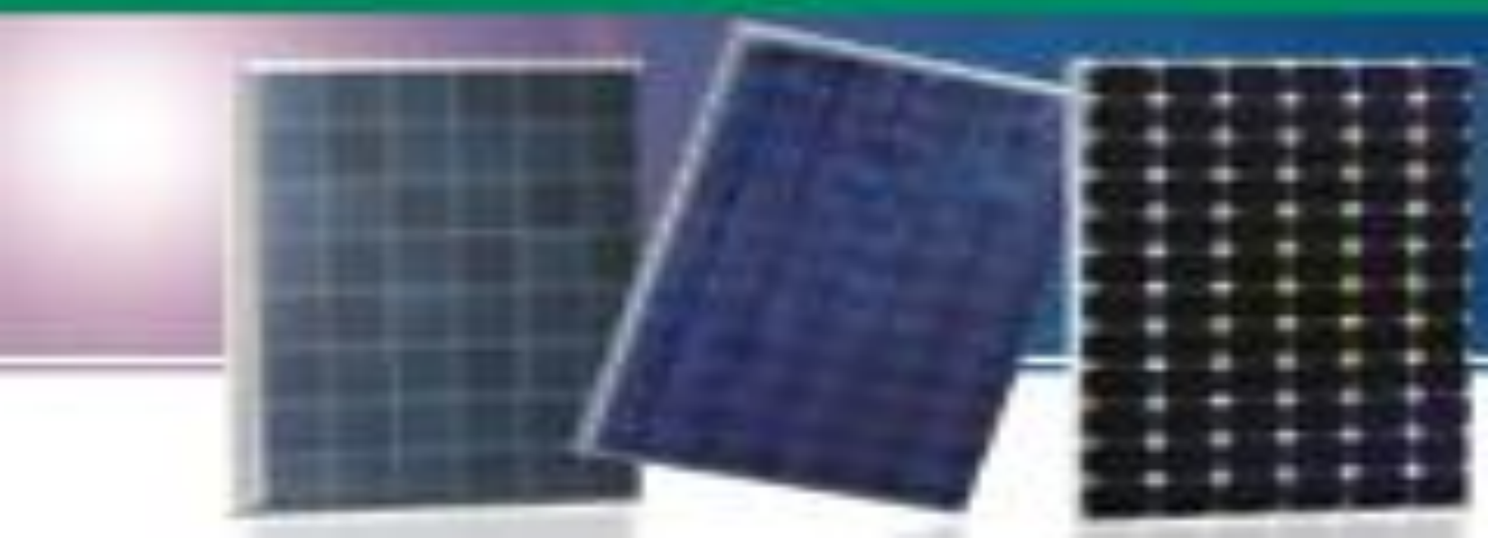

Cell defect analysis post Dynamic Mechanical Load and thermal cycling Testing at Jabil

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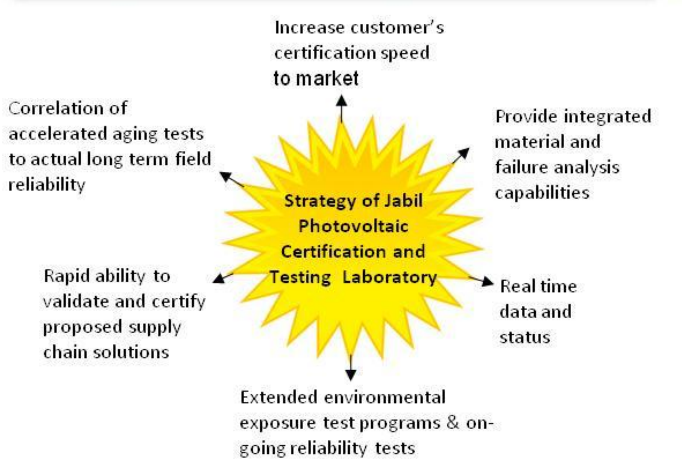
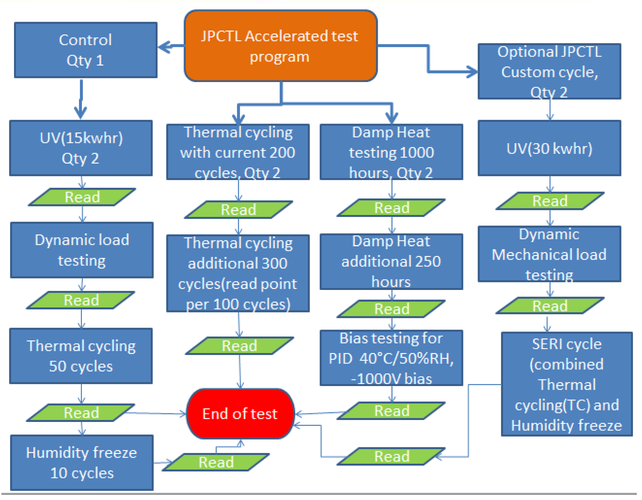
Introduction

Jabil's state-of-the-art photovoltaic certification and testing laboratory in St Petersburg, Florida provides wide range of photovoltaic testing services such as prototyping, certification, product validation, extended testing and Failure analysis. Specialized tests such as potential induced degradation, glass soiling, array & individual module monitoring and dynamic mechanical load testing is regularly performed in the Jabil laboratory. Technical Data is presented here involving dynamic mechanical load testing performed using a unique test set up that very closely simulates the field conditions as observed by the mounted module. A group of modules were studied and analyzed as part of new cell validation and qualification process. Modules were taken through the sequential tests involving 1000 cycles of dynamic mechanical loading performed at 1440 Pascals followed by 50 thermal cycles similar to IEC 61215 10.11. Cell area defects particularly cracks were mapped to understand root cause and help further improve yield in manufacturing. Some of the data and analysis is presented in this poster.

Jabil Photovoltaic Certification & Testing Laboratory(JPCTL)





Experiment: Dynamic mechanical load testing

IEC 61215 Static Mechanical load testing for wind and snow load while the actual conditions in the field are not always static. The Dynamic mechanical Load test (DML) is called out in IEEE 1262 PV standard and ASTM e-1830 standard. These standard call for 1440 Pascal's of pressure for 10,000 cycles at least 3 s per cycle. This test is not yet required by IEC 61215, but is being considered as a potential addition. BP Solar reported power losses up to 20% after combining this test with climate chamber tests on intentionally damaged modules with micro cracks [1]. JPCTL has been using its special test set up to perform DML on customers panels to access long term reliability. The test program has been very effective in assisting to find damaged cells due to latent defects, micro cracks, solder joint stresses and other defects introduced during manufacturing. The cell cracking was classified based on severity. The location was mapped out to understand what process in manufacturing (solder bonding, stringing or lamination) would have more impact and if the issue was inherent to the latent defects in the cells.

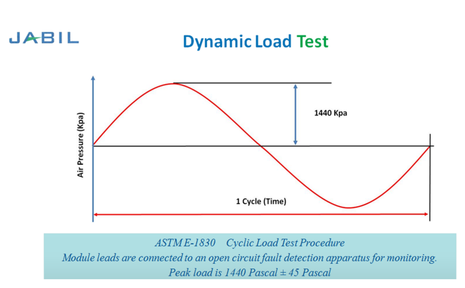
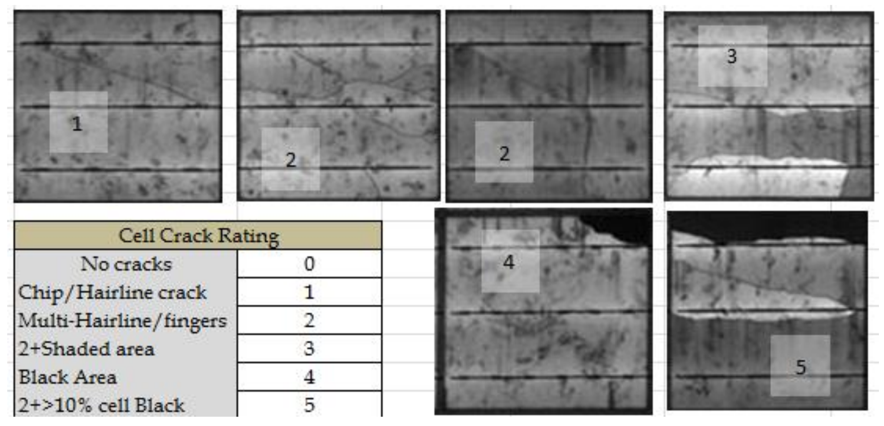


Figure 1: Dynamic mechanical load test profile

Table I: Test plan

Test type	Standard		Control	Cell type 1		Cell type 2		Cell type 3
				Except for cells the modules used all same components				All together different componenets compared to module 1-4
Pre-Tests (All)	Standard	Reference		Module1	Module2	Module3	Module4	Module5
Visual Inspection	IEC 61215	10.1						
Maximum Power Determination	IEC 61215	10.2	Control					
Electroluminesence (Hi/Lo w Current)	n/a	n/a						
Dynamic Load Test at 1440pa for 1000 cycles								
Dynamic Load Test	ASTM	E1830-09						
Visual Inspection	IEC 61215	10.1						
Maximum Power Determination	IEC 61215	10.2	Control					
Electroluminesence (Hi/Lo w Current)	n/a	n/a						
Temperature Cycle (+85°C to -40°C)								
TC85-50	IEC 61215	10.11						
Visual Inspection	IEC 61215	10.1						
Maximum Power Determination	IEC 61215	10.2	Control					
Electroluminesence (Hi/Lo w Current)	n/a	n/a						

Results



Cell Crack Rating	
No cracks	0
Chip/Hairline crack	1
Multi-Hairline/fingers	2
2+Shaded area	3
Black Area	4
2+>10% cell Black	5

Figure 2: Cell cracks scoring/rating criteria

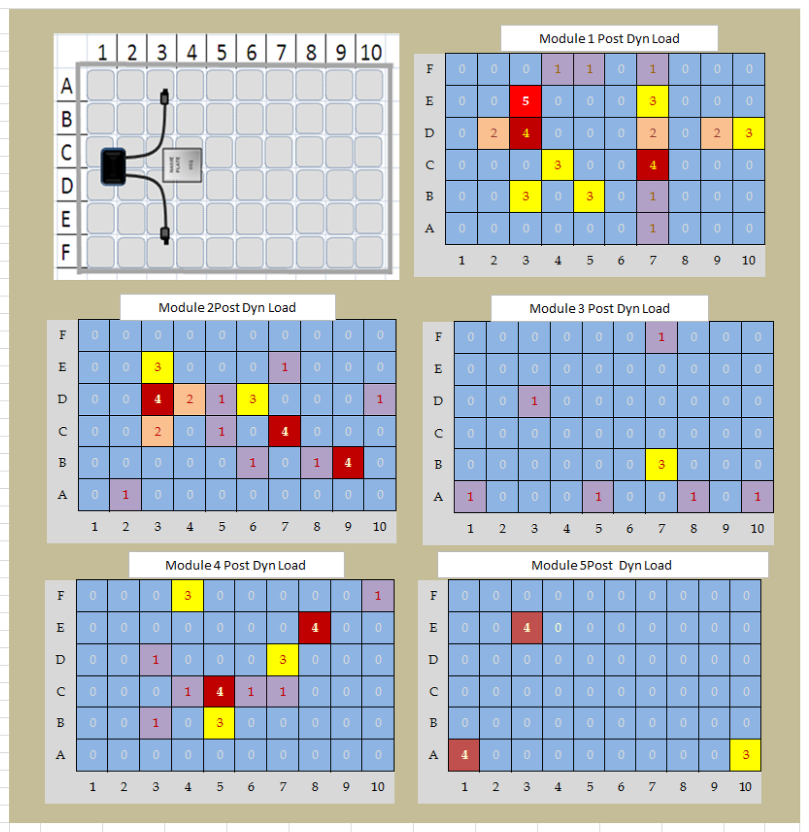
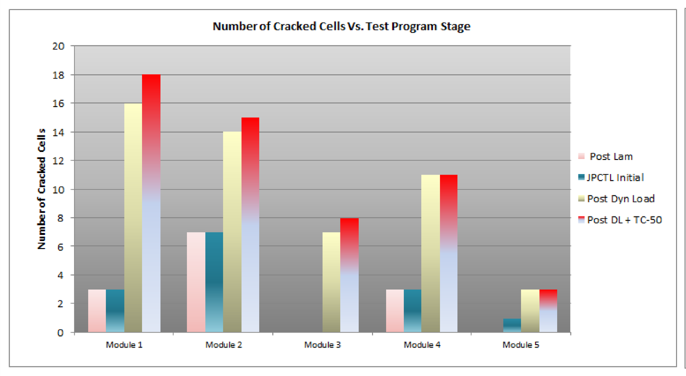


Figure 3: Cracked cell map post dynamic load testing based on severity of cracks



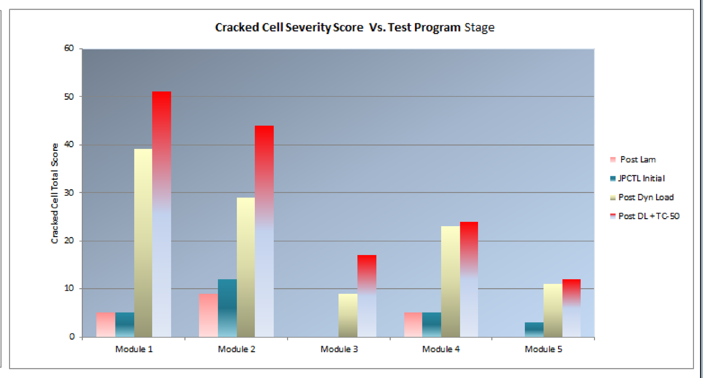


Figure 4: Quantity of cracks and cumulative severity scores at different stages of testing

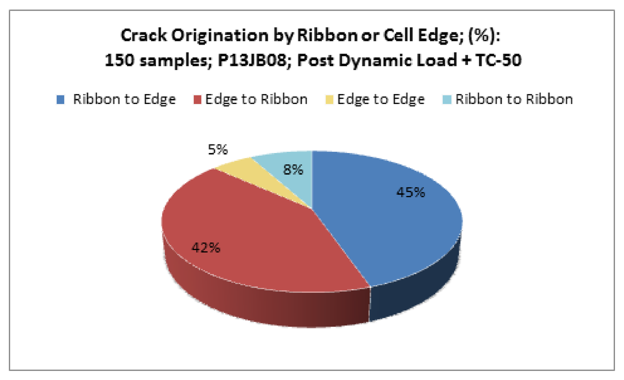


Figure 5: Pie chart for crack origination distribution

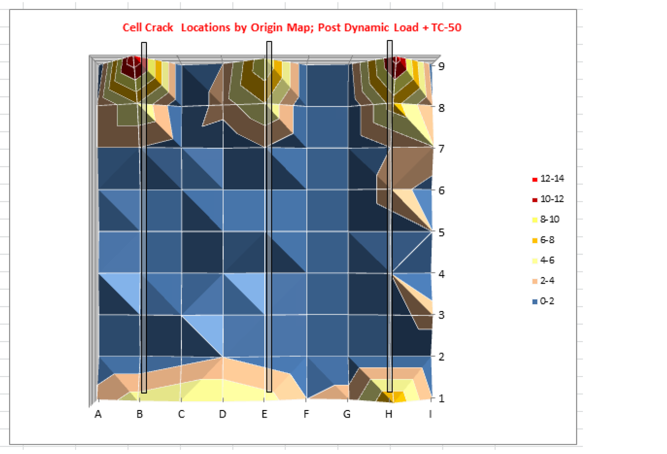
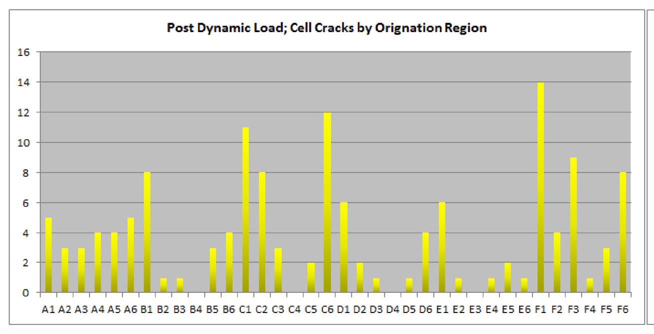


Figure 6: Mapping of crack location/origination on cell



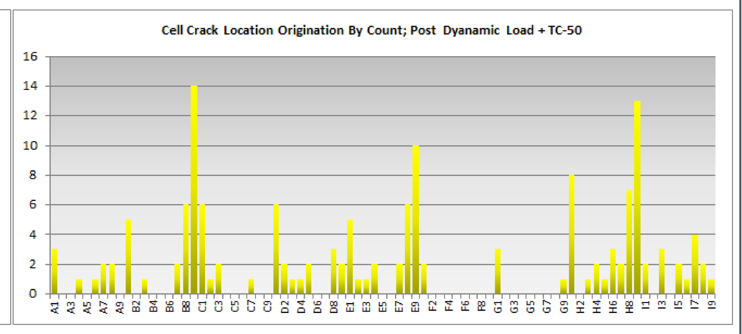


Figure 7: Cumulative crack count based on location on the cell area as mapped in figure 6 above.

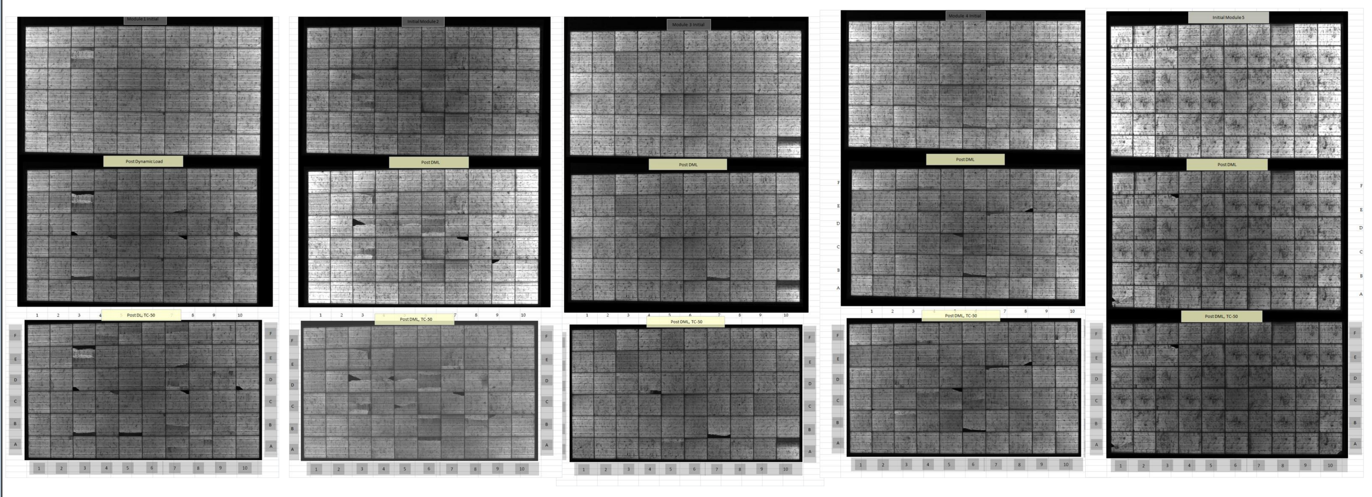


Figure 8: Electroluminescence images of all the modules in test during initial, post DML and post TC50 stages.

Results and discussion

Table 2: Change of Power and I-V Characteristics at the completion of final test stage

% Change from Initial post DML and TC50 JPCTL (-ve number indicates decrease)						
Module #	Pmax	FF	Voc	Isc	Vpm	Ipm
Module 1	0.0%	-2.0%	-0.3%	2.4%	-0.8%	0.8%
Module 2	-0.6%	-2.3%	-0.3%	2.1%	-0.4%	-0.2%
Module 3	1.4%	-1.0%	0.0%	2.5%	-0.2%	1.6%
Module 4	0.0%	-1.9%	-0.3%	2.2%	0.4%	-0.3%
Module 5	-0.6%	0.1%	-0.1%	-0.5%	-0.2%	-0.4%

- The overall power did not decline more than 2% in spite of evidence of several cracks post dynamic mechanical load testing. This was still the case even after they completed the thermal cycling segment of the test schedule.
- Post TC-50, the severity score rate increased more compared to the number of cracks formed.
- Cell inter-distance was at least 50% higher for module 5 compared to the rest of the module. Glass, back sheet and encapsulation material properties were assumed to be relatively similar. All modules used softer ribbons with low yield strength.
- There appears to be a direct correlation of cell crack origination location to the overlapping ribbon "connected end" locations. Most of cracks originated from the ribbon end of the cell.
- As seen in Figure 6 crack origination is concentrated around the soldered ribbon area that is overlapping the edge of the cell.
- There were no cell shunts that developed in the tests. Overall the modules pass the reliability test. A power degradation of >5% would have been a cause of concern. This further establishes our confidence in the fact that minimal stresses are introduced in the cells and joints during the manufacturing processes.

Conclusion

- Though the modules tested did not show significant loss/degradation post DML and 50 thermal cycles, the data generated through electroluminescence imaging and power performance testing is of great value to manufacturing.
- Severity rating can be used to provide certain ratings to arrive at a rough estimate for yield estimation/breakage rate using typical material set during the validation and qualification process of new cells.
- Factors that will help explain few of the defects would be characterization of cells and ribbon material for latent defects and physical properties. Other influencing factors would be ribbon soldering pattern on the silver bus. Pattern would be defined as number of soldering points, distance to the edge and inter-distance.
- Defect mapping can help predict weak areas that needs to be analyzed to further improve yield (reduce cell breakage rate) and also potentially help address long term reliability issues that could occur in the field.

References

[1] Wohlgemuth, John H.; Cunningham, Daniel W.; Placer Neil V.; Kelly George J.; Nguyen Andy M. "The effect of cell thickness on module reliability". 33rd IEEE Photovoltaic Specialist Conference, San Diego, 11-16 May 2008, pp. 444-445

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