Introduction to Module Assembly

George McClellan – REC Technical Sales Manager

February 10-13, 2013

“Delivering success”
COURSE AGENDA

• REC Company History
  • Why are we here and why should you listen to us?
• Module Assembly Technology
  • Review of Module assembly steps
  • Review of module materials of construction
  • Review of quality control and in-line testing
Founded in Norway in 1996, REC is a leading vertically integrated player in the solar energy industry and employs more than 2400 people worldwide – including over 800 in the US.

REC is among the world's largest producers of polysilicon and wafers for solar applications, and a rapidly growing manufacturer of solar cells and modules.

REC had revenues close to $2.1 billion in 2011.

2012 numbers are currently being audited.

REC is listed on the Oslo Stock Exchange under the ticker: REC.
REC – an integrated company

<table>
<thead>
<tr>
<th>Polysilicon</th>
<th>Wafer</th>
<th>Cells</th>
<th>Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical process</td>
<td>Casting and cutting</td>
<td>Surface treatment</td>
<td>Assembly</td>
</tr>
</tbody>
</table>

- Industry pioneer with commitment to PV
- Presence throughout the entire value chain
- World-class manufacturing facilities
- Strong focus on operational excellence
- Increased market presence through partners
REC Module Plant
- Etched Glass with Anti-Reflective Coating
- 4 Module lines
- 8 Operators/line
- total 320 Modules / hour
REC Peak Energy Series

- REC Peak Energy (PE) series 60 Cell
  - Power output 230-265Wp
- REC Peak Energy (PE) series 72 Cell
  - Power output 295-315 Wp
  - 1000 VDC UL Certified
- -0/+5Wp tolerance
- 3 Bus Bar REC Peak Energy Cells
- US Silicon
- IP 67 JBox with MC4 Connectors
- 25 Year linear power output warranty
- 10 year materials and workmanship warranty
Introduction to Module Assembly Technology

- Most solar modules are manufactured using similar materials and processes:
  - Glass
  - Solar Cells
  - Encapsulant
  - Backsheet
  - Frame
  - Junction Box

- Modules also share similar manufacturing processes:
  - Stringing/tabbing
  - Laminating
  - Framing
  - Flashing

- This will be a discussion of:
  - how modules are assembled, materials used, and inspection steps used to ensure a reliable, high quality product makes it to the end user

- There will be variations between manufacturers and this is meant to be a general overview
Construction of a Solar Panel

- What we are making....
- 6x10 solar module
- Current industry workhorse
- 200-280 Watts

![Solar Panel Diagram]
Granular Silicon is manufactured into ingots

REC Wafer produces G4 ingots, weighing 265 kg each. Out of one ingot we get sixteen blocks and about 10 000 wafers.
Ingots are sawed into blocks, and then blocks into wafers.
Construction of a Solar Panel

- Frame molding/foaming
- Framing/glazing
- Edge gluing/corner jointing
- Cell sandwich encapsulation
- Side seal
- Foil replacement or back affixing
- Junction box potting and sealing
- Junction box attachment
Process flow with quality inspection

1. Glass Preparation
   - Glass
   - EVA
   - Cells
   - Ribbon

2. Stringer
   - Cross Connector
   - EVA
   - Tedlar

3. Lamination
   - String Layer
   - String Matrix

4. Trimming
   - Junction Box
   - Frame Bars
   - Brackets

5. Framing
   - Laminated Module
   - Boxed Module

6. Palletizing
   - Framed Module
   - Flash tester

7. 100% Control
   - Manual inspection
Construction of a Solar Panel

- Frames
- Edge Tape
- Glass
- EVA
- Ribbon & Interconnect
- Cells
- EVA
- Backsheet
- Junction Box connections

- To provide weather proof housing for solar cells
- To provide electrical connection to tap generated power
So now that we know a little bit about modules and their construction, lets go in to the factory and take a look.....

Starting at the front end of the production line with glass preparation
Glass Preparation

Materials
- 3.2mm Solar Glass
- Tempered
- low iron content
- high transparency
- Sunarc Antireflective treatment
  - In house treatment
- Multiple suppliers

Inspection steps
- Transmission verification
- Glass is washed and inspected
- Check for chipping and cracking

Process
- Prepare glass which is the main structural element in the module
Cell Stringing

Materials
- Prepared cells
  - REC Peak Energy Series cells
  - Texture etched
- Interconnect ribbon
  - 1.5 x .25 mm
  - Sn/Ag/Cu
- Solder

Inspection steps
- Cells optical inspection
  - Chips, cracks, color match
- Cell Electrical
  - Cells are flash tested and binned according to current
  - After matrix is soldered electrical and optical inspections are performed
  - EL testing for microcracks and electrical performance
- This is the last chance for rework!

Process
- Build cell matrix (6 x 10 matrix of cells)
- Electrical connections between cells
Cell Stringing

100% Controlled Robotics Soldering

Automated interconnection soldering for accurate placement and consistent good soldering

100% controlled induction soldering

Dual Interconnection Preparation unit
Manual Assembly and Soldering
Cell Stringing

- Vision systems for 100% quality inline check
Cell Stringing

- Manual Inspection for 100% quality inline check
Lamination

Materials

- Glass
- Matrix – 6 x 10 cell matrix
- EVA
- Backsheet
  - 3 layer composite backsheet

Process

- Matrix is sandwiched between layers of EVA, with an outside layer of glass and backsheet
- This is rolled into a laminator where it is laminated under pressure heat and vacuum
- EVA liquefies and covers entire matrix
- Vacuum removes air pockets

Inspection steps

- Visual inspection for bubbles (front and back), cracked cells, wrinkling of EVA and misalignment
Lamination

Laminate Vision Inspection
100% inspection of laminates for classification
Trimming

Materials
- Laminate

Inspection steps
- Visual inspection for complete removal of excess material
- Cracking or chipping of glass

Process
- Excess EVA and backsheet are trimmed away from the edges of the laminate
- Prep for framing
Junction Box Installation

Materials

- Laminate
- Junction Box
- Solder

Process

- Jbox is attached to laminate using double sided tape and adhesive
  - Double-sided tape ensures jbox stays in place while adhesive dries

Inspection steps

- 100% visual and electrical inspection of all soldered joints
- Visual inspection of adhesive bond line
Junction Box Installation

- Corona process improves adhesion between junction box and back sheet.
Materials
- Laminate
- Edge tape
  - Butyl rubber
  - Environmental barrier
  - Mechanical buffer between glass and frame
- Aluminum frame
  - Hard anodized

Process
- Continuous line of tape is applied to outside edges of laminate
- Frame is positioned on laminate edges and pneumatically pressed into position
- Corner pieces lock frame into position

Inspection steps
- Visual inspection
- Alignment /exposure of edge tape
Automated Framing Process
Flash Testing

Materials
- Complete Module

Inspection steps
- Modules are flash tested after assembly to ensure “live” modules arrive at customer site.
- Modules are binned according to Watt class in 5 Watt increments
- Modules that do not meet minimum power requirements are rejected
- Modules do not get label until they pass flash test and HiPot
- REC sorts modules with Positive Power tolerance -0/+5Wp

Process
- Module is flashed with a calibrated dose of full spectrum light at STC (Air Mass AM 1.5, Irradiance 1000 W/m2, Cell temperature 25 °C)
- Modules are also HiPot tested for ground continuity, dielectric withstand and leakage current
SunFlasher and Hi Pot Inspection

→ 100% inline Hi Pot (High Potential) and Ground Continuity Test

Sunflasher – flash testing
Final Inspection

All modules are visually inspected before binning
Automated Palletizing

Optimized packaging, 40 module

Automated Palletizing Process
• More efficient packaging means more efficient transportation
  
  40 modules per pallet,  
  560 modules per sea container (14 pallets)  
  720 modules per truckload (18 pallets)  
• Corner pieces keep modules from moving and protect from shipping damage  
• Reduced packaging means less waste and on site disposal  
• 4 way pallet for easy movement  
• Bar code on frame  
• Pallet List is applied
Pallet Design reduces shipping damage

- Protect bottom module damage from fork lift / pallet jack
- Reduces Handing claims
You’re Invited

› Professional certification program
› You can offer an extended warranty (10+2) to your customers.
› Service fee
› REC provides you with marketing tools to prospect new business.
› You will have access to an Installer portal with quality content and tools
› REC Welcome Pack

Join us on Wednesday, February 13 from 8:30 am – 1:30 pm
Send your installation photos to photos@recamericas.com for a chance to win a trip to Singapore and to be featured in a marketing campaign with REC.