

Anti fire protection for :

- Galley
- Air passenger compartment
- Panels in cargo hold
- Panels for ULD



## "8th European Workshop on

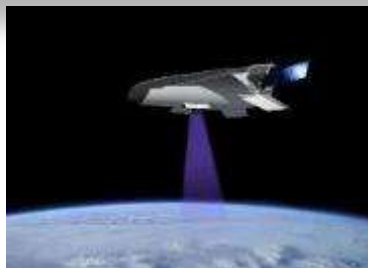
## Thermal Protection Systems and Hot Structures

19 - 22 April 2016

ESA-ESTEC, Noordwijk, The Netherlands + updated with some  
DGA (Delgation Generale de l'Armement) study results

Inexpensive, fast, green and easy to build

**TOUGH CERAM**® for TPS & nozzle



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## RAW MATERIALS reinforcing agents

PATENTED TOUGH CERAM ® macro reinforcing fibers can be :

- a. Glass fibers ,
- b. Silica fiber ,
- c. Quartz fiber ,
- d. Carbon fiber ,
- e. Basalt fibers ,
- f. Silicon carbide fiber ,
- g. Ceramic fiber ,
- h. Zirconium fibers
- i. Polysilazanes fibers

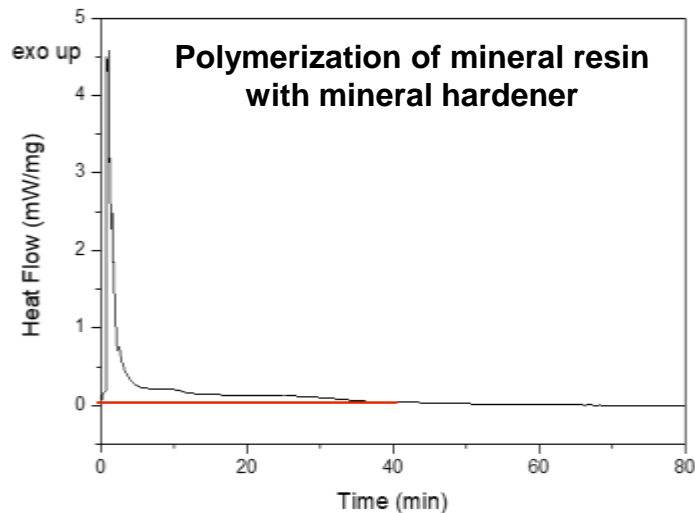
PATENTED TOUGH CERAM ® reinforcing and interlocking micro particles aggregate can be any dendritic material as:

- a. Metallic oxides ,
- b. Metalloid oxides (silica , boron etc)
- c. Nonmetal (carbon black)

TOUGH CERAM in DSC measurement.

Like in the case of organic polymerization;

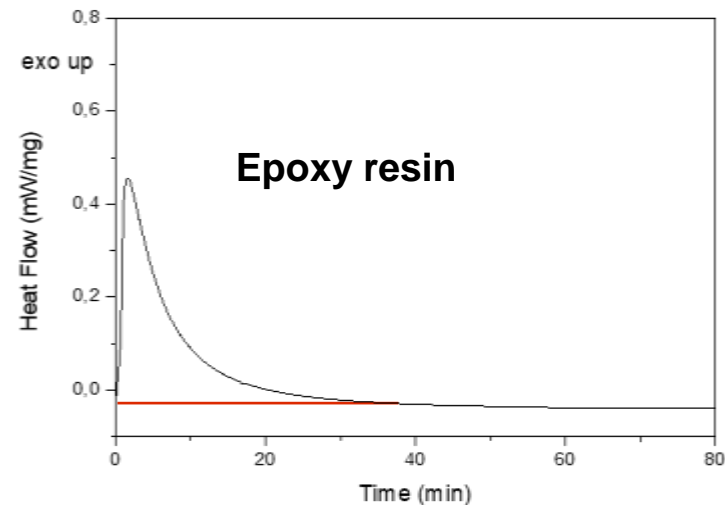
We observe an exothermal pick after 5 minutes of polymerization, and after 40 minutes à 60°C the material is fully polymerized & is perfectly stable,



**Isotherm - @ 60°C**

TOUGH CERAM polycristalization is complete after 40 min at 60°C

Enthalpy: 314 J/g

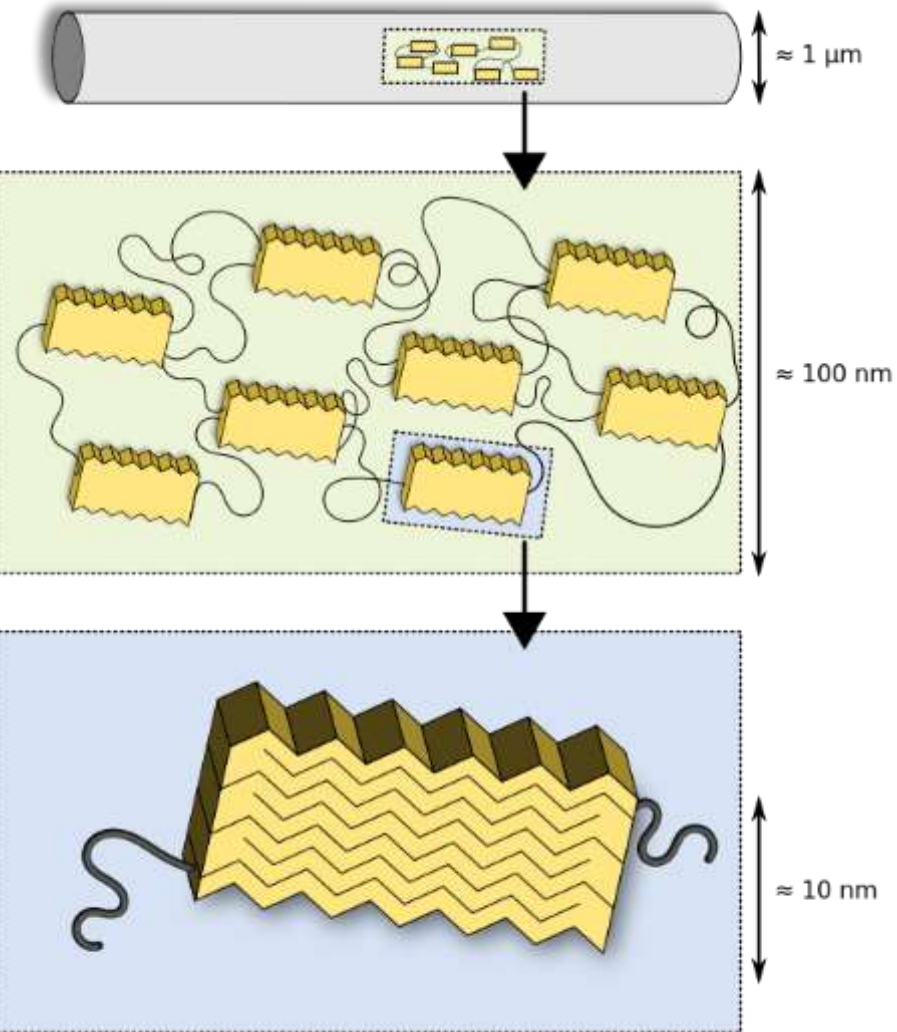


**Isotherm - @ 190°C**

Reticulation is complete after 35 min at 190°C

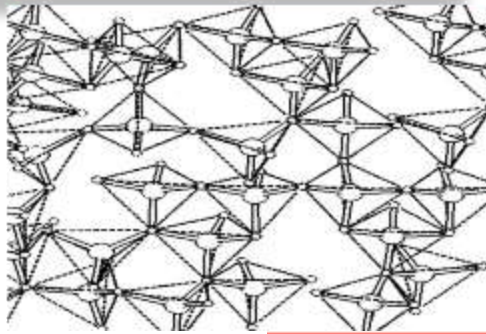
Enthalpy: 338 J/g

## Principle of **TOUGH CERAM**® flexibilized:



The spider  
Toughening strategy

**TOUGH CERAM**®  
polymerized ceramic domain

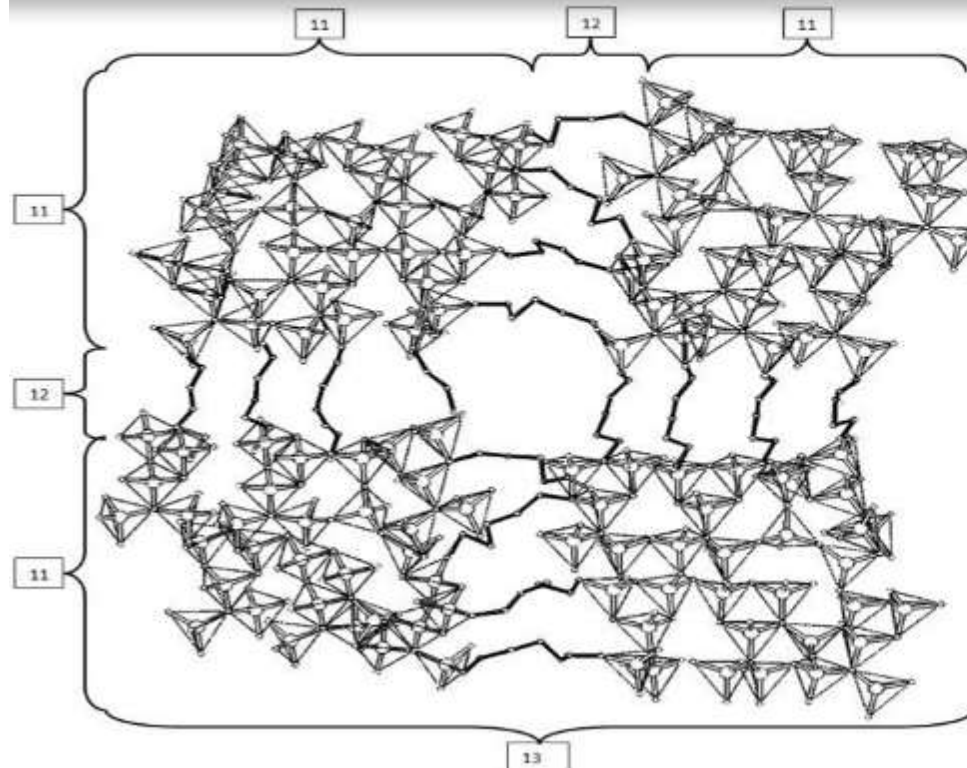


## Flexible molecules

Typical mechanical properties

Tensile stress	11 N/mm <sup>2</sup>
Elongation at break	100-1100%
Maximum operating temperature	+300 °C
Minimum operating temperature	-120 °C

## Flexibilized TOUGH CERAM® polymerized



Benefit are high :  
Springiness  
Toughness  
Damage tolerance

12= flexible molecules  
11= ceramic domain

**UNIQUE DESING !**

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**TOUGH CERAM ®**

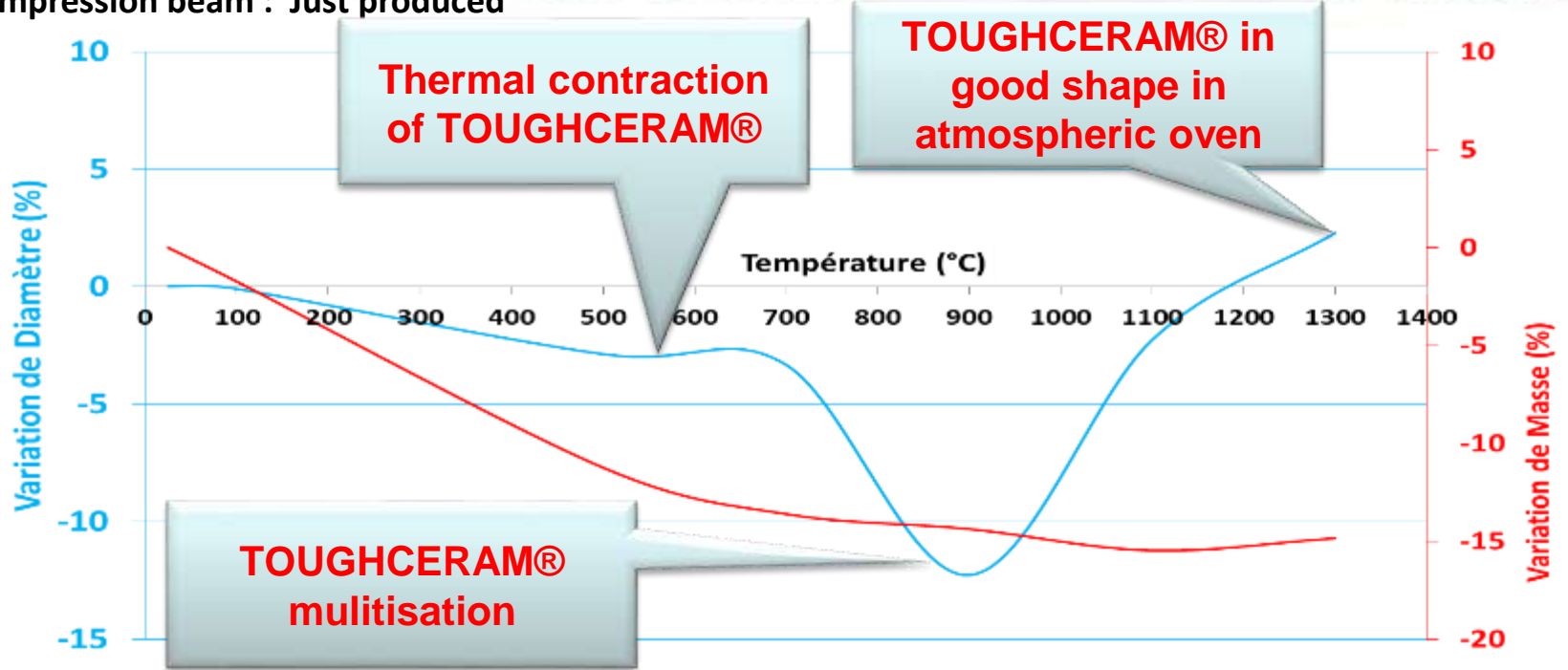
**Unique mechanical properties**

Normalized Beam 15 diam\*30 high mm



RECHERCHE - DÉVELOPPEMENT - INGENIERIE - DESIGN

<= Compression beam : Just produced



	STRESS MPa maximum	Modulus Gpa	DL/L à 50MPa %	DL/L Max %
JUST PRODUCED	79	9,1	0,56	1,03
AFTER 1 HOUR AT 650°C	78	8,8	0,55	0,93

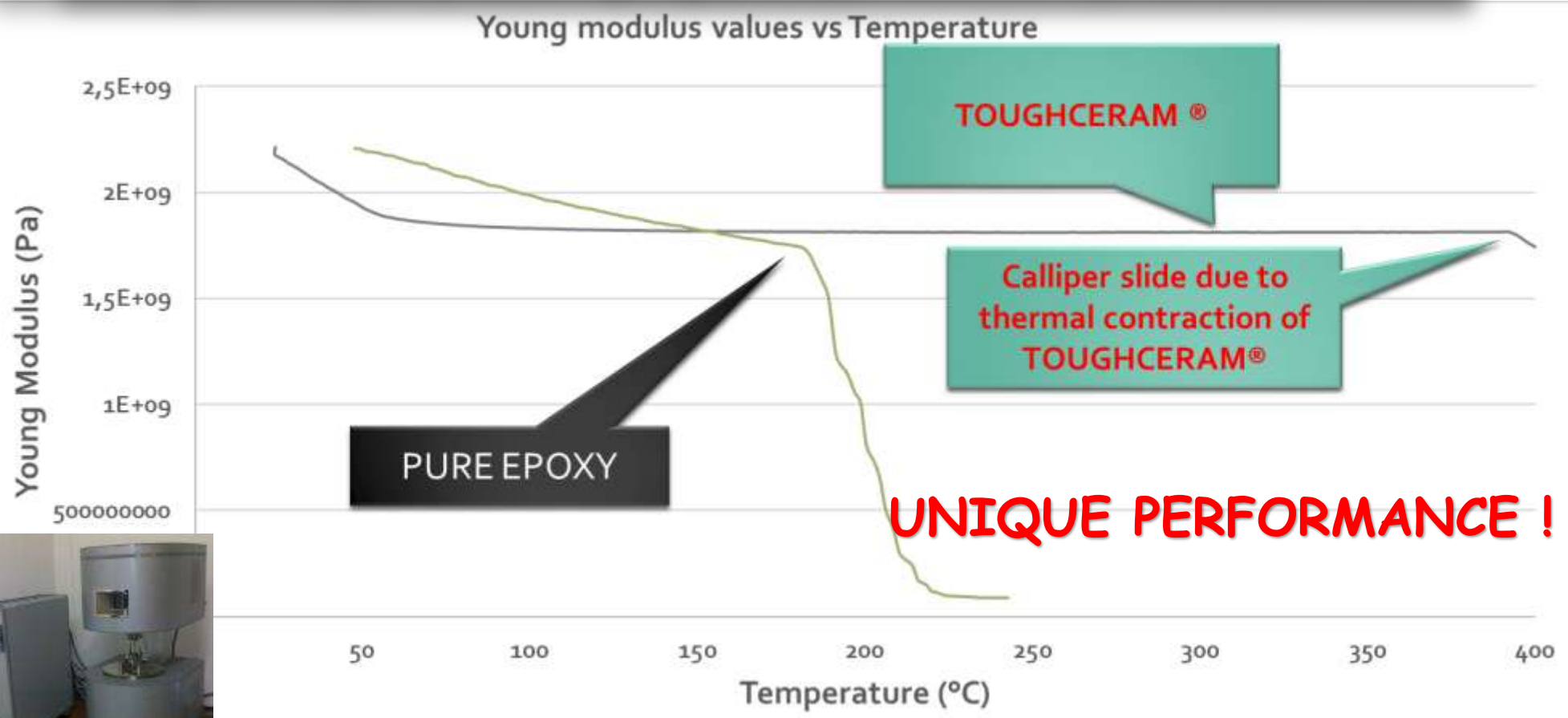
<= Compression beam : after 1 hour at 650°C

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DMA "traction-compression" test :  
**TOUGH CERAM<sup>®</sup> + basalt fibers** give good mechanical properties

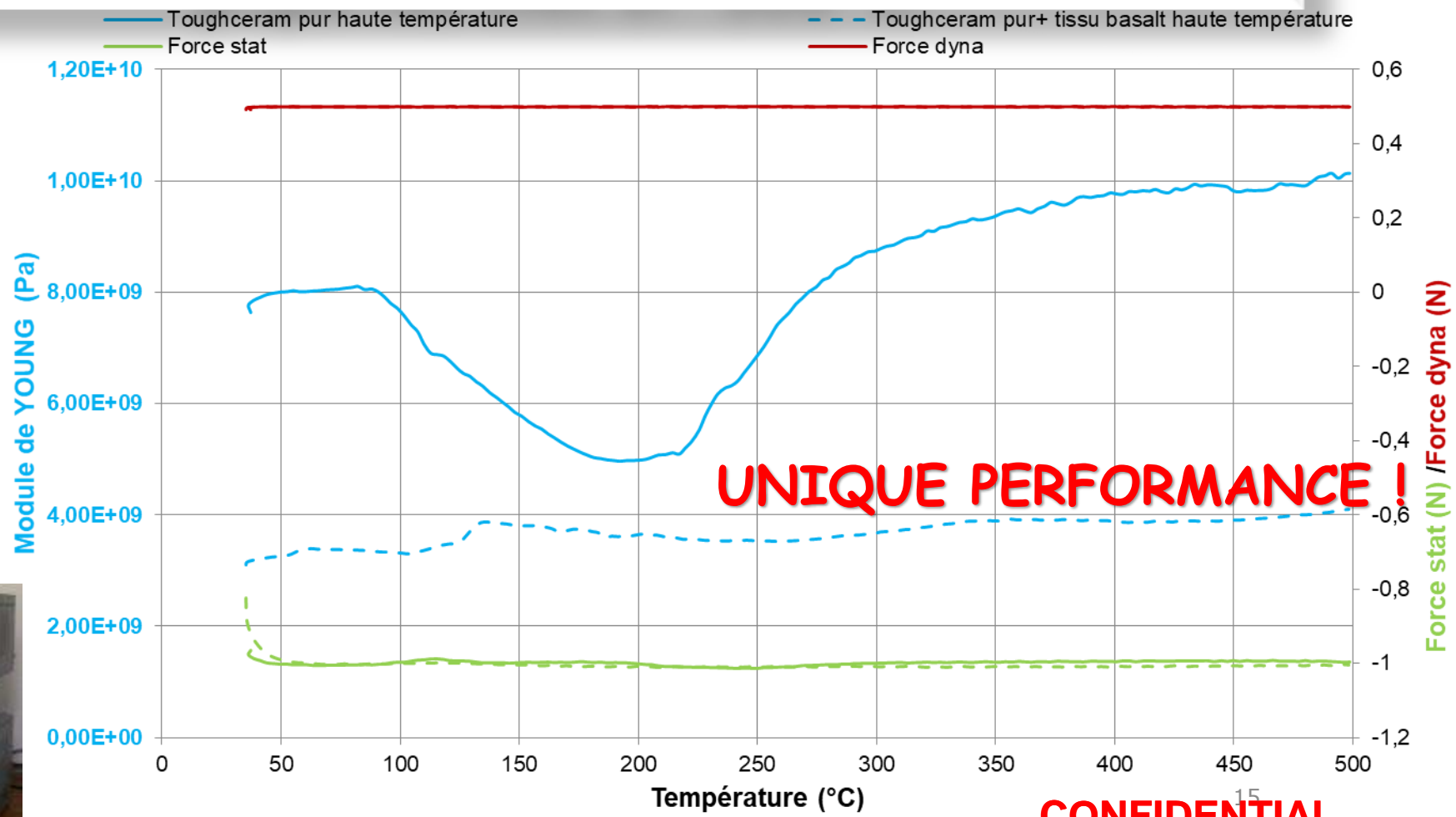


**UNIQUE PERFORMANCE !**





DMA 3 points test : TOUGH CERAM<sup>®</sup> and TOUGH CERAM<sup>®</sup>+basalt fibers give good mechanical properties even at 500°C!



**UNIQUE PERFORMANCE !**

500°C = Maximum temperature of this DMA



Ultimate 3 points test

3 points bending test bed =>

Samples after test



Epoxy + Basalt fabric

Tougheram + Basalt fabric

Tougheram + Glass fabric

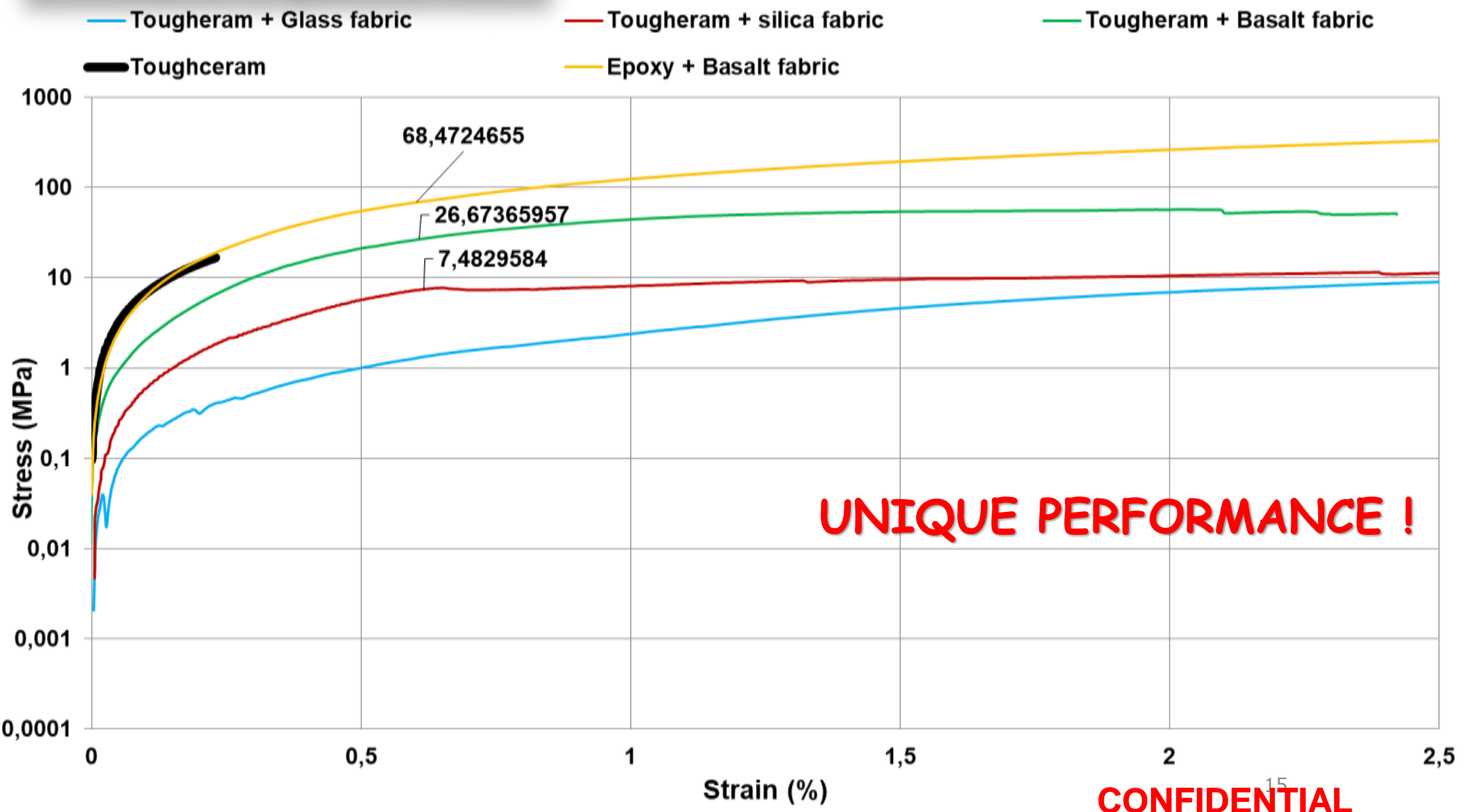
Tougheram + silica fabric

Toughceram



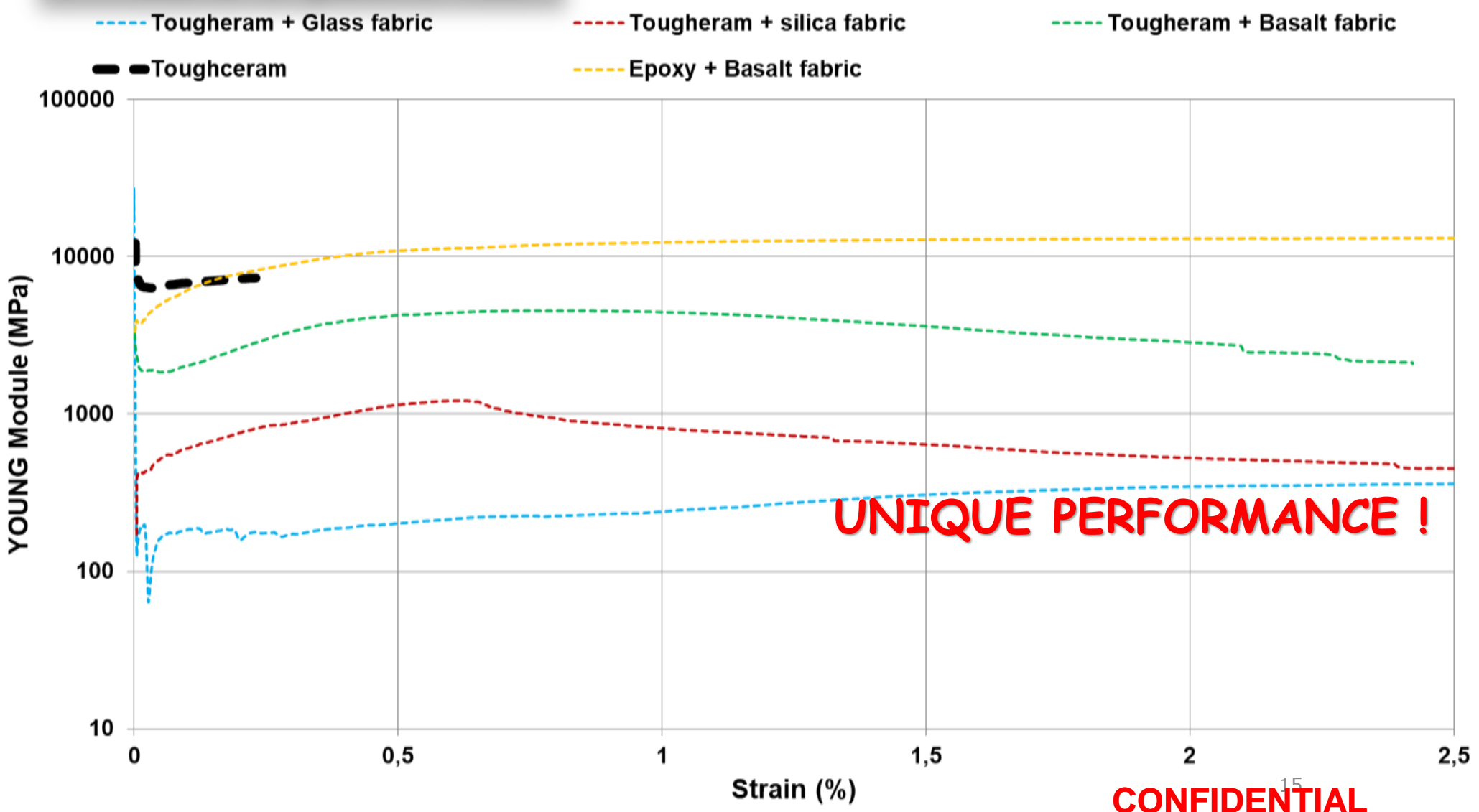


## Ultimate 3 points test





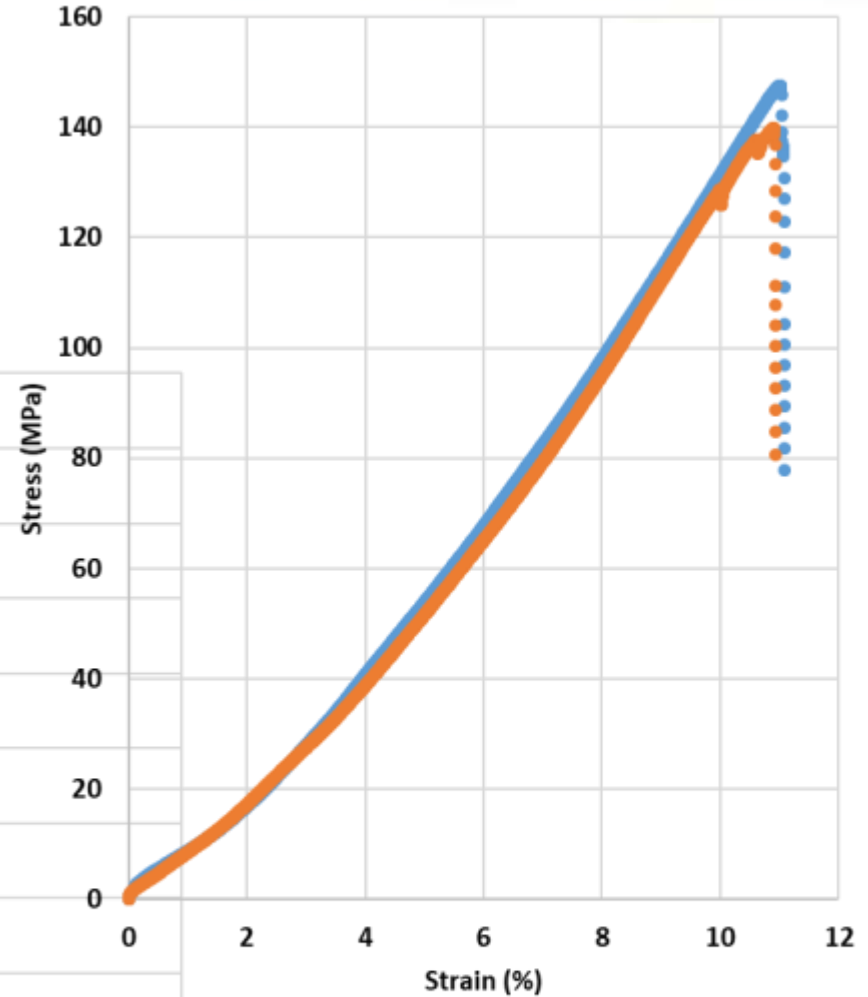
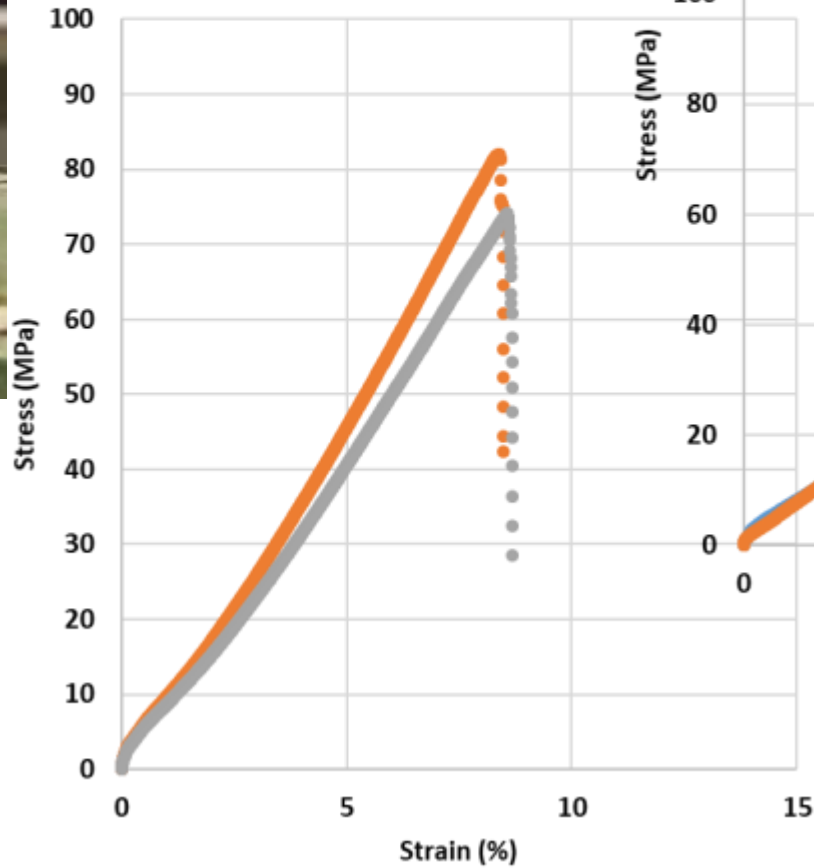
## Ultimate 3 points test





## TOUGH CERAM® tensile test

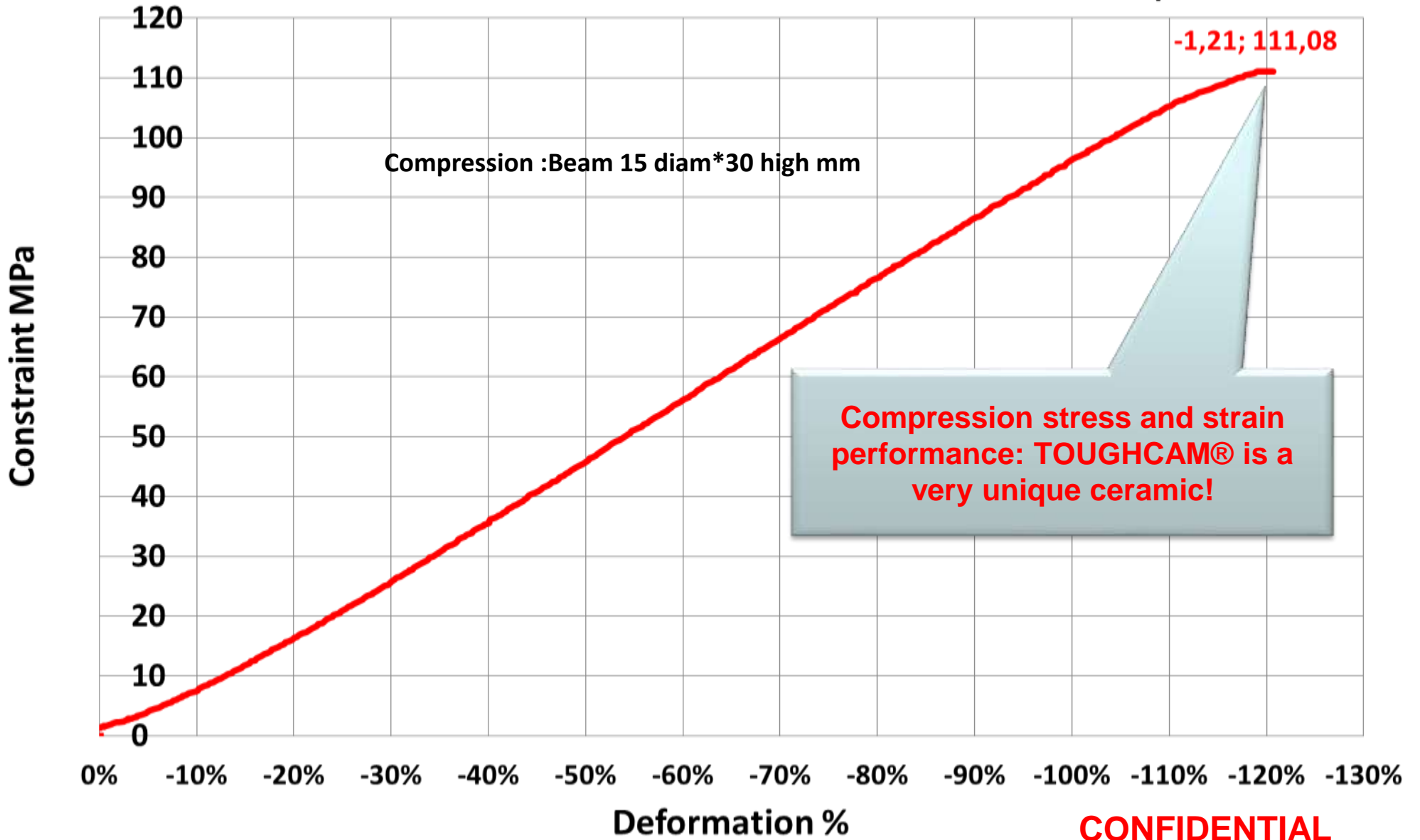
- TOUGH CERAM®  
+ Twill 300g basalt :



- TOUGH CERAM®  
+ UD 300g basalt @ 0° :

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**TOUGH CERAM<sup>®</sup> normalized compression**

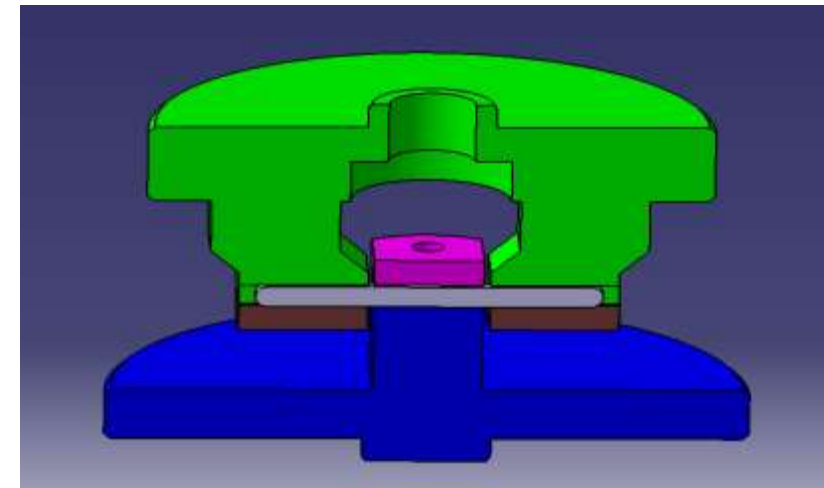


## SHEAR SET UP

Test sample dimensions = 4\*2\*50 mm

Shear gap = 0,9 mm

Test samples = 10 units minimum





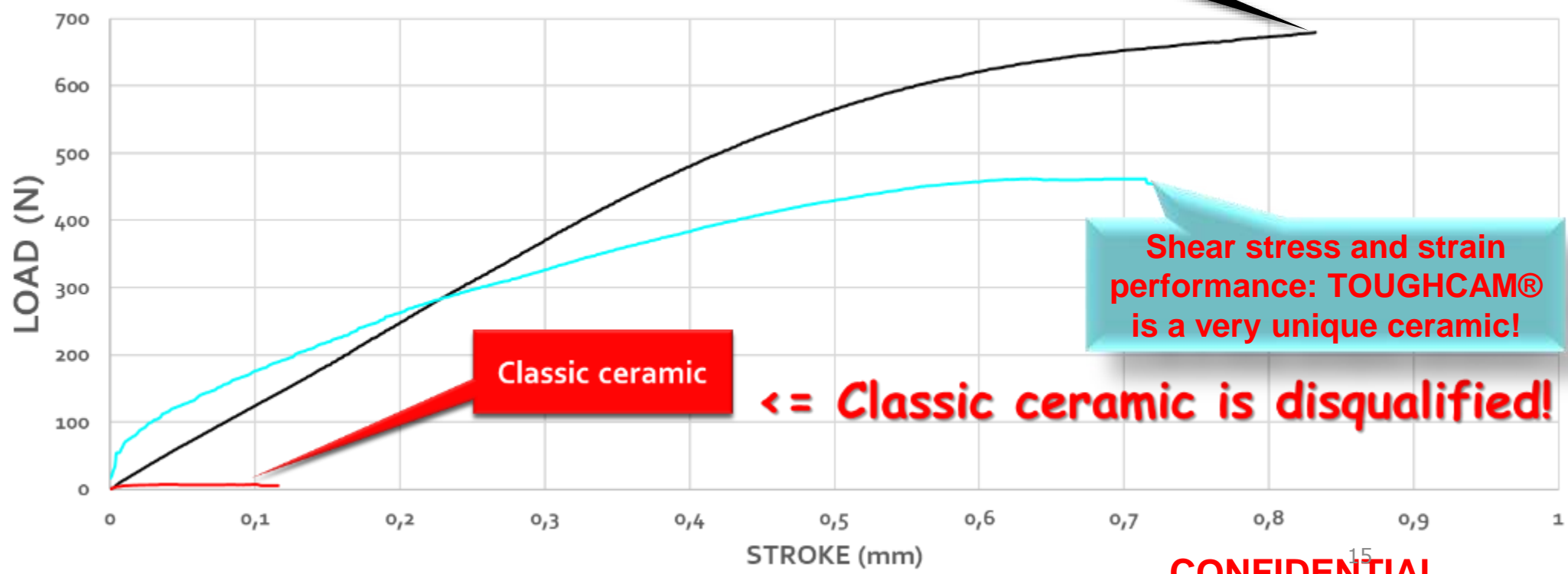


Shear comparison with organic epoxy: TOUGH CERAM<sup>®</sup>+basalt fibers has:

86% of ultimate stroke  
67% of ultimate load

**UNIQUE PERFORMANCE !**

PURE EPOXY



Shear stress and strain performance: TOUGH CERAM<sup>®</sup> is a very unique ceramic!

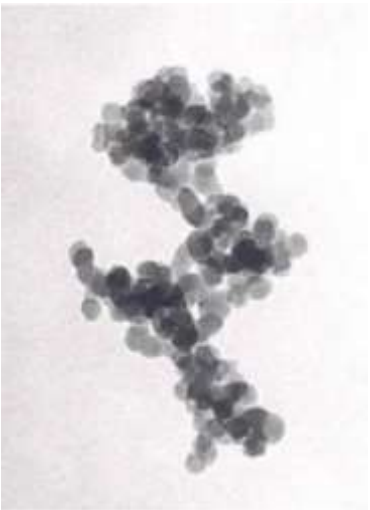
Classic ceramic

<= Classic ceramic is disqualified!

**TOUGH CERAM ®**

**processing example # 1**

# TOUGH CERAM® LDN



TOUGH CERAM® is a compound of ultra low cost, easy to use mineral epoxy and silica reinforcing . Silica has a high specific surface area. During the polymerization , interlocked dendritic silica reinforce the matrix

TOUGH CERAM® is an excellent "green" & low cost thermal structure (see annex for more)

0,1 µm  
↔

Nozzle  
preform

TOUGH CERAM®  
LDN HP RTM

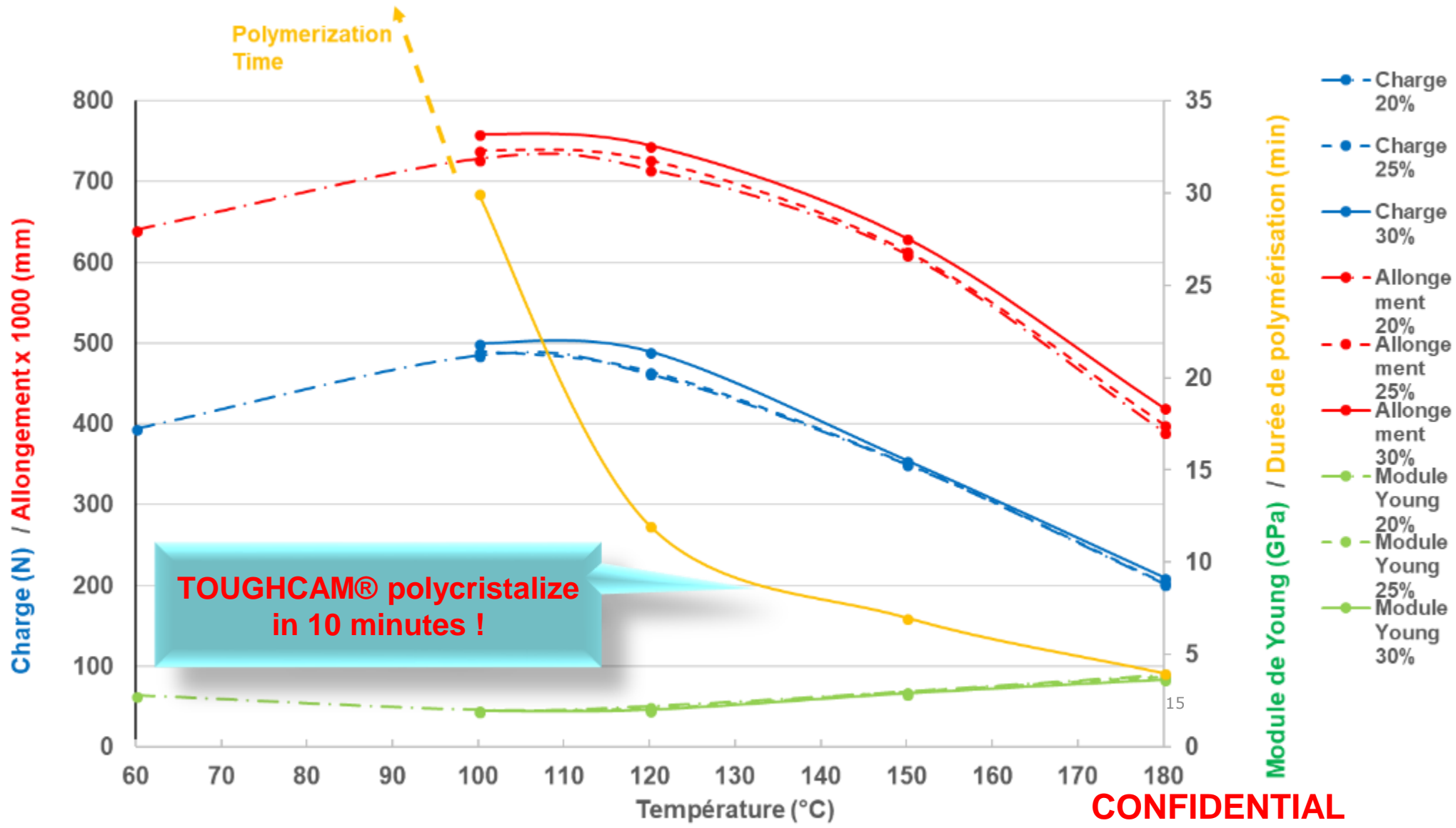
polymerization  
@ 120°C

Drying  
@ 120°C

Finished  
part



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Testing in plenum

NORMALISED MARINE TEST

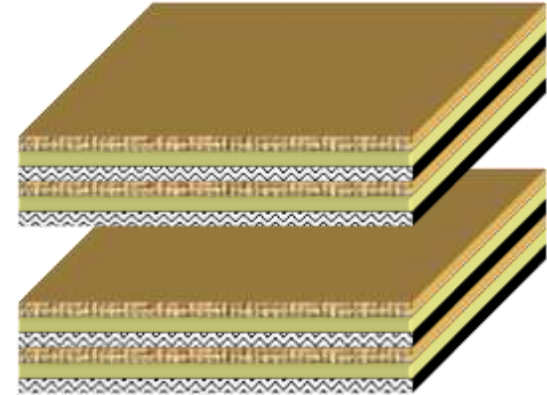
TOUGH CERAM® "anti fire panel"  
kerosene flame test done at 1000°C  
for 1 hour  
by southwest research institute

## Thermal conductivity measurement by Hot-Disc method

- Caractéristiques de échantillons de composite fournis par Sardou SA le 02/02/2017 :  
2 échantillons parallélépipédiques :

1) Échantillon 1 : environ 47x36x11mm<sup>3</sup>

2) Échantillon 2 : environ 47x39x11mm<sup>3</sup>



- Mesure moyenne : le volume de matière inspecté correspond à une pseudo-sphère de 13.4mm de diamètre autour de la sonde de 3mm de diamètre

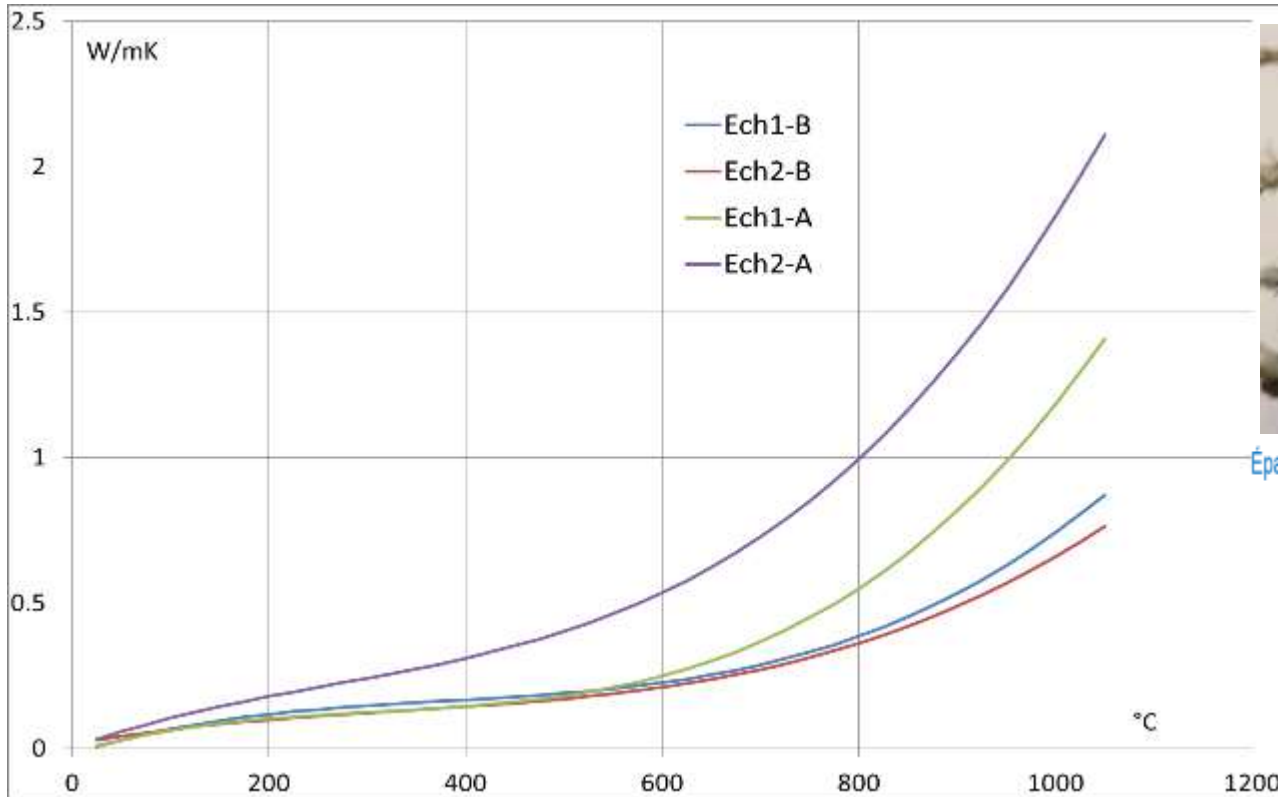
- résultats (3 essais) :  $\lambda_{\text{essai n}^\circ 1} = 0.764 \text{ W.m}^{-1}.\text{K}^{-1}$   
:  $\lambda_{\text{essai n}^\circ 2} = 0.738 \text{ W.m}^{-1}.\text{K}^{-1}$   
:  $\lambda_{\text{essai n}^\circ 3} = 0.752 \text{ W.m}^{-1}.\text{K}^{-1}$

$\lambda_{\text{Mean}} = 0.75 \pm 0.013 \text{ W.m}^{-1}.\text{K}^{-1}$

**Massive TOUGH CERAM® mean  
conductivity value**

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## Measurement of thermal conductivity under vacuum



Épaisseur locale : 1.6 1.2 1.6 1.2

TYPE A  
 Dimension des cellules :  
 Hauteur : 9mm  
 Largeur : 20mm  
 Épaisseur totale : 31 mm  
 Épaisseur pli = 0.4mm

**Hollow TOUGH CERAM®  
 conductivity value**

$$\lambda_0 @ 200 \text{ °C} = 0.12 \pm 0.013 \text{ W.m}^{-1}.\text{K}^{-1}$$

$$\lambda_0 @ 400 \text{ °C} = 0.148 \pm 0.013 \text{ W.m}^{-1}.\text{K}^{-1}$$

$$\lambda_0 @ 600 \text{ °C} = 0.15 \pm 0.013 \text{ W.m}^{-1}.\text{K}^{-1}$$

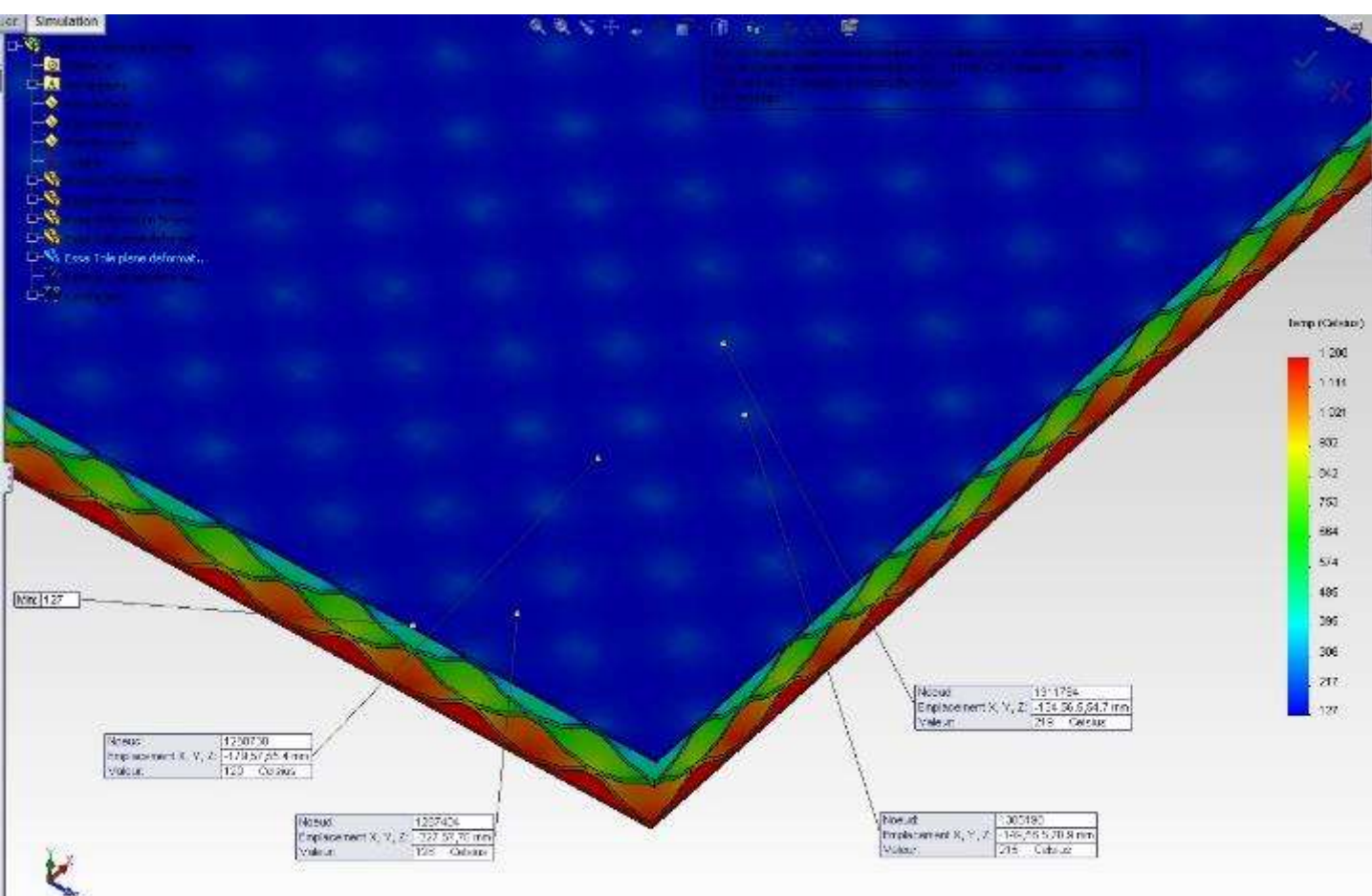
$$\lambda_0 @ 800 \text{ °C} = 0.3 \pm 0.013 \text{ W.m}^{-1}.\text{K}^{-1}$$

$$\lambda_0 @ 1000 \text{ °C} = 0.71 \pm 0.013 \text{ W.m}^{-1}.\text{K}^{-1}$$

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# TOUGH CERAM®

## "anti fire panel structure"





**SOUTHWEST RESEARCH INSTITUTE®**

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 CHEMISTRY AND CHEMICAL ENGINEERING DIVISION  
 FIRE TECHNOLOGY DEPARTMENT  
 WWW.FIRE.SWRI.ORG  
 FAX (210) 622-3377



**FIRE PERFORMANCE EVALUATION OF A MATERIAL IN ACCORDANCE WITH PART 1 OF ANNEX 1 OF IMO RESOLUTION MSC.307(88), INTERNATIONAL CODE FOR APPLICATION OF FIRE TEST PROCEDURES 2010**

**MATERIAL ID: TOUGH CERAM LDN**

**FINAL REPORT**

**5.0 TEST RESULTS**

Testing was conducted in accordance with IMO Part 1, on April 7, 2014, beginning at approximately 10:55 a.m. by Abraham Mata, Senior Technician. No flaming was observed on any of the five runs. As required by the standard, average moisture and organic content data are presented in Table 2. Tabular test data and graphs of the measured temperatures, plotted with respect to time, are presented in Appendix A.

**Table 2. Moisture Content.**

Material ID	~ Moisture Content by Weight*	~ Organic Content by Weight*
<i>Toughceram LDN</i>	3.2 %	5.8 % (6.1%)*

\* Calculated/Measured by SwRI Personnel.

**6.0 CONCLUSIONS**

The material, *Toughceram LDN*, tested in this program meets the test criteria for non-combustibility, as outlined in Part 1 of Annex 1 to the IMO FTP Code “Non-Combustibility Test”, using the end-of-test criteria specified in Annex 3 to IMO FP 44/18.

**ILLUSTRATION OF THE GOOD  
THERMAL BEHAVIOUR OF  
TOUGH CERAM®**

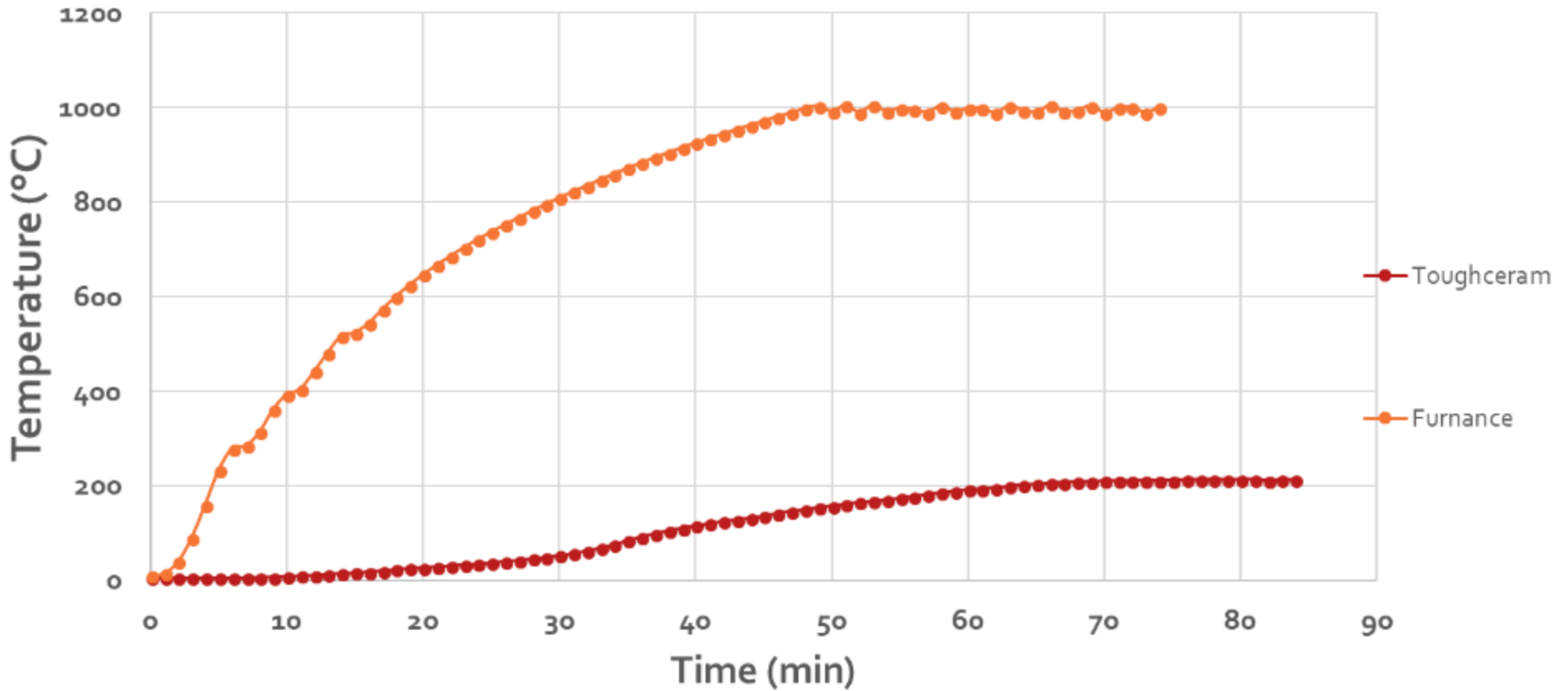
Pictures of the test rig of a  
TOUGH CERAM® "anti fire panel" test  
in a kerosene flame test done @  
1000°C for 1 hour: IMO FTP 44/18

panel after a test done in a kerosene flame =>



# TOUGH CERAM ®

R&D Sardou panels - Furnace test results



**TOUGH CERAM ®**

**Testing panel in open air @ 1900°C**

**For 20 minutes!**

**TOUGH CERAM®**

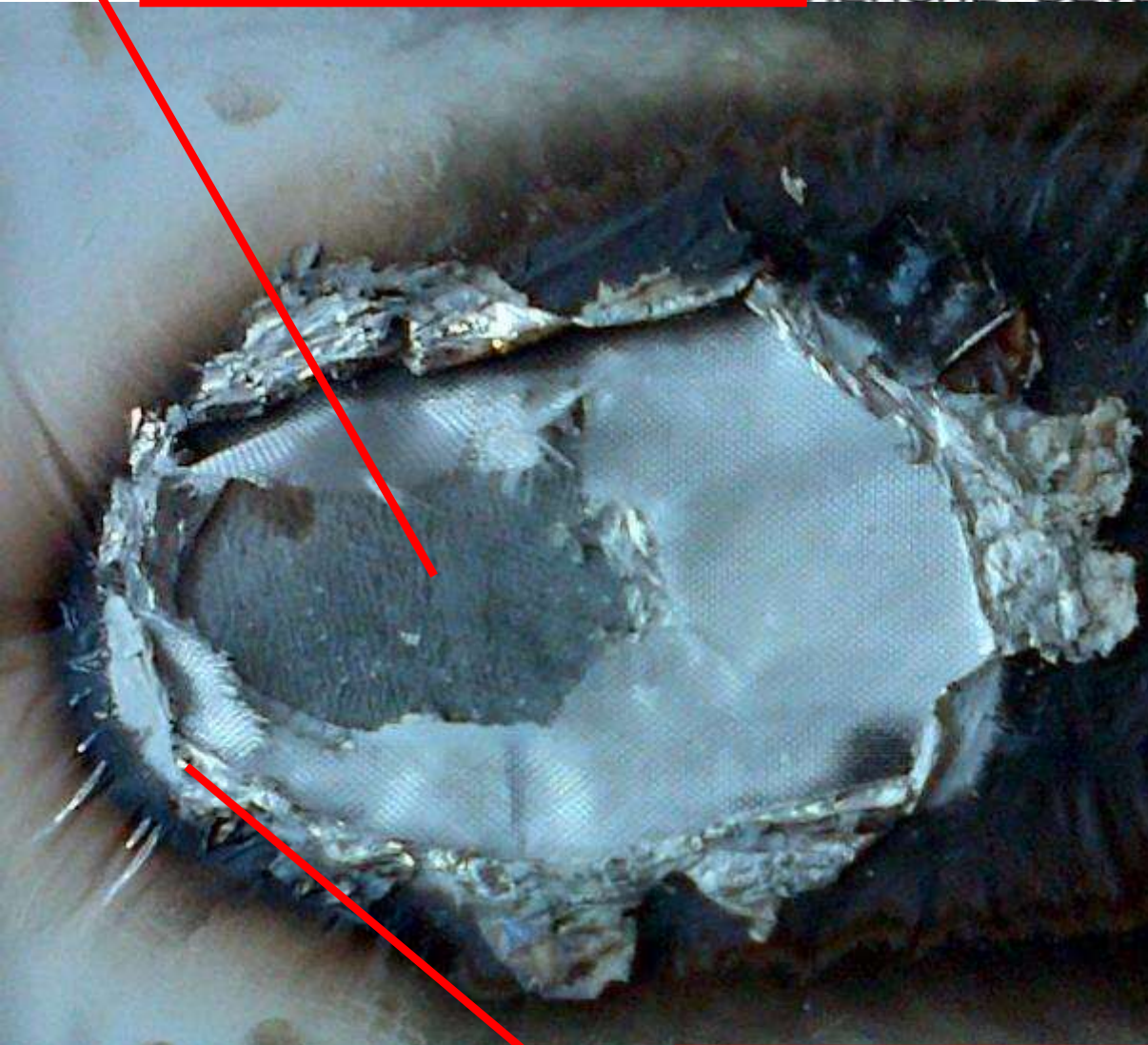
**TOUGH CERAM®**



RECHERCHE - DÉVELOPPEMENT - INGÉNIERIE - DESIGN

**ILLUSTRATION OF THE GOOD  
THERMAL BEHAVIOUR OF  
TOUGH CERAM®**

**Pictures of the two sides of a  
TOUGH CERAM® "anti fire panel"  
after a 20 minutes propane flame  
test @ 1900°C**



**Decorative Aluminum &  
silica taffeta layer**

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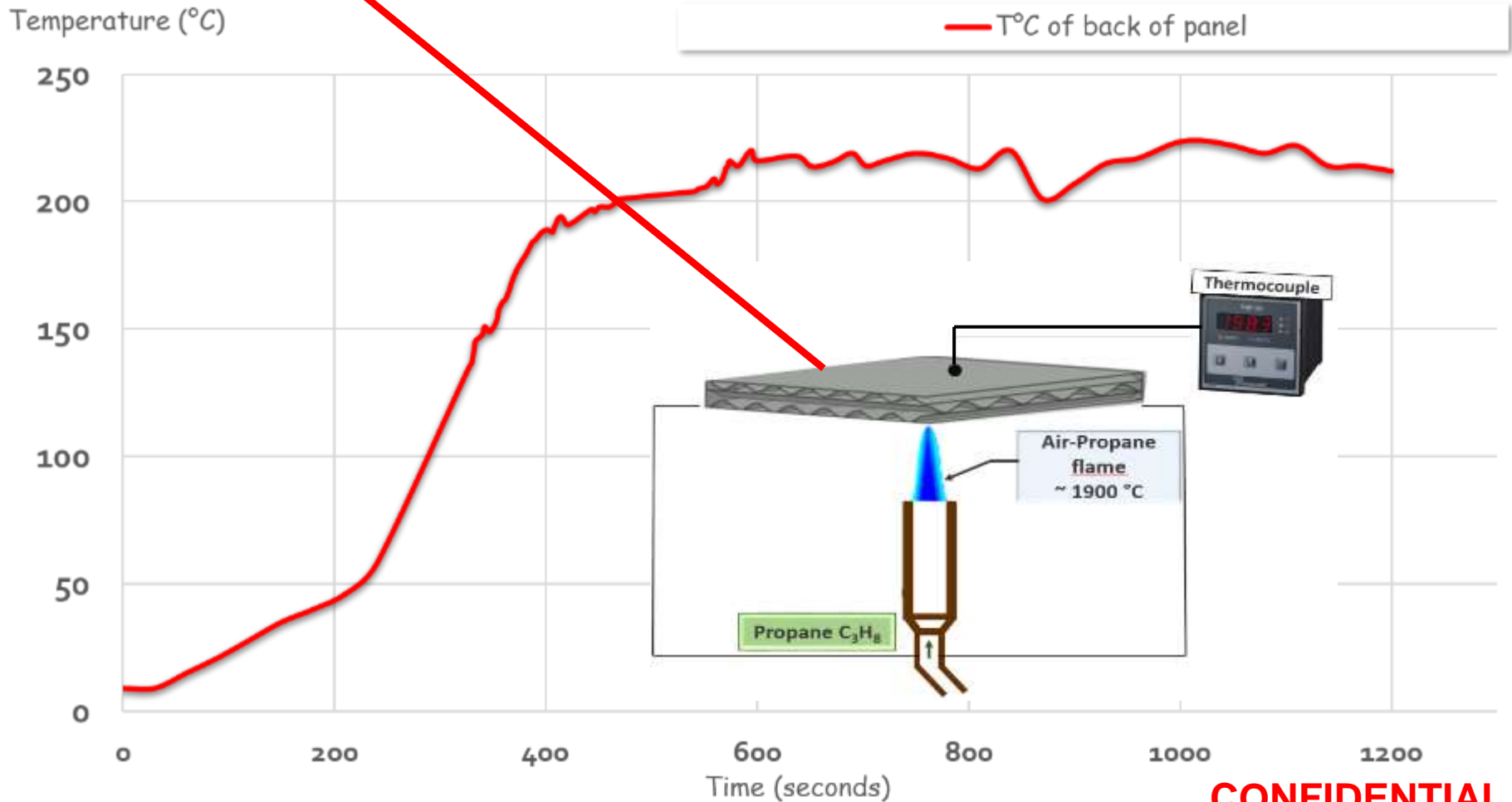
**TOUGH CERAM®**

**TOUGH CERAM®**



RECHERCHE - DÉVELOPPEMENT - INGÉNIERIE - DESIGN

**TOUGH CERAM® 20 minutes propane flame test @ 1900°C**



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**TOUGH CERAM<sup>®</sup> new generation panel**

**Plenum simulation**

**Testing panel @ 1900°C**

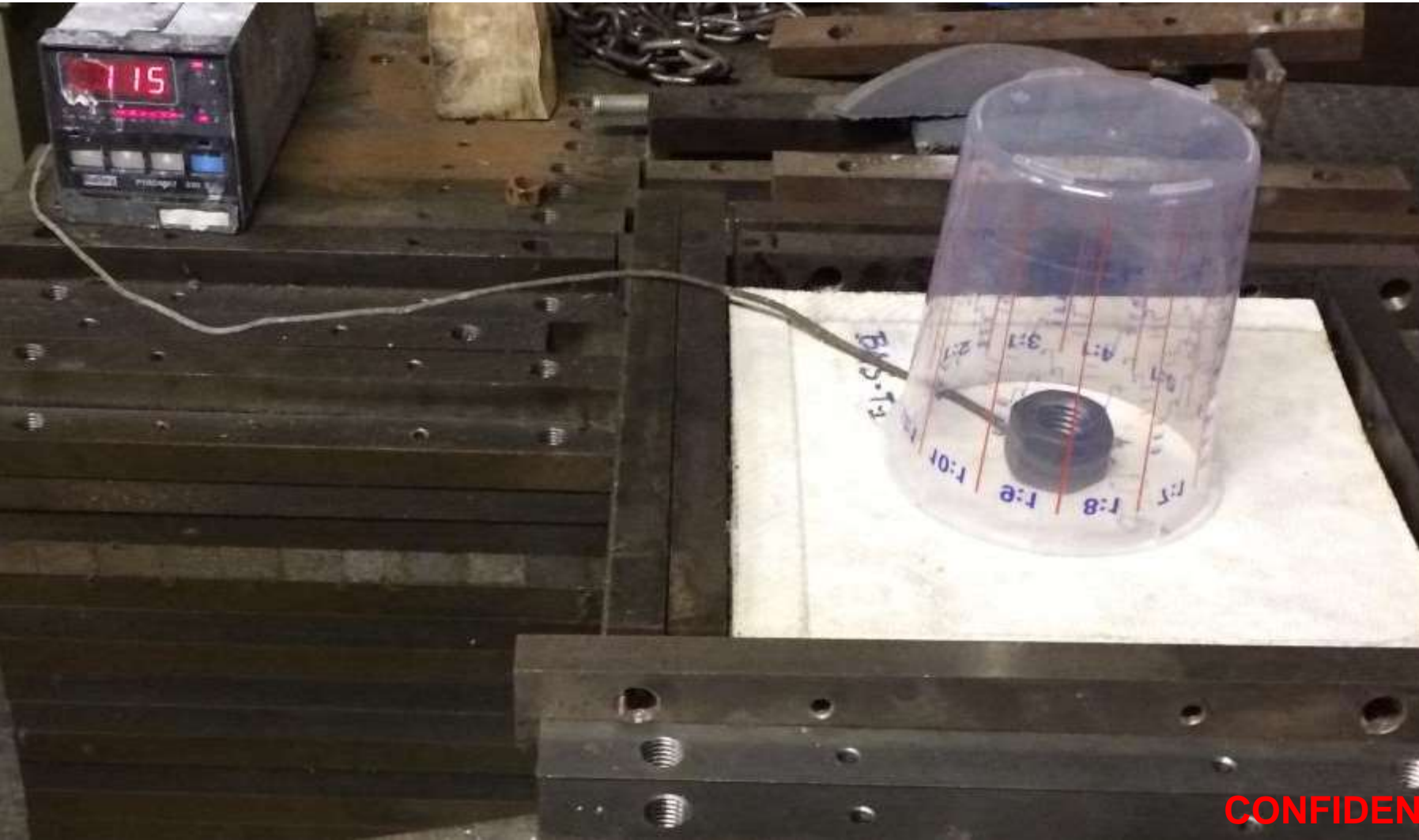
**For 90 minutes!**

**TOUGH CERAM® 90 minutes propane flame test @ 1900°C**



RECHERCHE - DÉVELOPPEMENT - INGENIERIE - DESIGN

Plenum is used in order to simulate confined gap between TPS and aluminum structure of the IXV



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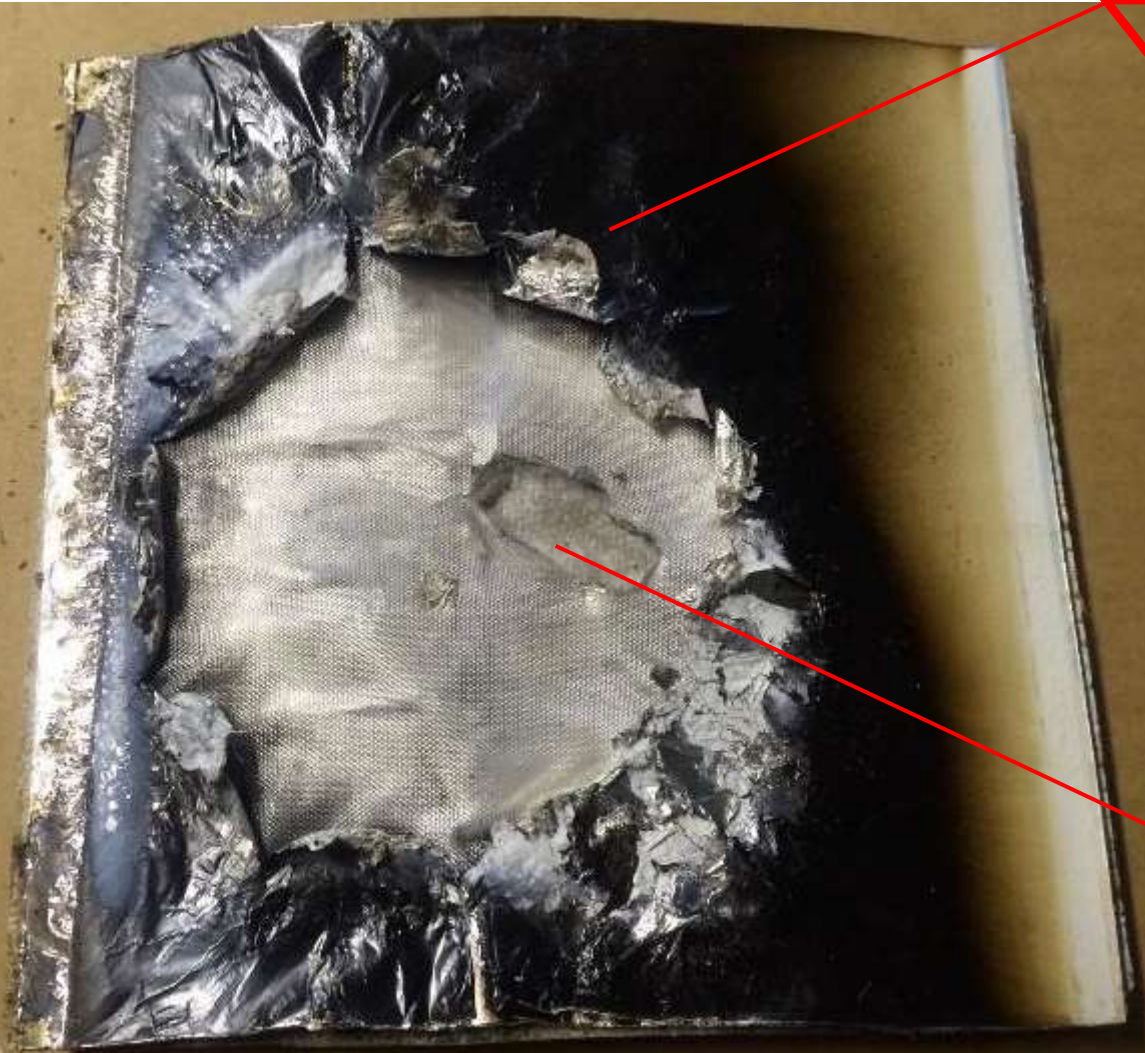


**TOUGH CERAM® 90 minutes propane flame test @ 1900°C**



RECHERCHE - DÉVELOPPEMENT - INGENIERIE - DESIGN

Pictures of the front side after test  
sides of a **TOUGH CERAM®** panel  
**TOUGH CERAM®** is in perfect condition



Decorative Aluminum & silica taffeta layer



**TOUGH CERAM®**

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# Rear view of the first TOUGH CERAM® skin



RECHERCHE - DÉVELOPPEMENT - INGENIERIE - DESIGN

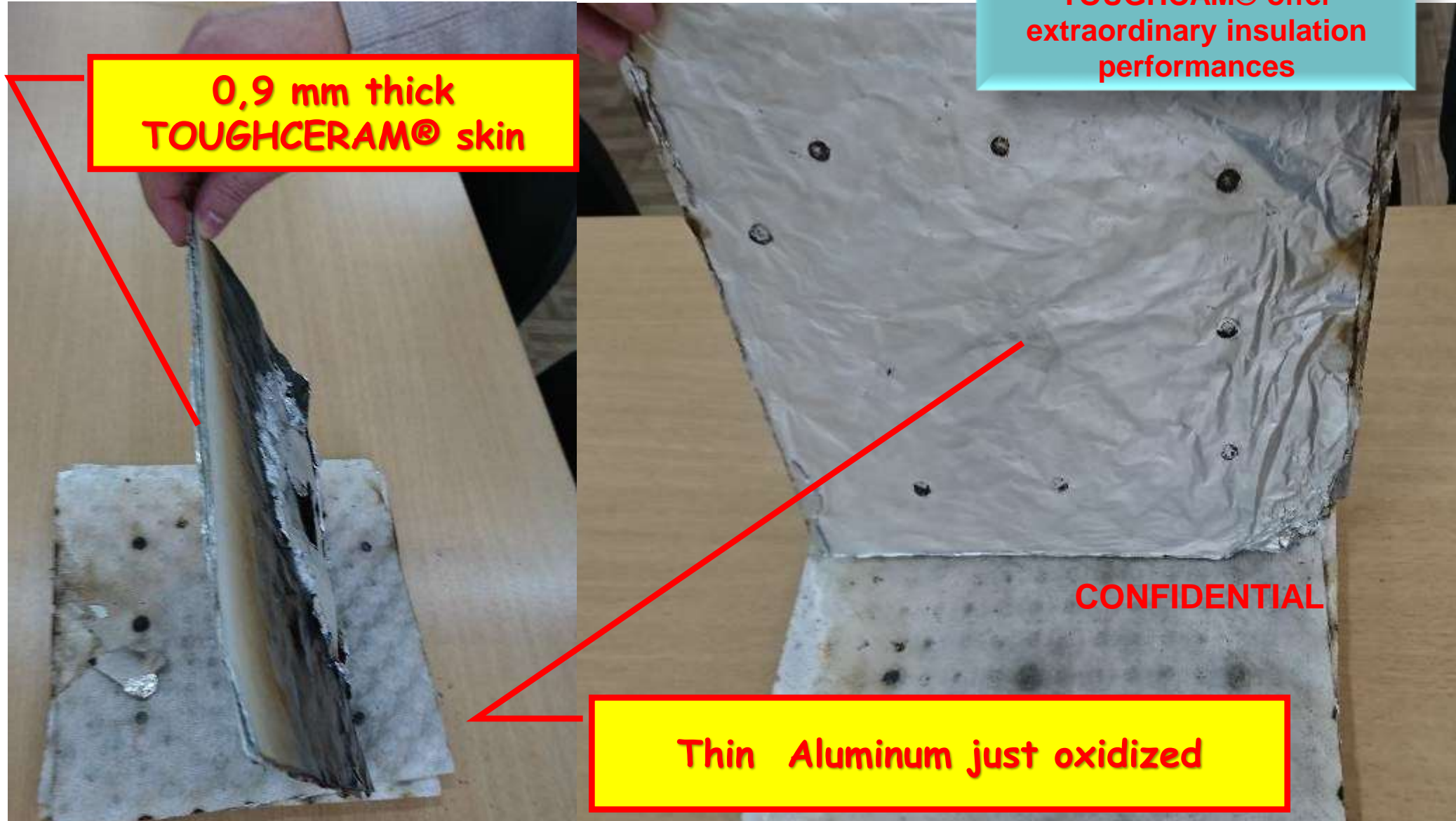
Aluminum melt at  $660^{\circ}\text{C}$  so we have a gradient of about  $1300^{\circ}\text{C}$  across 0,9 mm of TOUGH CERAM® skin !

TOUGH CERAM® offer extraordinary insulation performances

0,9 mm thick TOUGH CERAM® skin

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Thin Aluminum just oxidized

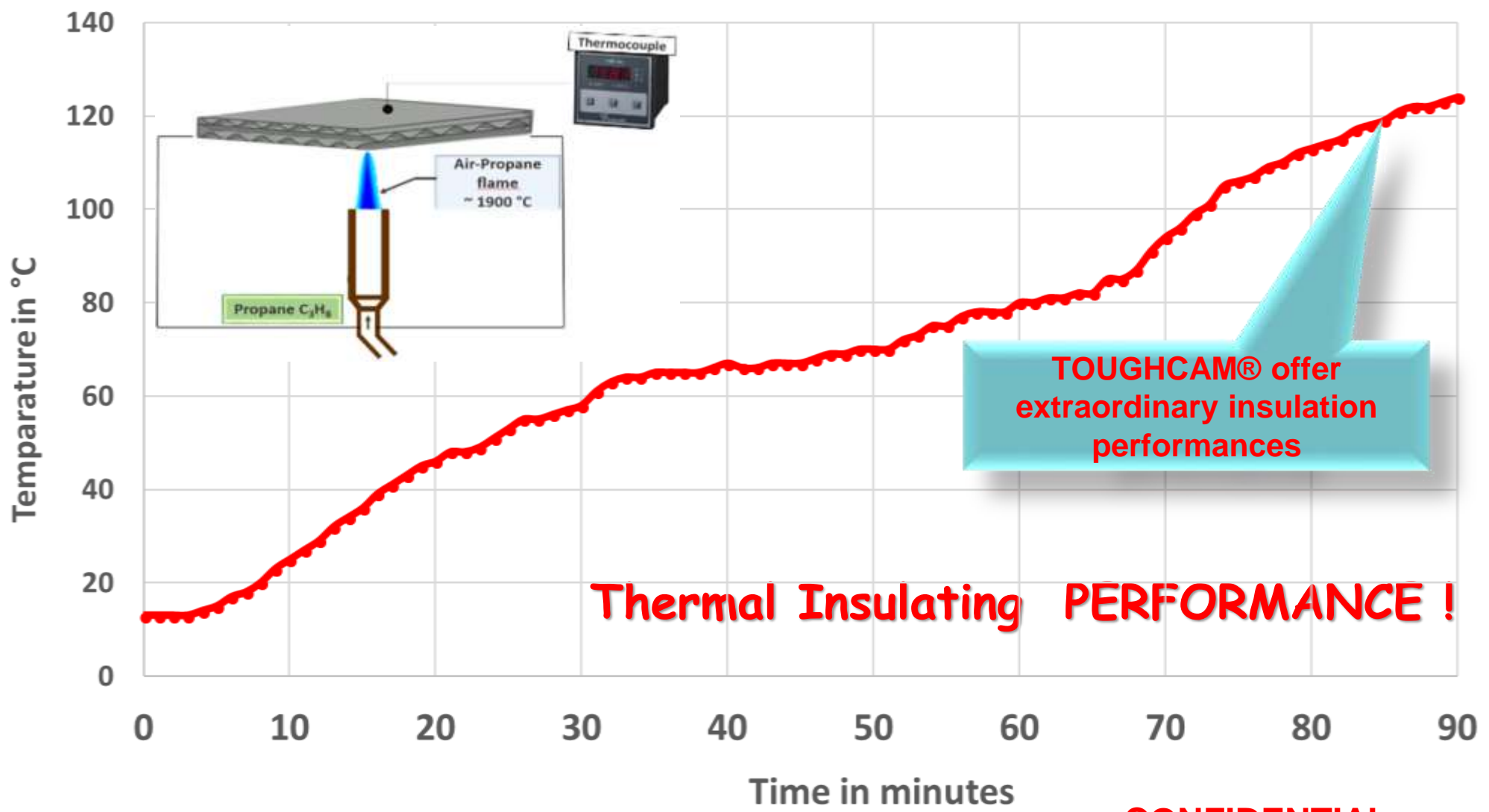


# TOUGH CERAM® 90 minutes propane flame test @ 1900°C



RECHERCHE - DÉVELOPPEMENT - INGENIERIE - DESIGN

Temperature measured on Non-fire side of the panel

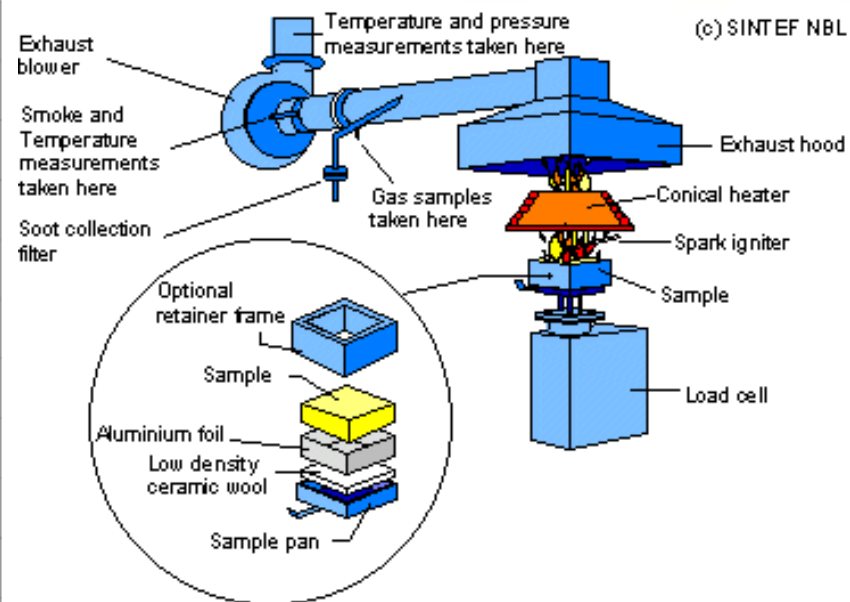


TOUGH CERAM® offer extraordinary insulation performances

Thermal Insulating PERFORMANCE !

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testing mode		
irradiance of	75 KW/m <sup>2</sup>	
extraction rate of	0,024 m <sup>3</sup> /s	
test samples		
square samples	100*100mm	
exposed surface	0,084 m <sup>2</sup>	
laminates	sample 1	sample 2
thoughceram®	0,5 mm	3,6 mm
epoxy carbon	2,5 mm	



laminates	sample 1	sample 2	2/1 ratio
thickness (mm)	3	3,6	
initial mass (g)	37,4	57,3	
final mass (g)	23	52,5	
ratio (init/end)	61%	92%	
average mass loss( g/(m <sup>2</sup> *s))	2,12	0,09	4,2%
total heat release MJ/m <sup>2</sup>	27,2	0,8	2,9%
maximum heat release value Kw/m <sup>2</sup>	374	22,9	6,1%
time to sustain flaming (s)	23	104	
extinguishing time (s)	118	114	
test duration (s)	744	742	

**TOUGH CERAM®**  
does not burn nor smoke

Following are examples of  
potential applications

We are searching for

- OEM
- ESA
- HORIZON 2020
- etc

interested in the following fields

Our following suggestion is made in humility and with the deepest respect  
of previous solutions and works

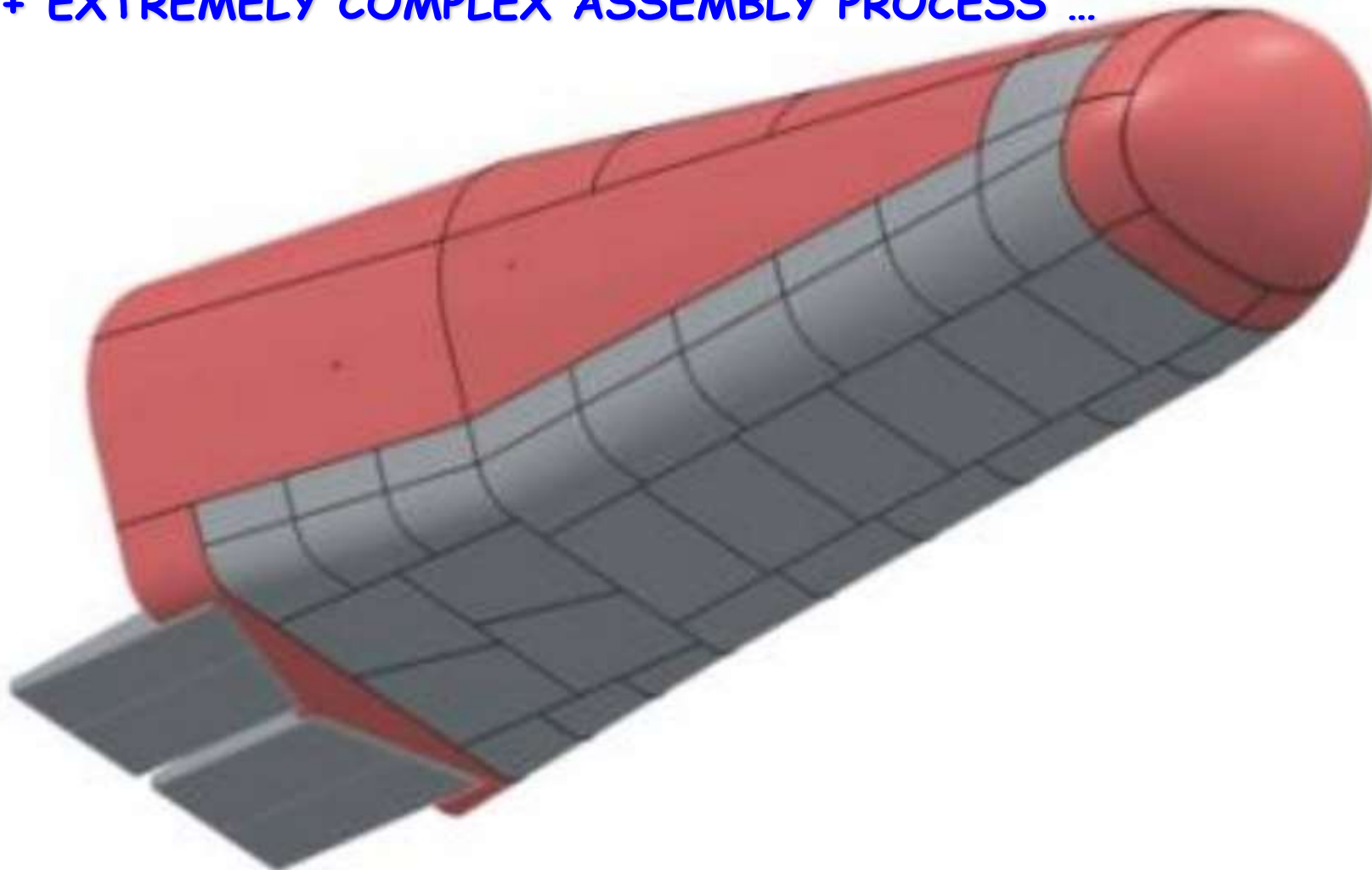
**TOUGH CERAM ®**  
**TPS SLIPPER**  
**concept...**



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# TOUGH CERAM <sup>®</sup> Application

State of the art solution: 30 CERAMIC TILES + NOSE CONE  
+ EXTREMELY COMPLEX ASSEMBLY PROCESS ...



# TOUGH CERAM<sup>®</sup> structural solution

$\lambda_0$  @ 200 °C = 0.12-+0.013 W.m-1.K-1



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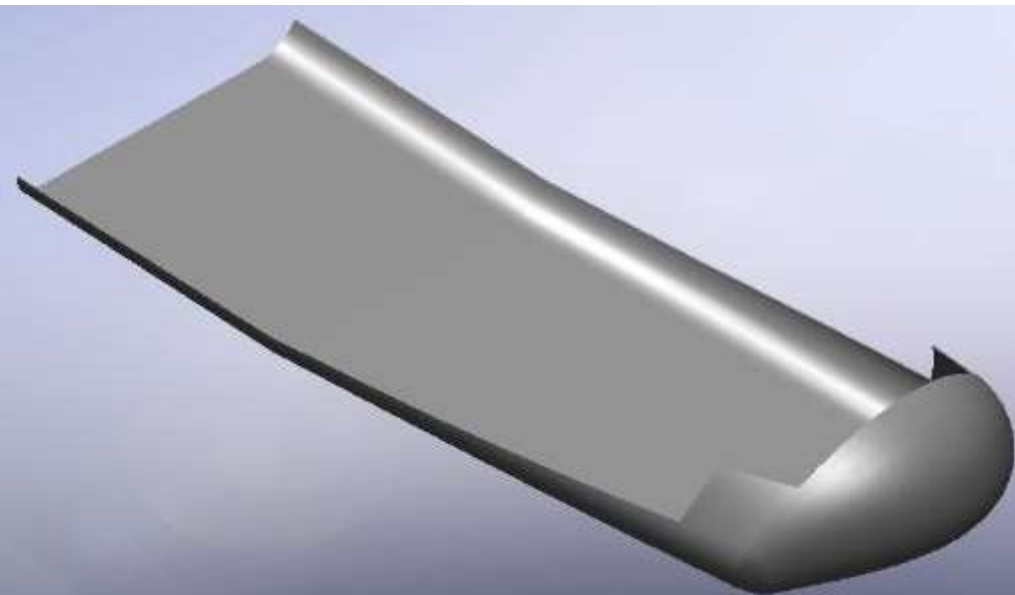
Poly-crystallization of one piece structural panel in complex "ventilated" shape as big than an hypersonic air craft fuselage at only 60°C (no glue, no additional insulation needed! )



# TOUGH CERAM<sup>®</sup> solution

One piece disposable low cost structural TPS skin produce with a low cost mold in one week

Polycrystalization at only 60°C in 40 MINUTES



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# TOUGH CERAM <sup>®</sup>

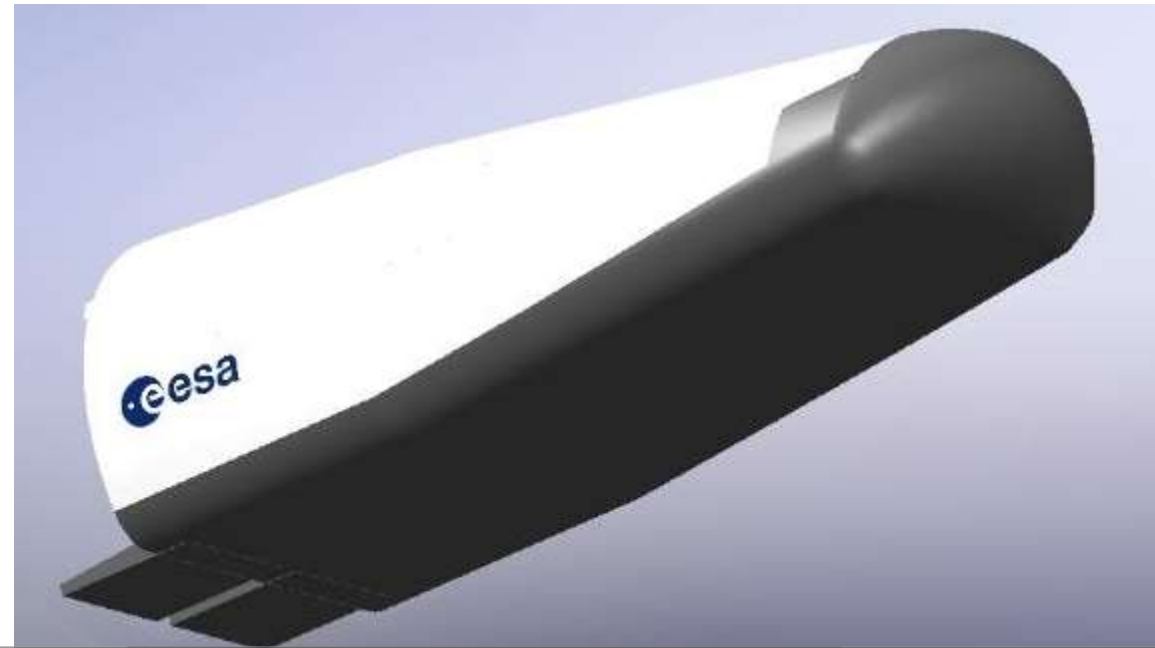


One piece disposable low cost structural TPS skin  
integrated on IXV & SpaceRider as easy to fix as a SLIPPER...

We are perfectly conscious  
that there is a lot of tests  
to pass in order to validate  
this kind of technology!

I repeat

**WE ARE SEARCHING FOR OEM  
WILLING TO IMPLEMENT OUR  
TECHNOLOGY FOR THEIR  
APPLICATIONS**



Computed need for IXV is 16 minutes 1800°C

Measured temperature for IXV is 16 minutes 1400°C

**TOUGH CERAM <sup>®</sup>** has been demonstrated 90 minutes at 1900°C

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# TOUGH CERAM® Used as Satellite shield

- \* It is possible to produce panels with dyneema, or aramid fibers with the below structure in one co polymerization, such panels can destroy micro debris and protect satellite.
- \* Such panel with ceramic fibers could be used in solar probe in order to be an efficient heat shield



# TOUGH CERAM® Used as DEPLOYABLE heat shield

TOUGH CERAM® flexibilized  
can be used for thermal insulation  
fire protection and  
reentry heat shield



# TOUGH CERAM® Used as DEPLOYABLE heat shield



# TOUGH CERAM®

**sardou**  
RECHERCHE - DÉVELOPPEMENT - INGÉNIERIE - DESIGN

## Tough & flexible low cost ceramic



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# TOUGH CERAM®

**sardou**  
RECHERCHE - DÉVELOPPEMENT - INGENIERIE - DESIGN



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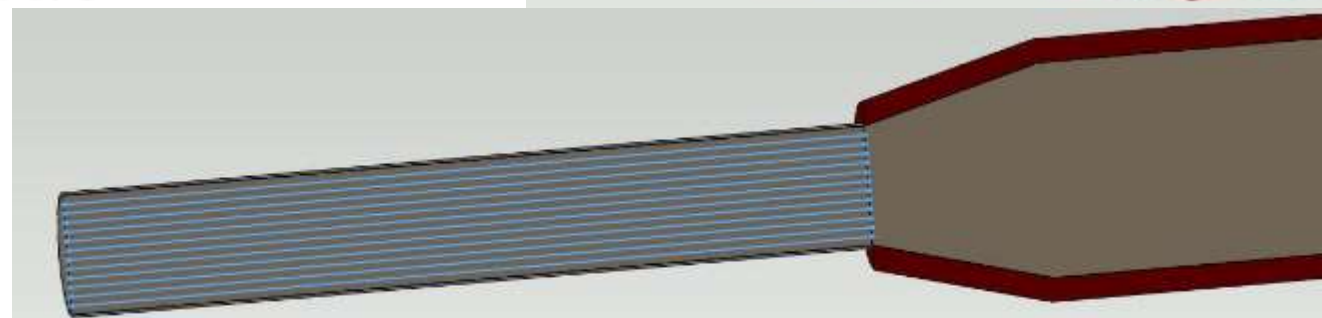
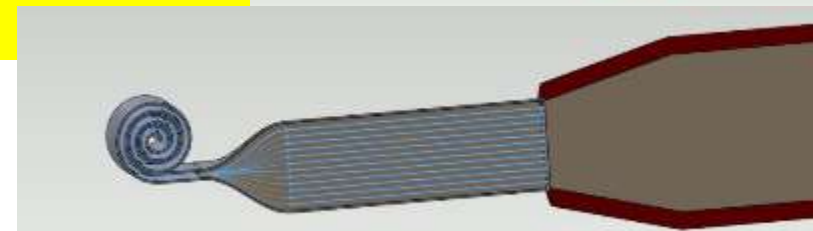
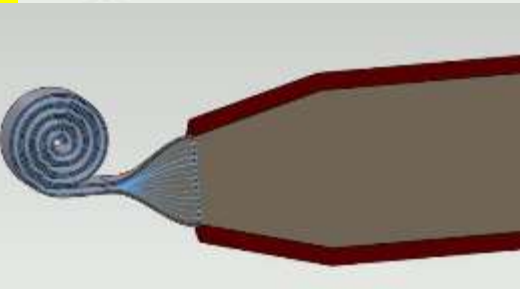
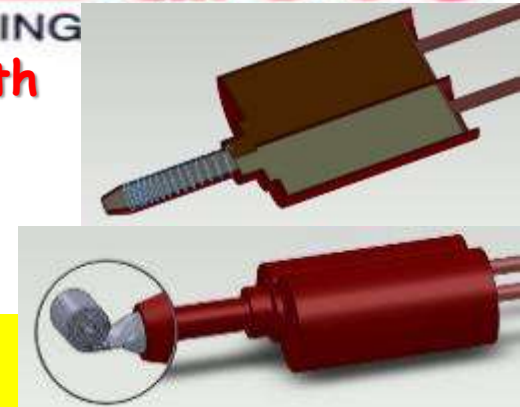
# GIANT structural components

RECHERCHE - DÉVELOPPEMENT - ING



A two component dispenser with its static mixing unit =>

Rolled up thin tube containing :UD & braided carbon fibers =>



# In SPACE DEPLOYMENT and SUN CURING of TOUGH CERAM®

Thin tube fully deployed containing :

- \* UD plus braided carbon fibers
- \* TOUGH CERAM ®

& ready for solar polymerization =>

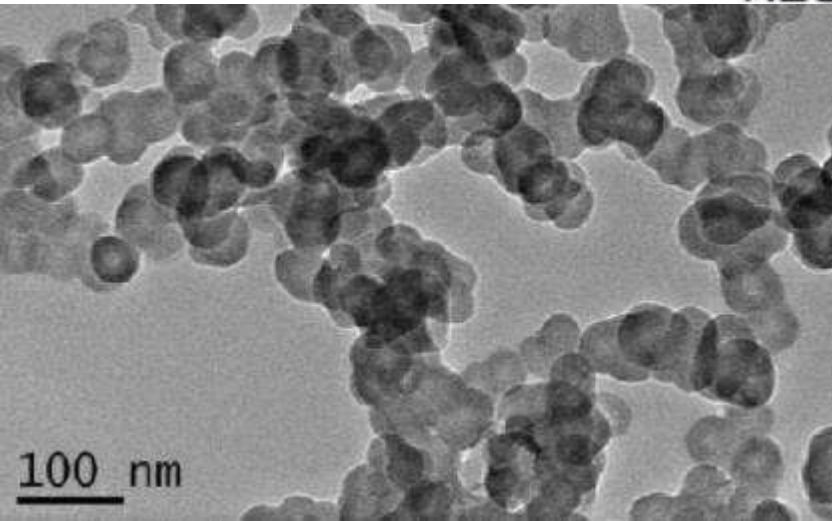
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**TOUGH CERAM ® ceramized**

**For NOZZEL application**

**processing example # 2**



TOUGH CERAM® C is a compound of ultra low cost, easy to use alumina & metakaolin. Alumina has a high specific surface area. During the sintering, interlocked dendritic alumina reinforce the matrix

Sintering @ 1410°C under vacuum. During sintering aluminum, and silicon turn to a dense and POROUS MULLITE needles interlocked NETWORK. 20% POROUS NETWORK is an excellent thermal insulating & tough structure

Nozzle preform

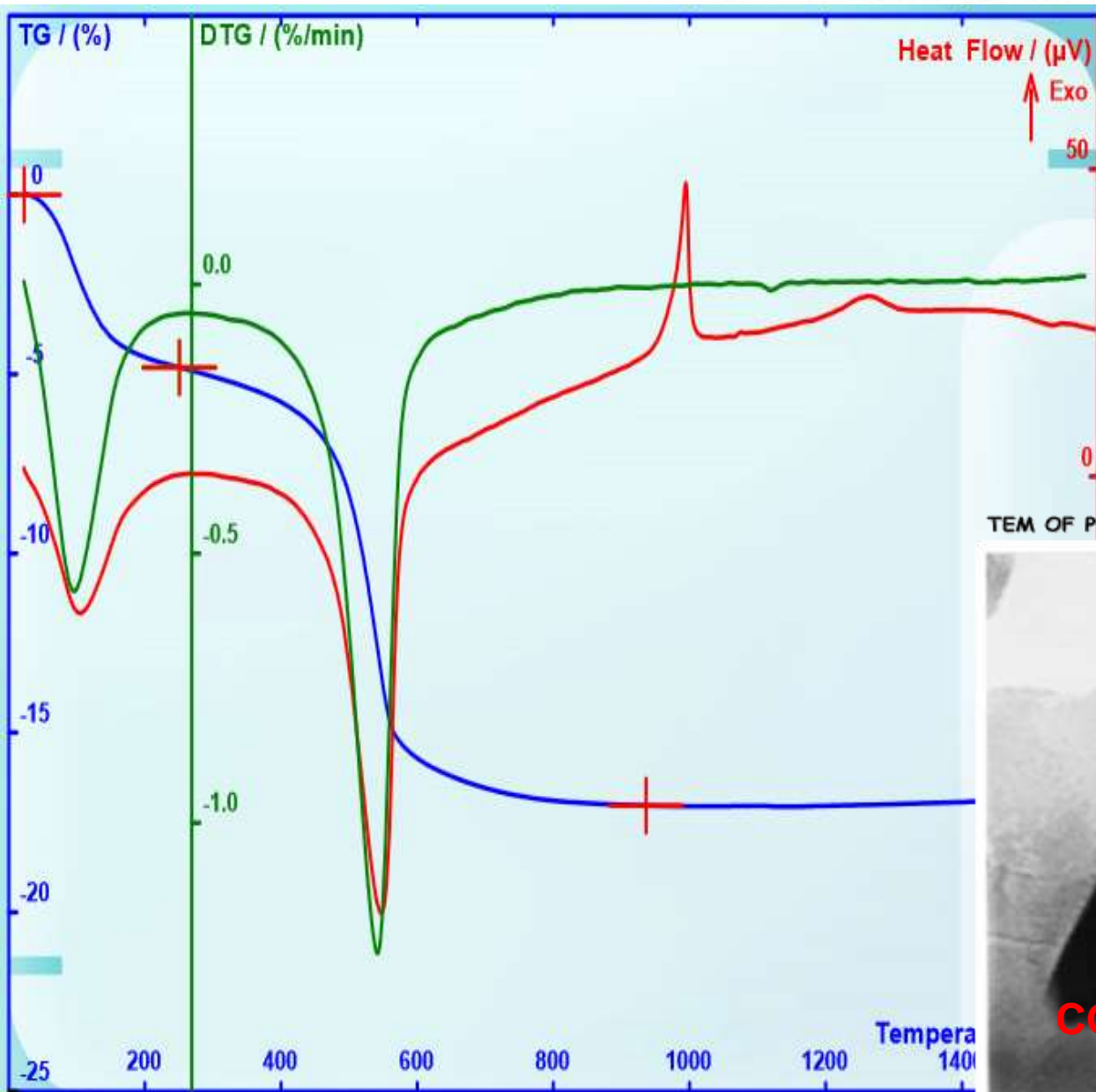
TOUGH CERAM® C  
HP RTM

Drying  
@ 300°C

SINTERING  
under vacuum @ between  
1270°C & 1410°C

Finished  
Nozzle





**ATG & DTG OF PURE KAOLIN**

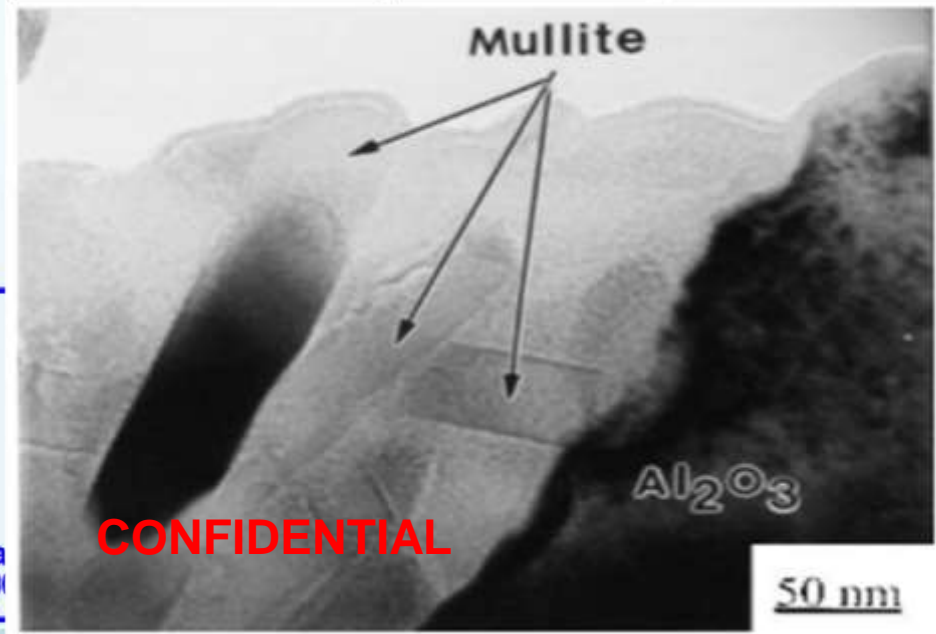
**@10°C/min**

**KAOLIN turn to METAKAOLIN @940°C**

**METAKAOLIN turn to MULLITE @993°C**

**MULLITE turn to SECONDARY MULLITE @1263°C**

TEM OF PURE KAOLIN during pressure less sintering @ 1300°C for 30 min

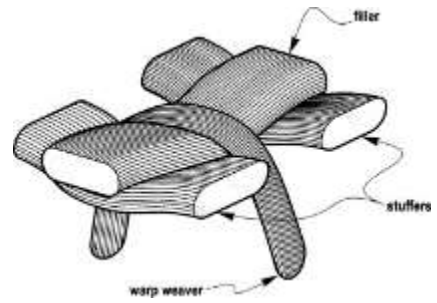


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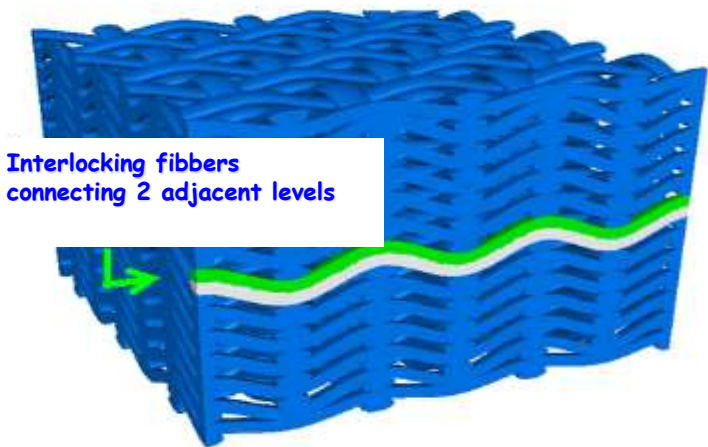
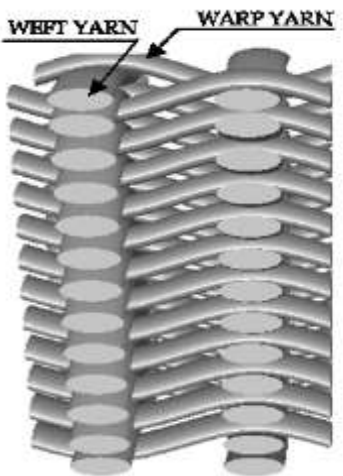


# NOZZEL application

<= Nozzle preform is produced by interlocked braiding on a mandrel



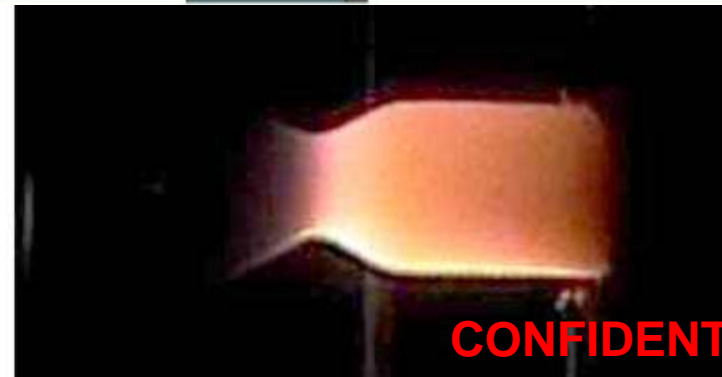
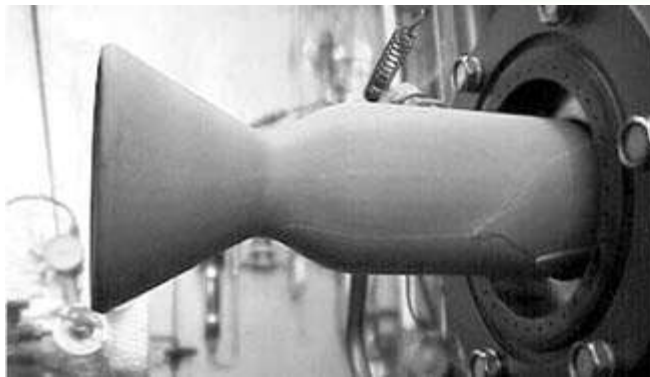
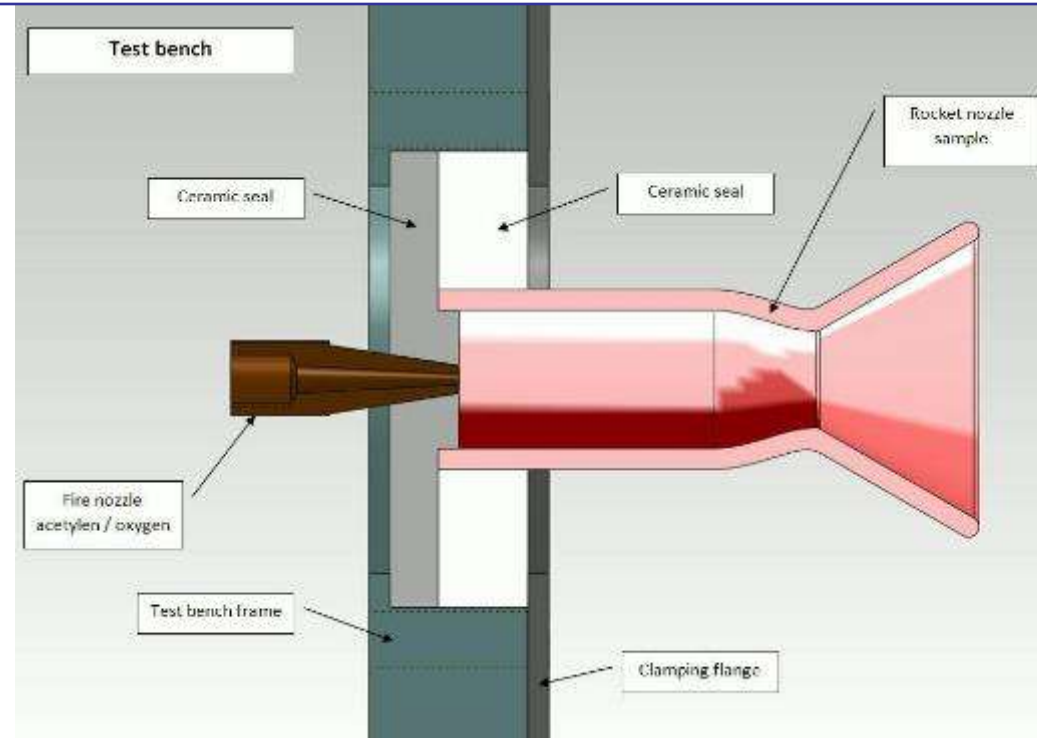
interlocked braiding detail



<= Cross section of a 3 D Multi layers interlocked braiding

*Welding blowtorch create 3000°C ,produce gas flow and are inexpensive! We plan to use such device in order to build up a mini test bench. Nozzle can be just a 2 mm diameter , easy to produce and to test!*

# Principle of a SMALL TEST BENCH For NOZZEL application



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# Small NOZZEL demonstrator



Nozzle impregnated with TOUGH CERAM  
ceramized @ 1100°C



Nozzle impregnated with TOUGH CERAM  
and its mold



3 D interlocked Braided  
carbon fiber structure

# "CARBON FREE GREEN MINERAL POLYMER"

**TOUGH CERAM<sup>®</sup> mold and nozzle insert for hybrid rocket motor test bench** (massive shape is in order to replace graphite insert)

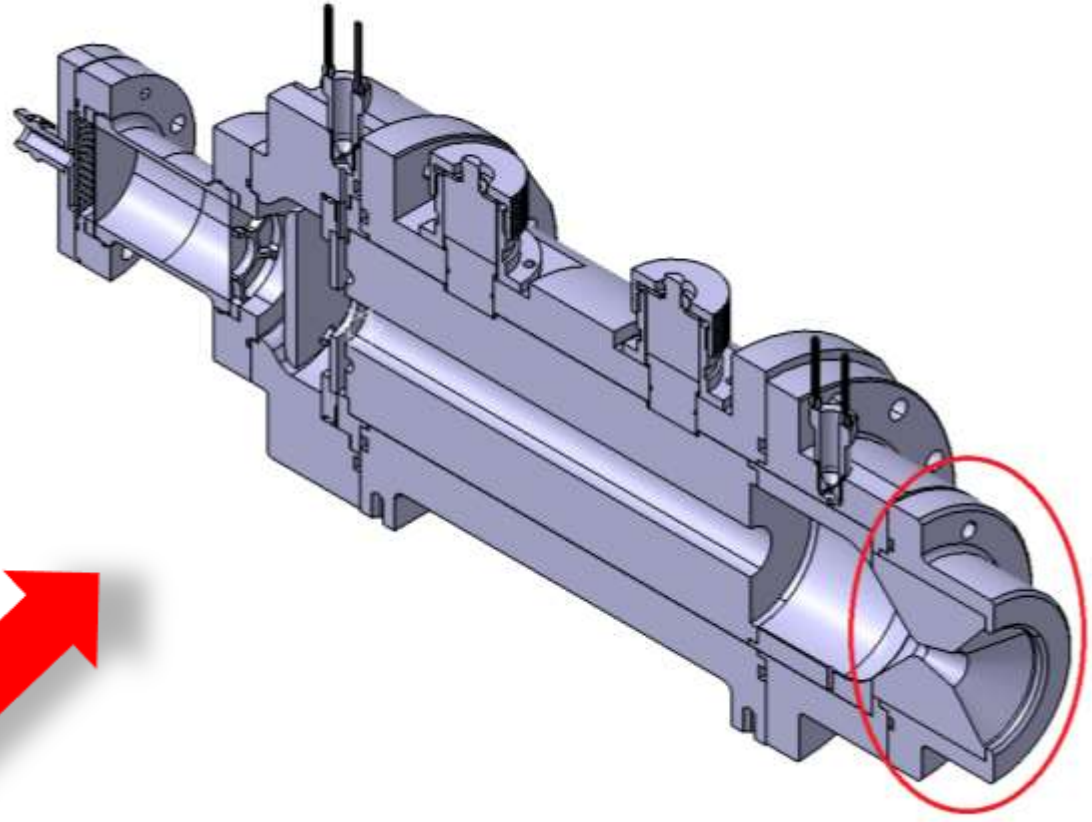
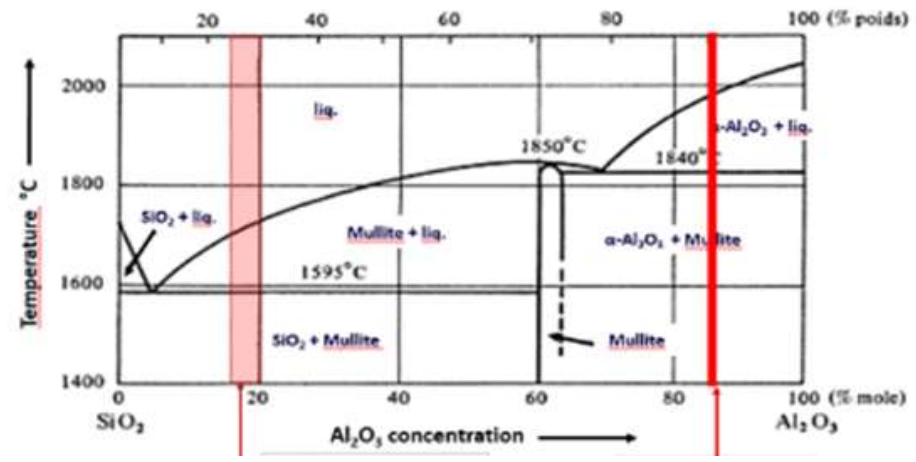


Polycrystallization done at 60°C



Detail of the collar after machining  
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### Nozzle for engine HYCOM 130 ONERA



Perspective view of the engine.  
The nozzle area is circled in red.  
Atmosphere:  
**CO2 @ 35%**  
**Water vapor @ 60%**  
**Oxidizing medium**  
**Flame 2700 ° k (2426 ° C)**  
**6.3 output ratio**

Basalt fibers resist a temperature of -260 ° C to 815 ° C.  
The vitrification temperature is 1050 ° C .  
The melting temperature of 1450 ° C.






Ceramic  
after  
removal of  
the melted  
layer

Thin layer  
of melted  
ceramic

Thin layer  
of melted  
ceramic



Ceramic after  
removal of the  
melted layer

Shadow of  
the thin  
layer

Thin layer  
of melted  
ceramic

"CARBON FREE GREEN MINERAL POLYMER"

**TOUGH CERAM ®**

**Other application field**

## can be used as heat shield



<= "foamed" TOUGH CERAM®

Interface between "foamed" & massive TOUGH CERAM® =>

TOUGH CERAM®  
can be used for thermal insulation  
fire protection and **reentry**  
heat shield in ablative  
mode.

It is possible:

- \* to get a combination of FOAMED AND STRUCTURAL TPS
- \* to impregnate the foam with phenolic resin



# TOUGH CERAM®



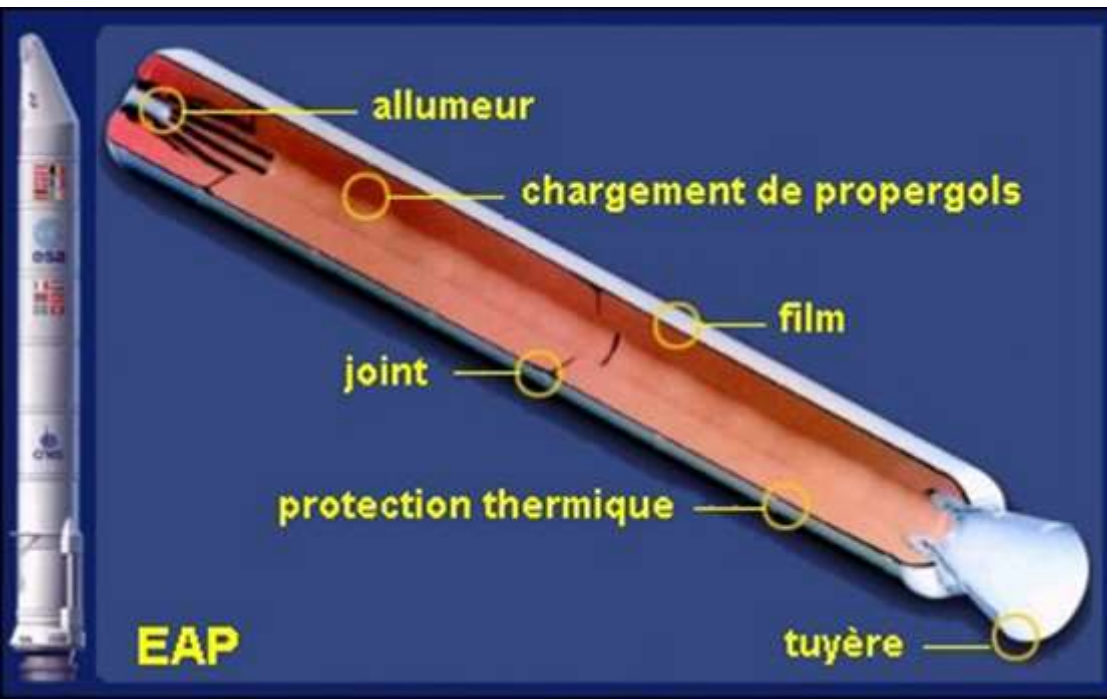
RECHERCHE - DÉVELOPPEMENT - INGENIERIE - DESIGN

can be used in Solid-fuel rocket as:

**Internal Thermal protection** (foamed)

**CASSING** Structural component (fiber reinforced)

**NOZZEL** Structural component (fiber reinforced)



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# TOUGH CERAM®



RECHERCHE - DÉVELOPPEMENT - INGÉNIERIE - DESIGN

## is FIRE & SMOKE PROOF

"foamed" TOUGH CERAM® ==>

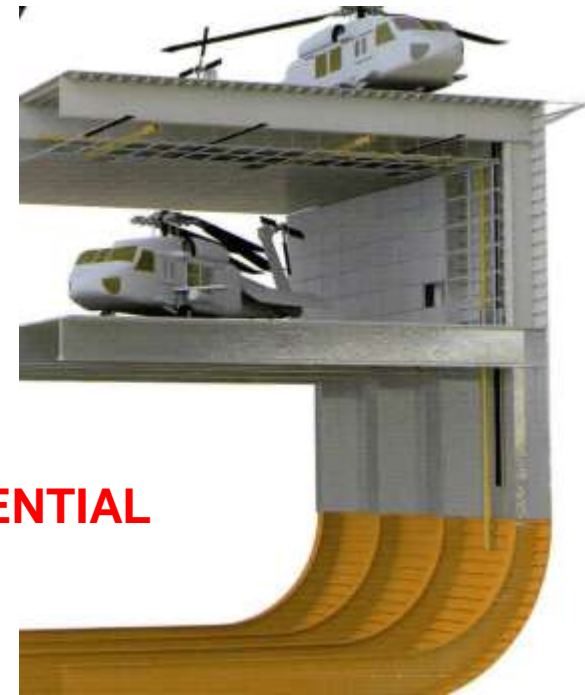


HELICOPTER WEIGHT REDUCTION examples

engine thermal insulation & fire protection  
compartment with TOUGH CERAM®

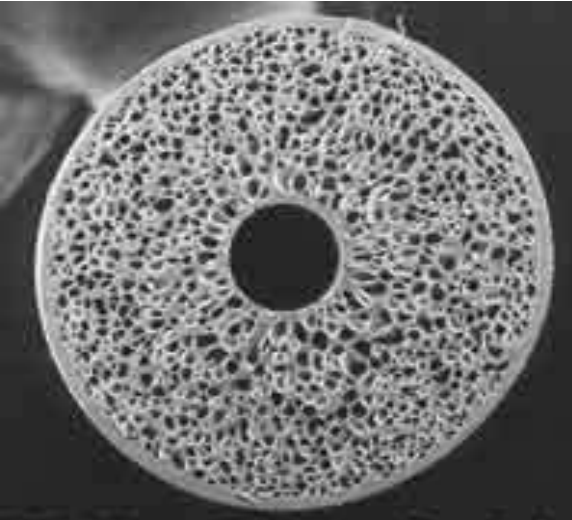


MARINE examples acoustic thermal  
insulation & fire protection compartment  
In an air craft carrier deck  
TOUGH CERAM®



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# TOUGH CERAM®

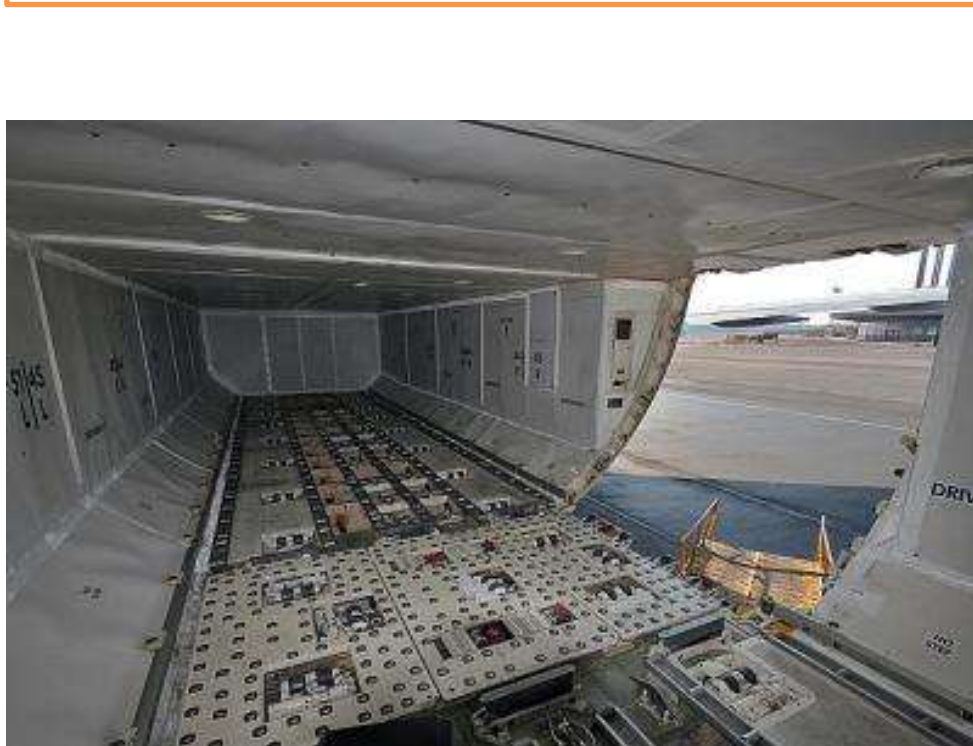


Structural parts  
massive or foamed

Where to use TOUGH CERAM® and save a lot of WEIGHT & get  
MECHANICAL PROPERTIES ACOUSTIC, THERMAL  
INSULATION & FIRE PROTECTION

# TOUGH CERAM®

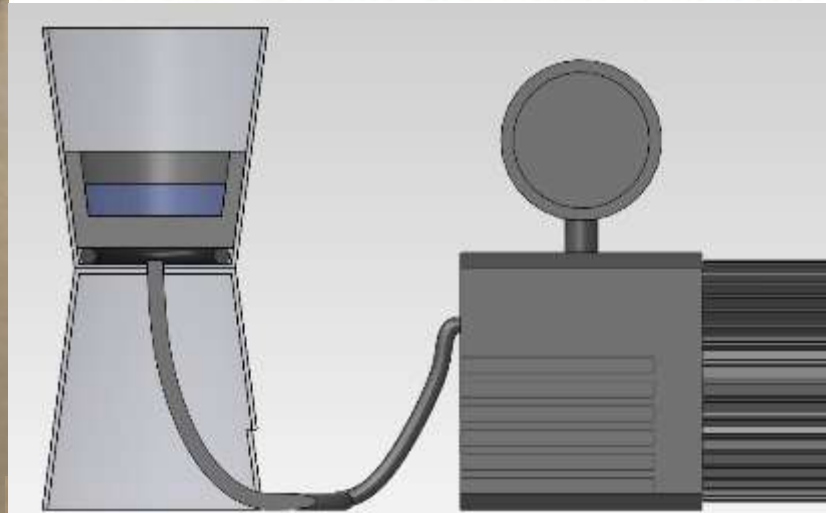
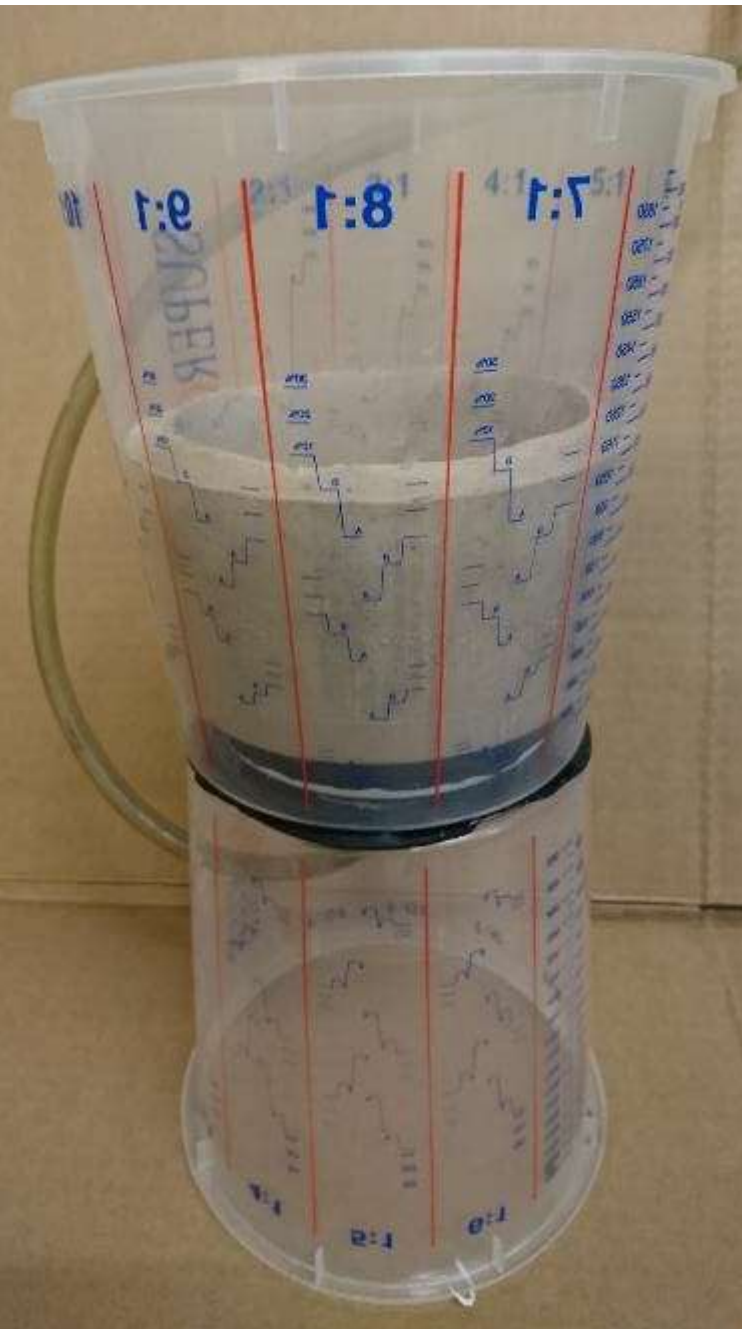
habillage intérieur d'avion, container à bagages de soutes et soutes structurales anti incendie  
aircraft : interior, cargo compartment and unit load device ( fire and explosion proof container ULD ).







Nous proposons de remplacer le béton dans les Conteneur destiné au stockage des déchets .MAVL (déchets de moyenne activité à vie longue)  
Par du **TOUGH CERAM®**



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Vacuum permeation tests,

We have compared :

- TOUGH CERAM®
- geopolymer
- Cement

Drain 150 ml in 5 minutes with Geopolymer and cement

Drain only 25 ml in 3 days with TOUGH CERAM®

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"CARBON FREE GREEN MINERAL POLYMER"

**TOUGH CERAM ®**

**DAMAGE TOLERANT high performance "heat shields" & "thermal encapsulation" applications examples for thermic cars**

“heat shields” & “thermal encapsulation”  
=> perfect applications for **TOUGH CERAM**®



"CARBON FREE GREEN MINERAL POLYMER"

TOUGH CERAM ®

DAMAGE TOLERANT SHIELD &

ANTI FIRE SOLUTION FOR  
HYDROGEN TANKS

# TOUGH CERAM®

Mirai, Toyota :hydrogen fuel cell car

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IT WOULD BE BETTER TO PROTECT HYDROGEN HP TANK WITH TOUGH CERAM®

Where to use TOUGH CERAM® and save a lot of WEIGHT & get MECHANICAL PROPERTIES ACOUSTIC, THERMAL INSULATION & FIRE PROTECTION with a shield under the car or a wrapping around the HP Hydrogen tank

# TOUGH CERAM®

RECHERCHE - DÉVELOPPEMENT - INGENIERIE - DESIGN



hydrogen fuel cell car

UNDERNEATH SHIELD IN  
TOUGH CERAM® = anti fire + anti  
stonning + aerodynamic smoothing +  
NVH improvement

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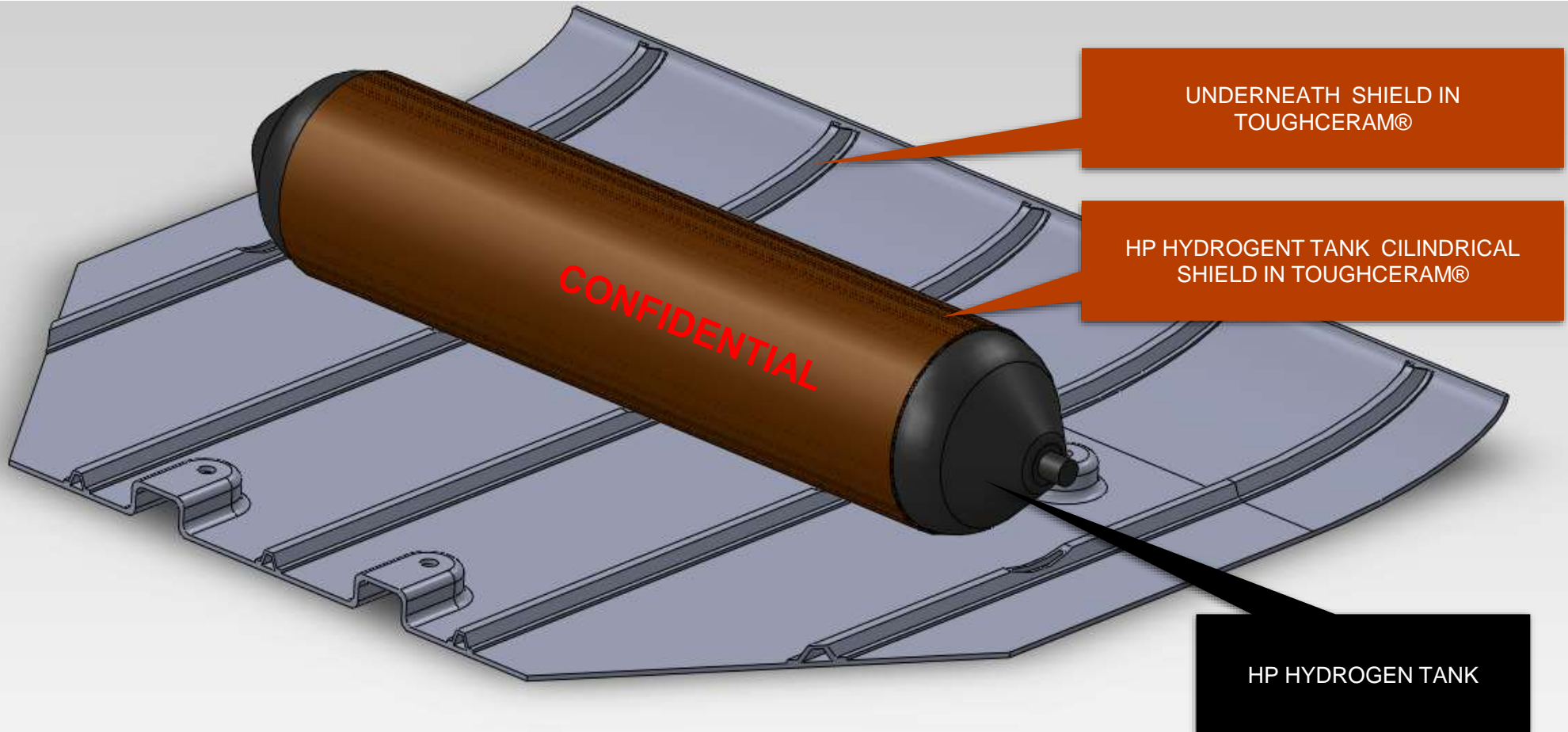
Where to use TOUGH CERAM® and save a lot of WEIGHT & get MECHANICAL  
PROPERTIES ACOUSTIC, THERMAL INSULATION & FIRE PROTECTION of  
HP Hydrogen tank with a shield under the car

# TOUGH CERAM®

RECHERCHE - DÉVELOPPEMENT - INGENIERIE - DESIGN



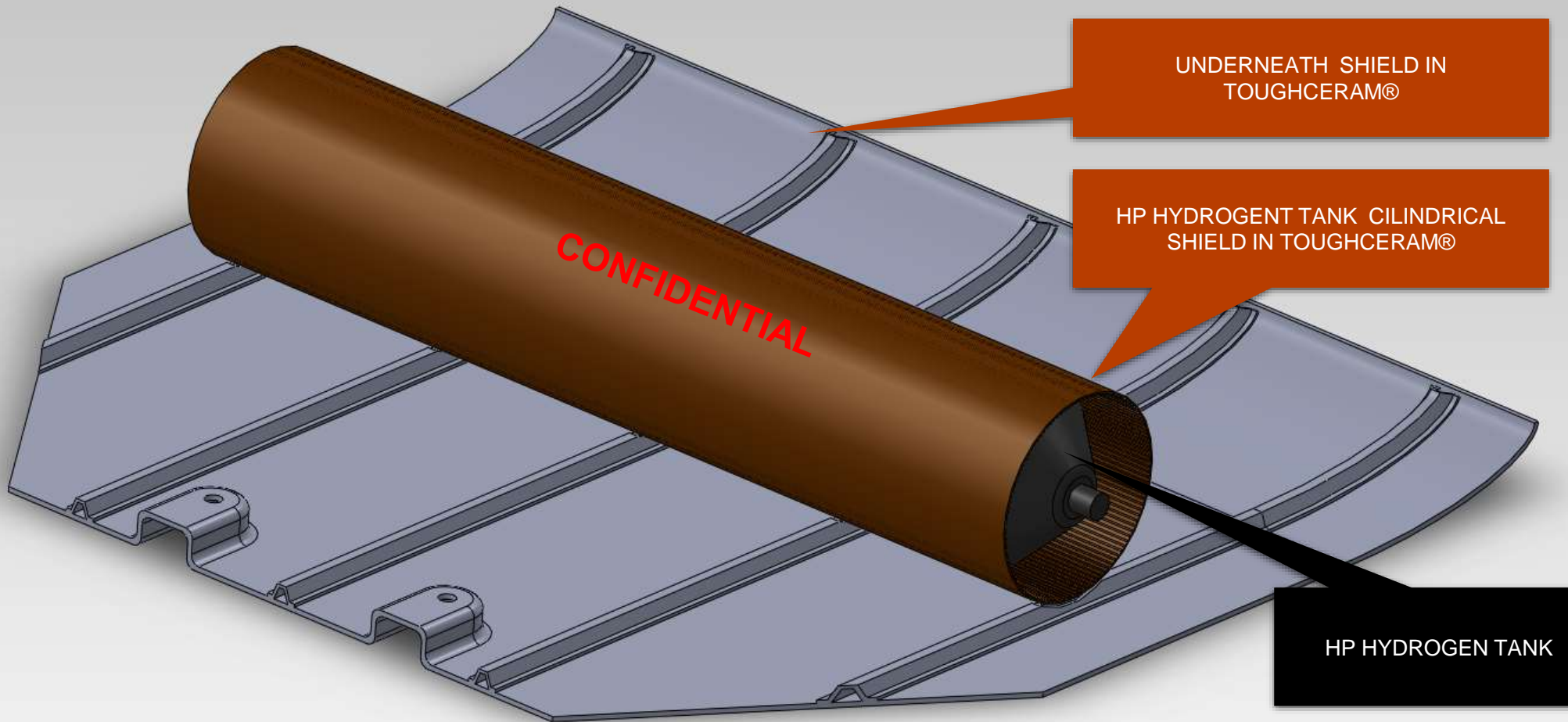
hydrogen fuel cell car



Where to use TOUGH CERAM® and save a lot of WEIGHT & get MECHANICAL PROPERTIES ACOUSTIC, THERMAL INSULATION & FIRE PROTECTION of HP Hydrogen tank with a shield under the car



## hydrogen fuel cell car



Where to use TOUGH CERAM® and save a lot of WEIGHT & get MECHANICAL PROPERTIES ACOUSTIC, THERMAL INSULATION & FIRE PROTECTION of HP Hydrogen tank with a shield under the car

# TOUGH CERAM®

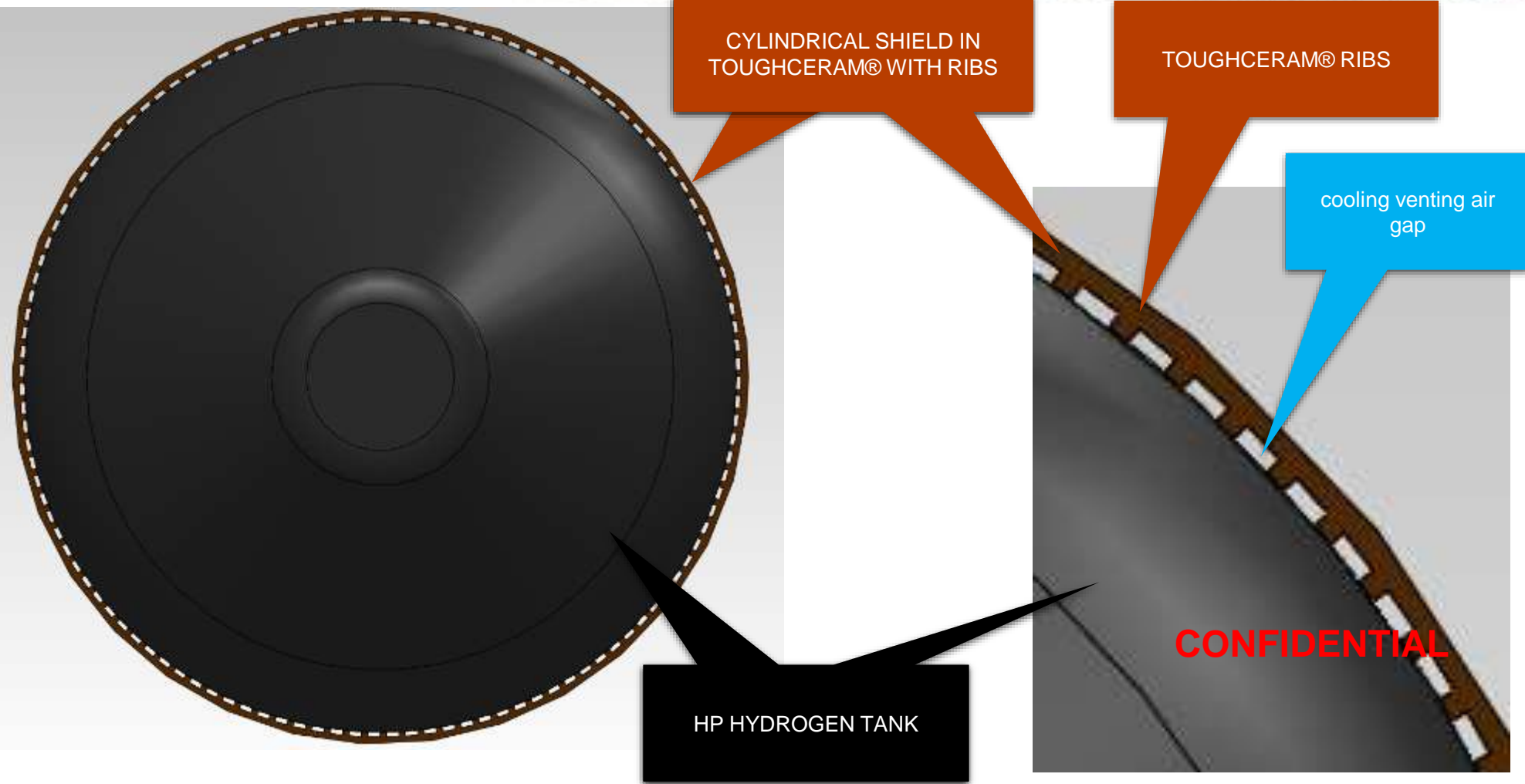
Hyundai ix35 hydrogen fuel cell car



THIS COULD BE IN TOUGH CERAM®

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Where to use TOUGH CERAM® and save a lot of WEIGHT & get MECHANICAL PROPERTIES ACOUSTIC, THERMAL INSULATION & FIRE PROTECTION with a shield under the car or a wrapping around the HP Hydrogen tank



Where to use TOUGH CERAM® and save a lot of WEIGHT wrapping around the HP Hydrogen tank air gap improve cooling

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Full length CYLINDRICAL SHIELD IN  
TOUGH CERAM® with RIBS

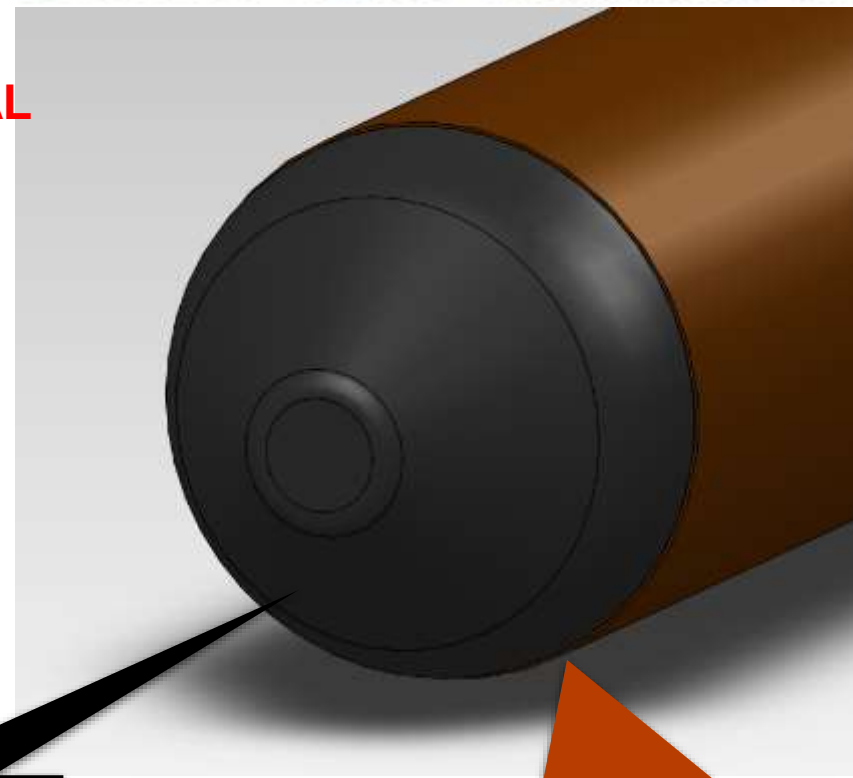
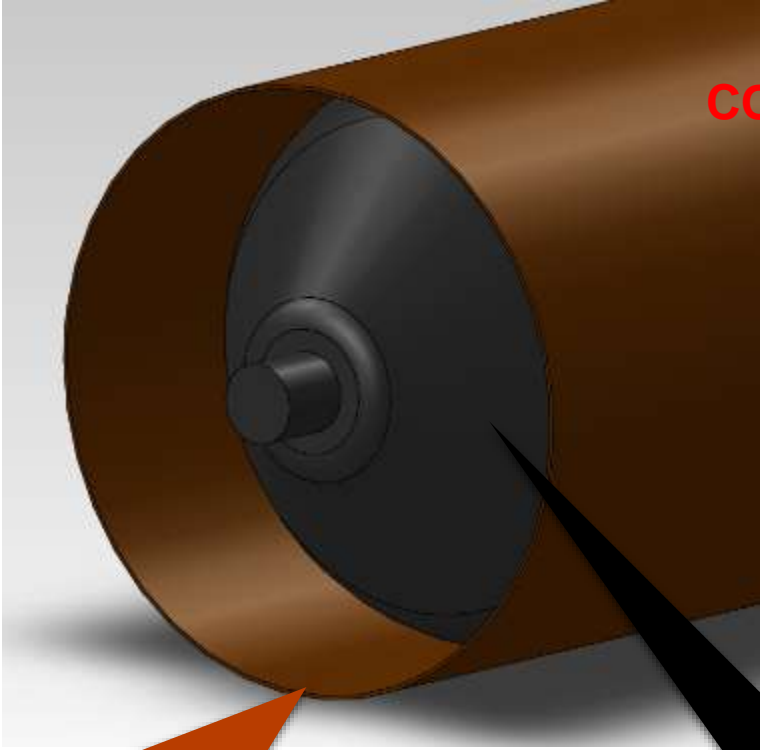
HP HYDROGEN TANK



Short CYLINDRICAL SHIELD IN TOUGH CERAM®  
with RIBS

Where to use TOUGH CERAM® and save a lot of WEIGHT  
wrapping around the HP Hydrogen tank

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Full length CYLINDRICAL SHIELD IN TOUGH CERAM® without RIBS

HP HYDROGEN TANK

Short CYLINDRICAL SHIELD IN TOUGH CERAM® without RIBS

Where to use TOUGH CERAM® and save a lot of WEIGHT wrapping around the HP Hydrogen tank

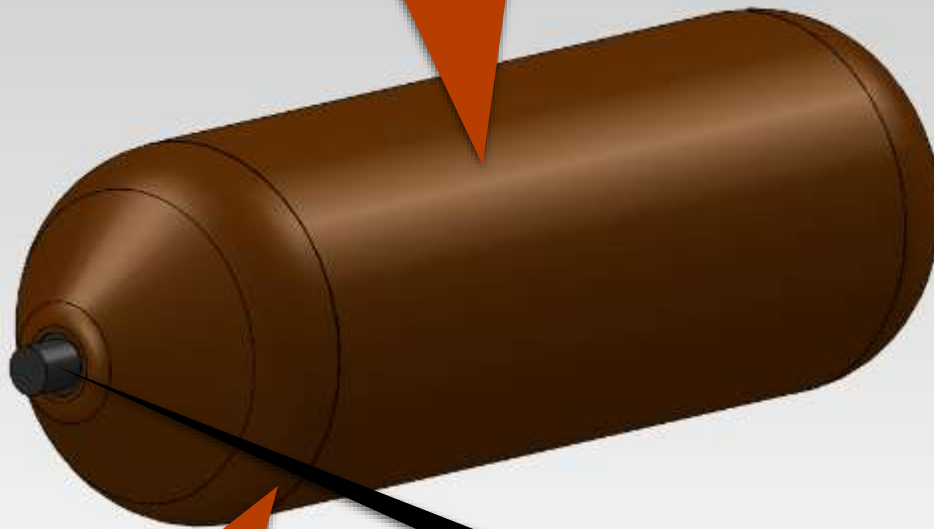
Wrapping can be in foam or in solid composite state

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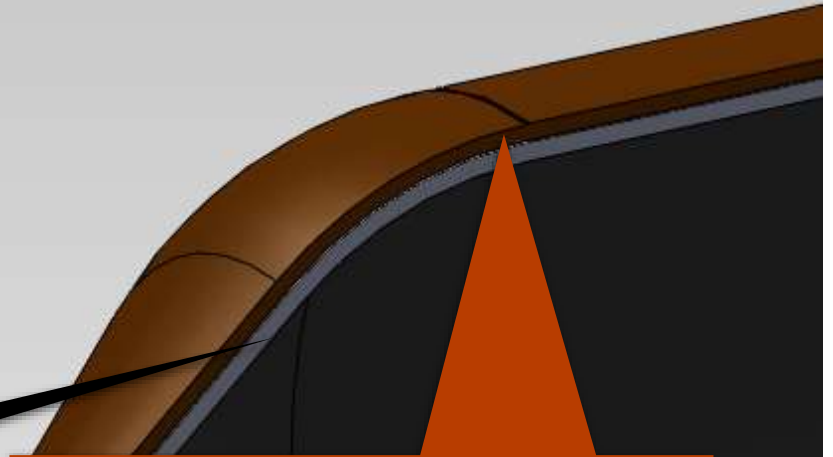
$$\lambda_{\text{composit}} = 0.75 \pm 0.013 \text{ W.m}^{-1}.\text{K}^{-1}$$

$$\lambda_{\text{foam}} = 0.35 \pm 0.013 \text{ W.m}^{-1}.\text{K}^{-1}$$



Full wrapping SHIELD IN TOUGH CERAM®

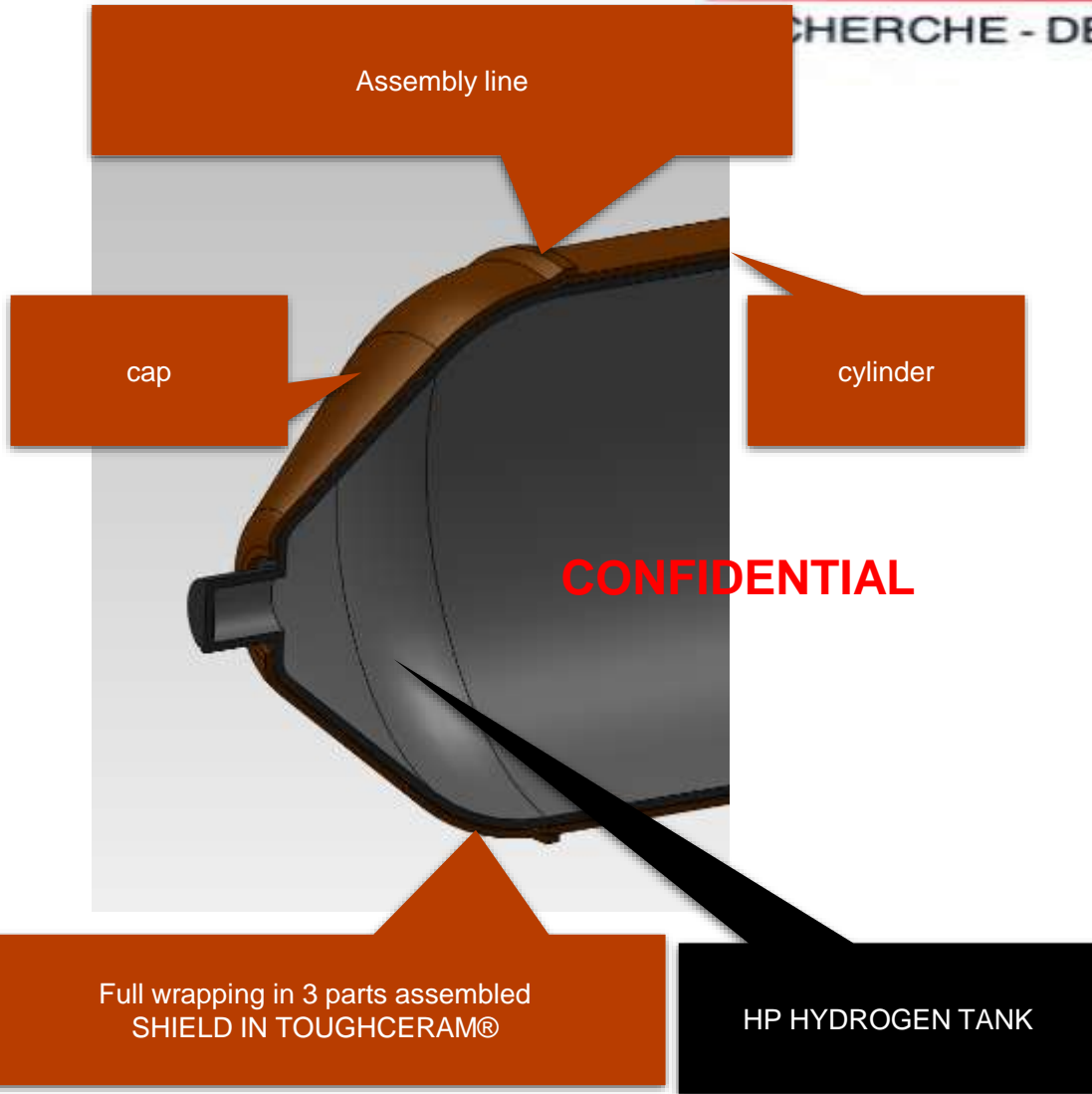
HP HYDROGEN TANK



Short Full wrapping

Where to use TOUGH CERAM® and save a lot of WEIGHT wrapping around the HP Hydrogen tank

$$\lambda_{\text{composit}} = 0.75 \pm 0.013 \text{ W.m}^{-1}.\text{K}^{-1}$$



Where to use TOUGH CERAM® and save a lot of WEIGHT wrapping around the HP Hydrogen tank

"CARBON FREE GREEN MINERAL POLYMER"

**TOUGH CERAM ®**

**DAMAGE TOLERANT SHIELD &  
ANTI FIRE UNIQUE SOLUTION  
FOR BATTERIES HYBRID VEHICLE**

**This feature is as much important in the car  
than during batteries cargo transportation  
and in workshop storage!**



ENVELOP OF THIS BATTERY COULD BE IN  
**TOUGH CERAM ®**



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**THANK YOU FOR YOUR ATTENTION**

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**CEL +336 1939 8957**