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**Report: 21.3568.1-02**

**INTERNAL PV MODULE TEMPERATURE  
ESTIMATION BASED ON STANDAR STAGNATION  
TEMPERATURE TEST**

**PHOTOVOLTAIC SOLAR ENERGY DEPARTMENT  
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**Title:** Internal PV module Temperature Estimation based  
on standard stagnation temperature test

**Report:** **21.3568.1-02**

**Report Emission Office:** Pamplona

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## **1.- EXECUTIVE SUMMARY**

### **1.1.- PRELIMINARY**

This report is compiled according to the conditions laid down in the offer nº **21.3568.0 Rev.0** for the company **FEGENSOLAR, LLC** dated in **July 2018**.

### **1.2.- OBJECT**

The purpose of this report is to present internal PV module temperature estimation based on standard stagnation temperature test performed to 1 PVT module of manufacturer **FEGENSOLAR**.

### **1.3.- SCOPE**

The results presented in this report relate only to tested modules with serial number listed in section 1 SAMPLE CHARACTERISTICS.

### **1.4.- CONCLUSIONS**

The estimated maximum cell temperature at 40° of ambient temperature for the PVT component studied is 89.2 °C.

This temperature is close to the upper limits recommended for a standard PV module to work.

The inclusion of a metallic absorber and the insulation foil in the PV product evaluated modifies the thermal behavior of the PV module; therefore in order to qualify the PVT collector the tests related with the risk of fire shall be performed.



## 2.- TECHNICAL REPORT

### 2.1.- SAMPLE DESCRIPTION

#### 2.1.1.1.- Collector

|                                        |                         |                                     |
|----------------------------------------|-------------------------|-------------------------------------|
| Name of manufacturer:                  |                         | HANSOL                              |
| Brand Name:                            |                         | Multi crystalline 270Wp (PB-AN1)    |
| Serial Number :                        |                         | HI322BSQBB0408                      |
| Type name:                             |                         | PVT flat-plate collector            |
| Drawing Document N°:                   |                         | --                                  |
| Collector mounting possibilities (SC): | On sloping roof         | <input checked="" type="checkbox"/> |
|                                        | Sloping roof integrated | <input checked="" type="checkbox"/> |
|                                        | On flat roof            | <input checked="" type="checkbox"/> |
|                                        | In flat roof            | <input checked="" type="checkbox"/> |
|                                        | On flat roof with stand | <input checked="" type="checkbox"/> |
|                                        | Façade                  | <input checked="" type="checkbox"/> |

#### 2.1.1.2.- Characteristics module PV

| Module type             |                     |
|-------------------------|---------------------|
| Model designation (SC): | HS270PB-AN1         |
| Dimensi3ns (SC):        | 1670 x 1000 x 35 mm |
| Area (SC):              | 1.67 m <sup>2</sup> |
| Weight (SC):            | 18.9 kg             |

| Solar cells                  |                                  |
|------------------------------|----------------------------------|
| Type (SC) :                  | Multicrystalline Silicon         |
| Cell type reference : (SC) : | Tainergy / T1M<br>TSEC / TSM65TN |
| Cell dimensions L x W (SC) : | 156,75 x 156,75 mm               |

|                       |                     |
|-----------------------|---------------------|
| Cell thickness (SC) : | 200 $\mu\text{m}$   |
| Cell area (SC):       | 245.7 $\text{cm}^2$ |

| Identification of materials      |                                |
|----------------------------------|--------------------------------|
| Front cover (SC):                | Tempered safety glass with ARC |
| Rear cover : (SC) :              | Multi-layer polymer backsheet  |
| Encapsulant (SC):                | Homogeneous Layer              |
| Frame (SC):                      | Anodized aluminium             |
| Adhesive for frame (SC) :        | Silicone                       |
| Adhesive for junction box (SC) : | Silicone                       |
| Soldering material (SC) :        | Multi-layer polymer backsheet  |

| Identification of components |                                         |
|------------------------------|-----------------------------------------|
| Junction box (SC) :          | IP68                                    |
| Cable (SC):                  | H1Z2Z2-K 1x4.0 $\text{mm}^2$ / QC Solar |
| Connector (SC) :             | MC4 compatible / QC Solar               |
| Bypass diode (SC) :          | Trench Schottky / SB3050DY              |
| Cell connectors (SC) :       | Not specified                           |
| String connectors (SC) :     | Not specified                           |
| Junction box (SC) :          | Not specified                           |

| Module design - minimum distances                            |           |
|--------------------------------------------------------------|-----------|
| Between cells (SC):                                          | 3.5~5.5mm |
| Between cell and edge of laminate (SC) :                     | 14~18mm   |
| Between any current carrying part and edge of laminate (SC): | 13~17mm   |

| Module design - electrical configuration |    |
|------------------------------------------|----|
| Total number of cells (SC):              | 60 |

|                                            |    |
|--------------------------------------------|----|
| Serial-parallel connection of cells (SC) : | 1  |
| Cells per bypass diode (SC):               | 20 |
| Number of bypass diodes (SC):              | 3  |

#### 2.1.1.3.- Proteccion mechanism

|                              |                                                                     |
|------------------------------|---------------------------------------------------------------------|
| Self-protecting collector:   | Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> |
| Freeze resistant collector:  | Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> |
| Freeze resistant heat pipes: | Yes <input type="checkbox"/> No <input type="checkbox"/>            |

#### 2.1.1.4.- Operational range

|                                                                      |               |
|----------------------------------------------------------------------|---------------|
| Minimum and maximum operation temperature (SC) :                     | Not specified |
| Maximum operating pressure at maximum temperature of operation (SC): | 600 Pa        |
| Minimum and maximum installation orientation:                        | Not specified |
| Recommended heat transfer fluids:                                    | Not specified |
| Minimum, recommended, maximum flow rate:                             | Not specified |
| Other limitations (SC):                                              | Not specified |

#### 2.1.1.5.- Dimensions and general information

|                                               |      |                |
|-----------------------------------------------|------|----------------|
| Gross Length :                                | 1670 | mm             |
| Gross Width:                                  | 1000 | mm             |
| Gross height:                                 | 35   | mm             |
| Measured gross area:                          | 1.67 | m <sup>2</sup> |
| Measured aperture area:                       | 1.61 | m <sup>2</sup> |
| Gross área provided by the manufacturer (SC): | 1.67 | m <sup>2</sup> |



|                                                  |               |                |
|--------------------------------------------------|---------------|----------------|
| Aperture area provided by the manufacturer (SC): | Not specified |                |
| Absorber area (SC):                              | 1.49          | m <sup>2</sup> |
| Weight empty :                                   | 29.67         | kg             |
| Fluid content :                                  | 0.8           | l              |

#### 2.1.1.6.- Frame, enclosure, casing

|                                                     |    |
|-----------------------------------------------------|----|
| Enclosure material(s):                              | -- |
| Joining method(s) (pop rivets, screws, glued, etc): | -- |

#### 2.1.1.7.- Absorber

|                                          |               |    |
|------------------------------------------|---------------|----|
| Material (SC) :                          | Cooper        |    |
| Number of absorber elements (SC):        | 3             |    |
| Absorber plate/lfins/tubes length (SC):  | --            | mm |
| Absorber plate/lfins/tubes width (SC):   | --            | mm |
| Absorber total length (SC):              | 1553          | mm |
| Absorber total width (SC) :              | 960           | mm |
| Absorbedor thickness (SC) :              | --            | mm |
| Solar absorptance $\alpha$ (SC):         | Not specified |    |
| Hemispherical emittance $\epsilon$ (SC): | Not specified |    |
| Absorber coating (SC) :                  | Not specified |    |
| Bond between riser and fin/plate :       | Not specified |    |



**2.1.1.8.- Hydraulic System**

|                                                 |                            |
|-------------------------------------------------|----------------------------|
| Flow pattern as tested (SC):                    | Vertical tube-grid         |
| Number of risers (SC):                          | 8                          |
| Risers Material (SC) :                          | Copper                     |
| Risers Length:                                  | --                         |
| Riser outer/inner diameter (SC):                | --                         |
| Distance between risers :                       | --                         |
| Manifold material:                              | Copper                     |
| Manifold length (SC):                           | --                         |
| Manifold outer/inner diameter (SC):             | Ø ext 9 mm<br>Ø int 7.8 mm |
| Collector hydraulic connector type / size (SC): | Not specified              |

**2.1.1.9.- Glazing**

|                                  |                   |
|----------------------------------|-------------------|
| Material (SC) :                  | Safety glass      |
| Glass type (SC) :                | Tempered with ARC |
| Number of covers :               | 1                 |
| Cover thickness:                 | Not specified     |
| Solar transmittance $\tau$ (SC): | Not specified     |
| Glazing surface characteristics: | Not specified     |

**2.1.1.10.- Thermal insulation**

|                                     |               |
|-------------------------------------|---------------|
| Insulation material (SC) :          | Not specified |
| Thermal insulation thickness (SC) : | Not specified |

Thermal conductivity:

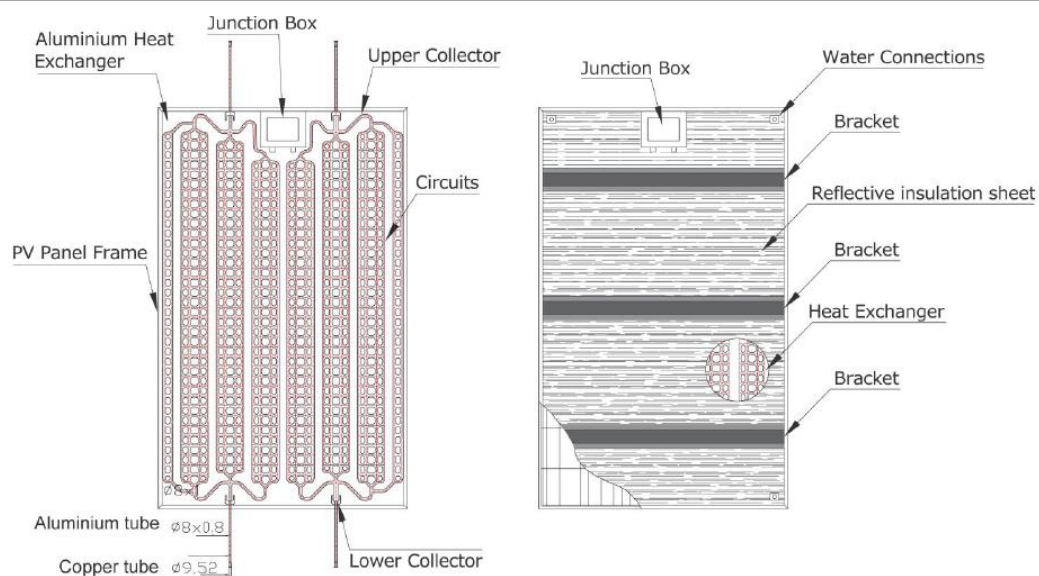
Not specified

**(SC)** Specified by the customer

**Photograph of the collector**



**Schematic diagram of collector mounting**



## 2.2.- TEST

According to the “IEC60904-5 Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method” describes the method to obtain the equivalent cell temperature of the PV module using the open circuit voltage (Voc) measurement.

In order to being able to estimate the equivalent cell temperature of the PV module at the end of the stagnation test of the PVT, the electrical parameters of the module have been measured.

The measurement of the I-V curve and the electrical parameters has been done according to clause 11.6 of the IEC 61215-1-1:2016.

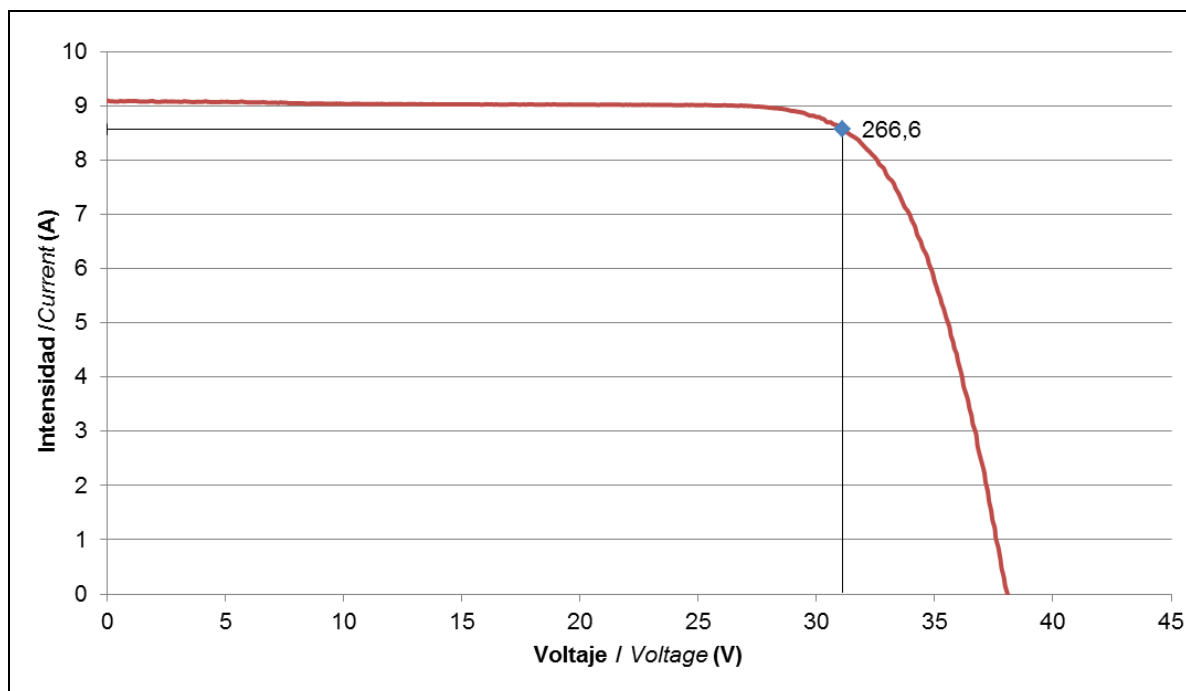
All values from I-V curves have been measured at conditions very similar to the Standard Test Conditions (STC: Module temperature 25 °C, Solar irradiance 1000 W/m<sup>2</sup> and spectral distribution AM1.5G). The values presented correspond to the data corrected to STC.

The short-circuit current temperature coefficient ( $\alpha$ ) and the open-circuit voltage coefficient ( $\beta$ ) used in the corrections have been taken from the manufacturer data sheet.

The modules have not been preconditioned before the I-V curve measurement.

| TEST PARAMETERS |                                     |                                     |
|-----------------|-------------------------------------|-------------------------------------|
| Model           | Temperature coefficient of $I_{SC}$ | Temperature coefficient of $V_{OC}$ |
| HS270PB-AN1     | 1.8 mA/°C                           | -118.7 mV/°C                        |

| TEST RESULT                    |                   |                 |                 |                 |                 |                |
|--------------------------------|-------------------|-----------------|-----------------|-----------------|-----------------|----------------|
| TEST NUMBER                    | $P_{MAX}$         | $I_{SC}$        | $V_{OC}$        | $I_{MP}$        | $V_{MP}$        | FF             |
| 21.3568.1-002-MQT06.1FCEM-R001 | 266.6 W<br>±2.5 % | 9.09 A<br>±2.1% | 38.1 V<br>±1.0% | 8.57 A<br>±2.2% | 31.1 V<br>±1.6% | 77.1%<br>±0.6% |



## 2.3.- INTERPOLATION OF CELL TEMPERATURE AT STANDARD STAGNATION TEMPERATURE

After the thermal stagnation test performed, the final open circuit voltage of the module at the end of the test was 32.45 V at an ambient temperature of 26.5°C and an irradiance of 996 W/m<sup>2</sup>.

Following the method described at IEC60904-5, using the value of the open circuit voltage thermal coefficient that is, after the manufacturer specification sheet, -118.7 mV/°C. The equivalent cell temperature of the module is 74.7°C.

According to temperature test for PV modules and a reference ambient temperature of 40°C, the estimated cell temperature for this ambient temperature is **89.2°C**.

## 2.4.- CONCLUSIONS

The main purpose of this test is to verify in a quick and easy way if the PV module used in the PV collector will achieve a temperature higher than the recommended by PV module manufacturer when is working at the worst operation condition of the PVT collector.

According to the test results, the estimated maximum temperature is close to the standard upper limits (typically 90°C, but depends of manufacturer specification) of a commercial PV module, therefore a complete requalification of the module would not be necessary according to the IEC61215 and IEC61730 standards.

Besides this verification, CENER will need to do a complete study of the tests and documentation in order to qualify the PVT collector according to the IEC61215 and IEC61730 standards. This study will be based on the retesting guidelines published by IECEE for PV modules.

The main modifications detected from the standard PV module to the PVT collector are:

- The inclusion of metallic profiles in contact with the frame of PV modules: in this circumstance, the verification of the continuous electrical path between all the accessible conductive parts is mandatory. Therefore, the Ground continuity test MST 13 described in the IEC61730-2:2004 is mandatory.
- The inclusion of a metal absorber and the thermal insulation foil in the PVT modifies the thermal behavior of the PV module, therefore the safety tests related with the risk of fire described in the IEC61730-2:2004 shall be performed. These tests are:
  - MST21 Temperature test.
  - MST22 Hot-spot endurance test
  - MST23 Fire test<sup>1</sup>
  - MST26 Reverse current overload test.

The following documentation shall be mandatory:

- Qualification certificates of the PV module according to IEC61215:2005 and IEC61730:2004 (or EN61730:2004).
- Qualification test reports (or at least the test reports identification) according to IEC61215:2005 and IEC61730:2004.
- Installation Manual of the PV module.
- Installation Manual of the PV collector.
- Bill Of Materials (BOM) of the hybrid collector, including the PV module manufacturer, drawings and material and datasheet of each component.
- Any other documentation that could be required by the testing lab or the certification body.

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<sup>1</sup> This test is only mandatory if the module is qualified according the IEC61730 (international standard). In case that the qualification of the PV module is according to EN61730-2 (European standard) the test is not necessary. CENER does not perform this test and it shall be subcontracted.