Reliability Testing of Monolithic CIGSS in a Glass-Glass Package

Richard Wickham – Director of Quality & Reliability

STION

Outline

- Monolithic Cell Structure
  - Cell Interconnection using MOCVD
  - Stion Process Overview

- Package Design advantages and challenges
  - Glass-Glass Package Assembly
  - Managing Mechanical Stress
- Testing
  - Testing Procedures & Frequency
    - PID Test results

  - Results of Short & Long term Accelerated Aging
  - ALT Stresses

    Damp Heat

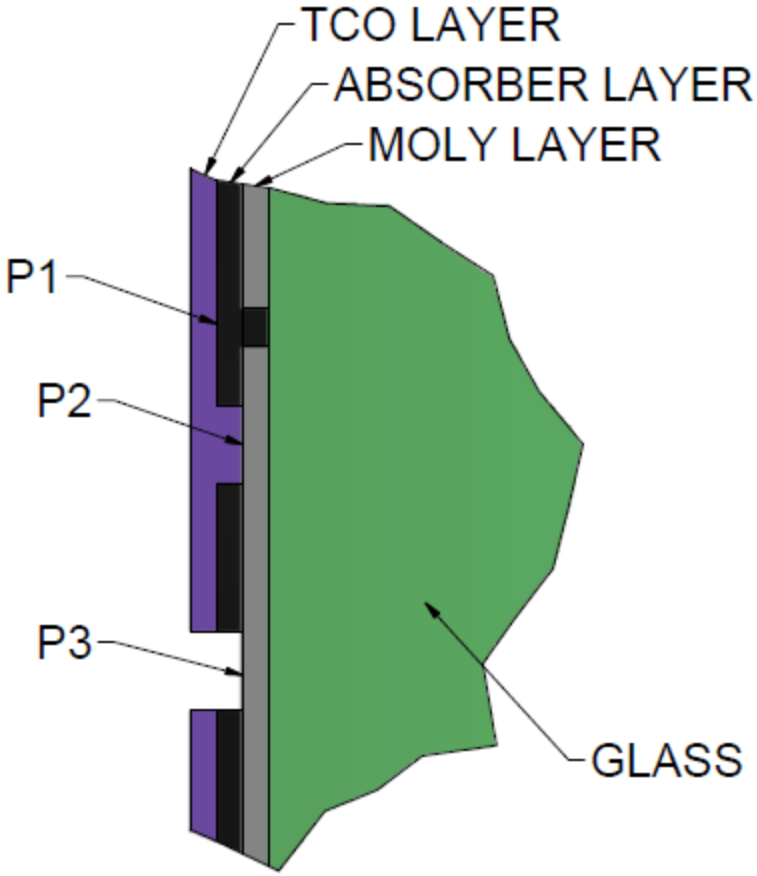
    Thermo-mechanical

Stion Corporation © Copyright 2010

Finished Monolithic Circuit Structure

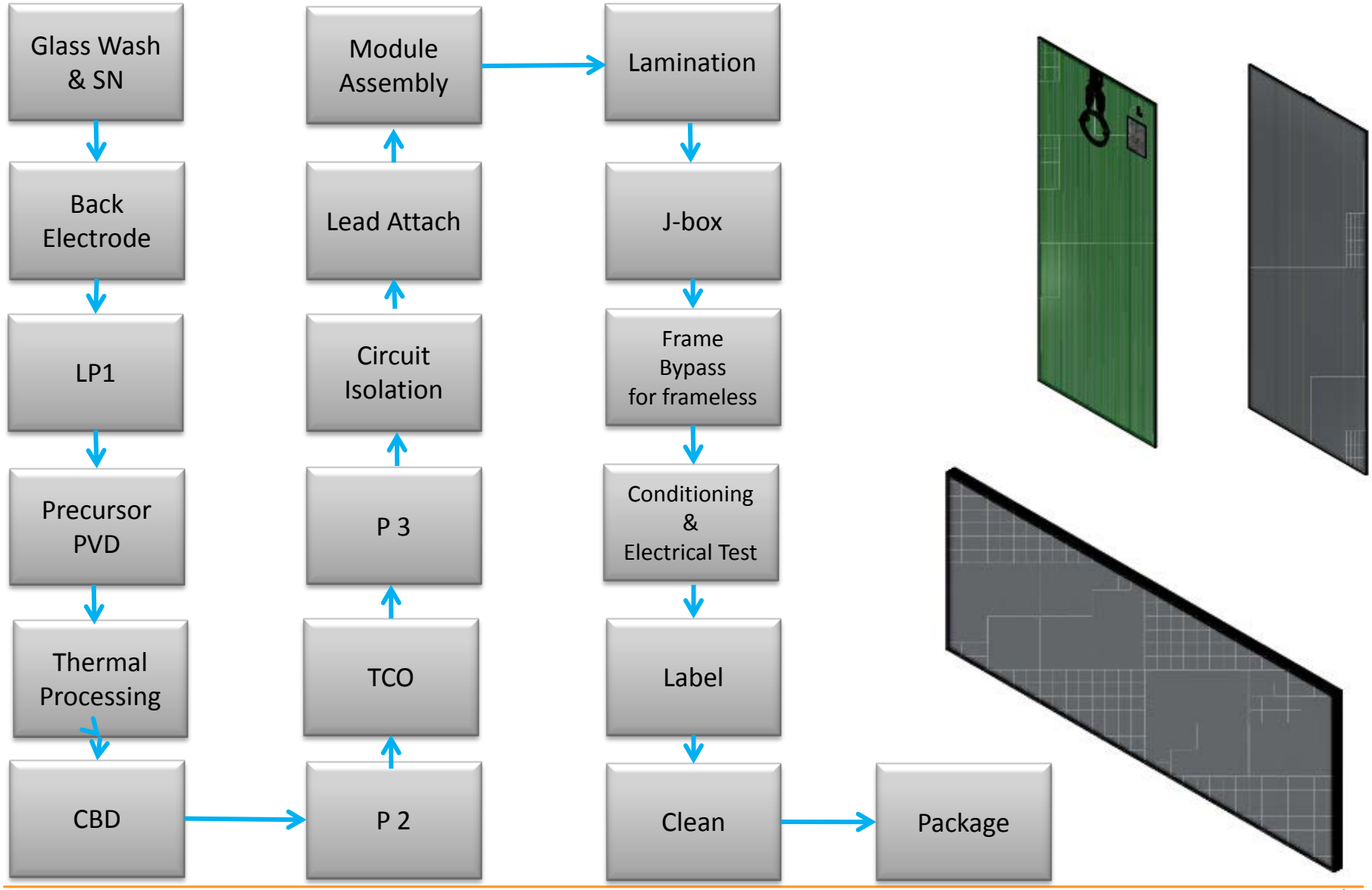
Key Elements of the Monolithic Structure

Additive film process with laser scribed P1 & mechanically scribed P2 / P3



Stion Corporation © Copyright 2010

Monolithic CIGSS Manufacturing Process



Stion Corporation © Copyright 2010

Advantages & Challenges

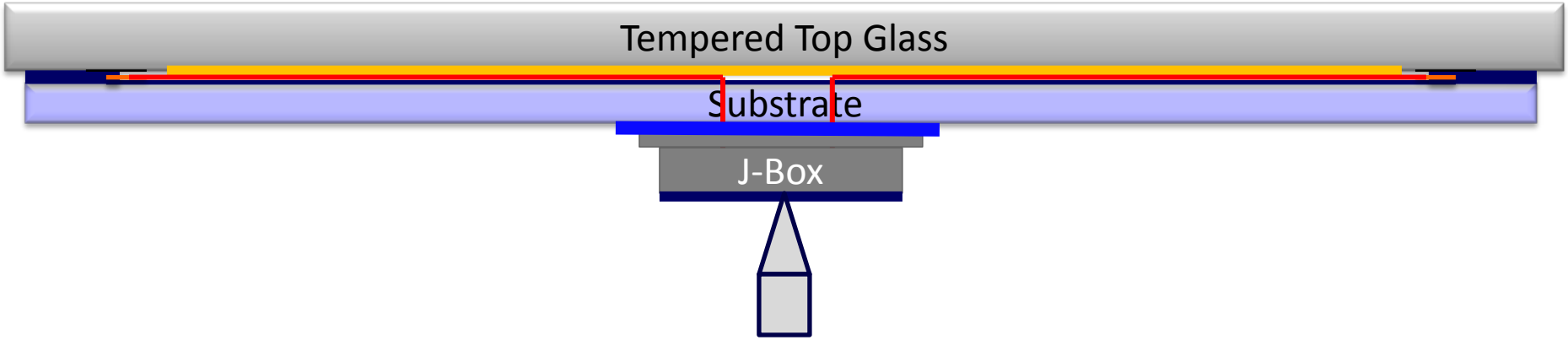
- Advantages
  - Glass permeability to moisture is extremely low – protects moisture sensitive films
  - Excellent insulator to build a circuit on
  - Planar & smooth surfaces aid in production
  - Easy to work with at elevated temperatures
  - Cleaned easily at low cost

- **Challenges**
  - Fragile until laminated
  - Subject to stress fractures / thermal breaks
  - Can be warped if not heat treated properly

Stion Corporation © Copyright 2010

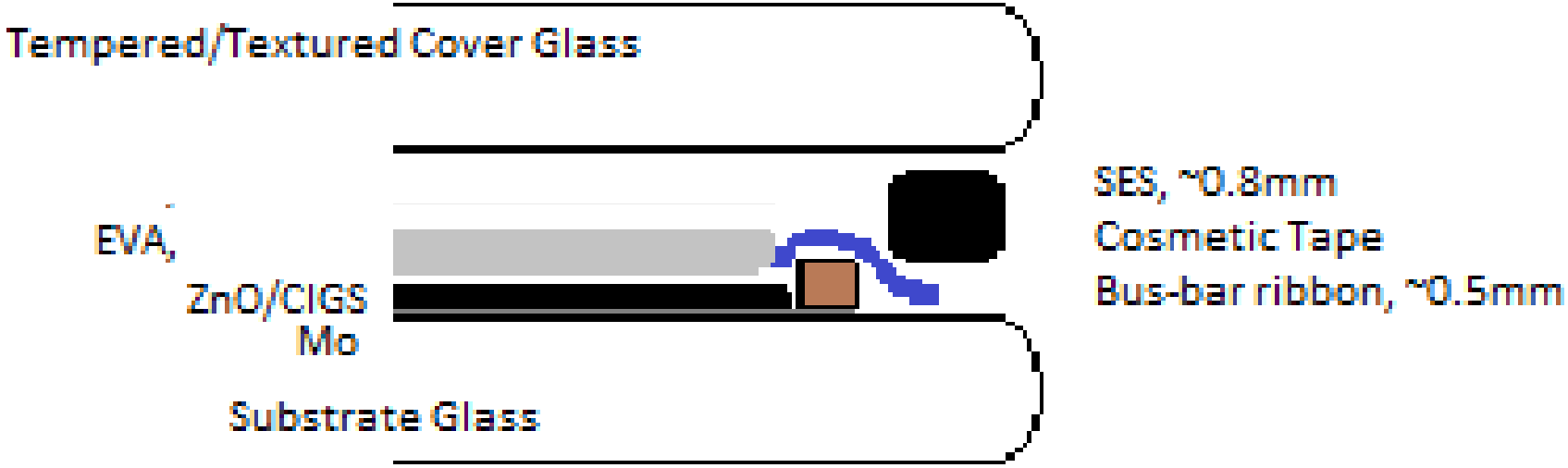
Module Assembly Process (frameless)

Stion Module Assembly
Process Overview

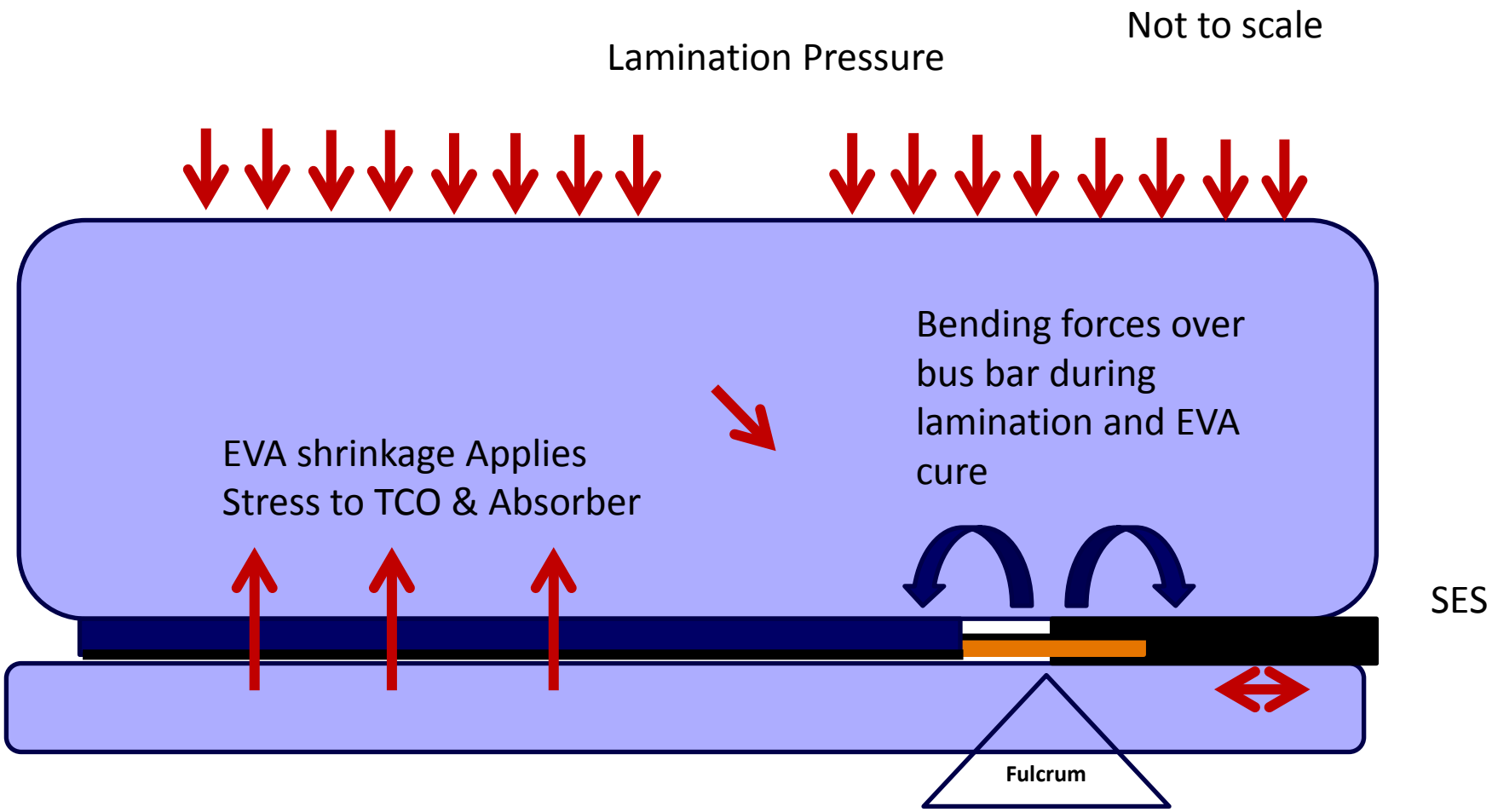


Block Diagram of edge of module

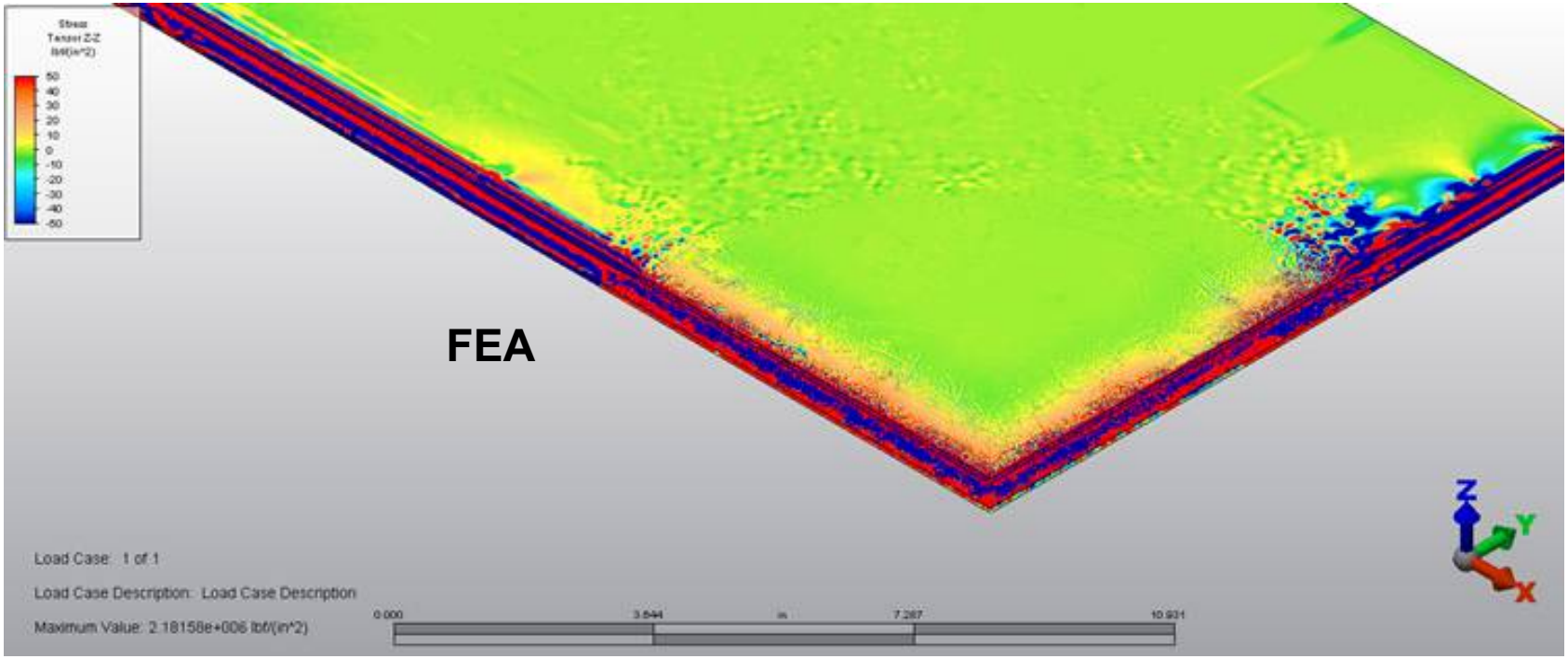
Not to scale



Managing Stresses



Managing Mechanical Stresses (modeling)

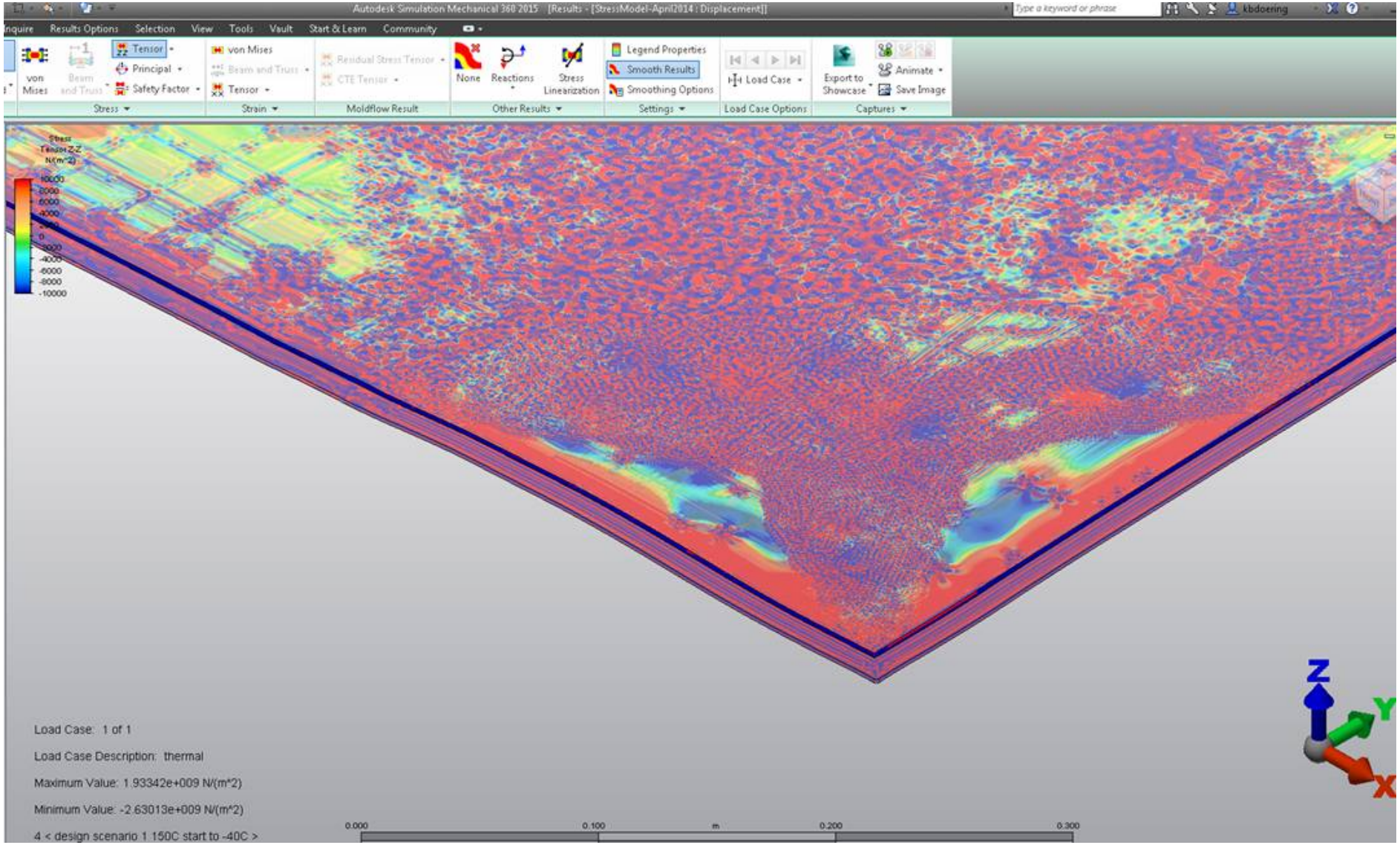


Edge Thickness Measurement Map

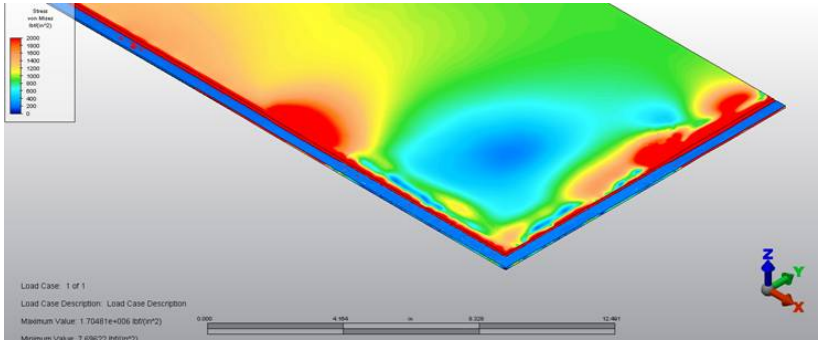
Red is thinner / Green is thicker

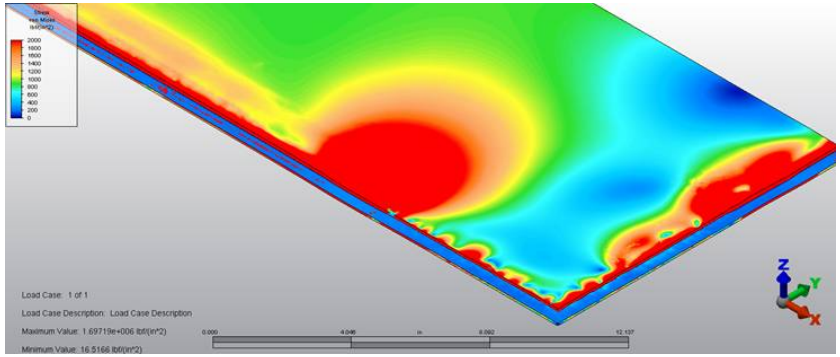
Stion Corporation © Copyright 2010

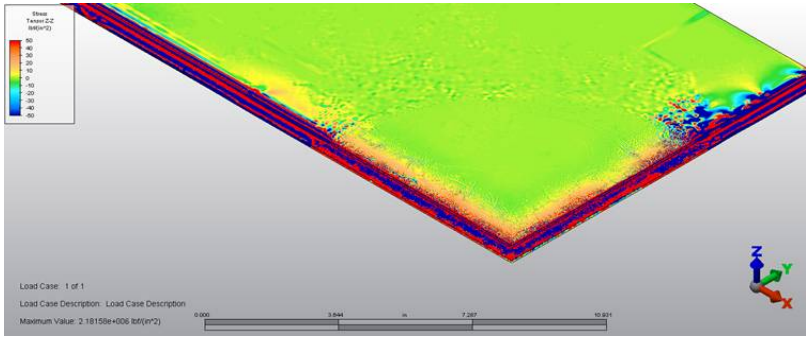
FEA Modeling-complex to achieve high resolution

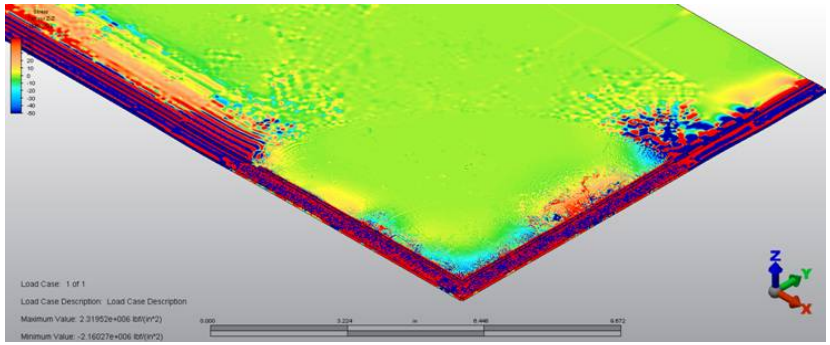


FEA Models to explore internal stress





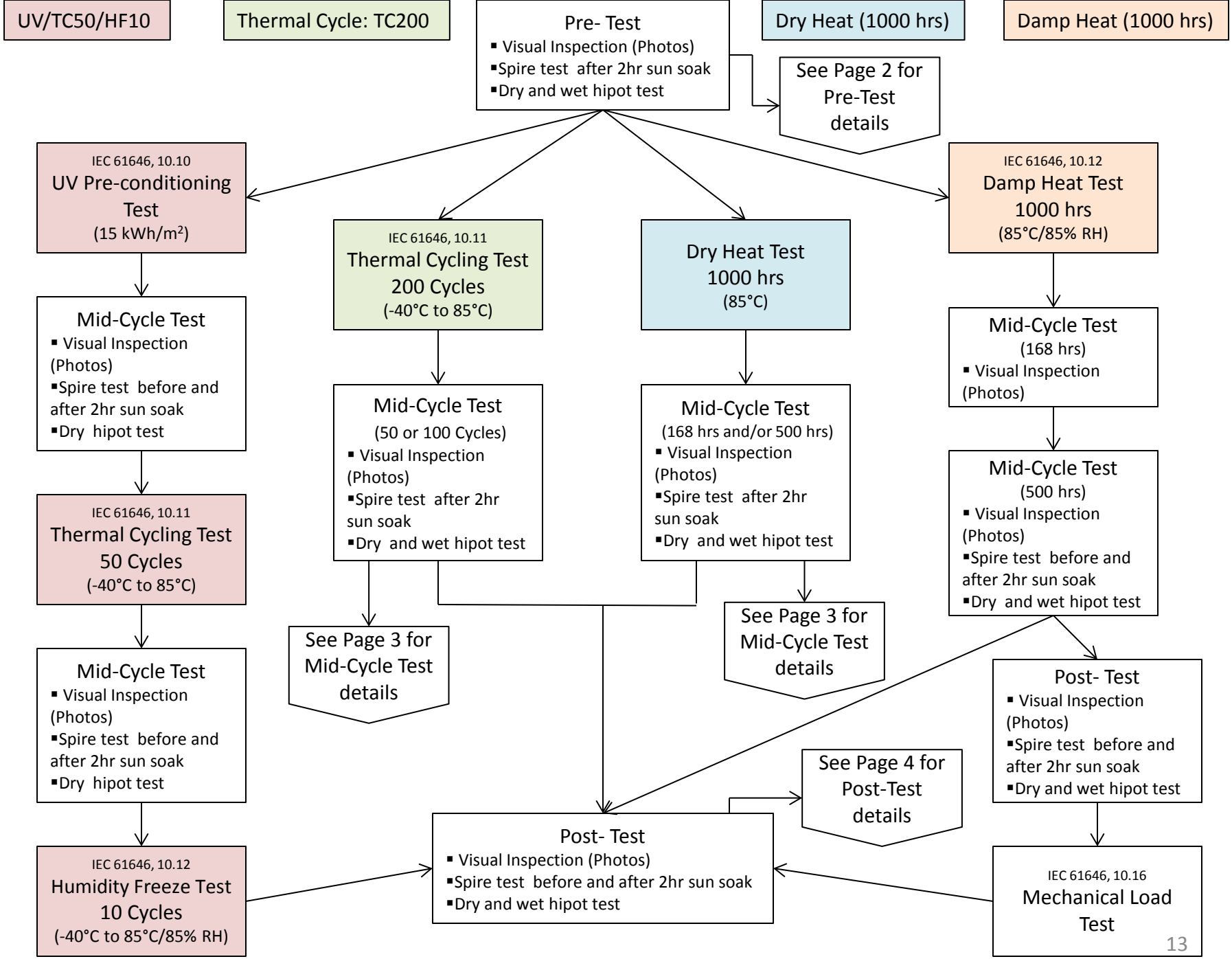




STION

Reliability Process Flow Chart

7/5/13 J. Dees


UV/TC50/HF10
Thermal Cycle: TC200
Dry Heat (1000 hrs)
Damp Heat (1000 hrs)
Pre- Test
▪ Visual Inspection (Photos)
▪Spire test after 2hr sun soak
▪Dry and wet hipot test
See Page 2 for Pre-Test details
IEC 61646, 10.10
UV Pre-conditioning Test
(15 kWh/m²)
IEC 61646, 10.11
Thermal Cycling Test
200 Cycles
(-40°C to 85°C)
Dry Heat Test
1000 hrs
(85°C)
IEC 61646, 10.12
Damp Heat Test
1000 hrs
(85°C/85% RH)
Mid-Cycle Test
▪ Visual Inspection (Photos)
▪Spire test before and after 2hr sun soak
▪Dry hipot test
Mid-Cycle Test
(50 or 100 Cycles)
▪ Visual Inspection (Photos)
▪Spire test after 2hr sun soak
▪Dry and wet hipot test
Mid-Cycle Test
(168 hrs and/or 500 hrs)
▪ Visual Inspection (Photos)
▪Spire test after 2hr sun soak
▪Dry and wet hipot test
Mid-Cycle Test
(168 hrs)
▪ Visual Inspection (Photos)
Mid-Cycle Test
(500 hrs)
▪ Visual Inspection (Photos)
▪Spire test before and after 2hr sun soak
▪Dry and wet hipot test
IEC 61646, 10.11
Thermal Cycling Test
50 Cycles
(-40°C to 85°C)
See Page 3 for Mid-Cycle Test details
See Page 3 for Mid-Cycle Test details
Mid-Cycle Test
▪ Visual Inspection (Photos)
▪Spire test before and after 2hr sun soak
▪Dry hipot test
Post- Test
▪ Visual Inspection (Photos)
▪Spire test before and after 2hr sun soak
▪Dry and wet hipot test
See Page 4 for Post-Test details
IEC 61646, 10.12
Humidity Freeze Test
10 Cycles
(-40°C to 85°C/85% RH)
Post- Test
▪ Visual Inspection (Photos)
▪Spire test before and after 2hr sun soak
▪Dry and wet hipot test
IEC 61646, 10.16
Mechanical Load Test

Reliability: Ongoing Monitoring & Qualification Testing

Weekly Product Monitors			
Test Description	Specifications	Test Conditions	
Damp Heat (DH)	200, 500, 1000 Hours	85 °C / 85% RH	2 samples from End-of-line or FGI per week
Thermal Cycle (TC)	3, 50, 200 Cycles	-40 °C to 85 °C	2 samples from End-of-line or FGI per week

Monthly Product Monitors			
Test Description	Specifications	Test Conditions	
Damp Heat (DH)	200, 500, 1000, 2000, 3000 Hours	85 °C / 85% RH	1 sample from End-of-line or FGI per month
Thermal Cycle (TC)	3, 50, 200, 400, 600 Cycles	-40 °C to 85 °C	1 sample from End-of-line or FGI per month

Stion Corporation © Copyright 2010

Reliability: Ongoing Monitoring & Qualification Testing

Quarterly Product Monitors			
Test Description	Specifications	Test Conditions	
Damp Heat (DH)	4000, 5000, 6000 Hours	85 °C / 85% RH	1 sample from the 3 previous months of Monthly Monitors
Thermal Cycle (TC)	800, 1000, 1200 Cycles	-40 °C to 85 °C	1 sample from the 3 previous months of Monthly Monitors

Monthly Direct to Long-Term Product Monitors			
Test Description	Specifications	Test Conditions	
Damp Heat (DH)	500, 1000, 2000, 3000, 4000, 5000, 6000 Hours	85 °C / 85% RH	1 sample from End-of-line or FGI per month
Thermal Cycle (TC)	200, 400, 600, 800, 1000, 1200 Cycles	-40 °C to 85 °C	1 sample from End-of-line or FGI per month

Stion Corporation © Copyright 2010

Determining Warranty Reserve

STION

FIT (**F**ailures **I**n **T**ime Testing (failures in parts per billion)

- Standard methodology in the Semiconductor Industry
- Based on material characteristics and impurities migration
- Follows recommendations from NREL
- Na^+ Effects on semiconductor performance (CIGSS film or Si)
- Failure of seals and H_2O ingress
- General circuit breakdown from thermal stresses
- Recovery after stress by sun soak
- Uses IEC standard ALT techniques (**A**ccelerated **L**ifetime **T**est)
- DH 85/85-1000hrs. / TC +85/-40C-200Cycles
- Must be samples from standard production (we test 2 per week)
- Samples must pass all warranty requirements or be logged as failures

Stion Corporation © Copyright 2010

Referenced Documents for FIT Testing

1. "Accelerated Testing and Failure of Thin-film PV Modules," T. J. McMahon [NREL], Progress in Photovoltaics: Research and Applications, 2004, vol. 12, p. 235-248.

2. "Long Term Reliability of Photovoltaic Modules," J. Wohlgemuth et al [BP Solar], WCPEC-4 (2006).

3. "Semiconductor Device Reliability Failure Models," R. Blish [AMD] and N. Durrant [Intel], International SEMATECH, Technology Transfer #00053955A-XFR, May 2000.

Stion Corporation © Copyright 2010

FIT Calculation Sheet

STION

Damp heat acceleration				
From Reference 1, Ea ranges from 0.5eV to 1.2eV				
From Reference 2, 1% change in RH corresponds to 1-deg C rise in temperature				
Tacc ('C)	85			
Tacc (K)	358		Temperature in Kelvin	
Top ('C)	50			
Top (K)	323		Temperature in Kelvin	
Ea (eV)	0.8		activation energy of soda lime glass	
Ea (J)	1.28E-19		Ea conversion to J	
kB (J/K)	1.38E-23		Boltzmann's constant	
AF-thermal	16.57		E-model	
RH,acc (%)	85	358	RH,acc (K)	
RH,op (%)	50	323	RH,op (K)	
AF-RH	16.57		E-model	
AF-total, DH	274.49		AF Total	AF-thermal*AF-RH (E-model)
DH FIT rate	13943	FITs	Failures-in-time expressed as failure per billion device hours	
OP FIT rate	50.79589	FITs		
2 yrs = >	57077.63			
After 2 yrs	0.1%	population failure after 2 yrs operation (50C / 50% RH)		
5 yrs = >	22831.05			
After 5 yrs	0.2%	population failure after 5 yrs operation (50C / 50% RH)		
25 yrs = >	4566.21			
After 25 yrs	1.1%	population failure after 25 yrs operation (50C / 50% RH)		

Temperature cycling acceleration			
From Reference 3 (modified Coffin-Manson equation)			
# of cycles to failure = Co*(deltaT-deltaT0)^(-q)			
Co = material-dependent constant			
deltaT = entire temperature cycle-range for device			
deltaT0 = portion of the temperature cycle range in the elastic region			
q = Coffin-Manson exponent, empirically derived constant			
Assume deltaT >> deltaT0			
Assume q = 3 (based on solder / ribbon failures)			
Then AF (acceleration factor) = (# of cycles to failure @ op)/(# of cycles to failure @ accel)			
deltaT-acc	125	(-40 to 85C)	accelerated
deltaT-op	35	(20 to 55C)	real world
q	3		
AF	273.3236	Multiply by 6 because 6 cycles per day in TC	
TC FIT rate	28275	FITs	
OP FIT rate	103.4488		
2 yrs = >	57077.63		
After 2 yrs	0.2%	population failure after 2 yrs operation (24-hr TC)	
5 yrs = >	22831.05		
After 5 yrs	0.5%	population failure after 5 yrs operation (24-hr TC)	
25 yrs =>	4566.21		
After 25 yrs	2.3%	population failure after 25 yrs operation (24-hr TC)	

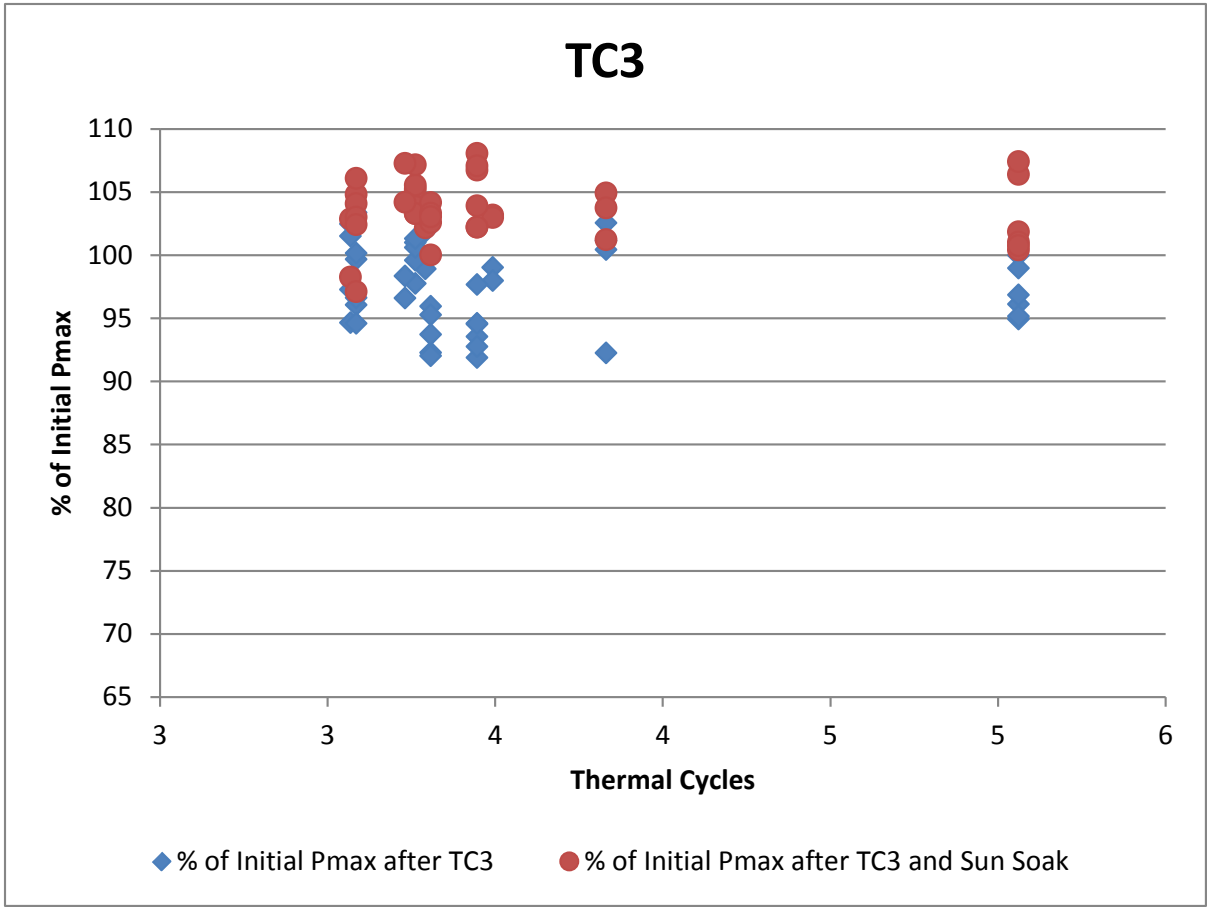
COMBINED FAILURE RATE 3.4%

References:

1. "Accelerated Testing and Failure of Thin-film PV Modules," T. J. McMahon [NREL], Progress in Photovoltaics: Research and Applications, 2004, vol. 12, p. 235-248.
2. "Long Term Reliability of Photovoltaic Modules," J. Wohlgemuth et al [BP Solar], WCPEC-4 (2006).
3. "Semiconductor Device Reliability Failure Models," R. Blish [AMD] and N. Durrant [Intel], International SEMATECH, Technology Transfer #00053955A-XFR, May 2000.

Stion Corporation © Copyright 2010

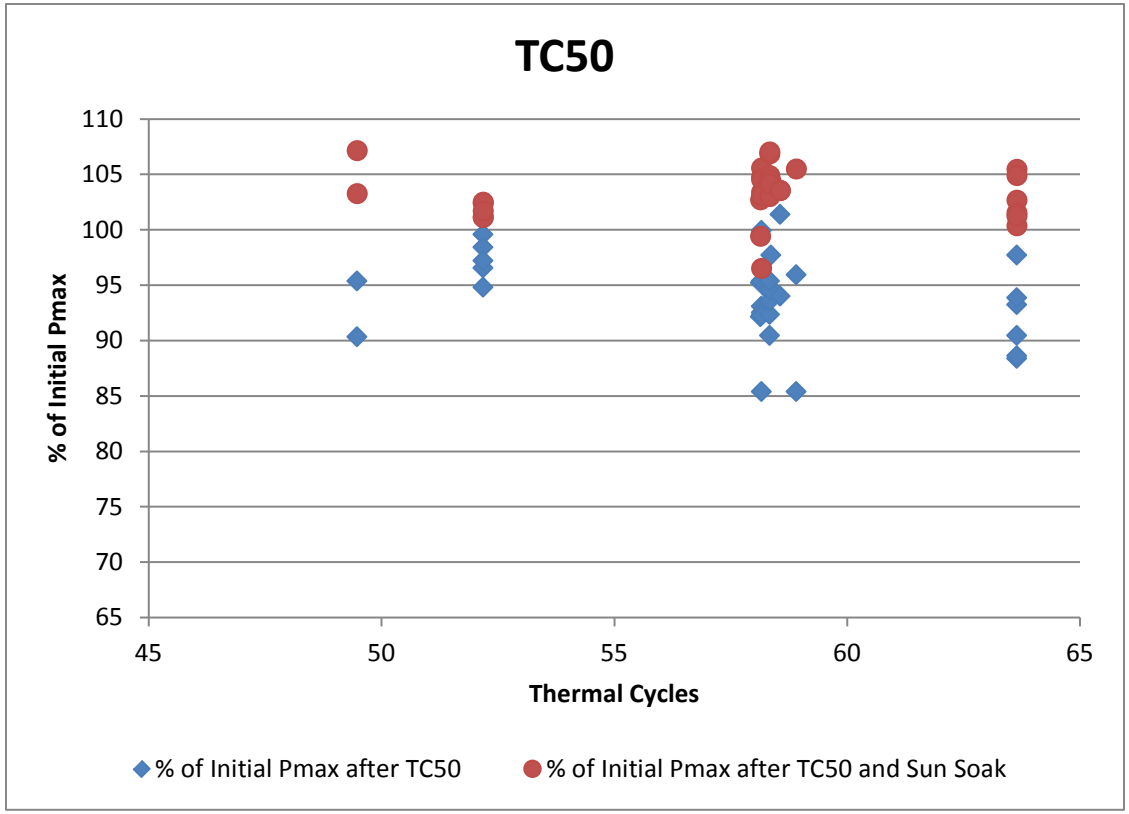
TC3 Recovery



Module Type	SN	Initial Pmax	Actual # of cycles for TC3	Pmax after TC3 Chamber	% of Initial Pmax after TC3	Pmax after TC3 Sun Soak	% of Initial Pmax after TC3 and Sun Soak
STL	100108521	133.73	3	138.23	103.37	140.15	104.80
STL	100109551	132.20	3	126.99	96.06	140.23	106.07
STO	100125805	131.54	3	134.78	102.47	135.31	102.87
STL	100125967	132.40	3	125.32	94.65	130.11	98.27
STL	100126378	133.97	3	135.99	101.50	-	-
STL	100126849	134.19	3	130.53	97.27	-	-
STO	100137292	143.60	3	135.85	94.60	139.44	97.10
STO	100137464	145.47	3	145.00	99.68	151.40	104.08
STO	100142411	141.36	3	141.59	100.16	145.61	103.01
STO	100142414	140.88	3	136.12	96.62	144.26	102.40
STO	100149666	143.66	3	142.11	98.92	149.45	104.03
STO	100149707	143.72	3	146.43	101.89	146.81	102.15
STO	100150941	138.17	3	137.59	99.58	142.69	103.27
STO	100150945	138.56	3	135.46	97.76	145.80	105.23
STO	100152008	135.43	3	136.80	101.01	140.64	103.84
STO	100152022	134.06	3	134.88	100.62	138.48	103.30
STL	100154585	149.84	4	150.49	100.44	151.66	101.21
STO	100154974	126.93	3	128.58	101.30	133.97	105.55
STO	100155009	134.96	3	141.09	104.54	144.62	107.16
STO	100159103	140.56	4	142.18	101.15	147.50	104.93
STO	100159572	124.14	4	114.51	92.25	140.70	113.34
STL	100160644	144.86	4	148.55	102.55	150.29	103.75
STL	100163602	142.60	5	135.36	94.92	145.25	101.86
STO	100164193	143.54	5	137.95	96.11	144.11	100.40
STO	100164202	143.30	3	141.90	99.02	147.83	103.16
STO	100164209	145.20	3	142.28	97.99	149.52	102.97
STO	100167811	138.42	3	136.14	98.36	144.21	104.18
STO	100167831	132.84	3	128.32	96.60	142.49	107.26
STO	100169362	144.64	3	133.47	92.28	144.65	100.01
STO	100169561	144.53	3	138.66	95.94	148.25	102.58
STO	100175563	143.87	3	134.84	93.72	149.85	104.16
STO	100176233	136.28	3	125.41	92.02	140.80	103.32
STO	100176306	138.38	3	131.85	95.27	142.57	103.03
STO	100180897	139.85	5	133.08	95.16	141.29	101.03
STL	100181862	124.51	5	124.50	99.99	132.48	106.40
STL	100182153	131.04	5	129.70	98.97	140.75	107.40
STO	100183735	139.02	5	134.66	96.87	140.05	100.74
STL	100189811	125.67	3	118.82	94.54	135.79	108.05
STL	100189831	124.58	3	116.55	93.55	132.97	106.74
STL	100191373	123.46	3	113.43	91.88	128.30	103.92
STL	100191510	127.28	3	124.30	97.66	136.27	107.06
STL	100195501	134.83	3	127.53	94.58	137.82	102.22
STL	100196142	134.17	3	124.44	92.75	137.15	102.22
	Averages:			133.54	97.59	141.99	103.78

Stion Corporation © Copyright 2015

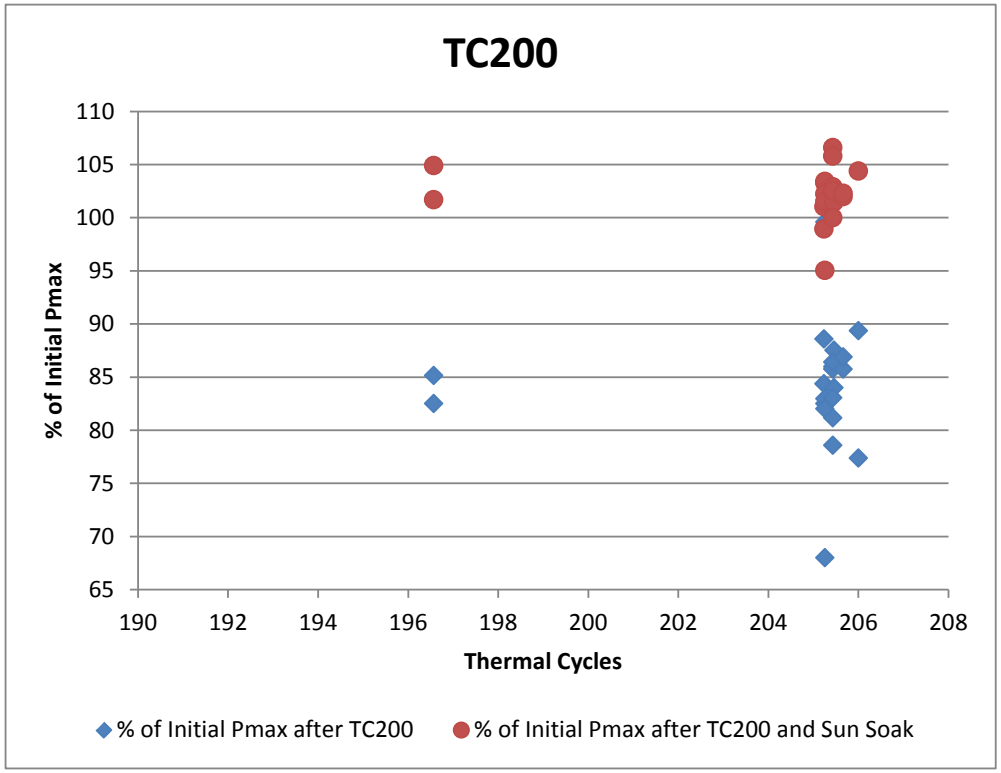
TC50 Recovery



Module Type	SN	Initial Pmax	Actual # of cycles for TC50	Pmax after TC50 Chamber	% of Initial Pmax after TC50	Pmax after TC50 Sun Soak	% of Initial Pmax after TC50 and Sun Soak
STL	100108521	133.73	58	133.65	99.94	140.07	104.74
STL	100109551	132.20	58	123.07	93.09	139.56	105.57
STO	100125805	131.54	58	125.28	95.24	135.06	102.68
STL	100125967	132.40	58	122.02	92.16	131.61	99.41
STO	100137292	143.60	58	122.63	85.40	138.58	96.50
STO	100137464	145.47	58	138.76	95.39	152.06	104.54
STO	100142411	141.36	58	130.80	92.53	146.14	103.38
STO	100142414	140.88	58	130.01	92.28	145.16	103.04
STO	100149666	143.66	58	135.43	94.28	149.92	104.36
STO	100149707	143.72	58	140.44	97.72	149.79	104.22
STO	100150941	138.17	58	125.00	90.47	142.30	102.99
STO	100150945	138.56	58	127.96	92.35	145.33	104.89
STO	100152008	135.43	58	126.73	93.57	141.50	104.48
STO	100152022	134.06	58	127.09	94.81	139.62	104.15
STO	100154974	126.93	58	120.04	94.57	135.59	106.82
STO	100155009	134.96	58	128.72	95.38	144.44	107.03
STO	100159103	140.56	59	134.85	95.94	148.24	105.46
STO	100159572	124.14	59	105.99	85.38	138.42	111.51
STL	100163602	142.60	64	126.04	88.39	146.41	102.67
STO	100164193	143.54	64	133.82	93.23	145.69	101.50
STO	100164202	143.30	59	134.70	94.00	148.33	103.51
STO	100164209	145.20	59	147.21	101.39	150.33	103.53
STO	100167811	138.42	49	125.03	90.33	142.93	103.26
STO	100167831	132.84	49	126.68	95.36	142.31	107.13
STO	100169362	144.64	52	139.66	96.56	146.29	101.14
STO	100169561	144.53	52	143.91	99.57	148.13	102.49
STO	100175563	143.87	52	141.58	98.41	147.30	102.39
STO	100176233	136.28	52	129.20	94.81	137.78	101.10
STO	100176306	138.38	52	134.54	97.22	140.71	101.68
STO	100180897	139.85	64	123.94	88.62	140.35	100.36
STL	100181862	124.51	64	112.61	90.44	131.30	105.45
STL	100182153	131.04	64	128.05	97.71	137.43	104.87
STO	100183735	139.02	64	130.47	93.85	140.72	101.23
	Averages:			129.57	93.95	142.71	103.58

Stion Corporation © Copyright 2015

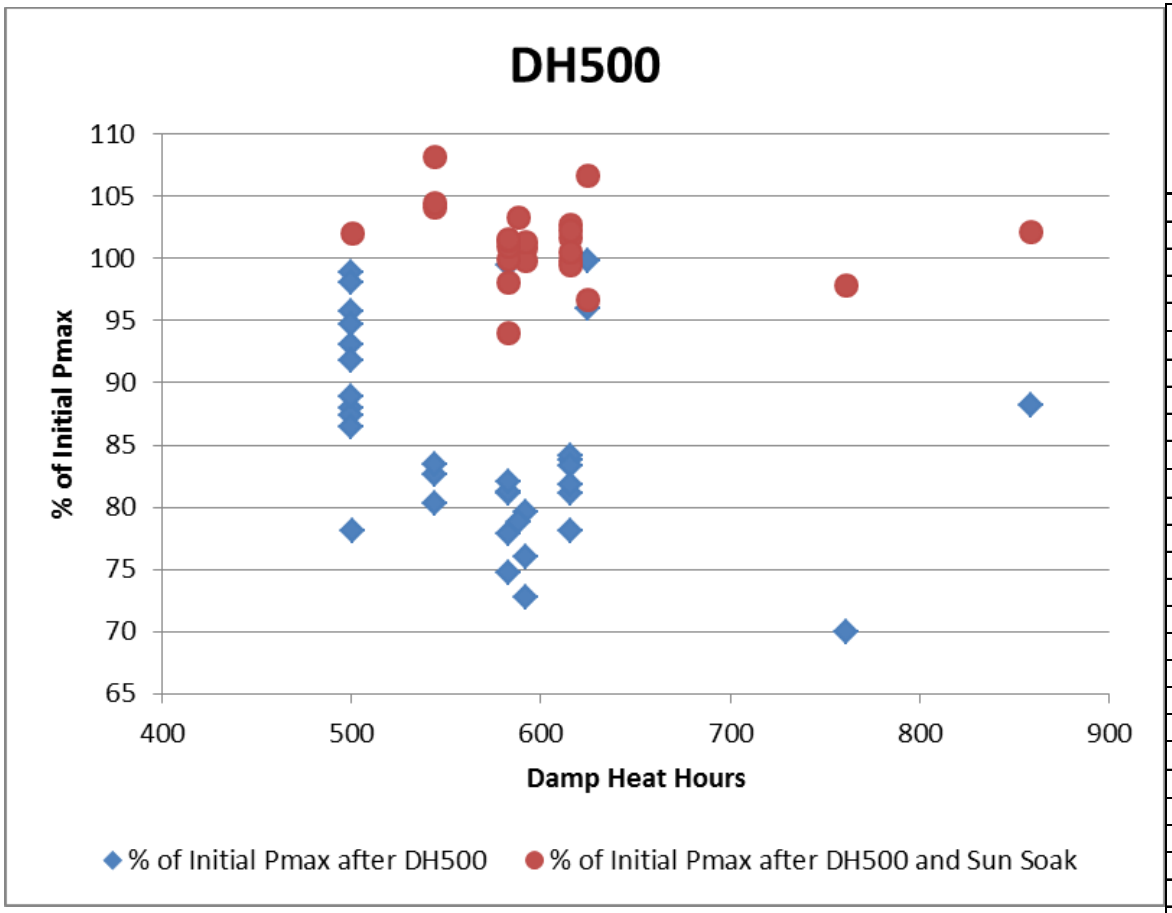
TC200 Recovery



Module Type	SN	Initial Pmax	Actual # of cycles for TC200	Pmax after TC200 Chamber	% of Initial Pmax after TC200	Pmax after TC200 Sun Soak	% of Initial Pmax after TC200 and Sun Soak
STL	100108521	133.73	205	133.17	99.58	138.08	103.26
STL	100109551	132.20	205	109.07	82.51	136.71	103.41
STO	100125805	131.54	205	116.51	88.58	132.90	101.04
STL	100125967	132.40	205	111.70	84.37	130.97	98.93
STO	100137292	143.60	205	97.66	68.01	136.48	95.04
STO	100142411	141.36	205	117.29	82.97	144.50	102.22
STO	100142414	140.88	205	115.54	82.01	143.01	101.51
STO	100149666	143.66	205	120.67	83.99	147.20	102.47
STO	100149707	143.72	205	125.78	87.52	145.81	101.46
STO	100150941	138.17	205	108.59	78.59	138.17	100.00
STO	100150945	138.56	205	112.47	81.17	142.52	102.86
STO	100152008	135.43	205	112.48	83.05	139.34	102.88
STO	100152022	134.06	205	115.25	85.97	137.44	102.53
STO	100154974	126.93	205	108.83	85.74	135.30	106.59
STO	100155009	134.96	205	116.60	86.39	142.78	105.80
STO	100159103	140.56	206	125.59	89.35	146.72	104.38
STO	100159572	124.14	206	96.04	77.36	137.17	110.50
STO	100164202	143.30	206	122.88	85.75	146.13	101.98
STO	100164209	145.20	206	126.17	86.89	148.52	102.29
STO	100167811	138.42	197	117.84	85.13	140.74	101.68
STO	100167831	132.84	197	109.60	82.50	139.34	104.89
	Averages:			115.22	84.16	140.47	102.65

Stion Corporation © Copyright 2015

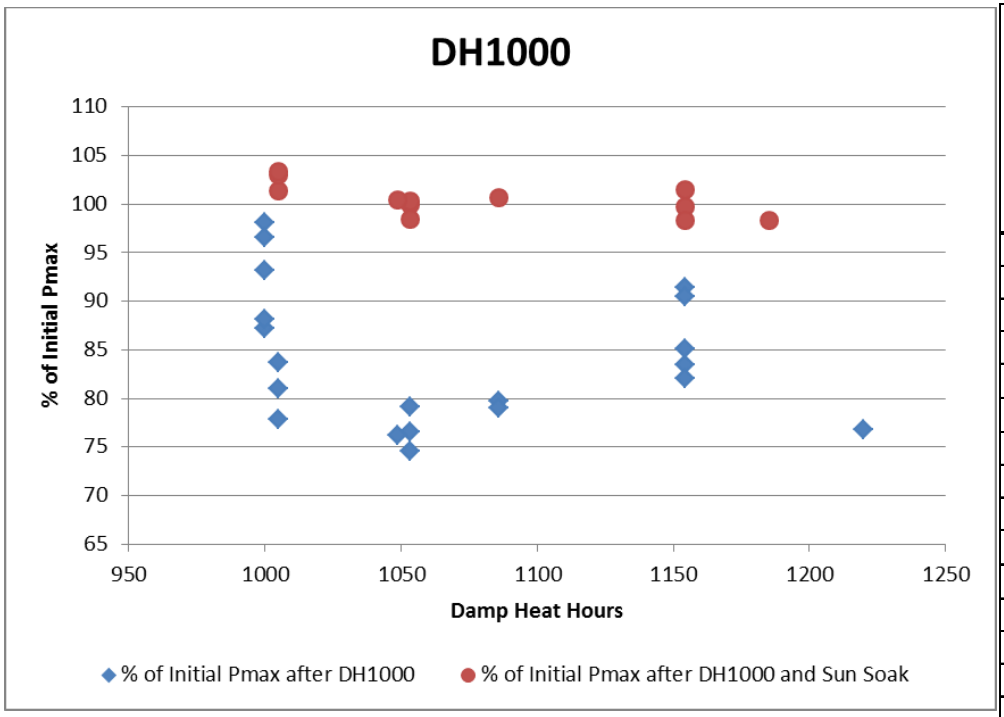
Long Term Stability-Damp Heat 500hrs.



Module Type	SN	Initial Pmax	Actual # of hours for DH500	Pmax after DH500 Chamber	% of Initial Pmax after DH500	Pmax after DH500 Sun Soak	% of Initial Pmax after DH500 and Sun Soak
STO	100091995	134.17	500	132.70	98.91	-	-
STO	100092000	136.70	500	134.00	98.02	-	-
STO	100095396	144.98	500	135.00	93.12	-	-
STO	100095402	139.91	500	123.00	87.91	-	-
STO	100095427	137.23	500	126.00	91.82	-	-
STO	100106140	145.15	500	126.86	87.40	-	-
STO	100106146	143.15	500	127.32	88.94	-	-
STO	100106154	147.85	500	127.85	86.47	-	-
STO	100106192	130.07	500	124.46	95.69	-	-
STO	100106194	127.57	500	120.76	94.66	-	-
STO	100108802	140.18	592	111.53	79.57	141.38	100.86
STO	100125945	122.24	859	107.74	88.14	124.79	102.08
STO	100137343	146.00	592	110.90	75.96	145.71	99.80
STO	100142421	137.69	592	100.12	72.72	139.46	101.29
STO	100149642	143.07	588	112.73	78.79	147.75	103.27
STO	100150953	134.49	544	107.94	80.26	140.02	104.11
STO	100151979	136.74	544	113.00	82.64	142.83	104.45
STL	100154580	151.54	625	145.52	96.03	146.42	96.62
STO	100154969	135.02	544	112.68	83.45	145.97	108.11
STO	100159464	139.44	625	139.15	99.79	148.76	106.69
STO	100163593	141.72	500	110.69	78.10	144.64	102.06
STO	100163933	144.54	616	121.12	83.79	148.50	102.74
STO	100163937	144.99	616	121.97	84.13	147.39	101.65
STO	100167805	140.51	761	98.39	70.02	137.44	97.82
STO	100169482	144.68	583	112.71	77.90	144.61	99.95
STO	100171817	134.30	583	100.32	74.70	131.69	98.06
STO	100175553	140.43	583	113.89	81.10	141.72	100.92
STO	100175555	138.41	583	112.45	81.24	130.07	93.98
STO	100176206	133.02	583	109.16	82.07	134.92	101.43
STO	100176225	136.18	583	135.44	99.46	138.29	101.55
STL	100182205	148.00	616	120.03	81.10	147.75	99.83
STL	100182414	138.86	616	108.50	78.14	138.10	99.46
STO	100183729	139.33	616	116.12	83.35	140.09	100.55
STO	100183736	139.72	616	114.33	81.83	142.90	102.28
	Averages:			118.66	85.21	141.30	101.23

Stion Corporation © Copyright 2015

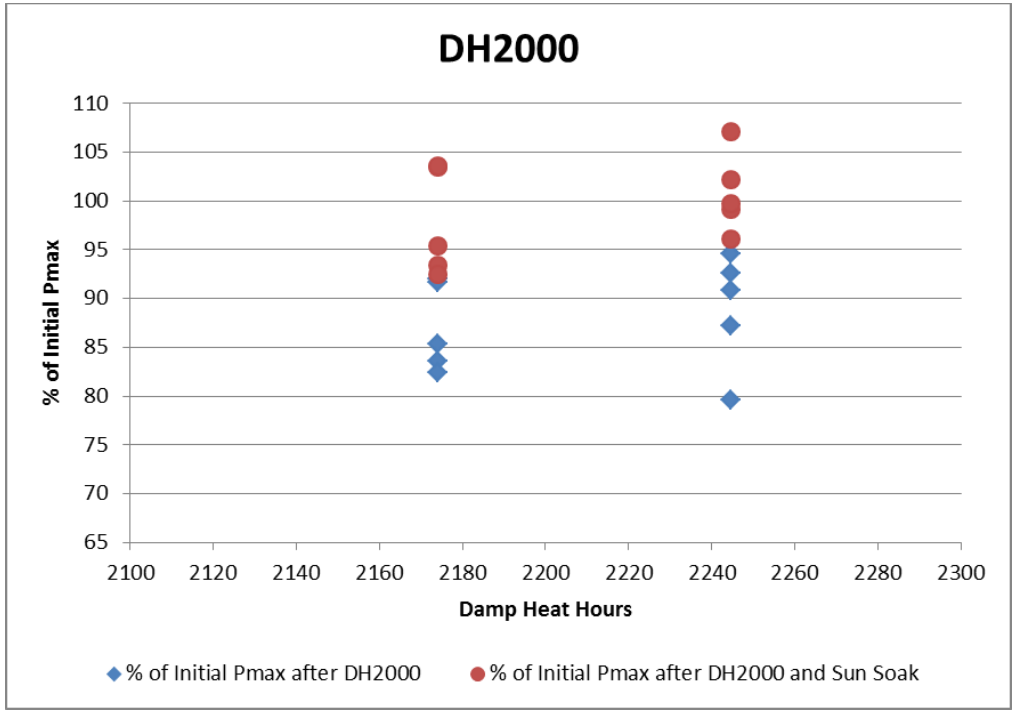
Long Term Stability-Damp Heat 1000hrs.



Module Type	SN	Initial Pmax	Actual # of hours for DH1000	Pmax after DH1000 Chamber	% of Initial Pmax after DH1000	Pmax after DH1000 Sun Soak	% of Initial Pmax after DH1000 and Sun Soak
STO	100091995	134.172	1000	131.64	98.11	-	-
STO	100092000	136.7	1000	132.00	96.56	-	-
STO	100095396	144.98	1000	135.00	93.12	-	-
STO	100095402	139.909	1000	122.00	87.20	-	-
STO	100095427	137.228	1000	121.00	88.17	-	-
STO	100106140	145.145	1154	121.22	83.51	144.79	99.75
STO	100106146	143.15	1154	121.73	85.04	145.19	101.42
STO	100106154	147.852	1154	121.36	82.08	145.34	98.30
STO	100106192	130.066	1154	118.93	91.44	144.37	111.00
STO	100106194	127.57	1154	115.42	90.48	141.21	110.69
STO	100108802	140.177	1053	110.98	79.17	140.06	99.92
STL	100126768	136.807	1220	105.04	76.78	-	-
STO	100137343	145.999	1053	111.82	76.59	143.77	98.47
STO	100142421	137.685	1053	102.58	74.51	138.10	100.30
STO	100149642	143.07	1049	108.99	76.18	143.71	100.45
STO	100150953	134.49	1005	104.65	77.81	136.31	101.36
STO	100151979	136.742	1005	114.47	83.71	140.82	102.98
STL	100154580	151.539	1086	120.78	79.70	-	-
STO	100154969	135.022	1005	109.32	80.97	139.47	103.30
STO	100159464	139.436	1086	110.17	79.01	140.31	100.62
STO	100163593	141.723	1185	91.99	64.90	139.30	98.29
	Averages:			115.77	83.10	141.62	101.92

Stion Corporation © Copyright 2015

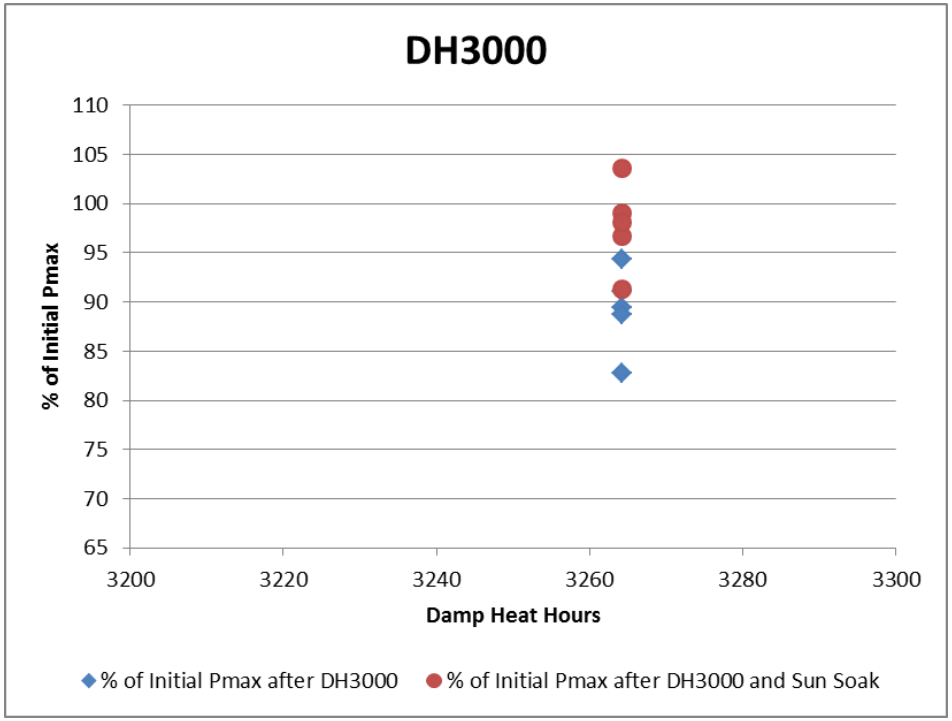
Long Term Stability-Damp Heat 2000hrs.



Module Type	SN	Initial Pmax	Actual # of hours for DH2000	Pmax after DH2000 Chamber	% of Initial Pmax after DH2000	Pmax after DH2000 Sun Soak	% of Initial Pmax after DH2000 and Sun Soak
STO	100091995	134.17	2245	106.82	79.61	143.71	107.11
STO	100092000	136.70	2245	129.34	94.61	139.74	102.22
STO	100095396	144.98	2245	134.29	92.63	143.66	99.09
STO	100095402	139.91	2245	127.04	90.80	139.53	99.73
STO	100095427	137.23	2245	119.70	87.23	131.86	96.09
STO	100106140	145.15	2174	121.35	83.61	135.55	93.39
STO	100106146	143.15	2174	122.23	85.38	136.55	95.39
STO	100106154	147.85	2174	121.91	82.46	136.75	92.49
STO	100106192	130.07	2174	119.65	91.99	134.54	103.44
STO	100106194	127.57	2174	116.85	91.60	132.21	103.64
	Averages:			121.92	87.99	137.41	99.26

Stion Corporation © Copyright 2015

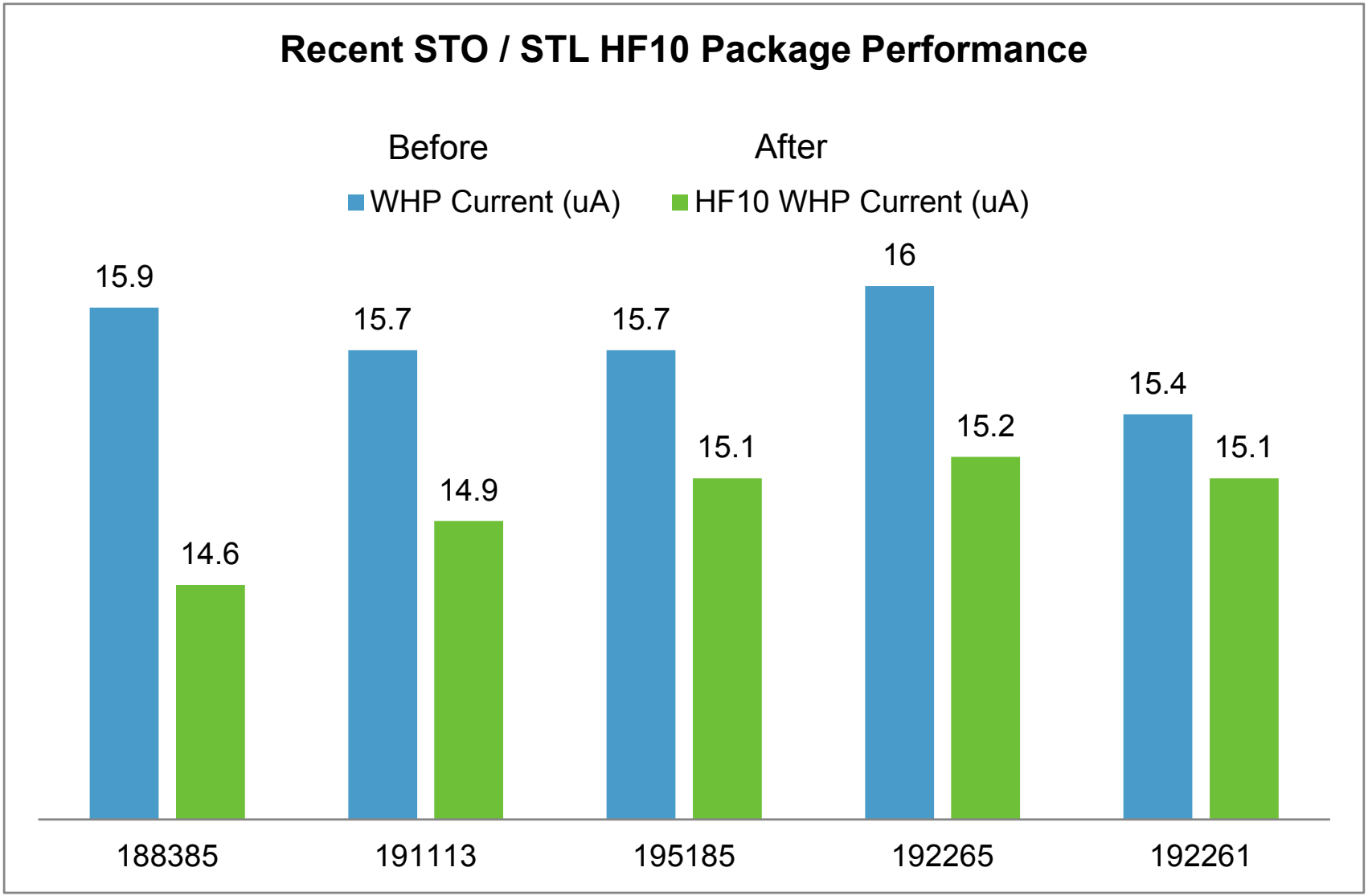
Long Term Stability-Damp Heat 3000hrs.



Module Type	SN	Initial Pmax	Actual # of hours for DH3000	Pmax after DH3000 Chamber	% of Initial Pmax after DH3000	Pmax after DH3000 Sun Soak	% of Initial Pmax after DH3000 and Sun Soak
STO	100091995	134.17	3264	126.57	94.34	138.98	103.58
STO	100092000	136.70	3264	124.50	91.08	135.44	99.07
STO	100095396	144.98	3264	129.69	89.46	140.15	96.67
STO	100095402	139.91	3264	124.19	88.77	137.20	98.06
STO	100095427	137.23	3264	113.58	82.76	125.36	91.35
	Averages:			123.71	89.28	135.42	97.75

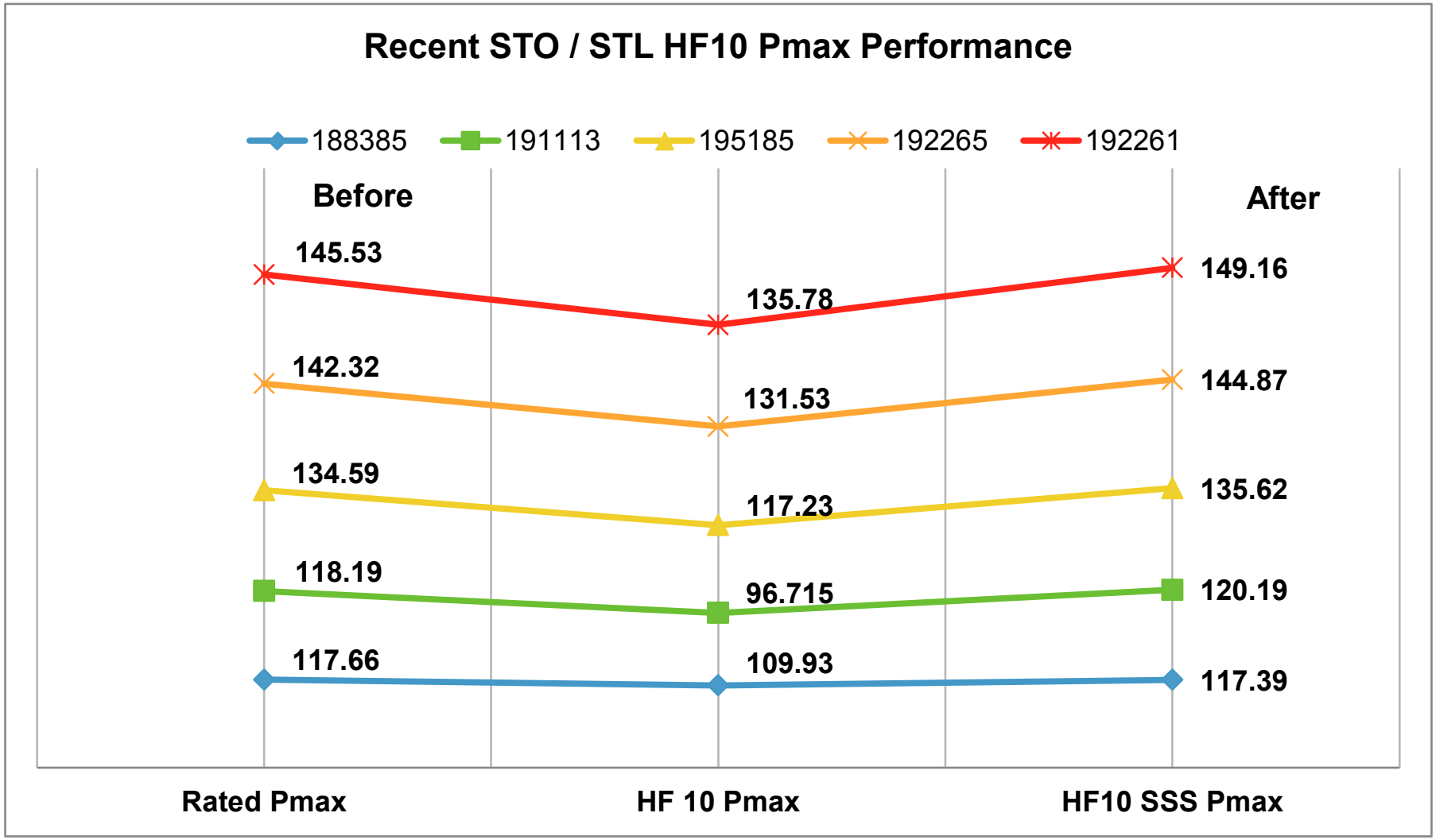
Stion Corporation © Copyright 2015

Recent HF 10 Testing



Stion Corporation © Copyright 2015

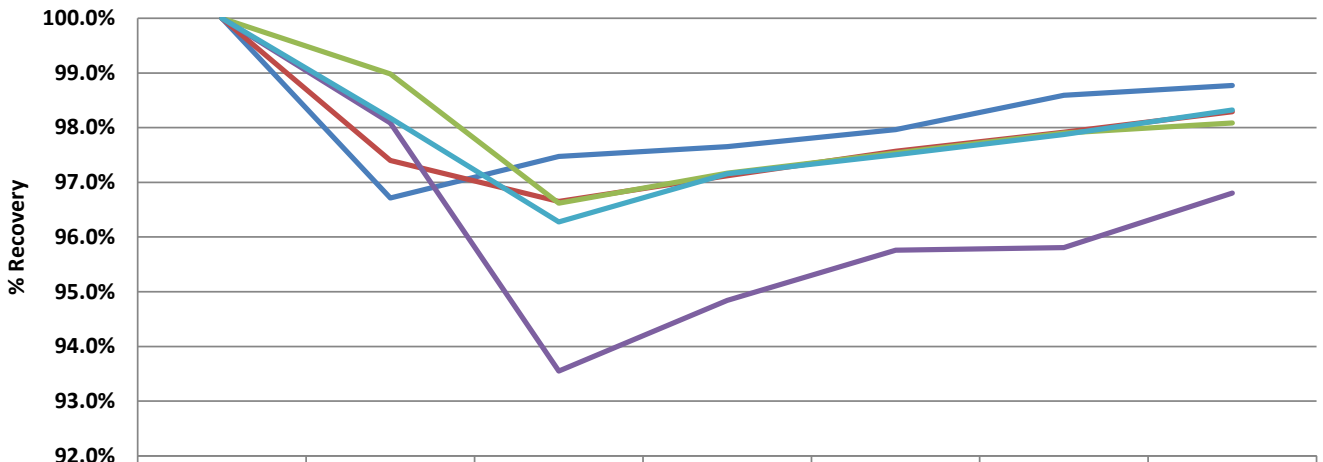
P-max Before & After HF10



All modules recovered to ≥ Production Line Measurements

Stion Corporation © Copyright 2015

PID (+) (85^{0}C /85% rH) (Class "A" Rating)



	Initial	PID	5 hr SS	10 hr SS	15 hr SS	20 hr SS	25 hr SS
94898	100.0%	96.7%	97.5%	97.7%	98.0%	98.6%	98.8%
95073	100.0%	97.4%	96.7%	97.1%	97.6%	97.9%	98.3%
95071	100.0%	99.0%	96.6%	97.2%	97.5%	97.9%	98.1%
95072	100.0%	98.1%	93.6%	94.8%	95.8%	95.8%	96.8%
95409	100.0%	98.2%	96.3%	97.2%	97.5%	97.9%	98.3%

Recent Testing -Sun Soak to 100% Recovery = 31kWh / m^2

SN	Before PID+ Pmax	Post-PID+ Pmax	Post SS Pmax	kWh/m2 for SS	% of Initial Pmax
100166005	141	110	141	30.97	100.00
100166007	143	114	143	30.97	100.00
100166008	144	112	145	30.97	100.69
1001660010	142	116	143	30.97	100.70

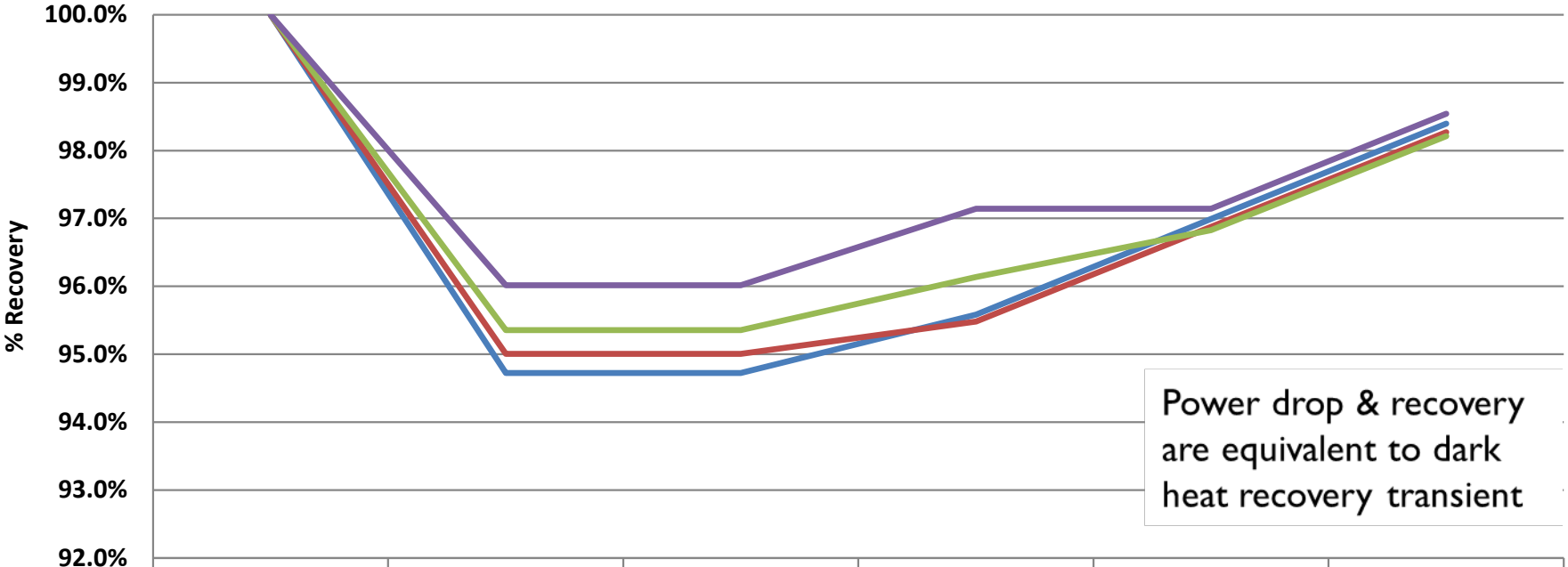
Power drop & recovery are equivalent to dark heat recovery transient

Stion Corporation © Copyright 2015

PID (-) (85^{0}C /85% rH) (Class "A" Rating)

STION

96hr. PID(-)
Recovery After Stress
Sun Soaking



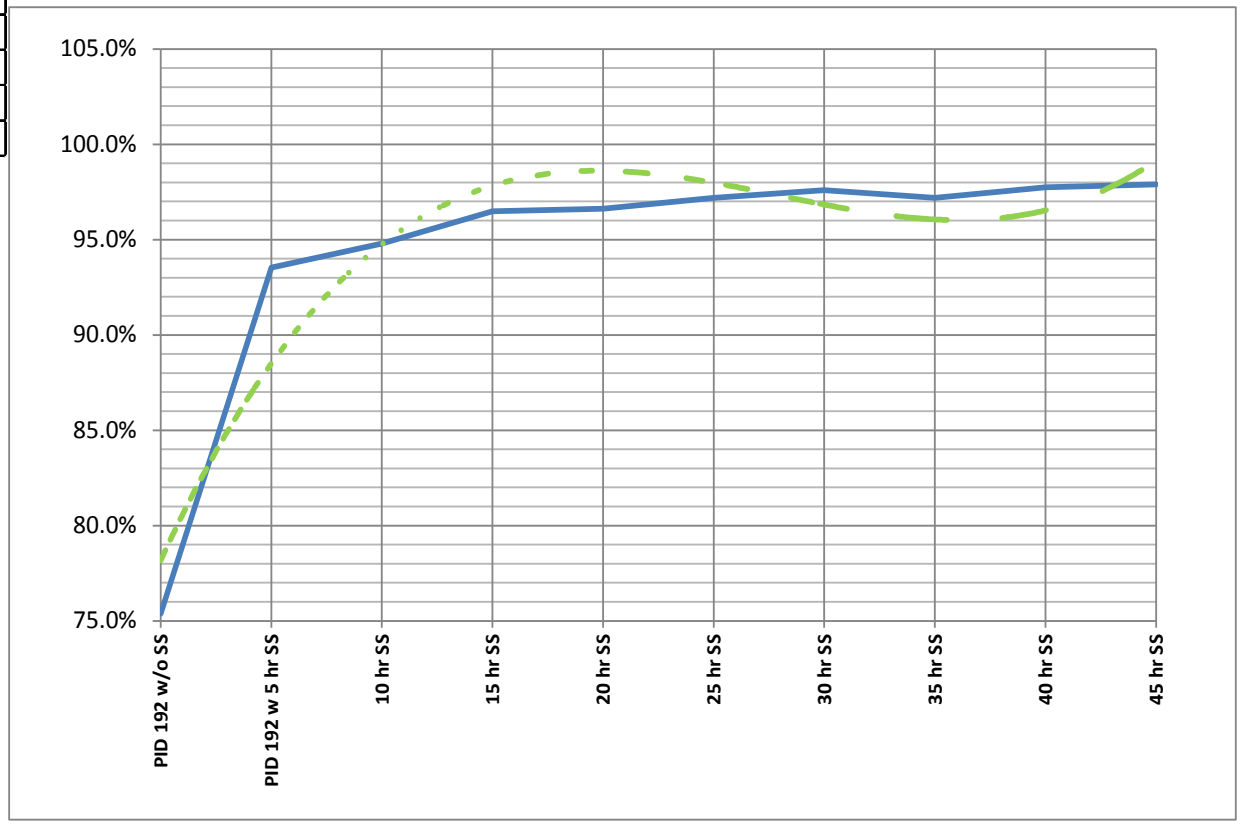
	Initial	PID	5 hr SS	10 hr SS	15 hr SS	20 hr SS
95413	100.0%	94.7%	94.7%	95.6%	97.0%	98.4%
94983	100.0%	95.0%	95.0%	95.5%	96.9%	98.3%
95069	100.0%	95.4%	95.4%	96.1%	96.8%	98.2%
94894	100.0%	96.0%	96.0%	97.1%	97.1%	98.5%

Stion Corporation © Copyright 2015

PID Testing (-1000V / 192hrs, 85/85) SS recovery

Condition	Avg	Median	Min	Max
SS	97.2%	97.2%	96.5%	97.9%
5 hr SS	100.8%	100.0%	100.0%	104.2%
PID 192 w/o SS	75.4%	74.6%	72.3%	78.8%
PID 192 w 5 hr SS	93.5%	92.9%	92.3%	97.2%
10 hr SS	94.8%	94.4%	94.3%	95.8%
15 hr SS	96.5%	97.2%	94.3%	97.2%
20 hr SS	96.6%	96.5%	96.5%	97.2%
25 hr SS	97.2%	97.2%	97.2%	97.2%
30 hr SS	97.6%	97.6%	97.2%	98.0%
35 hr SS	97.2%	97.2%	96.5%	97.9%
40 hr SS	97.8%	97.9%	97.2%	97.9%
45 hr SS	97.9%	97.9%	97.9%	97.9%

Full Recovery @ 30 hrs.

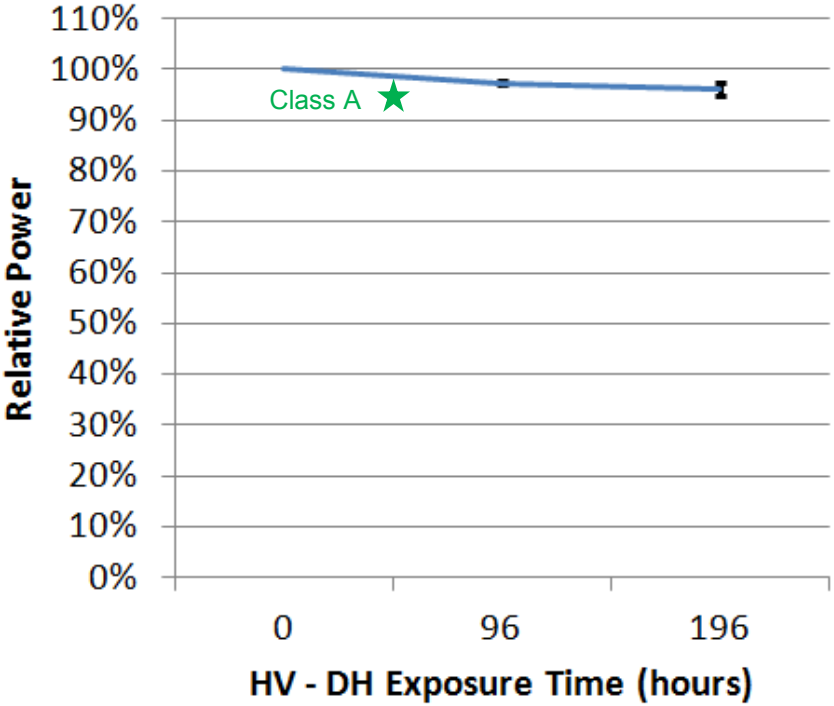


Stion Corporation © Copyright 2010

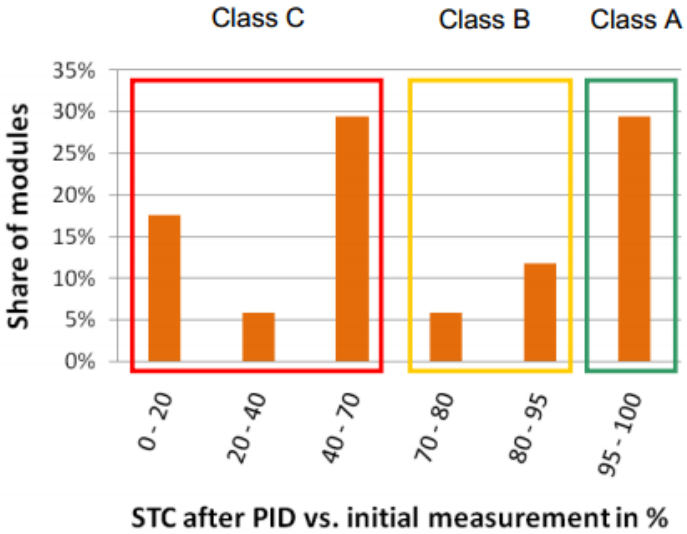
Stion – Class A PID Rating Equivalent

PI- Berlin Ratings

- Class A → ΔP <5%
- Class B → 5% < ΔP < 30%
- Class C → ΔP > 30%



- PI Berlin PID Test Procedure
  - 85%RH, 85°C, -1000 V, 48 hours
  - 2 modules
- Stion Test
  - 85%RH, 85°C, -1000 V, 196 hours
  - 5 modules

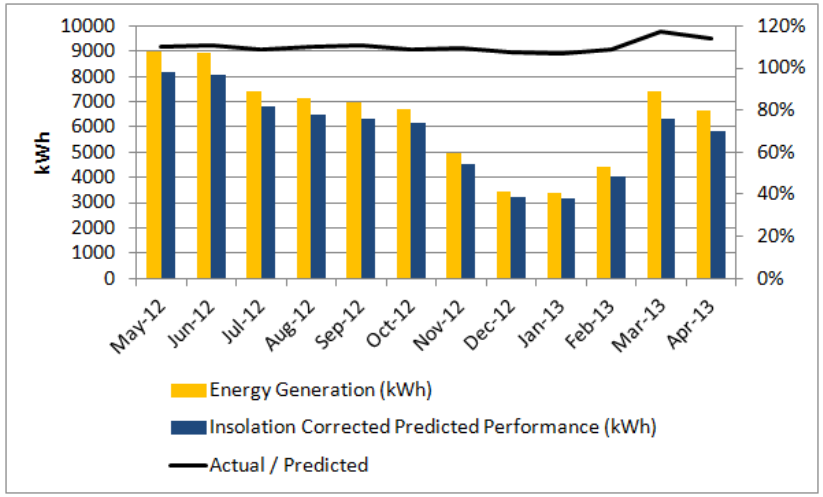


From Pi Berlin Test. http://www.pi-berlin.com/images/pdf/investorsday/2011/6-PID-Tests.pdf

Stion Corporation © Copyright 2010

World Class Quality, Reliability & System Performance

- Industry Participation
  - National Renewable Energy Laboratory – Boulder, Colorado (NREL)
  - Photovoltaic Manufacturing Consortium- SUNY, Albany, New York (PVMC)
  - Colorado State University – Photovoltaic Testing Laboratory, Denver, Colorado (CSU)
  - US Department of Energy
- Outdoor Arrays with Performance Monitoring
  - NREL – Boulder, Co – Long Term, installed 2006
  - PVMC- Albany, New York Long Term installed 2010
  - HMS 50KW Carport Array –Hattiesburg, Mississippi
  - US Continental 228KW Array- Corona, California
  - Mississippi Power 4.86KW Array- Gulfport Mississippi
- All arrays have stable performance since installation
  - Data Available



Stion Corporation © Copyright 2010

STION

Thank You

Q & A

rwickham@stion.com