

# Stress analysis of SAPPHIRE GLASS protecting CO2 IR Sensor in Open Revolution eCCR

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## 1. Introduction

Summary of a FEM analysis on Sapphire Crystal Glass to protect IR sensor in CO2 monitor.

The window is 14mm in diameter and 1mm thick, made from a sapphire crystal normally supplied for high quality watch glass applications. It is compressed onto an O ring on the front face of the sensor. Failure of the seal or glass will cause high pressure gas onto the sensor and likely detachment of the 3.9um and 4.2um filters. This will result in malfunction of the PPCO2 monitor.

### Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. EDA tools help reduce time-to-market by reducing but not eliminating field tests.

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## 2. File Information

**Model name:** GLASS  
**Model location:** C:\REBRETHEL\HEAT STICK\GLASS.SLDPRT  
**Results location:** C:\DOCUME~1\A\_KUDR~1\LOCALS~1\Temp  
**Study name:** Study 1 (-Ïî ôîê÷âfèþ-)

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## 3. Materials

No.	Part Name	Material	Mass	Volume
1	GLASS	<a href="#">SAPPHIRE</a>	0.000495622 kg	1.24216e-007 m <sup>3</sup>

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## 4. Load & Restraint Information

Restraint	
<b>Restraint-1 &lt;GLASS&gt;</b>	on 1 Face(s) fixed.
<b>Description:</b>	

Load		
<b>Pressure-1 &lt;GLASS&gt;</b>	on 1 Face(s) with Pressure <b>70 kgf/cm<sup>2</sup></b> along direction normal to selected face	Sequential Loading
<b>Description:</b>		

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## 5. Study Property

Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	0.49922 mm
Tolerance:	0.024961 mm
Quality:	High
Number of elements:	5175
Number of nodes:	9367

Solver Information	
Quality:	High
Solver Type:	FFE
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 298 Kelvin

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## 6. Contact

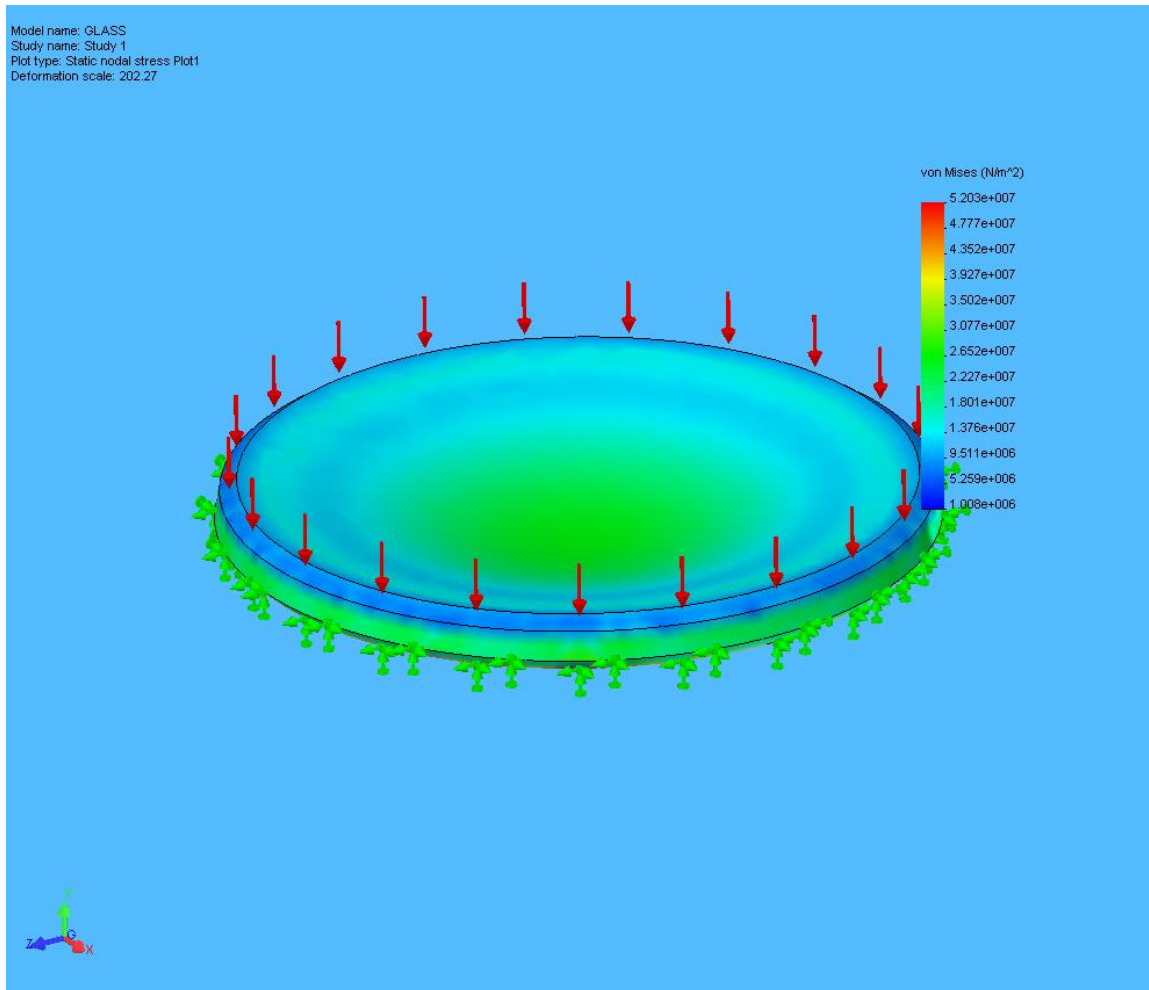
Contact state: Touching faces - Bonded

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## 7. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	6.90567e+006 N/m <sup>2</sup> Node: 3507	(5.66896 mm, 7.67402 mm, 0.186619 mm)	3.39485e+008 N/m <sup>2</sup> Node: 8945	(5.11066 mm, 7.36739 mm, 3.05665 mm)

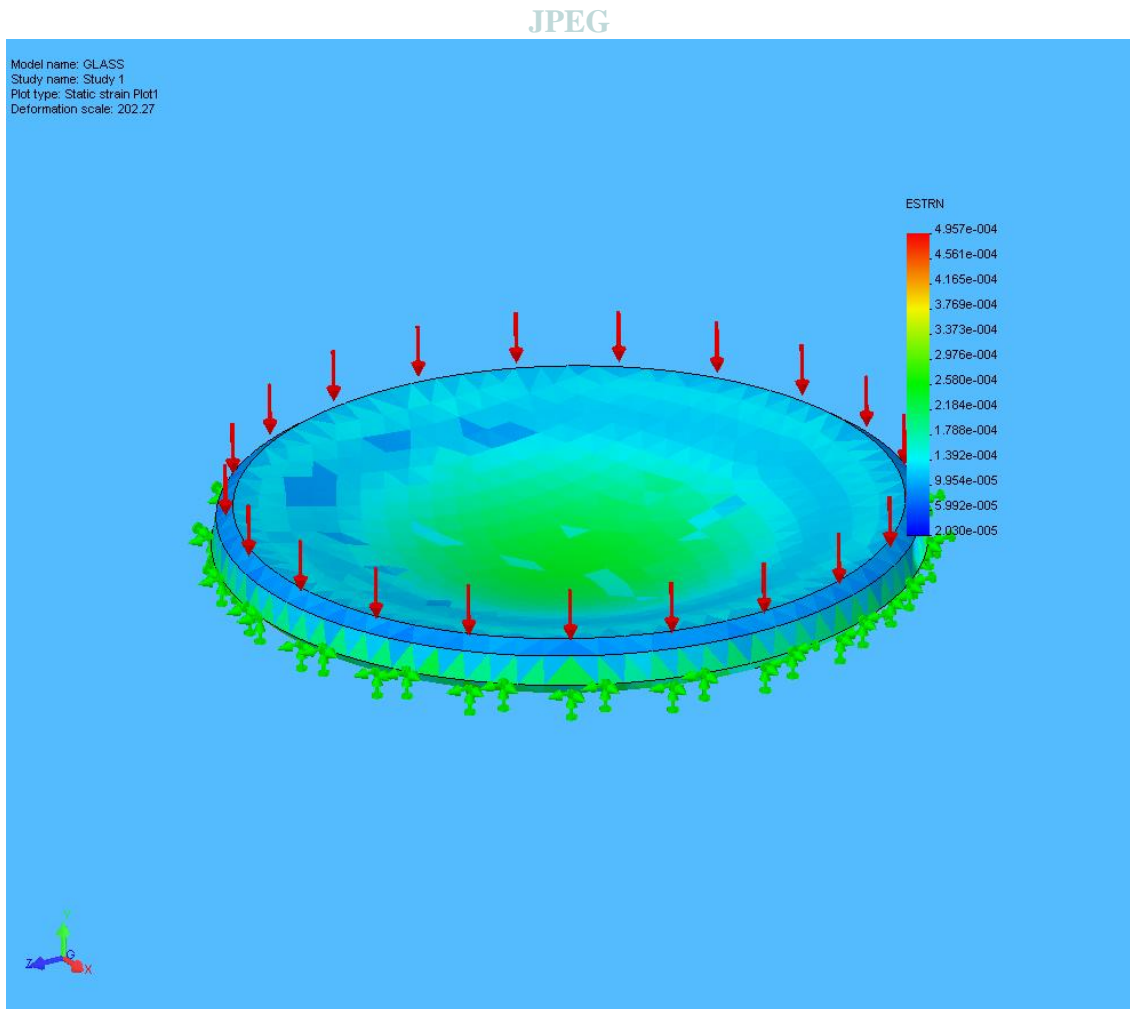
**GLASS-Study 1-Stress-Plot1**  
JPEG



## 8. Strain Results

Name	Type	Min	Location	Max	Location
Plot1	ESTRN: Equivalent strain	2.37787e-005	(1.41643 mm, 7.74782 mm, -0.495285 mm)	0.000538471	(5.10244 mm, 7.45055 mm, 3.16092 mm)
		Element: 3789		Element: 4328	

### GLASS-Study 1-Strain-Plot1

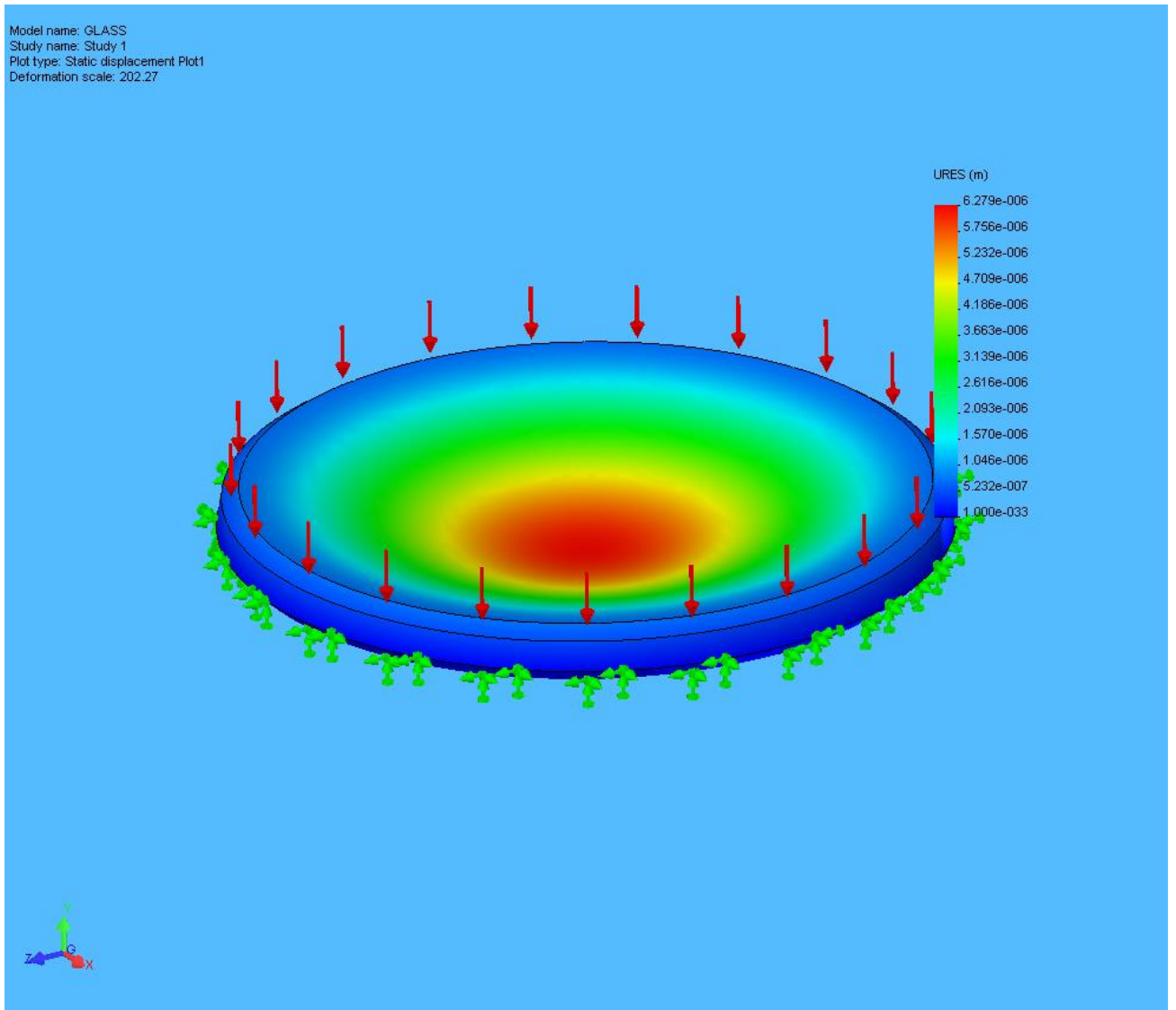


## 9. Displacement Results

Name	Type	Min	Location	Max	Location		
Plot1	URES: Resultant displacement	0 m	(5.28276 mm,	6.53428e-006 m	(-0.000205545 mm,		
		Node: 1	7.36739 mm,			Node: 1348	7.86719 mm,
			-3.05 mm)				-0.000205545 mm)

GLASS-Study 1-Displacement-Plot1

JPEG

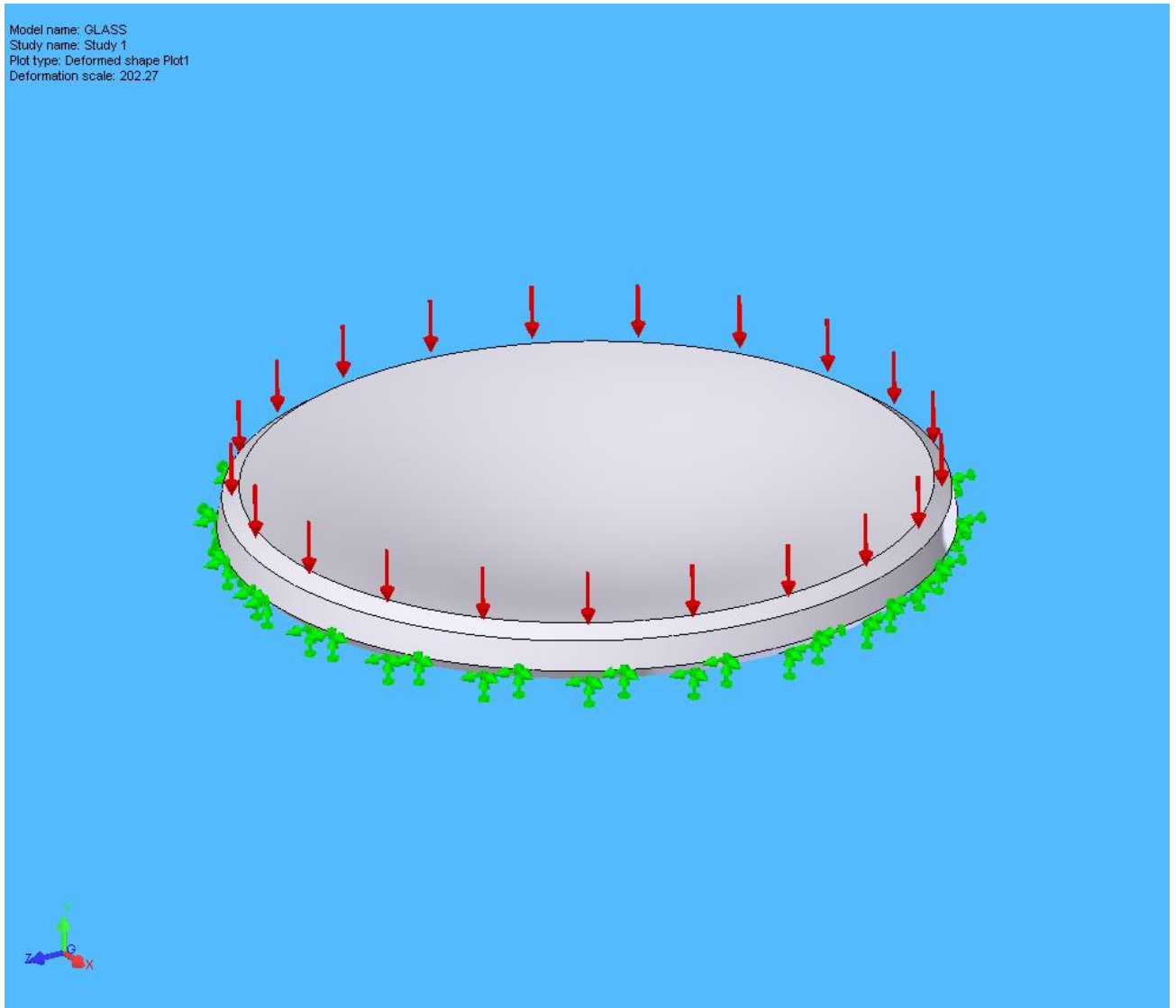


## 10. Deformation Results

Plot No.	Scale Factor
1	194.36

### GLASS-Study 1-Deformation-Plot1

JPEG



## 11. Conclusion

The Sapphire window fitted for sport diving applications (to 100m) has a x7 margin of safety. Cracking occurs at 70 bar.

For the expedition version of the rebreather, designed to a depth of 600m, the window should be increased to 1.5mm.

Failure of the window will lead to loss of PPCO2 monitoring.

## 12. Appendix

**Material name:** SAPPHIRE

**Description:**

**Material Source:** Library files

**Material Library Name:** materials

**Material Model Type:** Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	4.4e+011	N/m <sup>2</sup>	Constant
Poisson's ratio	0.3	NA	Constant
Shear modulus	2.8e+010	N/m <sup>2</sup>	Constant
Mass density	3990	kg/m <sup>3</sup>	Constant
Tensile strength	1.9e+008	N/m <sup>2</sup>	Constant
Compressive strength	2.1e+009	N/m <sup>2</sup>	Constant
Thermal expansion coefficient	9e-006	/Kelvin	Constant
Thermal conductivity	0.7498	W/(m.K)	Constant
Specific heat	834.6	J/(kg.K)	Constant