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Senergy Technical Services

pv magazine webinars

Learning from PV module manufacturing nonconformities

10 November 2022

8:00 am – 9:00 am | PST, Los Angeles
11:00 am – 12:00 pm | EST, New York City
4:00 pm – 5:00 pm | GMT, London
5:00 pm – 6:00 pm | CET, Berlin, Madrid

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SOLARPACK

Welcome!

pv magazine webinars

Do you have any questions? ? 🙋

Send them in via the Q&A tab. 👉 We aim to answer as many as we can today!

You can also let us know of any tech problems there.

We are recording this webinar today. 📹

We‘ll let you know by email where to find it and the slide deck, so you can re-watch it at your convenience. 👀 💡

Disclaimer

- Any non-conformities and images shared here are for educational purposes, and not referring to any specific company or project.

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ABOUT US

Beyond inspection

EST. 2010
ACCREDITED ISO9001 I ISO17020

Est. in 2010, STS is an ISO/IEC17020:2012 accredited company specialized in Conformity Assessment, Risk Assessment, and Technical Advisory in the renewables sector. With the largest operations in Asia, we support leading developers and financiers globally.

LEADING TRACK-RECORD
IN SOLAR & STORAGE

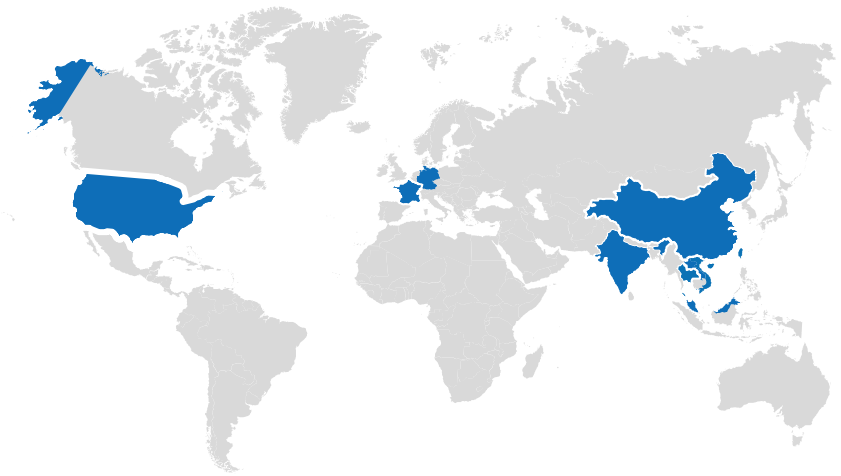
>35GW
PV MODULES PROD. ASSESSED

>6GWh
BESS ASSESSED

>55GW
SUPPLY CHAIN ASSESSED

PRESENT ON 3 CONTINENTS

FRANCE – USA – GERMANY – SINGAPORE
CHINA – INDIA – VIETNAM – MALAYSIA – THAILAND – CHINESE TAIPEI



CONFORMITY ASSESSMENT
INSPECTION I TESTING
ADVISORY & RISK ASSESSMENT
AUDITING I TECHNICAL ADVISORY

60+
INSPECTORS
AUDITORS
ENGINEERS

200+
ASSESSMENTS PERFORMED YEARLY

01

Nonconformity Definition

- What is a nonconformity?
- Example of requirements

Nonconformity Definition

What is a nonconformity?

- In quality management, a **nonconformity (NC)** is a **failure to meet a requirement**

- Nonconformities (or nonconformances) can be classified by level of severity, typically:

- **Critical:** NC likely to result in hazardous or unsafe conditions for individuals or equipment
- **Major:** NC likely to endanger the ability of a Product to fulfill its function
- **Minor**: NC that does not have immediate consequences on the ability of the Products to fulfill their function but represents a risk

Examples of requirements:

- Product specification (BOM, dimensions, electrical parameters, design….)
- Applicable standards and product qualifications
- Manufacturing process parameters and QC control points all along the line
- Pass/Fail criteria for Visual inspection, Maximum power measurement, EL images…

► Agreed between the buyer and the vendor before the order manufacturing starts
► **Important that the buyer clearly specify his needs as early as possible in the order process**
► Requirement gathered by STS in a single document: Order Technical Requirements (OTR)
► STS support the buyers during purchase contract negotiation (risk assessment, recommendations)

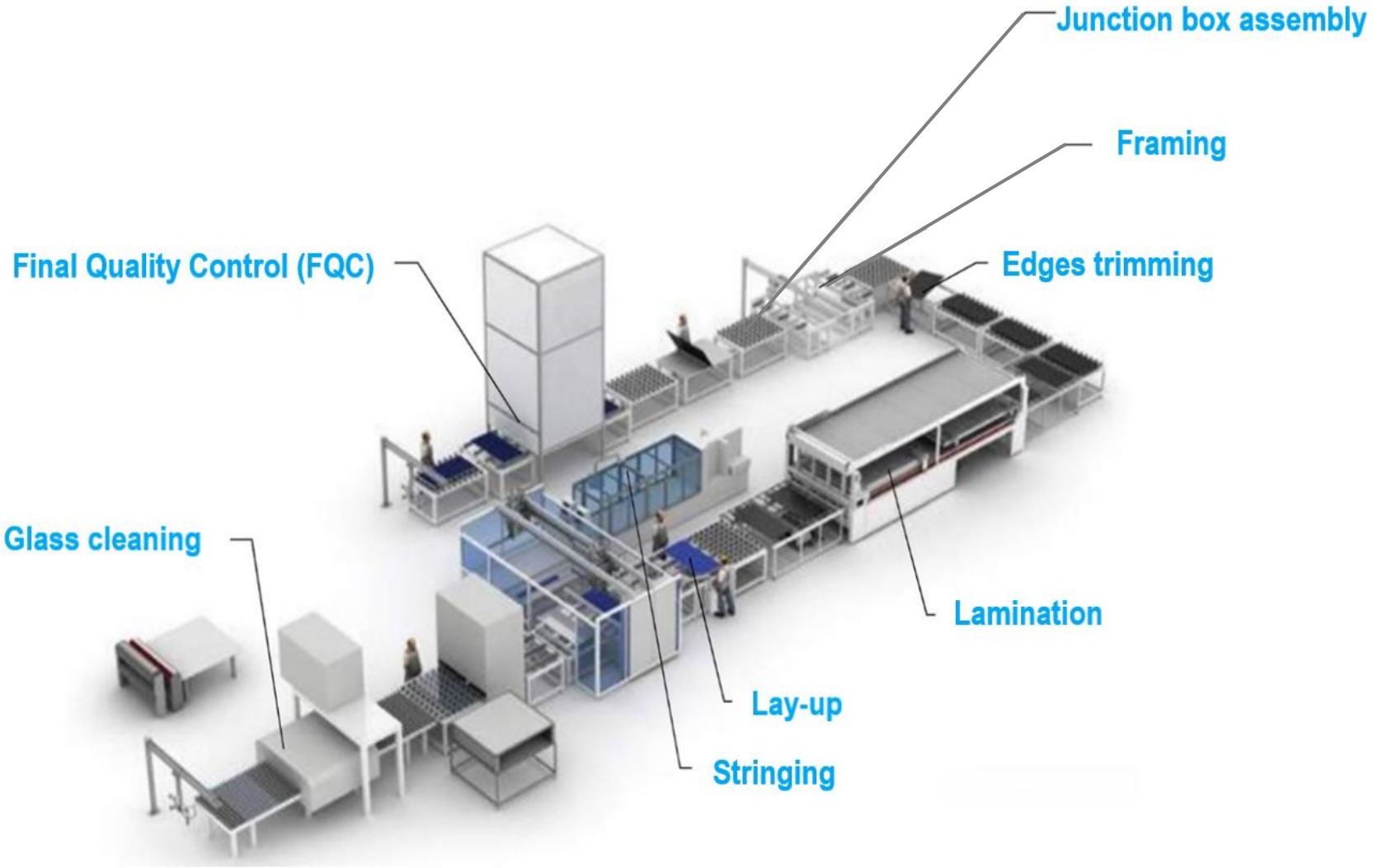
02

Nonconformities Distribution

- NCs distribution along the manufacturing line
- TOP10 NCs during Production Supervision

Nonconformities Distribution

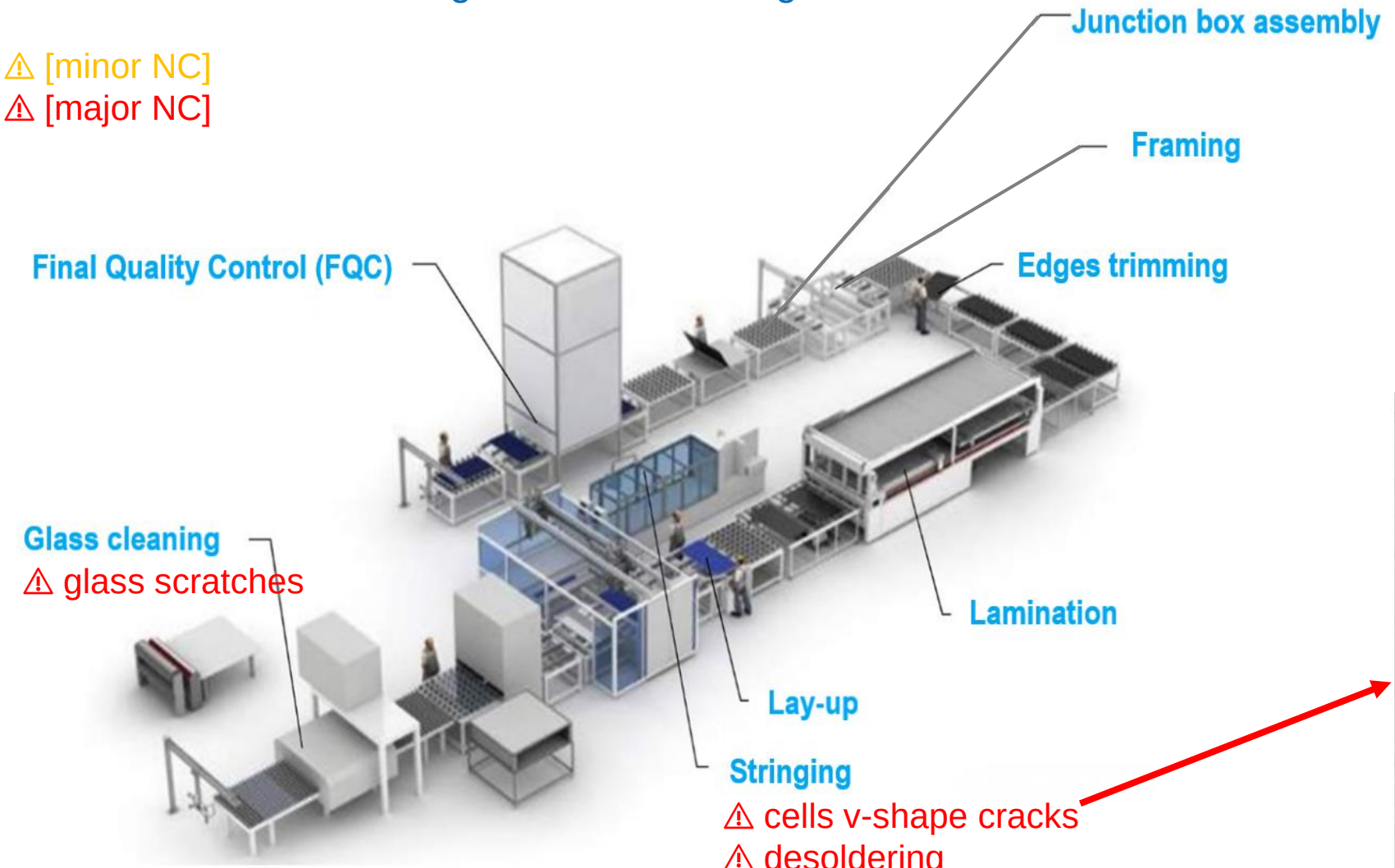
Main NCs distribution along the manufacturing line



Nonconformities Distribution

Main NCs distribution along the manufacturing line

⚠ [minor NC]
⚠ [major NC]



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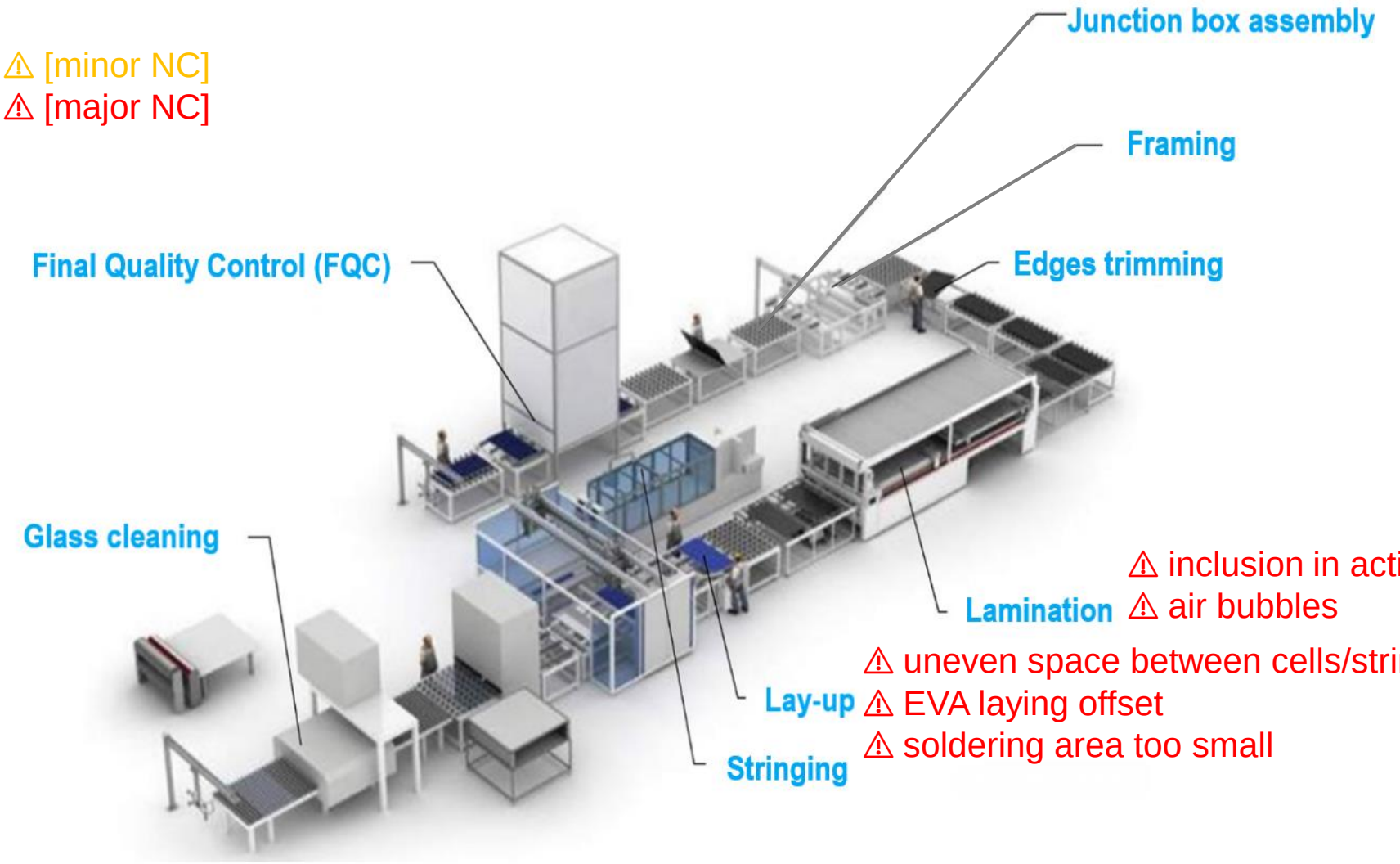

⚠ inclusion in active area
⚠ air bubbles
⚠ uneven space between cells/strings
⚠ EVA laying offset
⚠ soldering area too small

Nonconformities Distribution

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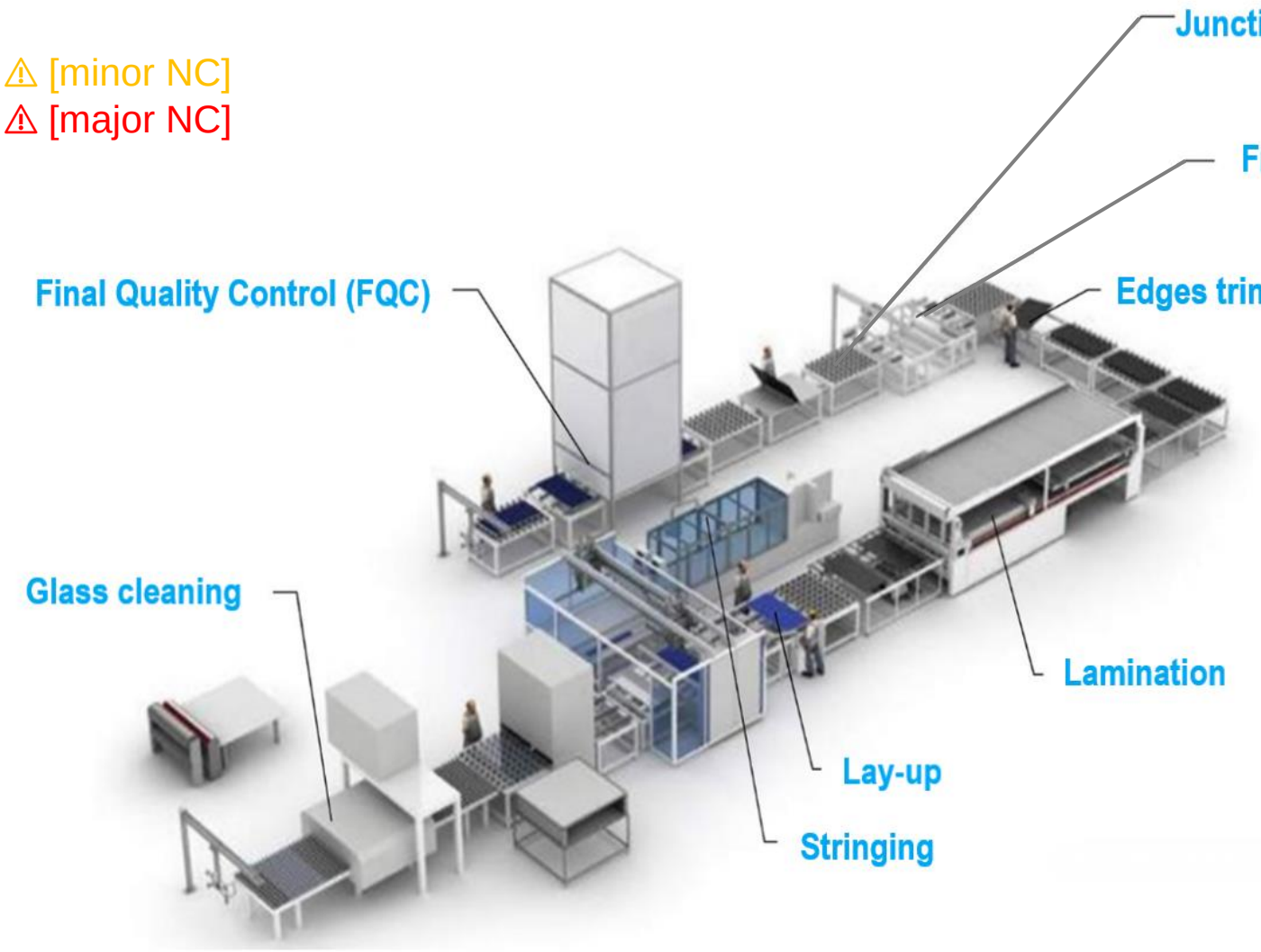
⚠ [major NC]



⚠ soldering area too small

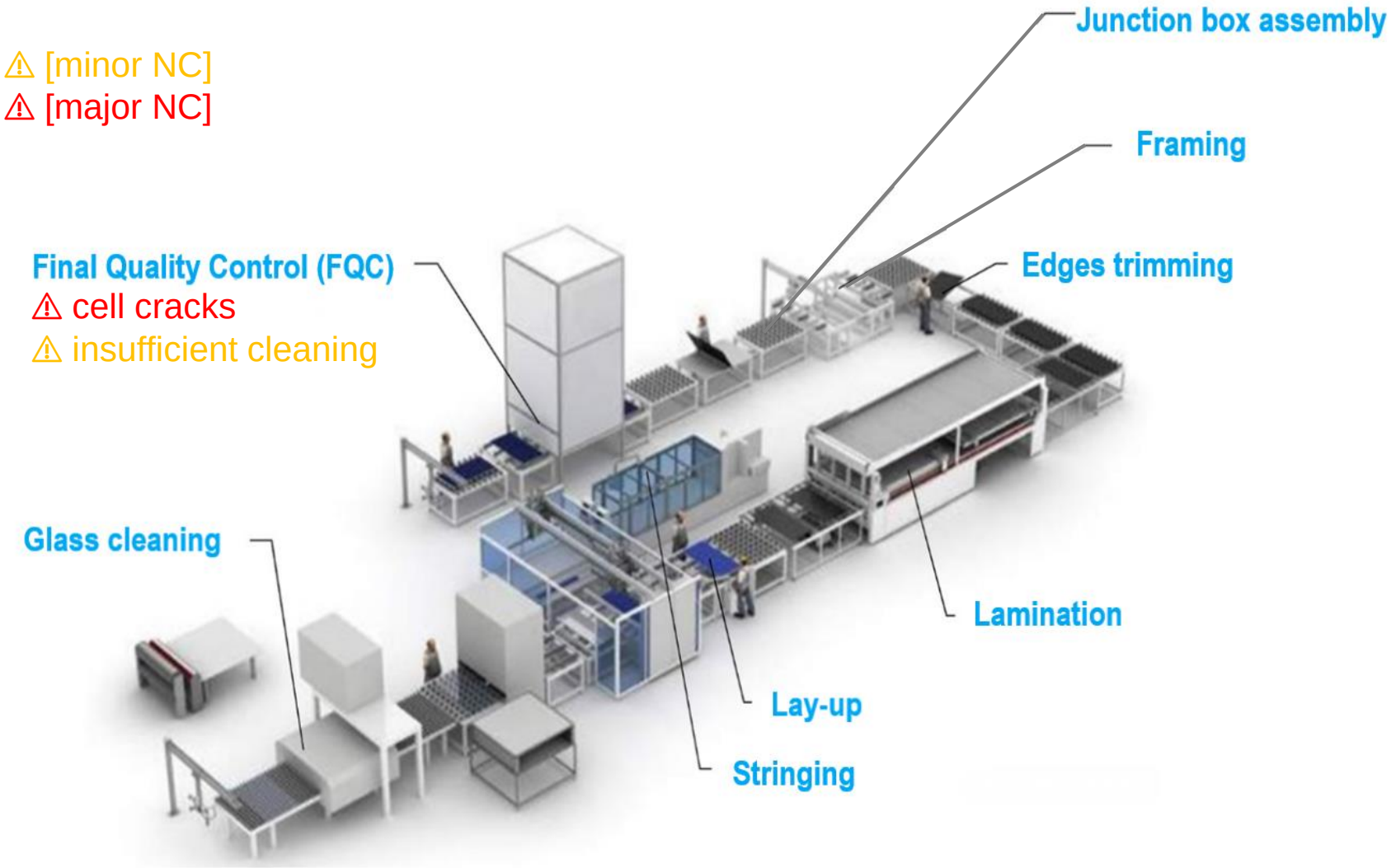
⚠ frame gap / misalignment
⚠ lack of silicone sealant
⚠ overflow of silicone sealant

⚠ unclean edges trimming

Nonconformities Distribution

Main NCs distribution along the manufacturing line

⚠ [minor NC]
⚠ [major NC]



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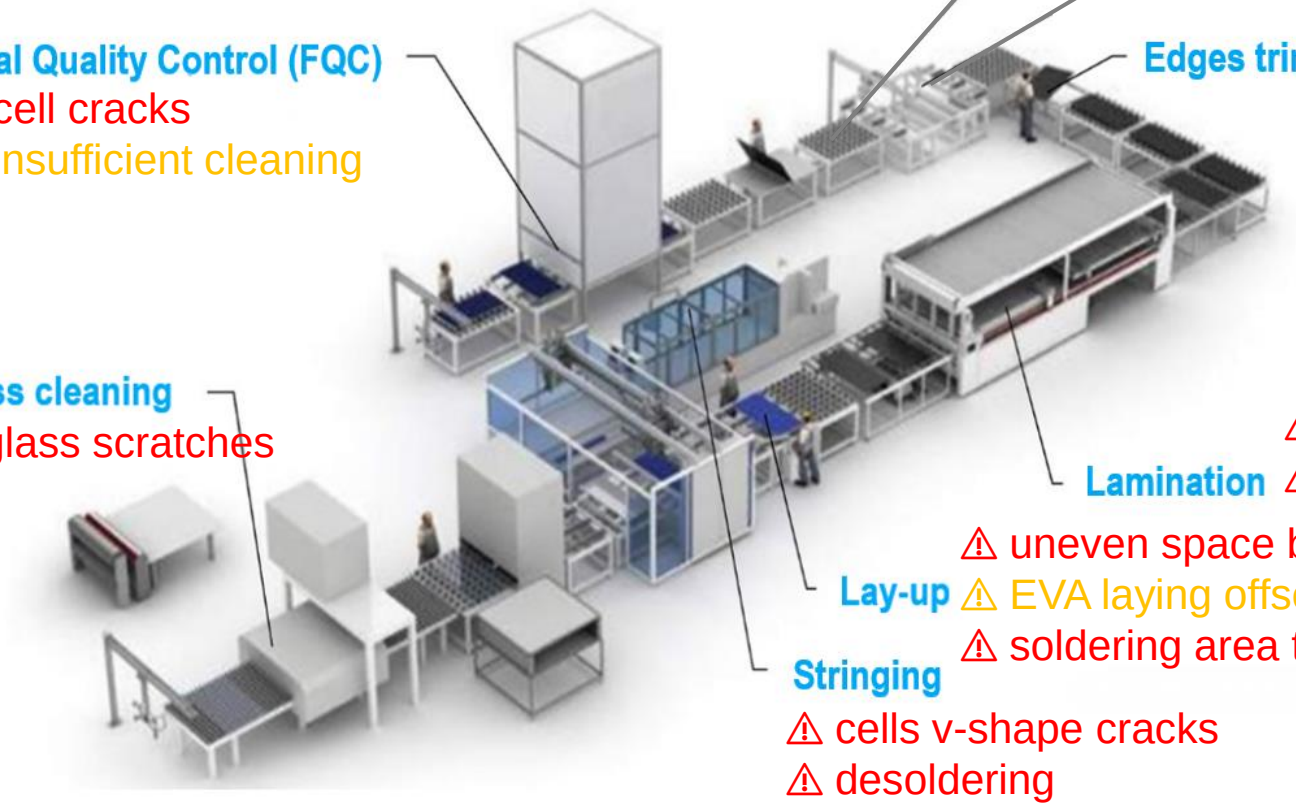


Junction box assembly ⚠ soldering area too small

Framing
⚠ frame gap / misalignment
⚠ lack of silicone sealant
⚠ overflow of silicone sealant

Edges trimming ⚠ unclean edges trimming

Final Quality Control (FQC)
⚠ cell cracks
⚠ insufficient cleaning

Glass cleaning
⚠ glass scratches

Lamination
⚠ inclusion in active area
⚠ air bubbles

Lay-up
⚠ uneven space between cells/strings
⚠ EVA laying offset
⚠ soldering area too small

Stringing
⚠ cells v-shape cracks
⚠ desoldering
⚠ ribbons/wires deviations
⚠ flux residue

No process step is NC-free

Nonconformities Distribution

During Production Supervision:

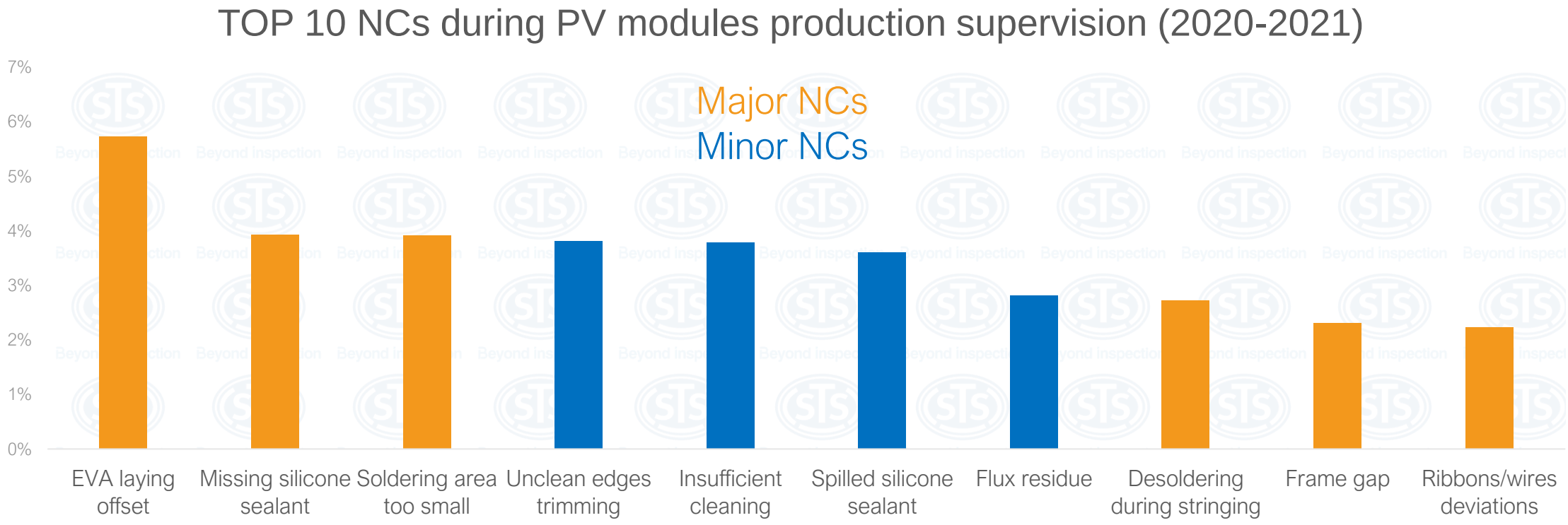
Inspection activity: Production Supervision

Product: PV modules (crystalline technology)

Covered period: 2020-2021 (2 years)

Total quantity of nonconformities (NCs): 9129

Source: STS BI database



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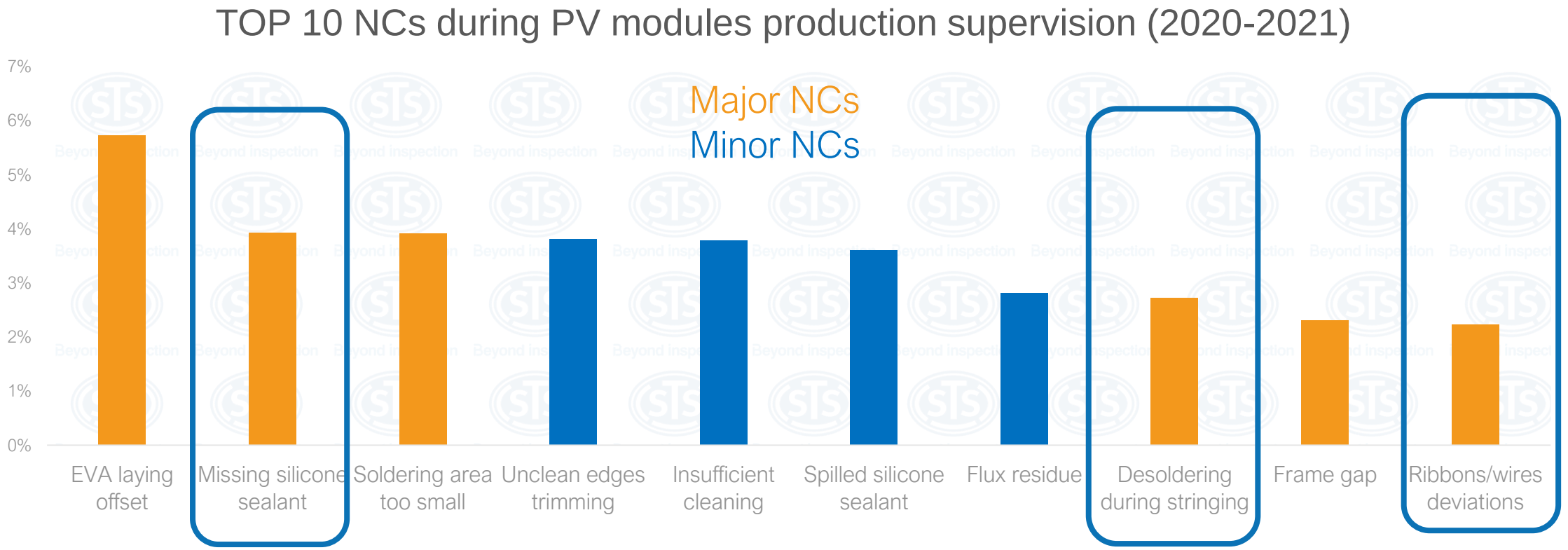
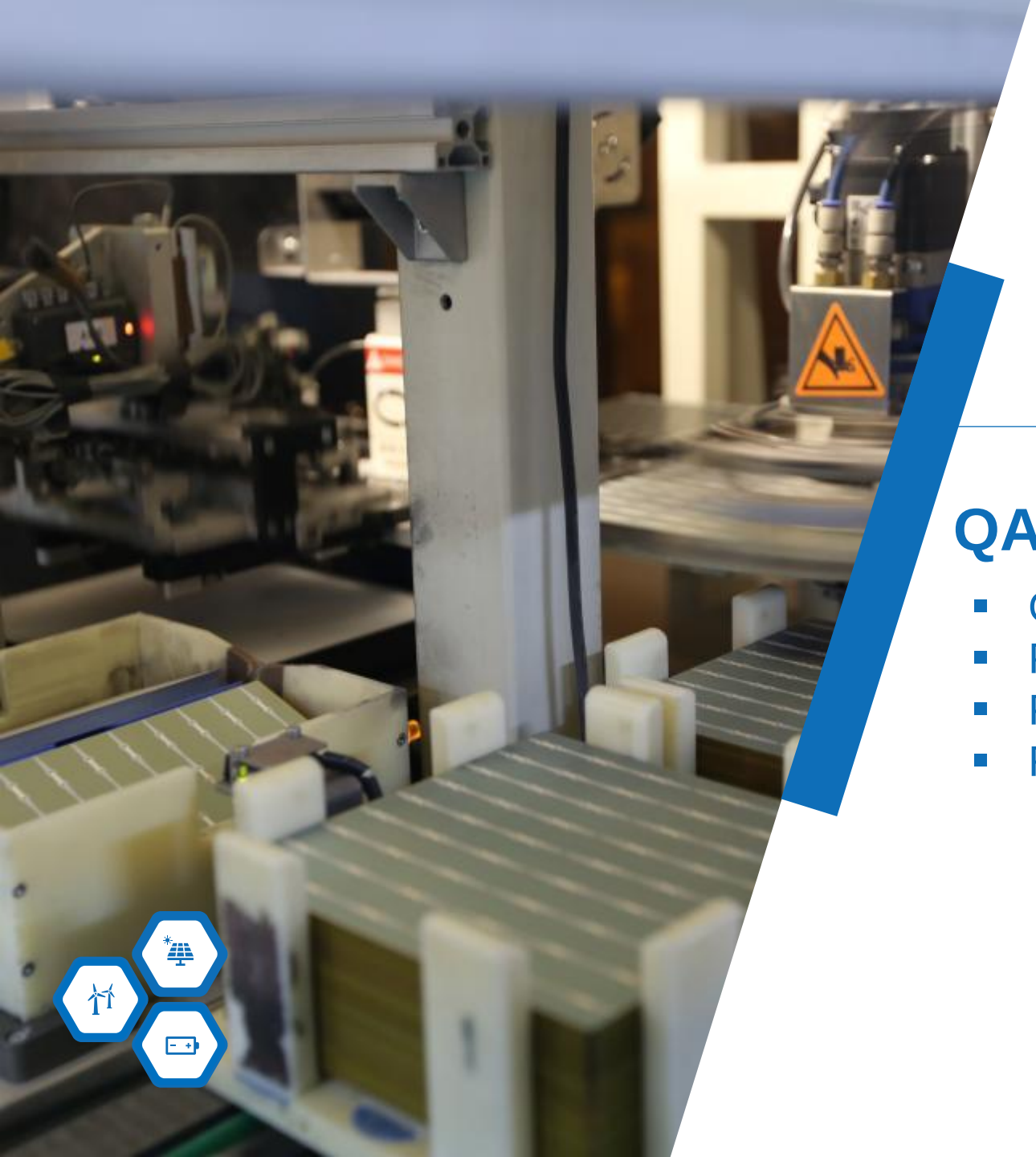




Beyond inspection

03

QA/QC for PV modules manufacturing

- Quality Assurance vs Quality control
- PV modules Quality Assurance (QA)
- PV modules Quality Control (QC)
- Root causes identification method

Our purpose is… **"to accelerate the transition to clean and affordable energy for all"**

QA/QC FOR PV MODULES MANUFACTURING

November, 2022

OBJECTIVE

- Failure rate reduction ⟹ Overall quality improvement

QA/QC DIFFERENCE

- QA: Processes and procedures are appropriate and are correctly implemented to **prevent** defects
- QC: Verification of quality requirements to **identify** defects

PV MODULES QA/QC

- QA
  - Contract review
  - Pre-production Audit
- QC
  - Production supervision
  - Pre-shipment inspection
  - Loading supervision

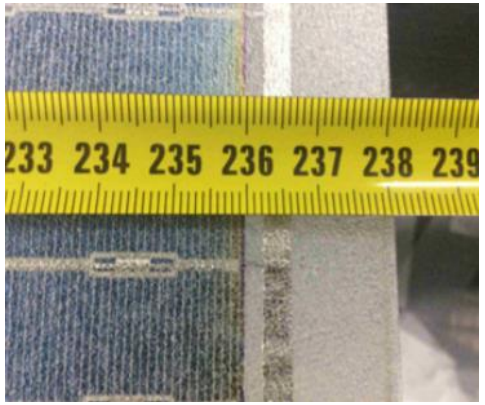
PV MODULES QUALITY ASSURANCE

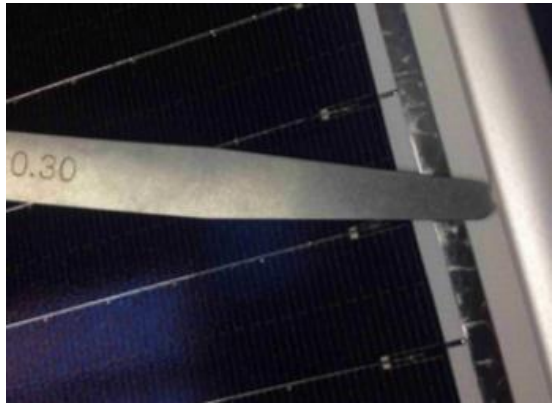
- Contract review
  - Technical specifications
  - Quality control to be implemented
- Pre-production Audit
  - Certifications
  - BOM
  - Lab/testing equipment
  - Manufacturing
    - Material storage
    - Products storage
    - Material control
    - Production control
    - Dispatch control

❖ Outputs: Findings → Counter Audit → Notice to proceed

PV MODULES QUALITY CONTROL

- Production supervision
  - Used material
  - Material storage conditions
  - Incoming quality control
  - Production quality control
  - Verification of sun simulation equipment
  - Storage of finished products





PV MODULES QUALITY CONTROL

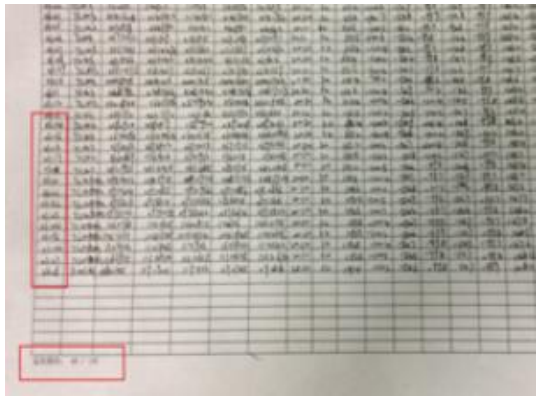
- Pre-shipment inspection
  - Manufacturer with an accredited internal Lab
    - Tests and checks carried out in the internal Lab
  - Manufacturer without an accredited internal Lab
    - Pre-shipment inspection (Manufacturer facilities): ISO 2859-1 testing sampling
      - Visual inspection (batch basis)
      - EL (batch basis)
      - Flash/bifaciality (batch basis)

      Other possible tests: Safety tests, EVA gel content,… (customized)
    - Tests carried out in external Lab: Reduced testing sampling
      - Flash/bifaciality (batch basis)
      - LeTID/LID (cell basis, customized)
      - PID (batch/BOM basis, customized)

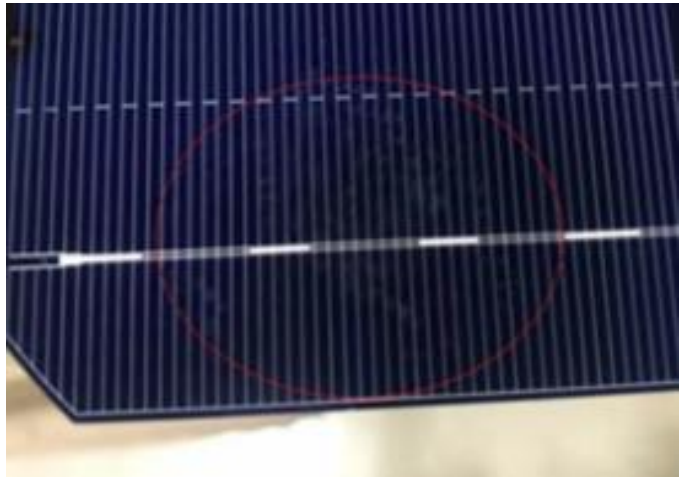
      Other possible tests: Low irradiance, EVA gel content, mechanical load test, EL,… (customized)
- Loading supervision

FINDINGS EXAMPLES DURING PRE-MANUFACTURING AUDIT/PRODUCTION INSPECTIONS

- Material placed in a wrong area
- Inspections forms not correctly filled
- Calibration of testing instruments expired
- Settings/conditions don’t meet SOP requirements
- Temperature/humidity not properly controlled
- EL inspectors not familiar with inspection standard
- Naked hand work

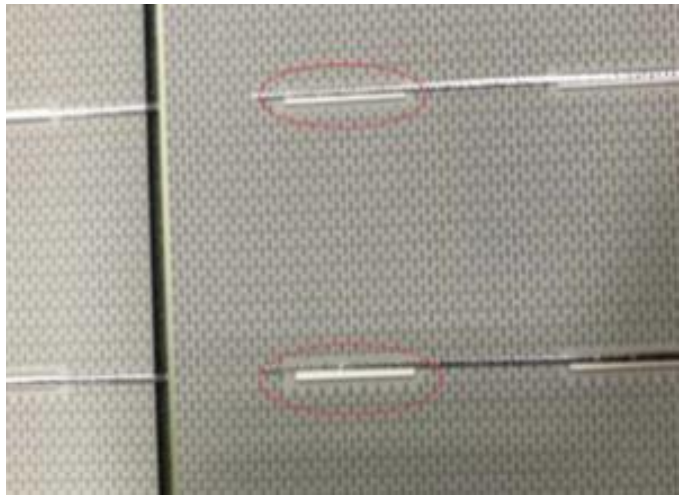


- Fingerprint on cell surface

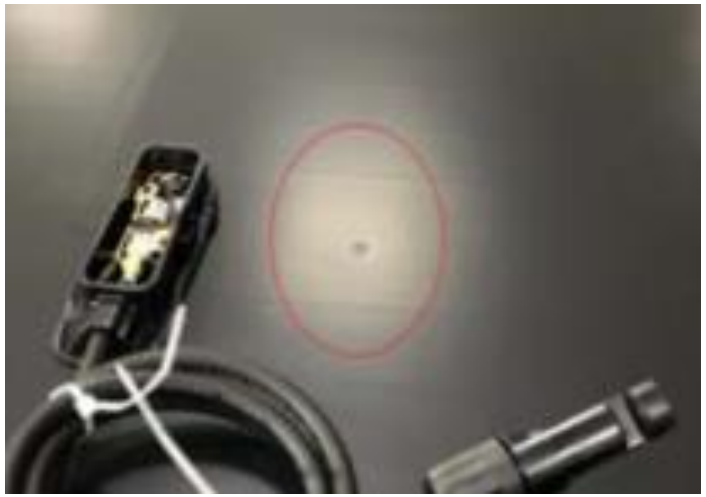


- Unqualified spilled sealant

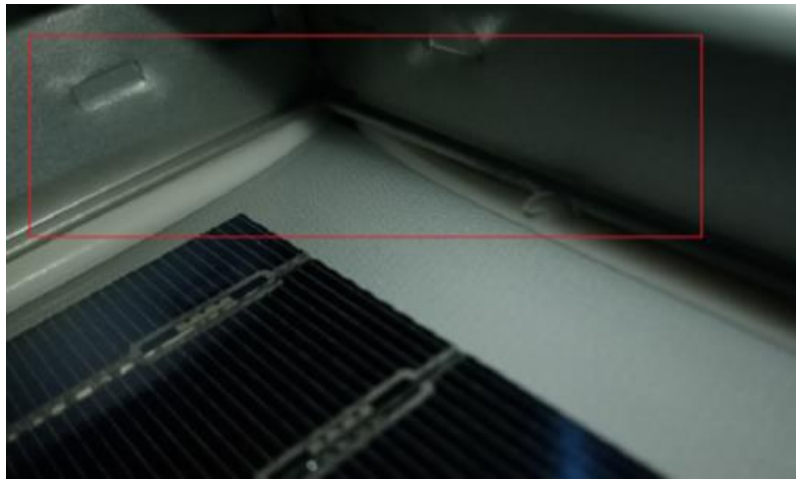
- Soldering misalignment



- Dent on backsheet

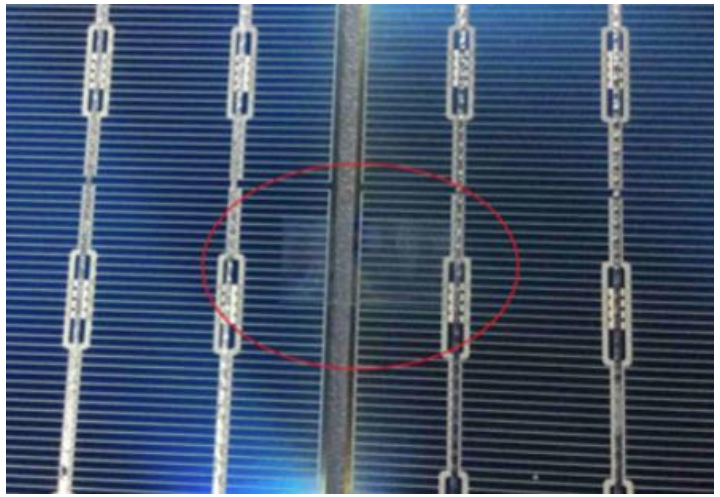


- Missing silicon sealant

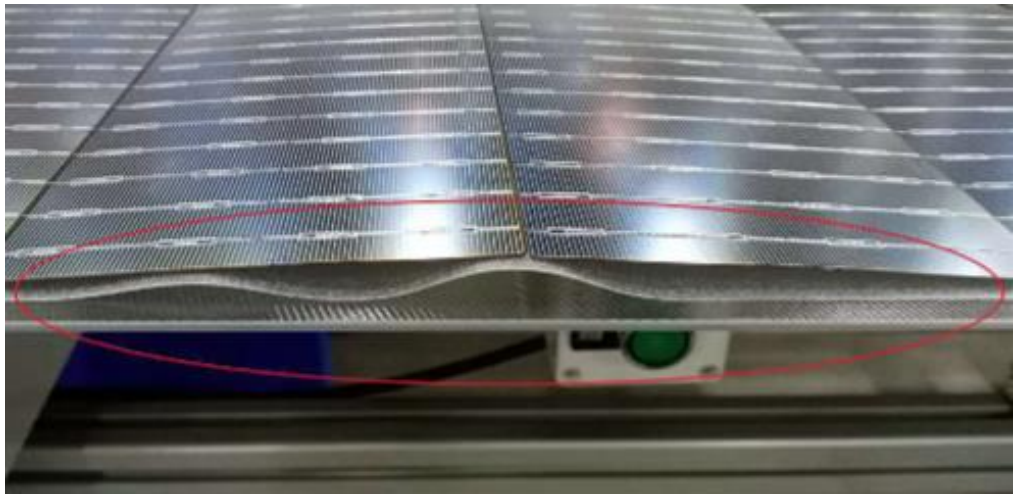


- Junction box position does not meet the requirements

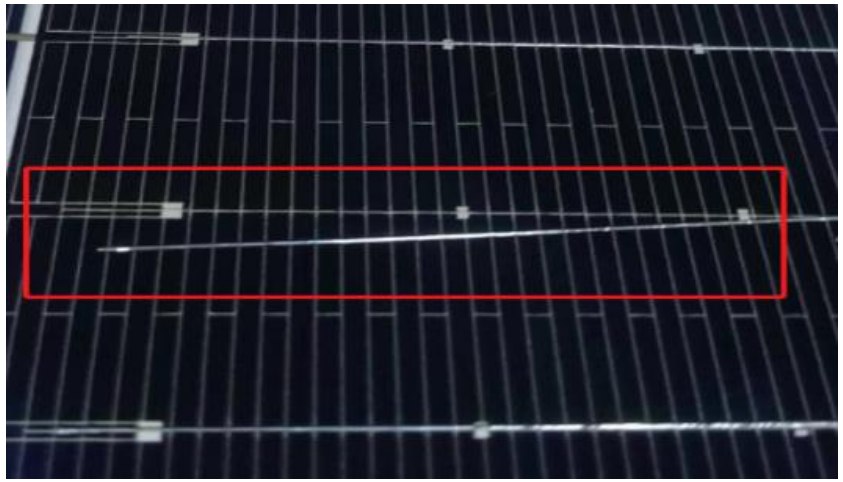
- Fixing tape sticked on the ribbon



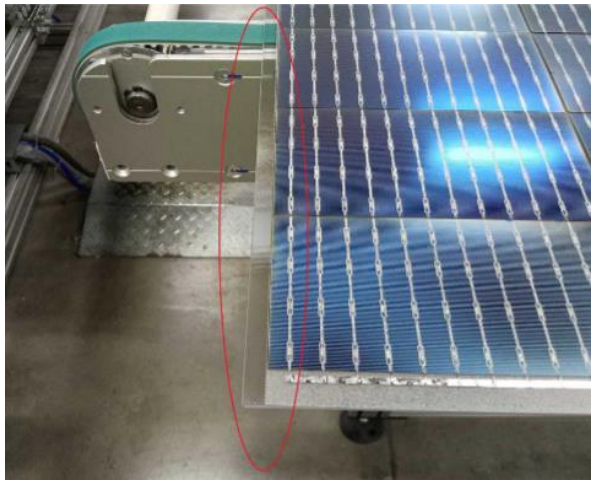
- Folds/unevenness during EVA laying



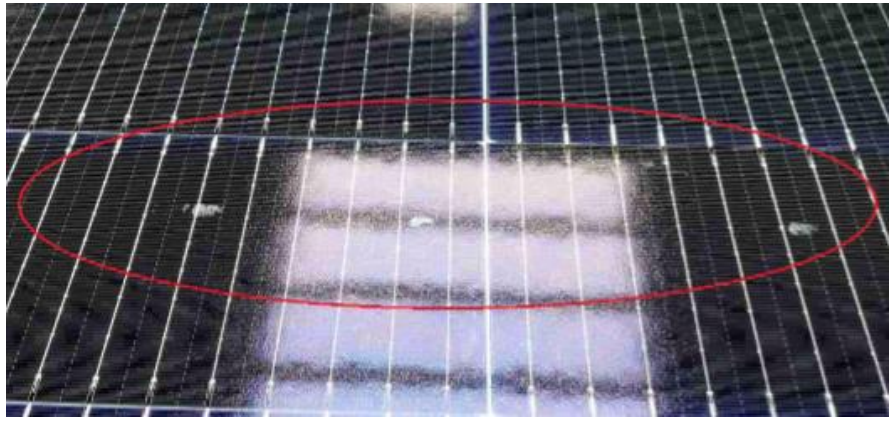
- Ribbon deviation/de-soldering



- EVA not placed in center



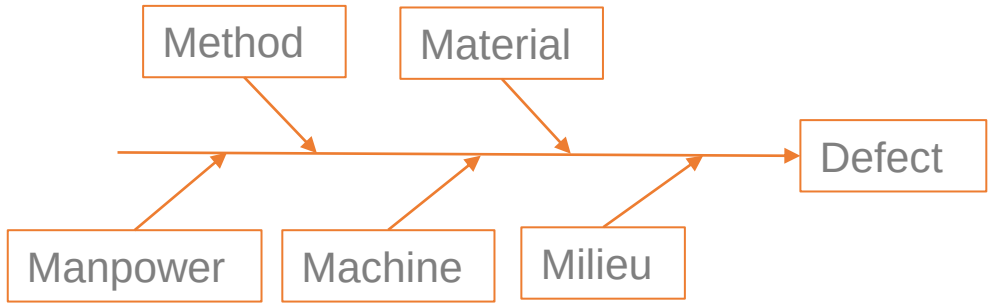
- Cleaning process not done correctly



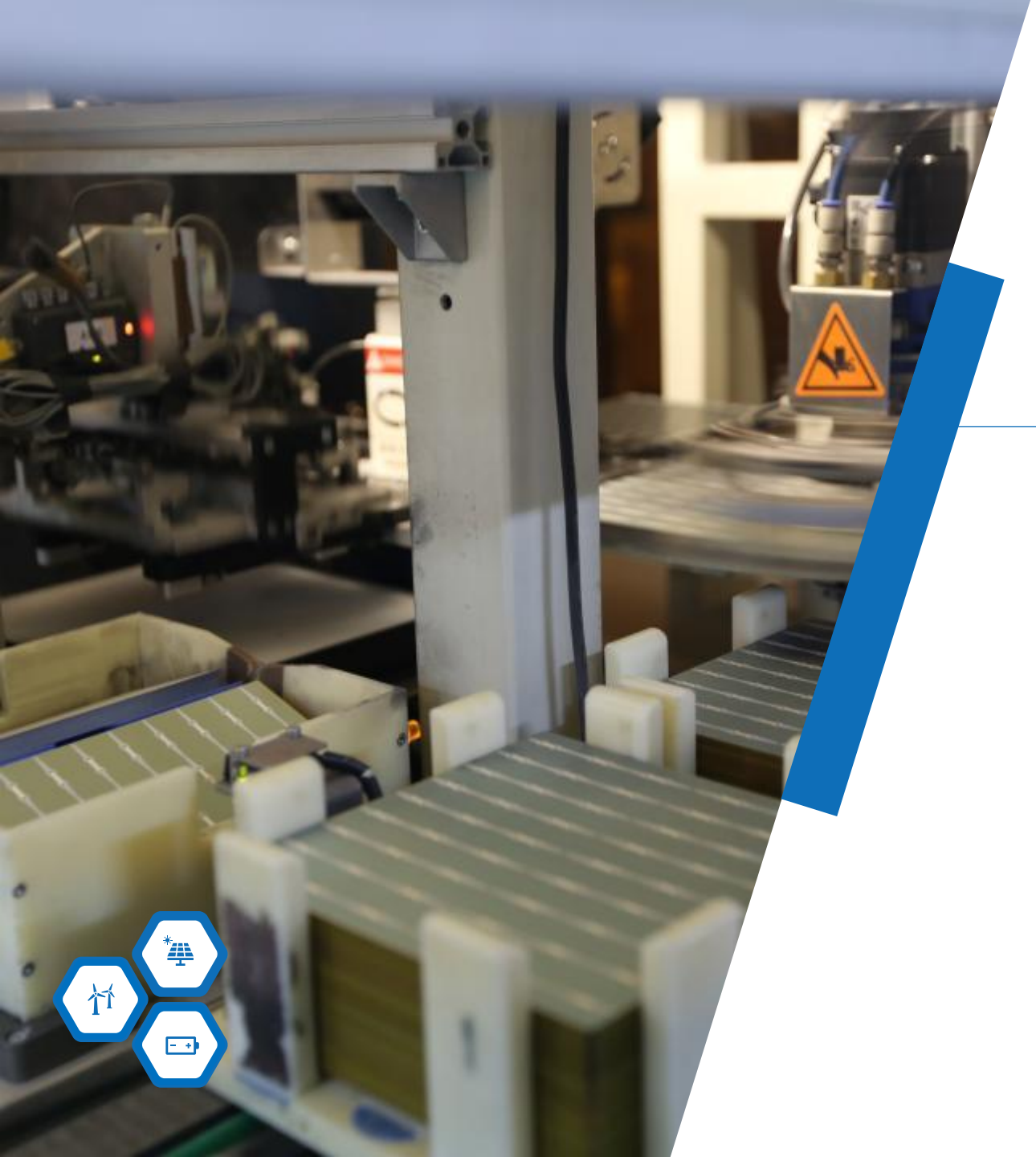
IDENTIFYING THE ROOT CAUSE OF A NON CONFORMITY

- 5 Whys: Ask 5 "whys" in succession or till “whys” don’t produce more useful responses. Used for simple/moderate issues

- 5M (Ishikawa diagram): Diagram with the form of a fishbone, being the defect shown as the fish's head, and being the causes extended as fishbones showing all the possible causes
  - Manpower: Workers
  - Method: Procedures
  - Machine: Equipment and tools
  - Material: Raw material
  - Milieu (environment/safety): Workplace



- 8D (8 disciplines model): This model identify, correct, and eliminate problems establishing corrective actions by determining the root causes
  - D1: Problem description: What happened?
  - D2: Establishing the team: Defining team leader and team members
  - D3: Containment actions: Actions to isolate the problem
  - D4: Failure analisis: Use of 5M, 5 whys or similar
  - D5: Corrective actions: Modifications to prevent the recurrence of the problem
  - D6: Verification: Effectiveness check of actions taken
  - D7: Standarization: Preventing problems on similar products/processes updating procedures
  - D8: Recognizing team efforts: Congratulate the team for the efforts



04

Examples of Nonconformities

- Wires position deviation / desoldering
- Air bubbles during lamination
- Lack of silicone sealant
- V-shape microcracks (EL images)

Examples of Nonconformities

Non-conformity: wire position deviation / wire desoldering

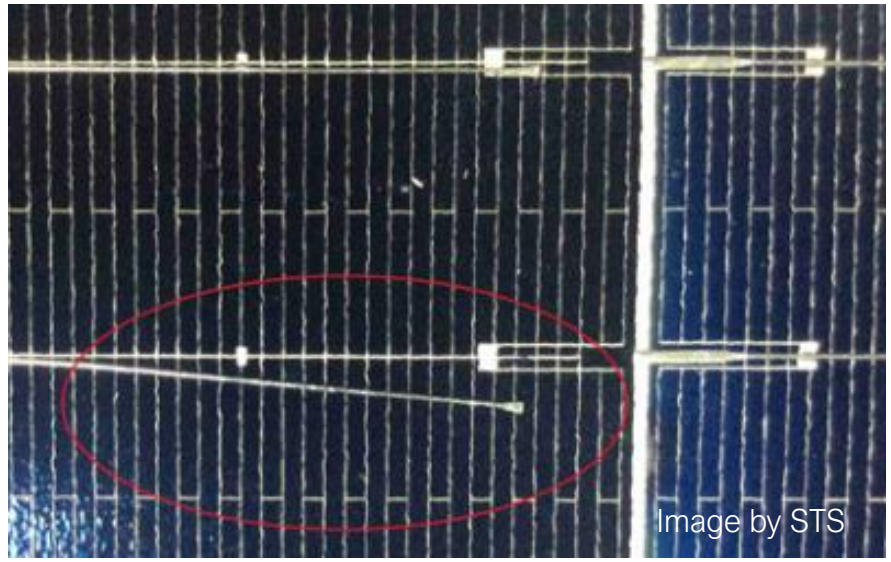
Manufacturing process: stringing

Severity: Major

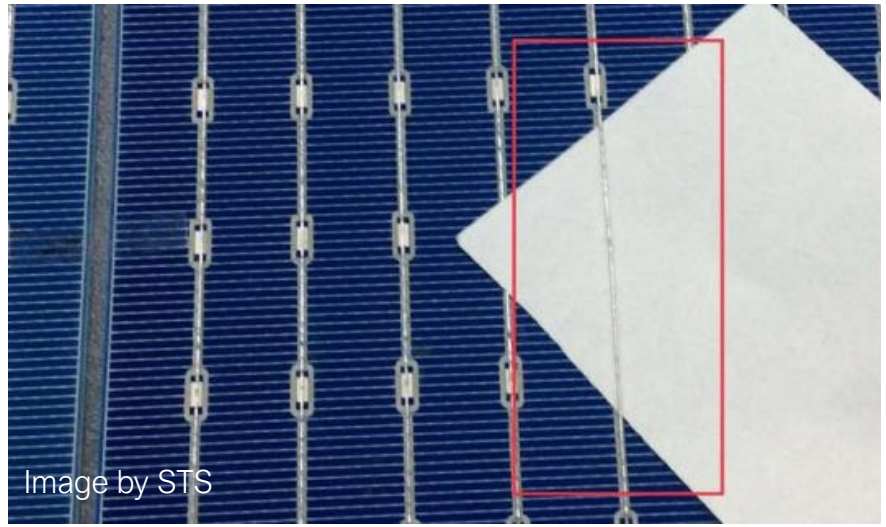
Detection:

- **Wire position deviation:** visual inspection before lamination
- **Wire desoldering (also called cold-soldering):**
  - Before lamination: measure soldering strength on sampled cells, at least once per manufacturing shift
  - After lamination: EL images after lamination or during FQC

⚠ Risk: hot spots leading to accelerated performance degradation and/or fire hazard



Wire position deviation



Wire desoldering from pad

Examples of Nonconformities

Potential root causes:

- Soldering temperature outside of range
- Soldering heating process not uniform
- Cell or wire positioning not accurate

⇨ **All related to soldering equipment adjustment / maintenance**

5M category:

METHOD
MANPOWER
MACHINE
MATERIAL
MILIEU

Risk mitigation:

- Ensure that the manufacturer has validated all gates during new product introduction or capacity expansion

⇨ **STS services: PRODUCT DESIGN AND DEVELOPMENT AUDIT / FACTORY AUDITS**

- Apply STS standard specific to multibusbars (Addendum #3 released in 2020)

⇨ **STS service: TECHNICAL EXHIBIT PREPARATION**

- EL images to be performed by experienced operators (duration > 10s per module)

⇨ **STS service: PRODUCTION SUPERVISION**

Examples of Nonconformities

Non-conformity: air bubbles

Manufacturing process: lamination

Severity: Major

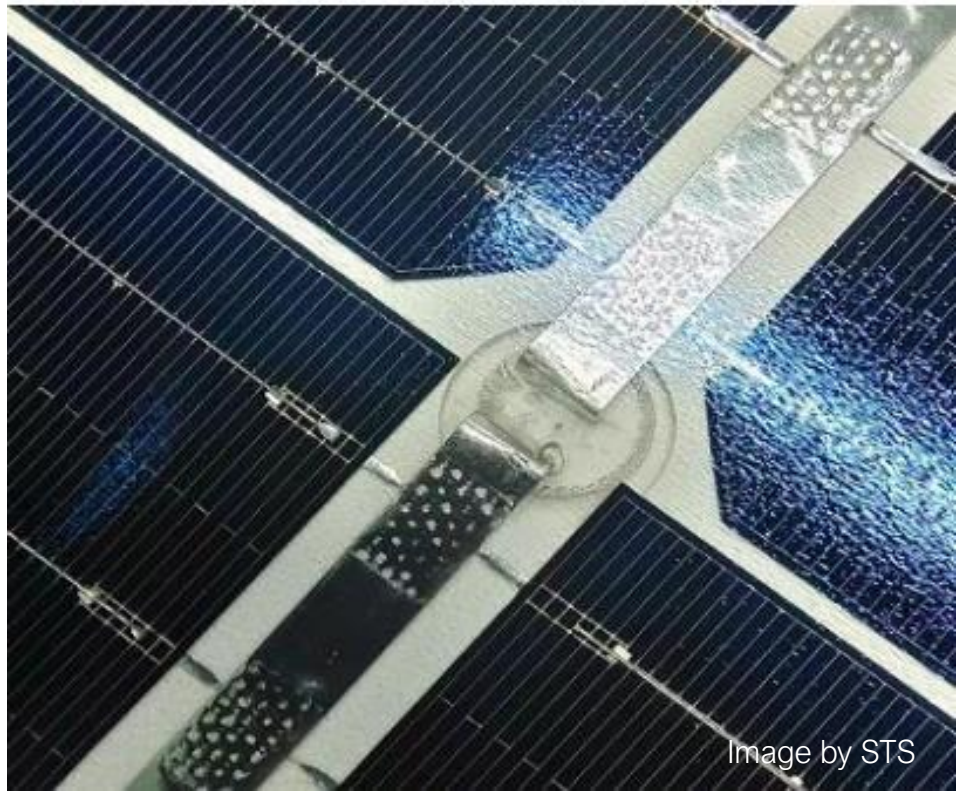
Detection:

- Visual inspection after lamination

Recurrent issue in the PV industry history:

- CO2 or CH4 released during lamination - from early EVA formulations
- Introduction of ultra-fast cure EVA formulations in the 2010s
- Use of new encapsulation materials (e.g. POE)

⚠ Risk: delamination and hot spots leading to accelerated performance degradation and/or fire hazard



Air ingress picture

Examples of Nonconformities

Potential root causes (recent cases):

- Flux-encapsulant reaction on the cell surface
- Laminator parameters (temperature, vacuum, time) not well adjusted
- **Not enough encapsulant inside the busbar holes on glass-glass modules**

5M category:

METHOD
MANPOWER
MACHINE
MATERIAL
MILIEU

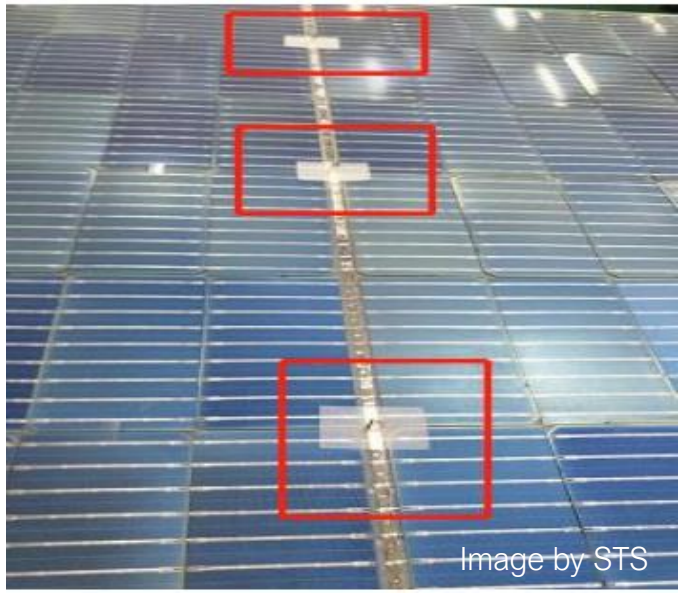
Risk mitigation:

► Example: at the lay-up stage, a patch of POE is placed at the rear hole location to ensure there is enough POE to fill-in the hole during lamination

⇨ **STS service: PRODUCT DESIGN AND DEVELOPMENT AUDIT**

► Perform a thorough visual inspection after lamination as well as during FQC (Final Quality Control)

⇨ **STS service: PRODUCTION SUPERVISION**



Encapsulant patches

Examples of Nonconformities

Non-conformity: lack of silicon sealant

Manufacturing process: framing

Severity: Major

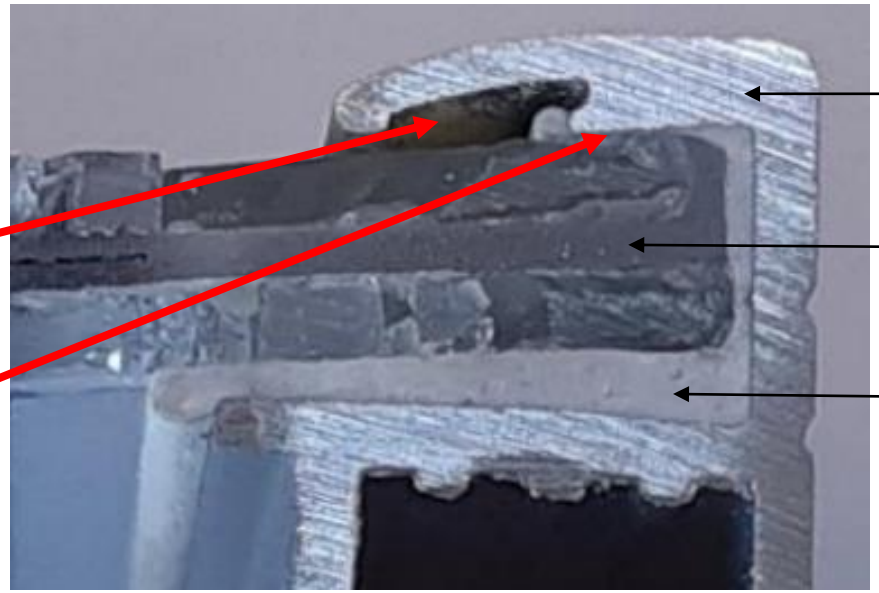
⚠ Risk: front glass breakage

Detection:

- Visual inspection to identify locations where there is no sealant overflow between the glass and the frame
- Measurement with feeler gauge to quantify the clearance between the glass and the frame on the front side

⚠ absence of silicone sealant on the top part of the frame groove

⚠ front glass in direct contact with the frame profile



PV module cross-section

Examples of Nonconformities

Potential root causes:

- Uneven silicone sealant application along the frame groove (especially at the corners)
- Module transfer to the next process step while the sealant curing is incomplete

5M category:

METHOD

MANPOWER

MACHINE

MATERIAL

MILIEU

Risk mitigation:

- Ensure during the framing process that the silicone sealant is evenly applied in the frame profiles groove, including at the corners, where there is a higher risk of missing sealant

⇨ **STS service: PRODUCTION SUPERVISION**

- Inspect the module with feeler gauge to measure the clearance between the glass and the frame
- If no silicone sealant is visible on the front side, measure the empty cavity depth

⇨ **STS services: PRODUCTION SUPERVISION / PRE-SHIPMENT INSPECTION**

- Verify during FQC that there is silicone overflow on the rear side.

⇨ **STS services: PRODUCTION SUPERVISION / PRE-SHIPMENT INSPECTION**

Examples of Nonconformities

Non-conformity: v-shape cracks

Manufacturing process: EL imaging (detection)

Severity: Major

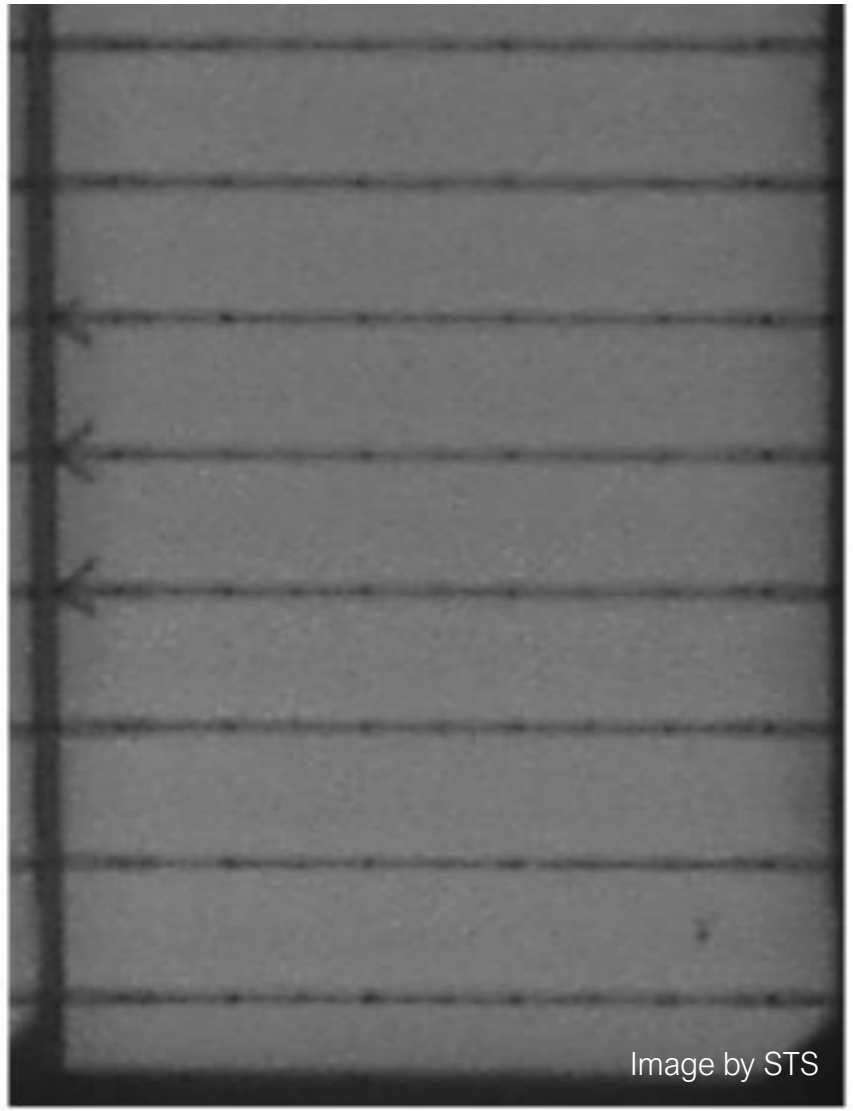
Detection:

- EL imaging (after lamination or during FQC

Remarks:

- **Mostly happening on half-cut cells,** located at the interface between the edge of the cell and the wires
- Small size (length 2 to 5mm) : risk of remaining undetected during quality control at factory

⚠ Risk: Crack length may increase during transportation, installation and/or operation, leading to hot spots



v-shape cracks

Examples of Nonconformities

Potential root causes:

- Local microdefect on the cell edge created during laser cutting
- High mechanical pressure on the cell during stringing or lamination induced by technology changes:
  - Use of new wires design and materials
  - Space reduction between cells

5M category:

METHOD
MANPOWER
MACHINE
MATERIAL
MILIEU

Risk mitigation:

- Ensure that the manufacturer has validated all gates during new product introduction or capacity expansion

⇨ **STS service: PRODUCT DESIGN AND DEVELOPMENT AUDIT**

- Apply EL imaging equipment settings recommended by STS standard (e.g. EL images resolution>12Mpix)

⇨ **STS services: FACTORY AUDIT / PRE-PRODUCTION INSPECTION**

- EL images inspection to be performed by experienced operator (duration > 10s per module)

⇨ **STS service: PRODUCTION SUPERVISION**

05

Take-aways

Take-aways

Assess the risk related to inspection requirements

- If the inspection requirements contain criteria defined by the manufactuer, assess the risk
- STS can support on risk assessment of criteria proposed by manufacturers vs. STS standard

Request a production supervision at each step of the manufacturing

- No step on a PV modules manufacturing line is risk-free
- Have a clear understanding of the Nonconformities happening at each step (Minor, Major, Critical)

Ensure that Final Quality Control is efficiently performed

- 5M application (machine, milieu, manpower, method, material)
- Pre-shipment inspection on sampled products

Understand the PV modules technology evolution

- New technology = new risks
- Be informed about the changes in PV modules design and manufacturing process (e.g. STS White Papers)

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Learning from PV module manufacturing nonconformities

Q&A

10 November 2022

8:00 am – 9:00 am | PST, Los Angeles
11:00 am – 12:00 pm | EST, New York City
4:00 pm – 5:00 pm | GMT, London
5:00 pm – 6:00 pm | CET, Berlin, Madrid

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3:00 pm – 4:00 pm CET, Berlin, Madrid

Tuesday, 15 November 2022
9:00 am – 10:00 am GMT, London
10:00 am – 11:00 am CET, Berlin, Madrid

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