SILICON SOLAR MODULE VISUAL INSPECTION GUIDE

Catalogue of Defects to be used as a Screening Tool

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Contents

ABOUT THIS DOCUMENT

This document is designed to be used as a guide to visually inspect front-contact poly-crystalline and mono-crystalline silicon solar photovoltaic (PV) modules for major defects (less common types of PV modules such as back-contact silicon cells or thin film technologies are not covered here). The modules under consideration may be of any size or rated power, however some specific use-cases for solar modules may have different requirements and therefore adaption of this document is application and institution dependent (ex. labelling may not be present for a solar module sold as part of a small off-grid lighting kit). This document is meant to supplement and support rather than replace international testing standards (for example IEC 61215 or UL 1703 [1], [2]). A lack of visually observable defects is necessary but not sufficient to determine if a module would pass IEC 61215 testing.

Motivation

This document was developed as a response to observations of sub-standard quality and counterfeit solar products present in developing world markets. Many consumers and retailers are not aware of the presence of significant visually observable defects that may limit performance and/or lead to premature product failure. Nor are they aware that good quality PV modules should last 25 years or more. Note that no amount of visual inspection or electrical product testing can guarantee that a module will perform reliably for 25 years.

Although visual inspection cannot catch all possible defects, it can be used as a screening method to identify poor performing products and potential early failure modes. This document was designed with the intention of being a quick tool that is inexpensive to implement, as it does not require any test equipment. Although helpful, no prior knowledge of solar photovoltaics is required to benefit from this guide, and an inspector should be able to be trained in its use in two days or less.

Applications

Several applications could be envisioned for this document, including use by:

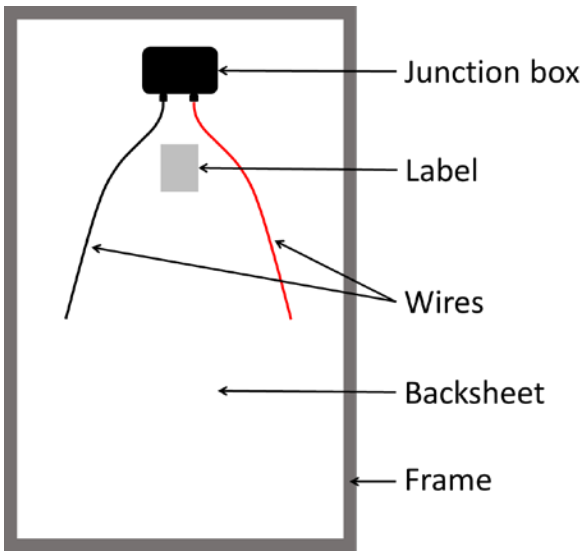
- border agents to inspect product shipments at ports of entry to a country. Standardized rejection criteria could be used as grounds for barring defective products for import in conjunction with an adopted IEC standard such as IEC 61215.
- standards agencies or regulatory authorities in search and seizure efforts. A tool that can be used onsite to determine if defective or fraudulent products are found for sale in markets.
- Retailers/distributors to ensure they are receiving acceptable quality products from manufacturers.
- installers/technicians when selecting product from retailers or distributors for customers.
- educators as a teaching tool for students of solar energy, for example when training technicians.
- inspectors of already installed solar products to catalogue defects and attempt to trouble-shoot failures. However, as this guide deals primarily with new modules, alternative tools are recommended for this task (please see for example [3]).

Structure

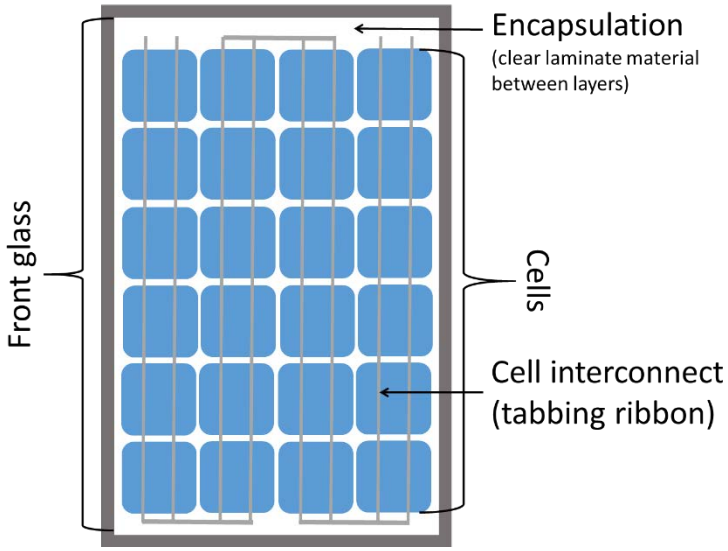
This document is organized into a Terminology section and a Checklist, followed by a table cataloguing and describing the defects to be visually inspected. The schematics in the Terminology section describe where each component is found on a common solar PV module. A Severity Rating is also defined to give users guidelines on how concerning a particular defect may be. In the Checklist and the Catalogue of Defects, defects have been organized by the component of the module on which they appear, followed by severity rating. The order in which components are inspected goes from the back to the front of the module, following a procedure developed elsewhere [3]. The Catalogue of Defects is subdivided into two sections: the first referring to defects that might be found on new modules, and the second describing defects that might appear over time. This document is principally focused on defects that are observable at the beginning of product life. Selected significant defects that may appear over time are also included for completeness and to address the second-hand market.

CLARIFICATION OF TERMINOLOGY

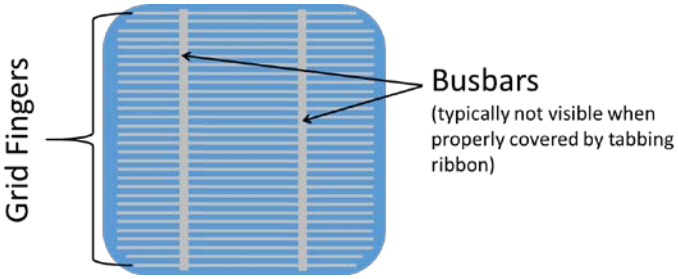
Rear side of silicon module



Front side of silicon module



Individual silicon solar cell

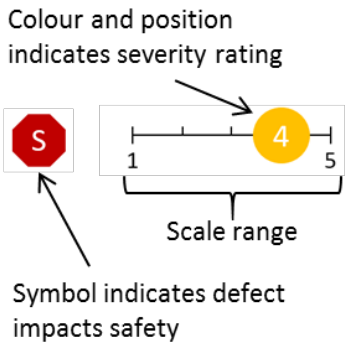


CLARIFICATION OF SEVERITY RATING

Efforts were made by the authors to provide a comparative rating of the severity of the defects. The range of the scale indicates influence to performance and/or reliability, and given is from 1 (low severity) to 5 (high severity). A range is provided when the severity of a defect can vary, for example with the size of the affected area. An additional icon is given if the defect poses a potential safety risk to the installer or the end user. The authors assume no liability for actions taken as a result of this document.

S: Symbol indicating a safety risk, separate from quantitative scale

1. The defect is an indicator of poor quality with no direct effect on performance or reliability
2. The defect has a minor impact on performance and/or reliability
3. The defect has a moderate impact on performance and/or reliability
4. The defect has a high impact on performance and/or reliability
5. The defect is indicative of a major quality issue, a critical failure, or a counterfeit panel



RECOMMENDATIONS

The following section provides recommended guidelines for the use of this document. This includes recommendations on an inspection procedure and accept/reject criteria.

Institutions may choose to adapt the checklist into a format unique to the needs of the given application. A cover page could be used to accomplish this. For example, different institutions/application might require specific administrative details to be recorded beyond the fields of Module ID, Inspector and Date that are currently included (ex. location, reason for inspection, shipment, company, actions taken, comments, etc.)

Inspection Procedure:

The following procedure should be followed for each product lot to be inspected (ex. shipment, retail location, installation, etc.).

1. Identify and differentiate the different product types/sizes to be inspected within the lot.
2. Select a minimum of 8 samples of each size/type randomly for inspection (see IEC 61215 for sampling recommendations). Care should be taken to select samples from different locations (boxes, containers, etc.) within a lot (for example do not simply select the first 8 samples that are seen). Depending on the application this may not be sufficient: for example if inspecting existing modules at a solar installation, it would likely be desirable to inspect 100% of samples.
3. The inspector should complete one checklist per sample, proceeding through the list of defects in the order in which they are presented in order to ensure completeness.
    a. For each defect in sequence complete the checklist with an indication of defect presence, severity and whether or not the defect represents a potential safety risk.
    b. Depending on the requirements and the resources of the institution, it may be of interest to take photos of defects for inclusion in an inspection report, along with overview photos of the front, back, and label of a module.
    c. If further information or clarification is needed, refer to the detailed Catalogue of Defects which includes a description of the affected component, defect photos, a description of the defect, why it's important and guidelines on assessing defect severity.
    d. For used samples, both "new" and "used" checklists should be completed in this order. Inspectors should be sufficiently familiar with defects unique to used modules such they can be identified during the inspection of ostensibly new products.
4. Once the inspection checklist is complete the inspector can review the results to determine whether the inspected module is acceptable for the intended application. The accept/reject criteria for a single module and an entire lot may be based on the recommendations below, or as per a standardized procedure determined by a given institution.

Accept/Reject Criteria:

Acceptance and rejection criteria may be application and end user dependent. For example; small modules for off-grid applications may have slightly different quality requirements than full sized modules for utility scale applications. The market for small off-grid module may tolerate minor defects whereas the utility-scale market may not allow any visual defects which might pose even a small risk to the reliability and therefore the long term economic viability of the project.

Users of this document should make final accept/reject decisions based on a consistent, standardized and documented process which is justified by the needs of the market being served. The following section provides a recommended set of guidelines for deciding on the acceptability of modules under visual inspection.

A solar PV module sample will be considered to be rejected due to its observable quality defects if any one of the following conditions are met:

1. If any single observed defect has been evaluated as a Severity of 5. A Severity of 5 indicates a major quality issue; a critical failure or a fraudulent module. This evaluation alone is sufficient justification for the rejection of a sample.
2. If any single observed defect has been evaluated to pose a Safety Risk. Under no conditions should a module that risks the safety of an installer or end user be considered acceptable.
3. If any combination of observed defects that have a summed Severity score greater than or equal to 5 (acceptable summed value could be raised or lowered at the discretion of a given institution). This condition allows for the possibility to accept modules with minor defects that do not critically affect performance or reliability. This is done with the intent of not putting prohibitively stringent demands on developing markets that can tolerate minor deficiencies.
4. If any module that is expected to be new shows any of the used module defects. The defects listed under the used module checklist should be exclusively visible on used modules. At the discretion of the institution, the inspector might be directed to also always complete the used module checklist in order to rule out these defects, or alternatively simply complete the last row of the new module checklist to indicate the module does not appear to be used previously.

If one or more samples are rejected for any of the above conditions then further action is required. Dependent on the application to which this process is applied and the goals of the inspection, several options are possible at the discretion of the responsible institution:

1. Reject the entire lot under inspection.
2. If only one of initial 8 samples is defective, reselect at minimum 8 random samples from the lot and repeat the above inspection procedure. If rejects are again found then reject the entire lot.
3. Require 100% inspection on all samples within the lot and reject all non-conforming samples.
4. Instigate a more in-depth secondary inspection to further investigate the quality of the lot under question, likely including electrical testing. The procedure for this testing is beyond the scope of this document.

Module ID: _____ Inspector: _____ Date: _____

CHECKLIST: New Module

COMPONENT	DEFECT		Defect Present? No	Yes	If Yes, Score	Safety issue?
1. Label	1.1	Missing				
	1.2	Poorly attached				
	1.3	Information is missing				
	1.4	Incorrect spelling				
2. Backsheet	2.1	Delamination				
3. Junction Box	3.1	Faulty electrical connection				
	3.2	Cracks/breaks/gaps in housing				
	3.3	Sealant failure				
	3.4	Electrical polarity not indicated				
4. Wiring	4.1	Wire(s) missing or poorly attached				
	4.2	Too short and/or too thin				
5. Frame	5.1	Damaged				
	5.2	Adhesive/sealant failure				
6. Front Glass	6.1	Cracking				
	6.2	Scratches				
7. Encapsulation	7.1	Delamination				
8. Cells	8.1	Fake				
	8.2	Dummy pieces disguising missing material				
	8.3	Cracks				
	8.4	Partially covered				
	8.5	Scratches				
	8.6	Differently sized				
	8.7	Edge chips				
	8.8	All cells very shiny				
9. Cell Metallization	9.1	Fingers not connected to busbar				
	9.2	Not the same pattern on all cells				
	9.3	Fingers off of edge of corner of cells				
10. Cell Interconnection	10.1	Interconnection is discontinuous				
	10.2	Cells connected in parallel (counterfeit)				
	10.3	Poorly aligned and/or soldered				
	10.4	Cells connected in parallel (real cells)				
Defects are present suggesting module is used rather than new						
SUMMARY Indicate if any defects and safety issues are present and sum score						

ACCEPT: ☐ **REJECT:** ☐

CHECKLIST: Used Module

COMPONENT	DEFECT		Defect Present? No	Yes	If Yes, Score	Safety issue?
1. Label	See New Module Checklist					
2. Backsheet	2.2	Burn marks				
	2.3	Discolouration				
3. Junction Box	See New Module Checklist					
4. Wiring	4.3	Cracks or exposed metal				
5. Frame	See New Module Checklist					
6. Front Glass	See New Module Checklist					
7. Encapsulation	7.2	Discolouration				
8. Cells	8.9	"Snail trails"				
	8.10	Shiny locally/inconsistent colour				
9. Cell Metallization	See New Module Checklist					
10. Cell Interconnection	See New Module Checklist					
SUMMARY Indicate if any defects and safety issues are present and sum score						

CATALOGUE OF DEFECTS: New Modules

1. LABEL

Provides important product information. Adhered to the rear of a module by the module manufacturer.

1.1 Missing

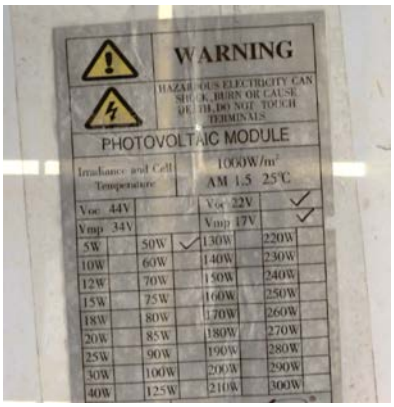
Description: A label must be present. This may be unlikely if the panel is small (<5W)

Why it's important: Lack of label implies sub-standard manufacture. Lack of this information is a potential safety issue. Label information is needed to properly install and operate the panel.

Severity:

S 1 5

1.2 Poorly attached



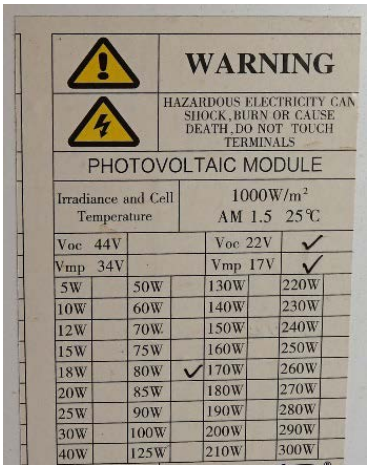
Description: Label should be made of material that resists water or light damage. Label should not be peeling or bubbling. Label should be permanently adhered (example at right uses clear tape overtop of a poorly affixed label).

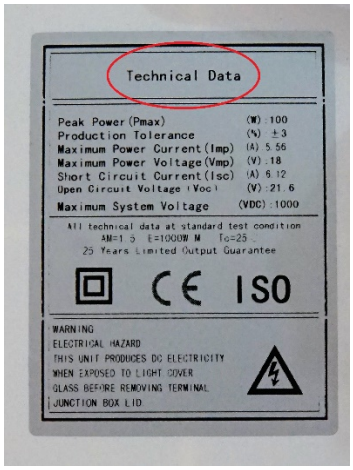
Why it's important: Label needs to provide panel information for the duration of the panel lifetime. Lack of this information is a potential safety issue as described above.

Severity:

S 1 5

1.3 Information is missing





Label on left gives no Current data. Label on right gives no Manufacturer data. Neither gives Model or Serial #.

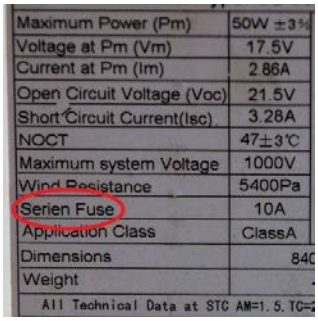
Description: Label should give the following: Maximum Power, Current and Voltage at Maximum Power, Short-Circuit Current, Open-Circuit Voltage, Maximum system voltage, Manufacturer name, Model #, Serial # (sometimes on a small label on the front of the module, can be a barcode). High quality products will have marking symbols from UL, IEC or TUV.

Why it's important: Data is needed to properly install, operate and maintain equipment. Lack of this information is a potential safety issue.

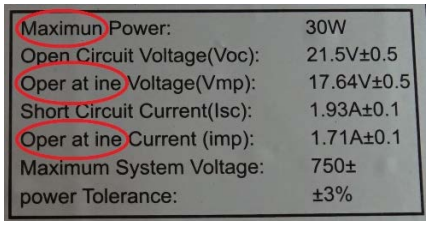
Severity:

S 1 5

1.4 Incorrect spelling



Maximum Power (Pm)	50W ±3%
Voltage at Pm (Vm)	17.5V
Current at Pm (Im)	2.86A
Open Circuit Voltage (Voc)	21.5V
Short Circuit Current(Isc)	3.28A
NOCT	47±3℃
Maximum system Voltage	1000V
Wind Resistance	5400Pa
Serien Fuse	10A
Application Class	ClassA
Dimensions	840
Weight	
All Technical Data at STC AM=1.5,TC=	



Maximun Power:	30W
Open Circuit Voltage(Voc):	21.5V±0.5
Oper at ine Voltage(Vmp):	17.64V±0.5
Short Circuit Current(Isc):	1.93A±0.1
Oper at ine Current (imp):	1.71A±0.1
Maximum System Voltage:	750±
power Tolerance:	±3%

Description: Words should be spelt correctly in whatever language is used

Why it's important: Does not affect performance, reliability or safety, but is an indicator of the lack of professionalism of the manufacturer.

Severity:

2. BACKSHEET

Back substrate of module. Protects module interior from the elements.

2.1 Delamination

[3]

Description: Backsheet not well laminated to module. Surface is bubbled or peeling.

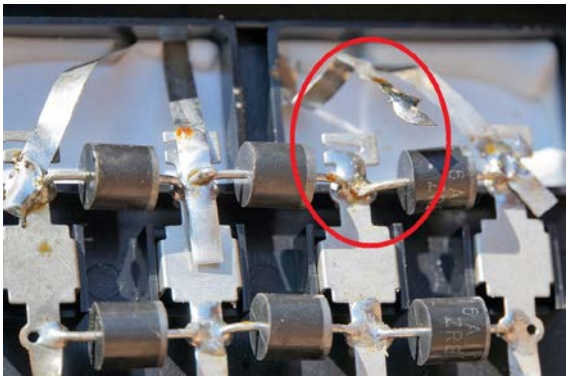
Why it's important: Bubbles are space for moisture to accumulate. Moisture in the module will decrease performance and affect long term reliability.

Severity:

3. JUNCTION BOX

Electrical enclosure on the rear of the module where external wires connect to the internal tabbing ribbon. The junction box also contains the diode(s).

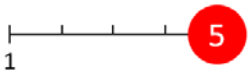
3.1 Faulty electrical connection



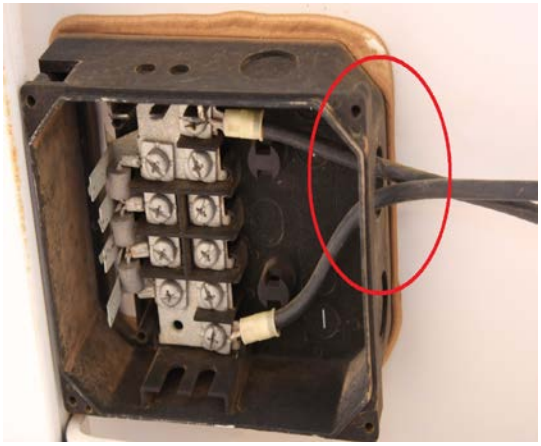
Description: Broken solder joints, broken wire or tabbing ribbon.

Why it's important: Broken electrical contacts can cause module failure.

Severity:



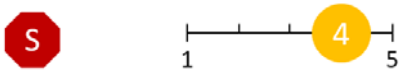
3.2 Cracks/breaks/gaps in housing



Description: Cracks in the housing, missing a continuous seal for the lid or around the wires. Possibility of water ingress.

Why it's important: Accumulated moisture can cause short circuits or corrosion of the metal contacts, increasing the risk of melting or fire. The junction boxes on high quality modules will be permanently sealed to mitigate this risk.

Severity:

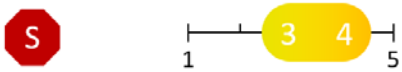


3.3 Sealant failure

Description: Holes in the seal, brittle material (should feel rubbery with fingernail) or adhesion failure. Possibility of water ingress.

Why it's important: Accumulated moisture in the junction box can cause short circuits or corrosion of the metal contacts. Corrosion can increase the risk of melting or fire.

Severity: If the sealant is brittle but not yet failed then the severity should be 3. If means of water ingress is visible, the severity should be 4.



3.4 Electrical polarity not indicated

Photo not available

Description: Does not include a clear indication of the positive (+ or red) and negative (- or black) terminal of the module. Can be done with colour-coded wires instead of marked on junction box.

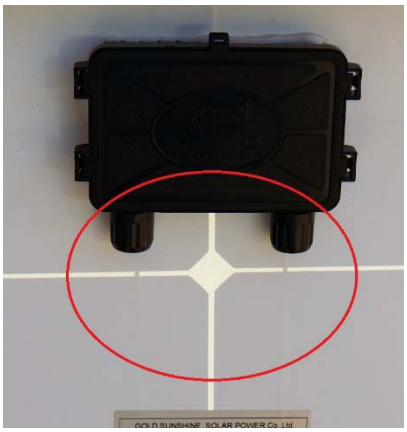
Why it's important: Improper wiring of the module could cause a safety risk or lead to equipment failure.

Severity:

4. WIRING

The wires carry electricity from the module to the charge controller or inverter.

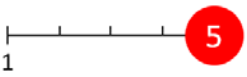
4.1 Wire(s) missing or insecurely attached



Description: One or both wires are missing or loosely connected to the module.

Why it's important: Two wires are necessary to make a circuit. All new modules come with wires securely soldered to the tabbing ribbon and diodes inside the junction box.

Severity: If the product is intended to be sold directly to the consumer, then wires are required for module function and severity is a 5. If further assembly is intended, no defect is present.

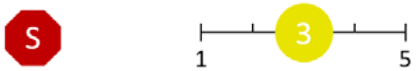


4.2 Too short and/or too thin

Description: Wires aren't long enough to make a robust (waterproof, electrically sound) connection to the rest of the system. Wires too short to reach past the frame of the module are likely a concern. Thickness requirements depend on module current. Examples of max ratings include: 2.9A for 17AWG (1.04mm^2), 7.4A for 13AWG (2.63mm^2), 15A for 10AWG (5.26mm^2), 30A for 7AWG (10.55mm^2)[4]

Why it's important: If wires are too thin they could melt or burn. For safety, all electrical connections must take place inside a sealed enclosure, ex. junction box.

Severity:



5. FRAME

The frame provides structure, rigidity, and mounting features. Sometimes non-metal for small modules (for example <10W). Metal is needed for rigidity for large modules. If metal is used, electrical grounding is required.

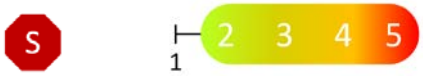
5.1 Damaged

Photo not available

Description: Bent or cracked frame or the corners are not well aligned.

Why it's important: Loss of mechanical integrity, to the extent that the installation and/or operation of the module would be impaired. For example, may not be rigid enough to withstand handling during installation and/or high winds.

Severity: Low severity and no safety risk if dents/cracks in the frame are unlikely to affect mechanical integrity. High severity and safety risk if damage could lead to safety issues from cracked glass, poor electrical grounding, or if installation and/or operation are likely to be impaired.



5.2 Adhesive/Sealant failure

Description: Discontinuous perimeter seal or loose attachment to module.

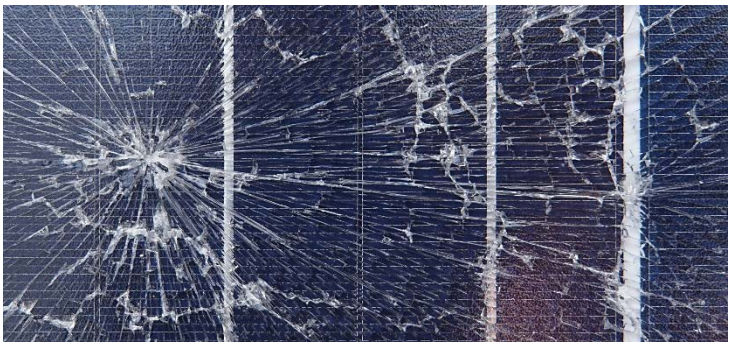
Why it's important: The adhesive is also a sealant that prevents water ingress into the module. Water in the module layers will decrease performance and affects long term reliability. Severity depends on atmospheric humidity.

Severity:

6. FRONT GLASS

Provides structure to the module and protects the cells. Allows transmission of light to the cells.

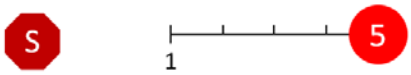
6.1 Cracking



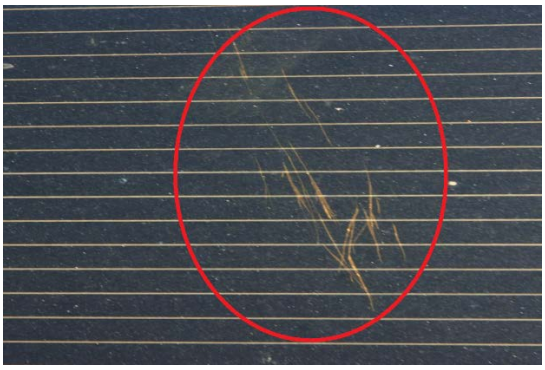
Description: Front glass is cracked locally or over the full area.

Why it's important: Module mechanical integrity is compromised. Possible path for water ingress. Mechanical and electrical safety issue.

Severity:



6.2 Scratches



[3]

Description: Permanent scratches in the surface of the front glass. Cannot be removed with cleaning.

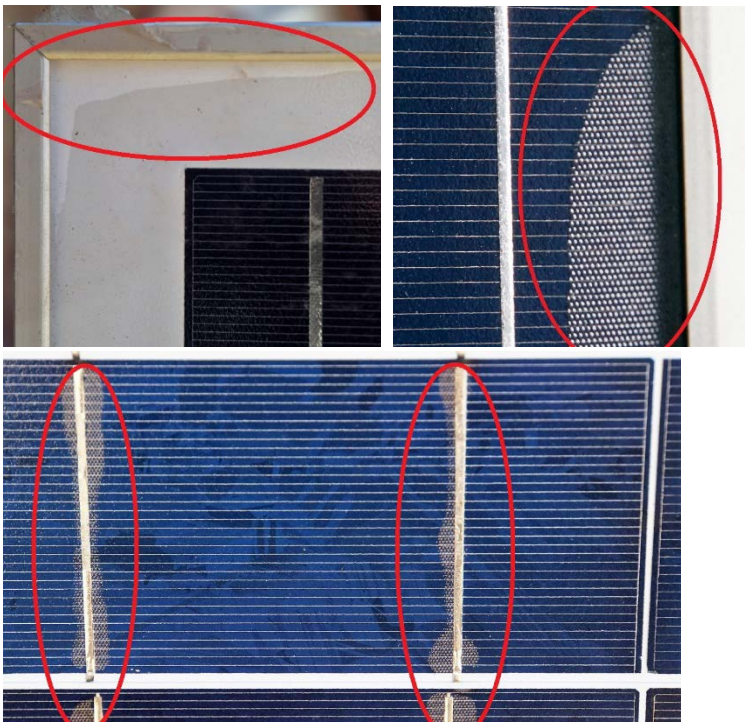
Why it's important: Transmission of light to the underlying cells, and therefore module power, is reduced.

Severity: Severity increases with affected area. A score of 5 should be given If 10% or greater area is affected above any individual cell.

7. ENCAPSULATION

Used to laminate module layers together. Transparent to allow light to reach cells.

7.1 Delamination



Description: Any local separation of the layers between the front glass and the cells or the front glass and the backsheet. May appear continuous (top left) or spotted (right and bottom, due to texture of glass). Also could be bubbles. Most commonly appears around busbars or at the edge of the panel.

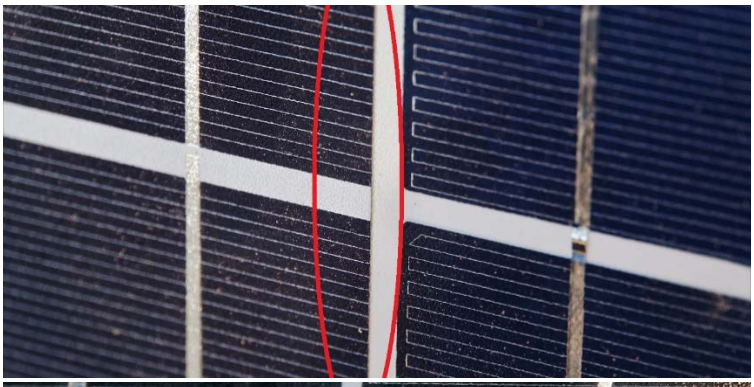
Why it's important: Can reduce structural integrity of the module. Transmission of light to the underlying cells, and therefore module current, is reduced.

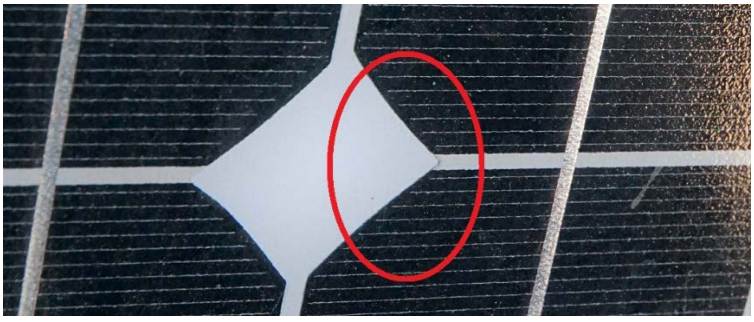
Severity: Bubbles of delamination forming a continuous path between any part of the electrical circuit and the edge of the module is a safety risk due to possible water ingress. If delamination does not form such a path no safety risk exists. Influence on performance increases with affected area. A score of 5 is given If 10% or greater of any individual cell's area is affected. A barely visible bubble would correspond to a score of 2.

8. CELLS

Active component of the solar module. Electricity producing material converts sunlight to electricity.

8.1 Fake

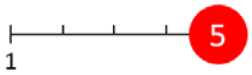




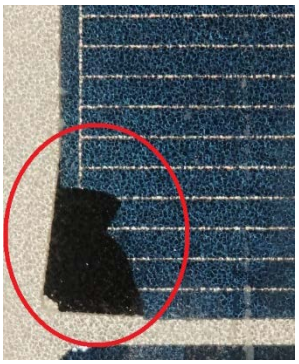
Description: Cells not made of active material, are instead printed paper images. Likely only a portion of the cells in a given module may be fake. May be evident in the white space between fake cells, where the edge of the paper can be seen. Examples of fake poly and mono-crystalline cells in top and bottom images respectively. If counterfeiters instead cut around each paper cell individually it will be harder to spot, and instead might be caught when inspecting the cell interconnection.

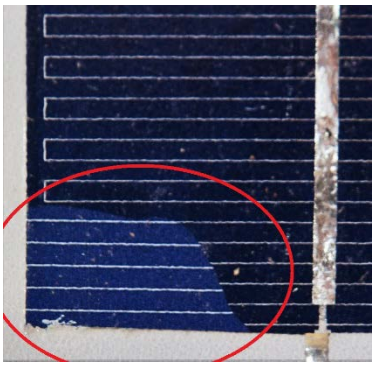
Why it's important: Purposely deceitful behaviour of manufacturer. The customer pays for fraudulent material that will not produce power.

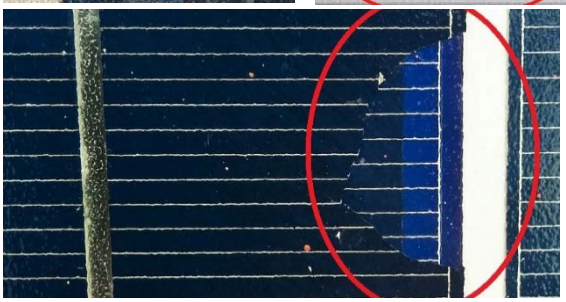
Severity:



8.2 Dummy pieces disguising missing material





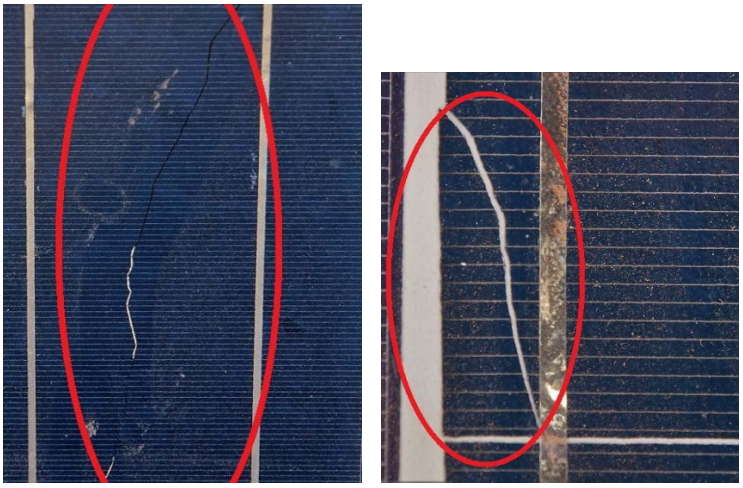


Description: Inactive material (dummy cell fragment or dark paper) has been placed behind an active cell in order to hide the fact that the cell has broken and has a piece missing.

Why it's important: Power output of the module limited by the missing material area. Purposely deceitful behaviour by the manufacturer. Indication of sub-standard cells and practices.

Severity: Power loss depends on size; a score of 5 should be given If 10% or greater of any individual cell's area is missing. If the piece that is missing extends up to the edge of the metallization, a score of 3 is given. If the piece does not contain any metallization, this defect is instead an Edge Chip (section 8.7).

8.3 Cracks



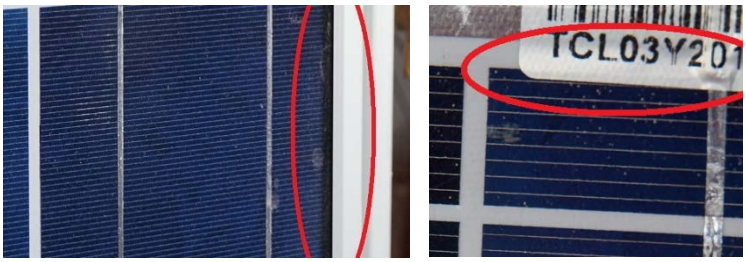
Left: large crack across the cell, but both halves are still connected to busbars. Right: smaller crack is actually more severe: a portion of the cell is no longer electrically connected.

Description: Cell is cracked. Crack may be partially or all the way across a cell. Partial cracks are likely to propagate over time. Depending on size cracks may be hard or impossible to spot. The white backsheet may be visible through large cracks.

Why it's important: Power output of the module limited if portions are removed from the electrical circuit. Visible cracks indicate poor mechanical handling by manufacturer; likely more cracks exist that are not currently visible.

Severity: Severity depends on affected area. A crack is considered a major defect (score of 5) when its propagation could remove more than 10% of that cell's area from the electrical circuit [1]. The presence of a crack of any size that does not, or likely will not through its propagation, isolate any portion of the cell from the electrical circuit is a score of 2.

8.4 Partially covered

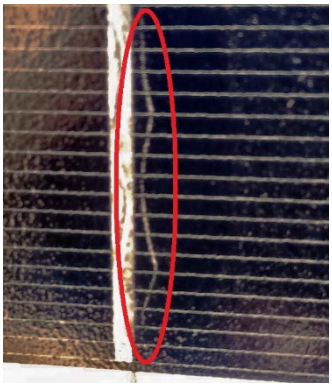


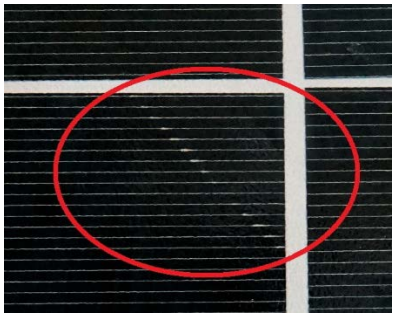
Description: A cell is partially and permanently covered, for example by the frame, a label, or by another cell.

Why it's important: Reduces active cell area. Current will be limited by the smallest cell area. An indicator of sub-standard manufacturer design and fabrication.

Severity: Influence on performance increases with affected area. A score of 5 is given if 10% or greater of any individual cell's area is covered.

8.5 Scratches

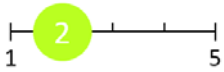




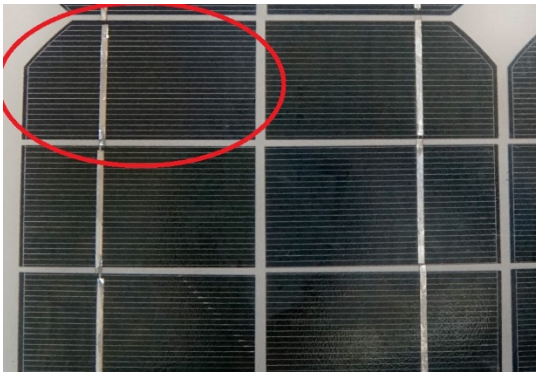
Description: Scratches in the surface of the cell from poor handling during module assembly. Often next to tabbing ribbon and caused by operator scraping the cell during soldering.

Why it's important: Deep scratches risk shorting the cell, but shallow scratches may have minimal impact.

Severity: Severity hard to evaluate visually.



8.6 Differently sized

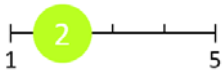


The circled cell is a different shape and size than the other cells having full corners.

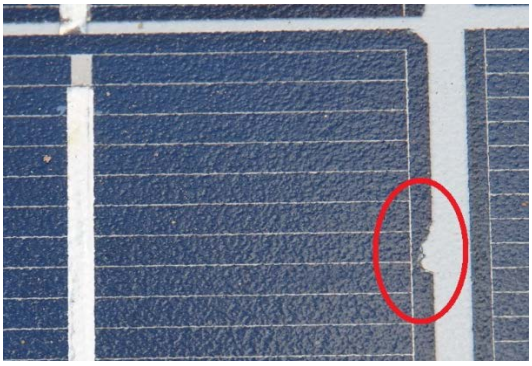
Description: Cell fragments of different sizes connected in series within a module.

Why it's important: Current will be limited by the smallest cell area. Larger cells will operate at a higher temperature as they burn off excess current, potentially decreasing product lifetime. Indication of a poor module design. Can be compensated for by increasing height, which can be roughly checked by comparing the number of metal fingers on differently sized cells.

Severity:



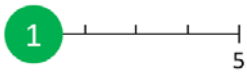
8.7 Edge chips



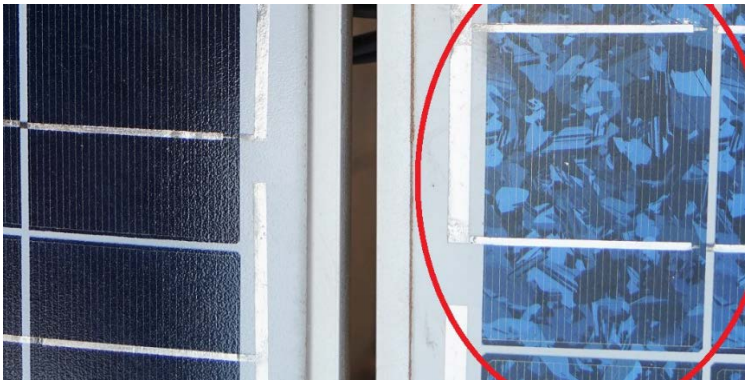
Description: A small region is missing from the edge of the cell. Does not enter metallized region.

Why it's important: Edge region is generally low power producing, so defect has minimal impact. Is a concern if many cells in a module have this defect; it indicates poor mechanical handling.

Severity:



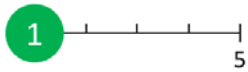
8.8 All cells very shiny



Description: Cells are very shiny, reflecting instead of absorbing light.

Why it's important: May be less efficient than darker cells, which is not inherently a problem if a module is sold based on rated power. Retailers selling such modules at a higher price to uninformed consumers who associate "shiny" with "new" or better is deceitful practice.

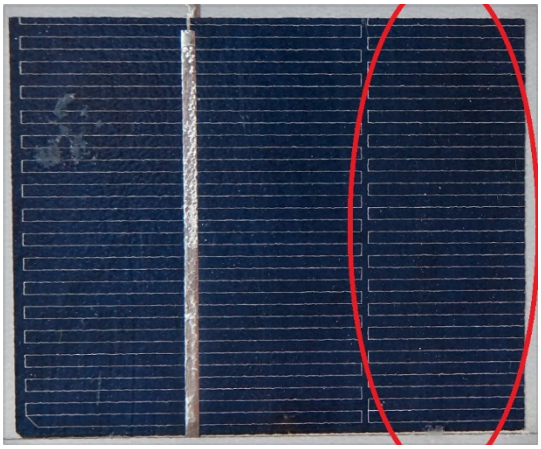
Severity:



9. CELL METALLIZATION

Metal fingers collect and conduct current from the cell to the busbars (covered by tabbing ribbon)

9.1 Fingers not connected to busbar

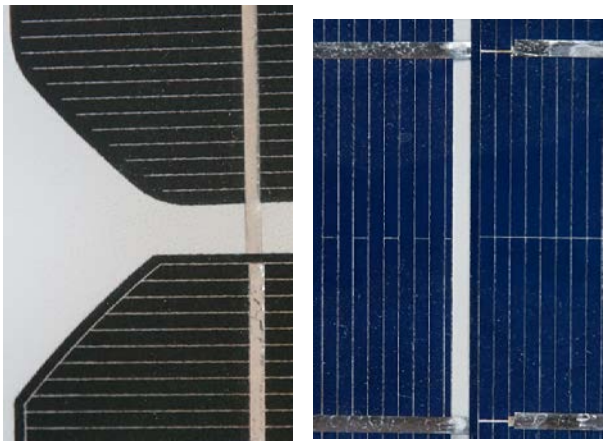


Description: Metal fingers are not connected to the busbars of a cell.

Why it's important: Current of unconnected region cannot be used. Severity depends on effected region. In the example here 1/3 of the cell area is effectively unused. Indicates a poor design and a sub-standard manufacturer.

Severity: Severity depends on affected area. Considered a major defect when 10% or greater of a cell's area is excluded from the electrical circuit [1].

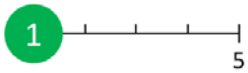
9.2 Not the same pattern on all cells



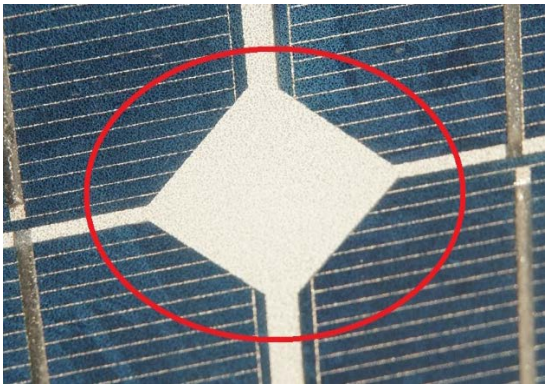
Description: Different metallization patterns apparent on different cells in the same module.

Why it's important: Not inherently an issue if cells have the same performance characteristics. However if mis-matched cells are combined in a module, higher performing cells will be limited by lower performers. Potential indicator of poor manufacturing practices.

Severity:



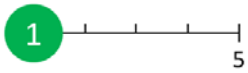
9.3 Fingers off of edge of corner of cells



Description: Metal fingers go right to cell edge in corner of cell.

Why it's important: Indicates deceitful behaviour of manufacturer; lower cost/performance poly-crystalline cells cut to look like high cost/performance mono-crystaline cells.

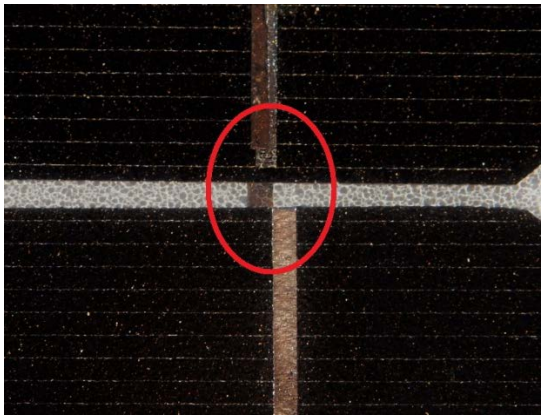
Severity:



10. CELL INTERCONNECTION

Tabbing ribbon that is soldered to busbars. Connects cells together and conducts current to external circuit.

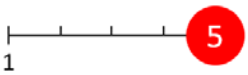
10.1 Interconnection is discontinuous



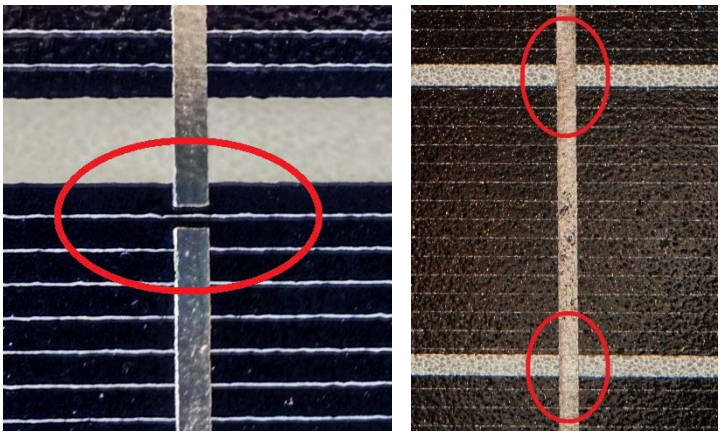
Description: There is no cell interconnection, or tabbing ribbon is present but does not connect cells together (is discontinuous). Note that some small consumer products cover the tabbing ribbon with black material for aesthetic purposes.

Why it's important: Power of unconnected cells does not contribute to module power. Indicator of a partially or completely counterfeit/fake product.

Severity:



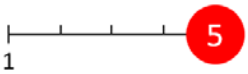
10.2 Cells connected in parallel (counterfeit)



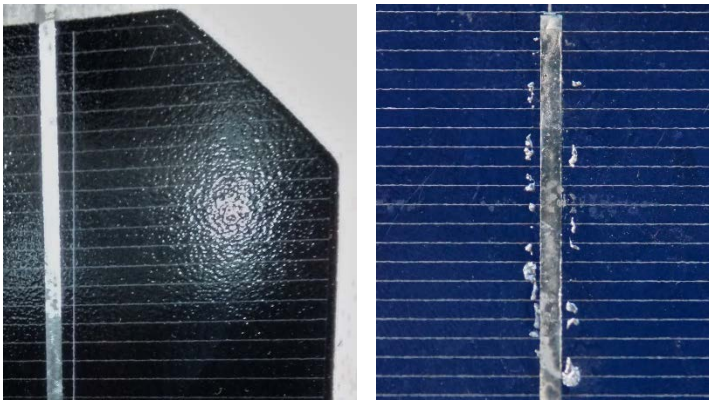
Description: Tabbing ribbon appears two dimensional in the area between cells. Rather than connecting the bottom of one cell to the top of the next (standard series connection), the top of one cell is connected to the top of the next (parallel connection).

Why it's important: Often indicates a counterfeit product with fake printed paper instead of soldered tabbing ribbon.

Severity:



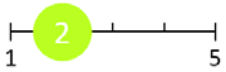
10.3 Poorly aligned and/or soldered



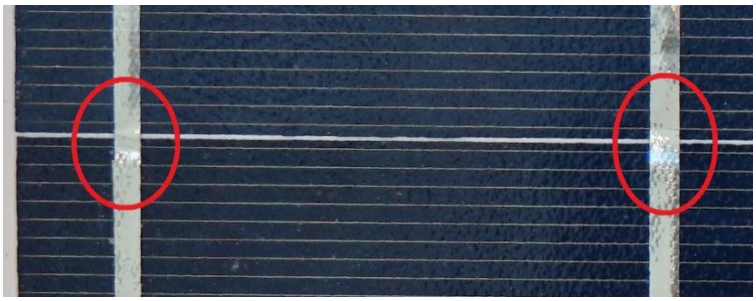
Description: Poorly soldered tabbing ribbon. For example misaligned to busbars or excess solder dripped on cell.

Why it's important: Tabbing ribbon mis-aligned to busbars increases resistances and decreases module power. Excess solder shades cells locally, decreasing current. Overall indicators of low quality control standards of the manufacturer.

Severity:



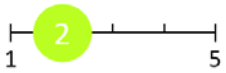
10.4 Cells connected in parallel (real cells)



Description: Real cells tabbed together in a parallel connection to combine small cut cell fragments with full-sized cells in one module

Why it's important: Poor manufacturing practice. Typically correlates with a manual process and broken cells.

Severity:



CATALOGUE OF DEFECTS: Used Modules

The defects included in this section would not appear on a new module, only a module that has already been used in operation. These defects therefore appear over time as gradually worsening or catastrophic events. This section is included so that if these defects are found at border inspections or at retail locations, it can be immediately identified that the modules are not new and should be rejected.

If the intended use is specifically to inspect used modules, for example to evaluate PV arrays after a given time of operation, other resources would likely be more suited and complete. Please see for example "Development of a Visual Inspection Data Collection Tool for Evaluation of Fielded PV Module Condition" [3], which is specifically intended for this purpose and is available online. Note that all used modules can also have all defects that new modules have, but the converse is not true. Therefore when evaluating used modules, both "new" and "used" module checklists should be employed.

2. BACKSHEET

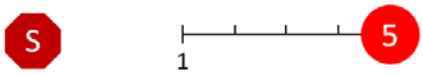
Back substrate of module. Protects module interior from the elements.

2.1 Burn marks

Description: Burnt, blackened area. Damage cannot be cleaned off. There may be a hole in the backsheet.

Why it's important: Indicates a catastrophic failure event occurred. Performance, reliability and safety are likely to be severely compromised.

Severity:



2.2 Discolouration

[3]

Description: Colour varies across the backsheet, and cannot be cleaned off

Why it's important: Backsheet material is likely degraded. This indicates that the module is suffering from a reliability problem.

Severity:

4. WIRING

The wires carry electricity from the module to the charge controller or inverter.

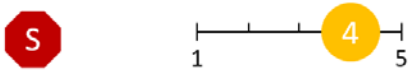
4.1 Cracks or exposed metal


[3]

Description: The wire insulation is cracked or revealing the metal conductor

Why it's important: Exposed metal in the electrical circuit is a safety risk.

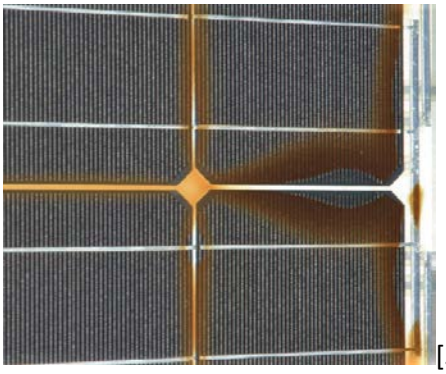
Severity:

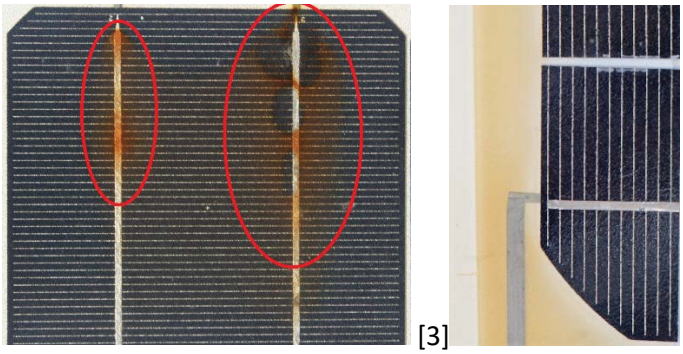


7. ENCAPSULATION

Used to laminate module layers together. Transparent to allow light to reach cells.

7.2 Discolouration


[3]


[3]

Description: Colour variation anywhere inside the module. Can be next to or above the cells, along the busbars or cell interconnects. Could be from a catastrophic event or degradation over time.

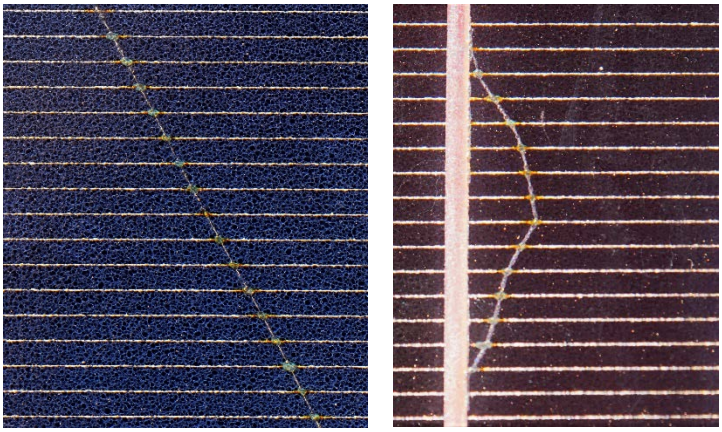
Why it's important: Indicates encapsulation material is degraded. Transmission of light to the underlying cells, and therefore module current, is reduced. Likely to degrade further over time.

Severity: Severity depends on affected area. Considered a major defect when 10% or greater of a cell's area is affected [1].

8. CELLS

Active component of the solar module. Electricity producing material converts sunlight to electricity.

8.9 "Snail trails"

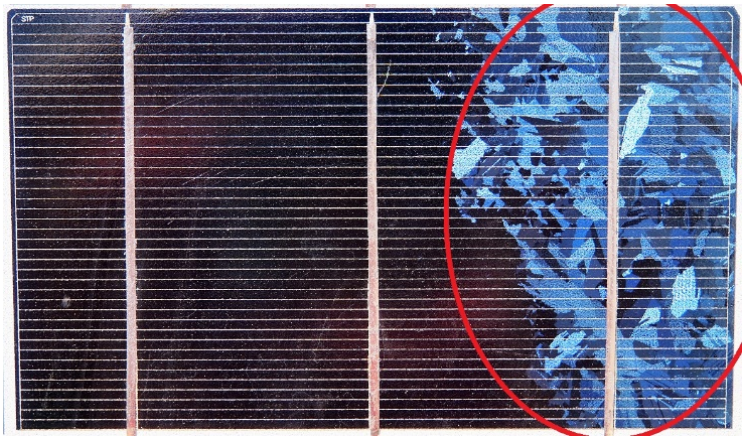


Description: Lines on cell surfaces; might appear silvered as well as yellow or brownish around metal fingers. Appears after several months of sun exposure. Correlates to presence of under-lying micro-crack that may have previously been invisible. May be difficult to distinguish from cracks or scratches.

Why it's important: Same as for cracks (Section 8.3).

Severity: Severity depends on affected area. A crack is considered a major defect when its propagation could remove more than 10% of that cell's area from the electrical circuit [1]. The presence of a crack of any size that does not, or likely will not through its propagation, isolate any portion of the cell from the electrical circuit is a score of 2.

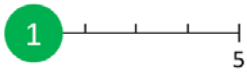
8.10 Shiny locally/significantly varying colour



Description: Shiny silicon crystals are visible on a cell locally. Some colour variation from cell to cell can be expected (ex. slightly different shades of blue), but largely varying colour across one cell can be a concern.

Why it's important: A shiny cell is reflecting significant light instead of absorbing it and generating power. Where cells have become shiny or changed colour locally, cells have a poor or degrading anti-reflective coating which is an indicator of poor module performance.

Severity:



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[1] "IEC 61215: Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualifications and type approval 2nd Edition," International Electrotechnical Commission, Geneva, 2005.
[2] "UL Standard for Safety for Flat-Plate Photovoltaic Modules and Panels, UL 1703. Third Edition.," Underwriters Laboratories Inc, Northbrook, Mar. 2002.
[3] C. E. Packard, J. H. Wohlgemuth, and S. R. Kurtz, "Development of a Visual Inspection Data Collection Tool for Evaluation of Fielded Pv Module Condition," National Renewable Energy Laboratory (NREL), Golden, CO., NREL/TP-5200-56154, Aug. 2012.
[4] "Wire Gauge and Current Limits Including Skin Depth and Strength," Jun-2006. [Online]. Available: http://www.powerstream.com/Wire_Size.htm.