SUMMER INTERNSHIP REPORT

Manufacturing Industry of Solar PV Modules

At,

WAAREE Energies Ltd.

Submitted by,

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BE 4th year of Bachelor in Electrical Engineering at,

G H PATEL COLLEGE OF ENGINEERING AND TECHNOLOGY, VALLABH VIDYANAGAR

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CERTIFICATE

This is to certify that a report submitted as an internship entitled "**MANUFACTURING OF SOLAR MODULES"** was carried out by the following student from GCET for the partial fulfillment of B.E. Degree to be awarded by Charutar Vidya Mandal University. This Internship work has been carried out under my supervision and is to my satisfaction.

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Date: 22/07/2023

Place: WAAREE Energies Ltd.

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DECLARATION OF ORIGINALITY

I hereby certify that I am the sole author of this internship report and that neither part of this report nor the report as a whole has been submitted for a degree to any other University of Institute. I certify that, to the best of my knowledge, my report does not infringe upon anyone's copyright nor violate any proprietary rights and that any ideas, techniques, quotations, or any other material from the work of other people included in my report, published or otherwise, are fully acknowledged in accordance with the standard referencing practices. I declare that this is a true copy of my report, including any final revisions, as approved by my report review committee.

Date: 22nd July , 2023
Place: WAAREE Energies Ltd.

Divyen Soni

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Acknowledgment

I would start by thanking my honorable faculty **Prof. Chintan Patel** who has provided me with the necessary guidance and information needed to complete this internship report. I would like to thank **Mr. Vishal Trivedi** (HR Head at Chikhli Plant) for all his support, necessary tips and guidelines during the activation period, and the entire team of engineers for being helpful and supportive in solving all my queries and every little help I needed and for creating the opportunity for me to bring out my best performance.

Also, I would like to thank **Mr. Mohit Puranik** (Quality Department – Assistant Manager LINE 2) for teaching me all the basics of my tasks, patiently showing me every elaborate detail on Quality Inspection, and guiding me throughout my internship period.

Finally, I would like to express my gratitude to the company for allowing me to attend the internship program.

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INTRODUCTION (Solar over other alternatives)

- Solar energy is one of the most abundant energy resources on Earth. As a renewable CO2-free power source, the environmental impact of solar power is significantly smaller than other power generation methods. A few reasons to choose Solar over other alternatives is as follows:

- It is a free energy source
- It does not emit greenhouse gases
- It Can Make Use of the Underutilized Land
- It Can Cause Less Electricity Loss

- Solar power is a powerful energy resource that can provide suitable electricity for your home. It's the cleanest and most abundant renewable resource that can efficiently power your place cost-effectively.

- The industry is expanding exponentially each year. The advent of EV technology and the government initiative to promote Renewable energy over Oil and thermal alternatives will surely grow the solar industry even further.

- Therefore, it is beneficial to learn the particularities of the Solar module industry, thus I have decided for an internship in solar module manufacturing industry.

ABOUT THE COMPANY

- Waaree Energies Ltd. is the flagship company of Waaree Group, founded in 1989 with headquarters in Mumbai, India. Waaree Energy is today one of the largest vertically integrated new energy companies. It has India's largest Solar panel manufacturing capacity of 12GW at its plants in Chikhli, Surat and Umbergaon in Gujarat and is a top player in EPC Services, Project Development, Solar Rooftop Solutions, Solar Inverter, and Solar Water Pumps. It is also an Independent Power Producer. Waaree has a presence in over 388 locations nationally and 20 countries internationally. The company has supplied 6+GW of solar modules and commissioned 1+ GW of solar EPC projects.
- The vision is to provide high-quality and cost-effective sustainable energy solutions across all the markets, reducing carbon footprint- paving way for sustainable energy thereby improving the quality of present and future human life. The core values of the organization are those values that underlie our work & strategies we employ to fulfill our vision & mission.

BRIEF THEORY OF SOLAR MODULE

O Module Structure

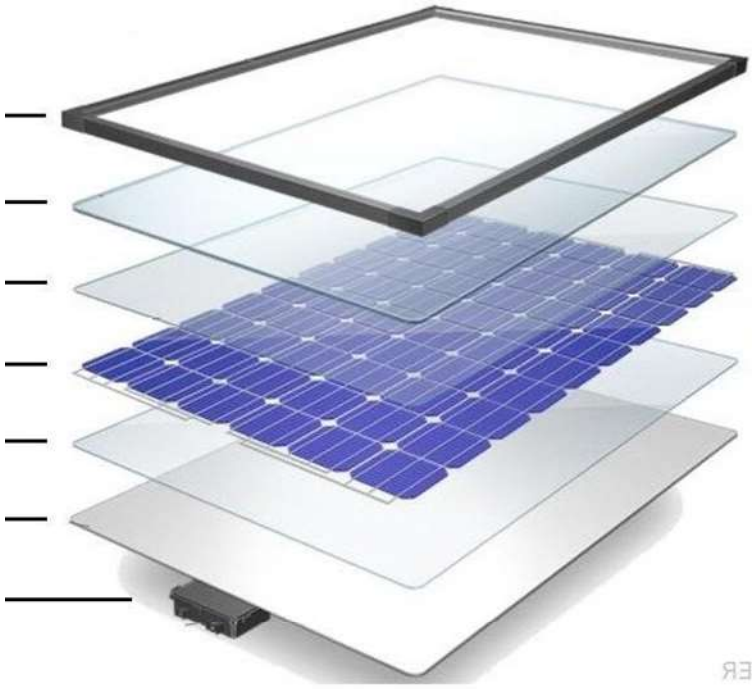
- A PV module consists of several interconnected solar cells encapsulated into a single, long-lasting, stable unit. The key purpose of encapsulating a set of electrically connected solar cells is to protect them and their interconnecting wires from the typically harsh environment in which they are used.

- Module lifetimes and warranties on bulk silicon PV modules are over 20 years, indicating the robustness of an encapsulated PV module. A typical warranty will guarantee that the module produces 90% of its rated output for the first 10 years and 80% of its rated output up to 25 years.

- Many different types of PV modules exist and the module structure is often different for different types of solar cells for different applications. The most common modules have either 60 cells or 72 cells with three bypass diodes.

- The modules are assembled layer by layer in a sandwich pattern, as seen in the figure the different layers are as follows.

1. Frame
2. Tempered Glass
3. First EVA layer
4. Solar cell layer
5. Second EVA layer
6. Current-collector busbars
7. Backsheet
8. Junction Box and Connecters



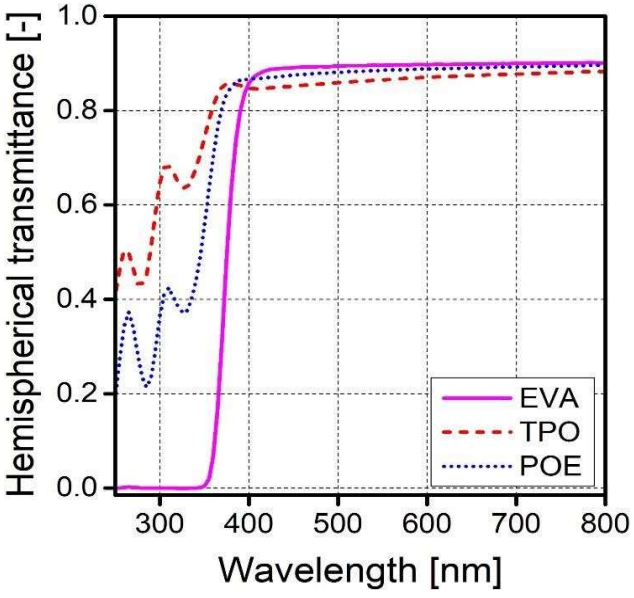
- **Tempered Glass:**

Protects the solar panel from falling debris and makes it weatherproof. For silicon solar cells, the glass surface must have high transmission of light, in addition, the reflection from the front surface should be low. For tempered glass this reflection is as low as 5% of the incident light. The reflection could be reduced by applying a coating to the top surface or roughening the texture of the surface. However, in this case, the dust and dirt are more likely to settle.

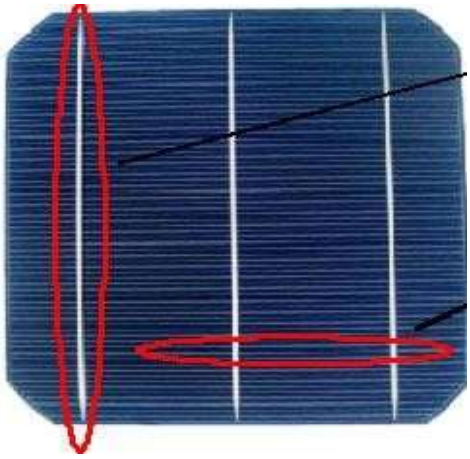
- **Encapsulant:**

An encapsulant is used to provide adhesion between the solar cells, the top surface, and the rear surface of the PV module. The encapsulant should be stable at elevated temperatures and high UV exposure. It should also be optically transparent and should have a low thermal resistance.

EVA (Ethylene-vinyl acetate) is the most commonly used encapsulant material. It polymerizes at 150^{o} C and bonds the cells and module together. In case bifacial cells and a transparent backsheet are used in a module then POE (Poly-Olefin Elastomer) encapsulant is used instead of EVA. POE shows properties like higher transparency and light transmission. POE-based modules maintain low leakage current, enhancing electrical performance and module reliability.



- **Solar Cell Layer and Busbars:**
  This is the layer of solar cells that converts the sunlight into electricity through the photovoltaic effect. A series of such cells in a single line are collectively called a **string**. In this layer, the solar cells are aligned in series or parallel connections connected with conducting material of string and tab wires, which are soldered to busbars.



  - The Silicon solar cells are metalized with thin strips printed on the front and rear of a solar cell. These busbars are placed on both the front side and the backside of the cell. Usually, solar cell busbars are made of a silver paste or similar high conductivity materials.
  - Perpendicular to the busbars is the metallic and super-thin grid fingers, which are connected by the busbar. The fingers collect the generated DC power and deliver it to the busbars.
  - The maximum amount of current that can be safely carried is determined by the size of the busbar. It can be as small as 5*0.2 mm. The number of busbars in a cell is represented by BB. It is recommended not to increase or decrease the number of busbars in the cell too much because the increase in the number of BB reduces the cell area and a decrease in the number of BB causes loss of productive energy.
  - The company works with different types of cells such as mono and poly crystalline 5BB, 9BB bifacial, 10BB bifacial, etc.

5BB Mono PERC Cells
156,75 * 156.75 mm
158 * 158 mm

9BB Mono Bifacial Cell
182mm*182mm

OVERVIEW OF THE WORK

This report is a detailed overview of the internship at Waaree (Chikhli). During my internship, I have learned a lot about all the different manufacturing process which takes place in solar module manufacturing.

The process in the industry can be broadly classified into three departments,

i. Production
ii. Quality Checking
iii. Maintenance

Each sector is supervised by multiple engineers and managed by a head of the department.

As an intern, I learned and worked in all three sectors with a special interest in Quality Checking. The branch I was assigned for internship runs in 3-shifts seven days a week. The internship program lasts for 15 days, 6 days a week where one works closely with the engineers learning thoroughly all the processes.

The Chikhli branch of Waaree is a manual production facility where most of the processes and material handling are carried out manually.

There are 2 big domes in which there are several plants.

They are named as – **MLB – 1 & MLB – 2**. The full form of MLB is **Module Line Building**.

MLB – 1 has plants from **1GW to 5GW.**MLB – 2 has **6 & 7 GW**.4GW to 7 GW has **different machines** from 1GW to 3GW.

There are **2 lines of production** in plants **1GW , 2 GW & 3GW**.Each line has capacity of producing modules of **500MW** in one year. Total 1 GW is produced in one year in each of these 3 plants.

4 & 5GW plant are combined and has **3 lines of production** with capacity of **600MW** on each line in 1 year.

6 & 7 GW plant are combined and has **4 lines of production** with capacity of **650MW** on each line in 1year.

The company is also constructing **2 Cell Production Plants.** They are also extending the plant to **12GW**.

OVERVIEW OF THE MANUFACTURING PROCESS

1. Cell Cut Machine
2. T&S [Tabber and Stringer] Machine
3. Auto Layup Machine
4. EVA Cutting & Placement Machine
5. Glass Lading Machine
6. Auto Bussing Machine
7. Auto Tapping Machine
8. Back EVA Cutting & Placement Machine
9. Backsheet / Glass Loading Machine
10. Pre-Lamination EL & Visual
11. Laminator
12. Edge Trimming Machine
13. 90 Degree Visual Inspection
14. Auto Framing Machine
15. Junction Box Fixing
16. Junction Box Soldering
17. Junction Box Potting
18. Curing
19. Auto Cover Filling
20. 180 Degree Flipper
21. Sun Simulator / Flasher – 1000W/m^2
22. Hi – Pot Test
23. Past Laminator EL & Visual
24. Auto Sorting
25. Packing & Dispatch

1.CELL CUT MACHINE

Double Track NDC Cut Machine

- This machine is used to cut the cell into half. The machine that is used in this process is of the Chinese company named **" Autoway".**
- The cells are first loaded in the load box. There 2 slots to put the cells in them. In each slot total 240 cells are kept and the conveyor move them further.
- The dimensions of the cells are – **182 mm × 182 mm**.
- This machine has 2 sides through which the cells are cut.
- The machine has robot with vacuum that pick up the cells and put it on a surface.
- There are 2 red lights that are incident on the cells. This lights are inclined at some angle. There are also 2 cameras on the top to scan the whole cell. Camera scan the full cell and the red light on the full cell is used to completely observe the BB of the cell. These scanned cells are shown on HMI.
- The dimensions of the cut cells are – **182 mm × 91 mm**.
- If the cells are okay then they are cut into half. If the cells are not good then they are considered as NG and are kept aside. The scanned cells are then kept on a plate that have gap in between it. There are 2 plates on which 2 cells can be kept on each plate.
- The cells are cut into half using laser. The plate move further through laser and cells are cut into half.
- There are 2 lasers and 1 water pipe on each side. The slotting laser is used to make slot on the corners of the cell. They make these slots to make the thermal laser cut the cell easily. This laser has violet light which slots the cell.

- The Thermal laser has red colour and it cuts the cell into half. There is one red dot at the bottom of the laser to guide the laser.
- The **power** of Thermal Laser 1 (%) is **60% (+15 , -10).**
- The **frequency** of the Thermal Laser (kHz) is **100 (+10 , -30).**
- After the cutting of the cell, water is sprayed on the region of laser to cool down the cell. The cell is cooled down to avoid the breakage of the cell.
- The pressure of the **Demineralized Water Spray** (Mpa) is **0.1 (+0 , -0.05).**
- The **total pressure** of the machine is between **0.4 to 0.6.**
- The pair of cells is cut into 4 half cut cells.
- After cutting, the cells are kept on a conveyor belt. This belt moves the cells further for unloading.
- There are 5 heating platforms to dry water that has been on the cell. First the cells are heated on the conveyor and then cooled. After cooling, they are picked up by the robot and kept on the unload box.
- The temperature of each platform is 80 (± 25) º C.
- In unload box, the 480 half cut cells are kept in 4 parts with 2 sides.
- After unloading, the cells are taken by the worker and they arrange the pair of 240 cells in proper manner. If the cells are broken at the ends then they are kept aside and the good cells are then loaded to the TS Machine.

2. TABBING AND STRINGER MACHINE

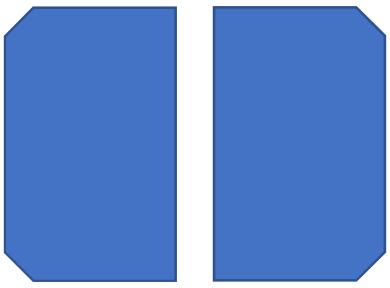
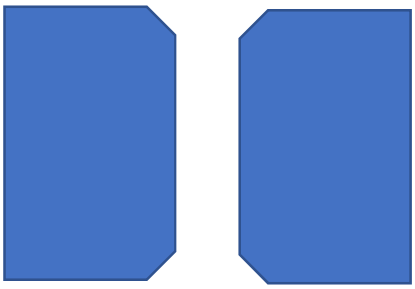
MBB High Speed Weld Machine

- The tabbing and stringing is the process in which the cells are lined up together and connected in series with the help of ribbons forming a string. A string generally consists of 12 cells in series. This process is carried out by using a tabbing and stringing machine. This machine is automated and increases the string generation speed several times as opposed to manual stringing.
- The tabbing and stringing machine shortly abbreviated as TS machine is configured based on cell BBs. The TS machine makes use of air pressure, vacuum, and heat to carry out its Processes.
- There are rolls of ribbons that has 15,600m of ribbon in 1 roll. The ribbon is a thin wire of **Copper and Silver coating**.
- The cells are loaded at both the sides of the machine.
- The cells are unloaded from the load box by robot. They are kept on conveyor belt and moved further.
- After that the cells are scanned through the red light. If they are NG then they are kept on NG plate.
- There is camera on the top to determine the cell is whether NG or OK.
- If they are OK then they are picked up by the robot along with the frame at the side.
- The ribbons are dipped into flux which is a liquid .
- After dipping, the ribbons are rolled ahead for stringing.
- They are cut into specific length.
- The cell is kept on conveyor and the ribbon is pulled by the machine which holds the ribbon like clip and kept it on the cell. Another cell is kept on the conveyor and the previous ribbon goes

below the cell. Another ribbon is pulled and kept on the 2nd cell. This process is continuous.

- As the ribbon is laid on the cell , the frame is kept on it so that the ribbon does not dislocate form its position. The frame is also kept to solder the ribbon with the cell.
- When 12 half cells are connected in series, they are called a **String**. The gap between each cell is **1.2 mm**.
- The string is moved forward for soldering. For soldering, **Xenon lamps** are used. They are in a box type structure through which exhaust pipe is also connected and at top are 4 fans.
- The soldering is done in pairs of cells. The frame has spring points which are pressed along the cell for soldering.
- The heat generated is pulled by the hose pipe and thrown out through the **Exhaust Motor**. The fans are placed on the top of the lamps to cool them down.The press time is **1.7 to 2.6 seconds**.
- The soldering temperature is around **150ºC**.
- After soldering, the string is moved forward and the pairs of frames are pulled up by 2 pairs of magnets on each side and kept on conveyor and moved again to the starting part.
- The string is cut at the end to separate the 12th cell of 1st string and 1st cell of 2nd string. They are moved forward through conveyor.
- Each string is pulled and hold through a robot through vacuum. They are moved and pushed against two points with conducting screws. Both the ends of the string is slightly pushed against this conducting material to get the **EL (Electoluminous)** image. These images are seen on the monitor screen. There are 2 buttons – OK and NG.
- If it is NG then it is kept on the NG plate by pressing NG button.

- If it is OK then it is kept on the conveyor. They are kept one on one.
- As 12 strings are kept, the conveyor is moved and the strings are carried to the other machine.
  The machines are of Lead Company.
- There are 2 types of machines – LDDS 3600B AND 3600C.

3600 B	3600 C
The robot that took the cell from the load box has 4 hands in shape of addition.	The robot that took the cell from the load box has only 1 hand .
The red light that incidents is at the top and in circular shape.	The red light is at side at some angle and in tube light shape.
The cell position in the load box is- 	The cell position in the load box is- 

PARAMETERS	SPECIFICATIONS
Set Temperature 1	230 ± 30 º C
Set Temperature 2	190 ± 30 º C
Welding Time 1 to 6	1.6 to 2.5 Seconds
Press Time	1.7 to 2.6 Seconds
Over Temperature	30 ± 20 º C
Standard Power	40 to 70 %
Highest Power	45 to 80 %
Heating Platform 1	80 ± 30 º C
Heating Platform 2	90 ± 30 º C
Heating Platform 3	110 ± 30 º C
Heating Platform 4	100 ± 30 º C
Heating Platform 5	90 ± 30 º C
Heating Platform 6	80 ± 30 º C
Lowest Temperature Setting	10 º C
Highest Temperature Setting	400 º C

(MLB – 2)

1.TS MACHINE

MBB PV CELL SOLDERING STRINGER

- In this machine, the **Cell Cutting and TS** is done in **single machine.**
- The machine is of **ATW** company. The model number is **AM050F**.
- After loading the cells, you don't have to unload it and again load it into the TS Machine.
- Once you load the cell, it will directly come out after becoming a String.
- **240 cells** are loaded into machine by keeping them in **Cassette**.
- The loading is at both sides and cutting is also at both sides like in Lead machine**.**
- After loading the cells, they are moved forward for cell cutting. Only **1 Cassette** is considered at a time. The cells are kept on conveyor and same process is followed .
- There is a **square red light** at **bottom** and at **top** there is **Camera** with **Laser Radiation**.

- The cells are scanned and NG cells are kept aside. At a time only **1 cell** is cut into half.

- After cutting it is kept on conveyor and moved forward to **TS Machine**.

- The conveyor has **5 heating plates** to dry the cell.

- The direction of the cell is **reverse** of the **Lead Machine.**

- The **frames are bigger** with more solder slots and the **Solder Machine has 12 Xenon Lamps.**

- The soldering temperature is around **350 º C.**

- There are **6 heating plates** in this machine.

- The robot that picks up the String is at both sides. At **one side** , there are **2 robots** (**Up** and **Down)** to pick the String. At the **other side**, there is only **1 robot** as in 1-3GW.

- There are **3 machines** on **each line**. **Total 12 machines**.

- After TS Machine and before Auto Bussing, the modules are moved for **String Rework** if needed.

- The **robots** are of **YASKAWA** Company.

Specifications for Cell Cutting

PARAMETERS	SPECIFICATIONS
#1 #3 Drying Plate Temperature	70 ± 30 º C
#2 #4 Drying Plate Temperature	70 ± 30 º C
#5 Drying Plate Temperature	70 ± 30 º C
Laser Power	50 ± 10 %
Laser Slotting Power	45 ± 5 %

Specifications for ATW Stringer

PARAMETERS	SPECIFICATIONS
Flux Temperature	50 ± 15 º C
Pre Heat Base Temperature	110 ± 30 º C
Soldering Base Plate Temperature	130 ± 30 º C
#1 Holding Base Plate	125 ± 30 º C
Combined Plates Temperature	120 ± 30 º C
#2 Holding Base Plate	110 ± 30 º C
#3 Holding Base Plate	105 ± 30 º C
Lamp Intensity	55 ± 5 %
Soldering Time (Power Mode)	2000 ± 400 mSec

3.GLASS LOADING MACHINE

- The glass is the main part of the Solar Module. The bunch of **150 Front Glasses** are loaded in the Glass loading machine.
- The dimension of the glass is – **2267 mm × 1128 mm**.
- This glass is called **ARC** glass because it has **Anti Reflective Coating** on it.
- Two groups of 150 – 150 glasses are loaded in the machine. The machine has 2 robots.
- One robot has vacuum at its end and the other has Rubber at its 4 ends.
- 1st robot come and pickup the glass. First the glass are picked only from the two edges and the speed is slow. After that all the vacuum works equally and pick the glass at some speed and put it on the conveyor.
- During this cycle, the 2nd robot come and catches the butter paper through its rubber tips and put it on the right side.
- The butter paper is provided to protect the glass from scratching each other.
- The glass is further moved to EVA cut machine.

4.EVA CUTTING & PLACEMENT MACHINE

- In this machine, a large roll of EVA is connected in the input side.
- EVA stands for **Ethylene Vinyl Acetate**.
- It is used for **Lamination** purpose. The thickness of the sheet of EVA is **0.60 mm**.
- The machine has rollers which pulls the EVA from the role. A specific dimension is set in the machine of the size of the EVA sheet.
- After pulling appropriate size of the EVA, the machine has inbuilt blade which cuts the EVA.
- After cutting of the EVA, its sheet is laid on the glass.
- The glass is moved further through the conveyor belt to the **Auto Layup Machine**.

5.AUTO LAYUP MACHINE

- After the TS machine, the strings are passed to the auto layup machine through conveyor. The glass with the EVA is also loaded in this machine.

- The glass is moved to the layup part. The strings are kept on the conveyor in the unloading part.

- Robot is used to pick up the strings. The strings have two sides positive and negative.

- The part from which the strings are coming from down is called the negative part and the part from which the strings are coming from upwards is called the positive part.

- The robot first picks up on string and then rotate 180 degree and then pick up the second string together and put it in a particular manner. Both positive sides or both negative sides are faced towards each other.

- They are captain of plate to arrange them in a straight order. After this time the another robot from the layer part comes and picks up the strings and place it on the EVA on the glass. All the 12 strings are placed on a single glass total 144 half cells.

- After laying up the tab module more through the conveyor belt to the **Auto Bussing Machine**.

- It takes 45 to 50 seconds to place solar cells on the glass.

PARAMETERS	SPECIFICATIONS
String to String Gap	1.3 ± 0.5 mm
Cell to Cell Gap	1.2 ± 0.2 mm
Cell Edge to Busbar	3 ± 0.5 mm
Busbar Width	5 ± 0.1 mm
Top Side Gap (Gap between Cell Edge and Glass Edge)	23 ± 1.0 mm
Bottom Side Gap (Gap between Cell Edge and Glass Edge)	23 ± 1.0 mm
Width Side Gap (Gap between Cell Edge and Glass Edge)	14 ± 1.0 mm
Centre Gap	11 ± 0.5 mm

6.AUTO BUSSING MACHINE

3 – IN – 1 Integrated Auto Bussing Machine For HCC

- In this machine the module is bussed. There are rolls of bus bars which are made up of copper and coated with silver.
- The bus bars come in rolls like ribbon. The bus bars are first stretched and cut into appropriate length.
- The bus bar is cut at two sides of the machine. Three types of bus bars produced.
- I type, U type and L type bus bars are produced by the machine.
- At one side I, L and U type bus bars are made and other side only I type was bar is made.
- The bus bars are stretched cut and then they are pressed in the machine through robot to get the appropriate shape.
- Then this bus bars are taken by the robot using vacuum.
- The I type bus bars are laid on the sides of the module. The U and L bus bars are laid in the middle of the module.

- After laying the bus bars , they are soldered with solar cells through ribbons.

- The solder press hold down time is between 2 seconds to 5 seconds. After soldering , the bus bars are cooled within 6 to 7 seconds to avoid hard soldering.

- To cool the bus bar, small chiller is also attached with the machine and its temperature is set to **17.9 º C.**

- The whole process takes 32 to 35 seconds. Total 10 bars are shoulder with the panel.
- The length of **U bus bar** is **400 mm. (360 + 20 + 20)**
- The length of **I bus bar** is **350 mm**.
- The length of **L bus bar** is **195 mm. (175 + 20)**

PARAMETERS	SPECIFICATIONS
Solder Press Hold Down Time	2 to 5 Seconds
Front TCA1 to TCA6	1 to 2.5 Seconds
Middle TCA1 to TCA6	1 to 2.5 Seconds
Back TCA1 to TCA6	1 to 2.5 Seconds

7.AUTO TAPPING MACHINE

- After the bussing of the module it is loaded into **Auto Tap Machine.**
- The module is arranged in a proper position for tapping.
- The cello tape is already fixed in the machine in the robot at 2 sides. As the module is arranged, the tapping starts and total 36 tapes are taped by the robot in the module, 18 on which side.
- This machine takes 28 to 35 seconds to tap the module.
- There is one screen to control this machine. Controller has three operations namely- **Holding operation, Shield operation and Immediacy operation.**
- In shield operation, there is shield warming which rings the alarm if taping is not done.
- The main function of the vacuum in this machine is to hold tape and then it press it to the cells.

8. BACK EVA CUTTING AND PLACEMENT MACHINE

- The module is loaded in this machine after auto taping.
- This machine has one screen to operate it. There is also 1 Edge/Line position controller.
- Again, the EVA is pulled by the machine but now there are 3 holes in the middle of the EVA sheet for the bus. These holes are created in the sheet using three round cutters which cuts the EVA automatically.
- The screen shows the cycle time and speed of the machine.
- It generally took 80 - 90 minutes to empty one roll of EVA.
- Some customers also demand for **solar POE film. (Polyolefin Elastomer).**
- POE is more efficient than EVA.
- The sticker of WAAREE is sticked to the glass and **unique barcode** is also sticked.

9.BACKSHEET / GLASS LOADING MACHINE

- After sticking the sticker and barcode, back sheet or glass is loaded on the module.

- For Glass to Backsheet module, the **Backsheet Cutting & Placement Machine** come into work.

- In this machine the process is similar to the EVA cutting and placement machine. The only difference is that white Backsheet is laid on the module with three holes in the middle for bus bar.

- For Glass to Glass module, the **Back-Glass Loading Machine** comes into operation and Back Sheet Cutting and Placement Machine is **Bypassed**.

- The Back Glass also have three holes in between them for bus bars.

- After loading of back sheet or glass, **Teflon sheet** is inserted which have gaps in between them to insert the bus bar ends. This Teflon sheet protects the module from air and also from water.

- In Glass to Glass module, EVA sheet strips are laid before loading the back glass and also square EVA cutouts are also laid between the bus bars.

10.PRE LAM INSPECTION

- After all this process, the module is inspected before lamination and hence the name is pre-lam inspection.
- In this inspection machine, there are total 8 cameras to click pictures of the module. Two large LED screens are also placed to check the module.
- Two types of images are produced in this machine.
  EL [ELECTOLUMINOUS] (X – RAY)
  Visual

- 4 cameras are for EL image and the other 4 for Visual image.
- The EL image is like x-ray image of the module and this image is generated by giving power to the three bus bar ends.
- This inspection is necessary to determine the fault in the module.
- If the module is faulty or the cells are broken then these modules are sent for **Rework** at **Rework Station**.
- If the module is OK then it is directly sent for Lamination.
- The fault is first mark on the screen in the inspection and then send for the Rework. The Barcode is stick to (-) side of Solar cell.
- The faults are given some unique codes to simply the process.
- At Rework as they scan the barcode, the workers come to know about the fault and they solve it.
- After Rework, the modules are once again inspected at other inspection station and if they are OK then they are sent for lamination.
- If any fault is there again then it is again sent for Rework.

EL FAULTS

CODE	FAULT
E1	Micro Crack
E2	Branch Cracks (Tree, Spider Crack)
E3	Cross Crack
E4	Poor Soldering
E5	Dead Cell / Shor Circuit Cell
E6	Dark area due to cell broken
E7	Finger Interruption
E8	Current Mismatch/ Different Brightness
E9	Dark Area / Dark Spots
E10	Firing Belt Marks
E11	Cell Pollution
E12	Black Heart Cell
E13	Cell Scratch
E14	Dark Edge

VISUAL FAULTS

CODE	FAULT
D1	Cell Crack
D2	Cell Chip
D3	Cell Scratch
D4	Finger Interruption
D5	Pin Hole in Cell
D6	Paste Stain on Cell
D7	Colour Variation
D8	Cell to Cell Gap (C to C)
D9	String to String Gap (S to S)
D10	Ribbon Misalignment (RMA)
D11	String Misalignment (Matrix Shift)
D12	Gap btw cell Edge & Interconnect
D13	String Offset
D14	Offset of Cell / Cell Location
D15	L cone short
D16	Misalignment between cell & String connector (Cross Tie)
D17 (I)	Foreign Particle (Non-Conductive)
D17 (ii)	Foreign Particle (Conductive)
D18	Distance between Cross Ties
D19	Distance btw Cross Tie & Frame

11. LAMINATOR

- After inspection, 5 modules are sent for lamination in the lamination chamber.
- There are two floors in this chamber, first floor and second floor. The lamination is done in both the chambers.
- Group of 5 modules are send for lamination together. The conditions are little bit different for glass to back sheet module and glass to glass module.
- There are total 3 stages in the Laminator .
- The first state is the **vacuum stage** in which the module is vacuumed for 350 seconds.
- The second stage is the **lamination stage** in which the module is heated and laminated. EVA melts down in this stage.
- The third stage is the **cooling stage**. The modules are cooled at 50 degree Celsius.
- The vacuum is used in all the three stages
- For glass to bed sheet module, the temperature in the laminator is **150 degree Celsius** for first 2 stages.
- In the cooling stage, that temperature is **50 ^{0} C .**

- For glass to glass model, the module is vacuumed at **125 degree Celsius** for 350 seconds.

- After stage 1, the module moves towards stage 2 in which the temperature is **150 degree Celsius.** The lamination takes place in this stage and EVA melts.

- At stage 3, the module cools down at **50 degree Celsius**.

- It took **27 to 30 minutes** to complete the whole process of lamination.

- The vacuum pump works on **5.5kW (7.5 HP) , 11.6 A , 50 Hz , 380 V**.

- The speed of the motor is **1443 RPM**.

(4 & 5 GW)

- In this plant, there are only **2 stages for lamination.**

- Also there are **2 separate screens** for both the floors. You have to individually handle them both.

- The cooling is not inbuilt in the Laminator. It is done after the module come out of the machine. There are **4 fans** to cool down the laminated module.

12. AUTO TRIMMING MACHINE

- After lamination, the module travels through the conveyor to the auto trimming machine.
- During lamination as the EVA melts, some extra part comes out from the edge of the glass which needs to be removed.
- Auto trimming machine have 4 blades on the robot on 4 sides. As the module is loaded in the machine, it is perfectly arranged and then trimming is done automatically by the robot.
- The robot cuts down the extra unwanted edges and the module now only contain glass at the edge.
- This trimmed part is disposed of by the company.

13. 90^{0} VISUAL INSPECTION

- After auto trimming of the module , they are then moved to 90-degree inspection station.
- There are **Two slots** for 90-degree inspection . The module is first moved in the machine. After this the machine holds the module and flip it to 90 degree.
- After flipping 90 degree, the tube lights are turned on in the machine automatically.
- At this stage, the modules are checked visually by human.
- If there is any fault in the module, it is considered as NG and then it becomes scrap because nothing can be changed after lamination.
- The NG modules are moved aside.
- The OK modules are moved further to Auto Framing Machine.

14. AUTO FRAMING MACHINE

- After the inspection, the module is loaded in this machine for framing.
- Framing is very essential to protect the module from breakage and also from weather conditions.
- The frames are of **Aluminium** . There are total 4 frames to be fitted on the module. Two groups of two frames of same size.
- Two frames are smaller and the other two are larger.
- The dimension of **larger frame** is – **2272*35*35.**
- The dimension of **smaller frame** is – **1133*35*20.**
- These frames are moved forward through machine automatically.
- There is a gun like machine which fills sealant in the gaps of the frame. The sealant used as a glue to stick the module in the gaps in the frame.
- These frames are moved into the machine. The module is also brought into the machine.
- The frames are adjusted by the robot on the edges of the module .

15. JUNCTION BOX FIXING

(MLB 1)

- The junction box is a device which carries out the electrical power from the module.
- It is also a most important part in the module.
- There are **three types** of junction box.
  Positive, Negative and Bypass.
- The junction box is eventually a diode.
- Firstly, the junction box is kept in a machine where sealant is applied on the back of it.
- After the sealant is applied, the JB is stick to the back of the module. The bus bar ends are kept in the middle of the junction box.
- The negative JB is connected to the negative side of the solar cell and positive JB is connected to the positive side of the solar cell. The bypass diode is connected in the middle.
- The bypass diode is connected to bypass the current if hotspot occurs.
- After this the lead wire is used to solder the bus bar and the bus bar are turned from vertical to horizontal and are connected to the junction box. The temperature of the solder machine is **450^{0} C.**

(MLB 2)

- The JB fitting is done manually.

AUTO SOLDERING MACHINE

- After fixing the JB, the soldering is done by machine. The module first enters the machine through conveyor.
- After that it is set to the required position. After setting, the robot come and the soldering is done by the robot.
- After Soldering, the module is moved forward.
- If the soldering is not done properly by the machine then it is done manually by human.
- The chiller plant is also connected to this machine and temperature is set to **24ºC.**

16. JB POTTING

- to protect the JB from short circuit and other danger.
- In this machine, the gap in the JB is filled with **Two Component RTV Silicon.**
- Two components are mixed where one is **Base** which provides water proofing to the JB and another is **Catling** used to dry the base .
- Where is a pen like structure through which silicon is filled into the JB.
- After potting, the modules are moved through the conveyor for further process.

17. CURING LINE

- After potting , the silicon needs to be dried before moving for the further process.
- In this machine, the modules are pick up by the robot and kept systematically on the conveyor of the curing line.
- In curing the modules are kept to dry.
- Panels are kept on conveyor for 4 hours. The curing line is a room type structure.
- The temperature is kept between **22 to 27 degree Celsius** and humidity should be greater than **50%.**
- Generally, the humidity is 72 to 75%.
- After curing , the corners of the module are **buffed** automatically using machine. This is called **Corner Buffing.**
- After corner buffing, a **contact block** is connected to positive and negative JB of the module for testing.
- After this, the modules are 180 degree flipped using **180-degree Flipper**.
- The modules are flipped for testing.

18. SUN SIMULATOR

- After flipping of the module, they are moved forward into Sun Simulator. As we know that testing the module with sunlight is not adequate and weather conditions also affects.
- So, we artificially create the sunlight from lamps for testing.
- There are **2 Xenon Lamps** with our faced upwards and their reflection are incident on the module.
- **Filter glass** is also in the middle to divide the light equally.
- The intensity of the light is **1000 W/m².**
- Contact block is connected with electric wires with a directly connected to the monitor screen to get readings.
- After scanning the barcode of the module, the light incidence automatically and eventually gets the **Readings And V-I Graph .**
- The graph shows relation between **Short Circuit Current** in **Red** colour and **Open Circuit Voltage** in **Blue** colour.
- **Imax, Field Factor, Pm** are the readings we got from the test.
- The module with **High Field Factor Is Best.** Based on the **Imax,** the category of the module is given.
- The modules are categorized on the basis of Imax as follows-

CURRENT BIN	Imp Range
I1	≤12.900
I2	12.901 to 13.000
I3	13.001 to 13.100
I4	13.101 to 13.200
I5	≥13.201

- The modules are categorized to easily determine the same current rating of the modules for installation.

- The Temperature rating that should be in the Sun Simulator is **25 ± 2 ⁰ C.**

- After sun simulator, the module is again flipped 180 degree and moved to Hi-pot test.

- In **MLB 2,** the charging voltage is **315 – 330 V.** The **barcode is also scanned Automatically.**
- There are **4 Xenon lamps** and the room is also darker than MLB-1.

19. HI POT TESTER

- This is the testing machine which tests the module at **High Voltage**.

- The contact block is connected with to screw like conducting materials that are connected with electrical wires with a screen.

- There are 2 Hi-Pot testing machines.

- Three types of tests are done in this machine.

- **DC (Dielectric)** – In this test, the module is provided **4.8kV** and the reading is taken in the machine and it is displayed on the screen. The modules are tested at voltage that are **2.5 times** the regular voltage that will be given to the module in industry. This is tested to check whether the module can bare High Voltage or not. In industry generally **1500 V** is supplied.

- **IR (Insulation Resistance) –** in this test, the module is tested at **1.8kV** to measure the **Leakage Current** in the frame. This test is done to check the safety of the module that whether the current is leaked from the frame or not.

- **GD (Grounding) –** In this test, **62.5 A** current is given to the module and it is tested that whether the current in grounded or not .

20. POST EL INSPECTION

- After Hi- Pot Test, the modules are once again inspected.
- The EL and Visual images are displayed on the screen and the modules are check once again.
- **Cracks, poor soldering** and other defects that has been formed in the module and that were not visible are checked here.
- If there are Cracks or other defects, the module is thrown into scrap.
- If the module is OK, then it is moved further.
- After inspection, the back cover of the JB called **Cap** is attached. Cap is basically a plastic that is attached to JB to close it.
- The contact block is also removed at the station and the sticker of WAAREE is sticked at the back of the module.
- At next station, the barcode of the module is scanned and cardboard is attached at four corners of the module.
- There are special cuttings of the cardboard to cover the corners. Total 4 cardboard pieces are attached with the module.
- In **MLB 2**, the module is **finally inspected** by **flipping 90º.**

21. AUTO SORTING MACHINE

(MLB – 1)

- After the cardboard is attached at corners, the modules are moved forward using conveyor and their sent to auto sorting machine.
- This machine has robot which scans the barcode of the module and automatically sorts the modules in the category of I1 to I5.
- The modules are sorted here in their category and kept one on one.
- There are total eight slots to keep the modules.
- After Auto Sorting, the modules are once again check at the **final inspection** and they are given grade – **A, B & C.**
- After grading, the panels are packed. **31 panels** are kept in 1 box and then they are dispatched.

(MLB – 2)

- The modules are kept **Vertically** using robot and are picked from the **Centre** using **Vacuum**.
- There are **5 Slotting Stations** – I1 to I5.

CONCLUSION

Here I conclude my report about my summer internship executed at WAAREE Energies Ltd., and thanks to all the department of the company which helped me to grab this opportunity to do internship in this company.

Thank You
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