

SAND Calorimeter DUNE

F. Raffaelli

Calorimeter module refurbishing .

Steps envisage to consolidate the calorimeter modules:

- Removing the outside tape and cleaning (in Progress).
- A visual inspection (report).
- Measure the calorimeter modules.(Laser Tracker Done)
- Preparation of the outer surfaces to improve the adhesivity.
- Mechanical test on test specimens on tape and on glue (infiltration Glue done).
- Qualified the consolidation method.
- Module repair procedures (tooling necessary).
- Define the qualification Test on a repaired modules.
- We need to get an approval of the Fermilab safety office on the qualification process of repaired modules.
- We need to evaluate if we need to increase the calorimeter radii.

The study of the calorimeter refurbishing is in progress.

- Choice of glue to consolidate the modules (done).
- A test stand has been made to test various solutions (done).
- Wrapping with tape test (done).
- Gluing Stainless steel sheet 0.4 mm thick (soon).

EA 9483 Loctite Henkel

Glue to consolidate the modules (done).

We contact major glue Producer (3M, Henkel, Giba) asking advice for our purposes.

We choose a glue with low viscosity that have a set time large 2h at room temperature. The Glue is optical grade. We test mechanically on the lead material.

Polimerizzato per 5giorni a 22 °C.		
Forza a taglio , ISO 4587:		
Acciaio dolce (sabbiato)	N/mm ²	23
	(psi)	(3 300)
Alluminio (abraso)	N/mm ²	10
(Carta in Carburo di Silicio, grit A166, grana P400A)	(psi)	(1 500)
Alluminio (anodizzato)	N/mm ²	21
	(psi)	(3 100)
Acciaio inox	N/mm ²	10
	(psi)	(1 500)
Polycarbonato	N/mm ²	3,3
	(psi)	(480)
Nylon	N/mm ²	2,4
	(psi)	(350)
Legno (Fir)	N/mm ²	12
	(psi)	(1 800)
ABS	N/mm ²	4
	(psi)	(580)
Vetroresina (Matrice in resina di poliestere)	N/mm ²	2
	(psi)	(290)
Epossidica rinforzata con fibra di vetro	N/mm ²	13
	(psi)	(1 900)
Carico rottura a trazione , ISO 6922:		
Cilindretto in acciaio dolce incollato di testa (sabbiato) su vetro sodico	N/mm ²	13
	(psi)	(1 900)
Resistenza a pelatura 180°, ISO 8510-2:		
Acciaio dolce (sabbiato)	N/mm	1,5
	(piw)	(8,6)

Bulk properties

PROPRIETA' TIPICHE DEL PRODOTTO POLIMERIZZATO

campioni con spessore 4 mm polimerizzati per 7giorni a 22 °C

Proprietà fisiche:

Coefficiente di espansione termica, ISO 11359-1, K⁻¹:

Range di temperatura 20 °C su 45 °C 50×10⁻⁶

Range di temperatura: 55 °C su 200 °C 164×10⁻⁶

campioni con spessore 1,2 mm polimerizzati per 7giorni a 22 °C

Proprietà fisiche:

Coefficiente di conducibilità termica, ISO 8302, 0,3

W/(m·K)

Durezza Shore , ISO 868, Durometro D, ISO 868 65

Temperatura di transizione vetrosa ASTM E 1640, 61 °C

Elongazione , ISO 527-3,% 3,2

Resistenza a trazione, ISO 527-3 N/mm² 47

(psi) (6 800)

Modulo a trazione , ISO 527-3 N/mm² 2 100

(psi) (300 000)

Resistenza a compressione, ISO 604 N/mm² 78

(psi) (11 000)

Proprietà elettriche:

Capacità dielettrica, IEC 60243-1, kV/mm 30

Volume resistività, IEC 60093, Ω·cm 7×10¹⁸

Resistività superficiale, IEC 60093, Ω 4×10¹⁵

Costante dielettrica / Fattore di dissipazione, IEC 60250:

1 kHz 4,3 / 0,01

1 MHz 3,7 / 0,05

10 MHz 3,5 / 0,05

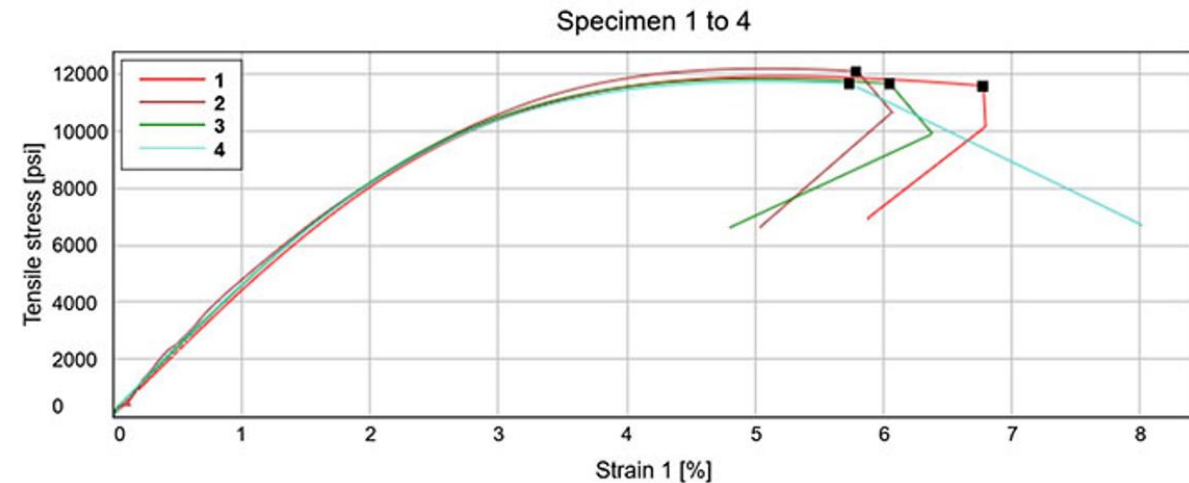
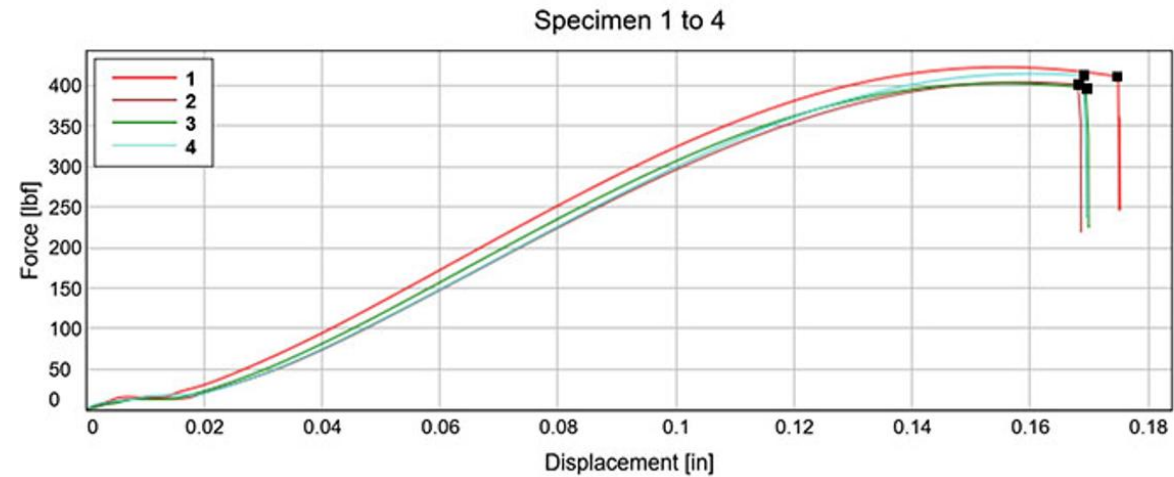
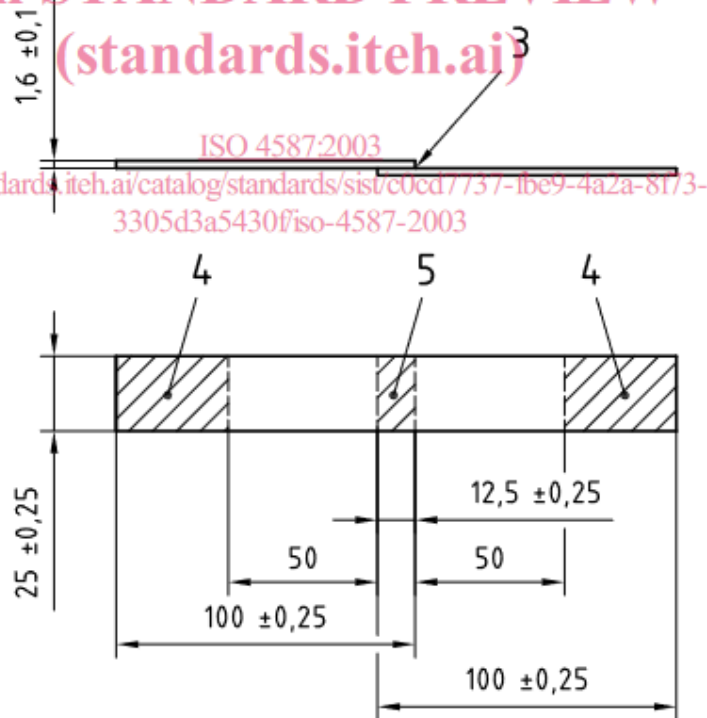
Average value of the shear strength 4.6 N/mm²

Graph 1: Force vs. Displacement

Single lap shear test
ISO 4587-2003

Standard test panel

iTeh STANDARD PREVIEW
(standards.iteh.ai)



Average value of the shear strength 5 N/mm²

Shear Glue Joint test on the Infiltration glue Optical grade



ASTM D638 - 14 Standard

Single lap shear test
ISO 4587-2003



Supporto: tessuto di vetro/alluminio
Adesivo: silconico

Resistente ad altissime temperature 316° C

Prodotto	SAP ID	Colore	Dimensioni	Spessore totale nastro
	7000001165	argento brillante	25mm x 33m	0.15mm
	7000028867	argento brillante	50mm x 33m	0.15mm
	7100140900	argento brillante	450mm x 33m	0.15mm

Adesivo standard da tape è acrilico.

Mercati	Aerospaziale, Automobilistico, Edilizia, Elettrodomestici, Industriale generico, Lavorazione dei metalli, Settore elettronico, Settore militare e pubblica amministrazione, Trasporti, Veicolo speciale
Quantità per confezione	36/case,24/case
Resistenza alla trazione (misure metriche)	57 N/100mm, 2364 N/100mm
Specifiche soddisfatte	ASTM D3330, ASTM D3758, D3652, F.A.R. 25.853(a)
Spessore del supporto (misure metriche)	0.06 mm
Spessore lato posteriore adesivo (misure metriche)	0.1 mm
Spessore totale senza liner (misure metriche)	0.19 mm
Temperatura operativa massima (Celsius)	316 °C
Temperatura operativa minima (Celsius)	-54 °C
Tipo di Adesivo	Silicone
Vita utile	36 Mese

Buongiorno,
facendo seguito alla conversazione telefonica, le inoltro i codici dei prodotti che potreste testare.

890 MSR Scotch

Supporto: poliestere
Adesivo: gomma resina modificata (Hot Melt)

Adesione N/om: B10
Carico di rottura N/om: 1380
Allungamento %: 8

Prodotto	SAP ID	Colore	Dimensioni	Spessore totale nastro
	7000095844	trasparente	25mm x 50m	200µm
	7000035410	trasparente	50mm x 50m	200µm
	7000095843	trasparente	100mm x 50m	200µm

Supporto: tessuto di vetro/alluminio
Adesivo: silconico

Resistente ad altissime temperature 316° C

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	7000001165	argento brillante	25mm x 33m	0.15mm
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3M Science.
Applied to Life.™

We contact major
glue Producer
(3M,Henkel, Giba)
asking advice for our
purposes.

11/10/2025

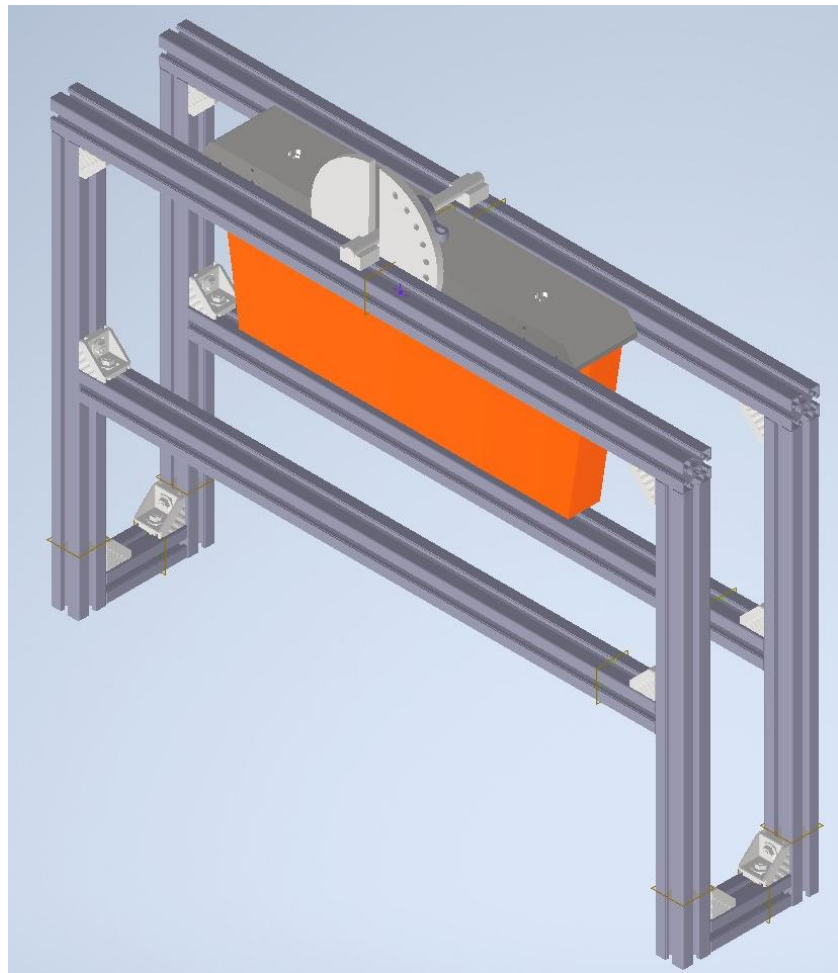


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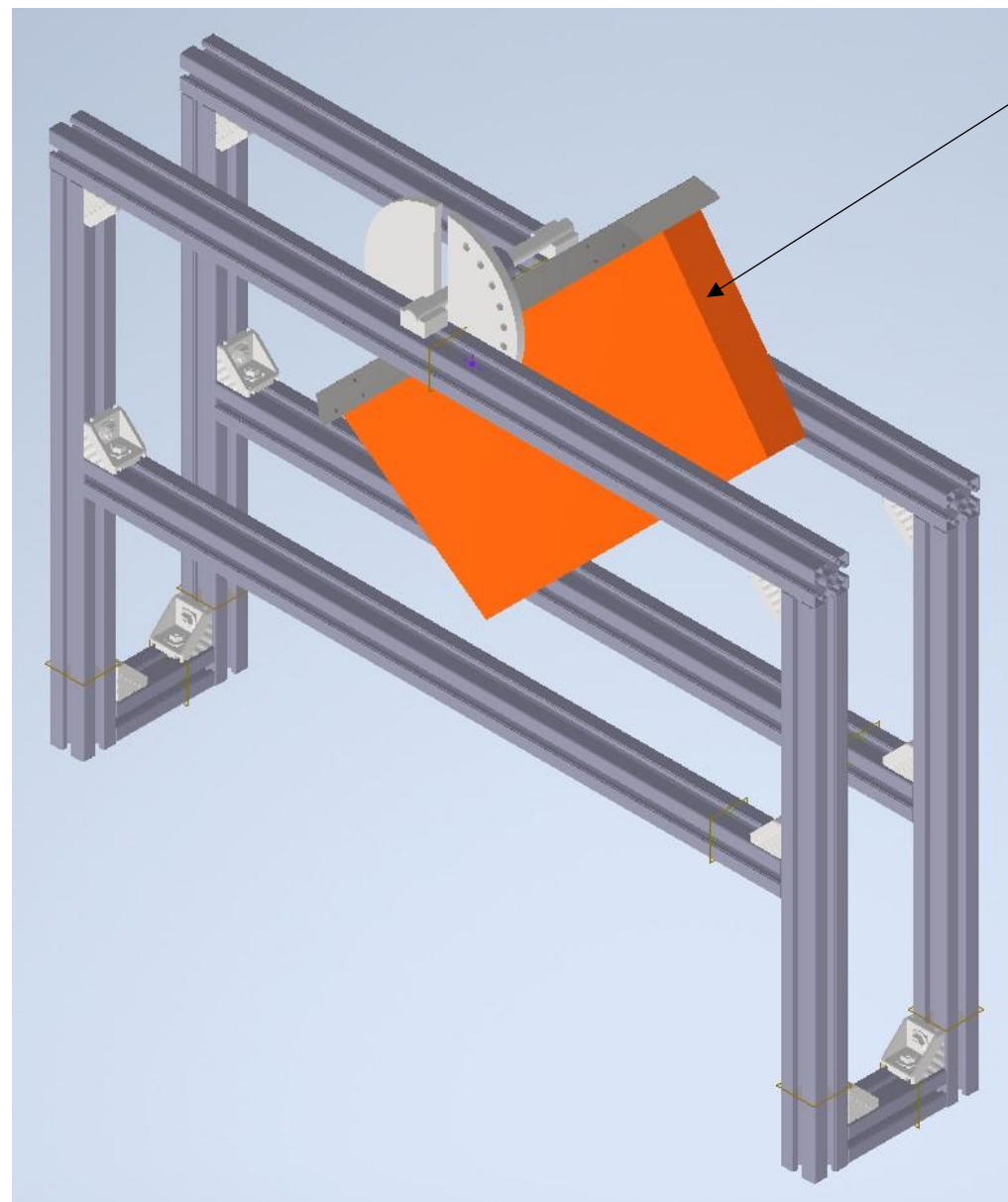
Tapes Test



Rotational stand



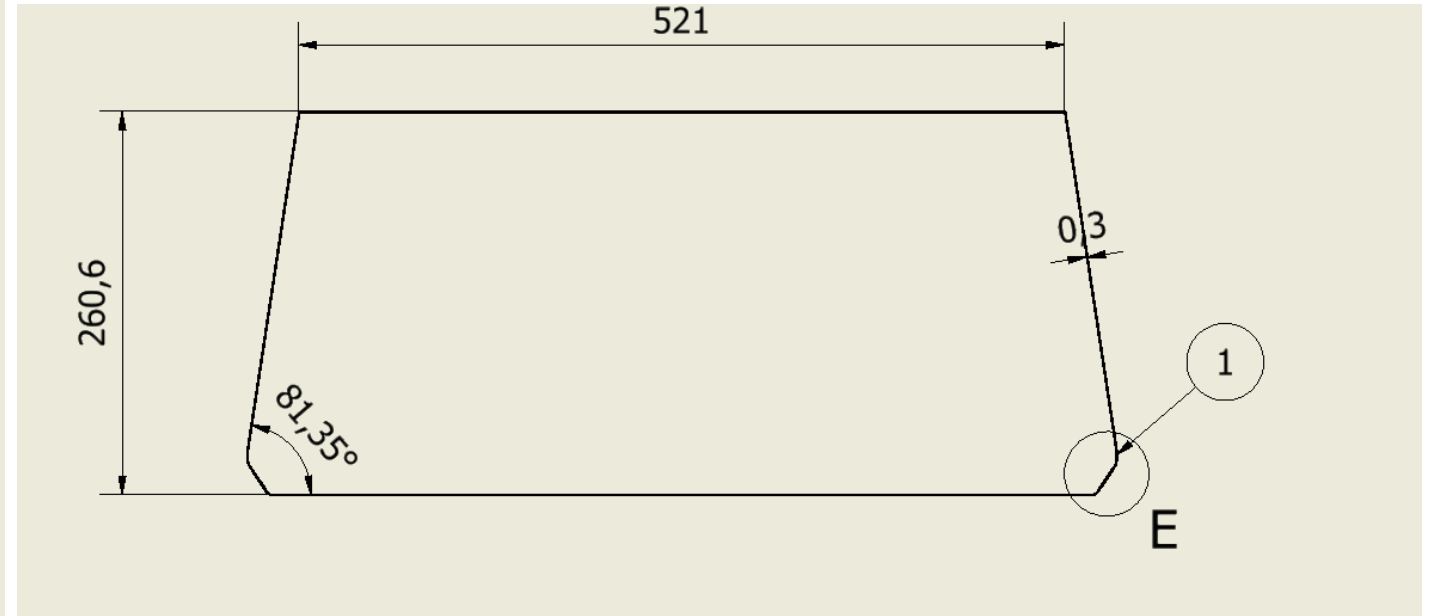
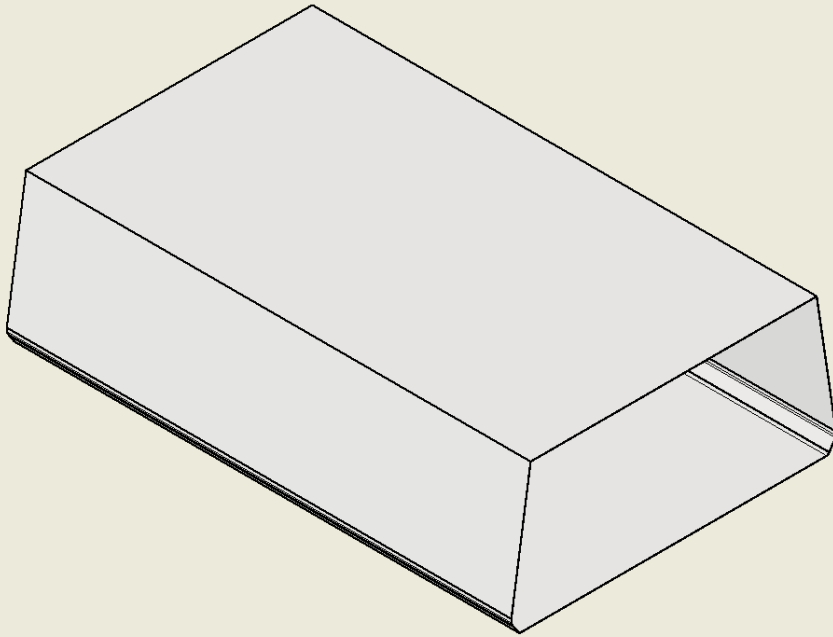
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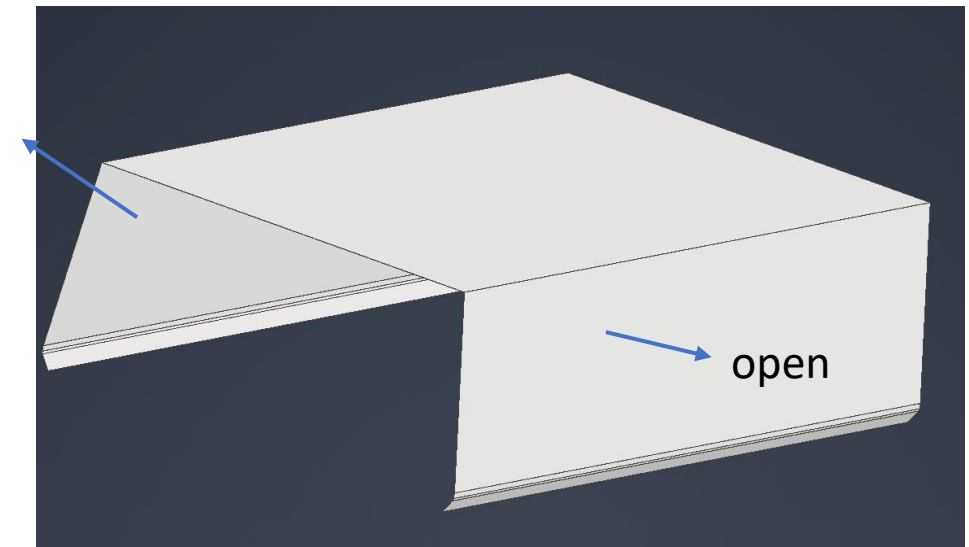
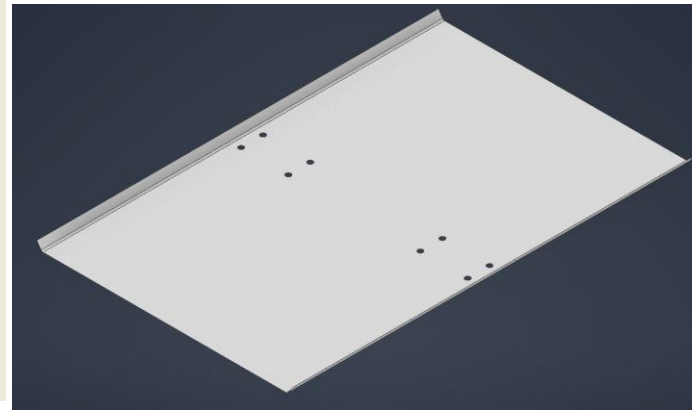
Carbon steel
block density
 7850 kg/m^3
Almost 1.5 time
the calorimeter
density.
(54 kg)

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New metal sheet in construction.



We are thinking to use an elastic bend to glue the Stainless-steel sheet.
We can wrap the sheet around the calorimeter to apply pressure to the
glue joint



Gluing stainless steel 0.4 mm strips with Epoxy Glue 3M 2216.

3M Scotch-Weld™ Epoxy Adhesive 2216 B/A

Technical Data October 2018

Product Description 3M™ Scotch-Weld™ Epoxy Adhesive 2216 B/A is a flexible, two-part, room temperature curing epoxy with high peel and shear strength, available in three versions. 2216 B/A Gray meets DOD-A-82720.

Typical Uncured Physical Properties Note: The following technical information and data should be considered representative or typical only and should not be used for specification purposes.

Product	3M™ Scotch-Weld™ Epoxy Adhesive					
	2216 B/A Gray		2216 B/A Tan NS		2216 B/A Translucent	
	Base	Accelerator	Base	Accelerator	Base	Accelerator
Color:	White	Gray	White	Tan	Translucent	Amber
Base:	Modified Epoxy	Modified Amine	Modified Epoxy	Modified Amine	Modified Epoxy	Modified Amine
Net Wt.: (lb/gal)	11.1-11.6	10.5-11.0	11.1-11.6	10.5-11.0	9.4-9.8	8.0-8.5
Viscosity: (cps) (Approx.) Brookfield RVF #7 sp. @ 20 rpm	75,000 - 150,000	40,000 - 80,000	75,000 - 150,000	550,000 - 900,000	11,000 - 15,000	5,000 - 9,000
Mix Ratio: (by weight)	5 parts	7 parts	5 parts	7 parts	1 part	1 part
Mix Ratio: (by volume)	2 parts	3 parts	2 parts	3 parts	1 part	1 part
Work Life: 100 g Mass @ 75°F (24°C)	90 minutes	90 minutes	120 minutes	120 minutes	120 minutes	120 minutes

- Features
- Excellent for bonding many metals, woods, plastics, rubbers, and masonry products.
 - Base and Accelerator are contrasting colors.
 - Good retention of strength after environmental aging.
 - Resistant to extreme shock, vibration, and flexing.
 - Excellent for cryogenic bonding applications.
 - Excellent for potting parts subject to thermal cycling.
 - The tan NS Adhesive is non-sag for greater bond-line control.
 - The translucent can be injected.
 - Meets DOD-A-82720.

Typical Cured Physical Properties

Product	3M™ Scotch-Weld™ Epoxy Adhesive		
	2216 Gray	2216 Tan NS	2216 Translucent
Color	Gray	Tan	Translucent
Shore D Hardness ASTM D 2240	50-65	65-70	35-50
Time to Handling Strength	8-12 hrs.	8-12 hrs.	12-16 hrs.

Typical Cured Electrical Properties

Product	3M™ Scotch-Weld™ Epoxy Adhesive	
	2216 Gray	2216 Translucent
Arc Resistance	130 seconds	
Dielectric Strength	408 volts/mil	630 volts/mil
Dielectric Constant@ 73°F (23°C)	5.51—Measured @ 1.00 KHz	6.3 @ 1 KHz
Dielectric Constant@ 140°F (60°C)	14.17—Measured @ 1.00 KHz	—
Dissipation Factor 73°F (23°C)	0.112 Measured @ 1.00 KHz	0.119 @ 1 KHz
Dissipation Factor 140°F (60°C)	0.422—Measured @ 1.00 KHz	—
Surface Resistivity @ 73°F (23°C)	5.5 x 10 ¹⁶ ohm—@ 500 volts DC	—
Volume Resistivity @ 73°F (23°C)	1.9 x 10 ¹² ohm-cm—@ 500 volts DC	3.0 x 10 ¹² ohm-cm @ 500 volts DC

Typical Cured Thermal Properties

Product	3M™ Scotch-Weld™ Epoxy Adhesive	
	2216 Gray	2216 Translucent
Thermal Conductivity	0.228 Btu-ft/ft ² h°F	0.114 Btu-ft/ft ² h°F
Coefficient of Thermal Expansion	102 x 10 ⁻⁶ in/in/°C between 0-40°C 134 x 10 ⁻⁶ in/in/°C between 40-80°C	81 x 10 ⁻⁶ in/in/°C between -50-0°C 207 x 10 ⁻⁶ in/in/°C between 60-150°C

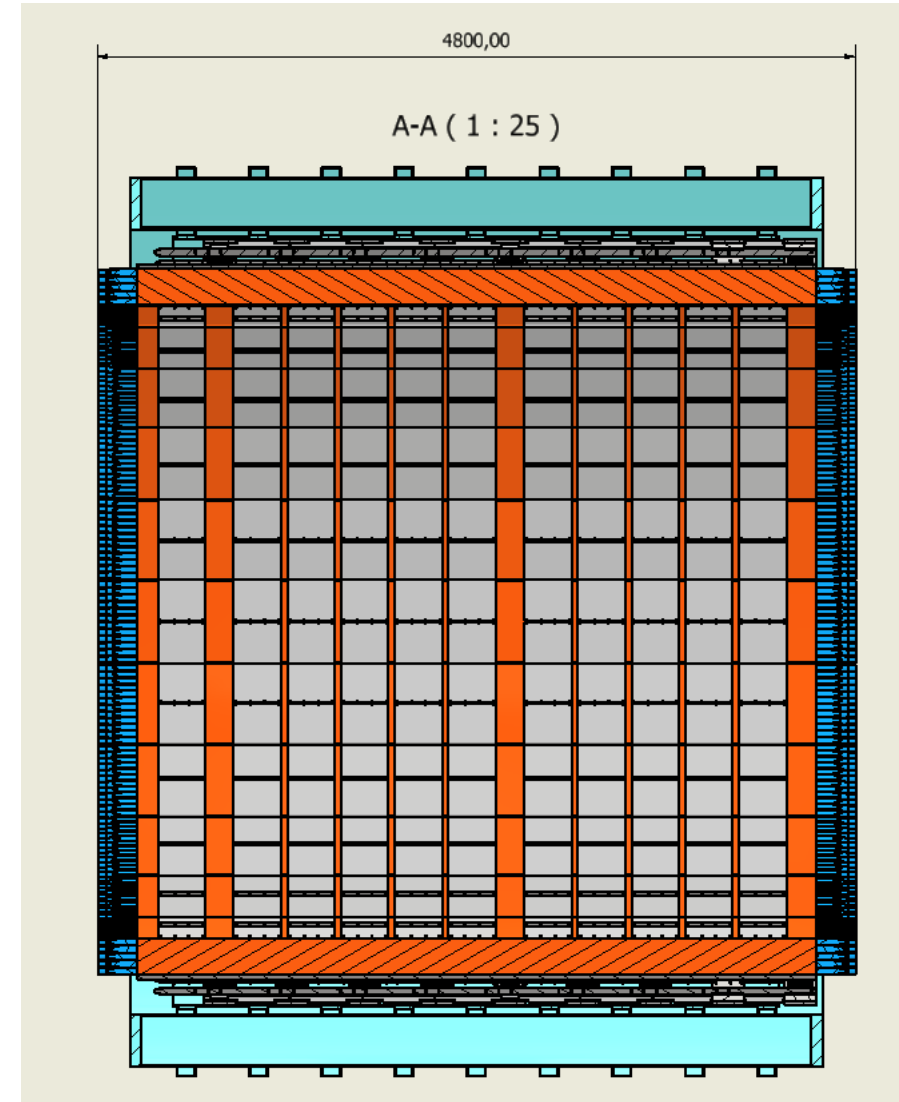
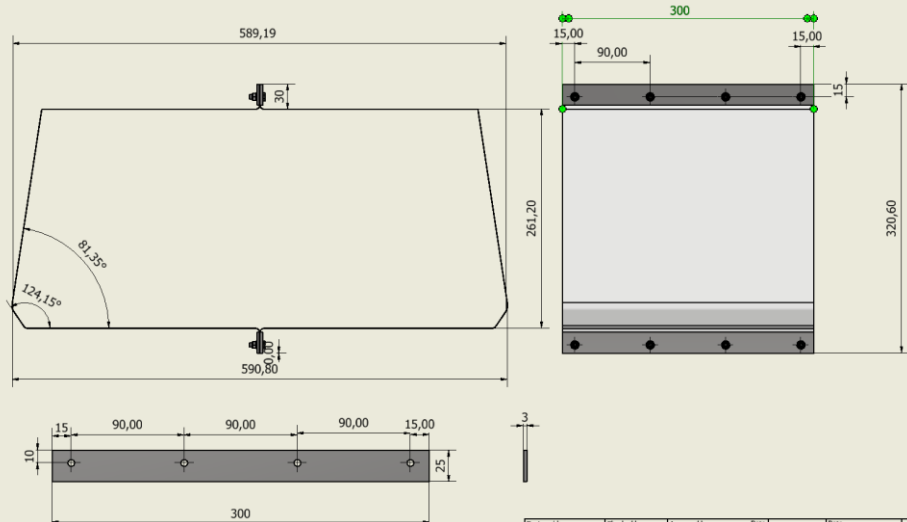
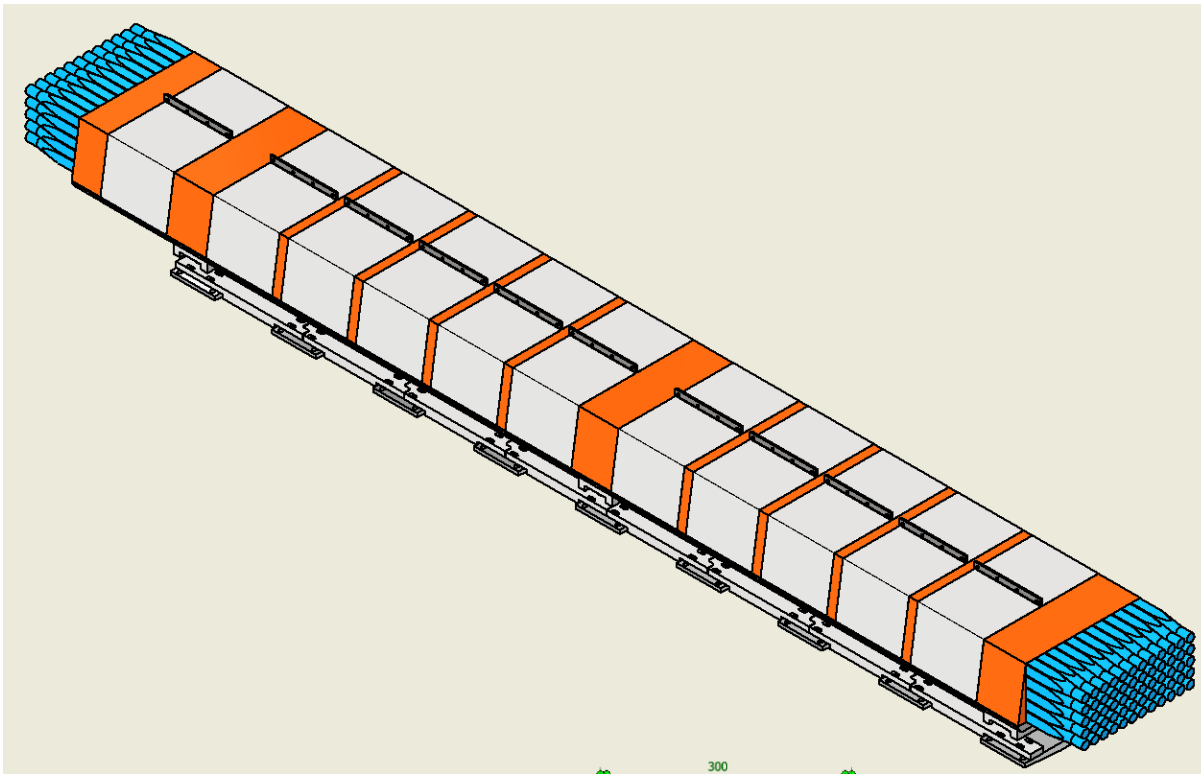
Typical Cured Outgassing Properties

Outgassing Data NASA 1124 Revision 4

3M™ Scotch-Weld™ Epoxy Adhesive 2216 Gray	% TML	% CVCM	% Wtr
	.77	.04	.23

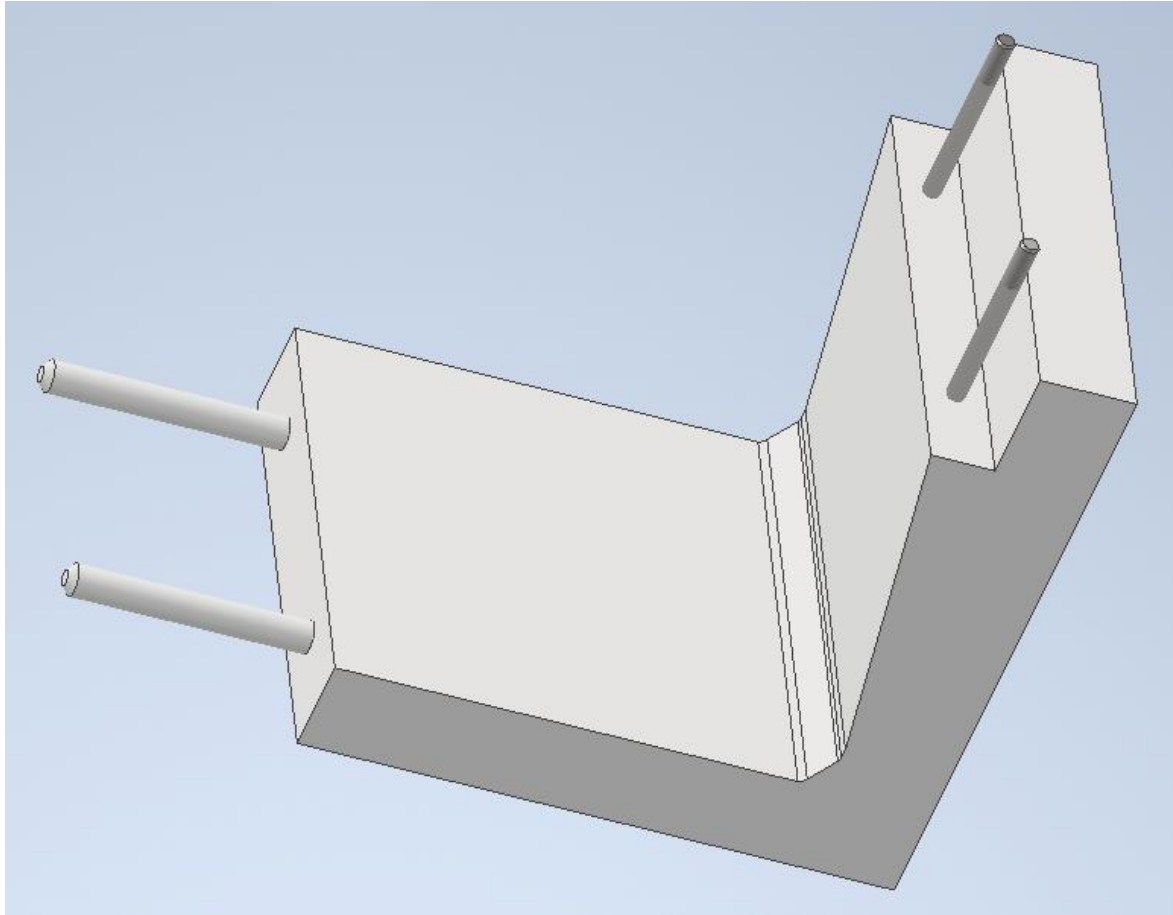
Cured in air for 7 days @ 77°F (25°C).

We have two hours to made the glue joint after the glue has been prepared

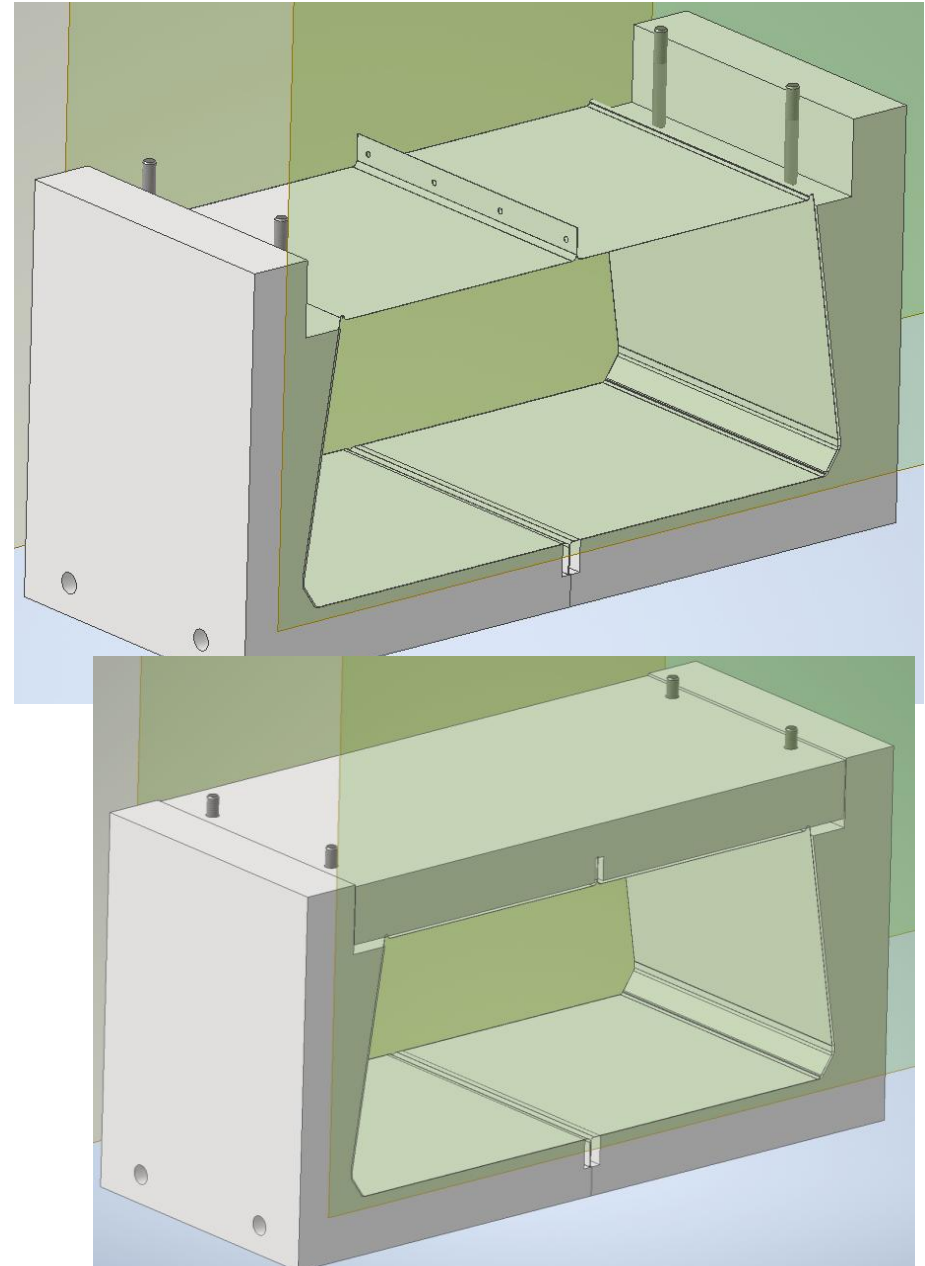


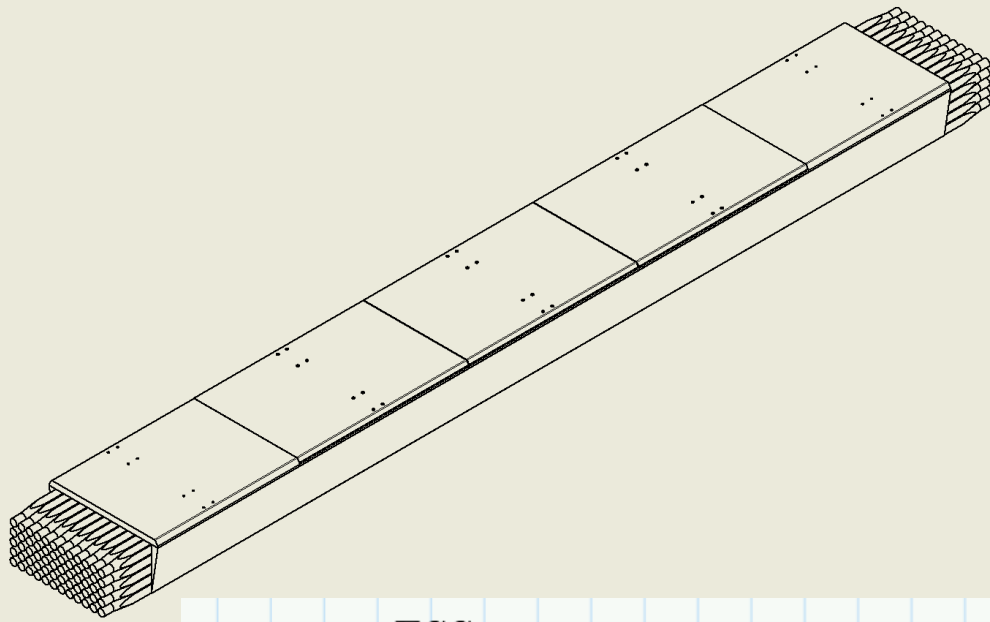
Gluing stainless steel 0.4 mm strips with Epoxy Glue 3M 2216.

Gluing feature in three parts. Two lateral molds and one top part.



Gluing stainless steel 0.4 mm strips with Epoxy Glue 3M 2216.

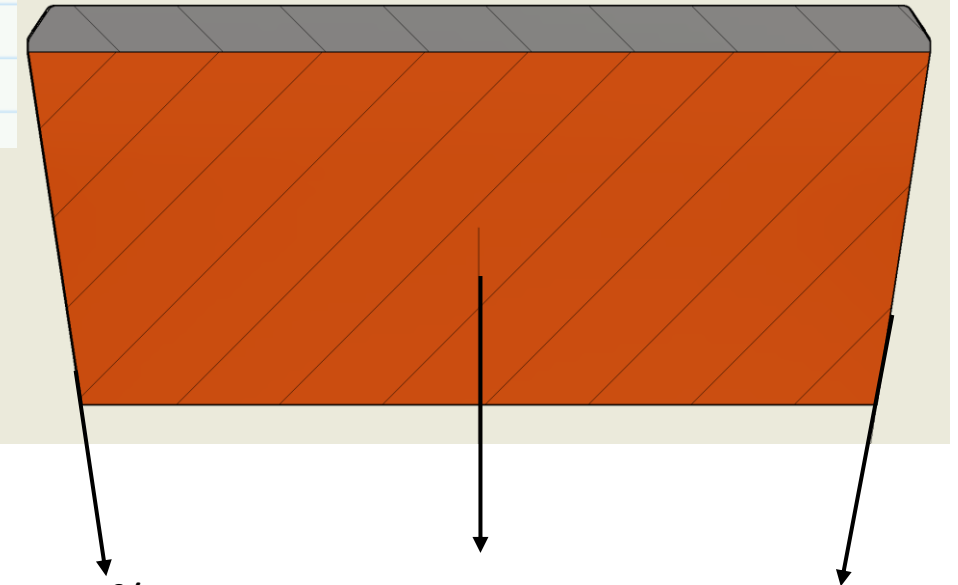




$$\tau_{con} = 0.115 \frac{N}{mm^2}$$

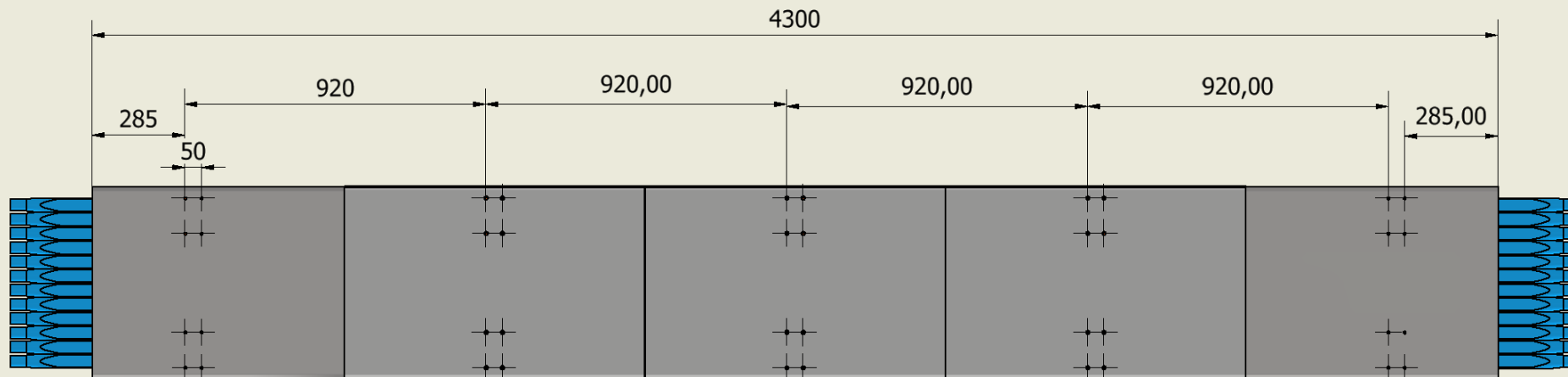
$$\sigma_{ss} := \frac{F_{ss}}{Th_{ss} \cdot Lu}$$

$$\sigma_{ss} = 11.607 \text{ MPa}$$

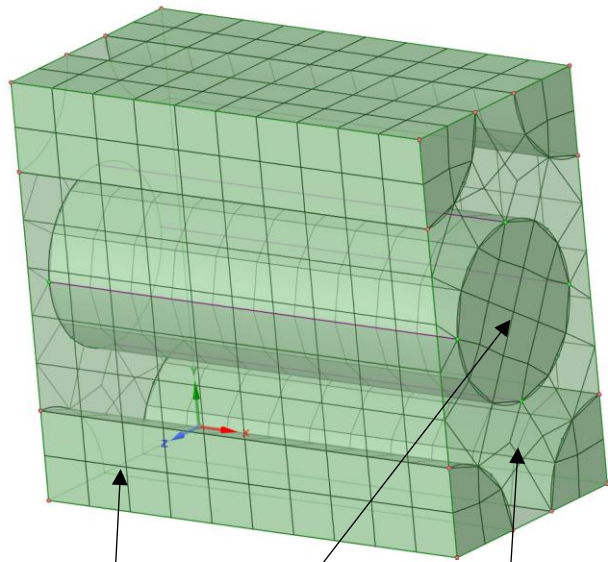


$$F_s = 0.355 \text{ Tonnef/metro}$$

$$F = 0.74 \text{ tonnef /metro}$$

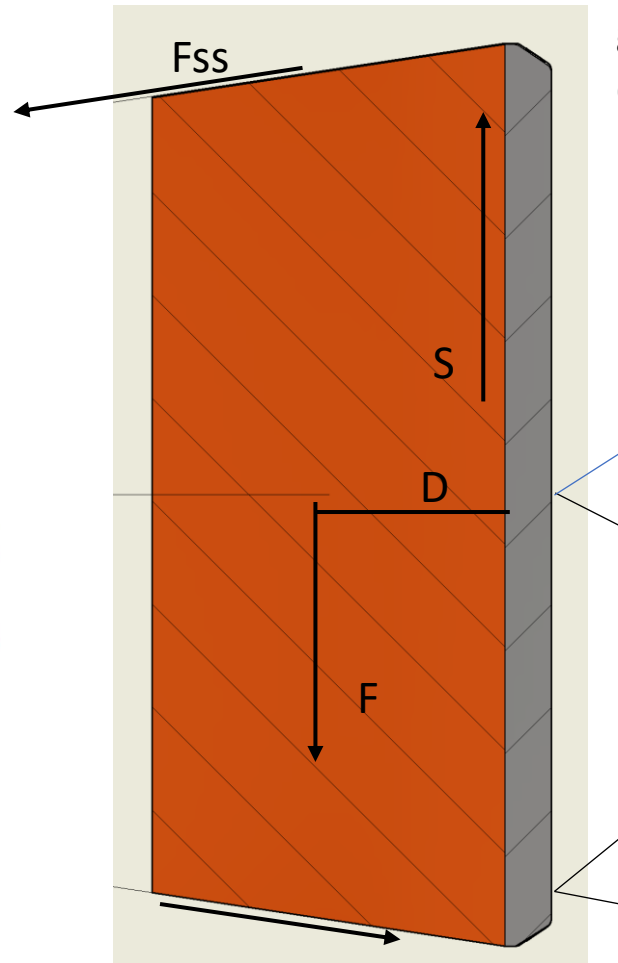


In this configuration there are not problem on the SS sheet and Glue joint



Fibers

Lead

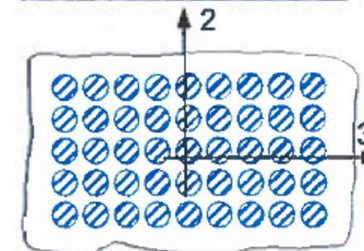
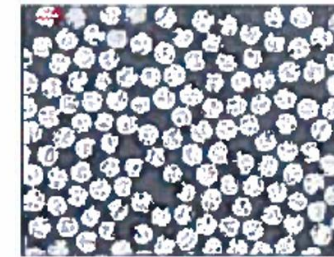


It is progress a simulation of calorimeter module with the glued SS sheet. The connection between the aluminum plate can be frictionless or with a given friction coefficient.

Horizontal module

Momentum is in equilibrium with the compression and traction on the SS sheet
 $M = D \cdot F_{ss}$

Rules of Mixture, Halpin-Tsai Equations

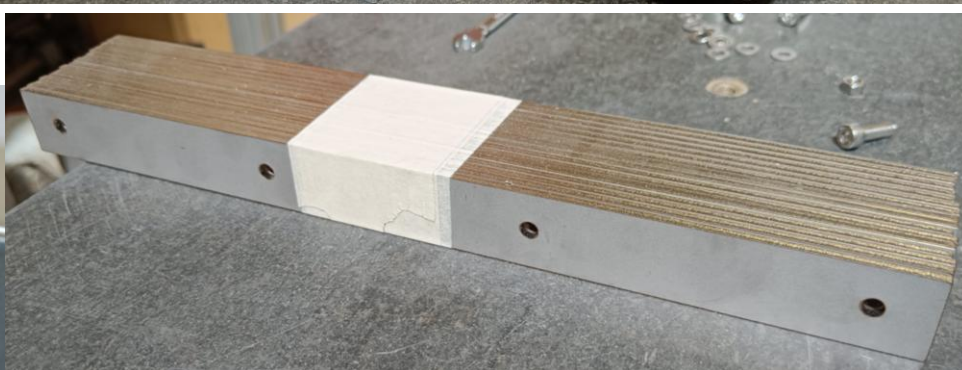
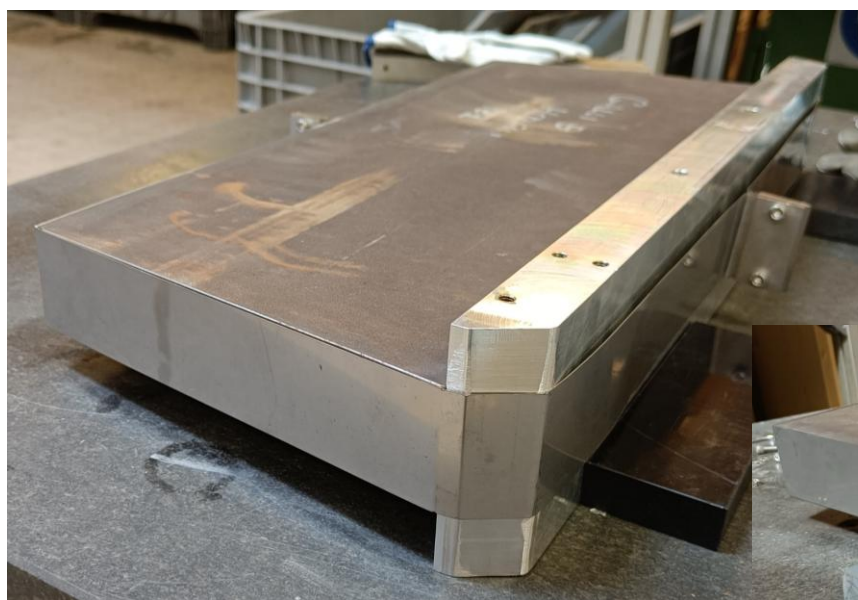


$$\frac{E_2}{E_m} = \frac{1 + \eta \cdot \xi \cdot V_f}{1 - \eta \cdot V_f}$$

$$\eta = \frac{\frac{E_f}{E_m} - 1}{\frac{E_f}{E_m} + \xi}$$

$$\xi = 2$$

Using the micromechanical formula, we can evaluate the orthotropic characteristic that can be used on a FEM model



11/10/2025

S. Mamaeli F.Raffaelli

Conclusions.

- Next step it is to glue on the small calorimeter mockup.
- We can try the steel sheet on the module zero.
- We must develop a comp to distribute the right amount of glue.