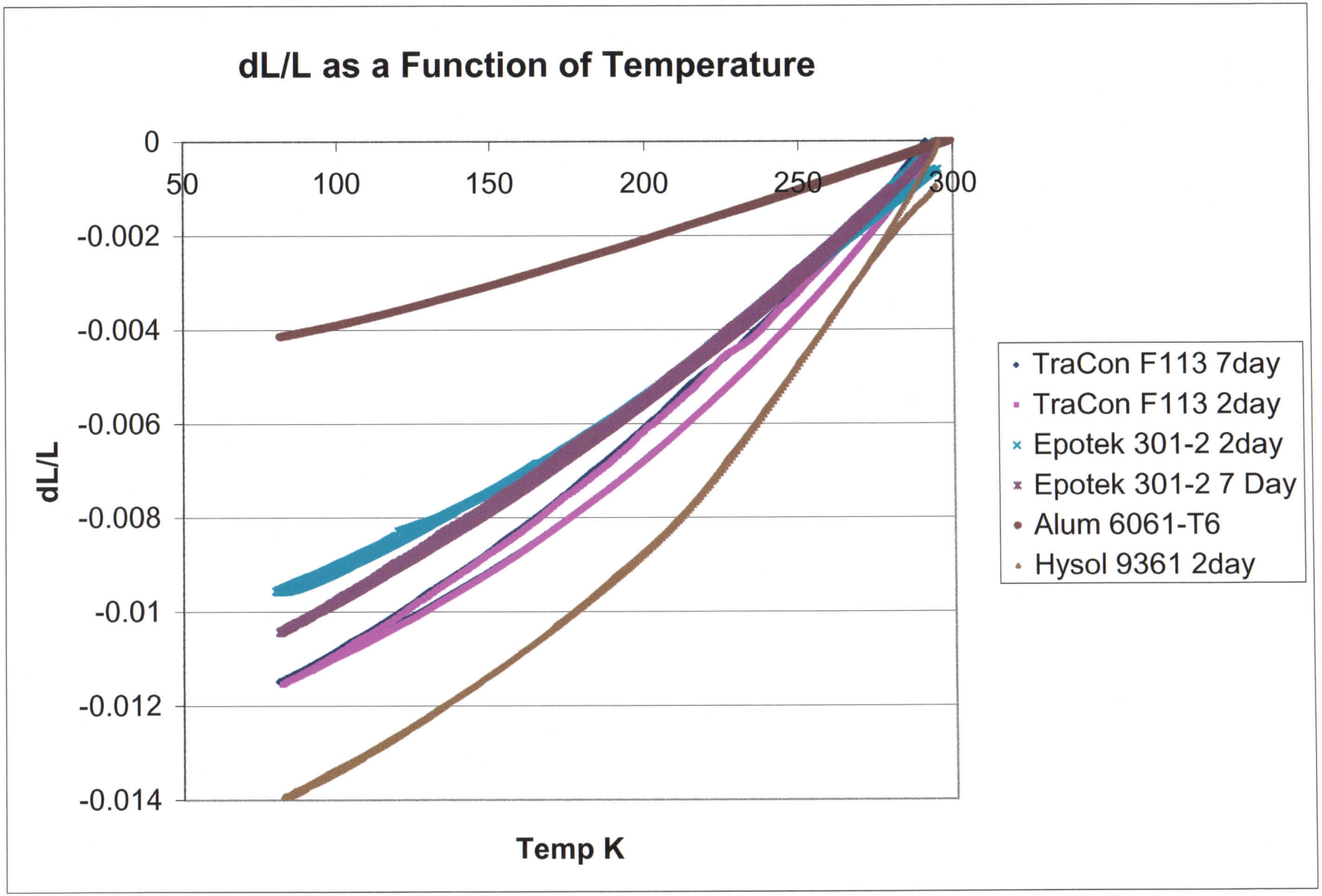
Hysol EA 9361									
Sample	1	2	3	4	5	ave	std	%	Catalogue
modulus (KSI)	115.7	141.4	126.5	144.1	159.8	137.5	16.97277	0.123438	105
ultimate tensile strength (PSI)	2120	2633	2438	2331	2480	2400.4	190.5867	0.079398	

Tracon F113								
Sample	1	2	3	4	5	ave	std	
modulus (KSI)	518.2	311.8	325	421.2	348	384.84	85.70267	0.222697
ultimate tensile strength (PSI)	4858	4082	4573	5651	4827	4798.2	569.063	0.118599

Epotek 301-2								
Sample	1	2	3	4	5	ave	std	
modulus (KSI)	534.8	637.5	613.3	952	515.2	650.56	176.173	0.270802
ultimate tensile strength (PSI)	11010	7253	10320	8388	11350	9664.2	1769.586	0.183107

Fermilab CTE Measurements

Summary Chart
and
Summary Table


dL/L as a Function of Temperature
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
dL/L
50
100
150
200
250
300
Temp K
TraCon F113 7day
TraCon F113 2day
Epotek 301-2 2day
Epotek 301-2 7 Day
Alum 6061-T6
Hysol 9361 2day

Summary Data

dL/L	295.5 K	250K	200K	150K	100K
Aluminum 6061-T6	0	-0.00106	-0.00209	-0.00307	-0.0039
Eptoek 301-2 2 day cure	0	-0.00272	-0.00541	-0.00744	-0.009072
Epotek 301-2 7 day cure	0	-0.00284	-0.00555	-0.00778	-0.00975
Tracon F113 7 day cure	0	-0.00339	-0.00639	-0.00889	-0.01084
Tracon F113 2 day cure	0	-0.00343	-0.00645	-0.00894	-0.01092
Hysol 9361 2 day cure	0	-0.0047	-0.00869	-0.01133	-0.01335

Summary is the average of the warm up and cool down datapoints for each run