

REPORT No. 056269-004-4

CUSTOMER	ONYX SOLAR ENERGY, S.L.
APPLICANT	TEODOSIO DEL CAÑO
ADDRESS	C/ RIO CEA 1-46 05004 ÁVILA (SPAIN)
PURPOSE	SUPERVISION OF TEST OF PEEL STRENGTH
MATERIAL TESTED	LAMINATED GLASS REF. «Ionoplast interlayer» REF. «Ethylene-vinyl acetate interlayer EVA» REF. «Polyvinyl butyral interlayer PVB»
TEST DATE	10.05.2016
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* The results of this report solely and exclusively concern the material tested at the time and under the conditions in which the measurements were taken.
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1. PURPOSE

This document resumes the procedures and results obtained at the test carried out for determining the peel strength of the interlayer from glass at ONYX SOLAR ENERGY, S.L. site in Ávila (Spain), conducted under the supervision of TECNALIA.

The final proposal was for Tecnalía to verify compliance of test carried out as an internal method for determining the peel strength of the interlayer.

The test was performed on 10th May 2016.

This test report has been elaborated by request of the company ONYX SOLAR ENERGY, S.L.

The contact person has been Mr. Teodosio del Caño.

2. CHARACTERISTICS OF THE TEST SPECIMENS

The reference laminated glass constructions are made of:

- Two sheets of toughened glass of 8 mm, two layers of ionoplast interlayer of 0.89 mm and photovoltaic silicon float glass of 3.2 mm
- Two sheets of toughened glass of 6 mm and one layer of ethylene-vinyl acetate interlayer EVA of 0.45 mm
- Two sheets of toughened glass of 6 mm and one layer of polyvinyl butyral interlayer PVB of 0.76 mm.

The company ONYX SOLAR ENERGY, S.L. has prepared three test specimens of laminated glass measuring 360 mm x 360 mm and referred to as:

«Ionoplast interlayer»

«Ethylene-vinyl acetate interlayer EVA»

«Polyvinyl butyral interlayer PVB»

The test specimens are produced in normal production under consistent controlled conditions.

To have test specimens available in which the interlayer is only glued to one of the glass panes using aluminium film as a separator.

The test specimen of laminated glass ref. «Ionoplast interlayer» setup consists of:

- ✓ Upper pane: Toughened float glass of 8 mm
- ✓ Interlayer: Ionoplast interlayer of 0.89 mm
- ✓ Aluminium film
- ✓ Inner pane: Photovoltaic silicon float glass of 3.2 mm
- ✓ Aluminium film
- ✓ Interlayer: Ionoplast interlayer of 0.89 mm
- ✓ Lower pane: Toughened float glass of 8 mm

The test specimen of laminated glass ref. «Ethylene-vinyl acetate interlayer EVA» setup consists of:

- ✓ Upper pane: Toughened float glass of 6 mm
- ✓ Aluminium film
- ✓ Interlayer: Ethylene-vinyl acetate interlayer EVA of 0.45 mm
- ✓ Lower pane: Toughened float glass of 6 mm

The test specimen of laminated glass ref. «Polyvinyl butyral interlayer PVB» setup consists of:

- ✓ Upper pane: Toughened float glass of 6 mm
- ✓ Aluminium film
- ✓ Interlayer: Polyvinyl butyral interlayer PVB of 0.76 mm
- ✓ Lower pane: Toughened float glass of 6 mm

The customer has provided this information.

3. TEST REQUESTED

The work requested is **the supervision** of the test carried out for determining the **peel strength** of the interlayer from glass.

The peel strength is defined as the average load per unit width of bond line required to separate progressively the interlayer from the glass at a separation angle of approximately 180°.

4. TEST EQUIPMENT

The equipment required for carrying out the test is the following:

- Hand force gauge
- Grip
- Ruler
- Cutter



Picture 1: Hand force gauge and grip

5. TEST SEQUENCE

Once the test specimens have been prepared under normal conditions and they have reached room temperature, separate the laminated glass pack so that the test is carried out on the toughened glass pane, interlayer and aluminium film.



Grey - Aluminium film

White - Interlayer

Green – Toughened glass pane

It is possible to place a piece of aluminium film over the edge beforehand in order to fasten the grip; otherwise the edge of the interlayer should be lifted using the cutter.



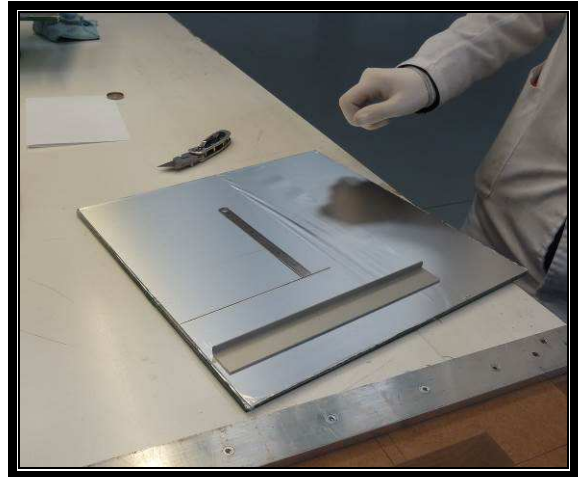
Picture 2: Edge of interlayer with aluminium film on both sides

The test sequence is the next one:

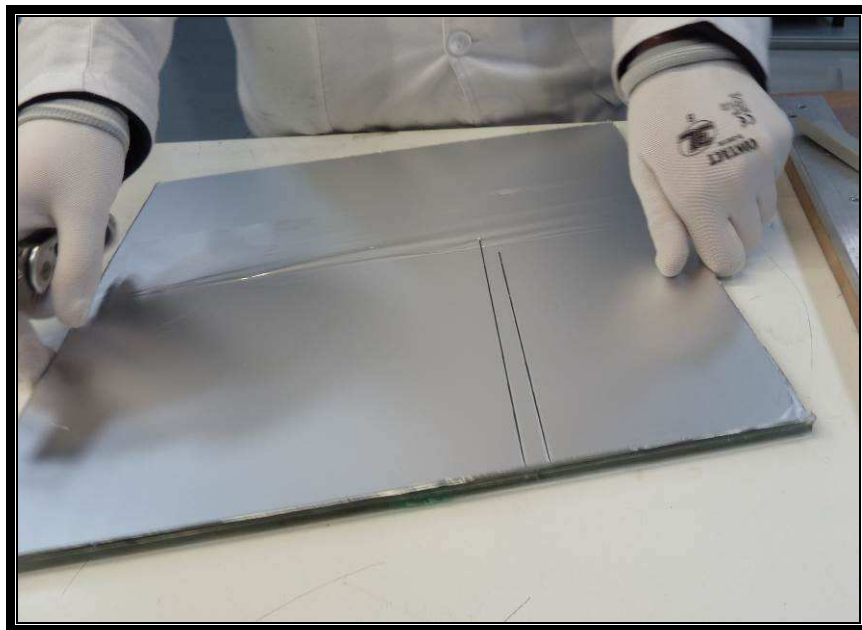
- Cut a 1 cm wide strip from the interlayer and aluminium film with a cutter so that there is no adhesion on the sides of the strip.



Picture 3: Cutting process of the 1 cm strip



Picture 4: Cut of one of the sides of the 1 cm strip



Picture 5: 1 cm strip

- Fasten the grip firmly to the end. If a piece of aluminium film has previously been placed on the edge, fasten the grip to this area. Otherwise lift the edge of the interlayer using the cutter in order to fasten it to the grip.

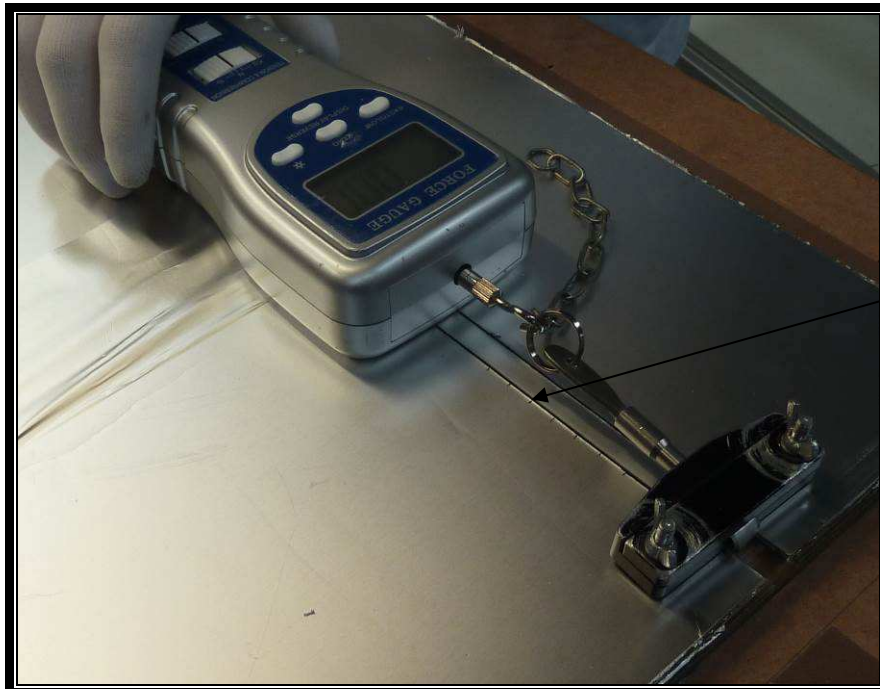


Picture 6: Strip lifted



Picture 7: Grip fastened to the strip

- Mark it as an initial area from where the interlayer is fastened to the glass and mark the aluminium film every 1 cm. Then place the hand force gauge holding the grip tightly.



Picture 8: Marks every 1 cm and force gauge in place

- Start to pull the interlayer continuously with an angle of 180° to separate it from the glass lengthways over a distance of 1 cm and make a note of the maximum force exerted to separate a surface area of 1 cm² of interlayer from the glass.



Picture 9: Taking off process

- Repeat this process a minimum of 5 times obtaining the peel strength value in N/cm. For the peel strength end value, calculate the average of the measurements is taken.

The **assessment criterion** is a minimum value of peel strength for each interlayer.

For ionoplast interlayer the minimum value of peel strength is **45 N/cm**, for ethylene-vinyl acetate interlayer **53 N/cm** and for polyvinyl butyral interlayer **35 N/cm**.

Annex A includes the internal procedure of ONYX SOLAR ENERGY, S.L. for this test.

6. TEST CARRIED OUT

On 10th May 2016 three test specimens of laminated glass was tested. In the case of ionoplast interlayer, both the interlayer in contact with the upper glass pane and that in contact with the lower glass pane were tested.

The sequence described in the above section was carried out without deviation in the case of the upper glass pane of the ionoplast interlayer, the ethylene-vinyl acetate interlayer and the polyvinyl butyral interlayer.

Conversely on the lower glass pane of the ionoplast interlayer, the interlayer broke when pulled without peeling away from the glass. The maximum force exerted to the interlayer to break it was recorded.

7. TEST RESULTS

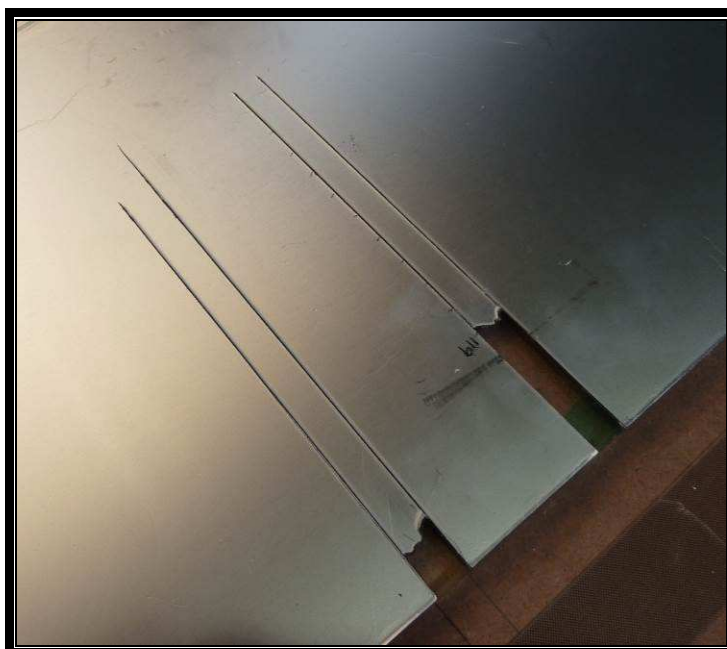
The values supported by each one of the interlayers are listed in the following table:

Type		Peel strength N/cm							Average peel strength N/cm
Ionoplast interlayer	Upper pane	67	69	71	94	74	74	-	72
	Lower pane	119	-	-	-	-	-	-	>119
Ethylene-vinyl acetate interlayer		58	58	59	61	64	66	-	61
Polyvinyl butyral interlayer		47	55	52	56	50	56	53	53

The following photographs show the status of each one of the glass panes after the test.



Picture 10: Final status of the upper pane of the ionoplast interlayer.



Picture 11: Final status of the lower pane of the ionoplast interlayer.




Picture 12: Final status of the ethylene-vinyl acetate interlayer.



Picture 13: Final status of the polyvinyl butyral interlayer.

All of the interlayers **comply** with the requirements determine in the internal procedure of ONYX SOLAR ENERGY, S.L.

ANNEX A: INTERNAL PROCEDURE

	ADHESIÓN AL VIDRIO 180º PEEL TEST	Fecha:	04/16
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MANUAL DE INSTRUCCIONES DE TRABAJO			

1. OBJETIVO.

El objetivo del ensayo es conocer la adhesión al vidrio de los distintos encapsulantes usados en el proceso.

Se ha propuesto como límite aceptable del proceso, los siguientes valores mínimos de adhesión:

EVA	N/cm	53	Lb/inch	30
IONOMERO	N/cm	45	Lb/inch	25.69
PVB	N/cm	35	Lb/inch	20,0


2. MATERIALES

- ✚ Vidrios muestra.
- ✚ Encapsulante (EVA, PVB, IONÓMERO...).
- ✚ Alcohol Isopropílico.
- ✚ Papel aluminio.
- ✚ Cutter
- ✚ Regla
- ✚ Dinamómetro.

3. PROCEDIMIENTO.

- ✚ Limpiar la cara del vidrio con alcohol isopropílico y secar con papel.
- ✚ Colocar el encapsulante encima.
- ✚ Colocar un pliego de papel de aluminio encima con el objeto de no permitir que el encapsulante no se adhiera al vidrio superior.
- ✚ Colocar, un vidrio, del mismo espesor que el anterior.
- ✚ Sujetar con cinta ambos vidrios.
- ✚ Introducir en laminador colocando una membrana encima.

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	ADHESIÓN AL VIDRIO 180° PEEL TEST	Fecha:	04/16
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MANUAL DE INSTRUCCIONES DE TRABAJO			

- ✚ Laminar con el mismo ciclo de laminación que se utilice en producción.
- ✚ Dejar enfriar el laminado.



- ✚ Una vez frío quitar el vidrio de encima y proceder a realizar el peel test.
- ✚ Cortar sobre la muestra, una tira de 1cm de ancho.




- ✚ Sobre la tira hacer marcas a 1 cm.



- ✚ Sujetar la muestra con las pinzas del dinamómetro.



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MANUAL DE INSTRUCCIONES DE TRABAJO			

✚ Encender el dinamómetro en la posición N/cm.



✚ Hacer el cero en el dinamómetro.

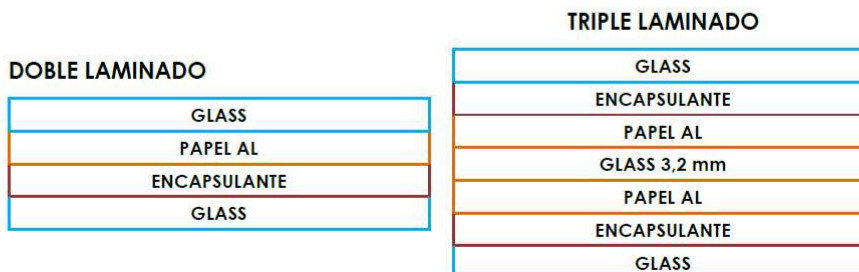


✚ Tirar de manera constante a 180° anotando la media de los valores cada 1 cm.

✚ Los resultados se reflejaran en la hoja de registro.

NOTA: En el caso de triples laminados se introducirá un vidrio front envuelto en papel de aluminio en el interior del material encapsulante y se medirá la adhesión en el vidrio superior y en el inferior.

En el siguiente esquema se resume la preparación de las muestras.



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